



TECHNICAL REPORT

**Long term view on Fixed Services
in frequency bands below 10 GHz;
Assessment of low frequency bands importance
in delivering ubiquitous network coverage**

ReferenceDTR/ATTMTMmWT-0033

Keywordsbackhaul, microwave, wireless

ETSI650 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 2026.
All rights reserved.

Contents

Intellectual Property Rights	5
Foreword.....	5
Modal verbs terminology.....	5
Executive summary	5
Introduction	6
1 Scope	8
2 References	8
2.1 Normative references	8
2.2 Informative references.....	8
3 Definition of terms, symbols and abbreviations.....	9
3.1 Terms.....	9
3.2 Symbols.....	10
3.3 Abbreviations	10
4 Spectrum Considerations.....	11
4.1 Available Microwave Spectrum	11
4.2 Spectrum Requirements	13
5 Spectrum Segmentation in Wireless Backhaul.....	14
5.1 Wireless Backhaul Trends.....	14
5.2 Low Bands Application Scenarios	15
5.3 Bands below 10 GHz Statistics	15
5.3.1 Worldwide wireless backhaul statistics	15
5.3.2 CEPT Countries - ECC Report 173 and ECC Report 365	16
5.3.3 Real Networks - Tier 1 Operators.....	17
5.3.4 USA statistics.....	17
5.3.5 Vendors statistics	18
5.4 Bands < 10 GHz Trends	19
6 Planning Considerations and Link Lengths Statistics	20
6.1 Microwave Planning Basic Concepts.....	20
6.1.1 Overview	20
6.1.2 Multipath fading	20
6.1.2.1 Multipath fading highlights.....	20
6.1.2.2 Outage due to non-selective fading.....	21
6.1.2.3 Outage due to selective fading	21
6.1.2.4 Space Diversity improvement	21
6.1.2.5 Total outage caused by multipath.....	21
6.1.3 Rain attenuation	22
6.1.4 Availability prediction	22
6.2 Low Bands Performances Comparison	23
6.2.1 Planning assumptions	23
6.2.2 Impacts of rain attenuation and multipath fading	23
6.2.3 60 mm/h link planning results.....	24
6.2.4 95 mm/h link planning results.....	25
6.2.5 Short Haul planning results.....	26
6.2.6 Conclusions.....	27
6.3 Link Length Statistics.....	27
6.3.1 Europe link length statistics	27
6.3.2 Sub-Saharan Africa link distribution	28
6.3.3 USA link length distribution	28
7 Conclusions	30
Annex A: ECC Report 173 responding countries	31

Annex B:	Country Split	32
Annex C:	Change history	37
History		38

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.

Foreword

This Technical Report (TR) has been produced by ETSI Technical Committee Access, Terminals, Transmission and Multiplexing (ATTM).

Modal verbs terminology

In the present document "**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.

Executive summary

Wireless Backhaul is and has always been a key asset in building transport networks not only for reaching locations not yet connected by fibre thanks to the high capacity delivered and the fast time to market, but also to provide effective disaster recovery networks and fibre back-up.

Notwithstanding fibre penetration and mobile networks evolution shifted network topology towards short link at in high bands (15 GHz to 80 GHz), infrastructure network in developing countries, rural areas, mountain sites and islands require long reliable MW links.

Moreover, last mile links connecting mobile sites to the first fibre PoP and feeder links and high capacity backbones that aggregate the traffic of multiple sites are deployed also in low bands: hops longer than 15-30 km rely on frequency bands lower than 10 GHz thanks to reduced rain attenuation and favourable propagation conditions.

In the present document different aspects of wireless backhaul have been analysed in order to have a picture of the usage of different bands, in general, and bands lower than 10 GHz in detail.

Clause 4 gives overview on bands available for Fixed Services and relevant application scenarios. Capacity requirements and MW capability to fulfil them are the key point to understand the necessity to have enough spectrum in different frequency bands to grant ubiquitous ultra-broadband connectivity.

Clause 5 collects analysts, vendors and international organizations bands statistics to present actual bands deployments and trends for wireless backhaul. Focusing on bands below 10 GHz regional segmentations have been analysed highlighting huge differences across the world on band usage. The relevance of the discussion on low bands allocation is underlined by the operators' contributions: some global level operators disclosed their network statistics giving an insight of configurations and applications of these bands and confirming their unique value to deliver reliable high-capacity connections.

Clause 6 gives a high-level introduction of microwave planning rules defined by ITU-R and compare the link performances in low bands (6 GHz to 13 GHz). Since propagation losses vary with the frequency band and geographical area, 6 GHz, 7 GHz and 11 GHz have been considered, using different configurations and setting the parameters for designing hypothetical links. The analysis demonstrates that under specific propagation conditions the performances of 11 GHz over medium long links do not meet the KPI usually set in mobile backhaul networks. Link length statistics in Europe, Sub-Saharan Africa and USA have been reported showing a great spread in average and maximum link length deployed mainly due to different application scenarios and wide variations in rainfall across the regions.

The information collected confirm the need of granting enough spectrum to wireless backhaul, including bands below 10 GHz, to build ubiquitous, reliable and ultra-Gbps communication networks.

Introduction

Microwave Radio, Fixed Service as per ITU-R Radio Regulation, represents a key technology for building infrastructure communication networks since early 1950's of last century serving multiple application scenarios, evolving from long haul nationwide backbones to present wireless backhaul links capable to deliver ultra-Gbps capacities required by 5G mobile access.

Mobile backhaul network topology is evolving from tree topology to hub-and-spoke as long as the fibre penetration and mobile network densification increase: not only chains of cascading links are shortening but high frequency bands became predominant in wireless backhaul (ETSI White Paper No.25 [i.1]).

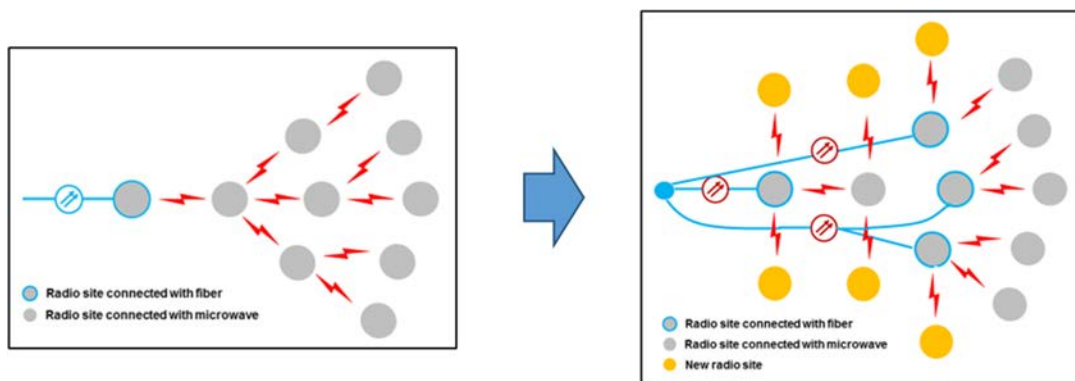


Figure 1: Topology evolution in the macro cell backhaul network

Nevertheless, widespread 4G/5G coverage requires nationwide transport network capable to reach remote locations, small rural/mountain communities or island/offshore sites and microwave technology is a key enabler in delivering ultra-broadband connectivity wherever fibre is not available.

Moreover, even though Mobile Sites Backhaul (MBH) is the main application scenario, wireless transport complements or substitute wirelines in multiple telecom and vertical deployments:

- National Broadband Networks, to deliver fixed broadband connection remote areas like mountains communities or islands.
- Local operators, WISP/ISP infrastructure networks.

- Army/police, utilities and broadcasters' private communication networks and data collection.
- Private line connection to Small and Medium Enterprises, schools, hospitals.
- Disaster recovery communication networks after emergencies like floods, earthquakes, fires.

Microwave Radio delivers fast, flexible and reliable broadband and ultra-broadband connections, the choice of frequency band according to different application scenario, required capacity and link length:

- Short haul radios are available in all MW bands (6 GHz to 80 GHz) and are mainly used in last mile connections: split mount or full outdoor architecture in high bands (≥ 18 GHz) or mm-wave deliver ultra-Gbps connectivity over short distances. Mid/low bands are chosen to collect the traffic from sites far from fibre PoP.
- Long haul radios are available in low bands (≤ 13 GHz) and are mainly used in long feeder links or high capacity backbones, even though they can be selected in the last mile for covering distances higher than 30-40 km to deliver ultra-Gbps connectivity.

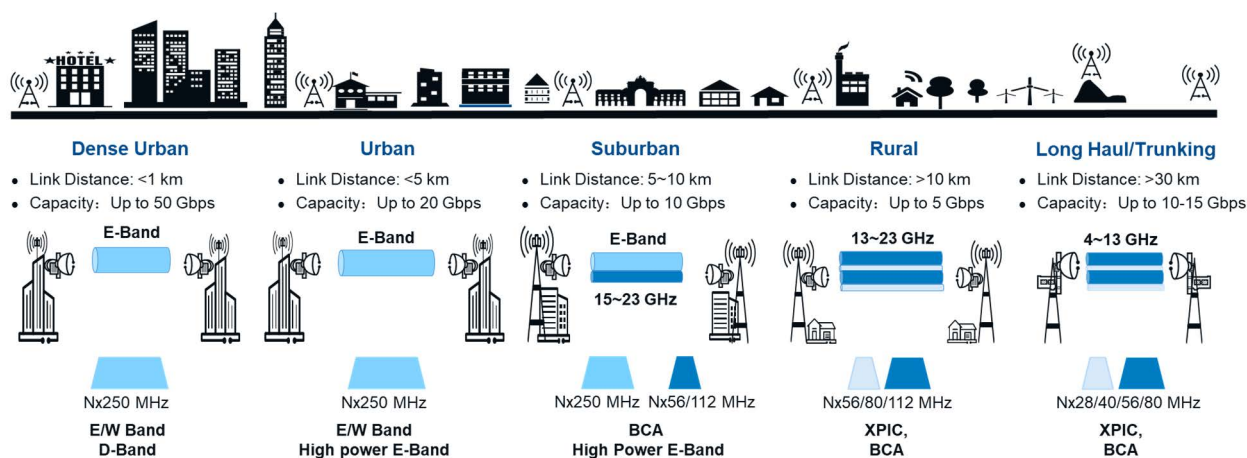


Figure 2: Microwave application scenarios

The availability of enough spectrum in each segment is paramount important to grant broadband connectivity in each network layer: high power E-Band, E-Band and E-Band-traditional bands BCA provide ultra-Gbps capacities with simple configurations over relatively small distances for both access and feeder links, while the lack of very wide channels in lower frequency bands leads necessarily to multi-channels single band or multiple bands configurations to deliver the required capacity over longer distances either as last mile connection or as fibre alternative/complement over long haul backbones.

The present document will report microwave bands usage and application scenarios focusing on low bands assessing the actual deployment inside and outside Europe to map present and future needs to fulfil operators backhauling needs.

1 Scope

The present document assesses the importance of low frequency bands in wireless backhaul networks collecting information on current use by Fixed Services of the bands lower than 10 GHz, expected use on medium term and reporting technical considerations on why bands below 10 GHz are necessary to deploy long haul links, supported by link planning examples and bands performances comparison in different areas.

2 References

2.1 Normative references

Normative references are not applicable in the present document.

2.2 Informative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

NOTE: While any hyperlinks included in this clause were valid at the time of publication, ETSI cannot guarantee their long term validity.

The following referenced documents may be useful in implementing an ETSI deliverable or add to the reader's understanding, but are not required for conformance to the present document.

- [i.1] ETSI White Paper No. 25 (February 2018): "Microwave and Millimetre-wave for 5G Transport".
- [i.2] Recommendation ITU-R P.530-17: "Propagation data and prediction methods required for the design of terrestrial line-of-sight systems".
- [i.3] Recommendation ITU-R F.746-11: "Radio-frequency arrangements for fixed service systems".
- [i.4] ETSI GR mWT 012 (V1.1.1): "5G Wireless Backhaul/X-Haul".
- [i.5] Radio Regulation, Edition of 2024: Articles (Vol.1) and WRC-23 Final Acts (Vol.3).
- [i.6] ETSI White Paper No. 58 (July 2023): "Worldwide Analysis and proposals to promote and facilitate the wireless transport networks as the key enabler for fat mobile backhaul network modernization".
- [i.7] GSMA Wireless Backhaul Evolution-Delivering next-generation connectivity (2021).
- [i.8] ECC Report 173: "Fixed Service in Europe Current use and future trends post 2022".
- [i.9] ECC Report 365: "Fixed Links in CEPT; Technical characteristics and statistical review".
- [i.10] Recommendation ITU-R P.530-19: "Propagation data and prediction methods required for the design of terrestrial line-of-sight systems".
- [i.11] Recommendation ITU-R P.837-8: "Characteristics of precipitation for propagation".
- [i.12] Recommendation ITU-R PN.837-1: "Characteristics of precipitation for propagation".

3 Definition of terms, symbols and abbreviations

3.1 Terms

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

access link: last mile connection to site (fixed or mobile)

dense urban: location in highly populated areas (malls, business districts, city centres) very close to fibre PoP: distances less than 1 km and very high capacity, up to 50 Gbps

NOTE: Usually, one single hop is enough to connect the base station to fibre PoP.

feeder link: connection aggregating traffic from more than one site

long haul: long distance multichannel connections in frequency bands ≤ 13 GHz.

NOTE: Long haul systems are typically designed for easily deliver multichannel ($N \geq 8$), BCA, space diversity combiner, narrow band filters and could be either all indoor mount or split mount.

n+0: multi-channel link configuration where n channels in one or more than one band are transmitted together

NOTE: In Ethernet era, the channels are aggregated together at Layer-1 level to increase the capacity of the link; this type of configuration is generally addressed also as Band and Carrier Aggregation.

rural: locations like small communities or scarcely populated areas generally far from fibre PoP: distances higher than 10 km and capacity up to 5 Gbps

short haul: split mount systems delivering connectivity in all bands

NOTE: Typical configurations are up to 4 + 0 according to the network layer they are used. Short haul radio in bands ≤ 13 GHz can be used for delivering long haul connections in configuration simpler than long haul systems.

sub-urban: location in less populated areas (like suburbs or small cities) with distances in the range of 5 km to 10 km to fibre PoP and delivering capacity up to 10 Gbps

NOTE: Usually one/two hops are enough to connect the base station to fibre PoP.

trunk / trunking: general terminology including both Long Haul and Short haul radio in multi-channel configuration delivering feeder long distance multichannel connections in frequency bands ≤ 13 GHz

NOTE: Capacity may vary according to type of service backhauled and number of mobile sites aggregated reaching 10 Gbps to 15 Gbps.

urban: location in populated areas close to fibre PoP: distances less than 5 km and relatively high capacity up to 20 Gbps

NOTE: Usually, one single hop is enough to connect the base station to fibre PoP.

6 GHz: 5 925 MHz to 7 110 MHz

L6 GHz: Lower 6 GHz: 5 925 MHz to 6 425 MHz

U6 GHz: Upper 6 GHz: 6 425 MHz to 7 110 MHz

7 GHz: 7,11 GHz to 7,9 GHz

L7 GHz: Lower 7 GHz: 7,125 GHz to 7,425 GHz

U7 GHz: Upper 7 GHz: 7,425 GHz to 7,725 GHz

8 GHz: 7,725 GHz to 8,5 GHz

L8 GHz: Lower 8 GHz: 7,725 GHz to 8,8275 GHz

U8 GHz: Upper 8 GHz: 8,275 GHz to 8,5 GHz

3.2 Symbols

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

p_0	Multipath occurrence factor
$R_{0,01}$	Rainfall intensity exceeded for 0,01 % of an average year (mm/h)
dN_1	Point refractivity gradient in the lowest 65 m of the atmosphere not exceeded for 1 % of an average year
s_a	Area terrain roughness as defined in Recommendation ITU-R P.530-17 [i.2]

3.3 Abbreviations

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

4G	4 th Generation Mobile Networks
5G	5 th Generation Mobile Networks
AI	Action Item
APAC	Asia-Pacific
APT	Asia-Pacific Telecommunity
ASMG	Arab Spectrum Management Group
ATU	African Telecommunications Union
BCA	Band and Carrier Aggregation
CCDP	Co-Channel Dual Polarization
CDF	Cumulative Distribution Function
CEPT	European Conference of Postal and Telecommunications Administrations
CIS	Commonwealth of Independent States
CITEL	Inter-American Telecommunications Commission
CS	Channel Spacing
ECC	Electronic Communications Committee
FCC	Federal Communication Commission
FDD	Frequency Division Duplex
FS	Fixed Services
FSS	Fixed Satellite Services
IMT	International Mobile Telecommunications
ISP	Internet Service Providers
KPI	Key Performance Indicator
LATAM	Latin America
LTE	Long Term Evolution
MBH	Mobile Backhaul
MEA	Middle East and Africa
MIMO	Multiple Input Multiple Output
mmW	millimeter Wave
MNO	Mobile Network Operator
MW	Microwave
NAM	North America
OLO	Other Local Operators
PoP	Point of Presence
PtP	Point-to-Point
QAM	Quadrature Amplitude Modulation
RCC	Regional Commonwealth in the field of Communications
RLAN	Radio Local Area Networks
SD	Space Diversity
WISP	Wireless Internet Service Providers
WRC-19	World Radiocommunication Conference (WRC) 2019
WRC-23	World Radiocommunication Conference (WRC) 2023
WRC-27	World Radiocommunication Conference (WRC) 2027
WRC-31	World Radiocommunication Conference (WRC) 2031
XPIC	Cross Polar Interference Canceller

4 Spectrum Considerations

4.1 Available Microwave Spectrum

Frequency bands used in modern Wireless Backhaul Networks range from 4 GHz to 86 GHz and studies for going beyond 90 GHz are in an advanced stage with prototypes showcased in W-Band (92 GHz to 114,25 GHz) and D-Band (130 GHz to 174,8 GHz).

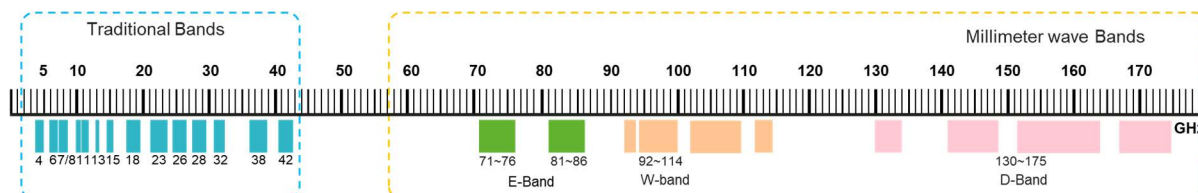


Figure 3: Microwave Spectrum

Frequency band choice takes into account different aspects as the required capacity, link distance and required KPI:

- Frequency bands up to 13 GHz allow to cope medium-long distances but the limited spectrum availability limits the capacity per channel and typically Bands and Carrier Aggregation is required to scale up the throughput.
- Frequency bands from 15 GHz to 42 GHz achieve shorter distances but thanks to higher spectrum amount wider channels are feasible allowing to deliver high throughput with simpler systems.
- E-Band (71 GHz to 76 GHz and 81 GHz to 86 GHz) is suitable for short ultra-high capacity links

Microwave radio systems work in Frequency Division Duplex (FDD) scheme: Recommendation ITU-R F.746 (1st edition 1991) (Recommendation ITU-R F.746-11 [i.3]) defines radio patterns general rules for minimizing the carrier-to-interference and allowing the deployment of single carrier system (one go channel + one return channel) or multi-carrier system (n go channels + n return channels).

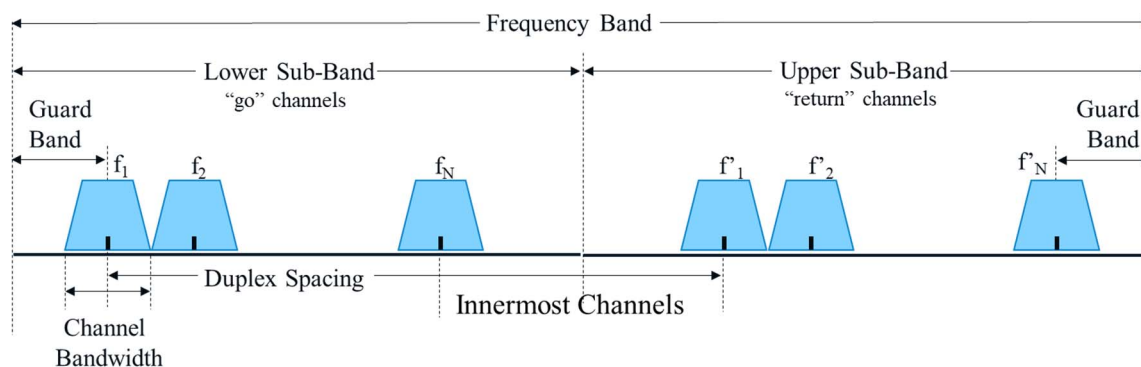


Figure 4: FDD channel arrangement

The net band available for wireless backhaul typically considers only the number of channels available per band and actual backhaul capacity of a FDD microwave link is calculated on one single channel (see note), being the transmission symmetrical.

NOTE: Air Capacity is calculated according to the Nyquist Law:

$$\text{Air Capacity} = \frac{BW \times N_{\text{bits}}}{1 + \alpha}$$

Where:

BW = Channel Bandwidth [MHz]

$N_{\text{bits}} = \log_2 X$ are the bits per symbol of X^{th} modulation level

α = Nyquist Filter Roll-Off

Channel allocation on link basis or per block to different users (e.g. MNO, Utilities, Government, Army, WISP and OLO) and limitations on frequency channel reuse to avoid interferences, prevent to use the entire amount of available channels and therefore the available backhaul capacity per link. Moreover, the available spectrum greatly varies from country to country in term of bands open to commercial use and channel bandwidth allowed. Table 1 updates the one reported in ETSI GR mWT 012 [i.4] and gives an overview of the wireless backhaul spectrum providing information on:

- the total available bandwidth and the maximum channel size as per ITU-R Recommendations;
- the typical area of deployment in single-carrier and band and carrier aggregation arrangements;
- which bands are candidate for access technologies, focusing on bands below 10 GHz.

Table 1: Spectrum Availability

Candidate/Allocated Access Bands	Frequency Band	Total BW	Max Channel Size	Areas of Deployment (Typical)	
				Single Carrier	BCA
RLAN	L6 GHz	533,7 MHz	59,3 MHz	Rural	Long Haul/Trunking
IMT WRC-23 (see note 1)	U6 GHz	640 MHz	80 MHz	Rural	Long Haul/Trunking
IMT WRC-27 (candidate within AI 1.7)	L7 GHz	238 MHz	56 MHz	Rural	Long Haul/Trunking
	U7 GHz	224 MHz	56 MHz	Rural	Long Haul/Trunking
	L8 GHz	533,7 MHz	59,3 MHz	Rural	Long Haul/Trunking
	U8 GHz	168 MHz	28 MHz	Rural	Long Haul/Trunking
IMT WRC-23 (see note 2)	10 GHz	664 MHz	28 MHz	Rural	Long Haul/Trunking
	11 GHz	960 MHz	80 MHz	Rural	Long Haul/Trunking
	13 GHz	448 MHz	56 MHz	Rural	Long Haul/Trunking
IMT WRC-27 (candidate within AI 1.7)	15 GHz	336 MHz	112 MHz	Sub-Urban/ Semi-Rural/Rural	
	18 GHz	1 870 MHz	220 MHz	Sub-Urban	Semi-Rural/Rural
	23 GHz	1 008 MHz	224 MHz	Urban/Sub-Urban	Semi-Rural/Rural
IMT WRC-19 (see note 3)	26 GHz	1 736 MHz	112 MHz	Urban	
Mobile (Selected Countries (see note 4))	28 GHz	1 750 MHz	224 MHz	Urban	Sub-Urban/Rural
	32 GHz	1 484 MHz	224 MHz	Urban	Sub-Urban/Rural
IMT WRC-19 (see note 5)	38 GHz	2 240 MHz	224 MHz	Urban	
	42 GHz	3 GHz	224 MHz	Urban	
FSS WRC-27 AI 1.10	E-Band	10 GHz	nx250 MHz	Dense Urban / Urban	Sub-Urban
IMT (WRC-31 candidate AI (see note 6))	W-Band	12 GHz	nx250 MHz	Dense Urban / Urban	Sub-Urban
	D-Band	32 GHz	nx250 MHz	Dense Urban / Urban	
NOTE 1: Radio Regulation [i.5]:					
<ul style="list-style-type: none"> • IMT identification according to WRC-23 footnotes RR 5.457E (Region 1), 5.457D (Cambodia, Lao P.D.R., Maldives), 5.457F (Brazil and Mexico). • Resolution 220 (WRC-23) applies. 					
NOTE 2: IMT identification in 10 GHz to 10,5 GHz in some Region 2 countries according to WRC-23 footnotes RR 5.480A [i.5].					
NOTE 3: Radio Regulation [i.5]:					
<ul style="list-style-type: none"> • Global IMT identification for 24,25 GHz to 27,5 GHz according to RR footnote 5.532AB. Resolution 242 (WRC-19) applies. 					
NOTE 4: No regional harmonization, some initiatives at national level.					
NOTE 5: Radio Regulation [i.5]:					
<ul style="list-style-type: none"> • Global IMT identification for 37 GHz to 43,5 GHz (or portions thereof) according to RR footnote 5.550B. • Resolution 243 (WRC-19) applies. 					
NOTE 6: WRC-31 preliminary AI 2.6 [i.5].					

4.2 Spectrum Requirements

In past years, evolution of MW application from medium-long distance infrastructure network to Wireless Backhaul of thousands mobile sites and wider fibre availability, shifted major requirements from low bands to high bands: higher spectrum amount allows to serve multiple sites minimizing the interferences and achieve wide channels for delivering high throughput (ETSI White Paper No. 25 [i.1]).

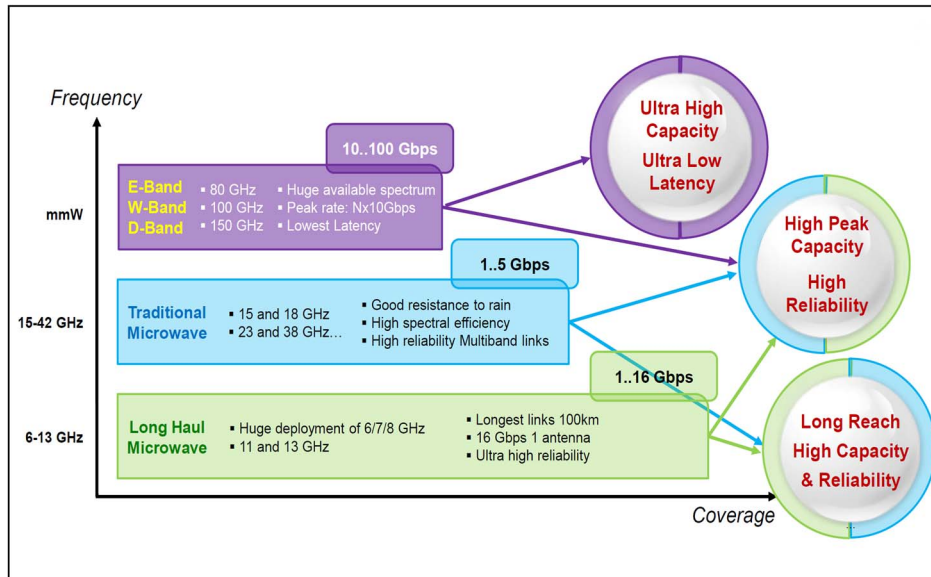


Figure 5: Microwave Spectrum Capacity vs. Coverage

Nevertheless, 5G coverage extension from urban to rural areas and national plans for extending broadband services to white areas are increasing wireless backhaul capacity demand over medium-long distances.

Moreover, not only in developing countries the fibre availability is still scarce or even negligible outside the big cities, but also in developed countries there could be areas not yet reached or not easy reachable by fiber that require high capacity on medium/long BCA microwave links.

Finally, vertical players, like power utilities or broadcasters, and small operators and WISP/ISP rely on microwave radios for building their infrastructure network.

Access site distance to the closest fiber PoP greatly varies across different networks. Mobile Backhaul capacity required according to different deployment scenario are summarized in Table 2 (ETSI GR mWT 012 [i.4]).

Table 2: Backhaul/X-Haul Capacity Requirements

Area Type	Sites Configurations	Cell Type	Tail Link Capacity Requirements		Access (Pre-)Aggregation Capacity Requirements	
			5G "Early Stage"	5G "Mature Stage"		
Dense Urban ('DU')	<ul style="list-style-type: none"> 5G 100 MHz 16L MIMO ~4 GHz 5G ≤ 800 MHz 4L MIMO ~30 GHz 	<ul style="list-style-type: none"> Small-cell 	< 5 Gbps	Mix of 5 Gbps to 10 Gbps & ≥ 10 Gbps sites	- (single-hop)	
Urban ('U')	<ul style="list-style-type: none"> LTE 50 - 100 MHz 5G 100 MHz 16L MIMO ~4 GHz 5G ≤ 800 MHz 4L MIMO ~30 GHz 	<ul style="list-style-type: none"> Macro-cell 				
Sub-Urban ('SU')	<ul style="list-style-type: none"> LTE 50-100 MHz 5G 100 MHz 8L MIMO ~4 GHz 	<ul style="list-style-type: none"> Macro-cell 	< 3 Gbps	< 5 Gbps	< 10 Gbps (2 nd hop 'U')	
Semi-Rural ('SR')						
Rural ('R')	<ul style="list-style-type: none"> LTE 50-100 MHz 5G 50 MHz 4L MIMO ~2 GHz 5G 20 MHz 4L MIMO ~700 MHz 	<ul style="list-style-type: none"> Macro-cell 	< 2 Gbps	< 3 Gbps	< 5 Gbps (2 nd hop 'SU')	< 10 Gbps (3 rd hop 'U')

Even though advanced coding modulation schemes allow to reach 16k levels and cross Polar Interference Cancellation (XPIC) technique doubles the spectral efficiency per channels, the capacity delivered by microwave links ranges from 250 Mbps per channel up to 1 Gbps per channel (x2 using XPIC) on traditional bands forcing to bundle more channels or bands in multicarrier systems for delivering ultra-Gbps capacity.

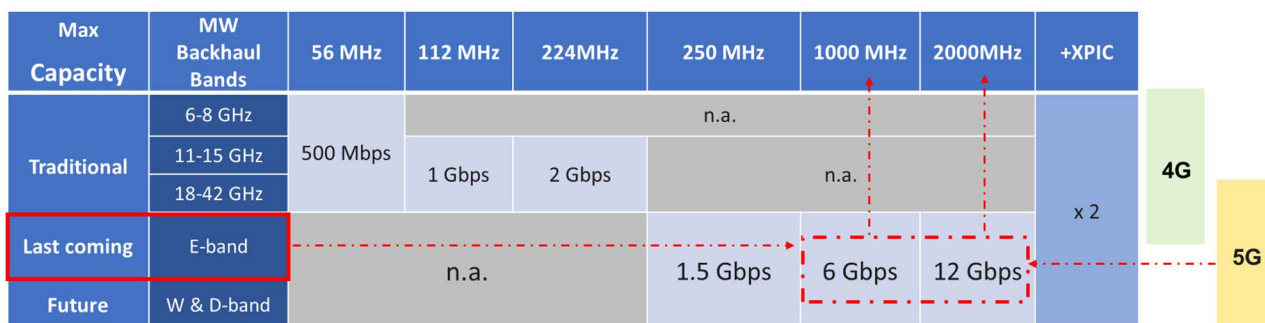


Figure 6: 4G and 5G requirements vs Spectrum bands and channel size

The availability of enough spectrum resources is necessary to enable wireless backhaul and wide channels allow to deliver the capacity required for fulfilling broadband targets set by government to enable the digital transformation (ETSI White Paper No. 58 [i.6]).

5 Spectrum Segmentation in Wireless Backhaul

5.1 Wireless Backhaul Trends

The study in on evolution of wireless backhaul published by ABI Research for GSMA in 2021 [i.7] touched multiple aspects, from technology innovation to spectrum availability, allocation and pricing, including capacity analysis and link forecasts.

According to this study there will be 17,2 million backhaul links to collect traffic from Macro and Small Cells by 2027 (see note): 66 % (9,6 million) will be backhauled by Fixed Services, 42 % by fibre and only 2 % by satellite, confirming that microwave will be a key asset for transport networks of MNOs (Figure 7).

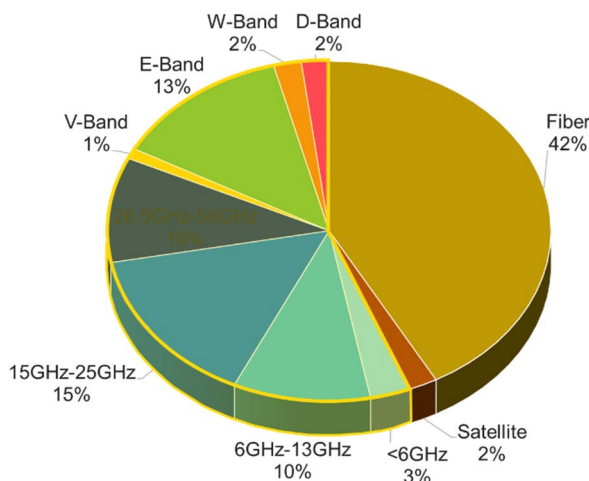


Figure 7: Macro and Small Cell Backhaul Links Technology Segmentation (2027)

NOTE: Research takes into account operators and regulators feedbacks in 40 countries involving and insights of backhaul vendors.

5.2 Low Bands Application Scenarios

Frequency band segmentation is related to region/country specific reasons related to applications and propagation conditions:

- Long haul high capacity backbone. Countries lacking nationwide fibre infrastructure rely on MW technology deploying multichannel links to carry 5-10 Gbps. These links are in the uppermost layer of aggregation network and are designed with very high availability over medium long distances.
- Remote area connections. This type of application could be either a feeder link or a last mile link to connect sites to the first fibre PoP: typical locations include but are not limited to islands, remote rural community, mountain sites. High availability and medium long distances require multichannel configurations on feeder links, while access sites direct connection may have antenna diameter limitations on the tail site.
- Remote areas disaster recovery/fibre backup. infrastructure networks rely on MW links to guarantee connectivity continuity especially in mountain areas and islands.

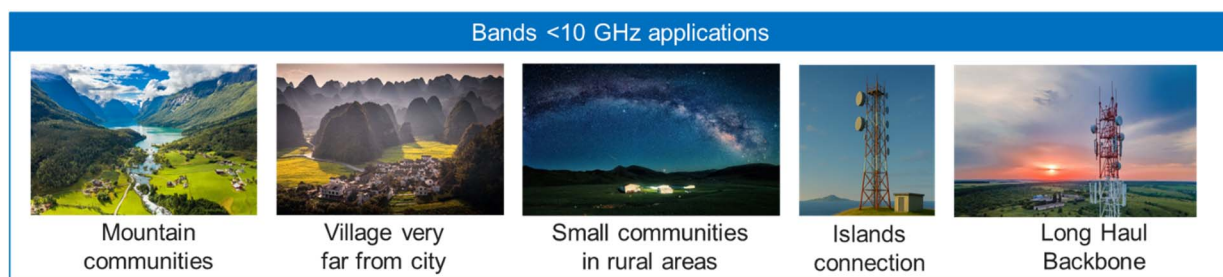


Figure 8: Low Bands application scenarios

5.3 Bands below 10 GHz Statistics

5.3.1 Worldwide wireless backhaul statistics

Starting from ABI Research for GSMA study [i.7] snapshot of technologies used for mobile backhaul in 2021, it is possible to extrapolate traditional band segmentation: out of 5,1 million links installed in 2021, about 2 million are deployed in low bands (< 13 GHz) representing more than 30 % of the overall installed MW links and 40 % of traditional bands links (Figure 9).

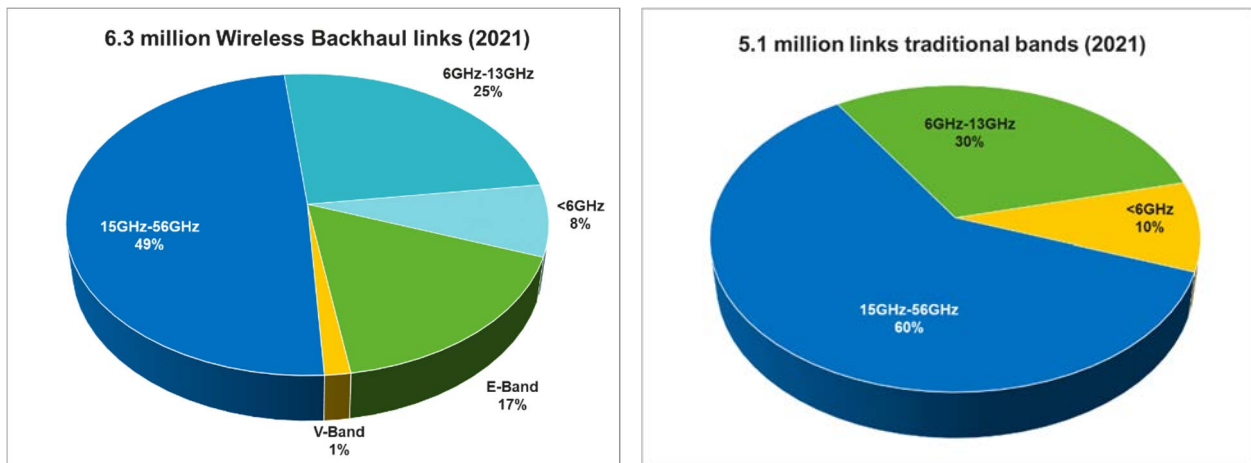


Figure 9: Frequency Band segmentation in 2021

5.3.2 CEPT Countries - ECC Report 173 and ECC Report 365

CEPT has analysed Fixed Service use and trends several times since 1997 asking Administrations to answer to questionnaires: ECC Report 3 was issued in 1997 and revised in 2001, ECC Report 173 was issued in 2012 and revised in 2018 and 2022.

Latest ECC Report 173 [i.8] collected the feedbacks of 26 administrations: deployment statistics includes all responding administrations feedbacks, while trends have been evaluated considering only those administrations that answered also to 2018 revision. Responding countries in 2022 and 2018 have been reported in Annex A.

About 690 000 FS active links have been declared in traditional bands (1 GHz to 42 GHz), out of which about 66 000 are in bands below 10 GHz: frequency bands statistics are reported in Figure 10.

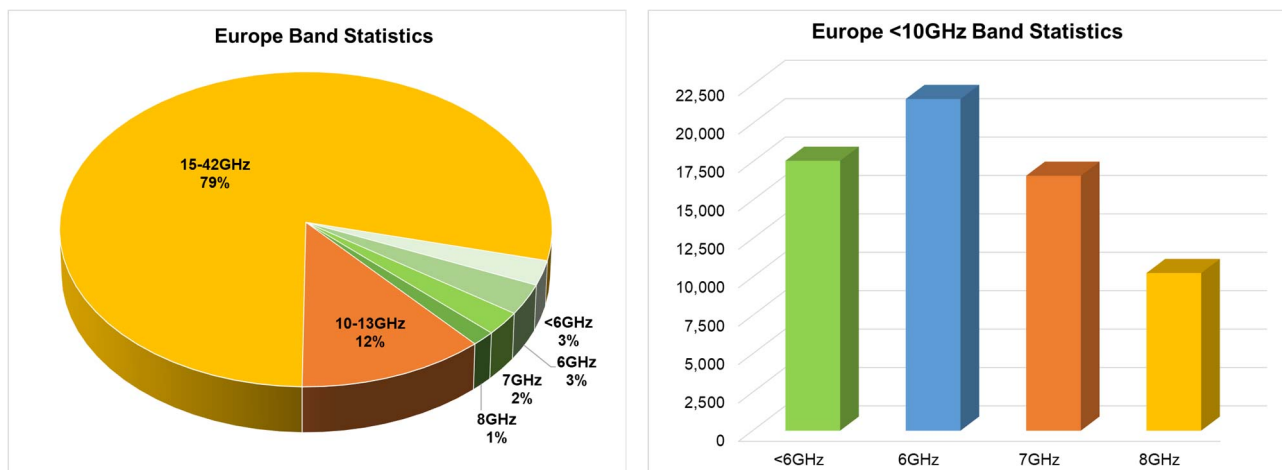


Figure 10: PtP links 1 GHz to 42 GHz frequency bands distribution

Responding administrations will continue using bands below 10 GHz for reaching sites on islands, rural areas and location not yet reached by fibre and in many countries is even expected an increase in 6 GHz and 7 GHz with consequent increase of congestion in such bands.

ECC Report 365 [i.9] is a statistical review of fixed services characteristics: it collects the feedbacks of 14 administrations and provides an update on links per frequency band. Figure 11 reports the statistics of countries with more than 1 000 links in bands below 10 GHz.

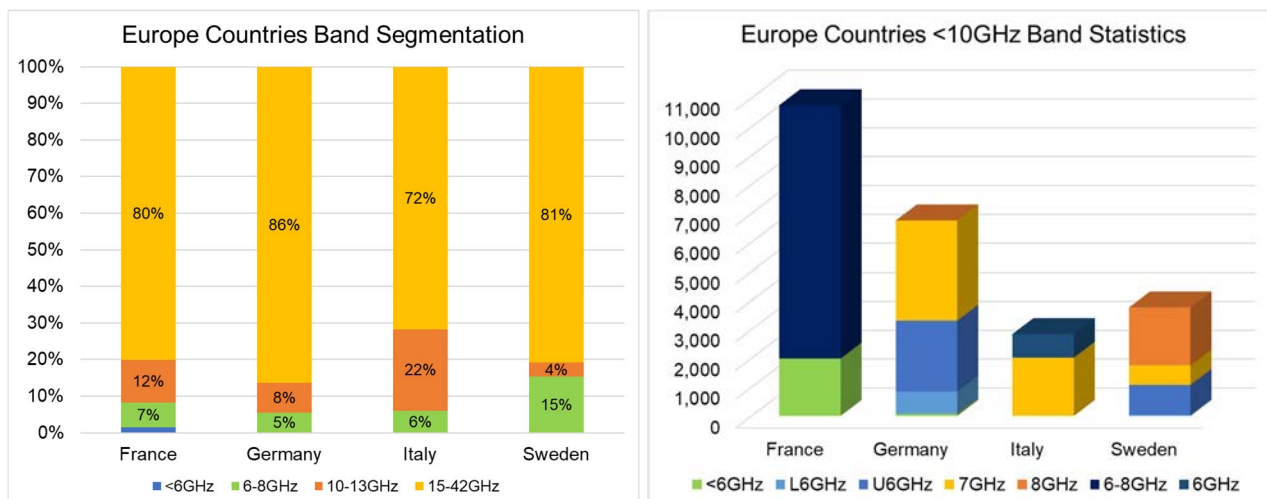


Figure 11: 1 GHz to 42 GHz frequency bands distribution

5.3.3 Real Networks - Tier 1 Operators

Bands segmentation of links deployed by Tier-1 Operators with affiliates across Europe and MEA countries is reported in Figure 12. About 3 600 links are deployed in Europe and more than 11 000 in MEA leading to two considerations:

- 1) In Europe, where fibre has a deeper penetration, links in bands below 10 GHz are deployed to connect remote locations such as islands and mountains where fibre is either not yet available or it is too difficult to lay.
- 2) In MEA links in these bands are key part of the operators' infrastructure network for building nationwide long haul backbones.

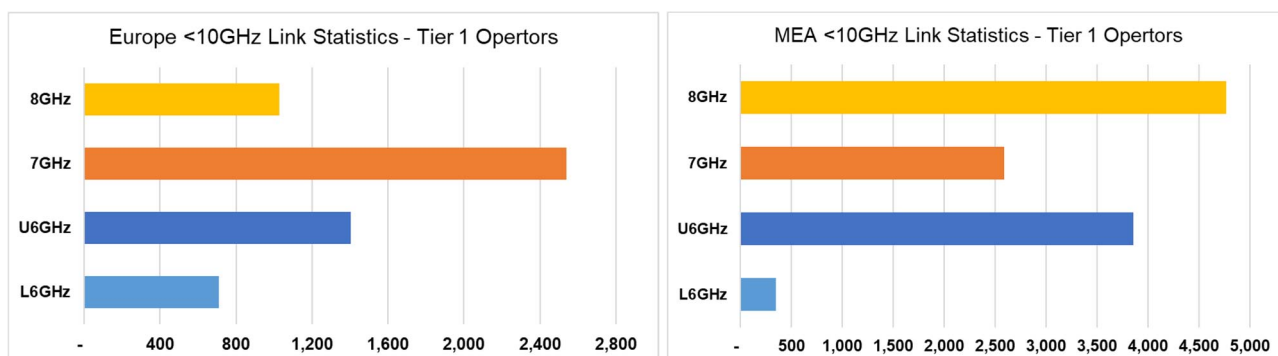


Figure 12: Bands below 10 GHz deployment segmentation - Tier 1 Operators

Configurations vary from 2+0/4+0 for access links to 8+0/10+0 for feeder links and backbones, with capacities requested up to 10 Gbps. Low bands are used for delivering high availability, since these links are deployed in the highest hierarchy of the access network and on backbones, aggregating the traffic of 10 to 20 sites and, due to narrow channels available in these bands, BCA is required for delivering the requested capacity.

The capacity is expected to increase to meet mobile traffic growth, therefore configurations will bundle more and more channels and eventually different bands. Bands usage re-shuffle is expected due to L6 GHz and U6 GHz allocation to RLAN and IMT.

5.3.4 USA statistics

Basic licenses attributes of MW point-to-point link installed in USA can be retrieved searching FCC Universal Licensing Scheme database. Six bands are included in the analysis: 6 GHz, 11 GHz, 18 GHz, 23 GHz and 38 GHz. U4 GHz, 7 GHz and 8 GHz are not available for fixed service.

More than 360 000 MW links are deployed across USA: high fibre availability in the cities is confirmed by the small deployment in high frequency bands, while the large use of low bands suggests wide deployment to connect rural areas and small/remote communities (Figure 13).

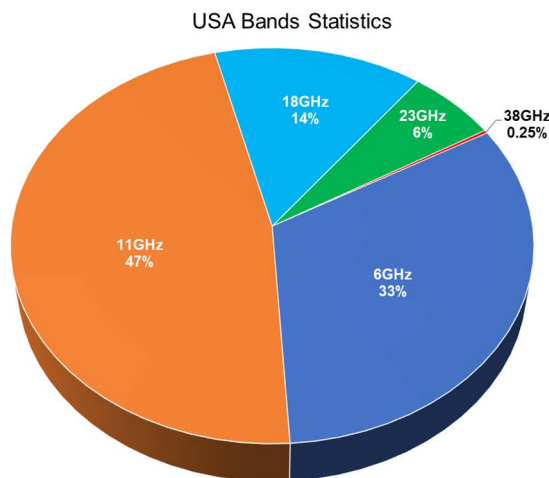


Figure 13: USA 6 GHz to 38 GHz Bands Distribution

5.3.5 Vendors statistics

Vendors delivery statistics from 2019 to 2024 have been collected to define the band distribution across different regions: Europe, Commonwealth of Independent States, Asia Pacific, Middle East, Africa, North and Latin America. Country split is reported in Annex B.

Notwithstanding country split may not completely overlap across different vendors sales organization, the countries that may belong to two different regions are not many and the statistical error can be considered reasonably low.

About 3 million links have been delivered considered period in traditional bands (see note): low bands represent about 20 % of the overall traditional bands confirming their importance in infrastructure networks; out of them 7 GHz and 8 GHz are more than 65 % (Figure 14).

NOTE: Link configuration is 1+0 (bidirectional) to better track the spectrum required for implementing N+0 BCA configurations avoiding mutual interference.

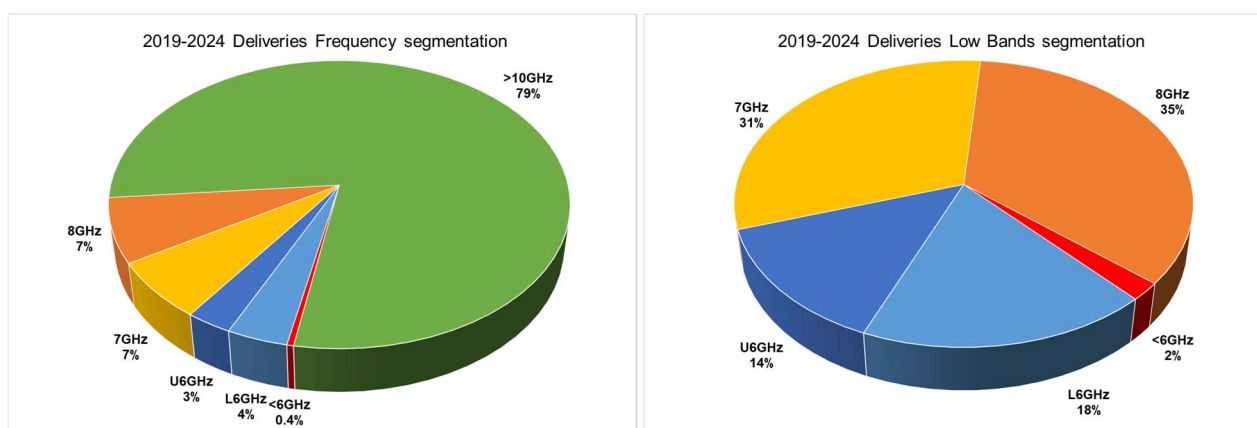


Figure 14: 2019-2024 deliveries bands segmentation

Microwave deployment segmentation confirms the importance of wireless backhaul in regions where fibre is not widely deployed, while the band segmentation reflects the region-specific application (Figure 15).

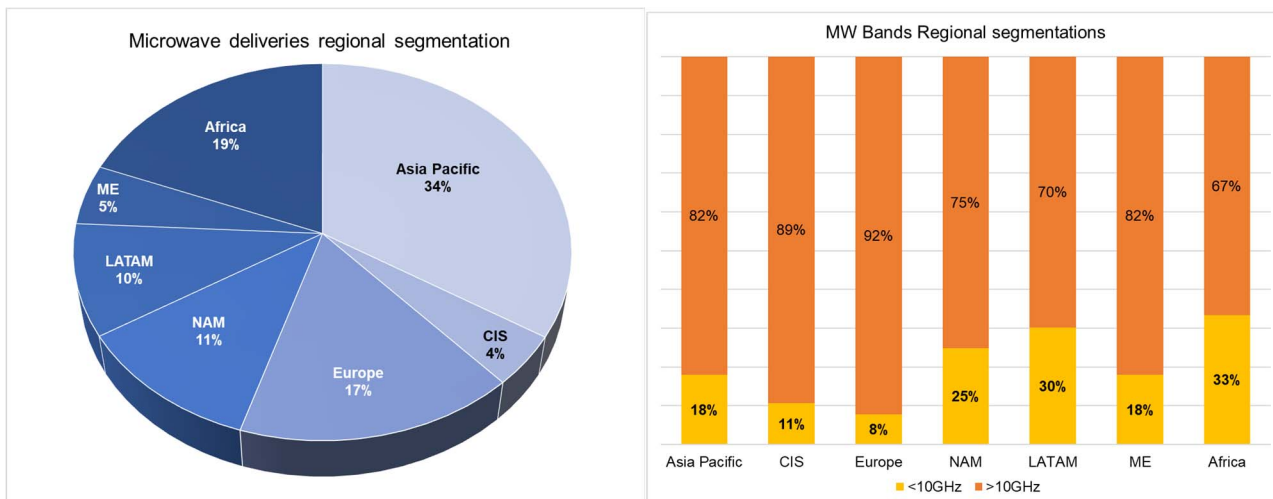


Figure 15: Traditional bands 2019-2024 deliveries regional segmentation

mmWave (V/E-Band) and subTHz (W/D-Band) are not included in the band's segmentations reported in this clause and in clause 5.4 since their applications are mainly in dense urban and urban scenarios in stand-alone configuration and sub-urban scenario in BCA configurations.

Traditional bands are widely deployed in regions where fibre is not available even in urban areas, high bands fitting the capacity requirements in the access layer and low bands deployed in the rural areas and for the long haul high capacity backbones. Apart from North America where L6 GHz and U6 GHz are almost the only bands < 10 GHz deployed, in all the other region 7 GHz and 8 GHz are the most deployed ones, with 50 % to 80 % of share (Figure 16).

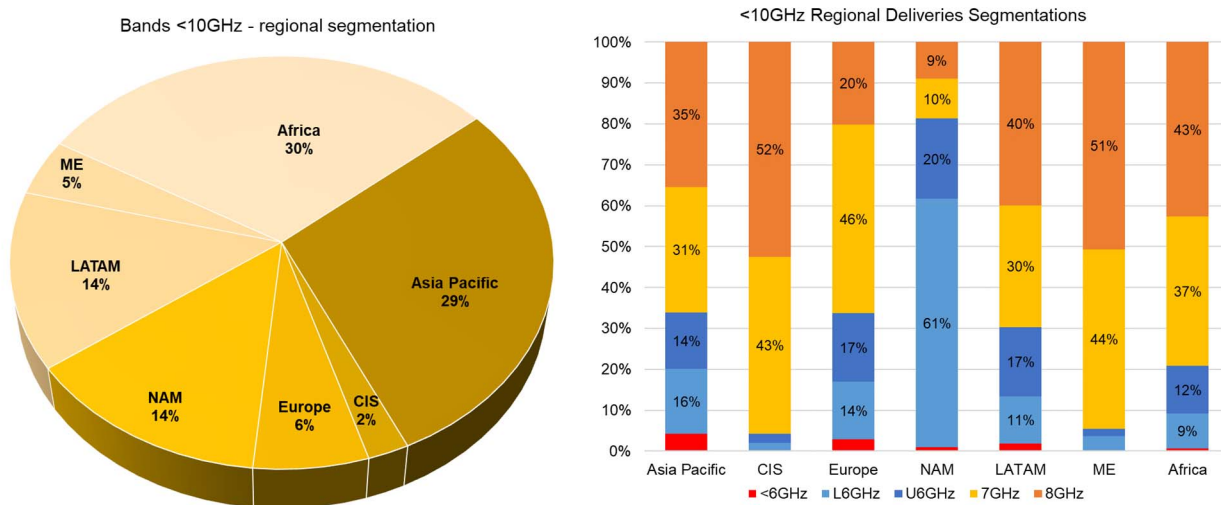


Figure 16: Bands below 10 GHz, 2019-2024 deliveries regional segmentation

5.4 Bands < 10 GHz Trends

Focusing on wireless backhaul links forecast reported in ABI Research for GSMA report [i.7], bands up to 13 GHz will represent almost one fourth of the overall installed links (Figure 17), increasing from 2,1 million links (2021) to more than 2,2 million links in 2027 and confirming that medium-long haul applications will not be completely replaced by fibre.

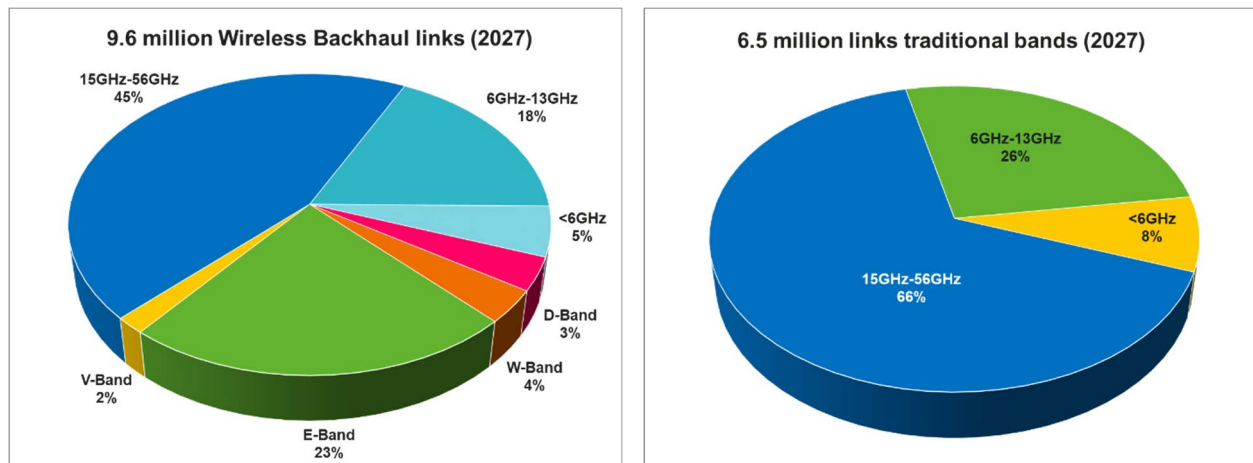


Figure 17: Frequency Band segmentation by 2027

6 Planning Considerations and Link Lengths Statistics

6.1 Microwave Planning Basic Concepts

6.1.1 Overview

Prediction methods required for Line-Of-Sight MW link design are described in Recommendation ITU-R P.530-19 [i.10] and takes into account both clear-air and rainfall conditions. Propagation loss includes different contributions:

- Attenuation due to atmospheric gases: attenuation due to oxygen and water vapour is always present and it is included in the total propagation loss for frequencies above 10 GHz.
- Diffraction fading due to obstruction or partial obstruction.
- Fading due to multipath, beam spreading and scintillation.
- Attenuation due to variation of the angle-of arrival/launch.
- Attenuation due to precipitation: it depends on rainfall rate; link length and frequency band and it is relevant for frequencies above 10 GHz.
- Attenuation due to sand and dust storm.

Each contribution depends on the frequency, the path length and the geographic location.

Rainfall and multipath are the main phenomena affecting the availability of a MW link: brief descriptions based on Recommendation ITU-R P.530-17 [i.2] are reported in next clauses.

6.1.2 Multipath fading

6.1.2.1 Multipath fading highlights

In case of atmosphere stratification (refractivity gradient varying with altitude), the MW signal may be divided in different rays along the path.

These rays arrive on the receiver antenna with different delays due to the length of their paths and are combined together causing attenuation (down-fading) or enhancement (up-fading) in comparison of the signal received in normal propagation conditions.

Recommendation ITU-R P.530-17 [i.2] gives formulas to calculate the outage of the link caused by multipath divided in two categories: outage due to non-selective fading and outage due to distortion caused by selective fading.

6.1.2.2 Outage due to non-selective fading

The graph in Figure 18 shows the relation between the fade depth A (dB) on the X axis and the percentage of time in which this fade depth is exceeded (on the Y axis) according to the values of a parameter named p_0 .

Link will be in outage when the fade depth is bigger or equal to the fade margin of the link.

p_0 depends on various parameters combined by the Recommendation ITU-R P.530-17 [i.2] formulas:

- Geographical: Inclination of the path, flatness of the surfaces, link length.
- Frequency band used.
- Atmospheric: Refractivity gradient variability in the area.

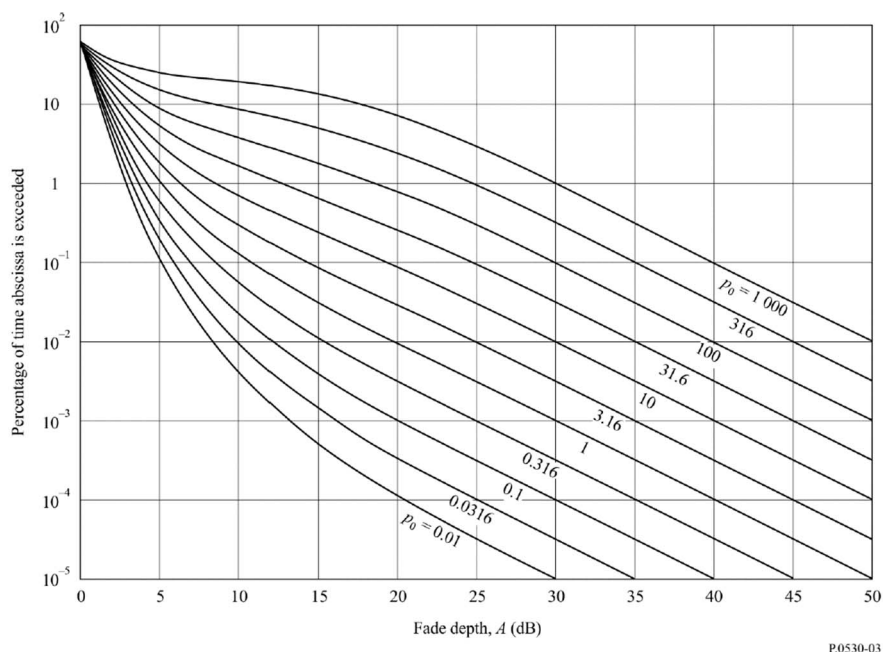


Figure 18: Percentage of time fade depth exceeded in average worst month

6.1.2.3 Outage due to selective fading

Selective fading can cause an in-band distortion that may not be recovered by the system equalizer therefore causing an outage of the link.

Calculation of the outage cause by selective fading is based on the p_0 parameter and on the signature of the modem that gives the system capability of recovering the distortion.

6.1.2.4 Space Diversity improvement

Space diversity is the most used technique to counteract multipath fading, in particular for long haul links.

SD is based on the use of two antennas on the receiver side and on the combination/switching of the signal coming from the two antennas to improve the Rx signal quality.

Recommendation ITU-R P.530-17 [i.2] defines an SD Improvement Factor based on p_0 , Frequency band, Spacing between the two receiving antennas, link length.

6.1.2.5 Total outage caused by multipath

Total outage caused by multipath is given by the combination of the contributions of P_{ns} (outage due to non-selective fading) and P_s (outage due to selective fading).

6.1.3 Rain attenuation

Recommendation ITU-R P.837-8 [i.11] provides the rainfall statistics required for rain attenuation prediction described in Recommendation ITU-R P.530-17 [i.2].

Notwithstanding ITU-R has updated the rainfall database reported in in past years (latest update in 2017) and common planning tools utilize it as option for predicting outages due to rain, it is common practice to refer to rainfall area and relevant rainfall rate $R_{0,01}$ (mm/hr) as defined in the earlier versions: Figure 19 and Table 3 report rainfall areas and relevant rain rate as defined in Recommendation ITU-R PN.837-1 [i.12]. For sake of simplicity planning results presented in next clauses consider these rainfall areas.



Figure 19: Rain climatic zones

Table 3: Rainfall Areas, Rainfall intensity exceeded for 0,01 % of an average year (mm/h)

	A	B	C	D	E	F	G	H	J	K	L	M	N	P	Q
0,01 %	8	12	15	19	22	28	30	32	35	42	60	63	95	145	115

Recommendation ITU-R P.530-17 [i.2] defines outage caused by rain using formulas based on the rain rate, link length and frequency band used.

6.1.4 Availability prediction

The total bi-directional outage of the link is usually given by the sum of the outage due to rain plus two times the outage given by multipath fading. The rain outage is considered correlated in two directions (attenuation in the two direction is the same at the same time), but is considered un-correlated for the multipath fading (attenuation is different in the two directions at the same time).

Link availability is the percentage of time of the year when the link is not in outage condition.

6.2 Low Bands Performances Comparison

6.2.1 Planning assumptions

Link planning evaluation presented in this clause are theoretical links with full clearance along the path, in low and high multipath probability areas, fixed roughness and four rainfall areas; calculations are based on Recommendation ITU-R P.530-17 [i.2] using parameters reported in Table 4 and Table 5.

Roughness and dN_1 are used in Recommendation ITU-R P.530-17 [i.2] for refractivity gradient calculation and therefore for p_0 evaluation: radio planning tools use ITU-R geographical databases for correct p_0 evaluation on real links based on different versions of Recommendation ITU-R P.530. The choice of -17 version instead of -19 version is related to the easier p_0 evaluation on a theoretical link.

Table 4: Long Haul link planning assumptions

Planning Parameters - Multipath outage calculation	
Roughness	$S_a = 200$
dN_1	-1 000 (high multipath activity) -300 (low multipath activity)
Planning Parameters - Rain outage calculation	
$R_{0,01}$ (mm/h)	60, 95, 145
Availability objectives	
Year availability	99,995 % of Reference Modulation
System Parameters	
System Configuration	4+0 CCDP with and without Space Diversity
Frequency Bands	L6 GHz, 7 GHz, 11 GHz; 28 MHz CS; 128QAM Reference Modulation
Antenna diameters	1,8 m (for $R_{0,01}$ 60 mm/h) and 3 m (for $R_{0,01}$ 95 mm/h and 145 mm/h)
Space Diversity antenna distance	10 m
Sites heights a.s.l.	Site 1: 200 m, Site 2: 400 m

Table 5: Short Haul link planning assumptions

Planning Parameters - Multipath outage calculation	
Roughness	$S_a = 200$
dN_1	-300 (low multipath activity)
Planning Parameters - Rain outage calculation	
$R_{0,01}$ (mm/h)	60, 95, 145
Availability objectives	
Year availability	99,995 % of Reference Modulation
System Parameters	
System configuration	2+0 CCDP
Frequency Bands	7 GHz, 11 GHz; 28 MHz CS; 128QAM Reference Modulation
Antenna diameters	0,6 m, 1,2 m
Sites heights a.s.l.	Site 1: 20 m, Site 2: 30 m

6.2.2 Impacts of rain attenuation and multipath fading

Separate effects of rain attenuation and multipath fading on link availability of lower band have been evaluated for a long haul system without space diversity.

As shown in Figure 20 rain attenuation caused huge differences of availability vs. distances for rain rates higher than 60 mm/h:

- 60 mm/h: L6 GHz and 7 GHz are always above 99,995 % for reference mode, even better than 99,999 %, while 11 GHz maximum distance is about 35 km.
- 145 mm/h: rain attenuation starts having effects also on bands lower than 10 GHz; while L6 GHz is still above 99,995 %, 11 GHz is well below even 99,99 %.

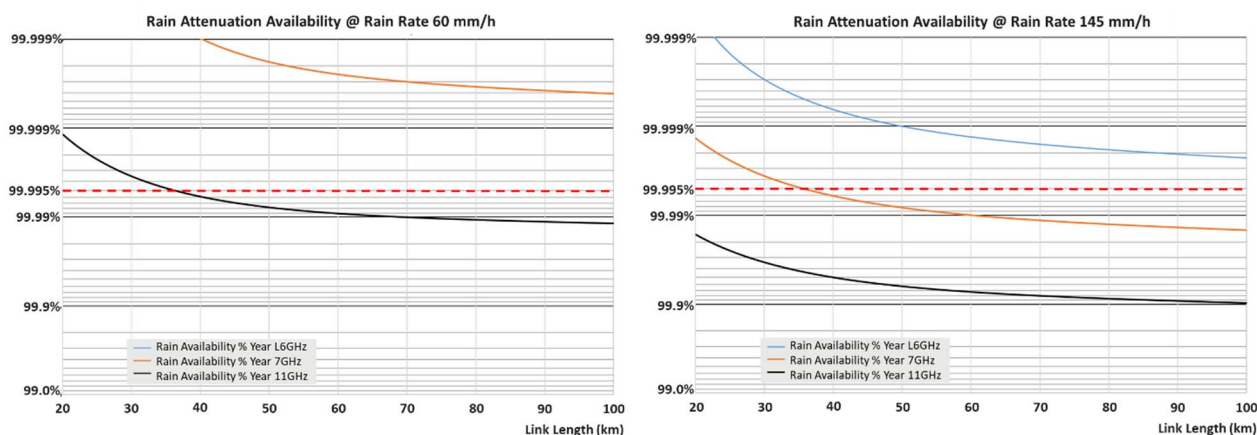


Figure 20: Link availability vs. distance - Rain attenuation only

On the contrary, as shown in Figure 21, multipath fading attenuation causes small differences of availability vs. distances across all the three bands considered.

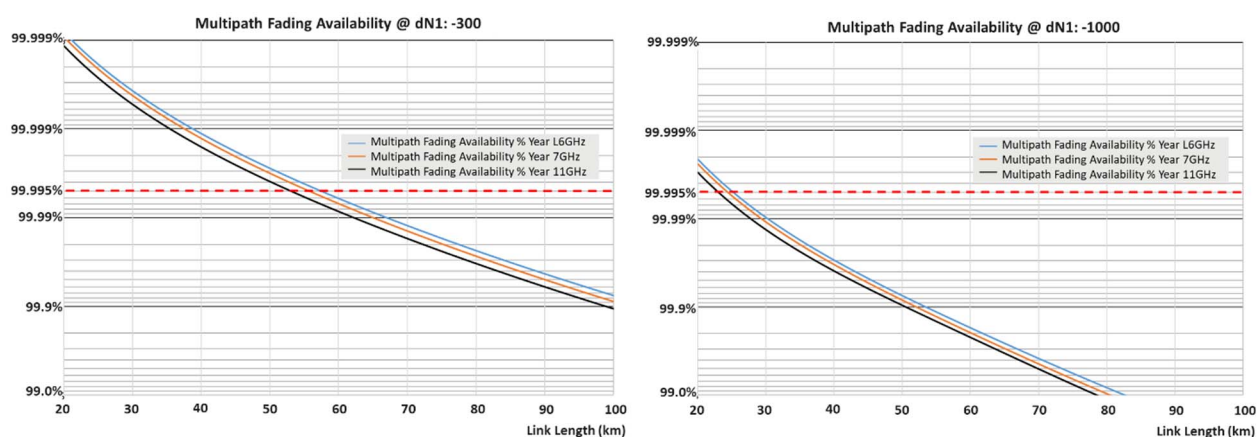


Figure 21: Link availability vs. distance - Multipath fading only - single receiver

Since space diversity counteracts the effects of multipath fading but has no benefits against the rain, that affects both main and diversity path equally, the behaviour of the different bands may greatly vary according to the different propagation conditions.

In clauses 6.2.3, 6.2.4 and 6.2.5 few examples of link planning are reported: performances comparison between low multipath probability area and high multipath probability area have been carried out for long haul and short haul systems in different rainfall areas. For sake of simplicity, the comparison is focused on 7 GHz and 11 GHz.

6.2.3 60 mm/h link planning results

Long haul system performances for both single receiver and space diversity configurations shown in Figure 22 confirm that rain attenuation has impact in lower multipath activity areas (dN_1 : -300), while in high multipath activity areas (dN_1 : -1 000) space diversity improves link availability reducing the differences among all bands:

- Single Receiver configuration: rain attenuation has impact on 11 GHz in areas with lower multipath probability resulting in more than 20 km difference between 7 GHz and 11 GHz, while in areas with high multipath probability link lengths are greatly reduced also for 7 GHz and the differences between the bands are negligible;
- Space Diversity configurations: 11 GHz link distances do not improve so much compared single receiver configuration ones, confirming rain attenuation has a huge impact on 11 GHz mainly in areas in areas with lower multipath probability; in these areas space diversity greatly improves 7 GHz performances leading to more than 50 km difference between 7 GHz and 11 GHz, while in high multipath probability areas the improvement is lower and the link difference is reduced to about 10 km.

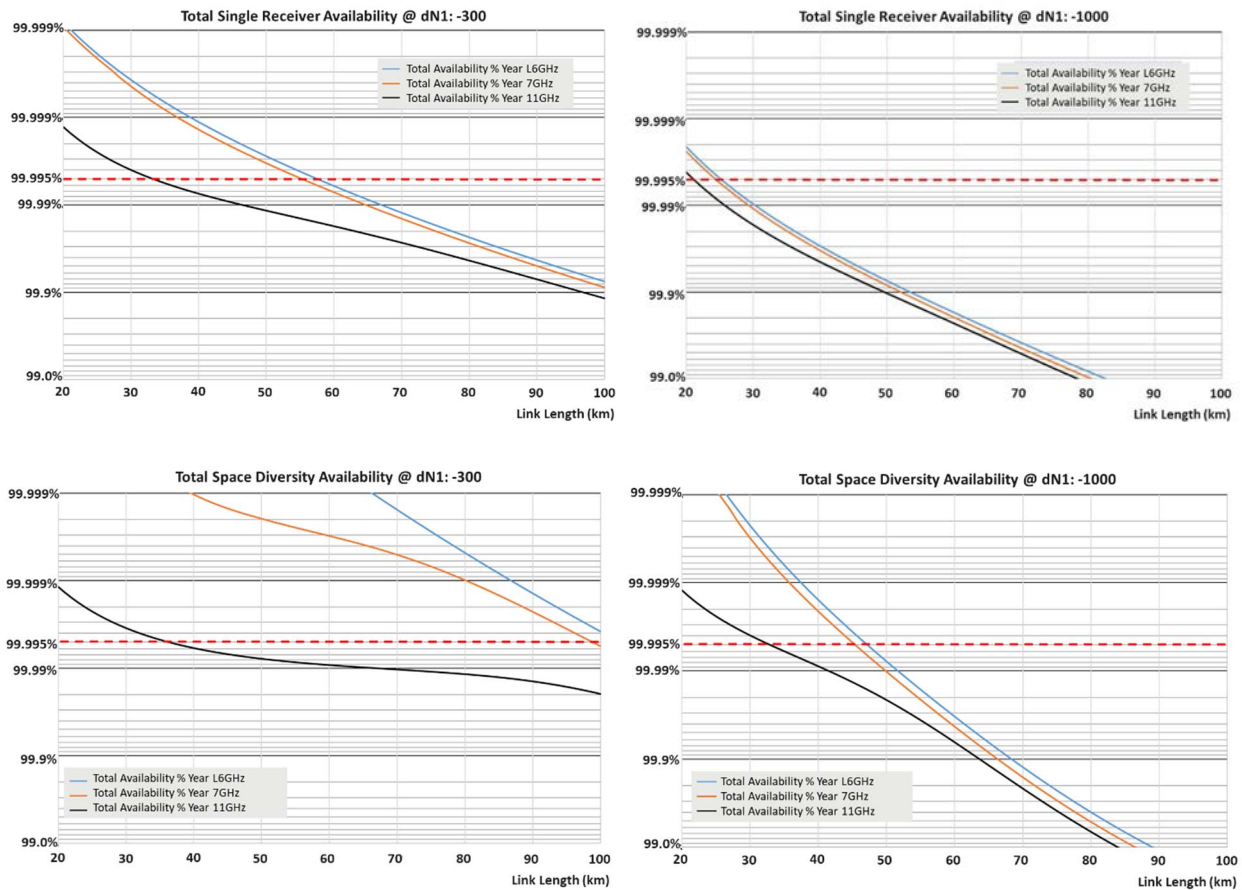


Figure 22: Link availability vs. distance - Long Haul - 1,8 m antenna - 60 mm/h

6.2.4 95 mm/h link planning results

Rainfall intensity increase strongly limits 11 GHz long haul performances as shown in Figure 23:

- Single Receiver configuration: rain attenuation has huge impact on 11 GHz and in areas with lower multipath probability the target objective is achieved only for less than 25 km (half the distance reached by 7 GHz), while if also multipath probability increases 11 GHz does not even reach 20 km.
- Space Diversity configurations: 11 GHz performances improve in areas with high multipath probability but the achievable distances remain around 25 km link distances; while 7 GHz performances improve.

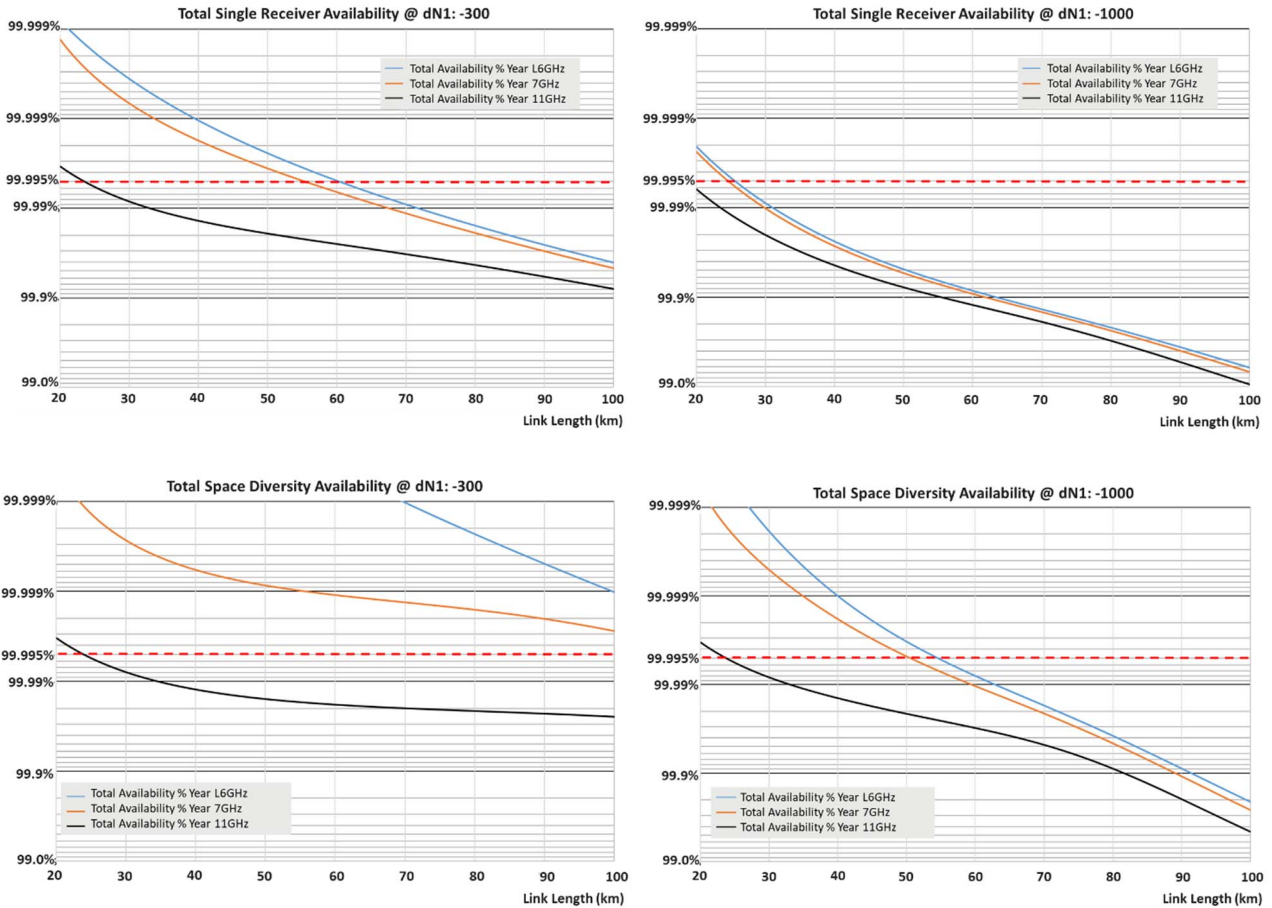


Figure 23: Link availability vs. distance - Long Haul - 3 m antenna - 95 mm/h

6.2.5 Short Haul planning results

Short Haul radio performances evaluations have been done for areas with low multipath probability, since such type of radio are mainly deployed for connecting mobile sites to first fibre PoP and not for high-capacity backbones or remote areas connections. Moreover, installation on mobile pole sites does not allow to use big antennas and to implement space diversity combination.

The difference between maximum distances that can be covered by 7 GHz and 11 GHz are increasing as rain rate increase strongly limiting 11 GHz applicability in high rainy areas.

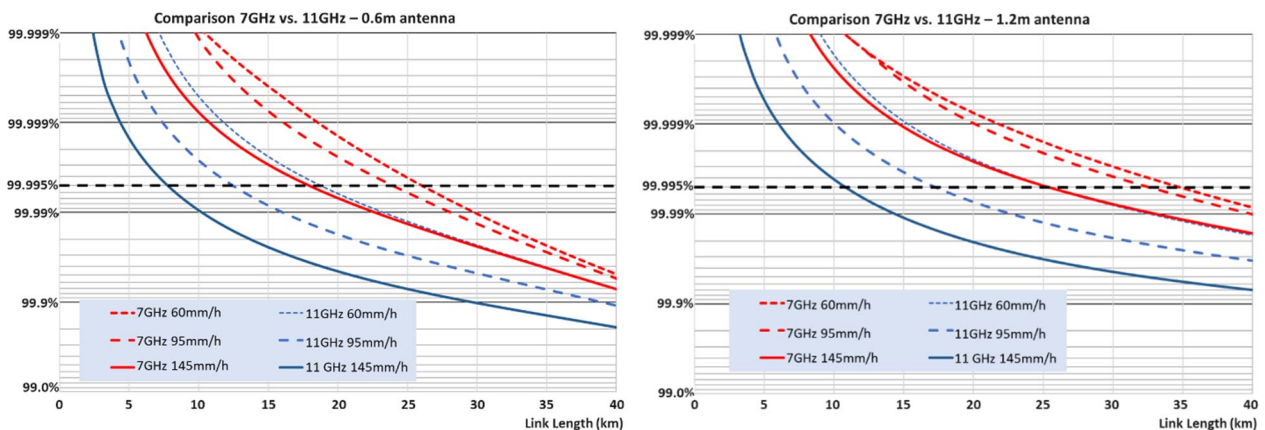


Figure 24: Link availability vs. distance - Short Haul

6.2.6 Conclusions

In high rainfall areas, 11 GHz is greatly impacted by rain attenuation which remains the limiting factor even in areas with high multipath probability while 7 GHz allows to reach medium-long distances even with smaller antennas. Moreover, space diversity improvement in long haul radios is higher in bands lower than 10 GHz, increasing the spread between 7 GHz and 11 GHz.

6.3 Link Length Statistics

6.3.1 Europe link length statistics

ECC Report 173 [i.8] reports link length statistics: the probability of a generic link, in X-axis frequency band, to be shorter than Y-axis values (km) can be determined by the value closest to the (X,Y) point.

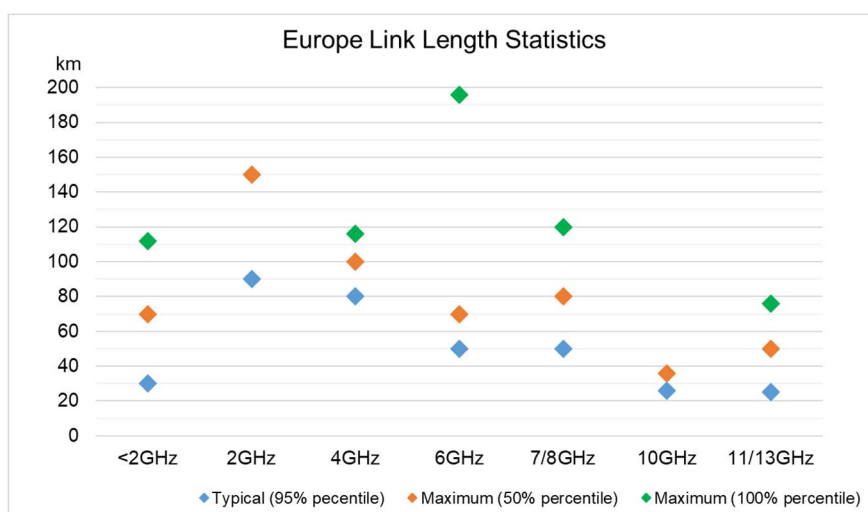


Figure 25: PtP links length distribution in Low Bands

Figure 25 shows that on average bands below 10 GHz allow to reach distances well above 60 km with a typical distance around 50 km, while low bands above 10 GHz have a lower typical distance and on average never exceed 50 km, in line with the planning considerations reported in clause 6.2.

A Tier-1 Operator provided an insight of links length distributions across selected European Countries and comparison between bands below and higher than 10 GHz in one selected European Country (Figure 26):

- 50 % of the links are between 15 km and 20 km: they are high availability links used for aggregating traffic from multiple mobile sites (e.g. head ring links or first link of a daisy chain or long haul trunk) preventing the use of mid bands as 11 GHz, 13 GHz or 15 GHz that are affected by rain attenuation and cannot reach the required KPI;
- remaining 50 % are between 20 km and 50 km: considering that on mobile sites the antenna diameter is strongly limited (typically 0,3 m-0,6 m, never bigger than 1,2 m), such distances cannot be achieved by mid-bands. This limitation is evident in the CDF comparison in one selected country where the gap between low and mid bands is about 10-15 km.

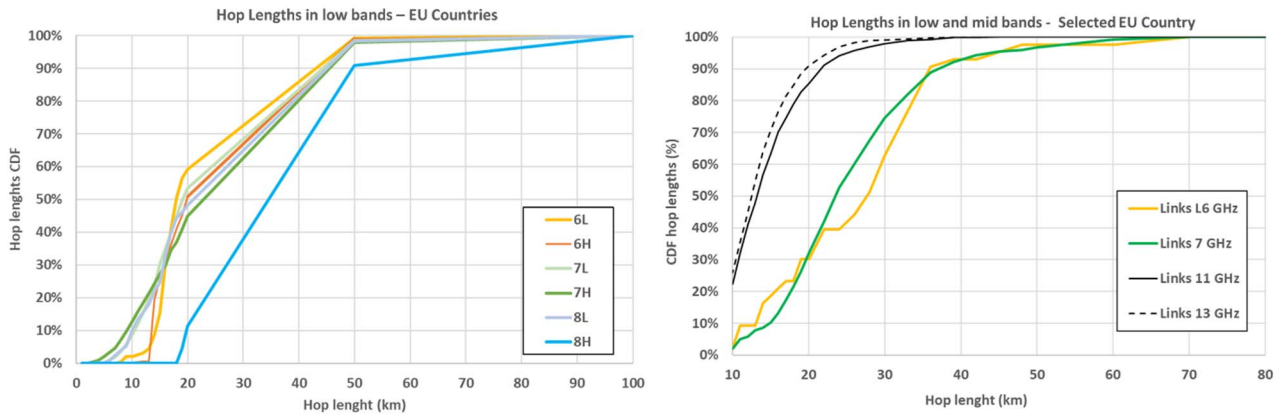


Figure 26: Hop length distribution in low and high bands

Europe rainfall rates vary from 15 mm/h and 60 mm/h, the highest rainfall rates are reported in the Mediterranean area where the island-mainland links are crucial to ensure the connectivity with highest reliability.

6.3.2 Sub-Saharan Africa link distribution

Vendor deployment statistics across different countries in sub-Saharan Africa show maximum link lengths distribution indicative of a long haul and backbone application of MW technology (Figure 27), while the average link length around 20-30 km indicates the use of these bands also on access sites that cannot install antennas larger than 0,9 m to 1,2 m. Almost all rainfall rates are present in this region ranging, for example, from 15 mm/h to 22 mm/h of Namibia up to 95 mm/h to 145 mm/h of Nigeria.

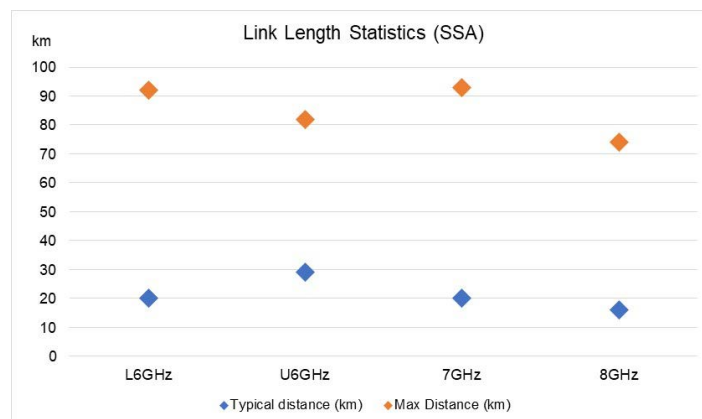


Figure 27: Sub-Saharan Africa link lengths distribution

6.3.3 USA link length distribution

Link length of MW links deployed in USA can be retrieved from FCC Universal Licensing Scheme database.

Five bands are included in the analysis: 6 GHz, 11 GHz, 18 GHz and 23 GHz. 38 GHz links and all links with 0 km length have not been included.

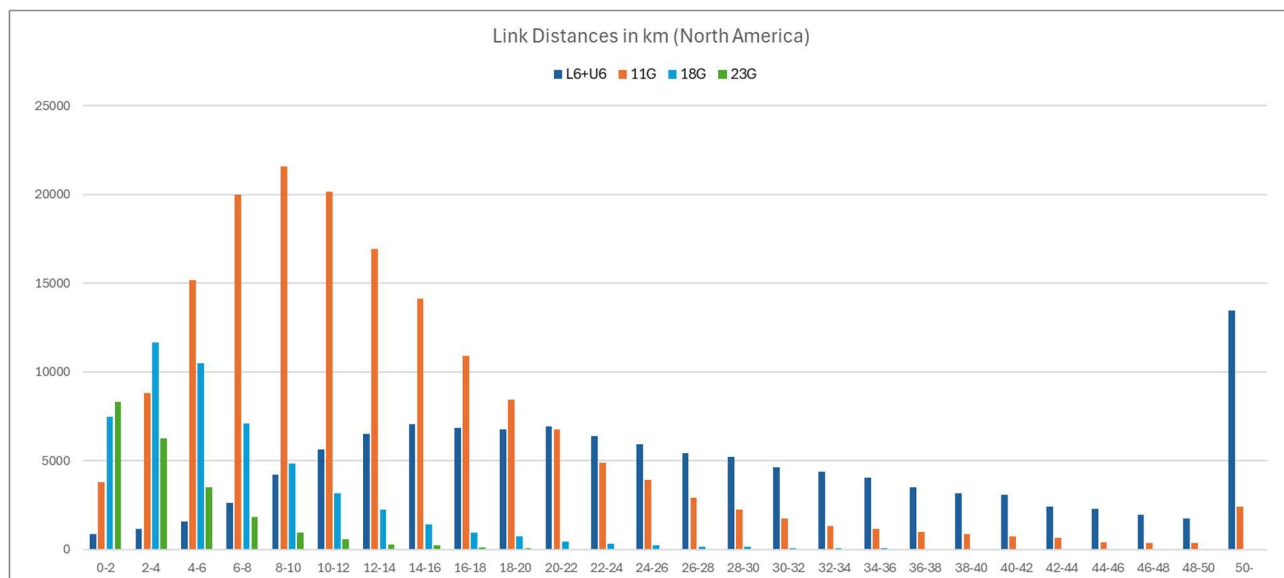


Figure 28: Link distance distribution 0-50 km

Focusing on low bands, 6 GHz and 11 GHz link lengths distribution reported in Figure 29 confirms the radio propagation consideration made in clause 6.2: considering that USA rain rates ranges from 12 mm/h up to 95 mm/h almost all rain zones are present, 11 GHz can achieve distances usually covered with 6 GHz when installed areas with low rain intensity. In fact, in the state of New Mexico (22 mm/h rain intensity) there is the longest 11 GHz link with hop length of 134 km.

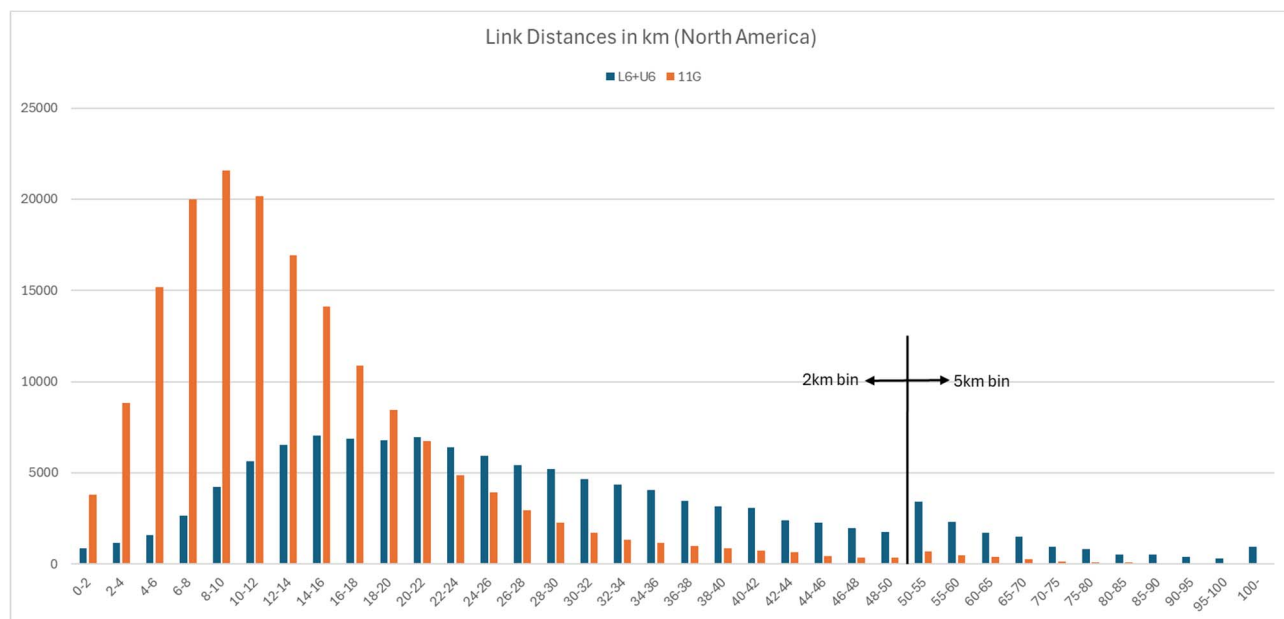


Figure 29: 6 GHz and 11 GHz link distance distribution 0 km to 100 km

As rain rate increases the effects on 11 GHz are evident: in heavy rain regions as Florida, Mississippi and Louisiana (90 mm/h) links longer than 20-25 km are very few and 6 GHz links are 2-3 times longer than 11 GHz ones. The upper limit of 70 km is driven by the link location: the three stated used are flat terrain region and higher distances cannot be physically achieved with realistic tower heights.

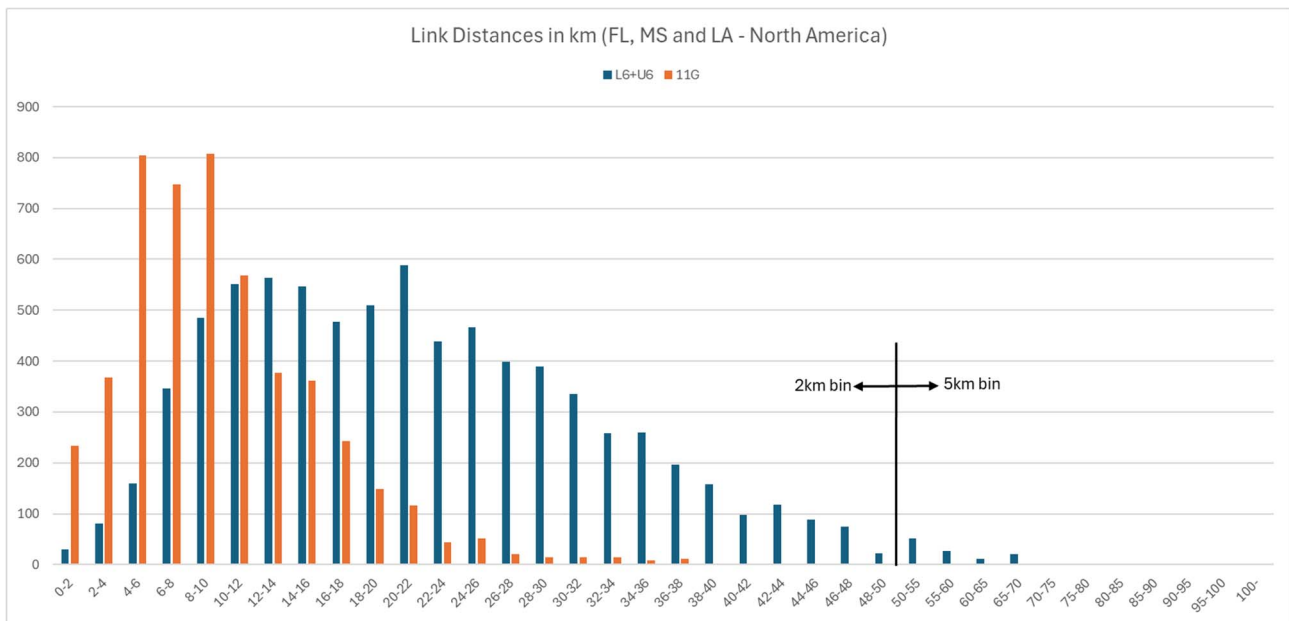


Figure 30: Southern States 6 GHz and 11 GHz link distance distribution 0-100 km

7 Conclusions

Ubiquitous broadband connectivity is the key requisite of digital era. Notwithstanding the increase of fibre availability, wireless backhaul confirms itself as a strategic asset in communication infrastructure networks and high capacity required to enable the digital transformation can be fulfilled only granting enough spectrum to meet different application scenarios.

While high bands (≥ 15 GHz) and mm-wave can deliver ultra-Gbps capacity in urban and suburban areas thanks to wide channels (≥ 112 MHz), low bands (≤ 13 GHz) used in rural areas and on wireless backbones lack enough spectrum to allow channels higher than 56/80 MHz and require multi-channels aggregation.

The band delivery statistics collected confirm that bands below 10 GHz still play an important role in modern communication networks: in developed countries there are still many areas where microwave is the only choice for delivering high capacity connection, while in developing countries lack of fibre requires long haul microwave links to deploy cross country ultra-Gbps backbones.

Bands below 10 GHz represent about 20 % of past five years microwave deliveries worldwide with the highest shares in Africa and Americas (from 25 % to 33 %). With the exception of North America, 7 GHz and 8 GHz are the most used bands ranging from 70 % to 90 % shares. While L6 GHz and U6 GHz were traditionally used for high capacity long haul links, 7 GHz and 8 GHz are widely used also as last mile connections.

Planning simulations done indicate that medium-long distance links cannot rely on other low bands (11 GHz and 13 GHz) not only to ensure the high reliability required by feeder link or aggregation backbones but also to meet the KPI of access links in high rainfall areas.

The results are confirmed by link length statistics collected in different regions: Europe 50 km typical distance suggests long haul and feeder links as major application of these bands while average link distance of 20-30 km in Sub-Saharan Africa and USA fits with last mile scenarios.

Data and feedbacks collected during the present document preparation confirm the need of keeping enough spectrum in bands below 10 GHz to meet capacity, distance and availability targets required by operators, utilities and enterprises to deliver broadband connectivity.

Annex A: ECC Report 173 responding countries

Table A.1: ECC Report 173 [i.8] responding countries

Country	2018	2022	Countries considered for the trends
Albania	Yes		
Austria	Yes	Yes	Yes
Azerbaijan		Yes	
Belgium		Yes	
Bosnia and Herzegovina	Yes	Yes	Yes
Bulgaria	Yes	Yes	Yes
Croatia	Yes	Yes	Yes
Cyprus		Yes	
Czech Republic	Yes	Yes	Yes
Estonia	Yes		
Finland	Yes	Yes	Yes
France	Yes	Yes	Yes
Germany	Yes	Yes	Yes
Greece	Yes		
Hungary	Yes	Yes	Yes
Ireland	Yes	Yes	Yes
Italy	Yes	Yes	Yes
Latvia	Yes	Yes	Yes
Malta	Yes	Yes	Yes
Moldova		Yes	
Netherlands	Yes	Yes	Yes
Norway	Yes	Yes	Yes
Portugal	Yes		
Romania	Yes	Yes	Yes
Russia	Yes		
Serbia		Yes	
Slovak Republic	Yes	Yes	Yes
Slovenia	Yes	Yes	Yes
Sweden	Yes	Yes	Yes
Switzerland	Yes	Yes	Yes
Türkiye	Yes	Yes	Yes
United Kingdom	Yes	Yes	Yes
Total	26	26	22

Annex B: Country Split

Table B.1: Vendor statistics country split

ITU-R Region	Country	Spectrum Regional Association	Aggregated Region	Aggregated Macro Region
Africa	Angola	ATU	Sub-Saharan Africa	Africa
Africa	Benin	ATU	Sub-Saharan Africa	Africa
Africa	Botswana	ATU	Sub-Saharan Africa	Africa
Africa	Burkina Faso	ATU	Sub-Saharan Africa	Africa
Africa	Burundi	ATU	Sub-Saharan Africa	Africa
Africa	Cape Verde	ATU	Sub-Saharan Africa	Africa
Africa	Cameroon	ATU	Sub-Saharan Africa	Africa
Africa	Central African Republic	ATU	Sub-Saharan Africa	Africa
Africa	Chad	ATU	Sub-Saharan Africa	Africa
Africa	Congo	ATU	Sub-Saharan Africa	Africa
Africa	Côte d'Ivoire	ATU	Sub-Saharan Africa	Africa
Africa	Democratic Republic of the Congo	ATU	Sub-Saharan Africa	Africa
Africa	Equatorial Guinea	ATU	Sub-Saharan Africa	Africa
Africa	Eritrea		Sub-Saharan Africa	Africa
Africa	Eswatini	ATU	Sub-Saharan Africa	Africa
Africa	Ethiopia	ATU	Sub-Saharan Africa	Africa
Africa	Gabon	ATU	Sub-Saharan Africa	Africa
Africa	Gambia	ATU	Sub-Saharan Africa	Africa
Africa	Ghana	ATU	Sub-Saharan Africa	Africa
Africa	Guinea	ATU	Sub-Saharan Africa	Africa
Africa	Guinea-Bissau	ATU	Sub-Saharan Africa	Africa
Africa	Kenya	ATU	Sub-Saharan Africa	Africa
Africa	Lesotho	ATU	Sub-Saharan Africa	Africa
Africa	Liberia	ATU	Sub-Saharan Africa	Africa
Africa	Madagascar	ATU	Sub-Saharan Africa	Africa
Africa	Malawi	ATU	Sub-Saharan Africa	Africa
Africa	Mali	ATU	Sub-Saharan Africa	Africa
Africa	Mauritius	ATU	Sub-Saharan Africa	Africa
Africa	Mozambique	ATU	Sub-Saharan Africa	Africa
Africa	Namibia	ATU	Sub-Saharan Africa	Africa
Africa	Niger	ATU	Sub-Saharan Africa	Africa
Africa	Nigeria	ATU	Sub-Saharan Africa	Africa
Africa	Rwanda	ATU	Sub-Saharan Africa	Africa
Africa	Sao Tome and Principe	ATU	Sub-Saharan Africa	Africa
Africa	Senegal	ATU	Sub-Saharan Africa	Africa
Africa	Seychelles		Sub-Saharan Africa	Africa
Africa	Sierra Leone	ATU	Sub-Saharan Africa	Africa
Africa	South Africa	ATU	Sub-Saharan Africa	Africa
Africa	South Sudan	ATU	Sub-Saharan Africa	Africa
Africa	Tanzania	ATU	Sub-Saharan Africa	Africa
Africa	Togo	ATU	Sub-Saharan Africa	Africa
Africa	Uganda	ATU	Sub-Saharan Africa	Africa
Africa	Zambia	ATU	Sub-Saharan Africa	Africa
Africa	Zimbabwe	ATU	Sub-Saharan Africa	Africa

Table B.2

ITU-R Region	Country	Spectrum Regional Association	Proposed Region	Aggregated Macro Region
Americas	Antigua and Barbuda	CITEL	Latina America (LATAM)	Americas
Americas	Argentina	CITEL	Latina America (LATAM)	Americas
Americas	Bahamas	CITEL	Latina America (LATAM)	Americas
Americas	Barbados	CITEL	Latina America (LATAM)	Americas
Americas	Belize	CITEL	Latina America (LATAM)	Americas
Americas	Bolivia	CITEL	Latina America (LATAM)	Americas
Americas	Brazil	CITEL	Latina America (LATAM)	Americas
Americas	Canada	CITEL	North America (NAM)	Americas
Americas	Chile	CITEL	Latina America (LATAM)	Americas
Americas	Colombia	CITEL	Latina America (LATAM)	Americas
Americas	Costa Rica	CITEL	Latina America (LATAM)	Americas
Americas	Cuba	CITEL	Latina America (LATAM)	Americas
Americas	Dominica	CITEL	Latina America (LATAM)	Americas
Americas	Dominican Republic	CITEL	Latina America (LATAM)	Americas
Americas	Ecuador	CITEL	Latina America (LATAM)	Americas
Americas	El Salvador	CITEL	Latina America (LATAM)	Americas
Americas	Grenada	CITEL	Latina America (LATAM)	Americas
Americas	Guatemala	CITEL	Latina America (LATAM)	Americas
Americas	Guyana	CITEL	Latina America (LATAM)	Americas
Americas	Haiti	CITEL	Latina America (LATAM)	Americas
Americas	Honduras	CITEL	Latina America (LATAM)	Americas
Americas	Jamaica	CITEL	Latina America (LATAM)	Americas
Americas	Mexico	CITEL	Latina America (LATAM)	Americas
Americas	Nicaragua	CITEL	Latina America (LATAM)	Americas
Americas	Panama	CITEL	Latina America (LATAM)	Americas
Americas	Paraguay	CITEL	Latina America (LATAM)	Americas
Americas	Peru	CITEL	Latina America (LATAM)	Americas
Americas	Saint Kitts and Nevis	CITEL	Latina America (LATAM)	Americas
Americas	Saint Lucia	CITEL	Latina America (LATAM)	Americas
Americas	Saint Vincent and the Grenadines	CITEL	Latina America (LATAM)	Americas
Americas	Suriname	CITEL	Latina America (LATAM)	Americas
Americas	Trinidad and Tobago	CITEL	Latina America (LATAM)	Americas
Americas	United States of America	CITEL	North America (NAM)	Americas
Americas	Uruguay	CITEL	Latina America (LATAM)	Americas
Americas	Venezuela	CITEL	Latina America (LATAM)	Americas

Table B.3

ITU-R Region	Country	Spectrum Regional Association	Proposed Region	Aggregated Macro Region
Arab States	Algeria	ASMG/ATU	North Africa	Africa
Arab States	Comoros	ASMG/ATU	North Africa	Africa
Arab States	Djibouti	ASMG/ATU	North Africa	Africa
Arab States	Egypt	ASMG/ATU	North Africa	Africa
Arab States	Libya	ASMG/ATU	North Africa	Africa
Arab States	Mauritania	ASMG/ATU	North Africa	Africa
Arab States	Morocco	ASMG/ATU	North Africa	Africa
Arab States	Somalia	ASMG/ATU	North Africa	Africa
Arab States	Sudan	ASMG/ATU	North Africa	Africa
Arab States	Tunisia	ASMG/ATU	North Africa	Africa
Arab States	Bahrain	ASMG	Middle East	Arab States
Arab States	Iraq	ASMG	Middle East	Arab States
Arab States	Jordan	ASMG	Middle East	Arab States
Arab States	Kuwait	ASMG	Middle East	Arab States
Arab States	Lebanon	ASMG	Middle East	Arab States
Arab States	Oman	ASMG	Middle East	Arab States
Arab States	Qatar	ASMG	Middle East	Arab States
Arab States	Saudi Arabia	ASMG	Middle East	Arab States
Arab States	Syria	ASMG	Middle East	Arab States
Arab States	United Arab Emirates	ASMG	Middle East	Arab States
Arab States	Yemen	ASMG	Middle East	Arab States

Table B.4

ITU-R Region	Country	Spectrum Regional Association	Proposed Region	Aggregated Macro Region
Asia and Pacific	Afghanistan	APT	Asia Pacific	Asia Pacific (APAC)
Asia and Pacific	Australia	APT	Asia Pacific	Asia Pacific (APAC)
Asia and Pacific	Bangladesh	APT	Asia Pacific	Asia Pacific (APAC)
Asia and Pacific	Bhutan	APT	Asia Pacific	Asia Pacific (APAC)
Asia and Pacific	Brunei	APT	Asia Pacific	Asia Pacific (APAC)
Asia and Pacific	Cambodia	APT	Asia Pacific	Asia Pacific (APAC)
Asia and Pacific	China	APT	Asia Pacific	Asia Pacific (APAC)
Asia and Pacific	Democratic People's Republic of Korea	APT	Asia Pacific	Asia Pacific (APAC)
Asia and Pacific	Fiji	APT	Asia Pacific	Asia Pacific (APAC)
Asia and Pacific	India	APT	Asia Pacific	Asia Pacific (APAC)
Asia and Pacific	Indonesia	APT	Asia Pacific	Asia Pacific (APAC)
Asia and Pacific	Iran	APT	Asia Pacific	Asia Pacific (APAC)
Asia and Pacific	Japan	APT	Asia Pacific	Asia Pacific (APAC)
Asia and Pacific	Kiribati	APT	Asia Pacific	Asia Pacific (APAC)
Asia and Pacific	Korea	APT	Asia Pacific	Asia Pacific (APAC)
Asia and Pacific	Laos	APT	Asia Pacific	Asia Pacific (APAC)
Asia and Pacific	Malaysia	APT	Asia Pacific	Asia Pacific (APAC)
Asia and Pacific	Maldives	APT	Asia Pacific	Asia Pacific (APAC)
Asia and Pacific	Marshall Islands	APT	Asia Pacific	Asia Pacific (APAC)
Asia and Pacific	Micronesia	APT	Asia Pacific	Asia Pacific (APAC)
Asia and Pacific	Mongolia	APT	Asia Pacific	Asia Pacific (APAC)
Asia and Pacific	Myanmar	APT	Asia Pacific	Asia Pacific (APAC)
Asia and Pacific	Nauru	APT	Asia Pacific	Asia Pacific (APAC)
Asia and Pacific	Nepal	APT	Asia Pacific	Asia Pacific (APAC)
Asia and Pacific	New Zealand	APT	Asia Pacific	Asia Pacific (APAC)
Asia and Pacific	Pakistan	APT	Asia Pacific	Asia Pacific (APAC)
Asia and Pacific	Palau	APT	Asia Pacific	Asia Pacific (APAC)
Asia and Pacific	Papua New Guinea	APT	Asia Pacific	Asia Pacific (APAC)
Asia and Pacific	Philippines	APT	Asia Pacific	Asia Pacific (APAC)
Asia and Pacific	Samoa	APT	Asia Pacific	Asia Pacific (APAC)

ITU-R Region	Country	Spectrum Regional Association	Proposed Region	Aggregated Macro Region
Asia and Pacific	Singapore	APT	Asia Pacific	Asia Pacific (APAC)
Asia and Pacific	Solomon Islands	APT	Asia Pacific	Asia Pacific (APAC)
Asia and Pacific	Sri Lanka	APT	Asia Pacific	Asia Pacific (APAC)
Asia and Pacific	Timor-Leste		Asia Pacific	Asia Pacific (APAC)
Asia and Pacific	Thailand	APT	Asia Pacific	Asia Pacific (APAC)
Asia and Pacific	Tonga	APT	Asia Pacific	Asia Pacific (APAC)
Asia and Pacific	Tuvalu	APT	Asia Pacific	Asia Pacific (APAC)
Asia and Pacific	Vanuatu	APT	Asia Pacific	Asia Pacific (APAC)
Asia and Pacific	Vietnam	APT	Asia Pacific	Asia Pacific (APAC)

Table B.5

ITU-R Region	Country	Spectrum Regional Association	Proposed Region	Aggregated Macro Region
Europe	Albania	CEPT	Europe	Europe
Europe	Andorra	CEPT	Europe	Europe
Europe	Austria	CEPT	Europe	Europe
Europe	Belgium	CEPT	Europe	Europe
Europe	Bosnia and Herzegovina	CEPT	Europe	Europe
Europe	Bulgaria	CEPT	Europe	Europe
Europe	Croatia	CEPT	Europe	Europe
Europe	Cyprus	CEPT	Europe	Europe
Europe	Czech Republic	CEPT	Europe	Europe
Europe	Denmark	CEPT	Europe	Europe
Europe	Estonia	CEPT	Europe	Europe
Europe	Finland	CEPT	Europe	Europe
Europe	France	CEPT	Europe	Europe
Europe	Georgia	CEPT	Europe	Europe
Europe	Germany	CEPT	Europe	Europe
Europe	Greece	CEPT	Europe	Europe
Europe	Holy See	CEPT	Europe	Europe
Europe	Hungary	CEPT	Europe	Europe
Europe	Iceland	CEPT	Europe	Europe
Europe	Ireland	CEPT	Europe	Europe
Europe	Israel		Europe	Europe
Europe	Italy	CEPT	Europe	Europe
Europe	Latvia	CEPT	Europe	Europe
Europe	Liechtenstein	CEPT	Europe	Europe
Europe	Lithuania	CEPT	Europe	Europe
Europe	Luxembourg	CEPT	Europe	Europe
Europe	Malta	CEPT	Europe	Europe
Europe	Moldova	CEPT	Europe	Europe
Europe	Monaco	CEPT	Europe	Europe
Europe	Montenegro	CEPT	Europe	Europe
Europe	Netherlands	CEPT	Europe	Europe
Europe	North Macedonia	CEPT	Europe	Europe
Europe	Norway	CEPT	Europe	Europe
Europe	Poland	CEPT	Europe	Europe
Europe	Portugal	CEPT	Europe	Europe
Europe	Romania	CEPT	Europe	Europe
Europe	San Marino	CEPT	Europe	Europe
Europe	Serbia	CEPT	Europe	Europe
Europe	Slovak Republic	CEPT	Europe	Europe
Europe	Slovenia	CEPT	Europe	Europe
Europe	Spain	CEPT	Europe	Europe
Europe	Sweden	CEPT	Europe	Europe
Europe	Switzerland	CEPT	Europe	Europe
Europe	Türkiye	CEPT	Europe	Europe
Europe	Ukraine	CEPT	Europe	Europe

ITU-R Region	Country	Spectrum Regional Association	Proposed Region	Aggregated Macro Region
Europe	United Kingdom	CEPT	Europe	Europe

Table B.6

ITU-R Region	Country	Spectrum Regional Association	Proposed Region	Aggregated Macro Region
Commonwealth of Independent States	Armenia	RCC	Commonwealth of Independent States (CIS)	Commonwealth of Independent States (CIS)
Commonwealth of Independent States	Azerbaijan	RCC	Commonwealth of Independent States (CIS)	Commonwealth of Independent States (CIS)
Commonwealth of Independent States	Belarus	RCC	Commonwealth of Independent States (CIS)	Commonwealth of Independent States (CIS)
Commonwealth of Independent States	Kazakhstan	RCC	Commonwealth of Independent States (CIS)	Commonwealth of Independent States (CIS)
Commonwealth of Independent States	Kyrgyzstan	RCC	Commonwealth of Independent States (CIS)	Commonwealth of Independent States (CIS)
Commonwealth of Independent States	Russian Federation	RCC	Commonwealth of Independent States (CIS)	Commonwealth of Independent States (CIS)
Commonwealth of Independent States	Tajikistan	RCC	Commonwealth of Independent States (CIS)	Commonwealth of Independent States (CIS)
Commonwealth of Independent States	Turkmenistan	RCC	Commonwealth of Independent States (CIS)	Commonwealth of Independent States (CIS)
Commonwealth of Independent States	Uzbekistan	RCC	Commonwealth of Independent States (CIS)	Commonwealth of Independent States (CIS)

Annex C: Change history

Date	Version	Information about changes
October 2024	V0.0.1	Draft Skeleton
May 2025	V0.1.0	Stable Draft
July 2025	V0.2.0	Final Draft
August 2025	V0.2.2	Final Draft first revision
September 2025	V0.2.3	Final Draft editorial revision
November 2025	V0.2.4	Final Draft second editorial revision
January 2026	V0.2.5	Final Draft third editorial revision

History

Version	Date	Status
V1.1.1	February 2026	Publication