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Technical Report

Access, Terminals, Transmission and Multiplexing (ATTM); Assessment of Cable Equipment with Digital Dividend; New Electronic Communication Networks (ECN) Operating in the UHF band 790 MHz to 862 MHz

Reference

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Foreword

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

Introduction

The present document is intended to provide information to those stakeholders typically from the wired fixed network sector i.e. the integrated broadband cable television network providers and their equipment suppliers, about the expected use of Electronic Communication Network (ECN) services within the Digital Dividend and its relevance to cable services. The present document addresses the potential Electronic Communication Network (ECN) services intended to operate within the digital dividend frequency range 790 MHz to 862 MHz.

The present document examines the relationship of proposed new ECN mobile services operating in the UHF frequency band 790 MHz to 862 MHz with the current users of this RF frequency range contained in wired line cables designed and operated according to CENELEC standards for system performance and electromagnetic compatibility, in particular to current services provided by CATV and Integrated Broadband Cable networks.

1 Scope

The present document presents an overview of cable architecture and the digital dividend for ECN800 services.

The present document is intended to provide information to non-radio engineers not familiar with the concept of digital dividend, the committees involved within ETSI, ECC and EC and intends to detail and explain the procedures that lead to the licensing of spectrum for new radio ECN services.

The present document also documents and references activities by various organisations both SDOs and non-SDOs involved in the assessment of the interference from ECN800 to viewers and users of current services such as broadband internet, TV (video) and telephony services.

NOTE: It should be noted that the present document is not intended to capture all of the assessments of digital dividend ECN800 interactions with RF Cable Network services carried out by industry. The present document only captures some of the industry studies known at the time of the development of te present document. It is recognised that various stakeholders and regulatory bodies have, since the development of the present document and since the finalisation of the present document, carried out further assessments.

The ETSI committee ATTM-AT3 may prepare a revision to the present document to accommodate new information and improvements as further studies from industry and developments become known. ATTM confirms that further comments received will be managed to produce a subsequent publication of the present document.

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.

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

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] CEPT Report 21 (1st July 2008): Report A from CEPT to the European Commission in response to the Mandate on: "Technical considerations regarding harmonisation options for the Digital Dividend" "Compatibility issues between "cellular / low power transmitter" networks and "larger coverage / high power / tower" type of networks".

[i.2] CEPT Report 22 (1st July 2008): Report B from CEPT to the European Commission in response to the Mandate on: "Technical considerations regarding harmonisation options for the Digital Dividend" "Technical Feasibility of Harmonising a Sub-band of Bands IV and V for Fixed/Mobile Applications (including uplinks), minimising the Impact on GE06".

[i.3] CEPT Report 23 (1st July 2008): Complementary Report to Report B (CEPT Report 22) from CEPT to the European Commission in response to the Mandate on:"Technical considerations regarding harmonisation options for the Digital Dividend" "Technical Options for the Use of a Harmonised Sub-Band in the Band 470 - 862 MHz for Fixed/Mobile Application (including Uplinks)".

[i.4] CEPT Report 19 (October 2002): Guidance material for assessing the spectrum requirements of the fixed service to provide infrastructure to support the UMTS/IMT-2000 networks.

[i.5] MoU between ETSI and CEPT revised April 2004.

NOTE: Available at http://www.ero.dk/AA0FDA9E-14AF-4718-8A12-724E4B086AF6?frames=no&.

[i.6] MoU between EC and CEPT.

NOTE: Available at http://www.ero.dk/DED471D2-A68C-4577-AD70-1F01EF3C9A72?frames=no&.

[i.7] Letter of understanding between ECCA and ECC dated 12th September 2006.

NOTE: Available at http://www.cept.org/D9296FE9-72FF-4791-B2CC-339028D7E199?frames=no&.

[i.8] Commission Decision 2010/267/EU 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.

[i.9] CEPT Report 30 (30th October 2009): Report from CEPT to the European Commission in response to the Mandate on "The identification of common and minimal (least restrictive) technical conditions for 790 - 862 MHz for the digital dividend in the European Union".

[i.10] 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.

[i.11] ETSI TS 136 300: "Universal Mobile Telecommunications System (UMTS); Evolved Universal Terrestrial Radio Access (E-UTRA) and Evolved Universal Terrestrial Radio Access (E-UTRAN); Overall description; Stage 2 (3GPP TS 36.300 Release 9)".

[i.12] ITU-R Recommendation F.1336: "Reference Radiation Patterns of Omnidirectional, Sectoral and other Antennas in Point-To-Multipoint Systems for use in Sharing Studies In The Frequency Range from 1 GHz to about 70 GHz".

[i.13] ETSI TS 136 101: "LTE; Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio transmission and reception (3GPP TS 36.101 Release 9)".

[i.14] ETSI TS 136 104: "LTE; Evolved Universal Terrestrial Radio Access (E-UTRA); Base Station (BS) radio transmission and reception (3GPP TS 36.104 Release 9)".

[i.15] ETSI TR 136 942: "LTE; Evolved Universal Terrestrial Radio Access (E-UTRA); Radio Frequency (RF) system scenarios (3GPP TR 36.942 Release 9)".

[i.16] ECC Decision of 30 October 2009 on harmonised conditions for mobile/fixed communication networks operating in the band 790-862 MHz.

[i.17] ETSI TR 102 881: "Access, Terminals, Transmission and Multiplexing (ATTM); Cable Network Handbook".

[i.18] CENELEC EN 50083 Series (CENELEC CLC/TC 209): "Cable networks for television signals, sound signals and interactive services".

[i.19] CENELEC EN 60728 Series (CENELEC CLC/TC 209): "Cable networks for television signals, sound signals and interactive services".

[i.20] CENELEC EN 55024: "Information technology equipment - Immunity characteristics - Limits and methods of measurement".

[i.21] CENELEC EN 61000-4-3: "Electromagnetic compatibility (EMC). Testing and measurement techniques. Radiated, radio-frequency, electromagnetic field immunity test".

[i.22] CENELEC EN 55020: "Sound and television broadcast receivers and associated equipment. Immunity characteristics. Limits and methods of measurement".

[i.23] CENELEC EN 50117: "Coaxial cables. Sectional specification for cables used in cabled distribution networks".

[i.24] CENELEC EN 60966: "Radio frequency and coaxial cable assemblies".

[i.25] CENELEC EN 50529-2: "EMC network standard. Wire-line telecommunications networks using coaxial cables".

[i.26] CENELEC EN 50083-8: "Cable networks for television signals, sound signals and interactive services. Electromagnetic compatibility for networks".

[i.27] CENELEC EN 50083-2: "Cable networks for television signals, sound signals and interactive services. Electromagnetic compatibility for equipment".

[i.28] Cable Europe: Trade Association of European Cable Operators.

NOTE: Available at http://www.cable-europe.eu/.

[i.29] Excentis: Providing excellence in telecom and ICT services.

NOTE: Available at http://www.excentis.com/about.php

[i.30] TNO - Dutch research center.

NOTE: Available at http://www.tno.nl/index.cfm?Taal=2.

[i.31] NLKabel - Dutch trade organization of Dutch Cable Operators.

NOTE: Available at http://www.nlkabel.nl/nl/Home.aspx

[i.32] CENELEC TC210 joint TC209 meeting held Dublin, Ireland, 12-13 August 2010; Decision D210/209-02.

[i.33] Report for the European Commission "Exploiting the Digital Dividend - A European Approach", Analysys Mason et al., 14 August 2009.

NOTE: Available at http://www.analysysmason.com.

[i.34] COM(2007) 700 final 13.11.2007, COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS "Reaping the full benefits of the digital dividend in Europe: A common approach to the use of the spectrum released by the digital switchover".

[i.35] Response to the Digital Dividend Public Consultation, Pearle (Ref: 2009/AD/P5911).

[i.36] Excel file.

NOTE: Available at http://www.ero.dk/40A95B5A-E01A-4E69-A3B6-986C08B6BE50?frames=no&.

[i.37] European process of standardisation and regulation for radiocommunications devices and systems - cooperation between CEPT and ETSI.

NOTE: Available at http://www.ero.dk/C01A05A6-F594-4C2D-8506-0BAF4589A5BB?frames=no&.

[i.38] ECC, ETSI: "The European regulatory environment for radio equipment and spectrum: an introduction".

[i.39] ITU Radio Regulations Edition of 2008.

NOTE: Available at http://www.itu.int/pub/R-REG-RR-2008.

[i.40] ETSI EN 300 429 (V1.2.1): "Digital Video Broadcasting (DVB); Framing structure, channel coding and modulation for cable systems".

[i.41] ETSI TS 102 639: "Access and Terminals, Transmission and Multiplexing (ATTM); Third Generation Transmission Systems for Interactive Cable Television Services - IP Cable Modems".

[i.42] ETSI EN 300 422: "Electromagnetic compatibility and Radio spectrum Matters (ERM); Wireless microphones in the 25 MHz to 3 GHz frequency range".

[i.43] ETSI EN 301 357 (all parts): "Electromagnetic compatibility and Radio spectrum Matters (ERM); Cordless audio devices in the range 25 MHz to 2 000 MHz".

[i.44] ETSI EN 301 489-9: "Electromagnetic compatibility and Radio spectrum Matters (ERM); ElectroMagnetic Compatibility (EMC) standard for radio equipment and services; Part 9: Specific conditions for wireless microphones, similar Radio Frequency (RF) audio link equipment, cordless audio and in-ear monitoring devices".

[i.45] ETSI EN 300 220: "Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD); Radio equipment to be used in the 25 MHz to 1 000 MHz frequency range with power levels ranging up to 500 mW".

[i.46] ETSI ES 202 127: "Electromagnetic compatibility and Radio spectrum Matters (ERM); Radio frequency amplifiers and pre-amplifiers used for broadcast TV and sound reception from 47 MHz to 860 MHz".

[i.47] ETSI/ECC joint website.

NOTE: Available at http://www.ero.dk/ecc-etsi.

[i.48] Radio Spectrum Committee working document: "RSCOM10-50".

[i.49] Directive 2004/108/EC of the European Parliament and of the Council of 15 December 2004 on the approximation of the laws of the Member States relating to electromagnetic compatibility and repealing Directive 89/336/EEC.

[i.50] ITU-R Recommendation P.1546: "Method for point-to-area predictions for terrestrial services in the frequency range 30 MHz to 3 000 MHz".

[i.51] CENELEC TC209: "Comité Européen de Normalisation Électrotechnique, Technical Committee 209".

[i.52] CENELEC TC210: "Comité Européen de Normalisation Électrotechnique, Technical Committee 210".

3 Abbreviations

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

AMC Adaptive Modulation and Coding
ANGA Association of German Cable Operators
ARQ Automatic Repeat reQuest
ATRT Auschuss Technische Regulierung in der Telekommunikation

NOTE: Consulting Committee on Technical Regulation in Telecommunications to BNetzA

BAKOM Switzerland Federal Office of Communications
BEM Block Edge Mask
BNetzA Bundesnetzagentur

NOTE: German National Regulator

BS Base Station
CATV Community Antenna TeleVision
CEPT Conference of European Postal and Telecommunications

CPE	Customer Premises Equipment
CRC	Cyclic Redundancy Check
DL	DownLink
DTT	Digital Terrestrial Television
DVB	Digital Video Broadcasting
DVB-C	Digital Video Broadcast - Cable
DVB-T	Digital Video Broadcast - Terrestrial
e.i.r.p.	equivalent isotropic radiated power
EC	European Commission
ECC	Electronic Communications Committee
ECCA	European Cable Communications Association
ECN	Electronic Communication Networks
ECN800	ECN operated in the frequency band 792 MHz to 862 MHz
EIRP	Equivalent Isotropically Radiated Power
EMC	ElectroMagnetic Compatibility
ETSI	European Telecommunications Standards Institute
EU	European Union
EuroDOCSIS	European data over cable service interface specification
EUT	Equipment Under Test
FDD	Frequency Division Duplex
GSM	Global System for Mobile
HFC	Hybrid Fibre-Coax
IDTV	Interactive Digital Television
IMT	International Mobile Telecommunications
IP	Internet Protocol
ITU	International Telecommunications Union
JWG DD	JWG Digital Dividend
JWG	Joint Working Group
LTE	Long-Term Evolution
LTE800	Long Term Evolution technology operated in the frequency band 792 MHz to 862 MHz
MBSFN	Multicast/Broadcast over Single Frequency Network
MFCN	Mobile/Fixed Communication Network
MHz	MegaHertz
MIMO	Multiple In Multiple Out
MoU	Memorandum of Understanding
MU-MIMO	Multi User Multiple Input Multiple Output
OFDM	Orthogonal Frequency-Division Multiplexing
PAL	Phase Alternating Line
PDSCH	High Speed - Physical Downlink Shared CHannel
PDU	Protocol Data Unit
PPDR	Public Protection and Disaster Relief
PUSCH	Physical Uplink Shared Channel
QoS	Quality of Service
QPP	Quadratic Permutation Polynomial
QPSK	Quadrature Phase Shift Keying
R&TTE	Radio and Telecommunication Terminal Equipment
RF	Radio Frequency
RMS	Root Mean Square
RSPG	Radio Spectrum Policy Group
SDM	Spatial Division Multiplexing
SDO	Standards Development Organisations
SIR	Signal Interference Ratio
STB	Set Top Box
TDD	Time Division Duplexing
TRP	Total Radiated Power
TS	Transmitter
TTI	Transmission Time Interval
TV	Television
UDP	User Datagram Protocol
UE	User Equipment
UHF	Ultra High Frequency
UL	UpLink

UMTS Universal Mobile Telecommunication System
WRC World Radio Conference

4 Digital Dividend

Digital Dividend refers to the portion of the radio frequency spectrum that is made available for new usages following switching off the analogue terrestrial broadcast television services and migrating to digital terrestrial services requiring less frequency bandwidth to deliver a similar service portfolio as with analogue signals. The saving in the frequencies is considered by the European Commission as a dividend that may be assigned for use for other electronic communication network (ECN) radio services. The Digital Dividend frequencies may be licensed by national regulators for use by ECN service providers through auction sales, similar to the GSM and UMTS auctions. The Digital Dividend frequencies 790 MHZ to 862 MHz may be licensed by national regulators.

The ITU Radio Regulations [i.39] incorporates the decisions of the World Radiocommunication Conferences, including all Appendices, Resolutions, Recommendations and ITU-R Recommendations incorporated by reference. The Radio Regulations edition of 2008 [i.39], contains the complete texts of the Radio Regulations as adopted by the World Radiocommunication Conference (Geneva, 1995) (WRC-95) and subsequently revised and adopted by the World Radiocommunication Conference (Geneva, 1997) (WRC-97), the World Radiocommunication Conference (Istanbul, 2000) (WRC-2000), the World Radiocommunication Conference (Geneva, 2003) (WRC-03), and the World Radiocommunication Conference (Geneva, 2007) (WRC-07), including all Appendices, Resolutions, Recommendations and ITU-R Recommendations incorporated by reference.

The footnote 5.316B of the ITU Radio Regulations [i.39] states:

> *"**5.316B** In Region 1, the allocation to the mobile, except aeronautical mobile, service on a primary basis in the frequency band 790-862 MHz shall come into effect from 17 June 2015 and shall be subject to agreement obtained under No. **9.21** with respect to the aeronautical radionavigation service in countries mentioned in No. **5.312**. For countries party to the GE06 Agreement, the use of stations of the mobile service is also subject to the successful application of the procedures of that Agreement. Resolutions **224 (Rev.WRC-07)** and **749 (WRC-07)** shall apply. (WRC-07)".*

The ITU Radio Regulations 5.3 [i.39] provides the definition of Region 1.

In January 2007, the European Commission issued a first mandate on the Digital Dividend "on technical considerations regarding harmonisation options for the digital dividend". The response to this mandate is contained in CEPT Report 21 [i.1], CEPT Report 22 [i.2] and CEPT Report 23 [i.3]. Prior to this, in July 2006, the Commission issued a Mandate to CEPT "to develop least restrictive technical conditions for frequency bands addressed in the context of WAPECS". The response to this mandate is contained in CEPT Report 19 [i.4].

The National Administrations from European Member States are responsible for frequency management within their respective jurisdiction and regulate the use of the spectrum. Coordination at European level is achieved through CEPT and on global level through the WRC.

4.1 European Players

An introduction to the European regulatory environment for radio equipment and spectrum is given in [i.38].

Further information on the cooperation between ETSI and ECC is available on the joint website [i.47] http://www.ero.dk/ecc-etsi.

The European players involved in the management of the spectrum, decisions on its use and development of technical parameters are:

- Standardisation Institutes such as ETSI and CENELEC. ETSI develops draft system reference documents that are approved by ETSI members and submitted to CEPT.

- ECC as the Electronic Communication Committee dealing with communication matters within CEPT which is the Conference of European Posts and Telecommunications Administrations. Established 1959 with over 44 member countries manage the frequency allocation in Europe.

- European Member State Administrations.

- European Commission.
- European Parliament.
- European Council.

ETSI develops System Reference Documents (SRDoc) providing technical background on new radio systems and informs ECC accordingly. ECC analyses ETSI SRDoc or other industry proposals, to identify possible new opportunities to use spectrum and where needed, conducts the relevant sharing studies and develops harmonised conditions to use spectrum and keeps ETSI informed on the further development.

ECC and ETSI representatives meet on a yearly basis in order to maintain strong coordination between the two organizations, to discuss strategic issues and to report on the ongoing activities in each of the organizations.

In this framework, ECC and ETSI are maintaining a relationship matrix [i.36], reflecting the work and information connections between groups of the ECC and ETSI. This matrix is intended to be used in order to ease the cooperation between related groups in ETSI and ECC, also to provide opportunities for possible joint meetings.

- An MoU is established between ETSI and CEPT signed 20th October 2004 [i.5].
- An MoU is established between EC and CEPT signed 31st January 2004 [i.6].
- A letter of understanding is established between ECCA and ECC signed 14th April 2003 [i.7].

4.2 ETSI and CEPT Process

The European process of standardisation and regulation for radiocommunications devices and systems - cooperation between CEPT and ETSI [i.37] presents the flowchart describing the procedures between ETSI and CEPT and within each organization

Figure 1 presents the current flow chart at the time of the preparation of the present document.

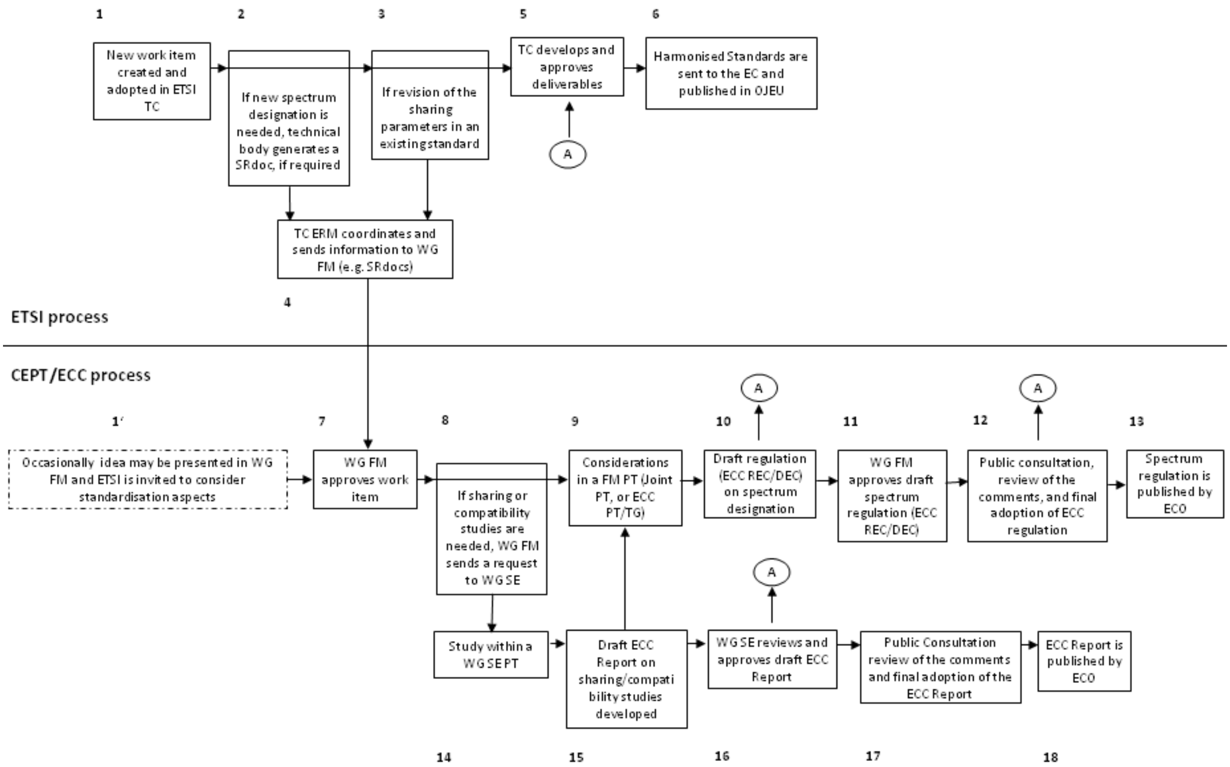


Figure 1: ETSI and CEPT/ECC Process Flow

4.3 Characteristics of ECN800 transmission

Technical conditions for the deployment of mobile services in the 800 MHz band (ECN800) are provided in the Decision of the Commission of the European Union of 6 May 2010 [i.8] on harmonised technical conditions of use in the 790 MHz to 862 MHz frequency band for terrestrial systems capable of providing electronic communications services in the European Union. The Commission Decision includes the technical parameters defined in CEPT Report 30 [i.9] which are also contained in ECC decision (09)03 of 30 October 2009 [i.16] where European administrations commit voluntarily to implement the assignment of frequencies to ECN800 services based on CEPT Report 30 [i.9].

Section 4.2 of the EC Decision 2010/267/EU [i8] states:

> *"(16) Member States may decide individually whether and at what point in time they designate or make available the 800 MHz band for networks other than high-power broadcasting networks, and this Decision is without prejudice to the use of the 800 MHz band for public order and public security purposes and defence in some Member States.*
> *Article 2 1. When they designate or make available the 800 MHz band for networks other than high-power broadcasting networks, Member States shall do so, on a non-exclusive basis, for terrestrial systems capable of providing electronic communications services in compliance with the parameters set out in the Annex to this Decision."*

Technical conditions that were defined in CEPT Report 30 [i.9] are reflected in the EC Decision [i.8] and aim to minimize the restrictions on mobile communication networks in the 800 MHz band whilst enabling the protection of broadcasting operations. The analysis limited its considerations to the coexistence with terrestrial broadcasting networks disregarding other incumbent users of the relevant RF frequencies such as HFC networks. The conditions that are defined include:

- A frequency arrangement using FDD and reflecting the preferred harmonised channelling arrangement as defined in CEPT Report 30 [i.9].
- A block edge mask defining the signal levels in the transmitting channel and in adjacent spectrum areas.
- Limits on transmission power of terminal devices and base stations taking into account outdoor and indoor signal propagation.

The technical conditions defined may not relate to the final conditions that may be found in practical deployments. It should be noted that the criterion defined in Commission Decision 2010/267 /EU of 6 May 2010 [i.8] on harmonised technical conditions of use in the 790 MHz to 862 MHz frequency".

Specifically it is stated by this Commission Decision that:

> "*(9) CEPT Report 30 identifies least restrictive technical conditions through the concept of Block-Edge Masks (BEMs), which are regulatory requirements aimed at managing the risk of harmful interference between neighbouring networks and are without prejudice to limits set in equipment standards under 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 (the R&TTE Directive). Based on this CEPT Report the BEMs are optimised for, but are not limited to, fixed and/or mobile communications networks using Frequency-Division Duplexing (FDD) and/or Time-Division Duplexing (TDD).*
>
> *(10) In cases where harmful interference has been caused or where it is reasonably considered that it could be caused, the measures identified in CEPT Report 30 could also be supplemented by proportionate national measures that could be imposed.*
>
> *(11) The avoidance of harmful interference and disturbance to television receiver equipment, including cable TV equipment, may depend on more effective interference rejection in such equipment. Conditions related to television receiver equipment should be addressed as a matter of urgency within the framework of the Directive 2004/108/EC of the European Parliament and of the Council of 15 December 2004 on the approximation of the laws of the Member States relating to electromagnetic compatibility and repealing Directive 89/336/EEC (EMC Directive)."*

The Radio Spectrum Committee working document RSCOM10-50 [i.48] provides information regarding the Commission activities related to the Radio Spectrum Policy Programme. In particular, it notes that "*on 20 September 2010 the Commission adopted its proposal for the first five-year radio spectrum policy programme which outlines actions and common principles to ensure that radio spectrum is used efficiently to best meet the needs of EU citizens, industry and policy-makers.*".

4.3.1 General Overview of LTE Mobile Services

4.3.1.1 Overview of the LTE Radio Interface

In the following clauses an overview of the LTE radio interface as it pertains to the system behaviour in the context of the Digital Dividend issue is provided. Further information can be found in TS 136 300 [i.11] which is also the source for the material below.

4.3.1.1.1 General

Downlink and uplink transmissions are organized into radio frames with 10 ms duration.

The frame structure is illustrated in figure 2. Each 10 ms radio frame is divided into ten equally sized sub-frames. Each sub-frame consists of two equally sized slots. For FDD, 10 sub frames are available for downlink transmission and 10 sub frames are available for uplink transmissions in each 10 ms interval. Uplink and downlink transmissions are separated in the frequency domain.

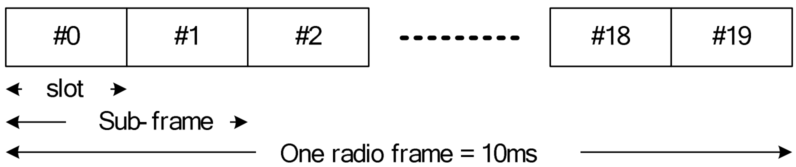


Figure 2: FDD Frame structure

4.3.1.1.2 Downlink Transmission

The downlink transmission scheme is based on conventional OFDM using a cyclic prefix. The OFDM sub-carrier spacing is 15 kHz. 12 consecutive sub-carriers during one slot correspond to one downlink resource block. In the frequency domain, the number of resource blocks can range from 6 to 110.

The downlink physical-layer processing of transport channels consists of the following steps:

- CRC insertion: 24 bit CRC is the baseline for PDSCH.
- Channel coding: Turbo coding based on QPP inner interleaving with trellis termination.
- Physical-layer hybrid-ARQ processing.
- Channel interleaving.
- Scrambling: transport-channel specific scrambling on DL-SCH, BCH, and PCH. Common MCH scrambling for all cells involved in a specific MBSFN transmission.
- Modulation: QPSK, 16QAM, and 64QAM.
- Layer mapping and pre-coding.
- Mapping to assigned resources and antenna ports.

Multi-antenna transmission with 2 and 4 transmit antennas is supported. The maximum number of codeword is two irrespective to the number of antennas with fixed mapping between codewords to layers.

Spatial Division Multiplexing (SDM) of multiple modulation symbol streams to a single UE using the same time-frequency (-code) resource, also referred to as Single-User MIMO (SU-MIMO) is supported. When a MIMO channel is solely assigned to a single UE, it is known as SU-MIMO. Spatial division multiplexing of modulation symbol streams to different UEs using the same time-frequency resource, also referred to as MU-MIMO, is also supported. There is semi-static switching between SU-MIMO and MU-MIMO per UE.

In addition, the following techniques are supported:

- Code-book-based pre-coding with a single pre-coding feedback per full system bandwidth when the system bandwidth (or subset of resource blocks) is smaller or equal to12RB and per 5 adjacent resource blocks or the full system bandwidth (or subset of resource blocks) when the system bandwidth is larger than 12RB.
- Rank adaptation with single rank feedback referring to full system bandwidth. Node B can override rank report.
- Link adaptation (AMC: Adaptive Modulation and Coding) with various modulation schemes and channel coding rates is applied to the shared data channel. The same coding and modulation is applied to all groups of resource blocks belonging to the same L2 PDU scheduled to one user within one TTI and within a single stream.
- Downlink power control can be used.

4.3.1.1.3 Uplink Transmission

For both FDD and TDD, the uplink transmission scheme is based on single-carrier FDMA, more specifically DFTS-OFDM.

The uplink sub-carrier spacing is 15 kHz. The sub-carriers are grouped into sets of 12 consecutive sub-carriers, corresponding to the uplink resource blocks. 12 consecutive sub-carriers during one slot correspond to one uplink resource block. In the frequency domain, the number of resource blocks can range from 6 to 110.

There are two cyclic-prefix lengths defined: Normal cyclic prefix and extended cyclic prefix corresponding to seven and six SC-FDMA symbol per slot respectively.

The uplink physical layer processing of transport channels consists of the following steps:

- CRC insertion: 24 bit CRC is the baseline for PUSCH.
- Channel coding: turbo coding based on QPP inner interleaving with trellis termination.
- Physical-layer hybrid-ARQ processing.
- Scrambling: UE-specific scrambling.
- Modulation: QPSK, 16QAM, and 64QAM (64 QAM optional in UE).
- Mapping to assigned resources and antennas ports.

The baseline antenna configuration for uplink MIMO is MU-MIMO. To allow for MU-MIMO reception at the Node B, allocation of the same time and frequency resource to several UEs, each of which transmitting on a single antenna, is supported.

Closed loop type adaptive antenna selection transmit diversity is supported for FDD (optional in UE).

Uplink link adaptation is used in order to guarantee the required minimum transmission performance of each UE such as the user data rate, packet error rate, and latency, while maximizing the system throughput.

Three types of link adaptation are performed according to the channel conditions, the UE capability such as the maximum transmission power and maximum transmission bandwidth etc., and the required QoS such as the data rate, latency, and packet error rate etc. Three link adaptation methods are as follows:

- Adaptive transmission bandwidth.
- Transmission power control.

- Adaptive modulation and channel coding rate.

4.3.1.1.4 Cell Search

Cell search is the procedure by which a UE acquires time and frequency synchronization with a cell and detects the Cell ID of that cell. E-UTRA cell search supports a scalable overall transmission bandwidth corresponding to 72 sub-carriers and upwards.

E-UTRA cell search is based on following signals transmitted in the downlink: the primary and secondary synchronization signals, the downlink reference signals.

The primary and secondary synchronization signals are transmitted over the centre 72 sub-carriers in the first and sixth sub frame of each frame.

Neighbour-cell search is based on the same downlink signals as initial cell search.

4.3.1.2 Deployment Scenarios

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.

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 1: List of parameters for ECN base station

e.i.r.p.	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 ITU-R Recommendation F.1336 [i.12]

Table 2: List of parameters for ECN terminal station

e.i.r.p.	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 ITU-R Recommendation F.1336 [i.12]

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 in table 3.

Table 3: Link budget used for ECN dimensioning

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 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**	Pn = kTB.NF plus any noise rise
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
Minimum SNR at cell-edge	dB	0.00	0.00	SNRmin 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	Ptarget = (Pn + SNR) + Lmargin
EIRP	**dBm**	**23.00**	**58.99**	P
Mean wall loss	dB	8.0	8.0	Lw
Receiver Antenna Gain (inc. losses)	dBi	15	0	Ga
Max allowed path loss	**dB**	**133.63**	**133.63**	Lp = (P - Lw + Ga) - Ptarget

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 an ECN cell coverage of 2,698 km when applying the JTG5-6 model.

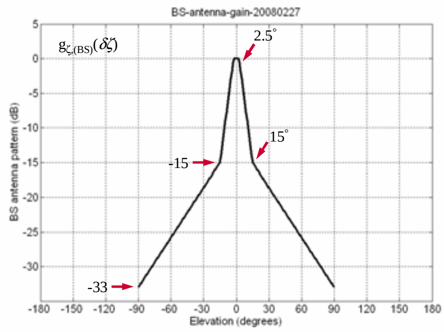
The same link budget applied to rural areas leads to an ECN cell radius of 3,46 km.

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.

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

Table 4: Assumptions related to ECN base station

ECN base station	
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	ITU-R Recommendation F.1336 [i.12] (section A1.2) or as in figure A1.5 (section A1.3)
Antenna tilt	0°



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

Figure 2a: BS antenna gain as a function of elevation

Table 5: Other sets of general assumptions

General	
Operating frequency	790 MHz
Min. horizontal separation between Tx and Rx	10 m
Mean path loss	Free space: -147,56 + 20 log10(*f*) + 20 log10(*d*) dB
	JTG model as described in annex 6 (Hata model up to 100 m, P.1546 [i.50] beyond 1 km and linear interpolation 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

4.3.2 Relevant ETSI Standards

The specifications for LTE are developed by the 3rd Generation Partnership Project (3GPP) and published as ETSI Technical Specifications (TS). The use of LTE in the 790 MHz to 862 MHz band is defined in Release 9 of the specifications.

Relevant information with regard to the coexistence of LTE with other technologies in terms of radio and electromagnetic compatibility is contained in:

- TS 136 101[i.13]: "LTE; Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio transmission and reception".

  This specification addresses the RF parameters of the physical layer for the LTE UE, both TDD and FDD.

- TS 136 104 [i.14]: "LTE; Evolved Universal Terrestrial Radio Access (E-UTRA); Base Station (BS) radio transmission and reception".

  This specification address the RF parameters of the physical layer for the LTE base station, both TDD and FDD.

- TR 136 942[i.15]: "LTE; Evolved Universal Terrestrial Radio Access (E-UTRA); Radio Frequency (RF) system scenarios".

  The present document describe deployment scenarios.

- TS 136 300 [i.11]: "LTE; Evolved Universal Terrestrial Radio Access (E-UTRA) and Evolved Universal Terrestrial Radio Access Network (E-UTRAN); Overall description; Stage 2".

4.3.3 CEPT Spectrum Band Plan

The ECC Decision of 30 October 2009 on harmonised conditions for mobile/fixed communication networks (MFCN) operating in the band 790 MHz to 862 MHz [i.16] refers to a preferred harmonised frequency arrangement as defined in Annex 1 of the ECC Decision ECC/DEC/(09)03 [i.16] and as illustrated in table 5. It is describing an arrangement of 2 × 30 MHz with a duplex gap of 11 MHz, based on a block size of 5 MHz, paired and with reverse duplex direction, and a guard band of 1 MHz starting at 790 MHz. The FDD downlink starts at 791 MHz and FDD uplink starts at 832 MHz.

The ECC also allows for an alternative frequency arrangement as defined in annex 2 of the same decision which is based on a block size of 5 MHz starting at 797 MHz, with a guard band of 7 MHz starting at 790 MHz containing 13 unpaired blocks of 5 MHz each. This frequency arrangement could be used e.g. for TDD allocation.

Table 6: Preferred harmonised frequency arrangement for FDD deployment of ECN800

790 to 791	791 to 796	796 to 801	801 to 806	806 to 811	811 to 816	816 to 821	821 to 832	832 to 837	837 to 842	842 to 847	847 to 852	852 to 857	857 to 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)					

The Commission Decision 2010/267/EU [i.8] of 6 May 2010 on harmonised technical conditions of use in the 790 MHz to 862 MHz frequency band defines a single frequency arrangement that is equivalent to the preferred harmonised frequency arrangement in the ECC Decision (see table 6). However, member states may implement alternative frequency arrangements provided that the apply the same technical conditions as defined in the Decision.

4.3.4 Block Edge Masks

Block Edge Masks allows for any transmission system within free space to be used providing that it performs to the technical characteristics of the BEM.

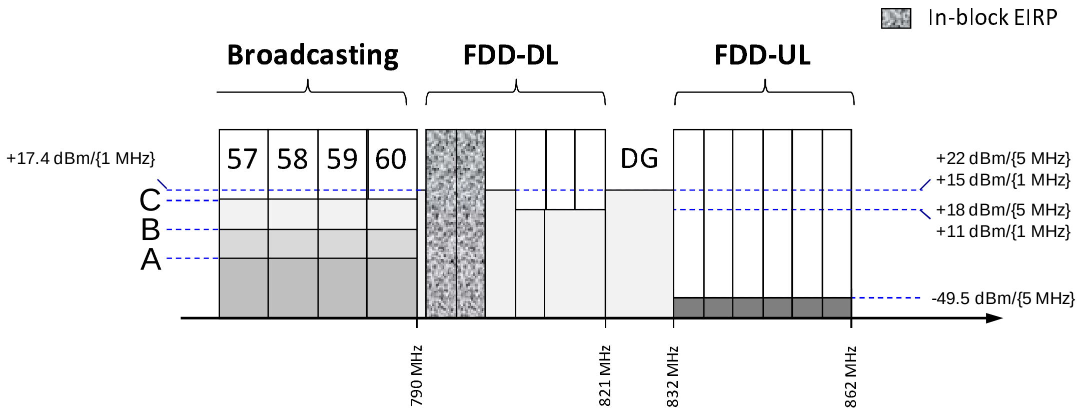
The BEMs are presented as upper limits on the mean EIRP or TRP (Total Radiated Power) over an averaging time interval, and over a measurement frequency bandwidth. In the time domain, the EIRP or TRP is averaged over the active portions of signal bursts and corresponds to a single power control setting. In the frequency domain, the EIRP or TRP is determined over the measurement bandwidth (e.g. block or TV channel) specified in the following tables. It should be noted that the actual measurement bandwidth of the measurement equipment used for purposes of compliance testing may be smaller than the measurement bandwidth provided in the tables.

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.

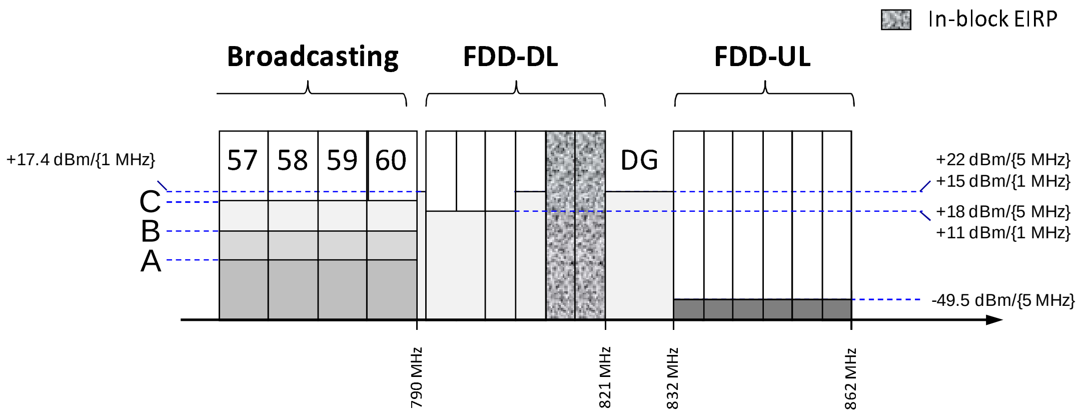
The term block edge refers to the frequency boundary of spectrum licensed to an ECN. The term band edge refers to the boundary of a range of frequencies allocated for a certain use (e.g. 790 MHz is the upper band edge for broadcasting, while 832 MHz is the lower band edge for FDD uplink). For requirements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

Figures 3 and 4 illustrate the base station block edge masks which are defined in ECC/DEC/(09)03 [i.16] for the preferred harmonised FDD frequency arrangement.



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

Figure 3: BS BEM for a FDD operator in the lowest two 5 MHz blocks in the preferred harmonized frequency arrangement



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

Figure 4: BS BEM for a FDD operator in the upper two 5 MHz blocks in the preferred harmonized frequency arrangement

For further information on BEMS and TRP (total radiated power), see section 6.6 of CEPT Report 30 [i.9].

4.4 Characteristics of HFC transmission

4.4.1 General Overview of HFC Networks

Hybrid Fibre-Coax (HFC) access networks are composed of optical fibre and coaxial cables to deliver broadcast television and high-quality video services as well as a range of multimedia communication services. Since most of today's networks allow for a bi-directional signal transmission, IP-based interactive services are provided such as very high-speed Internet access, telephony, Video on Demand, etc., figure 5 depicts the general architecture of an HFC network.

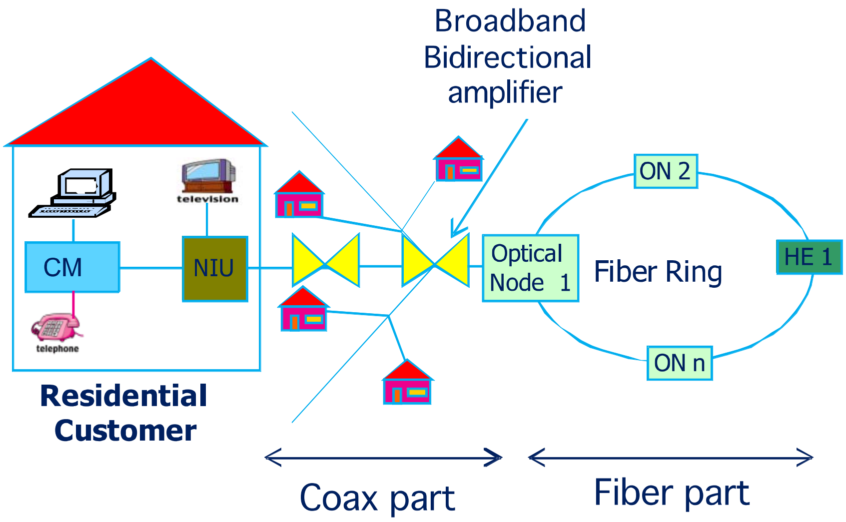


Figure 5: General architecture of HFC networks

Typically, optical fibre rings connect regional headends to optical nodes where the signals are transferred to electrical and transmitted on coaxial cables to be carried to the customer location. A headend may serve many tens of thousands of customer premises, with substantial resilience in the access network resulting in the need for network power at many roadside locations. Optical nodes typically serve between several hundreds to some thousands of homes.

The optical node is connected by two optical fibres to the optical ring (in practice 4 for redundancy reasons), one with the upstream signal and one with the downstream signal. Digital and analogue information is transmitted over the optical fibre by modulation of a sine carrier. Behind the optical node towards the homes, the coaxial distribution plant delivers all downstream signals to the homes and transports the upstream signals coming from the homes back to the optical node.

Two topologies for the coaxial part of the HFC network are in use in Europe: the tree-and-branch and the star architecture.

Tree-and-branch is the most typical architecture for the coaxial distribution plant (figure 6). The main trunk cable is split in branches through splitters. Splitters are bi-directional passive components used to split and combine signals over different paths.

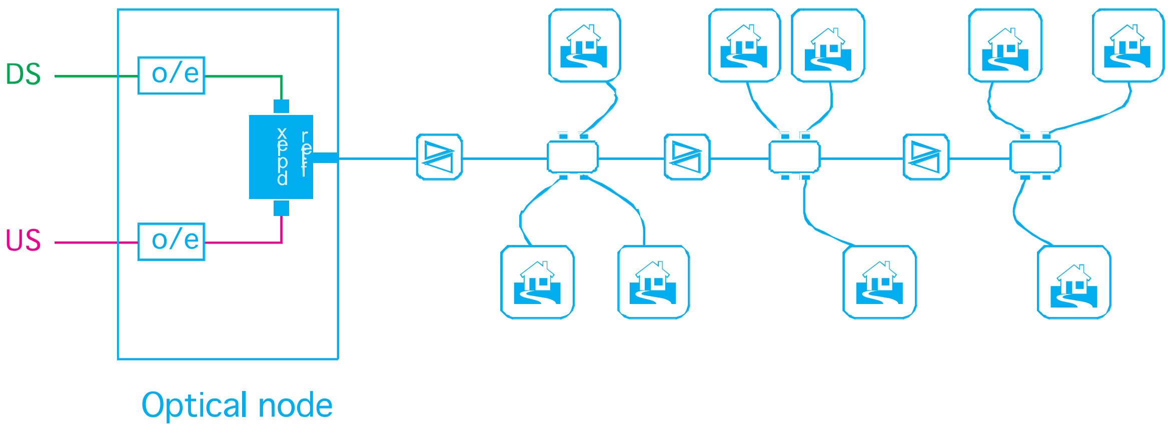
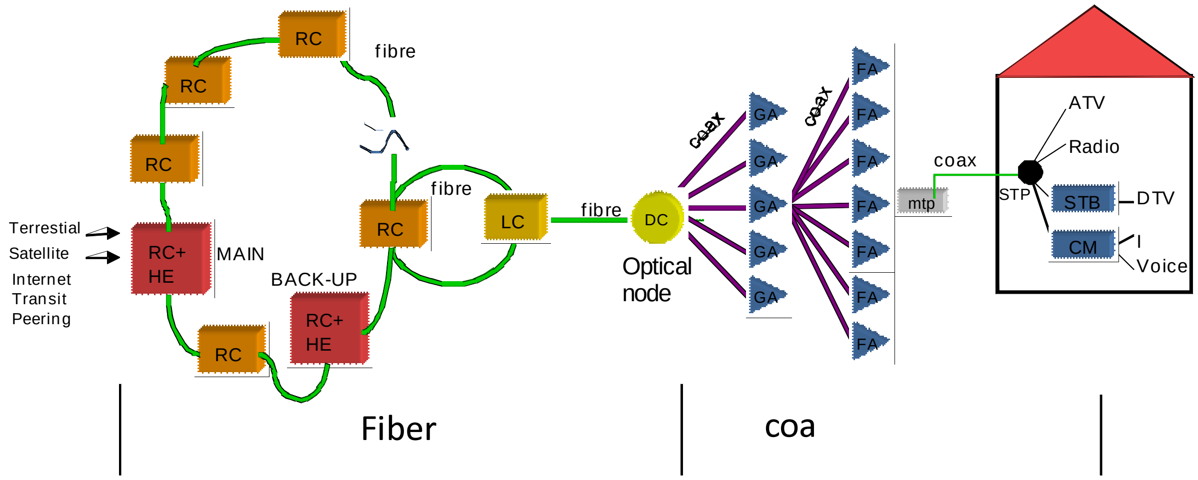


Figure 6: Tree-and-branch HFC network topology

An alternative topology is the star configuration as shown in figure 7. Splitters with multiple outputs or multi-taps (mtp) are used to connect several houses. This star topology is typical for the networks in the Netherlands.



RC	Regional Center.
LC	Local Center.
DC	District Center.
GA	Group Amplifier.
FA	Final Amplifier.

Figure 7: HFC network based on a star topology

The HFC network is a shared medium. This means that the signals transmitted by the different customers connected to the same segment of the optical node will be transported on the same cables. Therefore, solutions to avoid interference between the signals are needed. Moreover, the bandwidth provided by the spectrum of the HFC network will be shared among all customers of the coaxial segment connected to the optical node.

Further details on the architecture, technical features and services of HFC networks can be found in TR 102 881 [i.17].

4.4.2 Relevant Standards

The transmission system used to deliver signals across HFC networks in down- and upstream are mainly defined by ETSI standards, particularly:

- EN 300 429 [i.40]: "Digital Video Broadcasting (DVB);Framing structure, channel coding and modulation for cable systems".
- TS 102 639 series [i.41]: "Access and Terminals, Transmission and Multiplexing (ATTM); Third Generation Transmission Systems for Interactive Cable Television Services - IP Cable Modems".

Physical layer requirements are specified by CENELEC mainly in:

- EN 50083 [i.18]/EN 60728 series [i.19]: Cable networks for television signals, sound signals and interactive services.

4.5 Overview of initial activities to address coexistence

Fundamental technical conditions for the deployment of radio services in the Digital Dividend frequencies are laid out in CEPT Report 30 [i.9] with the intent to define 'common and minimal (least restrictive) conditions' for the 790 MHz to 862 MHz frequency band. CEPT SE42 for the development of CEPT Report 30 [i.9], considered the input from the cable sector was outside of their terms of reference. Input provided by the cable sector identifying itself as an incumbent user of the frequencies and a potential victim of interference from mobile communication services in the 800 MHz band despite well-defined EMC requirements in harmonized standards was not possible for CEPT to consider since this their scope did not address RF transmission services contained in wired/fixed networks. With the intent to address the gaps due to the lack of the assessment from CEPT, the Commission sent a letter to the Director Generals of ETSI and CENELEC with the request to conduct an analysis with the purpose to prepare standards that would identify measures to mitigate the interference from ECN800 to viewers of broadcast TV services and users of broadband internet services delivered by cable networks.

In reaction, CENELEC TC210 [i.52] took the initiative to create a working group and invite ETSI and other community interests to produce a report that provides some guidance to the standardization work that would be required by SDOs based on the characterization of the new and changing electromagnetic environment as well as potential mitigation measures that might be considered when reviewing the immunity and screening efficiency of equipment against currently published standards. The Joint Working Group Digital Dividend was established with its Terms of Reference as follows:

"To investigate the EMC requirements in accordance with the letter from the Commission of 30 November 2009. To propose a Technical Report to TC210 evaluating the emerging and future situation, including a description of the environment, and identifying relevant EMC immunity tests".

Concluding its analysis, the JWG delivered a concise report to CENELEC TC210 [i.52] as well as ETSI ERM. This report was also presented to the Commission responding to its letter. It contains fundamental conclusions and recommendations for the way forward:

- The radiated immunity test level for equipment containing DVB tuners for the frequency range 790 MHz to 862 MHz for the tuned channel is proposed as 1 V/m.
- and for other than the tuned channel in the 790 MHz to 862 MHz range 3 V/m is proposed.
- The present specifications for receiver parameters for CPE need revision due to the change in the ambient electromagnetic environment.
- Standards for coaxial networks need to be revised.
- Bandwidth requirements for terrestrial reception, antennas, head end and distribution amplifiers need to be revised appropriately.
- The immunity test requirements need to be revised to cover the frequency band 30 MHz to 1 GHz in some cases.
- Test methods, appropriate to the radiated electromagnetic environment, need to be reviewed to assess the screening performance of cables up to 1 GHz.
- A modulation specification for the test signal that will adequately represent the disturbing characteristics of the different radio technologies, which may be deployed, is needed. (Noting that the Commission decision is technology neutral.) At present, detailed technical information is only available on LTE and this has therefore been the basis of the work of the JWG.
- Further investigations are need to determine if the application of the present narrow band analogue test signal defined in EN 61000-4-3 [i.21] is adequate to simulate the disturbing aspects of the radio technologies which may be deployed. In particular the time domain and bandwidth aspects need urgent investigation.
- Once the work of CEPT FM 22 on measuring Block Edge Masks is finalised, consideration should be given to convert this method of measurement into a standard.

As well as proposals for measures to minimise interference.

A joint meeting of CENELEC TC209 [i.51] and CENELEC TC210 [i.52] was convened following the final meeting of the JWG DD and the meeting participants produced recommendations that were agreed to be made available to CENELEC and ETSI members for informational purposes. The key points from the document are as summarised above. The joint meeting of CENELEC TC210 [i.52] and CENELEC TC209 [i.51] decided on subsequent tasks for standardization and assigned the documents for review as listed in clause 8.

4.6 Immunity Requirements

The relevant standards for cable equipment immunity are as listed below:

- Refer to EN 55024 [i.20] and EN 61000-4-3 [i.21] applicable to Cable Modems.
- Refer to EN 55020 [i.22] applicable to Cable Set top box receivers and TV receivers.
- Refer to EN 50117 [i.23] for coaxial cable.

- Refer to EN 60966 [i.24] for coaxial cable assemblies.
- Refer to EN 50529-2 [i.25] for EMC Network Standard for wire-lines telecom networks using coaxial cables.

4.7 Incumbent and future users of the 800 MHz Frequency Spectrum

Potential co-existence issues arise mainly from the fact that the frequency band 790 MHz to 862 MHz is used in many HFC networks throughout Europe to deliver analogue and digital television as well as broadband and interactive services. Over-the-air transmissions originated from terminals in close proximity to HFC network installations and CPE particularly in an in-home environment using the same frequency spectrum simultaneously is reported through Laboratory and customer premises testing using test tools and simulators to represent the cable and over-the-air transmission environments (specifically EuroDOCSIS and DVB-C for cable and LTE800 for mobile) to potentially cause interference to services delivered to cable customers.

In addition to the re-allocation of the 800 MHz band to mobile communication services, the Digital Dividend gives rise to various other discussions regarding the re-organisation of the former UHF broadcast band. Figure 8 provides some examples, from the Analysys Mason report for the European commission (summer 2009) [i.33].

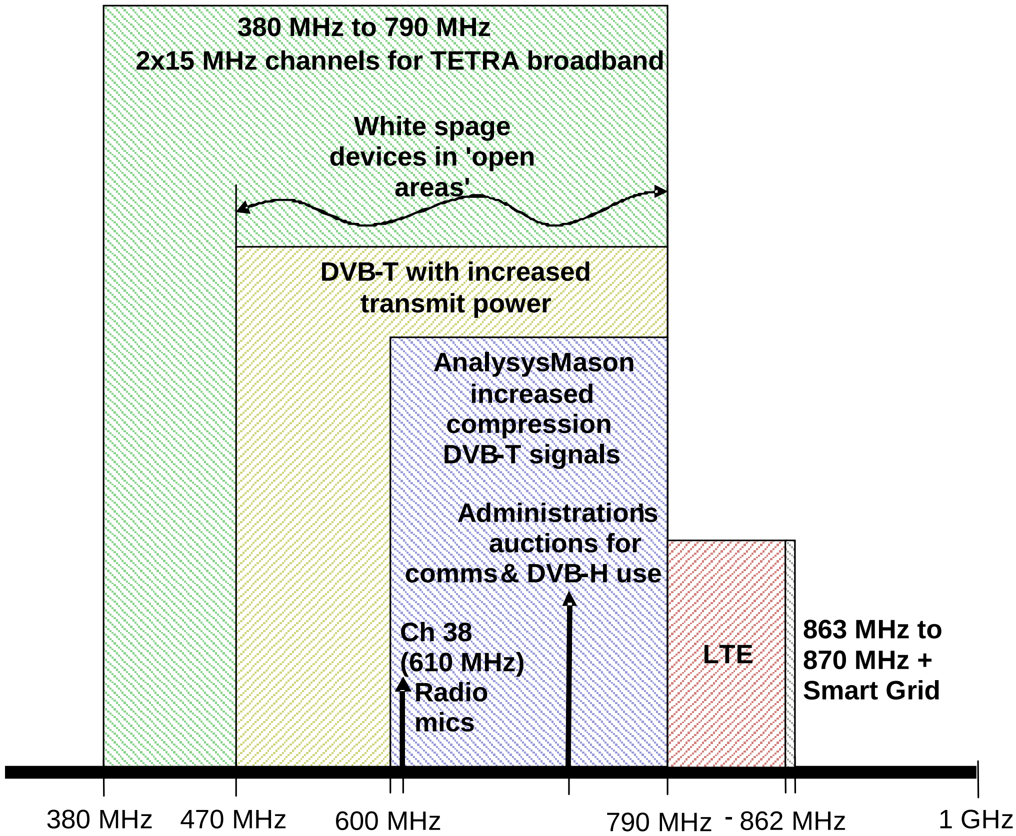


Figure 8: Further potential users of the Digital Dividend spectrum

4.8 Interference Studies

Various measurement campaigns under the responsibility of different stakeholders such as network operators, equipment manufacturers and administrations analysed the interference scenarios arising from the deployment of ECN800. Of the reports published, all stated that interference on both DVB-T and DVB-C receiving equipment (TV, STB and modems) will be caused when non broadcast transmitters are operating in channels that are at or adjacent to the tuned frequency. For some tuner architectures, interference has been found to occur also in channels that are 5/6 or 7 channels below the transmitting frequency of the ECN800.

The following presents coarse summaries of some of the testing reports.

The association of German cable operators (ANGA) report of 08 April 2009 reacted to the proposed changes to broadcast band allocations. Their report concluded that:

"The measurements show clearly, that massive disturbances of the cable signals is to be expected when exposed to an LTE signal. Operation of cable services would be impossible in the frequency range 790-862 MHz with the proposed RF transmission powers. It is irrelevant whether the interfering signal directly leaks into the cable network or if the ingress affects the end device, the viewer receives interference. However, due to different shielding properties and immunity requirements the end devices such as Set Top Box's (STBs) have been clearly identified as the most sensitive element of the cable infrastructure in the presence of a simulated LTE network in both up- and downlink transmissions."

In Germany, an extensive measurement campaign was conducted by an advisory group to the German regulator BNetzA (ATRT) with regard to the immunity of integrated TV receivers, set top boxes and data modems connected to broadband cable and TV networks against radiation from LTE user equipment. Their report concluded:

"This document describes joint measurements conducted on a selection of integrated TV receivers (IDTV), set-top boxes (STB) and data modems to assess the interference potential of LTE uplink signals in the frequency range 790 - 862 MHz. The measurements were conducted jointly under participation of the organisations indicated above in the EMC test facility of BNetzA in Kolberg, Germany, in December 2009.

The only interference mechanism investigated here was the radiated emission from an LTE terminal (uplink) directed into the IDTV receivers, STBs and data modems operating on a fully loaded hybrid fibre-coaxial (HFC) network. The receivers were fed with an interference free wanted signal and were exposed to interfering field strength from a generated LTE terminal signal.

Due to time constraints only frequency offsets regarded as critical have been investigated.

The following cable services were investigated:

- *Digital TV (DVB-C)*
- *Analogue TV (PAL)*
- *Internet access (EuroDOCSIS)*

A total of 15 receivers was evaluated. The failure criterion is derived from the subjective observation of a TV picture (DVB-C and PAL) and of the Internet service represented by an IP based video stream (EuroDOCSIS).

The main results were as follows:

- *The minimum LTE field strength at the location of the measured receivers causing disturbance heavily depends on the receiver itself and the radiation direction. Average immunity of the receivers tested ranges from 114 dBμV/m (0.5 V/m) to 148 dBμV/m (25 V/m) (AV-burst/10MHz, co-channel). The average is calculated across all measured directions and polarisations for a single receiver. The minimum LTE field strength that caused disturbance at the location of one tested receiver is 100 dBμV/m or 0.1 V/m when the receiver is exposed to radiated emissions from the most sensitive tested direction. At the most immune tested position one receiver still operated at interfering co-channel LTE field strengths of 150 dBμV/m or 31 V/m.*

- *The minimum LTE field strength at the location of the measured receivers causing disturbance is about 14 to 21 dB lower during data transfer of the LTE terminal than during idle phases where only the control channel is occupied. In the latter case, the measured LTE field strength ranges from 135 dBμV/m to more than 150 dBμV/m.*

- *When the LTE signal is 40 MHz (N+5) or 72 MHz (N+9) above the tuned frequency (oscillator and mirror frequency), the minimum LTE field strength at the location of the measured receiver with CAN-type tuners causing disturbance is only about 8 dB higher than in a co-channel situation. Exposure on adjacent channels is generally acceptable to a higher level than it is with the 5 and 9 channels offset. The tested IDTV with Silicon type tuner does not show this effect.*

- *The minimum LTE field strength at the location of the measured receivers causing disturbance is about equal for 64QAM and 256QAM modulated channels (DVB-C and EuroDOCSIS 2.0). This presumes the signal level reduction by 6 dB with 64QAM compared to 256QAM as accepted industry practice.*

- *Analogue PAL reception is not more sensitive to LTE interference than DVB-C.*

- *The loop-through antenna output is a method to physically connect TV sets via a set top box to the wall outlet of the HFC network. Receivers connected to the loopthrough outputs of the tested set-top boxes were already disturbed at up to 30 dB lower LTE field strengths compared to their direct connection to the HFC network.*
- *No direct relation of the receiver input level to the minimum LTE field strength at the location of the measured receivers causing disturbance could be observed.*
- *This measurement campaign was commissioned following a mandate by ATRT (consulting group to BNetzA) to investigate coexistence of mobile LTE and cable services. The results in this measurement report may be the basis for compatibility studies to fulfil the mandate mentioned above. They may be used as input to standardisation work at national and European level."*

The Swiss administration (BAKOM) issued a document issued on 30 September 2009 reporting on the findings of brief practical tests.

"The measurement campaign on two different CATV networks and with various receiving equipment shows that there exists a certain probability of interference in co-channel configuration between mobile services using the upper UHF band and services distributed over the cable infrastructure. Based on our measurements we believe that as long as the cable system meets the minimal standards defined in EN 50083-8 and EN 50083-2, interference will only be observed if the IMT system and the CATV system are in the same room."

The Dutch administration (AT) tested STB and TV with cable tuners and concluded:

"The following conclusions are of an approximate nature because of the very small number of random tests, i.e. the aforementioned eleven measurements using standard configurations and the four measurements performed on the optimised configurations.

- *If an LTE mobile phone with a transmitting power as indicated in the draft EC Decision is used at a distance of 3m from the television set, interference will be caused to three out of four of the television sets based on a standard configuration.*
- *Under the conditions described above, the cable reception of neighbours will be subject to interference in half of all cases due to an LTE application.*
- *Additional measures taken on four of the in-house systems (to reduce sensitivity to interference further) went beyond simply using an StAI cable from the subscriber transfer point to the television set. This optimisation resulted in a considerable improvement. However, it was observed that at the frequently occurring LTE bandwidths of 5 MHz to 10 MHz, after optimisation, there is still a 50% probability of interference when a mobile application is used at a distance of 1 m from the television set.*
- *The quality of shielding and the connection of the other cables (other than those from the subscribertransfer point to the television) were found in an optimised configuration to influence the in-house system's sensitivity to interference."*

Cable Europe [i.28] has undertaken testing of a range of equipment using DVB-T and DVB-C tuners. The findings are summarized as follows:

"*The provisional results obtained to date show that **all** tested STB and CM devices suffer with the high levels of interference from LTE terminal units with a separation distance of 4 metres.*

These effects were observed both on-channel (where the STB or CM are using the same radio channel as the interfering signal) and on adjacent channels; in some cases up to five Ultra-High Frequency (UHF) channels (5 x 8Mhz = 40MHz) away from the STB or CM receive frequency.

While the responses of different STB and CM models vary, in all cases the effects of in-band interference cause substantial degradation in TV audio and video quality and loss of internet traffic, whilst on-channel services are lost entirely.

Testing conducted on duplicate CPE system scenarios with different cables indicates that the variation between 'ideal' and 'realistic' cabling is not sufficient to generate a substantial difference in immunity.

Wanted DVB-C input signals were populated from 675-859MHz. The LTE interferer, a 10MHz bandwidth Frequency Division Duplex (FDD) uplink signal, was radiated at the EUT at 795MHz while the tuned channel of the STB was moved throughout the band. Mild interference in DVB-C usually appears as macroblocking or stuttering in the visual domain, and squeaking noises in the audio domain. Significant interference usually causes breakdown in the receiver and total loss of signal.

The EuroDOCSIS input signal was centred on 795MHz. The remaining channels from 675-859MHz were populated with DVB-C signals, also on 256QAM at -10dBmV. The LTE interferer, a 10MHz bandwidth FDD uplink signal, was radiated at the EUT on the centre frequency of the cable channels from 675-859MHz. Mild interference in DOCSIS is manifested as packet loss in User Datagram Protocol (UDP) transmissions. Significant interference usually causes breakdown in the receiver and total loss of signal."

Communication consulting firm and testing house **Excentis** [i.29] conducted a study on the influence on cable networks of the deployment of ECN services in the 790 MHz to 862 MHz band. The following conclusions are reached:

"*Based on the analysis it is very likely that a significant number of users will experience interference to their services delivered in the affected band over the HFC network… The primary source of interference will most likely be the TS (terminal station). With the deployment of the new services, a transmitter (the TS) will be operating close to the end user network and CPE-equipment for HFC networks. The analysis has shown that for those LTEdevices that are actively used (transmitting data) indoor a significant number (>10%) will be operating at the highest transmit power allowed (23 dBm). If the transmitter is close enough to the victim (in-house cable network or TV, settop box, cable modem) this is likely to result in interference problems. The required distance to avoid interference varies between different models of CPE-equipment, but for some models a distance of even more than 6 m is required. About 30% of the TSs used indoor will be transmitting at high (>20 dBm) power. At small distances (1 m) between TS and victim the chance of interference becomes very significant. The exact amount of how likely it is that interference will occur depends on the exact type and positioning of the victim (receiver).*

If one assumes that the mobile operators will continue using the current industry practices for wireless systems and not deploy basestations with high power (maximum EIRP) at low heights, interference caused by basestations is likely to only occur in cases where the cable access network and CPE equipment are located close to the basestation. The exact distance depends also on the exact location of the cable network and equipment, with the height of the "victim" network being the most important parameter. Note that typically mobile operators will use lower power and low mast heights in urban deployments.

CEPT report 30 suggests maximum EIRP limits for a basestation. Do note that from a technical point of view, the EIRP itself does not determine the chance of interference, but the power density at a potential victim determines the chance of interference. This power density is influenced by many parameters of which EIRP is only one. Environment, antenna tilt, pattern and height also have a big influence. It would be even better that the EIRP itself is not specified, but the maximum power density caused by the basestation at a potential "victim". This would be from a technical point of view the only unambiguous parameter. As a first step one could limit the maximum EIRP of the basestation as a function of the height of the basestation.

If mobile operators would start deploying micro-cells that are located very close to the houses and cable network, even systems with lower EIRP values may cause interference. The reason for this is that in those cases the distances will be much lower.

In the case that a multi-dwelling unit, house or cable network is close to the antenna of the basestation and at a "bad" location (based on antenna pattern and tilt) interference might also occur. Note that the power density received by the victim equipment at a certain location not only depends on the EIRP of the antenna, but also on the type of antenna (the antenna pattern) and its tilt.

We finally remark that if interference is caused by the basestation it is likely to be constantly present. Moreover, the user has no control on the signal of the basestation. With regards to the interference caused by the TS, the user will only suffer from interference when the LTE device is actively transmitting."

Also Dutch research centre **TNO** [i.30] analyzed the co-channel interference of LTE to cable EuroDOCSIS services. This study commissioned by the Dutch trade organization NLKabel [i.31] came to the following conclusions:

"1. For the current cable modems and in-home networks, co-channel LTE transmission from a user terminal operating at the proposed maximum transmit level of 23 dBm will strongly degrade the cable EuroDOCSIS service,

2. The ingress of the LTE signal takes place via both the cable modem and the in-home network.

3. The use of properly shielded cables (Class A or Class A+) reduces the ingress of the LTE signal and the risk of degradation of the EuroDOCSIS service, however, it does not provide enough protection to eliminate the disturbance to the cable services."

5 Regulatory and Economic Environment

The spectrum is recognised as a scarce resource and its efficient use is being managed at a regulatory level. The bodies involved in the decision making within Europe are the Commission RSPG and CEPT.

As consequence of Digital Dividend is that the available frequencies below 1 GHz are being made available to new ECN radio services and this results in a change in the radio environment and electromagnetic environment. The economic environment is affected by the potential availability of broadband mobile services in typically rural regions where broadband is currently not available. However the deployments may extend to the suburbs where broadband is already served by wired and terrestrial incumbent providers.

The auction of licenses is being regulated at a national level, with Germany being one of the first member states to complete its spectrum auction in the 800 Mhz band. There is monetary rewards to the national government from the sale of the spectrum through auctions and this present an economic benefit. In addition the economic benefit can be realised from the development of the new services and its consumption by customers.

There may be an economic consequence to customers of TV and Broadband services delivered by traditional terrestrial and cable networks from the need to replace existing TV sets and STBs for equipment designed to be more immune to the changing radio and electromagnetic environment.

There is no data currently published which quantifies the economic consequence to customers who may have to purchase new in-home equipment.

5.1 Spectrum Auctions and Usage of Unlicensed vs. Licensed

Germany is the first member state to auction their 800 MHz band, 790 MHz to 862 MHz with licenses awarded. Other member states are scheduling or have already completed local consultations on the use of the 800 Mhz band for ECN mobile services and are in the process of scheduling spectrum auctions subject to their local needs.

The 800 MHz band is proposed by member states to be licensed rather than it being made available unlicensed. Therefore the primary users of the frequency band in 'free space' would be the providers licensed to deploy ECN mobile services in this band.

Cable Networks are deployed with technology that also use the UHF frequencies but are not subject to license since the technology investment is confined to a design for a wired system and not 'free space' system use of the spectrum.

5.2 Spectrum Frequency Plan

The preferred harmonised frequency arrangement for a deployment of ECN800 with FDD has been presented in clause 4.2.3. In order to allow co-existence of ECN800 services with different frequency assignments as well as compatibility with incumbent users of the frequency spectrum in free space, CEPT Report 30 [i.9] defined appropriate Block Edge Masks (BEM) for base stations and terminals in clauses 6.6.1 and 6.6.2, respectively. The in-block EIRP limit for base stations has to be defined by administrations but may range from 56 dBm/{5 MHz} to 64 dBm/{5 MHz}. Under specific circumstances administrations may consider to authorize higher in-block EIRPs. For terminal devices, the maximum mean in-block power is defined to be 23 dBm. However, this value is subject to a tolerance of up to +2 dBm. Also administrations may relax the limit provided that protection of other services, networks and applications is not compromised. The power limit is to be interpreted as EIRP for fixed or installed terminal stations and as TRP for mobile or nomadic devices.

NOTE: The CEPT Report 30 [i.9] excluded compatibility studies with incumbent users such as broadband fixed cable networks that use the RF frequencies contained in a cable distribution in accordance with CENELEC standards.

Setting the preferred harmonised frequency arrangement as defined by the ECC Decision in relation to the common channel plan as used in HFC networks it can be shown that based on the different channel widths each cable channel may be affected by more than one LTE uplink channel. This is not only important for the assessment of the interference risk but also affects the potential mitigation as there is no direct relation between interference and a single mobile service provider. Figure 9 depicts this effect for the example of the LTE uplink.

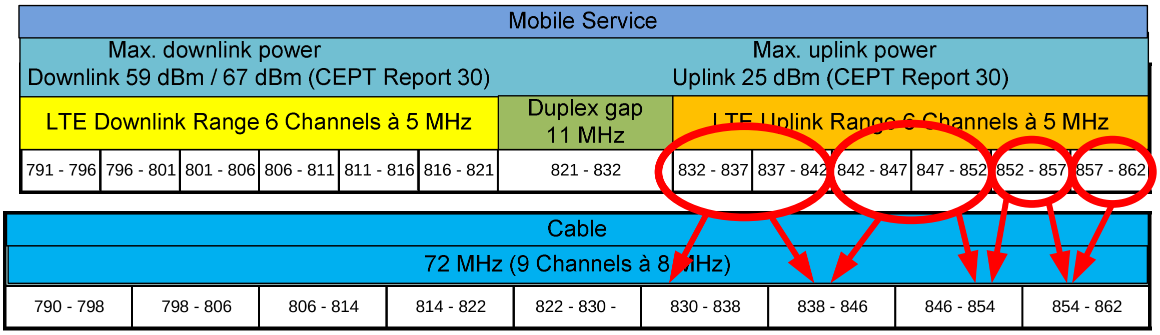


Figure 9: Preferred harmonised frequency arrangement for ECN800 in relation to channel assignment in HFC networks

6 Analysis of Interference Mechanisms

This clause gives general information to the cable community about the interference mechanisms in relation to adapting cable equipment and TV receivers to achieve increased immunity against the changing radio environment as a consequence of this new phenomena of Digital Dividend as described in the present document.

6.1 Interference Criteria and Characteristics

Interference can result in different types of service disruption depending on the type of interference and the service that is being interfered with.

6.1.1 Analogue versus digital services

Interference to analogue services results in a gradual degradation of the service. The service (e.g. quality of TV picture) is deteriorated for a small amount of interference but becomes more and more worse when the amount of interference is raised.

For services that are delivered by digital modulation, the system can cope with some maximum amount of interference, but once this level is reached the service is typically totally broken. Service that are delivered in a cable network using digital modulation are digital TV and internet (IP) services. Telephony service is also delivered over internet services.

For digital services it typically also takes some time to recover from the interference. Since the receiver has to recover QAM-lock on the signal and resynchronize with the wanted signal this takes time.

6.1.2 Signal characteristics

The impact of interference on a "wanted" signal is depending on different parameters of the interferer. The different parameters are:

- Power: the stronger the interferer power the higher the impact will be, one has to make the distinction here between average power (RMS) and peak power. The amount of interference is depending on both the modulation of the interferer and the wanted signal.
- Modulation: the used modulation on the interferer signal and the wanted signal has an impact on the amount of distortion. The modulation also defines the peak power versus average power of a signal. Additionally the modulation format has an impact on how the power is distributed over the spectrum (e.g. side-lobes).

- Bandwidth and spectral shaping: The bandwidth and spectral shaping (filtering) of the interferer and wanted signal have an influence on the impact of the interference. For some types of interference the exact frequencies might have an influence.

6.2 Interference Types

6.2.1 In-band

In-band interference refers to the kind of interference in which interferer and victim use the same frequencies to operate on. In the typical in-band interference cause, as a result of the interferer, the signal-to-noise ratio of the wanted signal at the victim deteriorates significantly makes that signal unusable by the victim.

6.2.2 Adjacent channel-band

Due to being close to the frequencies where the signal of interest is situated, interferers that operate in a band close to the band of the wanted signal can cause service degradation.

6.2.3 Out-of-band

Out-of-band interference refers to the kind of interference in which the frequencies used by the interferer are different than the wanted signals at the victim. Interference can still occur in these situations because of different mechanisms. Examples are:

- It could be that the signal that is picked up by the victim is so strong and close to the frequencies of the wanted signal that it causes problems at the victim.
- The frequencies used by the interferer are used internally in the victim (e.g. intermediate frequencies, clock circuitry) and the interferer signal is so strong that it causes problems.

6.2.4 Mirror Frequencies

Mirror frequencies are a special case of out-of-band interference. Due to the internals of the victim, the wanted signal in the device is present on the same frequency as the interfere signal, as such causing a deterioration in the signal-to-noise ratio although at first sight, it is expected that the interferer and victim use different frequencies it is not the case.

6.3 Statistical Modelling

Statistical modelling is required to analyse the likelihood of interference. Input parameters for the statistical models to use are:

- Wireless system parameters.
- Environmental parameters.
- Distribution of separation distance between "victim" and interferer.
- Immunity of victim.

For the statistical modelling itself two methods can be used:

- Monte Carlo analysis.
- Mathematical analysis.

6.3.1 Wireless system parameters

The wireless system parameters are required as input to the statistical modelling. These include height of the basestation, transmit power of the basestation, antenna gain and pattern. Note that the transmit power of the UE (terminal) is determined by a combination of different factors of which height of the basestation, antenna gain and pattern are also important ones.

6.3.2 Environmental parameters

The propagation of wireless systems is heavily dependent on the environment. Typically one when makes the distinction between "urban", "suburban" and "rural" environments. For each of these environments different propagation models needs to be used. Propagation models are a mathematical approximation of the expected propagation of wireless signals for the environment and itself typically have a number of parameters that need to be approximated.

6.3.3 Separation distance

The separation distance is the distance between the potential source of interference ("the interferer") and the potential subject of interference ("the victim"). In the case of short distance interference, e.g. handheld to TV-set, the amount of field-strength at the victim is directly related to the distance between interferer and victim. In the case of long distance interference, one has to take into account the environment in which the system operates.

6.3.4 Immunity of victim

The immunity of the victim defines the field-strength that the victim is immune to, i.e. can still operate without degradation. The amount of immunity depends on the victim, and will also have some distribution, i.e. statistical variation. Note that the immunity itself also depends on the exact positioning of the victim towards the interferer.

6.3.5 Monte Carlo analysis

Monte Carlo analysis is a statistical technique that is used to give as output a distribution of the result based on a large number of input parameter that each have their own distribution. The technique is based on the fact that if you perform a large set of simulations in which for each simulation you take the input parameters from a set of values according to the statistical distribution of that parameter, the distribution of your output value will be a representative value. It is clear that the input values are randomly for each parameter (i.e. independent from the selection of another parameter). Note that it is very important that the number of simulations is significantly large to be able to have representative results and that the correctness of the distribution of the input parameter is very important. The simulation model that is used is also developed for independent input parameters. E.g. it cannot be used that the transmission power and location of the device are independent parameters, since the transmission power is largely dependent on the location of the device.

6.3.6 Mathematical analysis

In the mathematical analysis method, the distribution of the input parameters are mathematically combined to calculate the distribution of the output parameter. This method cannot always be used since combining statistical distribution for complex mathematical calculations is not always feasible.

7 Economic and Society Impact

There are economic and society opportunities from exploiting the digital dividend. At the European Union level there are actions to promote the efficient use of the digital dividend spectrum in the 470 MHz to 862 MHz band. The report from Analysys Mason [i.33] identifies potential uses of the digital dividend with two of the highest being DTT (including high definition services) and commercial wireless broadband. They identified other potential uses include service ancillary to broadcast and programme making, broadcast mobile TV, wireless broadband for Public Protection and Disaster Relief (PPDR), cognitive technologies and an innovation reserve.

The European Commission is currently preparing a "Study on the Economic, Social and Cultural Benefits of the Digital Dividend" to which different stakeholders and the Member States can provide input.

The Commission issued a communication [i.34] "Reaping the full benefits of the digital dividend in Europe: A common approach to the use of the spectrum released by the digital switchover".

A report from Pearle [i.35] presents the transforming of the Digital Dividend opportunities into social benefits and economic growth in Europe.

The Cable Europe has also been preparing assessment on the economic impact from the potential interference to customer's services delivered by cable networks. Several administrations have tried to model the expected level of impact to viewers of TV services and consumers of fixed broadband services but the findings differ from minimal impact to significant impact. There remains insufficient practical data from real live LTE trials and deployments to gauge the severity of the impact to current viewer's services delivered by cable and terrestrial networks. Until such accurate data is available the society impact from the potential interference to customer's current TV and broadband services remains unqualified.

8 Recommendations for Standardisation

The present document does not intend to provide any recommendations but instead refers to the meeting of CENELEC TC210 joint with TC209 [i.32] where a list of standards were identified with the view that the relevant committee responsible for the standard should review and update them to accommodate increased immunity requirements for in-home cable equipment and TV receivers.

Harmonized standards:

- EN 50083-1 [i.18] CATV equipment ➔ CLC/TC209 [i.51].
- EN 50529-2 [i.25] Networks using coaxial cables ➔ CLC/ETSI JWG.
- EN 55020 [i.22] Broadcast receivers immunity ➔ CLC/TC210 [i.52].
- EN 55024 [i.20] ITE immunity ➔ CLC/TC210 [i.52].
- EN 300 422 [i.42] Radio microphones and assistive listening devices ➔ ETSI ERM TG17.
- EN 301 357 C [i.43] cordless audio ➔ ETSI ERM TG17.
- EN 301 489-9 [i.44] Radio microphones and cordless audio ➔ ETSI ERM EMC.

Other standards:

- EN 50083-8 [i.26] CATV networks ➔ CLC/TC209 [i.51].
- EN 50117 [i.23] Coaxial cables ➔ CLC/SC46XA.
- EN 60966 [i.24] Receiver leads ➔ CLC/SC46XA.
- EN 61000-4-3 [i.21] Radiated immunity basic standard ➔ CLC/TC210 [i.52].
- EN 300 220 [i.45] SRDs 25 MHz - 3 GHz ➔ ETSI ERM TG28.
- ES 202 127 [i.46] RF amplifiers for reception 47 MHz to 860 MHz ➔ ETSI ERM TG17.
- Radio performance standards where relevant ➔ ETSI.

Annex A: Bibliography

- Commission Decision on harmonised use in the 790-862 MHz frequency band for terrestrial systems capable of providing electronic communications services in the European Union.
- ITU: "Frequency allocations".

NOTE: Available at http://life.itu.int/radioclub/rr/art05.htm#Reg.

History

Document history		
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