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Technical Specification

**Digital Enhanced Cordless Telecommunications (DECT);
DECT derivative for implementation in the 2,45 GHz ISM Band
(DECT-ISM)**

Reference
DTS/DECT-A0180

Keywords
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Contents

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Foreword

This Technical Specification (TS) has been produced by ETSI Project Digital Enhanced Cordless Telecommunications (DECT).

1 Scope

The present document specifies the DECT derivative DECT-ISM for implementation in the 2,45 GHz ISM band [9], [10] and [11]. The main difference between DECT and DECT-ISM is the addition of frequency hopping patterns fulfilling the FCC part 15 rules [10].

The prime objective for specifying DECT-ISM is to allow for introduction of a DECT based technology in countries that have no spectrum allocated for DECT, but allow frequency hopping applications in the ISM band. The 2,4 GHz ISM band is available in all major markets world-wide.

DECT-ISM will compared to DECT have limitations in range due to restrictions imposed by the ISM band rules [9], [10] and limitations in quality of service mainly due to the fact that the ISM band is unprotected, while the DECT band is exclusively allocated for DECT. See further clause 4.1. The ISM band is unprotected in that sense that it allows for unco-ordinated usage of a variety of incompatible communication devices and also industrial, scientific and medical devices.

2 References

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

- References are either specific (identified by date of publication and/or edition number or version number) or non-specific.
- For a specific reference, subsequent revisions do not apply.
- For a non-specific reference, the latest version applies.

[1] ETSI EN 300 175-1: "Digital Enhanced Cordless Telecommunications (DECT); Common Interface (CI); Part 1: Overview".

[2] ETSI EN 300 175-2: "Digital Enhanced Cordless Telecommunications (DECT); Common Interface (CI); Part 2: Physical Layer (PHL)".

[3] ETSI EN 300 175-3: "Digital Enhanced Cordless Telecommunications (DECT); Common Interface (CI); Part 3: Medium Access Control (MAC) layer".

[4] ETSI EN 300 175-4: "Digital Enhanced Cordless Telecommunications (DECT); Common Interface (CI); Part 4: Data Link Control (DLC) layer".

[5] ETSI EN 300 175-5: "Digital Enhanced Cordless Telecommunications (DECT); Common Interface (CI); Part 5: Network (NWK) layer".

[6] ETSI EN 300 175-6: "Digital Enhanced Cordless Telecommunications (DECT); Common Interface (CI); Part 6: Identities and addressing".

[7] ETSI EN 300 175-7: "Digital Enhanced Cordless Telecommunications (DECT); Common Interface (CI); Part 7: Security features".

[8] ETSI EN 300 175-8: "Digital Enhanced Cordless Telecommunications (DECT); Common Interface (CI); Part 8: Speech coding and transmission".

[9] ETSI EN 300 328: "Electromagnetic compatibility and Radio Spectrum Matters (ERM); Wideband Transmission systems; data transmission equipment operating in the 2,4 GHz ISM band and using spread spectrum modulation techniques".

[10] FCC part 15: "Federal Communications Commission Part 15 Radio Frequency Devices". Updated February 28, 2001.

[11] RCR STD-33A: "Association of Radio Industries and Businesses, ARIB; Approval standard for ISM devices".

3 Definitions and abbreviations

3.1 Definitions

For the purposes of the present document, the terms and definitions given in EN 300 175-1 [1] and the following apply.

bearer hop sequence: sequence of ISM band RF carrier numbers used for a single bearer (slot), which is derived by cyclic repetition of a hopset and where a separate ISM band RF carrier number is selected in each 10 ms DECT frame

hopset: pseudo-random sequence of ISM band RF carrier numbers in which each of the defined ISM band RF carrier numbers is represented once and only once
(For the DECT derivative in the ISM band the hopset corresponds to the RF carrier of regular DECT.)

hopset number: number used to designate a hopset
See clause 6.2.

ISM band RF carrier: centre frequency occupied by one ISM band DECT transmission

physical layer hop sequence: sequence of ISM band RF carrier numbers derived by inter-leaving the bearer hop sequences of one or more active bearers (slots)
The physical layer hop sequence is the sequence of hopping channels to which the hopping rules in EN 300 328 [9] and FCC part 15 [10] apply.

3.2 Abbreviations

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

ARI	Access Rights Identity
DECT	Digital Enhanced Cordless Telecommunications
FCC	Federal Communications Commission
FP	Fixed Part
ISM	Industrial, Scientific, Medical
PP	Portable Part
PT	Portable Termination
RF	Radio Frequency
RFP	Radio Fixed Part
SARI	Secondary ARI
MAC	Medium Access Control
NTP	Nominal Transmitter Power

4 Overview

4.1 Introduction

The present document specifies the DECT derivative DECT-ISM for implementation in the 2,45 GHz ISM band [9], [11] and conforming to FCC Part 15 rules [10].

The major addition to the DECT base standard EN 300 175-1 [1] to EN 300 175-8 [8] is the definition of sequences of frequency hops applied to the ISM band.

The RF carriers of regular DECT equipment are for the ISM band application replaced by mutually non-interfering sequences of frequency hopping within the ISM band. Therefore dynamic channel selection can be made between these sequences, following the same procedures as regular DECT uses to make dynamic channel selection between the RF carriers.

Therefore, for the purpose of the present document, all "RF carrier" and "RF carrier number" notations in text and tables in the MAC layer (EN 300 175-3 [3]) are interpreted as "hopset" or "hopset number".

In this way, DECT services and profile standards can be implemented also in the ISM band with hardly any changes to the MAC layer except for the above interpretation of "RF carrier".

To avoid PTs achieving idle lock on transmissions received on any of the adjacent receiver channels, the FP transmits a Q-message indicating on which ISM band RF carrier c, the message was transmitted. Clause B.4 describes a preferred implementation of idle lock and channel selection procedures, which differ somewhat from implementations for regular DECT.

A major difference between DECT-ISM and DECT is that DECT-ISM is applied on the non-protected ISM spectrum, while DECT is applied on a spectrum exclusive for DECT. DECT-ISM will provide coexistence and high quality of service in unco-ordinated DECT-ISM systems. However the ISM band allows for unco-ordinated usage of a variety of incompatible communication devices and also industrial, scientific and medical devices. Therefore high quality of service will not be guaranteed when other types of ISM devices (non-DECT-ISM devices) are used in the same local area. This applies especially to speech and video services, but is less critical for packet data services where non-time-critical retransmissions are applied. DECT-ISM shares this inability to guarantee the quality of service with other technologies used for communication devices applied in the 2,4 GHz ISM band.

Another limitation for DECT-ISM compared to DECT is the range. Typical DECT-ISM link budget could be 10 dB lower than for DECT, or only 4 dB to 5 dB lower if prolonged preamble diversity is provided. See clause B.1.

In spite of these limitations compared to DECT, DECT-ISM does exhibit attractive properties and performance compared to many other technologies applied for communication in the ISM band.

4.2 Application of the DECT base standard

The base standards EN 300 175-1 [1] to EN 300 175-8 [8] apply, the present document only defines the amendments.

In clause 5 modifications of the physical layer and in clause 6 modifications of the MAC layer are described.

5 Modifications of the physical layer

5.1 Nominal position of ISM band RF carriers

This clause replaces clause 4.1.1 of the base standard EN 300 175-2 [2].

45 ISM band RF carriers shall be placed into the frequency band 2 400 MHz to 2 483,5 MHz with centre frequencies F_c given by:

$$Fc = F_0 + c \text{ x } 1{,}728 \text{ MHz.}$$

where: F_0 = 2 403,648 MHz; and

c = 0,1, ..., 44.

5.2 Accuracy and stability of ISM band RF carriers

This clause modifies clause 4.1.2 of the base standard EN 300 175-2 [2].

At an RFP the transmitted RF carrier frequency corresponding to RF channel c shall be in the range Fc ± 80 kHz at extreme conditions.

At a PP the centre frequency accuracy shall be within ±80 kHz at extreme conditions either relative to an absolute frequency reference or relative to the received carrier, except that during the first 1 s after the transition from the idle-locked state to the active-locked state the centre frequency accuracy shall be within ±140 kHz at extreme conditions relative to the received carrier.

5.3 Transmitter idle power output

This clause modifies clause 5.2.6 of the base standard EN 300 175-2 [2].

For the time period starting 27 µs after the end of the physical packet and finishing 27 µs before the next transmission of a data symbol p0, the transmitter idle power shall be less than 200 nW, except when p0 of the next transmitted packet occurs less than 54 µs after the end of the transmitted physical packet.

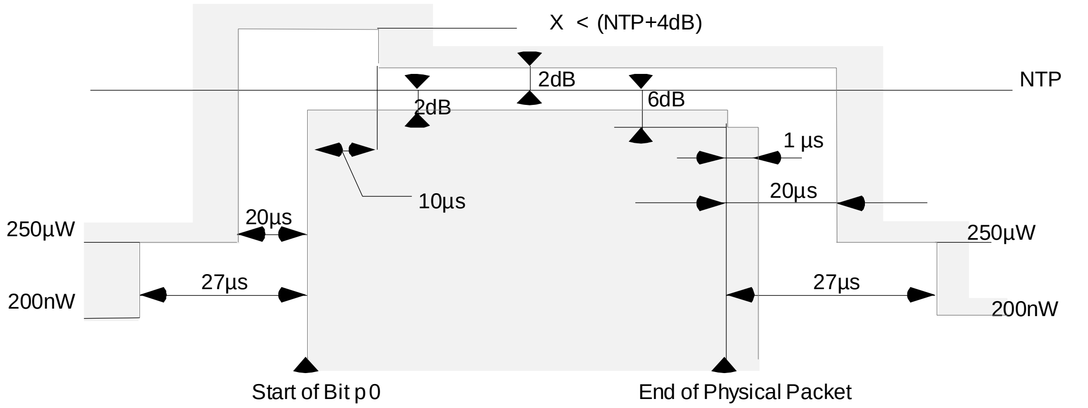

Figure 1: Physical packet power-time template

5.4 Peak power per transceiver

This clause modifies clause 5.3.1 of the base standard EN 300 175-2 [2].

The NTP shall be less than P_{NTP} per simultaneously active transceiver at nominal conditions.

The power measured at a connector is NTP. This connector is a temporary connector if the PP or FP has an integrated antenna.

The transmitter power P_{NTP}[dB] is 20 dBm - X, where X is the antenna gain [dBi].

5.5 Emissions due to transmitter transients

Clause 5.5.2 of the base standard EN 300 175-2 [2] does not apply.

NOTE: The requirements on out of band emissions (clause [10]) and spurious emissions (clause 5.6) will indirectly impose limits on transients.

5.6 Spurious emissions when allocated a transmit channel

This clause modifies clause 5.5.4 of the base standard EN 300 175-2 [2].

The peak power level of any RF emissions outside the ISM radio frequency band shall not exceed the limits defined in EN 300 328 [9] and FCC part 15 [10]. See clause B.3.

5.7 Spurious emissions when not allocated a transmit channel

This clause modifies clause 6.7 of the base standard EN 300 175-2 [2].

The power level of any RF emissions outside the ISM radio frequency band shall not exceed the limits defined in EN 300 328 [9] and FCC part 15 [10]. See clause B.3.

6 Modifications of the MAC layer

6.1 Hopset replaces references to RF carrier

For DECT in the ISM band the RF carriers of regular DECT equipment [2] are replaced by sequences of frequency hopping within the ISM band. Dynamic channel selection shall be made between these sequences, following the same procedures as regular DECT uses to make dynamic channel selection between the RF carriers.

Therefore, for the purpose of the present document, all references to "RF carrier" and "RF carrier number" in text and tables in the MAC layer (EN 300 175-3 [3]) shall be interpreted as "**hopset"** and "**hopset number"** respectively. This concerns for example clauses 7.2.3.2.8, 7.2.3.2.10 and 7.2.3.2.12 of EN 300 175-3 [3].

6.2 Hopset table

The frequency hopping is made on the 45 ISM band RF carriers (c_0 to c_{44}) defined in clause 5.1. Each hopset is pseudorandom with exactly one hop to each of the 45 carrier frequencies. The 10 hopsets with hopset numbers m from 0 to 9 are defined in table 1. A relative frame number i is used in the hop table. The formula for generating the hopsets is found in clause A.2.

Table 1: Mapping between hopsets and ISM band RF carrier number c

Frame	***Hopsets #m: 0 - 9 (corresponding to RF carriers # 0 -10 notations in the MAC)***									
# i	***0***	***1***	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***
0	0	4	8	12	16	20	24	28	32	36
1	4	8	12	16	20	24	28	32	36	40
2	8	12	16	20	24	28	32	36	40	44
3	12	16	20	24	28	32	36	40	44	3
4	16	20	24	28	32	36	40	44	3	7
5	20	24	28	32	36	40	44	3	7	11
6	24	28	32	36	40	44	3	7	11	15
7	28	32	36	40	44	3	7	11	15	19
8	32	36	40	44	3	7	11	15	19	23
9	36	40	44	3	7	11	15	19	23	27
10	40	44	3	7	11	15	19	23	27	31
11	44	3	7	11	15	19	23	27	31	35
12	3	7	11	15	19	23	27	31	35	39
13	7	11	15	19	23	27	31	35	39	43
14	11	15	19	23	27	31	35	39	43	2
15	15	19	23	27	31	35	39	43	2	6
16	19	23	27	31	35	39	43	2	6	10
17	23	27	31	35	39	43	2	6	10	14
18	27	31	35	39	43	2	6	10	14	18
19	31	35	39	43	2	6	10	14	18	22
20	35	39	43	2	6	10	14	18	22	26
21	39	43	2	6	10	14	18	22	26	30
22	43	2	6	10	14	18	22	26	30	34
23	2	6	10	14	18	22	26	30	34	38
24	6	10	14	18	22	26	30	34	38	42
25	10	14	18	22	26	30	34	38	42	1
26	14	18	22	26	30	34	38	42	1	5
27	18	22	26	30	34	38	42	1	5	9
28	22	26	30	34	38	42	1	5	9	13
29	26	30	34	38	42	1	5	9	13	17
30	30	34	38	42	1	5	9	13	17	21
31	34	38	42	1	5	9	13	17	21	25
32	38	42	1	5	9	13	17	21	25	29
33	42	1	5	9	13	17	21	25	29	33
34	1	5	9	13	17	21	25	29	33	37
35	5	9	13	17	21	25	29	33	37	41
36	9	13	17	21	25	29	33	37	41	0
37	13	17	21	25	29	33	37	41	0	4
38	17	21	25	29	33	37	41	0	4	8
39	21	25	29	33	37	41	0	4	8	12
40	25	29	33	37	41	0	4	8	12	16
41	29	33	37	41	0	4	8	12	16	20
42	33	37	41	0	4	8	12	16	20	24
43	37	41	0	4	8	12	16	20	24	28
44	41	0	4	8	12	16	20	24	28	32

6.3 Frame number counter for the hopset

A frame number counter for the hopset is introduced for generation of the physical layer hop sequence. It shall be increased by 1 (modulo 45) with every 10 ms frame.

6.4 Bearer hop sequence and Physical layer hop sequence

A pseudorandom bearer hop sequence is derived by cyclic repetition of a hopset from table 1 on one specific slot number of the DECT-ISM 10 ms frames.

Generally, several transmit bearers (slots) are active during a frame. In the case of full slots a transmitter interleaves up to 24 bearer hop sequences on the 10 ms frame basis. These 24 interleaved hop sequences correspond to the 24 bearers, one for each of the 24 slots of a 10 ms frame. An interleaved hop sequence is empty if the transmitter is inactive on the corresponding slot. These hop sequences are independently selected from the 10 defined pseudorandom bearer hop sequences, each meeting the FCC requirements. Which of the 10 hop sequences that is selected for each bearer is managed by the DECT dynamic channel selection procedure so that hopping on occupied channels is minimized.

The physical layer hop sequence consists of the above defined 24 interleaved bearer hop sequences, of which one or more are empty. Since every bearer hop sequence is pseudorandom, the physical layer hop sequence will have a higher degree of randomness than any of the original 10 bearer hop sequences. See annex A for formulas generating the hopset for the bearer hop sequences and the physical layer hop sequence.

A maximum of 15 of the 24 full-slot bearers are allowed to be active on average during any 30 second period. See clause B.2 for the corresponding FCC [10] requirement. This does not prevent transmission on more than 15 full-slots in a frame, as long as the average figure of 15 is not exceeded. See clause B.2.

6.5 RF carrier Q-channel message

The FP shall transmit the Q-message ($Q_H = 8$) indicating on which ISM band RF carrier, c, the message was transmitted. See annex C for the definition of the RF carrier Q-channel message ($Q_H = 8$).

This Q-message information shall be used in the PT to check if the PT is correctly synchronized with the base stations hopping pattern.

Once the Q-message ($Q_H = 8$) has been received and the static system info message ($Q_H = 0,1$) has also been received (from which the Carrier Number field can be used to determine the hopset number), the PT will be able to determine the relative hopset frame number (see clauses 6.2 and 6.3).

Annex A (informative): Formula used for generating the physical layer hop sequence

A.1 Definitions

$m = 0,1, \ldots 9$ is the hopset number and the corresponding bearer hop sequence number.

n is the DECT physical layer frame number.

$c(m)_n$ is the ISM band RF carrier number (see clause 5.1), of the ISM frequency that is used during frame n by a bearer hop sequence m consisting of cyclic repetition of hopset m.

A.2 Recursive formula generating the bearer hop sequences

The bearer hop sequence m (for any m, $m = 0, \ldots, 9$) is derived by:

$$c(m)_{n+1} = [c(0)_n + 4(m + 1)]_{\text{mod } 45}$$

By starting with $c(0)_0 = 0$ each column of table 1 will be generated by using a different hopset number m, where $m = 0, ..., 9$.

NOTE: A general formula for generating bearer hop sequences is:

$$c(m)_{n+1} = [c(0)_n + L(m + 1)]_{\text{mod } P}, \text{ where } m = 0, 1, 2, \ldots M-1$$

where: M is the number of bearer hop sequences;

P is the number of ISM band RF carriers.

To meet the requirement that a hop sequence of length P hops on each of the P frequencies exactly once, *L and P must not contain common factors*.

To keep constant frequency offset between any two bearer hop sequences at any time, M x L has to be less than or equal to P. Together with the requirement that L and P must not contain common factors, this gives the requirement: $M \times L < P$.

A.3 Formula generating the physical layer hop sequence

The physical layer hop sequence consists of a cyclic repetition of the sequence S0, S1, …S44 consisting of 45 sequences (one per 10 ms frame) Si, $i = 0, \ldots, 44$.

i is the same relative frame number as being used in clause 6.2.

Si is the sequence $c(m_0)_i, c(m_1)_i, \ldots\ldots, c(m_{K-1})_i$, corresponding to the K slot positions within frame i.

$c(m_j)_i$ is empty when no transmit bearer is active on slot number j.

The slot positions and the number of slots in a frame generally depend on the instant composition of slot types within the frame. If only full slots are used, which is common, K = 24.

The bearer hop sequence numbers m_j are selected mutually independent by the DECT dynamic channel selection procedure, and can have the values 0 to 9 corresponding to the 10 basic hopsets.

NOTE: The DECT dynamic channel selection procedure selects traffic bearers for a connection as pairs of simplex bearers (duplex bearers or double simplex bearers). Each pair uses slot positions separated by 5 ms and the two simplex bearers use the same hop-set.

Annex B (informative): Explanation of FCC requirements

B.1 Transmitter RF power level and coverage ranges

DECT-ISM has lower coverage range than DECT.

Table B.1 indicates the different power levels for DECT and for 2,4 GHz applications.

Table B.1

Equipment type	Total power	Antenna gain	EIRP	Typical handset EIRP
DECT	24 dBm (250 mW)	12 dBi	36 dBm	24 dBm
FCC [10]	21 dBm (125 mW)	6 dBi	27 dBm	21 dBm
EN 300 328 [9] FHSS	-	-	20 dBm	20 dBm
DECT_ISM	-	-	20 dBm	20 dBm

The transmitter power is typically 4 dB higher for DECT, but could be up to 16 dB higher for DECT using 12 dBi antennas. Furthermore, the ISM band requirement for frequency hopping has made the standard DECT FP switched antenna diversity inefficient. Typical DECT-ISM link budget could be 10 dB lower than for DECT (2 dB loss due to higher frequency band, 4 dB lower transmitter power and at least 4 dB diversity loss).

The link budget can be improved by implementing "Prolonged preamble diversity" (see EN 300 175-3 [3], clause 7.2.5.5.1) in the RFPs. The up-link will experience speed independent full diversity gain. Also the downlink will benefit, since the 7 MHz hop between estimate and execution normally is small compared to the coherence bandwidth.

B.2 Requirements on the pseudorandom hop sequences

FCC Part 15.247 [a] (1) (iii) [10] states:

- Frequency hopping systems in the 2 400 - 2 483,5 MHz band may utilize hopping channels whose 20 dB bandwidth is greater than 1 MHz provided the systems use at least 15 non-overlapping channels. The total span of hopping channels shall be at least 75 MHz. The average time of occupancy on any frequency shall not be greater than 0,4 s within a 30 second period.

Thus the minimum number of ISM carriers in the hop sequence is 15.

The maximum number is 47 with the defined 1,728 MHz DECT channel spacing. A lower maximum number may be preferred to ease meeting the out of band emission limits. On the other hand, it is required to span at least 75 MHz, which requires 44 channels (carriers) or more.

There is also a requirement to load all hop frequencies equally and not to load any frequency longer than 0,4 s within a 30 second interval. This corresponds to loading each frequency on average 1/75 of the time. This requirement gives a wish to have as many hopping frequencies as possible, in order to allow as many simultaneous (per frame) transmit bearers (active time slots) as possible.

If we define the number of hop carriers as P. Then, due to the DECT slot structure and guard bands, the above rule implies that the maximum number of simultaneously transmitted full-slots, #FSmax, is P/3. (One slot including ramp-up is typically 435 bits long providing an average load of 435/11 520 = 0,038. Thus #FSmax < P / (75 x 0,038) = 0,35 x P. For P = 45, #FSmax has to be < 15,75). Thus the defined 45 carriers allow for 15 full slots continuously transmitted in any direction e.g. for a residential multi-bearer connection. The temporary number of full-slot bearers may exceed 15 as long as the average number does not exceed 15,75 during a 30 second period.

In order to create a pseudorandom sequence in which every frequency will be passed exactly once in P hops, the number of carriers, P, must not have common factors with the value 4 (see the recursive formula in clause A.2). Therefore P was chosen to be 45, which has no common factors with 4. The maximum number 47 would not provide enough guardband at the ISM band edges, assuming 1,728 MHz carrier spacing. See clause B.3.

With this background, the hopsets in clause 6.2 and annex A were defined. But any one of these hopsets will compose the physical layer hop sequence only if only a single bearer (one slot) is active for a transmitter. Generally, several transmit bearers (slots) are active during a frame. In the case of full-slots a DECT transmitter interleaves up to 24 hopsets on a 10 ms basis. These hopsets are selected mutually independent by the DECT dynamic channel selection procedures, clause 11.4 in EN 300 175-3 [3].

B.3 Spurious and out-of-band emissions

For spurious and out of band emissions FCC Part 15.247 [c] only requires 20 dB attenuation related to maximum in-band power as measured over 100 kHz, but in restricted bands Part 15.209 limits apply. The Part 15 15.209 limit is 500 µV/m at 3 m distance, corresponding to -41 dBm. Restricted bands are below 2 390 MHz and above 2 483,45 MHz. See Part 15.205. Part 15.35 states that these emissions shall be measured averaged over 0,1 s over 1 MHz bandwidth or more. Thus if up to 15 of 24 slots are active, the average power will be 2 dB below the power level of a slot. Thus the -41 dBm will correspond to a "Maximum power level" of the emissions due to modulation in clause 5.5.1 of EN 300 175-2 [2] of -43 dBm or 50 nW.

The low band edge ISM carrier c_0 is at 2 403,648 MHz, and the upper band edge ISM carrier c_{44} is at 2 479,680 MHz. Thus the spacing between the edge carriers and the middle of the 1 MHz receive band just outside the band is: 4,148 MHz at the lower edge and 4,320 MHz at the upper edge.

Conformance to the emissions due to modulation in clause 5.5.1 of EN 300 175-2 [2] will meet FCC out of band requirements below the ISM band, since the restricted band start 10 MHz below the band edge. Clause 5.5.1 of EN 300 175-2 [2] requires 40 nW.

To meet FCC out of band requirements above the ISM band, conformance to the emissions due to modulation in clause 5.5.1 of EN 300 175-2 [2] has to be improved by about 7 dB to 8 dB, given the spacing of 4,3 MHz between carrier c_{44} and the middle of the 1 MHz receive band just outside the ISM band. This requirement is realistic (average measurements) for typical implementations.

NOTE: Part 15.247 [b] (1) and (3) states that the maximum power during a slot is 125 mW for less than 75 hopping frequencies. DECT is due to its bandwidth forced to have less than 75 hop frequencies. Up to 6 dB antenna gain is allowed.

B.4 Procedures for idle lock and channel selection

Due to the construction of the hopsets in clause 6.2, for any time instant the frequency offset between any two hopsets is constant. Therefore, least interfering "channel" lists can be built on a single instant RSSI measurement per "channel". A physical "channel" is for the ISM band a time slot/hopset combination (while for regular DECT a physical channel is a time slot/carrier combination). This feature of constant distance between two hopsets is only maintained for up to 11 hopsets. (If the number of carriers was changed to 43 and the digit 4 in the formula clause A.2 was changed to 3, then up to 17 carriers with constant distance between two hopsets could be designed. See clause A.3.)

To go into idle locked state, it is sufficient to listen on an arbitrary carrier frequency c, and when a first transmission is received, increase c by 4 every frame to stay locked on the actual hopset in order to receive full information to enter idle locked state. A first transmission will always be received within 450 ms (45 frames).

To avoid PTs achieving idle lock on transmissions received on any of the adjacent receiver channels, the FP transmits the Q-message ($Q_H = 8$) indicating on which ISM band RF carrier, c, the message was transmitted. Once the above message ($Q_H = 8$) has been received and the static system info message ($Q_H = 0,1$) has also been received (from which the Carrier Number field can be used to determine the hopset number), the PT will be able to determine the relative hopset frame number (see clauses 6.2 and 6.3).

The DECT MAC layer procedures for RFP primary scanning, RSSI measurement scanning and generation of least interfered channel lists can be kept unchanged for DECT-ISM, because the difference is only in the physical layer. The actual bearer frequency does in DECT directly correspond to the MAC RF carrier notation, but for DECT-ISM the bearer frequency is also frame number dependent. It is derived from the MAC hopset (= the DECT RF carrier) notation **and** the frame number. But the frame number dependency is a sub routine that can be performed in the physical layer independently from these MAC layer processes.

Annex C (normative): RF carrier Q-channel message, Q_H = 8 (hex)

C.1 General

This clause replaces clause 7.2.3.1 of the base standard EN 300 175-2 [2].

The multiframe marker is transmitted once every 16 frames. This marker is combined with the tail code for system information (Q). Q-channel information is therefore only transmitted by RFPs once every multiframe.

The basic format of the Q-field is to have a 4 bit header (the QH field) followed by a 36 bit information field. See figure C.1.

header Q_H	system information
a_8 - a_{11}	a_{12} … a_{47}

Figure C.1: System Information field

The QH field is used to identify 16 different system information fields. Any one of these fields can be transmitted in each multiframe. Some of these fields need never be transmitted. PTs are required to understand some of these fields. There is a maximum time interval between transmissions of mandatory fields. The exact sequencing of different Q fields by an RFP is not defined.

Table C.1

Q_H	SYSTEM INFORMATION	MAN	FREQ
000X	static system info	Yes	8
0010	extended RF carriers	note 1	8
0011	fixed part capabilities	Yes	8
0100	extended fixed part capabilities	note 2	8
0101	SARI list contents	No	4
0110	multi-frame number	note 3	8
0111	escape	No	-
1000	RF carrier	note 4	8
1001 to 1111	Reserved		

MAN = Mandatory transmission (Yes/No).

FREQ = Maximum repeat interval in multiframes, if implemented.

NOTE 1: If an extended frequency allocation is used this message shall be transmitted in the multiframe following every transmission of the static system information.

NOTE 2: If extended fixed part capabilities information is available this message shall be transmitted in the multiframe following every transmission of the fixed part capabilities information.

NOTE 3: If an RFP implements encryption then this message shall be transmitted at least once every 8 multiframes.

NOTE 4: If an RFP is operating in the ISM band then this message shall be transmitted at least once every 8 multiframes.

C.2 RF carrier

If the fixed part is operating in accordance with TS DECT in the ISM band then it shall transmit this message at least once every 8 multiframes. All PTs operating in accordance with TS DECT in the ISM Band shall be able to understand this message.

Q_H 1 0 0 0	0 spr	RF carrier number	0 spr	Number of hop sets
a_8 a_{11}	a_{12} a_{15}	a_{16} a_{23}	a_{24} a_{41}	a_{42} a_{47}

Figure C.2: RF carrier

Bits a_{16} - a_{23} are used to inform the PT on which RF carrier frequency this Q-message is transmitted. See clause B.4.

C.2.1 RF carrier number

This defines the frequency of the RF carrier (clause 5.1) of this transmission. See table C.2.

Table C.2: RF carrier number

bits								meaning	
a_{16}	a_{17}	a_{18}	a_{19}	a_{20}	a_{21}	a_{22}	a_{23}	c (clause 5.1)	f/MHz
0	0	1	0	1	1	1	0	0	2 403,648
0	0	1	0	1	1	1	1	1	2 405,376
0	0	1	1	0	0	0	0	2	2 407,104
.... etc.								...	...
0	1	0	1	1	0	1	0	44	2 479,680

Other field values are reserved.

The frequency of a DECT RF carrier can be calculated according to the formula:

$$F = (1\,881\,792 + k \times 1\,728)\ \text{kHz}$$

The value in the fields a_{16} - a_{23} corresponds to (k mod 256).

C.2.2 Number of hopsets

Bits a_{42} - a_{47} give the total number of hopsets that the RFP scans in a regular sequence. Bit a_{47} is the least significant bit.

Annex D (informative): Means to improve DECT-ISM resistance to local interference from other technologies

D.1 Introduction

A major difference between DECT-ISM and DECT is that DECT-ISM is applied on the non-protected ISM spectrum, while DECT is applied on a spectrum exclusive for DECT. DECT-ISM will provide coexistence and high quality of service in an environment of unco-ordinated DECT-ISM systems. However the ISM band allows for unco-ordinated usage of a variety of incompatible communication devices and also industrial, scientific and medical devices. Therefore high quality of service will not be guaranteed when other types of devices (non-DECT-ISM devices) are used in the same local area. This applies especially to speech and video services, but is not critical for packet data services where non-time-critical retransmissions are applied. DECT-ISM shares this inability to guarantee the quality of service with other technologies used for communication devices applied in the 2,4 GHz ISM band. Measures may however be taken to improve the resistance of DECT-ISM to the potential interference from other devices.

The most common sources of potential interference are characterized below:

A) **Industrial, scientific and medical devices.**

These devices are normally not portable. You have them, or you do not have them within the premises. The most common device is probably the microwave oven. Such devices are not in constant operation. When they operate, they often use an on/off modulated continuous carrier. During the on states, the continuous carrier drifts over an undefined but sometimes very large part of the ISM band.

B) **Communication devices using frequency hopping, FHSS.**

Infrastructure for another 2,4 GHz communication system should not be installed in the premises. There are however nomadic devices for personal networking and it could be hard to prevent them to be used. The most common device will probably be Bluetooth based cord replacement accessories to mobile phones and PCs. Such devices are not in constant operation. When they operate, they hop over the entire ISM spectrum with up to 5 MHz bandwidth bursts (1 MHz for Bluetooth). The DECT-ISM frame error rate could become up to 1 % to 2 % when interfered by a Bluetooth piconet (in practice less) and up to 5 % to 10 % for 5 MHz devices.

C) **Communication devices using direct sequence spread spectrum, DSSS.**

Infrastructure for another 2,4 GHz communication system should not be installed in the premises. There are however nomadic devices for personal networking and it could be hard them to prevent to be used. The most common technology will probably be IEEE 802.11b. It could be PCMCIA cards for networking between PC laptops. It could also be cord replacement accessories to desktop PCs, or even a local WLAN already in place before installing the DECT_ISM system. The IEEE 802.11b DSSS standard provides up to 11 Mbit/s and occupies a bandwidth of about 17 MHz. This 17 MHz carrier can be selected at specific frequencies over the whole ISM band. An access port and the associated communications normally use a fixed position for the carrier. The DECT-ISM frame error rate could become up to 20 % when interfered by an IEEE 802.11b device (in practice less).

D.2 Procedures for handling interference

As seen the above examples, it will not help if DECT-ISM could avoid hopping at part spectrum, because a frequency hopping interferer hops over the entire spectrum.

Therefore, the basic procedure to improve the DECT-ISM robustness for e.g. speech and video services, if errors are detected, is to set up a second duplex bearer with identical content, but using different hop sequences separated by 4, 5, 6 or 7 hop sequences. The receiver end should for each slot use the content of the bearer with the best quality. Separation by 4 hop sequences provides an instant ISM RF carrier separation of 16 carriers corresponding to 26,7 MHz. Thus transmissions within a 20 MHz band will be attenuated at least 40 dB. This guarantees that for example an 802.11 DSSS transmission cannot interfere with both bearers at the same time.

A DECT speech connection can from a quality aspect accept up to 1 % to 2 % frame errors. Having uncorrelated duplicated bearers as proposed will reduce interference of an FHSS 5 MHz transmission from up to 10 % to maximum 1 %. Using duplicated bearers as proposed, will also give a diversity gain.

The practical way to implement duplicated bearers is to base the procedure on the standard DECT seamless intra-cell handover for the minimum delay speech service.

Typical implementations of DECT intracell handover procedures are optimized for interference from other DECT transmissions supporting the DECT Dynamic Channel Selection procedures. A DECT-ISM interferer will interfere on consecutive frames. Therefore a typical handover trigger criteria could be detection of errors in 3 consecutive frames (40 ms). Non-DECT interferers produce a more random interference pattern. Therefore a second handover criterion has to be added, e.g. errors in 4 frames during one second and errors in 6 frames during 2 s.

Errors in 3 consecutive frames should result in a normal handover, releasing the old bearer as soon as the new has been established, because this indicates a DECT-ISM interferer.

The other handover criteria using error integration over 1 s or 2 s should follow a slightly different procedure as indicated below.

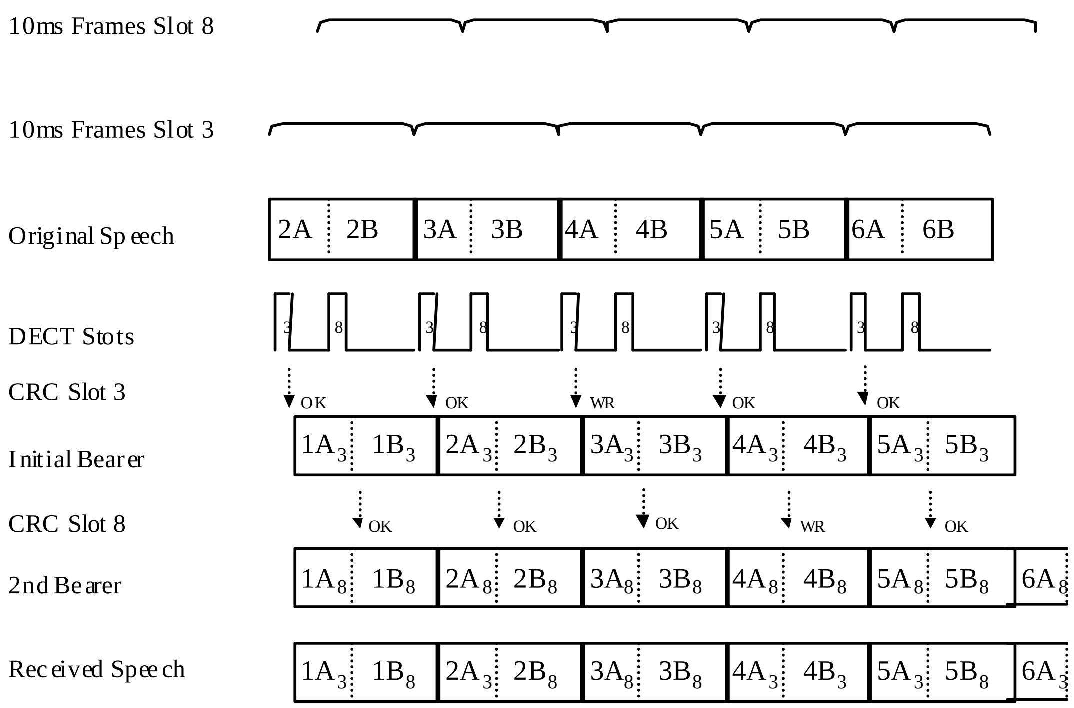

Figure 1: U plane data switching procedure

As seen in the figure 1 each receiving end will have two parallel flows with the same content, one flow from each of the two bearers. The main difference to the handover procedure is that both bearers are kept in parallel and the flow to the codec in switched between the two flows depending on whether there are errors or not in each received packet. The switching criteria is simple:

Each time a correct packet on any of the two flows is received, the codec input is seamlessly switched to this flow.

The resulting flow can be treated with traditional muting and/or frame repetition procedures to optimize the subjective speech perception.

Both bearers should be kept, either until the end of the connection, or if one of the bearers is error free, the other can be released. Error free in this context means e.g. no frame errors during 2 s. But since we regard a duplex bearer, this implies that the release decision has to be based on information that the bearer is error free in both directions during e.g. 2 s. This information is retrievable both at the RFP (PP Q-bit antenna switch commands) and at the PP (RFP Q-bit error indication). Thus the standard intracell handover release messages can be used for release also in this case. The RFP and the PP does not have to have exactly identical handover criteria in RFP and PPs to provide interoperability.

NOTE 1: Duplex bearer set up for speech services in line with the above procedures should be standardized for the next revision of the present document.

NOTE 2: For the case there is a WLAN 802.11 DSSS installation that we also want to protect from DECT-ISM interference, it is possible to remove 16 ISM RF carriers covering the part of the ISM band used by the WLAN. This implies that only P = 29 ISM RF carriers remain. This limits the number of hop sequences to M = 9, with RF carrier separation L = 3 instead of 4. The duplicated bearer procedure should still be used, but could have less restriction on hop sequence separation, since the broadband DSSS interference has been avoided by never using 16 of the RF carriers. A problem with this concept is that the RFPs and PPs have to be pre-programmed before registration with information on which carriers have been barred. The reduction to 29 ISM RF carriers reduces the average number of active transmit slots per frame during a 30 second period from 15 to 10. This option to bar the use of 16 channels is not recommended for standardization, since it imposes many limitations and difficulties from an interoperability point of view.

History

Document history		
V1.1.1	April 2001	Publication