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Technical Report

Digital Enhanced Cordless Telecommunications (DECT); DECT properties and radio parameters relevant for studies on compatibility with cellular technologies operating on frequency blocks adjacent to the DECT frequency band

Reference

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Contents

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Foreword

This Technical Report (TR) has been produced by ETSI Technical Committee Digital Enhanced Cordless Telecommunications (DECT).

Introduction

CEPT/ECC regularly facilitates studies on compatibility between new cellular technologies and existing technologies on adjacent bands, including DECT. Only during 2010 three such study reports including DECT were finalized and approved.

Among DECT manufacturers the type of knowledge on DECT that is required for the CEPT/ECC compatibility studies is scarce, and DECT manufacturers do normally not participate in these study groups.

The aim of the present document is to provide an up to date reference on DECT system properties and radio parameters and how these correctly should be applied in compatibility studies. The present document can be used as a reference document for future CEPT/ECC compatibility study projects involving DECT. It provides a means for educating regulators and engineers in the European context and is also useful for discussions on compatibility issues with non-European regulators.

Public DECT WLL systems are only dealt with to clarify the important distinction of the installation and radio environment between DECT WLL systems and private residential and enterprise systems.

1 Scope

The aim of the present document is to provide a reference on DECT system properties and radio parameters for usage in compatibility studies in CEPT/ECC. The document provides examples for compatibility studies throughout various annexes. The present document concentrates on private license exempted residential and enterprise (short range) systems.

2 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 reference document (including any amendments) applies.

Referenced documents which are not found to be publicly available in the expected location might be found at http://docbox.etsi.org/Reference.

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2.1 Normative references

The following referenced documents are necessary for the application of the present document.

Not applicable.

2.2 Informative references

The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

[i.1] ETSI EN 301 406: "Digital Enhanced Cordless Telecommunications (DECT); Harmonized EN for Digital Enhanced Cordless Telecommunications (DECT) covering the essential requirements under article 3.2 of the R&TTE Directive; Generic radio".

[i.2] ERC/DEC(94)03: "ERC Decision of 24th October 1994 on the frequency band to be designated for the coordinated introduction of the Digital European Cordless Telecommunications system (ERC/DEC/(94)03)".

[i.3] ERC/DEC(98)22: "ERC Decision of 23 November 1998 on Exemption from Individual Licensing of DECT equipment, except fixed parts which provide for public access (ERC/DEC/(98)22) - Corrected 30 march 2007".

[i.4] ERC Report 31 (June 1994): on "Compatibility between DECT and DCS1800".

[i.5] ERC Report 100 (February 2000): "Compatibility between certain radio communications systems operating in adjacent bands, evaluation of DECT / GSM 1800 compatibility".

[i.6] ECC Report 96 (March 2007): "Compatibility between UMTS 900/1800 and systems operating in adjacent bands".

[i.7] ECC Report 146 (June 2010): "Compatibility between GSM MCBTS and other services (TRR, RSBN/PRMG, HC-SDMA, GSM-R, DME, MIDS, DECT) operating in the 900 and 1800 MHz frequency bands".

[i.8] CEPT Report 41 (November 2010): " Compatibility between LTE and WiMAX operating within the bands 880-915 MHz / 925-960 MHz and 1710-1785 MHz / 1805-1880 MHz (900/1800 MHz bands) and systems operating in adjacent bands".

[i.9] ERC Report 65 (November 1999): "Adjacent band compatibility between UMTS and other services in the 2 GHz BAND.

[i.10] CEPT Report 39 (June 2010): "Report from CEPT to the European Commission in response to the Mandate to develop least restrictive technical conditions for 2 GHz bands".

[i.11] Void.

[i.12] ETSI EN 300 175-2: "Digital Enhanced Cordless Telecommunications (DECT); Common Interface (CI); Part 2: Physical Layer (PHL)".

[i.13] ETSI TS 125 105: "Universal Mobile Telecommunications System (UMTS); Base Station (BS) radio transmission and reception (TDD) (3GPP TS 25.105)".

[i.14] ETSI TS 125 102: "Universal Mobile Telecommunications System (UMTS); User Equipment (UE) radio transmission and reception (TDD) (3GPP TS 25.102)".

[i.15] ETSI TS 136 101: "LTE; Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio transmission and reception (3GPP TS 36.101)".

[i.16] ETSI TS 136 104: "LTE; Evolved Universal Terrestrial Radio Access (E-UTRA); Base Station (BS) radio transmission and reception (3GPP TS 36.104)".

[i.17] ECC PT1(09)164: "EC Mandate to CEPT on the 900/1800 MHz bands, WiMAX Forum® Response".

[i.18] CEPT Report 19: "Report from CEPT to the European Commission in response to the Mandate to develop least restrictive technical conditions for frequency bands addressed in the context of WAPECS".

[i.19] IEEE VTC Fall 2000 Boston: "Simple and Accurate Path Loss Modeling at 5 GHz in Indoor Environments with Corridors", Jonas Medebo, Jan-Erik Berg, Ericsson Radio Systems AB.

[i.20] Directive 1999/5/EC of the European Parliament and of the Council of 9 March 1999 on radio equipment and telecommunications terminal equipment and the mutual recognition of their conformity (R&TTE Directive).

[i.21] ETSI TR 101 310: "Digital Enhanced Cordless Telecommunications (DECT); Traffic capacity and spectrum requirements for multi-system and multi-service DECT applications co-existing in a common frequency band".

[i.22] ETSI TR 101 178: "Digital Enhanced Cordless Telecommunications (DECT); A high level guide to the DECT standardization".

[i.23] ECC Report 131: "Derivation of a Block Edge Mask (BEM) for terminal stations in the 2.6 GHz frequency band (2500-2690 MHz)".

[i.24] ETSI EN 300 175-3: "Digital Enhanced Cordless Telecommunications (DECT); Common Interface (CI); Part 3: Medium Access Control (MAC) layer".

[i.25] ETSI EN 300 175 (Parts 1 to 8): "Digital Enhanced Cordless Telecommunications (DECT); Common Interface (CI)".

3 Abbreviations

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

ACIR Adjacent Channel Interference Ratio
ACLR Adjacent Channel Leakage Ratio
ACRL Adjacent Channel Leakage Power Ratio
ACS Adjacent Channel Selectivity
BCCH Broadcasting Channel
BER Bit Error Rate
BS Base Station

BTS	Base Transceiver Station
CAT-iq	Cordless Advanced Technology - internet and quality
CDMA	Code Division Multiple Access
CE	Commission Europeans
CEPT	European Conference of Postal and Telecommunications Administrations
CI	Common Interface (standard)
CS-CS	Circuit Switched - Circuit Switched
CTA	Cordless Terminal Adaptor
DECT	Digital Enhanced Cordless Telecommunications
DL	Downlink
DL/UL	Downlink/Uplink
DME	Distance Measuring Equipment
EC	European Commission
ECC	Electronic Communications Committee
ECN	Electronic Communications Network
EIRP	Effective Isotropically Radiated Power
ERC	European Radiocommunications Committee
ETSI	European Telecommunications Standards Institute
E-UTRA	Evolved UTRA
F_C	Frequency of Carrier
FDD	Frequency Domain Duplexing
F_L	Frequency of Low band edge
F_U	Frequency of Upper band edge
FX	Frequency X
GOS	Grade of Service
GSM	Global System for Mobile communications
GSM	Global System for Mobile communications
GSM-R	GSM for Railways
HD	High Definition
ICS	Implementation Conformance Statements
iDCS	Instant Dynamic Channel Selection
IF	Intermediate Frequency
IP	Internet Protocol
ISDN	Integrated Services Digital Network
ISM	Industrial Scientific and Medical (frequency band)
IT	Information Technology
LIC	Least Interferred Channel
LOS	Line of Sight
LTE	Long Term Evolution
MCBTS	Multi Carrier Base Transceiver Station
MIDS	Multifunctional Information Distribution System
MS	Mobile Station
NLOS	Non Line of Sight
NTP	Nominal Terminal Power
OEM	Original Equipment Manufacturer
OOB	Out of Band
OOBE	Out of Band Emission
PBX	Private Branch Exchange
PP	Portable Part
PS-PS	Portable Station - Portable Station
PSTN	Public Switched Telephone Network
PTS	Profile Test Specifications
R&TTE	Radio equipment and Telecommunications Terminal Equipment
RF	Radio Frequency
RFP	Radio Fixed Part
RSSI	Received Signal Strength Indication
RX	Radio Reveiver
TCAM	Telecommunication Conformity Assessment and Market Surveillance Committee
TCL	Test Case Libraries
TDD	Time Domain Duplexing
TDMA	Time Division Multiple Access
TRR	Tactical Radio Relay

T_{SD}	Time of Slot length of Dect
TTE	Telecom Terminal Equipment
TX	Transmitter
UE	User Equipment
UL	Uplink
ULE	Ultra Low Energy
UMTS	Universal Mobile Telecommunications System
UTRA	Universal Terrestrial Radio Access
WAPECS	Wireless Access Policy for Electronic Communication Services
WiMAX	Worldwide Interoperability for Microwave Access
WLAN	Wireless Local Area Network
WLL	Wireless Local Loop

4 DECT services, applications and market size

DECT is a general radio access technology for wireless telecommunications. DECT is not a network like e.g. GSM, but can, as a general access technology, provide wireless access to principally any public or local network.

DECT contains a comprehensive set of protocols, which provide the flexibility to interwork between numerous different applications and networks, including PSTN/ISDN, GSM, UMTS and IP networks. DECT is also used for different kinds of intercom systems and numerous reliable remote control applications as e.g. for cranes in work shops or on trucks, forestry machines etc., and supervision applications like production control /alarms, nurse call systems, etc. [i.22].

One of the aims for the DECT standardization was to provide a quality and reliability that matches the PSTN/ISDN networks, even in their densest traffic environments. DECT meets these demands on the current spectrum by providing up to 0,2 E/20m^2/floor, equivalent to 10 000 E/km^2/floor [i.21]. The basic principles are results of very creative thinking, and the parameter settings are based on literally years of advanced simulations.

DECT is a high capacity digital technology, for cell radii ranging from a few meters to several kilometres, depending on application and environment.

The mandatory instant Dynamic Channel Selection (iDCS) messages and procedures provide effective co-existence of uncoordinated private and public systems on the common designated DECT frequency band and avoid any need for traditional frequency planning.

It provides telephony as well as HD quality voice services, and a broad range of data services, including Integrated Services Digital Network (ISDN) and packet data over the Internet.

It can be effectively implemented in a range from simple residential cordless telephones up to large multi-cell systems providing a wide range of telecommunications services.

For a comprehensive detailed overview of the DECT services and applications see [i.22]. New developments, not included in [i.22], are the DECT-NG profiles, especially designed for feature-rich wideband voice services connected to broadband wirelines, and the Ultra Low Energy (ULE) profile, especially designed for home automation.

The present document concentrates on private residential and enterprise systems.

4.1 DECT market size

The DECT technology and services have since many years been deployed worldwide in about 100 countries.

The applications are: Residential cordless telephones and home automation, Enterprise (multi-cell) local mobility systems, Public Wireless Local Loop (WLL) systems and Public Pedestrian mobility systems, etc.

The main market in Europe is residential and office/enterprise applications. The Public DECT systems exist in a few places in Eastern Europe, and the market is very small or rather non-existing.

To encourage new entrants, new applications, investments and innovation ETSI TC DECT has developed a large number (around 130) of support documents. These documents contain base standards, profile standards, technical application reports and test documents as Test Case Libraries (TCL), Profile Test Specifications (PTS) and Profile Implementation Conformance Statements (ICS).

Furthermore, cost effective programmable one chip solutions are available from different general suppliers. Protocol stacks and complete OEM modules are also available from different vendors.

The best evidence that the market mechanism works very well in the case of DECT is the large number of vendors of DECT equipment (about 80 worldwide) and that the DECT market keeps on expanding.

The market size information given below is taken from MZA Telecom & IT Analysts (http://www.mzaconsultants.com/): "DECT Market Update" DECT World & CAT-iq 2011 Conference, 26-27 January, Amsterdam.

In the year 2010 the value of the world DECT residential end user market was 4,3 Billion US$, which corresponds to 82 % of the total residential cordless world end user market. Corresponding figures for the DECT enterprise wireless PBX / IP PBX systems are 0,6 Billion US $ and 65 %. The DECT market share increases each year.

In the year 2010 the number of added DECT units was:

- Residential systems: 118 M handsets and 76 M base stations.
- Enterprise systems: 1,3 M (professional) handsets and 0,4 M base stations.

Base stations and handsets have the same maximum peak transmit power of 250 mW. The total number of added transmitters in year 2010 was 196 M. The majority are sold in Europe.

DECT is a mass market technology with several 100 million units in operation Europe in the band 1 880 - 1 900 MHz.

4.2 Basic quality characteristics of the DECT systems

The basic DECT service is a 3,1 kHz telephony service conveyed over a DECT link. With recent new developments such as DECT-NG, DECT now also offers wideband 7 kHz voice transmission and a super-wideband 14 kHz service and different data services.

In many residents and enterprises DECT is the main phone providing the telephony service. This DECT telephony service should provide a Grade-Of-Service (GOS) and a speech quality comparable to a wired PSTN phone. This implies a GOS < 1 %, typically 0,1 %. The quality requirement on the DECT radio link is < 0,1 % bit error rate, corresponding to < 1 % slot error rate.

4.2.1 The blocking requirement or Grade of Service

Regarding the Grade of Service (GOS) requirement of < 1 %, dense traffic enterprise applications may locally utilize up to the entire DECT spectrum, while one residential system normally only occupies a small fraction of the DECT spectrum. This information is important when judging how large part of the DECT spectrum could be allowed to be interfered by a cellular system. Capacity simulations are found in annex A of [i.21].

4.2.2 The link quality requirement

For a speech service the bit error rate on the DECT radio link should be < 0,1 %, corresponding to < 1 % slot error rate. Thus a specific DECT access channel should be regarded blocked (not usable) if the slot error rate is > 1 %. Only error detection, but not error correction has been applied to the speech user data of the radio channel.

Therefore a partial interference of a DECT slot is a blocked (or lost) slot. Furthermore, the < 1 % slot error rate implies that random intermittent interference with > 1 % duty cycle will block all slots on an interfered DECT carrier frequency. This conclusion is further explained in clause 6.2.2.

This information is essential to understand which kind of intermittent interference that blocks a DECT carrier, and to understand how different time domain properties of cellular technologies influence the ability of DECT to detect and successfully escape interference.

4.3 Residential systems (single cell)

The DECT residential systems are single cell systems, covering a flat or a villa including its basement, main floor, upper floor and garden (medium size). Since the DECT system normally provides the main telephony service of the home, it is very essential that good coverage is provided everywhere within the premises of the home.

DECT handsets have very small integral antennas. On account of the small size and interaction with other parts of the handset, the antenna pattern will not be circular but normally rather irregular. This irregularity may correspond to up to 1 or 2 dBi antenna gain in a specific direction.

Residential DECT base stations are not provided with specific antenna directivity, because both upper floor and the basement is supposed to be covered, and it is unknown where or how the customer will place his base station (see figure 1).

A residential base station is small and has small integral antennas, and acts normally also as a handset charger. On account of the small size and interaction with other parts of the transmitter and the charger, the antenna pattern will not be circular but normally rather irregular. The base station has two antennas for diversity purpose. They may use different polarization or use space diversity. This irregular pattern of an antenna may correspond to up to 2 or maximum 3 dBi antenna gain in a specific direction, because the antenna parts are somewhat larger than in a handset.

NOTE: The EIRP notation would with the above example of 2 dBi antenna gain, cause a 2 dB loss in total power, which will cause a link budget loss of 2 dB corresponding to a 20 % reduction of coverage area for a cellular system (propagation decay index 4) and 26 % (decay index 3) for DECT. 1 dB corresponds to 11 % and 14 % respectively.

4.4 Enterprise systems (multi-cell)

DECT enterprise systems provide on-premises local mobility and full coverage through seamless handover between pico-cell base stations. The services offered are the wireless PBX telephony service and different low and medium rate data services for supervision, control, maintenance and alarms. The DECT local mobility pico-cell system is preferred when the cellular service is unable to provide the required quality, coverage, services or required integration with local key administrative and production systems. A typical example is mission critical wireless services in hospitals.

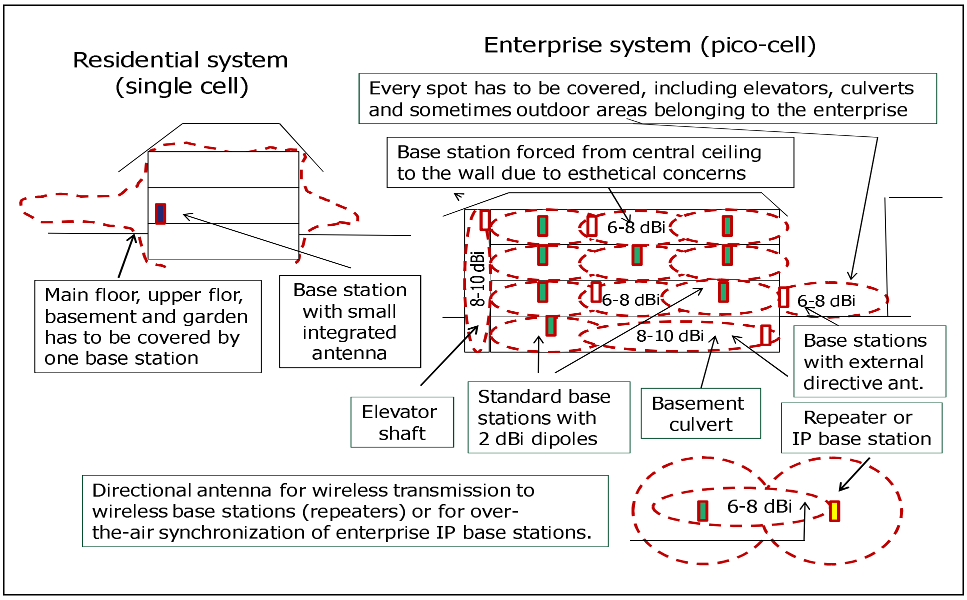


Figure 1: DECT cells in residential and enterprise systems

The enterprise handsets have the same antennas as the residential handsets. The enterprise base stations are mounted on walls or in the ceiling. They are normally equipped with two integrated half-wave dipole antennas. Enterprise base stations are larger and the antenna space is less encumbered than for residential base stations, thus they have 2 dBi antenna gain in the horizontal plane, typical for a half-wave dipole (see figure 1).

4.4.1 High gain antennas of DECT enterprise systems

About 5 % of the enterprise base stations have external antennas with 6 - 12 dBi antenna gain. This corresponds to 0,026 % of all DECT base stations, and 0,01 % of all DECT transmitters. These base stations are rare, but very important for meeting the requirements for coverage, cable access points and esthetical concerns. Figure 1 shows important examples where antenna gains of typically 6 - 8 dBi are required: covering an elevator shaft, a base station forced from the central ceiling to the wall due to esthetical concerns and cases where transmission cables or power outlets are not generally available. Besides, the wireless base stations (selective repeaters) and wireless synchronization links for IP base stations also benefit from use of 6 - 8 dBi directional antennas, sometimes as an outdoor base station to provide a wireless synchronization link to the bases in an adjacent building.

4.5 Distinction between deployment of DECT public WLL systems and private residential/enterprise systems

Public DECT WLL systems require line-of-sight between a base station site and the subscriber units due to the lack of equalizers. Therefore the DECT WLL systems are typically installed above roof-top. This implies that the DECT WLL base stations also are in line-of-sight (LOS) of cellular base stations, and existing CEPT/ECC studies show that coordination with adjacent band cellular system installations is needed. Furthermore, a DECT WLL base station site consists of 6-8 sectors with one or two 24 dBm base stations in each. The antenna gain can be up to 12 dBi. Therefore a DECT WLL site may provide a circular coverage pattern in the horizontal plane of 36 dBm EIRP, and a total emitted power of 6-16 base stations with 250 mW each.

The DECT private residential and enterprise systems install base stations indoors, and the few that are installed outdoors are typically installed below rooftop, e.g. to provide synchronization between buildings or cover pathways between buildings. Therefore residential and enterprise base stations and handsets are typically in non-line-of-sight (NLOS) of adjacent band cellular base stations. In relation to cellular base stations, the geographical position and interfering power of private DECT transmitters is similar to those of adjacent band cellular handsets. This is further explained in annex A of the present document.

5 Basic DECT regulatory documents and standards

5.1 A designated protected frequency band 1 880 - 1 900 MHz

The ERC Decision of 24th October 1994 (ERC/DEC(94)03) [i.2] makes available the frequency band 1 880 - 1 900 MHz to be designated for the coordinated introduction of DECT, and states that DECT has priority over other radio systems in that band, and be protected, in the designated band.

DECT deployments existed already when the frequency bands adjacent to the DECT band 1 880 - 1 900 MHz were allocated to cellular services.

This ERC Decision (94)03 is supposed to be reviewed by the ECC on a regularly basis to see if any revision is required. In the template used during such a review there is an item "technology neutrality". It is absolutely essential to have clear understanding that DECT is a justified case for not applying "technology neutrality". This fact has been understood and honoured in earlier reviews.

5.2 The harmonized standard for DECT EN 301 406

Equipment meeting the essential requirements of the Directive 1999/5/EC (R&TTE Directive [i.20]) as well as the other relevant provisions of this same Directive can be placed on the market. The simplest way for manufacturers to provide presumption of conformity to the essential requirements of the R&TTE Directive is to apply a Harmonized Standard, which for DECT is EN 301 406 [i.1].

The Commission's essential objective behind the R&TTE Directive [i.20] is to establish a regulatory framework for the placing on the market, free movement and putting into service in the Community of radio equipment and telecommunications terminal equipment. While the Member States and the Commission largely agree in respect of the placing on the market, the "putting into service in their territory of apparatus bearing the CE marking", (Articles 7 and 8 of the R&TTE Directive [i.20]), has become the subject of discussion in the case of equipment intended for frequency bands whose use is not harmonized throughout the Community. The use of the DECT band 1 880 -1 900 MHz is considered harmonized in the Community by a TCAM agreement and no notification according to article 6.4 of the R&TTE Directive [i.20] is required for class 1 DECT equipment.

5.3 Exemption from individual licensing based on ERC Decision (98)22

The ERC Decision (98)22 "*ERC Decision of 23 November 1998 on Exemption from Individual Licensing of DECT equipment, except fixed parts which provide for public access (ERC/DEC(98)22) - Corrected 30 march 2007*" [i.3], is an important European level document. It defines conditions for exemption from individual licensing of DECT equipment. It refers to the DECT Harmonized Standard EN 301 406 [i.1].

5.4 Radio system parameters for DECT

The base standard for DECT is the Common Interface (CI) standard EN 300 175 Parts 1 to 8 [i.25]. The Physical Layer is contained in EN 300 175-2 [i.12]. Updated radio parameters for DECT are available in annex B.

6 DECT system parameters and how to apply them

6.1 Transmit power

For DECT transmitter power the Terminal Power 24 dBm should be used for modelling the interference to and from DECT handsets and DECT base stations. Terminal power should also be used for cellular handsets. The Terminal Power of 24 dBm and an antenna gain of 0 dBi has been used in all existing ECC and CEPT compatibility studies for cellular handsets.

6.2 Receiver performance

Some basic DECT receiver parameters are presented below. Detailed information is found in annex B of the present document.

6.2.1 Noise floor and carrier to interference ratio in a typical fading environment

A receiver noise floor of -104 dBm and a C/(I + N) of 21 dB should be used for DECT for normal fading indoor environments. See annex B for more details.

6.2.2 Radio link quality requirements for DECT speech services

Cellular systems are normally planned for 5 % outage. DECT telephony services should be planned for < 1 % outage, and < 1 % slot error rate. The performance is summarized below, as explained in clauses 4.2.2 and 6.6.

- DECT provides a telephony teleservice which requires ≤ 1 % radio link blocking probability.
- DECT can suffer maximum 1 % packet (slot) loss rate for required speech quality.
- A partially interfered DECT packet(slot) is a lost packet(slot).

The implication of the above requirements is that all cellular technologies with intermittent transmissions, e.g. TDD systems and or packet type transmissions, block as much of the DECT spectrum as a continuous interference with the same peak power (the only exception is the UMTS TDD technology, which has a TDMA structure with 10 ms frame cycle, and where DECT can use the time gaps of the interfered carriers). This implies that only the CS-CS case of CEPT Report 39 [i.10] and ECC Report 131 [i.23] applies for any simulation. The PS-PS case cannot be used. See clause 4.2.

6.3 Basics on the DECT instant Dynamic Channel Selection (iDCS) feature and antenna gain

The mandatory Instant Dynamic Channel Selection (iDCS) messages and procedures provide effective co-existence of uncoordinated private and public systems on the common designated DECT frequency band and avoid any need for traditional frequency planning. Each device has access to all channels (time/frequency combinations). Ten DECT RF carriers are defined in the band 1 880 - 1 900 MHz and provide totally 120 duplex access channels. When a control channel or a connection is needed, then that channel is selected, which at that instant and at that locality, is least interfered of all the common access channels. This avoids any need for traditional frequency planning, and greatly simplifies the installations. This procedure also provides higher and higher capacity by closer and closer base station installation, while maintaining a high radio link quality. Not needing to split the frequency resource between different systems, services or users, results in a very efficient use of the allocated spectrum. A detailed description of the paging, control and traffic channels, how they are defined, how seamless handover is performed, etc. is found in TR 101 310 [i.21].

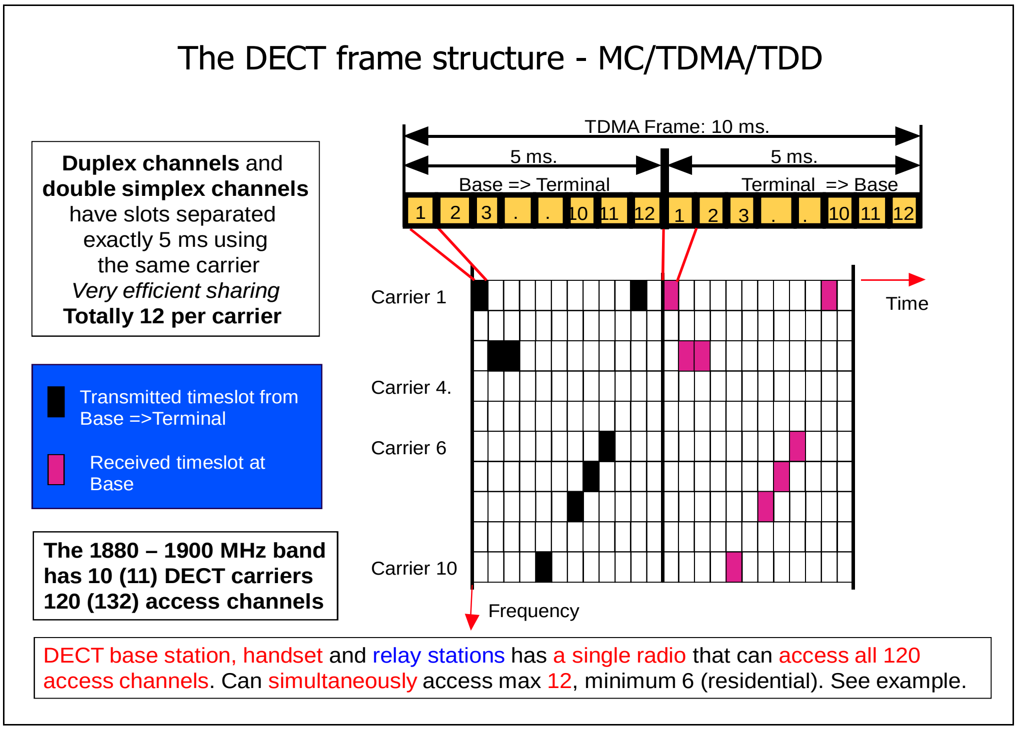


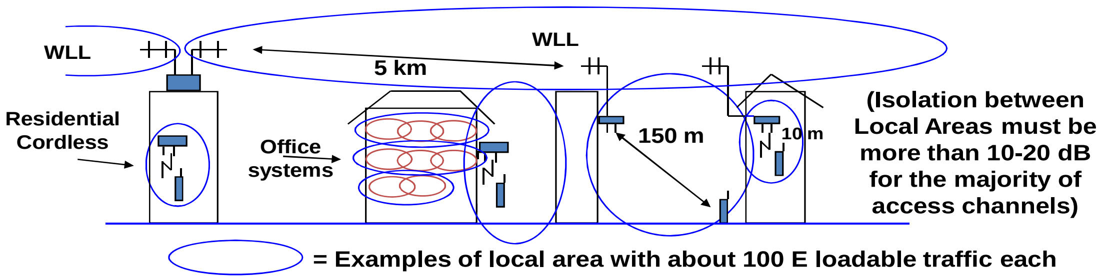
Figure 2: The DECT frame structure

Examples of parameters that interact to provide the unique DECT reliability and traffic capacity are: the 10 ms frame, the large numbers of timeslots, the large numbers of basic access channels, balance between numbers of frequency carriers and time slots, selecting duplex slot pairs on the same carrier, have exactly 5 ms between up- and downlink, always selecting resources as duplex pairs, all systems having the same access channel definitions, using a least interfered channel (LIC) procedure with a low lower limit and no upper limit, handset controlled channel selection and handover, seamless intra-cell and inter-cell handover, no specific control carriers, distributed and dynamic down-link control and paging channels, no frequency planning for multi-cell base stations, sliding collision detection at the beginning and end of each slot, defined frame clock stability, very quick bearer setup and handover, handsets not allowed to transmit if not locked to a base, not continue bearer setup unless reply from base within 5 ms, etc. The interaction of those features provides the combination of high capacity and reliable links ("interference free communication") in an environment of many nearby uncoordinated system installations.

Much unique knowledge and experience is available in the DECT community on the subject of sharing spectrum between uncoordinated installations. To assist regulators, operators and manufacturers, information on this subject has been collected in TR 101 310 [i.21]. The present document presents a novel concept, the local load on the spectrum, which has proven useful for basic traffic capacity estimates (see figure 3).

A new concept: *Local Load on the spectrum* for uncoordinated system installations

Local load on the spectrum: The number of *different* (full-slot) duplex (or equivalent) access channels that *on average* are occupied in a specific *local* area.
Local area: The area in which a traffic channel typically can not be reused.
Local loadable traffic: About 100 E *average traffic* with 0.5 % blocking probability.



The concept of "local load on the spectrum" is useful due to the ***unique*** **instant Dynamic Channel Selection** ***feature of DECT***, which makes it feasible to use the average load measure, since those few connections that become interfered from traffic in adjacent local areas can find escapes to non-interfered channels.

Figure 3: Local load on the spectrum

To provide effective and fair dynamic sharing of spectrum resources between radio end points, but also between uncoordinated system installations, the (conducted) terminal power of each radio has been limited to 250 mW or 24 dBm.

According to the DECT Harmonized Standard EN 301 406 [i.1] the RF power is specified as 24 dBm terminal power (NTP) and maximum 12 dBi antenna gain.

The DECT spectrum is shared in three geographical dimensions. Antenna gain improves in average the spectrum efficiency of the DECT installations.

DECT residential and enterprise systems are designed for, and generally used in, multi-storey buildings. The DECT spectrum is shared in a three dimensional space. The largest space (volume) that can be covered by the 250 mW, is in principle the coverage by using an ideal isotropic antenna (0 dBi). The reason is that a gain antenna (> 0 dBi in some direction), provides longer range in some direction and shorter in other directions, and the decay index of propagation models normally increases with the distance (see figure 4).

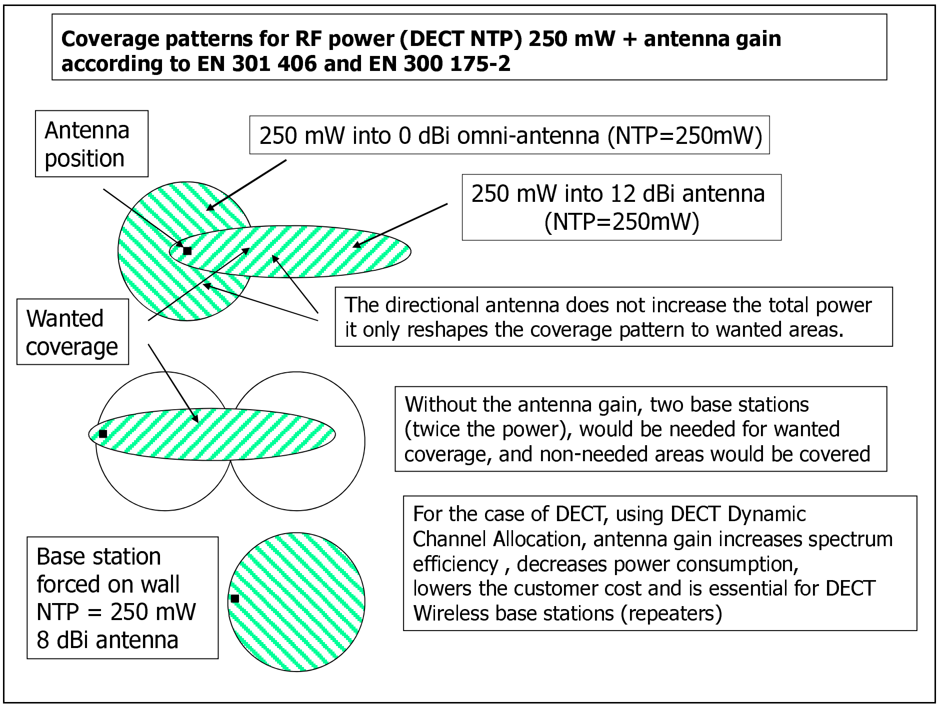


Figure 4: Coverage of DECT with different antenna radiation patterns

6.4 Directional antennas

6.4.1 Directional antennas improve the spectrum efficiency of DECT systems

Due to the DECT instant Dynamic Channel Selection provision, gain antennas do not jeopardize the coexistence between DECT base stations or systems. On the contrary, directional antennas in pico-cell systems on average increase the DECT spectrum efficiency, since they direct the signal were the own users are and decrease interference in the other directions. The antenna gain also reduces the total emitted power and reduces power consumption.

Furthermore, the antenna gain provision is important to give freedom for feasible design of the small antennas in handsets and residential base stations, and is essential to solve installation problems due to practical and esthetical restrictions on placement of base stations in enterprises.

6.4.2 Directional antennas in typical DECT NLOS environments

Passive antennas with directionality do not increase the total emitted power (24 dBm), but only redirect the same power. Nor does the passive antenna increase the space covered, as shown in clause 6.3.

DECT residential and enterprise systems are often installed and used below roof top and indoors. For dispersive non line of sight, NLOS, environments, the link budgets for both, the DECT wanted link and the interfering links are composed of the sum of all reflected radio waves, and are thus as a first approximation directly dependent on the total transmit power (24 dBm for DECT) and not on the specific shape of the passive antennas used by the DECT devices. Therefore the interference probabilities from DECT to cellular systems are also basically dependent on the total transmit power (24 dBm for DECT) and not on the specific shape of the passive antenna.

6.5 Interference scenarios between DECT systems and adjacent band cellular systems

An overview on relevant coexistence studies is provided in annex A.

The following scenarios are addressed:

- Cellular handsets visiting a DECT indoor site.
- Interference to and from outdoor cellular base stations.
- Interference to and from cellular pico-cell systems in the same indoor location as a DECT system.

6.6 The DECT ability to properly detect and escape interference from different radio technologies

The interference to a DECT device comes from other DECT devices and from cellular systems operating at the frequency blocks adjacent to the DECT band 1 880 - 1 900 MHz (see figure 5).

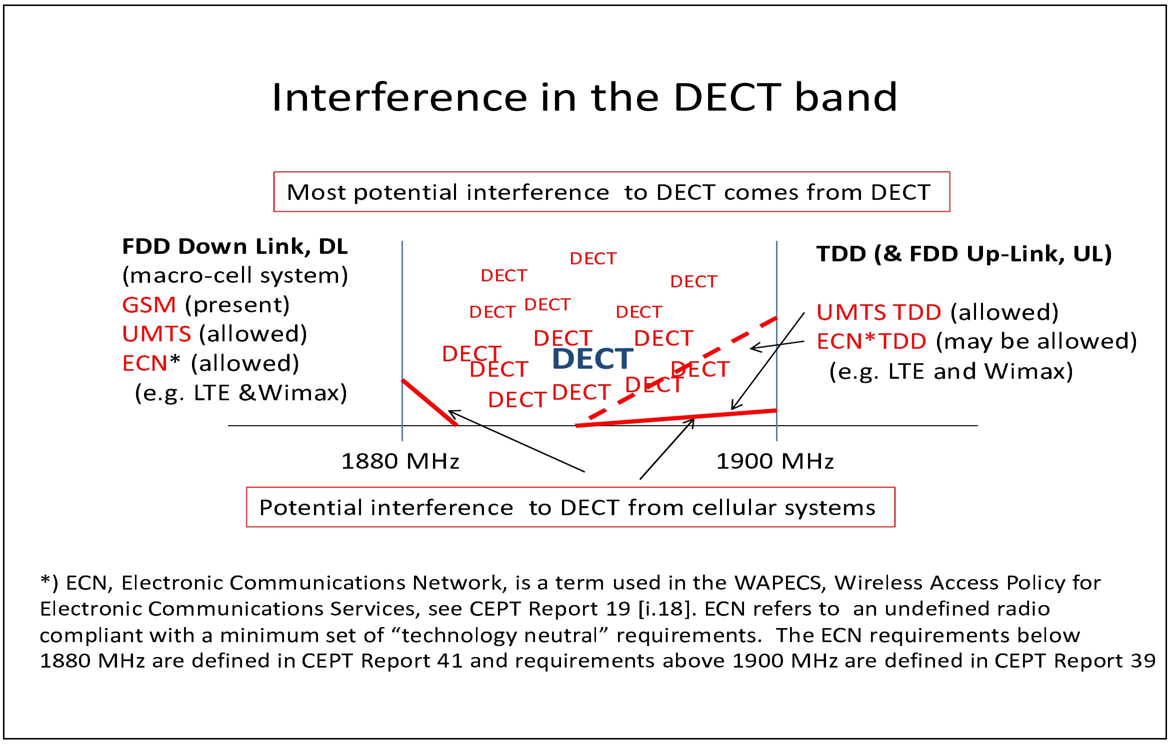


Figure 5: Interference to DECT in the DECT band

Figure 5 identifies cellular technologies adjacent to the DECT frequency band. ECN (Electronic Communications Network) is a term used in the WAPECS (Wireless Access Policy for Electronic Communications Services, see CEPT Report 19 [i.18]). ECN refers to an undefined radio system compliant with a minimum set of "technology neutral" requirements. The ECN requirements below 1 880 MHz are defined in CEPT Report 41 [i.8] and requirements above 1 900 MHz are defined in CEPT Report 39 [i.10]. As described in clause 6.2.2, each DECT device has access to all 120 duplex access channels (time/frequency combinations). When a device sets up a radio bearer or makes an handover to a better bearer, it makes an attempt on the least interfered channel, LIC, of the 120 access channels.

The potential interference in the DECT band comes mainly from other DECT devices, for which the dynamic channel selection procedures have been optimized. Other interference, which sometimes is harder to escape from, comes from the adjacent cellular systems on adjacent frequency blocks. This hardship depends on the time domain features of the cellular technology.

Related to the time domain the following types of interference have to be distinguished:

- DECT transmissions.
- Continuous transmissions.
- Asynchronous packets or slot transmissions. Asynchronous in relation to a DECT slot repeated every 10 ms.

- DECT-like transmissions (UMTS TDD).

Table 1 makes a summary.

Table 1: Cellular interference to DECT with principally different time domain structure

TIME DOMAIN STRUCTURE	EXAMPLE	COMMENT
DECT (Frame cycle 10 ms)	Adjacent DECT devices	One synchronized slot blocks only one slot (4 %) on each of the affected DECT carriers, and 2 slots if the slot is unsynchronized, since gaps in the time domain can be used by DECT transmissions. Easy to detect and escape from.
Continuous transmission	UMTS FDD ECN FDD (if continuous)	Blocks completely the affected DECT carriers. Easy to detect and escape from. Dynamic guard band created within the DECT spectrum.
Asynchronous transmission bursts (Asynchronous in relation to a DECT slot repeated every 10 ms)	GSM 8 TDMA slots with 60/13 ms repetition rate. ECN TDD (LTE / WiMax)	Blocks completely the affected DECT carriers. Complicated or difficult to detect and escape from. Dynamic guard band created within the DECT spectrum.
DECT like TDMA (Frame cycle 10/N ms)	UMTS/TDD 15 TDMA slots with 10 ms frame repetition rate.	One (UL) slot blocks only 2-3 slots (average 10 %) of the affected DECT carriers, since gaps in the time domain can be used by DECT transmissions. Easy to detect and escape from.

The information in table 1 is further elaborated in the following clauses.

6.6.1 Interference to DECT from other DECT devices

The DECT bearer set up procedure and the handover procedure are optimized supposing that the interference is coming from other DECT devices, because it is DECT devices that use the frequency band. This implies two important guide lines:

a) If an access channel is "free" during one 10 ms frame, it is supposed to be "free" also during the following frames.

b) If a channel is "occupied" during one 10 ms frame, it is supposed to be "occupies" also during the following frames.

Therefore DECT only makes RSSI measurement during one frame for ordering the least interfered channel (LIC) list. When setting up a new bearer, DECT also only makes an RSSI check on the LIC, and if still valid, starts transmission on the following frame (see figure 6).

It is obvious that the guidelines a) and b) are relevant when the interference comes from synchronized devices of the same DECT system. But the guidelines are also relevant when the interference comes from devices from a neighbour (unsynchronized) DECT system.

In this latter common case the interfering slot is slowly slipping over the slots of the own system, and normally blocks two slots, but the frequency of slot slips is so low that the guide lines above are still relevant. See figure 7, where the dark and light slots separated by 5 ms (half a frame) are slot pairs (on the same carrier) belonging to the same duplex transmission. Each DECT slot has bits at the beginning and at the end, which allow to detect a slowly sliding collision and to automatically perform, before the user data is affected, a seamless handover to another interference free access channel (time slot/carrier combination).

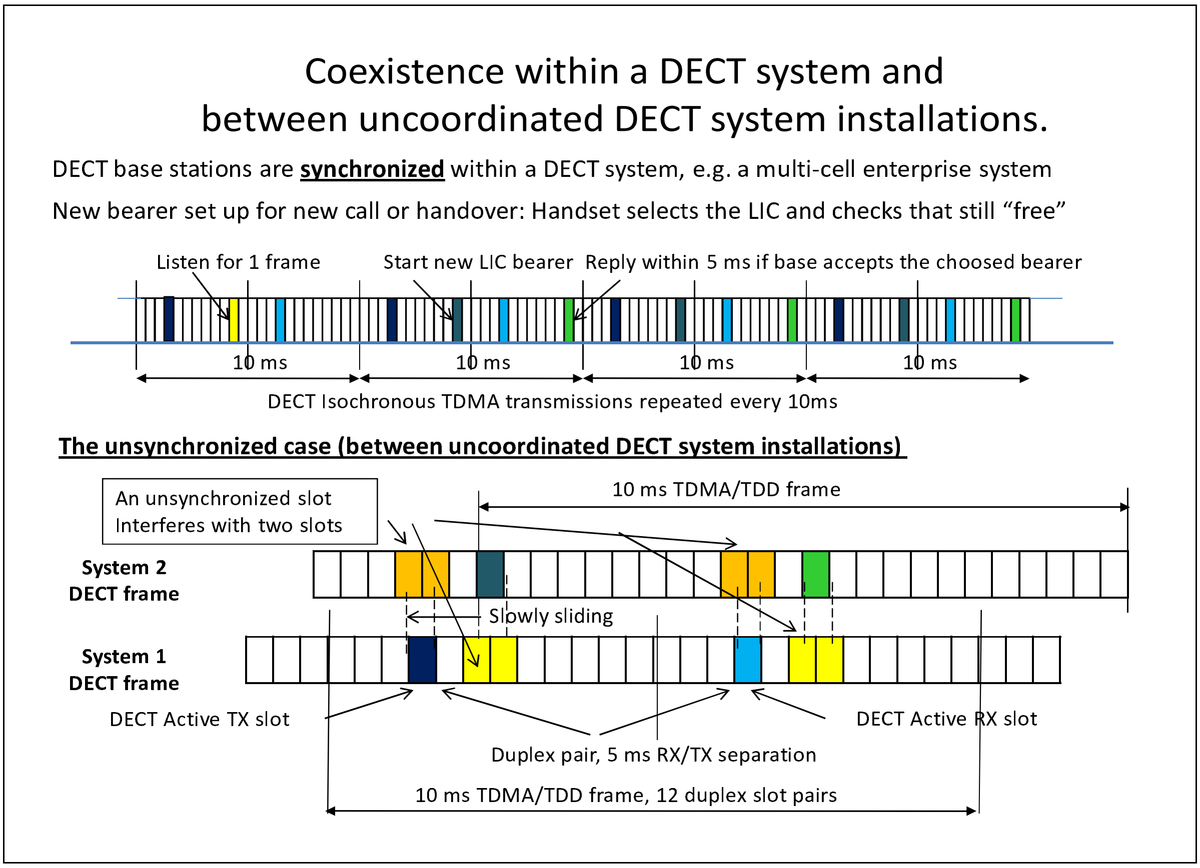


Figure 6: Coexistence between DECT systems

Making a bearer set up attempt, based on RSSI measurement in only one slot, works normally very well. The reason is that the dominating load on the DECT spectrum (interference) comes from DECT devices.

Much unique knowledge and experience is available in the DECT community on the subject of sharing spectrum between uncoordinated DECT installations. To assist regulators, operators and manufacturers, information on this subject, including extensive and detailed traffic capacity simulations, has been collected in TR 101 310 [i.21].

6.6.2 Interference from Continuous transmissions

When the interference comes from DECT devices, interference detected in one frame will continue in every consecutive frame, and a "free slot" detected in one frame, will be free also in consecutive frames. This also applies for interference from cellular devices operating on adjacent band frequencies, if their transmission is continuous (as for UMTS FDD and ECN FDD, e.g. LTE or WiMax in continuous transmit mode.

For the continuous case it is obvious that the all slots, 100 %, of each affected carrier will be blocked and that the interference detection will be easy.

6.6.3 Asynchronous transmission bursts (slots)

Interference from adjacent band cellular devices is often not continuous and does not have a 10 ms frame repetition rate. For such a case the one-frame-RSSI-measurement for the least interfered channel may have occurred on an interfered carrier during a gap in the interfering transmission. In such a case, a bearer set up on this least interfered channel, LIC, will be a wrong decision. Because, since the interfering transmission is asynchronous (has a random reception time) in relation to the DECT frame, the newly set up bearer will start to be interfered in a random fashion on the selected slot. The same will happen for any set up attempt on any "free" slot on the same carrier.

The asynchronous interference will thus make every DECT slot position, 100 %, on the affected carriers useless. An asynchronous bursty interference blocks as much as a continuous interference with the same peak power, but is much more difficult to detect.

This implies that DECT should implement an error detection and handover procedure that specifically considers the asynchronous interference case (see clause 6.5.5).

6.6.3.1 GSM

GSM, allocated below 1 880 MHz, is the most common source for cellular interference to DECT. The source for interference is the down-link, the GSM base stations. Studies, ERC Report 100 [i.5], show that the potential interference from GSM macro base stations to the DECT license exempt (residential and enterprise) systems is very low. However, DECT should be able to detect GSM interference when it occurs, and in an orderly way move to a non-interfered bearer.

GSM transmissions are not asynchronous in itself, but in relation to the DECT 10 ms frame structure. The interference pattern is shown in the figure 7.

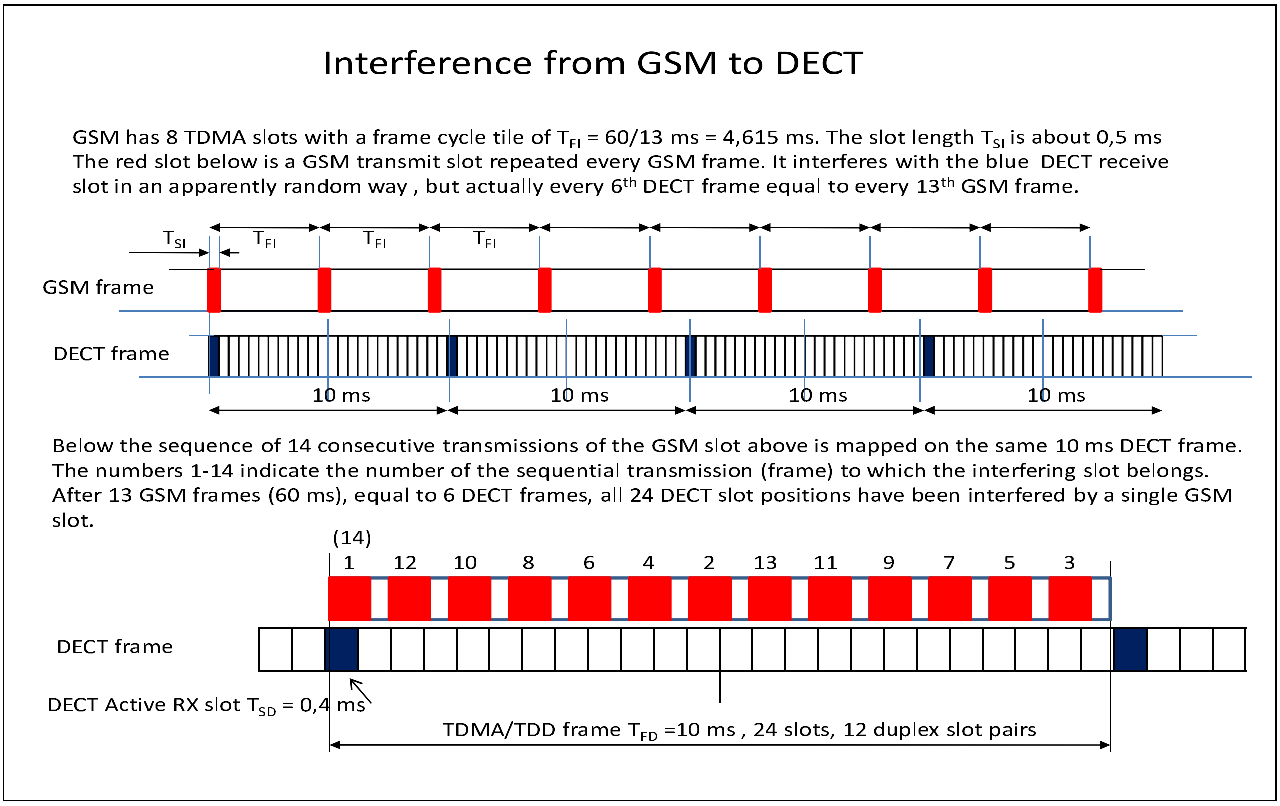


Figure 7: Interference from GSM to DECT

GSM has a TDMA frame cycle time of 60/13 ms, and after 13 GSM frames (60 ms), equal to 6 DECT frames, all 24 DECT slot positions have been interfered by a single GSM slot.

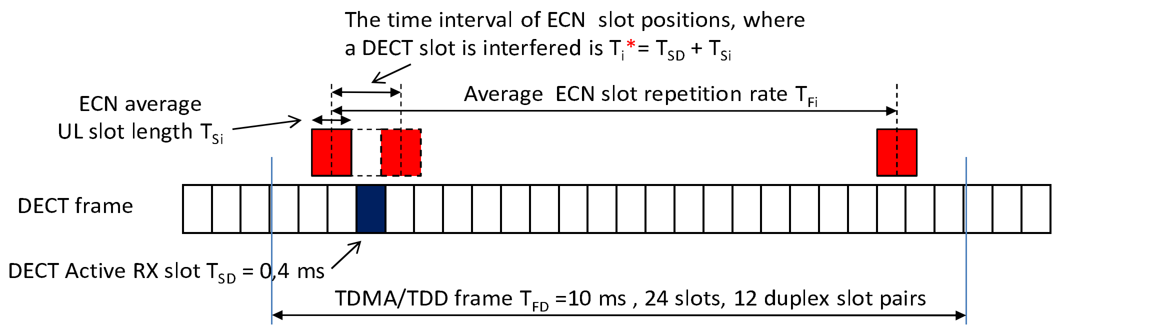
A GSM slot will interfere with a DECT specific slot (bearer) about every 6^{th} DECT frame. Interference every 6^{th} frame corresponds to 17 % slot error rate for DECT, which is much higher than the < 1 % slot error quality requirement (see clause 4.2.2). The GSM interference will thus make every DECT slot position on the affected carriers useless. Interference from one active GSM slot blocks as much as a continuous interference with the same peak power, but is much more difficult to detect. DECT has an error detection and handover procedure that specifically considers the GSM interference case (see clause 6.6.5).

6.6.3.2 ECN TDD (LTE/Wimax)

ECN TDD allocated above 1 900 MHz, could become a major source cellular interference to DECT. Due to the TDD, ECN TDD transmissions will be bursty. It has also to be assumed that these bursts are asynchronous in relation to DECT, because the ECN concept (technology neutral) cannot include a requirement of 10 ms burst repetition, as for UMTS TDD.

Due to the TDD, interference to DECT will be generated both by the down-link, ECN base stations, and the up-link, ECN terminals (handsets). The potential interference from macro cell ECN TDD base stations is low compared to the potential interference from the ECN terminals. See ERC Report 65 [i.9] and CEPT Report 39 [i.10]. Therefore an asynchronous burst sequence from an ECN TDD UL, terminal, is studied below. It is supposed that the average duty cycle of the ECN terminal transmissions is 12,5 % and the average repetition rate is 10 ms, as used in CEPT Report 39 [i.10]. Figure 8 shows calculations of an estimate of the average probability that an ECN TDD burst from a terminal interferes with a specific DECT slot.

Calculating the probability that an ECN TDD UL slot collides with a specific DECT slot



*) A partial collision of a DECT slot is a 100% lost slot, becuse DECT has only error detection (no error correction).
Thus $T_i = T_{SD} + T_{Si}$ is the equivalent time interval for 100 % overlap (partial overlap shall not occur in the calculations).

The probability that an ECN slot occurs within the DECT frame is: T_{FD} / T_{Fi}
And the probability that this ECN slot collides with a DECT slot becomes: $T_i / T_{FD} = (T_{SD} + T_{Si}) / T_{FD}$

Thus the average probability that a specific DECT slot position in a DECT frame is interfered by an ECN slot becomes:
$p_i = (T_{FD} / T_{Fi}) \times (T_{SD} + T_{Si}) / T_{FD} = T_{SD} / T_{Fi} + T_{Si} / T_{Fi} > T_{Si} / T_{Fi}$. T_{Si} / T_{Fi} is the average duty cycle of the ECN transmission

Examples of calculated collision propabilities p_i :

1) UMTS TDD. One UMTS slot T_{Si} = 0,6ms and T_{Fi} = 10 ms. Thus p_i = 10%.
2) General ECN TDD TS. In average 12,5 % of ECN TDD frame is UL transmit time . Thus T_{Si} / T_{Fi} is 12,5 %. Thus $p_i = 0{,}4 / T_{Fi}$ + 12,5 % > 12,5 % . p_i will be 16,5 % if T_{Fi} = 10 ms.

Figure 8: Probability that an ECN TDD UL slot collides with a specific DECT slot

The estimate of the average probability, p_i ,that an ECN TDD UL slot collides with a DECT slot is:

$$p_i = (T_{SD} + T_{Si}) / T_{Fi} > T_{Si} / T_{Fi} \text{ , where}$$

T_{SD} is the slot length of DECT, T_{Si} is the average length of the interfering ECN slots (packets) and T_{Fi} is the average interval (repetition rate) between ECN slots. T_{Si} / T_{Fi} is the average duty cycle of the ECN transmission, which is supposed to be in the order of 12,5 %. Thus p_i > 12,5 %. Applying the formula on GSM gives p_i = 19,5 %.

The quality requirement for DECT is p_i < 1 % (see clause 4.2.2), and thus a sequence of asynchronous packets, with an average duty cycle > 1 %, will block all slots of affected carriers, as a GSM slot does. See figure 9.

In the ECC Report 131 [i.23] and the CEPT Report 39 [i.10] there is a concept of calculating acceptable interference levels taking into account the probability of packet collisions between interferer and victim in such a way that the calculated interference levels are reduced when the interference has a duty cycle < 100 %, typically 12,5 %. The concept also makes reduction due to partial overlap of colliding packets. This concept is denoted Packet Switched, PS-PS. Using this concept is not possible when DECT is the victim. As explained above, the DECT slots for the common speech service are not retransmitted if lost, and a partially interfered slot is also a lost slot. (G_{Coll} in ECC Report 131 should be 0 dB, unless the duty cycle of the interferer to DECT is less that 1 %, which is unrealistic). Interference to DECT by intermittent packet transmissions, in reality blocks as much as a continuous transmission with the same peak power as the packets. In ECC Report 131 and CEPT Report 39 the latter case is the default case, and is denoted Circuit Switched, CS-CS. Only CS-CS applies to DECT for interference from cellular technologies, except for DECT-like transmissions where a kind of the PS-PS case applies (see clause 6.6.4).

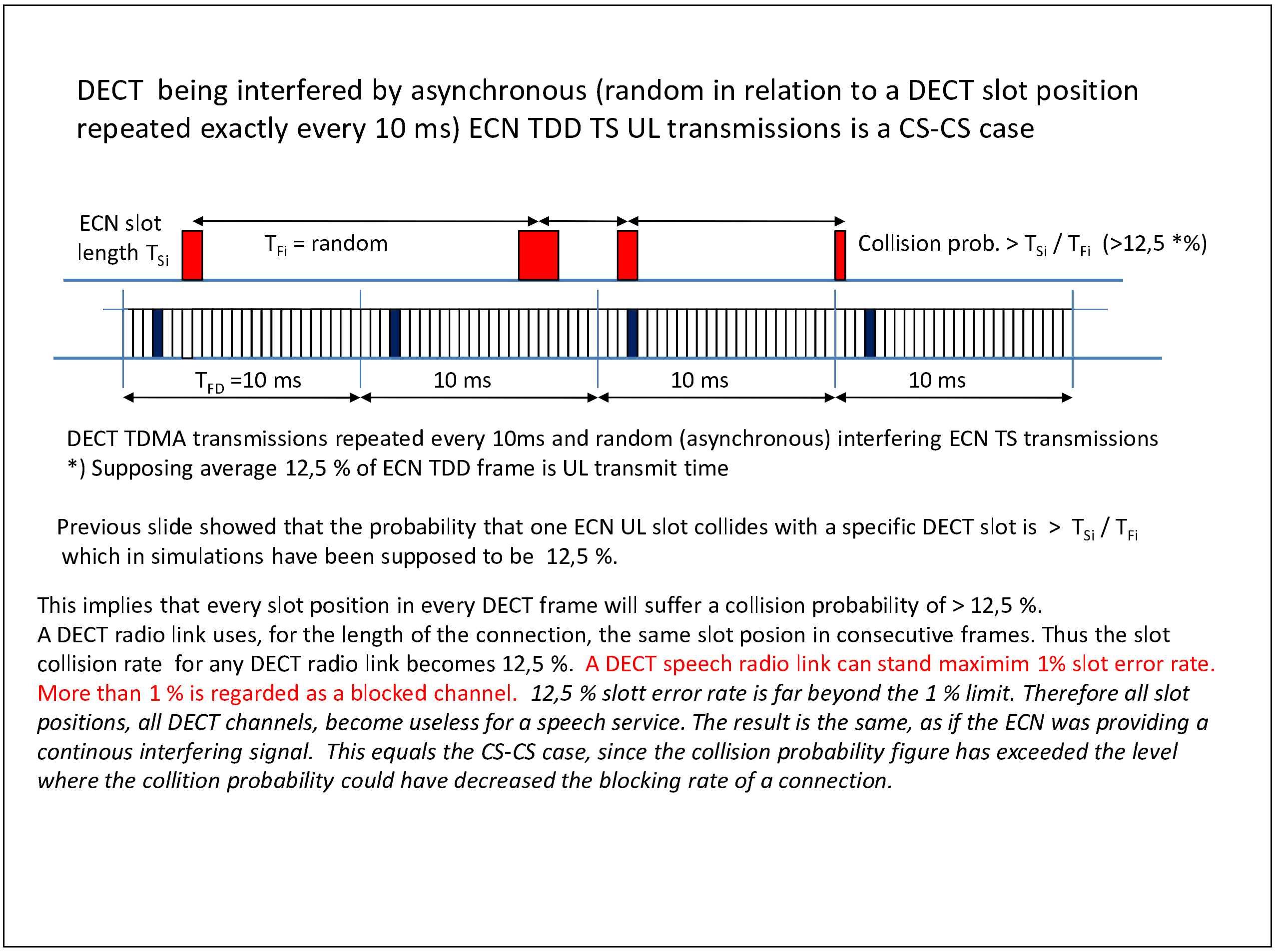


Figure 9: DECT being interfered by asynchronous ECN TDD TS UL transmissions

An asynchronous bursty interference blocks as much as a continuous interference with the same peak power, but is much more difficult to detect.

DECT will detect the poor quality, and make a quick intracell handover to a better channel. How this detection is made and how the new channel is selected is described in clause 6.6.5.

6.6.4 Interference from DECT-like transmissions

When the interference comes from DECT devices, interference detected in one frame will continue in every consecutive frame, and a "free slot" detected in one frame, will be free also in consecutive frames. This also applies for interference from cellular devices operating on adjacent band frequencies, if the cellular technology has a TDMA component with 10 ms frame repetition rate (DECT-like transmission) as for UMTS/TDD. More exact, the frame repetition rate should be 10/N ms, where N is an integer. The interference pattern from UMTS/TDD is equivalent to interference from an unsynchronized DECT device, with correction for the slot length, which is 0,6 ms for UMTS/TDD and 0,4 ms for DECT. This implies that 2-3 slot positions are blocked on the interfered carriers. For DECT-like transmissions a kind of the PS-PS case applies, but where a partial slot overlap always equals a full slot overlap (see figure 10).

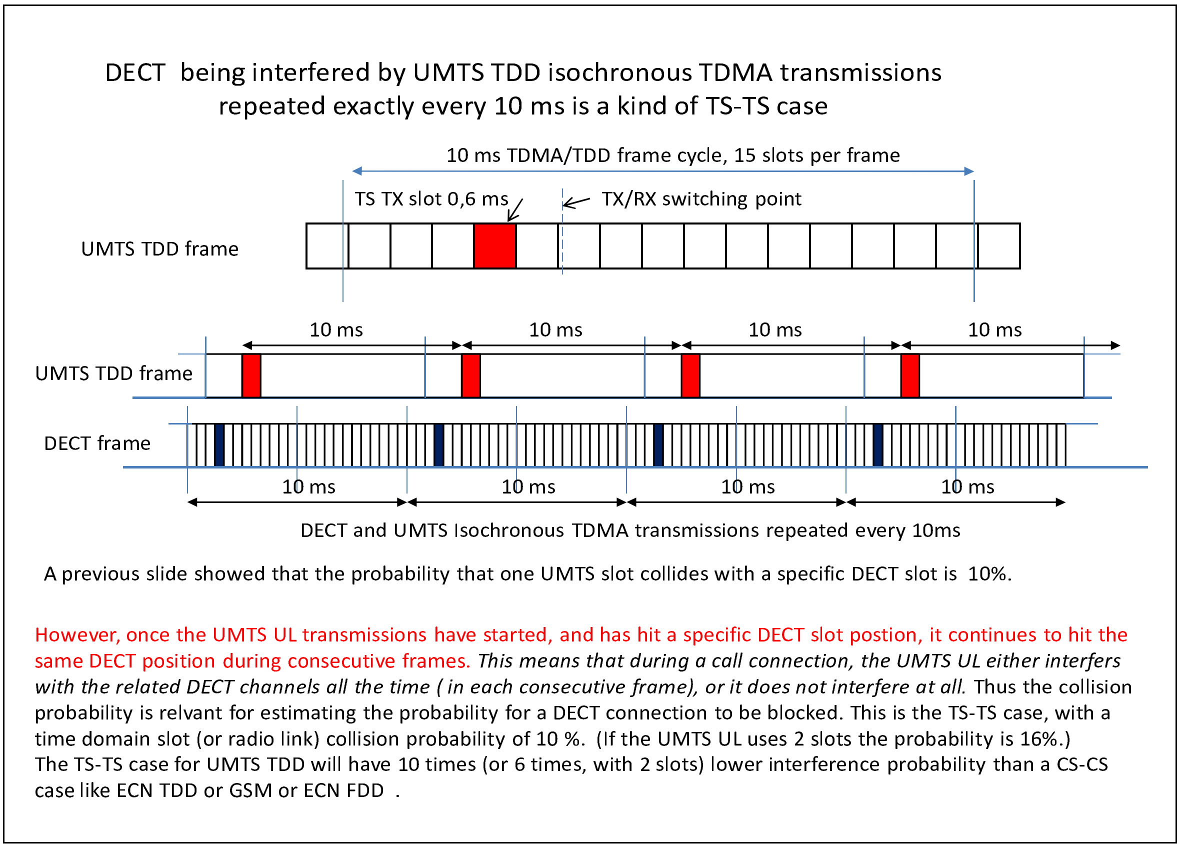


Figure 10: DECT being interfered by UMTS TDD isochronous TDMA transmissions

The time domain probability to collide with a specific DECT slot position has been calculated to 10 %. See figures 8 and 10.

Since DECT can share the time domain with DECT-like transmissions, those do not block whole carriers as the asynchronous packets do.

Thus a UMTS TDD UL transmission only blocks 10 % of the time domain, while an ECN TDD UL transmission blocks 100 % of the time domain.

The WAPECS [i.18] concept allowing ECN TDD in the band 1 900 - 1 920 MHz causes potentially 10 times more interference to DECT than the original UMTS TDD technology.

It is interesting to note that UMTS/TDD purposely was designed with a 10 ms TDMA structure to optimize coexistence with DECT. Without this 10ms frame repetition rate, the band 1 900 - 1 920 MHz would probably not had been allocated to UMTS/TDD. See ERC Report 65 [i.9].

No specific error detection and handover procedure is required for UMTS TDD.

6.6.5 The DECT intra-cell handover procedure

The guidelines a) and b) in clause 6.6.1 also influence the criteria for handover. A key for the maintenance of the DECT high link quality in an environment of uncoordinated (unsynchronized) DECT system installations, is the fast seamless handover. See annex E of TR 101 310 [i.21].

6.6.5.1 The handover triggering criteria

The decision to trigger a handover should be as quick as possible and still correct.

Therefore, the basic handover trigger criteria is the following:

- Slot errors in a few (3) consecutive 10 ms frames, which is optimized for DECT and DECT-like interference.

A second requirement is to detect interference from GSM below the 1 880 MHz boarder, which is the dominating cellular technology adjacent to the DECT frequency band. The GSM TDMA frame cycle is 60/13 ms, and a GSM slot will interfere with a DECT slot as seldom as every 6th DECT frame.

One way to provide both these criterias is to implement in the handsets a "leaking bucket" procedure to trigger handover when the bucket is empty (0). Max content is 32 (overflow limit), empty is 0. Start setting is 16. Correct slot adds one. Error slot subtracts 8. This example gives 30 - 40 ms trigger time for interference from DECT or UMTS/TDD and 480-540 ms for interference from a single GSM bearer. This is described in clause 11.4.5 of EN 300 175-3 [i.24].

The reason that UMTS/TDD, having spectrum above the 1 900 MHz border, gets a short trigger time, is because it is a DECT like transmission, due to its 10 ms TDMA frame. General asynchronous packet transmissions from ECN terminals are supposed to have an average inter packet time of no more than about 10 - 20 ms. If the duty cycle is around 12,5 % as for GSM, the above "leaking bucket" criteria is expected to work well also for the general asynchronous case. For low random duty cycles, the time to perform an handover from the interfered channel may be so long that users will hear the interference before the handover is performed.

Similar considerations on the time domain effects as made for terminals, also apply for base stations. For base stations the load in the time domain normally is much higher than for a terminal, and will thus not be critical regarding the handover criteria of DECT. A special case is frequency hopping for GSM. However, interference from GSM only comes from the base stations (DL), where normally several slots are activated simultaneously, therefore it is supposed that the "leaking bucket" handover triggering criteria above will do.

6.6.5.2 The channel selection criteria for handover

After handover has been triggered due to interference from an asynchronous packet sequence, the handset, through the one-frame-RSSI-measurement for the least interfered channel, may find a LIC access channel in the gaps between packets on the already interfered carrier (see figure 9). In such a case, the handover bearer set up on this "free" channel will be a wrong decision. The newly set up bearer will also start to be interfered in a random fashion on the selected slot. The same will happen for any set up attempt on any "free" slot on the same interfered carrier. To avoid or minimize the risk to be trapped in a loop on the same interfered carrier, the following criteria for channel selection should be added:

- At handover search for new access channel should start on a randomly selected carrier.

The DECT access channel selection is mobile controlled. In DECT handsets there is an updated list of RSSI values of access channels. The channels are ordered in RSSI bands with 6 dB resolution channels. Channels with RSSI below -93 dBm are denoted "Quiet", and can be used without any further ordering (see table 11.2 clause 11.4.1 in EN 300 175-3 [i.24]). Channels in the lowest RSSI band, normally "Quiet" channels, are usually find on several carriers. Thus starting search for access channels on a random carrier number helps to escape from being trapped on a carrier suffering interference from asynchronous packets.

6.7 The near/far problem

The critical scenarios are those when two devices are close to each other on adjacent blocks and one device is transmitting at the same time as the other device is receiving. This is called the near/far problem, if they also operate at full transmit power and at the receiver sensitivity limit. E.g. handsets which are far away from their base stations.

The near/far problem can either be solved in the time domain or in the frequency domain. It cannot be solved in the code domain, since the required isolation is much higher, than what practically can be provided by coding (CDMA).

6.7.1 Solution in the frequency domain

A simple calculation illustrates the required isolation. Assume the following typical parameters for indoor DECT radios and cellular handsets: Transmit power 23 dBm, maximum acceptable receiver interference level -99 dBm, and distance between devices 5 m. 5 m distance gives at 1 900 MHz 38 + 20log (5) = 52 dB free space attenuation. This results in a requirement ACIR >= 23 + 99 - 52 dB = 70 dB. Typical ACLR and ACS for cellular handsets and DECT is < 33 dB for the first adjacent channel. 60 - 70 dB may be reached for the 3rd, 4th or 5th adjacent channel, if reached at all.

This principally implies that a fixed or dynamic guard band corresponding to a number of adjacent carriers is required between the two devices.

A dynamic (frequency hopping, handover, iDCS) guard band is possible for DECT and GSM at the 1 880 MHz boarder, where each operator has access to several frequency channels. But this is not possible for a broad band technology like UMTS, if the operator has only one (or two) 5 MHz carriers.

The most common near/far situation is two close by handsets of cellular FDD systems (GSM or UMTS). The required isolation has been provided by guard bands between the UL spectrum and the DL spectrum allocation corresponding to 20 MHz (100 adjacent carrier spacings) for GSM 1 800 and 30 MHz (6 adjacent carrier spacings) for UMTS. For FDD systems the guard band is also required for isolation between DL and UL in the same handset.

Another inter-cellular near/far problem occurs if cellular indoor pico/femto cells are deployed, and a handset from the adjacent block cellular macro cell system enters the site of the indoor base station. This may work for GSM, where each operator has access to several frequency channels, but hardly for broadband technologies like UMTS.

6.7.2 Solution in the time domain

If a frequency guard band is not possible or not wanted, the only remaining solution is separation in the time domain. Time domain separation is low cost and provides total isolation. Examples of time domain isolation to solve near/far problems are:

WLAN devices within the 2,4 GHz ISM band

Each device listens for a short time if the spectrum is free, and then transmits a packet of limited length. There is a dynamic variable mandatory waiting time until the next packet can be transmitted. If the packet is interfered, it is retransmitted. This concept is very suitable for uncoordinated system installations on a common spectrum to provide best effort high data rate services.

DECT

DECT has 12 TDD duplex TDMA access channels on each of its 10 frequency carriers. These 120 access channels are accessible for each DECT handset and base station. The unique DECT instant dynamic channel selection automatically allocates channels on different time slots if required due to near/far situations. This works also when the two devices are unsynchronized (belong to different DECT systems). See explanation in clauses 6.3 and 6.5.1.

Cellular TDD systems with mutually synchronized DL/UL switching points

UMTS/TDD has been allocated four 5 MHz blocks for four macro cellular operators within the band 1 900 - 1 920 MHz. There is only one carrier per operator, and therefore the near/far problems between adjacent block handsets (and also adjacent block base stations) can only be solved in the time domain. Such a solution implies that all four systems are mutually synchronized in such a manner that they the same TDD frame and the same switching points between DL and UL. It will however be as difficult to deploy indoor base stations as for the above discussed UMTS FDD systems.

The UMTS/TDD allocation has been analysed in CEPT Report 39 [i.10] for technology neutral ECN systems. ECN systems can by default not be mutually synchronized, because TDD frame and DL/UL switching points may differ. A Monte Carlo simulation indicates that for unsynchronized systems, the handsets should have ACLR and ACS values of at least 53 dB for acceptable interference levels between handsets from adjacent block systems. This is 20 dB higher requirements than the ECN terminal specification, which is 33 dBm for ACLR and ACS.

6.8 Conceptual difference between public cellular systems and private DECT systems

For cellular systems, many systems serve (cover) the same geographical area, which leads to many close by terminals from different operators. The coexistence is solved by giving each operator an own spectrum block, and by providing good isolation between up-link and down-links. (Except for pico cell applications and for unsynchronized adjacent cellular TDD systems). There is also often a mutual coordination between operators regarding base station installations.

For DECT all operators share the DECT spectrum. The installation of all residential and enterprise DECT systems are uncoordinated. However typically no more than one system covers each local site. This means that a large part of the common spectrum is average is available for each system, and few users of different systems are close to each other. See figure 3. And those few transmissions that happen to interfere between systems, are automatically handed over to a free channel. For severe near/far cases the handover is made in the time domain, giving infinite isolation. (The DECT access channels on the spectrum is like a broad motorway with 120 lanes, where all DECT transmitters have access to all 120 lanes, and move between the lanes, if required not to collide.)

6.9 Technology dependant inherent mitigation techniques

Some radio technologies have built in inherent mitigation techniques, of which some are presented below.

6.9.1 GSM narrow bandwidth and frequency hopping

GSM is a TDMA FDD multi-carrier system, with 200 Hz carrier spacing.

On a 5 MHz cellular down-link block allocation the GSM system normally has 23 (narrow-band) carriers. Thus if some carriers close to the block edge are interfered, the system makes an intra-cell handover to a carrier more distant from the block edge.

Modern GSM systems often implement frequency hopping. GSM has inherent interleaving and error correction, allows a radio link to suffer loss of a slot at certain rate. This implies that at frequency hopping the slot at the carrier closed to the block edge could be lost and still corrected.

A basic requirement is though that the GSM down-link control channel BCCH, which is not hopping, is allocated on a carrier with some distance to the block edge.

The GSM technology with its narrow bandwidth, multiple carriers and frequency hopping provides more robust coexistence with DECT and with cellular technologies on adjacent blocks, that the new broad-band technologies. E.g. UMTS has only one carrier on a 5 MHz block, and has nowhere to escape to if interfered. And the handset transmitter emissions on adjacent channels is much more broadband than from GSM handsets.

6.9.2 The low duty cycle of DECT transmissions

One basic 3,1 kHz telephony teleservice duplex radio link occupies, in the time domain, about 7,4 % of a DECT frame (3,7 % in each direction), and the wideband 7 kHz voice transmission (DECT-NG) 13,1 % (6,6 % in each direction). A DECT base station has, in idle active mode, always beacon transmission every 10 ms with a duty cycle of about 1 %.

The DECT carriers are accessed randomly. A duplex single bearer connection uses one carrier.

In a home, one carrier is active for an external call, and normally two carriers for an internal "intercom" call. However, since the typical traffic load is below 0,1 E during busy hours, most of the time only the beacon is active. Thus normally the time domain is only loaded by 1 %, and less of 10 % of day time by 3,7 % from the handset and 3,7 % from the base.

In an enterprise multi-cell system, the typical average load per base station is 1 simultaneous call (3,7 % load). For high traffic applications 2-3 simultaneous calls (maximum 12). Thus there is always DECT traffic from the base station, with typically 3,7 % up to 11 % occupancy in the time domain (supposing 3,1 kHz telephony teleservice).

6.9.3 Error correction capabilities of cellular systems

All cellular systems implement interleaving and error correction. Systems with a CDMA component also provide some interference rejection through the processing gain. These inherent features can reduce the impact of interference in the time domain from DECT slots. See the clause 6.8.2 above for information on the DECT duty cycles.

All systems can probably stand interference from the DECT base station beacon, which has a duty cycle of about 1 %.

Test with GSM speech service has shown that it can stand interference from a DECT full-slot from an handset or a base station. A full slot has 3,7 % duty cycle. Theoretically GSM would have the capability to cope with two full-slots (7,4 %) or a HD speech long slot (6,6 % duty cycle).

The error correction capability of the cellular technologies depends on the coding, which normally differs for different services. The present document does not provide information on the error correction capabilities in relation to DECT for the broadband technologies UMTS, LTE or WiMax.

Supposing that the above broadband technologies can correct at least 3,7 % lost bits in the time domain. A consequence of this is that a cellular handset could tolerate a case where the harmful interference comes from only one close by handset or base station. This could be the case for interference through the second, third, etc adjacent channel. On the first adjacent broadband channel the attenuation is so low that the cellular hand set will be interfered simultaneously by both handset and base station (7,4 % loss).

6.9.4 Packet vs Circuit mode cellular transmissions

If the cellular transmission is of packet type, in the sense that lost packets are retransmitted, then the interference to a mobile handset entering a DECT site will not block the cellular handset, but just reduce the traffic capacity.

The traffic capacity reduction will in principle correspond to the load in the time domain of the harmful interference from the DECT transmissions. From clause 6.8.2 is seen the typical duty cycles vary from 1 - 11 %.

The above defined cellular packet mode will suffer very limited interference from DECT.

Regarding DECT, it has been explained in clauses 4.2.2. and 6.2.2 that DECT speech services have no error correction capabilities and always should be regarded as a circuit switched service.

6.9.5 DECT-like cellular transmissions

When the interference comes from DECT devices, interference detected in one frame will continue in every consecutive frame, and a "free slot" detected in one frame, will be free also in consecutive frames. This also applies for interference from cellular devices operating on adjacent band frequencies, if the cellular technology has a TDMA component with 10 ms frame repetition rate (DECT-like transmission) as for UMTS/TDD. More exact, the frame repetition rate should be 10/N ms, where N is an integer. DECT can use the gaps between the interfering packets for own transmissions.

Resulting interference to DECT in the time domain will typically be only about 10 % from a visiting UMTS TDD handset, while a "technology neutral" ECN handset will make 100 % of the interfered carriers useless. See clauses 6.6.4 and 6.10.

Interference from DECT-like systems are easy to detect and escape from, and will result in limited capacity reduction, even if several DECT carriers are affected in the frequency domain, which is the case for all broadband cellular technologies.

6.9.6 The DECT instant dynamic channel selection, iDCS, procedure

The DECT instant Dynamic Channel Selection, iDCS, procedures have been described in clause 6.3.

iDCS is optimized for DECT and DECT-like interference patterns, but can also more or less effectively cope with interference from adjacent band cellular technologies. How DECT copes with different time domain structures of different cellular technologies is described in clause 6.6.

When DECT is interfered by a visiting cellular (handset) operating adjacent to the DECT band, DECT moves to a carrier more distant from the band edge. Such a move also reduces the interference from DECT to the visiting handset.

This gain will be useful for the cellular system, but cannot always be fully utilized. The interference levels may not be reciprocal; the DECT connection may suffer less interference than the cellular connection, or active DECT transmissions may be pushed towards band edge by cellular interference to DECT from the other edge of the DECT spectrum.

6.9.7 Increasing base station density of DECT enterprise systems

Increasing the base station density is sometimes a viable mitigation technique for DECT multi-cell enterprise systems. Increasing the base station density increases on average the wanted signal strength for the DECT connections, and helps suppressing interference from e.g. cellular transmitters. The denser base station installation also increases the available DECT traffic density, given a fixed number of available DECT carriers. Thus if an enterprise system has capacity problems in a local area, this can be cured by adding one or a few base stations in that area. Adding DECT base stations is very easy administratively. No special planning is needed. The system does not need any information on the geographical position of the new base stations.

6.10 The concept of Technology Neutral spectrum usage adjacent to the DECT spectrum

The concept of Technology (and Service) Neutrality is a concept where cellular operators will have the right to choose any radio technology (and service) other than originally was defined when the spectrum block was granted to the operator. The new technology should meet some minimum radio requirements to guarantee proper coexistence with existing and future technologies on adjacent spectrum blocks. These requirements are typically transmit power and out-of block emission levels similar to those of the original technology (see CEPT Report 19 [i.18]).

A problem with the Technology Neutral concept is that the minimum radio requirement so far has been limited to power and out-of-block emissions, and any inherent mitigation techniques provided by the original technologies is lost.

Annex A: Overview of earlier coexistence studies on DECT

The following documents, which include compatibility studies concerning DECT, have been identified:

Studies for GSM, UMTS, LTE and WiMax operating at spectrum below 1 880 MHz:

- ERC Report 31 on "Compatibility between DECT and DCS1800" [i.4].
- ERC Report 100 on "Compatibility between certain radio communications systems operating in adjacent bands, evaluation of DECT / GSM 1800 compatibility" [i.5].
- ECC Report 96 on "Compatibility between UMTS 900/1800 and systems operating in adjacent bands" [i.6].
- ECC Report 146 on "Compatibility between GSM MCBTS and other services (TRR, RSBN/PRMG, HC-SDMA, GSM-R, DME, MIDS, DECT) operating in the 900 and 1800 MHz frequency bands" [i.7].
- CEPT Report 41 on " Compatibility between LTE and WiMAX operating within the bands 880-915 MHz / 925-960 MHz and 1710-1785 MHz / 1805-1880 MHz (900/1800 MHz bands) and systems operating in adjacent bands" [i.8].

Studies for GSM, UMTS, LTE and WiMax operating at spectrum above 1900 MHz:

- ERC Report 65 on "Adjacent band compatibility between UMTS and other services in the 2 GHz band" [i.9].
- CEPT Report 39 " Report from CEPT to the European Commission in response to the Mandate to develop least restrictive technical conditions for 2 GHz bands" [i.10].

In all the above reports 24 dBm total transmit power (terminal power) and 0 dBi gain is assumed for residential and enterprise systems, while 24 dBm transmit power and 12 dBi gain is assumed for the public systems.

It has been concluded in clause 6.4 of the present document, that the usage of 24 dBm total transmit power and an isotropic antenna (0 dBi antenna gain) is a valid approximation for analyzing below rooftop and indoor DECT systems complying with the DECT Harmonized Standard EN 301 406 [i.1], which specifies 24 dBm terminal power and a maximum antenna gain of 12 dBi.

All possible scenarios found in earlier studies are numbered from 1 to 30 in table A.1.

This table on the different interference scenarios is taken from ERC Report 65 [i.9]. RFP means "Radio Fixed Part", equivalent to a DECT base station; CTA means "Cordless Terminal Adaptor", i.e. fixed subscriber unit; PP means "Portable Part".

Table A.1: Possible interference scenarios

Cellular DECT	Above roof-top macro BTS	Below roof-top micro BTS	Indoor pico BTS	Outdoor MS	Indoor MS
Above roof-top WLL RFP (out of scope)	**1**	2	3	4	5
Above roof-top WLL CTA (out of scope)	**6**	7	8	9	10
Below roof-top outdoor RFP	11	12	13	14	15
Indoor RFP	16	17	**18**	19	**20**
Outdoor PP	21	22	23	24	25
Indoor PP	26	27	**28**	29	**30**
NOTE 1: Scenarios are numbered from 1 to 30. NOTE 2: The scenarios in bold are the most relevant.					

In ERC Report 65 [i.9] the (public) WLL systems, cases 1 - 10, are disregarded since they are out of the scope for this study. Only residential and enterprise systems are considered below.

A.1 General assessments of scenarios

DECT (24 dBm) RFPs and PPs have about the same transmit power as cellular MS. For residential and enterprise systems, the RFPs and PPs are in relation to the cellular base stations geographically used in the same positions as cellular MSs, but mainly indoors. Therefore, principally, the interference probability to cellular base stations from DECT will not exceed the interference probability from cellular MSs on an adjacent cellular block, especially since ACS and ACLR figures for DECT are similar or considerably better than for cellular MSs. See annex B for ACLR and ACS figures.

A.2 Non-critical scenarios

The above consideration makes the scenarios from the two first columns (outdoor cellular base stations) non-critical as interference between outdoor cellular base stations and cellular handsets on the adjacent frequency is not a critical scenario. This has also been confirmed by the existing studies. It is however a common scenario.

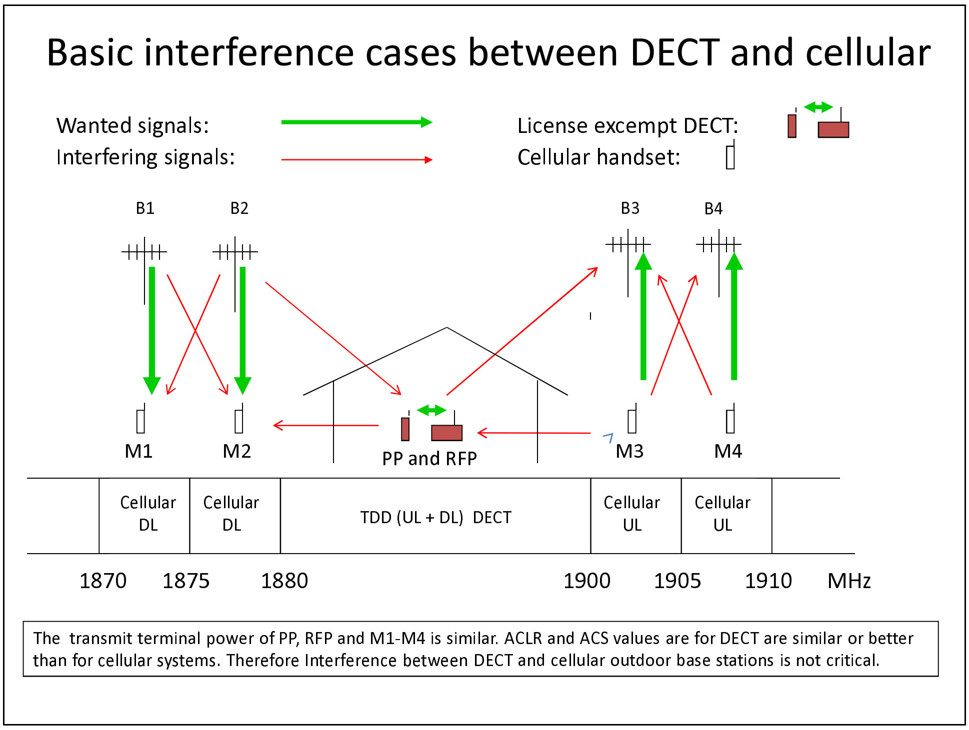


Figure A.1: Basic interference cases between DECT and public cellular systems

A.3 Critical scenarios

The critical scenarios are those when two devices are close to each other on adjacent blocks and one device is transmitting at the same time as the other device is receiving. Examples are when two devices operating on adjacent blocks are in the same location and one is a cellular handset (figures A.2 and A.3) or pico BS (FDD or TDD) (figure A.4) and the other a DECT device. This is the case for the scenarios of the three last columns of table A.1.1, cases 18 and 28, 14 and 24, and 20 and 30. However, since the DECT devices are predominantly used indoors, cases 14 and 24 will hardly occur and is therefore regarded as not critical.

A simple calculation illustrates cases 18, 28, 20 and 30 are critical. Let's assume the following typical parameters for indoor handsets and base stations:

- Transmit power: 23 dBm.
- Maximum acceptable interference level: -93 dBm.
- Distance between devices: 5 m.

At the DECT frequencies a 5 m distance corresponds to 52 dB of free space attenuation (38 + 20log (5) = 52).

This results in a requirement ACIR ≥ 23 + 93 - 52 dB = 63 dB. Typical ACLR and ACS for cellular handsets and DECT is < 33 dB for the first adjacent channel. 60 dB may be reached for the 3rd, 4th or 5th adjacent channel, if reached at all. This example implies that a fixed or dynamic guard band corresponding to a number of adjacent carriers may be required between the two devices. A dynamic (frequency hopping, handover, iDCS) guard band is possible for DECT and GSM, where each operator has access to several frequency channels. But this is difficult for a broad band technology like UMTS, if the operator has only one or two 5 MHz carriers.

The main scenario of interest to analyze is the near-far interference that occurs when cellular handsets linked to an outdoor cellular base station visits a home or enterprise having a DECT installation. That is cases 20 and 30.

In figure A.2 the cellular systems adjacent to DECT are FDD systems, DLs below DECT and ULs above.

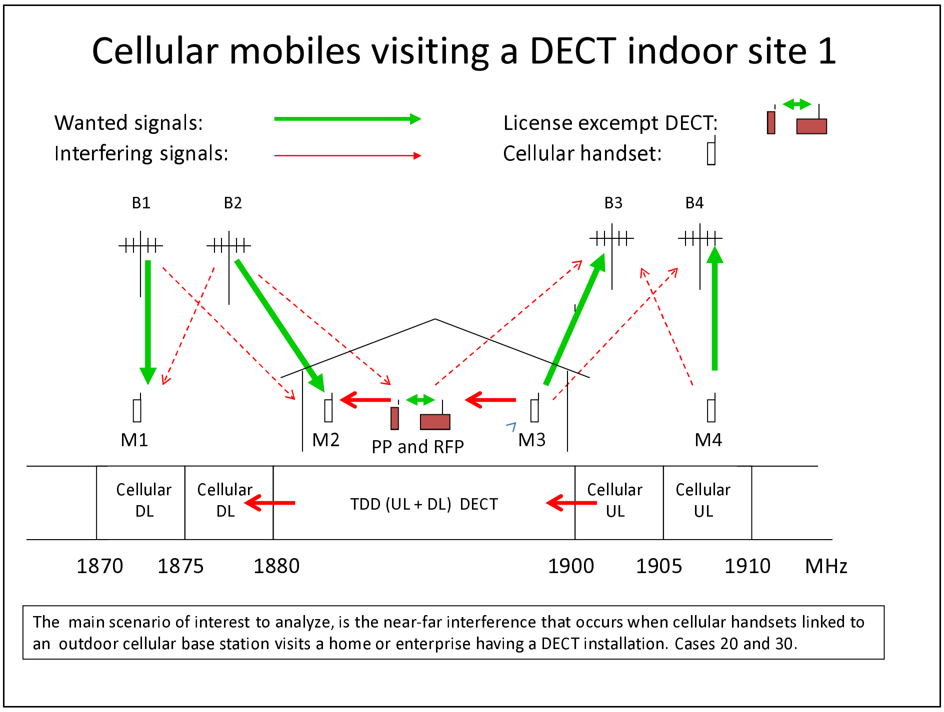


Figure A.2: Interference cases between DECT and indoor public mobile station of FDD network

In figure A.3 the cellular frequency blocks above the DECT band are TDD. This implies that the interference types are doubled (arrows bi-directional interference). Severe near-far interference also occurs between two cellular operators, unless when UL and DL are mutually time synchronized.

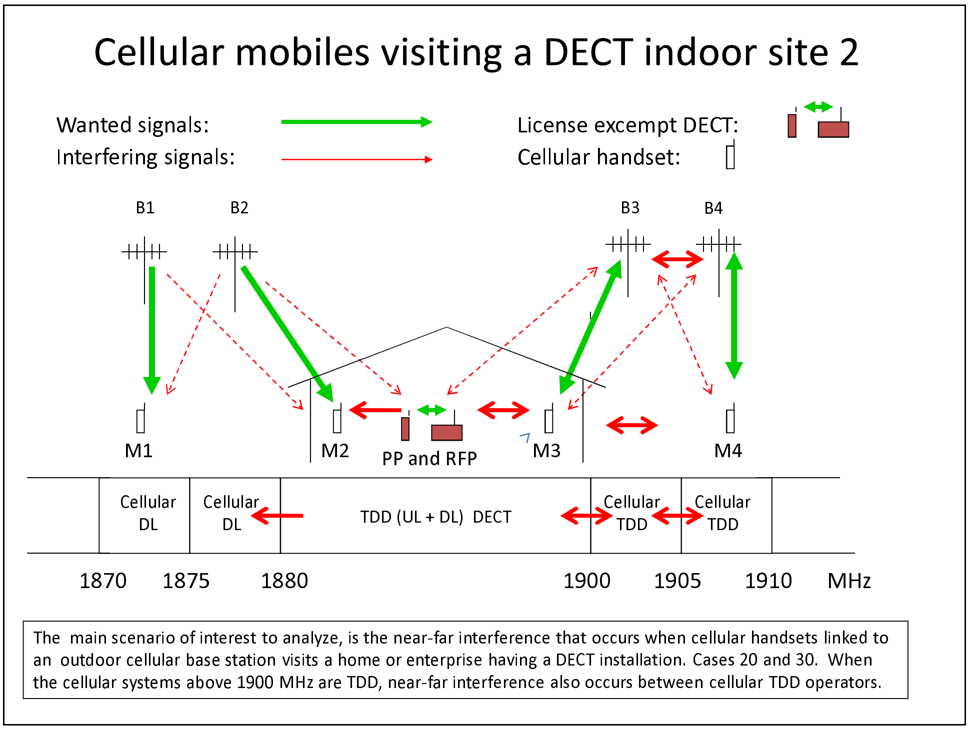


Figure A.3: Interference cases between DECT and indoor public mobile station of TDD network

Cases 20 and 30 are the highly probable scenarios that could exhibit significant interference ranges. The vast majority of cellular handsets, MSs, are connected to outdoor macro cell networks. Therefore the interference cases of major concern are cases 20 and 30 when an MS from a macro cell network enters a home or residence having a DECT installation. This is confirmed by the existing reports.

Indoor cellular pico cell indoor deployment is basically problematic not only in relation to DECT, but also in relation to macro cellular MSs visiting the indoor site. But the cases 18 and 28 with indoor cellular pico cells have not been seen as critical in existing studies. The reasons are that for enterprise systems, the site owner has control, and he is supposed to only install one pico cell system for local mobility, DECT or a cellular system. Furthermore, cellular pico cells have so far not had any wide deployment due to difficulties with the business case and due to challenges to provide coexistence with visiting handsets from macro cells belonging to the own operator or to the adjacent block operator. This scenario is not a highly probable case. It is not feasible to install cellular pico-cell systems in the same indoor location as a DECT system without a guard band. It is more feasible with GSM than with broadband technologies as UMTS, LTE and WiMax. In the band 1 900 - 1 905 MHz these broadband technologies will suffer interference from DECT if the cellular handsets enter a DECT site, because they have no second carrier to escape to. There would be no interference from DECT nor from adjacent operators, if the band 1 900 - 1 920 MHz would be used for UL only. Cases 18 and 28 need more attention than shown in earlier reports, should cellular pico cells (femto cells) become more common. Any need to review the pico-cell scenarios, is however basically not related to the antenna gain issue of this study. See studies on ECC Report 96 [i.6], ERC Report 65 [i.9] and CEPT Report 39 [i.10]. The late CEPT Report 41 however explicitly expresses the difficulty to deploy UMTS pico cells (without a guard band) in a DECT environment. See figure A.4.

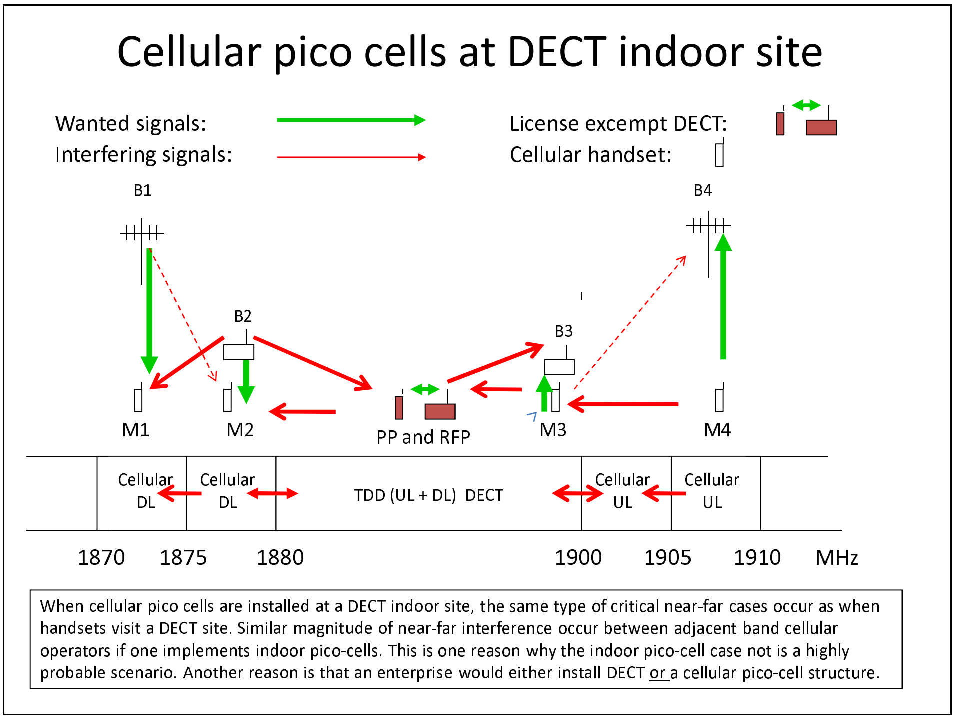


Figure A.4: Interference cases between DECT and public mobile pico-cell system

Annex B: DECT radio system parameters

Updated radio system parameters for DECT, UMTS, LTE and WiMax are provided in this annex. An essential part of the information is taken from recent report CEPT Report 39 [i.10] Annex 3. In the present document the technical parameters for DECT were converted to fit broadband cellular technologies like UMTS, LTE and WiMax, and the parameters of the broadband technologies were converted to fit DECT. Conversions to fit to the narrower band GSM systems are found in ERC Report 100 [i.5].

Technical parameters in CEPT Report 39 [i.10] Annex 3 are limited to interference to DECT from broadband technologies. In this annex technical parameters have been extended to include interference from DECT to cellular services.

For information on a new simplified statistical analysis to estimate interference from cellular indoor handsets to indoor DECT, see CEPT Report 39 [i.10], Annex 3, section A.3.2.

B.1 DECT carrier positions

Ten RF carriers are defined in the frequency band 1 880 MHz to 1 900 MHz with centre frequencies F_c given by:

$F_c = F_0 - c \times 1{,}728$ MHz where: $F_0 = 1\ 897{,}344$ MHz and c = 0, 1, ..., 9.

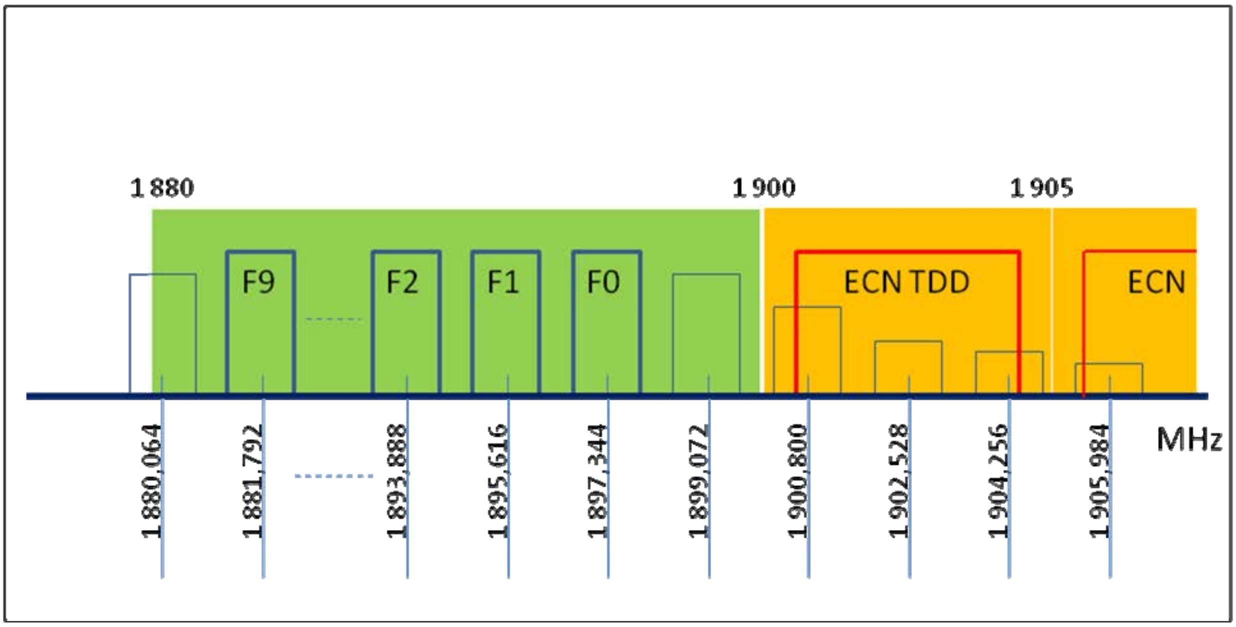


Figure B.1: Positions of DECT carriers and adjacent channels extended outside the DECT band

The carrier spacing is 1,752 MHz and the transmit bandwidth about 1 MHz (1,152 Mbps).

The bandwidth of UMTS, LTE and WiMAX operating in the TDD band 1 900 - 1 905 MHz is supposed to have a bandwidth of about 4 MHz.

In the calculations below a conversion factor of 6 dB (4 times) is used between the bandwidth of DECT and the broadband technologies in the band 1 900 - 1 905 MHz. The approximate figure of 6 dB is accurate enough for the purpose of this study.

B.2 Calculation of ACS for DECT

ACS for DECT is derived by combining clause 6.4 "Radio receiver interference performance" and clause 6.5 "Radio receiver blocking" of EN 300 175-2 [i.12].

<Start of quotation>

"6.4 Radio receiver interference performance

With a received signal strength of -73 dBm (i.e. 70 dBμV/m) on RF channel M, the BER in the D-field shall be maintained better than 0,001 when a modulated, reference DECT interferer of the indicated strength is introduced on the DECT RF channels shown in Table 4.

Table 4: Radio interference performance

Interferer on RF channel "Y":	*Interferer signal strength (dBμV/m)*	*(dBm)*
Y = M	*59*	*-84*
Y = M ± 1	*83*	*-60*
Y = M ± 2	*104*	*-39*
Y = any other DECT channel	*110*	*-33*
NOTE: The RF carriers "Y" shall include the three nominal DECT RF carrier positions immediately outside each edge of the DECT band.		

<End of quotation>

ACS (N[th] adj. ch.) = Interferer signal strength (Y = M) - Interferer signal strength (Y = M + N).

C/I = Received signal strength - Interferer signal strength (Y = M) = -73 + 84 = 11 dB.

Table B.1 shows the ACS figures for the first 3 adjacent channels.

Table B.1: ACS for DECT-like interferer

ACS (1st adj. ch.)	24 dB
ACS (2nd adj. ch.)	45 dB
ACS (3rd adj. ch.)	51 dB
ACS (4th adj. ch.)	See below
ACS (5th adj. ch.)	See below

ACS for the 4th adjacent channels is calculated from the blocking requirements.

<Start of quotation>

"6.5 Radio receiver blocking

....

With the desired signal set at -80 dBm, the BER shall be maintained below 0,001 in the D-field in the presence of any one of the signals shown in table 5.

The receiver shall operate on a frequency band allocation with the low band edge F_L MHz and the high band edge F_U MHz.

Table 5: Receiver blocking

Frequency (f)	*Continuous wave interferer level*	
	For radiated measurements dB μV/m	*For conducted measurements dBm*
25 MHz $\le f < F_L$ - 100 MHz	*120*	*-23*
F_L - 100 MHz $\le f < F_L$ - 5 MHz	*110*	*-33*
$/f - F_C/ >$ 6 MHz	*100*	*-43*
F_U + 5 MHz $< f \le F_U$ + 100 MHz	*110*	*-33*
F_U + 100 MHz $< f \le$ 12,75 GHz	*120*	*-23*

For the basic DECT frequency band allocation FL is 1 880 MHz and FU is 1 900 MHz. Receivers may support additional carriers, e.g. up to FU = 1 920 MHz."

<End of quotation>

Thus for F_U = 1 900 MHz the blocking level -33 dBm applies for the frequency range 1 905 MHz < f ≤ 2 000 MHz.

The blocking figure -33 dBm can be translated into an ACS figure:

ACS (1 905 MHz) = Blocking level - Desired signal + C/I = -33 + 80 + 11 = 58 dB.

Related to the DECT carrier F0, 1 905 MHz falls between the 4^{th} and 5^{th} adjacent carrier.

Thus it is possible to complement the ACS above table for the 4^{th} and 5^{th} adjacent carrier, where the figure for the 4^{th} adjacent carrier is derived through best guess interpolation:

Table B.2: ACS for DECT-like interferer

Adjacent channel #	**ACS**
1^{st} adj. ch	24 dB
2^{nd} adj. ch.	45 dB
3^{rd} adj. ch.	51 dB
4^{th} adj. ch.	55 dB
5^{th} & higher adj. ch.	58 dB

Table B.2 formally applies for DECT carrier F0, but at 1 905 MHz, just 5 MHz outside of the DECT band, the main attenuation comes from the IF-filter, and very little from the RF-filter, and thus the table is supposed to be relevant for all DECT carriers F0 to F9.

The next step is to relate the DECT ACS table to a broadband adjacent interferer with about 4 MHz bandwidth operating on the block 1 900 - 1 905 MHz. As an approximation the ACS related to a 4 MHz interferer is calculated as the sum of the weighted average linear attenuation (times not dB) of the three adjacent channels falling within the 4 MHz interfering channel (the centre channel is given the weight 0,5 and the two other channels the weight 0,25). Figure B.2 shows the three adjacent channels that should be used, depending on the interfered DECT carrier FX, X = 0, 1, …, 9.

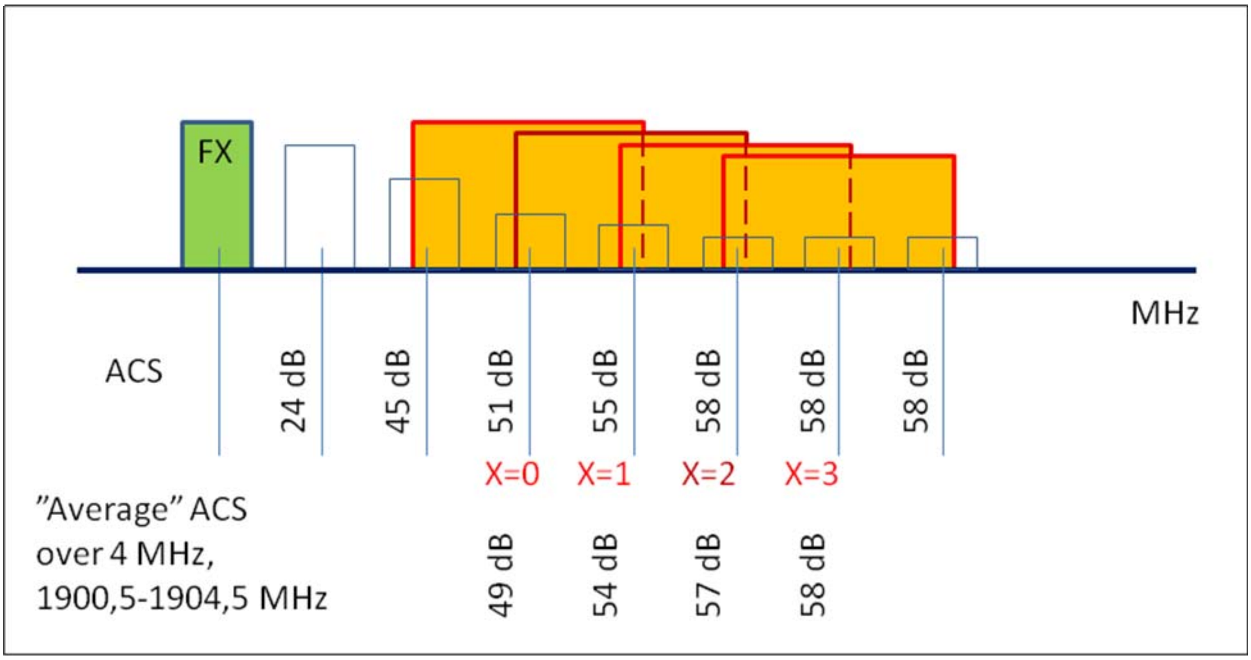


Figure B.2: Estimated ACS related to a 4 MHz wide interferer at 1 902,5 MHz, for DECT carriers F0-F9

The DECT ACS related to a 4 MHz interferer in the block 1 900 - 1 905 MHz becomes:

Table B.3: DECT ACS for a 4 MHz interferer within 1 900,5 - 1 904,5 MHz

DECT Carrier	ACS	Interference level for 3 dB desensitization
F0	49 dB	-54 dBm
F1	54 dB	-49 dBm
F2	57 dB	-46 dBm
F3 - F9	58 dB	-45 dBm

The power level of the interferer within the band 1 900 - 1 905 MHz is related to 3 dB desensitization of the DECT receiver, which corresponds to -103 dBm (= noise level).

B.3 Calculation of ACLR for DECT

ACLR for DECT is derived from clause 5.5.1 "Emissions due to modulation" of EN 300 175-2 [i.12]:

<Start of quotation>

Table B.4: Emissions modulation

Emissions on RF channel « Y »	*Maximum power level*
Y = M ± 1	*160 µW*
Y = M ± 2	*1 µW*
Y = M ± 3	*80 nW*
Y = any other DECT channel	*40 nW*
NOTE: For Y = "any other DECT channel", the maximum power level shall be less than 40 nW except for one instance of a 500 nW signal.	

<End of quotation>

The above power level measurements are made with 1 MHz bandwidth.

The DECT transmit power is 250 mW or 24 dBm.

From the table above, we derive the following ACLR figures.

Table B.5: ACLR for DECT (in 1 MHz channels)

Adjacent Channel No	Maximum power level	ACLR
1st	160 µW or -8 dBm	32 dB
2nd	1 µW or -30 dBm	54 dB
3rd	80 nW or -41 dBm	65 dB
4th and higher	40 nW or -44 dBm	68 dB

When the victim is UMTS, or any other technology, with a receive filter band approximately 1 900,5 - 1 904,5 MHz, an "average" ACLR (times and not dB) should be estimated from the ACLR of the three adjacent DECT channels which, depending on DECT carrier number FX, fall within the band 1 900,5 - 1 904,5 MHz. (The "average" is estimated by weighting the middle channel by a factor 0,5 and the other channels by a factor 0,25).

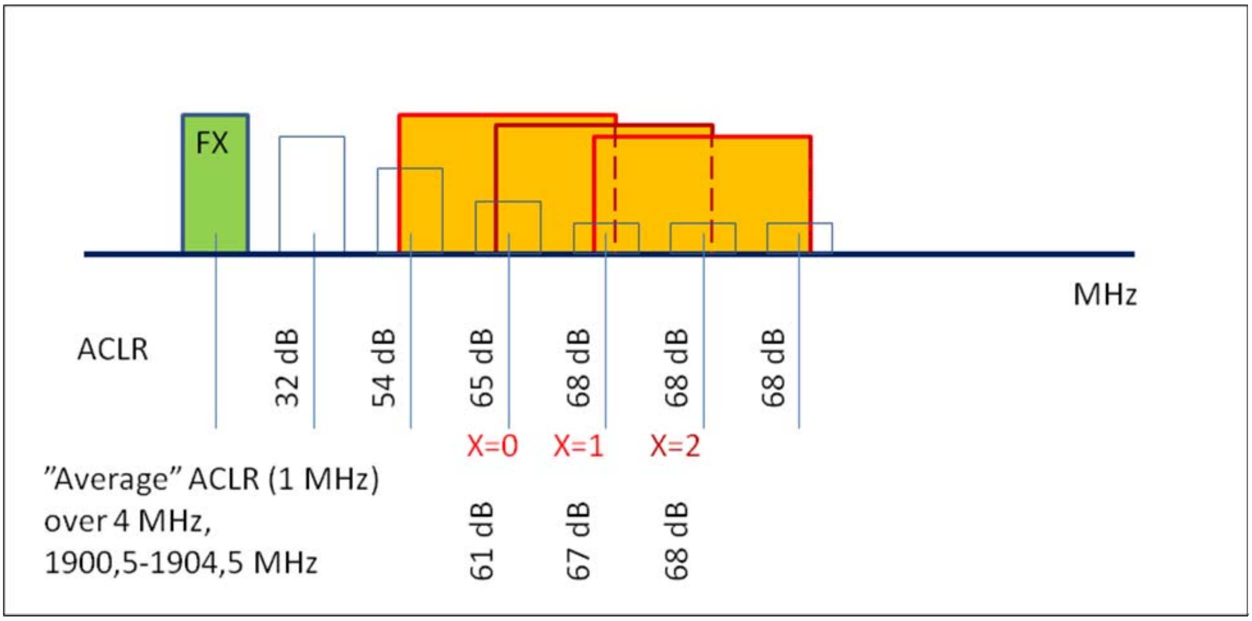


Figure B.3: Estimated ACLR (1 MHz) figures for DECT carriers F0 to F9, averaged over a receive channel 1 900,5 - 1 904,5 MHz

Thus the ACLR for different DECT carriers F0-F9 averaged over the band 1 900,5 - 1 904,5 MHz becomes as shown in table B.6.

Table B.6: DECT ACLR for a victim with a receive filter band 1 900,5 - 1 904,5 MHz

DECT Carrier	Average ACLR (1 MHz bandwidth)	ACLR (4 MHz bandwidth)	Maximum power level (4 MHz bandwidth)
F0	61 dB	55 dB	800 nW or -31 dBm
F1	67 dB	61 dB	200 nW or -37 dBm
F2 -F9	68 dB	62 dB	160 nW or -38 dBm

B.4 Maximum allowable interfering signal level for DECT and proper propagation models for DECT indoor scenarios

The thermal noise floor for DECT is -114 dBm. A noise figure of 11 dB gives a receiver noise level of -103 dBm. The maximum allowable interfering signal level for DECT is -103 dBm/MHz for 3dB desensitization of the DECT receiver.

As written in CEPT Report 19 [i.18] section 5.6.3:

> *"In order to provide an appropriate protection level to DECT system from adjacent band WAPECS systems, it is proposed to use the typical receiver sensitivity of -93 dBm (measured as a maximum total power within any bandwidth of 1.152 MHz) plus a margin of 10dB (leading to -103 dBm) as the upper limit for out of band emissions for the adjacent frequencies to the band 1880 to 1900 MHz ensuring a sufficient protection level of DECT."*

Note that the receiver sensitivity requirement of EN 300 175-2 [i.12] is only -83 dBm, (which can lead to confusion when deriving ACS figures from e.g. the DECT blocking requirements). The -83 dBm level was many years ago thought relevant to allow cost efficient design of a price sensitive consumer product at 2 GHz. But since the range had to be comparable to analogue cordless phones at 900 MHz, DECT manufacturers very early succeeded to make cost efficient DECT phones with -93 dBm sensitivity, which is the industry standard since then.

A receiver noise floor of -103 dBm, and a C/(I + N) of 21 dB should be used for DECT for normal fading indoor environments.

For the enterprise applications, a model based on measurements in a rather modern multi store office building is proposed (see [i.19] figure 3c). The model has the base station in the corridor and the users in surrounding rooms. A correction factor of 8 dB has been used to relate the 5 GHz measurements to 2 GHz. The propagation loss L has for the purpose of the present document been approximated to:

$$L = 38 + 30\log(d) \text{ [dB]},$$

where d is the distance in meters.

This formula is relevant for $d \geq 4$ m, since some kind of wall is in the path.

For $d < 4$ m "line-of-sight" $L = 38 + 20\log(d)$ applies.

This model is feasible to be used also for residential systems.

B.5 ACLR and ACS for broadband technologies (UMTS, LTE and WiMAX) operating on the band 1 900 - 1 905 MHz

ACLR and ACS for the broadband technologies are calculated below, related to the DECT carriers F0-F9. Table B.7 shows the frequency separation between DECT carriers and the broadband centre carrier 1 902,5 MHz as well as between DECT carriers and the band edge frequency 1 900 MHz.

Table B.7: Frequency separation between DECT carriers and the broadband centre carrier 1 902,5 MHz /band edge frequency 1 900 MHz

DECT Carrier	DECT carrier frequency, MHz	Broadband carrier (1 902,5 MHz) to DECT carrier separation, Δf MHz	Band edge (1 900 MHz) to DECT carrier separation, Δf_{OOB} MHz
F0	1 897,344	5,2	2,7
F1	1 895,616	6,9	4,4
F2	1 893,888	8,6	6,1
F3	1 892,160	10,3	7,8
F4	1 890,432	12,1	9,6
F5	1 888,704	13,8	11,3
F6	1 886,876	15,6	13,1

Below the broadband adjacent channel positions are shown in relation to the DECT carriers.

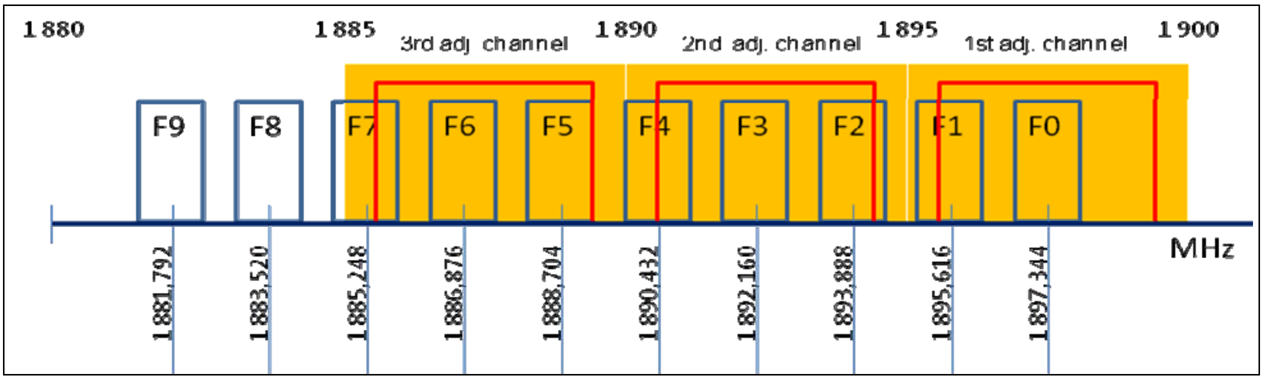


Figure B.4: Broadband adjacent channel positions within the DECT band 1 880 - 1 900 MHz

B.5.1 UMTS TDD 3.84 Mcps option

For UMTS UE transmit power 24 dBm (Power Class 2, see [i.14]) has been selected.
For UMTS BS transmit power 43 dBm has been selected.

B.5.1.1 UMTS TDD ACLR

Table B.8 indicates in bold figures the ACLR figures related to a DECT receiver.

Table B.8: ACLR for UMTS TDD 3,84 Mcps Option

DECT Carrier	UE (24 dBm Tx power)			BS (43 dBm Tx power)		
	OOBE dBm/MHz	ACLR 4 MHz RX	ACLR 1 MHz RX	OOBE dBm/MHz	ACLR 4 MHz RX	ACLR 1 MHz RX
F0	**(-16)**	-	40	**-13 (-35*)**	**-**	56 **(78*)**
F1	**(-20)**	-	44	**-13 (-35*)**	**-**	56 **(78*)**
F2	**-25**	-	49	**(-35*)**	**55 (72*)**	61 **(78*)**
F3	**-25**	-	49	**(-35*)**	**55 (72*)**	61 **(78*)**
F4	**-30**	-	54	**-30 (-35*)**	**67 (72*)**	73 **(78*)**
F5-F9	**-30**		54	**-30**	**67**	73
NOTE: Bold figures relate to DECT receivers.						

For UMTS UE the ACLRs are derived from table 6.5 of [i.14] ("Spectrum Emission Mask Requirement - 3,84 Mcps TDD Option"). The derived ACLR figures are better than the minimum ACLR requirements in table 6.6 of [i.14] ("UE ACRL - 3.84 Mcps TDD Option"), except for F0 and F1, where an estimated correction has been made. OOBE and ACLR figures for F4-F9 are derived from table 6.7A of [i.14] ("General Spurious emissions requirements -3,84 Mcps TDD Option").

For UMTS BS (3,84 Mcps TDD Option) the ACLRs are derived from table 6.3 of [i.13] ("Spectrum emission mask values, BS maximum output power P ≥ 43"). Except for F2-F4, where the OOBE and ACLR are derived from the minimum ACLR requirements as from table 6.7 of [i.13] ("BS ACLR"). For F5-F9, where the OOBE and ACLR are derived from table 6.11 of [i.13] ("BS Mandatory spurious emissions limits, Category B").

Figures with *) relate to unsynchronized UMTS TDD systems on the adjacent channel. See table 6.8 of [i.13] ("Adjacent channel leakage power limits for operation in the same geographic area with unsynchronized TDD on adjacent channels") but may not be relevant for the DECT band. These values are only relevant if the DECT system is an above rooftop WLL system.

B.5.1.2 UMTS TDD ACS

Table B.9 indicates ACS figures related to a DECT transmitter frequencies.

Interference levels below are related to 3 dB UMTS receiver desensitization.

Table B.9: ACS for UMTS TDD 3,84 Mcps Option

DECT Carrier	UE (Interf. Ref. level -99 dBm)		BS (Interf. Ref. level -103 dBm)	
	Interferer dBm	ACS dB	Interferer dBm	ACS dB
F0	-66	33	-57	46
F1	-66	33	-57	46
F2	(-59)	(40)	(-49)	(54)
F3	-56	43	-45	58
F4	-56	43	-45	58
F5	(-49)	(50)	-45	58
F6-F9	-44	55		

The ACS figures are derived from [i.13] and [i.14]. For the BS the column with interferer power has been adjusted to relate to 3 dB UMTS receiver desensitization.

B.5.2 LTE TDD 5 MHz channel bandwidth option

For LTE UE transmit power 23 dBm (see [i.15]) has been selected.
For LTE BS transmit power 43 dBm has been selected.

B.5.2.1 LTE TDD ACLR

Table B.10 below indicates in bold the ACLR figures related to a DECT receiver.

Table B.10: ACLR for LTE TDD 5 MHz Option

DECT Carrier	UE (23 dBm Tx power)			BS (43 dBm Tx power)		
	OOBE dBm/MHz	ACLR 4 MHz RX	ACLR 1 MHz RX	OOBE dBm/MHz	ACLR 4 MHz RX	ACLR 1 MHz RX
F0	**-13**	**30**	36	**-13**	**50**	56
F1	**-13**	**30**	36	**-13**	**50**	56
F2	**-25**	**42**	48	**-13**	**50**	56
F3	**-25**	**42**	48	**-13**	**50**	56
F4-F9	**-30**	**47**	53	**-30**	**67**	73
NOTE: Bold figures relate to DECT receivers.						

For LTE UE 5 MHz option the ACLRs are derived from table 6.6.2.1.1-1 [i.15] ("General E-UTRA spectrum emission mask"), except for F0 and F1 where OOBE and ACLR are derived from the minimum ACLR requirements as from table 6.6.2.3.1-1 of [i.15] ("General requirements for E-UTRA$_{ACLR}$", and F5-F9, where OOBE and ACLR are derived from table 6.6.3.1-2 of [i.15] ("Spurious emissions limits").

For LTE BS 5 MHz option the ACLRs are derived from table 6.6.3.2.1-6 of [i.16] ("General operating band unwanted emission limits for 5, 10, 15 and 20 MHz channel bandwidth (E-UTRA bands > 1GHz) for Category B"), except for F5-F9 where the OOBE and ACLR are derived from table 6.6.4.1.2.1-1 of [i.16] "BS Spurious emissions limits, Category B".

B.5.2.2 LTE TDD ACS

Table B.11 indicates ACS figures related to a DECT transmitter frequencies. Interference levels below are related to 3 dB LTE receiver desensitization.

Table B.11: ACS for LTE TDD 5 MHz Option

DECT Carrier	UE (Interf. Ref. level -95,4 dBm)		BS (Interf. Ref. level -102,4 dBm)	
	Interferer dBm	ACS dB	Interferer dBm	ACS dB
F0	-62,4	33	-56,4	46
F1		33		46
F2		33		46
F3				
F4				
F5-F9				

The ACS figures are derived from [i.15] and [i.16]. The columns with interferer power have been adjusted to relate to 3 dB LTE receiver desensitization.

B.5.3 WiMAX TDD

For WiMAX UE transmit power 23 dBm (see [i.17]) has been selected.
For WiMAX BS transmit power 43 dBm has been selected.

B.5.3.1 WiMAX TDD ACLR

Table B.12 indicates in bold the ACLR figures related to a DECT receiver.

Table B.12: ACLR for WiMAX TDD 5 MHz Option

DECT Carrier	UE (23 dBm Tx power)			BS (43 dBm Tx power)		
	OOBE dBm/MHz	ACLR 4 MHz RX	ACLR 1 MHz RX	OOBE dBm/MHz	ACLR 4 MHz RX	ACLR 1 MHz RX
F0	**-13**	**30**	36	**-13**	**50**	56
F1	**-13**	**30**	36	**-13**	**50**	56
F2	**-25**	**42**	48	**-13**	**50**	56
F3	**-27**	**44**	50	**-13**	**50**	56
F4-F9	**-30**	**47**	53	**-30**	**67**	73
NOTE: Bold figures relate to DECT receivers.						

For WiMAX UE 5 MHz option the OOBE and ACLRs are derived from the ACRL figures in table 2 of [i.17] ("Parameters for 1800 MHz Band"), except for F2 where OOBE and ACLR are derived from table 3 of [i.6] ("MS Spectrum Emission Mask"), and F5-F9, where OOBE and ACLR are derived from table 6 of [i.6] ("Spurious Emission for MS (1800 MHz)").

For WiMAX UE 5 MHz option the OOBE and ACLRs are derived from table 4 of [i.17] ("BS Spectrum Emission Mask - Europe"), except for F5-F9, where OOBE and ACLR are derived from table 10 of [i.17] ("Spurious Emission for BS (1800 MHz)"). The derived ACLR figures are better or equal to the minimum ACLRs specified in table 2 of [i.17] ("Parameters for 1800 MHz Band").

B.5.3.2 WiMAX TDD ACS

Table B.13 indicates ACS figures related to a DECT transmitter frequencies.

Interference levels below are related to 3 dB WiMAX receiver desensitization.

Table B.13: ACS for WiMAX TDD 5 MHz Option

DECT Carrier	UE (Interf. Ref. level -99 dBm)		BS (Interf. Ref. level -102 dBm)	
	Interferer dBm	ACS dB	Interferer dBm	ACS dB
F0	-66	33	-56	46
F1		33		46
F2		(42)		(53)
F3	-52	47	-46	56
F4		47		56
F5		47		56
F6-F9		(47)		(56)

The ACS figures are derived from [i.17]. The columns with interferer power have been adjusted to relate to 3 dB LTE receiver desensitization.

B.5.4 Summary of out of band emissions from UMTS, LTE and WiMAX

Out-of-band emissions from UMTS, LTE and WiMAX are shown in table B.14.

Table B.14: Comparison of OOBE figures of UMTS TDD, LTE and WiMAX

DECT Carrier	TS OOBE dBm/MHz			BS OOBE dBm/MHz Tx 43 dBm		
	UMTS Tx 24 dBm	LTE Tx 23 dBm	WiMAX Tx 23 dBm	UMTS Tx 43 dBm	LTE Tx 43 dBm	WiMAX Tx 43 dBm
F0	-16**	-13**	-13	-13 (-35*)	-13	-13
F1	-20**	-13**	-13	-13 (-35*)	-13	-13
F2	-25	-25	-25	-18 (-35*)	-13	-13
F3	-25	-25	-27	-18 (-35*)	-13	-13
F4-F9	-30	-30	-30	-30	-30	-30
NOTE 1: *) These figures relate to unsynchronized UMTS TDD systems on the adjacent channel.						
NOTE 2: **) Derived from ACLR.						

History

Document history		
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