



TECHNICAL REPORT

**Integrated broadband cable and telecommunication networks
(CABLE);
Characteristics of Evolving Electromagnetic Environment with
ECN800 parameters and Cable Network Equipment**

Reference

DTR/CABLE-00002

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Foreword

This Technical Report (TR) has been produced by ETSI Technical Committee Integrated broadband cable telecommunication networks (CABLE).

Modal verbs terminology

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1 Scope

The present document describes the current and evolving electromagnetic environment following introduction of new radio services in the digital dividend UHF frequency band from 790 MHz to 862 MHz. It compares and contrasts relevant parameters against the current and evolving cable network equipment parameters defined by adopted European Norms.

2 References

2.1 Normative references

Normative references are not applicable in the present document.

2.2 Informative references

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

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

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

- [i.1] CEPT Report 30: "The identification of common and minimal (least restrictive) technical conditions for 790 - 862 MHz for the digital dividend in the European Union", November 2009.
- [i.2] CEPT Report 31: "Frequency (channelling) arrangements for the 790-862 MHz band", November 2009.
- [i.3] CENELEC EN 50083-2:2012: "Cable networks for television signals, sound signals and interactive services - Part 2: Electromagnetic compatibility for equipment".
- [i.4] CENELEC EN 50083-8:2013: "Cable networks for television signals, sound signals and interactive services - Part 8: Electromagnetic compatibility for networks".
- [i.5] CENELEC EN 50117: "Coaxial Cables".
- [i.6] CENELEC EN 55013:2013: "Sound and television broadcast receivers and associated equipment - Radio disturbance characteristics - Limits and methods of measurement".
- [i.7] CENELEC EN 55020:2007/A11:2011: "Sound and television broadcast receivers and associated equipment - Immunity characteristics - Limits and methods of measurement".
- [i.8] CENELEC EN 55022:2010/AC:2011: "Information technology equipment - Radio disturbance characteristics - Limits and methods of measurement".
- [i.9] CENELEC EN 55024:2010/A1:2015: "Information technology equipment - Immunity characteristics - Limits and methods of measurement".
- [i.10] CENELEC EN 61000-4-3:2006/A1:2008/A2:2010: "Electromagnetic compatibility (EMC) - Part 4-3: Testing and measurement techniques - Radiated, radio-frequency, electromagnetic field immunity test".
- [i.11] ETSI EN 300 429 (V1.2.1) (04-1998): "Digital Video Broadcasting (DVB); Framing structure, channel coding and modulation for cable systems".
- [i.12] ETSI TR 103 288: "Electromagnetic compatibility and Radio spectrum Matters (ERM); Report of the CENELEC/ETSI Joint Working Group in response to the EC letter ENTRP/F5/DP/MM/entr.f5.(2013)43164 to the ESOs".

- [i.13] Recommendation ITU-R F.1336 (02-2014): "Reference radiation patterns of omnidirectional, sectoral and other antennas for the fixed and mobile service for use in sharing studies in the frequency range from 400 MHz to about 70 GHz".
- [i.14] G531/01077/09: "Measurement Report: Immunity of integrated TV receivers, settop boxes and data-modems connected to broadband cable and TV networks against radiation from LTE user equipment", January 2010, Federal Network Agency Germany.
- [i.15] "NorDig Unified Requirements for Integrated Receiver Decoders for use in cable, satellite, terrestrial and IP-based networks", August 2014.
- NOTE: Available at <http://www.nordig.org/specifications>.
- [i.16] D-Book 8: "Digital Terrestrial Television Requirements for Interoperability", March 2015, Digital Television Group (DTG).
- [i.17] ECC/DEC/(09)03: "ECC Decision of 30 October 2009 on harmonised conditions for mobile/fixed communications networks (MFCN) operating in the band 790 - 862 MHz", October 2009.
- [i.18] Commission Decision 2010/267/EU: "Commission Decision of 6 May 2010 on harmonised technical conditions of use in the 790-862 MHz frequency band for terrestrial systems capable of providing electronic communications services in the European Union", May 2010.
- [i.19] CEPT ERC Recommendation 74-01: "Unwanted emissions in the spurious domain", January 2011.
- [i.20] Recommendation ITU-R P.1546-5: "Method for point-to-area predictions for terrestrial services in the frequency range 30 MHz to 3 000 MHz", September 2013.

3 Symbols and abbreviations

3.1 Symbols

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

d	Distance
dB	Decibel
dB(μ V)	Decibel with reference to 1 μ V
dB(μ V/m)	Decibel with reference to 1 μ V/m
dBm	Decibel with reference to 1 mW
E	Electrical Field Strength
m	Meter
Mbit/s	Megabit per second
MHz	Megahertz
ms	Millisecond
mW	Milliwatt
P	Power
V/m	Volt per Meter
W	Watt

3.2 Abbreviations

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

3GPP	Third Generation Partnership Project
AM	Amplitude Modulation
APT	Asia-Pacific Telecommunity
ASMG	Arab Spectrum Management Group
ATU	African Telecommunications Union
BEM	Block Edge Mask
BS	Base Station
BTS	Base Transmitter Station

CATV	Community (Cable) Antenna Television
CEN	European Committee for Standardization
CEPT	European Conference of Postal and Telecommunications Administrations
CISPR	International Special Committee on Radio Interference
CITEL	Inter-American Telecommunication Commission
CPE	Customer Premises Equipment
DIN	German Industrial Norm
DKE	German Electrotechnical Commission
DL	DownLink
DTT	Digital Terrestrial Television
DVB	Digital Video Broadcasting
DVB-C	Digital Video Broadcasting - Cable
DVB-T	Digital Video Broadcasting - Terrestrial
ECC	Electronics Communications Committee (CEPT)
ECN	Electronic Communications Network
EIRP	Equivalent Isotropic Radiated Power
EMC	ElectroMagnetic Compatibility
EN	European Norm
ERC	European Radiocommunications Committee
ERP	Effective Radiated Power
ESO	European Standards Organization
EU	European Union
FDD	Frequency Division Duplex
FM	Frequency Modulation
FTTx	Fiber-To-The-x
GSM	Global System for Mobile Communication
HFC	Hybrid Fiber-Coax
IEC	International Electrotechnical Commission
IF	Intermediate Frequency
ITU	International Telecommunications Union
JTG	Joint Task Group
JWG	Joint Working Group
LTE	Long-Term Evolution
MFCN	Mobile/Fixed Communication Network
MNO	Mobile Network Operator
PAL	Phase Alternating Line
QAM	Quadrature Amplitude Modulation
QPSK	Quadrature Phase Shift Keying
RF	Radio Frequency
RX	Receiver
SDO	Standards Developing Organizations
SIR	Signal-to-Interference Ratio
SMS	Short Message Service
STB	Set-Top Box
TC	Technical Committee
TDD	Time Division Duplex
TRP	Total Radiated Power
TV	TeleVision
TX	Transmitter
UE	User Equipment
UHF	Ultra High Frequency
UL	Uplink
UMTS	Universal Mobile Telecommunications System
VCR	Video Cassette Recorder
WG	Working Group
WRC	World Radio Conference

4 General principles of HFC and LTE co-existence

4.1 Technical considerations

4.1.1 Radio frequency usage

For many decades the UHF spectrum between 470 MHz and 862 MHz was used for terrestrial and cable broadcast TV distribution. It was decided to use 8 MHz channels in the UHF spectrum. The relevant portion of the channel raster is displayed in Figure 1. The same frequency spectrum is used by terrestrial broadcasting over the air as well as by RF cable systems in a wired network. Co-existence is enabled by establishing a set of standards defining appropriate requirements for the separation of the wired transmission from its electromagnetic environment.

With the more efficient usage of the spectrum by digital television, the terrestrial service portfolio can be maintained by using fewer frequency resources. The parts of the spectrum becoming available for alternative use are known as the Digital Dividend. Resulting from the decisions of the ITU World Radiocommunication Conference (WRC) 2007 with regard to the future usage of the Digital Dividend many European countries are in the course of or have completed the reorganization of the relevant spectrum. Decisions by CEPT e.g. on the allotted bandplan in the 800 MHz band were taken with the aim to minimize impact on the Customer Premises Equipment (CPE). The idea was that a base transmitter station was expected to not have an impact to the disturbance situation to the same extent as UE.

For example, the German government decided to make available the frequency range from 790 MHz to 862 MHz for mobile broadband Internet in Germany while the usage for terrestrial broadcasting services ceases. The main difference resulting for the electromagnetic environment compared to the previous usage by broadcast services is the presence of radio signals in up- and downlink in close proximity to broadcasting CPE. Previously, there were no transmitters close to TV sets or other CPE like cable modems, VCRs or set-top boxes.

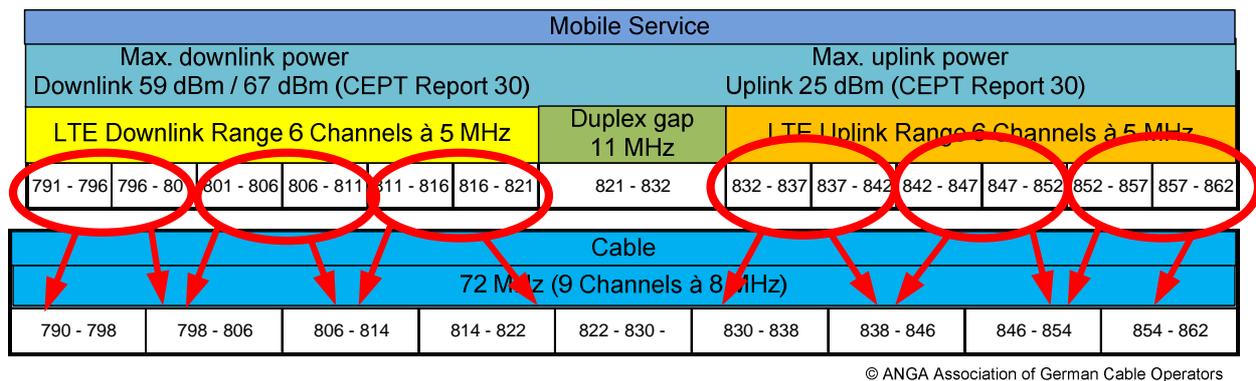


Figure 1: Co-Channel situation with the frequency assignment for new mobile services against the broadcast UHF channel raster

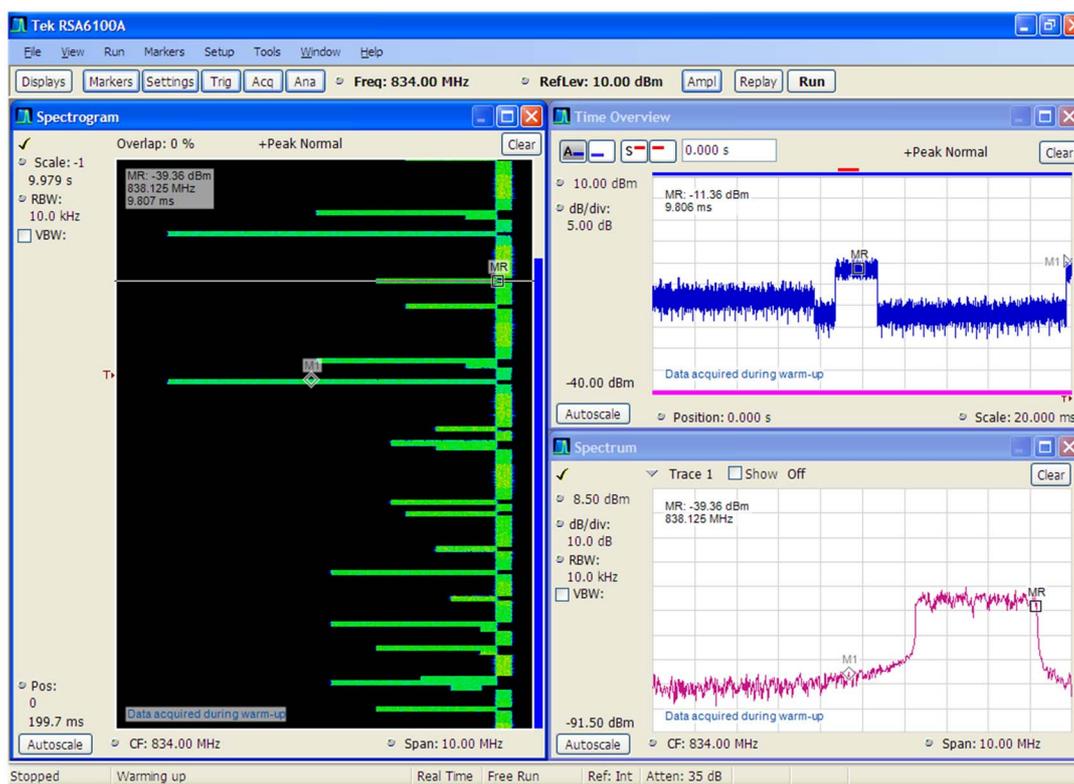
4.1.2 Reference signals for assessing co-existence

While the broadcast signals used in terrestrial and cable networks are well defined and exhibit fairly stable characteristics over time, LTE signals are highly variable and practical experience is still limited. Therefore, it is essential to define a set of reference signals that can be used consistently when assessing co-existence between LTE and cable. The reference signals should reflect specific characteristics of actual LTE transmissions as close as possible. In the present document, LTE UE uplink signals are considered when uploading and when idle. The focus on UE generated signals is following the principle as described in the previous Clause that the UE is expected to be the major source of potential disturbance.

The structures of the RF signals as they are transmitted by LTE UEs are shown in the figures 2 and 3. The highly variable nature of the signal is depicted by choosing two operational modes (i.e. upload and idle) that are resulting in significantly different signal shapes and spectral distribution of transmit power. The figures show the signal format in the time as well as in the frequency domain. These signal structures were used for the common measurements in Kolberg, Germany [i.14]. Participants from the German regulator BNetzA, mobile operators, cable operators and TV manufacturers agreed on the definition of the reference signals. The group used a 10 MHz UE (i.e. mobile terminal) signal.

Figure 2 shows the UE signal measured with a real time spectrum analyser. The shown signal is a multicarrier signal with a bandwidth of 10 MHz. The spectrogram (left portion of Figure 2) shows an actual capture of a LTE UE signal over 200 ms (y-Axis). Transmit power encoded in colours (blue - low power; red - high power) is distributed across time and frequency. The occupied Resource Blocks (unit of scheduling) are clearly visible across the frequency axis (x-Axis). The UE signal occupies different parts of the channel over time during a transmission.

The signal definition is based on a capture of a 2 Mbit/s upload from a UE in a live LTE 800 network. For the measurement campaign this signal was mapped for the use with a commercially available programmable LTE signal generator. Table 1 shows the statistical evaluation of the recorded LTE signal (2 Mbit/s upload) which was used in Figure 2. The widest allocation of Resource Blocks occupies 8,25 MHz but is only used 3 % of the time. This is despite the fact that the signal is configured for a 10 MHz channel.



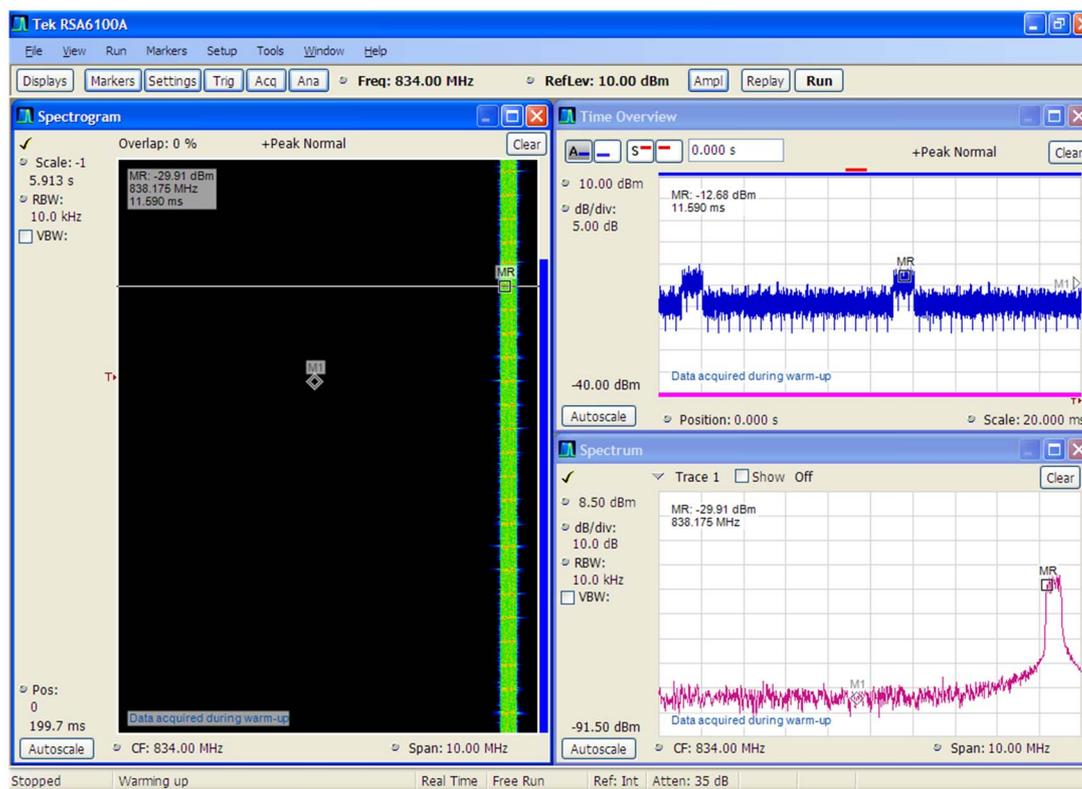
NOTE: Time span of spectrogram is 200 ms.

Figure 2: LTE signal (2 Mbit/s upload, generated by signal generator)

Table 1: Statistics of a LTE signal (2 Mbit/s upload) recorded at a live LTE 800 network

Time resolution:	1 ms	Counts	Probability
Total frames:		200	100,0 %
Width > 1:		37	18,5 %
Block width 0:	0,36 MHz	163	81,5 %
Block width 1:	1,00 MHz	6	3,0 %
Block width 2:	2,10 MHz	3	1,5 %
Block width 3:	3,20 MHz	6	3,0 %
Block width 4:	4,40 MHz	3	1,5 %
Block width 5:	5,00 MHz	7	3,5 %
Block width 6:	5,70 MHz	6	3,0 %
Block width 7:	7,10 MHz	0	0,0 %
Block width 8:	8,25 MHz	6	3,0 %

Figure 3 shows a mapped version of a real measured idle signal which is used in live LTE 800 networks. Only a small number of resource blocks is used for the transmission of management information in idle mode. The signal captured in a live LTE 800 network was mapped for the use with a commercially available programmable LTE signal generator.



NOTE: Time span of the spectrogram is 200 ms.

Figure 3: LTE signal (idle mode with control channel only)

4.2 Scheme of Harmonised Standards

HFC networks and their components are developed against international standards, Harmonised European standards and other European standards. The most relevant aspect for this report is the electromagnetic compatibility. Figure 4 depicts a high-level view on the architecture of current cable networks and identifies the European Harmonised Standards and the portions of the network they apply to as well as the modulation and channel coding given by ETSI EN 300 429 [i.11].

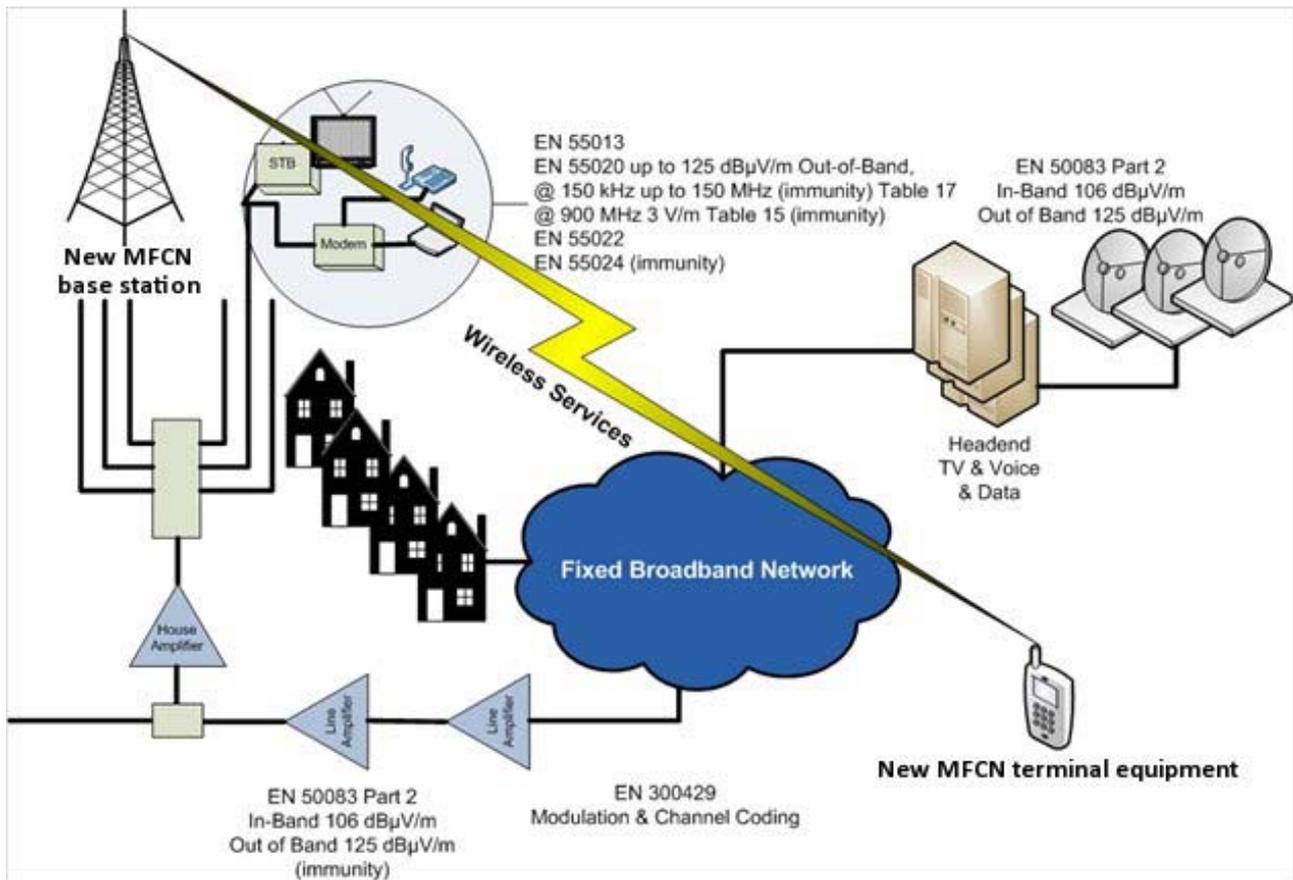


Figure 4: Relevant standards for emission of and immunity against electromagnetic field strength in HFC networks and attached equipment

Standards play a key role in establishing interoperability among devices but also in addressing regulatory and co-existence requirements. Particularly in the area of radio frequency co-existence and electromagnetic compatibility (EMC) a complex structure of various organizations on international and European level has evolved with the goal to appropriately take into account all relevant interests. In many cases, the establishment of joint activities (e.g. Joint Working Groups between CENELEC and ETSI) has been necessary in order to efficiently align various interests and develop technical deliverables. Figure 5 depicts the relation between international and European organizations when defining the electromagnetic environment. It is influenced by both, users of the radio frequency spectrum in free space as well as operators of RF modulated signals guided in wires.

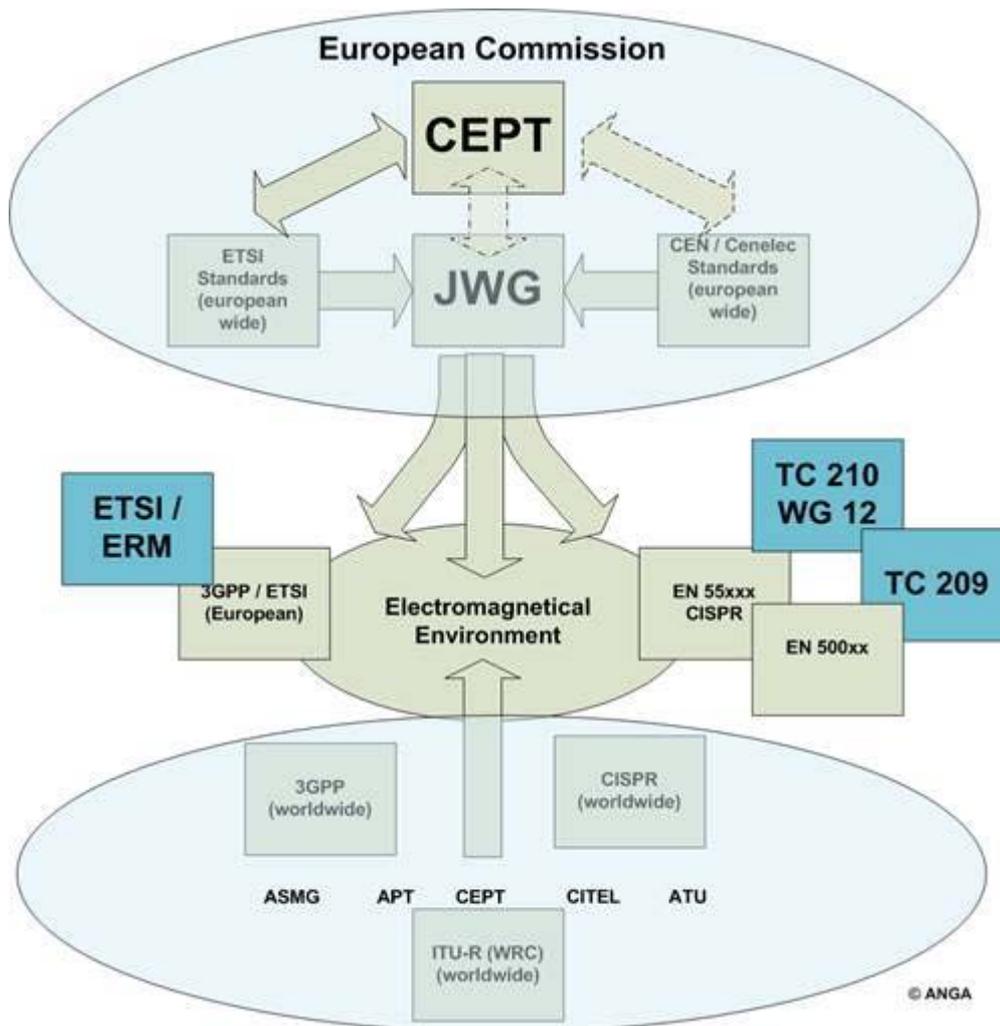


Figure 5: Relation of European and international standardization in the context of frequency co-existence and EMC

The usage of the radio frequency spectrum is defined and coordinated on a worldwide scale by ITU-R. Regularly, assignment of spectrum and other radio regulations are reviewed by the World Radio Conference (WRC). Various regional spectrum managing organizations (e.g. ASMG, APT, CEPT, CITEL, ATU) are contributing their requirements to WRC and coordinate cross-regional issues. Technical conditions for the usage of the frequency spectrum such as signal levels and out-of-band behaviour are technology dependent and are defined worldwide by technology standardization organizations such as 3GPP and CISPR. While ETSI is one of the organizational partners within 3GPP it does not have a special role in 3GPP's standardization process.

On a European level, the electromagnetic environment is first and foremost defined by regulatory decisions of the European Commission and by the agreements developed within CEPT. Technical details are defined by the ESOs CENELEC and ETSI which are engaging in joint work if appropriate. The function of ETSI in the European standardization scheme including its close coordination with CEPT should not be mixed up with ETSI's role in 3GPP.

Regulatory decisions on spectrum usage and technology specifications for wireless and wired communication systems define an electromagnetic environment. Additional specifications are required to ensure that all contributors to that electromagnetic environment are prevented from causing interference to each other while at the same time using the radio frequency spectrum efficiently. For wireless technologies this is specified as frequency co-existence, for wired technologies this is ElectroMagnetic Compatibility (EMC).

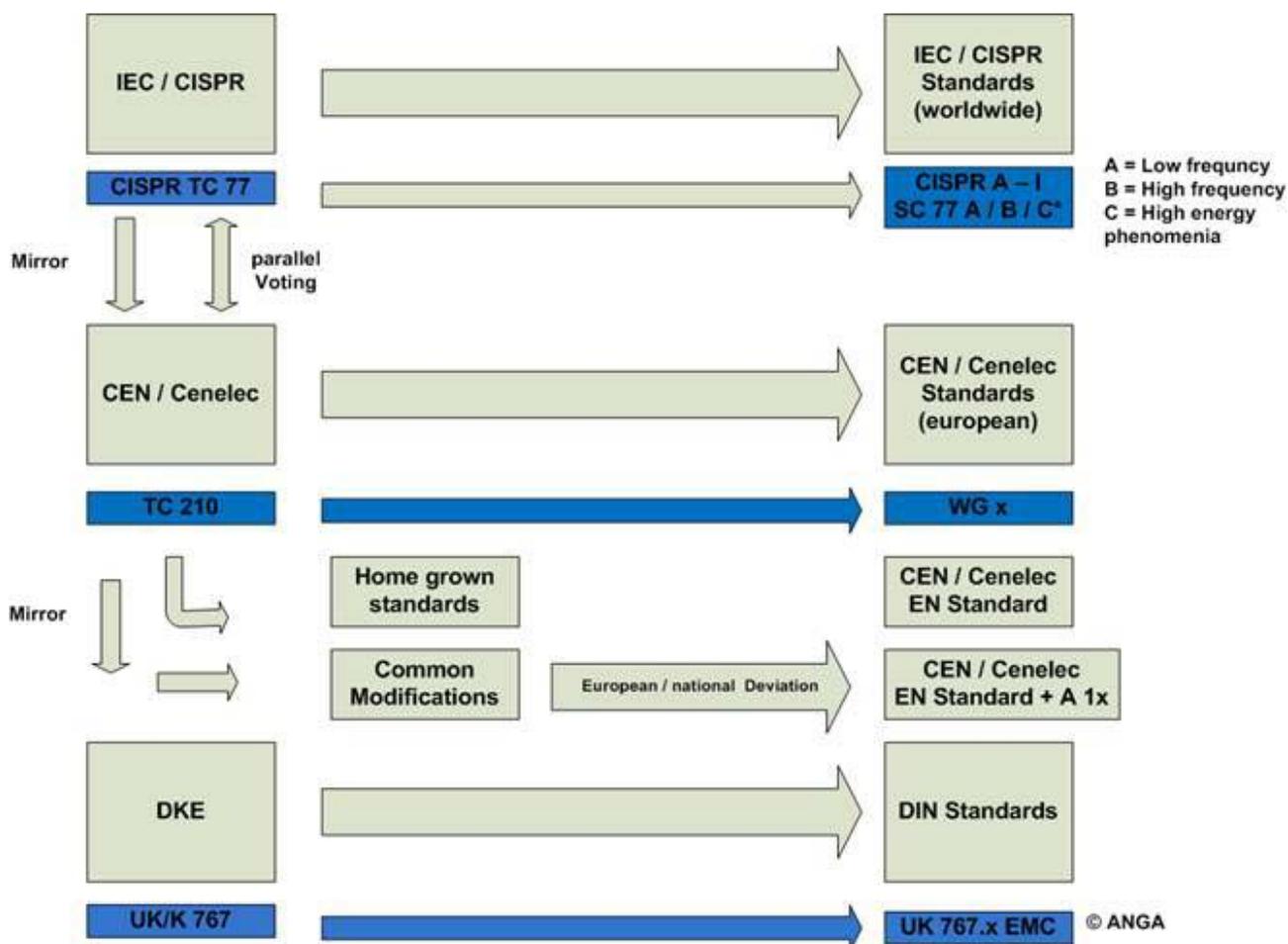


Figure 6: Process of EMC standardization (with German National Committee as example)

Figure 6 explains the process of developing globally applicable requirements for EMC. Taking the German National Committee as an example, the existence of mirror committees on international, European and national level ensures that requirements are aligned. The process demonstrates that the definition of requirements for EMC limited to the European context may be rendered useless if international agreements (e.g. APT band plan) cause changes to the electromagnetic environment in the global context.

Standardization in general enables the development of interoperable products which fosters the adoption in a wide market with the resulting economies of scale. However, to be compliant with a technical standard is the choice of the implementor. A manufacturer is free to choose to implement a standard if it is appropriate for the intended purpose of the product or its area of application. This choice may, particularly, be driven by the need to interoperate with products from other manufacturers or by customer requirements. But in principle, the application of a standard is voluntary.

In the system of European Standards Organizations (ESO) there is a notable exception to that principle. By developing Harmonized Standards, the ESOs CEN, CENELEC and ETSI play a key role in supporting European regulation and, thus, creating a single European market. The requirements for access to European markets of products and services in information and communication technology are harmonized by the European Commission via European Directives, Regulations and Decisions which are enforced by legislation. A Harmonized Standard is a technical standard that provides the technical detail necessary to conform to the 'essential requirements' as defined by the European regulatory documents. By complying to a Harmonized Standard, manufacturers and suppliers can demonstrate conformity with the relevant regulation which is a sufficient condition to make available products and services on the European market. A technical standard becomes a Harmonized Standard by listing it in the Official Journal of the European Union against the relevant European Directive.

5 Evolution of the electromagnetic environment due to Digital Dividend

5.1 History of ECN user equipment (UE)

Mobile communication technologies are ubiquitously available in virtually all populated parts of the world. An ever increasing number of users, demand on transmission capacity and feature capabilities of the terminal equipment have lead to an extension of spectrum usage from generation to generation of mobile technologies. With the usage of other frequency bands taking into account its varying physical transmission characteristics and the higher density of users more and more sophisticated mechanisms for spectrum access and frequency co-existence had to be developed. Also the consideration of the impact of electromagnetic fields on the human body have led to changes in the technology.

Current mobile terminals have evolved from the first generation of digital user equipment using GSM technology operating on the 900 MHz band. A typical transmission power capability of the first generation mobile terminal has been in the range of 2 W. GSM extended its frequency usage into the 1,8 GHz band with transmission power in the 1 W range. With UMTS, the 2,1 GHz has been introduced. Smaller cell sizes and other advancements allowed to reduce transmission power to 0,2 W. Since the licensed bands for cellular technologies has been well outside the frequency bands assigned to traditional wireless communication technologies such as television, issues of frequency co-existence and EMC have been very limited.

With regard to the services, there has been an evolution from voice telephony with limited additional services such as SMS to voice telephony with significant data communication capabilities towards technologies focusing on data communication such as LTE. Regulators have accommodated the introduction of more and more technologies and services by migrating from technology and service specific spectrum licensing to service and technology neutral assignment of frequencies as long as all technologies are observing common technical conditions.

5.2 ECN user equipment in the 800 MHz band

With the decision to make available the frequency range from 790 MHz to 862 MHz for mobile communication networks on a co-primary basis by the WRC and subsequent regional and national decisions, the electromagnetic environment has, fundamentally, changed. The newly assigned frequency band overlaps with the TV broadcasting band which is used for terrestrial transmission and communal aerial systems with a large legacy market in Europe and is widely implemented in RF modulated wired networks such as RF cable communication systems.

The key characteristic of a UE when analysing its impact on the electromagnetic environment is its transmission power and signal formats. For the 800 MHz band, technical conditions require the terminal output power to be limited to 23 dBm (+ 2 dB) (TRP). The actual transmit power will be highly variable and depend on the current link budget. It will be in the range between 0 dBm (outdoor close to base station) and the maximum limit as allowed by the technical conditions for use of the band. A typical scenario that has been identified by mobile operators and is documented in contributions and deliverables of various working groups, e.g. ETSI TR 103 288 [i.12], applies a UE transmit power of 14 dBm on average.

Relevant parameters such as UE transmit power are determined by typically applied operational values. Therefore, when assessing co-existence between LTE and cable, actual deployment scenarios should be considered.

5.3 ECN base transmitter stations (BTS) in the 800 MHz band

While the user equipment has been identified as the main potential source of interference due to its un-deterministic behaviour in terms of transmit power and location and due to the number of devices likely to be located in close proximity to other users of the radio frequencies, also base transmitter stations (BTS) will have an impact on the electromagnetic environment.

According to harmonized regulatory requirements, a BTS is limited in its transmission power to a range between 56 dBm in 5 MHz channels and 64 dBm in 5 MHz. However, this requirement is not as strict as for the terminal since member states may decide on different power limits. The actual power level will heavily depend on the network infrastructure, the business model of the mobile network operator and the specific services to be deployed. The latter information is, typically, commercially sensitive and, thus, cannot be used in preparing against potential interference. Also the concentration of the allowed transmit power into smaller transmission channels would cause an increase in power spectral density.

A transmit power level in the range around 59 dBm in 10 MHz EIRP for a cell radius of 2700 m in urban areas where the level is noise limited was used as a worst case scenario in co-existence simulation studies by CEPT Report 30 [i.1]. A typical scenario that has been identified by mobile operators and is documented in contributions and deliverables of various working groups applies a BTS transmit power of 40 dBm on average. An in house level of electrical field strength above 1 V/m is not expected from a base station.

Relevant parameters such as base station transmit power are determined by typically applied operational values. Therefore, when assessing co-existence between LTE and cable, actual deployment scenarios should be considered.

5.4 HFC customer premise equipment (CPE)

Co-existence considerations for HFC need to take into account user equipment such as TVs, STBs, recorders and cable modems that are normally connected to RF cable networks in order to receive television, data and telephony services (triple play). Until recently, the co-channel interference risk on HFC networks in the 470 MHz to 862 MHz range was from (high tower, high power) broadcast transmitters. The introduction of mobile communication services in the 800 MHz band will add additional sources of potential interference due to high numbers of in-band base stations and mobile terminals that are physically located adjacent to in-home equipment.

Current TVs and STBs are designed to withstand the environment determined by broadcast transmitters which was expected to exhibit moderate radiation field strengths. The key characteristic for protection against external electromagnetic fields is the screening effectiveness. The present requirement is 50 dB in CENELEC EN 55020 [i.7]. This implies good screening for an existing cable network including CPE. Current equipment is designed in accordance with existing global standards. Recent measurement campaigns have verified the actual level to be in the range of 36 dB to 65 dB [i.14]. The conclusion is that the present requirements for screening effectiveness for CPE are adequate.

Immunity requirements are specified based on measurements that are using a 80 % AM modulated carrier with 1 kHz bandwidth [i.10]. As described in clause 4.1.2, LTE signals have very specific characteristics and time and frequency that are not very well reflected by the currently used test signal. However, recent analysis has shown that both signals have a similar effect in terms of causing interference. The current measurement method [i.10] covers the impact of LTE as an interfering signal on equipment appropriately.

6 HFC network design and electromagnetic environment

6.1 Impact of ECN services

Figure 7 shows that the current networks (cable and FTTx) are based on spectrum use up to 862 MHz. These systems are protected against disturbance from normal broadcast transmitters by current standards. Any impact of handheld user devices or small base stations in close proximity to the network and CPE system was not required. After introduction of mobile services in the 800 MHz band, this situation will change from a high-power, high-tower to a high-power, low-tower scenario. Preparatory studies for the introduction of the mobile services such as CEPT Report 30 [i.1] do not take into account this aspect of co-channel interference that is relevant for both HFC networks and communal aerial systems. Therefore, these results cannot be used for the discussion on the electromagnetic environment.

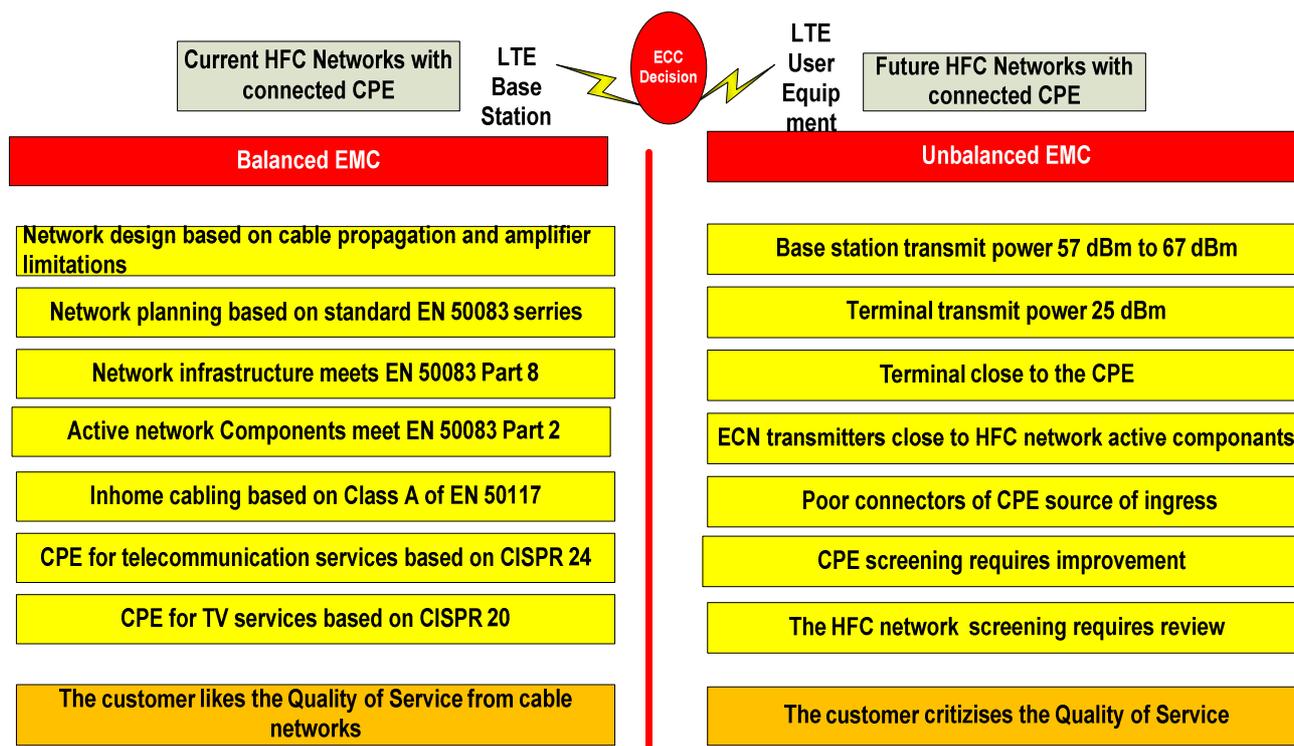


Figure 7: Illustration of the current balanced electromagnetic environment and the future unbalanced electromagnetic environment

6.2 Screening efficiency in cable networks

Table 2: Limits of in-band immunity of active equipment [i.3]

Frequency range MHz	Level (emf) dB(μV)	Field strength dB(μV/m)
0,15 to 80	106	---
80 to 1 000 (note 1)	---	106
790 to 862	---	120 (note 3)
950 (note 2) to 3 500	---	106
3 500 to 25 000	---	currently undefined

NOTE 1: Applicable for equipment with an upper frequency limit $\leq 1\,000$ MHz.
 NOTE 2: Applicable for equipment with a lower frequency limit ≥ 950 MHz.
 NOTE 3: In cases where digitally modulated wanted signals are applied.

Table 2 identifies the limits of in-band immunity of active equipment as given in CENELEC EN 50083-2 [i.3]. It shows that over the full frequency range from 150 kHz up to 3 500 MHz the immunity limit is 106 dB(μV/m) (with the exception of the presence of digitally modulated signals in the 800 MHz band).

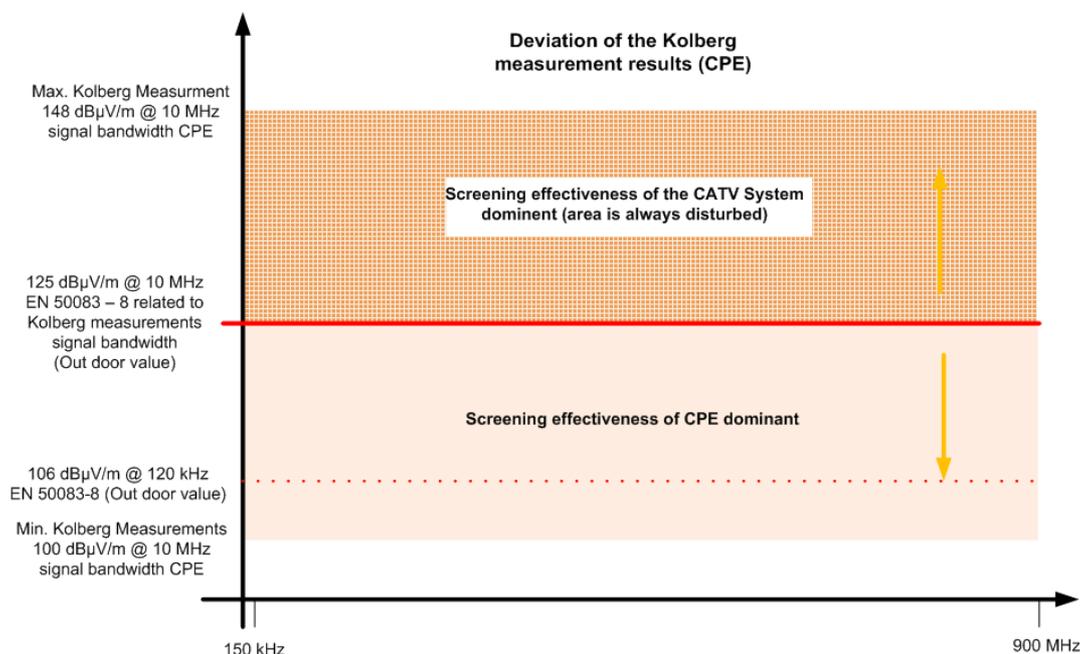
Table 3: Limits of screening effectiveness of passive equipment [i.3]

Frequency range MHz	Limit value dB	
	Class A	Class B
5 to 30	85	75
30 to 300	85	75
300 to 470	80	75
470 to 1 000 (note 1)	75	65
950 (note 2) to 3 500	55	50

NOTE 1: Applicable for equipment with an upper frequency limit $\leq 1\,000$ MHz.
 NOTE 2: Applicable for equipment with a lower frequency limit ≥ 950 MHz.

Table 3 shows that the screening effectiveness in the frequency range 470 MHz to 950 MHz is limited to 75 dB for Class A material. It is also possible to use material with 65 dB screening effectiveness (Class B) in this frequency range.

Screening effectiveness of CPE has been found to be in the range between 36 dB and 65 dB by recent studies, e.g. G531/01077/09 [i.14].



NOTE: 10 MHz measurement bandwidth.

Figure 8: Deviation of the Kolberg measurement results in relation to the standardized limit of 125 dB(μ V/m)

Figure 8 shows the variation of the results of the CPE measured in Kolberg. The immunity values vary from 100 dB(μ V/m) (@ 10 MHz) to 148 dB(μ V/m) (@ 10 MHz). In comparison, the immunity limit in cable networks is specified at 125 dB(μ V/m) (@ 10 MHz (calculated value)). The immunity limit of the cable system relates in this frequency range to a screening effectiveness of 75 dB.

For immunity limits below 125 dB(μ V/m), the screening effectiveness of the CPE is the limiting factor. Disturbances to cable TV services are caused by an interfering signal entering the CPE. Above 125 dB(μ V/m), the cable system screening effectiveness is the limiting factor. Interfering signals may enter the network.

When defining a screening effectiveness for the cable delivery chain, practical values for the individual network components and CPE have to be taken into account. In addition, by connecting the components to connectors, interfaces and to each other the screening effectiveness is further weakened. This is summarized in Table 4. An example for a system calculation of a cable TV system with a screening effectiveness of 75 dB is shown in Table 5. The disturbance radius for a cable TV system with varying screening effectiveness is depicted in Table 6 depending on the transmit power of the mobile signal.

Table 4: Expectations on screening effectiveness for cable TV system including connected CPE above 470 MHz

Cable system screening effectiveness	Value
Minimum of today deployments	36 dB
Maximum of today deployments	55 dB
Future limit for deployments	65 dB
Technology limit for deployments	75 dB

Table 5: System calculation of a cable network including connected CPE with screening effectiveness of 75 dB

DVB-C-receiver frequency	f	832 MHz bis 862 MHz
Modulation		64 QAM
Minimum level @ wall outlet	U_{min}	47 dB μ V
Modulation Error Ratio (min.)	MER	26 dB
Equivalent noise level @ receiver input U_r (75 Ω)	U_r	10,6 dB μ V
Antenna factor k_A @ $\lambda/2$ -Dipole (75 Ω) @ 850 MHz $E = U + k_A$	k_A	24,88 dB/m
Cable screening effectiveness A_S	A_S	75 dB
Correction value for measuring bandwidth @ 8 MHz	k_B	- 18,24 dB
Equivalent noise voltage @ the outside of the casing box	$E_N = U_r + k_A + k_B + A_S$	92 dB μ V/m
Level margin	$P_r = U_{min}-C/N-U_r$	10,4 dB
Increase in the total noise floor due to interference less than 0.5 dB	N_p	- 9 dB
Max. acceptable Field strength of disturbance	$E_p = E_N + P_r + N_p$	93,65 dB μ V/m
Radius of disturbance accordent to free space propagation related to $\lambda/2$ -Dipole	r	8 m

Table 6: Disturbance radius at different mobile transmit powers and at different values of screening effectiveness of a cable TV system including connected CPE

System screening effectiveness in a cable TV network including connected CPE	Mobile transmit power 8 dBm	Mobile transmit power 14 dBm	Mobile transmit power 25 dBm
System screening effectiveness 55 dB	14 m	28 m	99 m
System- screening effectiveness 65 dB (target as a rule)	4,7 m	9,3 m	33,14 m
System- screening effectiveness 75 dB (technology limit)	1,4 m	2,95 m	10,48 m

7 Immunity characteristics of HFC customer premise equipment

7.1 Immunity parameters

Customer premises equipment (CPE) is generally connected to telecommunication networks at a subscribers home or office and terminates one or several services of the network operator. In HFC networks, the main CPE are television sets terminating a broadcast video service and Cable Modems terminating a broadband data service. Immunity requirements for Cable Modems are defined in CENELEC EN 55024 [i.9].

The immunity requirements for television sets as defined in CENELEC EN 55022 [i.8] and are covering the following aspects:

- Immunity against differential mode RF voltages at the antenna terminal, i.e. input immunity (tuner test relating to adjacent channels).
- Requirements for the screening effectiveness of the antenna terminal.
- Immunity against radiated ElectroMagnetic fields.

Various organizations and markets have defined additional requirements for customer premises equipment that need to be complied to if the equipment is attached to digital broadcasting networks. Those national or regional specifications are usually based on international and European standards but are taking into account specific circumstances of the applicable markets. Examples for such regional and national specifications are NorDig [i.15] and D-Book [i.16].

7.2 Immunity (tuner test) against differential mode RF voltages at the antenna terminal

The input immunity is tested at the tuner related to adjacent channels.

The immunity test is applied as follows:

- Analog television: N+1, N-1, N+5, N-5, N+9 where N is the index of the tuned channel.
- DVB-T: N+1, N-1, N+9 where N is the index of the tuned channel.

For DVB-C, appropriate requirements are under consideration.

Requirements are depicted in Figure 9 (analog television) and Figure 10 (DVB-T) taking the channel with the centre frequency of 746 MHz as an example.

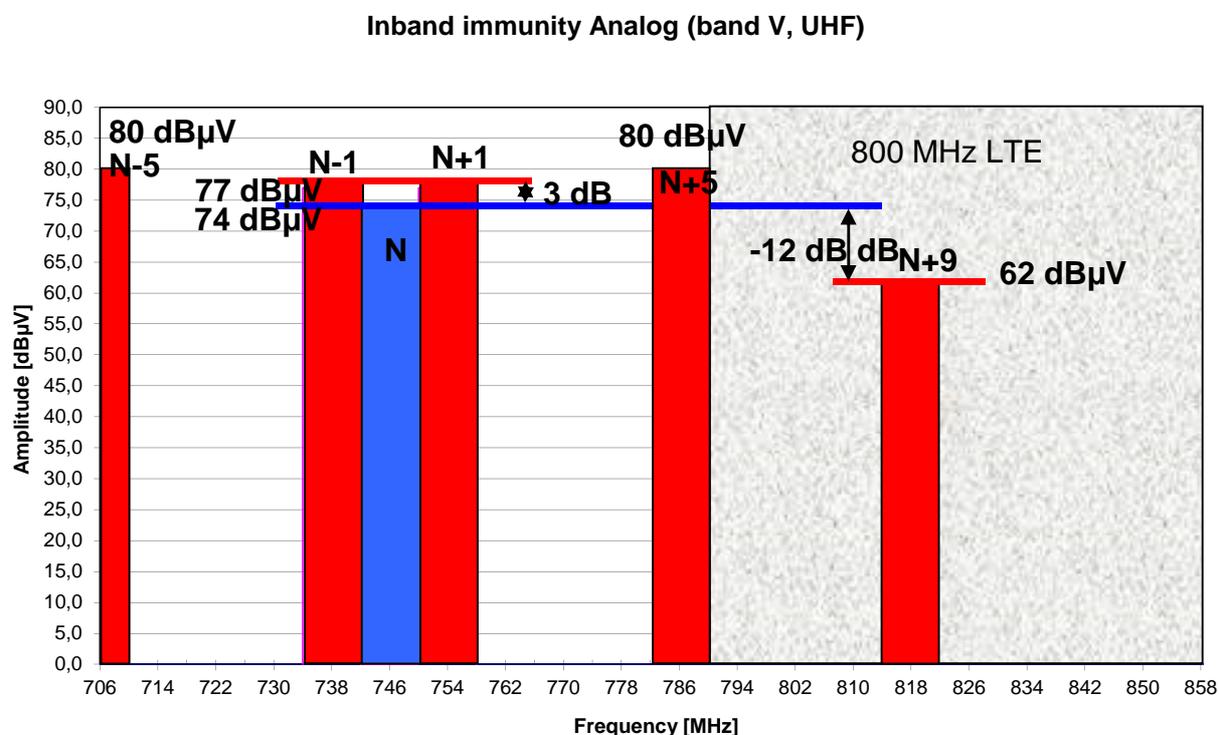


Figure 9: Inband immunity requirements of television sets for analog television according to CENELEC EN 55022 [i.8]

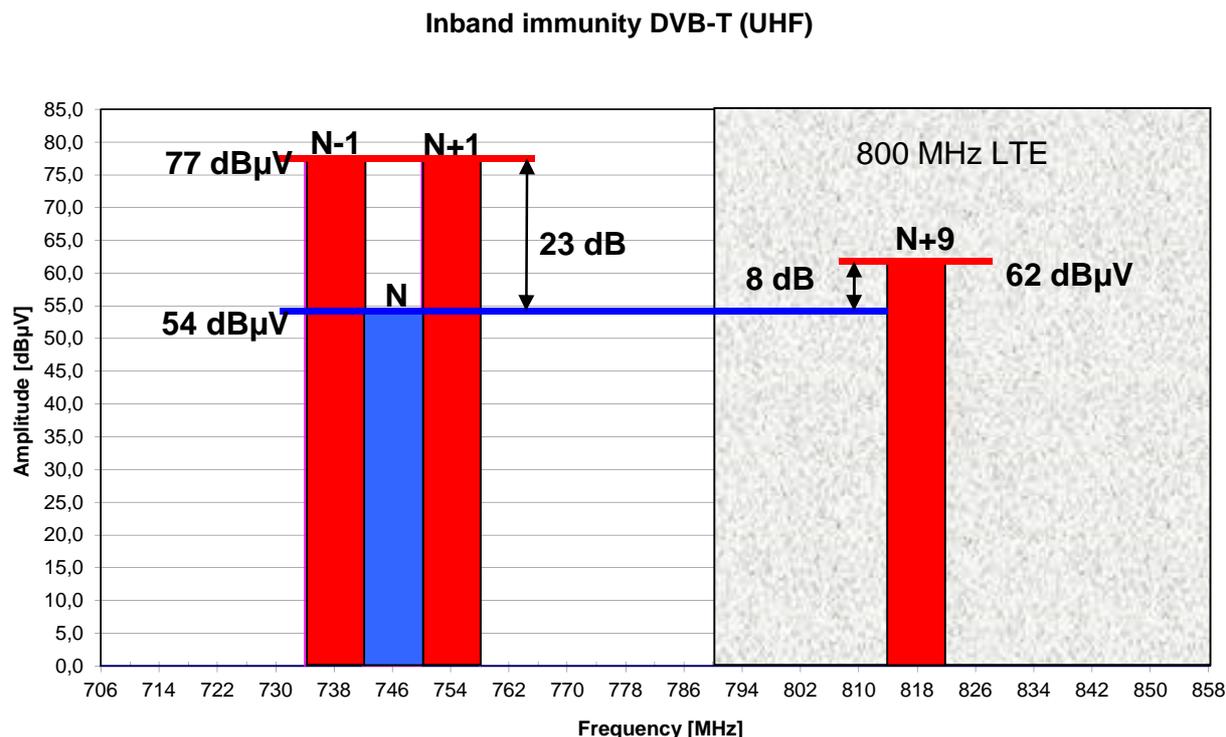


Figure 10: Inband immunity requirements of television sets for DVB-T according to CENELEC EN 55022 [i.8]

7.3 Screening effectiveness

The minimum requirement for the screening effectiveness at the antenna terminal is defined to be at least 50 dB. This value is valid over the complete receiving frequency range (47 MHz to 862 MHz).

NOTE: During the screening effectiveness test the quality of the contact at the antenna terminal significantly influences the test result. The quality of the connector will play a major role in improving the overall screening effectiveness for LTE signals at the customer premises.

In principle, the antenna connection cable between the wall outlet and the TV set is the responsibility of the end user.

To assist the customer in making an appropriate choice of cable, a quality mark like in the Netherlands (Kabelkeur) can be introduced.

7.4 Immunity against radiated electromagnetic fields

The following requirements are specified for immunity against radiated electromagnetic fields:

- 1) 3,0 V/m for 900 MHz (duty cycle 1/8, 217 Hz repetition frequency).

It should be noted that the maximum ERP of a GSM mobile is 2 W. With the formula $E = 7 \times \sqrt{P} / d$, the field strength is 3 V/m at a 3 m distance for out of band signals. Hence the protection distance between a GSM mobile and a TV is 3 m. To ensure the same protection distance for an LTE mobile (ERP = 200 mW) the test field strength results in 1 V/m (in-band immunity).

- 2) 1,8 V/m in the frequency range 150 kHz to 150 MHz (AM with 80 % 1 kHz).

Exceptions apply for:

- The tuned channel $\pm 0,5$ MHz where no requirements apply.
- The colour subcarrier frequency of an analog television signal $\pm 1,5$ MHz where the requirement is 0,1 V/m.
- The intercarrier sound frequency of an analog television signal $\pm 0,5$ MHz where the requirement is 0,1 V/m.

- The IF for sound -2,0 MHz to the IF for picture +2,0 MHz where the requirement is 0,1 V/m.
- For system L, the IF for picture -2,0 MHz to the IF for sound +2,0 MHz where the requirement is 0,1 V/m.

For the PAL systems B/G, the picture carrier is at 38,9 MHz and the sound carrier is at 33,4 MHz. The intercarrier sound frequency is 5,5 MHz and the colour subcarrier is located at 4,43 MHz. Figure 11 depicts the immunity requirements against radiated electromagnetic fields for the tuned channel with the centre frequency of 58 MHz.

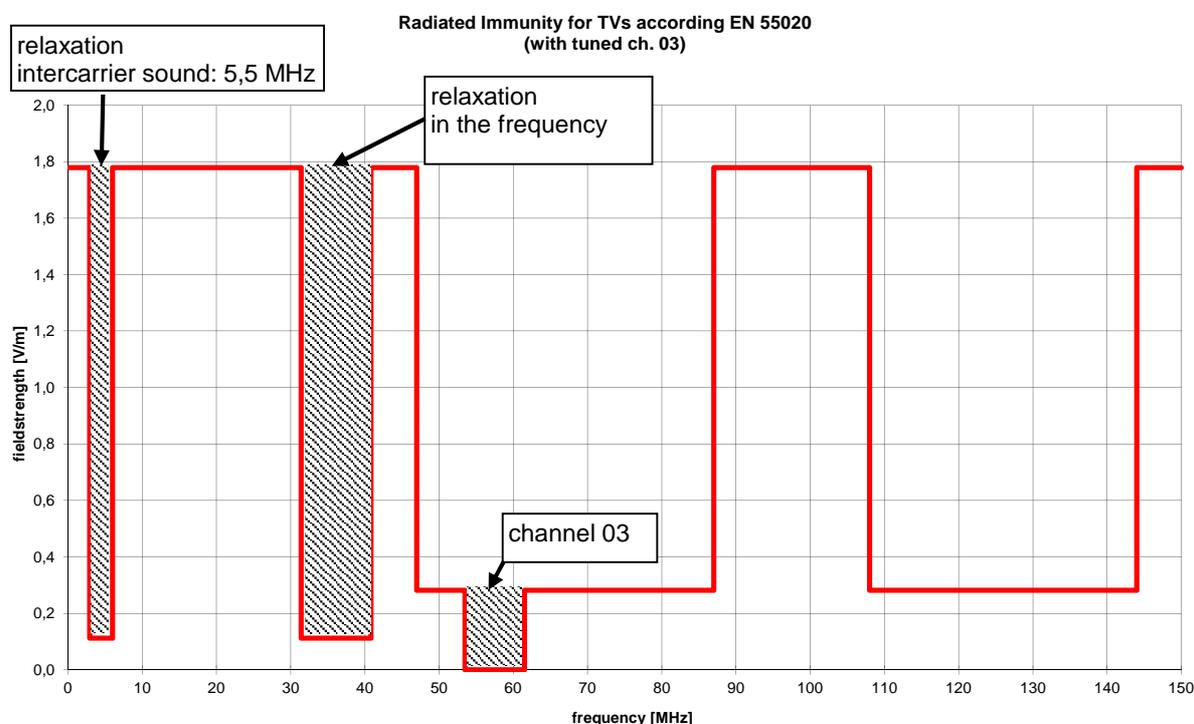


Figure 11: Radiated immunity requirements of television sets according to CENELEC EN 55020 [i.8]

7.5 Conclusions

Based on the information above and the results of the test made by various stakeholders the following conclusions can be drawn:

- LTE mobiles operating in the 800 MHz band produce interference to PAL and DVB-C cable channels at 3 m distance from TV-sets.
- The present protection distance between a TV-set and a 900 MHz GSM mobile is 3 meter.
- It is recommended to use the same 3 meter protection distance for LTE-mobiles.
- Hence, DVB-C channels will be adequately protected against co-channel interference from LTE-mobiles with an immunity test field strength for TV-sets of 1 V/m.
- The quality of the antenna cable and its connectors play an important role for screening effectiveness. Therefore a quality mark like in the Netherlands (Kabelkeur) should be considered for these components.
- Additional filtering (theoretically up to > 30 dB at 2 channels separation from LTE) is necessary in the antenna signal path to ensure interference free reception of DVB-T.

8 Parameters of mobile radio networks in the 800 MHz band

8.1 Frequency Arrangements for the 790 MHz to 862 MHz band

8.1.1 Introduction

As described in recital (6) of Commission Decision 2010/267/EU [i.18], "... on 3 April 2008 the Commission gave a mandate to the European Conference of Postal and Telecommunications Administrations (hereinafter 'the CEPT') to define the technical conditions to be applied to the 800 MHz band optimised for, but not limited to, fixed and/or mobile communications networks, with a particular focus on common and minimal (least restrictive) technical conditions, the most appropriate frequency arrangement and a recommendation on how to handle Programme Making and Special Events (PMSE) services."

This includes the development of the most appropriate channelling arrangements that are "sufficiently precise for the development of EU-wide equipment, but at the same time allow Member States to adapt these to national circumstances and market demand".

In response to this Mandate, CEPT has developed one preferred harmonised frequency arrangement based on the FDD mode, but for Administrations that might wish to deviate from the preferred harmonised frequency arrangement some approaches to meet specific national circumstances and market demand were considered. These are described in CEPT Report 31 [i.2].

Following this:

- The European Commission adopted the Commission Decision 2010/267/EU [i.18].
- The ECC adopted ECC Decision (09)03 [i.17].

European Commission Decision 2010/267/EU [i.18] mandates a block size of multiples of 5 MHz frequency assignments in the 790 MHz to 862MHz band. The duplex mode of operation is preferred to be FDD with the following arrangements: duplex spacing of 41 MHz with base station transmission (down link) located in the lower part of the band starting at 791 MHz and finishing at 821 MHz and terminal station transmission (up link) located in the upper part of the band starting at 832 MHz and finishing at 862 MHz. Member states are authorized to implement alternative frequency arrangements with the aim of:

- achieving general interest objectives;
- ensuring greater efficiency through market-based spectrum management;
- ensuring greater efficiency when sharing with existing rights of use during a coexistence period; or
- avoiding interference.

ECC Decision (09)03 [i.19] recommends the frequency arrangements according to Figure 12 for FDD and as shown in Figure 13 for TDD.

790-791	791-796	796-801	801-806	806-811	811-816	816-821	821-832	832-837	837-842	842-847	847-852	852-857	857-862
Guard band	Downlink						Duplex gap	Uplink					
1 MHz	30 MHz (6 blocks of 5 MHz)						11 MHz	30 MHz (6 blocks of 5 MHz)					

Figure 12: Preferred harmonised frequency arrangement for FDD according to ECC Decision (09)03 [i.17]

790-797	797-802	802-807	807-812	812-817	817-822	822-827	827-832	832-837	837-842	842-847	847-852	852-857	857-862
Guard band	Unpaired												
7 MHz	65 MHz (13 blocks of 5 MHz)												

Figure 13: Preferred frequency arrangement for TDD according to ECC Decision (09)03 [i.17]

8.1.2 Minimum separation between mobile and broadcast channels

The preferred harmonised frequency arrangement provides a separation of 42 MHz between the bottom of the uplink (terminal transmit) band and the top of the highest terrestrial TV channel that would continue to be used in this arrangement (channel 60 i.e. 782 MHz to 790 MHz) and a separation of 1 MHz for the downlink band. If this frequency arrangement is not followed, the same minimum separations would apply to uplink and downlink channels relative to channel 60, and there would be a minimum separation of 7 MHz for TDD channels.

Table 7 gives the minimum separation between TV channel 60 and 5 MHz and 10 MHz mobile carriers, according to ECC Decision (09)03 [i.17]. For the preferred harmonised frequency arrangement, the mobile carriers are always at a higher frequency than the broadcast channel.

Table 7: Minimum frequency separation between mobile and terrestrial broadcasting according to ECC Decision (09)03 [i.17]

Minimum Frequency Separation between mobile and terrestrial broadcasting around 790 MHz boundary			
	Between channel edges	Between channel centre frequencies	
		5 MHz mobile carrier	10 MHz mobile carrier
Uplink	42 MHz (> 5 TV channels)	48,5 MHz (> 6 TV channels)	51 MHz (> 6 TV channels)
Downlink	1 MHz	7,5 MHz (nearly 1 TV channel)	10 MHz (> 1 TV channel)
TDD	7 MHz (nearly 1 TV channel)	13,5 MHz (> 1½ TV channels)	16 MHz (2 TV channels)

8.1.3 Deployment of TDD within the 790-862 MHz band

A number of technical factors make it unlikely that TDD networks will be deployed in the 790 MHz to 862 MHz band:

- 1) Filtering would be required at the DTT receiver for TDD operation in the lowest 5 MHz block of the TDD frequency arrangement (797 MHz to 802 MHz), as described in annex 3 of CEPT Report 30 [i.1].
- 2) Administrations who wish to protect portable-indoor DTT reception would need to adopt a guard band that is larger than 7 MHz, and may also require filtering at the DTT receiver, as described in annex 3 of CEPT Report 30 [i.1].
- 3) Mixing TDD and FDD leads to inefficient use of spectrum, as described in annex 5 of CEPT Report 31 [i.2].
- 4) There is insufficient spectrum to efficiently support more than two TDD networks, as described in annex 5 of CEPT Report 31 [i.2].
- 5) To meet the requirement of -65 dBm/8 MHz below 790 MHz, the terminal will need to have a TX filter, but a frequency separation will still also be needed (possibly 15 MHz to 20 MHz for 10 MHz uplink transmission bandwidth). The maximum bandwidth available for filters for use in terminals at around 800 MHz is only 30 MHz to 35 MHz, and this is unlikely to increase substantially. Therefore, a TDD terminal would need two (or perhaps three) filters in order to support approximately only 50 MHz to 55 MHz out of the 72 MHz of spectrum. This is less than needed for two 3-sector networks.

8.2 Emissions limits of mobile emissions

8.2.1 Base stations

Co-channel

Co channel scenarios are only applicable to cable networks and communal aerial systems working in the 790 MHz to 862 MHz band, because a mobile network will never operate on the same frequency as digital terrestrial television in the same geographic area.

Commission Decision 2010/267/EU [i.18] defines the in-block EIRP limit for base stations as follows:

An in-block EIRP limit for base stations is not obligatory. However, Member States may set limits and, unless otherwise justified, such limits would normally lie within the range 56 dBm/5 MHz to 64 dBm/5 MHz.

In the studies in CEPT Report 30 [i.1], an ECN BS EIRP of 59 dBm balances the UL and DL link budgets. An increase in the ECN BS EIRP would not be beneficial in interference limited cells. This is because an increase in BS EIRP would not improve the signal-to-interference ratio (SIR). In environments where the cell is noise-limited, however, the BS EIRP can be increased (e.g. up to 64 or 67 dBm) to provide greater DL throughput (but the cell size would remain unchanged due limits in the UL link-budget).

Adjacent channel

Table 8 describes the requirements in ECC Decision (09)03 [i.17] applied to the preferred harmonised frequency arrangement.

Table 8: Emission limits for base station according to ECC Decision (09)03 [i.17] applied to the preferred harmonised frequency arrangement

Frequency range for the preferred harmonised frequency arrangement	Case or Frequency range of out-of-block emissions	Maximum mean out-of-block EIRP	Measurement bandwidth	
Below 790 MHz	Case A: For DTT frequencies where broadcasting is protected	0 dBm	8 MHz	
	Case B: For DTT frequencies where broadcasting is subject to an intermediate level of protection	10 dBm	8 MHz	
	Case C: For DTT frequencies where broadcasting is not protected	22 dBm	8 MHz	
790 MHz to 791 MHz	Guard band between broadcasting band edge and FDD downlink band edge	17,4 dBm	1 MHz	
791 MHz to 821 MHz	791 MHz up to -10 MHz from lower block edge	11 dBm (see note)	1 MHz	
	-10 MHz to -5 MHz from lower block edge	18 dBm	5 MHz	
	-5 MHz to 0 MHz from lower block edge	22 dBm	5 MHz	
	In-block			
	0 MHz to +5 MHz from upper block edge	22 dBm	5 MHz	
	+5 MHz to +10 MHz from upper block edge	18 dBm	5 MHz	
821 MHz to 832 MHz	+10 MHz from upper block edge to 821 MHz	11 dBm	1 MHz	
	Guard band between FDD downlink band edge and FDD uplink band edge (duplex gap)	15 dBm	1 MHz	
832 MHz to 862 MHz	Frequencies allocated to FDD uplink	-49,5 dBm	5 MHz	

NOTE: Per antenna, for one to four antennas.

8.2.2 Terminals

Co-channel

Co channel scenarios are only applicable to cable networks and communal aerial systems working in the 790 MHz to 862 MHz band, because a mobile network will never operate on the same frequency as digital terrestrial television in the same geographic area.

Commission Decision 2010/267/EU [i.18] defines the maximum mean in-block power limit for terminal stations to be 23 dBm. This power limit is specified as EIRP for terminal stations designed to be fixed or installed and as TRP for terminal stations designed to be mobile or nomadic. EIRP and TRP are equivalent for isotropic antennas. It is recognised that this value is subject to a tolerance of up to + 2 dB, to take account of operation under extreme environmental conditions and production spread. It is unlikely that terminals operated indoors will be subject to extreme environmental conditions.

ECC Decision (09)03 [i.17] states that Administrations may relax this limit in certain situations, for example fixed UE in rural areas, providing that protection of other services, networks and applications is not compromised and that cross-border obligations are fulfilled. This relaxation is unlikely in areas served by cable networks. In any case, the increase in coupling loss due to the larger separation of an outdoor fixed installation from cable TV equipment is likely to outweigh the increase in permitted power.

Adjacent channel

ECC Decision (09)03 [i.17] defines the out-of-band emission requirements for FDD UE for the preferred harmonised frequency arrangement.

Table 9: Out-of-band emission requirements for FDD UE according to ECC Decision (09)03 [i.17]

Frequency range of out-of-band emissions	Maximum mean out-of-band power	Measurement bandwidth
Below 790 MHz	-65 dBm (see note)	8 MHz
790 MHz to 791 MHz	-44 dBm	1 MHz
791 MHz to 821 MHz	-37 dBm	5 MHz
821 MHz to 822 MHz	-13 dBm	1 MHz
822 MHz to -5 MHz from FDD uplink lower channel edge	-6 dBm	5 MHz
-5 to 0 MHz from FDD uplink lower channel edge	1,6 dBm	5 MHz
0 to +5 MHz from FDD uplink upper channel edge	1,6 dBm	5 MHz
+5 MHz from FDD uplink upper channel edge to 862 MHz	-6 dBm	5 MHz
NOTE: Full duplex FDD terminal stations designed to operate in the preferred harmonized FDD channelling arrangement are expected to be inherently compliant with this out-of-band emission level.		

These out-of-band requirements apply without prejudice to spurious emission requirements (which continue to apply). ECC Decision (09)03 [i.17] does not address spurious emission levels; this is the responsibility of the standards development organisations (SDOs). The CEPT recommended spurious emission limits are given in ERC Recommendation 74-01 [i.19]. The technical conditions for these terminals are defined relative to the channel edge to enable them to be taken into account by the SDOs.

8.2.3 Definition of block edge masks

This description of block edge masks is taken from CEPT Report 30 [i.1].

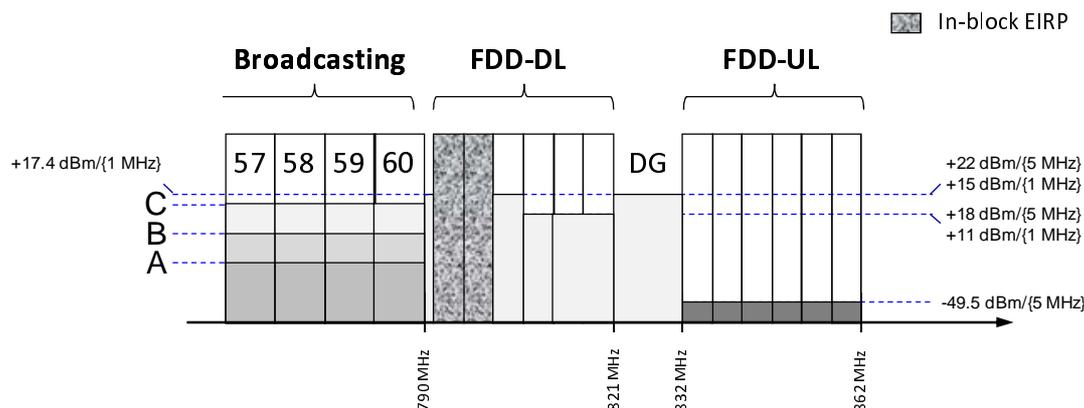
The BEMs are presented as upper limits on the mean EIRP or TRP (total radiated power) over an averaging time interval, and over a measurement frequency bandwidth. In the time domain, the EIRP or TRP is averaged over the active portions of signal bursts and corresponds to a single power control setting. In the frequency domain, the EIRP or TRP is determined over the measurement bandwidth (e.g. block or TV channel).

TRP is a measure of how much power the antenna actually radiates. The TRP is defined as the integral of the power transmitted in different directions over the entire radiation sphere. For an isotropic antenna radiation pattern, EIRP and TRP are equivalent. For a directional antenna radiation pattern, EIRP in the direction of the main beam is (by definition) greater than the TRP.

In general, and unless stated otherwise, the BEM levels correspond to the power radiated by the relevant device irrespective of the number of transmit antennas, except for the case of ECN base stations transition requirements which are specified per antenna.

The term block edge refers to the frequency boundary of spectrum licensed to an ECN. The term band edge refers to the boundary of a range of frequencies allocated for a certain use (e.g. 790 MHz is the upper band edge for broadcasting, while 832 MHz is the lower band edge for FDD uplink). For requirements with a measurement bandwidth of 5 MHz, the measurement bandwidth is aligned within a block.

Figure 14 and Figure 15 illustrate the base station block edge masks which are defined in ECC/DEC/(09)03 [i.17] for the preferred harmonised FDD frequency arrangement.



NOTE: Only baseline limit "A" applies over broadcasting channels that are in use.

Figure 14: BS BEM for a FDD operator in the lowest two 5 MHz blocks in the preferred harmonized frequency arrangement

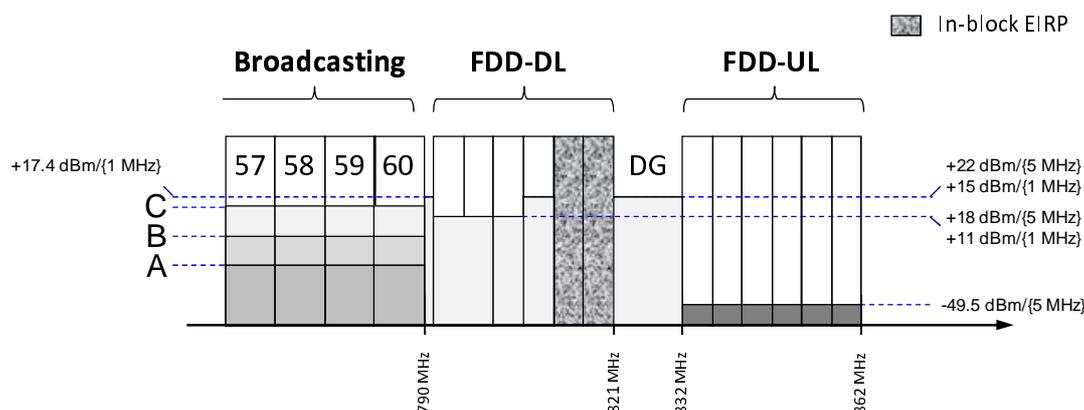


Figure 15: BS BEM for a FDD operator in the upper two 5 MHz blocks in the preferred harmonized frequency arrangement

Note that only baseline limit "A" applies over broadcasting channels that are in use at the time of deployment of mobile networks.

8.3 Deployment scenarios for mobile networks in the 790 MHz to 862 MHz

8.3.1 Introduction

This description of deployment scenarios is taken from CEPT Report 30 [i.1] and describes the assumptions used in the studies in that report

The most likely use of the band 790 MHz to 862 MHz for fixed/mobile communication networks is a cellular like topology with two-way communication. Therefore, two different block edge masks (BEM) are developed - one for the base station (BS) and one for the User Equipment (UE) - taking into consideration mobile service parameters. The most critical scenarios studied in this report concern compatibility issues between Electronic Communications Networks (ECN) and terrestrial broadcasting, but scenarios between two ECN have also been studied.

8.3.2 Reference ECN system characteristics

There is a need to define assumptions for the basic ECN system characteristics in order to conduct the necessary technical studies. The assumptions are based on the most likely systems characteristics envisaged for ECN in the 790 MHz to 862 MHz band.

Expected spectrum used by one network: 10 MHz (two blocks of 5 MHz).

Table 10: Parameters for ECN base stations as defined in CEPT Report 30 [i.1]

EIRP	between 59 dBm/10 MHz and 67 dBm/10 MHz
Antenna gain (feeder loss included)	15 dBi
Antenna height	30 m in urban environment 60 m in rural environment
Antenna pattern	Either based on existing antenna characteristics or modelled using Recommendation ITU-R F.1336 [i.13]

Table 11: Parameters for ECN terminal stations as defined in CEPT Report 30 [i.1]

EIRP	23 dBm
Antenna gain (feeder loss included)	0 dBd (2.15 dBi)
Antenna height	1,5 m a.g.l
Antenna pattern	Either based on existing antenna characteristics or modelled using Recommendation ITU-R F.1336 [i.13]

8.3.3 ECN cell radius

Most of the CEPT studies used Monte Carlo statistical analysis, in which the transmit power of a terminal is determined at each location in the cell, using the propagation models defined below.

Table 12: Link budget for ECN dimensioning used in CEPT Report 30 [i.1]

Parameter	Units	Uplink	Downlink	Comment
Carrier frequency	MHz	835.00	795.00	N/A
Bandwidth	MHz	9.00	9.00	Not all sub-carriers are used in LTE
Available number of RBs	N/A	50	50	Each RB has a bandwidth of 180 kHz
Number of used RBs in the link	N/A	1	50	For max UL range
Link BW	MHz	0.18	9.00	Bandwidth occupied by link
Thermal noise				
Thermal spectral density	dBm/Hz	-173.98	-173.98	kTB
Receiver noise figure	dB	5	9	N/A
Noise power (inc. NF) over link BW	dBm	-116.42	-95.43	$P_n = kTB.NF$ plus any noise rise
Losses				
Cell edge reliability	N/A	95.0%	95.0%	SE42 modelling assumption
Gaussian confidence factor	N/A	1.645	1.645	N/A
Shadowing loss standard deviation	dB	5.5	5.5	P.1546
Wall loss standard deviation	dB	5.5	5.5	GE06
Total loss standard deviation	dB	7.78	7.78	Root of sum of STD squares
Loss margin	dB	12.79	12.79	Lmargin
Power and throughput				
Minimum SNR at cell-edge	dB	0.00	0.00	SNR _{min} for 10 MHz LTE
Link throughput at cell-edge	kbps	72.00	5400.00	DL throughput is aggregate for cell
Target "mean" received signal level	dBm	-103.6	-82.6	$P_{target} = (P_n + SNR) + L_{margin}$
EIRP	dBm	23.00	58.99	P
Mean wall loss	dB	8.0	8.0	L _w
Receiver Antenna Gain (inc. losses)	dBi	15	0	G _a
Max allowed path loss	dB	133.63	133.63	$L_p = (P - L_w + G_a) - P_{target}$

In urban areas, a typical EIRP of 23 dBm for terminal station is considered. A maximum allowed path loss of 133,63 dB leads to a ECN cell coverage of 2 698 m when applying the JTG5-6 model.

The same link budget applied to rural areas leads to a ECN cell radius of 3 460 m.

As the link-budget suggests, for the above cell sizes, an ECN BS EIRP of 59 dBm balances the UL and DL. An increase in the ECN BS EIRP would not be beneficial in interference limited cells. This is because an increase in BS EIRP would not improve the SIR. It is noted that all cell radi considered in CEPT were noise-limited.

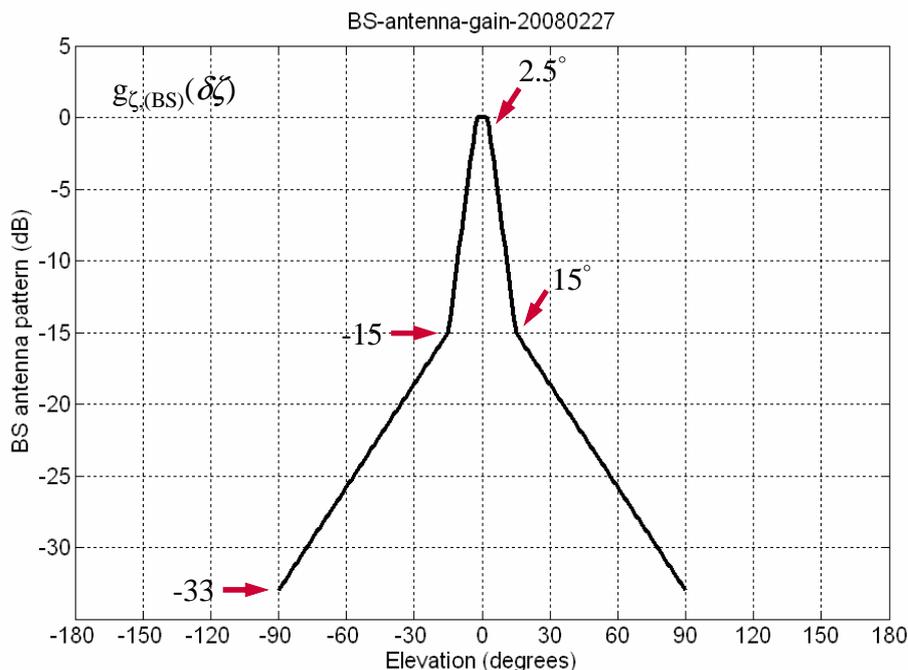
In environments where the cell is noise-limited, however, the BS EIRP can be increased (e.g. up to 64 or 67 dBm) to provide greater DL throughput (but the cell size would remain unchanged due limits in the UL link-budget).

8.3.4 General Assumptions related to ECN

Table 13: General assumptions related to ECN base stations according to CEPT Report 30 [i.1]

EIRP (noise limited scenario)	Urban: 64 dBm/(10 MHz) Rural: 67 dBm/(10 MHz)
EIRP (uplink limited scenario)	UL/DL balanced: 59 dBm/(10 MHz)
Cell radius	Urban: 2 698 m Rural: 3 460 m
Antenna height	Urban: 30 m Rural: 60 m
Antenna elevation pattern	Section A1.2 or Figure A1.5 in section A1.3 of Recommendation ITU-R F.1336 [i.13]
Antenna tilt	0°

It is noted that all cell radi provided above are noise-limited.



NOTE: BS antenna pattern is assumed to be omni-directional in azimuth.

Figure 16: BS antenna gain as a function of elevation

Table 14: General assumptions related to signal propagation used in CEPT Report 30 [i.1]

Operating frequency	790 MHz
Min. horizontal separation between Tx and Rx	10 m
Mean path loss	Free space: $-147,56 + 20\log_{10}(f) + 20 \log_{10}(d)$ dB JTG model as described in annex 6 of CEPT Report 30 [i.1] (Hata model up to 100 m, Recommendation ITU-R P.1546-5 [i.20] beyond 1 km and linear interpolation in between)
Log-normal shadowing standard deviation:	
3,5 dB for $d < d_0$ m,	
5,5 dB for $d > d_0$ m, where for $d_0 = 100$ m.	
Mean wall loss	8 dB
Log-normal wall loss standard deviation	5,5 dB
Cross polarization (in the main lobe)	3 dB or 16 dB

9 Interference scenarios

9.1 Modelling co-existence of HFC and ECN

9.1.1 Modelling Parameters

Modelling parameters are largely based on the parameters given in CEPT Report 30 [i.1] and Commission Decision 2010/267/EU [i.18] and as detailed in the clauses 7 and 8. Table 15 summarises the parameters.

Table 15: Modelling parameters for ECN base stations in interference scenarios

Parameter	Value
Downlink Operating Frequency	805 MHz
BS EIRP	From 59 dBm to 67 dBm in 9 MHz Occupied Bandwidth
BS Antenna Height	30 m (a.g.l.)
BS Antenna Relative Gain (Elevation)	0 dB if $0^\circ \leq \varphi < 2,5^\circ$ $15((\varphi-2,5)/(-12,5))$ dB if $2,5^\circ \leq \varphi < 15^\circ$ $[(18((\varphi-15)/(-75)))] - 15$ dB if $15^\circ \leq \varphi \leq 90^\circ$
BS Antenna Relative Gain (Azimuth)	Omnidirectional
BS Antenna Downtilt	0°
Mean Interference Path Loss Propagation Model	JTG 5-6 Model (as described in annex 6 of CEPT Report 30 [i.1])

The electromagnetic compatibility requirements of HFC equipment and networks are defined in CENELEC EN 50083-2 [i.3]. Immunity levels are provided in the form of field strength values expressed in dB μ V/m. The corresponding value for the frequency band of interest is given as 106 dB μ V/m. For the purposes of comparison, the impact of 3 V/m (129,5 dB μ V/m) has also been examined.

9.1.2 Modelling Approach

The analysis is based on the assessment of a single interference path into the victim HFC network elements. In the analysis, the distance between the interfering base station (BS) and the victim is increased in regular steps. At each distance, the implications of mean path loss and BS elevation antenna pattern are taken into account. The calculated interference powers are then compared against the immunity levels to determine the minimum distance at which the immunity is satisfied.

The propagation model is based on the simplified JTG 5-6 model described in CEPT Report 30 [i.1]. The model takes account of different BS and receiver heights. For the purposes of our analysis, the BS height of 30 metres and the receiver heights of 1,5 and 10 metres have been used. It has been noted that the simplified JTG 5-6 model (i.e. tabulated values in annex 6) is based on the assumption of 10 metre clutter height though the text refers to the clutter height of 20 metres in urban areas.

9.1.3 Modelling Results

This clause summarises the results of single-entry interference analysis.

Figure 17a provides an example of the variation of field strength at HFC network element with distance from an ECN BS transmitter.

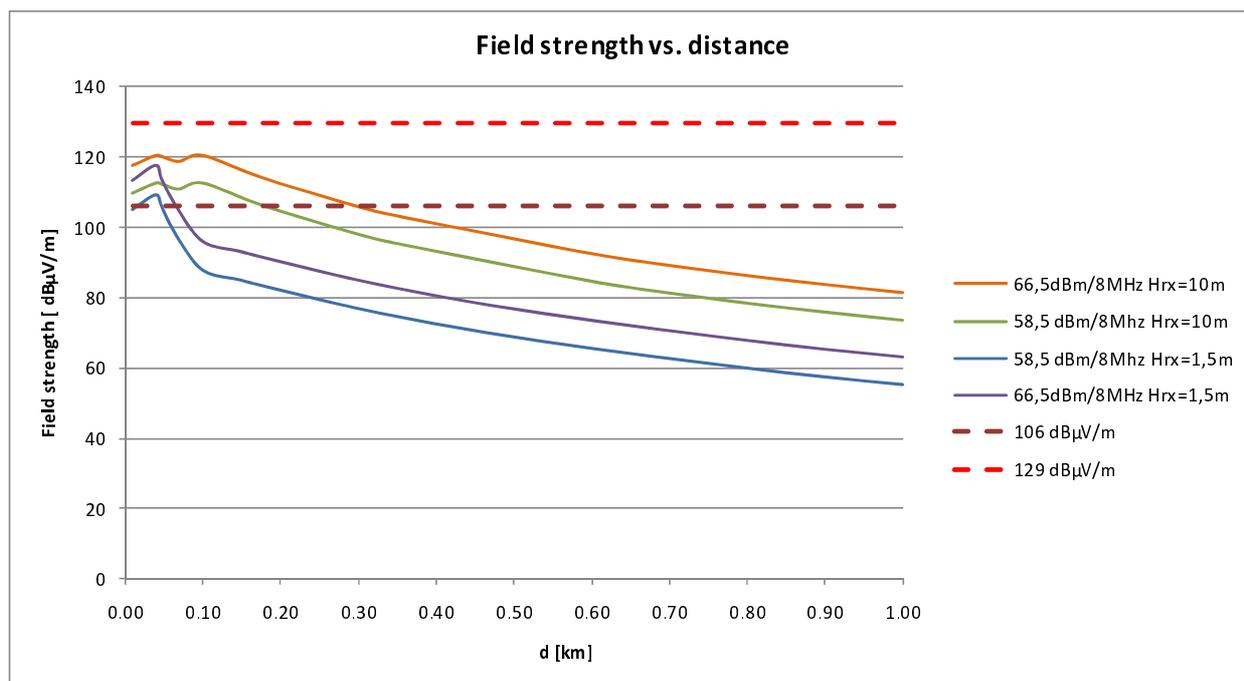


Figure 17a: Variation of field strength with distance according to co-existence model

Table 16 shows calculated separation distances for the scenarios examined.

Table 16: Separation distances for various interference scenarios

		58,5 dBm ECN BS EIRP in 8 MHz (Immunity Level of 106 dBµV/m)	66,5 dBm ECN BS EIRP in 8 MHz (Immunity Level of 106 dBµV/m)	58,5 dBm ECN BS EIRP in 8 MHz (Immunity Level of 129,5 dBµV/m)	66,5 dBm ECN BS EIRP in 8 MHz (Immunity Level of 129,5 dBµV/m)
Cable TV Network Element @ 1,5 m	JTG 5-6 (10 metre clutter)	48 m	66 m	0 m	0 m
Cable TV Network Element @ 10 m	JTG 5-6 (10 metre clutter)	350 m	680 m	0 m	0 m
	JTG 5-6 (20 metre clutter)	179 m	299 m	0 m	0 m

The analysis of interference from ECN base stations shows that both the assumed BS EIRP and the immunity criterion play a significant role in determining the co-existence conditions.

Clauses 9.1.4 and 9.1.5 illustrate example scenarios where the real-world topology of a HFC network and ECN base stations of mobile network operators are displayed:

- In clause 9.1.4 with the first scenario, it is assumed that the ECN BS EIRP is 58,5 dBm/8 MHz and 66,5 dBm/8 MHz. For a transmitter height of 10 m the field strength within the circle is above 106 dBµV/m (i.e. exceeding the immunity limit defined for HFC network elements). The corresponding separation distances are calculated to be 179 m and 299 m, respectively.

- In clause 9.1.5 with the second scenario, it is assumed that the ECN BS EIRP is 58,5 dBm/8MHz and 66,5 dBm/8 MHz. For a transmitter height at street level (e.g. 1,5 m) the field strength within the circle is above 106 dB μ V/m (i.e. exceeding the immunity limit defined for HFC network elements). The corresponding separation distances are calculated to be 48 m and 66 m, respectively.

In both scenarios, the ECN BS EIRP values stated in CEPT Report 30 [i.1] and Commission Decision 2010/267/EU [i.18] have been applied. They give a simplified overview to co-existence between ECN BS network and HFC networks in an urban area.

If there were 3 operators each with a 10 MHz channel then either:

- If operators used different cell sites, then the bandwidth transmitted at each cell site would be 10 MHz; or
- If operators shared sites for this frequency band, then not all of the cell sites would be used.

9.1.4 Prediction of field strength at an HFC network caused by a Base Station with an aerial height of 10 m



Figure 17b: Variation of field strength with distance in existing environment with base station in aerial height of 10 m

9.1.5 Prediction of field strength at an HFC network caused by a Base Station with an aerial height of 1,5 m

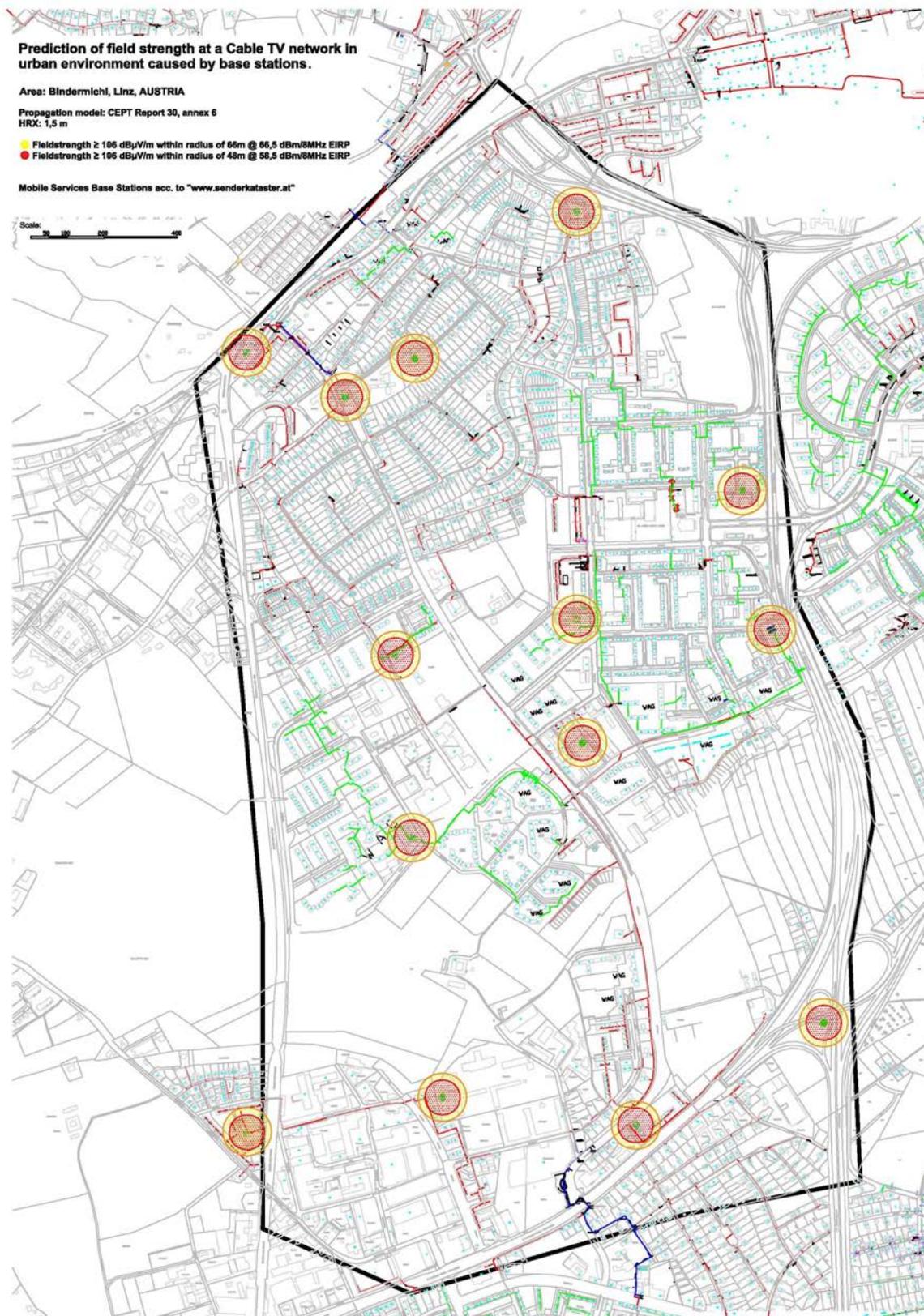


Figure 17c: Variation of field strength with distance in existing environment with base station in aerial height of 1,5 m

9.2 Modelling transmit power values in ECN

9.2.1 User equipment (UE)

In the assessment of interference potential of transmissions from mobile terminals the UE parameters as defined in CEPT Report 30 [i.1] and as listed in Table 11 have to be taken into account. However, since the use of external antennas is possible, their directional characteristics have to be considered as well. In this case, the disturbance radius may change dramatically in the preferred direction of the antenna.

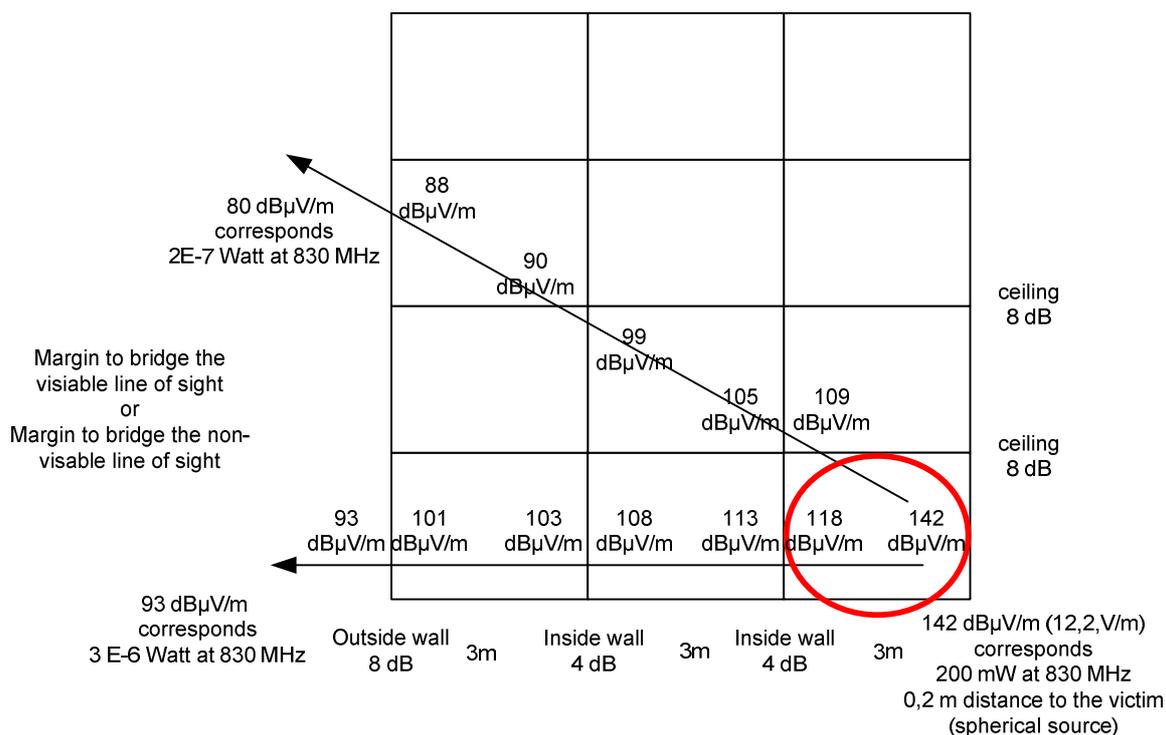
For the evaluation of the transmit power of a mobile terminal an average indoor environment is defined with the parameters outlined in Table 17.

Table 17: Parameters for the description of an indoor environment

Parameter	Value
Room size	3 m by 3 m
Attenuation of inner wall	4 dB
Attenuation of outer wall	8 dB
Attenuation of roof (tiles)	2 dB
Attenuation of roof (concrete)	8 dB

The values in Table 17 are derived by averaging across various relevant standards and specifications and have been accepted previously for use in analysis on European and national level.

Under consideration of these parameters of the indoor transmission path, the link budget for a mobile terminal operated in an apartment can be calculated.



NOTE: Values indicate the field strength at the location of the transmitter or immediately after traversal of the wall.

Figure 18: Field strengths at different locations in the (indoor) transmission path of an uplink transmission with 200 mW transmission power

Figure 18 shows the propagation of the field strength along the indoor transmission path for a UE assumed to transmit with 23 dBm from the far end of a building relative to the base station. This calculation takes into account the attenuation of the free space transmission within the room. Two variants of the transmission path with different attenuations are shown as indicated by the arrows. They represent two different heights of the base station. For the horizontal arrow, the signal has to traverse three rooms on the shortest path before it reaches optical visibility of the base station. For the diagonal arrow, the paths through the rooms are longer while the attenuation caused by walls remains at a constant level. The parameters for the attenuation of inner and outer walls are taken from Table 17. Reflections within the building are not taken into account. Since the distance of the base station is assumed to be below 100 m the Okumura-Hata model is not applicable.

The calculation results in a transmit power of -17 dBm (horizontal case) and -30 dBm (diagonal case) at the outer side of the building which is available for bridging the remaining distance to the base station. This has to be regarded as very low for the transmission of a relevant data rate (requiring less robust modulations than QPSK). The results indicate that a guarantee for the uplink transmission power of the mobile terminal to remain well below the maximum power of 23 dBm (+2 dBm) is unlikely.

Table 18: Transmit power values in mobile ECN networks

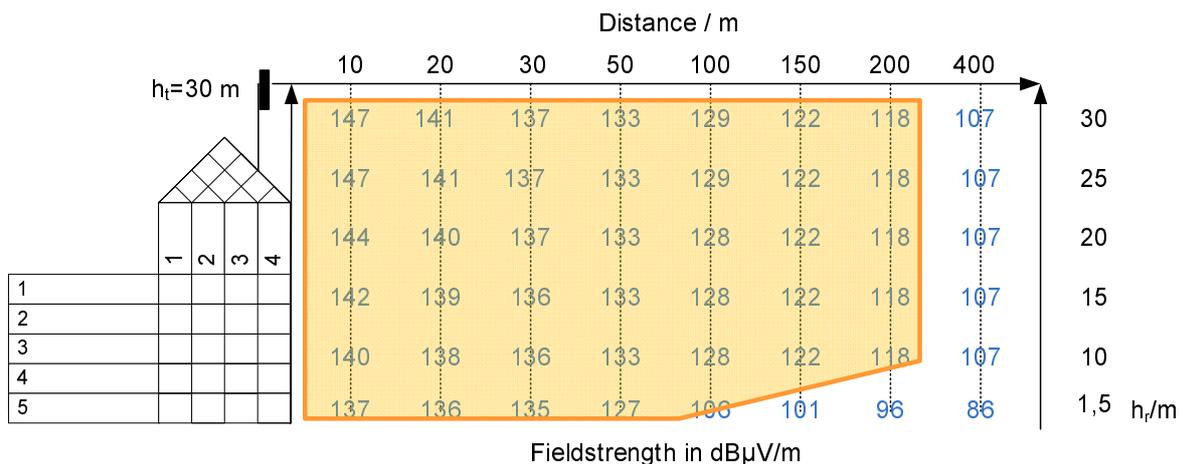
Power [dBm]	Power	Significance
-174 dBm		approximately noise power at 300 K temperature
-104 dBm	0,04 pW	minimum sensitivity of base station in GSM
-102 dBm	0,0633 pW	minimum sensitivity of mobile terminal in GSM
0 dBm	1 mW	typical minimal transmit power of mobile terminal in GSM 1800 with optical line of sight
5 dBm	3,17 mW	typical minimal transmit power of mobile terminal in GSM 900 with optical line of sight
21 dBm	125 mW	typical transmit power of mobile terminal
24 dBm	250 mW	approximately average transmit power of mobile terminal class 3 in GSM 900
30 dBm	1 W	maximum transmit power of mobile terminal class 1 in GSM 1800 ($\pm 2,5$ dB)
33 dBm	2 W	maximum transmit power of mobile terminal class 3 in GSM 900 ($\pm 2,5$ dB)
40 dBm	10 W	typical transmit power of base station in UMTS
43 dBm	20 W	typical transmit power of base station in GSM
60 dBm	1 kW	typical transmit power of FM broadcast transmitter

As indicated in Table 18, even in GSM networks with their comparably robust modulation and low data rates a transmit power of 0 dBm and more is required from the mobile terminal for an optical line-of-sight connection to the base station. Consequently, it cannot be expected that a transmit power of -17 dBm and below at the edge of the outdoor part of the uplink transmission path will be sufficient in urban areas with typical lack of optical line-of-sight. It is estimated that values around 5 dBm to 7 dBm are more appropriate for an LTE network.

9.2.2 Downlink transmission path

In the assessment of the interference potential of base station transmission the BS parameters as defined in CEPT Report 30 [i.1] and as listed in Table 10 have to be taken into account.

Figure 19 shows the calculation of the field strength caused by the base station transmission of a 5 MHz signal at 62,5 dBm EIRP according to the Okumura-Hata-Model. This propagation model for base station transmission was also used for the calculations in CEPT Report 30. In Figure 19, values of field strength are indicated at the receiver location at heights varying from 1,5 m up to 30 m above ground. All calculations are based on optical line-of-sight and are using the parameters as defined in CEPT Report 30 [i.1].



NOTE: Yellow shaded area were disturbance in co-channel and with N+5 and N+9 is likely to occur.

Figure 19: Field strengths caused by BS transmission (62,5 dBm/5 MHz EIRP) according to Okumura-Hata-Model

Figure 19 depicts the locations where interference of fixed broadband networks in co-channel and with N+5 and N+9 is likely to occur. Standard-compliant cable networks are defined not to be affected by interference with 106 dBµV/m in 3 m distance to the outside wall of the building. In the definition of the potentially disturbed area the attenuation of the outer wall with 8 dB as well as the better immunity against interferers in the mirror channels with 5 dB were taken into account. If the minimum immunity of CPE as found by the German measurements in Kolberg would be considered, the area of potential interference would increase significantly.

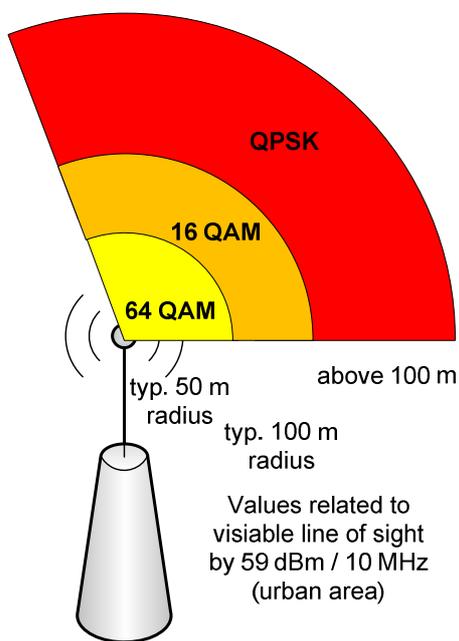


Figure 20: LTE 800 modulation schemes and Base Station power regarding to the distance in urban areas

Figure 20 shows that the 64 QAM transmission from Base stations to the UE related to the relevant transmit power and the used distance. For indoor reception, different values depending on the location of the UE in the premises will be observed.

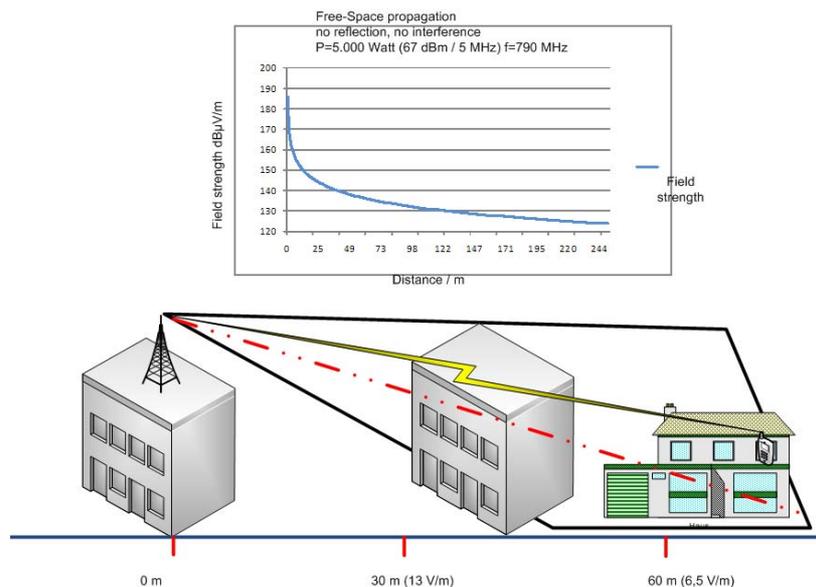


Figure 21: Free space propagation of a base station with a transmit power of 67 dBm/10 MHz

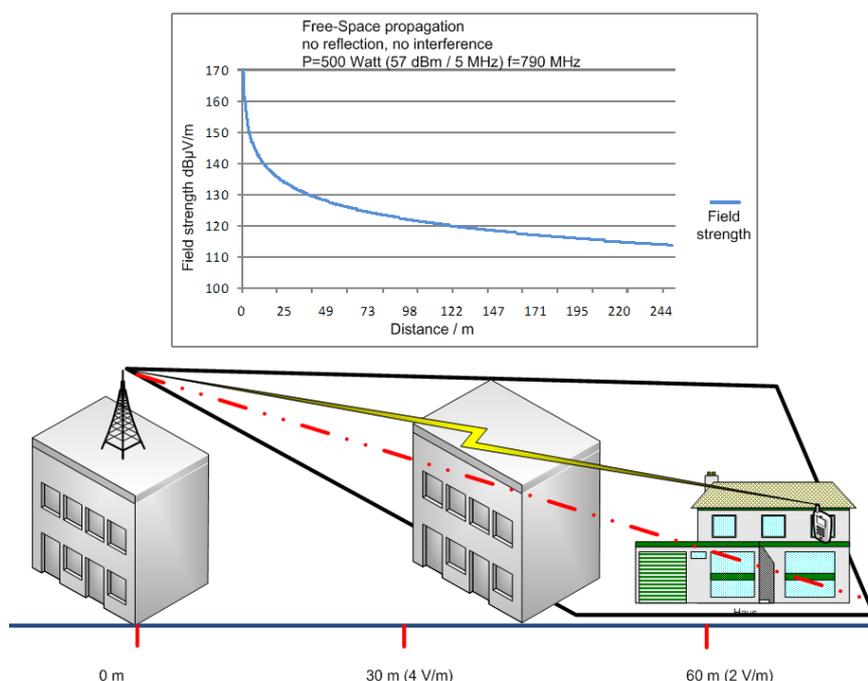


Figure 22: Free space propagation from a base station with a transmit power of 57 dBm

9.2.3 Summary of results

The above calculations show that for ECN in the 800 MHz band the highest power is necessary to transmit the relevant data rate to the customer. Also the UE has to use the highest power to transmit the uplink data rate to the base station, considering the case of an indoor reception. For the calculations and criteria of assessment of the electromagnetic environment the JWG has to use the case of the upper limits of the values of the CEPT Report 30 [i.1].

The business models of the MNO take the high data rates into account to generate the relevant business. For these data rates the MNO needs a high carrier to noise margin in the Base station and UE signals.

Taking into account the results of modelling transmit power in ECN networks, a disturbance radius can be calculated.

Calculation of the disturbance radius for a 64 QAM usage in broadband networks @ a system screening effectiveness 65 dB		
Parameter (Co-Channel)	Disturbance radius	Reference
Disturbance radius based on parameters table xx (@ 25 dBm)	33,14 m	German working group with BNetzA
Wall attenuation by 4 dB	21 m	Reducing of the disturbance radius to the immediate neighbour
Reducing of the mobile transmit power to 14 dBm	5,9 m	Reducing of the disturbance radius to the immediate neighbour
Reducing of the mobile transmit-power to 8 dBm Advice: 8 dBm transmit power relates to a power outside a building with 0 dBm with a calculated wall attenuation by 8 dB and no attenuation inside the building	3 m	Reducing of the disturbance radius to the immediate neighbour

Figure 23: Calculation of the disturbance radius with a 64 QAM modulation in the broadband network with a screening effectiveness in the system of 65 dB Co-Channel situation with a focus on the disturbance of the immediate neighbour

Calculation of the disturbance radius for a 64 QAM usage in broadband networks @ a system screening effectiveness 65 dB related to the if and mirror frequency		
Parameter (if and mirror frequency)	Disturbance radius	Reference
Disturbance radius based on parameters table xx (@ 25 dBm)	13,2 m	German working group with BNetzA
Wall attenuation by 4 dB	8,32 m	Reducing of the disturbance radius to the immediate neighbour
Reducing of the mobile transmit power to 14 dBm	2,35 m	Reducing of the disturbance radius to the immediate neighbour
Reducing of the mobile transmit-power to 8 dBm Advice: 8 dBm transmit power relates to a power outside a building with 0 dBm with a calculated wall attenuation by 8 dB and no attenuation inside the building	1,2 m	Reducing of the disturbance radius to the immediate neighbour

Figure 24: Calculation of the disturbance radius with a 64 QAM modulation in the broadband network with a screening effectiveness in the system of 65 dB IF and mirror frequency situation with a focus on the disturbance of the immediate neighbour

History

Document history		
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