

ETSI TS 138 211 V18.5.0 (2025-01)



**5G;
NR;
Physical channels and modulation
(3GPP TS 38.211 version 18.5.0 Release 18)**



Reference

RTS/TSGR-0138211 vi50

Keywords

5G

ETSI

650 Route des Lucioles
F-06921 Sophia Antipolis Cedex - FRANCE

Tel.: +33 4 92 94 42 00 Fax: +33 4 93 65 47 16

Siret N° 348 623 562 00017 - APE 7112B
Association à but non lucratif enregistrée à la
Sous-Préfecture de Grasse (06) N° w061004871

Important notice

The present document can be downloaded from the
[ETSI Search & Browse Standards application](#).

The present document may be made available in electronic versions and/or in print. The content of any electronic and/or print versions of the present document shall not be modified without the prior written authorization of ETSI. In case of any existing or perceived difference in contents between such versions and/or in print, the prevailing version of an ETSI deliverable is the one made publicly available in PDF format on [ETSI deliver repository](#).

Users should be aware that the present document may be revised or have its status changed, this information is available in the [Milestones listing](#).

If you find errors in the present document, please send your comments to the relevant service listed under [Committee Support Staff](#).

If you find a security vulnerability in the present document, please report it through our [Coordinated Vulnerability Disclosure \(CVD\)](#) program.

Notice of disclaimer & limitation of liability

The information provided in the present deliverable is directed solely to professionals who have the appropriate degree of experience to understand and interpret its content in accordance with generally accepted engineering or other professional standard and applicable regulations.

No recommendation as to products and services or vendors is made or should be implied.

No representation or warranty is made that this deliverable is technically accurate or sufficient or conforms to any law and/or governmental rule and/or regulation and further, no representation or warranty is made of merchantability or fitness for any particular purpose or against infringement of intellectual property rights.

In no event shall ETSI be held liable for loss of profits or any other incidental or consequential damages.

Any software contained in this deliverable is provided "AS IS" with no warranties, express or implied, including but not limited to, the warranties of merchantability, fitness for a particular purpose and non-infringement of intellectual property rights and ETSI shall not be held liable in any event for any damages whatsoever (including, without limitation, damages for loss of profits, business interruption, loss of information, or any other pecuniary loss) arising out of or related to the use of or inability to use the software.

Copyright Notification

No part may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm except as authorized by written permission of ETSI.

The content of the PDF version shall not be modified without the written authorization of ETSI.

The copyright and the foregoing restriction extend to reproduction in all media.

© ETSI 2025.
All rights reserved.

Intellectual Property Rights

Essential patents

IPRs essential or potentially essential to normative deliverables may have been declared to ETSI. The declarations pertaining to these essential IPRs, if any, are publicly available for **ETSI members and non-members**, and can be found in ETSI SR 000 314: "*Intellectual Property Rights (IPRs); Essential, or potentially Essential, IPRs notified to ETSI in respect of ETSI standards*", which is available from the ETSI Secretariat. Latest updates are available on the [ETSI IPR online database](#).

Pursuant to the ETSI Directives including the ETSI IPR Policy, no investigation regarding the essentiality of IPRs, including IPR searches, has been carried out by ETSI. No guarantee can be given as to the existence of other IPRs not referenced in ETSI SR 000 314 (or the updates on the ETSI Web server) which are, or may be, or may become, essential to the present document.

Trademarks

The present document may include trademarks and/or tradenames which are asserted and/or registered by their owners. ETSI claims no ownership of these except for any which are indicated as being the property of ETSI, and conveys no right to use or reproduce any trademark and/or tradename. Mention of those trademarks in the present document does not constitute an endorsement by ETSI of products, services or organizations associated with those trademarks.

DECT™, **PLUGTESTS™**, **UMTS™** and the ETSI logo are trademarks of ETSI registered for the benefit of its Members. **3GPP™**, **LTE™** and **5G™** logo are trademarks of ETSI registered for the benefit of its Members and of the 3GPP Organizational Partners. **oneM2M™** logo is a trademark of ETSI registered for the benefit of its Members and of the oneM2M Partners. **GSM®** and the GSM logo are trademarks registered and owned by the GSM Association.

Legal Notice

This Technical Specification (TS) has been produced by ETSI 3rd Generation Partnership Project (3GPP).

The present document may refer to technical specifications or reports using their 3GPP identities. These shall be interpreted as being references to the corresponding ETSI deliverables.

The cross reference between 3GPP and ETSI identities can be found at [3GPP to ETSI numbering cross-referencing](#).

Modal verbs terminology

In the present document "**shall**", "**shall not**", "**should**", "**should not**", "**may**", "**need not**", "**will**", "**will not**", "**can**" and "**cannot**" are to be interpreted as described in clause 3.2 of the [ETSI Drafting Rules](#) (Verbal forms for the expression of provisions).

"**must**" and "**must not**" are **NOT** allowed in ETSI deliverables except when used in direct citation.

Contents

| | |
|--|----|
| Intellectual Property Rights | 2 |
| Legal Notice | 2 |
| Modal verbs terminology..... | 2 |
| Foreword..... | 8 |
| 1 Scope | 9 |
| 2 References | 9 |
| 3 Definitions of terms, symbols and abbreviations | 9 |
| 3.1 Terms..... | 9 |
| 3.2 Symbols..... | 9 |
| 3.3 Abbreviations | 11 |
| 4 Frame structure and physical resources..... | 12 |
| 4.1 General | 12 |
| 4.2 Numerologies | 12 |
| 4.3 Frame structure..... | 12 |
| 4.3.1 Frames and subframes | 12 |
| 4.3.2 Slots | 13 |
| 4.4 Physical resources | 14 |
| 4.4.1 Antenna ports..... | 14 |
| 4.4.2 Resource grid..... | 14 |
| 4.4.3 Resource elements | 15 |
| 4.4.4 Resource blocks | 15 |
| 4.4.4.1 General | 15 |
| 4.4.4.2 Point A | 15 |
| 4.4.4.3 Common resource blocks..... | 15 |
| 4.4.4.4 Physical resource blocks | 15 |
| 4.4.4.5 Virtual resource blocks | 16 |
| 4.4.4.6 Interlaced resource blocks..... | 16 |
| 4.4.5 Bandwidth part..... | 16 |
| 4.4.6 Common MBS frequency resource..... | 16 |
| 4.5 Carrier aggregation..... | 17 |
| 5 Generic functions | 17 |
| 5.1 Modulation mapper | 17 |
| 5.1.1 $\pi/2$ -BPSK..... | 17 |
| 5.1.2 BPSK | 17 |
| 5.1.3 QPSK..... | 18 |
| 5.1.4 16QAM..... | 18 |
| 5.1.5 64QAM..... | 18 |
| 5.1.6 256QAM..... | 18 |
| 5.1.7 1024QAM..... | 18 |
| 5.2 Sequence generation..... | 18 |
| 5.2.1 Pseudo-random sequence generation | 18 |
| 5.2.2 Low-PAPR sequence generation type 1..... | 19 |
| 5.2.2.1 Base sequences of length 36 or larger | 19 |
| 5.2.2.2 Base sequences of length less than 36..... | 19 |
| 5.2.3 Low-PAPR sequence generation type 2..... | 23 |
| 5.2.3.1 Sequences of length 30 or larger | 23 |
| 5.2.3.2 Sequences of length less than 30..... | 23 |
| 5.3 OFDM baseband signal generation | 27 |
| 5.3.1 OFDM baseband signal generation for all channels except PRACH and RIM-RS | 27 |
| 5.3.2 OFDM baseband signal generation for PRACH..... | 29 |
| 5.3.3 OFDM baseband signal generation for RIM-RS | 31 |
| 5.4 Modulation and upconversion | 32 |

| | | |
|-------------|--|-----|
| 6 | Uplink..... | 32 |
| 6.1 | Overview | 32 |
| 6.1.1 | Overview of physical channels | 32 |
| 6.1.2 | Overview of physical signals | 32 |
| 6.2 | Physical resources | 33 |
| 6.3 | Physical channels | 33 |
| 6.3.1 | Physical uplink shared channel..... | 33 |
| 6.3.1.1 | Scrambling | 33 |
| 6.3.1.2 | Modulation | 34 |
| 6.3.1.3 | Layer mapping | 34 |
| 6.3.1.4 | Transform precoding | 35 |
| 6.3.1.5 | Precoding | 35 |
| 6.3.1.6 | Mapping to virtual resource blocks | 60 |
| 6.3.1.7 | Mapping from virtual to physical resource blocks | 61 |
| 6.3.2 | Physical uplink control channel | 61 |
| 6.3.2.1 | General | 61 |
| 6.3.2.2 | Sequence and cyclic shift hopping | 61 |
| 6.3.2.2.1 | Group and sequence hopping | 61 |
| 6.3.2.2.2 | Cyclic shift hopping | 62 |
| 6.3.2.3 | PUCCH format 0..... | 63 |
| 6.3.2.3.1 | Sequence generation | 63 |
| 6.3.2.3.2 | Mapping to physical resources | 63 |
| 6.3.2.4 | PUCCH format 1..... | 63 |
| 6.3.2.4.1 | Sequence modulation..... | 63 |
| 6.3.2.4.2 | Mapping to physical resources | 64 |
| 6.3.2.5 | PUCCH format 2..... | 65 |
| 6.3.2.5.1 | Scrambling..... | 65 |
| 6.3.2.5.2 | Modulation | 65 |
| 6.3.2.5.2A | Spreading..... | 65 |
| 6.3.2.5.3 | Mapping to physical resources | 66 |
| 6.3.2.6 | PUCCH formats 3 and 4 | 66 |
| 6.3.2.6.1 | Scrambling..... | 66 |
| 6.3.2.6.2 | Modulation | 67 |
| 6.3.2.6.3 | Block-wise spreading | 67 |
| 6.3.2.6.4 | Transform precoding | 68 |
| 6.3.2.6.5 | Mapping to physical resources | 68 |
| 6.3.3 | Physical random-access channel..... | 69 |
| 6.3.3.1 | Sequence generation..... | 69 |
| 6.3.3.2 | Mapping to physical resources | 75 |
| 6.4 | Physical signals | 95 |
| 6.4.1 | Reference signals | 95 |
| 6.4.1.1 | Demodulation reference signal for PUSCH | 95 |
| 6.4.1.1.1 | Sequence generation | 95 |
| 6.4.1.1.2 | (void) | 97 |
| 6.4.1.1.3 | Precoding and mapping to physical resources | 97 |
| 6.4.1.2 | Phase-tracking reference signals for PUSCH..... | 102 |
| 6.4.1.2.1 | Sequence generation | 102 |
| 6.4.1.2.1.1 | Sequence generation if transform precoding is not enabled..... | 102 |
| 6.4.1.2.1.2 | Sequence generation if transform precoding is enabled..... | 102 |
| 6.4.1.2.2 | Mapping to physical resources | 103 |
| 6.4.1.2.2.1 | Precoding and mapping to physical resources if transform precoding is not enabled..... | 103 |
| 6.4.1.2.2.2 | Mapping to physical resources if transform precoding is enabled..... | 105 |
| 6.4.1.3 | Demodulation reference signal for PUCCH..... | 106 |
| 6.4.1.3.1 | Demodulation reference signal for PUCCH format 1..... | 106 |
| 6.4.1.3.1.1 | Sequence generation | 106 |
| 6.4.1.3.1.2 | Mapping to physical resources..... | 107 |
| 6.4.1.3.2 | Demodulation reference signal for PUCCH format 2..... | 107 |
| 6.4.1.3.2.1 | Sequence generation | 107 |
| 6.4.1.3.2.2 | Mapping to physical resources..... | 108 |
| 6.4.1.3.3 | Demodulation reference signal for PUCCH formats 3 and 4 | 108 |
| 6.4.1.3.3.1 | Sequence generation | 108 |
| 6.4.1.3.3.2 | Mapping to physical resources..... | 108 |

| | | |
|-------------|--|-----|
| 6.4.1.4 | Sounding reference signal | 109 |
| 6.4.1.4.1 | SRS resource | 109 |
| 6.4.1.4.2 | Sequence generation | 109 |
| 6.4.1.4.3 | Mapping to physical resources | 111 |
| 6.4.1.4.4 | Sounding reference signal slot configuration | 117 |
| 7 | Downlink | 117 |
| 7.1 | Overview | 117 |
| 7.1.1 | Overview of physical channels | 117 |
| 7.1.2 | Overview of physical signals | 118 |
| 7.2 | Physical resources | 118 |
| 7.3 | Physical channels | 119 |
| 7.3.1 | Physical downlink shared channel | 119 |
| 7.3.1.1 | Scrambling | 119 |
| 7.3.1.2 | Modulation | 119 |
| 7.3.1.3 | Layer mapping | 120 |
| 7.3.1.4 | Antenna port mapping | 121 |
| 7.3.1.5 | Mapping to virtual resource blocks | 122 |
| 7.3.1.6 | Mapping from virtual to physical resource blocks | 122 |
| 7.3.2 | Physical downlink control channel (PDCCH) | 124 |
| 7.3.2.1 | Control-channel element (CCE) | 124 |
| 7.3.2.2 | Control-resource set (CORESET) | 124 |
| 7.3.2.3 | Scrambling | 126 |
| 7.3.2.4 | PDCCH modulation | 126 |
| 7.3.2.5 | Mapping to physical resources | 127 |
| 7.3.3 | Physical broadcast channel | 127 |
| 7.3.3.1 | Scrambling | 127 |
| 7.3.3.2 | Modulation | 127 |
| 7.3.3.3 | Mapping to physical resources | 127 |
| 7.4 | Physical signals | 127 |
| 7.4.1 | Reference signals | 127 |
| 7.4.1.1 | Demodulation reference signals for PDSCH | 127 |
| 7.4.1.1.1 | Sequence generation | 127 |
| 7.4.1.1.2 | Mapping to physical resources | 128 |
| 7.4.1.2 | Phase-tracking reference signals for PDSCH | 133 |
| 7.4.1.2.1 | Sequence generation | 133 |
| 7.4.1.2.2 | Mapping to physical resources | 133 |
| 7.4.1.3 | Demodulation reference signals for PDCCH | 134 |
| 7.4.1.3.1 | Sequence generation | 134 |
| 7.4.1.3.2 | Mapping to physical resources | 135 |
| 7.4.1.4 | Demodulation reference signals for PBCH | 135 |
| 7.4.1.4.1 | Sequence generation | 135 |
| 7.4.1.4.2 | Mapping to physical resources | 136 |
| 7.4.1.5 | CSI reference signals | 136 |
| 7.4.1.5.1 | General | 136 |
| 7.4.1.5.2 | Sequence generation | 136 |
| 7.4.1.5.3 | Mapping to physical resources | 136 |
| 7.4.1.6 | RIM reference signals | 139 |
| 7.4.1.6.1 | General | 139 |
| 7.4.1.6.2 | Sequence generation | 139 |
| 7.4.1.6.3 | Mapping to physical resources | 140 |
| 7.4.1.6.4 | RIM-RS configuration | 140 |
| 7.4.1.6.4.1 | General | 140 |
| 7.4.1.6.4.2 | Time-domain parameters and mapping from it to time-domain parameters | 141 |
| 7.4.1.6.4.3 | Frequency-domain parameters and mapping from it to frequency-domain parameters | 141 |
| 7.4.1.6.4.4 | Sequence parameters and mapping from it to sequence parameters | 142 |
| 7.4.1.6.4.5 | Mapping between resource triplet and set ID | 142 |
| 7.4.1.7 | Positioning reference signals | 143 |
| 7.4.1.7.1 | General | 143 |
| 7.4.1.7.2 | Sequence generation | 143 |
| 7.4.1.7.3 | Mapping to physical resources in a downlink PRS resource | 143 |
| 7.4.1.7.4 | Mapping to slots in a downlink PRS resource set | 144 |

| | | |
|-----------|--|-----|
| 7.4.2 | Synchronization signals | 145 |
| 7.4.2.1 | Physical-layer cell identities..... | 145 |
| 7.4.2.2 | Primary synchronization signal..... | 145 |
| 7.4.2.2.1 | Sequence generation..... | 145 |
| 7.4.2.2.2 | Mapping to physical resources | 145 |
| 7.4.2.3 | Secondary synchronization signal..... | 145 |
| 7.4.2.3.1 | Sequence generation..... | 145 |
| 7.4.2.3.2 | Mapping to physical resources | 146 |
| 7.4.3 | SS/PBCH block | 146 |
| 7.4.3.1 | Time-frequency structure of an SS/PBCH block | 146 |
| 7.4.3.1.1 | Mapping of PSS within an SS/PBCH block..... | 147 |
| 7.4.3.1.2 | Mapping of SSS within an SS/PBCH block..... | 147 |
| 7.4.3.1.3 | Mapping of PBCH and DM-RS within an SS/PBCH block..... | 148 |
| 7.4.3.2 | Time location of an SS/PBCH block..... | 148 |
| 8 | Sidelink..... | 148 |
| 8.1 | Overview | 148 |
| 8.1.1 | Overview of physical channels..... | 148 |
| 8.1.2 | Overview of physical signals..... | 148 |
| 8.2 | Physical resources | 149 |
| 8.2.1 | General..... | 149 |
| 8.2.2 | Numerologies..... | 149 |
| 8.2.3 | Frame structure | 149 |
| 8.2.3.1 | Frames and subframes..... | 149 |
| 8.2.3.2 | Slots..... | 149 |
| 8.2.4 | Antenna ports..... | 149 |
| 8.2.5 | Resource grid..... | 150 |
| 8.2.6 | Resource elements | 150 |
| 8.2.7 | Resource blocks | 150 |
| 8.2.8 | Bandwidth part..... | 150 |
| 8.3 | Physical channels | 150 |
| 8.3.1 | Physical sidelink shared channel | 150 |
| 8.3.1.1 | Scrambling | 150 |
| 8.3.1.2 | Modulation..... | 151 |
| 8.3.1.3 | Layer mapping | 152 |
| 8.3.1.4 | Precoding | 152 |
| 8.3.1.5 | Mapping to virtual resource blocks..... | 152 |
| 8.3.1.6 | Mapping from virtual to physical resource blocks | 152 |
| 8.3.2 | Physical sidelink control channel..... | 152 |
| 8.3.2.1 | Scrambling | 152 |
| 8.3.2.2 | Modulation..... | 153 |
| 8.3.2.3 | Mapping to physical resources..... | 153 |
| 8.3.3 | Physical sidelink broadcast channel..... | 153 |
| 8.3.3.1 | Scrambling | 153 |
| 8.3.3.2 | Modulation..... | 153 |
| 8.3.3.3 | Mapping to physical resources..... | 153 |
| 8.3.4 | Physical sidelink feedback channel..... | 153 |
| 8.3.4.1 | General | 153 |
| 8.3.4.2 | PSFCH format 0..... | 153 |
| 8.3.4.2.1 | Sequence generation..... | 153 |
| 8.3.4.2.2 | Mapping to physical resources | 154 |
| 8.4 | Physical signals | 154 |
| 8.4.1 | Reference signals | 154 |
| 8.4.1.1 | Demodulation reference signals for PSSCH | 154 |
| 8.4.1.1.1 | Sequence generation..... | 154 |
| 8.4.1.1.2 | Mapping to physical resources | 155 |
| 8.4.1.2 | Phase-tracking reference signals for PSSCH | 156 |
| 8.4.1.2.1 | Sequence generation..... | 156 |
| 8.4.1.2.2 | Mapping to physical resources | 156 |
| 8.4.1.3 | Demodulation reference signals for PSCCH..... | 157 |
| 8.4.1.3.1 | Sequence generation..... | 157 |
| 8.4.1.3.2 | Mapping to physical resources | 158 |

| | | |
|--|---|------------|
| 8.4.1.4 | Demodulation reference signals for PSBCH..... | 158 |
| 8.4.1.4.1 | Sequence generation..... | 158 |
| 8.4.1.4.2 | Mapping to physical resources | 158 |
| 8.4.1.5 | CSI reference signals..... | 158 |
| 8.4.1.5.1 | General | 158 |
| 8.4.1.5.2 | Sequence generation..... | 158 |
| 8.4.1.5.3 | Mapping to physical resources | 159 |
| 8.4.1.6 | Positioning reference signals..... | 159 |
| 8.4.1.6.1 | General | 159 |
| 8.4.1.6.2 | Sequence generation..... | 159 |
| 8.4.1.6.3 | Mapping to physical resources | 159 |
| 8.4.2 | Synchronization signals | 160 |
| 8.4.2.1 | Physical-layer sidelink synchronization identities | 160 |
| 8.4.2.2 | Sidelink primary synchronization signal..... | 161 |
| 8.4.2.2.1 | Sequence generation..... | 161 |
| 8.4.2.2.2 | Mapping to physical resources | 161 |
| 8.4.2.3 | Sidelink secondary synchronization signal | 161 |
| 8.4.2.3.1 | Sequence generation..... | 161 |
| 8.4.2.3.2 | Mapping to physical resources | 161 |
| 8.4.3 | S-SS/PSBCH block..... | 161 |
| 8.4.3.1 | Time-frequency structure of an S-SS/PSBCH block..... | 161 |
| 8.4.3.1.1 | Mapping of S-PSS within an S-SS/PSBCH block..... | 162 |
| 8.4.3.1.2 | Mapping of S-SSS within an S-SS/PSBCH block..... | 162 |
| 8.4.3.1.3 | Mapping of PSBCH and DM-RS within an S-SS/PSBCH block | 162 |
| 8.4.3.2 | Time location of an S-SS/PSBCH block..... | 163 |
| 8.5 | Timing | 163 |
| Annex A (informative): Change history | | 164 |
| History | | 170 |

Foreword

This Technical Specification has been produced by the 3rd Generation Partnership Project (3GPP).

The contents of the present document are subject to continuing work within the TSG and may change following formal TSG approval. Should the TSG modify the contents of the present document, it will be re-released by the TSG with an identifying change of release date and an increase in version number as follows:

Version x.y.z

where:

- x the first digit:
 - 1 presented to TSG for information;
 - 2 presented to TSG for approval;
 - 3 or greater indicates TSG approved document under change control.
- y the second digit is incremented for all changes of substance, i.e. technical enhancements, corrections, updates, etc.
- z the third digit is incremented when editorial only changes have been incorporated in the document.

1 Scope

The present document describes the physical channels and signals for 5G-NR.

2 References

The following documents contain provisions which, through reference in this text, constitute provisions of the present document.

- [1] 3GPP TR 21.905: "Vocabulary for 3GPP Specifications".
- [2] 3GPP TS 38.201: "NR; Physical Layer – General Description"
- [3] 3GPP TS 38.202: "NR; Services provided by the physical layer"
- [4] 3GPP TS 38.212: "NR; Multiplexing and channel coding"
- [5] 3GPP TS 38.213: "NR; Physical layer procedures for control "
- [6] 3GPP TS 38.214: "NR; Physical layer procedures for data "
- [7] 3GPP TS 38.215: "NR; Physical layer measurements"
- [8] 3GPP TS 38.104: "NR; Base Station (BS) radio transmission and reception"
- [9] void
- [10] 3GPP TS 38.306: "NR; User Equipment (UE) radio access capabilities"
- [11] 3GPP TS 38.321: "NR; Medium Access Control (MAC) protocol specification"
- [12] 3GPP TS 38.133: "NR; Requirements for support of radio resource management"
- [13] 3GPP TS 38.304: "NR; User Equipment (UE) procedures in Idle mode and RRC Inactive state"
- [14] 3GPP TS 38.101-1: "NR; User Equipment (UE) radio transmission and reception; Part 1: Range 1 Standalone"
- [15] 3GPP TS 38.101-2: "NR; User Equipment (UE) radio transmission and reception; Part 2: Range 2 Standalone"
- [16] 3GPP TS 38.101-5: "NR; User Equipment (UE) radio transmission and reception; Part 5: Satellite access Radio Frequency (RF) and performance requirements"
- [17] 3GPP TS 38.108: "Satellite Access Node radio transmission and reception"

3 Definitions of terms, symbols and abbreviations

3.1 Terms

For the purposes of the present document, the following definitions apply:

3.2 Symbols

For the purposes of the present document, the following symbols apply:

| | |
|---|---|
| $(k,l)_{p,\mu}$ | Resource element with frequency-domain index k and time-domain index l for antenna port p and subcarrier spacing configuration μ ; see clause 4.4.3 |
| $a_{k,l}^{(p,\mu)}$ | Value of resource element (k,l) for antenna port p and subcarrier spacing configuration μ ; see clause 4.4.3 |
| β | Amplitude scaling for a physical channel/signal |
| $c(n)$ | PN sequence; see clause 5.2.1 |
| Δf | Subcarrier spacing |
| Δf_{RA}^f | Subcarrier spacing for random-access preambles |
| κ | The ratio between T_s and T_c ; see clause 4.1 |
| k | Subcarrier index relative to a reference |
| l | OFDM symbol index relative to a reference |
| μ | Subcarrier spacing configuration, $\Delta f = 2^\mu \cdot 15$ [kHz] |
| $M_{\text{bit}}^{(q)}$ | Number of coded bits to transmit on a physical channel [for codeword q] |
| $M_{\text{symb}}^{(q)}$ | Number of modulation symbols to transmit on a physical channel [for codeword q] |
| $M_{\text{symb}}^{\text{layer}}$ | Number of modulation symbols to transmit per layer for a physical channel |
| $M_{\text{sc}}^{\text{PUSCH}}$ | Scheduled bandwidth for uplink transmission, expressed as a number of subcarriers |
| $M_{\text{RB}}^{\text{PUSCH}}$ | Scheduled bandwidth for uplink transmission, expressed as a number of resource blocks |
| $M_{\text{symb}}^{\text{ap}}$ | Number of modulation symbols to transmit per antenna port for a physical channel |
| ν | Number of transmission layers |
| $N_{\text{BWP},i}^{\text{size}}$ | Size of bandwidth part i ; see clause 4.4.4.4 |
| $N_{\text{BWP},i}^{\text{start}}$ | Start of bandwidth part i ; see clause 4.4.4.4 |
| $N_{\text{CP},l}^\mu$ | Cyclic prefix length; see clause 5.3.1 |
| $N_{\text{grid},x}^{\text{size},\mu}$ | The size of the resource grid; see clauses 4.4.2 and 5.3 |
| $N_{\text{grid},x}^{\text{start},\mu}$ | The start of the resource grid; see clause 4.4.2 |
| $N_{\text{group}}^{\text{PT-RS}}$ | The number of PT-RS groups; see clause 6.3.1.4 |
| $N_{\text{ID}}^{\text{cell}}$ | Physical layer cell identity; see clause 7.4.2.1 |
| $N_{\text{ID}}^{\text{SL}}$ | Physical-layer sidelink identity; see clause 8.4.2.1 |
| $N_{\text{RB}}^{\text{CORESET}}$ | Frequency-domain size of a control resource set; see clause 7.3.2.2 |
| $N_{\text{REG}}^{\text{CORESET}}$ | Number of resource-element groups in a CORESET; see clause 7.3.2.2 |
| $N_{\text{samp}}^{\text{group}}$ | Number of samples per PT-RS group; see clause 6.3.1.4 |
| $N_{\text{sc}}^{\text{RB}}$ | Number of subcarriers per resource block, see clause 4.4.4.1 |
| $N_{\text{slot}}^{\text{subframe},\mu}$ | Number of slots per subframe for subcarrier spacing configuration μ , see clause 4.3.2 |
| $N_{\text{slot}}^{\text{frame},\mu}$ | Number of slots per frame for subcarrier spacing configuration μ , see clause 4.3.2 |
| $N_{\text{symb}}^{\text{CORESET}}$ | Time duration of a control resource set; see clause 7.3.2.2 |
| $N_{\text{symb}}^{\text{PUCCH}}$ | Length of the PUCCH transmission in OFDM symbols; see clause 6.3.2.1 |
| $N_{\text{symb}}^{\text{subframe},\mu}$ | Number of OFDM symbols per subframe for subcarrier spacing configuration μ ; see clause 4.3.1 |
| $N_{\text{symb}}^{\text{slot}}$ | Number of symbols per slot |
| N_{TA} | Timing advance between downlink and uplink; see clause 4.3.1 |
| $N_{\text{TA,offset}}$ | A fixed offset used to calculate the timing advance; see clause 4.3.1 |
| $N_{\text{TA,adj}}^{\text{common}}$ | Network-controlled timing correction; see clause 4.3.1 |
| $N_{\text{TA,adj}}^{\text{UE}}$ | UE-derived timing correction; see clause 4.3.1 |
| $N_{\text{Rx-Tx}}$ | Minimum time from reception to transmission for a half-duplex UE; see clause 4.3.2 |
| n_f | System frame number (SFN) |
| n_{CRB}^μ | Common resource block number for subcarrier spacing configuration μ , see clause 4.4.4.3 |
| n_{HFN} | Hyper-frame number |
| n_{PRB} | Physical resource block number; see clause 4.4.4.4 |
| n_{RNTI} | Radio network temporary identifier |
| n_s^μ | Slot number within a subframe for subcarrier spacing configuration μ ; see clause 4.3.2 |
| $n_{s,f}^\mu$ | Slot number within a frame for subcarrier spacing configuration μ ; see clause 4.3.2 |
| p | Antenna port number |
| Q_m | Modulation order |

| | |
|--------------------------------|---|
| ρ | Number of antenna ports |
| $\bar{r}_{u,v}(n)$ | Low-PAPR base sequence; see clause 5.2.2 |
| $r_{u,v}^{(\alpha,\delta)}(n)$ | Low-PAPR sequence; see clause 5.2.2 |
| $s_l^{(p,\mu)}(t)$ | The time-continuous signal on antenna port p and subcarrier spacing configuration μ for OFDM symbol l in a subframe; see clause 5.3.1 |
| T_c | Basic time unit for NR; see clause 4.1 |
| T_f | Radio frame duration; see clause 4.3.1 |
| T_s | Basic time unit for LTE |
| T_{sf} | Subframe duration; see clause 4.3.1 |
| T_{slot} | Slot duration; see clause 4.3.2 |
| T_{TA} | Timing advance between downlink and uplink; see clause 4.3.1 |
| W | Precoding matrix for spatial multiplexing |

3.3 Abbreviations

For the purposes of the present document, the following abbreviations apply:

| | |
|---------|---|
| BWP | Bandwidth Part |
| CCE | Control Channel Element |
| CORESET | Control Resource Set |
| CRB | Common Resource Block |
| CSI | Channel-State Information |
| CSI-RS | CSI Reference Signal |
| DCI | Downlink Control Information |
| DM-RS | Demodulation Reference Signal |
| FR1 | Frequency Range 1 as defined in TS 38.104 [8] |
| FR2 | Frequency Range 2 as defined in TS 38.104 [8] |
| FR2-NTN | Frequency Range 2 for Non-terrestrial networks as defined in TS 38.101-5 [16] |
| IAB | Integrated Access and Backhaul |
| IAB-MT | IAB Mobile Termination |
| IE | Information Element |
| NCR | Network-Controlled repeater |
| NCR-MT | NCR Mobile Termination |
| PBCH | Physical Broadcast Channel |
| PDCCH | Physical Downlink Control Channel |
| PDSCH | Physical Downlink Shared Channel |
| PRACH | Physical Random-Access Channel |
| PRB | Physical Resource Block |
| PSS | Primary Synchronization Signal |
| PT-RS | Phase-tracking reference signal |
| PUCCH | Physical Uplink Control Channel |
| PUSCH | Physical Uplink Shared Channel |
| RAR | Random Access Response |
| REG | Resource-Element Group |
| RIM | Remote Interference Management |
| RIM-RS | Remote Interference Management Reference Signal |
| SRS | Sounding Reference Signal |
| SSS | Secondary Synchronization Signal |
| VRB | Virtual Resource Block |

4 Frame structure and physical resources

4.1 General

Throughout this specification, unless otherwise noted, the size of various fields in the time domain is expressed in time units $T_c = 1/(\Delta f_{\max} \cdot N_f)$ where $\Delta f_{\max} = 480 \cdot 10^3$ Hz and $N_f = 4096$. The constant $\kappa = T_s/T_c = 64$ where $T_s = 1/(\Delta f_{\text{ref}} \cdot N_{f,\text{ref}})$, $\Delta f_{\text{ref}} = 15 \cdot 10^3$ Hz and $N_{f,\text{ref}} = 2048$.

Throughout this specification, unless otherwise noted, statements using the term "UE" in clauses 4, 5, 6, or 7 are equally applicable to the IAB-MT part of an IAB-node and the NCR-MT part of an NCR node.

4.2 Numerologies

Multiple OFDM numerologies are supported as given by Table 4.2-1 where μ and the cyclic prefix for a downlink or uplink bandwidth part are obtained from the higher-layer parameters *subcarrierSpacing* and *cyclicPrefix*, respectively.

Table 4.2-1: Supported transmission numerologies.

| μ | $\Delta f = 2^\mu \cdot 15$ [kHz] | Cyclic prefix |
|-------|-----------------------------------|------------------|
| 0 | 15 | Normal |
| 1 | 30 | Normal |
| 2 | 60 | Normal, Extended |
| 3 | 120 | Normal |
| 4 | 240 | Normal |
| 5 | 480 | Normal |
| 6 | 960 | Normal |

4.3 Frame structure

4.3.1 Frames and subframes

Downlink, uplink, and sidelink transmissions are organized into frames with $T_f = (\Delta f_{\max} N_f / 100) \cdot T_c = 10$ ms duration, each consisting of ten subframes of $T_{sf} = (\Delta f_{\max} N_f / 1000) \cdot T_c = 1$ ms duration. The number of consecutive OFDM symbols per subframe is $N_{\text{symb}}^{\text{subframe},\mu} = N_{\text{symb}}^{\text{slot}} N_{\text{slot}}^{\text{subframe},\mu}$. Each frame is divided into two equally-sized half-frames of five subframes each with half-frame 0 consisting of subframes 0 – 4 and half-frame 1 consisting of subframes 5 – 9.

There is one set of frames in the uplink and one set of frames in the downlink on a carrier.

Uplink frame number i for transmission from the UE shall start $T_{TA} = (N_{TA} + N_{TA,\text{offset}} + N_{TA,\text{adj}}^{\text{common}} + N_{TA,\text{adj}}^{\text{UE}}) T_c$ before the start of the corresponding downlink frame at the UE where

- N_{TA} and $N_{TA,\text{offset}}$ are given by clause 4.2 of [5, TS 38.213], except for msgA transmission on PUSCH where $N_{TA} = 0$ shall be used;
- $N_{TA,\text{adj}}^{\text{common}}$ given by clause 4.2 of [5, TS 38.213] is derived from the higher-layer parameters *ta-Common*, *ta-CommonDrift*, and *ta-CommonDriftVariant* if configured, otherwise $N_{TA,\text{adj}}^{\text{common}} = 0$;
- $N_{TA,\text{adj}}^{\text{UE}}$ given by clause 4.2 of [5, TS 38.213] is computed by the UE based on UE position and serving-satellite-ephemeris-related higher-layers parameters if configured, or is computed by the UE based on UE position and gNB location provided by *atg-gNB-Location* if configured, otherwise $N_{TA,\text{adj}}^{\text{UE}} = 0$.

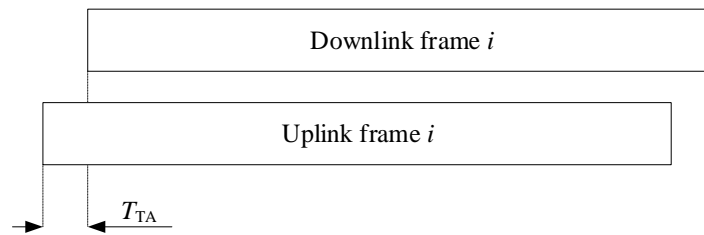


Figure 4.3.1-1: Uplink-downlink timing relation.

4.3.2 Slots

For subcarrier spacing configuration μ , slots are numbered $n_s^\mu \in \{0, \dots, N_{\text{slot}}^{\text{subframe}, \mu} - 1\}$ in increasing order within a subframe and $n_{s,f}^\mu \in \{0, \dots, N_{\text{slot}}^{\text{frame}, \mu} - 1\}$ in increasing order within a frame. There are $N_{\text{symbol}}^{\text{slot}}$ consecutive OFDM symbols in a slot where $N_{\text{symbol}}^{\text{slot}}$ depends on the cyclic prefix as given by Tables 4.3.2-1 and 4.3.2-2. The start of slot n_s^μ in a subframe is aligned in time with the start of OFDM symbol $n_s^\mu N_{\text{symbol}}^{\text{slot}}$ in the same subframe.

OFDM symbols in a slot in a downlink or uplink frame can be classified as 'downlink', 'flexible', or 'uplink'. Signaling of slot formats is described in clause 11.1 of [5, TS 38.213].

In a slot in a downlink frame, the UE shall assume that downlink transmissions only occur in 'downlink' or 'flexible' symbols.

In a slot in an uplink frame, the UE shall only transmit in 'uplink' or 'flexible' symbols.

A UE not capable of full-duplex communication and not supporting simultaneous transmission and reception as defined by parameter *simultaneousRxTxInterBandENDC*, *simultaneousRxTxInterBandCA* or *simultaneousRxTxSUL* [10, TS 38.306] among all cells within a group of cells is not expected to transmit in the uplink in one cell within the group of cells earlier than $N_{\text{Rx-Tx}} T_c$ after the end of the last received downlink symbol in the same or different cell within the group of cells where $N_{\text{Rx-Tx}}$ is given by Table 4.3.2-3.

A UE not capable of full-duplex communication and not supporting simultaneous transmission and reception as defined by parameter *simultaneousRxTxInterBandENDC*, *simultaneousRxTxInterBandCA* or *simultaneousRxTxSUL* [10, TS 38.306] among all cells within a group of cells is not expected to receive in the downlink in one cell within the group of cells earlier than $N_{\text{Tx-Rx}} T_c$ after the end of the last transmitted uplink symbol in the same or different cell within the group of cells where $N_{\text{Tx-Rx}}$ is given by Table 4.3.2-3.

For DAPS handover operation, a UE not capable of full-duplex communication is not expected to transmit in the uplink to a cell earlier than $N_{\text{Rx-Tx}} T_c$ after the end of the last received downlink symbol in the different cell where $N_{\text{Rx-Tx}}$ is given by Table 4.3.2-3.

For DAPS handover operation, a UE not capable of full-duplex communication is not expected to receive in the downlink from a cell earlier than $N_{\text{Tx-Rx}} T_c$ after the end of the last transmitted uplink symbol in the different cell where $N_{\text{Tx-Rx}}$ is given by Table 4.3.2-3.

A UE not capable of full-duplex communication is not expected to transmit in the uplink earlier than $N_{\text{Rx-Tx}} T_c$ after the end of the last received downlink symbol in the same cell where $N_{\text{Rx-Tx}}$ is given by Table 4.3.2-3.

A UE not capable of full-duplex communication is not expected to receive in the downlink earlier than $N_{\text{Tx-Rx}} T_c$ after the end of the last transmitted uplink symbol in the same cell where $N_{\text{Tx-Rx}}$ is given by Table 4.3.2-3.

Table 4.3.2-1: Number of OFDM symbols per slot, slots per frame, and slots per subframe for normal cyclic prefix.

| μ | $N_{\text{symb}}^{\text{slot}}$ | $N_{\text{slot}}^{\text{frame},\mu}$ | $N_{\text{slot}}^{\text{subframe},\mu}$ |
|-------|---------------------------------|--------------------------------------|---|
| 0 | 14 | 10 | 1 |
| 1 | 14 | 20 | 2 |
| 2 | 14 | 40 | 4 |
| 3 | 14 | 80 | 8 |
| 4 | 14 | 160 | 16 |
| 5 | 14 | 320 | 32 |
| 6 | 14 | 640 | 64 |

Table 4.3.2-2: Number of OFDM symbols per slot, slots per frame, and slots per subframe for extended cyclic prefix.

| μ | $N_{\text{symb}}^{\text{slot}}$ | $N_{\text{slot}}^{\text{frame},\mu}$ | $N_{\text{slot}}^{\text{subframe},\mu}$ |
|-------|---------------------------------|--------------------------------------|---|
| 2 | 12 | 40 | 4 |

Table 4.3.2-3: Transition time $N_{\text{Rx-Tx}}$ and $N_{\text{Tx-Rx}}$

| Transition time | FR1 | FR2 |
|--------------------|-------|-------|
| $N_{\text{Tx-Rx}}$ | 25600 | 13792 |
| $N_{\text{Rx-Tx}}$ | 25600 | 13792 |

4.4 Physical resources

4.4.1 Antenna ports

An antenna port is defined such that the channel over which a symbol on the antenna port is conveyed can be inferred from the channel over which another symbol on the same antenna port is conveyed.

Two antenna ports are said to be quasi co-located if the large-scale properties of the channel over which a symbol on one antenna port is conveyed can be inferred from the channel over which a symbol on the other antenna port is conveyed. The large-scale properties include one or more of delay spread, Doppler spread, Doppler shift, average gain, average delay, and spatial Rx parameters.

4.4.2 Resource grid

For each numerology and carrier, a resource grid of $N_{\text{grid},x}^{\text{size},\mu} N_{\text{sc}}^{\text{RB}}$ subcarriers and $N_{\text{symb}}^{\text{subframe},\mu}$ OFDM symbols is defined, starting at common resource block $N_{\text{grid}}^{\text{start},\mu}$ indicated by higher-layer signalling. There is one set of resource grids per transmission direction (uplink, downlink, or sidelink) with the subscript x set to DL, UL, and SL for downlink, uplink, and sidelink, respectively. When there is no risk for confusion, the subscript x may be dropped. There is one resource grid for a given antenna port p , subcarrier spacing configuration μ , and transmission direction (downlink, uplink, or sidelink).

For uplink and downlink, the carrier bandwidth $N_{\text{grid}}^{\text{size},\mu}$ for subcarrier spacing configuration μ is given by the higher-layer parameter *carrierBandwidth* in the *SCS-SpecificCarrier* IE. The starting position $N_{\text{grid}}^{\text{start},\mu}$ for subcarrier spacing configuration μ is given by the higher-layer parameter *offsetToCarrier* in the *SCS-SpecificCarrier* IE.

The frequency location of a subcarrier refers to the center frequency of that subcarrier.

For the downlink, the higher-layer parameter *txDirectCurrentLocation* in the *SCS-SpecificCarrier* IE indicates the location of the transmitter DC subcarrier in the downlink for each of the numerologies configured in the downlink. Values in the range 0 – 3299 represent the number of the DC subcarrier and the value 3300 indicates that the DC subcarrier is located outside the resource grid.

For the uplink, the higher-layer parameter *txDirectCurrentLocation* in the *UplinkTxDirectCurrentBWP* IE indicates the location of the transmitter DC subcarrier in the uplink for each of the configured bandwidth parts, including whether the DC subcarrier location is offset by 7.5 kHz relative to the center of the indicated subcarrier or not. Values in the range 0 – 3299 represent the number of the DC subcarrier, the value 3300 indicates that the DC subcarrier is located outside the resource grid, and the value 3301 indicates that the position of the DC subcarrier in the uplink is undetermined.

4.4.3 Resource elements

Each element in the resource grid for antenna port p and subcarrier spacing configuration μ is called a resource element and is uniquely identified by $(k, l)_{p,\mu}$ where k is the index in the frequency domain and l refers to the symbol position in the time domain relative to some reference point. Resource element $(k, l)_{p,\mu}$ corresponds to a physical resource and the complex value $a_{k,l}^{(p,\mu)}$. When there is no risk for confusion, or no particular antenna port or subcarrier spacing is specified, the indices p and μ may be dropped, resulting in $a_{k,l}^{(p)}$ or $a_{k,l}$.

4.4.4 Resource blocks

4.4.4.1 General

A resource block is defined as $N_{sc}^{RB} = 12$ consecutive subcarriers in the frequency domain.

4.4.4.2 Point A

Point A serves as a common reference point for resource block grids and is obtained from:

- *offsetToPointA* for a PCell downlink where *offsetToPointA* represents the frequency offset between point A and the lowest subcarrier of the lowest resource block, which overlaps with the SS/PBCH block, or the SS/PBCH block after puncturing if applicable, used by the UE for initial cell selection, expressed in units of resource blocks assuming 15 kHz subcarrier spacing for FR1 and 60 kHz subcarrier spacing for FR2 and FR2-NTN;
- for operation without shared spectrum channel access in FR1, FR2-1 and FR2-NTN, the lowest resource block has the subcarrier spacing provided by the higher layer parameter *subCarrierSpacingCommon*;
- for operation with shared spectrum channel access in FR1 or FR2, and for operation without shared spectrum channel access in FR2-2, the lowest resource block has the subcarrier spacing same as the SS/PBCH block used by the UE for initial cell selection;
- *absoluteFrequencyPointA* for all other cases where *absoluteFrequencyPointA* represents the frequency-location of point A expressed as in ARFCN.

4.4.4.3 Common resource blocks

Common resource blocks are numbered from 0 and upwards in the frequency domain for subcarrier spacing configuration μ . The center of subcarrier 0 of common resource block 0 for subcarrier spacing configuration μ coincides with 'point A'.

The relation between the common resource block number n_{CRB}^{μ} in the frequency domain and resource elements (k, l) for subcarrier spacing configuration μ is given by

$$n_{CRB}^{\mu} = \left\lfloor \frac{k}{N_{sc}^{RB}} \right\rfloor$$

where k is defined relative to point A such that $k = 0$ corresponds to the subcarrier centered around point A.

4.4.4.4 Physical resource blocks

Physical resource blocks for subcarrier spacing configuration μ are defined within a bandwidth part and numbered from 0 to $N_{BWP,i}^{size,\mu} - 1$ where i is the number of the bandwidth part. The relation between the physical resource block n_{PRB}^{μ} in bandwidth part i and the common resource block n_{CRB}^{μ} is given by

$$n_{\text{CRB}}^{\mu} = n_{\text{PRB}}^{\mu} + N_{\text{BWP},i}^{\text{start},\mu}$$

where $N_{\text{BWP},i}^{\text{start},\mu}$ is the common resource block where bandwidth part i starts relative to common resource block 0. When there is no risk for confusion the index μ may be dropped.

4.4.4.5 Virtual resource blocks

Virtual resource blocks are defined within a bandwidth part and numbered from 0 to $N_{\text{BWP},i}^{\text{size}} - 1$ where i is the number of the bandwidth part.

4.4.4.6 Interlaced resource blocks

Multiple interlaces of resource blocks are defined where interlace $m \in \{0, 1, \dots, M - 1\}$ consists of common resource blocks $\{m, M + m, 2M + m, 3M + m, \dots\}$, with M being the number of interlaces given by Table 4.4.4.6-1. The relation between the interlaced resource block $n_{\text{IRB},m}^{\mu} \in \{0, 1, \dots\}$ in bandwidth part i and interlace m and the common resource block n_{CRB}^{μ} is given by

$$n_{\text{CRB}}^{\mu} = Mn_{\text{IRB},m}^{\mu} + N_{\text{BWP},i}^{\text{start},\mu} + \left((m - N_{\text{BWP},i}^{\text{start},\mu}) \bmod M \right)$$

where $N_{\text{BWP},i}^{\text{start},\mu}$ is the common resource block where bandwidth part starts relative to common resource block 0. When there is no risk for confusion the index μ may be dropped.

The UE expects that the number of common resource blocks in an interlace contained within bandwidth part i is no less than 10.

Table 4.4.4.6-1: The number of resource block interlaces.

| μ | M |
|-------|-----|
| 0 | 10 |
| 1 | 5 |

4.4.5 Bandwidth part

A bandwidth part is a subset of contiguous common resource blocks defined in clause 4.4.4.3 for a given numerology μ_i in bandwidth part i on a given carrier. The starting position $N_{\text{BWP},i}^{\text{start},\mu}$ and the number of resource blocks $N_{\text{BWP},i}^{\text{size},\mu}$ in a bandwidth part shall fulfil $N_{\text{grid},x}^{\text{start},\mu} \leq N_{\text{BWP},i}^{\text{start},\mu} < N_{\text{grid},x}^{\text{start},\mu} + N_{\text{grid},x}^{\text{size},\mu}$ and $N_{\text{grid},x}^{\text{start},\mu} < N_{\text{BWP},i}^{\text{start},\mu} + N_{\text{BWP},i}^{\text{size},\mu} \leq N_{\text{grid},x}^{\text{start},\mu} + N_{\text{grid},x}^{\text{size},\mu}$, respectively. Configuration of a bandwidth part is described in clause 12 of [5, TS 38.213].

A UE can be configured with up to four bandwidth parts in the downlink with a single downlink bandwidth part being active at a given time. The UE is not expected to receive PDSCH, PDCCH, or CSI-RS (except for RRM) outside an active bandwidth part.

A UE can be configured with up to four bandwidth parts in the uplink with a single uplink bandwidth part being active at a given time. If a UE is configured with a supplementary uplink, the UE can in addition be configured with up to four bandwidth parts in the supplementary uplink with a single supplementary uplink bandwidth part being active at a given time. The UE shall not transmit PUSCH or PUCCH outside an active bandwidth part. For an active cell, the UE shall not transmit SRS configured by *SRS-Resource* outside an active bandwidth part.

Unless otherwise noted, the description in this specification applies to each of the bandwidth parts. When there is no risk of confusion, the index μ may be dropped from $N_{\text{BWP},i}^{\text{start},\mu}$, $N_{\text{BWP},i}^{\text{size},\mu}$, $N_{\text{grid},x}^{\text{start},\mu}$, and $N_{\text{grid},x}^{\text{size},\mu}$.

4.4.6 Common MBS frequency resource

A common MBS frequency resource is a contiguous set of common resource blocks. The starting position $N_{\text{MBS},i}^{\text{start},\mu}$ of the common MBS frequency resource i is defined relative to point A and the size of the common MBS frequency resource is given by $N_{\text{MBS},i}^{\text{size},\mu}$. Resource blocks in a common MBS frequency resource are numbered in the same way as resource blocks in clause 4.4.4.4 with $N_{\text{BWP},i}^{\text{start},\mu}$ and $N_{\text{BWP},i}^{\text{size},\mu}$ replaced by $N_{\text{MBS},i}^{\text{start},\mu}$ and $N_{\text{MBS},i}^{\text{size},\mu}$, respectively.

A UE is not expected to receive PDSCH or PDCCH associated with MBS transmissions scheduled with G-RNTI, G-CS-RNTI, MCCH-RNTI, or Multicast-MCCH-RNTI outside the common MBS frequency resource.

4.5 Carrier aggregation

Transmissions in multiple cells can be aggregated. Unless otherwise noted, the description in this specification applies to each of the serving cells.

For carrier aggregation of cells with unaligned frame boundaries, the slot offset $N_{\text{slot, offset}}^{\text{CA}}$ between a PCell/PSCell and an SCell is determined by higher-layer parameter *ca-SlotOffset* for the SCell. The quantity μ_{offset} is defined as the maximum of the lowest subcarrier spacing configuration among the subcarrier spacings given by the higher-layer parameters *scs-SpecificCarrierList* configured for PCell/PSCell and the SCell, respectively. The slot offset $N_{\text{slot, offset}}^{\text{CA}}$ fulfills

- when the lowest subcarrier spacing configuration among the subcarrier spacings configured for the cell is $\mu = 2$ for both cells or $\mu = 3$ for both cells, the start of slot 0 for the cell whose point A has a lower frequency coincides with the start of slot $q N_{\text{slot, offset}}^{\text{CA}} \bmod N_{\text{slot}}^{\text{frame}, \mu_{\text{offset}}}$ for the other cell where $q = -1$ if point A of the PCell/PSCell has a frequency lower than the frequency of point A for the SCell, otherwise $q = 1$;
- otherwise, the start of slot 0 for the cell with the lower subcarrier spacing of the lowest subcarrier spacing given by the higher-layer parameters *scs-SpecificCarrierList* configured for the two cells, or the Pcell/PSCell if both cells have the same lowest subcarrier spacing given by the higher-layer parameters *scs-SpecificCarrierList* configured for the two cells, coincides with the start of slot $q N_{\text{slot, offset}}^{\text{CA}} \bmod N_{\text{slot}}^{\text{frame}, \mu_{\text{offset}}}$ for the other cell where $q = -1$ if the lowest subcarrier spacing configuration given by *scs-SpecificCarrierList* of the PCell/PSCell is smaller than or equal to the lowest subcarrier spacing given by *scs-SpecificCarrierList* for the SCell, otherwise $q = 1$.

5 Generic functions

5.1 Modulation mapper

The modulation mapper takes binary digits, 0 or 1, as input and produces complex-valued modulation symbols as output.

5.1.1 $\pi/2$ -BPSK

In case of $\pi/2$ -BPSK modulation, bit $b(i)$ is mapped to complex-valued modulation symbol $d(i)$ according to

$$d(i) = \frac{e^{j\frac{\pi}{2}(i \bmod 2)}}{\sqrt{2}} [(1 - 2b(i)) + j(1 - 2b(i))]$$

5.1.2 BPSK

In case of BPSK modulation, bit $b(i)$ is mapped to complex-valued modulation symbol $d(i)$ according to

$$d(i) = \frac{1}{\sqrt{2}} [(1 - 2b(i)) + j(1 - 2b(i))]$$

5.1.3 QPSK

In case of QPSK modulation, pairs of bits, $b(2i), b(2i+1)$, are mapped to complex-valued modulation symbols $d(i)$ according to

$$d(i) = \frac{1}{\sqrt{2}} \left[(1 - 2b(2i)) + j(1 - 2b(2i+1)) \right]$$

5.1.4 16QAM

In case of 16QAM modulation, quadruplets of bits, $b(4i), b(4i+1), b(4i+2), b(4i+3)$, are mapped to complex-valued modulation symbols $d(i)$ according to

$$d(i) = \frac{1}{\sqrt{10}} \left\{ (1 - 2b(4i)) \left[2 - (1 - 2b(4i+2)) \right] + j(1 - 2b(4i+1)) \left[2 - (1 - 2b(4i+3)) \right] \right\}$$

5.1.5 64QAM

In case of 64QAM modulation, hexuplets of bits, $b(6i), b(6i+1), b(6i+2), b(6i+3), b(6i+4), b(6i+5)$, are mapped to complex-valued modulation symbols $d(i)$ according to

$$d(i) = \frac{1}{\sqrt{42}} \left\{ (1 - 2b(6i)) \left[4 - (1 - 2b(6i+2)) \left[2 - (1 - 2b(6i+4)) \right] \right] + j(1 - 2b(6i+1)) \left[4 - (1 - 2b(6i+3)) \left[2 - (1 - 2b(6i+5)) \right] \right] \right\}$$

5.1.6 256QAM

In case of 256QAM modulation, octuplets of bits, $b(8i), b(8i+1), b(8i+2), b(8i+3), b(8i+4), b(8i+5), b(8i+6), b(8i+7)$, are mapped to complex-valued modulation symbols $d(i)$ according to

$$d(i) = \frac{1}{\sqrt{170}} \left\{ (1 - 2b(8i)) \left[8 - (1 - 2b(8i+2)) \left[4 - (1 - 2b(8i+4)) \left[2 - (1 - 2b(8i+6)) \right] \right] \right] \right. \\ \left. + j(1 - 2b(8i+1)) \left[8 - (1 - 2b(8i+3)) \left[4 - (1 - 2b(8i+5)) \left[2 - (1 - 2b(8i+7)) \right] \right] \right] \right\}$$

5.1.7 1024QAM

In case of 1024QAM modulation, 10-tuplets of bits, $b(10i), b(10i+1), b(10i+2), b(10i+3), b(10i+4), b(10i+5), b(10i+6), b(10i+7), b(10i+8), b(10i+9)$, are mapped to complex-valued modulation symbols $d(i)$ according to

$$d(i) = \\ \frac{1}{\sqrt{682}} (1 - 2b(10i+0)) \left[16 - (1 - 2b(10i+2)) \left[8 - (1 - 2b(10i+4)) \left[4 - (1 - 2b(10i+6)) \left[2 - (1 - 2b(10i+8)) \right] \right] \right] \right. \\ \left. + j \frac{1}{\sqrt{682}} (1 - 2b(10i+1)) \left[16 - (1 - 2b(10i+3)) \left[8 - (1 - 2b(10i+5)) \left[4 - (1 - 2b(10i+7)) \left[2 - (1 - 2b(10i+9)) \right] \right] \right] \right] \right]$$

5.2 Sequence generation

5.2.1 Pseudo-random sequence generation

Generic pseudo-random sequences are defined by a length-31 Gold sequence. The output sequence $c(n)$ of length M_{PN} , where $n = 0, 1, \dots, M_{\text{PN}} - 1$, is defined by

$$\begin{aligned}
c(n) &= (x_1(n + N_C) + x_2(n + N_C)) \bmod 2 \\
x_1(n + 31) &= (x_1(n + 3) + x_1(n)) \bmod 2 \\
x_2(n + 31) &= (x_2(n + 3) + x_2(n + 2) + x_2(n + 1) + x_2(n)) \bmod 2
\end{aligned}$$

where $N_C = 1600$ and the first m-sequence $x_1(n)$ shall be initialized with $x_1(0) = 1, x_1(n) = 0, n = 1, 2, \dots, 30$. The initialization of the second m-sequence, $x_2(n)$, is denoted by $c_{\text{init}} = \sum_{i=0}^{30} x_2(i) \cdot 2^i$ with the value depending on the application of the sequence.

5.2.2 Low-PAPR sequence generation type 1

The low-PAPR sequence $r_{u,v}^{(\alpha,\delta)}(n)$ is defined by a cyclic shift α of a base sequence $\bar{r}_{u,v}(n)$ according to

$$r_{u,v}^{(\alpha,\delta)}(n) = e^{j\alpha n} \bar{r}_{u,v}(n), \quad 0 \leq n < M_{\text{ZC}}$$

where $M_{\text{ZC}} = mN_{\text{sc}}^{\text{RB}}/2^\delta$ is the length of the sequence. Multiple sequences are defined from a single base sequence through different values of α and δ .

Base sequences $\bar{r}_{u,v}(n)$ are divided into groups, where $u \in \{0, 1, \dots, 29\}$ is the group number and v is the base sequence number within the group, such that each group contains one base sequence ($v = 0$) of each length $M_{\text{ZC}} = mN_{\text{sc}}^{\text{RB}}/2^\delta$, $1/2 \leq m/2^\delta \leq 5$ and two base sequences ($v = 0, 1$) of each length $M_{\text{ZC}} = mN_{\text{sc}}^{\text{RB}}/2^\delta$, $6 \leq m/2^\delta$. The definition of the base sequence $\bar{r}_{u,v}(0), \dots, \bar{r}_{u,v}(M_{\text{ZC}} - 1)$ depends on the sequence length M_{ZC} .

5.2.2.1 Base sequences of length 36 or larger

For $M_{\text{ZC}} \geq 3N_{\text{sc}}^{\text{RB}}$, the base sequence $\bar{r}_{u,v}(0), \dots, \bar{r}_{u,v}(M_{\text{ZC}} - 1)$ is given by

$$\begin{aligned}
\bar{r}_{u,v}(n) &= x_q(n \bmod N_{\text{ZC}}) \\
x_q(m) &= e^{-j \frac{\pi q m(m+1)}{N_{\text{ZC}}}}
\end{aligned}$$

where

$$\begin{aligned}
q &= \lfloor \bar{q} + 1/2 \rfloor + v \cdot (-1)^{\lfloor 2\bar{q} \rfloor} \\
\bar{q} &= N_{\text{ZC}} \cdot (u + 1) / 31
\end{aligned}$$

The length N_{ZC} is given by the largest prime number such that $N_{\text{ZC}} < M_{\text{ZC}}$.

5.2.2.2 Base sequences of length less than 36

For $M_{\text{ZC}} \in \{6, 12, 18, 24\}$ the base sequence is given by

$$\bar{r}_{u,v}(n) = e^{j\varphi(n)\pi/4}, \quad 0 \leq n \leq M_{\text{ZC}} - 1$$

where the value of $\varphi(n)$ is given by Tables 5.2.2.2-1 to 5.2.2.2-4.

For $M_{\text{ZC}} = 30$, the base sequence $\bar{r}_{u,v}(0), \dots, \bar{r}_{u,v}(M_{\text{ZC}} - 1)$ is given by

$$\bar{r}_{u,v}(n) = e^{-j \frac{\pi(u+1)(n+1)(n+2)}{31}}, \quad 0 \leq n \leq M_{\text{ZC}} - 1$$

Table 5.2.2.2-1: Definition of $\varphi(n)$ for $M_{ZC} = 6$.

| u | $\varphi(0), \dots, \varphi(5)$ | | | | | |
|-----|---------------------------------|----|----|----|----|----|
| 0 | -3 | -1 | 3 | 3 | -1 | -3 |
| 1 | -3 | 3 | -1 | -1 | 3 | -3 |
| 2 | -3 | -3 | -3 | 3 | 1 | -3 |
| 3 | 1 | 1 | 1 | 3 | -1 | -3 |
| 4 | 1 | 1 | 1 | -3 | -1 | 3 |
| 5 | -3 | 1 | -1 | -3 | -3 | -3 |
| 6 | -3 | 1 | 3 | -3 | -3 | -3 |
| 7 | -3 | -1 | 1 | -3 | 1 | -1 |
| 8 | -3 | -1 | -3 | 1 | -3 | -3 |
| 9 | -3 | -3 | 1 | -3 | 3 | -3 |
| 10 | -3 | 1 | 3 | 1 | -3 | -3 |
| 11 | -3 | -1 | -3 | 1 | 1 | -3 |
| 12 | 1 | 1 | 3 | -1 | -3 | 3 |
| 13 | 1 | 1 | 3 | 3 | -1 | 3 |
| 14 | 1 | 1 | 1 | -3 | 3 | -1 |
| 15 | 1 | 1 | 1 | -1 | 3 | -3 |
| 16 | -3 | -1 | -1 | -1 | 3 | -1 |
| 17 | -3 | -3 | -1 | 1 | -1 | -3 |
| 18 | -3 | -3 | -3 | 1 | -3 | -1 |
| 19 | -3 | 1 | 1 | -3 | -1 | -3 |
| 20 | -3 | 3 | -3 | 1 | 1 | -3 |
| 21 | -3 | 1 | -3 | -3 | -3 | -1 |
| 22 | 1 | 1 | -3 | 3 | 1 | 3 |
| 23 | 1 | 1 | -3 | -3 | 1 | -3 |
| 24 | 1 | 1 | 3 | -1 | 3 | 3 |
| 25 | 1 | 1 | -3 | 1 | 3 | 3 |
| 26 | 1 | 1 | -1 | -1 | 3 | -1 |
| 27 | 1 | 1 | -1 | 3 | -1 | -1 |
| 28 | 1 | 1 | -1 | 3 | -3 | -1 |
| 29 | 1 | 1 | -3 | 1 | -1 | -1 |

Table 5.2.2.2-2: Definition of $\varphi(n)$ for $M_{ZC} = 12$.

| u | $\varphi(0), \dots, \varphi(11)$ | | | | | | | | | | | |
|-----|----------------------------------|----|----|----|----|----|----|----|----|----|----|----|
| 0 | -3 | 1 | -3 | -3 | -3 | 3 | -3 | -1 | 1 | 1 | 1 | -3 |
| 1 | -3 | 3 | 1 | -3 | 1 | 3 | -1 | -1 | 1 | 3 | 3 | 3 |
| 2 | -3 | 3 | 3 | 1 | -3 | 3 | -1 | 1 | 3 | -3 | 3 | -3 |
| 3 | -3 | -3 | -1 | 3 | 3 | 3 | -3 | 3 | -3 | 1 | -1 | -3 |
| 4 | -3 | -1 | -1 | 1 | 3 | 1 | 1 | -1 | 1 | -1 | -3 | 1 |
| 5 | -3 | -3 | 3 | 1 | -3 | -3 | -3 | -1 | 3 | -1 | 1 | 3 |
| 6 | 1 | -1 | 3 | -1 | -1 | -1 | -3 | -1 | 1 | 1 | 1 | -3 |
| 7 | -1 | -3 | 3 | -1 | -3 | -3 | -3 | -1 | 1 | -1 | 1 | -3 |
| 8 | -3 | -1 | 3 | 1 | -3 | -1 | -3 | 3 | 1 | 3 | 3 | 1 |
| 9 | -3 | -1 | -1 | -3 | -3 | -1 | -3 | 3 | 1 | 3 | -1 | -3 |
| 10 | -3 | 3 | -3 | 3 | 3 | -3 | -1 | -1 | 3 | 3 | 1 | -3 |
| 11 | -3 | -1 | -3 | -1 | -1 | -3 | 3 | 3 | -1 | -1 | 1 | -3 |
| 12 | -3 | -1 | 3 | -3 | -3 | -1 | -3 | 1 | -1 | -3 | 3 | 3 |
| 13 | -3 | 1 | -1 | -1 | 3 | 3 | -3 | -1 | -1 | -3 | -1 | -3 |
| 14 | 1 | 3 | -3 | 1 | 3 | 3 | 3 | 1 | -1 | 1 | -1 | 3 |
| 15 | -3 | 1 | 3 | -1 | -1 | -3 | -3 | -1 | -1 | 3 | 1 | -3 |
| 16 | -1 | -1 | -1 | -1 | 1 | -3 | -1 | 3 | 3 | -1 | -3 | 1 |
| 17 | -1 | 1 | 1 | -1 | 1 | 3 | 3 | -1 | -1 | -3 | 1 | -3 |
| 18 | -3 | 1 | 3 | 3 | -1 | -1 | -3 | 3 | 3 | -3 | 3 | -3 |
| 19 | -3 | -3 | 3 | -3 | -1 | 3 | 3 | 3 | -1 | -3 | 1 | -3 |
| 20 | 3 | 1 | 3 | 1 | 3 | -3 | -1 | 1 | 3 | 1 | -1 | -3 |
| 21 | -3 | 3 | 1 | 3 | -3 | 1 | 1 | 1 | 1 | 3 | -3 | 3 |
| 22 | -3 | 3 | 3 | 3 | -1 | -3 | -3 | -1 | -3 | 1 | 3 | -3 |
| 23 | 3 | -1 | -3 | 3 | -3 | -1 | 3 | 3 | 3 | -3 | -1 | -3 |
| 24 | -3 | -1 | 1 | -3 | 1 | 3 | 3 | 3 | -1 | -3 | 3 | 3 |
| 25 | -3 | 3 | 1 | -1 | 3 | 3 | -3 | 1 | -1 | 1 | -1 | 1 |
| 26 | -1 | 1 | 3 | -3 | 1 | -1 | 1 | -1 | -1 | -3 | 1 | -1 |
| 27 | -3 | -3 | 3 | 3 | 3 | -3 | -1 | 1 | -3 | 3 | 1 | -3 |
| 28 | 1 | -1 | 3 | 1 | 1 | -1 | -1 | -1 | 1 | 3 | -3 | 1 |
| 29 | -3 | 3 | -3 | 3 | -3 | -3 | 3 | -1 | -1 | 1 | 3 | -3 |

Table 5.2.2.2-3: Definition of $\varphi(n)$ for $M_{ZC} = 18$

| u | $\varphi(0), \dots, \varphi(17)$ | | | | | | | | | | | | | | | | | |
|-----|----------------------------------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0 | -1 | 3 | -1 | -3 | 3 | 1 | -3 | -1 | 3 | -3 | -1 | -1 | 1 | 1 | 1 | -1 | -1 | -1 |
| 1 | 3 | -3 | 3 | -1 | 1 | 3 | -3 | -1 | -3 | -3 | -1 | -3 | 3 | 1 | -1 | 3 | -3 | 3 |
| 2 | -3 | 3 | 1 | -1 | -1 | 3 | -3 | -1 | 1 | 1 | 1 | 1 | 1 | -1 | 3 | -1 | -3 | -1 |
| 3 | -3 | -3 | 3 | 3 | 3 | 1 | -3 | 1 | 3 | 3 | 1 | -3 | -3 | 3 | -1 | -3 | -1 | 1 |
| 4 | 1 | 1 | -1 | -1 | -3 | -1 | 1 | -3 | -3 | -3 | 1 | -3 | -1 | -1 | 1 | -1 | 3 | 1 |
| 5 | 3 | -3 | 1 | 1 | 3 | -1 | 1 | -1 | -1 | -3 | 1 | 1 | -1 | 3 | 3 | -3 | 3 | -1 |
| 6 | -3 | 3 | -1 | 1 | 3 | 1 | -3 | -1 | 1 | 1 | -3 | 1 | 3 | 3 | -1 | -3 | -3 | -3 |
| 7 | 1 | 1 | -3 | 3 | 3 | 1 | 3 | -3 | 3 | -1 | 1 | 1 | -1 | 1 | -3 | -3 | -1 | 3 |
| 8 | -3 | 1 | -3 | -3 | 1 | -3 | -3 | 3 | 1 | -3 | -1 | -3 | -3 | -3 | -1 | 1 | 1 | 3 |
| 9 | 3 | -1 | 3 | 1 | -3 | -3 | -1 | 1 | -3 | -3 | 3 | 3 | 3 | 1 | 3 | -3 | 3 | -3 |
| 10 | -3 | -3 | -3 | 1 | -3 | 3 | 1 | 1 | 3 | -3 | -3 | 1 | 3 | -1 | 3 | -3 | -3 | 3 |
| 11 | -3 | -3 | 3 | 3 | 3 | -1 | -1 | -3 | -1 | -1 | -1 | 3 | 1 | -3 | -3 | -1 | 3 | -1 |
| 12 | -3 | -1 | -3 | -3 | 1 | 1 | -1 | -3 | -1 | -3 | -1 | -1 | 3 | 3 | -1 | 3 | 1 | 3 |
| 13 | 1 | 1 | -3 | -3 | -3 | -3 | 1 | 3 | -3 | 3 | 3 | 1 | -3 | -1 | 3 | -1 | -3 | 1 |
| 14 | -3 | 3 | -1 | -3 | -1 | -3 | 1 | 1 | -3 | -3 | -1 | -1 | 3 | -3 | 1 | 3 | 1 | 1 |
| 15 | 3 | 1 | -3 | 1 | -3 | 3 | 3 | -1 | -3 | -3 | -1 | -3 | -3 | 3 | -3 | -1 | 1 | 3 |
| 16 | -3 | -1 | -3 | -1 | -3 | 1 | 3 | -3 | -1 | 3 | 3 | 3 | 1 | -1 | -3 | 3 | -1 | -3 |
| 17 | -3 | -1 | 3 | 3 | -1 | 3 | -1 | -3 | -1 | 1 | -1 | -3 | -1 | -1 | -1 | 3 | 3 | 1 |
| 18 | -3 | 1 | -3 | -1 | -1 | 3 | 1 | -3 | -3 | -3 | -1 | -3 | -3 | 1 | 1 | 1 | -1 | -1 |
| 19 | 3 | 3 | 3 | -3 | -1 | -3 | -1 | 3 | -1 | 1 | -1 | -3 | 1 | -3 | -3 | -1 | 3 | 3 |
| 20 | -3 | 1 | 1 | -3 | 1 | 1 | 3 | -3 | -1 | -3 | -1 | 3 | -3 | 3 | -1 | -1 | -1 | -3 |
| 21 | 1 | -3 | -1 | -3 | 3 | 3 | -1 | -3 | 1 | -3 | -3 | -1 | -3 | -1 | 1 | 3 | 3 | 3 |
| 22 | -3 | -3 | 1 | -1 | -1 | 1 | 1 | -3 | -1 | 3 | 3 | 3 | 3 | -1 | 3 | 1 | 3 | 1 |
| 23 | 3 | -1 | -3 | 1 | -3 | -3 | -3 | 3 | 3 | -1 | 1 | -3 | -1 | 3 | 1 | 1 | 3 | 3 |
| 24 | 3 | -1 | -1 | 1 | -3 | -1 | -3 | -1 | -3 | -3 | -1 | -3 | 1 | 1 | 1 | -3 | -3 | 3 |
| 25 | -3 | -3 | 1 | -3 | 3 | 3 | 3 | -1 | 3 | 1 | 1 | -3 | -3 | -3 | 3 | -3 | -1 | -1 |
| 26 | -3 | -1 | -1 | -3 | 1 | -3 | 3 | -1 | -1 | -3 | 3 | 3 | -3 | -1 | 3 | -1 | -1 | -1 |
| 27 | -3 | -3 | 3 | 3 | -3 | 1 | 3 | -1 | -3 | 1 | -1 | -3 | 3 | -3 | -1 | -1 | -1 | 3 |
| 28 | -1 | -3 | 1 | -3 | -3 | -3 | 1 | 1 | 3 | 3 | -3 | 3 | 3 | -3 | -1 | 3 | -3 | 1 |
| 29 | -3 | 3 | 1 | -1 | -1 | -1 | -1 | 1 | -1 | 3 | 3 | -3 | -1 | 1 | 3 | -1 | 3 | -1 |

Table 5.2.2-4: Definition of $\varphi(n)$ for $M_{ZC} = 24$

| u | $\varphi(0), \dots, \varphi(23)$ | | | | | | | | | | | | | | | | | | | | | | | | |
|-----|----------------------------------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0 | -1 | -3 | 3 | -1 | 3 | 1 | 3 | -1 | 1 | -3 | -1 | -3 | -1 | 1 | 3 | -3 | -1 | -3 | 3 | 3 | 3 | -3 | -3 | -3 | |
| 1 | -1 | -3 | 3 | 1 | 1 | -3 | 1 | -3 | -3 | 1 | -3 | -1 | -1 | 3 | -3 | 3 | 3 | 3 | -3 | 1 | 3 | 3 | -3 | -3 | |
| 2 | -1 | -3 | -3 | 1 | -1 | -1 | -3 | 1 | 3 | -1 | -3 | -1 | -1 | -3 | 1 | 1 | 3 | 1 | -3 | -1 | -1 | 3 | -3 | -3 | |
| 3 | 1 | -3 | 3 | -1 | -3 | -1 | 3 | 3 | 1 | -1 | 1 | 1 | 3 | -3 | -1 | -3 | -3 | -3 | -1 | 3 | -3 | -1 | -3 | -3 | |
| 4 | -1 | 3 | -3 | -3 | -1 | 3 | -1 | -1 | 3 | 1 | 3 | 1 | 3 | -1 | -1 | -3 | 1 | 3 | 1 | -1 | -3 | 1 | -1 | -3 | -3 |
| 5 | -3 | -1 | 1 | -3 | -3 | 1 | 1 | -3 | 3 | -1 | -1 | -3 | 1 | 3 | 1 | -1 | -3 | -1 | -3 | 1 | -3 | -3 | -3 | -3 | |
| 6 | -3 | 3 | 1 | 3 | -1 | 1 | -3 | 1 | -3 | 1 | -1 | -3 | -1 | -3 | -3 | -3 | -3 | -1 | -1 | -1 | 1 | 1 | -3 | -3 | |
| 7 | -3 | 1 | 3 | -1 | 1 | -1 | 3 | -3 | 3 | -1 | -3 | -1 | -3 | 3 | -1 | -1 | -1 | -3 | -1 | -1 | -3 | 3 | 3 | -3 | |
| 8 | -3 | 1 | -3 | 3 | -1 | -1 | -1 | -3 | 3 | 1 | -1 | -3 | -1 | 1 | 3 | -1 | 1 | -1 | 1 | -3 | -3 | -3 | -3 | -3 | |
| 9 | 1 | 1 | -1 | -3 | -1 | 1 | 1 | -3 | 1 | -1 | 1 | -3 | 3 | -3 | -3 | 3 | -1 | -3 | 1 | 3 | -3 | 1 | -3 | -3 | |
| 10 | -3 | -3 | -3 | -1 | 3 | -3 | 3 | 1 | 3 | 1 | -3 | -1 | -1 | -3 | 1 | 1 | 3 | 1 | -1 | -3 | 3 | 1 | 3 | -3 | |
| 11 | -3 | 3 | -1 | 3 | 1 | -1 | -1 | -1 | 3 | 3 | 1 | 1 | 1 | 3 | 3 | 1 | -3 | -3 | -1 | 1 | -3 | 1 | 3 | -3 | |
| 12 | 3 | -3 | 3 | -1 | -3 | 1 | 3 | 1 | -1 | -1 | -3 | -1 | 3 | -3 | 3 | -1 | -1 | 3 | 3 | -3 | -3 | 3 | -3 | -3 | |
| 13 | -3 | 3 | -1 | 3 | -1 | 3 | 3 | 1 | 1 | -3 | 1 | 3 | -3 | 3 | -3 | -3 | -1 | 1 | 3 | -3 | -1 | -1 | -3 | -3 | |
| 14 | -3 | 1 | -3 | -1 | -1 | 3 | 1 | 3 | -3 | 1 | -1 | 3 | 3 | -1 | -3 | 3 | -3 | -1 | -1 | -3 | -3 | -3 | 3 | -3 | |
| 15 | -3 | -1 | -1 | -3 | 1 | -3 | -3 | -1 | -1 | 3 | -1 | 1 | -1 | 3 | 1 | -3 | -1 | 3 | 1 | 1 | -1 | -1 | -3 | -3 | |
| 16 | -3 | -3 | 1 | -1 | 3 | 3 | -3 | -1 | 1 | -1 | -1 | 1 | 1 | -1 | -1 | 3 | -3 | 1 | -3 | 1 | -1 | -1 | -1 | -3 | |
| 17 | 3 | -1 | 3 | -1 | 1 | -3 | 1 | 1 | -3 | -3 | 3 | -3 | -1 | -1 | -1 | -1 | -1 | -3 | -3 | -1 | 1 | 1 | -3 | -3 | |
| 18 | -3 | 1 | -3 | 1 | -3 | -3 | 1 | -3 | 1 | -3 | -3 | -3 | -3 | -3 | 1 | -3 | -3 | 1 | 1 | -3 | 1 | 1 | -3 | -3 | |
| 19 | -3 | -3 | 3 | 3 | 1 | -1 | -1 | -1 | 1 | -3 | -1 | 1 | -1 | 3 | -3 | -1 | -3 | -1 | -1 | 1 | -3 | 3 | -1 | -3 | |
| 20 | -3 | -3 | -1 | -1 | -1 | -3 | 1 | -1 | -3 | -1 | 3 | -3 | 1 | -3 | 3 | -3 | 3 | 3 | 1 | -1 | -1 | 1 | -3 | -3 | |
| 21 | 3 | -1 | 1 | -1 | 3 | -3 | 1 | 1 | 3 | -1 | -3 | 3 | 1 | -3 | 3 | -1 | -1 | -1 | -1 | 1 | -3 | -3 | -3 | -3 | |
| 22 | -3 | 1 | -3 | 3 | -3 | 1 | -3 | 3 | 1 | -1 | -3 | -1 | -3 | -3 | -3 | -3 | 1 | 3 | -1 | 1 | 3 | 3 | 3 | -3 | |
| 23 | -3 | -1 | 1 | -3 | -1 | -1 | 1 | 1 | 1 | 3 | 3 | -1 | 1 | -1 | 1 | -1 | -1 | -3 | -3 | -3 | 3 | 1 | -1 | -3 | |
| 24 | -3 | 3 | -1 | -3 | -1 | -1 | 3 | -1 | -1 | 3 | -1 | 3 | -3 | -1 | 3 | -3 | 3 | -3 | -1 | 3 | 1 | 1 | -1 | -3 | |
| 25 | -3 | 1 | -1 | -3 | -3 | -1 | 1 | -3 | -1 | -3 | 1 | 1 | -1 | 1 | 1 | 3 | 3 | 3 | -1 | 1 | -1 | 1 | -1 | -3 | |
| 26 | -1 | 3 | -1 | -1 | 3 | 3 | -1 | -1 | -1 | 3 | -1 | -3 | 1 | 3 | 1 | 1 | -3 | -3 | -3 | -1 | -3 | -1 | -3 | -3 | |
| 27 | 3 | -3 | -3 | -1 | 3 | 3 | -3 | -1 | 3 | 1 | 1 | 1 | 3 | -1 | 3 | -3 | -1 | 3 | -1 | 3 | 1 | -1 | -3 | -3 | |
| 28 | -3 | 1 | -3 | 1 | -3 | 1 | 1 | 3 | 1 | -3 | -3 | -1 | 1 | 3 | -1 | -3 | 3 | 1 | -1 | -3 | -3 | -3 | -3 | -3 | |
| 29 | 3 | -3 | -1 | 1 | 3 | -1 | -1 | -3 | -1 | 3 | -1 | -3 | -1 | -3 | 3 | -1 | 3 | 1 | 1 | -3 | 3 | -3 | -3 | -3 | |

5.2.3 Low-PAPR sequence generation type 2

The low-PAPR sequence $r_{u,v}^{(\alpha,\delta)}(n)$ is defined by a base sequence $\tilde{r}_{u,v}(n)$ according to

$$r_{u,v}^{(\alpha,\delta)}(n) = \tilde{r}_{u,v}(n), \quad 0 \leq n < M$$

where $M = mN_{sc}^{RB}/2^\delta$ is the length of the sequence.

Base sequences $\tilde{r}_{u,v}(n)$ are divided into groups, where $u \in \{0, 1, \dots, 29\}$ is the group number and v is the base sequence number within the group, such that each group contains one base sequence ($v = 0$) of length $M = mN_{sc}^{RB}/2^\delta$, $1/2 \leq m/2^\delta$. The sequence $\tilde{r}_{u,v}(0), \dots, \tilde{r}_{u,v}(M - 1)$ is defined by

$$\tilde{r}_{u,v}(n) = \frac{1}{\sqrt{M}} \sum_{i=0}^{M-1} \tilde{r}_{u,v}(i) e^{-j\frac{2\pi in}{M}}$$

$$n = 0, \dots, M - 1$$

where the definition of $\tilde{r}_{u,v}(i)$ depends on the sequence length.

5.2.3.1 Sequences of length 30 or larger

For $M \geq 30$, the sequence $\tilde{r}_{u,v}(i)$ is obtained as the complex-valued modulations symbols resulting from $\pi/2$ -BPSK modulation as defined in clause 5.1.1 applied to the binary sequence $c(i)$ given by clause 5.2.1, initialized with c_{init} .

5.2.3.2 Sequences of length less than 30

For $M = 6$, the sequence $\tilde{r}_{u,v}(i)$ is given by

$$\tilde{r}_{u,v}(i) = e^{j\varphi(i)\pi/8}, 0 \leq i \leq M - 1$$

where the value of $\varphi(i)$ is given by Table 5.2.3.2-1.

For $M \in \{12, 18, 24\}$, the sequence $\tilde{r}_{u,v}(i)$ is obtained as the complex-valued modulations symbols resulting from $\pi/2$ -BPSK modulation as defined in clause 5.1.1 applied to the binary sequence $b(i)$ given by Tables 5.2.3.2-2 to 5.2.3.2-4.

Table 5.2.3.2-1: Definition of $\varphi(i)$ for $M = 6$.

| u | $\varphi(0), \dots, \varphi(5)$ | | | | | |
|-----|---------------------------------|----|----|----|----|----|
| 0 | -1 | -7 | -3 | -5 | -1 | 3 |
| 1 | -1 | 3 | 7 | -3 | 7 | 3 |
| 2 | -1 | 3 | 1 | 5 | -1 | -5 |
| 3 | -7 | -3 | -7 | 5 | -7 | -3 |
| 4 | 7 | 5 | -1 | -7 | -3 | 1 |
| 5 | 3 | -3 | 1 | 5 | -1 | -1 |
| 6 | -7 | -3 | -7 | -3 | 7 | -5 |
| 7 | -7 | -3 | 1 | -5 | -1 | -5 |
| 8 | -7 | -3 | 3 | -3 | -7 | -3 |
| 9 | -7 | -7 | -1 | 1 | -5 | 1 |
| 10 | -7 | -3 | -7 | 5 | -1 | 5 |
| 11 | -7 | -7 | -3 | 1 | 5 | -1 |
| 12 | 5 | 7 | -3 | -5 | 5 | -5 |
| 13 | -3 | 7 | -5 | -1 | -5 | -1 |
| 14 | 5 | -7 | 7 | 1 | 5 | 1 |
| 15 | -7 | 3 | 1 | 5 | -1 | 3 |
| 16 | -7 | -5 | -1 | -7 | -5 | 5 |
| 17 | -7 | 1 | -3 | 3 | 7 | 5 |
| 18 | -7 | -7 | 3 | 5 | 1 | 5 |
| 19 | -7 | -3 | 3 | -1 | 3 | -5 |
| 20 | -7 | -5 | 5 | 3 | -7 | -1 |
| 21 | 1 | 5 | 1 | 5 | 3 | 7 |
| 22 | 1 | -3 | 1 | -5 | -1 | 3 |
| 23 | 1 | 7 | 1 | -5 | -7 | -1 |
| 24 | 1 | -1 | 3 | -1 | -7 | -3 |
| 25 | 1 | -1 | -5 | -1 | 3 | -3 |
| 26 | 1 | -1 | 3 | -1 | 3 | 7 |
| 27 | -5 | 3 | 7 | 5 | 3 | 7 |
| 28 | -7 | 1 | -3 | 1 | 5 | 1 |
| 29 | 1 | 5 | 3 | -7 | 5 | -3 |

Table 5.2.3.2-2: Definition of $b(i)$ for $M = 12$.

| u | $b(0), \dots, b(11)$ | | | | | | | | | | | |
|-----|----------------------|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 0 |
| 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 |
| 2 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 |
| 3 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 |
| 4 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 1 |
| 5 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 1 |
| 6 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 |
| 7 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 |
| 8 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 |
| 9 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 |
| 10 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 |
| 11 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 0 |
| 12 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 |
| 13 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 1 |
| 14 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 1 |
| 15 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 |
| 16 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| 17 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 0 |
| 18 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 |
| 19 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 20 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 1 |
| 21 | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 1 |
| 22 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 |
| 23 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| 24 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 |
| 25 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 0 |
| 26 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 |
| 27 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 |
| 28 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 29 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 |

Table 5.2.3.2-3: Definition of $b(i)$ for $M = 18$.

| u | $b(0), \dots, b(17)$ | | | | | | | | | | | | | | | | | | | |
|-----|----------------------|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | | |
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | | |
| 2 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | | |
| 3 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | | |
| 4 | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | | |
| 5 | 0 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | | |
| 6 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | | |
| 7 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | | |
| 8 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | | |
| 9 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | | |
| 10 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | | |
| 11 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | | |
| 12 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | | |
| 13 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | | |
| 14 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | |
| 15 | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | |
| 16 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | |
| 17 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | |
| 18 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | |
| 19 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | |
| 20 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | |
| 21 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | |
| 22 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | |
| 23 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 1 |
| 24 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 0 |
| 25 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 |
| 26 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 27 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 |
| 28 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 |
| 29 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 |

Table 5.2.3.2-4: Definition of $b(i)$ for $M = 24$

| u | $b(0), \dots, b(23)$ | | | | | | | | | | | | | | | | | | | | | | | |
|-----|----------------------|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 |
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 0 |
| 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 |
| 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 1 |
| 4 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 1 |
| 5 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 1 |
| 6 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 1 |
| 7 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 1 |
| 8 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 |
| 9 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 1 |
| 10 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 0 |
| 11 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 |
| 12 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 1 |
| 13 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 0 |
| 14 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 1 |
| 15 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 |
| 16 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 1 |
| 17 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 0 |
| 18 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 1 |
| 19 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 |
| 20 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 |
| 21 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 |
| 22 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 1 |
| 23 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 |
| 24 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 |
| 25 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 0 |
| 26 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 0 |
| 27 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 1 |
| 28 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 1 |
| 29 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 1 |

5.3 OFDM baseband signal generation

5.3.1 OFDM baseband signal generation for all channels except PRACH and RIM-RS

The time-continuous signal $s_l^{(p,\mu)}(t)$ on antenna port p and subcarrier spacing configuration μ for OFDM symbol $l \in \{0, 1, \dots, N_{\text{slot}}^{\text{subframe}, \mu} N_{\text{symb}}^{\text{slot}} - 1\}$ in a subframe for any physical channel or signal except PRACH is defined by

$$s_l^{(p,\mu)}(t) = \begin{cases} \bar{s}_l^{(p,\mu)}(t) & t_{\text{start},l}^{\mu} \leq t < t_{\text{start},l}^{\mu} + T_{\text{symb},l}^{\mu} \\ 0 & \text{otherwise} \end{cases}$$

$$\bar{s}_l^{(p,\mu)}(t) = \sum_{k=0}^{N_{\text{grid},x}^{\text{size},\mu} N_{\text{sc}}^{\text{RB}} - 1} a_{k,l}^{(p,\mu)} e^{j2\pi \left(k + k_0^{\mu} - N_{\text{grid},x}^{\text{size},\mu} N_{\text{sc}}^{\text{RB}} / 2 \right) \Delta f (t - N_{\text{CP},l}^{\mu} T_c - t_{\text{start},l}^{\mu})}$$

$$k_0^{\mu} = \left(N_{\text{grid},x}^{\text{start},\mu} + N_{\text{grid},x}^{\text{size},\mu} / 2 \right) N_{\text{sc}}^{\text{RB}} - \left(N_{\text{grid},x}^{\text{start},\mu_0} + N_{\text{grid},x}^{\text{size},\mu_0} / 2 \right) N_{\text{sc}}^{\text{RB}} 2^{\mu_0 - \mu}$$

$$T_{\text{symb},l}^{\mu} = (N_{\text{u}}^{\mu} + N_{\text{CP},l}^{\mu}) T_c$$

where $t = 0$ at the start of the subframe,

$$N_{\text{u}}^{\mu} = 2048\kappa \cdot 2^{-\mu}$$

$$N_{\text{CP},l}^{\mu} = \begin{cases} 512\kappa \cdot 2^{-\mu} & \text{extended cyclic prefix} \\ 144\kappa \cdot 2^{-\mu} + 16\kappa & \text{normal cyclic prefix, } l = 0 \text{ or } l = 7 \cdot 2^{\mu} \\ 144\kappa \cdot 2^{-\mu} & \text{normal cyclic prefix, } l \neq 0 \text{ and } l \neq 7 \cdot 2^{\mu} \end{cases}$$

and

- Δf is given by clause 4.2;
- μ is the subcarrier spacing configuration;
- μ_0 is the largest μ value among the subcarrier spacing configurations by *scs-SpecificCarrierList* for each of uplink and downlink and by *sl-SCS-SpecificCarrierList* for sidelink.

The starting position of OFDM symbol l for subcarrier spacing configuration μ in a subframe is given by

$$t_{\text{start},l}^{\mu} = \begin{cases} 0 & l = 0 \\ t_{\text{start},l-1}^{\mu} + T_{\text{symb},l-1}^{\mu} & \text{otherwise} \end{cases}$$

In case of cyclic prefix extension of the first OFDM symbol l allocated for PUSCH, SRS, PUCCH, PSCCH/PSSCH, PSFCH, or S-SS/PSBCH block transmission, the time-continuous signal $s_{\text{ext}}^{(p,\mu)}(t)$ for the interval $t_{\text{start},l}^{\mu} - T_{\text{ext}} \leq t < t_{\text{start},l}^{\mu}$ preceding the first OFDM symbol for PUSCH, SRS, PUCCH, PSCCH/PSSCH, PSFCH, or S-SS/PSBCH block is given by

$$s_{\text{ext}}^{(p,\mu)}(t) = \bar{s}_l^{(p,\mu)}(t)$$

where $t < 0$ refers to the signal in the previous subframe and

- for dynamically scheduled PUSCH, SRS, and PUCCH transmissions

$$T_{\text{ext}} = \min\left(\max(T'_{\text{ext}}, 0), T_{\text{symb},(l-1)\bmod 7 \cdot 2^{\mu}}^{\mu}\right)$$

$$T'_{\text{ext}} = \sum_{k=1}^{C_i} T_{\text{symb},(l-k)\bmod 7 \cdot 2^{\mu}}^{\mu} - \Delta_i$$

where Δ_i is given by Table 5.3.1-1 with $C_1 = 1$ for $\mu \in \{0,1\}$, $C_1 = 2$ for $\mu = 2$, and C_2 and C_3 given by the higher-layer parameters *cp-ExtensionC2* and *cp-ExtensionC3*, respectively, and T_{TA} given by clause 4.3.1. For contention-based random access, or in absence of higher-layer configuration of C_2 and C_3 , the value of C_i shall be set to the largest integer fulfilling $T'_{\text{ext}} < T_{\text{symb},(l-1)\bmod 7 \cdot 2^{\mu}}^{\mu}$ for each of the values of $i \in \{2,3\}$. T_{ext} is applied to the first UL transmission scheduled by the scheduling DCI.

- for a PUSCH transmission using configured grant

$$T_{\text{ext}} = \sum_{k=1}^{2^{\mu}} T_{\text{symb},(l-k)\bmod 7 \cdot 2^{\mu}}^{\mu} - \Delta_i$$

where Δ_i is given by Table 5.3.1-2 with the index i given by the procedure in [6, TS 38.214].

- for PSCCH/PSSCH, PSFCH, and S-SS/PSBCH block transmission

$$T_{\text{ext}} = \max\left(\sum_{k=1}^{C_i} T_{\text{symb},(l-k)\bmod 7 \cdot 2^{\mu}}^{\mu} - \Delta_i, 0\right)$$

where Δ_i and C_i are given by Table 5.3.1-3 with the index i given by the procedure in [5, TS 38.213] or [6, TS 38.214].

Table 5.3.1-1: The variables C_i and Δ_i for uplink cyclic prefix extension

| T_{ext} index i | C_i | Δ_i |
|----------------------------|-------|------------------------------------|
| 0 | - | - |
| 1 | C_1 | $25 \cdot 10^{-6}$ |
| 2 | C_2 | $16 \cdot 10^{-6} + T_{\text{TA}}$ |
| 3 | C_3 | $25 \cdot 10^{-6} + T_{\text{TA}}$ |

Table 5.3.1-2: The variable Δ_i for uplink cyclic prefix extension with configured grants.

| index i | Δ_i |
|-----------|--|
| 0 | $16 \cdot 10^{-6}$ |
| 1 | $25 \cdot 10^{-6}$ |
| 2 | $34 \cdot 10^{-6}$ |
| 3 | $43 \cdot 10^{-6}$ |
| 4 | $52 \cdot 10^{-6}$ |
| 5 | $61 \cdot 10^{-6}$ |
| 6 | $\sum_{k=1}^{2^\mu} T_{\text{symbol},(l-k) \bmod 7 \cdot 2^\mu}^\mu$ |

Table 5.3.1-3: The variables C_i and Δ_i for sidelink cyclic prefix extension

| Index i | $\mu = 0$ | | $\mu = 1$ | | $\mu = 2$ | |
|-----------|-----------|--------------------|-----------|--------------------|-----------|--------------------|
| | C_i | Δ_i | C_i | Δ_i | C_i | Δ_i |
| 0 | - | - | - | - | - | - |
| 1 | 1 | $16 \cdot 10^{-6}$ | 1 | $16 \cdot 10^{-6}$ | 1 | $16 \cdot 10^{-6}$ |
| 2 | 1 | $25 \cdot 10^{-6}$ | 1 | $25 \cdot 10^{-6}$ | 2 | $16 \cdot 10^{-6}$ |
| 3 | 1 | $34 \cdot 10^{-6}$ | 2 | $16 \cdot 10^{-6}$ | 2 | $25 \cdot 10^{-6}$ |
| 4 | 1 | $43 \cdot 10^{-6}$ | 2 | $25 \cdot 10^{-6}$ | reserved | reserved |
| 5 | 1 | $52 \cdot 10^{-6}$ | 2 | $34 \cdot 10^{-6}$ | reserved | reserved |
| 6 | 1 | $61 \cdot 10^{-6}$ | 2 | $43 \cdot 10^{-6}$ | reserved | reserved |
| 7 | reserved | reserved | 2 | $52 \cdot 10^{-6}$ | reserved | reserved |
| 8 | reserved | reserved | 2 | $61 \cdot 10^{-6}$ | reserved | reserved |

5.3.2 OFDM baseband signal generation for PRACH

The time-continuous signal $s_l^{(p,\mu)}(t)$ on antenna port p for PRACH is defined by

$$s_l^{(p,\mu)}(t) = \sum_{k=0}^{L_{\text{RA}}-1} a_k^{(p,\text{RA})} e^{j2\pi(k+Kk_1+k)\Delta f_{\text{RA}}(t-N_{\text{CP},l}^{\text{RA}}T_c-t_{\text{start}}^{\text{RA}})}$$

$$K = \Delta f / \Delta f_{\text{RA}}$$

$$k_1 = k_0^\mu + \left(N_{\text{BWP},i}^{\text{start}} - N_{\text{grid}}^{\text{start},\mu} \right) N_{\text{sc}}^{\text{RB}} - N_{\text{grid}}^{\text{size},\mu} N_{\text{sc}}^{\text{RB}} / 2 + n_{\text{RA}}^{\text{start}} N_{\text{sc}}^{\text{RB}}$$

$$+ \begin{cases} n_{\text{RA}} N_{\text{RB}}^{\text{RA}} N_{\text{sc}}^{\text{RB}} & \text{if } L_{\text{RA}} \in \{139, 839\} \\ n_{\text{RA}} N_{\text{RB}}^{\text{RA}} N_{\text{sc}}^{\text{RB}} & \text{if } L_{\text{RA}} \in \{571, 1151\} \text{ in FR2-2} \\ \left(N_{\text{RB,UL},n_0+n_{\text{RA}}}^{\text{start},\mu} - N_{\text{RB,UL},n_0}^{\text{start},\mu} \right) N_{\text{sc}}^{\text{RB}} & \text{if } L_{\text{RA}} \in \{571, 1151\} \text{ in FR1} \end{cases}$$

$$k_0^\mu = \left(N_{\text{grid}}^{\text{start},\mu} + N_{\text{grid}}^{\text{size},\mu} / 2 \right) N_{\text{sc}}^{\text{RB}} - \left(N_{\text{grid}}^{\text{start},\mu_0} + N_{\text{grid}}^{\text{size},\mu_0} / 2 \right) N_{\text{sc}}^{\text{RB}} 2^{\mu_0-\mu}$$

where $t_{\text{start}}^{\text{RA}} \leq t < t_{\text{start}}^{\text{RA}} + (N_u + N_{\text{CP},l}^{\text{RA}}) T_c$ and

- \bar{k} is given by clause 6.3.3;
- Δf is the subcarrier spacing of the initial uplink bandwidth part during initial access. If the PRACH transmission is for a candidate cell Δf is provided by *lim-PRACH-SubcarrierSpacing* in *EarlyUL-SyncConfig*. Otherwise, Δf is the subcarrier spacing of the active uplink bandwidth part;
- μ_0 is the largest μ value among the subcarrier spacing configurations by the higher-layer parameter *scs-SpecificCarrierList*;
- $N_{\text{BWP},i}^{\text{start}}$ is the lowest numbered resource block of the initial uplink bandwidth part and is derived by the higher-layer parameter *initialUplinkBWP* or *initialUplinkBWP-RedCap* during initial access and from the higher-layer parameters *bwp-GenericParameters* in *EarlyUL-SyncConfig* if the PRACH transmission is for a candidate cell. Otherwise, $N_{\text{BWP},i}^{\text{start}}$ is the lowest numbered resource block of the active uplink bandwidth part and is derived by the higher-layer parameter *BWP-Uplink*;

- $n_{\text{RA}}^{\text{start}}$ is the frequency offset of the lowest PRACH transmission occasion in frequency domain with respect to physical resource block 0 of the active uplink bandwidth part. The quantity $n_{\text{RA}}^{\text{start}}$ is given by the higher-layer parameter *msgA-RO-FrequencyStart* if configured and a type-2 random-access procedure is initiated as described in clause 8.1 of [5, TS 38.213], otherwise by *msg1-FrequencyStart* as described in clause 8.1 of [5 TS 38.213];
- n_{RA} is the PRACH transmission occasion index in frequency domain for a given PRACH transmission occasion in one time instance as given by clause 6.3.3.2;
- $N_{\text{RB}}^{\text{RA}}$ is the number of resource blocks occupied and is given by the parameter allocation expressed in number of RBs for PUSCH in Table 6.3.3.2-1.
- $N_{\text{RB,UL},n}^{\text{start},\mu}$ is the start CRB index of uplink RB set n corresponding to the quantity $RB_{n,\text{UL}}^{\text{start},\mu}$. The UE assumes that the RB set is defined as when the UE is not provided *IntraCellGuardBandsPerSCS* for an UL carrier as described in Clause 7 of [6, TS 38.214]
- n_0 is the index of the RB set which contains the lowest PRACH transmission occasion in frequency domain indicated by $n_{\text{RA}}^{\text{start}}$. The UE may assume that $n_{\text{RA}}^{\text{start}}$ is configured such that each PRACH transmission occasion is fully contained within an RB set.
- L_{RA} and N_u are given by clause 6.3.3
- $N_{\text{CP},l}^{\text{RA}} = N_{\text{CP}}^{\text{RA}} + n \cdot 16\kappa$ where
 - for $\Delta f_{\text{RA}} \in \{1.25, 5\}$ kHz, $n = 0$
 - for $\Delta f_{\text{RA}} \in \{15, 30, 60, 120, 480, 960\}$ kHz, n is the number of times the interval $[t_{\text{start},l}^{\text{RA}}, t_{\text{start},l}^{\text{RA}} + (N_u^{\text{RA}} + N_{\text{CP}}^{\text{RA}})T_c]$ overlaps with either time instance 0 or time instance $(\Delta f_{\text{max}} N_f / 2000) \cdot T_c = 0.5$ ms in a subframe

The starting position $t_{\text{start}}^{\text{RA}}$ of the PRACH preamble in a subframe (for $\Delta f_{\text{RA}} \in \{1.25, 5, 15, 30\}$ kHz) or in a 60 kHz slot (for $\Delta f_{\text{RA}} \in \{60, 120, 480, 960\}$ kHz) is given by

$$t_{\text{start}}^{\text{RA}} = t_{\text{start},l}^{\mu}$$

$$t_{\text{start},l}^{\mu} = \begin{cases} 0 & l = 0 \\ t_{\text{start},l-1}^{\mu} + (N_u^{\mu} + N_{\text{CP},l-1}^{\mu}) \cdot T_c & \text{otherwise} \end{cases}$$

where

- the subframe or 60 kHz slot is assumed to start at $t = 0$;
- a timing advance value $N_{\text{TA}} = 0$ shall be assumed;
- N_u^{μ} and $N_{\text{CP},l-1}^{\mu}$ are given by clause 5.3.1;
- $\mu = 0$ shall be assumed for $\Delta f_{\text{RA}} \in \{1.25, 5\}$ kHz, otherwise the value of μ corresponds to $\Delta f_{\text{RA}} \in \{15, 30, 60, 120, 480, 960\}$ kHz and the symbol position l is given by

$$l = l_0 + n_t^{\text{RA}} N_{\text{dur}}^{\text{RA}} + 14n_{\text{slot}}^{\text{RA}}$$

where

- l_0 is given by the parameter "starting symbol" in Tables 6.3.3.2-2 to 6.3.3.2-4;
- n_t^{RA} is the PRACH transmission occasion within the PRACH slot, numbered in increasing order from 0 to $N_t^{\text{RA,slot}} - 1$ within a RACH slot where $N_t^{\text{RA,slot}}$ is given Tables 6.3.3.2-2 to 6.3.3.2-4 for $L_{\text{RA}} \in \{139, 571, 1151\}$ and fixed to 1 for $L_{\text{RA}} = 839$;
- $N_{\text{dur}}^{\text{RA}}$ is given by Tables 6.3.3.2-2 to 6.3.3.2-4;

- $n_{\text{slot}}^{\text{RA}}$ is given by
 - if $\Delta f_{\text{RA}} \in \{1.25, 5, 15, 60\}$ kHz, then $n_{\text{slot}}^{\text{RA}} = 0$
 - if $\Delta f_{\text{RA}} \in \{30, 120\}$ kHz and either of "Number of PRACH slots within a subframe" in Tables 6.3.3.2-2 to 6.3.3.2-3 or "Number of PRACH slots within a 60 kHz slot" in Table 6.3.3.2-4 is equal to 1, then $n_{\text{slot}}^{\text{RA}} = 1$, otherwise $n_{\text{slot}}^{\text{RA}} \in \{0,1\}$
 - if $\Delta f_{\text{RA}} \in \{480, 960\}$ kHz and
 - the "Number of PRACH slots within a 60 kHz slot" in Table 6.3.3.2-4 is equal to 1, then $n_{\text{slot}}^{\text{RA}} = 7$ for $\Delta f_{\text{RA}} = 480$ kHz and $n_{\text{slot}}^{\text{RA}} = 15$ for $\Delta f_{\text{RA}} = 960$ kHz, or
 - the "Number of PRACH slots within a 60 kHz slot" in Table 6.3.3.2-4 is equal to 2, then $n_{\text{slot}}^{\text{RA}} \in \{3,7\}$ for $\Delta f_{\text{RA}} = 480$ kHz and $n_{\text{slot}}^{\text{RA}} \in \{7,15\}$ for $\Delta f_{\text{RA}} = 960$ kHz.

If the preamble format given by Tables 6.3.3.2-2 to 6.3.3.2-4 is A1/B1, A2/B2 or A3/B3, then

- if $n_t^{\text{RA}} = N_t^{\text{RA,slot}} - 1$, then the PRACH preamble with the corresponding PRACH preamble format from B1, B2 and B3 is transmitted in the PRACH transmission occasion;
- otherwise the PRACH preamble with the corresponding PRACH preamble format from A1, A2 and A3 is transmitted in the PRACH transmission occasion

5.3.3 OFDM baseband signal generation for RIM-RS

The time-continuous signal $s_l^{(p,\mu)}(t)$ on antenna port p for RIM-RS is defined by

$$s_l^{(p,\mu)}(t) = \sum_{k=0}^{L_{\text{RIM}}-1} a_k^{(p,\text{RIM})} e^{j2\pi(k+k_1)\Delta f_{\text{RIM}}(t - N_{\text{CP}}^{\text{RIM}}T_c - t_{\text{start},l_0}^{\mu})}$$

where

$$t_{\text{start},l_0}^{\text{RIM}} \leq t < t_{\text{start},l_0}^{\text{RIM}} + (N_u^{\text{RIM}} + N_{\text{CP}}^{\text{RIM}})T_c$$

$$N_u^{\text{RIM}} = 2 \cdot 2048\kappa \cdot 2^{-\mu}$$

$$N_{\text{CP}}^{\text{RIM}} = N_{\text{CP},l_0}^{\text{RIM}} + N_{\text{CP},l}^{\text{RIM}}$$

$$\bar{l} = \begin{cases} 0 & \text{if } l_0 = N_{\text{ymb}}^{\text{slot}} - 1 \\ l_0 + 1 & \text{otherwise} \end{cases}$$

and

- $\Delta f_{\text{RIM}} = 15 \cdot 2^{\mu}$ kHz where $\mu \in \{0,1\}$ is the subcarrier spacing configuration for the RIM-RS;
- k_1 is the starting frequency offset of the RIM-RS as given by clause 7.4.1.6.4.3;
- $L_{\text{RIM}} = 12N_{\text{RB}}^{\text{RIM}}$ is the length of the RIM-RS sequence where $N_{\text{RB}}^{\text{RIM}}$ is the bandwidth of the RIM-RS in resource blocks;
- l_0 is the starting symbol given by clause 7.4.1.6.3;
- $t_{\text{start},l_0}^{\text{RIM}} = t_{\text{start},l}^{\mu}$ is given by clause 5.3.1 with $l = l_0$;
- $N_{\text{CP},l_0}^{\text{RIM}} = N_{\text{CP},l}^{\mu}$ is given by clause 5.3.1 with $l = l_0$.

5.4 Modulation and upconversion

Modulation and upconversion to the carrier frequency f_0 of the complex-valued OFDM baseband signal for antenna port p , subcarrier spacing configuration μ , and OFDM symbol l in a subframe assumed to start at $t=0$ is given by

- for PRACH

$$\operatorname{Re}\left\{s_l^{(p,\mu)}(t)e^{j2\pi f_0 t}\right\}$$

- for RIM-RS

$$\operatorname{Re}\left\{s_l^{(p,\mu)}(t)e^{j2\pi f_0^{\text{RIM}}(t-t_{\text{start},l}^{\mu}-N_{\text{CP}}^{\text{RIM}}T_c)}\right\}$$

where f_0^{RIM} is the configured reference point for RIM-RS;

- for all other channels and signals

$$\operatorname{Re}\left\{s_l^{(p,\mu)}(t) \cdot e^{j2\pi f_0(t-t_{\text{start},l}^{\mu}-N_{\text{CP},l}^{\mu}T_c)}\right\}$$

NOTE: For the uplink, the signal $s_l^{(p,\mu)}(t)$ and the baseband signals part thereof should be filtered per UE implementation, as required, to meet the minimum requirements as specified in [14, 38.101-1], [15, 38.101-2], and [16, 38.101-5] for the respective frequency range.

6 Uplink

6.1 Overview

6.1.1 Overview of physical channels

An uplink physical channel corresponds to a set of resource elements carrying information originating from higher layers. The following uplink physical channels are defined:

- Physical Uplink Shared Channel, PUSCH
- Physical Uplink Control Channel, PUCCH
- Physical Random Access Channel, PRACH

6.1.2 Overview of physical signals

An uplink physical signal is used by the physical layer but does not carry information originating from higher layers. The following uplink physical signals are defined:

- Demodulation reference signals, DM-RS
- Phase-tracking reference signals, PT-RS
- Sounding reference signal, SRS

6.2 Physical resources

The frame structure and physical resources the UE shall use when transmitting in the uplink transmissions are defined in Clause 4.

The following antenna ports are defined for the uplink:

- Antenna ports starting with 0 for demodulation reference signals for PUSCH
- Antenna ports starting with 1000 for SRS, PUSCH
- Antenna ports starting with 2000 for PUCCH

- Antenna port 4000 for PRACH

If PUSCH repetition Type B as described in clause 6.1 of [6, TS38.214] is applied to a physical channel, the UE transmission shall be such that the channel over which a symbol on the antenna port used for uplink transmission is conveyed can be inferred from the channel over which another symbol on the same antenna port is conveyed if the two symbols correspond to the same actual repetition of a PUSCH transmission with repetition Type B.

If intra-slot frequency hopping is not enabled for a physical channel and PUSCH repetition Type B is not applied to the physical channel, the UE transmission shall be such that the channel over which a symbol on the antenna port used for uplink transmission is conveyed can be inferred from the channel over which another symbol on the same antenna port is conveyed if the two symbols correspond to the same slot.

If intra-slot frequency hopping is enabled for a physical channel, the UE transmission shall be such that the channel over which a symbol on the antenna port used for uplink transmission is conveyed can be inferred from the channel over which another symbol on the same antenna port is conveyed only if the two symbols correspond to the same frequency hop, regardless of whether the frequency hop distance is zero or not.

If DM-RS bundling is applied to PUSCH and/or PUCCH repetitions and/or transport-block processing over multiple slots as described in clause 6.1.7 of [6, 38.214], the UE transmission shall be such that the channel over which a symbol on the antenna port used for uplink transmission is conveyed can be inferred from the channel over which another symbol on the same antenna port is conveyed if the two symbols are transmitted within the same actual time-domain window.

6.3 Physical channels

6.3.1 Physical uplink shared channel

6.3.1.1 Scrambling

Up to two codewords $q \in \{0,1\}$ can be transmitted. In case of single-codeword transmission, $q = 0$.

For each codeword, the block of bits $b^{(q)}(0), \dots, b^{(q)}(M_{\text{bit}}^{(q)} - 1)$, where $M_{\text{bit}}^{(q)}$ is the number of bits in codeword q transmitted on the physical channel, shall be scrambled prior to modulation, resulting in a block of scrambled bits $\tilde{b}^{(q)}(0), \dots, \tilde{b}^{(q)}(M_{\text{bit}}^{(q)} - 1)$ according to the following pseudo code

Set $i = 0$

while $i < M_{\text{bit}}^{(q)}$

if $b^{(q)}(i) = x$ // UCI placeholder bits

$\tilde{b}^{(q)}(i) = 1$

else

if $b^{(q)}(i) = y$ // UCI placeholder bits

$\tilde{b}^{(q)}(i) = \tilde{b}^{(q)}(i - 1)$

else

$\tilde{b}^{(q)}(i) = (b^{(q)}(i) + c^{(q)}(i)) \bmod 2$

end if

end if

$i = i + 1$

end while

where x and y are tags defined in [4, TS 38.212] and where the scrambling sequence $c^{(q)}(i)$ is given by clause 5.2.1. The scrambling sequence generator shall be initialized with

$$c_{\text{init}} = \begin{cases} n_{\text{RNTI}} \cdot 2^{16} + n_{\text{RAPID}} \cdot 2^{10} + n_{\text{ID}} & \text{for msgA on PUSCH} \\ n_{\text{RNTI}} \cdot 2^{15} + q \cdot 2^{14} + n_{\text{ID}} & \text{otherwise} \end{cases}$$

where

- $n_{\text{ID}} \in \{0,1, \dots, 1023\}$ equals the higher-layer parameter *dataScramblingIdentityPUSCH* if configured and the RNTI equals the C-RNTI, MCS-C-RNTI, SP-CSI-RNTI or CS-RNTI, and the transmission is not scheduled using DCI format 0_0 in a common search space;
- $n_{\text{ID}} \in \{0,1, \dots, 1023\}$ equals the higher-layer parameter *msgA-DataScramblingIndex* if configured and the PUSCH transmission is triggered by a Type-2 random access procedure as described in clause 8.1A of [5, TS 38.213];
- $n_{\text{ID}} = N_{\text{ID}}^{\text{cell}}$ otherwise
- n_{RAPID} is the index of the random-access preamble transmitted for msgA as described in clause 5.1.3A of [11, TS 38.321]

and where n_{RNTI} equals the RA-RNTI for msgA and otherwise corresponds to the RNTI associated with the PUSCH transmission as described in clause 6.1 of [6, TS 38.214] and clause 8.3 of [5, TS 38.213].

6.3.1.2 Modulation

For each codeword q , the block of scrambled bits $\tilde{b}^{(q)}(0), \dots, \tilde{b}^{(q)}(M_{\text{bit}}^{(q)} - 1)$ shall be modulated as described in clause 5.1 using one of the modulation schemes in Table 6.3.1.2-1, resulting in a block of complex-valued modulation symbols $d^{(q)}(0), \dots, d^{(q)}(M_{\text{symb}}^{(q)} - 1)$.

Table 6.3.1.2-1: Supported modulation schemes.

| Transform precoding disabled | | Transform precoding enabled | |
|------------------------------|------------------------|-----------------------------|------------------------|
| Modulation scheme | Modulation order Q_m | Modulation scheme | Modulation order Q_m |
| | | $\pi/2$ -BPSK | 1 |
| QPSK | 2 | QPSK | 2 |
| 16QAM | 4 | 16QAM | 4 |
| 64QAM | 6 | 64QAM | 6 |
| 256QAM | 8 | 256QAM | 8 |

6.3.1.3 Layer mapping

The complex-valued modulation symbols for each of the codewords to be transmitted shall be mapped onto up to four layers according to Table 7.3.1.3-1. Complex-valued modulation symbols $d^{(q)}(0), \dots, d^{(q)}(M_{\text{symb}}^{(q)} - 1)$ for codeword q shall be mapped onto the layers $x(i) = [x^{(0)}(i) \ \dots \ x^{(v-1)}(i)]^T$, $i = 0, 1, \dots, M_{\text{symb}}^{\text{layer}} - 1$ where v is the number of layers and $M_{\text{symb}}^{\text{layer}}$ is the number of modulation symbols per layer.

6.3.1.4 Transform precoding

If transform precoding is not enabled according to 6.1.3 of [6, TS38.214], $y^{(\lambda)}(i) = x^{(\lambda)}(i)$ for each layer $\lambda = 0, 1, \dots, v-1$.

If transform precoding is enabled according to 6.1.3 of [6, TS38.214], $v = 1$ and $\tilde{x}^{(0)}(i)$ depends on the configuration of phase-tracking reference signals.

If the procedure in [6, TS 38.214] indicates that phase-tracking reference signals are not being used, the block of complex-valued symbols $x^{(0)}(0), \dots, x^{(0)}(M_{\text{sy mb}}^{\text{layer}} - 1)$ for the single layer $\lambda = 0$ shall be divided into $M_{\text{sy mb}}^{\text{layer}}/M_{\text{sc}}^{\text{PUSCH}}$ sets, each corresponding to one OFDM symbol and $\tilde{x}^{(0)}(i) = x^{(0)}(i)$.

If the procedure in [6, TS 38.214] indicates that phase-tracking reference signals are being used, the block of complex-valued symbols $x^{(0)}(0), \dots, x^{(0)}(M_{\text{sy mb}}^{\text{layer}} - 1)$ shall be divided into sets, each set corresponding to one OFDM symbol, and where set l contains $M_{\text{sc}}^{\text{PUSCH}} - \varepsilon_l N_{\text{s amp}}^{\text{group}} N_{\text{group}}^{\text{PTRS}}$ symbols and is mapped to the complex-valued symbols $\tilde{x}^{(0)}(lM_{\text{sc}}^{\text{PUSCH}} + i')$ corresponding to OFDM symbol l prior to transform precoding, with $i' \in \{0, 1, \dots, M_{\text{sc}}^{\text{PUSCH}} - 1\}$ and $i' \neq m$. The index m of PT-RS samples in set l , the number of samples per PT-RS group $N_{\text{s amp}}^{\text{group}}$, and the number of PT-RS groups $N_{\text{group}}^{\text{PT-RS}}$ are defined in clause 6.4.1.2.2.2. The quantity $\varepsilon_l = 1$ when OFDM symbol l contains one or more PT-RS samples, otherwise $\varepsilon_l = 0$.

Transform precoding shall be applied according to

$$y^{(0)}(l \cdot M_{\text{sc}}^{\text{PUSCH}} + k) = \frac{1}{\sqrt{M_{\text{sc}}^{\text{PUSCH}}}} \sum_{i=0}^{M_{\text{sc}}^{\text{PUSCH}} - 1} \tilde{x}^{(0)}(l \cdot M_{\text{sc}}^{\text{PUSCH}} + i) e^{-j \frac{2\pi i k}{M_{\text{sc}}^{\text{PUSCH}}}}$$

$$k = 0, \dots, M_{\text{sc}}^{\text{PUSCH}} - 1$$

$$l = 0, \dots, M_{\text{sy mb}}^{\text{layer}} / M_{\text{sc}}^{\text{PUSCH}} - 1$$

resulting in a block of complex-valued symbols $y^{(0)}(0), \dots, y^{(0)}(M_{\text{sy mb}}^{\text{layer}} - 1)$. The variable $M_{\text{sc}}^{\text{PUSCH}} = M_{\text{RB}}^{\text{PUSCH}} \cdot N_{\text{sc}}^{\text{RB}}$, where $M_{\text{RB}}^{\text{PUSCH}}$ represents the bandwidth of the PUSCH in terms of resource blocks, and shall fulfil

$$M_{\text{RB}}^{\text{PUSCH}} = 2^{\alpha_2} \cdot 3^{\alpha_3} \cdot 5^{\alpha_5}$$

where $\alpha_2, \alpha_3, \alpha_5$ is a set of non-negative integers.

6.3.1.5 Precoding

The block of vectors $[y^{(0)}(i) \ \dots \ y^{(u-1)}(i)]^T$ shall be precoded according to

$$\begin{bmatrix} z^{(p_0)}(i) \\ \vdots \\ z^{(p_{\rho-1})}(i) \end{bmatrix} = W \begin{bmatrix} y^{(0)}(i) \\ \vdots \\ y^{(u-1)}(i) \end{bmatrix}$$

where $i = 0, 1, \dots, M_{\text{sy mb}}^{\text{ap}} - 1$, $M_{\text{sy mb}}^{\text{ap}} = M_{\text{sy mb}}^{\text{layer}}$. The set of antenna ports $\{p_0, \dots, p_{\rho-1}\}$ shall be determined according to the procedure in [6, TS 38.214].

For non-codebook-based transmission, the precoding matrix W equals the identity matrix.

For codebook-based transmission, the precoding matrix W depends on the number of antenna ports used for the transmission:

- for single-layer transmission on a single antenna port, $W = 1$;
- for transmissions using 2, or 4 antenna ports, W is given by Tables 6.3.1.5-1 to 6.3.1.5-7;
- for transmissions using 8 antenna ports, W is given by

$$W_{f(i)} = W'_i$$

where

- the subscripts i and $f(i)$ denote the row of the respective matrix;
- $f(i)$ is given by Table 6.3.1.5-8;

- the intermediate precoding matrix W' is given by Tables 6.3.1.5-9 to 6.3.1.5-24, 6.3.1.5-29 to 6.3.1.5-36, and 6.3.1.5-39 to 6.3.1.5-47 with $0_{m \times n}$ representing the all-zero matrix with m rows and n columns;
- the submatrices $\bar{W}_{m,n}$ are given by Tables 6.3.1.5-25 to 6.3.1.5-28 and 6.3.1.5-37 to 6.3.1.5-38.

The TPMI index used in the tables above is obtained from the DCI scheduling the uplink transmission or the higher layer parameters according to the procedure in [6, TS 38.214].

When the higher-layer parameter $txConfig$ is not configured, the precoding matrix $W = 1$.

Table 6.3.1.5-1: Precoding matrix W for single-layer transmission using two antenna ports.

| TPMI index | W (ordered from left to right in increasing order of TPMI index) | | | | | | | |
|------------|---|---|---|---|--|---|--|---|
| | 0 – 5 | $\frac{1}{\sqrt{2}} \begin{bmatrix} 1 \\ 0 \end{bmatrix}$ | $\frac{1}{\sqrt{2}} \begin{bmatrix} 0 \\ 1 \end{bmatrix}$ | $\frac{1}{\sqrt{2}} \begin{bmatrix} 1 \\ 1 \end{bmatrix}$ | $\frac{1}{\sqrt{2}} \begin{bmatrix} 1 \\ -1 \end{bmatrix}$ | $\frac{1}{\sqrt{2}} \begin{bmatrix} 1 \\ j \end{bmatrix}$ | $\frac{1}{\sqrt{2}} \begin{bmatrix} 1 \\ -j \end{bmatrix}$ | - |

Table 6.3.1.5-2: Precoding matrix W for single-layer transmission using four antenna ports with transform precoding enabled.

| TPMI index | W (ordered from left to right in increasing order of TPMI index) | | | | | | | | |
|------------|---|--|--|--|---|--|---|--|---|
| | 0 – 7 | $\frac{1}{2} \begin{bmatrix} 1 \\ 0 \\ 0 \\ 0 \end{bmatrix}$ | $\frac{1}{2} \begin{bmatrix} 0 \\ 1 \\ 0 \\ 0 \end{bmatrix}$ | $\frac{1}{2} \begin{bmatrix} 0 \\ 0 \\ 1 \\ 0 \end{bmatrix}$ | $\frac{1}{2} \begin{bmatrix} 0 \\ 0 \\ 0 \\ 1 \end{bmatrix}$ | $\frac{1}{2} \begin{bmatrix} 1 \\ 0 \\ 1 \\ 0 \end{bmatrix}$ | $\frac{1}{2} \begin{bmatrix} 1 \\ 0 \\ -1 \\ 0 \end{bmatrix}$ | $\frac{1}{2} \begin{bmatrix} 1 \\ 0 \\ j \\ 0 \end{bmatrix}$ | $\frac{1}{2} \begin{bmatrix} 1 \\ 0 \\ -j \\ 0 \end{bmatrix}$ |
| 8 – 15 | $\frac{1}{2} \begin{bmatrix} 0 \\ 1 \\ 0 \\ 1 \end{bmatrix}$ | $\frac{1}{2} \begin{bmatrix} 0 \\ 1 \\ 0 \\ -1 \end{bmatrix}$ | $\frac{1}{2} \begin{bmatrix} 0 \\ 1 \\ 0 \\ j \end{bmatrix}$ | $\frac{1}{2} \begin{bmatrix} 0 \\ 1 \\ 0 \\ -j \end{bmatrix}$ | $\frac{1}{2} \begin{bmatrix} 1 \\ 1 \\ 1 \\ -1 \end{bmatrix}$ | $\frac{1}{2} \begin{bmatrix} 1 \\ 1 \\ j \\ j \end{bmatrix}$ | $\frac{1}{2} \begin{bmatrix} 1 \\ 1 \\ -1 \\ 1 \end{bmatrix}$ | $\frac{1}{2} \begin{bmatrix} 1 \\ 1 \\ -j \\ -j \end{bmatrix}$ | |
| 16 – 23 | $\frac{1}{2} \begin{bmatrix} 1 \\ j \\ 1 \\ j \end{bmatrix}$ | $\frac{1}{2} \begin{bmatrix} 1 \\ j \\ 1 \\ 1 \end{bmatrix}$ | $\frac{1}{2} \begin{bmatrix} 1 \\ j \\ -1 \\ -j \end{bmatrix}$ | $\frac{1}{2} \begin{bmatrix} 1 \\ j \\ -j \\ -1 \end{bmatrix}$ | $\frac{1}{2} \begin{bmatrix} 1 \\ -1 \\ 1 \\ 1 \end{bmatrix}$ | $\frac{1}{2} \begin{bmatrix} 1 \\ -1 \\ j \\ -j \end{bmatrix}$ | $\frac{1}{2} \begin{bmatrix} 1 \\ -1 \\ -1 \\ -1 \end{bmatrix}$ | $\frac{1}{2} \begin{bmatrix} 1 \\ -1 \\ -j \\ j \end{bmatrix}$ | |
| 24 – 27 | $\frac{1}{2} \begin{bmatrix} 1 \\ -j \\ 1 \\ -j \end{bmatrix}$ | $\frac{1}{2} \begin{bmatrix} 1 \\ -j \\ j \\ -1 \end{bmatrix}$ | $\frac{1}{2} \begin{bmatrix} 1 \\ -j \\ -1 \\ j \end{bmatrix}$ | $\frac{1}{2} \begin{bmatrix} 1 \\ -j \\ -j \\ 1 \end{bmatrix}$ | - | - | - | - | |

Table 6.3.1.5-3: Precoding matrix W for single-layer transmission using four antenna ports with transform precoding disabled.

| TPMI index | W (ordered from left to right in increasing order of TPMI index) | | | | | | | |
|------------|---|---|--|---|--|--|--|--|
| | 0 – 7 | $\frac{1}{2} \begin{bmatrix} 1 \\ 0 \\ 0 \\ 0 \end{bmatrix}$ | $\frac{1}{2} \begin{bmatrix} 0 \\ 1 \\ 0 \\ 0 \end{bmatrix}$ | $\frac{1}{2} \begin{bmatrix} 0 \\ 0 \\ 1 \\ 0 \end{bmatrix}$ | $\frac{1}{2} \begin{bmatrix} 0 \\ 0 \\ 0 \\ 1 \end{bmatrix}$ | $\frac{1}{2} \begin{bmatrix} 1 \\ 0 \\ 1 \\ 0 \end{bmatrix}$ | $\frac{1}{2} \begin{bmatrix} 1 \\ 0 \\ -1 \\ 0 \end{bmatrix}$ | $\frac{1}{2} \begin{bmatrix} 1 \\ 0 \\ j \\ 0 \end{bmatrix}$ |
| 8 – 15 | $\frac{1}{2} \begin{bmatrix} 0 \\ 1 \\ 0 \\ 1 \end{bmatrix}$ | $\frac{1}{2} \begin{bmatrix} 0 \\ 1 \\ 0 \\ -1 \end{bmatrix}$ | $\frac{1}{2} \begin{bmatrix} 0 \\ 1 \\ 0 \\ j \end{bmatrix}$ | $\frac{1}{2} \begin{bmatrix} 0 \\ 1 \\ 0 \\ -j \end{bmatrix}$ | $\frac{1}{2} \begin{bmatrix} 1 \\ 1 \\ 1 \\ 1 \end{bmatrix}$ | $\frac{1}{2} \begin{bmatrix} 1 \\ 1 \\ j \\ j \end{bmatrix}$ | $\frac{1}{2} \begin{bmatrix} 1 \\ 1 \\ -1 \\ -1 \end{bmatrix}$ | $\frac{1}{2} \begin{bmatrix} 1 \\ 1 \\ -j \\ -j \end{bmatrix}$ |
| 16 – 23 | $\frac{1}{2} \begin{bmatrix} 1 \\ j \\ 1 \\ j \end{bmatrix}$ | $\frac{1}{2} \begin{bmatrix} 1 \\ j \\ j \\ -1 \end{bmatrix}$ | $\frac{1}{2} \begin{bmatrix} 1 \\ j \\ -1 \\ -j \end{bmatrix}$ | $\frac{1}{2} \begin{bmatrix} 1 \\ j \\ -j \\ 1 \end{bmatrix}$ | $\frac{1}{2} \begin{bmatrix} 1 \\ -1 \\ 1 \\ -1 \end{bmatrix}$ | $\frac{1}{2} \begin{bmatrix} 1 \\ -1 \\ j \\ -j \end{bmatrix}$ | $\frac{1}{2} \begin{bmatrix} 1 \\ -1 \\ -1 \\ 1 \end{bmatrix}$ | $\frac{1}{2} \begin{bmatrix} 1 \\ -1 \\ -j \\ j \end{bmatrix}$ |
| 24 – 27 | $\frac{1}{2} \begin{bmatrix} 1 \\ -j \\ 1 \\ -j \end{bmatrix}$ | $\frac{1}{2} \begin{bmatrix} 1 \\ -j \\ j \\ 1 \end{bmatrix}$ | $\frac{1}{2} \begin{bmatrix} 1 \\ -j \\ -1 \\ j \end{bmatrix}$ | $\frac{1}{2} \begin{bmatrix} 1 \\ -j \\ -j \\ -1 \end{bmatrix}$ | - | - | - | - |

Table 6.3.1.5-4: Precoding matrix W for two-layer transmission using two antenna ports with transform precoding disabled.

| TPMI index | W (ordered from left to right in increasing order of TPMI index) | | | |
|------------|---|---|---|---|
| | 0 – 2 | $\frac{1}{\sqrt{2}} \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$ | $\frac{1}{2} \begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix}$ | $\frac{1}{2} \begin{bmatrix} 1 & 1 \\ j & -j \end{bmatrix}$ |

Table 6.3.1.5-5: Precoding matrix W for two-layer transmission using four antenna ports with transform precoding disabled.

| TPMI index | W (ordered from left to right in increasing order of TPMI index) | | | |
|------------|--|--|--|--|
| | 0 – 3 | $\frac{1}{2} \begin{bmatrix} 1 & 0 \\ 0 & 1 \\ 0 & 0 \\ 0 & 0 \end{bmatrix}$ | $\frac{1}{2} \begin{bmatrix} 1 & 0 \\ 0 & 0 \\ 0 & 1 \\ 0 & 0 \end{bmatrix}$ | $\frac{1}{2} \begin{bmatrix} 1 & 0 \\ 0 & 0 \\ 0 & 0 \\ 0 & 1 \end{bmatrix}$ |
| 4 – 7 | $\frac{1}{2} \begin{bmatrix} 0 & 0 \\ 1 & 0 \\ 0 & 0 \\ 0 & 1 \end{bmatrix}$ | $\frac{1}{2} \begin{bmatrix} 0 & 0 \\ 0 & 0 \\ 1 & 0 \\ 0 & 1 \end{bmatrix}$ | $\frac{1}{2} \begin{bmatrix} 1 & 0 \\ 0 & 1 \\ 1 & 0 \\ 0 & -j \end{bmatrix}$ | $\frac{1}{2} \begin{bmatrix} 1 & 0 \\ 0 & 1 \\ 1 & 0 \\ 0 & j \end{bmatrix}$ |
| 8 – 11 | $\frac{1}{2} \begin{bmatrix} 1 & 0 \\ 0 & 1 \\ -j & 0 \\ 0 & 1 \end{bmatrix}$ | $\frac{1}{2} \begin{bmatrix} 1 & 0 \\ 0 & 1 \\ -j & 0 \\ 0 & -1 \end{bmatrix}$ | $\frac{1}{2} \begin{bmatrix} 1 & 0 \\ 0 & 1 \\ -1 & 0 \\ 0 & -j \end{bmatrix}$ | $\frac{1}{2} \begin{bmatrix} 1 & 0 \\ 0 & 1 \\ -1 & 0 \\ 0 & j \end{bmatrix}$ |
| 12 – 15 | $\frac{1}{2} \begin{bmatrix} 1 & 0 \\ 0 & 1 \\ j & 0 \\ 0 & 1 \end{bmatrix}$ | $\frac{1}{2} \begin{bmatrix} 1 & 0 \\ 0 & 1 \\ j & 0 \\ 0 & -1 \end{bmatrix}$ | $\frac{1}{2\sqrt{2}} \begin{bmatrix} 1 & 1 \\ 1 & 1 \\ 1 & -1 \\ 1 & -1 \end{bmatrix}$ | $\frac{1}{2\sqrt{2}} \begin{bmatrix} 1 & 1 \\ 1 & 1 \\ j & -j \\ j & -j \end{bmatrix}$ |
| 16 – 19 | $\frac{1}{2\sqrt{2}} \begin{bmatrix} 1 & 1 \\ j & j \\ 1 & -1 \\ j & -j \end{bmatrix}$ | $\frac{1}{2\sqrt{2}} \begin{bmatrix} 1 & 1 \\ j & j \\ j & -j \\ -1 & 1 \end{bmatrix}$ | $\frac{1}{2\sqrt{2}} \begin{bmatrix} 1 & 1 \\ -1 & -1 \\ 1 & -1 \\ -1 & 1 \end{bmatrix}$ | $\frac{1}{2\sqrt{2}} \begin{bmatrix} 1 & 1 \\ -1 & -1 \\ j & -j \\ -j & j \end{bmatrix}$ |
| 20 – 21 | $\frac{1}{2\sqrt{2}} \begin{bmatrix} 1 & 1 \\ -j & -j \\ 1 & -1 \\ -j & j \end{bmatrix}$ | $\frac{1}{2\sqrt{2}} \begin{bmatrix} 1 & 1 \\ -j & -j \\ j & -j \\ 1 & -1 \end{bmatrix}$ | - | - |

Table 6.3.1.5-6: Precoding matrix W for three-layer transmission using four antenna ports with transform precoding disabled.

| TPMI index | W (ordered from left to right in increasing order of TPMI index) | | | |
|------------|--|--|--|---|
| | 0 – 3 | $\frac{1}{2} \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \\ 0 & 0 & 0 \end{bmatrix}$ | $\frac{1}{2} \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 1 & 0 & 0 \\ 0 & 0 & 1 \end{bmatrix}$ | $\frac{1}{2} \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ -1 & 0 & 0 \\ 0 & 0 & 1 \end{bmatrix}$ |
| 4 – 6 | $\frac{1}{2\sqrt{3}} \begin{bmatrix} 1 & 1 & 1 \\ 1 & -1 & 1 \\ j & j & -j \\ j & -j & -j \end{bmatrix}$ | $\frac{1}{2\sqrt{3}} \begin{bmatrix} 1 & 1 & 1 \\ -1 & 1 & -1 \\ 1 & 1 & -1 \\ -1 & 1 & 1 \end{bmatrix}$ | $\frac{1}{2\sqrt{3}} \begin{bmatrix} 1 & 1 & 1 \\ -1 & 1 & -1 \\ j & j & -j \\ -j & j & j \end{bmatrix}$ | - |

Table 6.3.1.5-7: Precoding matrix W for four-layer transmission using four antenna ports with transform precoding disabled.

| TPMI index | W (ordered from left to right in increasing order of TPMI index) | | | |
|------------|--|--|--|--|
| | 0-3 | $\frac{1}{2} \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$ | $\frac{1}{2\sqrt{2}} \begin{bmatrix} 1 & 1 & 0 & 0 \\ 0 & 0 & 1 & 1 \\ 1 & -1 & 0 & 0 \\ 0 & 0 & 1 & -1 \end{bmatrix}$ | $\frac{1}{2\sqrt{2}} \begin{bmatrix} 1 & 1 & 0 & 0 \\ 0 & 0 & 1 & 1 \\ j & -j & 0 & 0 \\ 0 & 0 & j & -j \end{bmatrix}$ |
| 4 | $\frac{1}{4} \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & -1 & 1 & -1 \\ j & j & -j & -j \\ j & -j & -j & j \end{bmatrix}$ | - | - | - |

Table 6.3.1.5-8: The port mapping function $f(i)$ for transmission using 8 antenna ports.

| i | Higher-layer parameter $CodebookTypeUL$ | | | | | | | |
|-----|---|--------|------------------------------------|--------|------------------------------------|--------|------------------------------------|--------|
| | codebook1 antenna port group | $f(i)$ | codebook2 antenna port group | $f(i)$ | codebook3 antenna port group | $f(i)$ | codebook4 antenna port group | $f(i)$ |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | | 1 | | 1 | | 4 | | 1 |
| 2 | | 2 | | 1 | 4 | 1 | 2 | 2 |
| 3 | | 3 | | | 5 | 5 | 3 | 3 |
| 4 | | 4 | 1 | 2 | 2 | 2 | 4 | 4 |
| 5 | | 5 | | 3 | | 6 | 5 | 5 |
| 6 | | 6 | | 6 | 3 | 3 | 6 | 6 |
| 7 | | 7 | | 7 | 3 | 7 | 7 | 7 |

Table 6.3.1.5-9: Intermediate precoding matrix W' for $codebook1=ng1n4n1$ and single-layer transmission using eight antenna ports.

| TPMI index | Intermediate precoder matrix W' (ordered from left to right in increasing order of TPMI index) | | | | | | | |
|------------|---|--|--|--|--|---|---|---|
| | 0-7 | $\frac{1}{2\sqrt{2}} \begin{bmatrix} 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \end{bmatrix}$ | $\frac{1}{2\sqrt{2}} \begin{bmatrix} 1 \\ 1 \\ 1 \\ 1 \\ j \\ j \\ j \\ j \end{bmatrix}$ | $\frac{1}{2\sqrt{2}} \begin{bmatrix} 1 \\ 1 \\ 1 \\ 1 \\ -1 \\ -1 \\ -1 \\ -1 \end{bmatrix}$ | $\frac{1}{2\sqrt{2}} \begin{bmatrix} 1 \\ 1 \\ 1 \\ 1 \\ -j \\ -j \\ -j \\ -j \end{bmatrix}$ | $\frac{1}{2\sqrt{2}} \begin{bmatrix} 1 \\ j \\ -1 \\ -j \\ 1 \\ j \\ -1 \\ -j \end{bmatrix}$ | $\frac{1}{2\sqrt{2}} \begin{bmatrix} 1 \\ j \\ -1 \\ -j \\ -1 \\ -j \\ 1 \\ 1 \end{bmatrix}$ | $\frac{1}{2\sqrt{2}} \begin{bmatrix} 1 \\ j \\ -1 \\ -j \\ -1 \\ -j \\ 1 \\ -1 \end{bmatrix}$ |
| 8-15 | $\frac{1}{2\sqrt{2}} \begin{bmatrix} 1 \\ -1 \\ 1 \\ -1 \\ 1 \\ -1 \\ 1 \\ -1 \end{bmatrix}$ | $\frac{1}{2\sqrt{2}} \begin{bmatrix} 1 \\ -1 \\ 1 \\ -1 \\ j \\ -j \\ j \\ -j \end{bmatrix}$ | $\frac{1}{2\sqrt{2}} \begin{bmatrix} 1 \\ -1 \\ 1 \\ -1 \\ -1 \\ 1 \\ -1 \\ 1 \end{bmatrix}$ | $\frac{1}{2\sqrt{2}} \begin{bmatrix} 1 \\ -1 \\ 1 \\ -1 \\ -j \\ j \\ -j \\ j \end{bmatrix}$ | $\frac{1}{2\sqrt{2}} \begin{bmatrix} 1 \\ -j \\ -1 \\ -1 \\ j \\ 1 \\ -j \\ j \end{bmatrix}$ | $\frac{1}{2\sqrt{2}} \begin{bmatrix} 1 \\ -j \\ -1 \\ -1 \\ j \\ 1 \\ -j \\ -1 \end{bmatrix}$ | $\frac{1}{2\sqrt{2}} \begin{bmatrix} 1 \\ -j \\ -1 \\ -1 \\ j \\ 1 \\ -j \\ -1 \end{bmatrix}$ | $\frac{1}{2\sqrt{2}} \begin{bmatrix} 1 \\ -j \\ -1 \\ -1 \\ j \\ -1 \\ -j \\ 1 \end{bmatrix}$ |

Table 6.3.1.5-10: Intermediate precoding matrix W' for $codebook1=ng1n4n1$ and two-layer transmission using eight antenna ports with transform precoding disabled.

| TPMI index | Intermediate precoder matrix W' (ordered from left to right in increasing order of TPMI index) | | | | | | | |
|------------|--|--|--|--|--|--|--|--|
| | 0 – 7 | $\frac{1}{4} \begin{bmatrix} 1 & 1 \\ 1 & 1 \\ 1 & 1 \\ 1 & 1 \\ 1 & -1 \\ 1 & -1 \\ 1 & -1 \\ 1 & -1 \end{bmatrix}$ | $\frac{1}{4} \begin{bmatrix} 1 & 1 \\ 1 & 1 \\ 1 & 1 \\ 1 & 1 \\ j & -j \\ j & -j \\ j & -j \\ j & -j \end{bmatrix}$ | $\frac{1}{4} \begin{bmatrix} 1 & 1 \\ 1 & j \\ 1 & -1 \\ 1 & -j \\ 1 & -1 \\ 1 & -j \\ 1 & 1 \\ 1 & j \end{bmatrix}$ | $\frac{1}{4} \begin{bmatrix} 1 & 1 \\ 1 & j \\ 1 & -1 \\ 1 & -j \\ j & -j \\ j & 1 \\ j & j \\ j & -j \end{bmatrix}$ | $\frac{1}{4} \begin{bmatrix} 1 & 1 \\ 1 & -1 \\ 1 & 1 \\ 1 & -1 \\ 1 & -1 \\ 1 & -1 \\ 1 & 1 \\ 1 & 1 \end{bmatrix}$ | $\frac{1}{4} \begin{bmatrix} 1 & 1 \\ 1 & -1 \\ 1 & 1 \\ 1 & -1 \\ j & -j \\ j & j \\ j & -j \\ j & j \end{bmatrix}$ | $\frac{1}{4} \begin{bmatrix} 1 & 1 \\ 1 & -j \\ 1 & -1 \\ 1 & j \\ 1 & -1 \\ 1 & j \\ 1 & 1 \\ 1 & -j \end{bmatrix}$ |
| 8 – 15 | $\frac{1}{4} \begin{bmatrix} 1 & 1 \\ j & j \\ -1 & -1 \\ -j & -j \\ 1 & -1 \\ j & -j \\ -1 & 1 \\ -j & j \end{bmatrix}$ | $\frac{1}{4} \begin{bmatrix} 1 & 1 \\ j & j \\ -1 & -1 \\ -j & -j \\ j & -j \\ -1 & 1 \\ -j & j \\ 1 & -1 \end{bmatrix}$ | $\frac{1}{4} \begin{bmatrix} 1 & 1 \\ j & -1 \\ -1 & 1 \\ -j & -1 \\ 1 & -1 \\ j & 1 \\ -1 & -1 \\ -j & 1 \end{bmatrix}$ | $\frac{1}{4} \begin{bmatrix} 1 & 1 \\ j & -1 \\ -1 & 1 \\ -j & -1 \\ j & -j \\ -1 & j \\ -j & -j \\ 1 & j \end{bmatrix}$ | $\frac{1}{4} \begin{bmatrix} 1 & 1 \\ j & -j \\ -1 & -1 \\ -j & j \\ 1 & -1 \\ j & j \\ -1 & 1 \\ -j & -j \end{bmatrix}$ | $\frac{1}{4} \begin{bmatrix} 1 & 1 \\ j & -j \\ -1 & -1 \\ -j & j \\ j & -j \\ -1 & -1 \\ -j & j \\ 1 & 1 \end{bmatrix}$ | $\frac{1}{4} \begin{bmatrix} 1 & 1 \\ j & 1 \\ -1 & 1 \\ -j & 1 \\ 1 & -1 \\ j & -1 \\ -1 & -1 \\ -j & -1 \end{bmatrix}$ | $\frac{1}{4} \begin{bmatrix} 1 & 1 \\ j & 1 \\ -1 & 1 \\ -j & 1 \\ j & -j \\ -1 & -j \\ -j & -j \\ 1 & -j \end{bmatrix}$ |
| 16 – 23 | $\frac{1}{4} \begin{bmatrix} 1 & 1 \\ -1 & -1 \\ 1 & 1 \\ -1 & -1 \\ 1 & -1 \\ -1 & 1 \\ 1 & -1 \\ -1 & 1 \end{bmatrix}$ | $\frac{1}{4} \begin{bmatrix} 1 & 1 \\ -1 & -1 \\ 1 & 1 \\ -1 & -1 \\ j & -j \\ -j & j \\ j & -j \\ -j & j \end{bmatrix}$ | $\frac{1}{4} \begin{bmatrix} 1 & 1 \\ -1 & -j \\ 1 & -1 \\ -1 & j \\ 1 & -1 \\ -1 & j \\ 1 & 1 \\ -1 & -j \end{bmatrix}$ | $\frac{1}{4} \begin{bmatrix} 1 & 1 \\ -1 & -j \\ 1 & -1 \\ -1 & j \\ j & -j \\ -j & -1 \\ j & j \\ -j & 1 \end{bmatrix}$ | $\frac{1}{4} \begin{bmatrix} 1 & 1 \\ -1 & 1 \\ 1 & 1 \\ -1 & 1 \\ 1 & -1 \\ -1 & -1 \\ 1 & -1 \\ -1 & -1 \end{bmatrix}$ | $\frac{1}{4} \begin{bmatrix} 1 & 1 \\ -1 & 1 \\ 1 & 1 \\ -1 & 1 \\ j & -j \\ -j & -j \\ j & -j \\ -j & -j \end{bmatrix}$ | $\frac{1}{4} \begin{bmatrix} 1 & 1 \\ -1 & j \\ 1 & -1 \\ -1 & -j \\ 1 & -1 \\ -1 & -j \\ 1 & 1 \\ -1 & j \end{bmatrix}$ | $\frac{1}{4} \begin{bmatrix} 1 & 1 \\ -1 & j \\ 1 & -1 \\ -1 & -j \\ j & -j \\ -j & 1 \\ j & j \\ -j & -1 \end{bmatrix}$ |
| 24 – 31 | $\frac{1}{4} \begin{bmatrix} 1 & 1 \\ -j & -j \\ -1 & -1 \\ j & j \\ 1 & -1 \\ -j & j \\ -1 & 1 \\ j & -j \end{bmatrix}$ | $\frac{1}{4} \begin{bmatrix} 1 & 1 \\ -j & -j \\ -1 & -1 \\ j & j \\ j & -j \\ 1 & -1 \\ -j & j \\ -1 & 1 \end{bmatrix}$ | $\frac{1}{4} \begin{bmatrix} 1 & 1 \\ -j & 1 \\ -1 & 1 \\ j & 1 \\ 1 & -1 \\ -j & -1 \\ -1 & -1 \\ j & -1 \end{bmatrix}$ | $\frac{1}{4} \begin{bmatrix} 1 & 1 \\ -j & 1 \\ -1 & 1 \\ j & 1 \\ j & -j \\ 1 & -j \\ -j & -j \\ -1 & -j \end{bmatrix}$ | $\frac{1}{4} \begin{bmatrix} 1 & 1 \\ -j & j \\ -1 & -1 \\ j & -j \\ 1 & -1 \\ -j & -j \\ -1 & 1 \\ j & j \end{bmatrix}$ | $\frac{1}{4} \begin{bmatrix} 1 & 1 \\ -j & j \\ -1 & -1 \\ j & -j \\ j & -j \\ 1 & 1 \\ -j & j \\ -1 & -1 \end{bmatrix}$ | $\frac{1}{4} \begin{bmatrix} 1 & 1 \\ -j & -1 \\ -1 & 1 \\ j & -1 \\ 1 & -1 \\ -j & 1 \\ -1 & -1 \\ j & 1 \end{bmatrix}$ | $\frac{1}{4} \begin{bmatrix} 1 & 1 \\ -j & -1 \\ -1 & 1 \\ j & -1 \\ j & -j \\ 1 & j \\ -j & -j \\ -1 & j \end{bmatrix}$ |

Table 6.3.1.5-11: Intermediate precoding matrix W' for $codebook1=ng1n4n1$ and three-layer transmission using eight antenna ports with transform precoding disabled.

| TPMI index | Intermediate precoder matrix W' (ordered from left to right in increasing order of TPMI index) | | | |
|------------|--|--|--|--|
| 0 – 3 | $\frac{1}{2\sqrt{6}} \begin{bmatrix} 1 & 1 & 1 \\ 1 & j & 1 \\ 1 & -1 & 1 \\ 1 & -j & 1 \\ 1 & 1 & -1 \\ 1 & j & -1 \\ 1 & -1 & -1 \\ 1 & -j & -1 \end{bmatrix}$ | $\frac{1}{2\sqrt{6}} \begin{bmatrix} 1 & 1 & 1 \\ 1 & j & 1 \\ 1 & -1 & 1 \\ 1 & -j & 1 \\ j & j & -j \\ j & -1 & -j \\ j & -j & -j \\ j & 1 & -j \end{bmatrix}$ | $\frac{1}{2\sqrt{6}} \begin{bmatrix} 1 & 1 & 1 \\ 1 & -1 & 1 \\ 1 & 1 & 1 \\ 1 & -1 & 1 \\ 1 & 1 & -1 \\ 1 & -1 & -1 \\ 1 & 1 & -1 \\ 1 & -1 & -1 \end{bmatrix}$ | $\frac{1}{2\sqrt{6}} \begin{bmatrix} 1 & 1 & 1 \\ 1 & -1 & 1 \\ 1 & 1 & 1 \\ 1 & -1 & 1 \\ j & j & -j \\ j & -j & -j \\ j & j & -j \\ j & -j & -j \end{bmatrix}$ |
| 4 – 7 | $\frac{1}{2\sqrt{6}} \begin{bmatrix} 1 & 1 & 1 \\ 1 & -j & 1 \\ 1 & -1 & 1 \\ 1 & j & 1 \\ 1 & 1 & -1 \\ 1 & -j & -1 \\ 1 & -1 & -1 \\ 1 & j & -1 \end{bmatrix}$ | $\frac{1}{2\sqrt{6}} \begin{bmatrix} 1 & 1 & 1 \\ 1 & -j & 1 \\ 1 & -1 & 1 \\ 1 & j & 1 \\ j & j & -j \\ j & 1 & -j \\ j & -j & -j \\ j & -1 & -j \end{bmatrix}$ | $\frac{1}{2\sqrt{6}} \begin{bmatrix} 1 & 1 & 1 \\ j & -1 & j \\ -1 & 1 & -1 \\ -j & -1 & -j \\ 1 & 1 & -1 \\ j & -1 & -j \\ -1 & 1 & 1 \\ -j & -1 & j \end{bmatrix}$ | $\frac{1}{2\sqrt{6}} \begin{bmatrix} 1 & 1 & 1 \\ j & -1 & j \\ -1 & 1 & -1 \\ -j & -1 & -j \\ j & j & -j \\ -1 & -j & 1 \\ -j & j & j \\ 1 & -j & -1 \end{bmatrix}$ |
| 8 – 11 | $\frac{1}{2\sqrt{6}} \begin{bmatrix} 1 & 1 & 1 \\ j & -j & j \\ -1 & -1 & -1 \\ -j & j & -j \\ 1 & 1 & -1 \\ j & -j & -j \\ -1 & -1 & 1 \\ -j & j & j \end{bmatrix}$ | $\frac{1}{2\sqrt{6}} \begin{bmatrix} 1 & 1 & 1 \\ j & -j & j \\ -1 & -1 & -1 \\ -j & j & -j \\ j & j & -j \\ -1 & 1 & 1 \\ -j & -j & j \\ 1 & -1 & -1 \end{bmatrix}$ | $\frac{1}{2\sqrt{6}} \begin{bmatrix} 1 & 1 & 1 \\ j & 1 & j \\ -1 & 1 & -1 \\ -j & 1 & -j \\ 1 & 1 & -1 \\ j & 1 & -j \\ -1 & 1 & 1 \\ -j & 1 & j \end{bmatrix}$ | $\frac{1}{2\sqrt{6}} \begin{bmatrix} 1 & 1 & 1 \\ j & 1 & j \\ -1 & 1 & -1 \\ -j & 1 & -j \\ j & j & -j \\ -1 & j & 1 \\ -j & j & j \\ 1 & j & -1 \end{bmatrix}$ |
| 12 – 15 | $\frac{1}{2\sqrt{6}} \begin{bmatrix} 1 & 1 & 1 \\ -1 & -j & -1 \\ 1 & -1 & 1 \\ -1 & j & -1 \\ 1 & 1 & -1 \\ -1 & -j & 1 \\ 1 & -1 & -1 \\ -1 & j & 1 \end{bmatrix}$ | $\frac{1}{2\sqrt{6}} \begin{bmatrix} 1 & 1 & 1 \\ -1 & -j & -1 \\ 1 & -1 & 1 \\ -1 & j & -1 \\ j & j & -j \\ -j & 1 & j \\ j & -j & -j \\ -j & -1 & j \end{bmatrix}$ | $\frac{1}{2\sqrt{6}} \begin{bmatrix} 1 & 1 & 1 \\ -1 & 1 & -1 \\ 1 & 1 & 1 \\ -1 & 1 & -1 \\ 1 & 1 & -1 \\ -1 & 1 & 1 \\ 1 & 1 & -1 \\ -1 & 1 & 1 \end{bmatrix}$ | $\frac{1}{2\sqrt{6}} \begin{bmatrix} 1 & 1 & 1 \\ -1 & 1 & -1 \\ 1 & 1 & 1 \\ -1 & 1 & -1 \\ j & j & -j \\ -j & j & j \\ j & j & -j \\ -j & j & j \end{bmatrix}$ |
| 16 – 19 | $\frac{1}{2\sqrt{6}} \begin{bmatrix} 1 & 1 & 1 \\ -1 & j & -1 \\ 1 & -1 & 1 \\ -1 & -j & -1 \\ 1 & 1 & -1 \\ -1 & j & 1 \\ 1 & -1 & -1 \\ -1 & -j & 1 \end{bmatrix}$ | $\frac{1}{2\sqrt{6}} \begin{bmatrix} 1 & 1 & 1 \\ -1 & j & -1 \\ 1 & -1 & 1 \\ -1 & -j & -1 \\ j & j & -j \\ -j & -1 & j \\ j & -j & -j \\ -j & 1 & j \end{bmatrix}$ | $\frac{1}{2\sqrt{6}} \begin{bmatrix} 1 & 1 & 1 \\ -j & 1 & -j \\ -1 & 1 & -1 \\ j & 1 & j \\ 1 & 1 & -1 \\ -j & 1 & j \\ -1 & 1 & 1 \\ j & 1 & -j \end{bmatrix}$ | $\frac{1}{2\sqrt{6}} \begin{bmatrix} 1 & 1 & 1 \\ -j & 1 & -j \\ -1 & 1 & -1 \\ j & 1 & j \\ j & j & -j \\ 1 & j & -1 \\ -j & j & j \\ -1 & j & 1 \end{bmatrix}$ |
| 20 – 23 | $\frac{1}{2\sqrt{6}} \begin{bmatrix} 1 & 1 & 1 \\ -j & j & -j \\ -1 & -1 & -1 \\ j & -j & j \\ 1 & 1 & -1 \\ -j & j & j \\ -1 & -1 & 1 \\ j & -j & -j \end{bmatrix}$ | $\frac{1}{2\sqrt{6}} \begin{bmatrix} 1 & 1 & 1 \\ -j & j & -j \\ -1 & -1 & -1 \\ j & -j & j \\ j & j & -j \\ 1 & -1 & -1 \\ -j & -j & j \\ -1 & 1 & 1 \end{bmatrix}$ | $\frac{1}{2\sqrt{6}} \begin{bmatrix} 1 & 1 & 1 \\ -j & -1 & -j \\ -1 & 1 & -1 \\ j & -1 & j \\ 1 & 1 & -1 \\ -j & -1 & j \\ -1 & 1 & 1 \\ j & -1 & -j \end{bmatrix}$ | $\frac{1}{2\sqrt{6}} \begin{bmatrix} 1 & 1 & 1 \\ -j & -1 & -j \\ -1 & 1 & -1 \\ j & -1 & j \\ j & j & -j \\ 1 & -j & -1 \\ -j & j & j \\ -1 & -j & 1 \end{bmatrix}$ |

Table 6.3.1.5-12: Intermediate precoding matrix W' for $codebook1=ng1n4n1$ and four-layer transmission using eight antenna ports with transform precoding disabled.

| TPMI index | Intermediate precoder matrix W' (ordered from left to right in increasing order of TPMI index) | | | |
|------------|--|--|--|--|
| 0 – 3 | $\frac{1}{4\sqrt{2}} \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & j & 1 & j \\ 1 & -1 & 1 & -1 \\ 1 & -j & 1 & -j \\ 1 & 1 & -1 & -1 \\ 1 & j & -1 & -j \\ 1 & -1 & -1 & 1 \\ 1 & -j & -1 & j \end{bmatrix}$ | $\frac{1}{4\sqrt{2}} \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & j & 1 & j \\ 1 & -1 & 1 & -1 \\ 1 & -j & 1 & -j \\ j & j & -j & -j \\ j & -1 & -j & 1 \\ j & -j & -j & j \\ j & 1 & -j & -1 \end{bmatrix}$ | $\frac{1}{4\sqrt{2}} \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & -1 & 1 & -1 \\ 1 & 1 & 1 & 1 \\ 1 & -1 & 1 & -1 \\ 1 & 1 & -1 & -1 \\ 1 & -1 & -1 & 1 \\ 1 & 1 & -1 & -1 \\ -1 & -1 & -1 & 1 \end{bmatrix}$ | $\frac{1}{4\sqrt{2}} \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & -1 & 1 & -1 \\ 1 & 1 & 1 & 1 \\ 1 & -1 & 1 & -1 \\ j & j & -j & -j \\ j & -j & -j & j \\ j & j & -j & -j \\ j & -j & -j & j \end{bmatrix}$ |
| 4 – 7 | $\frac{1}{4\sqrt{2}} \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & -j & 1 & -j \\ 1 & -1 & 1 & -1 \\ 1 & j & 1 & j \\ 1 & 1 & -1 & -1 \\ 1 & -j & -1 & j \\ 1 & -1 & -1 & 1 \\ 1 & j & -1 & -j \end{bmatrix}$ | $\frac{1}{4\sqrt{2}} \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & -j & 1 & -j \\ 1 & -1 & 1 & -1 \\ 1 & j & 1 & j \\ j & j & -j & -j \\ j & 1 & -j & -1 \\ j & -j & -j & j \\ j & -1 & -j & 1 \end{bmatrix}$ | $\frac{1}{4\sqrt{2}} \begin{bmatrix} 1 & 1 & 1 & 1 \\ j & -1 & j & -1 \\ -1 & 1 & -1 & 1 \\ -j & -1 & -j & -1 \\ 1 & 1 & -1 & -1 \\ j & -1 & -j & 1 \\ -1 & 1 & 1 & -1 \\ -j & -1 & j & 1 \end{bmatrix}$ | $\frac{1}{4\sqrt{2}} \begin{bmatrix} 1 & 1 & 1 & 1 \\ j & -1 & j & -1 \\ -1 & 1 & -1 & 1 \\ -j & -1 & -j & -1 \\ j & j & -j & -j \\ -1 & -j & 1 & j \\ -j & j & j & -j \\ 1 & -j & -1 & j \end{bmatrix}$ |
| 8 – 11 | $\frac{1}{4\sqrt{2}} \begin{bmatrix} 1 & 1 & 1 & 1 \\ j & -j & j & -j \\ -1 & -1 & -1 & -1 \\ -j & j & -j & j \\ 1 & 1 & -1 & -1 \\ j & -j & -j & j \\ -1 & -1 & 1 & 1 \\ -j & j & j & -j \end{bmatrix}$ | $\frac{1}{4\sqrt{2}} \begin{bmatrix} 1 & 1 & 1 & 1 \\ j & -j & j & -j \\ -1 & -1 & -1 & -1 \\ -j & j & -j & j \\ j & j & -j & -j \\ -1 & 1 & 1 & -1 \\ -j & -j & j & j \\ 1 & -1 & -1 & 1 \end{bmatrix}$ | $\frac{1}{4\sqrt{2}} \begin{bmatrix} 1 & 1 & 1 & 1 \\ j & 1 & j & 1 \\ -1 & 1 & -1 & 1 \\ -j & 1 & -j & 1 \\ 1 & 1 & -1 & -1 \\ j & 1 & -j & -1 \\ -1 & 1 & 1 & -1 \\ -j & 1 & j & -1 \end{bmatrix}$ | $\frac{1}{4\sqrt{2}} \begin{bmatrix} 1 & 1 & 1 & 1 \\ j & 1 & j & 1 \\ -1 & 1 & -1 & 1 \\ -j & 1 & -j & 1 \\ j & j & -j & -j \\ -1 & j & 1 & -j \\ -j & j & j & -j \\ 1 & j & -1 & -j \end{bmatrix}$ |
| 12 – 15 | $\frac{1}{4\sqrt{2}} \begin{bmatrix} 1 & 1 & 1 & 1 \\ -1 & -j & -1 & -j \\ 1 & -1 & 1 & -1 \\ -1 & j & -1 & j \\ 1 & 1 & -1 & -1 \\ -1 & -j & 1 & j \\ 1 & -1 & -1 & 1 \\ -1 & j & 1 & -j \end{bmatrix}$ | $\frac{1}{4\sqrt{2}} \begin{bmatrix} 1 & 1 & 1 & 1 \\ -1 & -j & -1 & -j \\ 1 & -1 & 1 & -1 \\ -1 & j & -1 & j \\ j & j & -j & -j \\ -j & 1 & j & -1 \\ j & -j & -j & j \\ -j & -1 & j & 1 \end{bmatrix}$ | $\frac{1}{4\sqrt{2}} \begin{bmatrix} 1 & 1 & 1 & 1 \\ -1 & 1 & -1 & 1 \\ 1 & 1 & 1 & 1 \\ -1 & 1 & -1 & 1 \\ 1 & 1 & -1 & -1 \\ -1 & 1 & 1 & -1 \\ 1 & 1 & -1 & -1 \\ -1 & 1 & 1 & -1 \end{bmatrix}$ | $\frac{1}{4\sqrt{2}} \begin{bmatrix} 1 & 1 & 1 & 1 \\ -1 & 1 & -1 & 1 \\ 1 & 1 & 1 & 1 \\ -1 & 1 & -1 & 1 \\ j & j & -j & -j \\ -j & j & j & -j \\ j & j & -j & -j \\ -j & j & j & -j \end{bmatrix}$ |
| 16 – 19 | $\frac{1}{4\sqrt{2}} \begin{bmatrix} 1 & 1 & 1 & 1 \\ -1 & j & -1 & j \\ 1 & -1 & 1 & -1 \\ -1 & -j & -1 & -j \\ 1 & 1 & -1 & -1 \\ -1 & j & 1 & -j \\ 1 & -1 & -1 & 1 \\ -1 & -j & 1 & j \end{bmatrix}$ | $\frac{1}{4\sqrt{2}} \begin{bmatrix} 1 & 1 & 1 & 1 \\ -1 & j & -1 & j \\ 1 & -1 & 1 & -1 \\ -1 & -j & -1 & -j \\ j & j & -j & -j \\ -j & -1 & j & 1 \\ j & -j & -j & j \\ -j & 1 & j & -1 \end{bmatrix}$ | $\frac{1}{4\sqrt{2}} \begin{bmatrix} 1 & 1 & 1 & 1 \\ -j & 1 & -j & 1 \\ -1 & 1 & -1 & 1 \\ j & 1 & j & 1 \\ 1 & 1 & -1 & -1 \\ -j & 1 & j & -1 \\ -1 & 1 & 1 & -1 \\ j & 1 & -j & -1 \end{bmatrix}$ | $\frac{1}{4\sqrt{2}} \begin{bmatrix} 1 & 1 & 1 & 1 \\ -j & 1 & -j & 1 \\ -1 & 1 & -1 & 1 \\ j & 1 & j & 1 \\ j & j & -j & -j \\ 1 & j & -1 & -j \\ -j & j & j & -j \\ -1 & j & 1 & -j \end{bmatrix}$ |
| 20 – 23 | $\frac{1}{4\sqrt{2}} \begin{bmatrix} 1 & 1 & 1 & 1 \\ -j & j & -j & j \\ -1 & -1 & -1 & -1 \\ j & -j & j & -j \\ 1 & 1 & -1 & -1 \\ -j & j & j & -j \\ -1 & -1 & 1 & 1 \\ j & -j & -j & j \end{bmatrix}$ | $\frac{1}{4\sqrt{2}} \begin{bmatrix} 1 & 1 & 1 & 1 \\ -j & j & -j & j \\ -1 & -1 & -1 & -1 \\ j & -j & j & -j \\ j & j & -j & -j \\ 1 & -1 & -1 & 1 \\ -j & -j & j & j \\ -1 & 1 & 1 & -1 \end{bmatrix}$ | $\frac{1}{4\sqrt{2}} \begin{bmatrix} 1 & 1 & 1 & 1 \\ -j & -1 & -j & -1 \\ -1 & 1 & -1 & 1 \\ j & -1 & j & -1 \\ 1 & 1 & -1 & -1 \\ -j & -1 & j & 1 \\ -1 & 1 & 1 & -1 \\ j & -1 & -j & 1 \end{bmatrix}$ | $\frac{1}{4\sqrt{2}} \begin{bmatrix} 1 & 1 & 1 & 1 \\ -j & -1 & -j & -1 \\ -1 & 1 & -1 & 1 \\ j & -1 & j & -1 \\ j & j & -j & -j \\ 1 & -j & -1 & j \\ -j & j & j & -j \\ -1 & -j & 1 & j \end{bmatrix}$ |

Table 6.3.1.5-13: Intermediate precoding matrix W' for $codebook1=ng1n4n1$ and five-layer transmission using eight antenna ports with transform precoding disabled.

| TPMI index | Intermediate precoder matrix W' (ordered from left to right in increasing order of TPMI index) | |
|------------|---|--|
| 0 – 1 | $\frac{1}{2\sqrt{10}}$ | $\begin{bmatrix} 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & j & j & -1 \\ 1 & 1 & -1 & -1 & 1 \\ 1 & 1 & -j & -j & -1 \\ 1 & -1 & 1 & -1 & 1 \\ 1 & -1 & j & -j & -1 \\ 1 & -1 & -1 & 1 & 1 \\ 1 & -1 & -j & j & -1 \end{bmatrix}$ |
| | $\frac{1}{2\sqrt{10}}$ | $\begin{bmatrix} 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & j & j & -1 \\ 1 & 1 & -1 & -1 & 1 \\ 1 & 1 & -j & -j & -1 \\ j & -j & 1 & -1 & 1 \\ j & -j & j & -j & -1 \\ j & -j & -1 & 1 & 1 \\ j & -j & -j & j & -1 \end{bmatrix}$ |
| 2 – 3 | $\frac{1}{2\sqrt{10}}$ | $\begin{bmatrix} 1 & 1 & 1 & 1 & 1 \\ j & j & -1 & -1 & -j \\ -1 & -1 & 1 & 1 & -1 \\ -j & -j & -1 & -1 & j \\ 1 & -1 & 1 & -1 & 1 \\ j & -j & -1 & 1 & -j \\ -1 & 1 & 1 & -1 & -1 \\ -j & j & -1 & 1 & j \end{bmatrix}$ |
| | $\frac{1}{2\sqrt{10}}$ | $\begin{bmatrix} 1 & 1 & 1 & 1 & 1 \\ j & j & -1 & -1 & -j \\ -1 & -1 & 1 & 1 & -1 \\ -j & -j & -1 & -1 & j \\ j & -j & 1 & -1 & 1 \\ -1 & 1 & -1 & 1 & -j \\ -j & j & 1 & -1 & -1 \\ 1 & -1 & -1 & 1 & j \end{bmatrix}$ |
| 4 – 5 | $\frac{1}{2\sqrt{10}}$ | $\begin{bmatrix} 1 & 1 & 1 & 1 & 1 \\ -1 & -1 & -j & -j & 1 \\ 1 & 1 & -1 & -1 & 1 \\ -1 & -1 & j & j & 1 \\ 1 & -1 & 1 & -1 & 1 \\ -1 & 1 & -j & j & 1 \\ 1 & -1 & -1 & 1 & 1 \\ -1 & 1 & j & -j & 1 \end{bmatrix}$ |
| | $\frac{1}{2\sqrt{10}}$ | $\begin{bmatrix} 1 & 1 & 1 & 1 & 1 \\ -1 & -1 & -j & -j & 1 \\ 1 & 1 & -1 & -1 & 1 \\ -1 & -1 & j & j & 1 \\ j & -j & 1 & -1 & 1 \\ -j & j & -j & j & 1 \\ j & -j & -1 & 1 & 1 \\ -j & j & j & -j & 1 \end{bmatrix}$ |
| 6 – 7 | $\frac{1}{2\sqrt{10}}$ | $\begin{bmatrix} 1 & 1 & 1 & 1 & 1 \\ -j & -j & 1 & 1 & j \\ -1 & -1 & 1 & 1 & -1 \\ j & j & 1 & 1 & -j \\ 1 & -1 & 1 & -1 & 1 \\ -j & j & 1 & -1 & j \\ -1 & 1 & 1 & -1 & -1 \\ j & -j & 1 & -1 & -j \end{bmatrix}$ |
| | $\frac{1}{2\sqrt{10}}$ | $\begin{bmatrix} 1 & 1 & 1 & 1 & 1 \\ -j & -j & 1 & 1 & j \\ -1 & -1 & 1 & 1 & -1 \\ j & j & 1 & 1 & -j \\ j & -j & 1 & -1 & 1 \\ 1 & -1 & 1 & -1 & j \\ -j & j & 1 & -1 & -1 \\ -1 & 1 & 1 & -1 & -j \end{bmatrix}$ |

Table 6.3.1.5-14: Intermediate precoding matrix W' for $codebook1=ng1n4n1$ and six-layer transmission using eight antenna ports with transform precoding disabled.

| TPMI index | Intermediate precoder matrix W' (ordered from left to right in increasing order of TPMI index) | |
|------------|---|--|
| 0-1 | $\frac{1}{4\sqrt{3}}$ | $\begin{bmatrix} 1 & 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & j & j & -1 & -1 \\ 1 & 1 & -1 & -1 & 1 & 1 \\ 1 & 1 & -j & -j & -1 & -1 \\ 1 & -1 & 1 & -1 & 1 & -1 \\ 1 & -1 & j & -j & -1 & 1 \\ 1 & -1 & -1 & 1 & 1 & -1 \\ 1 & -1 & -j & j & -1 & 1 \end{bmatrix}$ |
| 2-3 | $\frac{1}{4\sqrt{3}}$ | $\begin{bmatrix} 1 & 1 & 1 & 1 & 1 & 1 \\ j & j & -1 & -1 & -j & -j \\ -1 & -1 & 1 & 1 & -1 & -1 \\ -j & -j & -1 & -1 & j & j \\ 1 & -1 & 1 & -1 & 1 & -1 \\ j & -j & -1 & 1 & -j & j \\ -1 & 1 & 1 & -1 & -1 & 1 \\ -j & j & -1 & 1 & j & -j \end{bmatrix}$ |
| 4-5 | $\frac{1}{4\sqrt{3}}$ | $\begin{bmatrix} 1 & 1 & 1 & 1 & 1 & 1 \\ -1 & -1 & -j & -j & 1 & 1 \\ 1 & 1 & -1 & -1 & 1 & 1 \\ -1 & -1 & j & j & 1 & 1 \\ 1 & -1 & 1 & -1 & 1 & -1 \\ -1 & 1 & -j & j & 1 & -1 \\ 1 & -1 & -1 & 1 & 1 & -1 \\ -1 & 1 & j & -j & 1 & -1 \end{bmatrix}$ |
| 6-7 | $\frac{1}{4\sqrt{3}}$ | $\begin{bmatrix} 1 & 1 & 1 & 1 & 1 & 1 \\ -j & -j & 1 & 1 & j & j \\ -1 & -1 & 1 & 1 & -1 & -1 \\ j & j & 1 & 1 & -j & -j \\ 1 & -1 & 1 & -1 & 1 & -1 \\ -j & j & 1 & -1 & j & -j \\ -1 & 1 & 1 & -1 & -1 & 1 \\ j & -j & 1 & -1 & -j & j \end{bmatrix}$ |

Table 6.3.1.5-15: Intermediate precoding matrix W' for $codebook1=ng1n4n1$ and seven-layer transmission using eight antenna ports with transform precoding disabled.

| TPMI index | Intermediate precoder matrix W' (ordered from left to right in increasing order of TPMI index) | |
|------------|---|--|
| 0-1 | $\frac{1}{2\sqrt{14}}$ | $\begin{bmatrix} 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & j & -1 & -1 & -j & -j \\ 1 & 1 & -1 & 1 & 1 & -1 & -1 \\ 1 & 1 & -j & -1 & -1 & j & j \\ 1 & -1 & 1 & 1 & -1 & 1 & -1 \\ 1 & -1 & j & -1 & 1 & -j & j \\ 1 & -1 & -1 & 1 & -1 & -1 & 1 \\ 1 & -1 & -j & -1 & 1 & j & -j \end{bmatrix}$ |
| 2-3 | $\frac{1}{2\sqrt{14}}$ | $\begin{bmatrix} 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ j & j & -1 & -j & -j & 1 & 1 \\ -1 & -1 & 1 & -1 & -1 & 1 & 1 \\ -j & -j & -1 & j & j & 1 & 1 \\ 1 & -1 & 1 & 1 & -1 & 1 & -1 \\ j & -j & -1 & -j & j & 1 & -1 \\ -1 & 1 & 1 & -1 & 1 & 1 & -1 \\ -j & j & -1 & j & -j & 1 & -1 \end{bmatrix}$ |

Table 6.3.1.5-16: Intermediate precoding matrix W' for $codebook1=ng1n4n1$ and eight-layer transmission using eight antenna ports with transform precoding disabled.

| TPMI index | Intermediate precoder matrix W' (ordered from left to right in increasing order of TPMI index) | | | | | | | | | | | | | | | |
|------------|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|
| 0 – 1 | $\frac{1}{8} \begin{bmatrix} 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & j & j & -1 & -1 & -j & -j \\ 1 & 1 & -1 & -1 & 1 & 1 & -1 & -1 \\ 1 & 1 & -j & -j & -1 & -1 & j & j \\ 1 & -1 & 1 & -1 & 1 & -1 & 1 & -1 \\ 1 & -1 & j & -j & -1 & 1 & -j & j \\ 1 & -1 & -1 & 1 & 1 & -1 & -1 & 1 \\ 1 & -1 & -j & j & -1 & 1 & j & -j \end{bmatrix}$ | | | | | | | | $\frac{1}{8} \begin{bmatrix} 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & j & j & -1 & -1 & -j & -j \\ 1 & 1 & -1 & -1 & 1 & 1 & -1 & -1 \\ 1 & 1 & -j & -j & -1 & -1 & j & j \\ j & -j & j & -j & 1 & -1 & 1 & -1 \\ j & -j & -1 & 1 & -1 & 1 & -j & j \\ j & -j & -j & j & 1 & -1 & -1 & 1 \\ j & -j & 1 & -1 & -1 & 1 & j & -j \end{bmatrix}$ | | | | | | | |
| 2 – 3 | $\frac{1}{8} \begin{bmatrix} 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ j & j & -1 & -1 & -j & -j & 1 & 1 \\ -1 & -1 & 1 & 1 & -1 & -1 & 1 & 1 \\ -j & -j & -1 & -1 & j & j & 1 & 1 \\ 1 & -1 & 1 & -1 & 1 & -1 & 1 & -1 \\ j & -j & -1 & 1 & -j & j & 1 & -1 \\ -1 & 1 & 1 & -1 & -1 & 1 & 1 & -1 \\ -j & j & -1 & 1 & j & -j & 1 & -1 \end{bmatrix}$ | | | | | | | | $\frac{1}{8} \begin{bmatrix} 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ j & j & -1 & -1 & -j & -j & 1 & 1 \\ -1 & -1 & 1 & 1 & -1 & -1 & 1 & 1 \\ -j & -j & -1 & -1 & j & j & 1 & 1 \\ j & -j & j & -j & 1 & -1 & 1 & -1 \\ -1 & 1 & -j & j & -j & j & 1 & -1 \\ -j & j & j & -j & -1 & 1 & 1 & -1 \\ 1 & -1 & -j & j & j & -j & 1 & -1 \end{bmatrix}$ | | | | | | | |

Table 6.3.1.5-17: Intermediate precoding matrix W' for $codebook1=ng1n2n2$ and single-layer transmission using eight antenna ports.

| TPMI index | Intermediate precoder matrix W' (ordered from left to right in increasing order of TPMI index) | | | | | | | | | |
|------------|---|---|---|---|--|--|---|--|--|--|
| 0 – 7 | $\frac{1}{2\sqrt{2}} \begin{bmatrix} 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \end{bmatrix}$ | $\frac{1}{2\sqrt{2}} \begin{bmatrix} 1 \\ 1 \\ j \\ j \\ j \\ j \end{bmatrix}$ | $\frac{1}{2\sqrt{2}} \begin{bmatrix} 1 \\ 1 \\ -1 \\ -1 \\ -1 \\ -1 \end{bmatrix}$ | $\frac{1}{2\sqrt{2}} \begin{bmatrix} 1 \\ 1 \\ -j \\ -j \\ -j \\ -j \end{bmatrix}$ | $\frac{1}{2\sqrt{2}} \begin{bmatrix} 1 \\ 1 \\ 1 \\ -1 \\ -1 \\ 1 \\ -1 \end{bmatrix}$ | $\frac{1}{2\sqrt{2}} \begin{bmatrix} 1 \\ 1 \\ -1 \\ -1 \\ j \\ j \\ -j \end{bmatrix}$ | $\frac{1}{2\sqrt{2}} \begin{bmatrix} 1 \\ 1 \\ -1 \\ -1 \\ 1 \\ 1 \\ -1 \end{bmatrix}$ | $\frac{1}{2\sqrt{2}} \begin{bmatrix} 1 \\ 1 \\ -1 \\ -1 \\ 1 \\ 1 \\ -1 \end{bmatrix}$ | $\frac{1}{2\sqrt{2}} \begin{bmatrix} 1 \\ 1 \\ -1 \\ -1 \\ 1 \\ 1 \\ -1 \end{bmatrix}$ | $\frac{1}{2\sqrt{2}} \begin{bmatrix} 1 \\ 1 \\ -1 \\ -1 \\ 1 \\ 1 \\ -1 \end{bmatrix}$ |
| 8 – 15 | $\frac{1}{2\sqrt{2}} \begin{bmatrix} 1 \\ -1 \\ -1 \\ 1 \\ 1 \\ -1 \\ -1 \end{bmatrix}$ | $\frac{1}{2\sqrt{2}} \begin{bmatrix} 1 \\ -1 \\ -1 \\ j \\ j \\ -j \\ -j \end{bmatrix}$ | $\frac{1}{2\sqrt{2}} \begin{bmatrix} 1 \\ -1 \\ -1 \\ -1 \\ -1 \\ 1 \\ 1 \end{bmatrix}$ | $\frac{1}{2\sqrt{2}} \begin{bmatrix} 1 \\ -1 \\ -1 \\ -j \\ -j \\ j \\ j \end{bmatrix}$ | $\frac{1}{2\sqrt{2}} \begin{bmatrix} 1 \\ -1 \\ -1 \\ 1 \\ 1 \\ -1 \\ 1 \end{bmatrix}$ | $\frac{1}{2\sqrt{2}} \begin{bmatrix} 1 \\ -1 \\ -1 \\ 1 \\ 1 \\ -1 \\ 1 \end{bmatrix}$ | $\frac{1}{2\sqrt{2}} \begin{bmatrix} 1 \\ -1 \\ -1 \\ j \\ j \\ -j \\ -j \end{bmatrix}$ | $\frac{1}{2\sqrt{2}} \begin{bmatrix} 1 \\ -1 \\ -1 \\ 1 \\ 1 \\ -1 \\ 1 \end{bmatrix}$ | $\frac{1}{2\sqrt{2}} \begin{bmatrix} 1 \\ -1 \\ -1 \\ 1 \\ 1 \\ -1 \\ 1 \end{bmatrix}$ | $\frac{1}{2\sqrt{2}} \begin{bmatrix} 1 \\ -1 \\ -1 \\ 1 \\ 1 \\ -1 \\ 1 \end{bmatrix}$ |

Table 6.3.1.5-18: Intermediate precoding matrix W' for $codebook1=ng1n2n2$ and two-layer transmission using eight antenna ports with transform precoding disabled.

| TPMI index | Intermediate precoder matrix W' (ordered from left to right in increasing order of TPMI index) | | | | | | | |
|------------|--|--|--|---|--|---|---|--|
| 0 – 7 | $\frac{1}{4} \begin{bmatrix} 1 & 1 \\ 1 & 1 \\ 1 & 1 \\ 1 & 1 \\ 1 & -1 \\ 1 & -1 \\ 1 & -1 \\ 1 & -1 \end{bmatrix}$ | $\frac{1}{4} \begin{bmatrix} 1 & 1 \\ 1 & 1 \\ 1 & 1 \\ 1 & 1 \\ j & -j \\ j & -j \\ j & -j \\ j & -j \end{bmatrix}$ | $\frac{1}{4} \begin{bmatrix} 1 & 1 \\ 1 & 1 \\ 1 & -1 \\ 1 & -1 \\ 1 & -1 \\ 1 & -1 \\ 1 & 1 \\ 1 & 1 \end{bmatrix}$ | $\frac{1}{4} \begin{bmatrix} 1 & 1 \\ 1 & 1 \\ 1 & -1 \\ 1 & -1 \\ j & -j \\ j & -j \\ j & -j \\ j & -j \end{bmatrix}$ | $\frac{1}{4} \begin{bmatrix} 1 & 1 \\ 1 & -1 \\ 1 & 1 \\ 1 & -1 \\ 1 & -1 \\ 1 & -1 \\ 1 & 1 \\ -1 & 1 \end{bmatrix}$ | $\frac{1}{4} \begin{bmatrix} 1 & 1 \\ 1 & -1 \\ 1 & 1 \\ 1 & -1 \\ j & -j \\ j & -j \\ j & -j \\ j & -j \end{bmatrix}$ | $\frac{1}{4} \begin{bmatrix} 1 & 1 \\ 1 & -1 \\ 1 & 1 \\ 1 & -1 \\ 1 & 1 \\ 1 & -1 \\ 1 & 1 \\ -1 & -1 \end{bmatrix}$ | $\frac{1}{4} \begin{bmatrix} 1 & 1 \\ 1 & -1 \\ 1 & 1 \\ 1 & -1 \\ j & -j \\ j & -j \\ j & -j \\ j & -j \end{bmatrix}$ |
| 8 – 15 | $\frac{1}{4} \begin{bmatrix} 1 & 1 \\ -1 & -1 \\ 1 & 1 \\ -1 & -1 \\ 1 & -1 \\ -1 & 1 \\ 1 & -1 \\ -1 & 1 \end{bmatrix}$ | $\frac{1}{4} \begin{bmatrix} 1 & 1 \\ -1 & -1 \\ 1 & 1 \\ -1 & -1 \\ j & -j \\ -j & j \\ j & -j \\ -j & j \end{bmatrix}$ | $\frac{1}{4} \begin{bmatrix} 1 & 1 \\ -1 & -1 \\ 1 & -1 \\ -1 & 1 \\ 1 & -1 \\ -1 & 1 \\ 1 & 1 \\ -1 & -1 \end{bmatrix}$ | $\frac{1}{4} \begin{bmatrix} 1 & 1 \\ -1 & -1 \\ 1 & -1 \\ -1 & 1 \\ j & -j \\ -j & j \\ j & -j \\ -j & j \end{bmatrix}$ | $\frac{1}{4} \begin{bmatrix} 1 & 1 \\ -1 & 1 \\ 1 & 1 \\ -1 & 1 \\ 1 & -1 \\ -1 & -1 \\ 1 & -1 \\ -1 & -1 \end{bmatrix}$ | $\frac{1}{4} \begin{bmatrix} 1 & 1 \\ -1 & 1 \\ 1 & 1 \\ -1 & 1 \\ j & -j \\ -j & j \\ j & -j \\ -j & j \end{bmatrix}$ | $\frac{1}{4} \begin{bmatrix} 1 & 1 \\ -1 & 1 \\ 1 & -1 \\ -1 & -1 \\ 1 & -1 \\ -1 & -1 \\ 1 & 1 \\ -1 & 1 \end{bmatrix}$ | $\frac{1}{4} \begin{bmatrix} 1 & 1 \\ -1 & 1 \\ 1 & -1 \\ -1 & -1 \\ j & -j \\ -j & j \\ j & -j \\ -j & j \end{bmatrix}$ |
| 16 – 23 | $\frac{1}{4} \begin{bmatrix} 1 & 1 \\ 1 & 1 \\ -1 & -1 \\ -1 & -1 \\ 1 & -1 \\ 1 & -1 \\ -1 & 1 \\ -1 & 1 \end{bmatrix}$ | $\frac{1}{4} \begin{bmatrix} 1 & 1 \\ 1 & 1 \\ -1 & -1 \\ -1 & -1 \\ j & -j \\ j & -j \\ -j & j \\ -j & j \end{bmatrix}$ | $\frac{1}{4} \begin{bmatrix} 1 & 1 \\ 1 & 1 \\ -1 & 1 \\ -1 & 1 \\ 1 & -1 \\ 1 & -1 \\ -1 & -1 \\ -1 & -1 \end{bmatrix}$ | $\frac{1}{4} \begin{bmatrix} 1 & 1 \\ 1 & 1 \\ -1 & 1 \\ -1 & 1 \\ j & -j \\ j & -j \\ -j & -j \\ -j & -j \end{bmatrix}$ | $\frac{1}{4} \begin{bmatrix} 1 & 1 \\ 1 & -1 \\ -1 & -1 \\ -1 & -1 \\ 1 & -1 \\ 1 & -1 \\ -1 & 1 \\ -1 & -1 \end{bmatrix}$ | $\frac{1}{4} \begin{bmatrix} 1 & 1 \\ 1 & -1 \\ -1 & -1 \\ -1 & -1 \\ j & -j \\ j & -j \\ -j & -j \\ -j & -j \end{bmatrix}$ | $\frac{1}{4} \begin{bmatrix} 1 & 1 \\ 1 & -1 \\ -1 & 1 \\ -1 & -1 \\ 1 & -1 \\ 1 & -1 \\ -1 & -1 \\ -1 & 1 \end{bmatrix}$ | $\frac{1}{4} \begin{bmatrix} 1 & 1 \\ 1 & -1 \\ -1 & 1 \\ -1 & -1 \\ j & -j \\ j & -j \\ -j & -j \\ -j & -j \end{bmatrix}$ |
| 24 – 31 | $\frac{1}{4} \begin{bmatrix} 1 & 1 \\ -1 & -1 \\ -1 & -1 \\ 1 & 1 \\ 1 & -1 \\ -1 & 1 \\ -1 & 1 \\ 1 & -1 \end{bmatrix}$ | $\frac{1}{4} \begin{bmatrix} 1 & 1 \\ -1 & -1 \\ -1 & -1 \\ 1 & 1 \\ j & -j \\ -j & j \\ -j & j \\ j & -j \end{bmatrix}$ | $\frac{1}{4} \begin{bmatrix} 1 & 1 \\ -1 & -1 \\ -1 & 1 \\ 1 & -1 \\ 1 & -1 \\ -1 & 1 \\ -1 & -1 \\ 1 & 1 \end{bmatrix}$ | $\frac{1}{4} \begin{bmatrix} 1 & 1 \\ -1 & -1 \\ -1 & 1 \\ 1 & -1 \\ j & -j \\ -j & j \\ -j & -j \\ j & -j \end{bmatrix}$ | $\frac{1}{4} \begin{bmatrix} 1 & 1 \\ -1 & 1 \\ -1 & -1 \\ 1 & -1 \\ 1 & -1 \\ -1 & -1 \\ -1 & 1 \\ 1 & 1 \end{bmatrix}$ | $\frac{1}{4} \begin{bmatrix} 1 & 1 \\ -1 & 1 \\ -1 & -1 \\ 1 & -1 \\ j & -j \\ -j & -j \\ -j & j \\ j & -j \end{bmatrix}$ | $\frac{1}{4} \begin{bmatrix} 1 & 1 \\ -1 & 1 \\ -1 & 1 \\ 1 & 1 \\ 1 & -1 \\ -1 & -1 \\ -1 & -1 \\ 1 & -1 \end{bmatrix}$ | $\frac{1}{4} \begin{bmatrix} 1 & 1 \\ -1 & 1 \\ -1 & 1 \\ 1 & 1 \\ j & -j \\ -j & -j \\ -j & -j \\ j & -j \end{bmatrix}$ |

Table 6.3.1.5-19: Intermediate precoding matrix W' for $codebook1=ng1n2n2$ and three-layer transmission using eight antenna ports with transform precoding disabled.

| TPMI index | Intermediate precoder matrix W' (ordered from left to right in increasing order of TPMI index) | | | |
|------------|--|--|---|--|
| 0 – 3 | $\frac{1}{2\sqrt{6}} \begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & -1 & 1 \\ 1 & -1 & 1 \\ 1 & 1 & -1 \\ 1 & 1 & -1 \\ 1 & -1 & -1 \\ 1 & -1 & -1 \end{bmatrix}$ | $\frac{1}{2\sqrt{6}} \begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & -1 & 1 \\ 1 & -1 & 1 \\ j & j & -j \\ j & j & -j \\ j & -j & -j \\ j & -j & -j \end{bmatrix}$ | $\frac{1}{2\sqrt{6}} \begin{bmatrix} 1 & 1 & 1 \\ 1 & -1 & 1 \\ 1 & 1 & 1 \\ 1 & -1 & 1 \\ 1 & 1 & -1 \\ 1 & 1 & -1 \\ 1 & -1 & -1 \\ 1 & -1 & -1 \end{bmatrix}$ | $\frac{1}{2\sqrt{6}} \begin{bmatrix} 1 & 1 & 1 \\ 1 & -1 & 1 \\ 1 & 1 & 1 \\ 1 & -1 & 1 \\ j & j & -j \\ j & -j & -j \\ j & j & -j \\ j & -j & -j \end{bmatrix}$ |
| 4 – 7 | $\frac{1}{2\sqrt{6}} \begin{bmatrix} 1 & 1 & 1 \\ 1 & -1 & 1 \\ 1 & -1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & -1 \\ 1 & -1 & -1 \\ 1 & -1 & -1 \\ 1 & 1 & -1 \end{bmatrix}$ | $\frac{1}{2\sqrt{6}} \begin{bmatrix} 1 & 1 & 1 \\ 1 & -1 & 1 \\ 1 & -1 & 1 \\ 1 & 1 & 1 \\ j & j & -j \\ j & -j & -j \\ j & -j & -j \\ j & j & -j \end{bmatrix}$ | $\frac{1}{2\sqrt{6}} \begin{bmatrix} 1 & 1 & 1 \\ -1 & -1 & -1 \\ 1 & -1 & 1 \\ -1 & 1 & -1 \\ 1 & 1 & -1 \\ -1 & -1 & 1 \\ 1 & -1 & -1 \\ -1 & 1 & 1 \end{bmatrix}$ | $\frac{1}{2\sqrt{6}} \begin{bmatrix} 1 & 1 & 1 \\ -1 & -1 & -1 \\ 1 & -1 & 1 \\ -1 & 1 & -1 \\ j & j & -j \\ -j & -j & j \\ j & -j & -j \\ -j & j & j \end{bmatrix}$ |
| 8 – 11 | $\frac{1}{2\sqrt{6}} \begin{bmatrix} 1 & 1 & 1 \\ -1 & 1 & -1 \\ 1 & 1 & 1 \\ -1 & 1 & -1 \\ 1 & 1 & -1 \\ -1 & 1 & 1 \\ 1 & 1 & -1 \\ -1 & 1 & 1 \end{bmatrix}$ | $\frac{1}{2\sqrt{6}} \begin{bmatrix} 1 & 1 & 1 \\ -1 & 1 & -1 \\ 1 & 1 & 1 \\ -1 & 1 & -1 \\ j & j & -j \\ -j & j & j \\ j & j & -j \\ -j & j & j \end{bmatrix}$ | $\frac{1}{2\sqrt{6}} \begin{bmatrix} 1 & 1 & 1 \\ -1 & 1 & -1 \\ 1 & -1 & 1 \\ -1 & -1 & -1 \\ 1 & 1 & -1 \\ -1 & 1 & 1 \\ 1 & -1 & -1 \\ -1 & -1 & 1 \end{bmatrix}$ | $\frac{1}{2\sqrt{6}} \begin{bmatrix} 1 & 1 & 1 \\ -1 & 1 & -1 \\ 1 & -1 & 1 \\ -1 & -1 & -1 \\ j & j & -j \\ -j & j & j \\ j & -j & -j \\ -j & -j & j \end{bmatrix}$ |
| 12 – 15 | $\frac{1}{2\sqrt{6}} \begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ -1 & 1 & -1 \\ -1 & 1 & -1 \\ 1 & 1 & -1 \\ 1 & 1 & -1 \\ -1 & 1 & 1 \\ -1 & 1 & 1 \end{bmatrix}$ | $\frac{1}{2\sqrt{6}} \begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ -1 & 1 & -1 \\ -1 & 1 & -1 \\ j & j & -j \\ j & j & -j \\ -j & j & j \\ -j & j & j \end{bmatrix}$ | $\frac{1}{2\sqrt{6}} \begin{bmatrix} 1 & 1 & 1 \\ 1 & -1 & 1 \\ -1 & -1 & -1 \\ -1 & -1 & -1 \\ 1 & 1 & -1 \\ 1 & -1 & -1 \\ -1 & -1 & 1 \\ -1 & 1 & 1 \end{bmatrix}$ | $\frac{1}{2\sqrt{6}} \begin{bmatrix} 1 & 1 & 1 \\ 1 & -1 & 1 \\ -1 & -1 & -1 \\ -1 & -1 & -1 \\ j & j & -j \\ j & -j & -j \\ -j & -j & j \\ -j & -j & j \end{bmatrix}$ |
| 16 – 19 | $\frac{1}{2\sqrt{6}} \begin{bmatrix} 1 & 1 & 1 \\ 1 & -1 & 1 \\ -1 & 1 & -1 \\ -1 & -1 & -1 \\ 1 & 1 & -1 \\ 1 & -1 & -1 \\ -1 & 1 & 1 \\ -1 & -1 & 1 \end{bmatrix}$ | $\frac{1}{2\sqrt{6}} \begin{bmatrix} 1 & 1 & 1 \\ 1 & -1 & 1 \\ -1 & 1 & -1 \\ -1 & -1 & -1 \\ j & j & -j \\ j & -j & -j \\ -j & j & j \\ -j & j & j \end{bmatrix}$ | $\frac{1}{2\sqrt{6}} \begin{bmatrix} 1 & 1 & 1 \\ -1 & -1 & -1 \\ -1 & 1 & -1 \\ 1 & -1 & 1 \\ 1 & 1 & -1 \\ -1 & -1 & 1 \\ -1 & 1 & 1 \\ 1 & -1 & -1 \end{bmatrix}$ | $\frac{1}{2\sqrt{6}} \begin{bmatrix} 1 & 1 & 1 \\ -1 & -1 & -1 \\ -1 & 1 & -1 \\ 1 & -1 & 1 \\ j & j & -j \\ -j & -j & j \\ -j & j & j \\ j & -j & -j \end{bmatrix}$ |
| 20 – 23 | $\frac{1}{2\sqrt{6}} \begin{bmatrix} 1 & 1 & 1 \\ -1 & 1 & -1 \\ -1 & -1 & -1 \\ 1 & -1 & 1 \\ 1 & 1 & -1 \\ -1 & 1 & 1 \\ -1 & -1 & 1 \\ 1 & -1 & -1 \end{bmatrix}$ | $\frac{1}{2\sqrt{6}} \begin{bmatrix} 1 & 1 & 1 \\ -1 & 1 & -1 \\ -1 & -1 & -1 \\ 1 & -1 & 1 \\ j & j & -j \\ -j & j & j \\ -j & -j & j \\ j & -j & -j \end{bmatrix}$ | $\frac{1}{2\sqrt{6}} \begin{bmatrix} 1 & 1 & 1 \\ -1 & 1 & -1 \\ -1 & 1 & -1 \\ 1 & 1 & 1 \\ 1 & 1 & -1 \\ -1 & 1 & 1 \\ -1 & 1 & 1 \\ 1 & 1 & -1 \end{bmatrix}$ | $\frac{1}{2\sqrt{6}} \begin{bmatrix} 1 & 1 & 1 \\ -1 & 1 & -1 \\ -1 & 1 & -1 \\ 1 & 1 & 1 \\ j & j & -j \\ -j & j & j \\ -j & j & j \\ j & j & -j \end{bmatrix}$ |

Table 6.3.1.5-21: Intermediate precoding matrix W' for $codebook1=ng1n2n2$ and five-layer transmission using eight antenna ports with transform precoding disabled.

| TPMI index | Intermediate precoder matrix W' (ordered from left to right in increasing order of TPMI index) | |
|------------|---|--|
| 0 – 1 | $\frac{1}{2\sqrt{10}} \begin{bmatrix} 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & -1 \\ 1 & 1 & -1 & -1 & -1 \\ 1 & 1 & -1 & -1 & 1 \\ 1 & -1 & 1 & -1 & 1 \\ 1 & -1 & 1 & -1 & -1 \\ 1 & -1 & -1 & 1 & -1 \\ 1 & -1 & -1 & 1 & 1 \end{bmatrix}$ | $\frac{1}{2\sqrt{10}} \begin{bmatrix} 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & -1 \\ 1 & 1 & -1 & -1 & -1 \\ 1 & 1 & -1 & -1 & 1 \\ j & -j & 1 & -1 & 1 \\ j & -j & 1 & -1 & 1 \\ j & -j & 1 & -1 & -1 \\ j & -j & -1 & 1 & -1 \\ j & -j & -1 & 1 & 1 \end{bmatrix}$ |
| 2 – 3 | $\frac{1}{2\sqrt{10}} \begin{bmatrix} 1 & 1 & 1 & 1 & 1 \\ -1 & -1 & -1 & -1 & 1 \\ 1 & 1 & -1 & -1 & -1 \\ -1 & -1 & 1 & 1 & -1 \\ 1 & -1 & 1 & -1 & 1 \\ -1 & 1 & -1 & 1 & 1 \\ 1 & -1 & -1 & 1 & -1 \\ -1 & 1 & 1 & -1 & -1 \end{bmatrix}$ | $\frac{1}{2\sqrt{10}} \begin{bmatrix} 1 & 1 & 1 & 1 & 1 \\ -1 & -1 & -1 & -1 & 1 \\ 1 & 1 & -1 & -1 & -1 \\ -1 & -1 & 1 & 1 & -1 \\ j & -j & 1 & -1 & 1 \\ -j & j & -1 & 1 & 1 \\ j & -j & -1 & 1 & -1 \\ -j & j & 1 & -1 & -1 \end{bmatrix}$ |
| 4 – 5 | $\frac{1}{2\sqrt{10}} \begin{bmatrix} 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & -1 \\ -1 & -1 & 1 & 1 & 1 \\ -1 & -1 & 1 & 1 & -1 \\ 1 & -1 & 1 & -1 & 1 \\ 1 & -1 & 1 & -1 & -1 \\ -1 & 1 & 1 & -1 & 1 \\ -1 & 1 & 1 & -1 & -1 \end{bmatrix}$ | $\frac{1}{2\sqrt{10}} \begin{bmatrix} 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & -1 \\ -1 & -1 & 1 & 1 & 1 \\ -1 & -1 & 1 & 1 & -1 \\ j & -j & 1 & -1 & 1 \\ j & -j & 1 & -1 & -1 \\ -j & j & 1 & -1 & 1 \\ -j & j & 1 & -1 & -1 \end{bmatrix}$ |
| 6 – 7 | $\frac{1}{2\sqrt{10}} \begin{bmatrix} 1 & 1 & 1 & 1 & 1 \\ -1 & -1 & -1 & -1 & 1 \\ -1 & -1 & 1 & 1 & 1 \\ 1 & 1 & -1 & -1 & 1 \\ 1 & -1 & 1 & -1 & 1 \\ -1 & 1 & -1 & 1 & 1 \\ -1 & 1 & 1 & -1 & 1 \\ 1 & -1 & -1 & 1 & 1 \end{bmatrix}$ | $\frac{1}{2\sqrt{10}} \begin{bmatrix} 1 & 1 & 1 & 1 & 1 \\ -1 & -1 & -1 & -1 & 1 \\ -1 & -1 & 1 & 1 & 1 \\ 1 & 1 & -1 & -1 & 1 \\ j & -j & 1 & -1 & 1 \\ -j & j & -1 & 1 & 1 \\ -j & j & 1 & -1 & 1 \\ j & -j & -1 & 1 & 1 \end{bmatrix}$ |

Table 6.3.1.5-22: Intermediate precoding matrix W' for $codebook1=ng1n2n2$ and six-layer transmission using eight antenna ports with transform precoding disabled.

| TPMI index | Intermediate precoder matrix W' (ordered from left to right in increasing order of TPMI index) | |
|------------|--|--|
| 0 – 1 | $\frac{1}{4\sqrt{3}} \begin{bmatrix} 1 & 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & -1 & -1 \\ 1 & 1 & -1 & -1 & -1 & -1 \\ 1 & 1 & -1 & -1 & 1 & 1 \\ 1 & -1 & 1 & -1 & 1 & -1 \\ 1 & -1 & 1 & -1 & -1 & 1 \\ 1 & -1 & -1 & 1 & -1 & 1 \\ 1 & -1 & -1 & 1 & 1 & -1 \end{bmatrix}$ | $\frac{1}{4\sqrt{3}} \begin{bmatrix} 1 & 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & -1 & -1 \\ 1 & 1 & -1 & -1 & -1 & -1 \\ 1 & 1 & -1 & -1 & 1 & 1 \\ j & -j & j & -j & 1 & -1 \\ j & -j & j & -j & -1 & 1 \\ j & -j & -j & j & -1 & 1 \\ j & -j & -j & j & 1 & -1 \end{bmatrix}$ |
| 2 – 3 | $\frac{1}{4\sqrt{3}} \begin{bmatrix} 1 & 1 & 1 & 1 & 1 & 1 \\ -1 & -1 & -1 & -1 & 1 & 1 \\ 1 & 1 & -1 & -1 & -1 & -1 \\ -1 & -1 & 1 & 1 & -1 & -1 \\ 1 & -1 & 1 & -1 & 1 & -1 \\ -1 & 1 & -1 & 1 & 1 & -1 \\ 1 & -1 & -1 & 1 & -1 & 1 \\ -1 & 1 & 1 & -1 & -1 & 1 \end{bmatrix}$ | $\frac{1}{4\sqrt{3}} \begin{bmatrix} 1 & 1 & 1 & 1 & 1 & 1 \\ -1 & -1 & -1 & -1 & 1 & 1 \\ 1 & 1 & -1 & -1 & -1 & -1 \\ -1 & -1 & 1 & 1 & -1 & -1 \\ j & -j & j & -j & 1 & -1 \\ -j & j & -j & j & 1 & -1 \\ j & -j & -j & j & -1 & 1 \\ -j & j & j & -j & -1 & 1 \end{bmatrix}$ |
| 4 – 5 | $\frac{1}{4\sqrt{3}} \begin{bmatrix} 1 & 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & -1 & -1 \\ -1 & -1 & 1 & 1 & 1 & 1 \\ -1 & -1 & 1 & 1 & -1 & -1 \\ 1 & -1 & 1 & -1 & 1 & -1 \\ 1 & -1 & 1 & -1 & -1 & 1 \\ -1 & 1 & 1 & -1 & 1 & -1 \\ -1 & 1 & 1 & -1 & -1 & 1 \end{bmatrix}$ | $\frac{1}{4\sqrt{3}} \begin{bmatrix} 1 & 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & -1 & -1 \\ -1 & -1 & 1 & 1 & 1 & 1 \\ -1 & -1 & 1 & 1 & -1 & -1 \\ j & -j & j & -j & 1 & -1 \\ j & -j & j & -j & -1 & 1 \\ -j & j & j & -j & 1 & -1 \\ -j & j & j & -j & -1 & 1 \end{bmatrix}$ |
| 6 – 7 | $\frac{1}{4\sqrt{3}} \begin{bmatrix} 1 & 1 & 1 & 1 & 1 & 1 \\ -1 & -1 & -1 & -1 & 1 & 1 \\ -1 & -1 & 1 & 1 & 1 & 1 \\ 1 & 1 & -1 & -1 & 1 & 1 \\ 1 & -1 & 1 & -1 & 1 & -1 \\ -1 & 1 & -1 & 1 & 1 & -1 \\ -1 & 1 & 1 & -1 & 1 & -1 \\ 1 & -1 & -1 & 1 & 1 & -1 \end{bmatrix}$ | $\frac{1}{4\sqrt{3}} \begin{bmatrix} 1 & 1 & 1 & 1 & 1 & 1 \\ -1 & -1 & -1 & -1 & 1 & 1 \\ -1 & -1 & 1 & 1 & 1 & 1 \\ 1 & 1 & -1 & -1 & 1 & 1 \\ j & -j & j & -j & 1 & -1 \\ -j & j & -j & j & 1 & -1 \\ -j & j & j & -j & 1 & -1 \\ j & -j & -j & j & 1 & -1 \end{bmatrix}$ |

Table 6.3.1.5-23: Intermediate precoding matrix W' for $codebook1=ng1n2n2$ and seven-layer transmission using eight antenna ports with transform precoding disabled.

| TPMI index | Intermediate precoder matrix W' (ordered from left to right in increasing order of TPMI index) | |
|------------|---|---|
| 0-1 | $\frac{1}{2\sqrt{14}} \begin{bmatrix} 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & -1 & -1 & -1 & -1 \\ 1 & 1 & -1 & 1 & 1 & -1 & -1 \\ 1 & 1 & -1 & -1 & -1 & 1 & 1 \\ 1 & -1 & 1 & 1 & -1 & 1 & -1 \\ 1 & -1 & 1 & -1 & 1 & -1 & 1 \\ 1 & -1 & -1 & 1 & -1 & -1 & 1 \\ 1 & -1 & -1 & -1 & 1 & 1 & -1 \end{bmatrix}$ | $\frac{1}{2\sqrt{14}} \begin{bmatrix} 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & -1 & -1 & -1 & -1 \\ 1 & 1 & -1 & 1 & 1 & -1 & -1 \\ 1 & 1 & -1 & -1 & -1 & 1 & 1 \\ j & -j & j & 1 & -1 & 1 & -1 \\ j & -j & j & -1 & 1 & -1 & 1 \\ j & -j & -j & 1 & -1 & -1 & 1 \\ j & -j & -j & -1 & 1 & 1 & -1 \end{bmatrix}$ |
| 2-3 | $\frac{1}{2\sqrt{14}} \begin{bmatrix} 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ -1 & -1 & -1 & 1 & 1 & 1 & 1 \\ 1 & 1 & -1 & 1 & 1 & -1 & -1 \\ -1 & -1 & 1 & 1 & 1 & -1 & -1 \\ 1 & -1 & 1 & 1 & -1 & 1 & -1 \\ -1 & 1 & -1 & 1 & -1 & 1 & -1 \\ 1 & -1 & -1 & 1 & -1 & -1 & 1 \\ -1 & 1 & 1 & 1 & -1 & -1 & 1 \end{bmatrix}$ | $\frac{1}{2\sqrt{14}} \begin{bmatrix} 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ -1 & -1 & -1 & 1 & 1 & 1 & 1 \\ 1 & 1 & -1 & 1 & 1 & -1 & -1 \\ -1 & -1 & 1 & 1 & 1 & -1 & -1 \\ j & -j & j & 1 & -1 & 1 & -1 \\ -j & j & -j & 1 & -1 & 1 & -1 \\ j & -j & -j & 1 & -1 & -1 & 1 \\ -j & j & j & 1 & -1 & -1 & 1 \end{bmatrix}$ |
| 4-5 | $\frac{1}{2\sqrt{14}} \begin{bmatrix} 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & -1 & -1 & -1 & -1 \\ -1 & -1 & 1 & -1 & -1 & 1 & 1 \\ -1 & -1 & 1 & 1 & 1 & -1 & -1 \\ 1 & -1 & 1 & 1 & -1 & 1 & -1 \\ 1 & -1 & 1 & -1 & 1 & -1 & 1 \\ -1 & 1 & 1 & -1 & 1 & 1 & -1 \\ -1 & 1 & 1 & 1 & -1 & -1 & 1 \end{bmatrix}$ | $\frac{1}{2\sqrt{14}} \begin{bmatrix} 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & -1 & -1 & -1 & -1 \\ -1 & -1 & 1 & -1 & -1 & 1 & 1 \\ -1 & -1 & 1 & 1 & 1 & -1 & -1 \\ j & -j & j & 1 & -1 & 1 & -1 \\ j & -j & j & -1 & 1 & -1 & 1 \\ -j & j & j & -1 & 1 & 1 & -1 \\ -j & j & j & 1 & -1 & -1 & 1 \end{bmatrix}$ |
| 6-7 | $\frac{1}{2\sqrt{14}} \begin{bmatrix} 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ -1 & -1 & -1 & 1 & 1 & 1 & 1 \\ -1 & -1 & 1 & -1 & -1 & 1 & 1 \\ 1 & 1 & -1 & -1 & -1 & 1 & 1 \\ 1 & -1 & 1 & 1 & -1 & 1 & -1 \\ -1 & 1 & -1 & 1 & -1 & 1 & -1 \\ -1 & 1 & 1 & -1 & 1 & 1 & -1 \\ 1 & -1 & -1 & -1 & 1 & 1 & -1 \end{bmatrix}$ | $\frac{1}{2\sqrt{14}} \begin{bmatrix} 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ -1 & -1 & -1 & 1 & 1 & 1 & 1 \\ -1 & -1 & 1 & -1 & -1 & 1 & 1 \\ 1 & 1 & -1 & -1 & -1 & 1 & 1 \\ j & -j & j & 1 & -1 & 1 & -1 \\ -j & j & -j & 1 & -1 & 1 & -1 \\ -j & j & j & -1 & 1 & 1 & -1 \\ j & -j & -j & -1 & 1 & 1 & -1 \end{bmatrix}$ |

Table 6.3.1.5-24: Intermediate precoding matrix W' for $codebook1=ng1n2n2$ and eight-layer transmission using eight antenna ports with transform precoding disabled.

| TPMI index | Intermediate precoder matrix W' (ordered from left to right in increasing order of TPMI index) | |
|------------|--|--|
| 0-1 | $\frac{1}{8} \begin{bmatrix} 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & -1 & -1 & -1 & -1 \\ 1 & 1 & -1 & -1 & 1 & 1 & -1 & -1 \\ 1 & 1 & -1 & -1 & -1 & -1 & 1 & 1 \\ 1 & -1 & 1 & -1 & 1 & -1 & 1 & -1 \\ 1 & -1 & 1 & -1 & -1 & 1 & -1 & 1 \\ 1 & -1 & -1 & 1 & 1 & -1 & -1 & 1 \\ 1 & -1 & -1 & 1 & -1 & 1 & 1 & -1 \end{bmatrix}$ | $\frac{1}{8} \begin{bmatrix} 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & -1 & -1 & -1 & -1 \\ 1 & 1 & -1 & -1 & 1 & 1 & -1 & -1 \\ 1 & 1 & -1 & -1 & -1 & -1 & 1 & 1 \\ j & -j & j & -j & 1 & -1 & 1 & -1 \\ j & -j & j & -j & -1 & 1 & -1 & 1 \\ j & -j & -j & j & 1 & -1 & -1 & 1 \\ j & -j & -j & j & -1 & 1 & 1 & -1 \end{bmatrix}$ |
| 2-3 | $\frac{1}{8} \begin{bmatrix} 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ -1 & -1 & -1 & -1 & 1 & 1 & 1 & 1 \\ 1 & 1 & -1 & -1 & 1 & 1 & -1 & -1 \\ -1 & -1 & 1 & 1 & 1 & 1 & -1 & -1 \\ 1 & -1 & 1 & -1 & 1 & -1 & 1 & -1 \\ -1 & 1 & -1 & 1 & 1 & -1 & 1 & -1 \\ 1 & -1 & -1 & 1 & 1 & -1 & -1 & 1 \\ -1 & 1 & 1 & -1 & 1 & -1 & -1 & 1 \end{bmatrix}$ | $\frac{1}{8} \begin{bmatrix} 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ -1 & -1 & -1 & -1 & 1 & 1 & 1 & 1 \\ 1 & 1 & -1 & -1 & 1 & 1 & -1 & -1 \\ -1 & -1 & 1 & 1 & 1 & 1 & -1 & -1 \\ j & -j & j & -j & 1 & -1 & 1 & -1 \\ -j & j & -j & j & 1 & -1 & 1 & -1 \\ j & -j & -j & j & 1 & -1 & -1 & 1 \\ -j & j & j & -j & 1 & -1 & -1 & 1 \end{bmatrix}$ |
| 4-5 | $\frac{1}{8} \begin{bmatrix} 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & -1 & -1 & -1 & -1 \\ -1 & -1 & 1 & 1 & -1 & -1 & 1 & 1 \\ -1 & -1 & 1 & 1 & 1 & 1 & -1 & -1 \\ 1 & -1 & 1 & -1 & 1 & -1 & 1 & -1 \\ 1 & -1 & 1 & -1 & -1 & 1 & -1 & 1 \\ -1 & 1 & 1 & -1 & -1 & 1 & 1 & -1 \\ -1 & 1 & 1 & -1 & 1 & -1 & -1 & 1 \end{bmatrix}$ | $\frac{1}{8} \begin{bmatrix} 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & -1 & -1 & -1 & -1 \\ -1 & -1 & 1 & 1 & -1 & -1 & 1 & 1 \\ -1 & -1 & 1 & 1 & 1 & 1 & -1 & -1 \\ j & -j & j & -j & 1 & -1 & 1 & -1 \\ j & -j & j & -j & -1 & 1 & -1 & 1 \\ -j & j & j & -j & -1 & 1 & 1 & -1 \\ -j & j & j & -j & 1 & -1 & -1 & 1 \end{bmatrix}$ |
| 6-7 | $\frac{1}{8} \begin{bmatrix} 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ -1 & -1 & -1 & -1 & 1 & 1 & 1 & 1 \\ -1 & -1 & 1 & 1 & -1 & -1 & 1 & 1 \\ 1 & 1 & -1 & -1 & -1 & -1 & 1 & 1 \\ 1 & -1 & 1 & -1 & 1 & -1 & 1 & -1 \\ -1 & 1 & -1 & 1 & 1 & -1 & 1 & -1 \\ -1 & 1 & 1 & -1 & -1 & 1 & 1 & -1 \\ 1 & -1 & -1 & 1 & -1 & 1 & 1 & -1 \end{bmatrix}$ | $\frac{1}{8} \begin{bmatrix} 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ -1 & -1 & -1 & -1 & 1 & 1 & 1 & 1 \\ -1 & -1 & 1 & 1 & -1 & -1 & 1 & 1 \\ 1 & 1 & -1 & -1 & -1 & -1 & 1 & 1 \\ j & -j & j & -j & 1 & -1 & 1 & -1 \\ -j & j & -j & j & 1 & -1 & 1 & -1 \\ -j & j & j & -j & -1 & 1 & 1 & -1 \\ j & -j & -j & j & -1 & 1 & 1 & -1 \end{bmatrix}$ |

Table 6.3.1.5-25: Submatrices $\overline{W}_{1,i}$ for $codebook2$ and used in Tables 6.3.1.5-29 to 6.3.1.5-31.

| i | $\overline{W}_{1,i}$ (ordered from left to right in increasing order of i) | | | | | | | |
|------|--|--|--|--|--|---|--|---|
| 0-7 | $\frac{1}{2} \begin{bmatrix} 1 \\ 1 \\ 1 \\ 1 \end{bmatrix}$ | $\frac{1}{2} \begin{bmatrix} 1 \\ 1 \\ j \\ j \end{bmatrix}$ | $\frac{1}{2} \begin{bmatrix} 1 \\ 1 \\ -1 \\ -1 \end{bmatrix}$ | $\frac{1}{2} \begin{bmatrix} 1 \\ 1 \\ -j \\ -j \end{bmatrix}$ | $\frac{1}{2} \begin{bmatrix} 1 \\ j \\ 1 \\ j \end{bmatrix}$ | $\frac{1}{2} \begin{bmatrix} 1 \\ j \\ j \\ -1 \end{bmatrix}$ | $\frac{1}{2} \begin{bmatrix} 1 \\ j \\ -1 \\ -j \end{bmatrix}$ | $\frac{1}{2} \begin{bmatrix} 1 \\ j \\ -j \\ 1 \end{bmatrix}$ |
| 8-15 | $\frac{1}{2} \begin{bmatrix} 1 \\ -1 \\ 1 \\ -1 \end{bmatrix}$ | $\frac{1}{2} \begin{bmatrix} 1 \\ -1 \\ j \\ -j \end{bmatrix}$ | $\frac{1}{2} \begin{bmatrix} 1 \\ -1 \\ -1 \\ 1 \end{bmatrix}$ | $\frac{1}{2} \begin{bmatrix} 1 \\ -1 \\ -j \\ j \end{bmatrix}$ | $\frac{1}{2} \begin{bmatrix} 1 \\ -j \\ 1 \\ -j \end{bmatrix}$ | $\frac{1}{2} \begin{bmatrix} 1 \\ -j \\ j \\ 1 \end{bmatrix}$ | $\frac{1}{2} \begin{bmatrix} 1 \\ -j \\ -1 \\ j \end{bmatrix}$ | $\frac{1}{2} \begin{bmatrix} 1 \\ -j \\ -j \\ -1 \end{bmatrix}$ |

Table 6.3.1.5-26: Submatrices $\overline{W}_{2,i}$ for $codebook2$ and used in Tables 6.3.1.5-30 to 6.3.1.5-33.

| i | $\overline{W}_{2,i}$ (ordered from left to right in increasing order of i) | | | |
|-----|--|--|--|--|
| 0-3 | $\frac{1}{2\sqrt{2}} \begin{bmatrix} 1 & 1 \\ 1 & 1 \\ 1 & -1 \\ 1 & -1 \end{bmatrix}$ | $\frac{1}{2\sqrt{2}} \begin{bmatrix} 1 & 1 \\ 1 & 1 \\ j & -j \\ j & -j \end{bmatrix}$ | $\frac{1}{2\sqrt{2}} \begin{bmatrix} 1 & 1 \\ j & j \\ 1 & -1 \\ j & -j \end{bmatrix}$ | $\frac{1}{2\sqrt{2}} \begin{bmatrix} 1 & 1 \\ j & j \\ j & -j \\ -1 & 1 \end{bmatrix}$ |
| 4-7 | $\frac{1}{2\sqrt{2}} \begin{bmatrix} 1 & 1 \\ -1 & -1 \\ 1 & -1 \\ -1 & 1 \end{bmatrix}$ | $\frac{1}{2\sqrt{2}} \begin{bmatrix} 1 & 1 \\ -1 & -1 \\ j & -j \\ -j & j \end{bmatrix}$ | $\frac{1}{2\sqrt{2}} \begin{bmatrix} 1 & 1 \\ -j & -j \\ 1 & -1 \\ -j & j \end{bmatrix}$ | $\frac{1}{2\sqrt{2}} \begin{bmatrix} 1 & 1 \\ -j & -j \\ j & -j \\ 1 & -1 \end{bmatrix}$ |

Table 6.3.1.5-27: Submatrices $\bar{W}_{3,i}$ for codebook2 and used in Tables 6.3.1.5-31, 6.3.1.5-33, 6.3.1.5-34, and 6.3.1.5-35.

| i | $\bar{W}_{3,i}$ (ordered from left to right in increasing order of i) | | | |
|-----|--|--|--|--|
| 0-3 | $\frac{1}{2\sqrt{3}} \begin{bmatrix} 1 & 1 & 1 \\ 1 & -1 & 1 \\ 1 & 1 & -1 \\ 1 & -1 & -1 \end{bmatrix}$ | $\frac{1}{2\sqrt{3}} \begin{bmatrix} 1 & 1 & 1 \\ 1 & -1 & 1 \\ j & j & -j \\ j & -j & -j \end{bmatrix}$ | $\frac{1}{2\sqrt{3}} \begin{bmatrix} 1 & 1 & 1 \\ -1 & 1 & -1 \\ 1 & 1 & -1 \\ -1 & 1 & 1 \end{bmatrix}$ | $\frac{1}{2\sqrt{3}} \begin{bmatrix} 1 & 1 & 1 \\ -1 & 1 & -1 \\ j & j & -j \\ -j & j & j \end{bmatrix}$ |

Table 6.3.1.5-28: Submatrices $\bar{W}_{4,i}$ for codebook2 and used in Tables 6.3.1.5-32, 6.3.1.5-35, and 6.3.1.5-36.

| i | $\bar{W}_{4,i}$ (ordered from left to right in increasing order of i) | |
|-----|--|--|
| 0-1 | $\frac{1}{4} \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & -1 & 1 & -1 \\ 1 & 1 & -1 & -1 \\ 1 & -1 & -1 & 1 \end{bmatrix}$ | $\frac{1}{4} \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & -1 & 1 & -1 \\ j & j & -j & -j \\ j & -j & -j & j \end{bmatrix}$ |

Table 6.3.1.5-29: Intermediate precoding matrix W' for codebook2 and single-layer transmission using eight antenna ports.

| TPMI index i | Intermediate precoder matrix W' |
|----------------|--|
| 0-15 | $\frac{1}{\sqrt{2}} \begin{bmatrix} \bar{W}_{1,i} \\ 0_{4 \times 1} \end{bmatrix}$ |
| 16-31 | $\frac{1}{\sqrt{2}} \begin{bmatrix} 0_{4 \times 1} \\ \bar{W}_{1,(i-16)} \end{bmatrix}$ |
| 32 | $\frac{1}{2\sqrt{2}} \begin{bmatrix} 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \end{bmatrix}$ |

Table 6.3.1.5-30: Intermediate precoding matrix W' for codebook2 and two-layer transmission using eight antenna ports with transform precoding disabled.

| TPMI index i | Intermediate precoder matrix W' |
|----------------|--|
| 0-7 | $\frac{1}{\sqrt{2}} \begin{bmatrix} \bar{W}_{2,i} \\ 0_{4 \times 2} \end{bmatrix}$ |
| 8-15 | $\frac{1}{\sqrt{2}} \begin{bmatrix} 0_{4 \times 2} \\ \bar{W}_{2,(i-8)} \end{bmatrix}$ |
| 16-271 | $\frac{1}{\sqrt{2}} \begin{bmatrix} \bar{W}_{1,[(i-16)/16]} & 0_{4 \times 1} \\ 0_{4 \times 1} & \bar{W}_{1,(i \bmod 16)} \end{bmatrix}$ |

Table 6.3.1.5-31: Intermediate precoding matrix W' for *codebook2* and three-layer transmission using eight antenna ports with transform precoding disabled.

| TPMI index i | Intermediate precoder matrix W' |
|----------------|--|
| 0 – 3 | $\frac{1}{\sqrt{2}} \begin{bmatrix} \bar{W}_{3,i} \\ 0_{4 \times 3} \end{bmatrix}$ |
| 4 – 7 | $\frac{1}{\sqrt{2}} \begin{bmatrix} 0_{4 \times 3} \\ \bar{W}_{3,(i-4)} \end{bmatrix}$ |
| 8 – 135 | $\frac{1}{\sqrt{2}} \begin{bmatrix} \bar{W}_{1, (i-8)/8} & 0_{4 \times 2} \\ 0_{4 \times 1} & \bar{W}_{2,(i \bmod 8)} \end{bmatrix}$ |
| 136 – 263 | $\frac{1}{\sqrt{2}} \begin{bmatrix} \bar{W}_{2, (i-136)/16} & 0_{4 \times 1} \\ 0_{4 \times 2} & \bar{W}_{1,((i-136) \bmod 16)} \end{bmatrix}$ |

Table 6.3.1.5-32: Intermediate precoding matrix W' for *codebook2* and four-layer transmission using eight antenna ports with transform precoding disabled.

| TPMI index i | Intermediate precoder matrix W' |
|----------------|--|
| 0 – 1 | $\frac{1}{\sqrt{2}} \begin{bmatrix} \bar{W}_{4,i} \\ 0_{4 \times 4} \end{bmatrix}$ |
| 2 – 3 | $\frac{1}{\sqrt{2}} \begin{bmatrix} 0_{4 \times 4} \\ \bar{W}_{4,(i-2)} \end{bmatrix}$ |
| 4 – 67 | $\frac{1}{\sqrt{2}} \begin{bmatrix} \bar{W}_{2, (i-4)/8} & 0_{4 \times 2} \\ 0_{4 \times 2} & \bar{W}_{2,((i-4) \bmod 8)} \end{bmatrix}$ |

Table 6.3.1.5-33: Intermediate precoding matrix W' for *codebook2* and five-layer transmission using eight antenna ports with transform precoding disabled.

| TPMI index i | Intermediate precoder matrix W' |
|----------------|--|
| 0 – 31 | $\frac{1}{\sqrt{2}} \begin{bmatrix} \bar{W}_{2, i/4} & 0_{4 \times 3} \\ 0_{4 \times 2} & \bar{W}_{3,(i \bmod 4)} \end{bmatrix}$ |

Table 6.3.1.5-34: Intermediate precoding matrix W' for *codebook2* and six-layer transmission using eight antenna ports with transform precoding disabled.

| TPMI index i | Intermediate precoder matrix W' |
|----------------|--|
| 0 – 15 | $\frac{1}{\sqrt{2}} \begin{bmatrix} \bar{W}_{3, i/4} & 0_{4 \times 3} \\ 0_{4 \times 3} & \bar{W}_{3,(i \bmod 4)} \end{bmatrix}$ |

Table 6.3.1.5-35: Intermediate precoding matrix W' for *codebook2* and seven-layer transmission using eight antenna ports with transform precoding disabled.

| TPMI index i | Intermediate precoder matrix W' |
|----------------|--|
| 0 – 7 | $\frac{1}{\sqrt{2}} \begin{bmatrix} \bar{W}_{3, i/2} & 0_{4 \times 4} \\ 0_{4 \times 3} & \bar{W}_{4,(i \bmod 2)} \end{bmatrix}$ |

Table 6.3.1.5-36: Intermediate precoding matrix W' for *codebook2* and eight-layer transmission using eight antenna ports with transform precoding disabled.

| TPMI index i | Intermediate precoder matrix W' |
|----------------|--|
| 0 – 3 | $\frac{1}{\sqrt{2}} \begin{bmatrix} \bar{W}_{4, i/2} & 0_{4 \times 4} \\ 0_{4 \times 4} & \bar{W}_{4,(i \bmod 2)} \end{bmatrix}$ |

Table 6.3.1.5-37: Submatrices $\bar{W}_{1,i}$ for codebook3 and used in Tables 6.3.1.5-39 to 6.3.1.5-45.

| i | $\bar{W}_{1,i}$ (ordered from left to right in increasing order of i) | | | |
|-------|---|--|---|--|
| 0 – 3 | $\frac{1}{\sqrt{2}} \begin{bmatrix} 1 \\ 1 \end{bmatrix}$ | $\frac{1}{\sqrt{2}} \begin{bmatrix} 1 \\ -1 \end{bmatrix}$ | $\frac{1}{\sqrt{2}} \begin{bmatrix} 1 \\ j \end{bmatrix}$ | $\frac{1}{\sqrt{2}} \begin{bmatrix} 1 \\ -j \end{bmatrix}$ |

Table 6.3.1.5-38: Submatrices $\bar{W}_{2,i}$ for codebook3 and used in Tables 6.3.1.5-40 to 6.3.1.5-46.

| i | $\bar{W}_{2,i}$ (ordered from left to right in increasing order of i) | |
|-------|---|---|
| 0 – 1 | $\frac{1}{2} \begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix}$ | $\frac{1}{2} \begin{bmatrix} 1 & 1 \\ j & -j \end{bmatrix}$ |

Table 6.3.1.5-39: Intermediate precoding matrix W' for codebook3 and single-layer transmission using eight antenna ports.

| TPMI index i | Intermediate precoder matrix W' |
|----------------|--|
| 0 – 3 | $\frac{1}{2} \begin{bmatrix} \bar{W}_{1,i} \\ 0_{2 \times 1} \\ 0_{2 \times 1} \\ 0_{2 \times 1} \end{bmatrix}$ |
| 4 – 7 | $\frac{1}{2} \begin{bmatrix} 0_{2 \times 1} \\ \bar{W}_{1,(i-4)} \\ 0_{2 \times 1} \\ 0_{2 \times 1} \end{bmatrix}$ |
| 8 – 11 | $\frac{1}{2} \begin{bmatrix} 0_{2 \times 1} \\ 0_{2 \times 1} \\ \bar{W}_{1,(i-8)} \\ 0_{2 \times 1} \end{bmatrix}$ |
| 12 – 15 | $\frac{1}{2} \begin{bmatrix} 0_{2 \times 1} \\ 0_{2 \times 1} \\ 0_{2 \times 1} \\ \bar{W}_{1,(i-12)} \end{bmatrix}$ |
| 16 | $\frac{1}{2\sqrt{2}} \begin{bmatrix} 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \end{bmatrix}$ |

Table 6.3.1.5-40: Intermediate precoding matrix W' for *codebook3* and two-layer transmission using eight antenna ports with transform precoding disabled.

| TPMI index i | Intermediate precoder matrix W' |
|----------------|---|
| 0 – 1 | $\frac{1}{2} \begin{bmatrix} \bar{W}_{2,i} \\ 0_{2 \times 2} \\ 0_{2 \times 2} \\ 0_{2 \times 2} \end{bmatrix}$ |
| 2 – 3 | $\frac{1}{2} \begin{bmatrix} 0_{2 \times 2} \\ \bar{W}_{2,(i-2)} \\ 0_{2 \times 2} \\ 0_{2 \times 2} \end{bmatrix}$ |
| 4 – 5 | $\frac{1}{2} \begin{bmatrix} 0_{2 \times 2} \\ 0_{2 \times 2} \\ \bar{W}_{2,(i-4)} \\ 0_{2 \times 2} \end{bmatrix}$ |
| 6 – 7 | $\frac{1}{2} \begin{bmatrix} 0_{2 \times 2} \\ 0_{2 \times 2} \\ 0_{2 \times 2} \\ \bar{W}_{2,(i-6)} \end{bmatrix}$ |
| 8 – 23 | $\frac{1}{2} \begin{bmatrix} \bar{W}_{1,\lfloor(i-8)/4\rfloor} & 0_{2 \times 1} \\ 0_{2 \times 1} & \bar{W}_{1,(i \bmod 4)} \\ 0_{2 \times 1} & 0_{2 \times 1} \\ 0_{2 \times 1} & 0_{2 \times 1} \end{bmatrix}$ |
| 24 – 39 | $\frac{1}{2} \begin{bmatrix} \bar{W}_{1,\lfloor(i-24)/4\rfloor} & 0_{2 \times 1} \\ 0_{2 \times 1} & 0_{2 \times 1} \\ 0_{2 \times 1} & \bar{W}_{1,(i \bmod 4)} \\ 0_{2 \times 1} & 0_{2 \times 1} \end{bmatrix}$ |
| 40 – 55 | $\frac{1}{2} \begin{bmatrix} \bar{W}_{1,\lfloor(i-40)/4\rfloor} & 0_{2 \times 1} \\ 0_{2 \times 1} & 0_{2 \times 1} \\ 0_{2 \times 1} & 0_{2 \times 1} \\ 0_{2 \times 1} & \bar{W}_{1,(i \bmod 4)} \end{bmatrix}$ |
| 56 – 71 | $\frac{1}{2} \begin{bmatrix} 0_{2 \times 1} & 0_{2 \times 1} \\ \bar{W}_{1,\lfloor(i-56)/4\rfloor} & 0_{2 \times 1} \\ 0_{2 \times 1} & \bar{W}_{1,(i \bmod 4)} \\ 0_{2 \times 1} & 0_{2 \times 1} \end{bmatrix}$ |
| 72 – 87 | $\frac{1}{2} \begin{bmatrix} 0_{2 \times 1} & 0_{2 \times 1} \\ \bar{W}_{1,\lfloor(i-72)/4\rfloor} & 0_{2 \times 1} \\ 0_{2 \times 1} & 0_{2 \times 1} \\ 0_{2 \times 1} & \bar{W}_{1,(i \bmod 4)} \end{bmatrix}$ |
| 88 – 103 | $\frac{1}{2} \begin{bmatrix} 0_{2 \times 1} & 0_{2 \times 1} \\ 0_{2 \times 1} & 0_{2 \times 1} \\ \bar{W}_{1,\lfloor(i-88)/4\rfloor} & 0_{2 \times 1} \\ 0_{2 \times 1} & \bar{W}_{1,(i \bmod 4)} \end{bmatrix}$ |
| 104 | $\frac{1}{2\sqrt{2}} \begin{bmatrix} 1 & 0 \\ 1 & 0 \\ 1 & 0 \\ 1 & 0 \\ 0 & 1 \\ 0 & 1 \\ 0 & 1 \\ 0 & 1 \end{bmatrix}$ |

Table 6.3.1.5-41: Intermediate precoding matrix W' for *codebook3* and three-layer transmission using eight antenna ports with transform precoding disabled.

| TPMI index i | Intermediate precoder matrix W' |
|----------------|--|
| 0 – 7 | $\frac{1}{2} \begin{bmatrix} \bar{W}_{2, \lfloor i/4 \rfloor} & 0_{2 \times 1} \\ 0_{2 \times 2} & \bar{W}_{1, (i \bmod 4)} \\ 0_{2 \times 2} & 0_{2 \times 1} \\ 0_{2 \times 2} & 0_{2 \times 1} \end{bmatrix}$ |
| 8 – 15 | $\frac{1}{2} \begin{bmatrix} \bar{W}_{2, \lfloor (i-8)/4 \rfloor} & 0_{2 \times 1} \\ 0_{2 \times 2} & 0_{2 \times 1} \\ 0_{2 \times 2} & \bar{W}_{1, (i \bmod 4)} \\ 0_{2 \times 2} & 0_{2 \times 1} \end{bmatrix}$ |
| 16 – 23 | $\frac{1}{2} \begin{bmatrix} \bar{W}_{2, \lfloor (i-16)/4 \rfloor} & 0_{2 \times 1} \\ 0_{2 \times 2} & 0_{2 \times 1} \\ 0_{2 \times 2} & 0_{2 \times 1} \\ 0_{2 \times 2} & \bar{W}_{1, (i \bmod 4)} \end{bmatrix}$ |
| 24 – 31 | $\frac{1}{2} \begin{bmatrix} 0_{2 \times 2} & 0_{2 \times 1} \\ \bar{W}_{2, \lfloor (i-24)/4 \rfloor} & 0_{2 \times 1} \\ 0_{2 \times 2} & \bar{W}_{1, (i \bmod 4)} \\ 0_{2 \times 2} & 0_{2 \times 1} \end{bmatrix}$ |
| 32 – 39 | $\frac{1}{2} \begin{bmatrix} 0_{2 \times 2} & 0_{2 \times 1} \\ \bar{W}_{2, \lfloor (i-32)/4 \rfloor} & 0_{2 \times 1} \\ 0_{2 \times 2} & 0_{2 \times 1} \\ 0_{2 \times 2} & \bar{W}_{1, (i \bmod 4)} \end{bmatrix}$ |
| 40 – 47 | $\frac{1}{2} \begin{bmatrix} 0_{2 \times 2} & 0_{2 \times 1} \\ 0_{2 \times 2} & 0_{2 \times 1} \\ \bar{W}_{2, \lfloor (i-40)/4 \rfloor} & 0_{2 \times 1} \\ 0_{2 \times 2} & \bar{W}_{1, (i \bmod 4)} \end{bmatrix}$ |
| 48 – 111 | $\frac{1}{2} \begin{bmatrix} \bar{W}_{1, \lfloor (i-48)/16 \rfloor} & 0_{2 \times 1} & 0_{2 \times 1} \\ 0_{2 \times 1} & \bar{W}_{1, \lfloor (i \bmod 16)/4 \rfloor} & 0_{2 \times 1} \\ 0_{2 \times 1} & 0_{2 \times 1} & \bar{W}_{1, (i \bmod 4)} \\ 0_{2 \times 1} & 0_{2 \times 1} & 0_{2 \times 1} \end{bmatrix}$ |
| 112 – 175 | $\frac{1}{2} \begin{bmatrix} \bar{W}_{1, \lfloor (i-112)/16 \rfloor} & 0_{2 \times 1} & 0_{2 \times 1} \\ 0_{2 \times 1} & \bar{W}_{1, \lfloor (i \bmod 16)/4 \rfloor} & 0_{2 \times 1} \\ 0_{2 \times 1} & 0_{2 \times 1} & 0_{2 \times 1} \\ 0_{2 \times 1} & 0_{2 \times 1} & \bar{W}_{1, (i \bmod 4)} \end{bmatrix}$ |
| 176 – 239 | $\frac{1}{2} \begin{bmatrix} \bar{W}_{1, \lfloor (i-176)/16 \rfloor} & 0_{2 \times 1} & 0_{2 \times 1} \\ 0_{2 \times 1} & 0_{2 \times 1} & 0_{2 \times 1} \\ 0_{2 \times 1} & \bar{W}_{1, \lfloor (i \bmod 16)/4 \rfloor} & 0_{2 \times 1} \\ 0_{2 \times 1} & 0_{2 \times 1} & \bar{W}_{1, (i \bmod 4)} \end{bmatrix}$ |
| 240 – 303 | $\frac{1}{2} \begin{bmatrix} 0_{2 \times 1} & 0_{2 \times 1} & 0_{2 \times 1} \\ \bar{W}_{1, \lfloor (i-240)/16 \rfloor} & 0_{2 \times 1} & 0_{2 \times 1} \\ 0_{2 \times 1} & \bar{W}_{1, \lfloor (i \bmod 16)/4 \rfloor} & 0_{2 \times 1} \\ 0_{2 \times 1} & 0_{2 \times 1} & \bar{W}_{1, (i \bmod 4)} \end{bmatrix}$ |
| 304 | $\frac{1}{2\sqrt{2}} \begin{bmatrix} 1 & 0 & 0 \\ 1 & 0 & 0 \\ 1 & 0 & 0 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \\ 0 & 0 & 1 \end{bmatrix}$ |

Table 6.3.1.5-42: Intermediate precoding matrix W' for *codebook3* and four-layer transmission using eight antenna ports with transform precoding disabled.

| TPMI index i | Intermediate precoder matrix W' |
|----------------|--|
| 0 – 255 | $\frac{1}{2} \begin{bmatrix} \bar{W}_{1,\lfloor i/64 \rfloor} & 0_{2 \times 1} & 0_{2 \times 1} & 0_{2 \times 1} \\ 0_{2 \times 1} & \bar{W}_{1,\lfloor (i \bmod 64)/16 \rfloor} & 0_{2 \times 1} & 0_{2 \times 1} \\ 0_{2 \times 1} & 0_{2 \times 1} & \bar{W}_{1,\lfloor (i \bmod 16)/4 \rfloor} & 0_{2 \times 1} \\ 0_{2 \times 1} & 0_{2 \times 1} & 0_{2 \times 1} & \bar{W}_{1,\lfloor (i \bmod 4) \rfloor} \end{bmatrix}$ |
| 256 – 259 | $\frac{1}{2} \begin{bmatrix} \bar{W}_{2,\lfloor (i-256)/2 \rfloor} & 0_{2 \times 2} \\ 0_{2 \times 2} & \bar{W}_{2,\lfloor (i \bmod 2) \rfloor} \\ 0_{2 \times 2} & 0_{2 \times 2} \\ 0_{2 \times 2} & 0_{2 \times 2} \end{bmatrix}$ |
| 260 – 263 | $\frac{1}{2} \begin{bmatrix} \bar{W}_{2,\lfloor (i-260)/2 \rfloor} & 0_{2 \times 2} \\ 0_{2 \times 2} & 0_{2 \times 2} \\ 0_{2 \times 2} & \bar{W}_{2,\lfloor (i \bmod 2) \rfloor} \\ 0_{2 \times 2} & 0_{2 \times 2} \end{bmatrix}$ |
| 264 – 267 | $\frac{1}{2} \begin{bmatrix} \bar{W}_{2,\lfloor (i-264)/2 \rfloor} & 0_{2 \times 2} \\ 0_{2 \times 2} & 0_{2 \times 2} \\ 0_{2 \times 2} & 0_{2 \times 2} \\ 0_{2 \times 2} & \bar{W}_{2,\lfloor (i \bmod 2) \rfloor} \end{bmatrix}$ |
| 268 – 271 | $\frac{1}{2} \begin{bmatrix} 0_{2 \times 2} & 0_{2 \times 2} \\ \bar{W}_{2,\lfloor (i-268)/2 \rfloor} & 0_{2 \times 2} \\ 0_{2 \times 2} & \bar{W}_{2,\lfloor (i \bmod 2) \rfloor} \\ 0_{2 \times 2} & 0_{2 \times 2} \end{bmatrix}$ |
| 272 – 275 | $\frac{1}{2} \begin{bmatrix} 0_{2 \times 2} & 0_{2 \times 2} \\ \bar{W}_{2,\lfloor (i-272)/2 \rfloor} & 0_{2 \times 2} \\ 0_{2 \times 2} & 0_{2 \times 2} \\ 0_{2 \times 2} & \bar{W}_{2,\lfloor (i \bmod 2) \rfloor} \end{bmatrix}$ |
| 276 – 279 | $\frac{1}{2} \begin{bmatrix} 0_{2 \times 2} & 0_{2 \times 2} \\ 0_{2 \times 2} & 0_{2 \times 2} \\ \bar{W}_{2,\lfloor (i-276)/2 \rfloor} & 0_{2 \times 2} \\ 0_{2 \times 2} & \bar{W}_{2,\lfloor (i \bmod 2) \rfloor} \end{bmatrix}$ |

Table 6.3.1.5-43: Intermediate precoding matrix W' for *codebook3* and five-layer transmission using eight antenna ports with transform precoding disabled.

| TPMI index i | Intermediate precoder matrix W' |
|----------------|---|
| 0 – 15 | $\frac{1}{2} \begin{bmatrix} \bar{W}_{2,\lfloor i/8 \rfloor} & 0_{2 \times 2} & 0_{2 \times 1} \\ 0_{2 \times 2} & 0_{2 \times 2} & 0_{2 \times 1} \\ 0_{2 \times 2} & \bar{W}_{2,\lfloor (i \bmod 8)/4 \rfloor} & 0_{2 \times 1} \\ 0_{2 \times 2} & 0_{2 \times 2} & \bar{W}_{1,\lfloor (i \bmod 4) \rfloor} \end{bmatrix}$ |
| 16 – 31 | $\frac{1}{2} \begin{bmatrix} 0_{2 \times 2} & 0_{2 \times 2} & 0_{2 \times 1} \\ \bar{W}_{2,\lfloor (i-16)/8 \rfloor} & 0_{2 \times 2} & 0_{2 \times 1} \\ 0_{2 \times 2} & \bar{W}_{2,\lfloor (i \bmod 8)/4 \rfloor} & 0_{2 \times 1} \\ 0_{2 \times 2} & 0_{2 \times 2} & \bar{W}_{1,\lfloor (i \bmod 4) \rfloor} \end{bmatrix}$ |
| 32 – 159 | $\frac{1}{2} \begin{bmatrix} \bar{W}_{1,\lfloor (i-32)/32 \rfloor} & 0_{2 \times 1} & 0_{2 \times 2} & 0_{2 \times 1} \\ 0_{2 \times 1} & \bar{W}_{1,\lfloor (i \bmod 32)/8 \rfloor} & 0_{2 \times 2} & 0_{2 \times 1} \\ 0_{2 \times 1} & 0_{2 \times 1} & \bar{W}_{2,\lfloor (i \bmod 8)/4 \rfloor} & 0_{2 \times 1} \\ 0_{2 \times 1} & 0_{2 \times 1} & 0_{2 \times 2} & \bar{W}_{1,\lfloor (i \bmod 4) \rfloor} \end{bmatrix}$ |

Table 6.3.1.5-44: Intermediate precoding matrix W' for *codebook3* and six-layer transmission using eight antenna ports with transform precoding disabled.

| TPMI index i | Intermediate precoder matrix W' |
|----------------|--|
| 0 – 7 | $\frac{1}{2} \begin{bmatrix} \bar{W}_{2,\lfloor i/4 \rfloor} & 0_{2 \times 2} & 0_{2 \times 2} \\ 0_{2 \times 2} & \bar{W}_{2,\lfloor (i \bmod 4)/2 \rfloor} & 0_{2 \times 2} \\ 0_{2 \times 2} & 0_{2 \times 2} & \bar{W}_{2,\lfloor (i \bmod 2) \rfloor} \\ 0_{2 \times 2} & 0_{2 \times 2} & 0_{2 \times 2} \end{bmatrix}$ |
| 8 – 15 | $\frac{1}{2} \begin{bmatrix} \bar{W}_{2,\lfloor (i-8)/4 \rfloor} & 0_{2 \times 2} & 0_{2 \times 2} \\ 0_{2 \times 2} & 0_{2 \times 2} & 0_{2 \times 2} \\ 0_{2 \times 2} & \bar{W}_{2,\lfloor (i \bmod 4)/2 \rfloor} & 0_{2 \times 2} \\ 0_{2 \times 2} & 0_{2 \times 2} & \bar{W}_{2,\lfloor (i \bmod 2) \rfloor} \end{bmatrix}$ |
| 16 – 79 | $\frac{1}{2} \begin{bmatrix} \bar{W}_{2,\lfloor (i-16)/32 \rfloor} & 0_{2 \times 1} & 0_{2 \times 2} & 0_{2 \times 1} \\ 0_{2 \times 2} & \bar{W}_{1,\lfloor ((i-16) \bmod 32)/8 \rfloor} & 0_{2 \times 2} & 0_{2 \times 1} \\ 0_{2 \times 2} & 0_{2 \times 1} & \bar{W}_{2,\lfloor (i \bmod 8)/4 \rfloor} & 0_{2 \times 1} \\ 0_{2 \times 2} & 0_{2 \times 1} & 0_{2 \times 2} & \bar{W}_{1,\lfloor (i \bmod 4) \rfloor} \end{bmatrix}$ |

Table 6.3.1.5-45: Intermediate precoding matrix W' for *codebook3* and seven-layer transmission using eight antenna ports with transform precoding disabled.

| TPMI index i | Intermediate precoder matrix W' |
|----------------|--|
| 0 – 31 | $\frac{1}{2} \begin{bmatrix} \bar{W}_{2,\lfloor i/16 \rfloor} & 0_{2 \times 1} & 0_{2 \times 2} & 0_{2 \times 2} \\ 0_{2 \times 2} & \bar{W}_{1,\lfloor (i \bmod 16)/4 \rfloor} & 0_{2 \times 2} & 0_{2 \times 2} \\ 0_{2 \times 2} & 0_{2 \times 1} & \bar{W}_{2,\lfloor (i \bmod 4)/2 \rfloor} & 0_{2 \times 2} \\ 0_{2 \times 2} & 0_{2 \times 1} & 0_{2 \times 2} & \bar{W}_{2,\lfloor (i \bmod 2) \rfloor} \end{bmatrix}$ |

Table 6.3.1.5-46: Intermediate precoding matrix W' for *codebook3* and eight-layer transmission using eight antenna ports with transform precoding disabled.

| TPMI index i | Intermediate precoder matrix W' |
|----------------|--|
| 0 – 15 | $\frac{1}{2} \begin{bmatrix} \bar{W}_{2,\lfloor i/8 \rfloor} & 0_{2 \times 2} & 0_{2 \times 2} & 0_{2 \times 2} \\ 0_{2 \times 2} & \bar{W}_{2,\lfloor (i \bmod 8)/4 \rfloor} & 0_{2 \times 2} & 0_{2 \times 2} \\ 0_{2 \times 2} & 0_{2 \times 2} & \bar{W}_{2,\lfloor (i \bmod 4)/2 \rfloor} & 0_{2 \times 2} \\ 0_{2 \times 2} & 0_{2 \times 2} & 0_{2 \times 2} & \bar{W}_{2,\lfloor (i \bmod 2) \rfloor} \end{bmatrix}$ |

Table 6.3.1.5-47: Intermediate precoding matrix W' for codebook4 and transmission using eight antenna ports. Up to 8 layers are supported with transform precoding disabled and up to one layer with transform precoding enabled.

| TPMI index | Intermediate precoder matrix W' |
|---------------------|---|
| $0 - \Delta(v) - 1$ | $W' = \frac{1}{2\sqrt{2}} [e_{p_0} \dots e_{p_{v-1}}]$ <p>where column i of W', denoted e_i, has an element 1 on the row corresponding to the port p_i on which layer i is to be transmitted, and element 0 in all other rows, $p_i < p_{i+1}$, $L = \sum_{p=0}^7 \delta(p) 2^p$, where $\delta(p) = 1$ if a layer is to be transmitted on port p and $\delta(p) = 0$ otherwise, and $\Delta(z) = \sum_{k=1}^z C(8, k)$ for $z \geq 1$, where $C(x, y)$ is defined by Table 5.2.2.2.5-4 of [6, TS 38.214].</p> <p>TPMI indices 0 to $\Delta(v) - 1$ are mapped to values of L, first by increasing values of the number of transmitted layers, and then by increasing values of L for a given number of layers.</p> |
| 255 | $\frac{1}{2\sqrt{2}} \begin{bmatrix} 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \end{bmatrix}$ |
| 256 | $\frac{1}{2\sqrt{2}} \begin{bmatrix} 1 & 0 \\ 1 & 0 \\ 0 & 1 \\ 0 & 1 \\ 1 & 0 \\ 1 & 0 \\ 0 & 1 \\ 0 & 1 \end{bmatrix}$ |
| 257 | $\frac{1}{2\sqrt{2}} \begin{bmatrix} 1 & 0 & 0 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \\ 1 & 0 & 0 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$ |
| 258 | $\frac{1}{2\sqrt{2}} \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$ |

6.3.1.6 Mapping to virtual resource blocks

For each of the antenna ports used for transmission of the PUSCH, the block of complex-valued symbols $z^{(p)}(0), \dots, z^{(p)}(M_{\text{symb}}^{\text{ap}} - 1)$ shall be multiplied with the amplitude scaling factor β_{PUSCH} in order to conform to the transmit power specified in [5, TS 38.213] and mapped in sequence starting with $z^{(p)}(0)$ to resource elements $(k', l)_{p,\mu}$ in the virtual resource blocks assigned for transmission which meet all of the following criteria:

- they are in the virtual resource blocks assigned for transmission, and
- the corresponding resource elements in the corresponding physical resource blocks are not used for transmission of the associated DM-RS, PT-RS, or DM-RS intended for other co-scheduled UEs as described in clause 6.4.1.1.3

The mapping to resource elements $(k', l)_{p,\mu}$ allocated for PUSCH according to [6, TS 38.214] shall be in increasing order of first the index k' over the assigned virtual resource blocks, where $k' = 0$ is the first subcarrier in the lowest-

numbered virtual resource block assigned for transmission, and then the index l , with the starting position given by [6, TS 38.214].

6.3.1.7 Mapping from virtual to physical resource blocks

Virtual resource blocks shall be mapped to physical resource blocks according to non-interleaved mapping.

For non-interleaved VRB-to-PRB mapping for uplink resource allocation types 0 and 1 [6, TS 38.214], virtual resource block n is mapped to physical resource block n except for PUSCH scheduled by RAR UL grant or PUSCH scheduled by DCI format 0_0 with CRC scrambled by TC-RNTI in active uplink bandwidth part i starting at $N_{\text{BWP},i}^{\text{start}}$, including all resource blocks of the initial uplink bandwidth part starting at $N_{\text{BWP},0}^{\text{start}}$, and having the same subcarrier spacing and cyclic prefix as the initial uplink bandwidth part, in which case virtual resource block n is mapped to physical resource block $n + N_{\text{BWP},0}^{\text{start}} - N_{\text{BWP},i}^{\text{start}}$.

For non-interleaved VRB-to-PRB mapping for uplink resource allocation type 2 [6, TS 38.214], virtual resource block n is mapped to physical resource block n .

6.3.2 Physical uplink control channel

6.3.2.1 General

The physical uplink control channel supports multiple formats as shown in Table 6.3.2.1-1. In case intra-slot frequency hopping is configured for PUCCH formats 1, 3, or 4 according to clause 9.2.1 of [5, TS38.213], the number of symbols in the first hop is given by $\lfloor N_{\text{symb}}^{\text{PUCCH}}/2 \rfloor$ where $N_{\text{symb}}^{\text{PUCCH}}$ is the length of the PUCCH transmission in OFDM symbols.

Table 6.3.2.1-1: PUCCH formats.

| PUCCH format | Length in OFDM symbols $N_{\text{symb}}^{\text{PUCCH}}$ | Number of bits |
|--------------|--|----------------|
| 0 | 1 – 2 | ≤ 2 |
| 1 | 4 – 14 | ≤ 2 |
| 2 | 1 – 2 | > 2 |
| 3 | 4 – 14 | > 2 |
| 4 | 4 – 14 | > 2 |

6.3.2.2 Sequence and cyclic shift hopping

PUCCH formats 0, 1, 3, and 4 use sequences $r_{u,v}^{(\alpha,\delta)}(n)$ given by clause 5.2.2 with $\delta = 0$ where the sequence group u and the sequence number v depend on the sequence hopping in clause 6.3.2.2.1 and the cyclic shift α depends on the cyclic shift hopping in clause 6.3.2.2.2.

6.3.2.2.1 Group and sequence hopping

The sequence group $u = (f_{\text{gh}} + f_{\text{ss}}) \bmod 30$ and the sequence number v within the group depends on the higher-layer parameter *pucch-GroupHopping*:

- if *pucch-GroupHopping* equals 'neither'

$$\begin{aligned} f_{\text{gh}} &= 0 \\ f_{\text{ss}} &= n_{\text{ID}} \bmod 30 \\ v &= 0 \end{aligned}$$

where n_{ID} is given by the higher-layer parameter *hoppingId* if configured, otherwise $n_{\text{ID}} = N_{\text{ID}}^{\text{cell}}$.

- if *pucch-GroupHopping* equals 'enable'

$$f_{gh} = \left(\sum_{m=0}^7 2^m c(8(2n_{s,f}^{\mu} + n_{hop}) + m) \right) \bmod 30$$

$$f_{ss} = n_{ID} \bmod 30$$

$$v = 0$$

where the pseudo-random sequence $c(i)$ is defined by clause 5.2.1 and shall be initialized at the beginning of each radio frame with $c_{init} = \lfloor n_{ID}/30 \rfloor$ where n_{ID} is given by the higher-layer parameter *hoppingId* if configured, otherwise $n_{ID} = N_{ID}^{cell}$.

- if *pucch-GroupHopping* equals 'disable'

$$f_{gh} = 0$$

$$f_{ss} = n_{ID} \bmod 30$$

$$v = c(2n_{s,f}^{\mu} + n_{hop})$$

where the pseudo-random sequence $c(i)$ is defined by clause 5.2.1 and shall be initialized at the beginning of each radio frame with $c_{init} = 2^5 \lfloor n_{ID}/30 \rfloor + (n_{ID} \bmod 30)$ where n_{ID} is given by the higher-layer parameter *hoppingId* if configured, otherwise $n_{ID} = N_{ID}^{cell}$.

The frequency hopping index $n_{hop} = 0$ if intra-slot frequency hopping is disabled by the higher-layer parameter *intraSlotFrequencyHopping*. If frequency hopping is enabled by the higher-layer parameter *intraSlotFrequencyHopping*, $n_{hop} = 0$ for the first hop and $n_{hop} = 1$ for the second hop.

6.3.2.2.2 Cyclic shift hopping

The cyclic shift α varies as a function of the symbol and slot number according to

$$\alpha_l = \frac{2\pi}{N_{sc}^{RB}} \left((m_0 + m_{cs} + m_{int} + n_{cs}(n_{s,f}^{\mu} l + l')) \bmod N_{sc}^{RB} \right)$$

where

- $n_{s,f}^{\mu}$ is the slot number in the radio frame
- l is the OFDM symbol number in the PUCCH transmission where $l = 0$ corresponds to the first OFDM symbol of the PUCCH transmission,
- l' is the index of the OFDM symbol in the slot that corresponds to the first OFDM symbol of the PUCCH transmission in the slot given by [5, TS 38.213]
- m_0 is given by [5, TS 38.213] for PUCCH format 0 and 1 while for PUCCH format 3 and 4 is defined in clause 6.4.1.3.3.1
- $m_{cs} = 0$ except for PUCCH format 0 when it depends on the information to be transmitted according to clause 9.2 of [5, TS 38.213].
- m_{int} is given by
 - $m_{int} = 5n_{IRB}^{\mu}$ for PUCCH formats 0 and 1 if PUCCH shall use interlaced mapping according to any of the higher-layer parameters *useInterlacePUCCH-PUSCH* in *BWP-UplinkCommon* or *useInterlacePUCCH-PUSCH* in *BWP-UplinkDedicated*, where n_{IRB}^{μ} is the resource block number within the interlace;
 - $m_{int} = 0$ otherwise

The function $n_{cs}(n_c, l)$ is given by

$$n_{cs}(n_{s,f}^{\mu}, l) = \sum_{m=0}^7 2^m c(8N_{symb}^{slot} n_{s,f}^{\mu} + 8l + m)$$

where the pseudo-random sequence $c(i)$ is defined by clause 5.2.1. The pseudo-random sequence generator shall be initialized with $c_{\text{init}} = n_{\text{ID}}$, where n_{ID} is given by the higher-layer parameter *hoppingId* if configured, otherwise $n_{\text{ID}} = N_{\text{ID}}^{\text{cell}}$.

6.3.2.3 PUCCH format 0

6.3.2.3.1 Sequence generation

The sequence $x(n)$ shall be generated according to

$$x(lM_{\text{RB}}^{\text{PUCCH},0}N_{\text{sc}}^{\text{RB}} + n) = r_{u,v}^{(\alpha,\delta)}(n)$$

$$n = 0, 1, \dots, M_{\text{RB}}^{\text{PUCCH},0}N_{\text{sc}}^{\text{RB}} - 1$$

$$l = \begin{cases} 0 & \text{for single-symbol PUCCH transmission} \\ 0,1 & \text{for double-symbol PUCCH transmission} \end{cases}$$

where $r_{u,v}^{(\alpha,\delta)}(n)$ is given by clause 6.3.2.2 with m_{cs} depending on the information to be transmitted according to clause 9.2 of [5, TS 38.213]. The quantity $M_{\text{RB}}^{\text{PUCCH},0}$ is given by clause 9.2.1 of [5, TS 38.213].

6.3.2.3.2 Mapping to physical resources

The sequence $x(n)$ shall be multiplied with the amplitude scaling factor $\beta_{\text{PUCCH},0}$ in order to conform to the transmit power specified in [5, TS 38.213] and mapped in sequence starting with $x(0)$ to resource elements $(k, l)_{p,\mu}$ assigned for transmission according to clause 9.2.1 of [5, TS 38.213] in increasing order of first the index k over the assigned physical resources spanning $M_{\text{RB}}^{\text{PUCCH},0}$ resource blocks, and then the index l on antenna port $p = 2000$.

For interlaced transmission, the mapping operation shall be repeated for each resource block in the interlace and in the active bandwidth part over the assigned physical resource blocks according to clause 9.2.1 of [5, TS 38.213], with the resource-block dependent sequence generated according to clause 6.3.2.2.

6.3.2.4 PUCCH format 1

6.3.2.4.1 Sequence modulation

The block of bits $b(0), \dots, b(M_{\text{bit}} - 1)$ shall be modulated as described in clause 5.1 using BPSK if $M_{\text{bit}} = 1$ and QPSK if $M_{\text{bit}} = 2$, resulting in a complex-valued symbol $d(0)$.

The complex-valued symbol $d(0)$ shall be multiplied with a sequence $r_{u,v}^{(\alpha,\delta)}(n)$ according to

$$y(n) = d(0)r_{u,v}^{(\alpha,\delta)}(n)$$

$$n = 0, 1, \dots, M_{\text{RB}}^{\text{PUCCH},1}N_{\text{sc}}^{\text{RB}} - 1$$

where $r_{u,v}^{(\alpha,\delta)}(n)$ is given by clause 6.3.2.2. The quantity $M_{\text{RB}}^{\text{PUCCH},1}$ is given by clause 9.2.1 of [5, TS 38.213].

The block of complex-valued symbols $y(0), \dots, y(M_{\text{RB}}^{\text{PUCCH},1}N_{\text{sc}}^{\text{RB}} - 1)$ shall be block-wise spread with the orthogonal sequence $w_i(m)$ according to

$$z(m'M_{\text{RB}}^{\text{PUCCH},1}N_{\text{sc}}^{\text{RB}}N_{\text{SF},0}^{\text{PUCCH},1} + mM_{\text{RB}}^{\text{PUCCH},1}N_{\text{sc}}^{\text{RB}} + n) = w_i(m)y(n)$$

$$n = 0, 1, \dots, M_{\text{RB}}^{\text{PUCCH},1}N_{\text{sc}}^{\text{RB}} - 1$$

$$m = 0, 1, \dots, N_{\text{SF},m'}^{\text{PUCCH},1} - 1$$

$$m' = \begin{cases} 0 & \text{no intra-slot frequency hopping} \\ 0,1 & \text{intra-slot frequency hopping} \end{cases}$$

where $N_{\text{SF},m'}^{\text{PUCCH},1}$ is given by Table 6.3.2.4.1-1. Intra-slot frequency hopping shall be assumed when the higher-layer parameter *intraSlotFrequencyHopping* is provided, regardless of whether the frequency-hop distance is zero or not, and interlaced mapping is not enabled, otherwise no intra-slot frequency hopping shall be assumed.

The orthogonal sequence $w_i(m)$ is given by Table 6.3.2.4.1-2 where i is the index of the orthogonal sequence to use according to clause 9.2.1 of [5, TS 38.213]. In case of a PUCCH transmission spanning multiple slots according to clause 9.2.6 of [5, TS38.213], the complex-valued symbol $d(0)$ is repeated for the subsequent slots.

Table 6.3.2.4.1-1: Number of PUCCH symbols and the corresponding $N_{SF,m'}^{PUCCH,1}$.

| PUCCH length, $N_{\text{symb}}^{PUCCH,1}$ | $N_{SF,m'}^{PUCCH,1}$ | | |
|--|---------------------------------|--------------------|--------|
| | No intra-slot hopping $m'=0$ | Intra-slot hopping | |
| | | $m'=0$ | $m'=1$ |
| 4 | 2 | 1 | 1 |
| 5 | 2 | 1 | 1 |
| 6 | 3 | 1 | 2 |
| 7 | 3 | 1 | 2 |
| 8 | 4 | 2 | 2 |
| 9 | 4 | 2 | 2 |
| 10 | 5 | 2 | 3 |
| 11 | 5 | 2 | 3 |
| 12 | 6 | 3 | 3 |
| 13 | 6 | 3 | 3 |
| 14 | 7 | 3 | 4 |

Table 6.3.2.4.1-2: Orthogonal sequences $w_i(m) = e^{j2\pi\phi(m)/N_{SF,m'}^{PUCCH,1}}$ for PUCCH format 1.

| $N_{SF,m'}^{PUCCH,1}$ | ϕ | | | | | | |
|-----------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| | $i=0$ | $i=1$ | $i=2$ | $i=3$ | $i=4$ | $i=5$ | $i=6$ |
| 1 | [0] | - | - | - | - | - | - |
| 2 | [0 0] | [0 1] | - | - | - | - | - |
| 3 | [0 0 0] | [0 1 2] | [0 2 1] | - | - | - | - |
| 4 | [0 0 0 0] | [0 2 0 2] | [0 0 2 2] | [0 2 2 0] | - | - | - |
| 5 | [0 0 0 0 0] | [0 1 2 3 4] | [0 2 4 1 3] | [0 3 1 4 2] | [0 4 3 2 1] | - | - |
| 6 | [0 0 0 0 0 0] | [0 1 2 3 4 5] | [0 2 4 0 2 4] | [0 3 0 3 0 3] | [0 4 2 0 4 2] | [0 5 4 3 2 1] | - |
| 7 | [0 0 0 0 0 0 0] | [0 1 2 3 4 5 6] | [0 2 4 6 1 3 5] | [0 3 6 2 5 1 4] | [0 4 1 5 2 6 3] | [0 5 3 1 6 4 2] | [0 6 5 4 3 2 1] |

6.3.2.4.2 Mapping to physical resources

The sequence $z(n)$ shall be multiplied with the amplitude scaling factor $\beta_{PUCCH,1}$ in order to conform to the transmit power specified in [5, TS 38.213] and mapped in sequence starting with $z(n)$ to resource elements $(k, l)_{p,\mu}$ which meet all of the following criteria:

- they are in the resource blocks assigned for transmission,
- they are not used by the associated DM-RS

The mapping to resource elements $(k, l)_{p,\mu}$ not reserved for other purposes shall be in increasing order of first the index k over the assigned physical resource blocks according to clause 9.2.1 of [5, TS 38.213], and then the index l on antenna port $p = 2000$.

For interlaced transmission, the mapping operation shall be repeated for each resource block in the interlace and in the active bandwidth part over the assigned physical resource blocks according to clause 9.2.1 of [5, TS 38.213], with the resource-block dependent sequence generated according to clause 6.3.2.2.

6.3.2.5 PUCCH format 2

6.3.2.5.1 Scrambling

The block of bits $b(0), \dots, b(M_{\text{bit}} - 1)$, where M_{bit} is the number of bits transmitted on the physical channel, shall be scrambled prior to modulation, resulting in a block of scrambled bits $\tilde{b}(0), \dots, \tilde{b}(M_{\text{bit}} - 1)$ according to the following pseudo code

Set $i = 0$

while $i < M_{\text{bit}}$

if $b(i) = y$ // UCI placeholder bits

$\tilde{b}(i) = \tilde{b}(i - 1)$

else

$\tilde{b}(i) = (b(i) + c(i)) \bmod 2$

end if

$i = i + 1$

end while

where y is the tag defined in [4, TS38.212] and the scrambling sequence $c(i)$ is given by clause 5.2.1. The scrambling sequence generator shall be initialized with

$$c_{\text{init}} = n_{\text{RNTI}} \cdot 2^{15} + n_{\text{ID}}$$

where

- $n_{\text{ID}} \in \{0, 1, \dots, 1023\}$ equals the higher-layer parameter *dataScramblingIdentityPUSCH* if configured,
- $n_{\text{ID}} = N_{\text{ID}}^{\text{cell}}$ otherwise

and n_{RNTI} is given by the C-RNTI.

6.3.2.5.2 Modulation

The block of scrambled bits $\tilde{b}(0), \dots, \tilde{b}(M_{\text{bit}} - 1)$ shall be modulated as described in clause 5.1 using QPSK, resulting in a block of complex-valued modulation symbols $d(0), \dots, d(M_{\text{symb}} - 1)$ where $M_{\text{symb}} = M_{\text{bit}}/2$.

6.3.2.5.2A Spreading

Spreading shall be applied according to

$$\begin{aligned} z(m N_{\text{SF}}^{\text{PUCCH},2} + i) &= w_n(i) d(m) \\ i &= 0, 1, \dots, N_{\text{SF}}^{\text{PUCCH},2} - 1 \\ m &= 0, 1, \dots, M_{\text{symb}} - 1 \end{aligned}$$

resulting in a block of complex-valued symbols $z(0), \dots, z(N_{\text{SF}}^{\text{PUCCH},2} M_{\text{symb}} - 1)$.

If the higher layer parameter *interlace1* is not configured, and the higher-layer parameter *occ-Length* is configured,

- $N_{\text{SF}}^{\text{PUCCH},2} \in \{2, 4\}$ is given by the higher-layer parameter *occ-Length*;
- $w_n(i)$ is given by Tables 6.3.2.5A-1 and 6.3.2.5A-2 where $n = (n_0 + n_{\text{IRB}}) \bmod N_{\text{SF}}^{\text{PUCCH},2}$, the quantity n_0 is the index of the orthogonal sequence to use given by the higher-layer parameter *occ-Index*, and n_{IRB} is the interlaced resource block number as defined in clause 4.4.4.6 within the interlace given by the higher-layer parameter *Interlace0*.

otherwise $N_{\text{SF}}^{\text{PUCCH},2} = 1$ and $w_n(i) = 1$.

Table 6.3.2.5A-1: Orthogonal sequences $w_n(i)$ for PUCCH format 2 when $N_{\text{SF}}^{\text{PUCCH},2} = 2$.

| n | $w_n(i)$ |
|-----|----------|
| 0 | [+1 +1] |
| 1 | [+1 -1] |

Table 6.3.2.5A-2: Orthogonal sequences $w_n(i)$ for PUCCH format 2 when $N_{\text{SF}}^{\text{PUCCH},2} = 4$.

| n | $w_n(i)$ |
|-----|---------------|
| 0 | [+1 +1 +1 +1] |
| 1 | [+1 -1 +1 -1] |
| 2 | [+1 +1 -1 -1] |
| 3 | [+1 -1 -1 +1] |

6.3.2.5.3 Mapping to physical resources

The block of complex-valued symbols $z(0), \dots, z(N_{\text{SF}}^{\text{PUCCH},2} M_{\text{symb}} - 1)$ shall be multiplied with the amplitude scaling factor $\beta_{\text{PUCCH},2}$ in order to conform to the transmit power specified in [5, TS 38.213] and mapped in sequence starting with $z(0)$ to resource elements $(k, l)_{p,\mu}$ which meet all of the following criteria:

- they are in the resource blocks assigned for transmission,
- they are not used by the associated DM-RS.

The mapping to resource elements $(k, l)_{p,\mu}$ not reserved for other purposes shall be in increasing order of first the index k over the assigned physical resource blocks according to clause 9.2.1 of [5, TS 38.213], and then the index l on antenna port $p = 2000$.

6.3.2.6 PUCCH formats 3 and 4

6.3.2.6.1 Scrambling

The block of bits $b(0), \dots, b(M_{\text{bit}} - 1)$, where M_{bit} is the number of bits transmitted on the physical channel, shall be scrambled prior to modulation, resulting in a block of scrambled bits $\tilde{b}(0), \dots, \tilde{b}(M_{\text{bit}} - 1)$ according to the following pseudo code

Set $i = 0$

while $i < M_{\text{bit}}$

if $b(i) = y$ // UCI placeholder bits

$\tilde{b}(i) = \tilde{b}(i - 1)$

else

$\tilde{b}(i) = (b(i) + c(i)) \bmod 2$

end if

$i = i + 1$

end while

where y is the tag defined in [4, TS38.212] and the scrambling sequence $c(i)$ is given by clause 5.2.1. The scrambling sequence generator shall be initialized with

$$c_{\text{init}} = n_{\text{RNTI}} \cdot 2^{15} + n_{\text{ID}}$$

where

- $n_{ID} \in \{0,1, \dots, 1023\}$ equals the higher-layer parameter *dataScramblingIdentityPUSCH* if configured,
- $n_{ID} = N_{ID}^{cell}$ otherwise

and n_{RNTI} is given by the C-RNTI.

6.3.2.6.2 Modulation

The block of scrambled bits $\tilde{b}(0), \dots, \tilde{b}(M_{bit} - 1)$ shall be modulated as described in clause 5.1 using QPSK unless $\pi/2$ -BPSK is configured, resulting in a block of complex-valued modulation symbols $d(0), \dots, d(M_{symp} - 1)$ where $M_{symp} = M_{bit}/2$ for QPSK and $M_{symp} = M_{bit}$ for $\pi/2$ -BPSK.

6.3.2.6.3 Block-wise spreading

For both PUCCH format 3 and 4, $M_{sc}^{PUCCH,s} = M_{RB}^{PUCCH,s} N_{sc}^{RB}$ with $M_{RB}^{PUCCH,s}$ representing the bandwidth of the PUCCH in terms of resource blocks according to clauses 9.2.3, 9.2.5.1 and 9.2.5.2 of [5, TS 38.213] and shall for non-interlaced mapping fulfil

$$M_{RB}^{PUCCH,s} = 2^{\alpha_2} \cdot 3^{\alpha_3} \cdot 5^{\alpha_5}$$

where $\alpha_2, \alpha_3, \alpha_5$ is a set of non-negative integers and $s \in \{3,4\}$. For interlaced mapping, $M_{RB}^{PUCCH,3} = 10$ if a single interlace is configured and $M_{RB}^{PUCCH,3} = 20$ if two interlaces are configured.

For PUCCH format 3, if interlaced mapping is not configured, no block-wise spreading is applied and

$$\begin{aligned} y(lM_{sc}^{PUCCH,3} + k) &= d(lM_{sc}^{PUCCH,3} + k) \\ k &= 0, 1, \dots, M_{sc}^{PUCCH,3} - 1 \\ l &= 0, 1, \dots, (M_{symp}/M_{sc}^{PUCCH,3}) - 1 \end{aligned}$$

where $M_{RB}^{PUCCH,3} \geq 1$ is given by clauses 9.2.3, 9.2.5.1 and 9.2.5.2 of [5, TS 38.213] and $N_{SF}^{PUCCH,3} = 1$.

For PUCCH format 3 with interlaced mapping and PUCCH format 4, block-wise spreading shall be applied according to

$$\begin{aligned} y(lM_{sc}^{PUCCH,s} + k) &= w_n \left(\left[k \frac{N_{SF}^{PUCCH,s}}{M_{sc}^{PUCCH,s}} \right] \right) d \left(l \frac{M_{sc}^{PUCCH,s}}{N_{SF}^{PUCCH,s}} + k \bmod \frac{M_{sc}^{PUCCH,s}}{N_{SF}^{PUCCH,s}} \right) \\ k &= 0, 1, \dots, M_{sc}^{PUCCH,s} - 1 \\ l &= 0, 1, \dots, (N_{SF}^{PUCCH,s} M_{symp} / M_{sc}^{PUCCH,s}) - 1 \end{aligned}$$

where

- for PUCCH format 3 with interlaced mapping, $N_{SF}^{PUCCH,3} \in \{1,2,4\}$ if a single interlace is configured and $N_{SF}^{PUCCH,3} = 1$, $w_n = 1$ if two interlaces are configured;
- for PUCCH format 4, $M_{RB}^{PUCCH,4}$ is given by clause 9.2.1 of [5, TS 38.213] and $N_{SF}^{PUCCH,4} \in \{2,4\}$ is given by the higher-layer parameter *occ-Length*;

and w_n is given by Tables 6.3.2.6.3-1 and 6.3.2.6.3-2 for $N_{SF}^{PUCCH,s} > 1$ where n is the index of the orthogonal sequence to use according to clause 9.2.1 of [5, TS 38.213]. The quantity $N_{SF}^{PUCCH,3} \in \{2,4\}$ is given by the higher-layer parameter *occ-Length* if provided, otherwise $N_{SF}^{PUCCH,3} = 1$.

Table 6.3.2.6.3-1: Orthogonal sequences $w_n(m)$ for PUCCH format 3 with interlaced mapping and PUCCH format 4 when $N_{SF}^{PUCCH,s} = 2$.

| n | w_n |
|-----|---------|
| 0 | [+1 +1] |
| 1 | [+1 -1] |

Table 6.3.2.6.3-2: Orthogonal sequences $w_n(m)$ for PUCCH format 3 with interlaced mapping and PUCCH format 4 when $N_{SF}^{PUCCH,s} = 4$.

| n | w_n |
|-----|---------------|
| 0 | [+1 +1 +1 +1] |
| 1 | [+1 -j -1 +j] |
| 2 | [+1 -1 +1 -1] |
| 3 | [+1 +j -1 -j] |

6.3.2.6.4 Transform precoding

The block of complex-valued symbols $y(0), \dots, y(N_{SF}^{PUCCH,s} M_{\text{symb}} - 1)$ shall be transform precoded according to

$$z(l \cdot M_{sc}^{PUCCH,s} + k) = \frac{1}{\sqrt{M_{sc}^{PUCCH,s}}} \sum_{m=0}^{M_{sc}^{PUCCH,s} - 1} y(l \cdot M_{sc}^{PUCCH,s} + m) e^{-j \frac{2\pi mk}{M_{sc}^{PUCCH,s}}}$$

$$k = 0, \dots, M_{sc}^{PUCCH,s} - 1$$

$$l = 0, \dots, \left(N_{SF}^{PUCCH,s} M_{\text{symb}} / M_{sc}^{PUCCH,s} \right) - 1$$

resulting in a block of complex-valued symbols $z(0), \dots, z(N_{SF}^{PUCCH,s} M_{\text{symb}} - 1)$.

6.3.2.6.5 Mapping to physical resources

The block of modulation symbols $z(0), \dots, z(N_{SF}^{PUCCH,s} M_{\text{symb}} - 1)$ shall be multiplied with the amplitude scaling factor $\beta_{PUCCH,s}$ in order to conform to the transmit power specified in [5, TS 38.213] and mapped in sequence starting with $z(0)$ to resource elements $(k, l)_{p,\mu}$ which meet all of the following criteria:

- they are in the resource blocks assigned for transmission,
- they are not used by the associated DM-RS

The mapping to resource elements $(k, l)_{p,\mu}$ not reserved for other purposes shall be in increasing order of first the index k over the assigned physical resource blocks according to clause 9.2.1 of [5, TS 38.213], and then the index l on antenna port $p = 2000$.

In case of intra-slot frequency hopping according to clause 9.2.1 of [5, TS 38.213], $\lfloor N_{\text{symb}}^{PUCCH,s} / 2 \rfloor$ OFDM symbols shall be transmitted in the first hop and $N_{\text{symb}}^{PUCCH,s} - \lfloor N_{\text{symb}}^{PUCCH,s} / 2 \rfloor$ symbols in the second hop where $N_{\text{symb}}^{PUCCH,s}$ is the total number of OFDM symbols used in one slot for PUCCH transmission.

6.3.3 Physical random-access channel

6.3.3.1 Sequence generation

The set of random-access preambles $x_{u,v}(n)$ shall be generated according to

$$x_{u,v}(n) = x_u((n + C_v) \bmod L_{RA})$$

$$x_u(i) = e^{-j \frac{\pi i(i+1)}{L_{RA}}}, i = 0, 1, \dots, L_{RA} - 1$$

from which the frequency-domain representation shall be generated according to

$$y_{u,v}(n) = \sum_{m=0}^{L_{RA}-1} x_{u,v}(m) \cdot e^{-j \frac{2\pi mn}{L_{RA}}}$$

where $L_{RA} = 839$, $L_{RA} = 139$, $L_{RA} = 1151$, or $L_{RA} = 571$ depending on the PRACH preamble format as given by Tables 6.3.3.1-1 and 6.3.3.1-2.

There are 64 preambles defined in each time-frequency PRACH occasion, enumerated in increasing order of first increasing cyclic shift C_v of a logical root sequence, and then in increasing order of the logical root sequence index, starting with the index obtained from the higher-layer parameter *prach-RootSequenceIndex* or *rootSequenceIndex-BFR* or by *msgA-PRACH-RootSequenceIndex* if configured and a type-2 random-access procedure is initiated as described in clause 8.1 of [5, TS 38.213] or by *prach-RootSequenceIndex in EarlyUL-SyncConfig* if the PRACH transmission is for a candidate cell. Additional preamble sequences, in case 64 preambles cannot be generated from a single root Zadoff-Chu sequence, are obtained from the root sequences with the consecutive logical indexes until all the 64 sequences are found. The logical root sequence order is cyclic; the logical index 0 is consecutive to $L_{RA} - 2$. The sequence number u is obtained from the logical root sequence index according to Tables 6.3.3.1-3 to 6.3.3.1-4B.

The cyclic shift C_v is given by

$$C_v = \begin{cases} vN_{CS} & v = 0, 1, \dots, \lfloor L_{RA}/N_{CS} \rfloor - 1, N_{CS} \neq 0 & \text{for unrestricted sets} \\ 0 & N_{CS} = 0 & \text{for unrestricted sets} \\ \overline{d}_{start} \lfloor v/n_{shift}^{RA} \rfloor + (v \bmod n_{shift}^{RA})N_{CS} & v = 0, 1, \dots, w-1 & \text{for restricted sets type A and B} \\ \overline{d}_{start} + (v-w)N_{CS} & v = w, \dots, w + \overline{n}_{shift}^{RA} - 1 & \text{for restricted sets type B} \\ \overline{d}_{start} + (v-w-\overline{n}_{shift}^{RA})N_{CS} & v = w + \overline{n}_{shift}^{RA}, \dots, w + \overline{n}_{shift}^{RA} + \overline{\overline{n}}_{shift}^{RA} - 1 & \text{for restricted sets type B} \end{cases}$$

$$w = n_{shift}^{RA} n_{group}^{RA} + \overline{n}_{shift}^{RA}$$

where N_{CS} is given by Tables 6.3.3.1-5 to 6.3.3.1-7. The type of restricted sets (unrestricted, restricted type A, restricted type B) is given by

- the higher-layer parameter *msgA-RestrictedSetConfig*, if provided;
- or the higher-layer parameter *ltm-restrictedSetConfig* associated with a candidate cell indicated in Cell indicator field of a PDCCH order, if provided;
- otherwise, the higher-layer parameter *restrictedSetConfig*.

Tables 6.3.3.1-1 and 6.3.3.1-2 indicate the type of restricted sets supported for the different preamble formats.

The variable d_u is given by

$$d_u = \begin{cases} q & 0 \leq q < L_{RA}/2 \\ L_{RA} - q & \text{otherwise} \end{cases}$$

where q is the smallest non-negative integer that fulfils $(qu) \bmod L_{RA} = 1$. The parameters for restricted sets of cyclic shifts depend on d_u .

For restricted set type A, the parameters are given by:

- for $N_{CS} \leq d_u < L_{RA}/3$

$$\begin{aligned} n_{\text{shift}}^{\text{RA}} &= \lfloor d_u / N_{CS} \rfloor \\ d_{\text{start}} &= 2d_u + n_{\text{shift}}^{\text{RA}} N_{CS} \\ n_{\text{group}}^{\text{RA}} &= \lfloor L_{RA} / d_{\text{start}} \rfloor \\ \bar{n}_{\text{shift}}^{\text{RA}} &= \max\left(\lfloor (L_{RA} - 2d_u - n_{\text{group}}^{\text{RA}} d_{\text{start}}) / N_{CS} \rfloor, 0\right) \end{aligned}$$

- for $L_{RA}/3 \leq d_u \leq (L_{RA} - N_{CS})/2$

$$\begin{aligned} n_{\text{shift}}^{\text{RA}} &= \lfloor (L_{RA} - 2d_u) / N_{CS} \rfloor \\ d_{\text{start}} &= L_{RA} - 2d_u + n_{\text{shift}}^{\text{RA}} N_{CS} \\ n_{\text{group}}^{\text{RA}} &= \lfloor d_u / d_{\text{start}} \rfloor \\ \bar{n}_{\text{shift}}^{\text{RA}} &= \min\left(\max\left(\lfloor (d_u - n_{\text{group}}^{\text{RA}} d_{\text{start}}) / N_{CS} \rfloor, 0\right), n_{\text{shift}}^{\text{RA}}\right) \end{aligned}$$

For restricted set type B, the parameters are given by:

- for $N_{CS} \leq d_u < L_{RA}/5$

$$\begin{aligned} n_{\text{shift}}^{\text{RA}} &= \lfloor d_u / N_{CS} \rfloor \\ d_{\text{start}} &= 4d_u + n_{\text{shift}}^{\text{RA}} N_{CS} \\ n_{\text{group}}^{\text{RA}} &= \lfloor L_{RA} / d_{\text{start}} \rfloor \\ \bar{n}_{\text{shift}}^{\text{RA}} &= \max\left(\lfloor (L_{RA} - 4d_u - n_{\text{group}}^{\text{RA}} d_{\text{start}}) / N_{CS} \rfloor, 0\right) \end{aligned}$$

- for $L_{RA}/5 \leq d_u \leq (L_{RA} - N_{CS})/4$

$$\begin{aligned} n_{\text{shift}}^{\text{RA}} &= \lfloor (L_{RA} - 4d_u) / N_{CS} \rfloor \\ d_{\text{start}} &= L_{RA} - 4d_u + n_{\text{shift}}^{\text{RA}} N_{CS} \\ n_{\text{group}}^{\text{RA}} &= \lfloor d_u / d_{\text{start}} \rfloor \\ \bar{n}_{\text{shift}}^{\text{RA}} &= \min\left(\max\left(\lfloor (d_u - n_{\text{group}}^{\text{RA}} d_{\text{start}}) / N_{CS} \rfloor, 0\right), n_{\text{shift}}^{\text{RA}}\right) \end{aligned}$$

- for $(L_{RA} + N_{CS})/4 \leq d_u < 2L_{RA}/7$

$$\begin{aligned} n_{\text{shift}}^{\text{RA}} &= \lfloor (4d_u - L_{RA}) / N_{CS} \rfloor \\ d_{\text{start}} &= 4d_u - L_{RA} + n_{\text{shift}}^{\text{RA}} N_{CS} \\ \bar{d}_{\text{start}} &= L_{RA} - 3d_u + n_{\text{group}}^{\text{RA}} d_{\text{start}} + \bar{n}_{\text{shift}}^{\text{RA}} N_{CS} \\ \bar{\bar{d}}_{\text{start}} &= L_{RA} - 2d_u + n_{\text{group}}^{\text{RA}} d_{\text{start}} + \bar{\bar{n}}_{\text{shift}}^{\text{RA}} N_{CS} \\ n_{\text{group}}^{\text{RA}} &= \lfloor d_u / d_{\text{start}} \rfloor \\ \bar{n}_{\text{shift}}^{\text{RA}} &= \max\left(\lfloor (L_{RA} - 3d_u - n_{\text{group}}^{\text{RA}} d_{\text{start}}) / N_{CS} \rfloor, 0\right) \\ \bar{\bar{n}}_{\text{shift}}^{\text{RA}} &= \lfloor \min(d_u - n_{\text{group}}^{\text{RA}} d_{\text{start}}, 4d_u - L_{RA} - \bar{n}_{\text{shift}}^{\text{RA}} N_{CS}) / N_{CS} \rfloor \\ \bar{\bar{\bar{n}}}_{\text{shift}}^{\text{RA}} &= \lfloor \left((1 - \min(1, \bar{\bar{n}}_{\text{shift}}^{\text{RA}})) (d_u - n_{\text{group}}^{\text{RA}} d_{\text{start}}) + \min(1, \bar{n}_{\text{shift}}^{\text{RA}}) (4d_u - L_{RA} - \bar{\bar{n}}_{\text{shift}}^{\text{RA}} N_{CS}) \right) / N_{CS} \rfloor - \bar{\bar{n}}_{\text{shift}}^{\text{RA}} \end{aligned}$$

- for $2L_{RA}/7 \leq d_u \leq (L_{RA} - N_{CS})/3$

$$\begin{aligned}
n_{\text{shift}}^{\text{RA}} &= \lfloor (L_{\text{RA}} - 3d_u) / N_{\text{CS}} \rfloor \\
d_{\text{start}} &= L_{\text{RA}} - 3d_u + n_{\text{shift}}^{\text{RA}} N_{\text{CS}} \\
\bar{d}_{\text{start}} &= d_u + n_{\text{group}}^{\text{RA}} d_{\text{start}} + \bar{n}_{\text{shift}}^{\text{RA}} N_{\text{CS}} \\
\bar{\bar{d}}_{\text{start}} &= 0 \\
n_{\text{group}}^{\text{RA}} &= \lfloor d_u / d_{\text{start}} \rfloor \\
\bar{n}_{\text{shift}}^{\text{RA}} &= \max(\lfloor (4d_u - L_{\text{RA}} - n_{\text{group}}^{\text{RA}} d_{\text{start}}) / N_{\text{CS}} \rfloor, 0) \\
\bar{\bar{n}}_{\text{shift}}^{\text{RA}} &= \lfloor \min(d_u - n_{\text{group}}^{\text{RA}} d_{\text{start}}, L_{\text{RA}} - 3d_u - \bar{n}_{\text{shift}}^{\text{RA}} N_{\text{CS}}) / N_{\text{CS}} \rfloor \\
\bar{\bar{\bar{n}}}_{\text{shift}}^{\text{RA}} &= 0
\end{aligned}$$

- for $(L_{\text{RA}} + N_{\text{CS}}) / 3 \leq d_u < 2L_{\text{RA}} / 5$

$$\begin{aligned}
n_{\text{shift}}^{\text{RA}} &= \lfloor (3d_u - L_{\text{RA}}) / N_{\text{CS}} \rfloor \\
d_{\text{start}} &= 3d_u - L_{\text{RA}} + n_{\text{shift}}^{\text{RA}} N_{\text{CS}} \\
\bar{d}_{\text{start}} &= 0 \\
\bar{\bar{d}}_{\text{start}} &= 0 \\
n_{\text{group}}^{\text{RA}} &= \lfloor d_u / d_{\text{start}} \rfloor \\
\bar{n}_{\text{shift}}^{\text{RA}} &= \max(\lfloor (L_{\text{RA}} - 2d_u - n_{\text{group}}^{\text{RA}} d_{\text{start}}) / N_{\text{CS}} \rfloor, 0) \\
\bar{\bar{n}}_{\text{shift}}^{\text{RA}} &= 0 \\
\bar{\bar{\bar{n}}}_{\text{shift}}^{\text{RA}} &= 0
\end{aligned}$$

- for $2L_{\text{RA}} / 5 \leq d_u \leq (L_{\text{RA}} - N_{\text{CS}}) / 2$

$$\begin{aligned}
n_{\text{shift}}^{\text{RA}} &= \lfloor (L_{\text{RA}} - 2d_u) / N_{\text{CS}} \rfloor \\
d_{\text{start}} &= 2(L_{\text{RA}} - 2d_u) + n_{\text{shift}}^{\text{RA}} N_{\text{CS}} \\
\bar{d}_{\text{start}} &= 0 \\
\bar{\bar{d}}_{\text{start}} &= 0 \\
n_{\text{group}}^{\text{RA}} &= \lfloor (L_{\text{RA}} - d_u) / d_{\text{start}} \rfloor \\
\bar{n}_{\text{shift}}^{\text{RA}} &= \max(\lfloor (3d_u - L_{\text{RA}} - n_{\text{group}}^{\text{RA}} d_{\text{start}}) / N_{\text{CS}} \rfloor, 0) \\
\bar{\bar{n}}_{\text{shift}}^{\text{RA}} &= 0 \\
\bar{\bar{\bar{n}}}_{\text{shift}}^{\text{RA}} &= 0
\end{aligned}$$

For all other values of d_u , there are no cyclic shifts in the restricted set.

Table 6.3.3.1-1: PRACH preamble formats for $L_{\text{RA}} = 839$ and $\Delta f_{\text{RA}} \in \{1.25, 5\}$ kHz.

| Format | L_{RA} | Δf_{RA} | N_u | $N_{\text{CP}}^{\text{RA}}$ | Support for restricted sets |
|--------|-----------------|------------------------|-----------------------|-----------------------------|-----------------------------|
| 0 | 839 | 1.25 kHz | 24576κ | 3168κ | Type A, Type B |
| 1 | 839 | 1.25 kHz | $2 \cdot 24576\kappa$ | 21024κ | Type A, Type B |
| 2 | 839 | 1.25 kHz | $4 \cdot 24576\kappa$ | 4688κ | Type A, Type B |
| 3 | 839 | 5 kHz | $4 \cdot 6144\kappa$ | 3168κ | Type A, Type B |

Table 6.3.3.1-2: Preamble formats for $L_{RA} \in \{139, 571, 1151\}$ and $\Delta f_{RA} = 15 \cdot 2^\mu$ kHz where $\mu \in \{0, 1, 2, 3, 5, 6\}$.

| Format | L_{RA} | | | Δf_{RA} | N_u | N_{CP}^{RA} | Support for restricted sets |
|--------|--------------------------------|--------------------|-----------------------|----------------------|--------------------------------------|-----------------------------|-----------------------------|
| | $\mu \in \{0, 1, 2, 3, 5, 6\}$ | $\mu \in \{0, 3\}$ | $\mu \in \{1, 3, 5\}$ | | | | |
| A1 | 139 | 1151 | 571 | $15 \cdot 2^\mu$ kHz | $2 \cdot 2048\kappa \cdot 2^{-\mu}$ | $288\kappa \cdot 2^{-\mu}$ | - |
| A2 | 139 | 1151 | 571 | $15 \cdot 2^\mu$ kHz | $4 \cdot 2048\kappa \cdot 2^{-\mu}$ | $576\kappa \cdot 2^{-\mu}$ | - |
| A3 | 139 | 1151 | 571 | $15 \cdot 2^\mu$ kHz | $6 \cdot 2048\kappa \cdot 2^{-\mu}$ | $864\kappa \cdot 2^{-\mu}$ | - |
| B1 | 139 | 1151 | 571 | $15 \cdot 2^\mu$ kHz | $2 \cdot 2048\kappa \cdot 2^{-\mu}$ | $216\kappa \cdot 2^{-\mu}$ | - |
| B2 | 139 | 1151 | 571 | $15 \cdot 2^\mu$ kHz | $4 \cdot 2048\kappa \cdot 2^{-\mu}$ | $360\kappa \cdot 2^{-\mu}$ | - |
| B3 | 139 | 1151 | 571 | $15 \cdot 2^\mu$ kHz | $6 \cdot 2048\kappa \cdot 2^{-\mu}$ | $504\kappa \cdot 2^{-\mu}$ | - |
| B4 | 139 | 1151 | 571 | $15 \cdot 2^\mu$ kHz | $12 \cdot 2048\kappa \cdot 2^{-\mu}$ | $936\kappa \cdot 2^{-\mu}$ | - |
| C0 | 139 | 1151 | 571 | $15 \cdot 2^\mu$ kHz | $2048\kappa \cdot 2^{-\mu}$ | $1240\kappa \cdot 2^{-\mu}$ | - |
| C2 | 139 | 1151 | 571 | $15 \cdot 2^\mu$ kHz | $4 \cdot 2048\kappa \cdot 2^{-\mu}$ | $2048\kappa \cdot 2^{-\mu}$ | - |

Table 6.3.3.1-3: Mapping from logical index i to sequence number u for preamble formats with $L_{RA} = 839$.

| i | Sequence number u in increasing order of i | | | | | | | | | | | | | | | | | | | |
|-----------|--|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 0 – 19 | 129 | 710 | 140 | 699 | 120 | 719 | 210 | 629 | 168 | 671 | 84 | 755 | 105 | 734 | 93 | 746 | 70 | 769 | 60 | 779 |
| 20 – 39 | 2 | 837 | 1 | 838 | 56 | 783 | 112 | 727 | 148 | 691 | 80 | 759 | 42 | 797 | 40 | 799 | 35 | 804 | 73 | 766 |
| 40 – 59 | 146 | 693 | 31 | 808 | 28 | 811 | 30 | 809 | 27 | 812 | 29 | 810 | 24 | 815 | 48 | 791 | 68 | 771 | 74 | 765 |
| 60 – 79 | 178 | 661 | 136 | 703 | 86 | 753 | 78 | 761 | 43 | 796 | 39 | 800 | 20 | 819 | 21 | 818 | 95 | 744 | 202 | 637 |
| 80 – 99 | 190 | 649 | 181 | 658 | 137 | 702 | 125 | 714 | 151 | 688 | 217 | 622 | 128 | 711 | 142 | 697 | 122 | 717 | 203 | 636 |
| 100 – 119 | 118 | 721 | 110 | 729 | 89 | 750 | 103 | 736 | 61 | 778 | 55 | 784 | 15 | 824 | 14 | 825 | 12 | 827 | 23 | 816 |
| 120 – 139 | 34 | 805 | 37 | 802 | 46 | 793 | 207 | 632 | 179 | 660 | 145 | 694 | 130 | 709 | 223 | 616 | 228 | 611 | 227 | 612 |
| 140 – 159 | 132 | 707 | 133 | 706 | 143 | 696 | 135 | 704 | 161 | 678 | 201 | 638 | 173 | 666 | 106 | 733 | 83 | 756 | 91 | 748 |
| 160 – 179 | 66 | 773 | 53 | 786 | 10 | 829 | 9 | 830 | 7 | 832 | 8 | 831 | 16 | 823 | 47 | 792 | 64 | 775 | 57 | 782 |
| 180 – 199 | 104 | 735 | 101 | 738 | 108 | 731 | 208 | 631 | 184 | 655 | 197 | 642 | 191 | 648 | 121 | 718 | 141 | 698 | 149 | 690 |
| 200 – 219 | 216 | 623 | 218 | 621 | 152 | 687 | 144 | 695 | 134 | 705 | 138 | 701 | 199 | 640 | 162 | 677 | 176 | 663 | 119 | 720 |
| 220 – 239 | 158 | 681 | 164 | 675 | 174 | 665 | 171 | 668 | 170 | 669 | 87 | 752 | 169 | 670 | 88 | 751 | 107 | 732 | 81 | 758 |
| 240 – 259 | 82 | 757 | 100 | 739 | 98 | 741 | 71 | 768 | 59 | 780 | 65 | 774 | 50 | 789 | 49 | 790 | 26 | 813 | 17 | 822 |
| 260 – 279 | 13 | 826 | 6 | 833 | 5 | 834 | 33 | 806 | 51 | 788 | 75 | 764 | 99 | 740 | 96 | 743 | 97 | 742 | 166 | 673 |
| 280 – 299 | 172 | 667 | 175 | 664 | 187 | 652 | 163 | 676 | 185 | 654 | 200 | 639 | 114 | 725 | 189 | 650 | 115 | 724 | 194 | 645 |
| 300 – 319 | 195 | 644 | 192 | 647 | 182 | 657 | 157 | 682 | 156 | 683 | 211 | 628 | 154 | 685 | 123 | 716 | 139 | 700 | 212 | 627 |
| 320 – 339 | 153 | 686 | 213 | 626 | 215 | 624 | 150 | 689 | 225 | 614 | 224 | 615 | 221 | 618 | 220 | 619 | 127 | 712 | 147 | 692 |
| 340 – 359 | 124 | 715 | 193 | 646 | 205 | 634 | 206 | 633 | 116 | 723 | 160 | 679 | 186 | 653 | 167 | 672 | 79 | 760 | 85 | 754 |
| 360 – 379 | 77 | 762 | 92 | 747 | 58 | 781 | 62 | 777 | 69 | 770 | 54 | 785 | 36 | 803 | 32 | 807 | 25 | 814 | 18 | 821 |
| 380 – 399 | 11 | 828 | 4 | 835 | 3 | 836 | 19 | 820 | 22 | 817 | 41 | 798 | 38 | 801 | 44 | 795 | 52 | 787 | 45 | 794 |
| 400 – 419 | 63 | 776 | 67 | 772 | 72 | 767 | 76 | 763 | 94 | 745 | 102 | 737 | 90 | 749 | 109 | 730 | 165 | 674 | 111 | 728 |
| 420 – 439 | 209 | 630 | 204 | 635 | 117 | 722 | 188 | 651 | 159 | 680 | 198 | 641 | 113 | 726 | 183 | 656 | 180 | 659 | 177 | 662 |
| 440 – 459 | 196 | 643 | 155 | 684 | 214 | 625 | 126 | 713 | 131 | 708 | 219 | 620 | 222 | 617 | 226 | 613 | 230 | 609 | 232 | 607 |
| 460 – 479 | 262 | 577 | 252 | 587 | 418 | 421 | 416 | 423 | 413 | 426 | 411 | 428 | 376 | 463 | 395 | 444 | 283 | 556 | 285 | 554 |
| 480 – 499 | 379 | 460 | 390 | 449 | 363 | 476 | 384 | 455 | 388 | 451 | 386 | 453 | 361 | 478 | 387 | 452 | 360 | 479 | 310 | 529 |
| 500 – 519 | 354 | 485 | 328 | 511 | 315 | 524 | 337 | 502 | 349 | 490 | 335 | 504 | 324 | 515 | 323 | 516 | 320 | 519 | 334 | 505 |
| 520 – 539 | 359 | 480 | 295 | 544 | 385 | 454 | 292 | 547 | 291 | 548 | 381 | 458 | 399 | 440 | 380 | 459 | 397 | 442 | 369 | 470 |
| 540 – 559 | 377 | 462 | 410 | 429 | 407 | 432 | 281 | 558 | 414 | 425 | 247 | 592 | 277 | 562 | 271 | 568 | 272 | 567 | 264 | 575 |
| 560 – 579 | 259 | 580 | 237 | 602 | 239 | 600 | 244 | 595 | 243 | 596 | 275 | 564 | 278 | 561 | 250 | 589 | 246 | 593 | 417 | 422 |
| 580 – 599 | 248 | 591 | 394 | 445 | 393 | 446 | 370 | 469 | 365 | 474 | 300 | 539 | 299 | 540 | 364 | 475 | 362 | 477 | 298 | 541 |
| 600 – 619 | 312 | 527 | 313 | 526 | 314 | 525 | 353 | 486 | 352 | 487 | 343 | 496 | 327 | 512 | 350 | 489 | 326 | 513 | 319 | 520 |
| 620 – 639 | 332 | 507 | 333 | 506 | 348 | 491 | 347 | 492 | 322 | 517 | 330 | 509 | 338 | 501 | 341 | 498 | 340 | 499 | 342 | 497 |
| 640 – 659 | 301 | 538 | 366 | 473 | 401 | 438 | 371 | 468 | 408 | 431 | 375 | 464 | 249 | 590 | 269 | 570 | 238 | 601 | 234 | 605 |
| 660 – 679 | 257 | 582 | 273 | 566 | 255 | 584 | 254 | 585 | 245 | 594 | 251 | 588 | 412 | 427 | 372 | 467 | 282 | 557 | 403 | 436 |
| 680 – 699 | 396 | 443 | 392 | 447 | 391 | 448 | 382 | 457 | 389 | 450 | 294 | 545 | 297 | 542 | 311 | 528 | 344 | 495 | 345 | 494 |
| 700 – 719 | 318 | 521 | 331 | 508 | 325 | 514 | 321 | 518 | 346 | 493 | 339 | 500 | 351 | 488 | 306 | 533 | 289 | 550 | 400 | 439 |
| 720 – 739 | 378 | 461 | 374 | 465 | 415 | 424 | 270 | 569 | 241 | 598 | 231 | 608 | 260 | 579 | 268 | 571 | 276 | 563 | 409 | 430 |
| 740 – 759 | 398 | 441 | 290 | 549 | 304 | 535 | 308 | 531 | 358 | 481 | 316 | 523 | 293 | 546 | 288 | 551 | 284 | 555 | 368 | 471 |
| 760 – 779 | 253 | 586 | 256 | 583 | 263 | 576 | 242 | 597 | 274 | 565 | 402 | 437 | 383 | 456 | 357 | 482 | 329 | 510 | 317 | 522 |
| 780 – 799 | 307 | 532 | 286 | 553 | 287 | 552 | 266 | 573 | 261 | 578 | 236 | 603 | 303 | 536 | 356 | 483 | 355 | 484 | 405 | 434 |
| 800 – 819 | 404 | 435 | 406 | 433 | 235 | 604 | 267 | 572 | 302 | 537 | 309 | 530 | 265 | 574 | 233 | 606 | 367 | 472 | 296 | 543 |
| 820 – 837 | 336 | 503 | 305 | 534 | 373 | 466 | 280 | 559 | 279 | 560 | 419 | 420 | 240 | 599 | 258 | 581 | 229 | 610 | - | - |

Table 6.3.3.1-4: Mapping from *logical index i* to sequence number *u* for preamble formats with $L_{RA} = 139$.

| <i>i</i> | Sequence number <i>u</i> in increasing order of <i>i</i> | | | | | | | | | | | | | | | | | | | |
|-----------|--|-----|----|-----|----|-----|----|-----|----|-----|----|-----|----|-----|----|-----|----|-----|----|-----|
| 0 – 19 | 1 | 138 | 2 | 137 | 3 | 136 | 4 | 135 | 5 | 134 | 6 | 133 | 7 | 132 | 8 | 131 | 9 | 130 | 10 | 129 |
| 20 – 39 | 11 | 128 | 12 | 127 | 13 | 126 | 14 | 125 | 15 | 124 | 16 | 123 | 17 | 122 | 18 | 121 | 19 | 120 | 20 | 119 |
| 40 – 59 | 21 | 118 | 22 | 117 | 23 | 116 | 24 | 115 | 25 | 114 | 26 | 113 | 27 | 112 | 28 | 111 | 29 | 110 | 30 | 109 |
| 60 – 79 | 31 | 108 | 32 | 107 | 33 | 106 | 34 | 105 | 35 | 104 | 36 | 103 | 37 | 102 | 38 | 101 | 39 | 100 | 40 | 99 |
| 80 – 99 | 41 | 98 | 42 | 97 | 43 | 96 | 44 | 95 | 45 | 94 | 46 | 93 | 47 | 92 | 48 | 91 | 49 | 90 | 50 | 89 |
| 100 – 119 | 51 | 88 | 52 | 87 | 53 | 86 | 54 | 85 | 55 | 84 | 56 | 83 | 57 | 82 | 58 | 81 | 59 | 80 | 60 | 79 |
| 120 – 137 | 61 | 78 | 62 | 77 | 63 | 76 | 64 | 75 | 65 | 74 | 66 | 73 | 67 | 72 | 68 | 71 | 69 | 70 | - | - |
| 138 – 837 | N/A | | | | | | | | | | | | | | | | | | | |

Table 6.3.3.1-4A: Mapping from *logical index i* to sequence number *u* for preamble formats with $L_{RA} = 1151$.

| <i>i</i> | Sequence number <i>u</i> in increasing order of <i>i</i> | | | | | | | | | | | | | | | | | | | |
|-----------|--|------|-----|------|-----|------|-----|------|-----|------|-----|------|-----|------|-----|------|-----|------|-----|------|
| 0-19 | 1 | 1150 | 2 | 1149 | 3 | 1148 | 4 | 1147 | 5 | 1146 | 6 | 1145 | 7 | 1144 | 8 | 1143 | 9 | 1142 | 10 | 1141 |
| 20-39 | 11 | 1140 | 12 | 1139 | 13 | 1138 | 14 | 1137 | 15 | 1136 | 16 | 1135 | 17 | 1134 | 18 | 1133 | 19 | 1132 | 20 | 1131 |
| 40-59 | 21 | 1130 | 22 | 1129 | 23 | 1128 | 24 | 1127 | 25 | 1126 | 26 | 1125 | 27 | 1124 | 28 | 1123 | 29 | 1122 | 30 | 1121 |
| 60-79 | 31 | 1120 | 32 | 1119 | 33 | 1118 | 34 | 1117 | 35 | 1116 | 36 | 1115 | 37 | 1114 | 38 | 1113 | 39 | 1112 | 40 | 1111 |
| 80-99 | 41 | 1110 | 42 | 1109 | 43 | 1108 | 44 | 1107 | 45 | 1106 | 46 | 1105 | 47 | 1104 | 48 | 1103 | 49 | 1102 | 50 | 1101 |
| 100-119 | 51 | 1100 | 52 | 1099 | 53 | 1098 | 54 | 1097 | 55 | 1096 | 56 | 1095 | 57 | 1094 | 58 | 1093 | 59 | 1092 | 60 | 1091 |
| 120-139 | 61 | 1090 | 62 | 1089 | 63 | 1088 | 64 | 1087 | 65 | 1086 | 66 | 1085 | 67 | 1084 | 68 | 1083 | 69 | 1082 | 70 | 1081 |
| 140-159 | 71 | 1080 | 72 | 1079 | 73 | 1078 | 74 | 1077 | 75 | 1076 | 76 | 1075 | 77 | 1074 | 78 | 1073 | 79 | 1072 | 80 | 1071 |
| 160-179 | 81 | 1070 | 82 | 1069 | 83 | 1068 | 84 | 1067 | 85 | 1066 | 86 | 1065 | 87 | 1064 | 88 | 1063 | 89 | 1062 | 90 | 1061 |
| 180-199 | 91 | 1060 | 92 | 1059 | 93 | 1058 | 94 | 1057 | 95 | 1056 | 96 | 1055 | 97 | 1054 | 98 | 1053 | 99 | 1052 | 100 | 1051 |
| 200-219 | 101 | 1050 | 102 | 1049 | 103 | 1048 | 104 | 1047 | 105 | 1046 | 106 | 1045 | 107 | 1044 | 108 | 1043 | 109 | 1042 | 110 | 1041 |
| 220-239 | 111 | 1040 | 112 | 1039 | 113 | 1038 | 114 | 1037 | 115 | 1036 | 116 | 1035 | 117 | 1034 | 118 | 1033 | 119 | 1032 | 120 | 1031 |
| 240-259 | 121 | 1030 | 122 | 1029 | 123 | 1028 | 124 | 1027 | 125 | 1026 | 126 | 1025 | 127 | 1024 | 128 | 1023 | 129 | 1022 | 130 | 1021 |
| 260-279 | 131 | 1020 | 132 | 1019 | 133 | 1018 | 134 | 1017 | 135 | 1016 | 136 | 1015 | 137 | 1014 | 138 | 1013 | 139 | 1012 | 140 | 1011 |
| 280-299 | 141 | 1010 | 142 | 1009 | 143 | 1008 | 144 | 1007 | 145 | 1006 | 146 | 1005 | 147 | 1004 | 148 | 1003 | 149 | 1002 | 150 | 1001 |
| 300-319 | 151 | 1000 | 152 | 999 | 153 | 998 | 154 | 997 | 155 | 996 | 156 | 995 | 157 | 994 | 158 | 993 | 159 | 992 | 160 | 991 |
| 320-339 | 161 | 990 | 162 | 989 | 163 | 988 | 164 | 987 | 165 | 986 | 166 | 985 | 167 | 984 | 168 | 983 | 169 | 982 | 170 | 981 |
| 340-359 | 171 | 980 | 172 | 979 | 173 | 978 | 174 | 977 | 175 | 976 | 176 | 975 | 177 | 974 | 178 | 973 | 179 | 972 | 180 | 971 |
| 360-379 | 181 | 970 | 182 | 969 | 183 | 968 | 184 | 967 | 185 | 966 | 186 | 965 | 187 | 964 | 188 | 963 | 189 | 962 | 190 | 961 |
| 380-399 | 191 | 960 | 192 | 959 | 193 | 958 | 194 | 957 | 195 | 956 | 196 | 955 | 197 | 954 | 198 | 953 | 199 | 952 | 200 | 951 |
| 400-419 | 201 | 950 | 202 | 949 | 203 | 948 | 204 | 947 | 205 | 946 | 206 | 945 | 207 | 944 | 208 | 943 | 209 | 942 | 210 | 941 |
| 420-439 | 211 | 940 | 212 | 939 | 213 | 938 | 214 | 937 | 215 | 936 | 216 | 935 | 217 | 934 | 218 | 933 | 219 | 932 | 220 | 931 |
| 440-459 | 221 | 930 | 222 | 929 | 223 | 928 | 224 | 927 | 225 | 926 | 226 | 925 | 227 | 924 | 228 | 923 | 229 | 922 | 230 | 921 |
| 460-479 | 231 | 920 | 232 | 919 | 233 | 918 | 234 | 917 | 235 | 916 | 236 | 915 | 237 | 914 | 238 | 913 | 239 | 912 | 240 | 911 |
| 480-499 | 241 | 910 | 242 | 909 | 243 | 908 | 244 | 907 | 245 | 906 | 246 | 905 | 247 | 904 | 248 | 903 | 249 | 902 | 250 | 901 |
| 500-519 | 251 | 900 | 252 | 899 | 253 | 898 | 254 | 897 | 255 | 896 | 256 | 895 | 257 | 894 | 258 | 893 | 259 | 892 | 260 | 891 |
| 520-539 | 261 | 890 | 262 | 889 | 263 | 888 | 264 | 887 | 265 | 886 | 266 | 885 | 267 | 884 | 268 | 883 | 269 | 882 | 270 | 881 |
| 540-559 | 271 | 880 | 272 | 879 | 273 | 878 | 274 | 877 | 275 | 876 | 276 | 875 | 277 | 874 | 278 | 873 | 279 | 872 | 280 | 871 |
| 560-579 | 281 | 870 | 282 | 869 | 283 | 868 | 284 | 867 | 285 | 866 | 286 | 865 | 287 | 864 | 288 | 863 | 289 | 862 | 290 | 861 |
| 580-599 | 291 | 860 | 292 | 859 | 293 | 858 | 294 | 857 | 295 | 856 | 296 | 855 | 297 | 854 | 298 | 853 | 299 | 852 | 300 | 851 |
| 600-619 | 301 | 850 | 302 | 849 | 303 | 848 | 304 | 847 | 305 | 846 | 306 | 845 | 307 | 844 | 308 | 843 | 309 | 842 | 310 | 841 |
| 620-639 | 311 | 840 | 312 | 839 | 313 | 838 | 314 | 837 | 315 | 836 | 316 | 835 | 317 | 834 | 318 | 833 | 319 | 832 | 320 | 831 |
| 640-659 | 321 | 830 | 322 | 829 | 323 | 828 | 324 | 827 | 325 | 826 | 326 | 825 | 327 | 824 | 328 | 823 | 329 | 822 | 330 | 821 |
| 660-679 | 331 | 820 | 332 | 819 | 333 | 818 | 334 | 817 | 335 | 816 | 336 | 815 | 337 | 814 | 338 | 813 | 339 | 812 | 340 | 811 |
| 680-699 | 341 | 810 | 342 | 809 | 343 | 808 | 344 | 807 | 345 | 806 | 346 | 805 | 347 | 804 | 348 | 803 | 349 | 802 | 350 | 801 |
| 700-719 | 351 | 800 | 352 | 799 | 353 | 798 | 354 | 797 | 355 | 796 | 356 | 795 | 357 | 794 | 358 | 793 | 359 | 792 | 360 | 791 |
| 720-739 | 361 | 790 | 362 | 789 | 363 | 788 | 364 | 787 | 365 | 786 | 366 | 785 | 367 | 784 | 368 | 783 | 369 | 782 | 370 | 781 |
| 740-759 | 371 | 780 | 372 | 779 | 373 | 778 | 374 | 777 | 375 | 776 | 376 | 775 | 377 | 774 | 378 | 773 | 379 | 772 | 380 | 771 |
| 760-779 | 381 | 770 | 382 | 769 | 383 | 768 | 384 | 767 | 385 | 766 | 386 | 765 | 387 | 764 | 388 | 763 | 389 | 762 | 390 | 761 |
| 780-799 | 391 | 760 | 392 | 759 | 393 | 758 | 394 | 757 | 395 | 756 | 396 | 755 | 397 | 754 | 398 | 753 | 399 | 752 | 400 | 751 |
| 800-819 | 401 | 750 | 402 | 749 | 403 | 748 | 404 | 747 | 405 | 746 | 406 | 745 | 407 | 744 | 408 | 743 | 409 | 742 | 410 | 741 |
| 820-839 | 411 | 740 | 412 | 739 | 413 | 738 | 414 | 737 | 415 | 736 | 416 | 735 | 417 | 734 | 418 | 733 | 419 | 732 | 420 | 731 |
| 840-859 | 421 | 730 | 422 | 729 | 423 | 728 | 424 | 727 | 425 | 726 | 426 | 725 | 427 | 724 | 428 | 723 | 429 | 722 | 430 | 721 |
| 860-879 | 431 | 720 | 432 | 719 | 433 | 718 | 434 | 717 | 435 | 716 | 436 | 715 | 437 | 714 | 438 | 713 | 439 | 712 | 440 | 711 |
| 880-899 | 441 | 710 | 442 | 709 | 443 | 708 | 444 | 707 | 445 | 706 | 446 | 705 | 447 | 704 | 448 | 703 | 449 | 702 | 450 | 701 |
| 900-919 | 451 | 700 | 452 | 699 | 453 | 698 | 454 | 697 | 455 | 696 | 456 | 695 | 457 | 694 | 458 | 693 | 459 | 692 | 460 | 691 |
| 920-939 | 461 | 690 | 462 | 689 | 463 | 688 | 464 | 687 | 465 | 686 | 466 | 685 | 467 | 684 | 468 | 683 | 469 | 682 | 470 | 681 |
| 940-959 | 471 | 680 | 472 | 679 | 473 | 678 | 474 | 677 | 475 | 676 | 476 | 675 | 477 | 674 | 478 | 673 | 479 | 672 | 480 | 671 |
| 960-979 | 481 | 670 | 482 | 669 | 483 | 668 | 484 | 667 | 485 | 666 | 486 | 665 | 487 | 664 | 488 | 663 | 489 | 662 | 490 | 661 |
| 980-999 | 491 | 660 | 492 | 659 | 493 | 658 | 494 | 657 | 495 | 656 | 496 | 655 | 497 | 654 | 498 | 653 | 499 | 652 | 500 | 651 |
| 1000-1019 | 501 | 650 | 502 | 649 | 503 | 648 | 504 | 647 | 505 | 646 | 506 | 645 | 507 | 644 | 508 | 643 | 509 | 642 | 510 | 641 |
| 1020-1039 | 511 | 640 | 512 | 639 | 513 | 638 | 514 | 637 | 515 | 636 | 516 | 635 | 517 | 634 | 518 | 633 | 519 | 632 | 520 | 631 |
| 1040-1059 | 521 | 630 | 522 | 629 | 523 | 628 | 524 | 627 | 525 | 626 | 526 | 625 | 527 | 624 | 528 | 623 | 529 | 622 | 530 | 621 |
| 1060-1079 | 531 | 620 | 532 | 619 | 533 | 618 | 534 | 617 | 535 | 616 | 536 | 615 | 537 | 614 | 538 | 613 | 539 | 612 | 540 | 611 |
| 1080-1099 | 541 | 610 | 542 | 609 | 543 | 608 | 544 | 607 | 545 | 606 | 546 | 605 | 547 | 604 | 548 | 603 | 549 | 602 | 550 | 601 |
| 1100-1119 | 551 | 600 | 552 | 599 | 553 | 598 | 554 | 597 | 555 | 596 | 556 | 595 | 557 | 594 | 558 | 593 | 559 | 592 | 560 | 591 |
| 1120-1139 | 561 | 590 | 562 | 589 | 563 | 588 | 564 | 587 | 565 | 586 | 566 | 585 | 567 | 584 | 568 | 583 | 569 | 582 | 570 | 581 |
| 1140-1149 | 571 | 580 | 572 | 579 | 573 | 578 | 574 | 577 | 575 | 576 | - | - | - | - | - | - | - | - | - | - |

Table 6.3.3.1-4B: Mapping from *logical index i* to sequence number *u* for preamble formats with $L_{RA} = 571$.

| <i>i</i> | Sequence number <i>u</i> in increasing order of <i>i</i> | | | | | | | | | | | | | | | | | | | |
|----------|--|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 0-19 | 1 | 570 | 2 | 569 | 3 | 568 | 4 | 567 | 5 | 566 | 6 | 565 | 7 | 564 | 8 | 563 | 9 | 562 | 10 | 561 |
| 20-39 | 11 | 560 | 12 | 559 | 13 | 558 | 14 | 557 | 15 | 556 | 16 | 555 | 17 | 554 | 18 | 553 | 19 | 552 | 20 | 551 |
| 40-59 | 21 | 550 | 22 | 549 | 23 | 548 | 24 | 547 | 25 | 546 | 26 | 545 | 27 | 544 | 28 | 543 | 29 | 542 | 30 | 541 |
| 60-79 | 31 | 540 | 32 | 539 | 33 | 538 | 34 | 537 | 35 | 536 | 36 | 535 | 37 | 534 | 38 | 533 | 39 | 532 | 40 | 531 |
| 80-99 | 41 | 530 | 42 | 529 | 43 | 528 | 44 | 527 | 45 | 526 | 46 | 525 | 47 | 524 | 48 | 523 | 49 | 522 | 50 | 521 |
| 100-119 | 51 | 520 | 52 | 519 | 53 | 518 | 54 | 517 | 55 | 516 | 56 | 515 | 57 | 514 | 58 | 513 | 59 | 512 | 60 | 511 |
| 120-139 | 61 | 510 | 62 | 509 | 63 | 508 | 64 | 507 | 65 | 506 | 66 | 505 | 67 | 504 | 68 | 503 | 69 | 502 | 70 | 501 |
| 140-159 | 71 | 500 | 72 | 499 | 73 | 498 | 74 | 497 | 75 | 496 | 76 | 495 | 77 | 494 | 78 | 493 | 79 | 492 | 80 | 491 |
| 160-179 | 81 | 490 | 82 | 489 | 83 | 488 | 84 | 487 | 85 | 486 | 86 | 485 | 87 | 484 | 88 | 483 | 89 | 482 | 90 | 481 |
| 180-199 | 91 | 480 | 92 | 479 | 93 | 478 | 94 | 477 | 95 | 476 | 96 | 475 | 97 | 474 | 98 | 473 | 99 | 472 | 100 | 471 |
| 200-219 | 101 | 470 | 102 | 469 | 103 | 468 | 104 | 467 | 105 | 466 | 106 | 465 | 107 | 464 | 108 | 463 | 109 | 462 | 110 | 461 |
| 220-239 | 111 | 460 | 112 | 459 | 113 | 458 | 114 | 457 | 115 | 456 | 116 | 455 | 117 | 454 | 118 | 453 | 119 | 452 | 120 | 451 |
| 240-259 | 121 | 450 | 122 | 449 | 123 | 448 | 124 | 447 | 125 | 446 | 126 | 445 | 127 | 444 | 128 | 443 | 129 | 442 | 130 | 441 |
| 260-279 | 131 | 440 | 132 | 439 | 133 | 438 | 134 | 437 | 135 | 436 | 136 | 435 | 137 | 434 | 138 | 433 | 139 | 432 | 140 | 431 |
| 280-299 | 141 | 430 | 142 | 429 | 143 | 428 | 144 | 427 | 145 | 426 | 146 | 425 | 147 | 424 | 148 | 423 | 149 | 422 | 150 | 421 |
| 300-319 | 151 | 420 | 152 | 419 | 153 | 418 | 154 | 417 | 155 | 416 | 156 | 415 | 157 | 414 | 158 | 413 | 159 | 412 | 160 | 411 |
| 320-339 | 161 | 410 | 162 | 409 | 163 | 408 | 164 | 407 | 165 | 406 | 166 | 405 | 167 | 404 | 168 | 403 | 169 | 402 | 170 | 401 |
| 340-359 | 171 | 400 | 172 | 399 | 173 | 398 | 174 | 397 | 175 | 396 | 176 | 395 | 177 | 394 | 178 | 393 | 179 | 392 | 180 | 391 |
| 360-379 | 181 | 390 | 182 | 389 | 183 | 388 | 184 | 387 | 185 | 386 | 186 | 385 | 187 | 384 | 188 | 383 | 189 | 382 | 190 | 381 |
| 380-399 | 191 | 380 | 192 | 379 | 193 | 378 | 194 | 377 | 195 | 376 | 196 | 375 | 197 | 374 | 198 | 373 | 199 | 372 | 200 | 371 |
| 400-419 | 201 | 370 | 202 | 369 | 203 | 368 | 204 | 367 | 205 | 366 | 206 | 365 | 207 | 364 | 208 | 363 | 209 | 362 | 210 | 361 |
| 420-439 | 211 | 360 | 212 | 359 | 213 | 358 | 214 | 357 | 215 | 356 | 216 | 355 | 217 | 354 | 218 | 353 | 219 | 352 | 220 | 351 |
| 440-459 | 221 | 350 | 222 | 349 | 223 | 348 | 224 | 347 | 225 | 346 | 226 | 345 | 227 | 344 | 228 | 343 | 229 | 342 | 230 | 341 |
| 460-479 | 231 | 340 | 232 | 339 | 233 | 338 | 234 | 337 | 235 | 336 | 236 | 335 | 237 | 334 | 238 | 333 | 239 | 332 | 240 | 331 |
| 480-499 | 241 | 330 | 242 | 329 | 243 | 328 | 244 | 327 | 245 | 326 | 246 | 325 | 247 | 324 | 248 | 323 | 249 | 322 | 250 | 321 |
| 500-519 | 251 | 320 | 252 | 319 | 253 | 318 | 254 | 317 | 255 | 316 | 256 | 315 | 257 | 314 | 258 | 313 | 259 | 312 | 260 | 311 |
| 520-539 | 261 | 310 | 262 | 309 | 263 | 308 | 264 | 307 | 265 | 306 | 266 | 305 | 267 | 304 | 268 | 303 | 269 | 302 | 270 | 301 |
| 540-559 | 271 | 300 | 272 | 299 | 273 | 298 | 274 | 297 | 275 | 296 | 276 | 295 | 277 | 294 | 278 | 293 | 279 | 292 | 280 | 291 |
| 560-569 | 281 | 290 | 282 | 289 | 283 | 288 | 284 | 287 | 285 | 286 | - | - | - | - | - | - | - | - | - | - |

Table 6.3.3.1-5: N_{CS} for preamble formats with $\Delta f_{RA} = 1.25$ kHz.

| zeroCorrelationZoneConfig, msgA-ZeroCorrelationZoneConfig | N_{CS} value | | |
|--|------------------|-----------------------|-----------------------|
| | Unrestricted set | Restricted set type A | Restricted set type B |
| 0 | 0 | 15 | 15 |
| 1 | 13 | 18 | 18 |
| 2 | 15 | 22 | 22 |
| 3 | 18 | 26 | 26 |
| 4 | 22 | 32 | 32 |
| 5 | 26 | 38 | 38 |
| 6 | 32 | 46 | 46 |
| 7 | 38 | 55 | 55 |
| 8 | 46 | 68 | 68 |
| 9 | 59 | 82 | 82 |
| 10 | 76 | 100 | 100 |
| 11 | 93 | 128 | 118 |
| 12 | 119 | 158 | 137 |
| 13 | 167 | 202 | - |
| 14 | 279 | 237 | - |
| 15 | 419 | - | - |

Table 6.3.3.1-6: N_{CS} for preamble formats with $\Delta f_{RA} = 5$ kHz.

| zeroCorrelationZoneConfig, msgA-ZeroCorrelationZoneConfig | N_{CS} value | | |
|--|----------------------------------|----------------------------------|------------------------------|
| | Unrestricted set | Restricted set type A | Restricted set type B |
| 0 | 0 | 36 | 36 |
| 1 | 13 | 57 | 57 |
| 2 | 26 | 72 | 60 |
| 3 | 33 | 81 | 63 |
| 4 | 38 | 89 | 65 |
| 5 | 41 | 94 | 68 |
| 6 | 49 | 103 | 71 |
| 7 | 55 | 112 | 77 |
| 8 | 64 | 121 | 81 |
| 9 | 76 | 132 | 85 |
| 10 | 93 | 137 | 97 |
| 11 | 119 | 152 | 109 |
| 12 | 139 | 173 | 122 |
| 13 | 209 | 195 | 137 |
| 14 | 279 | 216 | - |
| 15 | 419 | 237 | - |

Table 6.3.3.1-7: N_{CS} for preamble formats with $L_{RA} \in \{139, 571, 1151\}$.

| zeroCorrelationZoneConfig, msgA-ZeroCorrelationZoneConfig | N_{CS} value | | |
|--|----------------------------------|----------------------------------|-----------------------------------|
| | $L_{RA} = 139$ | $L_{RA} = 571$ | $L_{RA} = 1151$ |
| 0 | 0 | 0 | 0 |
| 1 | 2 | 8 | 17 |
| 2 | 4 | 10 | 21 |
| 3 | 6 | 12 | 25 |
| 4 | 8 | 15 | 30 |
| 5 | 10 | 17 | 35 |
| 6 | 12 | 21 | 44 |
| 7 | 13 | 25 | 52 |
| 8 | 15 | 31 | 63 |
| 9 | 17 | 40 | 82 |
| 10 | 19 | 51 | 104 |
| 11 | 23 | 63 | 127 |
| 12 | 27 | 81 | 164 |
| 13 | 34 | 114 | 230 |
| 14 | 46 | 190 | 383 |
| 15 | 69 | 285 | 575 |

6.3.3.2 Mapping to physical resources

The preamble sequence shall be mapped to physical resources according to

$$a_k^{(p,RA)} = \beta_{PRACH} y_{u,v}(k)$$

$$k = 0, 1, \dots, L_{RA} - 1$$

where β_{PRACH} is an amplitude scaling factor in order to conform to the transmit power specified in [5, TS38.213], and $p = 4000$ is the antenna port. Baseband signal generation shall be done according to clause 5.3 using the parameters in Table 6.3.3.1-1 or Table 6.3.3.1-2 with \bar{k} given by Table 6.3.3.2-1.

Random access preambles can only be transmitted in the time resources obtained from Tables 6.3.3.2-2 to 6.3.3.2-4 and depends on FR1, FR2, or FR2-NTN and the spectrum type as defined in [8, TS38.104] or [17, TS38.108]. The PRACH configuration index in Tables 6.3.3.2-2 to 6.3.3.2-4 is

- for Table 6.3.3.2-3 given by the higher-layer parameter *prach-ConfigurationIndex*, or by *msgA-PRACH-ConfigurationIndex* if configured; and
- for Tables 6.3.3.2-2 and 6.3.3.2-4 given by the higher-layer parameter *prach-ConfigurationIndex*, or by *msgA-PRACH-ConfigurationIndex* if configured.

For the IAB-MT part of an IAB-node, the following applies:

- if the higher-layer parameter *prach-ConfigurationPeriodScaling-IAB* is configured, the variable x used in $n_f \bmod x = y$ of Tables 6.3.3.2-2 to 6.3.3.2-4 shall be replaced by x_{IAB} , where $x_{\text{IAB}} = \delta x$ and δ is given by the higher-layer parameter *prach-ConfigurationPeriodScaling-IAB* and the IAB-node does not expect x_{IAB} to be larger than 64;
- if the higher-layer parameter *prach-ConfigurationFrameOffset-IAB* is configured, the variable y used in $n_f \bmod x = y$ of Tables 6.3.3.2-2 to 6.3.3.2-4 shall be replaced by $y_{\text{IAB}} = (y + \Delta y) \bmod x$ where Δy is given by the higher-layer parameter *prach-ConfigurationFrameOffset-IAB*, and x is the value used in $n_f \bmod x = y$;
- if the higher-layer parameter *prach-ConfigurationSOffset-IAB* is configured, the subframe number s_n from Tables 6.3.3.2-2 to 6.3.3.2-3 and the slot number s_n from Table 6.3.3.2-4 shall be replaced by $(s_n + \Delta s) \bmod L$ where $\Delta s \in \{0, 1, \dots, L - 1\}$ is given by the higher-layer parameter *prach-ConfigurationSOffset-IAB*, and L is the number of subframes in a frame when using Tables 6.3.3.2-2 to 6.3.3.2-3 and the number of slots in a frame for 60 kHz subcarrier spacing when using in Table 6.3.3.2-4.

Random access preambles can only be transmitted in the frequency resources given by either the higher-layer parameter *msg1-FrequencyStart* or *msgA-RO-FrequencyStart* if configured as described in clause 8.1 of [5 TS 38.213]. The PRACH frequency resources $n_{\text{RA}} \in \{0, 1, \dots, M - 1\}$, where M equals the higher-layer parameter *msg1-FDM* or *msgA-RO-FDM* if configured, are numbered in increasing order within the initial uplink bandwidth part during initial access, starting from the lowest frequency. Otherwise, n_{RA} are numbered in increasing order within the active uplink bandwidth part, starting from the lowest frequency.

For operation with shared spectrum channel access, for $L_{\text{RA}} = 139$, a UE expects to be provided with higher-layer parameter *msg1-FrequencyStart* or *msgA-RO-FrequencyStart* if configured, and higher-layer parameter *msg1-FDM* or *msgA-RO-FDM* if configured, such that a random-access preamble is confined within a single RB set. The UE assumes that the RB set is defined as when the UE is not provided *intraCellGuardBandsPerSCS* for an UL carrier as described in Clause 7 of [6, TS 38.214].

For operation with shared spectrum channel access, for $L_{\text{RA}} = 571$ or 1151 and Type-2 random access, a UE expects to be provided with higher-layer parameter *msgA-RO-FDM* equals to one.

For the purpose of slot numbering in the tables, the following subcarrier spacing shall be assumed:

- 15 kHz for FR1
- 60 kHz for FR2 and FR2-NTN.

For handover purposes to a target cell in paired or unpaired spectrum where the target cell uses $L_{\text{max}} = 4$, the UE may assume the absolute value of the time difference between radio frame i in the current cell and radio frame i in the target cell is less than $153600T_s$ if the association pattern period in clause 8.1 of [5, TS 38.213] is not equal to 10 ms.

For inter frequency handover purposes where the source cell is either in paired or unpaired spectrum and the target cell is in unpaired spectrum and uses $L_{\text{max}} = 8$, the UE may assume the absolute value of the time difference between radio frame i in the current cell and radio frame i in the target cell is less than $76800T_s$.

Table 6.3.3.2-1: Supported combinations of Δf_{RA} and Δf , and the corresponding value of \bar{k} .

| L_{RA} | Δf_{RA} for PRACH | Δf for PUSCH | N_{RB}^{RA} , allocation expressed in number of RBs for PUSCH | \bar{k} |
|----------|---------------------------|----------------------|---|-----------|
| 839 | 1.25 | 15 | 6 | 7 |
| 839 | 1.25 | 30 | 3 | 1 |
| 839 | 1.25 | 60 | 2 | 133 |
| 839 | 5 | 15 | 24 | 12 |
| 839 | 5 | 30 | 12 | 10 |
| 839 | 5 | 60 | 6 | 7 |
| 139 | 15 | 15 | 12 | 2 |
| 139 | 15 | 30 | 6 | 2 |
| 139 | 15 | 60 | 3 | 2 |
| 139 | 30 | 15 | 24 | 2 |
| 139 | 30 | 30 | 12 | 2 |
| 139 | 30 | 60 | 6 | 2 |
| 139 | 60 | 60 | 12 | 2 |
| 139 | 60 | 120 | 6 | 2 |
| 139 | 120 | 60 | 24 | 2 |
| 139 | 120 | 120 | 12 | 2 |
| 139 | 120 | 480 | 3 | 1 |
| 139 | 120 | 960 | 2 | 23 |
| 139 | 480 | 120 | 48 | 2 |
| 139 | 480 | 480 | 12 | 2 |
| 139 | 480 | 960 | 6 | 2 |
| 139 | 960 | 120 | 96 | 2 |
| 139 | 960 | 480 | 24 | 2 |
| 139 | 960 | 960 | 12 | 2 |
| 571 | 30 | 15 | 96 | 2 |
| 571 | 30 | 30 | 48 | 2 |
| 571 | 30 | 60 | 24 | 2 |
| 571 | 120 | 120 | 48 | 2 |
| 571 | 120 | 480 | 12 | 1 |
| 571 | 120 | 960 | 7 | 47 |
| 571 | 480 | 120 | 192 | 2 |
| 571 | 480 | 480 | 48 | 2 |
| 571 | 480 | 960 | 24 | 2 |
| 1151 | 15 | 15 | 96 | 1 |
| 1151 | 15 | 30 | 48 | 1 |
| 1151 | 15 | 60 | 24 | 1 |
| 1151 | 120 | 120 | 97 | 6 |
| 1151 | 120 | 480 | 25 | 23 |
| 1151 | 120 | 960 | 13 | 45 |

Table 6.3.3.2-2: Random access configurations for FR1 and paired spectrum/supplementary uplink.

| PRACH Configuration Index | Preamble format | $n_t \bmod x = y$ | | Subframe number | Starting symbol | Number of PRACH slots within a subframe | $N_t^{RA,slot}$, number of time-domain PRACH occasions within a PRACH slot | N_{dur}^{RA} , PRACH duration |
|---------------------------|-----------------|-------------------|-----|---------------------|-----------------|---|---|---------------------------------|
| | | x | y | | | | | |
| 0 | 0 | 16 | 1 | 1 | 0 | - | - | 0 |
| 1 | 0 | 16 | 1 | 4 | 0 | - | - | 0 |
| 2 | 0 | 16 | 1 | 7 | 0 | - | - | 0 |
| 3 | 0 | 16 | 1 | 9 | 0 | - | - | 0 |
| 4 | 0 | 8 | 1 | 1 | 0 | - | - | 0 |
| 5 | 0 | 8 | 1 | 4 | 0 | - | - | 0 |
| 6 | 0 | 8 | 1 | 7 | 0 | - | - | 0 |
| 7 | 0 | 8 | 1 | 9 | 0 | - | - | 0 |
| 8 | 0 | 4 | 1 | 1 | 0 | - | - | 0 |
| 9 | 0 | 4 | 1 | 4 | 0 | - | - | 0 |
| 10 | 0 | 4 | 1 | 7 | 0 | - | - | 0 |
| 11 | 0 | 4 | 1 | 9 | 0 | - | - | 0 |
| 12 | 0 | 2 | 1 | 1 | 0 | - | - | 0 |
| 13 | 0 | 2 | 1 | 4 | 0 | - | - | 0 |
| 14 | 0 | 2 | 1 | 7 | 0 | - | - | 0 |
| 15 | 0 | 2 | 1 | 9 | 0 | - | - | 0 |
| 16 | 0 | 1 | 0 | 1 | 0 | - | - | 0 |
| 17 | 0 | 1 | 0 | 4 | 0 | - | - | 0 |
| 18 | 0 | 1 | 0 | 7 | 0 | - | - | 0 |
| 19 | 0 | 1 | 0 | 1,6 | 0 | - | - | 0 |
| 20 | 0 | 1 | 0 | 2,7 | 0 | - | - | 0 |
| 21 | 0 | 1 | 0 | 3,8 | 0 | - | - | 0 |
| 22 | 0 | 1 | 0 | 1,4,7 | 0 | - | - | 0 |
| 23 | 0 | 1 | 0 | 2,5,8 | 0 | - | - | 0 |
| 24 | 0 | 1 | 0 | 3, 6, 9 | 0 | - | - | 0 |
| 25 | 0 | 1 | 0 | 0,2,4,6,8 | 0 | - | - | 0 |
| 26 | 0 | 1 | 0 | 1,3,5,7,9 | 0 | - | - | 0 |
| 27 | 0 | 1 | 0 | 0,1,2,3,4,5,6,7,8,9 | 0 | - | - | 0 |
| 28 | 1 | 16 | 1 | 1 | 0 | - | - | 0 |
| 29 | 1 | 16 | 1 | 4 | 0 | - | - | 0 |
| 30 | 1 | 16 | 1 | 7 | 0 | - | - | 0 |
| 31 | 1 | 16 | 1 | 9 | 0 | - | - | 0 |
| 32 | 1 | 8 | 1 | 1 | 0 | - | - | 0 |
| 33 | 1 | 8 | 1 | 4 | 0 | - | - | 0 |
| 34 | 1 | 8 | 1 | 7 | 0 | - | - | 0 |
| 35 | 1 | 8 | 1 | 9 | 0 | - | - | 0 |
| 36 | 1 | 4 | 1 | 1 | 0 | - | - | 0 |
| 37 | 1 | 4 | 1 | 4 | 0 | - | - | 0 |
| 38 | 1 | 4 | 1 | 7 | 0 | - | - | 0 |
| 39 | 1 | 4 | 1 | 9 | 0 | - | - | 0 |
| 40 | 1 | 2 | 1 | 1 | 0 | - | - | 0 |
| 41 | 1 | 2 | 1 | 4 | 0 | - | - | 0 |
| 42 | 1 | 2 | 1 | 7 | 0 | - | - | 0 |
| 43 | 1 | 2 | 1 | 9 | 0 | - | - | 0 |
| 44 | 1 | 1 | 0 | 1 | 0 | - | - | 0 |
| 45 | 1 | 1 | 0 | 4 | 0 | - | - | 0 |
| 46 | 1 | 1 | 0 | 7 | 0 | - | - | 0 |
| 47 | 1 | 1 | 0 | 1,6 | 0 | - | - | 0 |
| 48 | 1 | 1 | 0 | 2,7 | 0 | - | - | 0 |
| 49 | 1 | 1 | 0 | 3,8 | 0 | - | - | 0 |
| 50 | 1 | 1 | 0 | 1,4,7 | 0 | - | - | 0 |
| 51 | 1 | 1 | 0 | 2,5,8 | 0 | - | - | 0 |
| 52 | 1 | 1 | 0 | 3,6,9 | 0 | - | - | 0 |
| 53 | 2 | 16 | 1 | 1 | 0 | - | - | 0 |
| 54 | 2 | 8 | 1 | 1 | 0 | - | - | 0 |
| 55 | 2 | 4 | 0 | 1 | 0 | - | - | 0 |

| | | | | | | | | |
|-----|-------|----|---|---------------------|---|---|---|---|
| 56 | 2 | 2 | 0 | 1 | 0 | - | - | 0 |
| 57 | 2 | 2 | 0 | 5 | 0 | - | - | 0 |
| 58 | 2 | 1 | 0 | 1 | 0 | - | - | 0 |
| 59 | 2 | 1 | 0 | 5 | 0 | - | - | 0 |
| 60 | 3 | 16 | 1 | 1 | 0 | - | - | 0 |
| 61 | 3 | 16 | 1 | 4 | 0 | - | - | 0 |
| 62 | 3 | 16 | 1 | 7 | 0 | - | - | 0 |
| 63 | 3 | 16 | 1 | 9 | 0 | - | - | 0 |
| 64 | 3 | 8 | 1 | 1 | 0 | - | - | 0 |
| 65 | 3 | 8 | 1 | 4 | 0 | - | - | 0 |
| 66 | 3 | 8 | 1 | 7 | 0 | - | - | 0 |
| 67 | 3 | 4 | 1 | 1 | 0 | - | - | 0 |
| 68 | 3 | 4 | 1 | 4 | 0 | - | - | 0 |
| 69 | 3 | 4 | 1 | 7 | 0 | - | - | 0 |
| 70 | 3 | 4 | 1 | 9 | 0 | - | - | 0 |
| 71 | 3 | 2 | 1 | 1 | 0 | - | - | 0 |
| 72 | 3 | 2 | 1 | 4 | 0 | - | - | 0 |
| 73 | 3 | 2 | 1 | 7 | 0 | - | - | 0 |
| 74 | 3 | 2 | 1 | 9 | 0 | - | - | 0 |
| 75 | 3 | 1 | 0 | 1 | 0 | - | - | 0 |
| 76 | 3 | 1 | 0 | 4 | 0 | - | - | 0 |
| 77 | 3 | 1 | 0 | 7 | 0 | - | - | 0 |
| 78 | 3 | 1 | 0 | 1,6 | 0 | - | - | 0 |
| 79 | 3 | 1 | 0 | 2,7 | 0 | - | - | 0 |
| 80 | 3 | 1 | 0 | 3,8 | 0 | - | - | 0 |
| 81 | 3 | 1 | 0 | 1,4,7 | 0 | - | - | 0 |
| 82 | 3 | 1 | 0 | 2,5,8 | 0 | - | - | 0 |
| 83 | 3 | 1 | 0 | 3, 6, 9 | 0 | - | - | 0 |
| 84 | 3 | 1 | 0 | 0,2,4,6,8 | 0 | - | - | 0 |
| 85 | 3 | 1 | 0 | 1,3,5,7,9 | 0 | - | - | 0 |
| 86 | 3 | 1 | 0 | 0,1,2,3,4,5,6,7,8,9 | 0 | - | - | 0 |
| 87 | A1 | 16 | 0 | 4,9 | 0 | 1 | 6 | 2 |
| 88 | A1 | 16 | 1 | 4 | 0 | 2 | 6 | 2 |
| 89 | A1 | 8 | 0 | 4,9 | 0 | 1 | 6 | 2 |
| 90 | A1 | 8 | 1 | 4 | 0 | 2 | 6 | 2 |
| 91 | A1 | 4 | 0 | 4,9 | 0 | 1 | 6 | 2 |
| 92 | A1 | 4 | 1 | 4,9 | 0 | 1 | 6 | 2 |
| 93 | A1 | 4 | 0 | 4 | 0 | 2 | 6 | 2 |
| 94 | A1 | 2 | 0 | 4,9 | 0 | 1 | 6 | 2 |
| 95 | A1 | 2 | 0 | 1 | 0 | 2 | 6 | 2 |
| 96 | A1 | 2 | 0 | 4 | 0 | 2 | 6 | 2 |
| 97 | A1 | 2 | 0 | 7 | 0 | 2 | 6 | 2 |
| 98 | A1 | 1 | 0 | 4 | 0 | 1 | 6 | 2 |
| 99 | A1 | 1 | 0 | 1,6 | 0 | 1 | 6 | 2 |
| 100 | A1 | 1 | 0 | 4,9 | 0 | 1 | 6 | 2 |
| 101 | A1 | 1 | 0 | 1 | 0 | 2 | 6 | 2 |
| 102 | A1 | 1 | 0 | 7 | 0 | 2 | 6 | 2 |
| 103 | A1 | 1 | 0 | 2,7 | 0 | 2 | 6 | 2 |
| 104 | A1 | 1 | 0 | 1,4,7 | 0 | 2 | 6 | 2 |
| 105 | A1 | 1 | 0 | 0,2,4,6,8 | 0 | 2 | 6 | 2 |
| 106 | A1 | 1 | 0 | 0,1,2,3,4,5,6,7,8,9 | 0 | 2 | 6 | 2 |
| 107 | A1 | 1 | 0 | 1,3,5,7,9 | 0 | 2 | 6 | 2 |
| 108 | A1/B1 | 2 | 0 | 4,9 | 0 | 1 | 7 | 2 |
| 109 | A1/B1 | 2 | 0 | 4 | 0 | 2 | 7 | 2 |
| 110 | A1/B1 | 1 | 0 | 4 | 0 | 1 | 7 | 2 |
| 111 | A1/B1 | 1 | 0 | 1,6 | 0 | 1 | 7 | 2 |
| 112 | A1/B1 | 1 | 0 | 4,9 | 0 | 1 | 7 | 2 |
| 113 | A1/B1 | 1 | 0 | 1 | 0 | 2 | 7 | 2 |
| 114 | A1/B1 | 1 | 0 | 7 | 0 | 2 | 7 | 2 |
| 115 | A1/B1 | 1 | 0 | 1,4,7 | 0 | 2 | 7 | 2 |
| 116 | A1/B1 | 1 | 0 | 0,2,4,6,8 | 0 | 2 | 7 | 2 |
| 117 | A2 | 16 | 1 | 2,6,9 | 0 | 1 | 3 | 4 |
| 118 | A2 | 16 | 1 | 4 | 0 | 2 | 3 | 4 |
| 119 | A2 | 8 | 1 | 2,6,9 | 0 | 1 | 3 | 4 |
| 120 | A2 | 8 | 1 | 4 | 0 | 2 | 3 | 4 |

| | | | | | | | | |
|-----|-------|----|---|---------------------|---|---|---|---|
| 121 | A2 | 4 | 0 | 2,6,9 | 0 | 1 | 3 | 4 |
| 122 | A2 | 4 | 0 | 4 | 0 | 2 | 3 | 4 |
| 123 | A2 | 2 | 1 | 2,6,9 | 0 | 1 | 3 | 4 |
| 124 | A2 | 2 | 0 | 1 | 0 | 2 | 3 | 4 |
| 125 | A2 | 2 | 0 | 4 | 0 | 2 | 3 | 4 |
| 126 | A2 | 2 | 0 | 7 | 0 | 2 | 3 | 4 |
| 127 | A2 | 1 | 0 | 4 | 0 | 1 | 3 | 4 |
| 128 | A2 | 1 | 0 | 1,6 | 0 | 1 | 3 | 4 |
| 129 | A2 | 1 | 0 | 4,9 | 0 | 1 | 3 | 4 |
| 130 | A2 | 1 | 0 | 1 | 0 | 2 | 3 | 4 |
| 131 | A2 | 1 | 0 | 7 | 0 | 2 | 3 | 4 |
| 132 | A2 | 1 | 0 | 2,7 | 0 | 2 | 3 | 4 |
| 133 | A2 | 1 | 0 | 1,4,7 | 0 | 2 | 3 | 4 |
| 134 | A2 | 1 | 0 | 0,2,4,6,8 | 0 | 2 | 3 | 4 |
| 135 | A2 | 1 | 0 | 0,1,2,3,4,5,6,7,8,9 | 0 | 2 | 3 | 4 |
| 136 | A2 | 1 | 0 | 1,3,5,7,9 | 0 | 2 | 3 | 4 |
| 137 | A2/B2 | 2 | 1 | 2,6,9 | 0 | 1 | 3 | 4 |
| 138 | A2/B2 | 2 | 0 | 4 | 0 | 2 | 3 | 4 |
| 139 | A2/B2 | 1 | 0 | 4 | 0 | 1 | 3 | 4 |
| 140 | A2/B2 | 1 | 0 | 1,6 | 0 | 1 | 3 | 4 |
| 141 | A2/B2 | 1 | 0 | 4,9 | 0 | 1 | 3 | 4 |
| 142 | A2/B2 | 1 | 0 | 1 | 0 | 2 | 3 | 4 |
| 143 | A2/B2 | 1 | 0 | 7 | 0 | 2 | 3 | 4 |
| 144 | A2/B2 | 1 | 0 | 1,4,7 | 0 | 2 | 3 | 4 |
| 145 | A2/B2 | 1 | 0 | 0,2,4,6,8 | 0 | 2 | 3 | 4 |
| 146 | A2/B2 | 1 | 0 | 0,1,2,3,4,5,6,7,8,9 | 0 | 2 | 3 | 4 |
| 147 | A3 | 16 | 1 | 4,9 | 0 | 1 | 2 | 6 |
| 148 | A3 | 16 | 1 | 4 | 0 | 2 | 2 | 6 |
| 149 | A3 | 8 | 1 | 4,9 | 0 | 1 | 2 | 6 |
| 150 | A3 | 8 | 1 | 4 | 0 | 2 | 2 | 6 |
| 151 | A3 | 4 | 0 | 4,9 | 0 | 1 | 2 | 6 |
| 152 | A3 | 4 | 0 | 4 | 0 | 2 | 2 | 6 |
| 153 | A3 | 2 | 1 | 2,6,9 | 0 | 2 | 2 | 6 |
| 154 | A3 | 2 | 0 | 1 | 0 | 2 | 2 | 6 |
| 155 | A3 | 2 | 0 | 4 | 0 | 2 | 2 | 6 |
| 156 | A3 | 2 | 0 | 7 | 0 | 2 | 2 | 6 |
| 157 | A3 | 1 | 0 | 4 | 0 | 1 | 2 | 6 |
| 158 | A3 | 1 | 0 | 1,6 | 0 | 1 | 2 | 6 |
| 159 | A3 | 1 | 0 | 4,9 | 0 | 1 | 2 | 6 |
| 160 | A3 | 1 | 0 | 1 | 0 | 2 | 2 | 6 |
| 161 | A3 | 1 | 0 | 7 | 0 | 2 | 2 | 6 |
| 162 | A3 | 1 | 0 | 2,7 | 0 | 2 | 2 | 6 |
| 163 | A3 | 1 | 0 | 1,4,7 | 0 | 2 | 2 | 6 |
| 164 | A3 | 1 | 0 | 0,2,4,6,8 | 0 | 2 | 2 | 6 |
| 165 | A3 | 1 | 0 | 0,1,2,3,4,5,6,7,8,9 | 0 | 2 | 2 | 6 |
| 166 | A3 | 1 | 0 | 1,3,5,7,9 | 0 | 2 | 2 | 6 |
| 167 | A3/B3 | 2 | 1 | 2,6,9 | 0 | 2 | 2 | 6 |
| 168 | A3/B3 | 2 | 0 | 4 | 0 | 2 | 2 | 6 |
| 169 | A3/B3 | 1 | 0 | 4 | 0 | 1 | 2 | 6 |
| 170 | A3/B3 | 1 | 0 | 1,6 | 0 | 1 | 2 | 6 |
| 171 | A3/B3 | 1 | 0 | 4,9 | 0 | 1 | 2 | 6 |
| 172 | A3/B3 | 1 | 0 | 1 | 0 | 2 | 2 | 6 |
| 173 | A3/B3 | 1 | 0 | 7 | 0 | 2 | 2 | 6 |
| 174 | A3/B3 | 1 | 0 | 1,4,7 | 0 | 2 | 2 | 6 |
| 175 | A3/B3 | 1 | 0 | 0,2,4,6,8 | 0 | 2 | 2 | 6 |
| 176 | A3/B3 | 1 | 0 | 0,1,2,3,4,5,6,7,8,9 | 0 | 2 | 2 | 6 |
| 177 | B1 | 16 | 0 | 4,9 | 0 | 1 | 7 | 2 |
| 178 | B1 | 16 | 1 | 4 | 0 | 2 | 7 | 2 |
| 179 | B1 | 8 | 0 | 4,9 | 0 | 1 | 7 | 2 |
| 180 | B1 | 8 | 1 | 4 | 0 | 2 | 7 | 2 |
| 181 | B1 | 4 | 0 | 4,9 | 0 | 1 | 7 | 2 |
| 182 | B1 | 4 | 1 | 4,9 | 0 | 1 | 7 | 2 |
| 183 | B1 | 4 | 0 | 4 | 0 | 2 | 7 | 2 |
| 184 | B1 | 2 | 0 | 4,9 | 0 | 1 | 7 | 2 |
| 185 | B1 | 2 | 0 | 1 | 0 | 2 | 7 | 2 |

| | | | | | | | | |
|-----|----|----|---|---------------------|---|---|---|----|
| 186 | B1 | 2 | 0 | 4 | 0 | 2 | 7 | 2 |
| 187 | B1 | 2 | 0 | 7 | 0 | 2 | 7 | 2 |
| 188 | B1 | 1 | 0 | 4 | 0 | 1 | 7 | 2 |
| 189 | B1 | 1 | 0 | 1,6 | 0 | 1 | 7 | 2 |
| 190 | B1 | 1 | 0 | 4,9 | 0 | 1 | 7 | 2 |
| 191 | B1 | 1 | 0 | 1 | 0 | 2 | 7 | 2 |
| 192 | B1 | 1 | 0 | 7 | 0 | 2 | 7 | 2 |
| 193 | B1 | 1 | 0 | 2,7 | 0 | 2 | 7 | 2 |
| 194 | B1 | 1 | 0 | 1,4,7 | 0 | 2 | 7 | 2 |
| 195 | B1 | 1 | 0 | 0,2,4,6,8 | 0 | 2 | 7 | 2 |
| 196 | B1 | 1 | 0 | 0,1,2,3,4,5,6,7,8,9 | 0 | 2 | 7 | 2 |
| 197 | B1 | 1 | 0 | 1,3,5,7,9 | 0 | 2 | 7 | 2 |
| 198 | B4 | 16 | 0 | 4,9 | 0 | 2 | 1 | 12 |
| 199 | B4 | 16 | 1 | 4 | 0 | 2 | 1 | 12 |
| 200 | B4 | 8 | 0 | 4,9 | 0 | 2 | 1 | 12 |
| 201 | B4 | 8 | 1 | 4 | 0 | 2 | 1 | 12 |
| 202 | B4 | 4 | 0 | 4,9 | 0 | 2 | 1 | 12 |
| 203 | B4 | 4 | 0 | 4 | 0 | 2 | 1 | 12 |
| 204 | B4 | 4 | 1 | 4,9 | 0 | 2 | 1 | 12 |
| 205 | B4 | 2 | 0 | 4,9 | 0 | 2 | 1 | 12 |
| 206 | B4 | 2 | 0 | 1 | 0 | 2 | 1 | 12 |
| 207 | B4 | 2 | 0 | 4 | 0 | 2 | 1 | 12 |
| 208 | B4 | 2 | 0 | 7 | 0 | 2 | 1 | 12 |
| 209 | B4 | 1 | 0 | 1 | 0 | 2 | 1 | 12 |
| 210 | B4 | 1 | 0 | 4 | 0 | 2 | 1 | 12 |
| 211 | B4 | 1 | 0 | 7 | 0 | 2 | 1 | 12 |
| 212 | B4 | 1 | 0 | 1,6 | 0 | 2 | 1 | 12 |
| 213 | B4 | 1 | 0 | 2,7 | 0 | 2 | 1 | 12 |
| 214 | B4 | 1 | 0 | 4,9 | 0 | 2 | 1 | 12 |
| 215 | B4 | 1 | 0 | 1,4,7 | 0 | 2 | 1 | 12 |
| 216 | B4 | 1 | 0 | 0,2,4,6,8 | 0 | 2 | 1 | 12 |
| 217 | B4 | 1 | 0 | 0,1,2,3,4,5,6,7,8,9 | 0 | 2 | 1 | 12 |
| 218 | B4 | 1 | 0 | 1,3,5,7,9 | 0 | 2 | 1 | 12 |
| 219 | C0 | 8 | 1 | 4 | 0 | 2 | 7 | 2 |
| 220 | C0 | 4 | 1 | 4,9 | 0 | 1 | 7 | 2 |
| 221 | C0 | 4 | 0 | 4 | 0 | 2 | 7 | 2 |
| 222 | C0 | 2 | 0 | 4,9 | 0 | 1 | 7 | 2 |
| 223 | C0 | 2 | 0 | 1 | 0 | 2 | 7 | 2 |
| 224 | C0 | 2 | 0 | 4 | 0 | 2 | 7 | 2 |
| 225 | C0 | 2 | 0 | 7 | 0 | 2 | 7 | 2 |
| 226 | C0 | 1 | 0 | 4 | 0 | 1 | 7 | 2 |
| 227 | C0 | 1 | 0 | 1,6 | 0 | 1 | 7 | 2 |
| 228 | C0 | 1 | 0 | 4,9 | 0 | 1 | 7 | 2 |
| 229 | C0 | 1 | 0 | 1 | 0 | 2 | 7 | 2 |
| 230 | C0 | 1 | 0 | 7 | 0 | 2 | 7 | 2 |
| 231 | C0 | 1 | 0 | 2,7 | 0 | 2 | 7 | 2 |
| 232 | C0 | 1 | 0 | 1,4,7 | 0 | 2 | 7 | 2 |
| 233 | C0 | 1 | 0 | 0,2,4,6,8 | 0 | 2 | 7 | 2 |
| 234 | C0 | 1 | 0 | 0,1,2,3,4,5,6,7,8,9 | 0 | 2 | 7 | 2 |
| 235 | C0 | 1 | 0 | 1,3,5,7,9 | 0 | 2 | 7 | 2 |
| 236 | C2 | 16 | 1 | 4,9 | 0 | 1 | 2 | 6 |
| 237 | C2 | 16 | 1 | 4 | 0 | 2 | 2 | 6 |
| 238 | C2 | 8 | 1 | 4,9 | 0 | 1 | 2 | 6 |
| 239 | C2 | 8 | 1 | 4 | 0 | 2 | 2 | 6 |
| 240 | C2 | 4 | 0 | 4,9 | 0 | 1 | 2 | 6 |
| 241 | C2 | 4 | 0 | 4 | 0 | 2 | 2 | 6 |
| 242 | C2 | 2 | 1 | 2,6,9 | 0 | 2 | 2 | 6 |
| 243 | C2 | 2 | 0 | 1 | 0 | 2 | 2 | 6 |
| 244 | C2 | 2 | 0 | 4 | 0 | 2 | 2 | 6 |
| 245 | C2 | 2 | 0 | 7 | 0 | 2 | 2 | 6 |
| 246 | C2 | 1 | 0 | 4 | 0 | 1 | 2 | 6 |
| 247 | C2 | 1 | 0 | 1,6 | 0 | 1 | 2 | 6 |
| 248 | C2 | 1 | 0 | 4,9 | 0 | 1 | 2 | 6 |
| 249 | C2 | 1 | 0 | 1 | 0 | 2 | 2 | 6 |
| 250 | C2 | 1 | 0 | 7 | 0 | 2 | 2 | 6 |

| | | | | | | | | |
|-----|----|---|---|---------------------|---|---|---|---|
| 251 | C2 | 1 | 0 | 2,7 | 0 | 2 | 2 | 6 |
| 252 | C2 | 1 | 0 | 1,4,7 | 0 | 2 | 2 | 6 |
| 253 | C2 | 1 | 0 | 0,2,4,6,8 | 0 | 2 | 2 | 6 |
| 254 | C2 | 1 | 0 | 0,1,2,3,4,5,6,7,8,9 | 0 | 2 | 2 | 6 |
| 255 | C2 | 1 | 0 | 1,3,5,7,9 | 0 | 2 | 2 | 6 |

Table 6.3.3.2-3: Random access configurations for FR1 and unpaired spectrum.

| PRACH Configuration Index | Preamble format | $n_t \bmod x = y$ | | Subframe number | Starting symbol | Number of PRACH slots within a subframe | $N_t^{RA,slot}$, number of time-domain PRACH occasions within a PRACH slot | N_{dur}^{RA} , PRACH duration |
|---------------------------|-----------------|-------------------|-----|-----------------|-----------------|---|---|---------------------------------|
| | | x | y | | | | | |
| 0 | 0 | 16 | 1 | 9 | 0 | - | - | 0 |
| 1 | 0 | 8 | 1 | 9 | 0 | - | - | 0 |
| 2 | 0 | 4 | 1 | 9 | 0 | - | - | 0 |
| 3 | 0 | 2 | 0 | 9 | 0 | - | - | 0 |
| 4 | 0 | 2 | 1 | 9 | 0 | - | - | 0 |
| 5 | 0 | 2 | 0 | 4 | 0 | - | - | 0 |
| 6 | 0 | 2 | 1 | 4 | 0 | - | - | 0 |
| 7 | 0 | 1 | 0 | 9 | 0 | - | - | 0 |
| 8 | 0 | 1 | 0 | 8 | 0 | - | - | 0 |
| 9 | 0 | 1 | 0 | 7 | 0 | - | - | 0 |
| 10 | 0 | 1 | 0 | 6 | 0 | - | - | 0 |
| 11 | 0 | 1 | 0 | 5 | 0 | - | - | 0 |
| 12 | 0 | 1 | 0 | 4 | 0 | - | - | 0 |
| 13 | 0 | 1 | 0 | 3 | 0 | - | - | 0 |
| 14 | 0 | 1 | 0 | 2 | 0 | - | - | 0 |
| 15 | 0 | 1 | 0 | 1,6 | 0 | - | - | 0 |
| 16 | 0 | 1 | 0 | 1,6 | 7 | - | - | 0 |
| 17 | 0 | 1 | 0 | 4,9 | 0 | - | - | 0 |
| 18 | 0 | 1 | 0 | 3,8 | 0 | - | - | 0 |
| 19 | 0 | 1 | 0 | 2,7 | 0 | - | - | 0 |
| 20 | 0 | 1 | 0 | 8,9 | 0 | - | - | 0 |
| 21 | 0 | 1 | 0 | 4,8,9 | 0 | - | - | 0 |
| 22 | 0 | 1 | 0 | 3,4,9 | 0 | - | - | 0 |
| 23 | 0 | 1 | 0 | 7,8,9 | 0 | - | - | 0 |
| 24 | 0 | 1 | 0 | 3,4,8,9 | 0 | - | - | 0 |
| 25 | 0 | 1 | 0 | 6,7,8,9 | 0 | - | - | 0 |
| 26 | 0 | 1 | 0 | 1,4,6,9 | 0 | - | - | 0 |
| 27 | 0 | 1 | 0 | 1,3,5,7,9 | 0 | - | - | 0 |
| 28 | 1 | 16 | 1 | 7 | 0 | - | - | 0 |
| 29 | 1 | 8 | 1 | 7 | 0 | - | - | 0 |
| 30 | 1 | 4 | 1 | 7 | 0 | - | - | 0 |
| 31 | 1 | 2 | 0 | 7 | 0 | - | - | 0 |
| 32 | 1 | 2 | 1 | 7 | 0 | - | - | 0 |
| 33 | 1 | 1 | 0 | 7 | 0 | - | - | 0 |
| 34 | 2 | 16 | 1 | 6 | 0 | - | - | 0 |
| 35 | 2 | 8 | 1 | 6 | 0 | - | - | 0 |
| 36 | 2 | 4 | 1 | 6 | 0 | - | - | 0 |
| 37 | 2 | 2 | 0 | 6 | 7 | - | - | 0 |
| 38 | 2 | 2 | 1 | 6 | 7 | - | - | 0 |
| 39 | 2 | 1 | 0 | 6 | 7 | - | - | 0 |
| 40 | 3 | 16 | 1 | 9 | 0 | - | - | 0 |
| 41 | 3 | 8 | 1 | 9 | 0 | - | - | 0 |
| 42 | 3 | 4 | 1 | 9 | 0 | - | - | 0 |
| 43 | 3 | 2 | 0 | 9 | 0 | - | - | 0 |
| 44 | 3 | 2 | 1 | 9 | 0 | - | - | 0 |
| 45 | 3 | 2 | 0 | 4 | 0 | - | - | 0 |
| 46 | 3 | 2 | 1 | 4 | 0 | - | - | 0 |
| 47 | 3 | 1 | 0 | 9 | 0 | - | - | 0 |
| 48 | 3 | 1 | 0 | 8 | 0 | - | - | 0 |
| 49 | 3 | 1 | 0 | 7 | 0 | - | - | 0 |
| 50 | 3 | 1 | 0 | 6 | 0 | - | - | 0 |
| 51 | 3 | 1 | 0 | 5 | 0 | - | - | 0 |
| 52 | 3 | 1 | 0 | 4 | 0 | - | - | 0 |
| 53 | 3 | 1 | 0 | 3 | 0 | - | - | 0 |
| 54 | 3 | 1 | 0 | 2 | 0 | - | - | 0 |
| 55 | 3 | 1 | 0 | 1,6 | 0 | - | - | 0 |

| | | | | | | | | |
|-----|----|----|---|---------------------|---|---|---|---|
| 56 | 3 | 1 | 0 | 1,6 | 7 | - | - | 0 |
| 57 | 3 | 1 | 0 | 4,9 | 0 | - | - | 0 |
| 58 | 3 | 1 | 0 | 3,8 | 0 | - | - | 0 |
| 59 | 3 | 1 | 0 | 2,7 | 0 | - | - | 0 |
| 60 | 3 | 1 | 0 | 8,9 | 0 | - | - | 0 |
| 61 | 3 | 1 | 0 | 4,8,9 | 0 | - | - | 0 |
| 62 | 3 | 1 | 0 | 3,4,9 | 0 | - | - | 0 |
| 63 | 3 | 1 | 0 | 7,8,9 | 0 | - | - | 0 |
| 64 | 3 | 1 | 0 | 3,4,8,9 | 0 | - | - | 0 |
| 65 | 3 | 1 | 0 | 1,4,6,9 | 0 | - | - | 0 |
| 66 | 3 | 1 | 0 | 1,3,5,7,9 | 0 | - | - | 0 |
| 67 | A1 | 16 | 1 | 9 | 0 | 2 | 6 | 2 |
| 68 | A1 | 8 | 1 | 9 | 0 | 2 | 6 | 2 |
| 69 | A1 | 4 | 1 | 9 | 0 | 1 | 6 | 2 |
| 70 | A1 | 2 | 1 | 9 | 0 | 1 | 6 | 2 |
| 71 | A1 | 2 | 1 | 4,9 | 7 | 1 | 3 | 2 |
| 72 | A1 | 2 | 1 | 7,9 | 7 | 1 | 3 | 2 |
| 73 | A1 | 2 | 1 | 7,9 | 0 | 1 | 6 | 2 |
| 74 | A1 | 2 | 1 | 8,9 | 0 | 2 | 6 | 2 |
| 75 | A1 | 2 | 1 | 4,9 | 0 | 2 | 6 | 2 |
| 76 | A1 | 2 | 1 | 2,3,4,7,8,9 | 0 | 1 | 6 | 2 |
| 77 | A1 | 1 | 0 | 9 | 0 | 2 | 6 | 2 |
| 78 | A1 | 1 | 0 | 9 | 7 | 1 | 3 | 2 |
| 79 | A1 | 1 | 0 | 9 | 0 | 1 | 6 | 2 |
| 80 | A1 | 1 | 0 | 8,9 | 0 | 2 | 6 | 2 |
| 81 | A1 | 1 | 0 | 4,9 | 0 | 1 | 6 | 2 |
| 82 | A1 | 1 | 0 | 7,9 | 7 | 1 | 3 | 2 |
| 83 | A1 | 1 | 0 | 3,4,8,9 | 0 | 1 | 6 | 2 |
| 84 | A1 | 1 | 0 | 3,4,8,9 | 0 | 2 | 6 | 2 |
| 85 | A1 | 1 | 0 | 1,3,5,7,9 | 0 | 1 | 6 | 2 |
| 86 | A1 | 1 | 0 | 0,1,2,3,4,5,6,7,8,9 | 7 | 1 | 3 | 2 |
| 87 | A2 | 16 | 1 | 9 | 0 | 2 | 3 | 4 |
| 88 | A2 | 8 | 1 | 9 | 0 | 2 | 3 | 4 |
| 89 | A2 | 4 | 1 | 9 | 0 | 1 | 3 | 4 |
| 90 | A2 | 2 | 1 | 7,9 | 0 | 1 | 3 | 4 |
| 91 | A2 | 2 | 1 | 8,9 | 0 | 2 | 3 | 4 |
| 92 | A2 | 2 | 1 | 7,9 | 9 | 1 | 1 | 4 |
| 93 | A2 | 2 | 1 | 4,9 | 9 | 1 | 1 | 4 |
| 94 | A2 | 2 | 1 | 4,9 | 0 | 2 | 3 | 4 |
| 95 | A2 | 2 | 1 | 2,3,4,7,8,9 | 0 | 1 | 3 | 4 |
| 96 | A2 | 1 | 0 | 2 | 0 | 1 | 3 | 4 |
| 97 | A2 | 1 | 0 | 7 | 0 | 1 | 3 | 4 |
| 98 | A2 | 2 | 1 | 9 | 0 | 1 | 3 | 4 |
| 99 | A2 | 1 | 0 | 9 | 0 | 2 | 3 | 4 |
| 100 | A2 | 1 | 0 | 9 | 9 | 1 | 1 | 4 |
| 101 | A2 | 1 | 0 | 9 | 0 | 1 | 3 | 4 |
| 102 | A2 | 1 | 0 | 2,7 | 0 | 1 | 3 | 4 |
| 103 | A2 | 1 | 0 | 8,9 | 0 | 2 | 3 | 4 |
| 104 | A2 | 1 | 0 | 4,9 | 0 | 1 | 3 | 4 |
| 105 | A2 | 1 | 0 | 7,9 | 9 | 1 | 1 | 4 |
| 106 | A2 | 1 | 0 | 3,4,8,9 | 0 | 1 | 3 | 4 |
| 107 | A2 | 1 | 0 | 3,4,8,9 | 0 | 2 | 3 | 4 |
| 108 | A2 | 1 | 0 | 1,3,5,7,9 | 0 | 1 | 3 | 4 |
| 109 | A2 | 1 | 0 | 0,1,2,3,4,5,6,7,8,9 | 9 | 1 | 1 | 4 |
| 110 | A3 | 16 | 1 | 9 | 0 | 2 | 2 | 6 |
| 111 | A3 | 8 | 1 | 9 | 0 | 2 | 2 | 6 |
| 112 | A3 | 4 | 1 | 9 | 0 | 1 | 2 | 6 |
| 113 | A3 | 2 | 1 | 4,9 | 7 | 1 | 1 | 6 |
| 114 | A3 | 2 | 1 | 7,9 | 7 | 1 | 1 | 6 |
| 115 | A3 | 2 | 1 | 7,9 | 0 | 1 | 2 | 6 |
| 116 | A3 | 2 | 1 | 4,9 | 0 | 2 | 2 | 6 |
| 117 | A3 | 2 | 1 | 8,9 | 0 | 2 | 2 | 6 |
| 118 | A3 | 2 | 1 | 2,3,4,7,8,9 | 0 | 1 | 2 | 6 |
| 119 | A3 | 1 | 0 | 2 | 0 | 1 | 2 | 6 |
| 120 | A3 | 1 | 0 | 7 | 0 | 1 | 2 | 6 |

| | | | | | | | | |
|-----|----|----|---|---------------------|---|---|---|----|
| 121 | A3 | 2 | 1 | 9 | 0 | 1 | 2 | 6 |
| 122 | A3 | 1 | 0 | 9 | 0 | 2 | 2 | 6 |
| 123 | A3 | 1 | 0 | 9 | 7 | 1 | 1 | 6 |
| 124 | A3 | 1 | 0 | 9 | 0 | 1 | 2 | 6 |
| 125 | A3 | 1 | 0 | 2,7 | 0 | 1 | 2 | 6 |
| 126 | A3 | 1 | 0 | 8,9 | 0 | 2 | 2 | 6 |
| 127 | A3 | 1 | 0 | 4,9 | 0 | 1 | 2 | 6 |
| 128 | A3 | 1 | 0 | 7,9 | 7 | 1 | 1 | 6 |
| 129 | A3 | 1 | 0 | 3,4,8,9 | 0 | 1 | 2 | 6 |
| 130 | A3 | 1 | 0 | 3,4,8,9 | 0 | 2 | 2 | 6 |
| 131 | A3 | 1 | 0 | 1,3,5,7,9 | 0 | 1 | 2 | 6 |
| 132 | A3 | 1 | 0 | 0,1,2,3,4,5,6,7,8,9 | 7 | 1 | 1 | 6 |
| 133 | B1 | 4 | 1 | 9 | 2 | 1 | 6 | 2 |
| 134 | B1 | 2 | 1 | 9 | 2 | 1 | 6 | 2 |
| 135 | B1 | 2 | 1 | 7,9 | 2 | 1 | 6 | 2 |
| 136 | B1 | 2 | 1 | 4,9 | 8 | 1 | 3 | 2 |
| 137 | B1 | 2 | 1 | 4,9 | 2 | 2 | 6 | 2 |
| 138 | B1 | 1 | 0 | 9 | 2 | 2 | 6 | 2 |
| 139 | B1 | 1 | 0 | 9 | 8 | 1 | 3 | 2 |
| 140 | B1 | 1 | 0 | 9 | 2 | 1 | 6 | 2 |
| 141 | B1 | 1 | 0 | 8,9 | 2 | 2 | 6 | 2 |
| 142 | B1 | 1 | 0 | 4,9 | 2 | 1 | 6 | 2 |
| 143 | B1 | 1 | 0 | 7,9 | 8 | 1 | 3 | 2 |
| 144 | B1 | 1 | 0 | 1,3,5,7,9 | 2 | 1 | 6 | 2 |
| 145 | B4 | 16 | 1 | 9 | 0 | 2 | 1 | 12 |
| 146 | B4 | 8 | 1 | 9 | 0 | 2 | 1 | 12 |
| 147 | B4 | 4 | 1 | 9 | 2 | 1 | 1 | 12 |
| 148 | B4 | 2 | 1 | 9 | 0 | 1 | 1 | 12 |
| 149 | B4 | 2 | 1 | 9 | 2 | 1 | 1 | 12 |
| 150 | B4 | 2 | 1 | 7,9 | 2 | 1 | 1 | 12 |
| 151 | B4 | 2 | 1 | 4,9 | 2 | 1 | 1 | 12 |
| 152 | B4 | 2 | 1 | 4,9 | 0 | 2 | 1 | 12 |
| 153 | B4 | 2 | 1 | 8,9 | 0 | 2 | 1 | 12 |
| 154 | B4 | 2 | 1 | 2,3,4,7,8,9 | 0 | 1 | 1 | 12 |
| 155 | B4 | 1 | 0 | 1 | 0 | 1 | 1 | 12 |
| 156 | B4 | 1 | 0 | 2 | 0 | 1 | 1 | 12 |
| 157 | B4 | 1 | 0 | 4 | 0 | 1 | 1 | 12 |
| 158 | B4 | 1 | 0 | 7 | 0 | 1 | 1 | 12 |
| 159 | B4 | 1 | 0 | 9 | 0 | 1 | 1 | 12 |
| 160 | B4 | 1 | 0 | 9 | 2 | 1 | 1 | 12 |
| 161 | B4 | 1 | 0 | 9 | 0 | 2 | 1 | 12 |
| 162 | B4 | 1 | 0 | 4,9 | 2 | 1 | 1 | 12 |
| 163 | B4 | 1 | 0 | 7,9 | 2 | 1 | 1 | 12 |
| 164 | B4 | 1 | 0 | 8,9 | 0 | 2 | 1 | 12 |
| 165 | B4 | 1 | 0 | 3,4,8,9 | 2 | 1 | 1 | 12 |
| 166 | B4 | 1 | 0 | 1,3,5,7,9 | 2 | 1 | 1 | 12 |
| 167 | B4 | 1 | 0 | 0,1,2,3,4,5,6,7,8,9 | 0 | 2 | 1 | 12 |
| 168 | B4 | 1 | 0 | 0,1,2,3,4,5,6,7,8,9 | 2 | 1 | 1 | 12 |
| 169 | C0 | 16 | 1 | 9 | 2 | 2 | 6 | 2 |
| 170 | C0 | 8 | 1 | 9 | 2 | 2 | 6 | 2 |
| 171 | C0 | 4 | 1 | 9 | 2 | 1 | 6 | 2 |
| 172 | C0 | 2 | 1 | 9 | 2 | 1 | 6 | 2 |
| 173 | C0 | 2 | 1 | 8,9 | 2 | 2 | 6 | 2 |
| 174 | C0 | 2 | 1 | 7,9 | 2 | 1 | 6 | 2 |
| 175 | C0 | 2 | 1 | 7,9 | 8 | 1 | 3 | 2 |
| 176 | C0 | 2 | 1 | 4,9 | 8 | 1 | 3 | 2 |
| 177 | C0 | 2 | 1 | 4,9 | 2 | 2 | 6 | 2 |
| 178 | C0 | 2 | 1 | 2,3,4,7,8,9 | 2 | 1 | 6 | 2 |
| 179 | C0 | 1 | 0 | 9 | 2 | 2 | 6 | 2 |
| 180 | C0 | 1 | 0 | 9 | 8 | 1 | 3 | 2 |
| 181 | C0 | 1 | 0 | 9 | 2 | 1 | 6 | 2 |
| 182 | C0 | 1 | 0 | 8,9 | 2 | 2 | 6 | 2 |
| 183 | C0 | 1 | 0 | 4,9 | 2 | 1 | 6 | 2 |
| 184 | C0 | 1 | 0 | 7,9 | 8 | 1 | 3 | 2 |
| 185 | C0 | 1 | 0 | 3,4,8,9 | 2 | 1 | 6 | 2 |

| | | | | | | | | |
|-----|-------|----|---|---------------------|---|---|---|---|
| 186 | C0 | 1 | 0 | 3,4,8,9 | 2 | 2 | 6 | 2 |
| 187 | C0 | 1 | 0 | 1,3,5,7,9 | 2 | 1 | 6 | 2 |
| 188 | C0 | 1 | 0 | 0,1,2,3,4,5,6,7,8,9 | 8 | 1 | 3 | 2 |
| 189 | C2 | 16 | 1 | 9 | 2 | 2 | 2 | 6 |
| 190 | C2 | 8 | 1 | 9 | 2 | 2 | 2 | 6 |
| 191 | C2 | 4 | 1 | 9 | 2 | 1 | 2 | 6 |
| 192 | C2 | 2 | 1 | 9 | 2 | 1 | 2 | 6 |
| 193 | C2 | 2 | 1 | 8,9 | 2 | 2 | 2 | 6 |
| 194 | C2 | 2 | 1 | 7,9 | 2 | 1 | 2 | 6 |
| 195 | C2 | 2 | 1 | 7,9 | 8 | 1 | 1 | 6 |
| 196 | C2 | 2 | 1 | 4,9 | 8 | 1 | 1 | 6 |
| 197 | C2 | 2 | 1 | 4,9 | 2 | 2 | 2 | 6 |
| 198 | C2 | 2 | 1 | 2,3,4,7,8,9 | 2 | 1 | 2 | 6 |
| 199 | C2 | 8 | 1 | 9 | 8 | 2 | 1 | 6 |
| 200 | C2 | 4 | 1 | 9 | 8 | 1 | 1 | 6 |
| 201 | C2 | 1 | 0 | 9 | 2 | 2 | 2 | 6 |
| 202 | C2 | 1 | 0 | 9 | 8 | 1 | 1 | 6 |
| 203 | C2 | 1 | 0 | 9 | 2 | 1 | 2 | 6 |
| 204 | C2 | 1 | 0 | 8,9 | 2 | 2 | 2 | 6 |
| 205 | C2 | 1 | 0 | 4,9 | 2 | 1 | 2 | 6 |
| 206 | C2 | 1 | 0 | 7,9 | 8 | 1 | 1 | 6 |
| 207 | C2 | 1 | 0 | 3,4,8,9 | 2 | 1 | 2 | 6 |
| 208 | C2 | 1 | 0 | 3,4,8,9 | 2 | 2 | 2 | 6 |
| 209 | C2 | 1 | 0 | 1,3,5,7,9 | 2 | 1 | 2 | 6 |
| 210 | C2 | 1 | 0 | 0,1,2,3,4,5,6,7,8,9 | 8 | 1 | 1 | 6 |
| 211 | A1/B1 | 2 | 1 | 9 | 2 | 1 | 6 | 2 |
| 212 | A1/B1 | 2 | 1 | 4,9 | 8 | 1 | 3 | 2 |
| 213 | A1/B1 | 2 | 1 | 7,9 | 8 | 1 | 3 | 2 |
| 214 | A1/B1 | 2 | 1 | 7,9 | 2 | 1 | 6 | 2 |
| 215 | A1/B1 | 2 | 1 | 4,9 | 2 | 2 | 6 | 2 |
| 216 | A1/B1 | 2 | 1 | 8,9 | 2 | 2 | 6 | 2 |
| 217 | A1/B1 | 1 | 0 | 9 | 2 | 2 | 6 | 2 |
| 218 | A1/B1 | 1 | 0 | 9 | 8 | 1 | 3 | 2 |
| 219 | A1/B1 | 1 | 0 | 9 | 2 | 1 | 6 | 2 |
| 220 | A1/B1 | 1 | 0 | 8,9 | 2 | 2 | 6 | 2 |
| 221 | A1/B1 | 1 | 0 | 4,9 | 2 | 1 | 6 | 2 |
| 222 | A1/B1 | 1 | 0 | 7,9 | 8 | 1 | 3 | 2 |
| 223 | A1/B1 | 1 | 0 | 3,4,8,9 | 2 | 2 | 6 | 2 |
| 224 | A1/B1 | 1 | 0 | 1,3,5,7,9 | 2 | 1 | 6 | 2 |
| 225 | A1/B1 | 1 | 0 | 0,1,2,3,4,5,6,7,8,9 | 8 | 1 | 3 | 2 |
| 226 | A2/B2 | 2 | 1 | 9 | 0 | 1 | 3 | 4 |
| 227 | A2/B2 | 2 | 1 | 4,9 | 6 | 1 | 2 | 4 |
| 228 | A2/B2 | 2 | 1 | 7,9 | 6 | 1 | 2 | 4 |
| 229 | A2/B2 | 2 | 1 | 4,9 | 0 | 2 | 3 | 4 |
| 230 | A2/B2 | 2 | 1 | 8,9 | 0 | 2 | 3 | 4 |
| 231 | A2/B2 | 1 | 0 | 9 | 0 | 2 | 3 | 4 |
| 232 | A2/B2 | 1 | 0 | 9 | 6 | 1 | 2 | 4 |
| 233 | A2/B2 | 1 | 0 | 9 | 0 | 1 | 3 | 4 |
| 234 | A2/B2 | 1 | 0 | 8,9 | 0 | 2 | 3 | 4 |
| 235 | A2/B2 | 1 | 0 | 4,9 | 0 | 1 | 3 | 4 |
| 236 | A2/B2 | 1 | 0 | 7,9 | 6 | 1 | 2 | 4 |
| 237 | A2/B2 | 1 | 0 | 3,4,8,9 | 0 | 1 | 3 | 4 |
| 238 | A2/B2 | 1 | 0 | 3,4,8,9 | 0 | 2 | 3 | 4 |
| 239 | A2/B2 | 1 | 0 | 1,3,5,7,9 | 0 | 1 | 3 | 4 |
| 240 | A2/B2 | 1 | 0 | 0,1,2,3,4,5,6,7,8,9 | 6 | 1 | 2 | 4 |
| 241 | A3/B3 | 2 | 1 | 9 | 0 | 1 | 2 | 6 |
| 242 | A3/B3 | 2 | 1 | 4,9 | 2 | 1 | 2 | 6 |
| 243 | A3/B3 | 2 | 1 | 7,9 | 0 | 1 | 2 | 6 |
| 244 | A3/B3 | 2 | 1 | 7,9 | 2 | 1 | 2 | 6 |
| 245 | A3/B3 | 2 | 1 | 4,9 | 0 | 2 | 2 | 6 |
| 246 | A3/B3 | 2 | 1 | 8,9 | 0 | 2 | 2 | 6 |
| 247 | A3/B3 | 1 | 0 | 9 | 0 | 2 | 2 | 6 |
| 248 | A3/B3 | 1 | 0 | 9 | 2 | 1 | 2 | 6 |
| 249 | A3/B3 | 1 | 0 | 9 | 0 | 1 | 2 | 6 |
| 250 | A3/B3 | 1 | 0 | 8,9 | 0 | 2 | 2 | 6 |

| | | | | | | | | |
|-----|-------|----|---|---------------------|---|---|---|---|
| 251 | A3/B3 | 1 | 0 | 4,9 | 0 | 1 | 2 | 6 |
| 252 | A3/B3 | 1 | 0 | 7,9 | 2 | 1 | 2 | 6 |
| 253 | A3/B3 | 1 | 0 | 3,4,8,9 | 0 | 2 | 2 | 6 |
| 254 | A3/B3 | 1 | 0 | 1,3,5,7,9 | 0 | 1 | 2 | 6 |
| 255 | A3/B3 | 1 | 0 | 0,1,2,3,4,5,6,7,8,9 | 2 | 1 | 2 | 6 |
| 256 | 0 | 16 | 1 | 7 | 0 | - | - | 0 |
| 257 | 0 | 8 | 1 | 7 | 0 | - | - | 0 |
| 258 | 0 | 4 | 1 | 7 | 0 | - | - | 0 |
| 259 | 0 | 2 | 0 | 7 | 0 | - | - | 0 |
| 260 | 0 | 2 | 1 | 7 | 0 | - | - | 0 |
| 261 | 0 | 2 | 0 | 2 | 0 | - | - | 0 |
| 262 | 0 | 2 | 1 | 2 | 0 | - | - | 0 |

Table 6.3.3.2-4: Random access configurations for FR2 and unpaired spectrum, and for FR2-NTN and paired spectrum.

| PRACH Config. Index | Preamble format | $n_f \bmod x = y$ | | Slot number | Starting symbol | Number of PRACH slots within a 60 kHz slot | $N_t^{RA,slot}$, number of time-domain PRACH occasions within a PRACH slot | N_{dur}^{RA} , PRACH duration |
|---------------------|-----------------|-------------------|-----|-----------------------------|-----------------|--|---|---------------------------------|
| | | x | y | | | | | |
| 0 | A1 | 16 | 1 | 4,9,14,19,24,29,34,39 | 0 | 2 | 6 | 2 |
| 1 | A1 | 16 | 1 | 3,7,11,15,19,23,27,31,35,39 | 0 | 1 | 6 | 2 |
| 2 | A1 | 8 | 1,2 | 9,19,29,39 | 0 | 2 | 6 | 2 |
| 3 | A1 | 8 | 1 | 4,9,14,19,24,29,34,39 | 0 | 2 | 6 | 2 |
| 4 | A1 | 8 | 1 | 3,7,11,15,19,23,27,31,35,39 | 0 | 1 | 6 | 2 |
| 5 | A1 | 4 | 1 | 4,9,14,19,24,29,34,39 | 0 | 1 | 6 | 2 |
| 6 | A1 | 4 | 1 | 4,9,14,19,24,29,34,39 | 0 | 2 | 6 | 2 |
| 7 | A1 | 4 | 1 | 3,7,11,15,19,23,27,31,35,39 | 0 | 1 | 6 | 2 |
| 8 | A1 | 2 | 1 | 7,15,23,31,39 | 0 | 2 | 6 | 2 |
| 9 | A1 | 2 | 1 | 4,9,14,19,24,29,34,39 | 0 | 1 | 6 | 2 |
| 10 | A1 | 2 | 1 | 4,9,14,19,24,29,34,39 | 0 | 2 | 6 | 2 |
| 11 | A1 | 2 | 1 | 3,7,11,15,19,23,27,31,35,39 | 0 | 1 | 6 | 2 |
| 12 | A1 | 1 | 0 | 19,39 | 7 | 1 | 3 | 2 |
| 13 | A1 | 1 | 0 | 3,5,7 | 0 | 1 | 6 | 2 |
| 14 | A1 | 1 | 0 | 24,29,34,39 | 7 | 1 | 3 | 2 |
| 15 | A1 | 1 | 0 | 9,19,29,39 | 7 | 2 | 3 | 2 |
| 16 | A1 | 1 | 0 | 17,19,37,39 | 0 | 1 | 6 | 2 |
| 17 | A1 | 1 | 0 | 9,19,29,39 | 0 | 2 | 6 | 2 |
| 18 | A1 | 1 | 0 | 4,9,14,19,24,29,34,39 | 0 | 1 | 6 | 2 |
| 19 | A1 | 1 | 0 | 4,9,14,19,24,29,34,39 | 7 | 1 | 3 | 2 |
| 20 | A1 | 1 | 0 | 3,5,7,9,11,13 | 7 | 1 | 3 | 2 |
| 21 | A1 | 1 | 0 | 23,27,31,35,39 | 7 | 1 | 3 | 2 |
| 22 | A1 | 1 | 0 | 7,15,23,31,39 | 0 | 1 | 6 | 2 |
| 23 | A1 | 1 | 0 | 23,27,31,35,39 | 0 | 1 | 6 | 2 |
| 24 | A1 | 1 | 0 | 13,14,15, 29,30,31,37,38,39 | 7 | 2 | 3 | 2 |
| 25 | A1 | 1 | 0 | 3,7,11,15,19,23,27,31,35,39 | 7 | 1 | 3 | 2 |
| 26 | A1 | 1 | 0 | 3,7,11,15,19,23,27,31,35,39 | 0 | 1 | 6 | 2 |
| 27 | A1 | 1 | 0 | 1,3,5,7,...,37,39 | 0 | 1 | 6 | 2 |
| 28 | A1 | 1 | 0 | 0,1,2,...,39 | 7 | 1 | 3 | 2 |
| 29 | A2 | 16 | 1 | 4,9,14,19,24,29,34,39 | 0 | 2 | 3 | 4 |
| 30 | A2 | 16 | 1 | 3,7,11,15,19,23,27,31,35,39 | 0 | 1 | 3 | 4 |
| 31 | A2 | 8 | 1 | 4,9,14,19,24,29,34,39 | 0 | 2 | 3 | 4 |
| 32 | A2 | 8 | 1 | 3,7,11,15,19,23,27,31,35,39 | 0 | 1 | 3 | 4 |
| 33 | A2 | 8 | 1,2 | 9,19,29,39 | 0 | 2 | 3 | 4 |
| 34 | A2 | 4 | 1 | 4,9,14,19,24,29,34,39 | 0 | 1 | 3 | 4 |
| 35 | A2 | 4 | 1 | 4,9,14,19,24,29,34,39 | 0 | 2 | 3 | 4 |
| 36 | A2 | 4 | 1 | 3,7,11,15,19,23,27,31,35,39 | 0 | 1 | 3 | 4 |
| 37 | A2 | 2 | 1 | 7,15,23,31,39 | 0 | 2 | 3 | 4 |
| 38 | A2 | 2 | 1 | 4,9,14,19,24,29,34,39 | 0 | 1 | 3 | 4 |
| 39 | A2 | 2 | 1 | 4,9,14,19,24,29,34,39 | 0 | 2 | 3 | 4 |
| 40 | A2 | 2 | 1 | 3,7,11,15,19,23,27,31,35,39 | 0 | 1 | 3 | 4 |
| 41 | A2 | 1 | 0 | 19,39 | 5 | 1 | 2 | 4 |
| 42 | A2 | 1 | 0 | 3,5,7 | 0 | 1 | 3 | 4 |
| 43 | A2 | 1 | 0 | 24,29,34,39 | 5 | 1 | 2 | 4 |
| 44 | A2 | 1 | 0 | 9,19,29,39 | 5 | 2 | 2 | 4 |
| 45 | A2 | 1 | 0 | 17,19,37,39 | 0 | 1 | 3 | 4 |
| 46 | A2 | 1 | 0 | 9, 19, 29, 39 | 0 | 2 | 3 | 4 |
| 47 | A2 | 1 | 0 | 7,15,23,31,39 | 0 | 1 | 3 | 4 |
| 48 | A2 | 1 | 0 | 23,27,31,35,39 | 5 | 1 | 2 | 4 |
| 49 | A2 | 1 | 0 | 23,27,31,35,39 | 0 | 1 | 3 | 4 |
| 50 | A2 | 1 | 0 | 3,5,7,9,11,13 | 5 | 1 | 2 | 4 |
| 51 | A2 | 1 | 0 | 3,5,7,9,11,13 | 0 | 1 | 3 | 4 |
| 52 | A2 | 1 | 0 | 4,9,14,19,24,29,34,39 | 5 | 1 | 2 | 4 |
| 53 | A2 | 1 | 0 | 4,9,14,19,24,29,34,39 | 0 | 1 | 3 | 4 |
| 54 | A2 | 1 | 0 | 13,14,15, 29,30,31,37,38,39 | 5 | 2 | 2 | 4 |
| 55 | A2 | 1 | 0 | 3,7,11,15,19,23,27,31,35,39 | 5 | 1 | 2 | 4 |

| | | | | | | | | |
|-----|----|----|-----|-----------------------------|---|---|---|----|
| 56 | A2 | 1 | 0 | 3,7,11,15,19,23,27,31,35,39 | 0 | 1 | 3 | 4 |
| 57 | A2 | 1 | 0 | 1,3,5,7,...,37,39 | 0 | 1 | 3 | 4 |
| 58 | A2 | 1 | 0 | 0,1,2,...,39 | 5 | 1 | 2 | 4 |
| 59 | A3 | 16 | 1 | 4,9,14,19,24,29,34,39 | 0 | 2 | 2 | 6 |
| 60 | A3 | 16 | 1 | 3,7,11,15,19,23,27,31,35,39 | 0 | 1 | 2 | 6 |
| 61 | A3 | 8 | 1 | 4,9,14,19,24,29,34,39 | 0 | 2 | 2 | 6 |
| 62 | A3 | 8 | 1 | 3,7,11,15,19,23,27,31,35,39 | 0 | 1 | 2 | 6 |
| 63 | A3 | 8 | 1,2 | 9,19,29,39 | 0 | 2 | 2 | 6 |
| 64 | A3 | 4 | 1 | 4,9,14,19,24,29,34,39 | 0 | 1 | 2 | 6 |
| 65 | A3 | 4 | 1 | 4,9,14,19,24,29,34,39 | 0 | 2 | 2 | 6 |
| 66 | A3 | 4 | 1 | 3,7,11,15,19,23,27,31,35,39 | 0 | 1 | 2 | 6 |
| 67 | A3 | 2 | 1 | 4,9,14,19,24,29,34,39 | 0 | 1 | 2 | 6 |
| 68 | A3 | 2 | 1 | 4,9,14,19,24,29,34,39 | 0 | 2 | 2 | 6 |
| 69 | A3 | 2 | 1 | 3,7,11,15,19,23,27,31,35,39 | 0 | 1 | 2 | 6 |
| 70 | A3 | 1 | 0 | 19,39 | 7 | 1 | 1 | 6 |
| 71 | A3 | 1 | 0 | 3,5,7 | 0 | 1 | 2 | 6 |
| 72 | A3 | 1 | 0 | 9,11,13 | 2 | 1 | 2 | 6 |
| 73 | A3 | 1 | 0 | 24,29,34,39 | 7 | 1 | 1 | 6 |
| 74 | A3 | 1 | 0 | 9,19,29,39 | 7 | 2 | 1 | 6 |
| 75 | A3 | 1 | 0 | 17,19,37,39 | 0 | 1 | 2 | 6 |
| 76 | A3 | 1 | 0 | 9,19,29,39 | 0 | 2 | 2 | 6 |
| 77 | A3 | 1 | 0 | 7,15,23,31,39 | 0 | 1 | 2 | 6 |
| 78 | A3 | 1 | 0 | 23,27,31,35,39 | 7 | 1 | 1 | 6 |
| 79 | A3 | 1 | 0 | 23,27,31,35,39 | 0 | 1 | 2 | 6 |
| 80 | A3 | 1 | 0 | 3,5,7,9,11,13 | 0 | 1 | 2 | 6 |
| 81 | A3 | 1 | 0 | 3,5,7,9,11,13 | 7 | 1 | 1 | 6 |
| 82 | A3 | 1 | 0 | 4,9,14,19,24,29,34,39 | 0 | 1 | 2 | 6 |
| 83 | A3 | 1 | 0 | 4,9,14,19,24,29,34,39 | 7 | 1 | 1 | 6 |
| 84 | A3 | 1 | 0 | 13,14,15, 29,30,31,37,38,39 | 7 | 2 | 1 | 6 |
| 85 | A3 | 1 | 0 | 3,7,11,15,19,23,27,31,35,39 | 7 | 1 | 1 | 6 |
| 86 | A3 | 1 | 0 | 3,7,11,15,19,23,27,31,35,39 | 0 | 1 | 2 | 6 |
| 87 | A3 | 1 | 0 | 1,3,5,7,...,37,39 | 0 | 1 | 2 | 6 |
| 88 | A3 | 1 | 0 | 0,1,2,...,39 | 7 | 1 | 1 | 6 |
| 89 | B1 | 16 | 1 | 4,9,14,19,24,29,34,39 | 2 | 2 | 6 | 2 |
| 90 | B1 | 8 | 1 | 4,9,14,19,24,29,34,39 | 2 | 2 | 6 | 2 |
| 91 | B1 | 8 | 1,2 | 9,19,29,39 | 2 | 2 | 6 | 2 |
| 92 | B1 | 4 | 1 | 4,9,14,19,24,29,34,39 | 2 | 2 | 6 | 2 |
| 93 | B1 | 2 | 1 | 4,9,14,19,24,29,34,39 | 2 | 2 | 6 | 2 |
| 94 | B1 | 2 | 1 | 3,7,11,15,19,23,27,31,35,39 | 2 | 1 | 6 | 2 |
| 95 | B1 | 1 | 0 | 19,39 | 8 | 1 | 3 | 2 |
| 96 | B1 | 1 | 0 | 3,5,7 | 2 | 1 | 6 | 2 |
| 97 | B1 | 1 | 0 | 24,29,34,39 | 8 | 1 | 3 | 2 |
| 98 | B1 | 1 | 0 | 9,19,29,39 | 8 | 2 | 3 | 2 |
| 99 | B1 | 1 | 0 | 17,19,37,39 | 2 | 1 | 6 | 2 |
| 100 | B1 | 1 | 0 | 9,19,29,39 | 2 | 2 | 6 | 2 |
| 101 | B1 | 1 | 0 | 7,15,23,31,39 | 2 | 1 | 6 | 2 |
| 102 | B1 | 1 | 0 | 23,27,31,35,39 | 8 | 1 | 3 | 2 |
| 103 | B1 | 1 | 0 | 23,27,31,35,39 | 2 | 1 | 6 | 2 |
| 104 | B1 | 1 | 0 | 3,5,7,9,11,13 | 8 | 1 | 3 | 2 |
| 105 | B1 | 1 | 0 | 4,9,14,19,24,29,34,39 | 8 | 1 | 3 | 2 |
| 106 | B1 | 1 | 0 | 4,9,14,19,24,29,34,39 | 2 | 1 | 6 | 2 |
| 107 | B1 | 1 | 0 | 3,7,11,15,19,23,27,31,35,39 | 8 | 1 | 3 | 2 |
| 108 | B1 | 1 | 0 | 13,14,15, 29,30,31,37,38,39 | 8 | 2 | 3 | 2 |
| 109 | B1 | 1 | 0 | 3,7,11,15,19,23,27,31,35,39 | 2 | 1 | 6 | 2 |
| 110 | B1 | 1 | 0 | 1,3,5,7,...,37,39 | 2 | 1 | 6 | 2 |
| 111 | B1 | 1 | 0 | 0,1,2,...,39 | 8 | 1 | 3 | 2 |
| 112 | B4 | 16 | 1,2 | 4,9,14,19,24,29,34,39 | 0 | 2 | 1 | 12 |
| 113 | B4 | 16 | 1,2 | 3,7,11,15,19,23,27,31,35,39 | 0 | 1 | 1 | 12 |
| 114 | B4 | 8 | 1,2 | 4,9,14,19,24,29,34,39 | 0 | 2 | 1 | 12 |
| 115 | B4 | 8 | 1,2 | 3,7,11,15,19,23,27,31,35,39 | 0 | 1 | 1 | 12 |
| 116 | B4 | 8 | 1,2 | 9,19,29,39 | 0 | 2 | 1 | 12 |
| 117 | B4 | 4 | 1 | 4,9,14,19,24,29,34,39 | 0 | 1 | 1 | 12 |
| 118 | B4 | 4 | 1 | 4,9,14,19,24,29,34,39 | 0 | 2 | 1 | 12 |
| 119 | B4 | 4 | 1,2 | 3,7,11,15,19,23,27,31,35,39 | 0 | 1 | 1 | 12 |
| 120 | B4 | 2 | 1 | 7,15,23,31,39 | 2 | 2 | 1 | 12 |

| | | | | | | | | |
|-----|----|----|-----|-----------------------------|---|---|---|----|
| 121 | B4 | 2 | 1 | 4,9,14,19,24,29,34,39 | 0 | 1 | 1 | 12 |
| 122 | B4 | 2 | 1 | 4,9,14,19,24,29,34,39 | 0 | 2 | 1 | 12 |
| 123 | B4 | 2 | 1 | 3,7,11,15,19,23,27,31,35,39 | 0 | 1 | 1 | 12 |
| 124 | B4 | 1 | 0 | 19, 39 | 2 | 2 | 1 | 12 |
| 125 | B4 | 1 | 0 | 17, 19, 37, 39 | 0 | 1 | 1 | 12 |
| 126 | B4 | 1 | 0 | 24,29,34,39 | 2 | 1 | 1 | 12 |
| 127 | B4 | 1 | 0 | 9,19,29,39 | 2 | 2 | 1 | 12 |
| 128 | B4 | 1 | 0 | 9,19,29,39 | 0 | 2 | 1 | 12 |
| 129 | B4 | 1 | 0 | 7,15,23,31,39 | 0 | 1 | 1 | 12 |
| 130 | B4 | 1 | 0 | 7,15,23,31,39 | 0 | 2 | 1 | 12 |
| 131 | B4 | 1 | 0 | 23,27,31,35,39 | 0 | 1 | 1 | 12 |
| 132 | B4 | 1 | 0 | 23,27,31,35,39 | 2 | 2 | 1 | 12 |
| 133 | B4 | 1 | 0 | 9,11,13,15,17,19 | 0 | 1 | 1 | 12 |
| 134 | B4 | 1 | 0 | 3,5,7,9,11,13 | 2 | 1 | 1 | 12 |
| 135 | B4 | 1 | 0 | 4,9,14,19,24,29,34,39 | 0 | 1 | 1 | 12 |
| 136 | B4 | 1 | 0 | 4,9,14,19,24,29,34,39 | 2 | 2 | 1 | 12 |
| 137 | B4 | 1 | 0 | 13,14,15, 29,30,31,37,38,39 | 2 | 2 | 1 | 12 |
| 138 | B4 | 1 | 0 | 3,7,11,15,19,23,27,31,35,39 | 0 | 1 | 1 | 12 |
| 139 | B4 | 1 | 0 | 3,7,11,15,19,23,27,31,35,39 | 2 | 1 | 1 | 12 |
| 140 | B4 | 1 | 0 | 3, 5, 7, ..., 23,25 | 2 | 1 | 1 | 12 |
| 141 | B4 | 1 | 0 | 3, 5, 7, ..., 23,25 | 0 | 2 | 1 | 12 |
| 142 | B4 | 1 | 0 | 1,3,5,7,...,37,39 | 0 | 1 | 1 | 12 |
| 143 | B4 | 1 | 0 | 0, 1, 2, ..., 39 | 2 | 1 | 1 | 12 |
| 144 | C0 | 16 | 1 | 4,9,14,19,24,29,34,39 | 0 | 2 | 7 | 2 |
| 145 | C0 | 16 | 1 | 3,7,11,15,19,23,27,31,35,39 | 0 | 1 | 7 | 2 |
| 146 | C0 | 8 | 1 | 4,9,14,19,24,29,34,39 | 0 | 1 | 7 | 2 |
| 147 | C0 | 8 | 1 | 3,7,11,15,19,23,27,31,35,39 | 0 | 1 | 7 | 2 |
| 148 | C0 | 8 | 1,2 | 9,19,29,39 | 0 | 2 | 7 | 2 |
| 149 | C0 | 4 | 1 | 4,9,14,19,24,29,34,39 | 0 | 1 | 7 | 2 |
| 150 | C0 | 4 | 1 | 4,9,14,19,24,29,34,39 | 0 | 2 | 7 | 2 |
| 151 | C0 | 4 | 1 | 3,7,11,15,19,23,27,31,35,39 | 0 | 1 | 7 | 2 |
| 152 | C0 | 2 | 1 | 7,15,23,31,39 | 0 | 2 | 7 | 2 |
| 153 | C0 | 2 | 1 | 4,9,14,19,24,29,34,39 | 0 | 1 | 7 | 2 |
| 154 | C0 | 2 | 1 | 4,9,14,19,24,29,34,39 | 0 | 2 | 7 | 2 |
| 155 | C0 | 2 | 1 | 3,7,11,15,19,23,27,31,35,39 | 0 | 1 | 7 | 2 |
| 156 | C0 | 1 | 0 | 19,39 | 8 | 1 | 3 | 2 |
| 157 | C0 | 1 | 0 | 3,5,7 | 0 | 1 | 7 | 2 |
| 158 | C0 | 1 | 0 | 24,29,34,39 | 8 | 1 | 3 | 2 |
| 159 | C0 | 1 | 0 | 9,19,29,39 | 8 | 2 | 3 | 2 |
| 160 | C0 | 1 | 0 | 17,19,37,39 | 0 | 1 | 7 | 2 |
| 161 | C0 | 1 | 0 | 9,19,29,39 | 0 | 2 | 7 | 2 |
| 162 | C0 | 1 | 0 | 23,27,31,35,39 | 8 | 1 | 3 | 2 |
| 163 | C0 | 1 | 0 | 7,15,23,31,39 | 0 | 1 | 7 | 2 |
| 164 | C0 | 1 | 0 | 23,27,31,35,39 | 0 | 1 | 7 | 2 |
| 165 | C0 | 1 | 0 | 3,5,7,9,11,13 | 8 | 1 | 3 | 2 |
| 166 | C0 | 1 | 0 | 4,9,14,19,24,29,34,39 | 8 | 1 | 3 | 2 |
| 167 | C0 | 1 | 0 | 4,9,14,19,24,29,34,39 | 0 | 1 | 7 | 2 |
| 168 | C0 | 1 | 0 | 13,14,15, 29,30,31,37,38,39 | 8 | 2 | 3 | 2 |
| 169 | C0 | 1 | 0 | 3,7,11,15,19,23,27,31,35,39 | 8 | 1 | 3 | 2 |
| 170 | C0 | 1 | 0 | 3,7,11,15,19,23,27,31,35,39 | 0 | 1 | 7 | 2 |
| 171 | C0 | 1 | 0 | 1,3,5,7,...,37,39 | 0 | 1 | 7 | 2 |
| 172 | C0 | 1 | 0 | 0,1,2,...,39 | 8 | 1 | 3 | 2 |
| 173 | C2 | 16 | 1 | 4,9,14,19,24,29,34,39 | 0 | 2 | 2 | 6 |
| 174 | C2 | 16 | 1 | 3,7,11,15,19,23,27,31,35,39 | 0 | 1 | 2 | 6 |
| 175 | C2 | 8 | 1 | 4,9,14,19,24,29,34,39 | 0 | 2 | 2 | 6 |
| 176 | C2 | 8 | 1 | 3,7,11,15,19,23,27,31,35,39 | 0 | 1 | 2 | 6 |
| 177 | C2 | 8 | 1,2 | 9,19,29,39 | 0 | 2 | 2 | 6 |
| 178 | C2 | 4 | 1 | 4,9,14,19,24,29,34,39 | 0 | 1 | 2 | 6 |
| 179 | C2 | 4 | 1 | 4,9,14,19,24,29,34,39 | 0 | 2 | 2 | 6 |
| 180 | C2 | 4 | 1 | 3,7,11,15,19,23,27,31,35,39 | 0 | 1 | 2 | 6 |
| 181 | C2 | 2 | 1 | 7,15,23,31,39 | 2 | 2 | 2 | 6 |
| 182 | C2 | 2 | 1 | 4,9,14,19,24,29,34,39 | 0 | 1 | 2 | 6 |
| 183 | C2 | 2 | 1 | 4,9,14,19,24,29,34,39 | 0 | 2 | 2 | 6 |
| 184 | C2 | 2 | 1 | 3,7,11,15,19,23,27,31,35,39 | 0 | 1 | 2 | 6 |
| 185 | C2 | 1 | 0 | 19,39 | 2 | 1 | 2 | 6 |

| | | | | | | | | |
|-----|-------|----|---|-----------------------------|---|---|---|---|
| 186 | C2 | 1 | 0 | 3,5,7 | 0 | 1 | 2 | 6 |
| 187 | C2 | 1 | 0 | 24,29,34,39 | 7 | 1 | 1 | 6 |
| 188 | C2 | 1 | 0 | 9,19,29,39 | 7 | 2 | 1 | 6 |
| 189 | C2 | 1 | 0 | 17,19,37,39 | 0 | 1 | 2 | 6 |
| 190 | C2 | 1 | 0 | 9,19,29,39 | 2 | 2 | 2 | 6 |
| 191 | C2 | 1 | 0 | 7,15,23,31,39 | 2 | 1 | 2 | 6 |
| 192 | C2 | 1 | 0 | 3,5,7,9,11,13 | 7 | 1 | 1 | 6 |
| 193 | C2 | 1 | 0 | 23,27,31,35,39 | 7 | 2 | 1 | 6 |
| 194 | C2 | 1 | 0 | 23,27,31,35,39 | 0 | 1 | 2 | 6 |
| 195 | C2 | 1 | 0 | 4,9,14,19,24,29,34,39 | 7 | 2 | 1 | 6 |
| 196 | C2 | 1 | 0 | 4,9,14,19,24,29,34,39 | 2 | 1 | 2 | 6 |
| 197 | C2 | 1 | 0 | 13,14,15, 29,30,31,37,38,39 | 7 | 2 | 1 | 6 |
| 198 | C2 | 1 | 0 | 3,7,11,15,19,23,27,31,35,39 | 7 | 1 | 1 | 6 |
| 199 | C2 | 1 | 0 | 3,7,11,15,19,23,27,31,35,39 | 0 | 1 | 2 | 6 |
| 200 | C2 | 1 | 0 | 1,3,5,7,...,37,39 | 0 | 1 | 2 | 6 |
| 201 | C2 | 1 | 0 | 0,1,2,...,39 | 7 | 1 | 1 | 6 |
| 202 | A1/B1 | 16 | 1 | 4,9,14,19,24,29,34,39 | 2 | 1 | 6 | 2 |
| 203 | A1/B1 | 16 | 1 | 3,7,11,15,19,23,27,31,35,39 | 2 | 1 | 6 | 2 |
| 204 | A1/B1 | 8 | 1 | 4,9,14,19,24,29,34,39 | 2 | 1 | 6 | 2 |
| 205 | A1/B1 | 8 | 1 | 3,7,11,15,19,23,27,31,35,39 | 2 | 1 | 6 | 2 |
| 206 | A1/B1 | 4 | 1 | 4,9,14,19,24,29,34,39 | 2 | 1 | 6 | 2 |
| 207 | A1/B1 | 4 | 1 | 3,7,11,15,19,23,27,31,35,39 | 2 | 1 | 6 | 2 |
| 208 | A1/B1 | 2 | 1 | 4,9,14,19,24,29,34,39 | 2 | 1 | 6 | 2 |
| 209 | A1/B1 | 1 | 0 | 19,39 | 8 | 1 | 3 | 2 |
| 210 | A1/B1 | 1 | 0 | 9,19,29,39 | 8 | 1 | 3 | 2 |
| 211 | A1/B1 | 1 | 0 | 17,19,37,39 | 2 | 1 | 6 | 2 |
| 212 | A1/B1 | 1 | 0 | 9,19,29,39 | 2 | 2 | 6 | 2 |
| 213 | A1/B1 | 1 | 0 | 23,27,31,35,39 | 8 | 1 | 3 | 2 |
| 214 | A1/B1 | 1 | 0 | 7,15,23,31,39 | 2 | 1 | 6 | 2 |
| 215 | A1/B1 | 1 | 0 | 23,27,31,35,39 | 2 | 1 | 6 | 2 |
| 216 | A1/B1 | 1 | 0 | 4,9,14,19,24,29,34,39 | 8 | 1 | 3 | 2 |
| 217 | A1/B1 | 1 | 0 | 4,9,14,19,24,29,34,39 | 2 | 1 | 6 | 2 |
| 218 | A1/B1 | 1 | 0 | 3,7,11,15,19,23,27,31,35,39 | 2 | 1 | 6 | 2 |
| 219 | A1/B1 | 1 | 0 | 1,3,5,7,...,37,39 | 2 | 1 | 6 | 2 |
| 220 | A2/B2 | 16 | 1 | 4,9,14,19,24,29,34,39 | 2 | 1 | 3 | 4 |
| 221 | A2/B2 | 16 | 1 | 3,7,11,15,19,23,27,31,35,39 | 2 | 1 | 3 | 4 |
| 222 | A2/B2 | 8 | 1 | 4,9,14,19,24,29,34,39 | 2 | 1 | 3 | 4 |
| 223 | A2/B2 | 8 | 1 | 3,7,11,15,19,23,27,31,35,39 | 2 | 1 | 3 | 4 |
| 224 | A2/B2 | 4 | 1 | 4,9,14,19,24,29,34,39 | 2 | 1 | 3 | 4 |
| 225 | A2/B2 | 4 | 1 | 3,7,11,15,19,23,27,31,35,39 | 2 | 1 | 3 | 4 |
| 226 | A2/B2 | 2 | 1 | 4,9,14,19,24,29,34,39 | 2 | 1 | 3 | 4 |
| 227 | A2/B2 | 1 | 0 | 19,39 | 6 | 1 | 2 | 4 |
| 228 | A2/B2 | 1 | 0 | 9,19,29,39 | 6 | 1 | 2 | 4 |
| 229 | A2/B2 | 1 | 0 | 17,19,37,39 | 2 | 1 | 3 | 4 |
| 230 | A2/B2 | 1 | 0 | 9,19,29,39 | 2 | 2 | 3 | 4 |
| 231 | A2/B2 | 1 | 0 | 23,27,31,35,39 | 6 | 1 | 2 | 4 |
| 232 | A2/B2 | 1 | 0 | 7,15,23,31,39 | 2 | 1 | 3 | 4 |
| 233 | A2/B2 | 1 | 0 | 23,27,31,35,39 | 2 | 1 | 3 | 4 |
| 234 | A2/B2 | 1 | 0 | 4,9,14,19,24,29,34,39 | 6 | 1 | 2 | 4 |
| 235 | A2/B2 | 1 | 0 | 4,9,14,19,24,29,34,39 | 2 | 1 | 3 | 4 |
| 236 | A2/B2 | 1 | 0 | 3,7,11,15,19,23,27,31,35,39 | 2 | 1 | 3 | 4 |
| 237 | A2/B2 | 1 | 0 | 1,3,5,7,...,37,39 | 2 | 1 | 3 | 4 |
| 238 | A3/B3 | 16 | 1 | 4,9,14,19,24,29,34,39 | 2 | 1 | 2 | 6 |
| 239 | A3/B3 | 16 | 1 | 3,7,11,15,19,23,27,31,35,39 | 2 | 1 | 2 | 6 |
| 240 | A3/B3 | 8 | 1 | 4,9,14,19,24,29,34,39 | 2 | 1 | 2 | 6 |
| 241 | A3/B3 | 8 | 1 | 3,7,11,15,19,23,27,31,35,39 | 2 | 1 | 2 | 6 |
| 242 | A3/B3 | 4 | 1 | 4,9,14,19,24,29,34,39 | 2 | 1 | 2 | 6 |
| 243 | A3/B3 | 4 | 1 | 3,7,11,15,19,23,27,31,35,39 | 2 | 1 | 2 | 6 |
| 244 | A3/B3 | 2 | 1 | 4,9,14,19,24,29,34,39 | 2 | 1 | 2 | 6 |
| 245 | A3/B3 | 1 | 0 | 19,39 | 2 | 1 | 2 | 6 |
| 246 | A3/B3 | 1 | 0 | 9,19,29,39 | 2 | 1 | 2 | 6 |
| 247 | A3/B3 | 1 | 0 | 17,19,37,39 | 2 | 1 | 2 | 6 |
| 248 | A3/B3 | 1 | 0 | 9,19,29,39 | 2 | 2 | 2 | 6 |
| 249 | A3/B3 | 1 | 0 | 7,15,23,31,39 | 2 | 1 | 2 | 6 |
| 250 | A3/B3 | 1 | 0 | 23,27,31,35,39 | 2 | 1 | 2 | 6 |

| | | | | | | | | |
|-----|-------|---|---|-----------------------------|---|---|---|---|
| 251 | A3/B3 | 1 | 0 | 23,27,31,35,39 | 2 | 2 | 2 | 6 |
| 252 | A3/B3 | 1 | 0 | 4,9,14,19,24,29,34,39 | 2 | 1 | 2 | 6 |
| 253 | A3/B3 | 1 | 0 | 4,9,14,19,24,29,34,39 | 2 | 2 | 2 | 6 |
| 254 | A3/B3 | 1 | 0 | 3,7,11,15,19,23,27,31,35,39 | 2 | 1 | 2 | 6 |
| 255 | A3/B3 | 1 | 0 | 1,3,5,7,...,37,39 | 2 | 1 | 2 | 6 |

6.4 Physical signals

6.4.1 Reference signals

6.4.1.1 Demodulation reference signal for PUSCH

6.4.1.1.1 Sequence generation

6.4.1.1.1.1 Sequence generation when transform precoding is disabled

If transform precoding for PUSCH is not enabled, the sequence $r(n)$ shall be generated according to

$$r(n) = \frac{1}{\sqrt{2}}(1 - 2 \cdot c(2n)) + j \frac{1}{\sqrt{2}}(1 - 2 \cdot c(2n+1)).$$

where the pseudo-random sequence $c(i)$ is defined in clause 5.2.1. The pseudo-random sequence generator shall be initialized with

$$c_{\text{init}} = \left(2^{17} (N_{\text{symb}}^{\text{slot}} n_{s,f}^{\mu} + l + 1) \left(2N_{\text{ID}}^{\bar{\lambda}} + 1 \right) + 2^{17} \left\lfloor \frac{\bar{\lambda}}{2} \right\rfloor + 2N_{\text{ID}}^{\bar{\lambda}} + \bar{n}_{\text{SCID}}^{\bar{\lambda}} \right) \bmod 2^{31}$$

where l is the OFDM symbol number within the slot, $n_{s,f}^{\mu}$ is the slot number within a frame, and

- $N_{\text{ID}}^0, N_{\text{ID}}^1 \in \{0, 1, \dots, 65535\}$ are given by the higher-layer parameters *scramblingID0* and *scramblingID1*, respectively, in the *DMRS-UplinkConfig* IE if provided and the PUSCH is scheduled by DCI format 0_1, 0_2, or 0_3, or by a PUSCH transmission with a configured grant;
- $N_{\text{ID}}^0 \in \{0, 1, \dots, 65535\}$ is given by the higher-layer parameter *scramblingID0* in the *DMRS-UplinkConfig* IE if provided and the PUSCH is scheduled by DCI format 0_0 with the CRC scrambled by C-RNTI, MCS-C-RNTI, or CS-RNTI;
- $N_{\text{ID}}^0, N_{\text{ID}}^1 \in \{0, 1, \dots, 65535\}$ are, for each msgA PUSCH configuration, given by the higher-layer parameters *msgA-ScramblingID0* and *msgA-ScramblingID1*, respectively, in the *msgA-DMRS-Config* IE if provided and the PUSCH transmission is triggered by a Type-2 random access procedure as described in clause 8.1A of [5, TS 38.213];
- $N_{\text{ID}}^{\bar{\lambda}} = N_{\text{ID}}^{\text{cell}}$ otherwise;
- $\bar{n}_{\text{SCID}}^{\bar{\lambda}}$ and $\bar{\lambda}$ are given by
 - if the higher-layer parameter *dmrs-Uplink* in the *DMRS-UplinkConfig* IE is provided

$$\bar{n}_{\text{SCID}}^{\bar{\lambda}} = \begin{cases} n_{\text{SCID}} & \lambda = 0 \text{ or } \lambda = 2 \\ 1 - n_{\text{SCID}} & \lambda = 1 \end{cases}$$

$$\bar{\lambda} = \lambda$$

where λ is the CDM group defined in clause 6.4.1.1.3.

- otherwise

$$\bar{n}_{\text{SCID}}^{\bar{\lambda}} = n_{\text{SCID}}$$

$$\bar{\lambda} = 0$$

The quantity $n_{\text{SCID}} \in \{0,1\}$ is

- indicated by the DM-RS initialization field, if present, either in the DCI associated with the PUSCH transmission if DCI format 0_1, 0_2, or 0_3, in [4, TS 38.212] is used;
- indicated by the higher layer parameter *dmrs-SeqInitialization*, if present, for a Type 1 PUSCH transmission with a configured grant;
- determined by the mapping between preamble(s) and a PUSCH occasion and the associated DMRS resource for a PUSCH transmission of Type-2 random access process in [5, TS 38.213];
- determined by the mapping between SS/PBCH block(s) and a PUSCH occasion and the associated DMRS resource for a configured-grant based PUSCH transmission in RRC_INACTIVE state [5, TS 38.213];
- otherwise $n_{\text{SCID}} = 0$.

6.4.1.1.1.2 Sequence generation when transform precoding is enabled

If transform precoding for PUSCH is enabled, the reference-signal sequence $r(n)$ shall be generated according to

$$r(n) = r_{u,v}^{(\alpha,\delta)}(n)$$

$$n = 0, 1, \dots, M_{\text{sc}}^{\text{PUSCH}} / 2^\delta - 1$$

where $r_{u,v}^{(\alpha,\delta)}(n)$ with $\delta = 1$ depends on the configuration:

- if the higher-layer parameter *dmrs-UplinkTransformPrecoding* is configured, $\pi/2$ -BPSK modulation is used for PUSCH, and the PUSCH transmission is not a msg3 transmission, and the transmission is not scheduled using DCI format 0_0 in a common search space, $r_{u,v}^{(\alpha,\delta)}(n)$ is given by clause 5.2.3 with c_{init} given by

$$c_{\text{init}} = (2^{17}(N_{\text{symb}}^{\text{slot}} n_{\text{s,f}}^\mu + l + 1)(2N_{\text{ID}}^{n_{\text{SCID}}} + 1) + 2N_{\text{ID}}^{n_{\text{SCID}}} + n_{\text{SCID}}) \bmod 2^{31}$$

where $n_{\text{SCID}} = 0$ unless given by the DCI according to clause 7.3.1.1.2 in [4, TS38.212] for a transmission scheduled by DCI format 0_1, or given by the DCI according to clause 7.3.1.1.3 in [4, TS38.212] for a transmission scheduled by DCI format 0_2 if the antenna ports field in the DCI format 0_2 is not 0 bit, or given by the DCI according to clause 7.3.1.1.4 in [4, TS38.212] for a transmission scheduled by DCI format 0_3, or given by the higher-layer parameter *antennaPort* for a PUSCH transmission scheduled by a type-1 configured grant; and

- $N_{\text{ID}}^0, N_{\text{ID}}^1 \in \{0,1, \dots, 65535\}$ are given by the higher-layer parameters *pi2BPSK-ScramblingID0* and *pi2BPSK-ScramblingID1*, respectively, in the *DMRS-UplinkConfig* IE if provided and the PUSCH is scheduled by DCI format 0_1, or by DCI format 0_2 if the antenna ports field in the DCI format 0_2 is not 0 bit, or by DCI format 0_3, or by a PUSCH transmission with a configured grant;
- $N_{\text{ID}}^0 \in \{0,1, \dots, 65535\}$ is given by the higher-layer parameter *pi2BPSK-ScramblingID0* in the *DMRS-UplinkConfig* IE if provided and the PUSCH is scheduled by DCI format 0_0 with the CRC scrambled by C-RNTI, MCS-C-RNTI, or CS-RNTI, or by DCI format 0_2 if the antenna ports field in the DCI format 0_2 is 0 bit;
- $N_{\text{ID}}^{n_{\text{SCID}}} = N_{\text{ID}}^{\text{cell}}$ otherwise;
- otherwise, $r_{u,v}^{(\alpha,\delta)}(n)$ is given by clause 5.2.2 with $\alpha = 0$.

The sequence group $u = (f_{\text{gh}} + n_{\text{ID}}^{\text{RS}}) \bmod 30$, where $n_{\text{ID}}^{\text{RS}}$ is given by

- $n_{\text{ID}}^{\text{RS}} = n_{\text{ID}}^{\text{PUSCH}}$ if $n_{\text{ID}}^{\text{PUSCH}}$ is configured by the higher-layer parameter *nPUSCH-Identity* in the *DMRS-UplinkConfig* IE, and
 - the higher-layer parameter *dmrs-UplinkTransformPrecoding* is not configured or the higher-layer parameter *dmrs-UplinkTransformPrecoding* is configured and $\pi/2$ -BPSK modulation is not used for PUSCH, and
 - the PUSCH is neither scheduled by RAR UL grant nor scheduled by DCI format 0_0 with CRC scrambled by TC-RNTI according to clause 8.3 in [5, TS 38.213];

- $n_{\text{ID}}^{\text{RS}} = N_{\text{ID}}^{\text{scID}}$ if the higher-layer parameter *dmrs-UplinkTransformPrecoding* is configured, $\pi/2$ -BPSK modulation is used for PUSCH, the PUSCH transmission is not a msg3 transmission, and the transmission is not scheduled using DCI format 0_0 in a common search space;
- $n_{\text{ID}}^{\text{RS}} = N_{\text{ID}}^{\text{cell}}$ otherwise

where f_{gh} and the sequence number v are given by:

- if neither group, nor sequence hopping is enabled

$$\begin{aligned} f_{\text{gh}} &= 0 \\ v &= 0 \end{aligned}$$

- if group hopping is enabled and sequence hopping is disabled

$$\begin{aligned} f_{\text{gh}} &= \left(\sum_{m=0}^7 2^m c \left(8 \left(N_{\text{symb}}^{\text{slot}} n_{\text{s,f}}^{\mu} + l \right) + m \right) \right) \bmod 30 \\ v &= 0 \end{aligned}$$

where the pseudo-random sequence $c(i)$ is defined by clause 5.2.1 and shall be initialized with $c_{\text{init}} = \lfloor n_{\text{ID}}^{\text{RS}} / 30 \rfloor$ at the beginning of each radio frame

- if sequence hopping is enabled and group hopping is disabled

$$\begin{aligned} f_{\text{gh}} &= 0 \\ v &= \begin{cases} c \left(N_{\text{symb}}^{\text{slot}} n_{\text{s,f}}^{\mu} + l \right) & \text{if } M_{\text{ZC}} \geq 6N_{\text{sc}}^{\text{RB}} \\ 0 & \text{otherwise} \end{cases} \end{aligned}$$

where the pseudo-random sequence $c(i)$ is defined by clause 5.2.1 and shall be initialized with $c_{\text{init}} = n_{\text{ID}}^{\text{RS}}$ at the beginning of each radio frame.

The hopping mode is controlled by higher-layer parameters:

- for PUSCH transmission scheduled by RAR UL grant or by DCI format 0_0 with CRC scrambled by TC-RNTI, sequence hopping is disabled and group hopping is enabled or disabled by the higher-layer parameter *groupHoppingEnabledTransformPrecoding*;
- for all other transmissions, sequence hopping and group hopping are enabled or disabled by the respective higher-layer parameters *sequenceHopping* and *sequenceGroupHopping* if these parameters are provided, otherwise, the same hopping mode as for Msg3 shall be used.

The UE is not expected to handle the case of combined sequence hopping and group hopping.

The quantity l above is the OFDM symbol number in the slot except for the case of double-symbol DMRS in which case l is the OFDM symbol number in the slot of the first symbol of the double-symbol DMRS.

6.4.1.1.2 (void)

6.4.1.1.3 Precoding and mapping to physical resources

The sequence $r(m)$ shall be mapped to the intermediate quantity $\tilde{a}_{k,l}^{(\tilde{p}_j,\mu)}$ according to

- if transform precoding is not enabled,
- if the higher-layer parameter *dmrs-TypeEnh* is configured

$$\begin{aligned} \tilde{a}_{k,l}^{(\tilde{p}_j,\mu)} &= w_{\text{t}}(k') w_{\text{t}}(l') r(4n + k') \\ k &= \begin{cases} 8n + 2k' + \Delta & \text{configuration type 1} \\ 12n + k' + \Delta & \text{configuration type 2, } k' = 0,1 \\ 12n + k' + \Delta + 4 & \text{configuration type 2, } k' = 2,3 \end{cases} \end{aligned}$$

$$\begin{aligned}
k' &= 0,1,2,3 \\
l &= \bar{l} + l' \\
n &= 0,1, \dots \\
j &= 0,1, \dots, v-1
\end{aligned}$$

- otherwise

$$\begin{aligned}
\tilde{a}_{k,l}^{(\tilde{p}_j, \mu)} &= w_f(k')w_t(l')r(2n + k') \\
k &= \begin{cases} 4n + 2k' + \Delta & \text{configuration type 1} \\ 6n + k' + \Delta & \text{configuration type 2} \end{cases} \\
k' &= 0,1 \\
l &= \bar{l} + l' \\
n &= 0,1, \dots \\
j &= 0,1, \dots, v-1
\end{aligned}$$

- if transform precoding is enabled

$$\begin{aligned}
\tilde{a}_{k,l}^{(\tilde{p}_0, \mu)} &= w_f(k')w_t(l')r(2n + k') \\
k &= 4n + 2k' + \Delta \\
k' &= 0,1 \\
l &= \bar{l} + l' \\
n &= 0,1, \dots
\end{aligned}$$

where $w_f(k')$, $w_t(l')$, and Δ are given by Tables 6.4.1.1.3-1 and 6.4.1.1.3-2 and the configuration type is given by the higher-layer parameter *DMRS-UplinkConfig*, and both k' and Δ correspond to $\tilde{p}_0, \dots, \tilde{p}_{v-1}$. The intermediate quantity $\tilde{a}_{k,l}^{(\tilde{p}_j, \mu)} = 0$ if Δ corresponds to any other antenna ports than \tilde{p}_j .

The intermediate quantity $\tilde{a}_{k,l}^{(\tilde{p}_j, \mu)}$ shall be precoded, multiplied with the amplitude scaling factor $\beta_{\text{PUSCH}}^{\text{DMRS}}$ in order to conform to the transmit power specified in [6, TS 38.214], and mapped to physical resources according to

$$\begin{bmatrix} a_{k,l}^{(p_0, \mu)} \\ \vdots \\ a_{k,l}^{(p_{\rho-1}, \mu)} \end{bmatrix} = \beta_{\text{PUSCH}}^{\text{DMRS}} W \begin{bmatrix} \tilde{a}_{k,l}^{(\tilde{p}_0, \mu)} \\ \vdots \\ \tilde{a}_{k,l}^{(\tilde{p}_{v-1}, \mu)} \end{bmatrix}$$

where

- the precoding matrix W is given by clause 6.3.1.5,
- the set of antenna ports $\{p_0, \dots, p_{\rho-1}\}$ is given by clause 6.3.1.5, and
- the set of antenna ports $\{\tilde{p}_0, \dots, \tilde{p}_{\rho-1}\}$ is given by [6, TS 38.214];

and the following conditions are fulfilled:

- the resource elements $\tilde{a}_{k,l}^{(\tilde{p}_j, \mu)}$ are within the common resource blocks allocated for PUSCH transmission.

The reference point for k is

- subcarrier 0 in common resource block 0 if transform precoding is not enabled, and
- subcarrier 0 of the lowest-numbered resource block of the scheduled PUSCH allocation if transform precoding is enabled.

The reference point for l and the position l_0 of the first DM-RS symbol depends on the mapping type:

- for PUSCH mapping type A:
 - l is defined relative to the start of the slot if frequency hopping is disabled and relative to the start of each hop in case frequency hopping is enabled

- l_0 is given by the higher-layer parameter *dmrs-TypeA-Position*
- for PUSCH mapping type B:
 - l is defined relative to the start of the scheduled PUSCH resources if frequency hopping is disabled and relative to the start of each hop in case frequency hopping is enabled
 - $l_0 = 0$

The position(s) of the DM-RS symbols is given by \bar{l} and duration l_d where

- l_d is the duration between the first OFDM symbol of the slot and the last OFDM symbol of the scheduled PUSCH resources in the slot for PUSCH mapping type A according to Tables 6.4.1.1.3-3 and 6.4.1.1.3-4 if intra-slot frequency hopping is not used, or
- l_d is the duration of scheduled PUSCH resources for PUSCH mapping type B according to Tables 6.4.1.1.3-3 and 6.4.1.1.3-4 if intra-slot frequency hopping is not used, or
- l_d is the duration per hop according to Table 6.4.1.1.3-6 if intra-slot frequency hopping is used.
- if the higher-layer parameter *maxLength* in *DMRS-UplinkConfig* is not configured, or for a msgA transmission *msgA-MaxLength* in *msgA-DMRS-Config* is not configured, the tables shall be used according to single-symbol DM-RS
- if the higher-layer parameter *maxLength* in *DMRS-UplinkConfig* is equal to 'len2', the associated DCI or configured grant configuration determines whether single-symbol or double-symbol DM-RS shall be used
- if the higher-layer parameter *msgA-MaxLength* in *msgA-DMRS-Config* is equal to 'len2', double-symbol DM-RS shall be used
- if the higher-layer parameter *dmrs-AdditionalPosition* is not set to 'pos0' and intra-slot frequency hopping is enabled according to clause 7.3.1.1.2 in [4, TS 38.212] and by higher layer, Tables 6.4.1.1.3-6 shall be used assuming *dmrs-AdditionalPosition* is equal to 'pos1' for each hop.

For PUSCH mapping type A,

- the case *dmrs-AdditionalPosition* is equal to 'pos3' is only supported when *dmrs-TypeA-Position* is equal to 'pos2';
- $l_d = 4$ symbols in Table 6.4.1.1.3-4 is only applicable when *dmrs-TypeA-Position* is equal to 'pos2'.

For msgA transmitted using PUSCH mapping type A,

- the case *msgA-DMRS-AdditionalPosition* is equal to 'pos3' is only supported when *dmrs-TypeA-Position* is equal to 'pos2';
- '*dmrs-AdditionalPosition*' in Tables 6.4.1.1.3-3 to 6.4.1.1.3-6 shall be replaced by *msgA-DMRS-AdditionalPosition*;
- only PUSCH DM-RS configuration type 1 is supported;
- only basic DM-RS multiplexing in Table 6.4.1.1.3-5 is supported.

For msgA transmitted using PUSCH mapping type B,

- '*dmrs-AdditionalPosition*' in Tables 6.4.1.1.3-3 to 6.4.1.1.3-6 shall be replaced by *msgA-DMRS-AdditionalPosition*;
- only PUSCH DM-RS configuration type 1 is supported;
- only basic DM-RS multiplexing in Table 6.4.1.1.3-5 is supported.

The time-domain index l' , and the supported antenna ports \tilde{p}_j are given by Table 6.4.1.1.3-5.

Table 6.4.1.1.3-1: Parameters for PUSCH DM-RS configuration type 1.

| \tilde{p} | CDM group λ | Δ | $[w_f(0) \dots w_f(3)]$ | $[w_t(0) \ w_t(1)]$ |
|-------------|---------------------|----------|-------------------------|---------------------|
| 0 | 0 | 0 | [+1 +1 +1 +1] | [+1 +1] |
| 1 | 0 | 0 | [+1 -1 +1 -1] | [+1 +1] |
| 2 | 1 | 1 | [+1 +1 +1 +1] | [+1 +1] |
| 3 | 1 | 1 | [+1 -1 +1 -1] | [+1 +1] |
| 4 | 0 | 0 | [+1 +1 +1 +1] | [+1 -1] |
| 5 | 0 | 0 | [+1 -1 +1 -1] | [+1 -1] |
| 6 | 1 | 1 | [+1 +1 +1 +1] | [+1 -1] |
| 7 | 1 | 1 | [+1 -1 +1 -1] | [+1 -1] |
| 8 | 0 | 0 | [+1 +j -1 -j] | [+1 +1] |
| 9 | 0 | 0 | [+1 -j -1 +j] | [+1 +1] |
| 10 | 1 | 1 | [+1 +j -1 -j] | [+1 +1] |
| 11 | 1 | 1 | [+1 -j -1 +j] | [+1 +1] |
| 12 | 0 | 0 | [+1 +j -1 -j] | [+1 -1] |
| 13 | 0 | 0 | [+1 -j -1 +j] | [+1 -1] |
| 14 | 1 | 1 | [+1 +j -1 -j] | [+1 -1] |
| 15 | 1 | 1 | [+1 -j -1 +j] | [+1 -1] |

Table 6.4.1.1.3-2: Parameters for PUSCH DM-RS configuration type 2.

| \tilde{p} | CDM group λ | Δ | $[w_f(0) \dots w_f(3)]$ | $[w_t(0) \ w_t(1)]$ |
|-------------|---------------------|----------|-------------------------|---------------------|
| 0 | 0 | 0 | [+1 +1 +1 +1] | [+1 +1] |
| 1 | 0 | 0 | [+1 -1 +1 -1] | [+1 +1] |
| 2 | 1 | 2 | [+1 +1 +1 +1] | [+1 +1] |
| 3 | 1 | 2 | [+1 -1 +1 -1] | [+1 +1] |
| 4 | 2 | 4 | [+1 +1 +1 +1] | [+1 +1] |
| 5 | 2 | 4 | [+1 -1 +1 -1] | [+1 +1] |
| 6 | 0 | 0 | [+1 +1 +1 +1] | [+1 -1] |
| 7 | 0 | 0 | [+1 -1 +1 -1] | [+1 -1] |
| 8 | 1 | 2 | [+1 +1 +1 +1] | [+1 -1] |
| 9 | 1 | 2 | [+1 -1 +1 -1] | [+1 -1] |
| 10 | 2 | 4 | [+1 +1 +1 +1] | [+1 -1] |
| 11 | 2 | 4 | [+1 -1 +1 -1] | [+1 -1] |
| 12 | 0 | 0 | [+1 +j -1 -j] | [+1 +1] |
| 13 | 0 | 0 | [+1 -j -1 +j] | [+1 +1] |
| 14 | 1 | 2 | [+1 +j -1 -j] | [+1 +1] |
| 15 | 1 | 2 | [+1 -j -1 +j] | [+1 +1] |
| 16 | 2 | 4 | [+1 +j -1 -j] | [+1 +1] |
| 17 | 2 | 4 | [+1 -j -1 +j] | [+1 +1] |
| 18 | 0 | 0 | [+1 +j -1 -j] | [+1 -1] |
| 19 | 0 | 0 | [+1 -j -1 +j] | [+1 -1] |
| 20 | 1 | 2 | [+1 +j -1 -j] | [+1 -1] |
| 21 | 1 | 2 | [+1 -j -1 +j] | [+1 -1] |
| 22 | 2 | 4 | [+1 +j -1 -j] | [+1 -1] |
| 23 | 2 | 4 | [+1 -j -1 +j] | [+1 -1] |

Table 6.4.1.1.3-3: PUSCH DM-RS positions \bar{l} within a slot for single-symbol DM-RS and intra-slot frequency hopping disabled.

| l_d in symbols | DM-RS positions \bar{l} | | | | | | | |
|------------------|--|-------------|--------------|-----------------|--|-------------|--------------|----------------|
| | PUSCH mapping type A <i>dmrs-AdditionalPosition</i> | | | | PUSCH mapping type B <i>dmrs-AdditionalPosition</i> | | | |
| | <i>pos0</i> | <i>pos1</i> | <i>pos2</i> | <i>pos3</i> | <i>pos0</i> | <i>pos1</i> | <i>pos2</i> | <i>pos3</i> |
| <4 | - | - | - | - | l_0 | l_0 | l_0 | l_0 |
| 4 | l_0 | l_0 | l_0 | l_0 | l_0 | l_0 | l_0 | l_0 |
| 5 | l_0 | l_0 | l_0 | l_0 | l_0 | $l_0, 4$ | $l_0, 4$ | $l_0, 4$ |
| 6 | l_0 | l_0 | l_0 | l_0 | l_0 | $l_0, 4$ | $l_0, 4$ | $l_0, 4$ |
| 7 | l_0 | l_0 | l_0 | l_0 | l_0 | $l_0, 4$ | $l_0, 4$ | $l_0, 4$ |
| 8 | l_0 | $l_0, 7$ | $l_0, 7$ | $l_0, 7$ | l_0 | $l_0, 6$ | $l_0, 3, 6$ | $l_0, 3, 6$ |
| 9 | l_0 | $l_0, 7$ | $l_0, 7$ | $l_0, 7$ | l_0 | $l_0, 6$ | $l_0, 3, 6$ | $l_0, 3, 6$ |
| 10 | l_0 | $l_0, 9$ | $l_0, 6, 9$ | $l_0, 6, 9$ | l_0 | $l_0, 8$ | $l_0, 4, 8$ | $l_0, 3, 6, 9$ |
| 11 | l_0 | $l_0, 9$ | $l_0, 6, 9$ | $l_0, 6, 9$ | l_0 | $l_0, 8$ | $l_0, 4, 8$ | $l_0, 3, 6, 9$ |
| 12 | l_0 | $l_0, 9$ | $l_0, 6, 9$ | $l_0, 5, 8, 11$ | l_0 | $l_0, 10$ | $l_0, 5, 10$ | $l_0, 3, 6, 9$ |
| 13 | l_0 | $l_0, 11$ | $l_0, 7, 11$ | $l_0, 5, 8, 11$ | l_0 | $l_0, 10$ | $l_0, 5, 10$ | $l_0, 3, 6, 9$ |
| 14 | l_0 | $l_0, 11$ | $l_0, 7, 11$ | $l_0, 5, 8, 11$ | l_0 | $l_0, 10$ | $l_0, 5, 10$ | $l_0, 3, 6, 9$ |

Table 6.4.1.1.3-4: PUSCH DM-RS positions \bar{l} within a slot for double-symbol DM-RS and intra-slot frequency hopping disabled.

| l_d in symbols | DM-RS positions \bar{l} | | | | | | | |
|------------------|--|-------------|-------------|-------------|--|-------------|-------------|-------------|
| | PUSCH mapping type A <i>dmrs-AdditionalPosition</i> | | | | PUSCH mapping type B <i>dmrs-AdditionalPosition</i> | | | |
| | <i>pos0</i> | <i>pos1</i> | <i>pos2</i> | <i>pos3</i> | <i>pos0</i> | <i>pos1</i> | <i>pos2</i> | <i>pos3</i> |
| <4 | - | - | | | - | - | | |
| 4 | l_0 | l_0 | | | - | - | | |
| 5 | l_0 | l_0 | | | l_0 | l_0 | | |
| 6 | l_0 | l_0 | | | l_0 | l_0 | | |
| 7 | l_0 | l_0 | | | l_0 | l_0 | | |
| 8 | l_0 | l_0 | | | l_0 | $l_0, 5$ | | |
| 9 | l_0 | l_0 | | | l_0 | $l_0, 5$ | | |
| 10 | l_0 | $l_0, 8$ | | | l_0 | $l_0, 7$ | | |
| 11 | l_0 | $l_0, 8$ | | | l_0 | $l_0, 7$ | | |
| 12 | l_0 | $l_0, 8$ | | | l_0 | $l_0, 9$ | | |
| 13 | l_0 | $l_0, 10$ | | | l_0 | $l_0, 9$ | | |
| 14 | l_0 | $l_0, 10$ | | | l_0 | $l_0, 9$ | | |

Table 6.4.1.1.3-5: PUSCH DM-RS time index l' .

| DM-RS multiplexing | DM-RS duration | l' | Supported antenna ports \tilde{p} | |
|--------------------|---------------------|------|-------------------------------------|----------------------|
| | | | Configuration type 1 | Configuration type 2 |
| Basic | single-symbol DM-RS | 0 | 0 – 3 | 0 – 5 |
| | double-symbol DM-RS | 0, 1 | 0 – 7 | 0 – 11 |
| Enhanced | single-symbol DM-RS | 0 | 0 – 3, 8 – 11 | 0 – 5, 12 – 17 |
| | double-symbol DM-RS | 0, 1 | 0 – 15 | 0 – 23 |

Table 6.4.1.1.3-6: PUSCH DM-RS positions \bar{l} within a slot for single-symbol DM-RS and intra-slot frequency hopping enabled.

| l_d in symbols | DM-RS positions \bar{l} | | | | | | | | | | | | |
|------------------------|---------------------------------|------------------------|------------------------|------------------------|---------------------------------|------------------------|------------------------|------------------------|---------------------------------|------------------------|------------------------|------|------|
| | PUSCH mapping type A | | | | | | | | PUSCH mapping type B | | | | |
| | $l_0 = 2$ | | | | $l_0 = 3$ | | | | $l_0 = 0$ | | | | |
| | dmrs-AdditionalPosition pos0 | | pos1 | | dmrs-AdditionalPosition pos0 | | pos1 | | dmrs-AdditionalPosition pos0 | | pos1 | | |
| 1 st hop | 2 nd hop | 1 st hop | 2 nd hop | 1 st hop | 2 nd hop | 1 st hop | 2 nd hop | 1 st hop | 2 nd hop | 1 st hop | 2 nd hop | | |
| ≤ 3 | - | - | - | - | - | - | - | - | - | 0 | 0 | 0 | 0 |
| 4 | 2 | 0 | 2 | 0 | 3 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5, 6 | 2 | 0 | 2 | 0, 4 | 3 | 0 | 3 | 0, 4 | 0 | 0 | 0, 4 | 0, 4 | 0, 4 |
| 7 | 2 | 0 | 2, 6 | 0, 4 | 3 | 0 | 3 | 0, 4 | 0 | 0 | 0, 4 | 0, 4 | 0, 4 |

6.4.1.2 Phase-tracking reference signals for PUSCH

6.4.1.2.1 Sequence generation

6.4.1.2.1.1 Sequence generation if transform precoding is not enabled

If transform precoding is not enabled, the precoded phase-tracking reference signal for subcarrier k on layer j is given by

$$r^{(\tilde{p}_j)}(m) = \begin{cases} r(m) & \text{if } j = j' \text{ or } j = j'' \\ 0 & \text{otherwise} \end{cases}$$

where

- antenna ports $\tilde{p}_{j'}$ or $\{\tilde{p}_{j'}, \tilde{p}_{j''}\}$ associated with PT-RS transmission are given by clause 6.2.3 of [6, TS 38.214]
- $r(m)$ is given by clause 6.4.1.1.1.1
- at the position of the first DM-RS symbol in absence of PUSCH intra-slot frequency hopping
- at the position of the first DM-RS symbol in hop $h \in \{0, 1\}$ in presence of PUSCH intra-slot frequency hopping

6.4.1.2.1.2 Sequence generation if transform precoding is enabled

If transform precoding is enabled, the phase-tracking reference signal $r_m(m')$ to be mapped in position m before transform precoding, where m depends on the number of PT-RS groups $N_{\text{group}}^{\text{PT-RS}}$, the number of samples per PT-RS group $N_{\text{samp}}^{\text{group}}$, and $M_{\text{sc}}^{\text{PUSCH}}$ according to Table 6.4.1.2.2-1, shall be generated according to

$$r_m(m') = w(k') \frac{e^{j\frac{\pi}{2}(m \bmod 2)}}{\sqrt{2}} \left[(1 - 2c(m')) + j(1 - 2c(m')) \right]$$

$$m' = N_{\text{samp}}^{\text{group}} s' + k'$$

$$s' = 0, 1, \dots, N_{\text{group}}^{\text{PT-RS}} - 1$$

$$k' = 0, 1, N_{\text{samp}}^{\text{group}} - 1$$

where the pseudo-random sequence $c(i)$ is defined in clause 5.2.1 and $w(i)$ is given by Table 6.4.1.2.1.2-1. The pseudo-random sequence generator shall be initialized with

$$c_{\text{init}} = \left(2^{17} (N_{\text{ymb}}^{\text{slot}} n_{\text{s,f}}^{\mu} + l + 1) (2N_{\text{ID}} + 1) + 2N_{\text{ID}} \right) \bmod 2^{31}$$

where l is the lowest OFDM symbol number in the PUSCH allocation in slot $n_{s,f}^{\mu}$ that contains PT-RS according to clause 6.4.1.2.2 and N_{ID} is given by the higher-layer parameter $nPUSCH-Identity$.

Table 6.4.1.2.1-1: The orthogonal sequence $w(i)$.

| $n_{RNTI} \bmod N_{smp}^{group}$ | $N_{smp}^{group} = 2$ | $N_{smp}^{group} = 4$ |
|----------------------------------|-----------------------|-------------------------------|
| | $[w(0) \ w(1)]$ | $[w(0) \ w(1) \ w(2) \ w(3)]$ |
| 0 | $[+1 \ +1]$ | $[+1 \ +1 \ +1 \ +1]$ |
| 1 | $[+1 \ -1]$ | $[+1 \ -1 \ +1 \ -1]$ |
| 2 | - | $[+1 \ +1 \ -1 \ -1]$ |
| 3 | - | $[+1 \ -1 \ -1 \ +1]$ |

6.4.1.2.2 Mapping to physical resources

6.4.1.2.2.1 Precoding and mapping to physical resources if transform precoding is not enabled

The UE shall transmit phase-tracking reference signals only in the resource blocks used for the PUSCH, and only if the procedure in [6, TS 38.214] indicates that phase-tracking reference signals are being used.

The PUSCH PT-RS shall be mapped to resource elements according to

- if the higher-layer parameter $dmrs-TypeEnh$ is configured

$$\begin{bmatrix} a_{k,l}^{(p_0,\mu)} \\ \vdots \\ a_{k,l}^{(p_{\rho-1},\mu)} \end{bmatrix} = \beta_{PT-RS} W \begin{bmatrix} r^{(\tilde{p}_0)}(4n + k') \\ \vdots \\ r^{(\tilde{p}_{v-1})}(4n + k') \end{bmatrix}$$

$$k = \begin{cases} 8n + 2k' + \Delta & \text{configuration type 1} \\ 12n + k' + \Delta & \text{configuration type 2, } k' \in \{0, 1\} \\ 12n + k' + \Delta + 4 & \text{configuration type 2, } k' \in \{2, 3\} \end{cases}$$

- otherwise

$$\begin{bmatrix} a_{k,l}^{(p_0,\mu)} \\ \vdots \\ a_{k,l}^{(p_{\rho-1},\mu)} \end{bmatrix} = \beta_{PT-RS} W \begin{bmatrix} r^{(\tilde{p}_0)}(2n + k') \\ \vdots \\ r^{(\tilde{p}_{v-1})}(2n + k') \end{bmatrix}$$

$$k = \begin{cases} 4n + 2k' + \Delta & \text{configuration type 1} \\ 6n + k' + \Delta & \text{configuration type 2} \end{cases}$$

when all the following conditions are fulfilled

- l is within the OFDM symbols allocated for the PUSCH transmission
- resource element (k, l) is not used for DM-RS
- k' and Δ correspond to $\tilde{p}_0, \dots, \tilde{p}_{v-1}$

The quantities k' and Δ are given by Tables 6.4.1.1.3-1 and 6.4.1.1.3-2, the configuration type is given by the higher-layer parameter $dmrs-Type$ in the $DMRS-UplinkConfig$ IE, and the precoding matrix W is given by clause 6.3.1.5. The quantity β_{PT-RS} is an amplitude scaling factor to conform with the transmit power specified in clause 6.2.2 of [6, TS 38.214].

The set of time indices l defined relative to the start of the PUSCH allocation is defined by

1. set $i = 0$ and $l_{ref} = 0$

2. if any symbol in the interval $\max(l_{\text{ref}} + (i - 1)L_{\text{PT-RS}} + 1, l_{\text{ref}}), \dots, l_{\text{ref}} + iL_{\text{PT-RS}}$ overlaps with a symbol used for DM-RS according to clause 6.4.1.1.3
 - set $i = 1$
 - set l_{ref} to the symbol index of the DM-RS symbol in case of a single-symbol DM-RS or to the symbol index of the second DM-RS symbol in case of a double-symbol DM-RS
 - repeat from step 2 as long as $l_{\text{ref}} + iL_{\text{PT-RS}}$ is inside the PUSCH allocation
3. add $l_{\text{ref}} + iL_{\text{PT-RS}}$ to the set of time indices for PT-RS
4. increment i by one
5. repeat from step 2 above as long as $l_{\text{ref}} + iL_{\text{PT-RS}}$ is inside the PUSCH allocation

where $L_{\text{PT-RS}} \in \{1,2,4\}$ is defined in Table 6.2.3.1-1 of [6, TS 38.214].

For the purpose of PT-RS mapping, the resource blocks allocated for PUSCH transmission are numbered from 0 to $N_{\text{RB}} - 1$ from the lowest scheduled resource block to the highest. The corresponding subcarriers in this set of resource blocks are numbered in increasing order starting from the lowest frequency from 0 to $N_{\text{sc}}^{\text{RB}} N_{\text{RB}} - 1$. The subcarriers to which the PT-RS shall be mapped are given by

$$k = k_{\text{ref}}^{\text{RE}} + (iK_{\text{PT-RS}} + k_{\text{ref}}^{\text{RB}}) N_{\text{sc}}^{\text{RB}}$$

$$k_{\text{ref}}^{\text{RB}} = \begin{cases} n_{\text{RNTI}} \bmod K_{\text{PT-RS}} & \text{if } N_{\text{RB}} \bmod K_{\text{PT-RS}} = 0 \\ n_{\text{RNTI}} \bmod (N_{\text{RB}} \bmod K_{\text{PT-RS}}) & \text{otherwise} \end{cases}$$

where

- $i = 0, 1, 2, \dots$
- $k_{\text{ref}}^{\text{RE}}$ is given by Table 6.4.1.2.2.1-1 for the DM-RS port associated with the PT-RS port according to clause 6.2.3 in [6, TS 38.214]. If the higher-layer parameter *resourceElementOffset* in *PTRS-UplinkConfig* is not configured, the column corresponding to 'offset00' shall be used.
- n_{RNTI} is the RNTI associated with the DCI scheduling the transmission using C-RNTI, CS-RNTI, MCS-C-RNTI, SP-CSI-RNTI, or is the CS-RNTI in case of configured grant
- N_{RB} is the number of resource blocks scheduled
- $K_{\text{PT-RS}} \in \{2,4\}$ is given by [6, TS 38.214].

Table 6.4.1.2.2.1-1: The parameter $k_{\text{ref}}^{\text{RE}}$.

| DM-RS antenna port \tilde{p} | $k_{\text{ref}}^{\text{RE}}$ | | | | | | | |
|-----------------------------------|------------------------------|----------|----------|----------|----------------------------|----------|----------|----------|
| | DM-RS Configuration type 1 | | | | DM-RS Configuration type 2 | | | |
| | resourceElementOffset | | | | resourceElementOffset | | | |
| | offset00 | offset01 | offset10 | offset11 | offset00 | offset01 | offset10 | offset11 |
| 0 | 0 | 2 | 6 | 8 | 0 | 1 | 6 | 7 |
| 1 | 2 | 4 | 8 | 10 | 1 | 6 | 7 | 0 |
| 2 | 1 | 3 | 7 | 9 | 2 | 3 | 8 | 9 |
| 3 | 3 | 5 | 9 | 11 | 3 | 8 | 9 | 2 |
| 4 | - | - | - | - | 4 | 5 | 10 | 11 |
| 5 | - | - | - | - | 5 | 10 | 11 | 4 |
| 8 | 4 | 6 | 10 | 0 | - | - | - | - |
| 9 | 6 | 8 | 0 | 2 | - | - | - | - |
| 10 | 5 | 7 | 11 | 1 | - | - | - | - |
| 11 | 7 | 9 | 1 | 3 | - | - | - | - |
| 12 | - | - | - | - | 6 | 7 | 0 | 1 |
| 13 | - | - | - | - | 7 | 0 | 1 | 6 |
| 14 | - | - | - | - | 8 | 9 | 2 | 3 |
| 15 | - | - | - | - | 9 | 2 | 3 | 8 |
| 16 | - | - | - | - | 10 | 11 | 4 | 5 |
| 17 | - | - | - | - | 11 | 4 | 5 | 10 |

6.4.1.2.2.2 Mapping to physical resources if transform precoding is enabled

The UE shall transmit phase-tracking reference signals only in the resource blocks and OFDM symbols used for the PUSCH, and only if the procedure in [6, TS 38.214] indicates that phase-tracking reference signals are being used.

The sequence $r_m(m')$ shall be multiplied by β' and mapped to $N_{\text{samp}}^{\text{group}} N_{\text{group}}^{\text{PT-RS}}$ complex valued symbols in $\tilde{x}^{(0)}(m)$ where

- $\tilde{x}^{(0)}(m)$ are the complex-valued symbols in OFDM symbol l before transform precoding according to clause 6.3.1.4
- m depends on the number of PT-RS groups $N_{\text{group}}^{\text{PT-RS}}$, the number of samples per PT-RS group $N_{\text{samp}}^{\text{group}}$, and $M_{\text{sc}}^{\text{PUSCH}}$ according to Table 6.4.1.2.2.2-1
- β' is the ratio between amplitude of one of the outermost constellation points for the modulation scheme used for PUSCH and one of the outermost constellation points for $\pi/2$ -BPSK as defined in clause 6.2.3 of [TS 38.214]

The set of time indices l for which PT-RS shall be transmitted is defined relative to the start of the PUSCH allocation and is defined by

1. set $i = 0$ and $l_{\text{ref}} = 0$
2. if any symbol in the interval $\max(l_{\text{ref}} + (i - 1)L_{\text{PT-RS}} + 1, l_{\text{ref}}), \dots, l_{\text{ref}} + iL_{\text{PT-RS}}$ overlaps with a symbol used for DM-RS according to clause 6.4.1.1.3
 - set $i = 1$
 - set l_{ref} to the symbol index of the DM-RS symbol in case of a single-symbol DM-RS and to the symbol index of the second DM-RS symbol in case of a double-symbol DM-RS
 - repeat from step 2 as long as $l_{\text{ref}} + iL_{\text{PT-RS}}$ is inside the PUSCH allocation
3. add $l_{\text{ref}} + iL_{\text{PT-RS}}$ to the set of time indices for PT-RS
4. increment i by one
5. repeat from step 2 above as long as $l_{\text{ref}} + iL_{\text{PT-RS}}$ is inside the PUSCH allocation

where $L_{\text{PT-RS}} \in \{1,2\}$ is given by the higher-layer parameter *timeDensityTransformPrecoding* in the *PTRS-UplinkConfig* IE.

Table 6.4.1.2.2-1: PT-RS symbol mapping.

| Number of PT-RS groups $N_{\text{group}}^{\text{PT-RS}}$ | Number of samples per PT-RS group $N_{\text{samp}}^{\text{group}}$ | Index m of PT-RS samples in OFDM symbol l prior to transform precoding |
|---|---|--|
| 2 | 2 | $s \lfloor M_{\text{sc}}^{\text{PUSCH}} / 4 \rfloor + k - 1$ where $s = 1,3$ and $k = 0,1$ |
| 2 | 4 | $s M_{\text{sc}}^{\text{PUSCH}} + k$ where $\begin{cases} s = 0 & \text{and } k = 0,1,2,3 \\ s = 1 & \text{and } k = -4, -3, -2, -1 \end{cases}$ |
| 4 | 2 | $\lfloor s M_{\text{sc}}^{\text{PUSCH}} / 8 \rfloor + k - 1$ where $s = 1,3,5,7$ and $k = 0,1$ |
| 4 | 4 | $s M_{\text{sc}}^{\text{PUSCH}} / 4 + n + k$ where $\begin{cases} s = 0 & \text{and } k = 0,1,2,3 & n = 0 \\ s = 1,2 & \text{and } k = -2, -1, 0, 1 & n = \lfloor M_{\text{sc}}^{\text{PUSCH}} / 8 \rfloor \\ s = 4 & \text{and } k = -4, -3, -2, -1 & n = 0 \end{cases}$ |
| 8 | 4 | $\lfloor s M_{\text{sc}}^{\text{PUSCH}} / 8 \rfloor + n + k$ where $\begin{cases} s = 0 & \text{and } k = 0,1,2,3 & n = 0 \\ s = 1,2,3,4,5,6 & \text{and } k = -2, -1, 0, 1 & n = \lfloor M_{\text{sc}}^{\text{PUSCH}} / 16 \rfloor \\ s = 8 & \text{and } k = -4, -3, -2, -1 & n = 0 \end{cases}$ |

6.4.1.3 Demodulation reference signal for PUCCH

6.4.1.3.1 Demodulation reference signal for PUCCH format 1

6.4.1.3.1.1 Sequence generation

The reference signal sequence is defined by

$$z(m' N_{\text{SF},0}^{\text{PUCCH},1} M_{\text{RB}}^{\text{PUCCH},1} N_{\text{sc}}^{\text{RB}} + m M_{\text{RB}}^{\text{PUCCH},1} N_{\text{sc}}^{\text{RB}} + n) = w_i(m) r_{u,v}^{(\alpha,\delta)}(n)$$

$$n = 0, 1, \dots, M_{\text{RB}}^{\text{PUCCH},1} N_{\text{sc}}^{\text{RB}} - 1$$

$$m = 0, 1, \dots, N_{\text{SF},m'}^{\text{PUCCH},1} - 1$$

$$m' = \begin{cases} 0 & \text{no intra-slot frequency hopping} \\ 0, 1 & \text{intra-slot frequency hopping} \end{cases}$$

where $N_{\text{SF},m'}^{\text{PUCCH},1}$ is given by Table 6.4.1.3.1.1-1, $M_{\text{RB}}^{\text{PUCCH},1}$ by clause 9.2.1 of [5, TS 38.213], and the sequence $r_{u,v}^{(\alpha,\delta)}(n)$ is given by clause 5.2.2.

Intra-slot frequency hopping shall be assumed when the higher-layer parameter *intraSlotFrequencyHopping* is enabled, regardless of whether the frequency-hop distance is zero or not, otherwise no intra-slot frequency hopping shall be assumed.

The orthogonal sequence $w_i(m)$ is given by Table 6.3.2.4.1-2 with the same index i as used in clause 6.3.2.4.1.

Table 6.4.1.3.1.1-1: Number of DM-RS symbols and the corresponding $N_{SF,m'}^{PUCCH,1}$.

| PUCCH length, $N_{\text{symb}}^{PUCCH,1}$ | $N_{SF,m'}^{PUCCH,1}$ | | |
|--|---------------------------------|-------------------------------------|---|
| | No intra-slot hopping $m'=0$ | Intra-slot hopping $m'=0$ $m'=1$ | |
| 4 | 2 | 1 | 1 |
| 5 | 3 | 1 | 2 |
| 6 | 3 | 2 | 1 |
| 7 | 4 | 2 | 2 |
| 8 | 4 | 2 | 2 |
| 9 | 5 | 2 | 3 |
| 10 | 5 | 3 | 2 |
| 11 | 6 | 3 | 3 |
| 12 | 6 | 3 | 3 |
| 13 | 7 | 3 | 4 |
| 14 | 7 | 4 | 3 |

6.4.1.3.1.2 Mapping to physical resources

The sequence shall be multiplied with the amplitude scaling factor $\beta_{PUCCH,1}$ in order to conform to the transmit power specified in [5, 38.213] and mapped in sequence starting with $z(0)$ to resource elements $(k, l)_{p,\mu}$ in a slot on antenna port $p = 2000$ according to

$$a_{k,l}^{(p,\mu)} = \beta_{PUCCH,1} z(m)$$

$$l = 0, 2, 4, \dots$$

where $l = 0$ corresponds to the first OFDM symbol of the PUCCH transmission and $(k, l)_{p,\mu}$ shall be within the resource blocks assigned for PUCCH transmission according to [5, TS 38.213].

For interlaced transmission, the mapping operation shall be repeated for each resource block in the interlace and in the active bandwidth part over the assigned physical resource blocks according to clause 9.2.1 of [5, TS 38.213], with the resource-block dependent sequence generated according to clause 6.3.2.2.

6.4.1.3.2 Demodulation reference signal for PUCCH format 2

6.4.1.3.2.1 Sequence generation

The reference-signal sequence $z_l(m)$ shall be generated according to

$$z_l(mN_{SF}^{PUCCH,2} + i) = w_n(i)r_l(m)$$

$$r_l(m) = \frac{1}{\sqrt{2}}(1 - 2c(2m)) + j\frac{1}{\sqrt{2}}(1 - 2c(2m + 1))$$

$$i = 0, 1, \dots, N_{SF}^{PUCCH,2} - 1$$

$$m = 0, 1, \dots$$

where the pseudo-random sequence $c(i)$ is defined in clause 5.2. The pseudo-random sequence generator shall be initialized with

$$c_{\text{init}} = (2^{17}(N_{\text{symb}}^{\text{slot}} n_{s,f}^{\mu} + l + 1)(2N_{\text{ID}}^0 + 1) + 2N_{\text{ID}}^0) \bmod 2^{31}$$

where l is the OFDM symbol number within the slot, $n_{s,f}^{\mu}$ is the slot number within the radio frame, and $w_n(i)$ and $N_{SF}^{PUCCH,2}$ are defined in clause 6.3.2.5.2A.

The quantity $N_{\text{ID}}^0 \in \{0, 1, \dots, 65535\}$ is given by the higher-layer parameter *scramblingID0* in the *DMRS-UplinkConfig* IE if provided and by $N_{\text{ID}}^{\text{cell}}$ otherwise. If a UE is configured with both *dmrs-UplinkForPUSCH-MappingTypeA* and *dmrs-UplinkForPUSCH-MappingTypeB*, *scramblingID0* is obtained from *dmrs-UplinkForPUSCH-MappingTypeB*.

6.4.1.3.2.2 Mapping to physical resources

The sequence shall be multiplied with the amplitude scaling factor $\beta_{\text{PUCCH},2}$ in order to conform to the transmit power specified in [5, 38.213] and mapped in sequence starting with $z_l(0)$ to resource elements $(k, l)_{p,\mu}$ in a slot on antenna port $p = 2000$ according to

$$a_{k,l}^{(p,\mu)} = \beta_{\text{PUCCH},2} z_l(m)$$

$$k = 3m + 1$$

where k is defined relative to subcarrier 0 of common resource block 0 and $(k, l)_{p,\mu}$ shall be within the resource blocks assigned for PUCCH transmission according to clause 9.2.1 of [5, TS 38.213].

6.4.1.3.3 Demodulation reference signal for PUCCH formats 3 and 4

6.4.1.3.3.1 Sequence generation

The reference-signal sequence $r_l(m)$ shall be generated according to

$$r_l(m) = r_{u,v}^{(\alpha,\delta)}(m)$$

$$m = 0, 1, \dots, M_{\text{sc}}^{\text{PUCCH},s} - 1$$

where $M_{\text{sc}}^{\text{PUCCH},s}$ is given by clause 6.3.2.6.3 and $r_{u,v}^{(\alpha,\delta)}(m)$ depends on the configuration:

- if the higher-layer parameter *dmrs-UplinkTransformPrecodingPUCCH* is configured, and $\pi/2$ -BPSK is used for PUCCH, $r_{u,v}^{(\alpha,\delta)}(m)$ is given by clause 5.2.3 with $\delta = 0$ and c_{init} given by clause 6.4.1.3.2.1. The sequence group u and the sequence number v depend on the sequence hopping in clause 6.3.2.2.1.
- otherwise, for PUCCH format 3, PUCCH format 4 with $M_{\text{RB}}^{\text{PUCCH},4} = 1$, and PUCCH format 4 with $M_{\text{RB}}^{\text{PUCCH},4} > 1$ when $\pi/2$ -BPSK is not used for PUCCH, $r_{u,v}^{(\alpha,\delta)}(m)$ is given by clause 6.3.2.2 and the cyclic shift α varies with the symbol number and slot number according to clause 6.3.2.2.2 with
 - $m_0 = 0$ for PUCCH format 3 without interlaced mapping;
 - m_0 obtained from Table 6.4.1.3.3.1-1 with the orthogonal sequence index n given by clause 6.3.2.6.3 for PUCCH format 3 with interlaced mapping and PUCCH format 4.

Table 6.4.1.3.3.1-1: Cyclic shift index m_0 for PUCCH format 3 with interlaced mapping and PUCCH format 4.

| Orthogonal sequence index n | Cyclic shift index m_0 | | |
|-------------------------------|--------------------------------------|--------------------------------------|--------------------------------------|
| | $N_{\text{SF}}^{\text{PUCCH},s} = 1$ | $N_{\text{SF}}^{\text{PUCCH},s} = 2$ | $N_{\text{SF}}^{\text{PUCCH},s} = 4$ |
| 0 | 0 | 0 | 0 |
| 1 | - | 6 | 6 |
| 2 | - | - | 3 |
| 3 | - | - | 9 |

6.4.1.3.3.2 Mapping to physical resources

The sequence shall be multiplied with the amplitude scaling factor $\beta_{\text{PUCCH},s}$, $s \in \{3,4\}$, in order to conform to the transmit power specified in [5, 38.213] and mapped in sequence starting with $r_l(0)$ to resource elements $(k, l)_{p,\mu}$ on antenna port $p = 2000$ according to

$$a_{k,l}^{(p,\mu)} = \beta_{\text{PUCCH},s} \cdot r_l(m)$$

$$m = 0, 1, \dots, M_{\text{sc}}^{\text{PUCCH},s} - 1$$

where

- k is defined relative to subcarrier 0 of the lowest-numbered resource block assigned for PUCCH transmission,
- l is given by Table 6.4.1.3.3.2-1 for the case with and without intra-slot frequency hopping and with and without additional DM-RS as described in clause 9.2.1 of [TS 38.213], where $l=0$ corresponds to the first OFDM symbol of the PUCCH transmission.

The resource elements $(k, l)_{p,\mu}$ shall be within the resource blocks assigned for PUCCH transmission according to clause 9.2.1 of [5, TS 38.213].

Table 6.4.1.3.3.2-1: DM-RS positions for PUCCH format 3 and 4.

| PUCCH length | DM-RS position l within PUCCH span | | | |
|--------------|--------------------------------------|---------|------------------|-------------|
| | No additional DM-RS | | Additional DM-RS | |
| | No hopping | Hopping | No hopping | Hopping |
| 4 | 1 | 0, 2 | 1 | 0, 2 |
| 5 | | 0, 3 | | 0, 3 |
| 6 | | 1, 4 | | 1, 4 |
| 7 | | 1, 4 | | 1, 4 |
| 8 | | 1, 5 | | 1, 5 |
| 9 | | 1, 6 | | 1, 6 |
| 10 | | 2, 7 | | 1, 3, 6, 8 |
| 11 | | 2, 7 | | 1, 3, 6, 9 |
| 12 | | 2, 8 | | 1, 4, 7, 10 |
| 13 | | 2, 9 | | 1, 4, 7, 11 |
| 14 | | 3, 10 | | 1, 5, 8, 12 |

6.4.1.4 Sounding reference signal

6.4.1.4.1 SRS resource

An SRS resource is configured by the *SRS-Resource* IE or the *SRS-PosResource* IE and consists of

- $N_{\text{ap}}^{\text{SRS}} \in \{1, 2, 4, 8\}$ antenna ports $\{p_i\}_{i=0}^{N_{\text{ap}}^{\text{SRS}}-1}$, where the number of antenna ports is given by the higher layer parameter *nrofSRS-Ports* or *nrofSRS-Ports-n8* if configured, otherwise $N_{\text{ap}}^{\text{SRS}} = 1$, and $p_i = 1000 + i$ when the SRS resource is in a SRS resource set with higher-layer parameter *usage* in *SRS-ResourceSet* not set to 'nonCodebook', or determined according to [6, TS 38.214] when the SRS resource is in a SRS resource set with higher-layer parameter *usage* in *SRS-ResourceSet* set to 'nonCodebook'.
- N_{hop} , the number of hops for SRS Tx hopping for an SRS resource configured by *SRS-PosResource* and given by the higher layer parameter *numberOfHops* if configured, otherwise $N_{\text{hop}} = 1$.
- $N_{\text{syms}}^{\text{SRS}} \in \{1, 2, 4, 8, 10, 12, 14\}$ consecutive OFDM symbols given by the field *nrofSymbols* contained in the higher layer parameter *resourceMapping*. If $N_{\text{hop}} > 1$, $N_{\text{syms}}^{\text{SRS}}$ is the number of consecutive OFDM symbol per hop.
- l_0 , the starting position in the time domain given by $l_0 = N_{\text{syms}}^{\text{slot}} - 1 - l_{\text{offset}}$ where the offset $l_{\text{offset}} \in \{0, 1, \dots, 13\}$ counts symbols backwards from the end of the slot and is given by the field *startPosition* contained in the higher layer parameter *resourceMapping* and $l_{\text{offset}} \geq N_{\text{syms}}^{\text{SRS}} - 1$. If $N_{\text{hop}} > 1$, l_0 is the starting position of each hop in the time domain, determined by the field *startPosition* for each SRS transmission hop.
- k_0 , the frequency-domain starting position of the sounding reference signal.

6.4.1.4.2 Sequence generation

The sounding reference signal sequence for an SRS resource, or if *numberOfHops* for *SRS-PosResource* is provided, for a given hop within an SRS resource, shall be generated according to

$$r^{(p_i)}(n, l') = w_{\text{TDM}}^{(p_i)}(l') r_{u,v}^{(\alpha_i, \delta)}(n)$$

$$0 \leq n \leq M_{sc,b}^{SRS} - 1$$

$$l' \in \{0, 1, \dots, N_{symb}^{SRS} - 1\}$$

where $M_{sc,b}^{SRS}$ is given by clause 6.4.1.4.3, $r_{u,v}^{(\alpha,\delta)}(n)$ is given by clause 5.2.2 with $\delta = \log_2(K_{TC})$ and the transmission comb number $K_{TC} \in \{2, 4, 8\}$ is contained in the higher-layer parameter *transmissionComb*. The quantity $l' \in \{0, 1, \dots, N_{symb}^{SRS} - 1\}$ is the OFDM symbol number within the SRS resource.

The quantity $w_{TDM}^{(p_i)}(l')$ is given by

- if the higher-layer parameter *nrofSRS-Ports-n8* equals *ports8tdm*

$$w_{TDM}^{(p_i)}(l') = \begin{cases} 1 & \text{if } l' \in \{0, 2, \dots, N_{symb}^{SRS} - 2\} \text{ and } p_i \in \{1000, 1001, 1004, 1005\} \\ 1 & \text{if } l' \in \{1, 3, \dots, N_{symb}^{SRS} - 1\} \text{ and } p_i \in \{1002, 1003, 1006, 1007\} \\ 0 & \text{otherwise} \end{cases}$$

- otherwise

$$w_{TDM}^{(p_i)}(l') = 1$$

The cyclic shift α_i for antenna port p_i is given as

$$\alpha_i = 2\pi \left(\frac{n_{SRS}^{cs,i}}{n_{SRS}^{cs,max}} + \frac{f_{csh}(n_f, n_{s,f}^\mu, l')}{K n_{SRS}^{cs,max}} \right)$$

where

$$n_{SRS}^{cs,i} = \begin{cases} \left(n_{SRS}^{cs} + \frac{n_{SRS}^{cs,max} \lfloor (\bar{p}_i - 1000)/4 \rfloor}{\bar{N}_{ap}^{SRS}/4} \right) \bmod n_{SRS}^{cs,max} & \text{if } \bar{N}_{ap}^{SRS} = 8 \text{ and } n_{SRS}^{cs,max} = 6 \\ \left(n_{SRS}^{cs} + \frac{n_{SRS}^{cs,max} \lfloor (\bar{p}_i - 1000)/2 \rfloor}{\bar{N}_{ap}^{SRS}/2} \right) \bmod n_{SRS}^{cs,max} & \text{if } \bar{N}_{ap}^{SRS} = 4 \text{ and } n_{SRS}^{cs,max} = 6; \text{ or if } \bar{N}_{ap}^{SRS} = 8 \text{ and } n_{SRS}^{cs,max} = 12 \\ \left(n_{SRS}^{cs} + \frac{n_{SRS}^{cs,max} (\bar{p}_i - 1000)}{\bar{N}_{ap}^{SRS}} \right) \bmod n_{SRS}^{cs,max} & \text{otherwise} \end{cases}$$

where $n_{SRS}^{cs} \in \{0, 1, \dots, n_{SRS}^{cs,max} - 1\}$ is contained in the higher layer parameter *transmissionComb*. The maximum number of cyclic shifts $n_{SRS}^{cs,max}$ is given by Table 6.4.1.4.2-1.

The quantities \bar{p}_i and \bar{N}_{ap}^{SRS} are given by

- if the higher-layer parameter *nrofSRS-Ports-n8* equals *ports8tdm*

$$\bar{p}_i = \begin{cases} 1000 + p_i \bmod 2 & \text{if } p_i - 1000 < 4 \\ 1000 + p_i \bmod 2 + 2 & \text{if } p_i - 1000 \geq 4 \end{cases}$$

$$\bar{N}_{ap}^{SRS} = 4$$

- otherwise

$$\bar{p}_i = p_i$$

$$\bar{N}_{ap}^{SRS} = N_{ap}^{SRS}$$

The quantity $f_{csh}(n_f, n_{s,f}^\mu, l')$ is given by

- if the higher-layer parameter *cyclicShiftHopping* is not configured:

$$f_{csh}(n_f, n_{s,f}^\mu, l') = 0$$

- if the higher-layer parameter *cyclicShiftHopping* is configured:

$$f_{\text{csh}}(n_f, n_{s,f}^\mu, l') = s_{\text{csh}}^{\text{SRS}} \left(\left(\sum_{m=0}^7 \left(c \left(8 \left((n_f \bmod 128) N_{\text{slot}}^{\text{frame}, \mu} N_{\text{slot}}^{\text{slot}} + n_{s,f}^\mu N_{\text{slot}}^{\text{slot}} + l_0 + l' \right) + m \right) 2^m \right) \right) \bmod n_{\text{csh}}^{\text{SRS}} \right)$$

where $s_{\text{csh}}^{\text{SRS}}(n)$ and $n_{\text{csh}}^{\text{SRS}}$ is the $(n + 1)$ th entry and the cardinality of the set

$$\mathcal{S}_{\text{csh}} = \{s_{\text{csh}}^{\text{SRS}}(0), s_{\text{csh}}^{\text{SRS}}(1), \dots, s_{\text{csh}}^{\text{SRS}}(n_{\text{csh}}^{\text{SRS}} - 1)\}$$

respectively, where \mathcal{S}_{csh} is given by the higher-layer parameter *hoppingSubset* in the *cyclicShiftHopping* IE if configured, otherwise $\mathcal{S}_{\text{csh}} = \{0, 1, \dots, K n_{\text{SRS}}^{\text{cs,max}} - 1\}$. The higher-layer parameter *hoppingSubset* in the *cyclicShiftHopping* IE includes a bitmap of $n_{\text{SRS}}^{\text{cs,max}}$ bits with $1 < n_{\text{csh}}^{\text{SRS}} < n_{\text{SRS}}^{\text{cs,max}}$ non-zero bits, where if the $(n + 1)$ th non-zero bit is the t :th bit in the bitmap, then $s_{\text{csh}}^{\text{SRS}}(n) = t - 1$.

The pseudo-random sequence $c(i)$ is defined by clause 5.2.1 and shall be initialized with $c_{\text{init}} = n_{\text{ID}}^{\text{hop}}$ at the beginning of each radio frame for which $n_f \bmod 128 = 0$, where the cyclic-shift hopping identity $n_{\text{ID}}^{\text{hop}}$ is contained in the higher-layer parameter *cyclicShiftHopping*.

If the higher-layer parameter *hoppingFinerGranularity* is configured, $K = 2$, otherwise $K = 1$.

The sequence group $u = (f_{\text{gh}}(n_{s,f}^\mu, l') + n_{\text{ID}}^{\text{SRS}}) \bmod 30$ and the sequence number v in clause 5.2.2 depends on the higher-layer parameter *groupOrSequenceHopping* in the *SRS-Resource* IE or the *SRS-PosResource* IE. The SRS sequence identity $n_{\text{ID}}^{\text{SRS}} \in \{0, 1, \dots, 65535\}$ is given by the higher layer parameter *sequenceId* in the *SRS-Resource* IE.

- if *groupOrSequenceHopping* equals 'neither', neither group, nor sequence hopping shall be used and

$$f_{\text{gh}}(n_{s,f}^\mu, l') = 0 \\ v = 0$$

- if *groupOrSequenceHopping* equals 'groupHopping', group hopping but not sequence hopping shall be used and

$$f_{\text{gh}}(n_{s,f}^\mu, l') = \left(\sum_{m=0}^7 c \left(8 \left(n_{s,f}^\mu N_{\text{slot}}^{\text{slot}} + l_0 + l' \right) + m \right) \cdot 2^m \right) \bmod 30 \\ v = 0$$

where the pseudo-random sequence $c(i)$ is defined by clause 5.2.1 and shall be initialized with $c_{\text{init}} = n_{\text{ID}}^{\text{SRS}}$ at the beginning of each radio frame.

- if *groupOrSequenceHopping* equals 'sequenceHopping', sequence hopping but not group hopping shall be used and

$$f_{\text{gh}}(n_{s,f}^\mu, l') = 0 \\ v = \begin{cases} c \left(n_{s,f}^\mu N_{\text{slot}}^{\text{slot}} + l_0 + l' \right) & M_{\text{sc},b}^{\text{SRS}} \geq 6N_{\text{sc}}^{\text{RB}} \\ 0 & \text{otherwise} \end{cases}$$

where the pseudo-random sequence $c(i)$ is defined by clause 5.2.1 and shall be initialized with $c_{\text{init}} = n_{\text{ID}}^{\text{SRS}}$ at the beginning of each radio frame.

Table 6.4.1.4.2-1: Maximum number of cyclic shifts $n_{\text{SRS}}^{\text{cs,max}}$ as a function of K_{TC} .

| K_{TC} | $n_{\text{SRS}}^{\text{cs,max}}$ |
|-----------------|----------------------------------|
| 2 | 8 |
| 4 | 12 |
| 8 | 6 |

6.4.1.4.3 Mapping to physical resources

Throughout this clause, when the higher layer parameter *numberOfHops* is provided for *SRS-PosResource*, the sounding reference signal sequence definitions applies to a given hop.

When SRS is transmitted on a given SRS resource, the sequence $r^{(p_i)}(n, l')$ for each OFDM symbol l' and for each of the antenna ports of the SRS resource shall be multiplied with the amplitude scaling factor β_{SRS} in order to conform to the transmit power specified in [5, 38.213] and mapped in sequence starting with $r^{(p_i)}(0, l')$ to resource elements (k, l) in a slot for each of the antenna ports p_i according to

$$a_{K_{\text{TC}}k' + k_0^{(p_i)}, l' + l_0}^{(p_i)} = \begin{cases} \frac{1}{\sqrt{N_{\text{ap}}}} \beta_{\text{SRS}} r^{(p_i)}(k', l') & \text{if } k' = 0, 1, \dots, M_{\text{sc}, b}^{\text{SRS}} - 1 \text{ and } l' = 0, 1, \dots, N_{\text{sym}}^{\text{SRS}} - 1 \\ 0 & \text{otherwise} \end{cases}$$

The length of the sounding reference signal sequence is given by

$$M_{\text{sc}, b}^{\text{SRS}} = m_{\text{SRS}, b} N_{\text{sc}}^{\text{RB}} / (K_{\text{TC}} P_{\text{F}})$$

where $m_{\text{SRS}, b}$ is given by a selected row of Table 6.4.1.4.3-1 with $b = B_{\text{SRS}}$ where $B_{\text{SRS}} \in \{0, 1, 2, 3\}$ is given by the field b -SRS contained in the higher-layer parameter *freqHopping* if configured, otherwise $B_{\text{SRS}} = 0$. The row of the table is selected according to the index $C_{\text{SRS}} \in \{0, 1, \dots, 63\}$ given by the field c -SRS contained in the higher-layer parameter *freqHopping*. The quantity $P_{\text{F}} \in \{2, 4\}$ is given by the higher-layer parameter *FreqScalingFactor* if configured, otherwise $P_{\text{F}} = 1$. When *FreqScalingFactor* is configured, the UE expects the length of the SRS sequence to be a multiple of 6.

The frequency-domain starting position $k_0^{(p_i)}$ is defined by

$$k_0^{(p_i)} = \bar{k}_0^{(p_i)} + n_{\text{offset}}^{\text{FH}} + n_{\text{offset}}^{\text{RPFS}} + n_{\text{offset2}}^{\text{FH}}$$

where

$$\bar{k}_0^{(p_i)} = n_{\text{shift}} N_{\text{sc}}^{\text{RB}} + \left(k_{\text{TC}}^{(p_i)} + k_{\text{offset}}^{l'} + f_{\text{coh}}(n_f, n_{s, p}^{\mu}, l') \right) \bmod K_{\text{TC}}$$

and

$$k_{\text{TC}}^{(p_i)} = \begin{cases} (\bar{k}_{\text{TC}} + 3K_{\text{TC}}/4) \bmod K_{\text{TC}} & \text{if } \bar{N}_{\text{ap}}^{\text{SRS}} = 8, \bar{p}_i \in \{1003, 1007\}, \text{ and } n_{\text{SRS}}^{\text{cs}, \text{max}} = 6 \\ (\bar{k}_{\text{TC}} + K_{\text{TC}}/2) \bmod K_{\text{TC}} & \text{if } \bar{N}_{\text{ap}}^{\text{SRS}} = 8, \bar{p}_i \in \{1002, 1006\}, \text{ and } n_{\text{SRS}}^{\text{cs}, \text{max}} = 6 \\ (\bar{k}_{\text{TC}} + K_{\text{TC}}/4) \bmod K_{\text{TC}} & \text{if } \bar{N}_{\text{ap}}^{\text{SRS}} = 8, \bar{p}_i \in \{1001, 1005\}, \text{ and } n_{\text{SRS}}^{\text{cs}, \text{max}} = 6 \\ (\bar{k}_{\text{TC}} + K_{\text{TC}}/2) \bmod K_{\text{TC}} & \text{if } \bar{N}_{\text{ap}}^{\text{SRS}} = 8, \bar{p}_i \in \{1001, 1003, 1005, 1007\}, \text{ and } n_{\text{SRS}}^{\text{cs}, \text{max}} = 12 \\ (\bar{k}_{\text{TC}} + K_{\text{TC}}/2) \bmod K_{\text{TC}} & \text{if } \bar{N}_{\text{ap}}^{\text{SRS}} = 8, \bar{p}_i \in \{1001, 1003, 1005, 1007\}, n_{\text{SRS}}^{\text{cs}, \text{max}} = 8, \text{ and } n_{\text{SRS}}^{\text{cs}} \geq n_{\text{SRS}}^{\text{cs}, \text{max}} / 2 \\ (\bar{k}_{\text{TC}} + K_{\text{TC}}/2) \bmod K_{\text{TC}} & \text{if } \bar{N}_{\text{ap}}^{\text{SRS}} = 4, \bar{p}_i \in \{1001, 1003\}, \text{ and } n_{\text{SRS}}^{\text{cs}, \text{max}} = 6 \\ (\bar{k}_{\text{TC}} + K_{\text{TC}}/2) \bmod K_{\text{TC}} & \text{if } \bar{N}_{\text{ap}}^{\text{SRS}} = 4, \bar{p}_i \in \{1001, 1003\}, n_{\text{SRS}}^{\text{cs}, \text{max}} \in \{8, 12\}, \text{ and } n_{\text{SRS}}^{\text{cs}} \geq n_{\text{SRS}}^{\text{cs}, \text{max}} / 2 \\ \bar{k}_{\text{TC}} & \text{otherwise} \end{cases}$$

$$n_{\text{offset}}^{\text{FH}} = \sum_{b=0}^{B_{\text{SRS}}} m_{\text{SRS}, b} N_{\text{sc}}^{\text{RB}} n_b$$

$$n_{\text{offset}}^{\text{RPFS}} = N_{\text{sc}}^{\text{RB}} m_{\text{SRS}, B_{\text{SRS}}} \left((k_{\text{F}} + k_{\text{hop}}) \bmod P_{\text{F}} \right) / P_{\text{F}}$$

$$n_{\text{offset2}}^{\text{FH}} = \left((n_{\text{init}}^{\text{hop}} + n_{\text{SRS}}^{\text{TxHopping}}) \bmod N_{\text{hop}} - n_{\text{init}}^{\text{hop}} \right) (m_{\text{SRS}, 0}^{\text{hop}} - m_{\text{overlap}}^{\text{hop}}) N_{\text{sc}}^{\text{RB}}$$

and

- $k_{\text{F}} \in \{0, 1, \dots, P_{\text{F}} - 1\}$ is given by the higher-layer parameter *StartRBIndex* if configured, otherwise $k_{\text{F}} = 0$;
- k_{hop} is given by Table 6.4.1.4.3-3 with

$$\bar{k}_{\text{hop}} = \left\lfloor \frac{n_{\text{SRS}}}{\prod_{b'=b_{\text{hop}}}^{B_{\text{SRS}}} N_{b'}} \right\rfloor \bmod P_{\text{F}}$$

$$N_{b_{\text{hop}}} = 1$$

if the higher-layer parameter *EnableStartRBHopping* is configured, otherwise $k_{\text{hop}} = 0$.

- $m_{\text{overlap}}^{\text{hop}} \in \{0,1,2,4\}$ is given by the higher-layer parameter *overlapValue* in *TxHoppingConfig*.
- $n_{\text{SRS}}^{\text{TxHopping}} = 0, 1, \dots, N_{\text{hops}}^{\text{SRS}} - 1$ is the hop transmission counter in the time domain, where $n_{\text{SRS}}^{\text{TxHopping}} = 1, 2, \dots, N_{\text{hops}}^{\text{SRS}} - 1$ corresponds to the order of the higher-layer parameter *SlotOffsetForRemainingHops* in *slotOffsetForRemainingHopsList*, wherein the UE expects to be configured with the starting slot offset and starting symbol of the $N_{\text{hops}}^{\text{SRS}}$ hops in an ascending order sequentially in time domain.
- $n_{\text{init}}^{\text{hop}} = \left\lfloor n_{\text{shift}} / \left(m_{\text{SRS},0} - m_{\text{overlap}}^{\text{hop}} \right) \right\rfloor$ is the initial hop index.

The quantity $f_{\text{coh}}(n_f, n_{s,p}^{\mu}, l'')$ is given by

- if the higher-layer parameter *combOffsetHopping* is not configured:

$$f_{\text{coh}}(n_f, n_{s,p}^{\mu}, l'') = 0$$

- if the higher-layer parameter *combOffsetHopping* is configured:

$$f_{\text{coh}}(n_f, n_{s,p}^{\mu}, l'') = s_{\text{coh}}^{\text{SRS}} \left(\left(\sum_{m=0}^7 c \left(8 \left((n_f \bmod 128) N_{\text{slot}}^{\text{frame},\mu} N_{\text{symb}}^{\text{slot}} + n_{s,f}^{\mu} N_{\text{symb}}^{\text{slot}} + l_0 + l'' \right) + m \right) 2^m \right) \bmod n_{\text{coh}}^{\text{SRS}} \right)$$

where $s_{\text{coh}}^{\text{SRS}}(n)$ and $n_{\text{coh}}^{\text{SRS}}$ is the $(n + 1)$ th entry and the cardinality of the set

$$\mathcal{S}_{\text{coh}} = \{s_{\text{coh}}^{\text{SRS}}(0), s_{\text{coh}}^{\text{SRS}}(1), \dots, s_{\text{coh}}^{\text{SRS}}(n_{\text{coh}}^{\text{SRS}} - 1)\}$$

respectively, where \mathcal{S}_{coh} is given by the higher-layer parameter *hoppingSubset* in the *combOffsetHopping* IE if configured, otherwise $\mathcal{S}_{\text{coh}} = \{0, 1, \dots, K_{\text{TC}} - 1\}$. The higher-layer parameter *hoppingSubset* in the *combOffsetHopping* IE includes a bitmap of K_{TC} bits with $1 < n_{\text{coh}}^{\text{SRS}} < K_{\text{TC}}$ non-zero bits, where if the $(n + 1)$ th non-zero bit is the t :th bit in the bitmap, then $s_{\text{coh}}^{\text{SRS}}(n) = t - 1$.

The pseudo-random sequence $c(i)$ is defined by clause 5.2.1 and shall be initialized with $c_{\text{init}} = n_{\text{ID}}^{\text{hop}}$ at the beginning of each radio frame for which $n_f \bmod 128 = 0$, where the comb offset hopping identity $n_{\text{ID}}^{\text{hop}}$ is contained in the higher-layer parameter *combOffsetHopping*.

If the higher-layer parameter *hoppingWithRepetition* is set to *repetition*, $l'' = \lfloor l'/R \rfloor R$, otherwise $l'' = l'$.

If *numberOfHops* is configured:

- The reference point for $k_0^{(p,i)} = 0$ is the lowest subcarrier of the configured bandwidth for SRS with Tx hopping configured by the parameter *bwp* in *SRS-PosTx-Hopping*.

otherwise:

- If $N_{\text{BWP}}^{\text{start}} \leq n_{\text{shift}}$ the reference point for $k_0^{(p,i)} = 0$ is subcarrier 0 in common resource block 0, otherwise the reference point is the lowest subcarrier of the BWP.

If the SRS is configured by the IE *SRS-PosResource*, the quantity $k_{\text{offset}}^{l'}$ is given by Table 6.4.1.4.3-2, otherwise $k_{\text{offset}}^{l'} = 0$.

The frequency domain shift value n_{shift} adjusts the SRS allocation with respect to the reference point grid and is contained in the higher-layer parameter *freqDomainShift* in the *SRS-Resource* IE or the *SRS-PosResource* IE. The transmission comb offset $k_{\text{TC}} \in \{0, 1, \dots, K_{\text{TC}} - 1\}$ is contained in the higher-layer parameter *transmissionComb* in the *SRS-Resource* IE or the *SRS-PosResource* IE and n_b is a frequency position index.

Frequency hopping of the sounding reference signal is configured by the parameter $b_{\text{hop}} \in \{0,1,2,3\}$, given by the field $b\text{-hop}$ contained in the higher-layer parameter freqHopping if configured, otherwise $b_{\text{hop}} = 0$.

If $b_{\text{hop}} \geq B_{\text{SRS}}$, frequency hopping is disabled and the frequency position index n_b remains constant (unless re-configured) and is defined by

$$n_b = \lfloor 4n_{\text{RRC}}/m_{\text{SRS},b} \rfloor \bmod N_b$$

for all $N_{\text{Symb}}^{\text{SRS}}$ OFDM symbols of the SRS resource. The quantity n_{RRC} is given by the higher-layer parameter $\text{freqDomainPosition}$ if configured, otherwise $n_{\text{RRC}} = 0$, and the values of $m_{\text{SRS},b}$ and N_b for $b = B_{\text{SRS}}$ are given by the selected row of Table 6.4.1.4.3-1 corresponding to the configured value of C_{SRS} .

If $b_{\text{hop}} < B_{\text{SRS}}$, frequency hopping is enabled and the frequency position indices n_b are defined by

$$n_b = \begin{cases} \lfloor 4n_{\text{RRC}}/m_{\text{SRS},b} \rfloor \bmod N_b & b \leq b_{\text{hop}} \\ \left(F_b(n_{\text{SRS}}) + \lfloor 4n_{\text{RRC}}/m_{\text{SRS},b} \rfloor \right) \bmod N_b & \text{otherwise} \end{cases}$$

where N_b is given by Table 6.4.1.4.3-1,

$$F_b(n_{\text{SRS}}) = \begin{cases} (N_b/2) \left[\frac{n_{\text{SRS}} \bmod \prod_{b'=b_{\text{hop}}}^b N_{b'}}{\prod_{b'=b_{\text{hop}}}^{b-1} N_{b'}} \right] + \left[\frac{n_{\text{SRS}} \bmod \prod_{b'=b_{\text{hop}}}^b N_{b'}}{2 \prod_{b'=b_{\text{hop}}}^{b-1} N_{b'}} \right] & \text{if } N_b \text{ even} \\ \lfloor N_b/2 \rfloor \lfloor n_{\text{SRS}} / \prod_{b'=b_{\text{hop}}}^{b-1} N_{b'} \rfloor & \text{if } N_b \text{ odd} \end{cases}$$

and where $N_{b_{\text{hop}}} = 1$ regardless of the value of N_b . The quantity n_{SRS} counts the number of SRS transmissions. For the case of an SRS resource configured as aperiodic by the higher-layer parameter resourceType , it is given by $n_{\text{SRS}} = \lfloor l'/(sR) \rfloor$ within the slot in which the $N_{\text{Symb}}^{\text{SRS}}$ symbol SRS resource is transmitted. The quantity s is given by $s = 2$ if the higher-layer parameter $\text{numberOfSRS-Ports-n8}$ equals 'ports8tdm', otherwise $s = 1$. The quantity $R \leq N_{\text{Symb}}^{\text{SRS}}/s$ is the repetition factor given by the field repetitionFactor if configured, otherwise $R = N_{\text{Symb}}^{\text{SRS}}$.

For the case of an SRS resource configured as periodic or semi-persistent by the higher-layer parameter resourceType , the SRS counter is given by

$$n_{\text{SRS}} = \left(\frac{N_{\text{slot}}^{\text{frame},\mu} n_f + n_{s,f}^{\mu} - T_{\text{offset}}}{T_{\text{SRS}}} \right) \left(\frac{N_{\text{Symb}}^{\text{SRS}}}{sR} \right) + \left\lfloor \frac{l'}{sR} \right\rfloor$$

for slots that satisfy $(N_{\text{slot}}^{\text{frame},\mu} n_f + n_{s,f}^{\mu} - T_{\text{offset}}) \bmod T_{\text{SRS}} = 0$. The periodicity T_{SRS} in slots and slot offset T_{offset} are given in clause 6.4.1.4.4.

Table 6.4.1.4.3-1: SRS bandwidth configuration.

| C_{SRS} | $B_{SRS} = 0$ | | $B_{SRS} = 1$ | | $B_{SRS} = 2$ | | $B_{SRS} = 3$ | |
|-----------|---------------|-------|---------------|-------|---------------|-------|---------------|-------|
| | $m_{SRS,0}$ | N_0 | $m_{SRS,1}$ | N_1 | $m_{SRS,2}$ | N_2 | $m_{SRS,3}$ | N_3 |
| 0 | 4 | 1 | 4 | 1 | 4 | 1 | 4 | 1 |
| 1 | 8 | 1 | 4 | 2 | 4 | 1 | 4 | 1 |
| 2 | 12 | 1 | 4 | 3 | 4 | 1 | 4 | 1 |
| 3 | 16 | 1 | 4 | 4 | 4 | 1 | 4 | 1 |
| 4 | 16 | 1 | 8 | 2 | 4 | 2 | 4 | 1 |
| 5 | 20 | 1 | 4 | 5 | 4 | 1 | 4 | 1 |
| 6 | 24 | 1 | 4 | 6 | 4 | 1 | 4 | 1 |
| 7 | 24 | 1 | 12 | 2 | 4 | 3 | 4 | 1 |
| 8 | 28 | 1 | 4 | 7 | 4 | 1 | 4 | 1 |
| 9 | 32 | 1 | 16 | 2 | 8 | 2 | 4 | 2 |
| 10 | 36 | 1 | 12 | 3 | 4 | 3 | 4 | 1 |
| 11 | 40 | 1 | 20 | 2 | 4 | 5 | 4 | 1 |
| 12 | 48 | 1 | 16 | 3 | 8 | 2 | 4 | 2 |
| 13 | 48 | 1 | 24 | 2 | 12 | 2 | 4 | 3 |
| 14 | 52 | 1 | 4 | 13 | 4 | 1 | 4 | 1 |
| 15 | 56 | 1 | 28 | 2 | 4 | 7 | 4 | 1 |
| 16 | 60 | 1 | 20 | 3 | 4 | 5 | 4 | 1 |
| 17 | 64 | 1 | 32 | 2 | 16 | 2 | 4 | 4 |
| 18 | 72 | 1 | 24 | 3 | 12 | 2 | 4 | 3 |
| 19 | 72 | 1 | 36 | 2 | 12 | 3 | 4 | 3 |
| 20 | 76 | 1 | 4 | 19 | 4 | 1 | 4 | 1 |
| 21 | 80 | 1 | 40 | 2 | 20 | 2 | 4 | 5 |
| 22 | 88 | 1 | 44 | 2 | 4 | 11 | 4 | 1 |
| 23 | 96 | 1 | 32 | 3 | 16 | 2 | 4 | 4 |
| 24 | 96 | 1 | 48 | 2 | 24 | 2 | 4 | 6 |
| 25 | 104 | 1 | 52 | 2 | 4 | 13 | 4 | 1 |
| 26 | 112 | 1 | 56 | 2 | 28 | 2 | 4 | 7 |
| 27 | 120 | 1 | 60 | 2 | 20 | 3 | 4 | 5 |
| 28 | 120 | 1 | 40 | 3 | 8 | 5 | 4 | 2 |
| 29 | 120 | 1 | 24 | 5 | 12 | 2 | 4 | 3 |
| 30 | 128 | 1 | 64 | 2 | 32 | 2 | 4 | 8 |
| 31 | 128 | 1 | 64 | 2 | 16 | 4 | 4 | 4 |
| 32 | 128 | 1 | 16 | 8 | 8 | 2 | 4 | 2 |
| 33 | 132 | 1 | 44 | 3 | 4 | 11 | 4 | 1 |
| 34 | 136 | 1 | 68 | 2 | 4 | 17 | 4 | 1 |
| 35 | 144 | 1 | 72 | 2 | 36 | 2 | 4 | 9 |
| 36 | 144 | 1 | 48 | 3 | 24 | 2 | 12 | 2 |
| 37 | 144 | 1 | 48 | 3 | 16 | 3 | 4 | 4 |
| 38 | 144 | 1 | 16 | 9 | 8 | 2 | 4 | 2 |
| 39 | 152 | 1 | 76 | 2 | 4 | 19 | 4 | 1 |
| 40 | 160 | 1 | 80 | 2 | 40 | 2 | 4 | 10 |
| 41 | 160 | 1 | 80 | 2 | 20 | 4 | 4 | 5 |
| 42 | 160 | 1 | 32 | 5 | 16 | 2 | 4 | 4 |
| 43 | 168 | 1 | 84 | 2 | 28 | 3 | 4 | 7 |
| 44 | 176 | 1 | 88 | 2 | 44 | 2 | 4 | 11 |
| 45 | 184 | 1 | 92 | 2 | 4 | 23 | 4 | 1 |
| 46 | 192 | 1 | 96 | 2 | 48 | 2 | 4 | 12 |
| 47 | 192 | 1 | 96 | 2 | 24 | 4 | 4 | 6 |
| 48 | 192 | 1 | 64 | 3 | 16 | 4 | 4 | 4 |
| 49 | 192 | 1 | 24 | 8 | 8 | 3 | 4 | 2 |
| 50 | 208 | 1 | 104 | 2 | 52 | 2 | 4 | 13 |
| 51 | 216 | 1 | 108 | 2 | 36 | 3 | 4 | 9 |
| 52 | 224 | 1 | 112 | 2 | 56 | 2 | 4 | 14 |
| 53 | 240 | 1 | 120 | 2 | 60 | 2 | 4 | 15 |
| 54 | 240 | 1 | 80 | 3 | 20 | 4 | 4 | 5 |
| 55 | 240 | 1 | 48 | 5 | 16 | 3 | 8 | 2 |
| 56 | 240 | 1 | 24 | 10 | 12 | 2 | 4 | 3 |
| 57 | 256 | 1 | 128 | 2 | 64 | 2 | 4 | 16 |
| 58 | 256 | 1 | 128 | 2 | 32 | 4 | 4 | 8 |
| 59 | 256 | 1 | 16 | 16 | 8 | 2 | 4 | 2 |
| 60 | 264 | 1 | 132 | 2 | 44 | 3 | 4 | 11 |
| 61 | 272 | 1 | 136 | 2 | 68 | 2 | 4 | 17 |

| | | | | | | | | |
|----|-----|---|----|----|---|----|---|---|
| 62 | 272 | 1 | 68 | 4 | 4 | 17 | 4 | 1 |
| 63 | 272 | 1 | 16 | 17 | 8 | 2 | 4 | 2 |

Table 6.4.1.4.3-2: The offset k'_{offset} for SRS as a function of K_{TC} and l' .

| K_{TC} | $k'_{\text{offset}}, \dots, k'_{\text{offset}}^{N_{\text{SRS}}^{\text{Symb}}-1}$ | | | | |
|-----------------|--|------------------------------------|------------------------------------|------------------------------------|-------------------------------------|
| | $N_{\text{SRS}}^{\text{Symb}} = 1$ | $N_{\text{SRS}}^{\text{Symb}} = 2$ | $N_{\text{SRS}}^{\text{Symb}} = 4$ | $N_{\text{SRS}}^{\text{Symb}} = 8$ | $N_{\text{SRS}}^{\text{Symb}} = 12$ |
| 2 | 0 | 0,1 | 0,1,0,1 | - | - |
| 4 | - | 0,2 | 0,2,1,3 | 0,2,1,3,0,2,1,3 | 0,2,1,3,0,2,1,3,0,2,1,3 |
| 8 | - | - | 0,4,2,6 | 0,4,2,6,1,5,3,7 | 0,4,2,6,1,5,3,7,0,4,2,6 |

Table 6.4.1.4.3-3: The quantity k_{hop} as a function of \bar{k}_{hop} .

| \bar{k}_{hop} | k_{hop} | | |
|------------------------|--------------------|--------------------|--------------------|
| | $P_{\text{F}} = 1$ | $P_{\text{F}} = 2$ | $P_{\text{F}} = 4$ |
| 0 | 0 | 0 | 0 |
| 1 | - | 1 | 2 |
| 2 | - | - | 1 |
| 3 | - | - | 3 |

6.4.1.4.4 Sounding reference signal slot configuration

Throughout this clause, when the higher layer parameter *numberOfHops* is provided for *SRS-PosResource*, the sounding reference signal slot configuration applies to a given hop.

For an SRS resource configured as periodic or semi-persistent by the higher-layer parameter *resourceType*, a periodicity T_{SRS} (in slots) and slot offset T_{offset} are configured according to the higher-layer parameter *periodicityAndOffset-p* or *periodicityAndOffset-sp* in the *SRS-Resource* IE, or *periodicityAndOffset-p* or *periodicityAndOffset-sp* in the *SRS-PosResource* IE. Candidate slots in which the configured SRS resource may be used for SRS transmission are the slots satisfying

$$(N_{\text{slot}}^{\text{frame},\mu} n_f + n_{\text{s},f}^{\mu} - T_{\text{offset}}) \bmod T_{\text{SRS}} = 0$$

and, if the higher-layer parameter *srs-PosPeriodicConfigHyperSFN-Index* is configured for a periodicity larger than or equal to $2^{\mu} \cdot 10240$ slots, also

$$(n_{\text{HFN}} + N_{\text{SRS}}^{\text{HFN}}) \bmod 2 = 0$$

where $N_{\text{SRS}}^{\text{HFN}} \in \{0,1\}$ is given by the higher-layer parameter *srs-PosPeriodicConfigHyperSFN-Index* and n_{HFN} is the hyper-frame number.

SRS is transmitted as described in clause 6.2.1 of [6, TS 38.214].

7 Downlink

7.1 Overview

7.1.1 Overview of physical channels

A downlink physical channel corresponds to a set of resource elements carrying information originating from higher layers. The following downlink physical channels are defined:

- Physical Downlink Shared Channel, PDSCH
- Physical Broadcast Channel, PBCH

- Physical Downlink Control Channel, PDCCH.

7.1.2 Overview of physical signals

A downlink physical signal corresponds to a set of resource elements used by the physical layer but does not carry information originating from higher layers.

The following downlink physical signals are defined:

- Demodulation reference signals, DM-RS
- Phase-tracking reference signals, PT-RS
- Positioning reference signal, PRS
- Channel-state information reference signal, CSI-RS
- Primary synchronization signal, PSS
- Secondary synchronization signal, SSS

7.2 Physical resources

The frame structure and physical resources the UE shall assume when receiving downlink transmissions are defined in Clause 4.

The following antenna ports are defined for the downlink:

- Antenna ports starting with 1000 for PDSCH
- Antenna ports starting with 2000 for PDCCH
- Antenna ports starting with 3000 for channel-state information reference signals
- Antenna ports starting with 4000 for SS/PBCH block transmission
- Antenna ports starting with 5000 for positioning reference signals

The UE shall not assume that two antenna ports are quasi co-located with respect to any QCL type unless specified otherwise.

For DM-RS associated with a PDSCH, the channel over which a PDSCH symbol on one antenna port is conveyed can be inferred from the channel over which a DM-RS symbol on the same antenna port is conveyed only if the two symbols are within the same resource as the scheduled PDSCH, in the same slot, and in the same PRG as described in clause 5.1.2.3 of [6, TS 38.214].

For DM-RS associated with a PDCCH, the channel over which a PDCCH symbol on one antenna port is conveyed can be inferred from the channel over which a DM-RS symbol on the same antenna port is conveyed only if the two symbols are within resources for which the UE may assume the same precoding being used as described in clause 7.3.2.2.

For DM-RS associated with a PBCH, the channel over which a PBCH symbol on one antenna port is conveyed can be inferred from the channel over which a DM-RS symbol on the same antenna port is conveyed only if the two symbols are within a SS/PBCH block transmitted within the same slot, and with the same block index according to clause 7.4.3.1.

7.3 Physical channels

7.3.1 Physical downlink shared channel

7.3.1.1 Scrambling

Up to two codewords $q \in \{0,1\}$ can be transmitted. In case of single-codeword transmission, $q=0$.

For each codeword q , the UE shall assume the block of bits $b^{(q)}(0), \dots, b^{(q)}(M_{\text{bit}}^{(q)} - 1)$, where $M_{\text{bit}}^{(q)}$ is the number of bits in codeword q transmitted on the physical channel, are scrambled prior to modulation, resulting in a block of scrambled bits $\tilde{b}^{(q)}(0), \dots, \tilde{b}^{(q)}(M_{\text{bit}}^{(q)} - 1)$ according to

$$\tilde{b}^{(q)}(i) = (b^{(q)}(i) + c^{(q)}(i)) \bmod 2$$

where the scrambling sequence $c^{(q)}(i)$ is given by clause 5.2.1. The scrambling sequence generator shall be initialized with

$$c_{\text{init}} = n_{\text{RNTI}} \cdot 2^{15} + q \cdot 2^{14} + n_{\text{ID}}$$

where

- $n_{\text{ID}} \in \{0,1,\dots,1023\}$ equals the higher-layer parameter *dataScramblingIdentityPDSCH* if configured and the RNTI equals the C-RNTI, MCS-C-RNTI, or CS-RNTI, and the transmission is not scheduled using DCI format 1_0 in a common search space;
- $n_{\text{ID}} \in \{0,1, \dots, 1023\}$ equals the higher-layer parameter *dataScramblingIdentityPDSCH* in *pdsch-ConfigMulticast* if configured in a common MBS frequency resource for multicast and the RNTI equals the G-RNTI or the G-CS-RNTI;
- $n_{\text{ID}} \in \{0,1, \dots, 1023\}$ equals the higher-layer parameter *dataScramblingIdentityPDSCH* in *pdsch-ConfigMCCH* or *pdsch-ConfigMTCH* if configured in a common MBS frequency resource for broadcast and the RNTI equals the MCCH-RNTI or G-RNTI, respectively;
- $n_{\text{ID}} \in \{0,1, \dots, 1023\}$ equals
 - the higher-layer parameter *dataScramblingIdentityPDSCH* if the codeword is scheduled using a CORESET with *CORESETPoolIndex* equal to 0;
 - the higher-layer parameter *dataScramblingIdentityPDSCH2* if the codeword is scheduled using a CORESET with *CORESETPoolIndex* equal to 1;

if the higher-layer parameters *dataScramblingIdentityPDSCH* and *dataScramblingIdentityPDSCH2* are configured together with the higher-layer parameter *CORESETPoolIndex* containing two different values, and the RNTI equals the C-RNTI, MCS-C-RNTI, or CS-RNTI, and the transmission is not scheduled using DCI format 1_0 in a common search space;

- $n_{\text{ID}} = N_{\text{ID}}^{\text{cell}}$ otherwise

and where n_{RNTI} corresponds to the RNTI associated with the PDSCH transmission as described in clause 5.1 of [6, TS 38.214].

7.3.1.2 Modulation

For each codeword q , the UE shall assume the block of scrambled bits $\tilde{b}^{(q)}(0), \dots, \tilde{b}^{(q)}(M_{\text{bit}}^{(q)} - 1)$ are modulated as described in clause 5.1 using one of the modulation schemes in Table 7.3.1.2-1, resulting in a block of complex-valued modulation symbols $d^{(q)}(0), \dots, d^{(q)}(M_{\text{sybm}}^{(q)} - 1)$.

Table 7.3.1.2-1: Supported modulation schemes.

| Modulation scheme | Modulation order Q_m |
|-------------------|---------------------------|
| QPSK | 2 |
| 16QAM | 4 |
| 64QAM | 6 |
| 256QAM | 8 |
| 1024QAM | 10 |

7.3.1.3 Layer mapping

The UE shall assume that complex-valued modulation symbols for each of the codewords to be transmitted are mapped onto one or several layers according to Table 7.3.1.3-1. Complex-valued modulation symbols $d^{(q)}(0), \dots, d^{(q)}(M_{\text{sy mb}}^{(q)} - 1)$ for codeword q shall be mapped onto the layers $x(i) = [x^{(0)}(i) \ \dots \ x^{(v-1)}(i)]^T$, $i = 0, 1, \dots, M_{\text{sy mb}}^{\text{layer}} - 1$ where v is the number of layers and $M_{\text{sy mb}}^{\text{layer}}$ is the number of modulation symbols per layer.

Table 7.3.1.3-1: Codeword-to-layer mapping for spatial multiplexing.

| Number of layers | Number of codewords | Codeword-to-layer mapping $i = 0, 1, \dots, M_{\text{symb}}^{\text{layer}} - 1$ |
|------------------|---------------------|---|
| 1 | 1 | $x^{(0)}(i) = d^{(0)}(i)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)}$ |
| 2 | 1 | $x^{(0)}(i) = d^{(0)}(2i)$ $x^{(1)}(i) = d^{(0)}(2i+1)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} / 2$ |
| 3 | 1 | $x^{(0)}(i) = d^{(0)}(3i)$ $x^{(1)}(i) = d^{(0)}(3i+1)$ $x^{(2)}(i) = d^{(0)}(3i+2)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} / 3$ |
| 4 | 1 | $x^{(0)}(i) = d^{(0)}(4i)$ $x^{(1)}(i) = d^{(0)}(4i+1)$ $x^{(2)}(i) = d^{(0)}(4i+2)$ $x^{(3)}(i) = d^{(0)}(4i+3)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} / 4$ |
| 5 | 2 | $x^{(0)}(i) = d^{(0)}(2i)$ $x^{(1)}(i) = d^{(0)}(2i+1)$ $x^{(2)}(i) = d^{(1)}(3i)$ $x^{(3)}(i) = d^{(1)}(3i+1)$ $x^{(4)}(i) = d^{(1)}(3i+2)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} / 2 = M_{\text{symb}}^{(1)} / 3$ |
| 6 | 2 | $x^{(0)}(i) = d^{(0)}(3i)$ $x^{(1)}(i) = d^{(0)}(3i+1)$ $x^{(2)}(i) = d^{(0)}(3i+2)$ $x^{(3)}(i) = d^{(1)}(3i)$ $x^{(4)}(i) = d^{(1)}(3i+1)$ $x^{(5)}(i) = d^{(1)}(3i+2)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} / 3 = M_{\text{symb}}^{(1)} / 3$ |
| 7 | 2 | $x^{(0)}(i) = d^{(0)}(3i)$ $x^{(1)}(i) = d^{(0)}(3i+1)$ $x^{(2)}(i) = d^{(0)}(3i+2)$ $x^{(3)}(i) = d^{(1)}(4i)$ $x^{(4)}(i) = d^{(1)}(4i+1)$ $x^{(5)}(i) = d^{(1)}(4i+2)$ $x^{(6)}(i) = d^{(1)}(4i+3)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} / 3 = M_{\text{symb}}^{(1)} / 4$ |
| 8 | 2 | $x^{(0)}(i) = d^{(0)}(4i)$ $x^{(1)}(i) = d^{(0)}(4i+1)$ $x^{(2)}(i) = d^{(0)}(4i+2)$ $x^{(3)}(i) = d^{(0)}(4i+3)$ $x^{(4)}(i) = d^{(1)}(4i)$ $x^{(5)}(i) = d^{(1)}(4i+1)$ $x^{(6)}(i) = d^{(1)}(4i+2)$ $x^{(7)}(i) = d^{(1)}(4i+3)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} / 4 = M_{\text{symb}}^{(1)} / 4$ |

7.3.1.4 Antenna port mapping

The block of vectors $[x^{(0)}(i) \ \dots \ x^{(v-1)}(i)]^T$, $i = 0, 1, \dots, M_{\text{symb}}^{\text{layer}} - 1$ shall be mapped to antenna ports according to

$$\begin{bmatrix} y^{(p_0)}(i) \\ \vdots \\ y^{(p_{v-1})}(i) \end{bmatrix} = \begin{bmatrix} x^{(0)}(i) \\ \vdots \\ x^{(v-1)}(i) \end{bmatrix}$$

where $i = 0, 1, \dots, M_{\text{symb}}^{\text{ap}} - 1$, $M_{\text{symb}}^{\text{ap}} = M_{\text{symb}}^{\text{layer}}$. The set of antenna ports $\{p_0, \dots, p_{v-1}\}$ shall be determined according to the procedure in [4, TS 38.212].

7.3.1.5 Mapping to virtual resource blocks

The UE shall, for each of the antenna ports used for transmission of the physical channel, assume the block of complex-valued symbols $y^{(p)}(0), \dots, y^{(p)}(M_{\text{symb}}^{\text{ap}} - 1)$ conform to the downlink power allocation specified in [6, TS 38.214] and are mapped in sequence starting with $y^{(p)}(0)$ to resource elements $(k', l)_{p,\mu}$ in the virtual resource blocks assigned for transmission which meet all of the following criteria:

- they are in the virtual resource blocks assigned for transmission;
- the corresponding physical resource blocks are declared as available for PDSCH according to clause 5.1.4 of [6, TS 38.214];
- the corresponding resource elements in the corresponding physical resource blocks are
 - not used for transmission of the associated DM-RS or DM-RS intended for other co-scheduled UEs as described in clause 7.4.1.1.2;
 - not used for non-zero-power CSI-RS, which is according to clause 7.4.1.5 and not configured by the *TRS-ResourceSet* IE, if the corresponding physical resource blocks are for a PDSCH scheduled by a PDCCH with the CRC scrambled by C-RNTI, MCS-C-RNTI, CS-RNTI, G-RNTI for multicast, G-CS-RNTI, or a PDSCH with SPS, except if the non-zero-power CSI-RS is a CSI-RS configured by the higher-layer parameter *CSI-RS-Resource-Mobility* in the *MeasObjectNR* IE or except if the non-zero-power CSI-RS is an aperiodic non-zero-power CSI-RS resource;
 - not used for PT-RS according to clause 7.4.1.2;
 - not declared as 'not available for PDSCH according to clause 5.1.4 of [6, TS 38.214].

The mapping to resource elements $(k', l)_{p,\mu}$ allocated for PDSCH according to [6, TS 38.214] and not reserved for other purposes shall be in increasing order of first the index k' over the assigned virtual resource blocks, where $k' = 0$ is the first subcarrier in the lowest-numbered virtual resource block assigned for transmission, and then the index l .

7.3.1.6 Mapping from virtual to physical resource blocks

The UE shall assume the virtual resource blocks are mapped to physical resource blocks according to the indicated mapping scheme, non-interleaved or interleaved mapping. If no mapping scheme is indicated, the UE shall assume non-interleaved mapping.

For non-interleaved VRB-to-PRB mapping, virtual resource block n is mapped to physical resource block n , except for PDSCH transmissions scheduled with DCI format 1_0 in a common search space in which case virtual resource block n is mapped to physical resource block $n + N_{\text{start}}^{\text{CORESET}}$ where $N_{\text{start}}^{\text{CORESET}}$ is the lowest-numbered physical resource block in the control resource set where the corresponding DCI was received. When two PDCCH candidates from two linked common search space sets as indicated by the higher-layer parameter *searchSpaceLinking* are detected, and the two linked common search space sets are associated with different control resource sets, the control resource set with the lowest number among the two linked control resource sets is used to determine $N_{\text{start}}^{\text{CORESET}}$.

For interleaved VRB-to-PRB mapping, the mapping process is defined by:

- Resource block bundles are defined as
 - for PDSCH transmissions scheduled with DCI format 1_0 with the CRC scrambled by SI-RNTI in Type0-PDCCH common search space in CORESET 0, the set of $N_{\text{BWP,init}}^{\text{size}}$ resource blocks in CORESET 0 are

divided into $N_{\text{bundle}} = \lceil N_{\text{BWP,init}}^{\text{size}} / L \rceil$ resource-block bundles in increasing order of the resource-block number and bundle number where $L = 2$ is the bundle size and $N_{\text{BWP,init}}^{\text{size}}$ is the size of CORESET 0.

- resource block bundle $N_{\text{bundle}} - 1$ consists of $N_{\text{BWP,init}}^{\text{size}} \bmod L$ resource blocks if $N_{\text{BWP,init}}^{\text{size}} \bmod L > 0$ and L resource blocks otherwise,
- all other resource block bundles consists of L resource blocks.
- for PDSCH transmissions scheduled with DCI format 1_0 in any common search space in bandwidth part i with starting position $N_{\text{BWP},i}^{\text{start}}$, other than Type0-PDCCH common search space in CORESET 0, the set of $N_{\text{BWP,init}}^{\text{size}}$ virtual resource blocks $\{0, 1, \dots, N_{\text{BWP,init}}^{\text{size}} - 1\}$, where $N_{\text{BWP,init}}^{\text{size}}$ is the size of CORESET 0 if CORESET 0 is configured for the cell and the size of initial downlink bandwidth part if CORESET 0 is not configured for the cell, are divided into N_{bundle} virtual resource-block bundles in increasing order of the virtual resource-block number and virtual bundle number and the set of $N_{\text{BWP,init}}^{\text{size}}$ physical resource blocks $\{N_{\text{start}}^{\text{CORESET}}, N_{\text{start}}^{\text{CORESET}} + 1, \dots, N_{\text{start}}^{\text{CORESET}} + N_{\text{BWP,init}}^{\text{size}} - 1\}$ are divided into N_{bundle} physical resource-block bundles in increasing order of the physical resource-block number and physical bundle number, where $N_{\text{bundle}} = \lceil (N_{\text{BWP,init}}^{\text{size}} + (N_{\text{BWP},i}^{\text{start}} + N_{\text{start}}^{\text{CORESET}}) \bmod L) / L \rceil$, $L = 2$ is the bundle size, and $N_{\text{start}}^{\text{CORESET}}$ is the lowest-numbered physical resource block in the control resource set where the corresponding DCI was received. When two PDCCH candidates from two linked search space sets as indicated by the higher-layer parameter *searchSpaceLinking* are detected, and the two linked search space sets are associated with different control resource sets, the control resource set with the lowest number among the two linked control resource sets is used to determine $N_{\text{start}}^{\text{CORESET}}$.
 - resource block bundle 0 consists of $L - ((N_{\text{BWP},i}^{\text{start}} + N_{\text{start}}^{\text{CORESET}}) \bmod L)$ resource blocks,
 - resource block bundle $N_{\text{bundle}} - 1$ consists of $(N_{\text{BWP,init}}^{\text{size}} + N_{\text{BWP},i}^{\text{start}} + N_{\text{start}}^{\text{CORESET}}) \bmod L$ resource blocks if $(N_{\text{BWP,init}}^{\text{size}} + N_{\text{BWP},i}^{\text{start}} + N_{\text{start}}^{\text{CORESET}}) \bmod L > 0$ and L resource blocks otherwise,
 - all other resource block bundles consists of L resource blocks.
- for all other PDSCH transmissions, the set of $N_{\text{BWP},i}^{\text{size}}$ resource blocks in bandwidth part i with starting position $N_{\text{BWP},i}^{\text{start}}$ are divided into $N_{\text{bundle}} = \lceil (N_{\text{BWP},i}^{\text{size}} + (N_{\text{BWP},i}^{\text{start}} \bmod L_i)) / L_i \rceil$ resource-block bundles in increasing order of the resource-block number and bundle number where L_i is the bundle size for bandwidth part i provided by the higher-layer parameter *vrb-ToPRB-Interleaver* for DCI formats 1_0, 1_1, and 1_3 in a UE-specific search space, or *vrb-ToPRB-InterleaverDCI-1-2* for DCI format 1_2, and
 - resource block bundle 0 consists of $L_i - (N_{\text{BWP},i}^{\text{start}} \bmod L_i)$ resource blocks,
 - resource block bundle $N_{\text{bundle}} - 1$ consists of $(N_{\text{BWP},i}^{\text{start}} + N_{\text{BWP},i}^{\text{size}}) \bmod L_i$ resource blocks if $(N_{\text{BWP},i}^{\text{start}} + N_{\text{BWP},i}^{\text{size}}) \bmod L_i > 0$ and L_i resource blocks otherwise,
 - all other resource block bundles consists of L_i resource blocks.
- Virtual resource blocks in the interval $j \in \{0, 1, \dots, N_{\text{bundle}} - 1\}$ are mapped to physical resource blocks according to
 - virtual resource block bundle $N_{\text{bundle}} - 1$ is mapped to physical resource block bundle $N_{\text{bundle}} - 1$
 - virtual resource block bundle $j \in \{0, 1, \dots, N_{\text{bundle}} - 2\}$ is mapped to physical resource block bundle $f(j)$ where

$$\begin{aligned}
 f(j) &= rC + c \\
 j &= cR + r \\
 r &= 0, 1, \dots, R-1 \\
 c &= 0, 1, \dots, C-1 \\
 R &= 2 \\
 C &= \lfloor N_{\text{bundle}}/R \rfloor
 \end{aligned}$$

- The UE is not expected to be configured with $L_i = 2$ simultaneously with a PRG size of 4 as defined in [6, TS 38.214]

The UE may assume that the same precoding in the frequency domain is used within a PRB bundle and the bundle size is determined by clause 5.1.2.3 in [6, TS 38.214]. The UE shall not make any assumption that the same precoding is used for different bundles of common resource blocks.

For PDSCH transmissions scheduled by DCI format 4_1 or 4_2, and using G-RNTI or G-CS-RNTI, the quantities $N_{\text{BWP},i}^{\text{start}}$ and $N_{\text{BWP},i}^{\text{size}}$ in this clause are replaced by $N_{\text{MBS},i}^{\text{start}}$ and $N_{\text{MBS},i}^{\text{size}}$, respectively, and L_i is the bundle size for the common MBS frequency resource provided by the higher-layer parameter *vrb-ToPRB-Interleaver* in *pdsch-ConfigMulticast*.

For PDSCH transmissions scheduled by DCI format 4_0, and using G-RNTI for broadcast, MCCH-RNTI, or Multicast-MCCH-RNTI, the quantities $N_{\text{BWP},i}^{\text{start}}$ and $N_{\text{BWP},i}^{\text{size}}$ in this clause are replaced by $N_{\text{MBS},i}^{\text{start}}$ and $N_{\text{MBS},i}^{\text{size}}$, respectively, and $L_i = 2$.

7.3.2 Physical downlink control channel (PDCCH)

7.3.2.1 Control-channel element (CCE)

A physical downlink control channel consists of one or more control-channel elements (CCEs) as indicated in Table 7.3.2.1-1.

Table 7.3.2.1-1: Supported PDCCH aggregation levels.

| Aggregation level | Number of CCEs |
|-------------------|----------------|
| 1 | 1 |
| 2 | 2 |
| 4 | 4 |
| 8 | 8 |
| 16 | 16 |

7.3.2.2 Control-resource set (CORESET)

A control-resource set consists of $N_{\text{RB}}^{\text{CORESET}}$ resource blocks in the frequency domain and $N_{\text{symb}}^{\text{CORESET}} \in \{1, 2, 3\}$ symbols in the time domain.

A control-channel element consists of 6 resource-element groups (REGs) where a resource-element group equals one resource block during one OFDM symbol. Resource-element groups within a control-resource set are numbered in increasing order in a time-first manner, starting with 0 for the first OFDM symbol and the lowest-numbered resource block in the control resource set.

A UE can be configured with multiple control-resource sets. Each control-resource set is associated with one CCE-to-REG mapping only.

The CCE-to-REG mapping for a control-resource set can be interleaved or non-interleaved and is described by REG bundles:

- REG bundle i is defined as REGs $\{iL, iL + 1, \dots, iL + L - 1\}$ where L is the REG bundle size, $i = 0, 1, \dots, N_{\text{REG}}^{\text{CORESET}}/L - 1$, and $N_{\text{REG}}^{\text{CORESET}} = N_{\text{RB}}^{\text{CORESET}} N_{\text{symb}}^{\text{CORESET}}$ is the number of REGs in the CORESET
- CCE j consists of REG bundles $\{f(6j/L), f(6j/L + 1), \dots, f(6j/L + 6/L - 1)\}$ where $f(\cdot)$ is an interleaver

For non-interleaved CCE-to-REG mapping, $L = 6$ and $f(x) = x$.

For interleaved CCE-to-REG mapping, $L \in \{2, 6\}$ for $N_{\text{symb}}^{\text{CORESET}} = 1$ and $L \in \{N_{\text{symb}}^{\text{CORESET}}, 6\}$ for $N_{\text{symb}}^{\text{CORESET}} \in \{2, 3\}$. The interleaver is defined by

$$\begin{aligned} f(x) &= (rC + c + n_{\text{shift}}) \bmod (N_{\text{REG}}^{\text{CORESET}}/L) \\ x &= cR + r \\ r &= 0, 1, \dots, R - 1 \\ c &= 0, 1, \dots, C - 1 \\ C &= N_{\text{REG}}^{\text{CORESET}}/(LR) \end{aligned}$$

where $R \in \{2, 3, 6\}$.

The UE is not expected to handle configurations resulting in the quantity C not being an integer.

For a CORESET configured by the *ControlResourceSet* IE:

- $N_{\text{RB}}^{\text{CORESET}}$ is given by the higher-layer parameter *frequencyDomainResources*;
- $N_{\text{symb}}^{\text{CORESET}}$ is given by the higher-layer parameter *duration*, where $N_{\text{symb}}^{\text{CORESET}} = 3$ is supported only if the higher-layer parameter *dmrs-TypeA-Position* equals 'pos3';
- interleaved or non-interleaved mapping is given by the higher-layer parameter *cce-REG-MappingType*;
- L equals 6 for non-interleaved mapping and is given by the higher-layer parameter *reg-BundleSize* for interleaved mapping;
- R is given by the higher-layer parameter *interleaverSize*;
- $n_{\text{shift}} \in \{0, 1, \dots, 274\}$ is given by the higher-layer parameter *shiftIndex* if provided, otherwise $n_{\text{shift}} = N_{\text{ID}}^{\text{cell}}$;
- for both interleaved and non-interleaved mapping:
 - if the higher-layer parameter *precoderGranularity* equals *sameAsREG-bundle* the UE may assume the same precoding being used within a REG bundle
 - if the higher-layer parameter *precoderGranularity* equals *allContiguousRBs*,
 - the UE may assume the same precoding being used across the all resource-element groups within the set of contiguous resource blocks in the CORESET;
 - the UE may assume that no resource elements in the CORESET overlap with an SSB;
 - if the UE is not provided with the higher-layer parameter *pdccch-CandidateReceptionWith-CRS-Overlap*, the UE may assume that no resource elements in the CORESET overlap with LTE cell-specific reference signals as indicated by the higher-layer parameter *lte-CRS-ToMatchAround*, *lte-CRS-PatternList1*, *lte-CRS-PatternList2*, *lte-CRS-PatternList3*, or *lte-CRS-PatternList4*.

For CORESET 0 configured by the *ControlResourceSetZero* IE:

- $N_{\text{RB}}^{\text{CORESET}}$ and $N_{\text{symb}}^{\text{CORESET}}$ are defined by clause 13 of [5, TS 38.213];
- the UE may assume interleaved mapping;
- $L = 6$;
- $R = 2$;
- $n_{\text{shift}} = N_{\text{ID}}^{\text{cell}}$;
- the UE may assume normal cyclic prefix when CORESET 0 is configured by MIB or SIB1;
- the UE may assume the same precoding being used within a REG bundle.

For CORESET 0 on a carrier where the SS/PBCH block is detected at sync raster points defined in Tables 5.4.3.1-2 or 5.4.3.1-3 of [14, TS 38.101-1] and configured by the *ControlResourceSetZero* IE:

- $N_{RB}^{CORESET}$ and $N_{symb}^{CORESET}$ are defined by Table 13-0 in clause 13 of [5, TS 38.213];
- if $N_{RB}^{CORESET} = 12$ on a carrier with a channel bandwidth of 3 MHz, the CORESET is obtained by applying the description above assuming interleaved mapping with $R = 2$;
- if $N_{RB}^{CORESET} = 24$ on a carrier with a channel bandwidth of 3 MHz, the CORESET is obtained by applying the description above assuming interleaved mapping with $R = 2$ or non-interleaved mapping as defined by clause 13 of [5, TS 38.213], followed by puncturing the 9 highest-numbered resource blocks to obtain the 15 resource blocks forming CORESET 0;
- if $N_{RB}^{CORESET} = 24$ on a carrier with a channel bandwidth of 5 MHz, the CORESET is obtained by applying the description above assuming interleaved mapping with $R = 2$, followed by puncturing the 4 highest-numbered resource blocks to obtain the 20 resource blocks forming CORESET 0;
- $L = 6$;
- $n_{shift} = N_{ID}^{cell}$;
- the UE may assume normal cyclic prefix when CORESET 0 is configured by MIB or SIB1;
- the UE may assume the same precoding being used within a REG bundle.

7.3.2.3 Scrambling

The UE shall assume the block of bits $b(0), \dots, b(M_{bit} - 1)$, where M_{bit} is the number of bits transmitted on the physical channel, is scrambled prior to modulation, resulting in a block of scrambled bits $\tilde{b}(0), \dots, \tilde{b}(M_{bit} - 1)$ according to

$$\tilde{b}(i) = (b(i) + c(i)) \bmod 2$$

where the scrambling sequence $c(i)$ is given by clause 5.2.1. The scrambling sequence generator shall be initialized with

$$c_{init} = (n_{RNTI} \cdot 2^{16} + n_{ID}) \bmod 2^{31}$$

where

- for a UE-specific search space as defined in clause 10 of [5, TS 38.213], $n_{ID} \in \{0,1,\dots,65535\}$ equals the higher-layer parameter *pdccch-DMRS-ScramblingID* if configured;
- for a PDCCH with the CRC scrambled by G-RNTI, G-CS-RNTI, MCCH-RNTI, or Multicast-MCCH-RNTI in a common search space as defined in clause 10 of [5, TS 38.213], $n_{ID} \in \{0,1, \dots, 65535\}$ equals the higher-layer parameter *pdccch-DMRS-ScramblingID* if configured in a common MBS frequency resource;
- $n_{ID} = N_{ID}^{cell}$ otherwise

and where

- n_{RNTI} is given by the C-RNTI for a PDCCH in a UE-specific search space if the higher-layer parameter *pdccch-DMRS-ScramblingID* is configured, and
- $n_{RNTI} = 0$ otherwise.

7.3.2.4 PDCCH modulation

The UE shall assume the block of bits $\tilde{b}(0), \dots, \tilde{b}(M_{bit} - 1)$ to be QPSK modulated as described in clause 5.1.3, resulting in a block of complex-valued modulation symbols $d(0), \dots, d(M_{symb} - 1)$.

7.3.2.5 Mapping to physical resources

The UE shall assume the block of complex-valued symbols $d(0), \dots, d(M_{\text{symb}} - 1)$ to be scaled by a factor β_{PDCCH} and mapped to resource elements $(k, l)_{p,\mu}$ used for the monitored PDCCH and not used for the associated PDCCH DMRS in increasing order of first k , then l . The antenna port $p = 2000$.

7.3.3 Physical broadcast channel

7.3.3.1 Scrambling

The UE shall assume the block of bits $b(0), \dots, b(M_{\text{bit}} - 1)$, where M_{bit} is the number of bits transmitted on the physical broadcast channel, are scrambled prior to modulation, resulting in a block of scrambled bits $\tilde{b}(0), \dots, \tilde{b}(M_{\text{bit}} - 1)$ according to

$$\tilde{b}(i) = (b(i) + c(i + vM_{\text{bit}})) \bmod 2$$

where the scrambling sequence $c(i)$ is given by clause 5.2. The scrambling sequence shall be initialized with $c_{\text{init}} = N_{\text{ID}}^{\text{cell}}$ at the start of each SS/PBCH block where

- for $\bar{L}_{\text{max}} = 4$, v is the two least significant bits of the candidate SS/PBCH block index
- for $\bar{L}_{\text{max}} > 4$, v is the three least significant bits of the candidate SS/PBCH block index

with \bar{L}_{max} being the maximum number of candidate SS/PBCH blocks in a half frame, as described in [5, TS 38.213].

7.3.3.2 Modulation

The UE shall assume the block of bits $\tilde{b}(0), \dots, \tilde{b}(M_{\text{bit}} - 1)$ are QPSK modulated as described in clause 5.1.3, resulting in a block of complex-valued modulation symbols $d_{\text{PBCH}}(0), \dots, d_{\text{PBCH}}(M_{\text{symb}} - 1)$.

7.3.3.3 Mapping to physical resources

Mapping to physical resources is described in clause 7.4.3.

7.4 Physical signals

7.4.1 Reference signals

7.4.1.1 Demodulation reference signals for PDSCCH

7.4.1.1.1 Sequence generation

The UE shall assume the sequence $r(n)$ is defined by

$$r(n) = \frac{1}{\sqrt{2}}(1 - 2 \cdot c(2n)) + j \frac{1}{\sqrt{2}}(1 - 2 \cdot c(2n + 1)).$$

where the pseudo-random sequence $c(i)$ is defined in clause 5.2.1. The pseudo-random sequence generator shall be initialized with

$$c_{\text{init}} = \left(2^{17} (N_{\text{symb}}^{\text{slot}} n_{\text{s,f}}^{\mu} + l + 1) \left(2N_{\text{ID}}^{\bar{\lambda}} + 1 \right) + 2^{17} \left\lfloor \frac{\bar{\lambda}}{2} \right\rfloor + 2N_{\text{ID}}^{\bar{\lambda}} + \bar{n}_{\text{SCID}}^{\bar{\lambda}} \right) \bmod 2^{31}$$

where l is the OFDM symbol number within the slot, $n_{\text{s,f}}^{\mu}$ is the slot number within a frame, and

- $N_{\text{ID}}^0, N_{\text{ID}}^1 \in \{0, 1, \dots, 65535\}$ are given by the higher-layer parameters *scramblingID0* and *scramblingID1*, respectively, in the *DMRS-DownlinkConfig* IE if provided and the PDSCH is scheduled by PDCCH using DCI format 1_1, 1_2, or 1_3 with the CRC scrambled by C-RNTI, MCS-C-RNTI, or CS-RNTI;
- $N_{\text{ID}}^0 \in \{0, 1, \dots, 65535\}$ is given by the higher-layer parameter *scramblingID0* in the *DMRS-DownlinkConfig* IE if provided and the PDSCH is scheduled by PDCCH using DCI format 1_0 with the CRC scrambled by C-RNTI, MCS-C-RNTI, or CS-RNTI;
- $N_{\text{ID}}^0, N_{\text{ID}}^1 \in \{0, 1, \dots, 65535\}$ are given by the higher-layer parameters *scramblingID0* and *scramblingID1*, respectively, in the *DMRS-DownlinkConfig* IE in *pdsch-ConfigMulticast* if provided in a common MBS frequency resource for multicast and the PDSCH is scheduled by PDCCH using DCI format 4_2 with the CRC scrambled by G-RNTI or G-CS-RNTI;
- $N_{\text{ID}}^0 \in \{0, 1, \dots, 65535\}$ is given by the higher-layer parameter *scramblingID0* in the *DMRS-DownlinkConfig* IE in *pdsch-ConfigMulticast* if provided in a common MBS frequency resource for multicast and the PDSCH is scheduled by PDCCH using DCI format 4_1 with the CRC scrambled by G-RNTI or G-CS-RNTI;
- $N_{\text{ID}}^0 \in \{0, 1, \dots, 65535\}$ is given by the higher-layer parameter *scramblingID0* in *pdsch-ConfigMCCH* or *pdsch-ConfigMTCH* if provided in a common MBS frequency resource for broadcast and the PDSCH is scheduled by PDCCH with the CRC scrambled by MCCH-RNTI or G-RNTI, respectively;
- $N_{\text{ID}}^{\bar{\lambda}} = N_{\text{ID}}^{\text{cell}}$ otherwise;
- $\bar{n}_{\text{SCID}}^{\bar{\lambda}}$ and $\bar{\lambda}$ are given by
 - if the higher-layer parameter *dmrs-Downlink* in the *DMRS-DownlinkConfig* IE is provided

$$\bar{n}_{\text{SCID}}^{\bar{\lambda}} = \begin{cases} n_{\text{SCID}} & \lambda = 0 \text{ or } \lambda = 2 \\ 1 - n_{\text{SCID}} & \lambda = 1 \end{cases}$$

$$\bar{\lambda} = \lambda$$

where λ is the CDM group defined in clause 7.4.1.1.2.

- otherwise by

$$\bar{n}_{\text{SCID}}^{\bar{\lambda}} = n_{\text{SCID}}$$

$$\bar{\lambda} = 0$$

The quantity $n_{\text{SCID}} \in \{0, 1\}$ is given by the DM-RS sequence initialization field, if present, in the DCI associated with the PDSCH transmission if DCI format 1_1, 1_2, 1_3, or 4_2 in [4, TS 38.212] is used, otherwise $n_{\text{SCID}} = 0$.

7.4.1.1.2 Mapping to physical resources

The UE shall assume the PDSCH DM-RS being mapped to physical resources according to configuration type 1 or configuration type 2 as given by the higher-layer parameter *dmrs-Type*.

The UE shall assume the sequence $r(m)$ is scaled by a factor $\beta_{\text{PDSCH}}^{\text{DMRS}}$ to conform with the transmission power specified in [6, TS 38.214] and mapped to resource elements $(k, l)_{p, \mu}$ according to

- if the higher-layer parameter *dmrs-TypeEnh* is configured and the PDSCH is not scheduled by DCI format 1_0, 4_0, or 4_1

$$\tilde{a}_{k,l}^{(p,j,\mu)} = \beta_{\text{PDSCH}}^{\text{DMRS}} w_f(k') w_i(l') r(4n + k')$$

$$k = \begin{cases} 8n + 2k' + \Delta & \text{configuration type 1} \\ 12n + k' + \Delta & \text{configuration type 2, } k' = 0, 1 \\ 12n + k' + \Delta + 4 & \text{configuration type 2, } k' = 2, 3 \end{cases}$$

$$k' = 0, 1, 2, 3$$

$$l = \bar{l} + l'$$

$$n = 0, 1, \dots$$

$$j = 0, 1, \dots, v - 1$$

- otherwise

$$\begin{aligned}\tilde{a}_{k,l}^{(p_j,\mu)} &= \beta_{\text{PDSCH}}^{\text{DMRS}} w_f(k') w_t(l') r(2n + k') \\ k &= \begin{cases} 4n + 2k' + \Delta & \text{configuration type 1} \\ 6n + k' + \Delta & \text{configuration type 2} \end{cases} \\ k' &= 0, 1 \\ l &= \bar{l} + l' \\ n &= 0, 1, \dots \\ j &= 0, 1, \dots, v - 1\end{aligned}$$

where $w_f(k')$, $w_t(l')$, and Δ are given by Tables 7.4.1.1.2-1 and 7.4.1.1.2-2 and the following conditions are fulfilled:

- the resource elements are within the common resource blocks allocated for PDSCH transmission

The reference point for k is

- subcarrier 0 of the lowest-numbered resource block in CORESET 0 if the corresponding PDCCH is associated with CORESET 0 and Type0-PDCCH common search space and is addressed to SI-RNTI;
- otherwise, subcarrier 0 in common resource block 0

The reference point for l and the position l_0 of the first DM-RS symbol depends on the mapping type:

- for PDSCH mapping type A:
 - l is defined relative to the start of the slot
 - $l_0 = 3$ if the higher-layer parameter *dmrs-TypeA-Position* is equal to 'pos3' and $l_0 = 2$ otherwise
- for PDSCH mapping type B:
 - l is defined relative to the start of the scheduled PDSCH resources
 - $l_0 = 0$

The position(s) of the DM-RS symbols is given by \bar{l} and duration l_d where

- for PDSCH mapping type A, l_d is the duration between the first OFDM symbol of the slot and the last OFDM symbol of the scheduled PDSCH resources in the slot
- for PDSCH mapping type B, l_d is the duration of the scheduled PDSCH resources

and according to Tables 7.4.1.1.2-3 and 7.4.1.1.2-4.

For PDSCH mapping type A

- the case *dmrs-AdditionalPosition* equals to 'pos3' is only supported when *dmrs-TypeA-Position* is equal to 'pos2';
- $l_d = 3$ and $l_d = 4$ symbols in Tables 7.4.1.1.2-3 and 7.4.1.1.2-4 respectively is only applicable when *dmrs-TypeA-Position* is equal to 'pos2';
- single-symbol DM-RS, $l_1 = 11$ except if all of the following conditions are fulfilled in which case $l_1 = 12$:
 - the higher-layer parameter *lte-CRS-ToMatchAround*, *lte-CRS-PatternList1*, *lte-CRS-PatternList2*, *lte-CRS-PatternList3*, or *lte-CRS-PatternList4* is configured; and
 - the higher-layer parameter *dmrs-AdditionalPosition* is equal to 'pos1' and $l_0 = 3$; and
 - the UE has indicated it is capable of *additionalDMRS-DL-Alt*

For PDSCH mapping type B

- if the PDSCH duration $l_d \in \{2,3,4,5,6,7,8,9,10,11,12,13\}$ OFDM symbols for normal cyclic prefix or $l_d \in \{2,4,6\}$ OFDM symbols for extended cyclic prefix, and the front-loaded DM-RS of the PDSCH allocation

collides with resources reserved for a search space set associated with a CORESET, \bar{l} shall be incremented such that the first DM-RS symbol occurs immediately after the CORESET and until no collision with any CORESET occurs, and

- if the PDSCH duration l_d is 2 symbols, the UE is not expected to receive a DM-RS symbol beyond the second symbol;
- if the PDSCH duration l_d is 5 symbols and if one additional single-symbol DMRS is configured, the UE only expects the additional DM-RS to be transmitted on the 5th symbol when the front-loaded DM-RS symbol is in the 1st symbol of the PDSCH duration, otherwise the UE should expect that the additional DM-RS is not transmitted;
- if the PDSCH duration l_d is 7 symbols for normal cyclic prefix or 6 symbols for extended cyclic prefix:
 - if one additional single-symbol DM-RS is configured, the UE only expects the additional DM-RS to be transmitted on the 5th or 6th symbol when the front-loaded DM-RS symbol is in the 1st or 2nd symbol, respectively, of the PDSCH duration, otherwise the UE should expect that the additional DM-RS is not transmitted;
- if the PDSCH duration $l_d \in \{5,6,7,8,9,10,11,12,13\}$ OFDM symbols, the UE is not expected to receive the front-loaded DM-RS beyond the 4th symbol;
- if the PDSCH duration l_d is 12 or 13 symbols, the UE is not expected to receive DM-RS mapped to symbol 12 or later in the slot;
- for all values of the PDSCH duration l_d other than 2, 5, and 7 symbols, the UE is not expected to receive DM-RS beyond the $(l_d - 1)$:th symbol;
- if the PDSCH duration l_d is less than or equal to 4 OFDM symbols, only single-symbol DM-RS is supported.
- if the higher-layer parameter *lte-CRS-ToMatchAround*, *lte-CRS-PatternList1*, *lte-CRS-PatternList2*, *lte-CRS-PatternList3*, or *lte-CRS-PatternList4* is configured, the PDSCH duration $l_d = 10$ symbols for normal cyclic prefix, the subcarrier spacing configuration $\mu = 0$, single-symbol DM-RS is configured, and at least one PDSCH DM-RS symbol in the PDSCH allocation collides with a symbol containing resource elements as indicated by the higher-layer parameter *lte-CRS-ToMatchAround*, *lte-CRS-PatternList1*, *lte-CRS-PatternList2*, *lte-CRS-PatternList3*, or *lte-CRS-PatternList4*, then \bar{l} shall be incremented by one in all slots.

The time-domain index l' and the supported antenna ports p are given by Table 7.4.1.1.2-5 where

- single-symbol DM-RS is used if the higher-layer parameter *maxLength* in the *DMRS-DownlinkConfig* IE is not configured;
- single-symbol or double-symbol DM-RS is determined by the associated DCI if the higher-layer parameter *maxLength* in the *DMRS-DownlinkConfig* IE is equal to 'len2';
- basic or enhanced DM-RS multiplexing is controlled by the higher-layer parameter *dmrs-TypeEnh*.

In absence of CSI-RS configuration, and unless otherwise configured, the UE may assume PDSCH DM-RS and SS/PBCH block to be quasi co-located with respect to Doppler shift, Doppler spread, average delay, delay spread, and, when applicable, spatial Rx parameters. Unless specified otherwise, the UE may assume that the PDSCH DM-RS within the same CDM group are quasi co-located with respect to Doppler shift, Doppler spread, average delay, delay spread, and spatial Rx (when applicable). The UE may assume that DMRS ports associated with a TCI state as described in clause 5.1.6.2 of [6, TS 38.214] of a PDSCH are QCL with QCL Type A, Type D (when applicable) and average gain.

The UE may assume that no DM-RS collides with the SS/PBCH block.

Table 7.4.1.1.2-1: Parameters for PDSCH DM-RS configuration type 1.

| p | CDM group λ | Δ | $[w_f(0) \dots w_f(3)]$ | $[w_t(0) \ w_t(1)]$ |
|------|---------------------|----------|-------------------------|---------------------|
| 1000 | 0 | 0 | [+1 +1 +1 +1] | [+1 +1] |
| 1001 | 0 | 0 | [+1 -1 +1 -1] | [+1 +1] |
| 1002 | 1 | 1 | [+1 +1 +1 +1] | [+1 +1] |
| 1003 | 1 | 1 | [+1 -1 +1 -1] | [+1 +1] |
| 1004 | 0 | 0 | [+1 +1 +1 +1] | [+1 -1] |
| 1005 | 0 | 0 | [+1 -1 +1 -1] | [+1 -1] |
| 1006 | 1 | 1 | [+1 +1 +1 +1] | [+1 -1] |
| 1007 | 1 | 1 | [+1 -1 +1 -1] | [+1 -1] |
| 1008 | 0 | 0 | [+1 +1 -1 -1] | [+1 +1] |
| 1009 | 0 | 0 | [+1 -1 -1 +1] | [+1 +1] |
| 1010 | 1 | 1 | [+1 +1 -1 -1] | [+1 +1] |
| 1011 | 1 | 1 | [+1 -1 -1 +1] | [+1 +1] |
| 1012 | 0 | 0 | [+1 +1 -1 -1] | [+1 -1] |
| 1013 | 0 | 0 | [+1 -1 -1 +1] | [+1 -1] |
| 1014 | 1 | 1 | [+1 +1 -1 -1] | [+1 -1] |
| 1015 | 1 | 1 | [+1 -1 -1 +1] | [+1 -1] |

Table 7.4.1.1.2-2: Parameters for PDSCH DM-RS configuration type 2.

| p | CDM group λ | Δ | $[w_f(0) \dots w_f(3)]$ | $[w_t(0) \ w_t(1)]$ |
|------|---------------------|----------|-------------------------|---------------------|
| 1000 | 0 | 0 | [+1 +1 +1 +1] | [+1 +1] |
| 1001 | 0 | 0 | [+1 -1 +1 -1] | [+1 +1] |
| 1002 | 1 | 2 | [+1 +1 +1 +1] | [+1 +1] |
| 1003 | 1 | 2 | [+1 -1 +1 -1] | [+1 +1] |
| 1004 | 2 | 4 | [+1 +1 +1 +1] | [+1 +1] |
| 1005 | 2 | 4 | [+1 -1 +1 -1] | [+1 +1] |
| 1006 | 0 | 0 | [+1 +1 +1 +1] | [+1 -1] |
| 1007 | 0 | 0 | [+1 -1 +1 -1] | [+1 -1] |
| 1008 | 1 | 2 | [+1 +1 +1 +1] | [+1 -1] |
| 1009 | 1 | 2 | [+1 -1 +1 -1] | [+1 -1] |
| 1010 | 2 | 4 | [+1 +1 +1 +1] | [+1 -1] |
| 1011 | 2 | 4 | [+1 -1 +1 -1] | [+1 -1] |
| 1012 | 0 | 0 | [+1 +1 -1 -1] | [+1 +1] |
| 1013 | 0 | 0 | [+1 -1 -1 +1] | [+1 +1] |
| 1014 | 1 | 2 | [+1 +1 -1 -1] | [+1 +1] |
| 1015 | 1 | 2 | [+1 -1 -1 +1] | [+1 +1] |
| 1016 | 2 | 4 | [+1 +1 -1 -1] | [+1 +1] |
| 1017 | 2 | 4 | [+1 -1 -1 +1] | [+1 +1] |
| 1018 | 0 | 0 | [+1 +1 -1 -1] | [+1 -1] |
| 1019 | 0 | 0 | [+1 -1 -1 +1] | [+1 -1] |
| 1020 | 1 | 2 | [+1 +1 -1 -1] | [+1 -1] |
| 1021 | 1 | 2 | [+1 -1 -1 +1] | [+1 -1] |
| 1022 | 2 | 4 | [+1 +1 -1 -1] | [+1 -1] |
| 1023 | 2 | 4 | [+1 -1 -1 +1] | [+1 -1] |

Table 7.4.1.1.2-3: PDSCH DM-RS positions \bar{l} for single-symbol DM-RS.

| l_d in symbols | DM-RS positions \bar{l} | | | | | | | |
|------------------|---------------------------|------------|--------------|-----------------|-------------------------|----------|-------------|----------------|
| | PDSCH mapping type A | | | | PDSCH mapping type B | | | |
| | dmrs-AdditionalPosition | | | | dmrs-AdditionalPosition | | | |
| | pos0 | pos1 | pos2 | pos3 | pos0 | pos1 | pos2 | pos3 |
| 2 | - | - | - | - | l_0 | l_0 | l_0 | l_0 |
| 3 | l_0 | l_0 | l_0 | l_0 | l_0 | l_0 | l_0 | l_0 |
| 4 | l_0 | l_0 | l_0 | l_0 | l_0 | l_0 | l_0 | l_0 |
| 5 | l_0 | l_0 | l_0 | l_0 | l_0 | $l_0, 4$ | $l_0, 4$ | $l_0, 4$ |
| 6 | l_0 | l_0 | l_0 | l_0 | l_0 | $l_0, 4$ | $l_0, 4$ | $l_0, 4$ |
| 7 | l_0 | l_0 | l_0 | l_0 | l_0 | $l_0, 4$ | $l_0, 4$ | $l_0, 4$ |
| 8 | l_0 | $l_0, 7$ | $l_0, 7$ | $l_0, 7$ | l_0 | $l_0, 6$ | $l_0, 3, 6$ | $l_0, 3, 6$ |
| 9 | l_0 | $l_0, 7$ | $l_0, 7$ | $l_0, 7$ | l_0 | $l_0, 7$ | $l_0, 4, 7$ | $l_0, 4, 7$ |
| 10 | l_0 | $l_0, 9$ | $l_0, 6, 9$ | $l_0, 6, 9$ | l_0 | $l_0, 7$ | $l_0, 4, 7$ | $l_0, 4, 7$ |
| 11 | l_0 | $l_0, 9$ | $l_0, 6, 9$ | $l_0, 6, 9$ | l_0 | $l_0, 8$ | $l_0, 4, 8$ | $l_0, 3, 6, 9$ |
| 12 | l_0 | $l_0, 9$ | $l_0, 6, 9$ | $l_0, 5, 8, 11$ | l_0 | $l_0, 9$ | $l_0, 5, 9$ | $l_0, 3, 6, 9$ |
| 13 | l_0 | l_0, l_1 | $l_0, 7, 11$ | $l_0, 5, 8, 11$ | l_0 | $l_0, 9$ | $l_0, 5, 9$ | $l_0, 3, 6, 9$ |
| 14 | l_0 | l_0, l_1 | $l_0, 7, 11$ | $l_0, 5, 8, 11$ | - | - | - | - |

Table 7.4.1.1.2-4: PDSCH DM-RS positions \bar{l} for double-symbol DM-RS.

| l_d in symbols | DM-RS positions \bar{l} | | | | | |
|------------------|---------------------------|-----------|------|-------------------------|----------|------|
| | PDSCH mapping type A | | | PDSCH mapping type B | | |
| | dmrs-AdditionalPosition | | | dmrs-AdditionalPosition | | |
| | pos0 | pos1 | pos2 | pos0 | pos1 | pos2 |
| <4 | | | | - | - | |
| 4 | l_0 | l_0 | | - | - | |
| 5 | l_0 | l_0 | | l_0 | l_0 | |
| 6 | l_0 | l_0 | | l_0 | l_0 | |
| 7 | l_0 | l_0 | | l_0 | l_0 | |
| 8 | l_0 | l_0 | | l_0 | $l_0, 5$ | |
| 9 | l_0 | l_0 | | l_0 | $l_0, 5$ | |
| 10 | l_0 | $l_0, 8$ | | l_0 | $l_0, 7$ | |
| 11 | l_0 | $l_0, 8$ | | l_0 | $l_0, 7$ | |
| 12 | l_0 | $l_0, 8$ | | l_0 | $l_0, 8$ | |
| 13 | l_0 | $l_0, 10$ | | l_0 | $l_0, 8$ | |
| 14 | l_0 | $l_0, 10$ | | - | - | |

Table 7.4.1.1.2-5: PDSCH DM-RS time index l' and antenna ports p .

| DM-RS multiplexing | DM-RS duration | l' | Supported antenna ports p | |
|--------------------|---------------------|------|-----------------------------|--------------------------|
| | | | Configuration type 1 | Configuration type 2 |
| Basic | single-symbol DM-RS | 0 | 1000 – 1003 | 1000 – 1005 |
| | double-symbol DM-RS | 0, 1 | 1000 – 1007 | 1000 – 1011 |
| Enhanced | single-symbol DM-RS | 0 | 1000 – 1003, 1008 – 1011 | 1000 – 1005, 1012 – 1017 |
| | double-symbol DM-RS | 0, 1 | 1000 – 1015 | 1000 – 1023 |

7.4.1.2 Phase-tracking reference signals for PDSCH

7.4.1.2.1 Sequence generation

The phase-tracking reference signal for subcarrier k is given by

- If the higher-layer parameter *dmrs-TypeEnh* is configured

$$r_k = r(4m + k')$$

- otherwise

$$r_k = r(2m + k')$$

where $r(\cdot)$ is the demodulation reference signal given by clause 7.4.1.1.2 at position l_0 and subcarrier k .

7.4.1.2.2 Mapping to physical resources

The UE shall assume phase-tracking reference signals being present only in the resource blocks used for the PDSCH, and only if the procedure in [6, TS 38.214] indicates phase-tracking reference signals being used.

If present, the UE shall assume the PDSCH PT-RS is scaled by a factor $\beta_{\text{PT-RS},i}$ to conform with the transmission power specified in clause 4.1 of [6, TS 38.214] and mapped to resource elements $(k, l)_{p,\mu}$ according to

$$a_{k,l}^{(p,\mu)} = \beta_{\text{PT-RS},i} r_k$$

when all the following conditions are fulfilled

- l is within the OFDM symbols allocated for the PDSCH transmission
- resource element $(k, l)_{p,\mu}$ is not used for DM-RS, non-zero-power CSI-RS (except for those configured for mobility measurements or with *resourceType* in corresponding *CSI-ResourceConfig* configured as 'aperiodic'), zero-power CSI-RS, SS/PBCH block, a detected PDCCH according to clause 5.1.4.1 of [6, TS38.214], or is declared as 'not available' by clause 5.1.4 of [6, TS 38.214]

The set of time indices l defined relative to the start of the PDSCH allocation is defined by

1. set $i = 0$ and $l_{\text{ref}} = 0$
2. if any symbol in the interval $\max(l_{\text{ref}} + (i - 1)L_{\text{PT-RS}} + 1, l_{\text{ref}}), \dots, l_{\text{ref}} + iL_{\text{PT-RS}}$ overlaps with a symbol used for DM-RS according to clause 7.4.1.1.2
 - set $i = 1$
 - set l_{ref} to the symbol index of the DM-RS symbol in case of a single-symbol DM-RS and to the symbol index of the second DM-RS symbol in case of a double-symbol DM-RS
 - repeat from step 2 as long as $l_{\text{ref}} + iL_{\text{PT-RS}}$ is inside the PDSCH allocation
3. add $l_{\text{ref}} + iL_{\text{PT-RS}}$ to the set of time indices for PT-RS
4. increment i by one
5. repeat from step 2 above as long as $l_{\text{ref}} + iL_{\text{PT-RS}}$ is inside the PDSCH allocation

where $L_{\text{PT-RS}} \in \{1, 2, 4\}$.

For the purpose of PT-RS mapping, the resource blocks allocated for PDSCH transmission are numbered from 0 to $N_{\text{RB}} - 1$ from the lowest scheduled resource block to the highest. The corresponding subcarriers in this set of resource blocks are numbered in increasing order starting from the lowest frequency from 0 to $N_{\text{sc}}^{\text{RB}} N_{\text{RB}} - 1$. The subcarriers to which the UE shall assume the PT-RS is mapped are given by

$$k = k_{\text{ref}}^{\text{RE}} + (iK_{\text{PT-RS}} + k_{\text{ref}}^{\text{RB}})N_{\text{sc}}^{\text{RB}}$$

$$k_{\text{ref}}^{\text{RB}} = \begin{cases} n_{\text{RNTI}} \bmod K_{\text{PT-RS}} & \text{if } N_{\text{RB}} \bmod K_{\text{PT-RS}} = 0 \\ n_{\text{RNTI}} \bmod (N_{\text{RB}} \bmod K_{\text{PT-RS}}) & \text{otherwise} \end{cases}$$

where

- $i = 0, 1, 2, \dots$
- $k_{\text{ref}}^{\text{RE}}$ is given by Table 7.4.1.2.2-1 for the DM-RS port associated with the PT-RS port according to clause 5.1.6.3 in [6, TS 38.214]. If the higher-layer parameter *resourceElementOffset* in the *PTRS-DownlinkConfig* IE is not configured, the column corresponding to 'offset00' shall be used.
- n_{RNTI} is the RNTI associated with the DCI scheduling the transmission
- N_{RB} is the number of resource blocks scheduled
- $K_{\text{PT-RS}} \in \{2, 4\}$ is given by [6, TS 38.214].

Table 7.4.1.2.2-1: The parameter $k_{\text{ref}}^{\text{RE}}$.

| DM-RS antenna port p | $k_{\text{ref}}^{\text{RE}}$ | | | | | | | |
|---------------------------|------------------------------|----------|----------|----------|------------------------------|----------|----------|----------|
| | DM-RS Configuration type 1 | | | | DM-RS Configuration type 2 | | | |
| | <i>resourceElementOffset</i> | | | | <i>resourceElementOffset</i> | | | |
| | offset00 | offset01 | offset10 | offset11 | offset00 | offset01 | offset10 | offset11 |
| 1000 | 0 | 2 | 6 | 8 | 0 | 1 | 6 | 7 |
| 1001 | 2 | 4 | 8 | 10 | 1 | 6 | 7 | 0 |
| 1002 | 1 | 3 | 7 | 9 | 2 | 3 | 8 | 9 |
| 1003 | 3 | 5 | 9 | 11 | 3 | 8 | 9 | 2 |
| 1004 | - | - | - | - | 4 | 5 | 10 | 11 |
| 1005 | - | - | - | - | 5 | 10 | 11 | 4 |
| 1008 | 4 | 6 | 10 | 0 | - | - | - | - |
| 1009 | 6 | 8 | 0 | 2 | - | - | - | - |
| 1010 | 5 | 7 | 11 | 1 | - | - | - | - |
| 1011 | 7 | 9 | 1 | 3 | - | - | - | - |
| 1012 | - | - | - | - | 6 | 7 | 0 | 1 |
| 1013 | - | - | - | - | 7 | 0 | 1 | 6 |
| 1014 | - | - | - | - | 8 | 9 | 2 | 3 |
| 1015 | - | - | - | - | 9 | 2 | 3 | 8 |
| 1016 | - | - | - | - | 10 | 11 | 4 | 5 |
| 1017 | - | - | - | - | 11 | 4 | 5 | 10 |

7.4.1.3 Demodulation reference signals for PDCCH

7.4.1.3.1 Sequence generation

The UE shall assume the reference-signal sequence $r_l(m)$ for OFDM symbol l is defined by

$$r_l(m) = \frac{1}{\sqrt{2}}(1 - 2 \cdot c(2m)) + j \frac{1}{\sqrt{2}}(1 - 2 \cdot c(2m + 1)).$$

where the pseudo-random sequence $c(i)$ is defined in clause 5.2.1. The pseudo-random sequence generator shall be initialized with

$$c_{\text{init}} = (2^{17}(N_{\text{slot}}^{\text{slot}} n_{\text{s,f}}^{\mu} + l + 1)(2N_{\text{ID}} + 1) + 2N_{\text{ID}}) \bmod 2^{31}$$

where l is the OFDM symbol number within the slot, $n_{\text{s,f}}^{\mu}$ is the slot number within a frame, and

- $N_{\text{ID}} \in \{0, 1, \dots, 65535\}$ is given by the higher-layer parameter *pdccch-DMRS-ScramblingID* if provided;

- $N_{ID} \in \{0,1, \dots, 65535\}$ is given by the higher-layer parameter *pdccch-DMRS-ScramblingID* if configured for a common search space in a common MBS frequency resource;
- $N_{ID} = N_{ID}^{\text{cell}}$ otherwise.

7.4.1.3.2 Mapping to physical resources

The UE shall assume the sequence $r_l(m)$ is mapped to resource elements $(k, l)_{p,\mu}$ according to

$$\begin{aligned} a_{k,l}^{(p,\mu)} &= \beta_{\text{DMRS}}^{\text{PDCCH}} \cdot r_l(3n+k') \\ k &= nN_{\text{sc}}^{\text{RB}} + 4k' + 1 \\ k' &= 0,1,2 \\ n &= 0,1,\dots \end{aligned}$$

where the following conditions are fulfilled

- they are within the resource element groups constituting the PDCCH the UE attempts to decode if the higher-layer parameter *precoderGranularity* equals *sameAsREG-bundle*,
- all resource-element groups within the set of contiguous resource blocks in the CORESET where the UE attempts to decode the PDCCH if the higher-layer parameter *precoderGranularity* equals *allContiguousRBs*.

The reference point for k is

- subcarrier 0 of the lowest-numbered resource block in the CORESET if the CORESET is configured by the PBCH or by the *controlResourceSetZero* field in the *PDCCH-ConfigCommon* IE,
- subcarrier 0 in common resource block 0 otherwise

The quantity l is the OFDM symbol number within the slot.

The antenna port $p = 2000$.

A UE not attempting to detect a PDCCH in a CORESET shall not make any assumptions on the presence or absence of DM-RS in the CORESET.

In absence of CSI-RS configuration, and unless otherwise configured, the UE may assume PDCCH DM-RS and SS/PBCH block to be quasi co-located with respect to Doppler shift, Doppler spread, average delay, delay spread, and, when applicable, spatial Rx parameters.

7.4.1.4 Demodulation reference signals for PBCH

7.4.1.4.1 Sequence generation

The UE shall assume the reference-signal sequence $r(m)$ for an SS/PBCH block is defined by

$$r(m) = \frac{1}{\sqrt{2}}(1 - 2 \cdot c(2m)) + j \frac{1}{\sqrt{2}}(1 - 2 \cdot c(2m+1))$$

where $c(n)$ is given by clause 5.2. The scrambling sequence generator shall be initialized at the start of each SS/PBCH block occasion with

$$c_{\text{init}} = 2^{11} (\bar{i}_{\text{SSB}} + 1) \left(\left\lfloor \frac{N_{\text{ID}}^{\text{cell}}}{4} \right\rfloor + 1 \right) + 2^6 (\bar{i}_{\text{SSB}} + 1) + (N_{\text{ID}}^{\text{cell}} \bmod 4)$$

where

- for $\bar{L}_{\text{max}} = 4$, $\bar{i}_{\text{SSB}} = i_{\text{SSB}} + 4n_{\text{hf}}$ where n_{hf} is the number of the half-frame in which the PBCH is transmitted in a frame with $n_{\text{hf}} = 0$ for the first half-frame in the frame and $n_{\text{hf}} = 1$ for the second half-frame in the frame, and i_{SSB} is the two least significant bits of the candidate SS/PBCH block index as defined in [5, TS 38.213]

- for $\bar{L}_{\max} > 4$, $\bar{l}_{\text{SSB}} = i_{\text{SSB}}$ where i_{SSB} is the three least significant bits of the candidate SS/PBCH block index as defined in [5, TS 38.213]

with \bar{L}_{\max} being the maximum number of candidate SS/PBCH blocks in a half frame, as described in [5, TS 38.213].

7.4.1.4.2 Mapping to physical resources

Mapping to physical resources is described in clause 7.4.3.

7.4.1.5 CSI reference signals

7.4.1.5.1 General

Zero-power (ZP) and non-zero-power (NZP) CSI-RS are defined

- for a non-zero-power CSI-RS configured by the *NZP-CSI-RS-Resource* IE or by the *CSI-RS-Resource-Mobility* field in the *CSI-RS-ResourceConfigMobility* IE or by the *TRS-ResourceSet* IE, the sequence shall be generated according to clause 7.4.1.5.2 and mapped to resource elements according to clause 7.4.1.5.3
- for a zero-power CSI-RS configured by the *ZP-CSI-RS-Resource* IE, the UE shall assume that the resource elements defined in clause 7.4.1.5.3 are not used for PDSCH transmission subject to clause 5.1.4.2 of [6, TS 38.214]. The UE performs the same measurement/reception on channels/signals except PDSCH regardless of whether they collide with ZP CSI-RS or not.

7.4.1.5.2 Sequence generation

The UE shall assume the reference-signal sequence $r(m)$ is defined by

$$r(m) = \frac{1}{\sqrt{2}}(1 - 2 \cdot c(2m)) + j \frac{1}{\sqrt{2}}(1 - 2 \cdot c(2m+1))$$

where the pseudo-random sequence $c(i)$ is defined in clause 5.2.1. The pseudo-random sequence generator shall be initialised with

$$c_{\text{init}} = (2^{10}(N_{\text{slot}}^{\text{slot}} n_{\text{s,f}}^{\mu} + l + 1)(2n_{\text{ID}} + 1) + n_{\text{ID}}) \bmod 2^{31}$$

at the start of each OFDM symbol where $n_{\text{s,f}}^{\mu}$ is the slot number within a radio frame, l is the OFDM symbol number within a slot, and n_{ID} equals the higher-layer parameter *scramblingID* or *sequenceGenerationConfig*.

7.4.1.5.3 Mapping to physical resources

For each CSI-RS configured, the UE shall assume the sequence $r(m)$ being mapped to resources elements $(k, l)_{p,\mu}$ according to

$$a_{k,l}^{(p,\mu)} = \beta_{\text{CSI-RS}} w_{\text{f}}(k') \cdot w_{\text{t}}(l') \cdot r_{l,n_{\text{s,f}}}^{\mu}(m')$$

$$m' = \lfloor n\alpha \rfloor + k' + \left\lfloor \frac{\bar{k}\rho}{N_{\text{sc}}^{\text{RB}}} \right\rfloor$$

$$k = nN_{\text{sc}}^{\text{RB}} + \bar{k} + k'$$

$$l = \bar{l} + l'$$

$$\alpha = \begin{cases} \rho & \text{for } X = 1 \\ 2\rho & \text{for } X > 1 \end{cases}$$

$$n = 0, 1, \dots$$

when the following conditions are fulfilled:

- the resource element $(k, l)_{p,\mu}$ is within the resource blocks occupied by the CSI-RS resource for which the UE is configured

The reference point for $k = 0$ is subcarrier 0 in common resource block 0.

The value of ρ is given by the higher-layer parameter *density* in the *CSI-RS-ResourceMapping* IE or the *CSI-RS-CellMobility* IE and the number of ports X is given by the higher-layer parameter *nrofPorts*. For NZP CSI-RS configured by the *TRS-ResourceSet* IE, the density $\rho = 3$ and number of ports $X = 1$.

The UE is not expected to receive CSI-RS and DM-RS on the same resource elements.

The UE shall assume $\beta_{\text{CSI-RS}} > 0$ for a non-zero-power CSI-RS where $\beta_{\text{CSI-RS}}$ is selected such that the power offset specified by the higher-layer parameter *powerControlOffsetSS* in the *NZP-CSI-RS-Resource* IE or in the *TRS-ResourceSet* IE, if provided, is fulfilled.

The quantities k' , l' , $w_f(k')$, and $w_t(l')$ are given by Tables 7.4.1.5.3-1 to 7.4.1.5.3-5 where each (\bar{k}, \bar{l}) in a given row of Table 7.4.1.5.3-1 corresponds to a CDM group of size 1 (no CDM) or size 2, 4, or 8. The CDM type is provided by the higher layer parameter *cdm-Type* in the *CSI-RS-ResourceMapping* IE. For NZP CSI-RS configured by the *TRS-ResourceSet* IE, the CDM type is 'noCDM'. The indices k' and l' index resource elements within a CDM group.

The time-domain locations $l_0 \in \{0,1, \dots, 13\}$ and $l_1 \in \{2, 3, \dots, 12\}$ are provided by the higher-layer parameters *firstOFDMSymbolInTimeDomain* and *firstOFDMSymbolInTimeDomain2*, respectively, in the *CSI-RS-ResourceMapping* IE or the *CSI-RS-ResourceConfigMobility* IE and defined relative to the start of a slot. For NZP CSI-RS configured by *TRS-ResourceSet* IE, the time-domain location $l_0 \in \{0,1, \dots, 13\}$ is provided by the higher-layer parameter *firstOFDMSymbolInTimeDomain* or *firstOFDMSymbolInTimeDomain+4*.

The frequency-domain location is given by a bitmap provided by the higher-layer parameter *frequencyDomainAllocation* in the *CSI-RS-ResourceMapping* IE, the *CSI-RS-ResourceConfigMobility* IE, or the *TRS-ResourceSet* IE, with the bitmap and value of k_i in Table 7.4.1.5.3-1 given by

- $[b_3 \dots b_0]$, $k_{i-1} = f(i)$ for row 1 of Table 7.4.1.5.3-1
- $[b_{11} \dots b_0]$, $k_{i-1} = f(i)$ for row 2 of Table 7.4.1.5.3-1
- $[b_2 \dots b_0]$, $k_{i-1} = 4f(i)$ for row 4 of Table 7.4.1.5.3-1
- $[b_5 \dots b_0]$, $k_{i-1} = 2f(i)$ for all other cases

where $f(i)$ is the bit number of the i^{th} bit in the bitmap set to one, repeated across every $[1/\rho]$ of the resource blocks configured for CSI-RS reception by the UE. The starting position and number of the resource blocks in which the UE shall assume that CSI-RS is transmitted are given by the higher-layer parameters *freqBand* and *density* in the *CSI-RS-ResourceMapping* IE for the bandwidth part given by the higher-layer parameter *BWP-Id* in the *CSI-ResourceConfig* IE or given by the higher-layer parameters *nrofPRBs* in the *CSI-RS-CellMobility* IE where the *startPRB* given by *csi-rs-MeasurementBW* is relative to common resource block 0. For NZP CSI-RS configured by *TRS-ResourceSet* IE, the starting position and number of the resource blocks in which the CSI-RS can be transmitted are given by the higher-layer parameters *nrofRBs*, and *startingRB* in the *TRS-ResourceSet* IE, where *startingRB* is relative to common resource block 0 and the density $\rho = 3$.

The UE shall assume that a CSI-RS is transmitted using antenna ports p numbered according to

$$\begin{aligned} p &= 3000 + s + jL; \\ j &= 0,1,\dots, N/L - 1 \\ s &= 0,1,\dots, L - 1; \end{aligned}$$

where s is the sequence index provided by Tables 7.4.1.5.3-2 to 7.4.1.5.3-5, $L \in \{1,2,4,8\}$ is the CDM group size, and N is the number of CSI-RS ports. The CDM group index j given in Table 7.4.1.5.3-1 corresponds to the time/frequency locations (\bar{k}, \bar{l}) for a given row of the table. The CDM groups are numbered in order of increasing frequency domain allocation first and then increasing time domain allocation.

For a CSI-RS resource configured as periodic or semi-persistent by the higher-layer parameter *resourceType*, configured by the higher-layer parameter *CSI-RS-CellMobility*, or configured by the higher-layer parameter *TRS-ResourceSet*, the UE shall assume that the CSI-RS is transmitted in slots satisfying

$$(N_{\text{slot}}^{\text{frame},\mu} n_f + n_{s,f}^{\mu} - T_{\text{offset}}) \bmod T_{\text{CSI-RS}} = 0$$

where the periodicity $T_{\text{CSI-RS}}$ (in slots) and slot offset T_{offset} are obtained from the higher-layer parameter *CSI-ResourcePeriodicityAndOffset*, *slotConfig*, *periodicityAndOffset*. The UE shall assume that CSI-RS is transmitted in a candidate slot as described in clause 11.1 of [5, TS 38.213], clause 10.4B of [5, TS 38.213].

The UE may assume that antenna ports within a CSI-RS resource are quasi co-located with QCL Type A, Type D (when applicable), and average gain.

Table 7.4.1.5.3-1: CSI-RS locations within a slot.

| Row | Ports X | Density ρ | <i>cdm-Type</i> | (\bar{k}, \bar{l}) | CDM group index j | k' | l' |
|-----|--------------|-------------------|-----------------|--|---------------------------------------|------|------------|
| 1 | 1 | 3 | noCDM | $(k_0, l_0), (k_0 + 4, l_0), (k_0 + 8, l_0)$ | 0,0,0 | 0 | 0 |
| 2 | 1 | 1, 0.5 | noCDM | (k_0, l_0) | 0 | 0 | 0 |
| 3 | 2 | 1, 0.5 | fd-CDM2 | (k_0, l_0) | 0 | 0, 1 | 0 |
| 4 | 4 | 1 | fd-CDM2 | $(k_0, l_0), (k_0 + 2, l_0)$ | 0,1 | 0, 1 | 0 |
| 5 | 4 | 1 | fd-CDM2 | $(k_0, l_0), (k_0, l_0 + 1)$ | 0,1 | 0, 1 | 0 |
| 6 | 8 | 1 | fd-CDM2 | $(k_0, l_0), (k_1, l_0), (k_2, l_0), (k_3, l_0)$ | 0,1,2,3 | 0, 1 | 0 |
| 7 | 8 | 1 | fd-CDM2 | $(k_0, l_0), (k_1, l_0), (k_0, l_0 + 1), (k_1, l_0 + 1)$ | 0,1,2,3 | 0, 1 | 0 |
| 8 | 8 | 1 | cdm4-FD2-TD2 | $(k_0, l_0), (k_1, l_0)$ | 0,1 | 0, 1 | 0, 1 |
| 9 | 12 | 1 | fd-CDM2 | $(k_0, l_0), (k_1, l_0), (k_2, l_0), (k_3, l_0), (k_4, l_0), (k_5, l_0)$ | 0,1,2,3,4,5 | 0, 1 | 0 |
| 10 | 12 | 1 | cdm4-FD2-TD2 | $(k_0, l_0), (k_1, l_0), (k_2, l_0)$ | 0,1,2 | 0, 1 | 0, 1 |
| 11 | 16 | 1, 0.5 | fd-CDM2 | $(k_0, l_0), (k_1, l_0), (k_2, l_0), (k_3, l_0), (k_0, l_0 + 1), (k_1, l_0 + 1), (k_2, l_0 + 1), (k_3, l_0 + 1)$ | 0,1,2,3,4,5,6,7 | 0, 1 | 0 |
| 12 | 16 | 1, 0.5 | cdm4-FD2-TD2 | $(k_0, l_0), (k_1, l_0), (k_2, l_0), (k_3, l_0)$ | 0,1,2,3 | 0, 1 | 0, 1 |
| 13 | 24 | 1, 0.5 | fd-CDM2 | $(k_0, l_0), (k_1, l_0), (k_2, l_0), (k_0, l_0 + 1), (k_1, l_0 + 1), (k_2, l_0 + 1), (k_0, l_1), (k_1, l_1), (k_2, l_1), (k_0, l_1 + 1), (k_1, l_1 + 1), (k_2, l_1 + 1), (k_3, l_1 + 1)$ | 0,1,2,3,4,5,6,7,8,9,10,11 | 0, 1 | 0 |
| 14 | 24 | 1, 0.5 | cdm4-FD2-TD2 | $(k_0, l_0), (k_1, l_0), (k_2, l_0), (k_0, l_1), (k_1, l_1), (k_2, l_1)$ | 0,1,2,3,4,5 | 0, 1 | 0, 1 |
| 15 | 24 | 1, 0.5 | cdm8-FD2-TD4 | $(k_0, l_0), (k_1, l_0), (k_2, l_0)$ | 0,1,2 | 0, 1 | 0, 1, 2, 3 |
| 16 | 32 | 1, 0.5 | fd-CDM2 | $(k_0, l_0), (k_1, l_0), (k_2, l_0), (k_3, l_0), (k_0, l_0 + 1), (k_1, l_0 + 1), (k_2, l_0 + 1), (k_3, l_0 + 1), (k_0, l_1), (k_1, l_1), (k_2, l_1), (k_3, l_1), (k_0, l_1 + 1), (k_1, l_1 + 1), (k_2, l_1 + 1), (k_3, l_1 + 1)$ | 0,1,2,3,4,5,6,7,8,9,10,11,12,13,14,15 | 0, 1 | 0 |
| 17 | 32 | 1, 0.5 | cdm4-FD2-TD2 | $(k_0, l_0), (k_1, l_0), (k_2, l_0), (k_3, l_0), (k_0, l_1), (k_1, l_1), (k_2, l_1), (k_3, l_1)$ | 0,1,2,3,4,5,6,7 | 0, 1 | 0, 1 |
| 18 | 32 | 1, 0.5 | cdm8-FD2-TD4 | $(k_0, l_0), (k_1, l_0), (k_2, l_0), (k_3, l_0)$ | 0,1,2,3 | 0,1 | 0,1, 2, 3 |

Table 7.4.1.5.3-2: The sequences $w_f(k')$ and $w_t(l')$ for *cdm-Type* equal to 'noCDM'.

| Index | $w_f(0)$ | $w_t(0)$ |
|-------|----------|----------|
| 0 | 1 | 1 |

Table 7.4.1.5.3-3: The sequences $w_f(k')$ and $w_t(l')$ for *cdm-Type* equal to 'fd-CDM2'.

| Index | $[w_f(0) \ w_f(1)]$ | $w_t(0)$ |
|-------|---------------------|----------|
| 0 | $[+1 \ +1]$ | 1 |
| 1 | $[+1 \ -1]$ | 1 |

Table 7.4.1.5.3-4: The sequences $w_f(k')$ and $w_t(l')$ for *cdm-Type* equal to 'cdm4-FD2-TD2'.

| Index | $[w_f(0) \ w_f(1)]$ | $[w_t(0) \ w_t(1)]$ |
|-------|---------------------|---------------------|
| 0 | $[+1 \ +1]$ | $[+1 \ +1]$ |
| 1 | $[+1 \ -1]$ | $[+1 \ +1]$ |
| 2 | $[+1 \ +1]$ | $[+1 \ -1]$ |
| 3 | $[+1 \ -1]$ | $[+1 \ -1]$ |

Table 7.4.1.5.3-5: The sequences $w_f(k')$ and $w_t(l')$ for *cdm-Type* equal to 'cdm8-FD2-TD4'.

| Index | $[w_f(0) \ w_f(1)]$ | $[w_t(0) \ w_t(1) \ w_t(2) \ w_t(3)]$ |
|-------|---------------------|---------------------------------------|
| 0 | $[+1 \ +1]$ | $[+1 \ +1 \ +1 \ +1]$ |
| 1 | $[+1 \ -1]$ | $[+1 \ +1 \ +1 \ +1]$ |
| 2 | $[+1 \ +1]$ | $[+1 \ -1 \ +1 \ -1]$ |
| 3 | $[+1 \ -1]$ | $[+1 \ -1 \ +1 \ -1]$ |
| 4 | $[+1 \ +1]$ | $[+1 \ +1 \ -1 \ -1]$ |
| 5 | $[+1 \ -1]$ | $[+1 \ +1 \ -1 \ -1]$ |
| 6 | $[+1 \ +1]$ | $[+1 \ -1 \ -1 \ +1]$ |
| 7 | $[+1 \ -1]$ | $[+1 \ -1 \ -1 \ +1]$ |

7.4.1.6 RIM reference signals

7.4.1.6.1 General

RIM-RS can be used by an gNB to measure inter-cell interference and to provide information about the experienced interference to other gNBs. Up to two different types of RIM-RS can be configured where

- the first RIM-RS type can be used to convey information,
- the second RIM-RS type depends on configuration only.

7.4.1.6.2 Sequence generation

The RIM-RS receiver shall assume the reference-signal sequence $r(m)$ is defined by

$$r(m) = \frac{1}{\sqrt{2}}(1 - 2c(2m)) + j\frac{1}{\sqrt{2}}(1 - 2c(2m + 1))$$

where the pseudo-random sequence $c(m)$ is defined in clause 5.2.1. The pseudo-random sequence generator shall be initialised with

$$c_{\text{init}} = (2^{10}f(n_t^{\text{RIM}}) + n_{\text{SCID}}) \bmod 2^{31}$$

where

- $n_{\text{SCID}} \in \{0, 1, \dots, 2^{10} - 1\}$ is given by clause 7.4.1.6.4.4;

- $f(n_t^{\text{RIM}}) = \sum_{i=0}^{2^0} 2^i \bar{c}(i)$ where the pseudo-random sequence $\bar{c}(i)$ is given by clause 5.2.1, initialized with $\bar{c}_{\text{init}}(i) = (\gamma n_t^{\text{RIM}} + \delta) \bmod 2^{31}$ where the multiplier factor $\gamma \in \{0, 1, \dots, 2^{31} - 1\}$ and the offset $\delta \in \{0, 1, \dots, 2^{31} - 1\}$;
- $n_t^{\text{RIM}} = \lfloor (t_{\text{RS}}^{\text{RIM}} - t_{\text{ref}}^{\text{RIM}}) / T_{\text{per}}^{\text{RIM}} \rfloor$ is the number of RIM-RS transmission periods since $t_{\text{ref}}^{\text{RIM}}$ where
 - $t_{\text{RS}}^{\text{RIM}} - t_{\text{ref}}^{\text{RIM}}$ is the time in seconds relative to $t_{\text{ref}}^{\text{RIM}}$ of 00:00:00 on 1 January 1900, calculated as continuous time without leap second and traceable to a common time reference, and
 - $T_{\text{per}}^{\text{RIM}} = N_{\text{slot}}^{P_t} / (1000 \cdot 2^\mu)$ is the RIM-RS transmission periodicity in seconds assuming that the first RIM-RS transmission period starts at $t_{\text{ref}}^{\text{RIM}}$, and where $N_{\text{slot}}^{P_t}$ is given by clause 7.4.1.6.4.2.

7.4.1.6.3 Mapping to physical resources

The RIM-RS receiver shall assume the reference signal being mapped to physical resources according to

$$a_k^{(p, \text{RIM})} = \beta_{\text{RIM}} r(k)$$

$$k = 0, 1, \dots, L_{\text{RIM}} - 1$$

where β_{RIM} is an amplitude scaling factor in order to control the RIM-RS transmission power and p is the antenna port. Baseband signal generation shall be done according to clause 5.3.3.

The starting position l_0 for RIM-RS type $i \in \{1, 2\}$ in slot $n_{s,f}^\mu$ in a frame is given by

$$l_0 = T_{\text{offset}}^{\text{UD, RIM}} \bmod N_{\text{symp}}^{\text{slot}}$$

in slots satisfying

$$\left(1024 N_{\text{slot}}^{\text{frame}, \mu} \bar{n}_f^{\text{RIM}} + N_{\text{slot}}^{\text{frame}, \mu} n_f^{\text{RIM}} + n_{s,f}^\mu - (\bar{T}_{\text{offset}} + \lfloor T_{\text{offset}}^{\text{UD, RIM}} / N_{\text{symp}}^{\text{slot}} \rfloor) \right) \bmod N_{\text{slot}}^{P_t} = 0$$

where

- $\bar{n}_f^{\text{RIM}} \in \{0, 1, \dots, N_{\text{slot}}^{P_t} / (1024 N_{\text{slot}}^{\text{frame}, \mu}) - 1\}$ counts the number of times the SFN periods within the RIM-RS transmission period;
- $T_{\text{offset}}^{\text{UD, RIM}} = N_{\text{ref}}^{\text{UD, RIM}} - N_{\text{symp, ref}}^{\text{RIM}, i}$ where $N_{\text{ref}}^{\text{UD, RIM}} \in \{2, 3, \dots, 20 \cdot 2 \cdot 14 - 1\}$ is the symbol offset of the reference point after the starting boundary of the uplink-downlink switching period in which the RIM-RS is mapped to and $N_{\text{symp, ref}}^{\text{RIM}, i}$ is obtained as described in clause 7.4.1.6.4.2;
- $N_{\text{slot}}^{P_t}$ is the total number of slots in a RIM-RS transmission period as defined in clause 7.4.1.6.4.2;
- \bar{T}_{offset} is the slot offset of the uplink-downlink switching period with index i_t^{RIM} with respect to the starting boundary of the RIM-RS transmission period and is defined in clause 7.4.1.6.4.2;
- P_t is the RIM-RS transmission periodicity in units of uplink-downlink switching period as defined in clause 7.4.1.6.4.2.

7.4.1.6.4 RIM-RS configuration

7.4.1.6.4.1 General

A resource for RIM-RS transmission is defined by the indices $i_t^{\text{RIM}} \in \{0, 1, \dots, P_t - 1\}$, $i_f^{\text{RIM}} \in \{0, 1, \dots, N_f^{\text{RIM}} - 1\}$, and $i_s^{\text{RIM}} \in \{0, 1, \dots, N_s^{\text{RIM}, i} - 1\}$ used as indices into configured lists of time, frequency, and sequence parameters, respectively.

All RIM-RS resources occupy the same number of resource blocks, $N_{\text{RB}}^{\text{RIM}}$. At most 32 RIM-RS resources can be configured within a 10 ms period.

7.4.1.6.4.2 Time-domain parameters and mapping from i_t to time-domain parameters

RIM-RS are transmitted periodically with the RIM-RS transmission period P_t defined in units of the uplink-downlink switching period determined from one or two configured uplink-downlink periods.

- If a single uplink-downlink period is configured for RIM-RS purposes,
 - P_t is the RIM-RS transmission periodicity in terms of uplink-downlink switching periods given by

$$P_t = \left\lceil \frac{2^\mu \bar{P}_t T_{\text{per},1}^{\text{RIM}}}{1024 N_{\text{slot}}^{\text{frame},\mu}} \right\rceil \frac{1024 N_{\text{slot}}^{\text{frame},\mu}}{2^\mu T_{\text{per},1}^{\text{RIM}}}$$

where $T_{\text{per},1}^{\text{RIM}} \in \{0.5, 0.625, 1, 1.25, 2, 2.5, 4, 5, 10, 20\}$ ms;

- $N_{\text{slot}}^{P_t} = 2^\mu P_t T_{\text{per},1}^{\text{RIM}}$ is the total number of slots in a RIM-RS transmission period;
- $\bar{T}_{\text{offset}} = 2^\mu i_t^{\text{RIM}} T_{\text{per},1}^{\text{RIM}}$ is the slot offset of the uplink-downlink switching period with index i_t^{RIM} with respect to the starting boundary of the RIM-RS transmission period
- If two uplink-downlink periods are configured for RIM-RS purposes,
 - P_t is the RIM-RS transmission periodicity in terms of $P_t/2$ pairs of uplink-downlink switching periods and is given by

$$P_t = \left\lceil \frac{2^\mu \bar{P}_t (T_{\text{per},1}^{\text{RIM}} + T_{\text{per},2}^{\text{RIM}})/2}{1024 N_{\text{slot}}^{\text{frame},\mu}} \right\rceil \frac{1024 N_{\text{slot}}^{\text{frame},\mu}}{2^\mu (T_{\text{per},1}^{\text{RIM}} + T_{\text{per},2}^{\text{RIM}})/2}$$

where each pair consists of a first period of $T_{\text{per},1}^{\text{RIM}} \in \{0.5, 0.625, 1, 1.25, 2, 2.5, 3, 4, 5, 10, 20\}$ ms and a second period of $T_{\text{per},2}^{\text{RIM}} \in \{0.5, 0.625, 1, 1.25, 2, 2.5, 3, 4, 5, 10\}$ ms and where $T_{\text{per},1}^{\text{RIM}} + T_{\text{per},2}^{\text{RIM}}$ divides 20 ms;

- $N_{\text{slot}}^{P_t} = 2^\mu P_t (T_{\text{per},1}^{\text{RIM}} + T_{\text{per},2}^{\text{RIM}})/2$ is the total number of slots in a RIM-RS transmission period;
- $\bar{T}_{\text{offset}} = 2^\mu \lfloor i_t^{\text{RIM}}/2 \rfloor (T_{\text{per},1}^{\text{RIM}} + T_{\text{per},2}^{\text{RIM}}) + 2^\mu (i_t^{\text{RIM}} \bmod 2) T_{\text{per},1}^{\text{RIM}}$ is the slot offset of the uplink-downlink switching period with index i_t^{RIM} with respect to the starting boundary of the RIM-RS transmission period

The intermediate quantity \bar{P}_t is given by

$$\bar{P}_t = \begin{cases} \left\lceil \frac{N_{\text{setID}}^{\text{RIM},1}}{N_f^{\text{RIM}} N_s^{\text{RIM},1}} \right\rceil R_1 + \left\lceil \frac{N_{\text{setID}}^{\text{RIM},2}}{N_f^{\text{RIM}} N_s^{\text{RIM},2}} \right\rceil R_2 & \text{if } \textit{EnoughIndication} \text{ is disabled} \\ \left\lceil \frac{2 N_{\text{setID}}^{\text{RIM},1}}{N_f^{\text{RIM}} N_s^{\text{RIM},1}} \right\rceil R_1 + \left\lceil \frac{N_{\text{setID}}^{\text{RIM},2}}{N_f^{\text{RIM}} N_s^{\text{RIM},2}} \right\rceil R_2 & \text{if } \textit{EnoughIndication} \text{ is enabled} \end{cases}$$

where

- $N_{\text{setID}}^{\text{RIM},1}$ and $N_{\text{setID}}^{\text{RIM},2}$ are the total number of setIDs for RIM-RS type 1 and RIM-RS type 2, respectively;
- $N_f^{\text{RIM}} \in \{1, 2, 4\}$ is the number of candidate frequency resources configured in the network;
- $N_s^{\text{RIM},i} \in \{1, 2, \dots, 8\}$ is the number of candidate sequences assigned for RIM-RS type $i \in \{1, 2\}$ in the network;
- R_1 and R_2 are the number of consecutive uplink-downlink switching periods for RIM-RS type 1 and RIM-RS type 2, respectively. If near-far functionality is not configured, $R_i \in \{1, 2, 4\}$, otherwise $R_i \in \{2, 4, 8\}$ and the first and second half of the R_i consecutive uplink-downlink switching periods are for near functionality and far functionality, respectively.

The quantity $N_{\text{symb,ref}}^{\text{RIM},i}$ is obtained from entry \bar{r} in a list of configured symbol offsets for RIM-RS i .

7.4.1.6.4.3 Frequency-domain parameters and mapping from i_f to frequency-domain parameters

The frequency-domain parameter k_1 in clause 5.3.3 is the frequency offset relative to a configured reference point for RIM-RS and is obtained from entry i_f^{RIM} in a list of configured frequency offsets expressed in units of resource blocks.

The number of candidate frequency resources configured in the network, N_f^{RIM} , shall fulfil

$$N_f^{\text{RIM}} \leq \left\lfloor \frac{N_{\text{grid}}^{\text{size},\mu} N_{\text{RB}}^{\text{sc}} \cdot 2^\mu \cdot 15}{40 \cdot 10^3} \right\rfloor + \left\lfloor \frac{N_{\text{grid}}^{\text{size},\mu} N_{\text{RB}}^{\text{sc}} \cdot 2^\mu \cdot 15}{80 \cdot 10^3} \right\rfloor + 1$$

If $N_f^{\text{RIM}} > 1$, the frequency difference between any pair of configured frequency offsets in the list is not smaller than $N_{\text{RB}}^{\text{RIM}}$.

The number of resource blocks for RIM-RS is given by

$$N_{\text{RB}}^{\text{RIM}} = \min(96, N_{\text{grid,DL}}^{\text{size},\mu}) \quad \text{for } \mu = 0$$

$$N_{\text{RB}}^{\text{RIM}} \in \left\{ \min(48, N_{\text{grid,DL}}^{\text{size},\mu}), \min(96, N_{\text{grid,DL}}^{\text{size},\mu}) \right\} \quad \text{for } \mu = 1$$

7.4.1.6.4.4 Sequence parameters and mapping from i_s to sequence parameters

The scrambling identity n_{SCID} clause 7.4.1.6.2 is obtained from entry i_s^{RIM} in a list of configured scrambling identities.

7.4.1.6.4.5 Mapping between resource triplet and set ID

The resource indices i_t^{RIM} , i_f^{RIM} , and i_s^{RIM} are determined from the index \bar{r} in the set ID n_{setID} according to

$$i_t^{\text{RIM}} = T_{\text{start}} + \left(\left\lfloor \frac{n_{\text{setID}}}{N_s^{\text{RIM}}} \right\rfloor \bmod N_t^{\text{RIM}} \right) R_i + \bar{r}$$

$$i_f^{\text{RIM}} = \left(\left\lfloor \frac{n_{\text{setID}}}{N_t^{\text{RIM}} N_s^{\text{RIM}}} \right\rfloor \bmod N_f^{\text{RIM}} \right)$$

$$i_s^{\text{RIM}} = S_{\text{start}} + (n_{\text{setID}} \bmod N_s^{\text{RIM}})$$

where

- N_t^{RIM} is given by

$$N_t^{\text{RIM}} = \begin{cases} \left\lfloor \frac{N_{\text{setID}}^{\text{RIM},1}}{N_f^{\text{RIM}} N_s^{\text{RIM},1}} \right\rfloor & \text{for RIM-RS type 1 and if } \textit{EnoughIndication} \text{ is disabled} \\ \left\lfloor \frac{2N_{\text{setID}}^{\text{RIM},1}}{N_f^{\text{RIM}} N_s^{\text{RIM},1}} \right\rfloor & \text{for RIM-RS type 1 and if } \textit{EnoughIndication} \text{ is enabled} \\ \left\lfloor \frac{N_{\text{setID}}^{\text{RIM},2}}{N_f^{\text{RIM}} N_s^{\text{RIM},2}} \right\rfloor & \text{for RIM-RS type 2} \end{cases}$$

- $N_f^{\text{RIM}} \in \{1, 2, 4\}$ is the number of candidate frequency resources configured in the network;
- N_s^{RIM} is the number of sequence candidates for the current RIM-RS resource given by

$$N_s^{\text{RIM}} = \begin{cases} N_s^{\text{RIM},1} & \text{for RIM-RS type 1 and if } \textit{EnoughIndication} \text{ is disabled} \\ N_s^{\text{RIM},1}/2 & \text{for RIM-RS type 1 and if } \textit{EnoughIndication} \text{ is enabled} \\ N_s^{\text{RIM},2} & \text{for RIM-RS type 2} \end{cases}$$

- T_{start} is the starting time offset given by

$$T_{\text{start}} = \begin{cases} 0 & \text{for RIM-RS type 1} \\ \left\lfloor \frac{N_{\text{setID}}^{\text{RIM},1}}{N_f^{\text{RIM}} N_s^{\text{RIM},1}} \right\rfloor R_1 & \text{for RIM-RS type 2 and if } \textit{EnoughIndication} \text{ is disabled} \\ \left\lfloor \frac{2N_{\text{setID}}^{\text{RIM},1}}{N_f^{\text{RIM}} N_s^{\text{RIM},1}} \right\rfloor R_1 & \text{for RIM-RS type 2 and if } \textit{EnoughIndication} \text{ is enabled} \end{cases}$$

- S_{start} is given by

$$S_{\text{start}} = \begin{cases} N_s^{\text{RIM},1}/2 & \text{if } \overline{\text{EnoughIndication}} \text{ is enabled and 'enough mitigation' is to be indicated} \\ 0 & \text{otherwise} \end{cases}$$

where $N_s^{\text{RIM},1}$ is the number of candidate sequences assigned for RIM-RS type 1

- R_i is the number of consecutive uplink-downlink periods for RIM-RS type i as given by clause 7.4.1.6.4.2;
- $\bar{r} \in \{0, 1, \dots, R_i - 1\}$.

The set ID is determined from the resource triplet according to

$$n_{\text{setID}} = (i_s^{\text{RIM}} - S_{\text{start}}) + N_s^{\text{RIM}} \left\lfloor \frac{i_t^{\text{RIM}} - T_{\text{start}}}{R_i} \right\rfloor + N_t^{\text{RIM}} N_s^{\text{RIM}} i_f^{\text{RIM}}$$

7.4.1.7 Positioning reference signals

7.4.1.7.1 General

A positioning frequency layer consists of one or more downlink PRS resource sets, each of which consists of one or more downlink PRS resources as described in [6, TS 38.214].

7.4.1.7.2 Sequence generation

The UE shall assume the reference-signal sequence $r(m)$ is defined by

$$r(m) = \frac{1}{\sqrt{2}}(1 - 2c(2m)) + j \frac{1}{\sqrt{2}}(1 - 2c(2m + 1))$$

where the pseudo-random sequence $c(i)$ is defined in clause 5.2.1. The pseudo-random sequence generator shall be initialised with

$$c_{\text{init}} = \left(2^{22} \left\lfloor \frac{n_{\text{ID,seq}}^{\text{PRS}}}{1024} \right\rfloor + 2^{10} (N_{\text{slot}}^{\text{slot}} n_{s,f}^{\mu} + l + 1) (2(n_{\text{ID,seq}}^{\text{PRS}} \bmod 1024) + 1) + (n_{\text{ID,seq}}^{\text{PRS}} \bmod 1024) \right) \bmod 2^{31}$$

where $n_{s,f}^{\mu}$ is the slot number, the downlink PRS sequence ID $n_{\text{ID,seq}}^{\text{PRS}} \in \{0, 1, \dots, 4095\}$ is given by the higher-layer parameter *dl-PRS-SequenceID*, and l is the OFDM symbol within the slot to which the sequence is mapped.

7.4.1.7.3 Mapping to physical resources in a downlink PRS resource

For each downlink PRS resource configured, the UE shall assume the sequence $r(m)$ is scaled with a factor β_{PRS} and mapped to resources elements $(k, l)_{p,\mu}$ according to

$$\begin{aligned} a_{k,l}^{(p,\mu)} &= \beta_{\text{PRS}} r(m) \\ m &= 0, 1, \dots \\ k &= m K_{\text{comb}}^{\text{PRS}} + \left((k_{\text{offset}}^{\text{PRS}} + k') \bmod K_{\text{comb}}^{\text{PRS}} \right) \\ l &= l_{\text{start}}^{\text{PRS}}, l_{\text{start}}^{\text{PRS}} + 1, \dots, l_{\text{start}}^{\text{PRS}} + L_{\text{PRS}} - 1 \end{aligned}$$

when the following conditions are fulfilled:

- the resource element $(k, l)_{p,\mu}$ is within the resource blocks occupied by the downlink PRS resource for which the UE is configured;
- the symbol l is not used by any SS/PBCH block used by a serving cell for downlink PRS transmitted from the same serving cell or any SS/PBCH block from a non-serving cell whose time frequency location is provided to the UE by higher layers for downlink PRS transmitted from the same non-serving cell;
- the slot number satisfies the conditions in clause 7.4.1.7.4.

and where

- the antenna port $p = 5000$
- $l_{\text{start}}^{\text{PRS}}$ is the first symbol of the downlink PRS within a slot and given by the higher-layer parameter *dl-PRS-ResourceSymbolOffset*;
- the size of the downlink PRS resource in the time domain $L_{\text{PRS}} \in \{1, 2, 4, 6, 12\}$ is given by the higher-layer parameter *dl-PRS-NumSymbols*;
- the comb size $K_{\text{comb}}^{\text{PRS}} \in \{2, 4, 6, 12\}$ is given by the higher-layer parameter *dl-PRS-CombSizeN-AndReOffset* for a downlink PRS resource configured for RTT-based propagation delay compensation, otherwise by the higher-layer parameter *dl-PRS-CombSizeN* such that the combination $\{L_{\text{PRS}}, K_{\text{comb}}^{\text{PRS}}\}$ is one of $\{1, 2\}, \{2, 2\}, \{4, 2\}, \{6, 2\}, \{12, 2\}, \{1, 4\}, \{4, 4\}, \{12, 4\}, \{1, 6\}, \{6, 6\}, \{12, 6\}, \{1, 12\}$ and $\{12, 12\}$;
- the resource-element offset $k_{\text{offset}}^{\text{PRS}} \in \{0, 1, \dots, K_{\text{comb}}^{\text{PRS}} - 1\}$ is obtained from the higher-layer parameter *dl-PRS-CombSizeN-AndReOffset*;
- the quantity k' is given by Table 7.4.1.7.3-1.

If the downlink PRS resource is configured for RTT based propagation delay compensation as described in clause 9 of [6, TS 38.214], the reference point for $k = 0$ is subcarrier 0 in common resource block 0; Otherwise, the reference point for $k = 0$ is the location of the point A of the positioning frequency layer, in which the downlink PRS resource is configured where point A is given by the higher-layer parameter *dl-PRS-PointA*.

Table 7.4.1.7.3-1: The frequency offset k' as a function of $l - l_{\text{start}}^{\text{PRS}}$.

| $K_{\text{comb}}^{\text{PRS}}$ | Symbol number within the downlink PRS resource $l - l_{\text{start}}^{\text{PRS}}$ | | | | | | | | | | | |
|--------------------------------|--|---|---|---|---|---|---|----|---|---|----|----|
| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| 2 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 |
| 4 | 0 | 2 | 1 | 3 | 0 | 2 | 1 | 3 | 0 | 2 | 1 | 3 |
| 6 | 0 | 3 | 1 | 4 | 2 | 5 | 0 | 3 | 1 | 4 | 2 | 5 |
| 12 | 0 | 6 | 3 | 9 | 1 | 7 | 4 | 10 | 2 | 8 | 5 | 11 |

7.4.1.7.4 Mapping to slots in a downlink PRS resource set

For a downlink PRS resource in a downlink PRS resource set, the UE shall assume the downlink PRS resource being transmitted when the slot and frame numbers fulfil

$$\left(N_{\text{slot}}^{\text{frame}, \mu} n_f + n_{s,f}^{\mu} - T_{\text{offset}}^{\text{PRS}} - T_{\text{offset, res}}^{\text{PRS}} \right) \bmod T_{\text{per}}^{\text{PRS}} \in \left\{ iT_{\text{gap}}^{\text{PRS}} \right\}_{i=0}^{T_{\text{rep}}^{\text{PRS}} - 1}$$

and one of the following conditions are fulfilled:

- the higher-layer parameters *dl-PRS-MutingOption1* and *dl-PRS-MutingOption2* are not provided;
- the higher-layer parameter *dl-PRS-MutingOption1* is provided with bitmap $\{b^1\}$ but *dl-PRS-MutingOption2* with bitmap $\{b^2\}$ is not provided, and bit b_i^1 is set;
- the higher-layer parameter *dl-PRS-MutingOption2* is provided with bitmap $\{b^2\}$ but *dl-PRS-MutingOption1* with bitmap $\{b^1\}$ is not provided, and bit b_i^2 is set;
- the higher-layer parameters *dl-PRS-MutingOption1* with bitmap $\{b^1\}$ and *dl-PRS-MutingOption2* with $\{b^2\}$ are both provided, and both bit b_i^1 and b_i^2 are set.

where

- b_i^1 is bit $i = \left\lfloor \left(N_{\text{slot}}^{\text{frame}, \mu} n_f + n_{s,f}^{\mu} - T_{\text{offset}}^{\text{PRS}} - T_{\text{offset, res}}^{\text{PRS}} \right) / \left(T_{\text{muting}}^{\text{PRS}} T_{\text{per}}^{\text{PRS}} \right) \right\rfloor \bmod L$ in the bitmap given by the higher-layer parameter *dl-PRS-MutingOption1* where $L \in \{2, 4, 6, 8, 16, 32\}$ is the size of the bitmap;
- b_i^2 is bit $i = \left\lfloor \left(\left(N_{\text{slot}}^{\text{frame}, \mu} n_f + n_{s,f}^{\mu} - T_{\text{offset}}^{\text{PRS}} - T_{\text{offset, res}}^{\text{PRS}} \right) \bmod T_{\text{per}}^{\text{PRS}} \right) / T_{\text{gap}}^{\text{PRS}} \right\rfloor \bmod T_{\text{rep}}^{\text{PRS}}$ in the bitmap given by the higher-layer parameter *dl-PRS-MutingOption2*;

- the periodicity $T_{\text{per}}^{\text{PRS}} \in 2^\mu\{4, 5, 8, 10, 16, 20, 32, 40, 64, 80, 160, 320, 640, 1280, 2560, 5120, 10240\}$ and the slot offset $T_{\text{offset}}^{\text{PRS}} \in \{0, 1, \dots, T_{\text{per}}^{\text{PRS}} - 1\}$ are given by the higher-layer parameter *dl-PRS-Periodicity-and-ResourceSetSlotOffset*;
- the downlink PRS resource slot offset $T_{\text{offset, res}}^{\text{PRS}}$ is given by the higher-layer parameter *dl-PRS-ResourceSlotOffset*;
- the repetition factor $T_{\text{rep}}^{\text{PRS}} \in \{1, 2, 4, 6, 8, 16, 32\}$ is given by the higher-layer parameter *dl-PRS-ResourceRepetitionFactor*;
- the muting repetition factor $T_{\text{muting}}^{\text{PRS}}$ is given by the higher-layer parameter *dl-PRS-MutingBitRepetitionFactor*;
- the time gap $T_{\text{gap}}^{\text{PRS}} \in \{1, 2, 4, 8, 16, 32\}$ is given by the higher-layer parameter *dl-PRS-ResourceTimeGap*;

For a downlink PRS resource in a downlink PRS resource set configured for RTT-based propagation delay compensation, the UE shall assume the downlink PRS resource being transmitted as described in clause 9 of [6, TS 38.214]; otherwise, the UE shall assume the downlink PRS resource being transmitted as described in clause 5.1.6.5 of [6, TS 38.214].

7.4.2 Synchronization signals

7.4.2.1 Physical-layer cell identities

There are 1008 unique physical-layer cell identities given by

$$N_{\text{ID}}^{\text{cell}} = 3N_{\text{ID}}^{(1)} + N_{\text{ID}}^{(2)}$$

where $N_{\text{ID}}^{(1)} \in \{0, 1, \dots, 335\}$ and $N_{\text{ID}}^{(2)} \in \{0, 1, 2\}$.

7.4.2.2 Primary synchronization signal

7.4.2.2.1 Sequence generation

The sequence $d_{\text{PSS}}(n)$ for the primary synchronization signal is defined by

$$\begin{aligned} d_{\text{PSS}}(n) &= 1 - 2x(m) \\ m &= (n + 43N_{\text{ID}}^{(2)}) \bmod 127 \\ 0 &\leq n < 127 \end{aligned}$$

where

$$x(i+7) = (x(i+4) + x(i)) \bmod 2$$

and

$$[x(6) \ x(5) \ x(4) \ x(3) \ x(2) \ x(1) \ x(0)] = [1 \ 1 \ 1 \ 0 \ 1 \ 1 \ 0]$$

7.4.2.2.2 Mapping to physical resources

Mapping to physical resources is described in clause 7.4.3.

7.4.2.3 Secondary synchronization signal

7.4.2.3.1 Sequence generation

The sequence $d_{\text{SSS}}(n)$ for the secondary synchronization signal is defined by

$$d_{\text{SSS}}(n) = [1 - 2x_0((n + m_0) \bmod 127)] [1 - 2x_1((n + m_1) \bmod 127)]$$

$$m_0 = 15 \left\lfloor \frac{N_{\text{ID}}^{(1)}}{112} \right\rfloor + 5N_{\text{ID}}^{(2)}$$

$$m_1 = N_{\text{ID}}^{(1)} \bmod 112$$

$$0 \leq n < 127$$

where

$$x_0(i+7) = (x_0(i+4) + x_0(i)) \bmod 2$$

$$x_1(i+7) = (x_1(i+1) + x_1(i)) \bmod 2$$

and

$$\begin{bmatrix} x_0(6) & x_0(5) & x_0(4) & x_0(3) & x_0(2) & x_0(1) & x_0(0) \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix}$$

$$\begin{bmatrix} x_1(6) & x_1(5) & x_1(4) & x_1(3) & x_1(2) & x_1(1) & x_1(0) \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix}$$

7.4.2.3.2 Mapping to physical resources

Mapping to physical resources is described in clause 7.4.3.

7.4.3 SS/PBCH block

7.4.3.1 Time-frequency structure of an SS/PBCH block

In the time domain, an SS/PBCH block consists of 4 OFDM symbols, numbered in increasing order from 0 to 3 within the SS/PBCH block, where PSS, SSS, and PBCH with associated DM-RS are mapped to symbols as given by Table 7.4.3.1-1.

In the frequency domain, an SS/PBCH block consists of 240 contiguous subcarriers with the subcarriers numbered in increasing order from 0 to 239 within the SS/PBCH block. The quantities k and l represent the frequency and time indices, respectively, within one SS/PBCH block. The UE may assume that the complex-valued symbols corresponding to resource elements denoted as 'Set to 0' in Table 7.4.3.1-1 are set to zero. The quantity v in Table 7.4.3.1-1 is given by $v = N_{\text{ID}}^{\text{cell}} \bmod 4$. The quantity k_{SSB} is the subcarrier offset from subcarrier 0 in common resource block $N_{\text{CRB}}^{\text{SSB}}$ to the lowest-numbered subcarrier of the SS/PBCH block, or the SS/PBCH block after puncturing if applicable, where $N_{\text{CRB}}^{\text{SSB}}$ is obtained from the higher-layer parameter *offsetToPointA*.

- For operation with shared spectrum channel access in FR2-2 and for operation without shared spectrum channel access, the 4 least significant bits of k_{SSB} are given by the higher-layer parameter *ssb-SubcarrierOffset* and for FR1 the most significant bit of k_{SSB} is given by $\bar{a}_{\bar{A}+5}$ in the PBCH payload as defined in clause 7.1.1 of [4, TS 38.212].
- For operation with shared spectrum channel access in FR1, the 4 least significant bits of \bar{k}_{SSB} are given by the higher-layer parameter *ssb-SubcarrierOffset* and the most significant bit of \bar{k}_{SSB} is given by $\bar{a}_{\bar{A}+5}$ in the PBCH payload as defined in clause 7.1.1 of [4, TS 38.212]. If $\bar{k}_{\text{SSB}} \geq 24$, $k_{\text{SSB}} = \bar{k}_{\text{SSB}}$; otherwise, $k_{\text{SSB}} = 2 \lfloor \bar{k}_{\text{SSB}} / 2 \rfloor$.

If *ssb-SubcarrierOffset* is not provided, k_{SSB} is derived from the frequency difference between the SS/PBCH block and Point A.

The UE may assume that the complex-valued symbols corresponding to resource elements that are part of a common resource block partially or fully overlapping with an SS/PBCH block, or an SS/PBCH block after puncturing if applicable, and not used for SS/PBCH transmission are set to zero in the OFDM symbols partially or fully overlapping with OFDM symbols where SS/PBCH is transmitted.

For an SS/PBCH block, the UE shall assume

- antenna port $p = 4000$ is used for transmission of PSS, SSS, PBCH and DM-RS for PBCH,
- the same cyclic prefix length and subcarrier spacing for the PSS, SSS, PBCH and DM-RS for PBCH,

- for SS/PBCH block type A, $\mu \in \{0,1\}$ and $k_{\text{SSB}} \in \{0, 1, 2, \dots, 23\}$ with the quantities k_{SSB} , and $N_{\text{CRB}}^{\text{SSB}}$ expressed in terms of 15 kHz subcarrier spacing, and
- for SS/PBCH block type B in FR2-1 and FR2-NTN, $\mu \in \{3,4\}$ and $k_{\text{SSB}} \in \{0, 1, 2, \dots, 11\}$ with the quantity k_{SSB} expressed in terms of the subcarrier spacing provided by the higher-layer parameter *subCarrierSpacingCommon* and $N_{\text{CRB}}^{\text{SSB}}$ expressed in terms of 60 kHz subcarrier spacing;
- for SS/PBCH block type B in FR2-2, $\mu \in \{3,5,6\}$ and $k_{\text{SSB}} \in \{0,1,2, \dots, 11\}$ with the quantity k_{SSB} expressed in terms of the SS/PBCH block subcarrier spacing and $N_{\text{CRB}}^{\text{SSB}}$ expressed in terms of 60 kHz subcarrier spacing;
- the centre of subcarrier 0 of resource block $N_{\text{CRB}}^{\text{SSB}}$ coincides with the centre of subcarrier 0 of a common resource block with the subcarrier spacing
 - provided by the higher-layer parameter *subCarrierSpacingCommon* for operation without shared spectrum channel access in FR1, FR2-1 and FR2-NTN; and
 - same as the subcarrier spacing of the SS/PBCH block for operation without shared spectrum access in FR2-2 and for operation with shared spectrum channel access.
- This common resource block overlaps with subcarrier 0 of the lowest-numbered resource block of the SS/PBCH block, or the SS/PBCH block after puncturing if applicable.

The UE may assume that SS/PBCH blocks transmitted with the same block index on the same center frequency location are quasi co-located with respect to Doppler spread, Doppler shift, average gain, average delay, delay spread, and, when applicable, spatial Rx parameters. The UE shall not assume quasi co-location for any other SS/PBCH block transmissions other than what is specified in [5, TS 38.213].

For cell search on a carrier with a channel bandwidth of 3 MHz, the UE is not expected to receive subcarriers 0 to 47 and 192 to 239 in any of the 4 OFDM symbols of the SS/PBCH block, where the remaining 12 resource blocks form the SS/PBCH block after puncturing.

Table 7.4.3.1-1: Resources within an SS/PBCH block for PSS, SSS, PBCH, and DM-RS for PBCH.

| Channel or signal | OFDM symbol number l relative to the start of an SS/PBCH block | Subcarrier number k relative to the start of an SS/PBCH block |
|-------------------|---|--|
| PSS | 0 | 56, 57, ..., 182 |
| SSS | 2 | 56, 57, ..., 182 |
| Set to 0 | 0 | 0, 1, ..., 55, 183, 184, ..., 239 |
| | 2 | 48, 49, ..., 55, 183, 184, ..., 191 |
| PBCH | 1, 3 | 0, 1, ..., 239 |
| | 2 | 0, 1, ..., 47, 192, 193, ..., 239 |
| DM-RS for PBCH | 1, 3 | $0+v, 4+v, 8+v, \dots, 236+v$ |
| | 2 | $0+v, 4+v, 8+v, \dots, 44+v$ $192+v, 196+v, \dots, 236+v$ |

7.4.3.1.1 Mapping of PSS within an SS/PBCH block

The UE shall assume the sequence of symbols $d_{\text{PSS}}(0), \dots, d_{\text{PSS}}(126)$ constituting the primary synchronization signal to be scaled by a factor β_{PSS} to conform to the PSS power allocation specified in [5, TS 38.213] and mapped to resource elements $(k, l)_{p, \mu}$ in increasing order of k where k and l are given by Table 7.4.3.1-1 and represent the frequency and time indices, respectively, within one SS/PBCH block.

7.4.3.1.2 Mapping of SSS within an SS/PBCH block

The UE shall assume the sequence of symbols $d_{\text{SSS}}(0), \dots, d_{\text{SSS}}(126)$ constituting the secondary synchronization signal to be scaled by a factor β_{SSS} and mapped to resource elements $(k, l)_{p, \mu}$ in increasing order of k where k and l are given by Table 7.4.3.1-1 and represent the frequency and time indices, respectively, within one SS/PBCH block.

7.4.3.1.3 Mapping of PBCH and DM-RS within an SS/PBCH block

The UE shall assume the sequence of complex-valued symbols $d_{\text{PBCH}}(0), \dots, d_{\text{PBCH}}(M_{\text{sy mb}} - 1)$ constituting the physical broadcast channel to be scaled by a factor β_{PBCH} to conform to the PBCH power allocation specified in [5, TS 38.213] and mapped in sequence starting with $d_{\text{PBCH}}(0)$ to resource elements $(k, l)_{p,\mu}$ which meet all the following criteria:

- they are not used for PBCH demodulation reference signals

The mapping to resource elements $(k, l)_{p,\mu}$ not reserved for PBCH DM-RS shall be in increasing order of first the index k and then the index l , where k and l represent the frequency and time indices, respectively, within one SS/PBCH block and are given by Table 7.4.3.1-1.

The UE shall assume the sequence of complex-valued symbols $r(0), \dots, r(143)$ constituting the demodulation reference signals for the SS/PBCH block to be scaled by a factor of $\beta_{\text{PBCH}}^{\text{DM-RS}}$ to conform to the PBCH power allocation specified in [5, TS 38.213] and to be mapped to resource elements $(k, l)_{p,\mu}$ in increasing order of first k and then l where k and l are given by Table 7.4.3.1-1 and represent the frequency and time indices, respectively, within one SS/PBCH block.

7.4.3.2 Time location of an SS/PBCH block

The locations in the time domain where a UE shall monitor for a possible SS/PBCH block are described in clause 4.1 of [5, TS 38.213].

8 Sidelink

8.1 Overview

8.1.1 Overview of physical channels

A sidelink physical channel corresponds to a set of resource elements carrying information originating from higher layers. The following sidelink physical channels are defined:

- Physical Sidelink Shared Channel, PSSCH
- Physical Sidelink Broadcast Channel, PSBCH
- Physical Sidelink Control Channel, PSCCH
- Physical Sidelink Feedback Channel, PSFCH

8.1.2 Overview of physical signals

A sidelink physical signal corresponds to a set of resource elements used by the physical layer but does not carry information originating from higher layers.

The following sidelink physical signals are defined:

- Demodulation reference signals, DM-RS
- Channel-state information reference signal, CSI-RS
- Phase-tracking reference signals, PT-RS
- Sidelink primary synchronization signal, S-PSS
- Sidelink secondary synchronization signal, S-SSS
- Sidelink positioning reference signal, SL PRS

8.2 Physical resources

8.2.1 General

In a shared SL PRS resource pool, the OFDM symbol immediately preceding the symbols which are configured for use by PSFCH if PSFCH is configured in this slot, and the last symbol configured for sidelink in a slot, serve as guard symbol(s). In a dedicated SL PRS resource pool, the last symbol configured for sidelink in a slot serves as a guard symbol. Otherwise, the OFDM symbol immediately following the last symbol used for PSSCH, PSFCH, or S-SSB serves as a guard symbol.

The first OFDM symbol of a PSSCH and its associated PSCCH is duplicated as described in clauses 8.3.1.5 and 8.3.2.3. The first OFDM symbol of a PSFCH is duplicated as described in clause 8.3.4.2.2.

The OFDM symbol immediately preceding an SL PRS resource in a dedicated SL PRS resource pool is generated as described in clause 8.4.1.6.3.

8.2.2 Numerologies

Multiple OFDM numerologies are supported as given by Table 8.2.2-1 where μ and the cyclic prefix for a sidelink bandwidth part are obtained from the higher-layer parameter *sl-BWP*.

Table 8.2.2-1: Supported transmission numerologies.

| μ | $\Delta f = 2^\mu \cdot 15$ [kHz] | Cyclic prefix |
|-------|-----------------------------------|------------------|
| 0 | 15 | Normal |
| 1 | 30 | Normal |
| 2 | 60 | Normal, Extended |
| 3 | 120 | Normal |

8.2.3 Frame structure

8.2.3.1 Frames and subframes

The frame and subframe structure for sidelink transmission is defined in clause 4.3.1.

8.2.3.2 Slots

The slot structure for sidelink transmission is defined in clause 4.3.2.

8.2.4 Antenna ports

An antenna port is defined in clause 4.4.1.

The following antenna ports are defined for the sidelink:

- Antenna ports starting with 1000 for PSSCH
- Antenna ports starting with 2000 for PSCCH
- Antenna ports starting with 3000 for CSI-RS
- Antenna ports starting with 4000 for S-SS/PSBCH block
- Antenna ports starting with 5000 for PSFCH
- Antenna ports starting with 6000 for SL PRS

For DM-RS associated with a PSBCH, the channel over which a PSBCH symbol on one antenna port is conveyed can be inferred from the channel over which a DM-RS symbol on the same antenna port is conveyed only if the two symbols are within a S-SS/PSBCH block transmitted within the same slot, and with the same block index.

For DM-RS associated with a PSSCH, the channel over which a PSSCH symbol on one antenna port is conveyed can be inferred from the channel over which a DM-RS symbol on the same antenna port is conveyed only if the two symbols are within the same frequency resource as the scheduled PSSCH and in the same slot.

For DM-RS associated with a PSCCH, the channel over which a PSCCH symbol on one antenna port is conveyed can be inferred from the channel over which a DM-RS symbol on the same antenna port is conveyed only if the two symbols are within the same frequency resource as the transmitted PSCCH and in the same slot.

8.2.5 Resource grid

The resource grid for sidelink transmission is defined in clause 4.4.2.

For sidelink, the carrier bandwidth $N_{\text{grid}}^{\text{size},\mu}$ and the starting position $N_{\text{grid}}^{\text{start},\mu}$ for subcarrier spacing configuration μ are obtained from the higher-layer parameter *sl-SCS-SpecificCarrierList*.

For the sidelink, the higher-layer parameter *sl-TxDirectCurrentLocation* indicates the location of the transmitter DC subcarrier in the sidelink for each of the configured bandwidth parts. Values in the range 0 – 3299 represent the number of the DC subcarrier, the value 3300 indicates that the DC subcarrier is located outside the resource grid, and the value 3301 indicates that the position of the DC subcarrier in the sidelink is undetermined. The DC subcarrier location offset relative to the center of the indicated subcarrier is given by $7.5 + 5N$ kHz if *frequencyShift7p5khzSL* is provided and by $5N$ kHz otherwise, where $N \in \{-1,0,1\}$ is given by the higher-layer parameter *valueN*.

8.2.6 Resource elements

Resource elements are defined in clause 4.4.3.

8.2.7 Resource blocks

Resource blocks are defined in clause 4.4.4.

Point A for sidelink transmission/reception is obtained from the higher-layer parameter *sl-AbsoluteFrequencyPointA*.

8.2.8 Bandwidth part

Configuration of the single bandwidth part for sidelink transmission is described in clause 16 of [5, TS 38.213].

8.3 Physical channels

8.3.1 Physical sidelink shared channel

8.3.1.1 Scrambling

For the single codeword $q = 0$, the block of bits $b^{(q)}(0), \dots, b^{(q)}(M_{\text{bit}}^{(q)} - 1)$, where $M_{\text{bit}}^{(q)} = M_{\text{bit,SCI2}}^{(q)} + M_{\text{bit,data}}^{(q)}$ is the number of bits in codeword q transmitted on the physical channel as defined in [4, TS 38.212], shall be scrambled prior to modulation.

Scrambling shall be done according to the following pseudo code

```
set  $i = 0$ 
```

```
set  $j = 0$ 
```

```
while  $i < M_{\text{bit}}^{(q)}$ 
```

```
    if  $b^{(q)}(i) = x // \text{SCI placeholder bits}$ 
```

$$\tilde{b}^{(q)}(i) = \tilde{b}^{(q)}(i - 2)$$

$$j = j + 1$$

else

$$\tilde{b}^{(q)}(i) = \left(b^{(q)}(i) + c^{(q)}(i - \tilde{M}_{i,j}^{(q)}) \right) \bmod 2$$

end if

$$i = i + 1$$

end while

where the scrambling sequence $c^{(q)}(i)$ is given by clause 5.2.1 and

- for $0 \leq i < M_{\text{bit,SCI2}}^{(q)}$
- $\tilde{M}_{i,j}^{(q)} = j$
- The scrambling sequence generator shall be initialized with

$$c_{\text{init}} = 2^{15} N_{\text{ID}} + 1010$$

where $N_{\text{ID}} = N_{\text{ID}}^{\text{X}} \bmod 2^{16}$ and the quantity N_{ID}^{X} equals the decimal representation of the CRC on the PSCCH associated with the PSSCH according to $N_{\text{ID}}^{\text{X}} = \sum_{i=0}^{L-1} p_i \cdot 2^{L-1-i}$ with p and L given by clause 8.3.2 in [4, TS 38.212].

- for $M_{\text{bit,SCI2}}^{(q)} \leq i < M_{\text{bit}}^{(q)}$
- $\tilde{M}_{i,j}^{(q)} = M_{\text{bit,SCI2}}^{(q)}$
- The scrambling sequence generator shall be initialized with

$$c_{\text{init}} = 2^{15} N_{\text{ID}} + 1010$$

where $N_{\text{ID}} = N_{\text{ID}}^{\text{X}} \bmod 2^{16}$ and the quantity N_{ID}^{X} equals the decimal representation of the CRC on the PSCCH associated with the PSSCH according to $N_{\text{ID}}^{\text{X}} = \sum_{i=0}^{L-1} p_i \cdot 2^{L-1-i}$ with p and L given by clause 8.3.2 in [4, TS 38.212].

8.3.1.2 Modulation

For the single codeword $q = 0$, the block of scrambled bits shall be modulated, resulting in a block of complex-valued modulation symbols $d^{(q)}(0), \dots, d^{(q)}(M_{\text{symb}}^{(q)} - 1)$ where $M_{\text{symb}}^{(q)} = M_{\text{symb},1}^{(q)} + M_{\text{symb},2}^{(q)}$.

Modulation for $0 \leq i < M_{\text{bit,SCI2}}^{(q)}$ shall be done as described in clause 5.1 using QPSK, where $M_{\text{symb},1}^{(q)} = M_{\text{bit,SCI2}}^{(q)} / 2$.

Modulation for $M_{\text{bit,SCI2}}^{(q)} \leq i < M_{\text{bit}}^{(q)}$ shall be done as described in clause 5.1 using one of the modulation schemes in Table 8.3.1.2-1 where $M_{\text{symb},2}^{(q)} = M_{\text{bit,data}}^{(q)} / Q_m$.

Table 8.3.1.2-1: Supported modulation schemes.

| Modulation scheme | Modulation order Q_m |
|-------------------|------------------------|
| QPSK | 2 |
| 16QAM | 4 |
| 64QAM | 6 |
| 256QAM | 8 |

8.3.1.3 Layer mapping

Layer mapping shall be done according to clause 7.3.1.3 with the number of layers $v \in \{1, 2\}$, resulting in $x(i) = [x^{(0)}(i) \ \dots \ x^{(v-1)}(i)]^T$, $i = 0, 1, \dots, M_{\text{symb}}^{\text{layer}} - 1$.

8.3.1.4 Precoding

The block of vectors $[x^{(0)}(i) \ \dots \ x^{(v-1)}(i)]^T$ shall be precoded according to clause 6.3.1.5 where the precoding matrix W equals the identity matrix and $M_{\text{symb}}^{\text{ap}} = M_{\text{symb}}^{\text{layer}}$.

8.3.1.5 Mapping to virtual resource blocks

For each of the antenna ports used for transmission of the PSSCH, the block of complex-valued symbols $z^{(p)}(0), \dots, z^{(p)}(M_{\text{symb}}^{\text{ap}} - 1)$ shall be multiplied with the amplitude scaling factor $\beta_{\text{DMRS}}^{\text{PSSCH}}$ in order to conform to the transmit power specified in [5, TS 38.213] and mapped to resource elements $(k', l)_{p, \mu}$ in the virtual resource blocks assigned for transmission, where $k' = 0$ is the first subcarrier in the lowest-numbered virtual resource block assigned for transmission.

The mapping operation shall be done in two steps:

- first, the complex-valued symbols corresponding to the bit for the 2nd-stage SCI in increasing order of first the index k' over the assigned virtual resource blocks and then the index l , starting from the first PSSCH symbol carrying an associated DM-RS and meeting all of the following criteria:
 - the corresponding resource elements in the corresponding physical resource blocks are not used for transmission of the associated DM-RS, PT-RS, or PSCCH;
- secondly, the complex-valued modulation symbols not corresponding to the 2nd-stage SCI shall be in increasing order of first the index k' over the assigned virtual resource blocks, and then the index l with the starting position given by [6, TS 38.214] and meeting all of the following criteria:
 - the resource elements are not used for 2nd-stage SCI in the first step;
 - the resource elements are not in the $L_{\text{SL-PRS}}$ symbols used for transmission of the associated SL PRS according to clause 8.2.4.1.1 of [6, TS 38.214];
 - the corresponding resource elements in the corresponding physical resource blocks are not used for transmission of the associated DM-RS, PT-RS, CSI-RS, or PSCCH.

The resource elements used for the PSSCH in the first OFDM symbol in the mapping operation above, including any DM-RS, PT-RS, or CSI-RS occurring in the first OFDM symbol, shall be duplicated in the OFDM symbol immediately preceding the first OFDM symbol in the mapping.

8.3.1.6 Mapping from virtual to physical resource blocks

Virtual resource blocks shall be mapped to physical resource blocks according to non-interleaved mapping.

For non-interleaved VRB-to-PRB mapping, virtual resource block n is mapped to physical resource block n .

8.3.2 Physical sidelink control channel

8.3.2.1 Scrambling

The block of bits $b(0), \dots, b(M_{\text{bit}} - 1)$, where M_{bit} is the number of bits transmitted on the physical channel, shall be scrambled prior to modulation, resulting in a block of scrambled bits $\tilde{b}(0), \dots, \tilde{b}(M_{\text{bit}} - 1)$ according to

$$\tilde{b}(i) = (b(i) + c(i)) \bmod 2$$

where the scrambling sequence $c(i)$ is given by clause 5.2.1. The scrambling sequence generator shall be initialized with

$$c_{\text{init}} = 1010$$

8.3.2.2 Modulation

The block of scrambled bits $\tilde{b}(0), \dots, \tilde{b}(M_{\text{bit}} - 1)$ shall be modulated as described in clause 5.1 using QPSK, resulting in a block of complex-valued modulation symbols $d(0), \dots, d(M_{\text{symb}} - 1)$ where $M_{\text{symb}} = M_{\text{bit}}/2$.

8.3.2.3 Mapping to physical resources

The set of complex-valued modulation symbols $d(0), \dots, d(M_{\text{symb}} - 1)$ shall be multiplied with the amplitude scaling factor $\beta_{\text{DMRS}}^{\text{PSCCH}}$ in order to conform to the transmit power specified in [5, TS 38.213] and mapped in sequence starting with $d(0)$ to resource elements $(k, l)_{p,\mu}$ assigned for transmission according to clause 16.4 of [5, TS 38.213], and not used for the demodulation reference signals associated with PSCCH, in increasing order of first the index k over the assigned physical resources, and then the index l on antenna port $p = 2000$.

The resource elements used for the PSCCH in the first OFDM symbol in the mapping operation above, including any DM-RS, PT-RS, or CSI-RS occurring in the first OFDM symbol, shall be duplicated in the immediately preceding OFDM symbol.

8.3.3 Physical sidelink broadcast channel

8.3.3.1 Scrambling

The block of bits $b(0), \dots, b(M_{\text{bit}} - 1)$, where M_{bit} is the number of bits transmitted on the physical sidelink broadcast channel, shall be scrambled prior to modulation, resulting in a block of scrambled bits $\tilde{b}(0), \dots, \tilde{b}(M_{\text{bit}} - 1)$ according to

$$\tilde{b}(i) = (b(i) + c(i)) \bmod 2$$

where the scrambling sequence $c(i)$ is given by clause 5.2.1. The scrambling sequence generator shall be initialized with $c_{\text{init}} = N_{\text{ID}}^{\text{SL}}$ at the start of each S-SS/PSBCH block.

8.3.3.2 Modulation

The block of bits $\tilde{b}(0), \dots, \tilde{b}(M_{\text{bit}} - 1)$ shall be QPSK modulated as described in clause 5.1.3, resulting in a block of complex-valued modulation symbols $d_{\text{PSBCH}}(0), \dots, d_{\text{PSBCH}}(M_{\text{symb}} - 1)$ where $M_{\text{symb}} = M_{\text{bit}}/2$.

8.3.3.3 Mapping to physical resources

Mapping to physical resources is described in clause 8.4.3.

8.3.4 Physical sidelink feedback channel

8.3.4.1 General

8.3.4.2 PSFCH format 0

8.3.4.2.1 Sequence generation

The sequence $x(n)$ shall be generated according to

$$x(n) = r_{u,v}^{\alpha,\delta}(n)$$

$$n = 0, 1, \dots, N_{\text{sc}}^{\text{RB}} - 1$$

where $r_{u,v}^{(\alpha,\delta)}(n)$ is given by clause 6.3.2.2 with the following exceptions:

- m_{cs} is given by clause 16.3 of [5, TS 38.213];
- m_0 is given by clause 16.3 of [5, TS 38.213];
- m_{int} is given by
 - $m_{int} = 5n_{IRB}^\mu$ if the higher-layer parameter *sl-TransmissionStructureForPSFCH* is configured and set to '*dedicatedInterlace*' and where n_{IRB}^μ is the resource block number within the interlace;
 - $m_{int} = 0$ otherwise
- $l = 0$;
- l' is the index of the OFDM symbol in the slot that corresponds to the second OFDM symbol of the PSFCH transmission in the slot given by [5, TS 38.213];
- $u = n_{ID} \bmod 30$ and $v = 0$ with n_{ID} given by the higher-layer parameter *sl-PSFCH-HopID* if configured; otherwise, $u = 0$.
- $c_{init} = n_{ID}$ with n_{ID} given by the higher-layer parameter *sl-PSFCH-HopID* if configured; otherwise, $c_{init} = 0$.

8.3.4.2.2 Mapping to physical resources

The sequence $x(n)$ shall be multiplied with the amplitude scaling factor β_{PSFCH} in order to conform to the transmit power specified in [5, TS 38.213] and mapped in sequence starting with $x(0)$ to resource elements $(k, l)_{p,\mu}$ assigned for transmission of the second PSFCH symbol according to clause 16.3 of [5, TS 38.213] in increasing order of the index k over the assigned physical resources on antenna port $p = 5000$.

The resource elements used for the PSFCH in the OFDM symbol in the mapping operation above shall be duplicated in the immediately preceding OFDM symbol.

If the higher-layer parameter *sl-TransmissionStructureForPSFCH* is configured and set to '*dedicatedInterlace*', the mapping operation shall be repeated for each resource block in the interlace and in the RB set over the assigned physical resource blocks according to clause 16.3 of [5, TS 38.213], with the resource-block dependent sequence generated according to clause 8.3.4.2.1.

If the higher-layer parameter *sl-TransmissionStructureForPSFCH* is configured and set to '*commonInterlace*', the mapping operation shall be repeated for each resource block over the assigned physical resource blocks according to clause 16.3 of [5, TS 38.213], with the resource-block dependent sequence generated according to clause 8.3.4.2.1, where the cyclic shift α on each resource block in the first interlace is up to UE implementation.

8.4 Physical signals

8.4.1 Reference signals

8.4.1.1 Demodulation reference signals for PSSCH

8.4.1.1.1 Sequence generation

The sequence $r_l(m)$ shall be generated according to

$$r_l(m) = \frac{1}{\sqrt{2}}(1 - 2c(2m)) + j \frac{1}{\sqrt{2}}(1 - 2c(2m + 1))$$

where the pseudo-random sequence $c(m)$ is defined in clause 5.2.1. The pseudo-random sequence generator shall be initialized with

$$c_{init} = (2^{17}(N_{\text{sym}}^{\text{slot}} n_{s,f}^\mu + l + 1)(2N_{ID} + 1) + 2N_{ID}) \bmod 2^{31}$$

where l is the OFDM symbol number within the slot, $n_{s,f}^\mu$ is the slot number within a frame, and $N_{ID} = N_{ID}^X \bmod 2^{16}$ where the quantity N_{ID}^X equals the decimal representation of CRC on the PSSCH associated with the PSSCH according to $N_{ID}^X = \sum_{i=0}^{L-1} p_i \cdot 2^{L-1-i}$ with p and L given by clause 7.3.2 in [4, TS 38.212].

8.4.1.1.2 Mapping to physical resources

The sequence $r(m)$ shall be mapped to the intermediate quantity $\tilde{a}_{k,l}^{(\tilde{p}_j,\mu)}$ according to clause 6.4.1.1.3 using configuration type 1 without transform precoding, and where $w_f(k')$, $w_t(l')$, and Δ are given by Table 8.4.1.1.2-2, and $r(m)$ is specified in clause 8.4.1.1.1.

The patterns used for the PSSCH DM-RS is indicated in the SCI as described in clause 8.3.1.1 of [4, TS 38.212].

The intermediate quantity $\tilde{a}_{k,l}^{(\tilde{p}_j,\mu)}$ shall be precoded, multiplied with the amplitude scaling factor β_{DMRS}^{PSSCH} specified in clause 8.3.1.5, and mapped to physical resources according to

$$\begin{bmatrix} a_{k,l}^{(p_0,\mu)} \\ \vdots \\ a_{k,l}^{(p_{\rho-1},\mu)} \end{bmatrix} = \beta_{DMRS}^{PSSCH} W \begin{bmatrix} \tilde{a}_{k,l}^{(\tilde{p}_0,\mu)} \\ \vdots \\ \tilde{a}_{k,l}^{(\tilde{p}_{v-1},\mu)} \end{bmatrix}$$

where

- the precoding matrix W is given by clause 8.3.1.4,
- the set of antenna ports $\{p_0, \dots, p_{\rho-1}\}$ is given by clause 8.3.1.4, and
- the set of antenna ports $\{\tilde{p}_0, \dots, \tilde{p}_{v-1}\}$ is given by [6, TS 38.214];

and the following conditions are fulfilled:

- the resource elements $\tilde{a}_{k,l}^{(\tilde{p}_j,\mu)}$ are within the common resource blocks allocated for PSSCH transmission.

The quantity k is defined relative to subcarrier 0 in common resource block 0 and the quantity l is defined relative to the start of the scheduled resources for transmission of PSSCH and the associated PSCCH, including the OFDM symbol duplicated as described in clauses 8.3.1.5 and 8.3.2.3.

The position(s) of the DM-RS symbols is given by \bar{l} according to Table 8.4.1.1.2-1 where the number of PSSCH DM-RS is indicated in the SCI, and l_d is the duration of the scheduled resources for transmission of PSSCH according to clause 8.1.2.1 of [6, TS 38.214] and the associated PSCCH, including the OFDM symbol duplicated as described in clauses 8.3.1.5 and 8.3.2.3.

Table 8.4.1.1.2-1: PSSCH DM-RS time-domain location.

| l_d in symbols | DM-RS position \bar{l} | | | | | |
|------------------|--------------------------|----------|-------------|--------------------------|----------|-------------|
| | PSCCH duration 2 symbols | | | PSCCH duration 3 symbols | | |
| | Number of PSSCH DM-RS | | | Number of PSSCH DM-RS | | |
| | 2 | 3 | 4 | 2 | 3 | 4 |
| 6 | 1, 5 | | | 1, 5 | | |
| 7 | 1, 5 | | | 1, 5 | | |
| 8 | 1, 5 | | | 1, 5 | | |
| 9 | 3, 8 | 1, 4, 7 | | 4, 8 | 1, 4, 7 | |
| 10 | 3, 8 | 1, 4, 7 | | 4, 8 | 1, 4, 7 | |
| 11 | 3, 10 | 1, 5, 9 | 1, 4, 7, 10 | 4, 10 | 1, 5, 9 | 1, 4, 7, 10 |
| 12 | 3, 10 | 1, 5, 9 | 1, 4, 7, 10 | 4, 10 | 1, 5, 9 | 1, 4, 7, 10 |
| 13 | 3, 10 | 1, 6, 11 | 1, 4, 7, 10 | 4, 10 | 1, 6, 11 | 1, 4, 7, 10 |

Table 8.4.1.1.2-2: Parameters for PSSCH DM-RS.

| p | CDM group λ | Δ | $w_{\text{f}}(k')$ | | $w_{\text{t}}(l')$ |
|------|---------------------|----------|--------------------|----------|--------------------|
| | | | $k' = 0$ | $k' = 1$ | |
| 1000 | 0 | 0 | +1 | +1 | +1 |
| 1001 | 0 | 0 | +1 | -1 | +1 |

8.4.1.2 Phase-tracking reference signals for PSSCH

8.4.1.2.1 Sequence generation

The precoded sidelink phase-tracking reference signal for subcarrier k on layer j is given by

$$r^{(\tilde{p}_j)}(m) = \begin{cases} r(m) & \text{if } j = j' \text{ or } j = j'' \\ 0 & \text{otherwise} \end{cases}$$

where

- antenna ports $\tilde{p}_{j'}$ or $\{\tilde{p}_{j'}, \tilde{p}_{j''}\}$ associated with PT-RS transmission are given by clause 8.2.3 of [6, TS 38.214];
- $r(m)$ is given by clause 8.4.1.1.1 at the position of the first PSSCH symbol carrying an associated DM-RS.

8.4.1.2.2 Mapping to physical resources

The UE shall transmit phase-tracking reference signals only in the resource blocks used for the PSSCH, and only if the procedure in [6, TS 38.214] indicates that phase-tracking reference signals are being used.

The PSSCH PT-RS shall be mapped to resource elements according to

$$\begin{bmatrix} a_{k,l}^{(p_0,\mu)} \\ \vdots \\ a_{k,l}^{(p_{\rho-1},\mu)} \end{bmatrix} = \beta_{\text{DMRS}}^{\text{PSSCH}} W \begin{bmatrix} r^{(\tilde{p}_0)}(2n + k') \\ \vdots \\ r^{(\tilde{p}_{v-1})}(2n + k') \end{bmatrix}$$

$$k = 4n + 2k' + \Delta$$

when all the following conditions are fulfilled

- l is within the OFDM symbols allocated for the PSSCH transmission;
- resource element (k, l) is not used for PSCCH, nor DM-RS associated with PSSCH;
- k' and Δ correspond to $\tilde{p}_0, \dots, \tilde{p}_{v-1}$

The precoding matrix W is given by clause 8.3.1.4.

The set of time indices l defined relative to the start of the PSSCH allocation is defined by

1. set $i = 0$ and $l_{\text{ref}} = 0$
2. if any symbol in the interval $\max(l_{\text{ref}} + (i - 1)L_{\text{PT-RS}} + 1, l_{\text{ref}}), \dots, l_{\text{ref}} + iL_{\text{PT-RS}}$ overlaps with a symbol used for DM-RS according to clause 8.4.1.1.2
 - set $i = 1$
 - set l_{ref} to the symbol index of the DM-RS symbol
 - repeat from step 2 as long as $l_{\text{ref}} + iL_{\text{PT-RS}}$ is inside the PSSCH allocation
3. add $l_{\text{ref}} + iL_{\text{PT-RS}}$ to the set of time indices for PT-RS
4. increment i by one
5. repeat from step 2 above as long as $l_{\text{ref}} + iL_{\text{PT-RS}}$ is inside the PSSCH allocation

where $L_{\text{PT-RS}} \in \{1,2,4\}$ is given by clause 8.4.3 of [6, TS 38.214].

For the purpose of PT-RS mapping, the resource blocks allocated for PSSCH transmission are numbered from 0 to $N_{\text{RB}} - 1$ from the lowest scheduled resource block to the highest. The corresponding subcarriers in this set of resource blocks are numbered in increasing order starting from the lowest frequency from 0 to $N_{\text{sc}}^{\text{RB}} N_{\text{RB}} - 1$. The subcarriers to which the PT-RS shall be mapped are given by

$$k = k_{\text{ref}}^{\text{RE}} + (iK_{\text{PT-RS}} + k_{\text{ref}}^{\text{RB}})N_{\text{sc}}^{\text{RB}}$$

$$k_{\text{ref}}^{\text{RB}} = \begin{cases} N_{\text{ID}} \bmod K_{\text{PT-RS}} & \text{if } N_{\text{RB}} \bmod K_{\text{PT-RS}} = 0 \\ N_{\text{ID}} \bmod (N_{\text{RB}} \bmod K_{\text{PT-RS}}) & \text{otherwise} \end{cases}$$

where

- $i = 0,1,2, \dots$
- $k_{\text{ref}}^{\text{RE}}$ is given by Table 8.4.1.2.2-1 for the DM-RS port associated with the PT-RS port according to clause 8.2.3 in [6, TS 38.214].
- N_{RB} is the number of resource blocks scheduled;
- $K_{\text{PT-RS}} \in \{2,4\}$ is given by [6, TS 38.214];
- $N_{\text{ID}} = N_{\text{ID}}^{\text{X}} \bmod 2^{16}$ where the quantity N_{ID}^{X} equals the decimal representation of CRC on the PSCCH associated with the PSSCH according to $N_{\text{ID}}^{\text{X}} = \sum_{i=0}^{L-1} p_i \cdot 2^{L-1-i}$ with p and L given by clause 7.3.2 in [4, TS 38.212].

PSSCH PT-RS shall not be mapped to resource elements containing PSCCH or PSCCH DMRS by puncturing PSSCH PT-RS.

A UE is not expected to receive sidelink CSI-RS and PSSCH PT-RS on the same resource elements.

Table 8.4.1.2.2-1: The parameter $k_{\text{ref}}^{\text{RE}}$.

| DM-RS antenna port \tilde{p} | $k_{\text{ref}}^{\text{RE}}$ | | | |
|-----------------------------------|------------------------------|----------|----------|----------|
| | resourceElementOffset | | | |
| | offset00 | offset01 | offset10 | offset11 |
| 0 | 0 | 2 | 6 | 8 |
| 1 | 2 | 4 | 8 | 10 |

8.4.1.3 Demodulation reference signals for PSCCH

8.4.1.3.1 Sequence generation

The sequence $r_l(m)$ shall be generated according to

$$r_l(m) = \frac{1}{\sqrt{2}}(1 - 2c(2m)) + j \frac{1}{\sqrt{2}}(1 - 2c(2m + 1))$$

where the pseudo-random sequence $c(m)$ is defined in clause 5.2.1. The pseudo-random sequence generator shall be initialized with

$$c_{\text{init}} = (2^{17}(N_{\text{slot}}^{\text{slot}} n_{\text{s,f}}^{\mu} + l + 1)(2N_{\text{ID}} + 1) + 2N_{\text{ID}}) \bmod 2^{31}$$

where

- l is the OFDM symbol number within the slot,
- $n_{\text{s,f}}^{\mu}$ is the slot number within a frame, and
- $N_{\text{ID}} \in \{0,1, \dots, 65535\}$ is given by the higher-layer parameter *sl-DMRS-ScrambleID*.

8.4.1.3.2 Mapping to physical resources

The sequence $r_l(m)$ shall be multiplied with the amplitude scaling factor $\beta_{\text{DMRS}}^{\text{PSCCH}}$ in order to conform to the transmit power specified in [5, 38.213] and mapped in sequence starting with $r_l(0)$ to resource elements $(k, l)_{p,\mu}$ in a slot on antenna port $p = 2000$ according to

$$\begin{aligned} a_{k,l}^{(p,\mu)} &= \beta_{\text{DMRS}}^{\text{PSCCH}} w_{f,i}(k') r_l(3n + k') \\ k &= nN_{\text{sc}}^{\text{RB}} + 4k' + 1 \\ k' &= 0,1,2 \\ n &= 0,1, \dots \end{aligned}$$

where the following conditions are fulfilled

- they are within the resource elements constituting the PSCCH

The quantity $w_{f,i}(k')$ is given by Table 8.4.1.3.2-1 and $i \in \{0,1,2\}$ shall be randomly selected by the UE.

The reference point for k is subcarrier 0 in common resource block 0.

The quantity l is the OFDM symbol number within the slot.

Table 8.4.1.3.2-1: The quantity $w_{f,i}(k')$.

| k' | $w_{f,i}(k')$ | | |
|------|---------------|----------------|----------------|
| | $i = 0$ | $i = 1$ | $i = 2$ |
| 0 | 1 | 1 | 1 |
| 1 | 1 | $e^{j2/3\pi}$ | $e^{-j2/3\pi}$ |
| 2 | 1 | $e^{-j2/3\pi}$ | $e^{j2/3\pi}$ |

8.4.1.4 Demodulation reference signals for PSBCH

8.4.1.4.1 Sequence generation

The reference-signal sequence $r(m)$ for an S-SS/PSBCH block is defined by

$$r(m) = \frac{1}{\sqrt{2}}(1 - 2c(2m)) + j \frac{1}{\sqrt{2}}(1 - 2c(2m + 1))$$

where $c(n)$ is given by clause 5.2. The scrambling sequence generator shall be initialized at the start of each S-SS/PSBCH block occasion with

$$c_{\text{init}} = N_{\text{ID}}^{\text{SL}}$$

8.4.1.4.2 Mapping to physical resources

Mapping to physical resources is described in clause 8.4.3.

8.4.1.5 CSI reference signals

8.4.1.5.1 General

8.4.1.5.2 Sequence generation

The sequence $r(m)$ shall be generated according to

$$r(m) = \frac{1}{\sqrt{2}}(1 - 2c(2m)) + j \frac{1}{\sqrt{2}}(1 - 2c(2m + 1))$$

where the pseudo-random sequence $c(i)$ is defined in clause 5.2.1. The pseudo-random sequence generator shall be initialised with

$$c_{\text{init}} = \left(2^{10} (N_{\text{symb}}^{\text{slot}} n_{s,f}^{\mu} + l + 1) (2n_{\text{ID}} + 1) + n_{\text{ID}} \right) \bmod 2^{31}$$

at the start of each OFDM symbol where $n_{s,f}^{\mu}$ is the slot number within a radio frame, l is the OFDM symbol number within a slot, and $n_{\text{ID}} = N_{\text{ID}}^{\text{X}} \bmod 2^{10}$ where the quantity N_{ID}^{X} equals the decimal representation of CRC for the sidelink control information mapped to the PSCCH associated with the CSI-RS according to $N_{\text{ID}}^{\text{X}} = \sum_{i=0}^{L-1} p_i \cdot 2^{L-1-i}$ with p and L given by clause 7.3.2 in [4, TS 38.212].

8.4.1.5.3 Mapping to physical resources

Mapping to resource elements shall be done according to clause 7.4.1.5.3 with the following exceptions:

- only 1 and 2 antenna ports are supported, $X \in \{1,2\}$;
- only density $\rho = 1$ is supported;
- zero-power CSI-RS is not supported;
- the quantity $\beta_{\text{CSI-RS}}$ is an amplitude scaling factor to conform with the transmit power specified in clause 8.2.1 of [6, TS 38.214].

8.4.1.6 Positioning reference signals

8.4.1.6.1 General

A SL PRS resource refers to a time-frequency resource within a slot, used for SL PRS transmission.

8.4.1.6.2 Sequence generation

The sequence $r(m)$ is defined by

$$r(m) = \frac{1}{\sqrt{2}} (1 - 2c(2m)) + j \frac{1}{\sqrt{2}} (1 - 2c(2m + 1))$$

where the pseudo-random sequence $c(i)$ is defined in clause 5.2.1. The pseudo-random sequence generator shall be initialised with

$$c_{\text{init}} = \left(2^{22} \left\lfloor \frac{n_{\text{ID,seq}}^{\text{SL-PRS}}}{1024} \right\rfloor + 2^{10} (N_{\text{symb}}^{\text{slot}} n_{s,f}^{\mu} + l + 1) (2(n_{\text{ID,seq}}^{\text{SL-PRS}} \bmod 1024) + 1) + (n_{\text{ID,seq}}^{\text{SL-PRS}} \bmod 1024) \right) \bmod 2^{31}$$

where

- $n_{s,f}^{\mu}$ is the slot number within the radio frame
- l is the OFDM symbol number within the slot to which the sequence is mapped
- $n_{\text{ID,seq}}^{\text{SL-PRS}} \in \{0,1, \dots, 4095\}$ is the sidelink PRS sequence ID, which, if not provided by higher layers, is obtained from the decimal representation of the CRC for the sidelink control information mapped to the PSCCH associated with the SL PRS according to $n_{\text{ID,seq}}^{\text{SL-PRS}} = (\sum_{i=0}^{L-1} p_i \cdot 2^{L-1-i}) \bmod 2^{12}$ with p and L given by clause 7.3.2 in [4, TS 38.212].

8.4.1.6.3 Mapping to physical resources

The sequence shall be multiplied with the amplitude scaling factor $\beta_{\text{SL-PRS}}$ in order to conform to the transmit power specified in [5, TS 38.213] and mapped to resources elements $(k, l)_{p,\mu}$ according to

$$a_{k,l}^{(p,\mu)} = \beta_{\text{SL-PRS}} r(m)$$

$$m = 0, 1, \dots$$

$$k = mK_{\text{comb}}^{\text{SL-PRS}} + \left((k_{\text{offset}}^{\text{SL-PRS}} + k') \bmod K_{\text{comb}}^{\text{SL-PRS}} \right)$$

$$l = l_{\text{start}}^{\text{SL-PRS}}, l_{\text{start}}^{\text{SL-PRS}} + 1, \dots, l_{\text{start}}^{\text{SL-PRS}} + L_{\text{SL-PRS}} - 1$$

when the following conditions are fulfilled:

- the resource element $(k, l)_{p,\mu}$ is within the common resource blocks occupied by the SL PRS resource

and where

- the comb size $K_{\text{comb}}^{\text{SL-PRS}}$ is provided by the higher layer parameter *sl-PRS-CombSizeN-AndReOffset* for a shared SL PRS resource pool and by the higher layer parameter *sl-CombSize* for a dedicated SL PRS resource pool
- the resource-element offset $k_{\text{offset}}^{\text{SL-PRS}} \in \{0, 1, \dots, K_{\text{comb}}^{\text{SL-PRS}} - 1\}$
- the frequency offset k' is given by Table 8.4.1.6.3-1
- the starting symbol $l_{\text{start}}^{\text{SL-PRS}}$ is provided by the higher-layer parameter *sl-PRS-starting-symbol* for a dedicated SL PRS resource pool, or is determined such that the symbols $\{l_{\text{start}}^{\text{SL-PRS}}, l_{\text{start}}^{\text{SL-PRS}} + 1, \dots, l_{\text{start}}^{\text{SL-PRS}} + L_{\text{SL-PRS}} - 1\}$ are mapped to the last consecutive $L_{\text{SL-PRS}}$ symbols in the slot that can be used for SL PRS for a shared SL PRS resource pool as described in clause 8.2.4.1.1 in [6, TS38.214]
- the number of symbols $L_{\text{SL-PRS}}$ is provided by the higher-layer parameter *mNumberOfSymbols* for a shared resource pool and by the higher layer parameter *sl-NumberOfSymbols* for a dedicated resource pool and limited to combinations $\{L_{\text{SL-PRS}}, K_{\text{comb}}^{\text{SL-PRS}}\}$ fulfilling
 - in a dedicated SL PRS resource pool: $\{1, 2\}, \{2, 2\}, \{2, 4\}, \{4, 4\}, \{6, 6\}$, and combinations with $K_{\text{comb}}^{\text{SL-PRS}} \in \{2, 4, 6\}$ and $L_{\text{SL-PRS}} \in \{3, 4, \dots, 9\}$ where $L_{\text{SL-PRS}} > K_{\text{comb}}^{\text{SL-PRS}}$
 - in a shared SL PRS resource pool: $\{1, 1\}, \{1, 2\}, \{2, 1\}, \{2, 2\}, \{2, 4\}, \{4, 1\}, \{4, 2\}, \{4, 4\}$
- the antenna port $p = 6000$

The reference point for k is subcarrier 0 in common resource block 0.

For transmission of an SL PRS in a dedicated SL PRS resource pool, the content of the OFDM symbol immediately preceding the SL PRS resource shall be generated based on 8.4.1.6.2 and mapped to resource elements with

- the time-domain index $l = l_{\text{start}}^{\text{SL-PRS}} - 1$
- the set of frequency-domain indices k shall be identical to those of the last OFDM symbol in the SL PRS resource
- the amplitude scaling factor shall be same as the amplitude scaling factor $\beta_{\text{SL-PRS}}$ of the SL PRS resource.

Table 8.4.1.6.3-1: The frequency offset k' as a function of $l - l_{\text{start}}^{\text{SL-PRS}}$.

| $K_{\text{comb}}^{\text{SL-PRS}}$ | Symbol number within the sidelink PRS resource $l - l_{\text{start}}^{\text{SL-PRS}}$ | | | | | | | | |
|-----------------------------------|---|---|---|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 |
| 4 | 0 | 2 | 1 | 3 | 0 | 2 | 1 | 3 | 0 |
| 6 | 0 | 3 | 1 | 4 | 2 | 5 | 0 | 3 | 1 |

8.4.2 Synchronization signals

8.4.2.1 Physical-layer sidelink synchronization identities

There are 672 unique physical-layer sidelink synchronization identities given by

$$N_{\text{ID}}^{\text{SL}} = N_{\text{ID},1}^{\text{SL}} + 336N_{\text{ID},2}^{\text{SL}}$$

where $N_{ID,1}^{SL} \in \{0,1, \dots, 335\}$ and $N_{ID,2}^{SL} \in \{0,1\}$. The sidelink synchronization identities are divided into two sets, id_net consisting of $N_{ID}^{SL} = 0,1, \dots, 335$ and id_oon consisting of $N_{ID}^{SL} = 336,337, \dots, 671$.

8.4.2.2 Sidelink primary synchronization signal

8.4.2.2.1 Sequence generation

The sequence $d_{S-PSS}(n)$ for the sidelink primary synchronization signal is defined by

$$\begin{aligned} d_{S-PSS}(n) &= 1 - 2x(m) \\ m &= (n + 22 + 43N_{ID,2}^{SL}) \bmod 127 \\ 0 &\leq n < 127 \end{aligned}$$

where

$$x(i + 7) = (x(i + 4) + x(i)) \bmod 2$$

and

$$[x(6) \ x(5) \ x(4) \ x(3) \ x(2) \ x(1) \ x(0)] = [1 \ 1 \ 1 \ 0 \ 1 \ 1 \ 0]$$

8.4.2.2.2 Mapping to physical resources

Mapping to physical resources is described in clause 8.4.3.

8.4.2.3 Sidelink secondary synchronization signal

8.4.2.3.1 Sequence generation

The sequence $d_{S-SSS}(n)$ for the sidelink secondary synchronization signal is defined by

$$\begin{aligned} d_{S-SSS}(n) &= [1 - 2x_0((n + m_0) \bmod 127)][1 - 2x_1((n + m_1) \bmod 127)] \\ m_0 &= 15 \left\lfloor \frac{N_{ID,1}^{SL}}{112} \right\rfloor + 5N_{ID,2}^{SL} \\ m_1 &= N_{ID,1}^{SL} \bmod 112 \\ 0 &\leq n < 127 \end{aligned}$$

where

$$\begin{aligned} x_0(i + 7) &= (x_0(i + 4) + x_0(i)) \bmod 2 \\ x_1(i + 7) &= (x_1(i + 1) + x_1(i)) \bmod 2 \end{aligned}$$

and

$$\begin{aligned} [x_0(6) \ x_0(5) \ x_0(4) \ x_0(3) \ x_0(2) \ x_0(1) \ x_0(0)] &= [0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 1] \\ [x_1(6) \ x_1(5) \ x_1(4) \ x_1(3) \ x_1(2) \ x_1(1) \ x_1(0)] &= [0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 1] \end{aligned}$$

8.4.2.3.2 Mapping to physical resources

Mapping to physical resources is described in clause 8.4.3.

8.4.3 S-SS/PSBCH block

8.4.3.1 Time-frequency structure of an S-SS/PSBCH block

In the time domain, an S-SS/PSBCH block consists of N_{syimb}^{S-SSB} OFDM symbols, numbered in increasing order from 0 to $N_{\text{syimb}}^{S-SSB} - 1$ within the S-SS/PSBCH block, where S-PSS, S-SSS, and PSBCH with associated DM-RS are mapped to symbols as given by Table 8.4.3.1-1. The number of OFDM symbols in an S-SS/PSBCH block $N_{\text{syimb}}^{S-SSB} = 13$ for normal

cyclic prefix and $N_{\text{sy mb}}^{\text{S-SSB}} = 11$ for extended cyclic prefix. The first OFDM symbol in an S-SS/PSBCH block is the first OFDM symbol in the slot.

In the frequency domain, an S-SS/PSBCH block consists of 132 contiguous subcarriers with the subcarriers numbered in increasing order from 0 to 131 within the sidelink S-SS/PSBCH block. The quantities k and l represent the frequency and time indices, respectively, within one sidelink S-SS/PSBCH block.

For an S-SS/PSBCH block, the UE shall use

- antenna port 4000 for transmission of S-PSS, S-SSS, PSBCH and DM-RS for PSBCH;
- the same cyclic prefix length and subcarrier spacing for the S-PSS, S-SSS, PSBCH and DM-RS for PSBCH,

Table 8.4.3.1-1: Resources within an S-SS/PSBCH block for S-PSS, S-SSS, PSBCH, and DM-RS.

| Channel or signal | OFDM symbol number l relative to the start of an S-SS/PSBCH block | Subcarrier number k relative to the start of an S-SS/PSBCH block |
|-------------------|---|--|
| S-PSS | 1, 2 | 2, 3, ..., 127, 128 |
| S-SSS | 3, 4 | 2, 3, ..., 127, 128 |
| Set to zero | 1, 2, 3, 4 | 0, 1, 129, 130, 131 |
| PSBCH | 0, 5, 6, ..., $N_{\text{sy mb}}^{\text{S-SSB}} - 1$ | 0, 1, ..., 131 |
| DM-RS for PSBCH | 0, 5, 6, ..., $N_{\text{sy mb}}^{\text{S-SSB}} - 1$ | 0, 4, 8, ..., 128 |

8.4.3.1.1 Mapping of S-PSS within an S-SS/PSBCH block

The sequence of symbols $d_{\text{S-PSS}}(0), \dots, d_{\text{S-PSS}}(126)$ constituting the sidelink primary synchronization signal in one OFDM symbol shall be scaled by a factor $\beta_{\text{S-PSS}}$ to conform to the S-PSS power allocation specified in [5, TS 38.213] and mapped to resource elements $(k, l)_{p, \mu}$ in increasing order of k in each of the symbols l , where k and l are given by Table 8.4.3.1-1 and represent the frequency and time indices, respectively, within one S-SS/PSBCH block.

8.4.3.1.2 Mapping of S-SSS within an S-SS/PSBCH block

The sequence of symbols $d_{\text{S-SSS}}(0), \dots, d_{\text{S-SSS}}(126)$ constituting the sidelink secondary synchronization signal in one OFDM symbol shall be scaled by a factor $\beta_{\text{S-SSS}}$ to conform to the S-SSS power allocation specified in [5, TS 38.213] and mapped to resource elements $(k, l)_{p, \mu}$ in increasing order of k in each of the symbols l , where k and l are given by Table 8.4.3.1-1 and represent the frequency and time indices, respectively, within one S-SS/PSBCH block.

8.4.3.1.3 Mapping of PSBCH and DM-RS within an S-SS/PSBCH block

The sequence of complex-valued symbols $d_{\text{PSBCH}}(0), \dots, d_{\text{PSBCH}}(M_{\text{sy mb}} - 1)$ constituting the physical sidelink broadcast channel shall be scaled by a factor $\beta_{\text{DMRS}}^{\text{PSBCH}}$ to conform to the PSBCH power allocation specified in [5, TS 38.213] and mapped in sequence starting with $d_{\text{PSBCH}}(0)$ to resource elements $(k, l)_{p, \mu}$ which meet all the following criteria:

- they are not used for PSBCH demodulation reference signals

The mapping to resource elements $(k, l)_{p, \mu}$ not reserved for PSBCH DM-RS shall be in increasing order of first the index k and then the index l , where k and l represent the frequency and time indices, respectively, within one S-SS/PSBCH block and are given by Table 8.4.3.1-1.

The sequence of complex-valued symbols $r(0), \dots, r(33(N_{\text{sy mb}}^{\text{S-SSB}} - 4) - 1)$ constituting the demodulation reference signals for the S-SS/PSBCH block shall be scaled by a factor of $\beta_{\text{DMRS}}^{\text{PSBCH}}$ to conform to the PSBCH power allocation specified in [5, TS 38.213] and mapped to resource elements $(k, l)_{p, \mu}$ in increasing order of first k and then l where k and l are given by Table 8.4.3.1-1 and represent the frequency and time indices, respectively, within one S-SS/PSBCH block.

8.4.3.2 Time location of an S-SS/PSBCH block

The locations in the time domain where a UE shall monitor for a possible S-SS/PSBCH block are described in clause 16.1 of [5, TS 38.213].

8.5 Timing

Transmission of a sidelink radio frame number i from the UE shall start $(N_{TA,SL} + N_{TA,offset}) \cdot T_c$ seconds before the start of the corresponding timing reference frame at the UE. The UE is not required to receive sidelink or downlink transmissions earlier than the value of $N_{TA,offset}$, which is given in [12, TS 38.133], after the end of a sidelink transmission.

For sidelink transmissions:

If the UE has a serving cell fulfilling the S criterion according to clause 8.2 of [13, TS 38.304]

- The timing of reference radio frame i equals that of downlink radio frame i in the cell with the same uplink carrier frequency as the sidelink and
- $N_{TA,offset}$ is given by clause 4.3.1 of [TS 38.211],

Otherwise

- The timing of reference radio frame i and $N_{TA,offset}$ value are given by clause 12.2.2, 12.2.3, 12.2.4 or 12.2.5 of [12, TS 38.133].

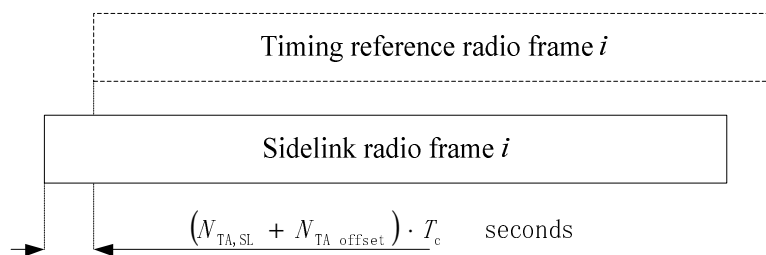


Figure 8.5-1: Sidelink timing relation

The quantity $N_{TA,SL}$ equals to 0.

Annex A (informative): Change history

| Change history | | | | | | | |
|----------------|----------|------------|------|-----|-----|--|-------------|
| Date | Meeting | TDoc | CR | Rev | Cat | Subject/Comment | New version |
| 2017-04 | RAN1#89 | R1-1708219 | | | | Draft skeleton | 0.0.0 |
| 2017-05 | AH_1706 | R1-1711366 | | | | Inclusion of agreements up to and including RAN1#89 | 0.0.1 |
| 2017-06 | AH_1706 | R1-1711886 | | | | Updated editor's version | 0.0.2 |
| 2017-06 | AH_1706 | R1-1712004 | | | | Clean version further to RAN1's endorsement | 0.1.0 |
| 2017-07 | AH_1706 | R1-1712011 | | | | Inclusion of agreements up to and including RAN1 NR AdHoc #2 | 0.1.1 |
| 2017-08 | AH_1706 | R1-1712950 | | | | Updated editor's version | 0.1.2 |
| 2017-08 | RAN1#90 | R1-1713296 | | | | Updated editor's version | 0.1.3 |
| 2017-08 | RAN1#90 | R1-1714656 | | | | Endorsed by RAN1#90 | 0.2.0 |
| 2017-08 | RAN1#90 | R1-1715321 | | | | Inclusion of agreements from RAN1#90 | 0.2.1 |
| 2017-09 | RAN1#90 | R1-1715329 | | | | Updated editor's version | 0.2.2 |
| 2017-09 | RAN#77 | RP-171994 | | | | For information to plenary | 1.0.0 |
| 2017-09 | AH_1709 | R1-1716927 | | | | Inclusion of agreements from AdHoc#3 | 1.0.1 |
| 2017-09 | AH_1709 | R1-1718318 | | | | Updated editor's version | 1.0.2 |
| 2017-10 | RAN1#90b | R1-1719105 | | | | Endorsed by RAN1#90bis | 1.1.0 |
| 2017-10 | RAN1#90b | R1-1719224 | | | | Inclusion of agreements from RAN1#90bis | 1.1.1 |
| 2017-11 | RAN1#90b | R1-1719685 | | | | Updated editor's version | 1.1.2 |
| 2017-11 | RAN1#90b | R1-1720850 | | | | Updated editor's version | 1.1.3 |
| 2017-11 | RAN1#90b | R1-1721048 | | | | Endorsed by RAN1#90bis | 1.2.0 |
| 2017-12 | RAN1#91 | R1-17xxxxx | | | | Inclusion of agreements from RAN1#91 | 1.2.1 |
| 2017-12 | RAN1#91 | R1-1721341 | | | | Endorsed by RAN1#91 | 1.3.0 |
| 2017-12 | RAN#78 | RP-172284 | | | | For approval by plenary | 2.0.0 |
| 2017-12 | RAN#78 | | | | | Approved by plenary – Rel-15 spec under change control | 15.0.0 |
| 2018-03 | RAN#79 | RP-180200 | 0001 | - | F | CR capturing the Jan18 ad-hoc and RAN1#92 meeting agreements | 15.1.0 |
| 2018-06 | RAN#80 | RP-181172 | 0002 | 1 | F | CR to 38.211 capturing the RAN1#92bis and RAN1#93 meeting agreements | 15.2.0 |
| 2018-09 | RAN#81 | RP-181789 | 0003 | - | F | Corrections according to agreements from RAN1#94 | 15.3.0 |
| 2018-12 | RAN#82 | RP-182523 | 0004 | 1 | F | Combined CR of all essential corrections to 38.211 from RAN1#94bis and RAN1#95 | 15.4.0 |
| 2019-03 | RAN#83 | RP-190447 | 0005 | - | F | CR for PUCCH Format 1 | 15.5.0 |
| 2019-03 | RAN#83 | RP-190447 | 0006 | - | F | CR on PDSCH mapping to virtual resource blocks | 15.5.0 |
| 2019-03 | RAN#83 | RP-190447 | 0007 | 2 | F | Alignment of terminology across specifications | 15.5.0 |
| 2019-03 | RAN#83 | RP-190447 | 0008 | - | F | Correction on physical resource mapping for PUSCH with configured grant | 15.5.0 |
| 2019-03 | RAN#83 | RP-190773 | 0009 | 1 | F | Correction to frequency-domain starting position for SRS resource mapping | 15.5.0 |
| 2019-06 | RAN#84 | RP-191281 | 0010 | - | F | CR on PUCCH format 1 | 15.6.0 |
| 2019-06 | RAN#84 | RP-191281 | 0011 | - | F | Correction on reference name of UE capability of additional DMRS for co-existence with LTE CRS | 15.6.0 |
| 2019-06 | RAN#84 | RP-191281 | 0012 | - | F | Correction on mapping from virtual to physical resource blocks | 15.6.0 |
| 2019-06 | RAN#84 | RP-191281 | 0014 | 2 | F | Corrections to 38.211 including alignment of terminology across specifications | 15.6.0 |
| 2019-06 | RAN#84 | RP-191281 | 0015 | - | F | Clarification regarding non-full-duplex UE communication | 15.6.0 |
| 2019-06 | RAN#84 | RP-191281 | 0016 | - | F | Corrections on PUSCH scheduled by RAR UL grant and Msg3 PUSCH retransmission | 15.6.0 |
| 2019-09 | RAN#85 | RP-191940 | 0017 | - | F | Correction on PUSCH scrambling | 15.7.0 |
| 2019-09 | RAN#85 | RP-191940 | 0018 | - | F | Correction on PDSCH resource allocation scheduled by PDCCH in Type 0 common search space | 15.7.0 |
| 2019-09 | RAN#85 | RP-191940 | 0019 | - | F | Corrections to 38.211 including alignment of terminology across specifications in RAN1#98 | 15.7.0 |
| 2019-12 | RAN#86 | RP-192624 | 0022 | - | F | Corrections to 38.211 including alignment of terminology across specifications in RAN1#98bis and RAN1#99 | 15.8.0 |
| 2019-12 | RAN#86 | RP-192634 | 0020 | 1 | B | Introduction of remote interference management | 16.0.0 |
| 2019-12 | RAN#86 | RP-192635 | 0023 | - | B | Introduction of two-step RACH | 16.0.0 |
| 2019-12 | RAN#86 | RP-192636 | 0024 | - | B | Introduction of NR-based access to unlicensed spectrum | 16.0.0 |
| 2019-12 | RAN#86 | RP-192637 | 0025 | - | B | Introduction of integrated access and backhaul for NR | 16.0.0 |
| 2019-12 | RAN#86 | RP-192638 | 0026 | - | B | Introduction of V2X | 16.0.0 |
| 2019-12 | RAN#86 | RP-192639 | 0027 | - | B | Introduction of eURLLC support | 16.0.0 |
| 2019-12 | RAN#86 | RP-192641 | 0028 | - | B | Introduction of MIMO enhancements | 16.0.0 |
| 2019-12 | RAN#86 | RP-192643 | 0029 | - | B | Introduction of NR positioning support | 16.0.0 |
| 2019-12 | RAN#86 | RP-192646 | 0030 | - | B | Introduction of enhanced support for dynamic spectrum sharing | 16.0.0 |

| | | | | | | | |
|---------|----------|-----------|------|---|---|--|--------|
| 2019-12 | RAN#86 | RP-192646 | 0031 | - | B | Introduction of additional RACH configurations for TDD FR1 | 16.0.0 |
| 2019-12 | RAN#86 | RP-192645 | 0032 | - | B | Introduction of cross-carrier scheduling with different numerologies | 16.0.0 |
| 2020-03 | RAN#87-e | RP-200186 | 0033 | - | F | Corrections to integrated access and backhaul for NR | 16.1.0 |
| 2020-03 | RAN#87-e | RP-200192 | 0034 | - | F | Corrections to NR positioning support | 16.1.0 |
| 2020-03 | RAN#87-e | RP-200184 | 0035 | - | F | Corrections to two-step RACH | 16.1.0 |
| 2020-03 | RAN#87-e | RP-200194 | 0036 | - | F | Corrections to cross-carrier scheduling with different numerologies | 16.1.0 |
| 2020-03 | RAN#87-e | RP-200185 | 0037 | - | F | Corrections to NR-based access to unlicensed spectrum | 16.1.0 |
| 2020-03 | RAN#87-e | RP-200187 | 0038 | - | F | Corrections to V2X | 16.1.0 |
| 2020-03 | RAN#87-e | RP-200190 | 0039 | - | F | Corrections to MIMO enhancements | 16.1.0 |
| 2020-06 | RAN#88-e | RP-200687 | 0040 | 1 | F | Corrections to NR-based access to unlicensed spectrum | 16.2.0 |
| 2020-06 | RAN#88-e | RP-200694 | 0041 | 1 | F | Corrections to NR positioning support | 16.2.0 |
| 2020-06 | RAN#88-e | RP-200692 | 0042 | 1 | F | Corrections to MIMO enhancements | 16.2.0 |
| 2020-06 | RAN#88-e | RP-200686 | 0043 | 1 | F | Corrections to two-step RACH | 16.2.0 |
| 2020-06 | RAN#88-e | RP-200696 | 0044 | 1 | F | Corrections to carrier aggregation with unaligned frame boundaries | 16.2.0 |
| 2020-06 | RAN#88-e | RP-200689 | 0045 | 1 | F | Corrections to V2X | 16.2.0 |
| 2020-06 | RAN#88-e | RP-200688 | 0046 | 1 | F | Corrections to integrated access and backhaul for NR | 16.2.0 |
| 2020-09 | RAN#89-e | RP-201804 | 0047 | - | F | CR on 2-step RACH for 38.211 | 16.3.0 |
| 2020-09 | RAN#89-e | RP-201812 | 0048 | - | F | CR on correction half duplex operation during DAPS HO | 16.3.0 |
| 2020-09 | RAN#89-e | RP-201807 | 0049 | - | F | Corrections to V2X | 16.3.0 |
| 2020-09 | RAN#89-e | RP-201809 | 0050 | - | F | Corrections to MIMO enhancements | 16.3.0 |
| 2020-09 | RAN#89-e | RP-201811 | 0051 | - | F | Corrections to NR positioning support | 16.3.0 |
| 2020-09 | RAN#89-e | RP-201805 | 0052 | - | F | Corrections to NR-based access to unlicensed spectrum | 16.3.0 |
| 2020-12 | RAN#90-e | RP-202380 | 0053 | - | F | CR on the determination of DMRS sequences in 38.211 | 16.4.0 |
| 2020-12 | RAN#90-e | RP-202383 | 0054 | - | F | Correction on sidelink timing definition | 16.4.0 |
| 2020-12 | RAN#90-e | RP-202381 | 0055 | - | F | Correction to UE assumption on RB set configuration for PRACH | 16.4.0 |
| 2020-12 | RAN#90-e | RP-202381 | 0057 | - | F | CR to 38.211 on NR-U PRACH RO configuration | 16.4.0 |
| 2020-12 | RAN#90-e | RP-202383 | 0058 | - | F | Corrections on sidelink for PHY layer structure | 16.4.0 |
| 2020-12 | RAN#90-e | RP-202383 | 0059 | - | F | Correction on SL PT-RS sequence generation | 16.4.0 |
| 2020-12 | RAN#90-e | RP-202383 | 0060 | - | F | Correction on PSFCH mapping | 16.4.0 |
| 2020-12 | RAN#90-e | RP-202387 | 0062 | - | F | Corrections to 38.211 for NR positioning | 16.4.0 |
| 2020-12 | RAN#90-e | RP-202381 | 0063 | - | F | CR to 38.211 to correct CP extension for SRS | 16.4.0 |
| 2020-12 | RAN#90-e | RP-202398 | 0064 | - | F | Alignment CR for TS 38.211 | 16.4.0 |
| 2021-03 | RAN#91-e | RP-210049 | 0065 | - | F | Correction on DM-RS presence with PDSCH mapping type B | 16.5.0 |
| 2021-03 | RAN#91-e | RP-210049 | 0066 | - | F | Correction on usage of subCarrierSpacingCommon for unlicensed | 16.5.0 |
| 2021-03 | RAN#91-e | RP-210050 | 0067 | - | F | Clarification on Sidelink SSID | 16.5.0 |

| | | | | | | | |
|---------|----------|-----------|------|---|---|---|--------|
| 2021-03 | RAN#91-e | RP-210059 | 0068 | - | F | Alignment of notation | 16.5.0 |
| 2021-06 | RAN#92-e | RP-211248 | 0069 | - | F | Correction on RIM RS resource and set ID mapping | 16.6.0 |
| 2021-06 | RAN#92-e | RP-211236 | 0070 | - | F | Correction on channel inference assumption for PUSCH repetition Type B | 16.6.0 |
| 2021-06 | RAN#92-e | RP-211243 | 0071 | 1 | F | Alignment of notation | 16.6.0 |
| 2021-06 | RAN#92-e | RP-211235 | 0072 | - | F | Correction on OFDM signal generation and PSSCH DM-RS time-domain OCC in TS 38.211 | 16.6.0 |
| 2021-06 | RAN#92-e | RP-211233 | 0074 | - | A | Correction on channel properties assumption of UL transmission | 16.6.0 |
| 2021-09 | RAN#93-e | RP-211850 | 0076 | - | F | Alignment of notation | 16.7.0 |
| 2021-12 | RAN#94-e | RP-212958 | 0078 | - | A | Correction to CCE-to-REG mapping and CSI-RS mapping | 16.8.0 |
| 2021-12 | RAN#94-e | RP-212960 | 0079 | - | F | Correction to VRB-to-PRB mapping for DCI format 1_2 | 16.8.0 |
| 2021-12 | RAN#94-e | RP-212966 | 0080 | - | B | Introduction of MIMO enhancements | 17.0.0 |
| 2021-12 | RAN#94-e | RP-212967 | 0081 | - | B | Introduction of extensions to 71 GHz | 17.0.0 |
| 2021-12 | RAN#94-e | RP-212969 | 0082 | - | B | Introduction of Non-Terrestrial Networks (NTN) | 17.0.0 |
| 2021-12 | RAN#94-e | RP-212973 | 0083 | - | B | Introduction of coverage enhancements | 17.0.0 |
| 2021-12 | RAN#94-e | RP-212979 | 0084 | - | B | Introduction of Multicast and Broadcast Services (MBS) support | 17.0.0 |
| 2021-12 | RAN#94-e | RP-212982 | 0085 | - | B | Introduction of DL 1024QAM for NR FR1 | 17.0.0 |
| 2022-03 | RAN#95-e | RP-220920 | 0086 | 2 | C | Pi/2-BPSK specification updates for the merger of 5Gi into 3GPP | 17.1.0 |
| 2022-03 | RAN#95-e | RP-220245 | 0088 | - | A | CR on corrections on SL timing | 17.1.0 |
| 2022-03 | RAN#95-e | RP-220251 | 0089 | - | F | Corrections to NR in the 52.6 – 71 GHz range | 17.1.0 |
| 2022-03 | RAN#95-e | RP-220263 | 0090 | - | F | Corrections to NR support of multicast and broadcast services | 17.1.0 |
| 2022-03 | RAN#95-e | RP-220250 | 0091 | - | F | Corrections to MIMO enhancements | 17.1.0 |
| 2022-03 | RAN#95-e | RP-220252 | 0092 | - | F | Corrections to IIoT and URLLC enhancements | 17.1.0 |
| 2022-03 | RAN#95-e | RP-220253 | 0093 | - | F | Corrections to NR NTN support | 17.1.0 |
| 2022-03 | RAN#95-e | RP-220270 | 0094 | - | F | Corrections to small data transmissions in RRC_INACTIVE state | 17.1.0 |
| 2022-06 | RAN#96 | RP-221606 | 0095 | - | F | Corrections on NR UE Power Saving Enhancements | 17.2.0 |
| 2022-06 | RAN#96 | RP-221600 | 0096 | - | F | Corrections to MIMO enhancements | 17.2.0 |
| 2022-06 | RAN#96 | RP-221603 | 0097 | - | F | Corrections to timing advance for NTN | 17.2.0 |
| 2022-06 | RAN#96 | RP-221620 | 0099 | - | A | Clarification of PUSCH DM-RS generation | 17.2.0 |
| 2022-09 | RAN#97-e | RP-222401 | 0100 | - | F | Correction on the subcarrier offset, kssb | 17.3.0 |
| 2022-09 | RAN#97-e | RP-222406 | 0101 | - | F | Corrections on UE Power Saving Enhancements for NR in TS 38.211 | 17.3.0 |
| 2022-09 | RAN#97-e | RP-222412 | 0102 | - | F | Corrections to NR support of multicast and broadcast services | 17.3.0 |
| 2022-12 | RAN#98-e | RP-222863 | 0103 | - | F | Correction on sidelink timing | 17.4.0 |
| 2022-12 | RAN#98-e | RP-222864 | 0104 | - | F | Corrections to NR support of multicast and broadcast services | 17.4.0 |
| 2023-06 | RAN#100 | RP-231226 | 0105 | 1 | F | Alignment of parameter names | 17.5.0 |
| 2023-09 | RAN#101 | RP-232449 | 0107 | - | F | Alignment of terminology across specifications | 17.6.0 |

| | | | | | | | |
|---------|---------|-----------|------|---|---|---|--------|
| 2023-09 | RAN#101 | RP-232469 | 0108 | - | B | Introduction of NR sidelink evolution | 18.0.0 |
| 2023-09 | RAN#101 | RP-232480 | 0109 | - | B | Introduction of expanded and improved NR positioning | 18.0.0 |
| 2023-09 | RAN#101 | RP-232458 | 0110 | - | B | Introduction of MIMO evolution for downlink and uplink | 18.0.0 |
| 2023-09 | RAN#101 | RP-232477 | 0111 | - | B | Introduction of NR support for dedicated spectrum less than 5MHz for FR1 | 18.0.0 |
| 2023-09 | RAN#101 | RP-232470 | 0112 | - | B | Introduction of dynamic spectrum sharing enhancements | 18.0.0 |
| 2023-09 | RAN#101 | RP-232471 | 0113 | - | B | Introduction of multi-carrier enhancements | 18.0.0 |
| 2023-12 | RAN#102 | RP-233722 | 0114 | - | B | Introduction of additional PRS configurations [1symbol_PRS] | 18.1.0 |
| 2023-12 | RAN#102 | RP-233707 | 0115 | - | F | Corrections to NR Dynamic Spectrum Sharing (DSS) | 18.1.0 |
| 2023-12 | RAN#102 | RP-233716 | 0116 | - | F | Corrections to NR support for dedicated spectrum less than 5MHz for FR1 | 18.1.0 |
| 2023-12 | RAN#102 | RP-233705 | 0117 | - | F | Corrections to MIMO enhancements | 18.1.0 |
| 2023-12 | RAN#102 | RP-233718 | 0118 | - | F | Corrections to NR Network-controlled Repeaters | 18.1.0 |
| 2023-12 | RAN#102 | RP-233719 | 0119 | - | F | Corrections to positioning enhancements | 18.1.0 |
| 2023-12 | RAN#102 | RP-233733 | 0120 | - | B | Introduction of multicast reception in RRC_INACTIVE | 18.1.0 |
| 2024-03 | RAN#103 | RP-240518 | 0122 | - | F | Corrections to MIMO enhancements | 18.2.0 |
| 2024-03 | RAN#103 | RP-240528 | 0123 | - | F | Corrections to positioning enhancements | 18.2.0 |
| 2024-03 | RAN#103 | RP-240535 | 0125 | - | A | Alignment of parameter names | 18.2.0 |
| 2024-03 | RAN#103 | RP-240519 | 0126 | - | F | Corrections to sidelink enhancements | 18.2.0 |
| 2024-06 | RAN#104 | RP-241061 | 0127 | - | F | Correction for hop counting in SRS for positioning with tx hopping | 18.3.0 |
| 2024-06 | RAN#104 | RP-241075 | 0128 | - | F | CR for 38.211 on TRS occasions for idle/inactive UEs | 18.3.0 |
| 2024-06 | RAN#104 | RP-241076 | 0129 | - | B | CR for TS 38.211 for introduction of FR2-NTN | 18.3.0 |
| 2024-06 | RAN#104 | RP-241061 | 0130 | - | F | Corrections to positioning enhancements | 18.3.0 |
| 2024-06 | RAN#104 | RP-241072 | 0131 | - | F | Corrections to sidelink enhancements | 18.3.0 |
| 2024-06 | RAN#104 | RP-241059 | 0133 | - | A | Corrections to NTN operation | 18.3.0 |
| 2024-09 | RAN#105 | RP-242209 | 0134 | - | F | CR on Precoding Matrices for 8TX UL MIMO Transmission | 18.4.0 |
| 2024-09 | RAN#105 | RP-242205 | 0135 | - | F | Correction on bandwidth part for SRS frequency hopping for positioning | 18.4.0 |
| 2024-09 | RAN#105 | RP-242205 | 0136 | - | F | Correction on staircase pattern for SRS frequency hopping for positioning | 18.4.0 |
| 2024-09 | RAN#105 | RP-242210 | 0137 | - | F | Correction on determination of restricted type for candidate cell PRACH transmission in LTM | 18.4.0 |
| 2024-09 | RAN#105 | RP-242204 | 0138 | - | F | Alignment of parameter names | 18.4.0 |
| 2024-09 | RAN#105 | RP-242203 | 0140 | - | A | Alignment of parameter names | 18.4.0 |
| 2024-12 | RAN#106 | RP-242931 | 0141 | - | F | Correction on mapping PSFCH to physical resources | 18.5.0 |
| 2024-12 | RAN#106 | RP-242930 | 0143 | 1 | F | Correction on the open loop timing advance calculation for ATG | 18.5.0 |
| 2024-12 | RAN#106 | RP-242924 | 0145 | 1 | A | Alignment of parameter names | 18.5.0 |
| 2024-12 | RAN#106 | RP-242925 | 0146 | 1 | F | Alignment of parameter names | 18.5.0 |
| 2024-12 | RAN#106 | RP-242929 | 0147 | - | F | Corrections to PRACH transmission for LTM | 18.5.0 |

History

| Document history | | |
|-------------------------|--------------|-------------|
| V18.2.0 | May 2024 | Publication |
| V18.3.0 | August 2024 | Publication |
| V18.4.0 | October 2024 | Publication |
| V18.5.0 | January 2025 | Publication |
| | | |