ECC REPORT 24

Electronic Communications Committee (ECC)
within the European Conference of Postal and Telecommunications Administrations (CEPT)

PLT, DSL, CABLE COMMUNICATIONS (INCLUDING CABLE TV), LANS AND THEIR EFFECT ON RADIO SERVICES

Cavtat, May 2003

EXECUTIVE SUMMARY

This report addresses the compatibility between cable communication systems including DSL, PLT, Cable TV, LANs… and radio services.

Owing to the very wide frequency range of wanted signals potentially running inside cables (DC to 3 GHz), the frequency range of interest in this report ranges from 9 kHz (radiocommunications starting frequency) to 3 GHz.

A description of the four main categories of cable applications used in telecommunications: PLT, DSL, transmissions on shielded cables and LANs is made together with a comparison of their respective EMC characteristics.

The various radio services potentially affected by unwanted radiation from telecommunication networks are described in detail with their associated protection requirements. For some radio services, the sensitivity of receivers and the protection ratio is given; for others, the protection requirements are derived from the ambient noise levels specified in ITU-R Recommendation P.372-7.

An overview of existing and planned standards and regulations related to this subject is provided:

- Limits in EMC standards;
- European national regulations and standards on telecommunication networks;
- Extracts from the Radio Regulations;
- Extracts from the EMC and R&TTE Directives;
- European Commission Mandate M313;
- Regulations in the United States.

Technical background on propagation in the near field zone at frequencies below 30 MHz is given.

Some measurement data on different kind of cable applications obtained in different European countries is presented that led to the following conclusions:

- The evaluated PLT systems were generally found to be over the example n°1 limit (see section 7.1) but compliant with the example n°5 limit (see section 7.5);
- The evaluated DSL systems were generally found to be compliant with the example n°1 limit;
- The evaluated LAN systems were generally found to be over the example n°1 limit but compliant with the example n°5 limit;
- A survey of some cable TV networks showed that most of the leakage locations were found in the network level 5, i.e. the customer's installation. Another measurement campaign pointed out the practical difficulties in applying the measurement method and limit defined in the standard EN 50083-8 (see section 4.3);
- Some peak measurements on devices such as computer screens, TV sets… showed emissions, most of them being discrete, slightly above the example n°1 limit and that other applications such as lamps radiate significantly above the example n°1 limit;
- Measurements made in residential areas generally showed that interference levels can be significantly lower than the limits set in EMC standards.

Compatibility studies in the frequency range of interest have been performed with the following conclusions:

- Cumulative effect of PLT below 30 MHz: depending on the injected power, equivalent antenna gain and density of sources of the PLT system under study, the overall EIRP density of all interference sources ranges from –170 dBW/m^2/10 kHz (no cumulative effect problem) to –80 dBW/m^2/10 kHz (definite cumulative effect problem);
- Compatibility between SRDs and cable transmission systems below 30 MHz: the protection of the SRDs is insufficient with limit example n° 1 and sufficient with limit example n° 2 (see section 7.2);
- Impact of cable transmission limits on the planning of a radio service: this impact can be quite significant with example n°1 limit if cable systems that radiate at the selected limit are very widely developed;
- Interference calculations based on the noise floor in the HF band. With regard to the ITU-R quiet rural noise level, the maximum interference distance is 900 m with the example n°1 limit, 95 m with the example n°2 limit and 38 m with the example N°4 limit (see section 7.4). With regard to the ITU-R business noise level, the maximum interference distance is 60 m with the example n°1 limit, 6 m with the example n°2 limit and 2.5 m with the example N°4 limit;
- Effects on amateur radio of the use of power lines for broadband data communications (PLT): for an antenna location as is common for most amateurs, close to or above the house, the reception of interference radiating from the mains is very serious for field strength levels equal to the example n°1 limit or the equivalent field

strength level of the conducted CISPR 22 Class B limit (see section 4.1). Even the example n°4 limit is inadequate to avoid interference in the above mentioned situation, in particular on the higher amateur bands;

- Compatibility between cable TV and aeronautical navigation systems above 30 MHz: two numerical models have been used to calculate the cumulative interference created in the sky by a cable TV network (assumed to be either analogue or digital) over a large city and the technical conditions under which ILS LOC, VOR, VHF COM, UHF COM and ILS GP are compatible or not with such a network under the studied scenarios are given. It is believed that some more measurement data would be useful to refine these results and a risk assessment analysis should be conducted in any case taking into account the safety of life nature of the aeronautical radio services studied here.

General conclusions of the report

- There should be a harmonised radiation limit and a common EMC-standard for Europe and preferably a worldwide agreement on the same limits for cable transmissions systems because:
  - Europe has a common market and trade develops towards global markets;
  - Propagation conditions (in the frequency range up to 30 MHz) are such that the risk of interference to radio services cannot be limited to a national or regional scale (cumulative effect, reflection by the ionosphere of wanted signals as well as interfering radiation originating from cable systems).

- The radio spectrum is a unique resource. In particular, the frequency range below 30 MHz has extremely favourable propagation conditions allowing economic long range as well as low power communication for important security and non-security radio services. Thus this part of the electromagnetic spectrum needs special protection by choosing an appropriate interfering radiation limit;
- Total protection of radio services is not possible due to the fact that this would require very low radiation limits which would prohibit high data rate telecommunication services using copper cable technologies in the local loop. Furthermore it has to be recognised that electronic equipment of any kind is an already existing source of interference, which would make any decision in favour of very tight radiation limits unrealistic and uneconomical;
- A radiation limit to be generally applied to all cable systems should take into account the interests of the radio users. This radiation limit is an environmental parameter being decisive for the future development of systems and services;
- Safety of life radio services used to safeguard human life and property must be protected on a priority basis, regardless of any limit met or not by the cable transmission system;
- Manufacturers should develop and cable operators should employ technologies and procedures enabling reduction of emissions in cases of interference (e.g. reduction of power levels in general or for specific frequencies or frequency ranges);
- The risk of interference to radio services depends not only on the compliance with a radiation limit but also on different network structures and technologies as well as on the frequency ranges used. For example, owing to the type and properties of cables installed, the frequency ranges used and the structure of the network, the risk of interference for the same radiation level caused by high frequency Power Line systems (i.e. using frequencies in the range 1.6 to 30 MHz) is much higher than with DSL or Cable TV systems;
- Given the high densities of deployment foreseen for PLT networks including in-house applications, there is a risk of significant rise in overall noise level even in rural areas. Every radiation limit to be developed for networks or output power values of individual PLT products should be judged on the cumulative interference effect using the models described in Annex 7;
- Special attention needs to be paid to the in-house part of the networks that are self-installed by private persons who generally don't have EMC expertise;
- The issue of monitoring of networks, which is outside the scope of the present EMC Directive but may be undertaken by national administrations, is addressed in Section 5.2.5;
- The frequency range covered by this report is from 9 kHz to 3 GHz, although in many sections, emphasis is put on frequencies below 30 MHz.
- In the frequency range above 30 MHz, the analysis has mostly concentrated on the issue of the compatibility between cable TV networks and aeronautical radio services that is addressed in details in Annex 9. Two calculation models have been established and calibrated based on the available ground and aerial measurements performed on existing cable TV networks. They led to the following conclusions:
  - an existing analogue cable TV network over a large city is not compatible with ILS LOC, VOR, UHF COM and VHF COM but is compatible with ILS GP;
  - an existing digital cable TV network over a large city is not compatible with UHF COM, but is compatible with ILS LOC, VOR, UVHF COM and ILS GP. Concerning VHF COM, the result depends on the modulation scheme and aircraft height (see Annex 9);

- Assuming all leakage values can be reduced below a given value, the limit that should be set to the leakage levels to ensure compatibility for each of the radio services and types of cable TV network (analogue or digital) studied here is given in Annex 9.

Evaluation of radiation limit examples

Section 9.4.2 of the report presents some calculations of the separation distances between cable transmission and radio systems assuming;

- That the cable system is at the proposed limits level (examples n°1 to 5);
- That the noise level is at the ITU-R Rec 372 noise levels (quiet rural, rural, residential and business);
- That the protection requirement of the radio services is that cable systems should not increase this noise level by more than 0.5 dB (quiet rural, rural, residential and business);
- Free space propagation between the two.

The following table summarises these results by giving the corresponding separation distances at two spot frequencies and for the two extreme ITU-R environments:

Separation distance	1.5 MHz quiet rural	30 MHz quiet rural	1.5 MHz business	30 MHz business
Example n°1 limit	920 m	320 m	63 m	52 m
Example n°2 limit	94 m	39 m	0 m	6 m
Example n°3 limit	770 m	Not applicable	53 m	Not applicable
Example n°4 limit	38 m	15 m	0 m	2 m
Example n°5 limit	35 km	46 km	2,4 km	7,4 km

Note: a minimum separation distance equal to 0 m means that the victim at any separation distance would not suffer sensitivity degradation of more than 0.5 dB.

- Concerning radiation from cable transmission systems, the setting of a general limit (flat or slowly varying) across the bands between 9 kHz and 3000 MHz is required;
- The example n°1 limit (see Section 7.1) puts great constraints on radio services and users and it is expected that there will be numerous cases of interference to be resolved. These levels are considered as maximum tolerable levels as far as radio services protection is concerned.
- The example n°2 limit (see Section 7.2; this limit is approximately 20 dB below the example n°1 limit quoted above) may be regarded as sufficient to protect radio services in the majority of cases;
- For safety of life radio services, the emissions must be at a level such that interference to these services is prevented in advance with a very high probability.

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<u>EDITORIAL NOTE: The annexes are not included but can be downloaded from a separate file</u>

1 INTRODUCTION

1.1 Scope

This ECC report considers the effects on radiocommunication services of four types of high data rates communications technologies that use wire lines :

- Power Line Telecommunications (PLT), is a means of transmitting high data rates on the mains electricity network ;
- Digital Subscriber Line (DSL) is a means of transmitting high data rates on existing copper wire telecommunication networks, for example plain ordinary telephone systems (POTS). There are variants of DSL according to the data rates provided and DSL is the generic term used to describe this family of technologies ;
- cable communications comprise a family of distribution networks that utilise dedicated coaxial cables, to provide traditional Cable TV and increasingly new Interactive services including Internet access ;
- Local Area Networks (LANs).

In the rest of this report, these four families of applications will be referred to under the generic term of "cable transmissions".

The frequency range covered by this report is from 9 kHz to 3 GHz, although in many sections, emphasis is put on frequencies below 30 MHz.

1.2 History of the work

In 1999, the UK Administration presented in CEPT ERC Working Group Spectrum Engineering (WG SE) papers on the PLT trials in the Manchester area and on the potential disturbances induced into radio services. A PLT correspondence group was soon established within WG SE.

After a questionnaire was sent in summer 1999 and a compilation of the answers was prepared, the idea of including other types of cable transmission systems (like DSL or cable TV) was expressed. In autumn 1999, ECCA (European Cable Communications Association) proposed to establish a cooperation with ERC.

A special meeting was held in Mainz (December 1999). The group recommended to WG SE the creation of a Project Team on PLT and cable transmission in general to study their effect on radiocommunication services.
In February 2000, at the CEPT ERC WG SE meeting in Naples, the example was endorsed and the new Project Team SE35 was created. One of the tasks assigned by WG SE to this Project Team was to prepare an ERC report on cable transmissions and their effect on radio services. At the end of 2001, the ECC was created and took over the ERC activities.

At the time of the studies, the terms of reference of this Project Team were as follows :

- *to obtain representation from both users of the spectrum and proponents of cable transmissions;*
- *to identify the frequency ranges over which cable transmissions are likely to operate now and for the future;*
- *to identify those services that are likely to be affected by cable transmissions and evaluate their protection needs;*
- *to investigate methods of measuring the emissions from PLT and cable transmissions, considering they may be broadband, distributed and peaky in nature. Also consider radiated and/or conducted measurements (e.g. cable clamp methods for common and differential mode currents);*
- *to perform compatibility studies to derive limiting values for emissions from cable transmissions to protect primary services;*
- *to propose an harmonised European approach for cable transmissions;*
- *to produce a report covering the various aspects for wide consultation within Europe;*

In the course of these studies, The Project Team will liaise closely with the relevant EMC standardisation Committees (newly created ETSI/CENELEC joint Working Group on EMC of extensive networks, CISPR…) and with ITU-R WP 1A and 1C.

1.3 Overview of the study

Chapter 1	is the introduction to present the background of PLT and the objectives of the CEPT studies.
Chapter 2	provides the characteristics of PLT and cable transmissions in general (DSL, cable TV…)
Chapter 3	presents the characteristics of the radio services and their associated protection needs.
Chapter 4	summarises the limits in existing standards and regulations
Chapter 5	deals with the regulatory aspects of cable transmissions
Chapter 6	provides information on propagation below 30 MHz
Chapter 7	presents different examples of limits below 30 MHz
Chapter 8	summarizes measurements results obtained in different field trials and discusses sensitivity issues
Chapter 9	provides the results of compatibility studies between cable transmissions and radio services.
Chapter 10	contains the conclusions of this Report.

2 CHARACTERISTICS OF CABLE TRANSMISSION SYSTEMS

The aim of this chapter is to describe the four main families of systems studied in this report and to compare their EMC behaviour: Power Line Telecommunications, DSL, transmissions on shielded cables and LANs.

2.1 PLT

Power Line Telecommunications (PLT) is a recent technology, aiming at the utilisation of the electricity power lines for the transmission of high data rates.

Signalling over the mains network has existed for many years at operating frequencies between 3 kHz and 148.5 kHz and many applications of low data rate transmission over the mains are currently in operation.

In 1998 and later, new developments in modem technology showed that it was possible to use higher frequencies and wider bandwidths to communicate along the mains, using frequencies from 1.6 to 30 MHz and with data rates of 1 or more Mbits/s.

This new family of applications is sometimes referred to as PLC (Power Line Communications) or PLT (Power Line Telecommunications or Power Line Technology). In the rest of this report we will use the generic term PLT.

PLT potentially offers several Mbit/s transmission rate (data and Voice over Internet Protocol “VoIP”) via normal electrical power lines that are incorporated in every household. In the case of access PLT, this data rate is shared among a number of simultaneous users. As PLT uses the Internet Protocol (IP), the main application of PLT could be also described as "Internet from the socket". The benefit of PLT is that it uses the already existing and widely deployed low power electricity network, permitting new services without the need for additional wiring.

In contrast to DSL-technology (supplying each DSL-customer separately with an individual telephone cable) PLT-technology is feeding a high data rate signal into a local mains power supply network to which all energy- as well as telecom-customers are connected in parallel.

Due to this, the transmission capacity of the system has to be shared between all telecom-users who are operating simultaneously. In addition if only one telecom-customer shall be supplied with a PLT-based data service the whole area of the local power supply network is carrying the transmission signal acting as an area radiator concerning unwanted radiation.

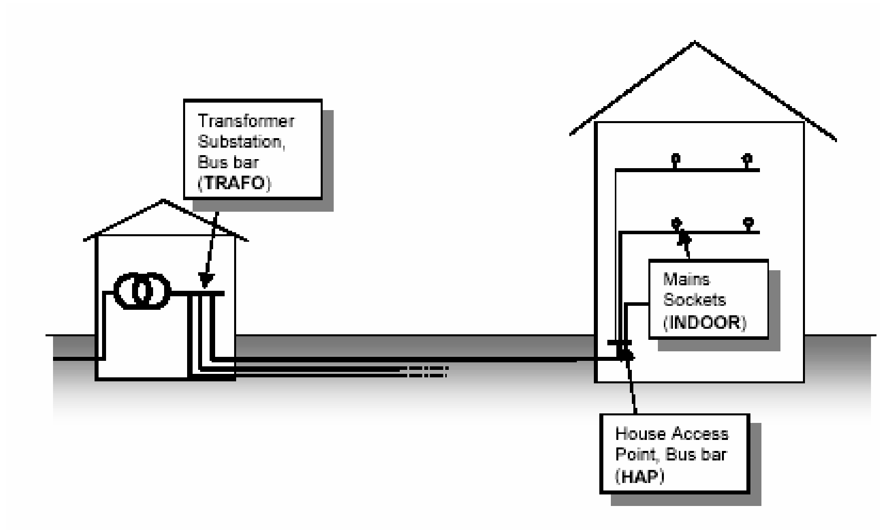

Figure 2.1: the three different potential connection points for PLT modems

There presently exists two main families of PLT applications :

- access PLT whose target market is the "last mile" between substation and the subscriber and is therefore an alternative solution for the access to the telecommunication local loop ;
- indoor PLT whose aim is to distribute signals (coming for example from access PLT or from DSL) from the meter to the electric plugs inside homes.

2.2 Transmissions on telecommunication lines (DSL)

ISDN, HDSL, ADSL, VDSL and SDSL are all DSL modem technologies designed to operate on telephone wires intended originally for voice-band communication (300Hz to 3.4kHz). Advances in DSP technology combined with innovation in algorithms and coding methods have allowed access to previously untapped information capacity. Bandwidth utilisation has increased by two orders of magnitude over the last ten years or so; from under 100kHz for narrow-band ISDN to over 10MHz for VDSL.

2.2.1 ISDN-BA (DSL)

The acronym DSL was originally used to refer to narrowband or Basic-rate Access transmission for the Integrated Services Digital Network (ISDN-BA).

ISDN-BA systems tend to have long ranges and good coverage in terms of the percentage of access loops they can operate on. The technology has been around for some time now and there have been significant advances in transceiver performance in recent years.

The DSL payload is usually 2 x ‘B’ or Bearer channels at 64kbit/s each, plus a ‘D’ or signalling channel at 16kbit/s, which can sometimes also be used for packet data. This gives the user access to 128kbit/s plus signalling (144kbit/s).

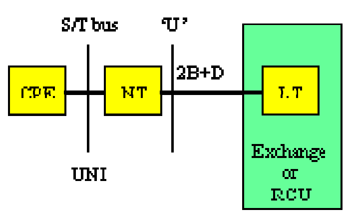

Figure 2.2.1: basic-rate ISDN-BA concept (DSL)

Several millions of ISDN-BA lines have been installed worldwide and demand for ISDN lines has become significant due to the high demand in higher Internet connection speeds.

2.2.2 HDSL

HDSL is a bi-directional symmetric transmission system (see Figure 2.2.2) that allows the transport of signals with a bit-rate of 1.544Mbit/s or 2.048Mbit/s on multiple access network wire-pairs.

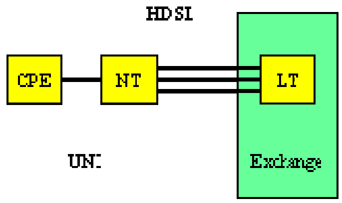

Figure 2.2.2: high bit-rate DSL concept (HDSL)

2.2.3 ADSL

Asymmetric DSL (ADSL) was conceived for the delivery of highly asymmetrical services such as Video on Demand, in which large bit-rates were required to be delivered to the Customer but only a small amount back towards the network from the Customer.

ADSL has highly asymmetric data rates and is rather different to ISDN-BA/HDSL insofar as it supports coexistence of narrow-band POTS on the same wire-pair via a service splitter.

ADSL uses Frequency Division Duplexing (FDD) in which a band of tones is allocated to upstream transmission (Customer to Exchange direction) and another band is allocated to downstream (Exchange to Customer). It pushes the usable access bandwidth up to around 1MHz.

When ADSL was first conceived, it was assumed that, the ADSL and POTS services would be carried on the same Cu pair by frequency division duplexing, and that frequency selective splitter units would be used to separate these services at the exchange-end and subscriber-end respectively. This arrangement was thought to be necessary to prevent interaction between terminal equipments of the two types. In particular, at the subscriber's end, the filter arrangement prevented quite large ADSL signals causing audible noise in phone instruments due to intermodulation, and DC signalling on the POTS service causing transmission errors to the ADSL signal.

This arrangement has the advantage of isolating in-premises telephony wiring from the ADSL modems, preventing any RFI egress in the LF and MF ranges and strong RFI ingress from AM broadcast stations causing interference reaching the ADSL modems.

Figure 2.2.3 shows the use of FDD to separate upstream and downstream and the function of the master service splitter.

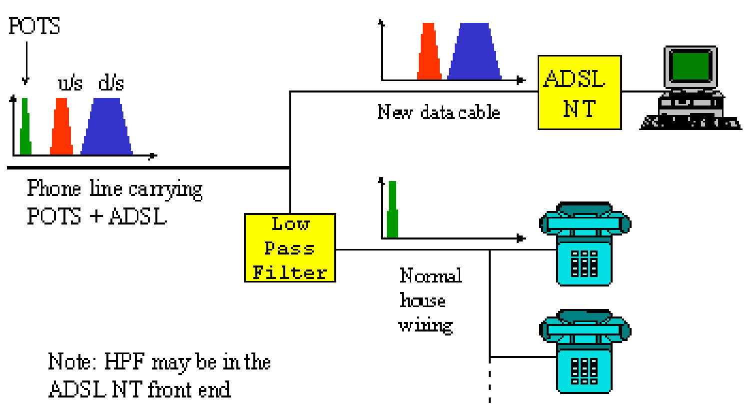

Figure 2.2.3: ADSL showing FDD and service splitter

Later it was observed that the splitter function in the customers premises could be distributed, placing a high pass filter element in the ADSL modem and low-pass filter elements located at each telephony instrument, in the form of a plug-in in-line filter. This arrangement is more suitable for customer self-installation, since it is not necessary for the network operator to send an engineer to install a splitter box in the home. Instead, the customer can install an ADSL modem by plugging it directly into the customer premises wiring at a convenient socket, and then install plug-in low-pass filters for each phone. A side effect is that the ADSL signals then travel over the telephony in-premises wiring that may have less well constrained egress and ingress properties than the network proper.

2.2.4 SDSL (also named SHDSL by ITU)

SDSL is short for symmetric digital subscriber line, a new technology that allows more data to be sent over existing copper telephone lines (POTS). SDSL supports data rates up to 3 Mbit/s. SDSL is called symmetric because it supports the same data rates for upstream and downstream traffic.

2.2.5 VDSL

Very high-speed DSL is a natural evolution of ADSL to higher bit-rates and the use of even more bandwidth. This can be contemplated because the effective loop length is shortened due to progress of fibre into the backbone of existing access networks in a Full Service Access Network (FSAN) architecture known as Fibre to the Cabinet (FTTCab) as shown in Figure 2.2.5.

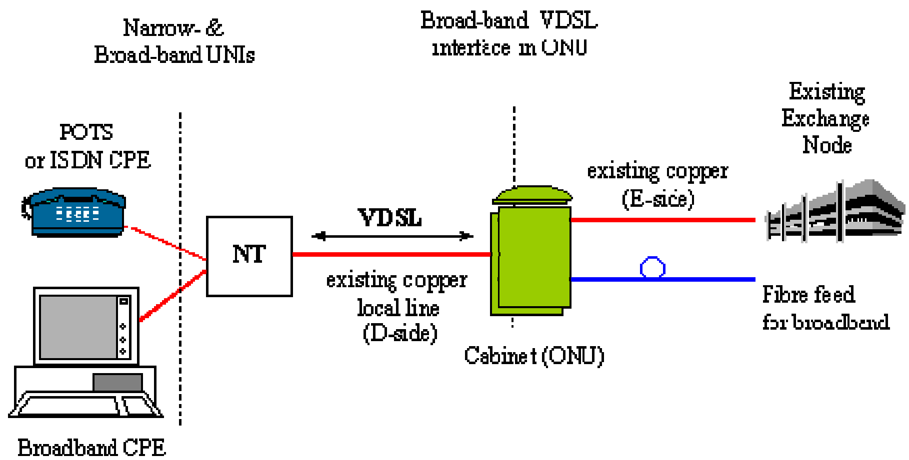

Figure 2.2.5: fibre to the Cabinet (FTTCab) used for VDSL

2.2.6 The DSL Family

Table 2.2.6 gives a summary of the indicative bandwidths and bitrates achievable with different members of the DSL family.

Member	Frequency Band	Target Bit Rates
ISDN 2B1D	10 Hz - 50 kHz	144 kbps
ADSL over POTS	25.875 kHz to 1.104 MHz	Up to 8 Mbps DS, 640 kbps US
ADSL over ISDN	138 kHz to 1.104 MHz	Up to 8 Mbps DS, 640 kbps US
HDSL 2B1Q (3 pairs)	0.1 kHz - 196 kHz	2.3 Mbps
HDSL 2B1Q (2 pairs)	0.1 kHz - 292 kHz	2.3 Mbps
HDSL CAP (1 pair)	0.1 kHz - 485 kHz	2.3 Mbps
SDSL	10 kHz - 500 kHz	192 kbps to 2.3 Mbps
VDSL	300 kHz - 10/20/30 MHz	Up to 24/4 DS/US, and up to 36/36 in symmetric mode

Table 2.2.6: indicative bandwidths and bitrates

2.3 Transmissions on shielded cables (cable TV…)

2.3.1 Frequency ranges used for upstream and downstream transmissions

CATV (Community Antenna Television), MATV (Master Antenna TV) and SMATV (Satellite MATV) networks are used for the simultaneous distribution of multi TV and radio signals. In CATV and MATV systems, frequencies from 5 – 860 MHz are used. In SMATV networks, frequencies up to 2.5 GHz are utilised. In future the frequency range used in CATV networks might be extended to 2.5 GHz as well.

The range from 5 to 30 MHz is used to support upstream transmissions if this is a network requirement. Many Cable Network Operators (CNO's) extend this return path to 65 MHz and as a consequence have ceased to use Broadcasting Band I (47 – 68 MHz) for distribution.

In some cable networks, trunk amplifiers are still deployed. Many trunk amplifiers use an 80 MHz pilot frequency in the downstream direction for the control of temperature dependent drifting. Since it will be difficult to change this pilot frequency, the 65 MHz boundary for return channel transmission seems to be ideal and practical.

The figure below shows a measurement example of the transmitted frequency range.

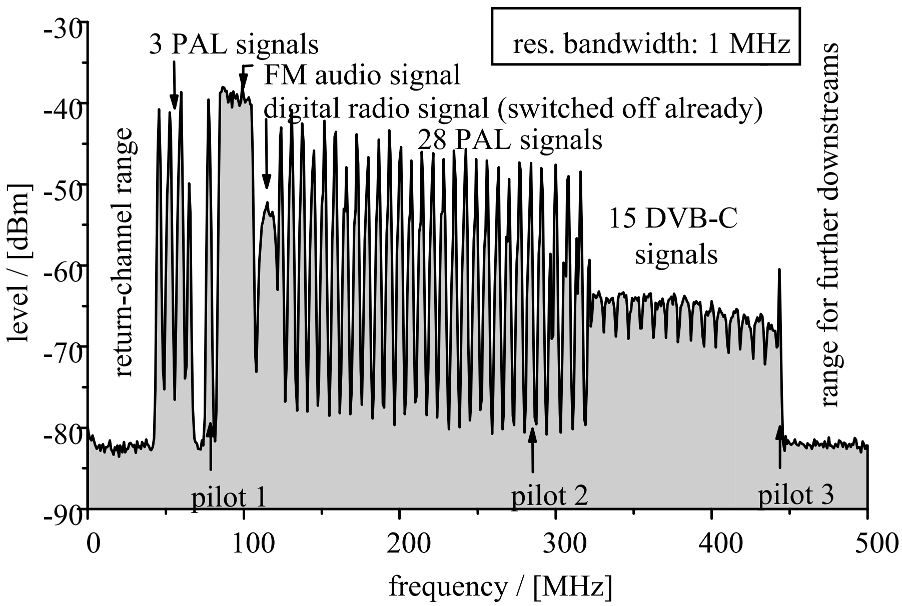

Figure 2.3.1: example of the frequency spectrum measured at a German cable network (date: 1998)

2.3.2 Network structure

The structure of cable networks is not uniform across Europe. Differences can be found not only in the general network-structure itself, but also at several specific points within the network, for example at the head-end which is the central point of the network, at the hubs and nodes within the networks, and at the user outlets which are installed in users' dwellings. The quality of coaxial cables themselves is different, for instance in terms of the shielding attenuation, which is the most critical parameter with respect to the EMC problem. Also the network structures, the frequency ranges occupied, the applied transmission techniques, the transmission protocols used, the services offered, and several other parameters that influence the operation of the network, differ from network to network.

The structure of modern cable networks can be described as follows.
The central point of the network is the main head-end at where the signals are prepared for transmission and insertion in the network in the downstream direction to the users. The upstream signals comprising telecommunications services are received via appropriate return-channels. The main head-end provides the networks' general operational and administrative centre.

The highest level of a cable network today mostly consists of fibre-optic rings that connect several sub head-ends together as well as to the main network head-end. Mainly analogue, but also digital transmission techniques are used for the distribution of broadcast signals. Parallel fibre-optic rings are used for the bi-directional transmission of telecommunication signals. SDH (Synchronous digital hierarchy) transmission techniques are often utilised for this purpose.

At the sub head-ends the signals are inserted into additional fibre-optic rings that overlay the trunk branches of the CATV networks, hence bridging the cascaded trunk amplifier chains. These secondary fibre optic rings terminate in so called optical nodes in which the signals are interfaced to the coaxial elements of the cable network.

The level of the access parts of the network start at the network's centre point and can be split into two levels:

- The higher sub level incorporating active elements such as amplifiers
- The lower sub level, which is the passive part of the network, with a length of up to several hundred meters.

Each access network ends at transition points. A transition point is not always located at the same place. In some countries the transition point can be the point where the access network starts. Transition points are important demarcation points, which very often indicate a change in ownership and/or areas of responsibility.

In-home networks are the final part of a cable network. In most countries the transition point is where the In-home network starts and the distribution network ends. It should be noted that the network structure and the quality parameters of a CNO customers' In-home network might not comply with the standards and engineering requirements that the CNO has implemented in their trunk and distribution network.

Cable Networks have to fulfil the performance requirements as defined in EN 50083-7 of which Chapter 5, paragraph 2.1. Table 2 is of particular importance. In this table the signal levels on the system-outlet are defined.

The table shows as follows:

Type of service	Minimum level dB(μV)	Maximum level dB(μV)
AM-VSB-television	60[1]	80[2]
FM-television	47	77
DSR (HF)	Under consideration (u.c.)	u.c.
DSR (1st IF)	u.c.	u.c.
FM sound Mono	40	70[3]
FM sound Stereo	50	See FM sound Mono
64 QAM	47	67
QPSK	47	77
COFDM	u.c.	u.c.
16 QAM	u.c.	u.c.
256 QAM	u.c.	u.c.

Table 2.3.2 : extract from EN 50083-7 Chapter 5 – paragraph 2.1 – Table 2

In Annex K of the standard some additional information is given concerning accurate power density measurement. Furthermore it is stated that other types of modulation are under consideration.

The maximum levels to be found on a system outlet, together with the attenuation characteristics of In-home (shielded) cabling and the performance of connected equipment define the immunity characteristics of the network and the level of radiated emissions, which may cause harmful disturbances to radio communications systems.

Although some problems have arisen from above ground coaxial networks especially under fault conditions, such problems are generally under the control of the operator and can be quickly remedied.

However in many countries the in-home parts of the cable network are not the direct responsibility of the operator providing the programming material and in general are therefore likely to be the culprit in the case of EMC problems (both harmful disturbances and a lack of immunity). The main EMC problems (ingress and egress) generally occur through insufficient shielding in In-Home networks and open access points (not terminated by an equipment or a resistor of equivalent impedance).

2.3.3 Problems if low quality material is used

In many cases the house (and in-home network) owners do not wish to invest in their installation. Hence the components and equipment used may not fulfil the same requirements as the material used in the higher network levels. In practice the shielding attenuation of the cables is often not higher than 50 dB instead of the 75 dB specified in CENELEC EN 50117. Cables used in the higher layers do not generally cause problems because they are specified to support shielding figures of 75 dB and often exhibit attenuation figures of above 100 dB. An

[1] 57 dB(μV) for systems with 8 and 12 MHz spacing only
[2] 77 dB(μV) for systems with > 20 channels load, which is merely the situation
[3] In order not to overload certain receivers, the figures quoted above for the maximum levels might have to be reduced for example by means of a separate attenuator at a specific outlet.

important factor here is that the cables employed in the higher network levels are usually installed in ducts below ground, whilst in-home networks are generally installed above ground level.

The outlets themselves can radiate spurious emissions, in particular when they are not terminated by connected end-user equipment. CENELEC EN 500 83 part 2 specifies a minimum shielding value of 75 dB for passive devices.

In general, "in-home networks" are not professionally installed. Problems of radio frequency leakage often arise from poorly formed connections such as the ones between cables and connectors and where the cable shield or braid is not connected effectively to ground. Cables that are laid with too sharp a curve can be damaged and thus have the potential to radiate particularly if there is a break or hole in the outer metallic sheath. In addition, there are known to have been extreme examples where in-home cabling has comprised of un-shielded twisted pair cables, causing considerable difficulties.

2.3.4 Problems caused by split responsibility

Problems involving split responsibilities can principally be solved if the whole network is within the responsibility of a single operator. A good example is the Swiss cable-operator association, SwissCable and the Austrian Telekabel Wien, which is a subsidiary of the large operator UPC. Both organisations have issued in-home network guidelines defining issues such as network structure, quality of material, and the quality of work. However, if several organisations are responsible for different network areas or levels, there is a risk that one party will not contribute effectively to ensure the high overall performance of the whole network. This is of course the case where the operator is not responsible for the in-home situation as described in 2.3.3 above. To combat this particular problem ECCA, the European trade association for cable operators is developing processes, which an operator may decide to implement to facilitate customer awareness and compliance with applicable EMC obligations.

2.3.5 SMATV and In-Home Broadcast Satellite Reception

SMATV operators install master satellite antennas for broadcasting satellite reception and after conversion to an appropriate intermediate frequency, the received signals are distributed around a building or within the curtilage of a defined property. The intermediate frequency used usually falls within the range 862 – 2500 MHz. Such systems can be considered to be telecommunications networks; the frequencies used should therefore not cause harmful interference to radio communication systems and should have sufficient immunity to ensure efficient operation of the network.

Domestic satellite receiving installations can also be considered to be in-home telecommunications networks since signals are transmitted from the LNA (Low Noise Amplifier) to the satellite receiver by means of a coaxial cable. A similar intermediate frequency range to SMATV equipment e.g. 862 – 2500 MHz is utilised. The same immunity and radiation requirements should therefore also apply to such domestic installations.

2.4 Local Area Networks (LANs)

Local Area Networks is the generic name for all cable networks linking together computer equipment (PC, printers, routers…). The protocols of the signals running into LANs can be of various types : Ethernet protocols such as 10BaseT or 100BaseT, USB…

2.5 Comparison of the various cable technologies

Data transmissions over wired media have a range of different characteristics. These are determined by the degree of screening or balance inherent in the transmission cable, the nature of the transmission itself, and the transmission power employed, the frequencies involved and the ability to take mitigation measures in cases of interference.

A comparison between three types of wideband transmission highlights the fundamental differences in aspects of the systems:

Nature	Coaxial Cable	DSL	PLT
Suitability of the transmission medium to carry wideband data	Very Good	Medium	**Poor**
Features of the cable system	Screened	Balanced	Unscreened and unbalanced
Available bandwidth and potential for expansion	Very Good	Fair	Poor
Practicality of applying mitigating measures	Good	Medium	Very poor

Table 2.5-1: Comparison of the cable technologies

The discussion of coexistence should not be restricted to radiation limits to be imposed on cable systems to protect radio services. The risk of interference is not only a matter of the limit itself but also a question how systems are deployed and used in an environment shared by radio services and wire systems. The difference becomes obvious, when comparing PLT and DSL, which are using frequencies below 30 MHz.

The following critical factors must be compared when evaluating the risk of interference to radio services caused by these two systems:

- The total bandwidth necessary to operate a cable system directly influences the number of services and frequencies potentially affected by a cable usage.
- The upper frequency limit of a cable system is decisive concerning the potential for unwanted radiation. This potential depends on "wavelengths of the frequencies used" related to the average "length of (unshielded) cable" to be found within the network. The higher this frequency limit is the more energy is likely to be radiated especially when using unshielded cable with bad symmetry.
  Example: A PLT-system may use spectrum up to 10 MHz (λ = 30 m); pieces of cable as short as 7,5 m (λ/4) are resonant and thus are very good radiators at this frequency. In contrast to this the ADSL-system mentioned in the table below is using a frequency range up to 1,1 MHz (λ = 270 m) only; therefore an unshielded piece of cable needs to be about 68 m long to radiate energy with the same "efficiency" than in the first case. The probability to find wires of efficiently radiating lengths is decreasing with increasing wavelengths of frequencies used within the cable system.
  The radiating efficiency of unshielded cables with resonant lengths of λ/4 or multiples of this is at least 20 dB higher than for dimensions $l < \lambda/4$. In this context the upper frequency limit of a cable system in relation to the cable dimensions found within the network is the decisive parameter.
- The potential of unwanted radiation is also depending on the structure of the cable network. A symmetrical telephone line properly matched and without resonant stubs radiates far less energy than a local mains distribution network. (Stubs are pieces of cable of random length without proper termination as to be found in great numbers in the mains power supply). In addition to supply only one PLT-customer a whole local power supply network has to be taken into operation and is radiating thus creating interference potential for a much bigger area than is necessary to bring service to a single DSL-customer.
- Another point is the probability for decoupling by distance between a random victim receiver and the radiating cable network. This is the case especially for broadcasting and amateur receivers being operated in the vicinity of PLT- or DSL-networks. The probability for a receiver location interfered by radiation being distributed by the mains power supply is much greater than the risk of interference caused by the telephone line. This is due to the fact that the power supply infrastructure is more widely distributed especially in private homes compared to the telephone infrastructure. In addition most radio communication receivers are connected directly to the mains power supply, increasing the risk of interference even more.

In Table 2.5-2 below these critical factors are compared between a DSL- and a PLT-system. The second generation of an ADSL-systems rolled out in Germany is taken as an example for the DSL-system.

Critical factors concerning coexistence with radio services	**ADSL** (example: 2. ADSL-generation to be deployed in Germany; 1,5 MBit/s to each customer)	**Access-/Last-Mile-PLT** (approx. 2 MBit/s shared by all users in the local network)
Frequency spectrum to be used by the cable system (resulting in unwanted radiation in this frequency range)	**100 kHz – 1,1 MHz**	**1 – 10 MHz**
Bandwidth **necessary to operate the cable system** **Radio services potentially affected** by operation of the cable system due to bandwidth	1 MHz Long- and Medium wave services	9 MHz Medium and short wave services
Quality of transmission line **used by the cable system** Attenuation of unwanted radiation **due to** **Symmetry of cables used** **Shielding of cables used** **(shielded/unshielded cables)**	medium 30 – 50 dB 40 dB / 0 dB **(partially shielded)**	poor less than 30 dB 0 dB **(not shielded)**
Potential for unwanted radiation **due to relation λ / l** **(wavelength of frequencies used / cable lengths involved)**	low	high **(at 10 MHz at least 20 dB higher than at 1 MHz compared to the ADSL-system)**
Structure of unwanted radiator	**Matched single line radiator** (supplying an individual customer), few stubs, very few resonant stubs	**Large area radiator** (independent from number of customers), many resonant stubs, no proper termination of stubs
Probability of decoupling by distance **between interfering source (cable) and random receiver location (in case of broadcasting or amateur receivers)**	**medium**	**small**
Conclusion: **Resulting risk of interference to radio services**	**moderate**	**high**

Table 2.5-2: Comparison of critical factors between ADSL- and PLT-systems concerning the coexistence with radio services

Notes:

- The first generation of ADSL currently deployed in high numbers in Germany is providing 768 kBit/s downstream/128 kBit/s upstream. More than 2,2 million customers are using this service at present (June 2002). No cases of interference observed.
- The second generation of this ADSL-system will provide 1,5 MBit/s downstream, service starting in autumn 2002
- The third generation will provide up to 5 MBit/s downstream

The upper frequency limit of all these ADSL-systems is or will be 1,1 MHz.

Conclusion
Due to the accumulation of critical factors the risk of interference to radio services caused by PLT-systems is considerably higher than with DSL-technology.

Even on the condition that the two different systems will meet the same radiation limits, the number of cases of interference caused by PLT-systems is expected to be higher than with DSL-technology because in DSL, the HF signal is only fed on the lines of the customer of the system, whereas in PLT, all the electrical infrastructure around the local transformer will be fed with the HF signal.

3 USE OF THE RADIO SPECTRUM AND ASSOCIATED PROTECTION REQUIREMENTS

The aim of this chapter is to provide the necessary information on the present and future use of the radio spectrum in the frequency range at which cable transmission systems transmit signals. For PLT and DSL, the frequency range of interest is the LF, MF and HF bands (below 30 MHz). For CATV, the return channel (5 to 65 MHz) uses the HF band, but the downstream signals extend to much higher frequencies (TV bands III and IV…) and can reach 2.5 GHz. LANs also use frequencies above 30 MHz.

General information on the use of frequencies below 30 MHz in Europe is given in the first paragraph. The remaining paragraphs give details for each of the following radio services : broadcasting, amateur radio, aeronautical, military, maritime, radioastronomy and short range devices. For each radio service, the following information where available is included: receiving frequency range, sensitivity or planning field strength level, protection ratio, modulation, bandwidth and field strength to be protected.

Although in principle, all radio services operating at frequencies between 9 kHz to 3 GHz are covered in this report, more detailed information is given on frequencies below 30 MHz and not all existing services above 30 MHz are described.

3.1 Frequency allocations in Europe below 30 MHz

A revision of ERC Report 25, entitled "European table of frequency allocations and utilisations covering the frequency range 9 kHz to 275 GHz" has been approved by WG FM at its Lisbon meeting in January 2002 and the new edition covers frequencies from 9 kHz onwards (29.7 MHz for the previous version). It therefore contains key information on allocations and applications in the frequency range of interest in the context of cable transmissions.

WG FM has also asked ERO to perform a study on the use of the LF, MF and HF bands within CEPT, that led to the finalisation of ERC Report 107 approved in February 2001 and entitled "Current and future use of frequencies in the LF, MF and HF bands". This document provides very detailed information on the allocations, applications, trends… in the frequency band 9 kHz to 30 MHz.

These two documents available on the ERO web site http://www.ero.dk contain information on the general situation in Europe. Information on the situation in some specific CEPT countries, including national frequency allocation tables, can be found on the ERO Frequency Information Service (EFIS) http://www.efis.dk, also available from the ERO website.

3.2 Noise level below 30 MHz

The following paragraphs provide a general explanation of noise in the HF band. More detailed reference is made to noise levels in the individual radio users' sections of this report.

The sensitivity of a high-grade radio receiver is determined by the noise generated in its low-level signal stages. This noise is generated by active components within the equipment. This noise level defines the ultimate sensitivity of the receiver.

In the HF radio spectrum however, communication is not generally limited by the internal noise in the receiver, but by other noise sources external to the receiver itself. These noise sources, taken together, comprise the "**ambient noise environment**".

3.2.1 The ambient noise environment

The ambient noise environment consists of two parts, the irreducible residual ambient noise which is more or less constant in any particular location, and incidental noise from local man-made sources. The combination of these two determines the minimum usable signal level. These have been termed the ambient noise floor and incidental noise respectively. The incidental noise generated even by devices compliant with relevant EMC standards can greatly exceed the noise floor. Reception of low-level HF signals is possible only because of the statistical nature of the incidental noise. Many devices radiate near the limit of their standard on only a few discrete frequencies, or on a narrow band of frequencies. In addition most incidental noise is relatively short lived. HF communication services are opportunistic. That is, frequencies and time are chosen to optimise the probability of a satisfactory signal to noise ratio. If incidental noise prevents communication at any particular time the transmission is repeated at a later time when the interference has ceased. In automatic systems this is built into the operating protocol.

Contributing to the ambient noise environment are:

Natural noise sources:

a) Atmospheric noise, a major source of which is almost continuous lightening activity around the equator from which interference is propagated to the rest of the world by ionospheric reflection. The overall noise level depends on frequency, time of day, season of the year and location. In temperate zones, noise from this source is relatively low, although there will be short bursts of noise from local electrical atmospheric activity at certain times.

b) Cosmic noise. Cosmic noise originates from outer space. The main generator of radio noise is the sun, along with atmospheric gases and star clusters. On the HF band the cosmic noise reaching the antenna depends on the screening effect of the ionosphere. At lower HF frequencies it is impractical to distinguish between cosmic noise and the general background noise from other sources.

Man-made noise sources:

Man-made noise exhibits two effects. Firstly there is the resultant of a large number of relatively distant sources. This is effectively "white" and one of the constituents of the ambient noise floor.

Secondly there is incidental noise from local sources the level of which varies, depending on the type of environment. Environments are often classified as business, residential, rural and quiet rural. Man-made noise derives from electrical, electronic or radio equipment. From the radio users point of view, the difference between these environments is the level of the noise and the length of time for which it persists. Experience has shown that in industrial or business locations, HF communication is very much impaired by incidental noise which may be present at a high level all the time. In residential locations the percentage of the time that severe incidental interference is evident on any particular band of frequencies is much less and HF communication is practical, though conditions are not ideal. In rural and quiet rural locations incidental noise is rare, and HF communication is optimal.

3.2.2 Measuring the ambient noise floor

Measuring the ambient noise floor has been carried out by a number of organisations including the BBC, DERA and the RSGB. Making these measurements requires great care. In particular it is essential to select a radio frequency that is not occupied by an existing radio signal. Intentional radio signals around any particular frequency must not be confused with noise It is possible to find spot frequencies where there is a 9kHz band without any signals, however this requires great care and experience, to avoid misleading results.

Because of this congestion, sweeping the HF band using an EMC measuring receiver with a 9kHz bandwidth does not measure the background noise level. Measurements made with a typical loop EMC measuring antenna will be limited by the noise of the receiver system, not the environmental noise.

To carry out a swept measurement of the true ambient noise floor at HF, a much narrower bandwidth than 9 kHz – something in the order of 100-200 Hz should be used. This is then converted to a 9kHz bandwidth for comparison purposes.

Usually it is impractical to measure the ambient noise floor in industrial or business locations where the incidental noise will exceed the noise floor all the time. In a residential location it is usually quite practical to choose a period when there is no significant incidental noise. This assumes that measurements are taken at a reasonable distance (greater than 10m) from any dwelling, and that the measuring antenna is suitably located. In interpreting published plots of the ambient noise floor, it is important to take into account the conditions of measurement, particularly the bandwidth and the detector used, peak, quasi-peak or average, and the type of antenna.

3.2.3 Determination of the noise level

The following are relevant extracts from ITU-R P.372-7 “Radio noise”. This ITU-R Recommendation is based on measurements performed in the United States in the 1970's.

The levels contained in this Recommendation are used as a reference throughout this report although the question remains whether they represent levels present today in Europe. CEPT has endeavoured a noise floor measurement campaign in Europe to evaluate if the noise floor levels in the LF, MF and HF bands given in ITU-R P.372-7 are representative or not of the levels present today in Europe.

3.2.3.1 Sources of radio noise

Radio noise external to the radio receiving system derives from the following causes:

- Radiation from lightning discharges (atmospheric noise due to lightning);
- Unintended radiation from electrical machinery, electrical and electronic equipments, power transmission lines, or from internal combustion engine ignition (man-made noise);
- Emissions from atmospheric gases and hydrometeors;
- The ground or other obstructions within the antenna beam;
- Radiation from celestial radio sources.

3.2.3.2 Thermal, man-made, galactic and atmospheric noise levels

In order to be able to cope with the major types of modulations of HF radios, the interference calculations of noise and interference are concentrated in a bandwidth of 1 Hz.

The noise sources considered are thermal noise inherent to radios and man-made as well as radio noise mentioned in the ITU-R Recommendation P.372-7.

Thermal noise per Hertz: No/Hz = kTo
where: k = Boltzmann Constant = 1.38×10^{-23} J/K
To = 300 Kelvin

The radio noise described in ITU-R Recommendation P 372-7 is used for the calculations. It contains man-made, galactic and atmospheric noise components. The details are as follows:

The median values above kTo is as follows:

$$F_{am} = c - d*\text{Log}(f)$$

The values for c and d can be found in the both above ITU-R references and f is frequency in MHz. The values are as follows:

Type of Area	c	d
Business	76.8	27.7
Residential	72.5	27.7
Rural	67.2	27.7
Quiet Rural	53.6	28.6
Galactic (10 – 30 MHz)	52.0	23.0

Table 3.2.3.2-1: the constants c and d of ITU Rec. P 372-6 for various types of area

The corresponding levels are given on the following graph.

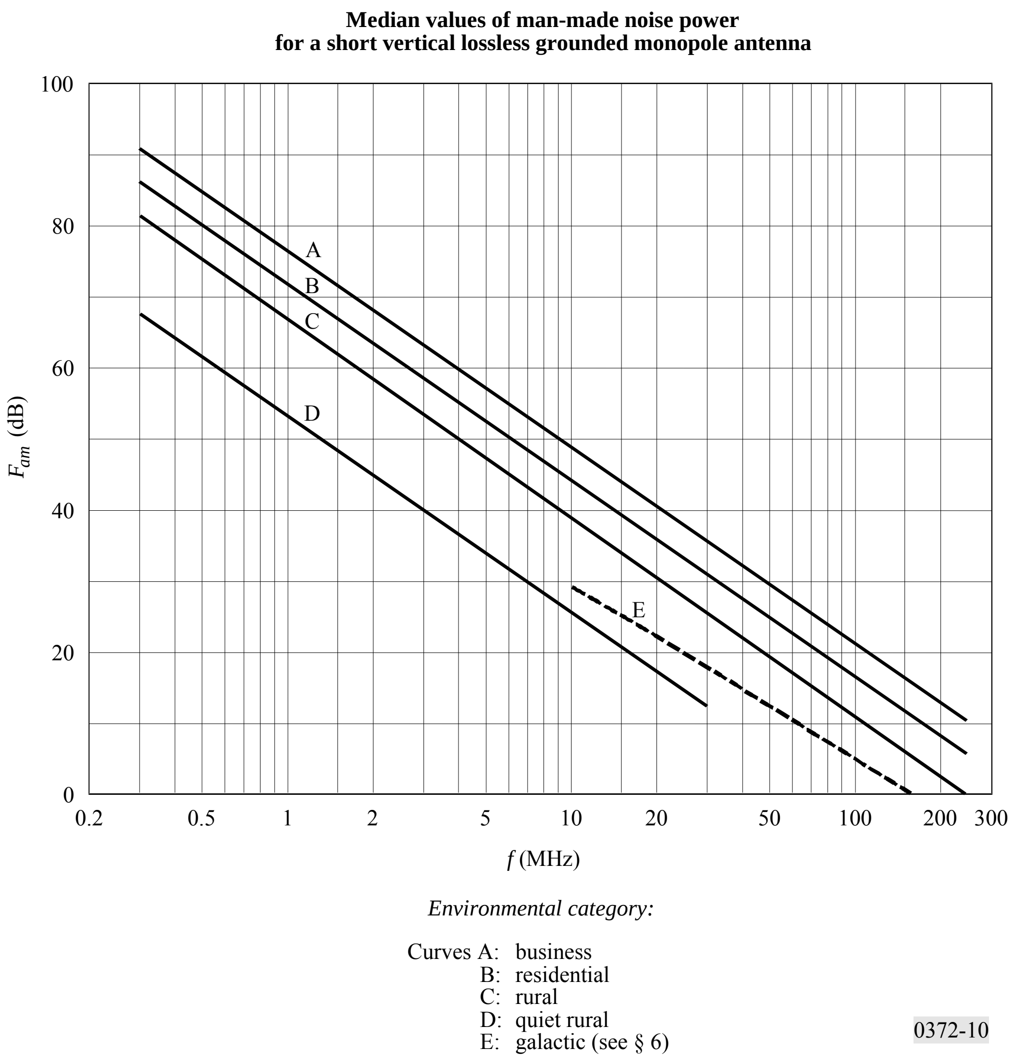

Figure 3.2.3.2: median values of man-made noise power for a short vertical lossless grounded monopole antenna (ITU-R P.372-7 "Radio noise", Figure 10)

The atmospheric noise is modelled as follows:

Frequency range	Formulae
1.5 – 10 MHz	Fa = 27.8 – 0.35*(8.2 – f(MHz))^2
10 – 15 MHz	Fa = 46.4 – 1.98*f(MHz)
15 – 20 MHz	Fa = 66.8 – 3.34*f(MHz)
20 – 30 MHz	0

Table 3.2.3.2-2: formulae reflecting the level of the atmospheric noise, 99.5% value exceeded

These formulae were derived from Rec. ITU-R P 372-7 using a graph that represents the 99.5% of time value exceeded situation and f is frequency in MHz. The above formulae were derived for this exercise only. Therefore, although the formulae do not fully match the original graph at points where the influences of other components are dominant, the final results are in practical terms correct and valid.

3.3 Broadcasting

Note: although only information concerning frequencies below 30 MHz is given in this section, the broadcasting service makes also an extensive use of frequencies above 30 MHz.

3.3.1 LF, MF and HF radio broadcasting frequency ranges

The following frequency bands are used for broadcasting:

LF: 148.5 – 283.5 kHz (Region 1)

MF: 526.5 – 1605.5 kHz (Regions 1, 3)
525 – 1707 kHz (Region 2)

HF: 3950 - 4000 kHz
5900 - 6200 kHz
7100 - 7350 kHz
9400 - 9900 kHz
11600 - 12100 kHz
13570 - 13870 kHz
15100 - 15800 kHz
17480 - 17900 kHz
18900 - 19020 kHz
21450 - 21850 kHz
25670 - 26100 kHz

Tropical bands (used for national broadcasting by tropical countries) :

2300-2498 kHz (Region 1, Tropical)
2300-2495 kHz (Regions 2+3)
3200-3400 kHz (All Regions)
4750-4995 kHz
5005-5060 kHz.

3.3.2 Noise

In order to receive a broadcast signal with an acceptable quality, the useful field strength at the point of reception must sufficiently exceed the ambient noise. Atmospheric and man-made radio noise considerations are given in Section 3.2 above.

3.3.3 General characteristics of analogue[4] LF, MF and HF broadcasting

The following physical characteristics and technical parameters are used in planning analogue broadcasting services below 10 MHz.

3.3.3.1 Bandwidth

The bandwidth of a typical modern AM receiver is [4.4 kHz] but a range may be encountered, with a very few receivers having selectable bandwidth.

3.3.3.2 Receiver noise

In additional to atmospheric and man-made noise, the intrinsic noise of the receiver must also be taken into account. This is described here.
The intrinsic receiver noise level E^0_i, is calculated by:

$$E_i^0(\text{dB}\ \mu\text{V/m}) = E_C\ (\text{dB}\ \mu\text{V/m}) + 20 \log M - SNR_{af}$$

Where E_c is the noise limited sensitivity of the receiver, M is the modulation depth, and SNR_{af} is the audio-frequency signal-to-noise ratio.

[4] Studies of planning parameters suitable for digital HF broadcasting are underway.

According to ITU-R Recommendation 703, the minimum sensitivity of an AM sound broadcasting sound receiver is :

	LF	MF	HF
E_C [5] (µV/m)	66	60	40

Thus :

	LF	MF	HF
M	0.3	0.3	0.3
SNR (dB)	32	32	26
E_i^0 (µV/m)	23.5	17.5	3.5

Table 3.3.3.2: Sensitivity and intrinsic receiver noise level

3.3.3.3 Minimum usable field strength

The noise floor to calculate the minimum field strength is determined as the largest one among the values of atmospheric noise, man-made noise and intrinsic receiver noise. The resulting values for noise (whatever the cause), E_n, usually lies between 3.5 to 7 dBµV/m in the frequency bands under consideration (1 - 10 MHz). The RF signal-to-noise ratio, $(S/N)_{RF}$, is taken to be 34 dB for the HF and 40 dB for the LF/MF bands. Thus the minimum usable field strength, F_{min}, is calculated as:

	LF	MF	HF
E_n (µV/m)	20	20	3.5-7
$(S/N)_{RF}$ (dB)	40	40	34
F_{min} (µV/m)	60	60	37.5-41

Table 3.3.3.3: Minimum usable field strength

3.3.3.4 Protection ratios

The co-channel and adjacent protection ratios given below are applicable for protecting AM broadcast transmissions against other AM transmissions and do not apply to protection from other services.

QUALITY GRADE	LF	MF	HF
3 (fair)	27 dB	27 dB	17 dB
4 (good)	30 dB	30 dB	27 dB

Table 3.3.3.4-1: co-channel protection ratios

ΔF_{kHz}	LF	MF	HF
0	0-9[6]	0-9	0
± 2	+10	+10	+10
± 5	-3	-3	-3
± 10	-35	-35	-35

Table 3.3.3.4-2: adjacent channel protection ratios

3.3.4 General characteristics of digital[7] LF, MF and HF broadcasting

The following physical characteristics and technical parameters are used in planning digital broadcasting services below 10 MHz. They are the characteristics specifically developed for the DRM (Digital Radio Mondiale) system. In the DRM system various 'robustness' modes, 'spectrum occupancy' types, modulation schemes, and protection levels are specified in order provide adequate service in a multitude of propagation and interference conditions. The possible combinations of these characteristics give rise to a range of values for S/N, minimum usable field strength, etc. These ranges will be indicated briefly in the following sections.

[5] This value was chosen as a compromise value between receivers with a good performance and cheap receivers or old receivers that are still in use in many parts of the world.
[6] The range of values corresponds to various degrees of modulation compression and bandwidths (e.g., 4.5 kHz/10 kHz)
[7] Studies of planning parameters suitable for digital HF broadcasting are underway.

3.3.4.1 DRM robustness modes

In the DRM specification four robustness modes with different parameters (subcarrier number and spacing, useful symbol and guard interval length, etc.) for the OFDM (Orthogonal Frequency Division Multiplex) transmission scheme are defined for the various propagation conditions in the LF, MF, and HF bands:

Robustness mode	Typical propagation conditions	Preferred frequency band
A	Ground-wave channels, with minor fading	LF, MF
B	Time- and frequency-selective channels, with longer delay spread	MF, HF
C	As robustness mode B, but with higher Doppler spread	Only HF
D	As robustness mode B, but with severe delay and Doppler spread	Only HF

Table 3.3.4.1: DRM robustness modes

3.3.4.2 Spectrum occupancy types

For each robustness mode the occupied signal bandwidth can be varied dependent on the frequency band and on the desired application.

Robustness mode	Spectrum occupancy type			
	0	1	2	3
A	4.208	4.708	8.542	9.542
B	4.266	4.828	8.578	9.703
C	-	-	-	9.477
D	-	-	-	9.536
Nominal bandwidth in kHz	4.5	5	9	10

Table 3.3.4.2: DRM spectrum occupancy

3.3.4.3 Modulation and protection levels

For all robustness modes two different modulation schemes (16- or 64-QAM) are defined which can be used in combination with one of two (16-QAM) or four (64-QAM) protection levels, respectively.

	Protection level	Average code rate
16-QAM	0	0.5
16-QAM	1	0.62
64-QAM	0	0.5
64-QAM	1	0.6
64-QAM	2	0.71
64-QAM	3	0.78

Table 3.3.4.3: DRM modulation and protection levels

3.3.4.4 Receiver noise

In additional to atmospheric and man-made noise, the intrinsic noise of the receiver must also be taken into account. This is described here.

The intrinsic receiver noise level $E^0{}_i$, is calculated by:

$$E_i^0(\text{dB }\mu\text{V/m}) = E_C\ (\text{dB }\mu\text{V/m}) + 20 \log M - SNR$$

Where E_c is the noise limited sensitivity of the receiver, M is the modulation depth, and SNR is the audio-frequency signal-to-noise ratio.

According to ITU-R Recommendation 703, the minimum sensitivity of an	LF	MF	HF

AM sound broadcasting sound receiver is :			
E_C [8] (µV/m)	66	60	40

thus :

	LF	MF	HF
M	[0.3]	[0.3]	0.3
SNR (dB)	[32]	[32]	26
E_i^0 (µV/m)	[23.5]	[17.5]	3.5

Table 3.3.4.4: DRM receiver noise

3.3.4.5 Minimum usable field strength

To achieve a sufficiently high quality of service for a DRM digital audio service, a bit-error ratio (BER) of about 10^{-4} is needed. The S/N required at the receiver input to achieve this BER is dependent, apart from the system parameters, also on the wave propagation conditions in the different frequency bands.

A range of relevant values for minimum usable field strength are given in the table below. The given ranges cover for the possible modulation schemes and protection levels. Only a few combinations of possibilities are indicated, sufficient to give an idea of the wide range of values that can arise.

	LF	MF	HF
Robustness mode A (Ground wave propagation)	39.1-49.7	33.1-43.7	
Robustness mode A (Ground-wave plus sky-wave propagation)		33.9-47.4	
Robustness mode B (Sky-wave propagation)	-		19.1-30.4

Table 3.3.4.5: DRM minimum usable field strength

3.3.4.6 Required signal-to-noise ratios for DRM reception

To achieve a sufficiently high quality of service for a DRM digital audio service, a bit-error ratio (BER) of about 10^{-4} is needed. In the following, values of signal-to-noise ratios (S/N) required to achieve this BER are given for typical propagation conditions on the relevant frequency bands.

	LF	MF	HF
Ground wave propagation (9, 10 kHz BW)	8.6-21.4	8.6-21.4	
Robustness mode A, B (4.5, 5 kHz BW) (Ground-wave propagation)	8.8-19.5	8.8-19.5	
Robustness mode B (Ground-wave plus sky-wave propagation)	-	9.4-22.8	14.6-30.9
Robustness mode C (Ground-wave plus sky-wave propagation)	-	-	14.6-33.3
Robustness mode D (Sky-wave propagation)	-	-	16.0-35.0

Table 3.3.4.6: Required signal-to-noise ratios for DRM reception

3.3.4.7 Protection ratios

The combinations of spectrum occupancy types and robustness modes lead to several transmitter RF spectra, which cause different interference and therefore require different RF protection ratios. The differences in protection ratios for the different DRM robustness modes are quite small. Therefore, the RF protection ratios presented in the following tables are restricted to the robustness mode B.

[8] This value was chosen as a compromise value between receivers with a good performance and cheap receivers or old receivers that are still in use in many parts of the world.

Wanted signal	**Unwanted signal**	PR range
AM	DRM	23.0-23.6
DRM	AM	4.8-7.8
DRM	DRM	12.8-16.4

Table 3.3.4.7: co-channel protection ratios

Values of adjacent channel protection ratio range over –20 kHz to +20 kHz frequency separation, but are not reproduced here.

3.4 Amateur radio

3.4.1 General characteristics

Article 1.56 of the ITU Radio Regulations (RR) defines the amateur radio service as: "*A radiocommunication service for the purpose of self-training, intercommunication and technical investigations carried out by amateurs, that is, by duly authorized persons interested in radio technique solely with a personal aim and without pecuniary interest"*

The maximum permitted transmitter power is dependant on national regulations, varying from around 100 Watts to 1kW output power. Amateurs are the only users of relatively high transmit power in residential areas. However many amateurs choose to operate using low transmit powers in the order of a few watts. Amateurs use a wide variety of antennas and equipment, depending on location and financial means. Consequently, there is no "standard" amateur radio station.

Amateurs do not generally have the opportunity to position antennas far away from electric wiring. They must install their antennas within the boundaries of their homes, which generally means in close proximity to mains and telephone wiring. Other sources of localized interference can be minimized by the amateur choosing not to use equipment such as luminaires, switch-mode power supplies, and other equipment generating interference when operating. That choice is not available in the case of many cable-borne cable transmission systems, where the emissions are present all the time. (Refer to 9.4.4 "Effect of various emission standards on HF reception").

Amateurs communicate over long distances on the HF bands, making optimum use of propagation windows. Amateurs frequently operate at or near to the minimum signal-to-noise ratio for effective communication. Limits of communication are generally determined by the received signal strength in relation to the background noise. Amateurs manage to communicate effectively with a signal-to-noise ratio of some 6dB for voice communications in a nominal 2.4 kHz bandwidth and as low as -6dB (related to the same bandwidth) for Morse code or spectrum-efficient data modes.

Amateur radio operators are also encouraged to support disaster relief operations. In many countries, amateur radio is seen as a valuable back-up service in case of breakdown or overload of normal communications systems. Governments rely on this capability at times of emergency. Radio Amateurs are generally permitted through the Radio Regulations of the International Telecommunications Union, to use all their HF frequency bands from 3.5MHz to 24.990 MHz and 144 to 146 MHz for this purpose.

3.4.2 Amateur frequency allocations

Frequency Bands (MHz)	Basis of allocation
0.1357 – 0.1378	Secondary
1.810 – 2.000	Primary/non-interference
3.500 – 3.800	Primary shared
7.000 – 7.100	Primary
10.100 – 10.150	Secondary
14.000 – 14.350	Primary
18.068 – 18.168	Primary
21.000 – 21.450	Primary
24.890 – 24.990	Primary
28.000 – 29.700	Primary
50.000 – 52.000	Primary/secondary
144.000 – 146.000	Primary
430.000 – 440.000	Secondary/primary
1240.000 – 1325.000	Secondary
2310.000 – 2450.000	Secondary

Table 3.4.2: amateur frequency allocations (LF, HF, VHF and UHF only shown)

3.4.3 The protection requirements of the HF amateur radio service

3.4.3.1 Choice of modes to calculate the protection requirement

HF amateur radio uses many different combinations of bandwidth and classes of emission. To illustrate the signal levels and noise environments amateurs operate with, two of the most widely used, but very different, modes have been selected: SSB voice in 2.4 kHz bandwidth and PSK31, a very spectrum efficient digital mode for text exchange at typing speeds. The antenna used as a reference is a half wave dipole.

3.4.3.2 The noise floor in amateur radio bands

In common with other HF services, the ability to achieve satisfactory amateur communications depends on the ratio between the wanted signal and the noise. The noise consists of four components, (internally generated) receiver noise, atmospheric, man-made and galactic (cosmic).

3.4.3.3 Sensitivity and internally generated noise of HF band amateur receivers

To satisfy the requirements of amateur stations at quiet rural sites and to be able to fully exploit periods with very low atmospheric noise levels, modern amateur radio HF receivers are very sensitive. In the frequency range of 1.8 - 18 MHz a noise figure of 11 dB is quite normal. High-quality amateur equipment is usually fitted with an additional RF pre-amplifier, which can be switched on when conditions permit, to improve the noise figure to 8 dB, albeit at the expense of large signal handling capability. Because of the existing noise levels in the lower HF region and the presence of very strong signals in broadcast bands adjacent to amateur bands, the additional RF pre-amplifier is used only above 18 MHz (i.e., in the 18.068 - 18.168 MHz amateur band and above). The calculated minimum RF input signal levels for SSB voice (2.4 kHz) and PSK31 (noise bandwidth 50 Hz) are as follows:

SSB voice mode	1.8 - 18 MHz	18 - 30 MHz
Thermal noise power at 290 K	-174 dBm/Hz	-174 dBm/Hz
Bandwidth factor 2400 Hz	33.8 dB	33.8 dB
Receiver noise figure	11 dB	8 dB
Noise power (in 2400 Hz)	-129.2 dBm	-132.2 dBm
Required Signal to Noise ratio	10 dB	10 dB
Input signal requirement	-119.2 dBm	-122.2 dBm
Converted into voltage in 50 Ohms	0.245 µV	0.174 µV

Table 3.4.3.3-1: sensitivity for SSB voice mode

PSK31 text mode	**1.8 - 18 MHz**	**18 - 30 MHz**
Thermal noise power at 290 K	-174 dBm/Hz	-174 dBm/Hz
Bandwidth factor 50 Hz	17 dB	17 dB
Receiver noise figure	11 dB	8 dB
Noise power (in 50 Hz)	-146 dBm	-149 dBm
REQUIRED SIGNAL TO NOISE RATIO	10 dB	10 dB
Input signal requirement	-136 dBm	-139 dBm
Converted into voltage in 50 Ohms	0.0354 µV	0.0251 µV

Table 3.4.3.3-2: sensitivity for PSK31 text mode

It should be noted that PSK31 appears to work well with a S/N of -6.8 dB referred to the standard 2400 Hz bandwidth. The required signal to noise ratios in the matched bandwidth of SSB (2400 Hz) and PSK31 (50 Hz) however are identical. This means that both modes can operate in the same noise power spectral density (W/Hz) environment, as long as the noise is Gaussian. The advantage of PSK31 is its spectrum efficiency, providing more chances to find an interference-free frequency in the busy amateur bands. Because the interference radiated by cable networks is treated as white noise, it is possible to define one protection criterion for both modes and in general, for the majority of amateur radio modes of operation. For ease of comparison with proposed noise fieldstrength limits, all noise powers are recalculated for the 9 kHz standard measurement bandwidth. The receiver noise power in the frequency range from 1.8 - 18 MHz (-129.2 dBm in 2.4 kHz) now becomes -123.5 dBm (-153.5 dBW) in 9 kHz. Above 18 MHz -132.2 dBm (2.4 kHz) becomes -126.5 dBm (-156.5 dBW) in 9 kHz.

3.4.3.4 Internally generated noise power compared to external noise fieldstrength

The receiver internal noise power can be represented as a noise field strength at a half wave dipole antenna, having the same effect on a noiseless receiver. The conversion to fieldstrength uses the reverse of the formula for received power as a function of fieldstrength, or:

Received power = power density x aperture or $P = \frac{E^2}{120\pi} \times \frac{G \times \lambda^2}{4\pi}$ where G=1.64.

The reverse operation then is: $E = \frac{4\pi}{\lambda} \times \sqrt{30 \times G \times P}$. Substituting 300/f(MHz) for λ and expressing E in µV/m, we get: E(µV/m) = f(MHz) x 293813 x $\sqrt{P_n}$, or in logarithmic form:

E(dBµV/m) = 109.4 + 20LOG10(f(MHz)) + 10LOG10(P_n).

Substituting -153.5 dBW for 10LOG10(P_n) simplifies this to:

E(dBµV/m) = -44.1 + 20LOG10(f(MHz)) below 18 MHz and

E(dBµV/m) = -47.1 + 20LOG(10(f(MHz)) above 18 MHz.

3.4.3.5 Atmospheric noise

One of the most important parts of amateur radio is "DX-ing": communicating over very long distances by making optimal use of propagation windows and periods of low atmospheric noise. ERC Report 69, Annex B, gives the expected noise field strength levels for the European area. Atmospheric noise has a stochastical character but there is a marked influence of the time of day, season and radio frequency. The atmospheric noise fieldstrength values for a 20% distribution percentage as shown in the graph in Annex B, figure B1, are representative for the amateur radio environment during HF long distance communications. The values for 2.7 kHz bandwidth and measured with a short monopole antenna as shown in the graph must be corrected for the 9 kHz reference bandwidth (+5.2 dB) and dipole (-3.5 dB), i.e. +1.7 dB.

3.4.3.6 Man-made noise

The man-made noise itself consists of the background noise floor (caused by many distant noise sources) which on frequency/amplitude plots looks rather like white noise, and incidental noise which is generated by nearby electrical or electronic equipment. In many cases incidental noise is either short-lived, or is confined to a limited bandwidth. Thus the risk of interference to radio communications is statistical. Generally HF communication can combat incidental noise by choosing times when noise is not present, or by changing frequency. An increase in noise floor such as might be caused by broadband data transmission systems is potentially much more damaging.

ITU-R has suggested likely noise level figures for various environments. It is understood that the levels in ITU-R Recommendation PI 372-7 are based on measurements made in the USA and are higher than the man-made noise levels in the UK and elsewhere in Europe. It therefore seems likely that the ITU-R levels are worst case noise figures in the European environment. Many HF amateur radio stations can be found in rural areas or in suburbs where HF antennas may be erected in the garden. Observations done in the UK (BBC and RSGB) and in The Netherlands (VERON) suggest that, under these circumstances, the man-made noise floor as defined above is at a level halfway between the quiet rural and rural levels as defined in ITU-R Recommendation PI 372-7. This level is further referred to as "curve M".

Expressed in a formula, this noise level (in dBµV/m) is:

$$E_n(\text{dB}\mu\text{V/m in 9 kHz}, \lambda/2 \text{ dipole}) = 0.94 - 8.15\text{LOG10}(f(\text{MHz})).$$

3.4.3.7 Galactic noise

The formula expressing the fieldstrength of galactic (or cosmic) noise as received on a half wave dipole can be taken from ITU-R report PI 372-7. The valid frequency range is from 10 MHz and higher, as below about 10 MHz, galactic noise is screened from earth by the ionosphere. The formula is:

$$E_n(\text{dB}\mu\text{V/m in 9 kHz}, \lambda/2 \text{ dipole}) = -7.46 - 3\text{LOG10}(f(\text{MHz})).$$

3.4.3.8 Fade margin and the 0.5 dB protection criterion of HF amateur radio

In professional broadcasting, ample fade margins are taken into account to guarantee a high degree of availability of the signal. This, coupled to the lower sensitivity of broadcast receivers, leads to the high power levels used in HF broadcasting. In the amateur radio service, the permitted transmitter powers are relatively low and in long distance communications the remaining fade margin above the minimum required fieldstrength of a long distance signal is around 0 to 1 dB. Given the form of the signal strength versus time curve of a narrow-band HF signal with fading, this means that in some long distance communication links, parts of the transmissions will be missed due to fading, necessitating repeat transmissions. Increasing the ambient noise floor by only a few dB would have a tremendous impact on the long distance communication capability of an amateur station.

For this reason, the maximum allowable increase in the total noise floor due to noise emitted by cable networks, in the reference scenario with a half wave dipole antenna at 10 m from the cable, should be 0.5 dB. For the increase not to exceed 0.5 dB, the average noise fieldstrength radiated by the cable network at 10 m distance must be 9.14 dB below the pre-existing noise level.

This protection criterion is also acceptable for radio amateurs used to higher ambient noise levels, e.g. when antennas are closer to electrical wiring, in which case the noise level received from cable networks will also be higher.

3.4.3.9 Calculation of the total noise fieldstrength and protection requirements based on the 0.5 dB criterion

The results of the calculations, as well as comparisons with existing examples for limits, are given in table 3.4.3.9.

To arrive at the total average existing noise fieldstrength, the power-sum of the four noise fieldstrength components has been calculated and given in the column marked “Total exist noise”. The maximum allowed radiated noise fieldstrength, average value in 9 kHz bandwidth at 10 m from the cable, is given in the next column “Max extra (avg)” and the power sum of the existing noise level and the additional network radiated noise is in “Total incl +0.5 dB”.

For the calculated limit to protect amateur radio, the values of the “Max extra (avg)” column have been recalculated in “Amat lim 3m (peak)” for 3 m distance from the cable (+10.46 dB) and 10 dB has been added to allow for the better defined peak measurements to be made.

For comparison, the example n°4 limit (all proposed limits are defined in Section 7) recalculated for 3 m (-9.54 dB), the example n°2 and the example n°1 limits been provided in the next columns to the right. The accompanying graph (figure 3.4.3.9) illustrates the relative position of the various limits.

Freq MHz	RX noise fs	Atm noise fs	Manm (curve "M") fs	Galact noise fs	Total exist noise	Max extra (avg)	Total incl + 0.5 dB	Amat lim 3m (peak)	Exampl e n°4 3m (peak)	Exampl e n°2 3m (peak)	Exampl e n°1 3m (peak)
1.8	-38.99	-29.00	-1.14		-1.13	-10.27	-0.63	10.19	10.18	18.03	37.75
3.5	-33.22	-27.30	-3.49		-3.47	-12.61	-2.97	7.85	7.83	15.81	35.21
7.0	-27.20	-13.30	-5.95		-5.19	-14.33	-4.69	6.13	5.37	13.49	32.56
10.1	-24.01	-7.50	-7.25	-10.47	-3.37	-12.51	-2.87	7.95	4.07	12.27	31.16
14.0	-21.18	-12.50	-8.40	-10.90	-5.38	-14.52	-4.88	5.94	2.92	11.17	29.91
18.1	-21.95	-23.30	-9.31	-11.23	-6.91	-16.05	-6.41	4.41	2.01	10.32	28.93
21.0	-20.66	-28.70	-9.84	-11.43	-7.31	-16.45	-6.81	4.01	1.48	9.82	28.36
24.9	-19.18	-37.00	-10.44	-11.65	-7.67	-16.81	-7.17	3.65	0.88	9.25	27.71
28.0	-18.16	-50.00	-10.85	-11.80	-7.87	-17.01	-7.37	3.45	0.47	8.86	27.26

Table 3.4.3.9: Calculation of proposed limit for amateur radio and comparison with other limits

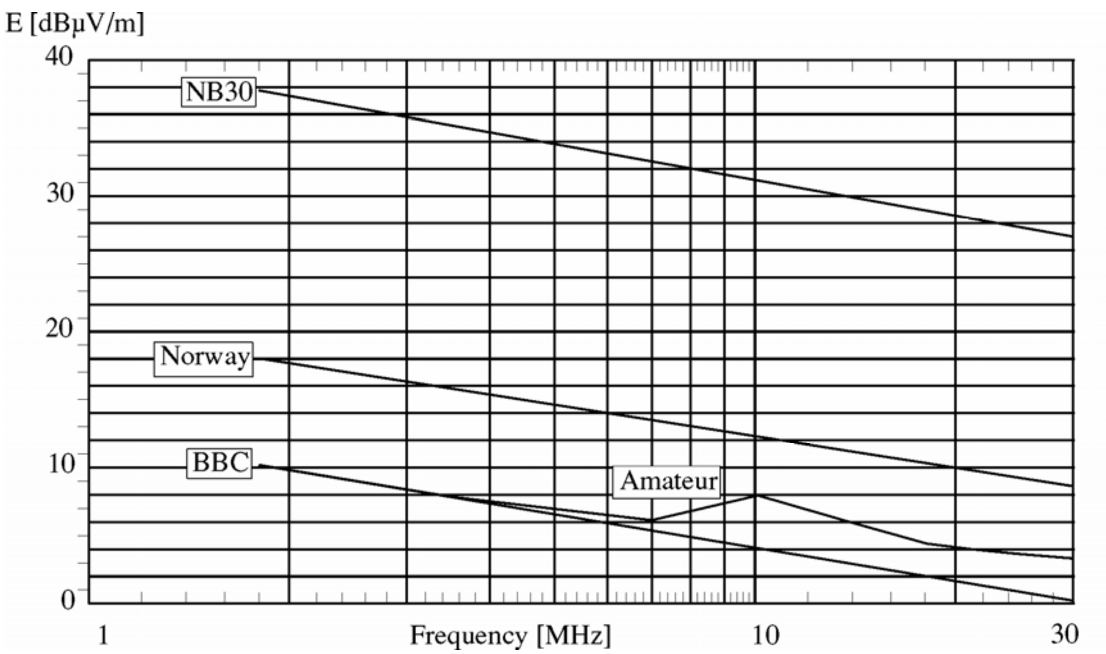

Figure 3.4.3.9: comparison of the calculated noise fieldstrength limit for amateur radio with other limit examples

3.4.3.10 Discussion of results and choice of proposed limit

The position of the calculated amateur limit line varying just above the example n°4 is not surprising, as the same assessment of the man-made noise environment and the presupposed peak-to-average ratio of 10 dB have been the basis for both calculations. The deviation from the example n°4 is attributable to the other noise sources taken into consideration: atmospheric noise, galactic noise and receiver internal noise. The calculated limit to protect amateur radio cannot be simplified to a curve following a simple logarithmic formula.

From several tests, indications are that the peak-to-average ratio of cable network generated noise fields and the "block length" of data transfer can vary widely from system to system and that the ratio may approach unity for relatively long periods of time during busy hours on the network. For this reason, the 10 dB which has been added above the average maximum allowable noise field strength from cable systems should actually be a value to be determined between 0 and 5 dB. Doing so, the amateur limit line just fits under the example n°4 that can be seen as the true protection limit, not only for the broadcast service, but for the amateur service as well.

Therefore, radioamateurs support the example n°4 limit.

3.5 Aeronautical

The following table provides the main characteristics, including the protection requirements, of aeronautical radio services operating in frequency bands where cable signals can be found (9 kHz to 3 GHz).

ICAO Annex 10 provides detailed information, including the protection requirements, on the Civil Aviation systems characteristics. Table 3.5 also include information regarding aeronautical systems used by military and governmental bodies.

Frequency Band	Application Abbreviation	Type of Service, short description	Designated operational coverage (DOC)	Interference threat	Receiving bandwidth (kHz)	Minimum wanted field strength dBμV/m
90-110 kHz	LORAN C			DSL		
255-526.5 kHz	NDB	Non-Directional Beacons		DSL		
2.8–22 MHz	HF Comms	HF Comms		PLT, DSL, CATV		
3023 kHz	Distress/ emergency			PLT, DSL		
5680 kHz	Distress/ emergency			PLT, DSL, CATV		
74.8–75.2 MHz	ILS/MKR	Aeronautical Radio Navigation Service (ARNS). Marker beacon belonging to the ILS system, provides a signal to the pilot or Flight Management System (FMS), when the plane is passing certain fixed points during final approach and landing.	**horizontal**: a circle of approximately 100m radius around the position of the beacon. **vertical**: from 30 m to 1 km, depending on the position of the beacon. position of the beacon: 2 or 3 points on the extended centre line of the runway, between 100 m and 7.5km from threshold.	CATV		63
108 – 111.975 MHz	ILS/LOC	ARNS. Precision Landing Aid, provides course guidance information to the pilot/FMS.	**horizontal**: angle sector ±10°, 46,3 km from TX, angle sector ±35°, 31,5 km from TX. **vertical**: from 300 m to 1905 m. within glide path sector increasing from 0 m to 300 m.	CATV		32
108 – 117.975 MHz	VOR	ARNS. En-route and terminal (landing) beacon, provides azimuth relating to beacon position to the pilot/FMS	**horizontal**: a circle of 30 to 180 km radius around the VOR **vertical**: from 300 m to 15000 m	CATV		39
108 – 117.975 MHz	GBAS	ARNS. Ground Based Augmentation System, provides enhanced accuracy of position data to satellite navigation systems on board of aircraft, especially during landing procedures	horizontal: a circle of 60 km radius around the ground station vertical: up to 3000 m	CATV		43

Frequency Band MHz	**Application Abbreviation**	**Type of Service, short description**	**Designated operational coverage (DOC)**	**Interference threat**	**Receiving Bandwidth (kHz)**	**Minimum wanted field strength dBµV/m**
118 – 136.975 138-143.975	VHF COM VHF COM Off Route (OR)	Aeronautical Mobile Service (AMS(R)), provides air/ground communication via voice (DSB-AM) and data (VDL2, VDL3, VDL4) on some frequencies in this band. Aeronautical Mobile Service Off Route (AMS(OR)), provides air/ground communication via voice (DSB-AM) and data links	**horizontal**: from circles of ca 30 km to polygon areas of ca 350 km extension. **vertical**: 300 m to 15000 m.	CATV	8.3 or 25	DSB-AM: 14 VDL2: 37 (airborne station) 26 (ground station) VDL3: TBD[9] VDL4: 37 (airborne station) 26 (ground station)
121.5 123.1 243.0 406-406.1	EPIRB	Emergency Position Indicating Radio Beacons		CATV		For the 406 MHz band, see ITU-R Rec SM 1051-2
230-399.9 (except 328-333.5; 380-385 and 390-395)	UHF Air-Ground-Air COM	Military Air-Ground-Air UHF Communications AMS, Provides Air-Ground-Air Voice and Data service	**horizontal**: from circles of ca 30 km to polygon areas of ca 400 km extension. **vertical**: 300m to 15000m	CATV	25	32
328.6 – 335.4	ILS/G P	ILS Glide Path ARNS. Precision Landing Aid, provides glide path information to the pilot/FMS.	**horizontal**: angle sector ±8° around the extended runway centre line, 18.5 km (certain States use 28 km) from TX. **vertical**: angle sector (1,75°x glide slope angle) above, and (0.3°x glide slope angle) below glide slope. Glide slope is from 2° to 3.3°	CATV		52
960 - 1215	DME	ARNS. En-route and terminal (landing) beacon, provides distance between beacon position and aircraft	**horizontal**: a circle around the beacon position from 30 to 180 km. **vertical**: from 300 m to 1500 m	CATV		57
1164 – 1215 1559 - 1610	GNSS/GPS	Radio Navigation Satellite Service (RNSS)/Global Positioning System. En-route and terminal (landing) means, provides position data for navigation to the pilot/FMS	**horizontal**: the whole surface of a State. **vertical**: from 300 m to 15000 m, for approach and landing from 0 m increasing according to glide slope to 300 m	CATV		tbd

[9] To be defined

Frequency Band MHz	**Application Abbreviation**	**Type of Service, short description**	**Designated operational coverage (DOC)**	**Interference threat**	**Receiving Bandwidth (kHz)**	**Minimum wanted field strength dBμV/m**
1025 – 1035 1085 - 1095	SSR	Radiolocation Service (RLS). Aircraft transponder transmits position and other information to air traffic controller, when aircraft transponder is interrogated by ground radar station. These facilities are also used for an air/ground data link, so called Mode S.	**horizontal**: the whole surface of a State. **vertical**: from 300 m to 15000 m.	CATV		**63** (1025 – 1035 MHz) **34** (1085 – 1095 MHz)
1025 – 1035 1085 – 1095	ACAS	ARNS. Airborne Collision Avoidance System, uses SSR airborne transponder for determining and solving of conflict situations caused by too close approximation of airplanes.	**horizontal**: the whole surface of a State **vertical**: from 300 m to 15000 m	CATV		**63** (1025 – 1035 MHz) **34** (1085 – 1095 MHz)
1215 – 1400 2700 - 2900	Surveillance Radar	Radiolocation Service (RLS). Primary radar stations on the ground, no airborne receiver	**horizontal**: circles with radius from some ten kilometres to radio horizon **vertical**: from 300 m to 15000 m.	CATV		See ITU-R Rec PN 525-2
1545 – 1555 1646.5 – 1656.5 1544 – 1545 1645.5 – 1646.5	SAT COM	AMS(R)S. Provides air/ground communication, and EPIRP via satellite. But this is not currently a system for the safeguarding of human life.	**horizontal**: the whole surface of a State. **vertical**: from 300 m to 15000 m.	CATV		tbd

Table 3.5: aeronautical systems characteristics

3.6 Military

Note: although only information concerning frequencies below 30 MHz is given in this section, military makes also an extensive use of frequencies above 30 MHz.

3.6.1 General

The experience in military missions shows, that HF communication is the only way to distribute missions and progress reports without delays and without the danger of signal jamming. In addition, in case of a nuclear explosion, SATCOM links will be disrupted. By contrast, the HF links will still be available. Disruptions on HF links will be only for a short time.

In general, adaptive radio systems are used which can automatically choose the best frequencies in relation to the best propagation conditions and the maximum of data throughput but only if the *noise floor is low enough* (i. e. below the decision threshold of the systems).

Beside these HF radio links special units (i.e. crisis reaction forces) are using low power radios for their internal communications.

Additionally the Armed Forces are using installations for radio monitoring (i.e. for detection of weak signals) throughout Europe within the entire band from 1.5 MHz to 30 MHz.

Modern communications in the HF band have specific attributes which make it a viable solution for many military requirements:

- HF can provide both local and beyond line-of-sight communications,
- It is capable of supporting low and medium data rates,
- It can support varying degrees of Electronic Protection Measures (EPM) ranging from protection from natural electronic interference to substantial protection from deliberate jamming,
- It is generally available, rapidly and readily deployable,
- It is the only fully military-controlled command system used for long-distance with secured transmissions without additional costs and easy frequency coordination,
- It can be integrated or used in conjunction with many commercial hardware products.

3.6.2 Military HF Utilisation

In view of the new strategic concept with its increased emphasis on dialogue, crisis management and the prevention of conflict, NATO forces need to possess military attributes such as readiness, deployability and inherent Command and Control capabilities. By the same token, the incorporation of potential non-NATO contributions in contingencies not related to collective defence will have to be accomplished. In addition to the requirements of the operational task and of the single services, there may be other requirements which will generate CIS requirements.

Modern HF technology with its specific technical attributes and features can meet the requirements derived from these new roles of the Alliance.

In conclusion, the development of both the doctrine concerning CIS planning for Crisis Response Operations (CRO) and the advancement in modern HF technology will equally contribute to the increasing importance of military HF communications in the future.

3.6.3 Particular aspects of military HF communications

Military HF radio communications contain the following signatures:

- *Airborne Platforms*
  Many of the military HF radios are located at airborne platforms. Therefore, they quickly suffer interference due to the low propagation loss of the interfering signals and also the large Radio Horizon Distance (RHD) of airborne radios.

- *Maritime / Ships*
  In addition to the airborne platforms, military radios are often mounted on ships to provide maritime services.

- *SIGINT*
  Signal Intelligence (SIGINT) activities are important to the military. Therefore, listening to (very weak) signals is done by the military and this activity can be disturbed by low level interference.

- *Use of Automatic Link Establishment (ALE) and Digital Modulations*
  Higher noise levels will reduce the performance of the ALE and also the general performance of digital radios.

- *Electrical power Supply*
  Military HF radio stations are also supplied by public power lines. The power supply system is not provided with special filters to remove HF signals. Filtering out PLT signals on power lines would not be practical.

3.6.4 Use by each military service

The use of the HF radio service by the individual military services is as follows:

Land Forces

Land Forces need HF communications to ensure effective Consultation, Command and Control, both within NATO and with PfP Nations. In addition, HF Combat Net Radio communications are used at lower echelons as primary or secondary means where terrain, distance, or mobility requirements preclude reliance on Tactical Area Communications Systems.

Air Forces

HF radio is used in the Air environment as the primary beyond-line-of-sight (BLOS) communication means to aircraft, land and maritime mobile platforms. Information is exchanged via HF radio in voice, message, and data link formats.

HF communications are used between Air Command and Control ground elements and aircraft for exchanging mission control and surveillance/sensor data at extended ranges and when other communications are not available due to equipment failure or interference. HF is also used for Air Traffic Control (ATC) purposes when beyond the range of VHF facilities.

HF communications are used between Air Command and Control elements and ground elements mainly in a back-up mode when primary and higher capacity means are not available.

This includes:

- backup to NATO Communications Systems
- links to PfP and non-NATO elements;
- links to deployed / mobile entities;
- links to tactical formations.

Maritime Forces

The NATO maritime community, due to its mobility, uses HF for BLOS communication requirements. Consequently, NATO is modernising its Broadcast and Ship Shore systems. Air/Ground/Air HF communications within the maritime environment are supported by the NATO CIS infrastructure. Within the maritime community, HF is widely fitted throughout NATO and PfP[10] nations, and is common to virtually all warships. Where HF equipment is already fitted, only inexpensive enhancements such as a modem and a PC are generally required to achieve near error-free communications at user data rates significantly better than those used prior to the development of digital signalling techniques.

3.6.5 Protection Criteria and Protection Requirement

3.6.5.1 Protection Criteria

In order to ensure HF military communications, the interference protection criteria is based on the levels of thermal, man-made, galactic and atmospheric noise levels defined in Section 3.2.3 of this report.

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[10] PfP = Partner for Peace

0.5 dB Degradation of Sensitivity
In order to be generic, the criterion of acceptable interference is based on a maximal sensitivity degradation of **0.5** dB. It means that the total noise and interference (generated by PLT) should not be more than 0.5 dB higher than the total noise at the HF receiver without interference from PLT.

IN OTHER WORDS: (TOTAL I AND N) (DBM/HZ) < N (DBM/HZ) + 0.5

where:

I = Interference generated by PLT (dBm) in a bandwidth of 1 Hz
N = Total of Receiver Noise and Man-made Noise (dBm) in a bandwidth of 1 Hz

The above 0.5 dB sensitivity degradation criterion is selected based on the fact that military radio systems are operated close to their sensitivity level.

Basic parameters of HF radios required for the calculations

The required parameters of the victim HF radios are as follows:

a. Receiver noise figure: 10 dB
b. Antenna Gain Rx: 0 dBi[11]
c. Thermal Noise: -174 dBm per Hz.

With this approach further parameters of HF radios are ***not*** required.

3.6.5.2 Protection Requirement

Based on the above protection criteria, the protection requirement of military HF radio systems are as follows:

a. The increase of background noise and interference per Hz should not exceed 0.5 dB due to the unwanted emissions of Cable Transmission Networks (CTN) including unwanted emissions from PLT systems.
b. The reference noise level, depending on the area, can be either that for Quiet Rural, Rural, Residential or Business.
c. The minimal separation between cable and victim HF Rx is assumed to be 10 m.

3.7 Maritime

In this chapter, the different frequency bands allocated for maritime communications and maritime mobile service are reviewed.
Note : although only information concerning frequencies below 30 MHz is given in this section, the maritime service makes also an extensive use of frequencies above 30 MHz.

3.7.1 Background

Maritime radio communications are heavily based on the use of MF and HF frequency bands, of which the most important is distress and safety communications, primarily based on the unique propagation conditions of the MF/HF bands.

Maritime communications is a defined *service* under the ITU Radio Regulations. Communications can be between coast stations and ships, or between ships; survival craft stations and emergency radio beacons may also participate in this service. It includes also port operations service and ship movement service.

Safety service is defined under RR S.1.59:

> *S1.59 safety service: Any radiocommunication service used permanently or temporarily for the safeguarding of human life and property.*

Maritime community also uses *radionavigation* that is also a defined service and having exclusive allocations as defined in the RR.

Terms for use of maritime radio communications are agreed under the Constitution and Convention of the ITU, which is complemented by the decisions of the World Radio Conferences published as the Radio Regulations (RR). RR has also

[11] The antenna gain of HF systems is normally around 0 dBi. A positive antenna gain will reduce the relative influence of the thermal noise.

binding provisions for all administrations to take all necessary actions to protect these radio frequencies from harmful interference.

3.7.2 Frequencies allocated for maritime communications

3.7.2.1 Distress and safety communications

RR AP S13 defines frequencies to be used for non-GMDSS distress and safety communications. Although it was the intention that GMDSS system will globally replace the AP S13 by 1 February 1999, it has been noted that still certain administrations and vessels, not subject of SOLAS, 1974 agreement as amended may wish to continue to use provisions of AP S13 for distress and safety communications for some time after 1 February 1999.

Frequencies defined in AP S13 to be protected from any emission capable of causing harmful interference to distress, alarm, urgency or safety communications:

Section II – Protection of Distress and Safety Frequencies

A – General

*§ 13 Except as provided for in these Regulations, any emission capable of causing harmful interference to distress, alarm, urgency or safety communications on the frequencies 500 kHz, 2 174.5 kHz, 2 182 kHz, 2 187.5 kHz, 4 125 kHz, 4 177.5 kHz, 4 207.5 kHz, 6 215 kHz, 6 268 kHz, 6 312 kHz, 8 291 kHz, 8 376.5 kHz, 8 414.5 kHz, 12 290 kHz, 12 520 kHz, 12 577 kHz, 16 420 kHz, 16 695 kHz, 16 804.5 kHz, 121.5 MHz, 156.525 MHz, 156.8 MHz or in the frequency bands 406-406.1 MHz, 1 544-1 545 MHz and 1 645.5-1 646.5 MHz (see also Appendix **S15**) is prohibited. Any emission causing harmful interference to distress and safety communications on any of the other discrete frequencies identified in Part A2, Section I of this Appendix and in Appendix **S15** is prohibited.*

3.7.2.2 Global Maritime Distress and Safety System

Global Maritime Distress and Safety System (GMDSS) is fully defined in the International Convention for the Safety of Life at Sea (SOLAS). WRC-97 Res 331 states that all ships subject to IMO SOLAS convention shall be fitted for the GMDSS by 1 February 1999. The frequencies to be used for the GMDSS are contained in RR Ap S15. In addition to frequencies listed in Ap S15, coast stations should use other appropriate frequencies for the transmission of safety messages.

3.7.2.3 Table of distress and safety frequencies in maritime mobile service below 30 MHz

	Distress				**Safety**	
	CW	**DSC**	**RT**	**TLX**	**MSI**	**SAR**
	kHz	kHz	kHz	kHz	KHz	kHz
MF	**500.0**	**2187.5**	**2182.0**	**2174.5**	**490.0**	**3023.0**
					518.0	
HF		**4207.5**	**4125.0**	**4177.5**	**4209.5**	**5680.0**
					4210.0	
		6312.0	**6215.0**	**6268.0**	**6314.0**	
		8414.5	**8291.0**	**8376.5**	**8416.5**	
		12577.0	**12290.0**	**12520.0**	**12579.0**	
		16804.5	**16420.0**	**16695.0**	**16806.5**	
					19680.5	
					22376.0	
					26100.5	
			MSI on Navtex			
			MSI on telex			

Table 3.7.2.3: Table of distress and safety frequencies in maritime mobile service below 30 MHz

Legend:

AERO-SAR These aeronautical carrier (reference) frequencies may be used for distress and safety purposes by mobile stations engaged in coordinated search and rescue operations.
DSC These frequencies are used exclusively for distress and safety calls using digital selective calling in accordance with No. **S32.5** (see Nos. **S32.9**, **S33.11** and **S33.34**).
MSI In the maritime mobile service, these frequencies are used exclusively for the transmission of maritime safety information (MSI) (including meteorological and navigational warnings and urgent information) by coast stations to ships, by means of narrow-band direct-printing telegraphy.
MSI-HF In the maritime mobile service, these frequencies are used exclusively for the transmission of high seas MSI by coast stations to ships, by means of narrow-band direct-printing telegraphy.
NBDP-COM These frequencies are used exclusively for distress and safety communications (traffic) using narrow-band direct-printing telegraphy.
RTP-COM These carrier frequencies are used for distress and safety communications (traffic) by radiotelephony.

3.7.2.4 Frequencies allocated to maritime mobile service

Table of Frequency Allocations (RRS5) contains the following frequencies below 30 MHz allocated exclusively for maritime mobile service in Region 1. These frequencies should also be protected from harmful interference within the sense of RR S15.12.

14 - 19.95 kHz	2 170 - 2 498 kHz
20.05 - 70 kHz	2 502 - 3 025 kHz
72 - 84 kHz	4 000 - 4 438 kHz
86 - 90 kHz	6 200 - 6 525 kHz
110 - 112 kHz	8 100 - 8 815 kHz
117.6 - 126 kHz	12 230 - 13 200 kHz
129 - 148.5 kHz	16 360 - 17 410 kHz
283.5 - 315 kHz	18 780 - 18 900 kHz
415 - 526.5 kHz	19 680 - 19 800 kHz
1 606.5 - 1 625 kHz	22 000 - 22 855 kHz
1 635 - 1 800 kHz	25 070 - 25 210 kHz
2 000 - 2 025 kHz	26 100 - 26 175 kHz
2 045 - 2 160 kHz	

Table 3.7.2.4: frequencies allocated to maritime mobile service

3.7.3 Receiver parameters for the maritime mobile service in MF and HF bands

The ETSI standard 300 373 contains the following values.

Maximum usable sensitivity :
In 1605-4000 kHz : 5 dBµV
In 4000-27500 kHz : 0dBµV

Adjacent signal selectivity :
With a narrowband filter :
-500Hz +500Hz : 40dB

Without a narrow band filter :
-1kHz, +4kHz : 40dB
-2kHz, +5kHz : 50dB
-5kHz, +8kHz : 60dB

Automatic Gain Control time constants :
attack time = 5 to 10 msec
recovery time = 1 to 4 sec

Cross modulation :
+/- 20kHz : max level of unwanted signal = +90dBµV

Intermodulation :
+70 dBµV

Spurious response rejection :

70dB

3.8 Radioastronomy

The frequency bands allocated to and intensively used by European radio astronomy are indicated below. Europe is extensively involved in leading edge research in radio astronomy frequencies below 2 GHz. This frequency range is also of great interest for future radio astronomy because of the development of a new generation of radio telescopes such as the Low Frequency Array Network, LOFAR, which will be built at a not yet known location in Europe. LOFAR, a new technology instrument, is currently being designed by an international radio astronomy consortium. The technology is also being developed for use in the new radio telescope, the Square Kilometer Array (SKA) interferometer. The SKA will become operational in about 2015 and is designed to operate in the frequency range 30 MHz - 20 GHz.

The protection criteria for radio astronomy are given in ITU-R Recommendation RA769. The interference acceptable for radio astronomy should remain below the levels of detrimental interference given in that recommendation. The table below reproduces the protection criteria for the frequency range where cable signal can be found, i.e. in the frequency range 9 kHz – 2 GHz.

Frequency band (MHz)	ECA allocation status	Reference bandwidth for spurious emissions	Level of detrimental interference (continuum observations)	Level of detrimental interference (spectral line observations)
13.36 - 13.41	Primary shared (FN S5.149)	10 kHz	-48.2 dB(μV/m)	
25.55 - 25.67	Primary (passive exclusive) (FN S5.149)		-52.4 dB(μV/m)	
37.5 - 38.25	Secondary (FN S5.149)	100 kHz	-50.2 dB(μV/m)	-
73.0 - 74.6	Secondary (FN S5.149)		-36.2 dB(μV/m)	-
79.25 - 80.25	-		-36.2 dB(μV/m)	-
150.05 - 153	primary shared (FN S5.149)		-33.5 dB(μV/m)	-
322.0 -328.6	primary shared (FN S5.149)		-25.0 dB(μV/m)	-68.2 dB(μV/m)
406.1 - 410.0	primary shared (FN S5.149)		-27.3 dB(μV/m)	-
608.0 - 614.0	secondary (FN S5.149)		-21.4 dB(μV/m)	-
1330.0 - 1400.0	FN S5.149	1 MHz	-19.9 dB(μV/m)	-67.2 dB(μV/m)
1400.0 - 1427.0	Primary (passive exclusive) (FN S5.340)		-19.9 dB(μV/m)	-67.2 dB(μV/m)
1610.6 - 1613.8	Primary shared (FN S5.149)		-	-65.2 dB(μV/m)
1660.0 - 1670.0	Primary shared (FN S5.149)		-25.2 dB(μV/m)	-65.2 dB(μV/m)
1718.8 - 1722.2	FN S5.149		-	-65.2 dB(μV/m)

Table 3.8: radioastronomy protection requirements

Notes:

- Footnote S5.149 states for the bands 13.36 - 13.41 MHz, 25.55 - 25.67 MHz, 37.5 - 38.25 MHz, 73.0 - 74.6 MHz, 150.05 - 153 MHz, 322.0 -328.6 MHz, 406.1 - 410.0 MHz, 608.0 - 614.0 MHz, 1330.0 - 1400.0 MHz, 1610.6 - 1613.8 MHz, 1660.0 - 1670.0 MHz and 1718.8 - 1722.2 MHz, that “administrations are urged to take all practicable steps to protect the radio astronomy service from harmful interference. Emissions from spaceborne or airborne stations can be particularly serious sources of interference to the radio astronomy service
- Footnote S5.340 states in the band 1400-1427 MHz: “all emissions are prohibited”.

3.9 Short Range Devices

Note : although only information concerning frequencies below 30 MHz is given in this section, Short Range Devices makes also an extensive use of frequencies above 30 MHz.

3.9.1 General characteristics

EAS (Electronic Article Surveillance) and RFID (Radio Frequency IDentification) started to appear in Europe in the mid seventies. Now this is grown into a major market, wherein large companies and a large number of smaller companies, are involved. In the frequency band of concern, 9 kHz - 30 MHz, these systems make use of inductive coupling, using radio frequencies.

EAS system

An EAS system is a loop coil transponder with coverage of about 1 - 2 m. An identified item is equipped with a small transponder (a security tag). For the band 7.4 - 8.8 MHz, the transponder is usually a passive L/C circuit. Since the re-radiated field from a transponder can be very low due to a small physical size, the practical communications distance is limited up to 2 meters. In many countries smaller distances are not permitted due to fire regulations and there are legal requirements for minimum exit door width.

The concept of source tagging is providing the growth vehicle moving to the future. Presently, EAS is sold to commercial retailers who place security tags on their merchandise to reduce the likelihood that it will be stolen. The retailer pays employees to place these tags on their merchandise which costs them money. Source tagging is the process where the security tag is placed on the merchandise at the point of manufacture. This eliminates the cost of tagging to the retailer and the manufacturer allowing the work to be done more efficiently. It is estimated that some 1000,000 inductive EAS systems are installed in Europe now.

RFID systems

The development of RFID systems also started in the mid seventies with applications as access control and cattle management systems. Since the late 1980's, new RFID systems have been developed. The tags are intelligent transponders, often microprocessor controlled, with a significant amount of memory.

Multi labels protocols has been developed enabling the reading of large numbers of labels in one detection zone, read/write options given the possibility to carry many kbytes of data in a label An EAS function has been incorporated to use the same label for identification of goods, and protection against shoplifting.

Also, the number of components has been reduced. For example, for inductive tags, the total number of components are a semiconductor chip, a simple coil and in some applications a fixed capacitor. Consequently, tags covered by this document are extremely low cost and the resulting volume is much higher. The Integrated Circuit card (IC card) versions will eventually replace today's magnetic cards. Product labelling in present Bar Code applications will be addressed by this technology (see the relevant ISO standards).

The range of applications is very wide: personal identification, possible in combination with biometric verification methods, wherein the card is carrying the biometric data, animal tagging, item tagging, replacement of barcode tagging, simultaneous reading of items on pallets, containers, autodebiting in supermarkets, library management (including theft protection), etc.

There are also other applications as variants of RFID which are used for example for tracing people with dementia. Still other applications are implemented which are based on ITU regulations S5.116 and the authorisation of the band 3155-3400 kHz for wireless hearing aids.

There are several ERC reports (44, 69, 74, 95, 96) and ECC Reports (001, 007) dealing with inductive technologies and their designated frequency bands.

There are several ISO standards to cover these Inductive Technologies operating in the bands below 30 MHz, such as ISO 11784/5 ISO 14225, ISO/IEC 14443, ISO 15693, ISO 18000-2, ISO 18000-3 and IATA RPC 1740.

Like an EAS label the basic circuit of an RFID label is formed by an LC circuit. A coil, air coil or one on a ferrite rod, couples with the magnetic interrogator field. The voltage over the capacitor is rectified and used as supply power for the integrated circuit, connected over the capacitor. The IC contains a clock generator or a clock extractor from the interrogation carrier, a read-only or a read/write memory, a modulator to modulate the load of the IC on the resonance circuit, enabling data transfer from label to the interrogator. This technique called "load-modulation" generates extremely weak signals (much below spurious level) which have to be filtered and processed in the interrogator.

Frequency bands

The main frequency band for inductive EAS systems is 7.4 - 8.8 MHz. This band is part of ERC Rec. 70-03. The main frequencies for the HF inductive RFID systems are 6.78 and 13.56 MHz. For purposes of data transmission from the interrogator to the label a transmitter spectrum mask of +/- 150 kHz from the carrier is defined. Besides that, the return modulation frequencies set by subcarrier frequencies as described in the already mentioned ISO standards. The values

of these subcarrier frequencies are: 1692 kHz, 846 kHz, 488 kHz, 423 kHz, 212 kHz, 106 kHz and 70 kHz. This means that the receiving frequencies of an RFID interrogator unit may lie between 4.750 and 8.815 MHz and between 11.56 and 15.56 MHz. These return frequencies are covered in ECC Report 001.
The frequency bands 3.155 - 3.4 MHz (EAS/RFID/Inductive hearing aids), 9.1 - 9.9 MHz, and 10.2 - 11.0 MHz (EAS) are expected to be incorporated in ERC Rec. 70-03 soon. In individual countries other bands are also used for EAS like 1.65 - 1.95 MHz, 1.9 - 2.1 MHz. Apart from these HF bands frequencies in the LF band are also being used such as 32, 58, 125, 128, 132, 134.2 kHz, to name just a few of the inductive radio services which are adversely affected by the anticipated PLT and DSL operation, using somewhat different technologies.

Summary table
The following table gives the frequency ranges and main characteristics of Short Range Devices between 2 and 41 MHz.

	Frequency Bands										Power Levels	Equipment Antenna Source			Channel Spacing	Duty cycle	
	2275 Hz	9-135 kHz	457 kHz	4.515 MHz	6.765-6.795 MHz	7.40-8.80 MHz	13.553-13.567 MHz	26.957-27.283 MHz	27.095 MHz	29.7-40.7 MHz	Maximum Power Level	Integral	Dedicated	External	Permitted Channel	High, < 10%	Very High, up to 100%
Non-specific Short Range Devices					Y		Y	Y			Annex 1	Y	Y	No	All		
Annex 1								Y			10 mW	Y	Y	No	All	Y	
Avalanche Detection Equipment	Y										Annex 2	Y	No	No	-		Y
Annex 2			Y								Annex 2	Y	No	No	-		Y
Eurobalise									Y		Annex 4		Y	No	Annex 4		
Euroloop				Y							Annex 4		Y	No	Annex 4		
Model Control, Annex 8								Y			100 mW	-	Y	No	10 kHz		
Inductive Applications, Annex 9		Y			Y	Y	Y	Y			Annex 9	Y	Y	Y	All		
Narrow band audio										Y	10 mW	Y	Y		50 kHz		Y

Table 3.9.1: SRD characteristics

The transponder uplink frequencies of RFID systems are covered in EEC Report 001, which gives the next frequency bands:

LF: 135 – 148.5 kHz
HF: 4.78 – 8.78 MHz
11.56 – 15.56 MHz.

3.9.2 Compatibility studies between SRDs and other radio services

In two cases CEPT WG SE made extensive compatibility studies, namely for the EAS band 7.4 - 8.8 MHz, and for the RFID band around the ISM frequency 13.56 MHz. In both studies a radiation limit was settled based on system calculations. The starting point of those calculations was the environmental noise levels as known through many years of experience of the companies involved. A slope of 3 dB/octave was found in the frequency dependency of the noise levels. This slope is used here to calculate the noise level for the other frequency bands, the outcome of which is very well in line with our practical experiences.

EAS systems
In the compatibility study on 7.4 - 8.8 MHz EAS systems as completed in SE24 the starting point for calculating a necessary radiation limit, was an indoors generic interference level of -13 dBμA/m. This is recalculated into **38 dBμV/m** in a 9 kHz CISPR QP measurement bandwidth. Upon this assumption the limit mentioned in ERC REC. 70-03, 9 dBμA/m@10m is based, and is mandatory for all HF based EAS equipment in Europe.

RFID systems
In the compatibility study on 13.56 MHz RFID systems as completed in SE24 the starting point for calculating a necessary radiation limit, was an indoors generic interference level of -16 dBμA/m. This is recalculated into **35 dBμV/m** in a 9 kHz CISPR QP measurement bandwidth. Upon this assumption the limit mentioned in ERC REc. 70-

03, 42 dBµA/m@10m is based, and is mandatory for all RFID equipment in Europe in the 6.78 and 13.56 MHz ISM band.

3.9.3 Protection requirements

Information concerning protection requirements of SRDs is given in section 9.2.

4 LIMITS IN EXISTING STANDARDS AND REGULATIONS

This section provides some examples of existing limits in EMC standards or National regulations.

4.1 CISPR 22 and EN 55022 conducted limits from 150 kHz to 30 MHz

CISPR 22 is an International standard produced by CISPR (International Special Committee on Radio Interference), EN 55022 is its European counterpart and is a harmonised standard under the EMC Directive. Both standard deal with "Information Technology Equipment (ITE) - Radio disturbance characteristics - Limits and methods of measurement".

Extracts from CISPR 22 and EN 55022 :

QUOTE:
Limits for conducted disturbance at mains terminals and telecommunication ports
The equipment under test (EUT) shall meet the limits in tables 1 and 3 or 2 and 4, as applicable, including the average limit and the quasi-peak limit when using, respectively, an average detector receiver and quasi-peak detector receiver and measured in accordance with the methods described in clause 9. Either the voltage limits or the current limits in table 3 or 4, as applicable, shall be met except for the measurement method of C.1.3 where both limits shall be met. If the average limit is met when using a quasi-peak detector receiver, the EUT shall be deemed to meet both limits and measurement with the average detector receiver is unnecessary.
If the reading of the measuring receiver shows fluctuations close to the limit, the reading shall be observed for at least 15 s at each measurement frequency; the higher reading shall be recorded with the exception of any brief isolated high reading which shall be ignored.

Limits of mains terminal disturbance voltage

Frequency range	***Limits*** *dB(μV)*	
MHz	***Quasi-peak***	***Average***
0.15 to 0.50	*79*	*66*
0.50 to 30	*73*	*60*
NOTE – The lower limit shall apply at the transition frequency.		

Table 1: limits for conducted disturbance at the mains ports of class A ITE

Frequency range	***Limits*** *dB(μV)*	
MHz	***Quasi-peak***	***Average***
0.15 to 0.50	*66 to 56*	*56 to 46*
0.50 to 5	*56*	*46*
5 to 30	*60*	*50*
NOTE 1 – The lower limit shall apply at the transition frequencies. *NOTE 2 – The limit decreases linearly with the logarithm of the frequency in the range 0.15 MHz to 0.50 MHz.*		

Table 2: limits for conducted disturbance at the mains ports of class B ITE

Limits of conducted common mode (asymmetric mode) disturbance at telecommunication ports

Frequency range	*Voltage limits* dB (µV)		*Current limits* dB (µA)	
MHz	***Quasi-peak***	***Average***	***Quasi-peak***	***Average***
0.15 to 0.5	*97 to 87*	*84 to 74*	*53 to 43*	*40 to 30*
0.5 to 30	*87*	*74*	*43*	*30*

NOTE 1 – The limits decrease linearly with the logarithm of the frequency in the range 0.15 MHz to 0.5 MHz.

NOTE 2 – The current and voltage disturbance limits are derived for use with an impedance stabilization network (ISN) which presents a common mode (asymmetric mode) impedance of 150 Ω to the telecommunication port under test (conversion factor is 20 $\log_{10}$ 150 / I = 44 dB).

Table 3: limits of conducted common mode (asymmetric mode) disturbance at telecommunication ports in the frequency range 0.15 MHz to 30 MHz for class A equipment

Frequency range	*Voltage limits* dB (µV)		*Current limits* dB (µA)	
MHz	***Quasi-peak***	***Average***	***Quasi-peak***	***Average***
0.15 to 0.5	*84 to 74*	*74 to 64*	*40 to 30*	*30 to 20*
0.5 to 30	*74*	*64*	*30*	*20*

NOTE 1 – The limits decrease linearly with the logarithm of the frequenc y in the range 0.15 MHz to 0.5 MHz.

NOTE 2 – The current and voltage disturbance limits are derived for use with an impedance stabilization network (ISN) which presents a common mode (asymmetric mode) impedance of 150 Ω to the telecommunication port under test (conversion factor is 20 $\log_{10}$ 150 / I = 44 dB).

NOTE 3 – Provisionally, a relaxation of 10 dB over the frequency range of 6 MHz to 30 MHz is allowed for high-speed services having significant spectral density in this band. However, this relaxation is restricted to the common mode disturbance converted by the cable from the wanted signal.

Table 4: limits of conducted common mode (asymmetric mode) disturbance at telecommunication ports in the frequency range 0.15 MHz to 30 MHz for class B equipment

END QUOTE

4.2 Radiated limits below 30 MHz in EMC standards

For the applicability of the existing EMC standards below 30 MHz for deriving radiation limits of cable transmission networks it is necessary to compare the interfering effects on the operation of radio services. This means on one hand the electromagnetic disturbances generated by apparatus for which the relevant existing EMC standards are valid, and on the other hand the electromagnetic disturbances generated by cable transmission systems.

Relevant aspects for both types of disturbances are: the unintended or intended generating of the signal causing the disturbance, the statistical or continuous appearance, and the narrow band or broadband demand on the radio spectrum. A further distinction is that existing EMC standards apply to equipment that is usually physically small compared with a wavelength, as are its connecting leads. Its ability to radiate is thus limited compared with data carrying cable structures having significant length. These differences have a considerable influence on the net effect on the operation of radio services. This justifies a differentiation in the interference levels.

In case this differentiation in limit levels is not feasible, and a lower level of interference is necessary to let all radio services operate as intended, an adaptation of the relevant existing EMC standards should be considered.

4.2.1 CISPR 11 (Ed 3) & EN 55011

CISPR 11 is an International standard produced by CISPR (International Special Committee on Radio Interference), EN 55011 is its European counterpart and is a harmonised standard under the EMC Directive. Both standards deal with "Radio disturbance characteristics of Industrial, Scientific and Medical (ISM) equipment".

Extracts from CISPR 11 and EN 55011 :

QUOTE:
§ 5.2 Limits of electromagnetic radiation disturbance
Measuring apparatus and methods of measurement are specified in clauses 6, 7 and 8. The equipment under test shall meet the limits when using a measuring instrument with a quasi-peak detector.
Below 30 MHz the limits refer to the magnetic component of the electromagnetic radiation disturbance. (...)

§5.2.1 Frequency band 9 kHz to 150 kHz
Limits for electromagnetic radiation disturbance in the frequency range 9 kHz to 150 kHz are under consideration except for induction cooking appliances.

§ 5.2.2 Frequency band 150 kHz to 1 GHz
Except for the designated frequency range listed in table 1, the electromagnetic radiation disturbance limits for the frequency band 150 kHz to 1 GHz for group 1, class A and B equipments are specified in table 3; for group 2 class B equipment in table 4; and for group 2 class A equipment in table 5. For induction cooking appliance falling within group 2 class, the limits are specified in tables 3a and 3b. Special provisions for the protection of specific safety services are given in 5.3 and table 6

Editorial note:
In Table 3 of CISPR II and EN55011 (not reproduced here), limits below 30 MHz are under consideration.

Frequency range MHz	*Limits in dB(μA) Quasi-peak*	
	Horizontal component	*Vertical component*
0.009 to 0.070	*88*	*106*
0.070 to 0.1485	*88 Decreasing linearly with logarithm of frequency to 58*	*106 Decreasing linearly with logarithm of frequency to 76*
0.1485 to 30	*58 Decreasing linearly with logarithm of frequency to 22*	*76 Decreasing linearly with logarithm of frequency to 40*
Note - The limits of table 33 apply to induction cooking appliance for domestic use which have a diagonal dimension of less than 1.6 m. Measurement is performed with the 'Van Veen loop method' as described in 7.5 of CISPR 16-2		

Table 3a: limits of the magnetic field induced current in a 2 m loop antenna around the device under test

Frequency range MHz	*Limits in dB(μA) at 3 m distance Quasi-peak*
0,009 to 0,070	*69*
0,070 to 0,1485	*69 Decreasing linearly with logarithm of frequency to 39*
0,1485 to 4,0	*39 Decreasing linearly with logarithm of frequency to 3*
4,0 to 30	*3*
Note - The limits of table 3a apply to induction cooking appliance for domestic use which have a diagonal dimension of less than 1.6 m. Measurements are performed at 3 m distance with a 0,6 m loop antenna as described in 15.2.1 in CISPR 16-1. The antenna shall be vertically installed, with the lower edge of the loop at 1 m height above the floor.	

Table 3b: limits of the magnetic field strength

Frequency band *MHz*	*Quasi-peak electric field measurement distance 10 m dB(μV/m)*	*Quasi-peak magnetic field measurement distance of 3 m dB(μA/m)*
0.15 to 30	*-*	*39* *Decreasing linearly with logarithm of frequency to 3*

Table 4: electromagnetic radiation disturbance limits for group 2, class B equipment measured on a test site

Frequency range *MHz*	*Limits with measuring distance 30 m*	
	Distance D from exterior wall of the building *dB(μV/m)*	*On a test site D = 30 m from the equipment* *dB(μV/m)*
0.15 – 0.49	*75*	*85*
0.49 – 1.705	*65*	*75*
1.705 – 2.194	*70*	*80*
2.194 – 3.95	*65*	*75*
3.95 - 20	*50*	*60*
20 - 30	*40*	*50*

Table 5: electromagnetic radiation disturbance limits for group 2 class A equipment

For equipment measured in situ, the measuring distance D from the exterior wall of the building in which the equipment is situated equals (30 + x/a) m or 100 m which ever is smaller, providing that the measuring distance D is within the boundary of the premises. In the case where the calculated distance D is beyond the boundary of the premises, the measuring distance D equals w or 30 m, which ever is the longer.
For the calculation of the above values:

- *x* *is the nearest distance between the outside wall of the building in which the equipment is situated and the boundary of the user's premises in each measuring direction;*
- *a* *= 2,5 for frequency lower than 1 MHz*
- *a* *= 4,5 for frequency equal to or higher than 1 MHz*

For the protection of specific aeronautical services in particular areas, national authorities may require that specific limits be met at 30m distance.

§5.3 Provisions for protection of safety services
ISM systems should be designed to avoid fundamental operations or radiation of high-level spurious and harmonic signals in bands used for safety-related radio services. A list of these bands is provided in annex E. For the protection of specific services, in particular areas, national authorities may require measurements to be made in situ and require the limits specified in table 6 to be met in the frequency band listed.

Frequency band *MHz*	*Limit* *dB(μV/m)*	*Measuring distance from exterior wall outside the building in which the equipment is situated* *m*
0.15 – 0.49	*65*	*30*

Table 6: limits for electromagnetic radiation disturbances to protect specific safety services in particular areas

§5.4 Provisions for protection of specific sensitive radio services
For the protection of specific sensitive services, in particular areas, national authorities may request additional suppression measures or designated separation zones for cases where harmful interference may occur. It is, therefore recommended to avoid fundamental operations or the radiation of high level harmonic signals in the bands. Some examples of these bands are listed for information in annex F.

§6.2.4 Antennas
In the frequency range below 30 MHz the antenna shall be a loop as specified in CISPR 16. The antenna shall be supported in the vertical plane and be rotatable about a vertical axis. The lowest point of the loop shall be 1 m above ground level.

§Annex E (informative) : safety related service bands

Frequency (MHz)	*Allocation/use*
0.010 – 0.014	*Radionavigation (Omega on board ships and aircraft only)*
0.090 – 0.11	*Radionavigation (LORAN-C and DECCA)*
0.2835 – 0.5265	*Aeronautical radionavigation (non-directional beacons)*
0.489 – 0.519	*Maritime safety information (coastal areas and shipboard only)*
1.82 – 1.88	*Radionavigation (LORAN-A region 3 only, coastal areas and on board ships only)*
2.1735 – 2.1905	*Mobile distress frequency*
2.09055 – 2.09105	*Emergency position indicating radio beacon (EPIRB)*
3.0215 – 3.0275	*Aeronautic mobile (search and rescue operations)*
4.122 – 4.2105	*Mobile distress frequency*
5.6785 – 5.6845	*Aeronautic mobile (search and rescue operations)*
6.212 – 6.314	*Mobile distress frequency*
8.288 – 8.417	*Mobile distress frequency*
12.287 – 12.5795	*Mobile distress frequency*
16.417 – 16.807	*Mobile distress frequency*
19.68 – 19.681	*Maritime safety information (coastal areas and shipboard only)*
22.3755 – 22.3765	*Maritime safety information (coastal areas and shipboard only)*
26.1 – 26.101	*Maritime safety information (coastal areas and shipboard only)*

§Annex F (informative) : sensitive service bands

Frequency (MHz)	*Allocation/use*
13.36 – 13.41	*Radio astronomy*
25.5 – 25.67	*Radio astronomy*
29.3 – 29.55	*Satellite downlink*

END QUOTE

4.2.2 CISPR 15 (1996) & EN 55015

CISPR 15 is an International standard produced by CISPR (International Special Committee on Radio Interference), EN 55015 is its European counterpart and is a harmonised standard under the EMC Directive. Both standards deal with "Lighting Equipment - Radio disturbance characteristics - Limits and methods of measurement".

Extracts from CISPR 15 and EN 55015:

QUOTE:
§ 4.4 Radiated electromagnetic disturbances:
The quasi-peak limits of the magnetic component of the radiated disturbance field strength in the frequency range 9 kHz to 30 MHz measured as a current in 2m, 3m, 4m loop antennas around the lighting equipment, are given in table 3. (...)

Frequency range	*Limits for loop diameter dB(μA)**		
	2 m	*3 m*	*4 m*
9 kHz to 70 kHz	*88*	*81*	*75*
70 kHz to 150 kHz	*88 to 58***	*81 to 51***	*75 to 45***
150 kHz to 2.2 MHz	*58 to 26***	*51 to 22***	*45 to 16***
2.2 MHz to 3.0 MHz	*58*	*51*	*45*
3.0 MHz to 30 MHz	*22*	*15 to 16 ****	*9 to 12****

**At the transition frequency, the lower limit applies*
***Decreasing linearly with the logarithm of the frequency*
****Increasing linearly with the logarithm of the frequency*

Table 3: radiated electromagnetic disturbance limits

§4.5 limits at designated frequencies

Certain frequencies are designated by the ITU for use as fundamental frequencies for ISM equipment. These frequencies and related field strength limits are listed in table 4.

Limits at the terminal disturbance voltages within the frequency bands 6.765 to 6.795, 13.553 to 13.567 and 26.957 to 27.283 MHz are under consideration.

Note: in individual countries, different or additional frequencies may be designated for the use of ISM.

Central frequency MHz	*Frequency band MHz*	*Limit of disturbance field strength dB(μV/m) measured at 10m distance*	*N° of appropriate footnote to the table of frequency allocation of the ITU regulation*
6,780	*6.765 to 6.795*	*100 (magnetic component)*	*524**
13.560	*13.553 to 13.567*	*100 (magnetic component)*	*534*
27.120	*26.957 to 27.283*	*100 (magnetic component)*	*546*
** Use of these frequency bands shall be subject to special authorization by administration concerned in agreement with other administrations whose radio communication services might be affected*			

Table 4: limits of disturbance field at frequencies designated for use by ISM equipment

§9 Method of measurement of radiated electromagnetic disturbances

§9.1 Measuring arrangement and procedure

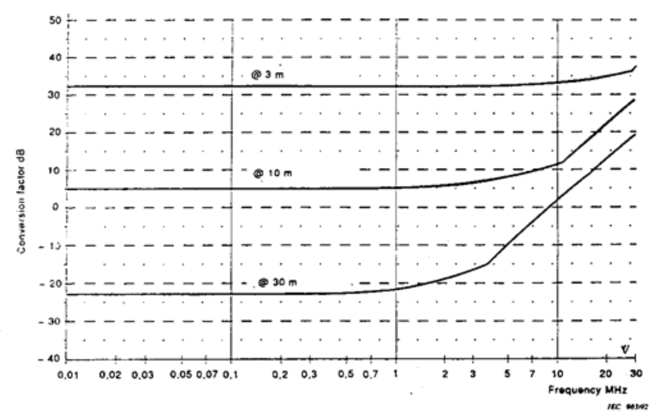
§Measuring equipment: the magnetic component shall be measured by means of a loop antenna as described in annex B. The lighting equipment shall be placed in the center of the antenna shown in figure B.1. The position is not critical.

§Annex C

Figure C2 give the correlation between the current in the 2 m loop antenna and the magnetic field at the indicated distances

current (dBμA) + conversion factor (dB) = magnetic field (dBμV/m)

distance measured from the centers of DUT and the antenna



[current (dBμA) + conversion factor (dB) = magnetic field (dBμV/M)]
(distance is measured from the centres of DUT and the antenna)

Figure C.2 – Correlation between the current in the 2 m loop antenna and the magnetic field at the indicated distances

<u>END QUOTE</u>

4.2.3 EN 50121-3-1

EN 50121-3-1 is a CENELEC standard entitled “railway applications – electromagnetic compatibility – Part 3-1: rolling stock – train and complete vehicle”.

Limits in this standard apply to intercity and suburban trains as well as to urban vehicles such as trams, trolleybuses… This standard specifies two tests against two limits: one for a stationary test and one for a slow moving test.

It should be noted that this standard was not developed on the basis of protection of any radio service and it should not therefore be used as any kind of precedent in developing standards. This is made clear in a report (AY 4110[12]) commissioned by the UK Radiocommunications Agency and produced by York EMC Services Ltd. Its Executive Summary contains the following text:
"Standards are available such as the CENELEC EN 50121:2000 series, which place limits on the emissions that should be seen at a railway boundary. The basis for these limits has been the actual levels measured at a number of railway locations around Europe, plus a margin to allow for measurement uncertainty, statistical variation of sites etc. This approach does not consider the wider impact on the radio spectrum but 'benchmarks' what is currently attainable. There is concern amongst CISPR and the radio community that the emission levels and measurement techniques set out in EN50121 do not provide adequate protection to radio services."

Extracts from EN 50121-3-1:

<u>QUOTE:</u>
EN 50121-3-1 limits for the stationary test

Frequency	*Measurement bandwidth*	*EN 50121-3-1 limit in dBμA/m at 10m*	*Equivalent limit in dBμA/m at 3m*
9 kHz to 150 kHz	*200 Hz*	*40 dBμA/m decreasing to 15 dBμA/m*	*50 dBμA/m decreasing to 25 dBμA/m*
150 kHz to 30 MHz	*10 kHz*	*45 dBμA/m decreasing to –5 dBμA/m*	*55 dBμA/m decreasing to 5 dBμA/m*

Note : EN 50121-3 defines three categories of limits depending on the power on the train. Values given above correspond to the lowest limit (C applicable to 750V d.c. conductors and to urban vehicles), limit B is 10 dB higher than C and limit A is 15 dB higher than C.

EN 50121-3-1 limits for the slow moving test

Frequency	*Measurement bandwidth*	*EN 50121-3-1 limit in dBμA/m at 10m*	*Equivalent limit in dBμA/m at 3m*
9 kHz to 150 kHz	*200 Hz*	*50 dBμA/m decreasing to 25 dBμA/m*	*60 dBμA/m decreasing to 35 dBμA/m*
150 kHz to 30 MHz	*10 kHz*	*60 dBμA/m decreasing to 10 dBμA/m*	*70 dBμA/m decreasing to 20 dBμA/m*

Note : EN 50121-3 defines three categories of limits depending on the power on the train. Values given above correspond to the lowest limit (C applicable to 750V d.c. conductors and to urban vehicles), limit B is 10 dB higher than C and limit A is 15 dB higher than C.

<u>END QUOTE</u>

[12] Available at <http://www.radio.gov.uk/topics/research/topics/emc/potential-interference.pdf>

4.2.4 Comparison between radiated limits below 30 MHz in EMC standards and the examples n°1 (NB30) and n°3 (MPT 1570) limits

This figure gives the relative values of the two sets of limits, but they are not directly comparable for the reasons explained in the beginning of section 4.2.

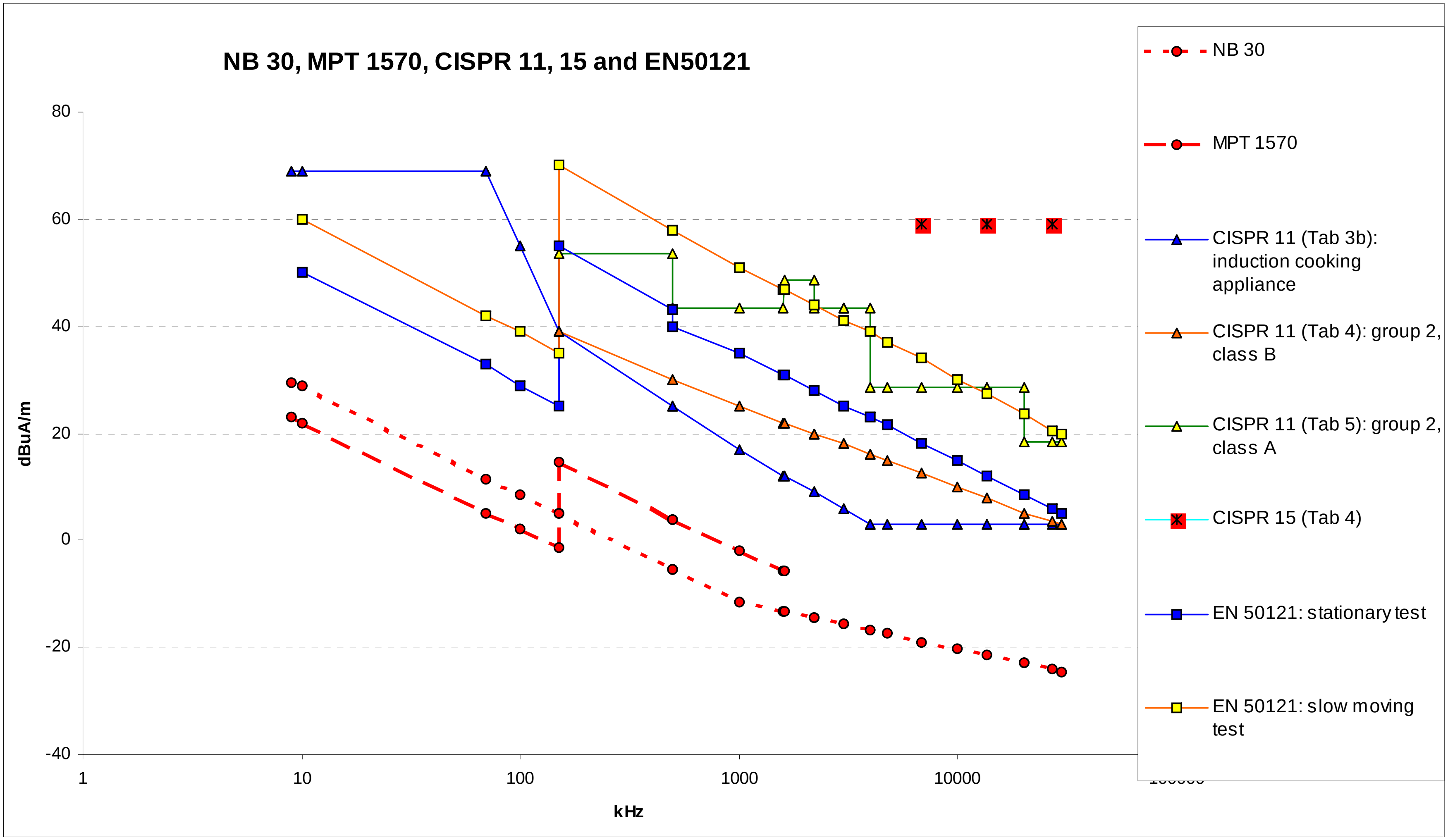


Figure 4.2.4: radiated limits comparison

4.3 CENELEC Cable TV standards

The EN 50083 series of standards address cable communications networks transporting television signals, sound signals and interactive services. Standards have been adopted for equipment, systems and installations, which cover:

- Head-end-reception, the processing and distribution of sound and television signals and their associated data signals and
- Processing, interfacing and transmitting all manner of signals for interactive services utilising all applicable transmission media.

All cable communications networks are covered, for example:

- CATV networks,
- MATV and SMATV networks and
- Individual receiving networks.

In addition all equipment, systems and installations, which form part of such networks are included within the scope of the standards.

The extent of this standardisation work ranges from the receiving antennas, signal source inputs at the head-end, or other interface points in the network, through to the system outlet or the terminal input, where no system outlet exists.

The standardisation of any user terminals (e.g. tuners, receives, decoders, multimedia terminals etc.) as well as the coaxial and optical cables employed in networks together with associated accessories are excluded.

Only Part 2 of EN50083 is classified as a Harmonised Standard in the context of the EMC Directive 89/336/EEC. In a revision of Part 2 dated November 2001, the limits contained in Part 8 and detailed in Section 6.2.1 below have been introduced as radiation limits for active equipment for which the standard is applicable. In practice this would appear to apply mainly to amplifiers incorporated within a CATV network. The latest date for implementation as a national standard is 1 June 2002. All conflicting national standards should be withdrawn by 1 April 2004.

Part 7 of EN50083 (see section 2.3 of this report) is also of relevance and deals with system performance. Part 8 entitled Electromagnetic compatibility for installations is not a harmonised standard in the context of the EMC Directive 89/336/EEC and covers radiation from CATV networks. The United Kingdom in Annex A of Part 8 has stated that it will deviate from this norm. Part 8 defines a maximum radiation level of 20 dBpW in the frequency range between 30 MHz and 1 GHz, increasing linearly with the logarithmic value of the frequency to 27 dBpW at 5MHz and 43 dBpW between 1 and 2.5 GHz.

Part 8 of EN50083 provides the radiated limits for CATV installations. In case of broadband interference (no single carrier interference) the radiation level is measured with a receiver having a quasi-peak detector and measuring bandwidths as stated in table 4.3 (according to CISPR 16-1). For single carrier measurements also other receivers can be used.

Frequency range	*Limits (Quasi-peak) 1)*		*Measuring Bandwidth*
MHz	*Field strength at 3 m distance dB(µV/m)*	*Equivalent 2) disturbance power dB(pW)*	*kHz*
5 to 30	*34 to 27 3)*	*27 to 20 3)*	*9*
30 to 950	*27*	*20*	*120*
950 to 2500	*50*	*43*	*1000*
2500 to 3000	*64*	*57*	*1000*

1) At frequencies above 1 GHz the peak detector is used.
2) Equivalent power radiated in free space from an elementary loop (f<30MHz) or dipole (f>30 MHz)
3) Decreasing linearly with the logarithmic of the frequency

Table 4.3: radiation limits

NOTE 1: If the radiated field strength is assumed to be the result of a point source of radiation at a distance of 3 m, the two methods are equivalent.

4.4 National limits

Currently, regulations regarding emission from cable transmission networks have been adopted in Germany and are nearly finalised in the United Kingdom, as detailed below.

4.4.1 Germany

Publication of the Frequency Band Allocation Ordinance (FreqBZPV), including Usage Provision 30, following approval by the Federal Government of the Federal Republic of Germany
Usage Provision 30 forms part of the Frequency Band Allocation Ordinance ("FreqBZPV"). The Ordinance is in line with the Table of Frequency Allocations in Article S5 of the Radio Regulations. Part A of the Annex to the Ordinance sets out all the frequency allocations, while Part B contains the usage provisions applicable to the allocations. The German Bundesrat (upper house of parliament) on 30 March 2001 gave its consent to the Ordinance as approved by the German Federal Government. The Ordinance has entered into force on 9 May 2001.

4.4.1.1 Extracts from Usage Provision 30 (NB 30)

OUOTE:

(1) Frequencies for telecommunications systems and telecommunications networks in the frequency band from 9 kHz to 3 GHz may be used freely in and along conductors

1. where the frequency usage is in a frequency band in which no safety-related radiocommunication services are operated, and

2. where, at the location of operation and along the conductor route, the interfering field strength (peak value) of the frequency usage does not exceed the values in Table 1 at a distance of three metres from the telecommunications system or network or from the connected conductors; the interfering field strength shall be measured on the basis of applicable EMC standards in accordance with Measurement Specification Reg TP 322 MV 05 "Measurement of Interfering Fields at Telecommunication Systems and Conductors in the Frequency Band from 9 kHz to 3 GHz".

(2) The frequency usage as provided for by para (1) may claim no protection from interference caused by emissions from radio transmitting equipment.

(3) The limiting conditions as set out in para (1) shall apply to frequencies up to 30 MHz as from 1 July 2001 and to frequencies above 30 MHz as from 1 July 2003.

(4) In the case of frequency usages in and along conductors for which no free use is provided for by para (1), the geographical, temporal and technical conditions may be laid down for each individual case in either the frequency usage plan or the required frequency assignment by the Regulatory Authority for Telecommunications and Posts, on the basis of proportionality and after hearing the parties concerned. Where safety-related radiocommunication services are concerned, account is to be taken in particular of the extent to which a specific threat to safety is to be feared.

Limits of the interfering field strength of telecommunications systems and networks

Frequency f [MHz] in the band	Limit of the interfering field strength (peak value) at a distance of 3 metres [dB(µV/m)]
0.009 to 1	$40 - 20 \cdot \log_{10}(f/MHz)$
Above 1 to 30	$40 - 8.8 \cdot \log_{10}(f/MHz)$
Above 30 to 1000	27 (1)
Above 1000 to 3000	40 (2)

(1) This corresponds to an effective radiated power of 20 dBpW.
(2) This corresponds to an effective radiated power of 33 dBpW.

4.4.1.2 Safety related frequencies and frequency bands associated with NB30 below 30 MHz

Extracts from Communication 363/2001 of RegTP Official Gazette 12/2001 (June 2001) :

“In accordance with section 3 of Usage Provision 30 the conditions limiting the free use of frequencies in and along conductors become effective on 1 July 2001 for frequencies up to 30 MHz. The interfering field strength limits are given in the Ordinance, but not the safety-related frequency bands. A list of the safety-related frequencies and frequency bands within the meaning of Usage Provision 30 for frequencies up to 30 MHz is therefore given below:

90	–	110 kHz	Radionavigation
255	–	495 kHz	Radionavigation
505	–	526.5 kHz	Radionavigation
2173.5	–	2190.5 kHz	Global Maritime Distress and Safety System (GMDSS)
2625	–	2650 kHz	Military radio application
2850	–	3155 kHz	Aeronautical radio
3400	–	3500 kHz	Aeronautical radio
3800	–	3950 kHz	Military radio application, aeronautical radio
4202.5	–	4212.5 kHz	GMDSS
4650	–	4850 kHz	Aeronautical radio
5450	–	5730 kHz	Aeronautical radio
6307	–	6317 kHz	GMDSS
6525	–	6765 kHz	Aeronautical radio
8409.5	–	8419.5 kHz	GMDSS
8815	–	9040 kHz	Aeronautical radio
10005	–	10100 kHz	Aeronautical radio
11175	–	11400 kHz	Aeronautical radio
12572	–	12582 kHz	GMDSS
13200	–	13360 kHz	Aeronautical radio
15010	–	15100 kHz	Aeronautical radio
16799.5	–	16809.5 kHz	GMDSS
17900	–	18030 kHz	Aeronautical radio
21924	–	22000 kHz	Aeronautical radio
23200	–	23350 kHz	Aeronautical radio

Additionally there are 137 single frequencies between 1.6 and 27.5 MHz within the field of competence of the Federal Ministry of the Interior, with a total bandwidth of 475 kHz.

It is planned for a transitional period of several years to grant a general assignment for some of these frequencies for use in and along conductors, in line with section 4 of Usage Provision 30, provided the interfering field strength limits as set out in Table 1 of Usage Provision 30 are observed. During this period, the conditions under which these frequencies can be used in and along conductors on a permanent basis will be examined. As soon as the Federal Government has clarified which of the above frequencies and frequency bands can be given a general assignment, this information will be published by RegTP in its Official Gazette.”

4.4.2 United Kingdom (MPT1570, August 2001)

In November 2000, following a period of consultation with interested parties, the UK government announced the national limits that will be introduced for emissions in the range 9kHz to 1.6MHz. The necessary national Regulations will be made under Section 10 of the UK Wireless Telegraphy Act 1949 and will enable action to be taken when undue interference from telecommunication systems occurs to authorised radio services. The regulatory limits for emissions from cables and/or wires, and an associated measurement method, are defined in the national specification MPT1570 (3rd August 2001) titled "*Electromagnetic radiation in the range 9kHz to 1.6MHz from material substances forming part of a telecommunication system*".

The draft Regulations, including the associated MPT1570 (3rd August 2001) were submitted to the European Commission in accordance with the provisions of Directive 98/34EC on 24th August 2001 and, simultaneously, published on the UK Radiocommunication Agency's website (www.radio.gov.uk). After the draft Regulations have been cleared through the EU procedure, they will be placed before the UK Parliament. The limits described in MPT1570 (3rd August 2001) are those defined within an earlier draft MPT1570 (February 2000) between 9 kHz and 1.6 MHz, and which formed the basis of the UK government's announcement in November. Earlier drafts of the MPT1570 specification are not included within the scope of the current draft Regulations.

4.4.2.1 MPT 1570 (August 2001) limits

Frequency band f (kHz)	Measuring bandwidth (peak detector)	Limit of interfering field strength at a distance not less than 1metre from the material substance (dBµA/m)
9 to 150	200 Hz	42 - 20log (f (kHz))
150 to 1600	9kHz	-1.5 -20log (f (MHz))

Table 4.4.2.1 MPT 1570 limits

4.4.2.2 Text of the proposed new UK regulation

The Wireless Telegraphy (Control of Interference from Material Substances forming part of Telecommunication Systems) Regulations 2001

Made *2001*

Laid before Parliament *2001*

Coming into force *2001*

The Secretary of State, in exercise of the powers conferred by section 10(1)(a) of the Wireless Telegraphy Act 1949[13], and now vested in him[14], hereby makes the following Regulations:

Citation, commencement and purpose

1.-(1) These Regulations may be cited as the Wireless Telegraphy (Control of Interference from Material Substances forming part of Telecommunication Systems) Regulations 2001 and shall come into force on [ ] 2001.

(2) These Regulations are made for the purpose specified in the said section 10(1)(a) (that is to say, for prescribing the requirements to be complied with in the case of any apparatus to which the said section 10 applies if the apparatus is to be used).

Interpretation

2.-(1) In these Regulations -

"the 1984 Act" means the Telecommunications Act 1984[15];

"material substance" means a metallic medium which does not form part of any other equipment and along which any of the matters referred to in section 4(1)(a) to (d) of the 1984 Act are conveyed by means of electromagnetic energy in the frequency range of 9 kHz to 1.6 MHz;

"MPT 1570" means Department of Trade and Industry Performance Specification 1570 published on 3 August 2001; and

"relevant system" means a telecommunication system of a type specified in the Schedule hereto.

[13] 1949 c.54; section 10 was extended to the Channel Islands by S.I. 1952/1900 (to which there are amendments not relevant to these Regulations), and to the Isle of Man by S.I. 1952/1899 (to which there are also amendments not relevant to these Regulations); section 10 was amended by sections 89 and 109(6) of, and Part IV of Schedule 7 to, the Telecommunications Act 1984 (c.12).
[14] Post Office Act 1969 (c.48), section 3; S.I. 1969/1369, article 3; S.I. 1969/1371, article 2; and S.I. 1974/691, article 2.
[15] 1984 c.12

(2) In these Regulations, "convey" and "telecommunication system" shall be construed in accordance with section 4 of the 1984 Act, and "public telecommunication system" shall be construed in accordance with section 9 of the 1984 Act.

Compliance with limits for emissions of electromagnetic energy

3.-(1) The requirements specified in MPT 1570 shall, except as provided in paragraph (2), be complied with in the case of a material substance forming part of a relevant system (other than by forming part of any other equipment which forms part of the system) where the system has first been put into service on or after the date on which these Regulations come into force.

(2) Paragraph (1) shall not apply in any case in which the material substance is relevant apparatus within the meaning of regulation 6(1) of the Electromagnetic Compatibility Regulations 1992[16] or apparatus to which the Radio Equipment and Telecommunications Terminal Equipment Regulations 2000[17] apply.

Minister of State for E-Commerce and Competitiveness,
Department of Trade and Industry

SCHEDULE

1. Digital Subscriber Line (DSL) - being a telecommunication system in which the material substance forming part of it (other than by forming part of any other equipment) is used, irrespective of any other function, for the purpose of providing a digital connection between an end user and a public telecommunication system.

2. Power Line Technology system (PLT) - being an electricity distribution system in which the material substance forming part of it (other than by forming part of any other equipment) is used, irrespective of any other function, for the purpose of providing a digital connection between an end user and a public telecommunication system.

3. Home Local Area Network (Home LAN) - being a system in the form of telephone extension wiring or an electricity distribution system in which (in either case) the material substance forming part of it (other than by forming part of any other equipment) is used, irrespective of any other function, for the purpose of providing a digital connection between two or more points within a single set of premises.

EXPLANATORY NOTE

(This Note is not part of the Regulations)

These Regulations prescribe requirements for the limits of emissions of electromagnetic energy from a metallic "material substance" (as defined in regulation 2(1)), such as an electricity cable or a telephone line, which forms part of a telecommunication system and can be used to carry Internet or other data at relatively high speeds (often called "broadband"). The requirements for these limits are specified in Department of Trade and Industry Performance Specification MPT 1570. The Schedule to these Regulations sets out the types of telecommunication system within the scope of these requirements.

The Regulations apply to a material substance forming part of a system put into service on or after the date that the Regulations come into force (regulation 3(1)). The Regulations do not apply where the Electromagnetic Compatibility Regulations 1992 or the Radio Equipment and Telecommunications Terminal Equipment Regulations 2000 apply (regulation 3(2)).

The Regulations are made under section 10(1)(a) of the Wireless Telegraphy Act 1949 for the purpose of ensuring that use of "apparatus" (which includes any "material substance" under these Regulations) will not cause undue interference with wireless telegraphy. Section 10(4) provides that use of apparatus which does not comply with the Regulations is not unlawful. Under section 11, any person in possession of non-complying apparatus may be served with a notice requiring it not to be used if in the Secretary of State's opinion-

> (i) its use is likely to cause undue interference to a "safety of life" service or to use of wireless telegraphy for a purpose upon which safety may depend, or

[16] S.I. 1992/2372; the relevant amending instrument is S.I. 1999/1957.
[17] S.I. 2000/730.

(ii) its use is likely to cause, and in fact has caused or is causing, interference to any other wireless telegraphy despite the taking of reasonable steps to minimise the interference.

Any person who uses the apparatus knowing of the notice is guilty of an offence.

Copies of MPT 1570 referred to in these Regulations may be obtained from the Radiocommunications Agency Library at Wyndham House, 189 Marsh Wall, London E14 9SX (Tel: 020 7211 0211). Also available to the public at the Library and on the Agency's Internet web site at **www.radio.gov.uk** is a full regulatory impact assessment report of the effect that these Regulations would have on the costs to business. Copies of the report have also been placed in the libraries of both Houses of Parliament.

The Regulations were notified in draft to the European Commission in accordance with Directive 98/34/EC, as amended by Directive 98/48/EC.

END QUOTE

4.4.3 Denmark (executive order 1008 from December 2001)

In Denmark, an "Executive order on limits for electromagnetic radiation from fixed telecommunication networks" was approved on 7th December 2001. The technical requirements are summarised in the following English translation of the most important parts:

The telecommunication networks covered by this executive order are defined as: all networks with a total cable length exceeding 30m, using any kind of conductive medium. Termination points and connections to connected terminals are included.

The frequency ranges are 108,0 – 137,0 MHz, 242,95 – 243,05 MHz, 328,6 – 335,4 MHz and 406,0 – 406,1 MHz. The general limit is 27 dBuV/m measured in 3 m distance. Measuring bandwidth is 9 kHz and a quasi peak detector shall be employed.

In the frequency ranges 121,45 – 121,55 MHz, 242,95 – 243,05 MHz, and 406,0 – 406,1 MHz no carriers or clock frequencies are allowed to exist on the cables.

5 REGULATORY FRAMEWORK FOR CABLE TRANSMISSIONS

5.1 Basic principles of the Radio Regulations of the ITU

The Radio Regulations (RR) of the ITU is part of the International Telecommunication Convention. These regulations are an international agreement facilitating rational, efficient and economical use of the frequency spectrum on a worldwide basis. In the RR radio services are defined as services using electromagnetic radiation propagating in free space. The very basic principles of the RR to be taken into account when discussing the coexistence of radio services with cable installations are the following:

The operation of a radio station of any radio service requires a "frequency assignment".
The legal basis for such an individual assignment is a "frequency allocation" for the radio service concerned. Only radio services defined in the RR can be granted an allocation in a certain part of the spectrum. Only a World Radiocommunication Conference (WRC) is competent to make an allocation of any kind. All stations must be established and operated in such a way that no interference of stations already in operation can be expected. Due to the shortage of frequencies the access to spectrum must be limited. Thus administrations are requested to grant frequency assignments to radio services only when other means of telecommunication cannot be used.

The bandwidth of transmissions and thus the consumption of spectrum shall be kept to a minimum. All radio stations shall use state of the art technology e.g. restricting unwanted emissions to the lowest level possible.
The frequency range between 5 MHz and 30 MHz shall be "reserved" for long-distance radio communication and frequency assignments shall be restricted in numbers (RR 4.11 and 4.12).

Cable equipment and installations must be operated in such a way not to interfere with radio services and radio equipment. According to the RR there is no possibility to allocate or assign frequency bands to cable systems.

Concerning the latter point (number 9.) RR 15.12 determines

Section II – Interference from electrical apparatus and installations of any kind except equipment used for industrial, scientific and medical applications

RR 15.12 : "Administrations shall take all practicable and necessary steps to ensure that the operation of electrical apparatus or installations of any kind, including power and telecommunication distribution networks, ...does not cause harmful interference to a radiocommunication service and, in particular, to the radionavigation or any other safety service operating in accordance with the provisions of these Regulations."

This very clear statement points out the current legal situation of cable systems in relation to radio services.

Further, 15.28 emphasises the absolute need for international protection and elimination of harmful interference to distress and safety frequencies:

15.28 § 20 Recognizing that transmissions on the distress and safety frequencies (see Article 31 and Appendix 13) require absolute international protection and that the elimination of harmful interference to such transmissions is imperative, administrations undertake to act immediately when their attention is drawn to any such harmful interference.

5.2 Applicability of the EMC Directive - 89/336/EEC

5.2.1 General

Cable networks are considered to be 'fixed installations' in terms of the EMC Directive. The EMC Working Party confirmed this position in February 2000. Clarification has also been provided concerning whether the Directive can apply to installations in place prior to the entry into force of the Directive where the installation in question has subsequent to the date of implementation been used for parallel (and new) purposes. The EMC Working Party determined that in this case Chapter 7.2 of the EMC Guide (**18**) was pertinent. This provision deals with 'as new' equipment in its broadest sense, in particular where the original equipment was not CE marked and is subject to substantial modifications so as to obtain similar performance characteristics as new equipment. In such a situation it is considered reasonable to request compliance with the EMC Directive. The R&TTE Directive (99/5/EC) may also be applicable.

The main route for assessing compliance with the Directive is conformity with harmonised standards. 'Harmonised Standards' (19) are European Standards, which are adopted by European Standards organisations, prepared in accordance with the General Guidelines agreed between the Commission and the European standards organisations, and follow a mandate issued by the Commission after consultation with the Member States. Although to date such standards have been product related a mandate issued by the Commission in April 2001 will require the standards bodies to develop a harmonised immunity and radiation standard for telecommunications networks.

5.2.2 The current Directive as applied to telecommunication networks - in brief

Article 4 of the Directive requires that EM disturbances generated do not exceed a level allowing radio and telecommunications equipment to operate as intended. It also requires a level of immunity. Article 6 allows Member States to take special measures to protect a specific site to overcome an EMC problem or to protect public telecommunications networks or receiving stations used for safety purposes. These special measures, if justified are published in the OJ. Article 7 presumes compliance with Article 4 if the network meets the protection requirements specified in a national standard which has been communicated to the Commission. Article 10 applies where no national standards exist; the manufacture/importer is then required to hold a 'technical construction file', which provides information on the measures taken to meet Article 4. Article 9 provides the measures that the Commission and Member States must take if Article 4 requirements are not met.

5.2.3 The Revision of the EMC Directive

The EMC Directive is in the course of revision. A draft text of the proposed revision is likely to be published during 2002. The following text again provides a brief overview of the approach likely to be taken concerning fixed installations and telecommunication networks. Article 3 states that a network must meet the 'essential requirements' of Annex I. Article 5 states that where equipment (including fixed installations) complies with a harmonised standard

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18 ISBN 92-828-0762-2, Guide to the Application of Directive 89/336/EEC © European Communities 1997

19 ISBN 92-828-7500-8, Guide to the Implementation of Directives based on the New Approach and the Global Approach © European Communities 2000

Member States shall presume compliance with the essential requirements. Article 10 refers to fixed installations.. In the case of suspected non-compliance, competent authorities may request evidence of compliance and initiate an assessment. The competent authorities may impose appropriate measures to ensure compliance. Annex I, Part A) re-states the requirements of 'old Article 4' in 7.1.2 above. Part C) states that a fixed installation shall be installed and maintained applying good engineering practice with a view to meeting the essential requirements set out in Part A).

5.2.4 Implications

Concerning the current version of the Directive (7.1.2 refers) in the absence of harmonised standards it would appear that Article 7 caters for national standards dealing with EMC matters. The question arises whether harmonised national limits at the CEPT level implemented via an ERC Decision could be construed as meeting the requirements of Article 7. However with the issue of a mandate for the development of a harmonised standard for telecommunications networks the Commission is clearly of the opinion that 89/336/EC covers the issue of EMC with respect to such networks.

5.2.5 Monitoring of networks

The following provisions are important from the frequency users point of view. These additional provisions would provide a better protection of the radio frequencies, but are outside the scope of the present EMC directive:

- monitoring of the general environmental limits to the benefit of the preservation of radio spectrum should be encouraged;
- in order to ensure that networks continue to comply with the limits mentioned above, provisions should be put in place in order to monitor cable transmission networks regularly.

However, it is a responsibility of individual administrations to decide whether monitoring actions are necessary.

5.3 Mandate for EMC harmonised standards for telecommunication networks

On August 7, 2001, the European Commission has issued the standardisation mandate M 313 addressed to CEN, CENELEC and ETSI, asking them to produce EMC harmonised standards for telecommunication networks. The full text of the mandate is given in Annex 1.

5.4 R&TTE Directive

The Directive 1999/5/EC of the European parliament and of the Council of 9 March 1999, referred to as the R&TTE (Radio and Terminal Telecommunication Equipment) Directive, contains the following definition of harmful interference:
Harmful interference means interference which endangers the functioning of a radionavigation service or other safety services or which otherwise seriously degrades, obstructs or repeatedly interrupts a radiocommunication service operating in accordance with the applicable Community or national regulations.

5.5 Other EU Directives

The recently adopted Framework, Authorisation and Access Directives also contain information that can be related to the subject of cable transmission and its effect on radio services and might therefore have an impact on the regulatory framework for these applications.

5.6 Overview of the present national regulations on cable TV in Europe

ERO has conducted a survey of the present CableTV regulations in Europe. A questionnaire was sent to CEPT administrations and the detailed results are given in Annex 2. This overview shows that there exists many different national legislations in CEPT countries regarding the use of frequencies (forbidden frequencies, radiation limits…) by cable networks.

5.7 Regulations in the United States

Two parts of the US Federal Regulations are relevant to cable networks, the first is Part 15 which deals with radio frequency devices and deals with the radiation limits from unintentional radiators, for shielded cable systems, cable system terminal device (cable-TV set-top box) fall into this category. The second series of regulations concerns Part 76, which deals with the United States' Multichannel Video and Cable Television Service and includes provisions to protect radiocommunications and specific arrangements designed to protect aeronautical services from emissions emanating from cable systems.

Relevant commented extracts of Part 15 and 76 are given in Annex 3.

The FCC 02-157 report and order adopted on May 23, 2002 and released on May 30, 2002 indicate that Part 15 will be amended to align the proposed limits with the CISPR conducted limits on the mains, but that this change does not apply to Carrier Current System (corresponding to PLT as defined in this report). Relevant extracts from FCC 02-157 are also given in Annex 3.

6 PROPAGATION ASPECTS AND FIELD DECREASE BELOW 30 MHZ

In this section, the results of two different studies are presented:

- Calculation of field strength in the far field area and effective radiated power from an electric or magnetic dipole;
- Field decrease with distance at frequencies below 30 MHz.

6.1 Radiation from an electric or magnetic dipole below 30 MHz

In order to illustrate the near field problems, particularly at the lower end of the 9 kHz-30 MHz frequency range, theoretical calculations have been made with three different hypothesis:

- Radiation from an infinitesimal electric dipole;
- Radiation from an infinitesimal magnetic dipole;
- Free space radiation (linear roll-off with distance).

These calculations give two kinds of output:

- The field strength at a distance of 100 m, assuming a field strength equal to the example n°1 (NB30) limit at a distance of 3 or 10 m;
- The interference range defined by the field strength being 3, 1, or 0.5 dB over the quiet rural noise level while assuming a field strength equal to the NB30 limit at a distance of 3 or 10 m. These interference ranges are true for the free space situation; the extra damping effect of groundwave propagation beyond the transition distance (see ERC Report 69) has not been taken into account.

The corresponding calculations are detailed in Annex 4.

At a 3 m distance, the main conclusion is that the difference between the dipole models and the free space model is particularly important at frequencies lower than 10 MHz : free space assumes a 1/d (d being the distance) fall off, whereas the electric dipole radiation decreases in $1/d^2$ and the magnetic dipole radiation in $1/d^3$. On the contrary, at frequencies above 10 MHz and particularly above 20 MHz, the three models give very comparable results and it means that both elementary dipoles becomes important sources of far field radiation.

At 10 m, the conclusions are very similar, except that the cut-off frequency for which the behaviour is changing is smaller: above 5 MHz, the three curves are very close and they deviate (1/d, $1/d^2$ and $1/d^3$) below 5 MHz.

The far field border, i.e. the distance after which the radiation can be considered as free space, is equal to $\lambda/2\pi$ (λ being the wavelength) and therefore ranges from 35 m at 1 MHz to less than 1 m at 30 MHz.

It means that most measurements specified by the different limit examples (see section 7) are in the near field zone. Measurements in the far field zone would be desirable, but they are generally not possible for sensitivity reasons (radiation from the cable lies in the overall measurement noise level).

One should notice that the radiation in the near field zone of cable networks can differ significantly from an infinitesimal electric or magnetic dipole because of the dimensions of the radiator. In this case the curves for inverse linear roll-off are more appropriate.

6.2 Field decrease with distance at frequencies below 30 MHz

In free space, the power surfacic density varies with the square of the distance. But the ground limits the propagation in a half plan. The transmitted wave in this half plan creates a direct signal between the source and the receiver, and an indirect signal corresponding to a path with reflection on the ground.

The resulting field strength is the vectorial sum of the fields resulting from those two paths[20]. These fields can be added or subtracted depending on the combination of their phases. The coefficient of reflection on the ground is therefore determining the final result.

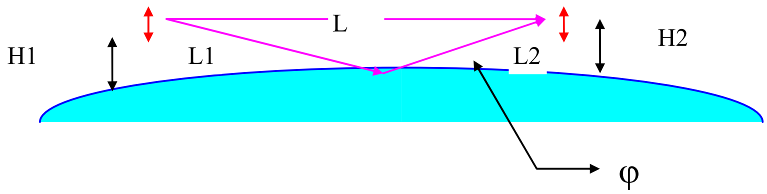


Figure 6.2-1: on sight propagation

With a ground impedance such as:

$$Z_s = \sqrt{\frac{\mu}{\varepsilon\left(1+\frac{\sigma}{j\omega\varepsilon}\right)}} = \sqrt{\frac{\mu}{\varepsilon}}\sqrt{\frac{1}{1+j\frac{\omega_0}{\omega}}} \qquad \text{with} \qquad \omega_0 = \frac{\sigma}{\varepsilon}$$

The reflection coefficient on the ground is expressed in function of the angle of incidence.

$$\Gamma_s = \frac{Sin\varphi - \sqrt{C}}{Sin\varphi + \sqrt{C}}$$

With, in horizontal polarisation:

$$C = C_H = Z_s - Cos^2\varphi$$

and, in vertical polarisation:

$$C = C_V = \frac{Z_s - Cos^2\varphi}{Z_s}$$

The difference of path length is then

$$\Delta = L_1 + L_2 - L = \frac{4.L_1.L_2.Sin^2\varphi}{L_1 + L_2 + L}$$

During propagation in visibility, the value of the factor of divergence resulting from the aperture of the link when reflecting on a spherical cap is close to 1.

$$D = \sqrt{\frac{1-m.\left(1+b^2\right)}{1+m.\left(1-3b^2\right)}} \xrightarrow{m\to 0;b<1} 1$$

and the expression of the difference of path length can be simplified:

$$\Delta \approx \frac{2.H1.H2}{L}$$

The method of geometrical optic disregards the phenomena of diffraction. The relation gives the angle of minimal reflection below which this type of approximation ceases of being available:

$$\varphi_{(mrad)} = \left(\frac{2100}{F_{(MHz)}}\right)^{1/3}$$

[20] In this calculation, the surface wave is not taken into account. Ground wave propagation curves are given in ITU-R Recommendation 368-7, “Ground-Wave Propagation Curves For Frequencies Between 10 kHz And 30 MHz”. These apply when transmitting and receiving antennas are on the ground, and show propagation of vertically-polarised signals with a loss that depends on surface conditions, and that can be very small, especially over wet ground or sea water.

F(MHz)	0,03	0,1	1	10	30	100	300	1000	3000	10000
φ°	2,36	1,58	0,73	0,34	0,23	0,16	0,1	0,07	0,05	0,03

Table 6.2-1: angle of minimum ground incidence for application of the geometric approximation

For the studies of propagation in visibility at distances lower than 1 km and at a certain height of the source of transmission, the geometrical approximation is considered as sufficient and the ground diffraction is neglected for highest frequencies (angle 5 time superior to the minimum angle) to those given in the table 6.2-2.

H (m)	1	3	6	10
F (kHz)	17 000	632	78	17

Table 6.2-2: frequencies from which the conditions of the geometrical optic are fulfilled

Thus, when the radiant element is situated at 1 m above the ground, the geometrical approximation can be applied from a frequency of some tens of megahertz.

With these conditions of approximation, the module of the resulting field is the following:

$$|E| = |E_0|.\sqrt{1+(\rho)^2 + 2\rho.Cos\left(\psi + 4\pi\frac{H1.H2}{\lambda.L}\right)}$$

Relationship in which rho and phi are respectively
the module and the phase of the coefficient of reflection,
and Eo is the free space field.

When the angle of reflection is small, the coefficient of reflection is equal to -1 and in the above conditions of approximations the expression of the field is simplified:

$$|E| = 2.|E_0|.\left|Sin\frac{2\pi.H1.H2}{\lambda.L}\right|$$

The field oscillates then between zero and two times the free space field.
At constant altitude but at increasing distance, the last maximum is met for

$$d = \frac{4H_1H_2}{\lambda}$$

At constant distance but at increasing altitude H2, the field reaches some maximums the first of which is obtained for

$$H2 = \frac{\lambda.L}{4.H_1}$$

Because the free space field E_0 is already decreasing like the distance, at constant altitude and beyond the last maximum, the field decrease constantly as the square of the distance in comparison with a reference measure.

$$E \approx E_0\frac{4\pi H_1H_2}{\lambda.L} = E_{ref}.\frac{4\pi H_1H_2.L_{ref}}{\lambda.L^2}$$

With $E_{réf.}$ and $L_{réf.}$ Which represent a reference field
measured at a reference distance (in far field and plan waves)
Lref = 20 m => Far field => F > 2,97 MHz
Dim. Antenna = 1 m Plan waves => F > 9,37 MHz

At constant altitude, near the ground, this decrease to 40 dB per decade is confirmed by the CISPR publications and by a measurement campaign realised by a laboratory from the French Ministry of Defence to study this law of decrease.

The model presented can be considered as valid for measurements realised at the level of the ground, without loosing the fact that the elevation of one extremity can reduce the effective attenuation.

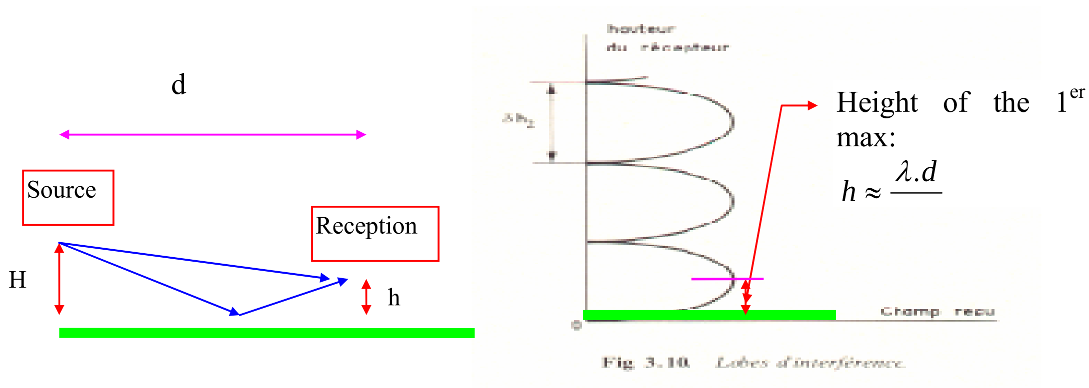


Figure 6.2-2: variations of the field with altitude

As demonstrated above, the hypothesis chosen in the FCC Part 15 regulation is a direct vision propagation at the level of the ground, in which are added the direct wave and the oblique reflected to ground waves. This hypothesis is questioned as soon as there is elevation of one extremity.

7 EXAMPLES OF LIMITS FOR CABLE TRANSMISSION SYSTEMS BELOW 30 MHZ

This section presents the limits that have been proposed by some interested parties involved in the CEPT studies on the compatibility between cable transmissions and radio services.

Their origin and background is presented here together with the corresponding limits for cable transmissions. In the following sections (measurement results and compatibility studies), reference is often made to the limits contained in these five examples.

7.1 Example n°1

7.1.1 Background

This example corresponds to the limits adopted in Germany and referred to as "NB 30". It has been proposed by Germany and is supported by some other CEPT administrations.

7.1.2 Proposed limit

Frequency Range MHz	*(Peak) Disturbance Field Strength Limit*[21] dB(µV/m)	Measurement Distance	Measuring Bandwidth
0.009 - 0.15	40-20*log f (MHz)	3 metres	200 Hz
0.15 – 1	40-20*log f (MHz)	3 metres	9 kHz
1 – 30	40-8.8*log f (MHz)	3 metres	9 kHz

Table 7.1.2: example n° 1 limits

[21] The limits are given in terms of the electric field strength. Below 30 MHz these limits apply for the magnetic field strength, assuming an intrinsic impedance of 377 Ohm.
These limits provide for free use of frequencies. In the case of frequency usages in and along conductors for which no free use is provided for, the geographical, temporal and technical conditions may be laid down for each individual case in either the national frequency usage plan or the required frequency assignment by the national Regulatory Authorities, on the basis of proportionality and after hearing the parties concerned. Where safety-related radio communication services are concerned, account is to be taken in particular of the extent to which a specific threat to safety is to be feared.

7.2 Example n°2

7.2.1 Background

This example was initially proposed by Norway and is supported by some other CEPT administrations.

7.2.2 Proposed limit

Frequency Range MHz	*(Peak) Disturbance Field Strength Limit* dB(µV/m)*	Measurement Distance	Measuring Bandwidth
0.15 - 1	20 - 20*log (f/MHz)	3 metres	9 kHz
1 - 30	20 - 7.7*log (f/MHz)	3 metres	9 kHz

* Measured with a loop antenna in dBµA/m and converted to an equivalent E-field by the factor of 51.5 dB, corresponding to the free space impedance of 120*π ohm.

Table 7.2.2: example n° 2 limits

7.3 Example n°3

7.3.1 Background

This example proposed by the UK administration corresponds to the limits adopted in the United Kingdom and contained in the standard MPT 1570 from August 2001.

7.3.2 Proposed limit

Frequency (MHz)	**Magnetic field strength peak limit at 1 m in dBµA/m**	**Measurement Distance**	**Measuring Bandwidth**
0.009 to 0.15	- 18 - 20·log f (MHz)	1 metre	200 Hz
0.15 to 1.6	- 1.5 - 20·log f (MHz)	1 metre	9 kHz

Table 7.3.2: example n° 3 limits

7.4 Example n°4

This example was initially proposed by BBC and NATO. It is supported by the radio users (military, broadcasting, civil aviation, amateur…) of the LF, MF and HF bands.

Protection Requirement of HF Radio Services

1. Protection Requirements

In order to provide proper protection to the HF Radio Services listed above, the HF radio users have come to the common conclusions that the essential protection requirements are as follows:

a. 0.5 dB Degradation of Sensitivity

Due to the presence of interference of unwanted emissions of PLT, the total noise and interference level should not increase with more than 0.5 dB compared to the total noise without the presence of interference from PLT.

b. Reference noise level

The reference noise level to be considered is the mid-way noise level of quiet-rural and rural areas defined in the ITU-R Recommendation P 372-7.

c. Protection Distance

Protection distance is the minimal separation distance between the source of interference and the victim receiver where the sensitivity will not degrade by more than 0.5 dB. The HF users are of the opinion that the practical distance should be 10 m.

The minimal separation distances between cables of Cable Transmission Networks (CTN) and HF receiving antennae as well as radio receivers are required. In many cases the available separation distances are very limited. The provision of the minimal separation distances is the responsibility of the CTN operators (as the new coming service) including if necessary to adapt the cable networks configurations if new HF receiving stations are to be installed in areas where cable transmission networks are already in operation.

d. Other mechanisms of interference

The protection criteria above are the criteria related to the direct wave interference. It is also recognized that there are other interference mechanisms that should be taken into account. For example, the interference caused by the cumulative effect of sky-wave transmissions and interference through the power supply circuitry of HF radios are to be taken into account.

2. Components of Protection

The above listed protection requirements could be translated in the following sharing components:

a. Radiation Limit
b. Protection of Safety-of-Life/Vital Governmental Frequencies
c. Protection of Exclusion Zones

2.1. Radiation Limit

The calculations of the above requirements lead to a radiation limit reflected by the following equations:

Magnetic field strength (measured)

$$H_n \text{ (dB}\mu\text{A/m in 9kHz, peak)} = -29.7 - 8.15 \text{ Log}_{10}[f_{\text{ MHz}}] \quad [1]$$

or

Equivalent electric field strength (calculated from [1])

$$E_n \text{ (dB}\mu\text{V/m in 9kHz, peak)} = 21.8 - 8.15 \text{ Log}_{10}[f_{\text{ MHz}}] \quad [2]$$

*Note: Measured with a loop antenna in dBµA/m and converted to an equivalent E-field by the factor of 51.5 dB, corresponding to the free space impedance of 120*π ohm.*

The above radiation limit should be measured at a distance of **1m** from the cable within a bandwidth of **9 kHz** (distance cable - centre of the measuring loop).

2.2 Protection of Safety-of-Life/Vital Governmental Frequencies

On case-by-case basis, following existing national procedures, it should be possible to protect safety-of-life and vital governmental frequencies suffering harmful interference from the radiation of cable transmissions networks.

2.3 Protection of Exclusion Zones

On case-by-case basis, following existing national procedures, it should be possible to protect vital sensitive radio sites suffering unacceptable performance degradation from the radiation of cable transmissions networks.

7.5 Example n°5

7.5.1 Background

This example was proposed by PLT manufacturers and electricity utilities and corresponds to the values of the FCC Part 15 limits.

7.5.2 Proposed limit

Frequency (MHz)	Field Strength (microvolts/metre)	Measurement Distance (metres)
0.009 - 0.490	2400/F(kHz)	300
0.490 - 1.705	24000/F(kHz)	30
1.705 - 30.0	**30**	30

Table 7.5.2: example n° 5 limits

8 MEASUREMENT RESULTS

A summary of measurement campaigns on PLT carried out in Finland, Germany and Norway, on DSL and LANs carried out in Germany and in the UK, on cable TV carried out in Germany, France and Ireland, on radiation from equipment below 30 MHz carried out in France, on antenna sensitivity issues carried out in the Netherlands and on electric cables characteristics carried out in Finland.

It should be noted that the radiated field measurement results do not aim as showing the noise floor in the measured frequencies, but present the superposition of the evaluated system's (equipment or network) radiation with the wanted signals of the radio services that are present on the measurement site, together with any other noise source that can be responsible for some emission in this range. The lowest measurable level is dictated by the noise floor of the measuring equipment (see section 8.5).

8.1 Measurement results from PLT field trials

8.1.1 Norway

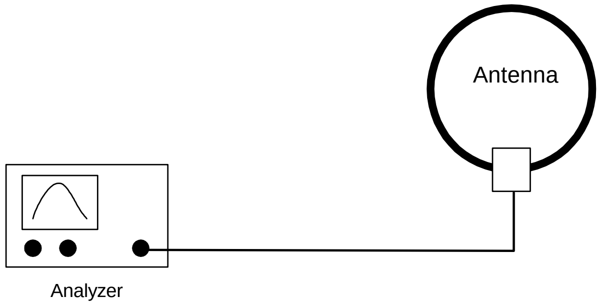
8.1.1.1 Introduction

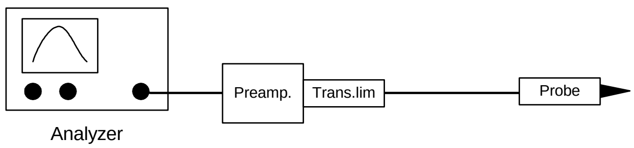
Some of the largest power suppliers in Norway have established pilot projects for testing PLT-systems. The Norwegian Post- and Telecommunications Authority has established a project group to do measuring tests on all systems with the intention of getting information on unwanted radiation in the radio frequency spectrum from the systems, recognising that the systems use frequencies in the HF- band (9kHz to 30 MHz) that are allocated for radio systems.

8.1.1.2 Measuring in general

Instruments
CISPR compliant measuring instruments were used: Spectrum Analyser, active loop antenna in the frequency band with 9 kHz to 30 MHz, measuring probe, transient limiter and preamplifier. The measuring results are the real levels as all the corrections are automatically done in the analyser. The measuring results are **peak levels,** with a measuring bandwidth of 9 kHz. The measurements have been done under the conditions available during "in situ" measurements.

Conducted measurements
In addition to field emission measurements, measurements were also taken with a probe placed direct onto the powerline cables. The measurements were done as differential mode (DM), between two phases, and between a phase and the earthing (PhE). The PLT signals were injected as a DM signal into the power cable. The PLT levels for PhE were 0 dB - 10 dB lower than the DM levels. The PhE level is the most interesting level because this is directly comparable to the requirements for the mains port in existing EMC standards. It is a correlation between the PhE levels and the field emission. In a distance of 3 metres from the system, the coupling factor is approximately minus 40 dB to minus 35 dB between the PhE and field emission. This coupling factor is valid for houses built of wood, this type of house being very common in Norway. For example, this means that a conducted PhE level of 85 dBμV will typically result in an EM field 3 m from the power cable of 45 dBμV/m.





EM field measurements.
The measuring distance is 3 m from the powerline structure.
The measurements are done with a loop antenna, and this antenna was oriented to catch the maximum field at the actual measuring site.
The results are presented as an equivalent electric field, obtained by using a correction of 51,5 dB corresponding to the free space impedance of 120*π ohm.

Variation of the electric power consumption, and measuring antenna position.
Variation of the electric power consumption had no impact on the radiation levels. The radiation levels were fairly constant in a moderate movement of the measuring antenna along the powerline cable trace. This tells us that the measuring results are fairly independent of both the power consumption and minor changes in position along the powerline cable.

Some measuring results:

PLT transmission system and Measuring site.	PLT power level. dBm	Phase to ground - max. PLT voltage. dBμV	Equivalent electric field - 3 m distance. dBμV/m
GMSK indoor Eltonveien 69	9	92	43
GMSK indoor Elgtråkket 102	9	Not measured.	55
GMSK outdoor Eltonveien 81	- 10	78	42
GMSK indoor Eltonveien 81	11	82	57
GMSK indoor Eltonveien 67	9	80	48
GMSK outdoor Eltonveien 107	- 7	70	37
GMSK outdoor Eltonveien 111	- 2,5	74	47
GMSK indoor Eltonveien 107	15	68	56

GMSK indoor Eltonveien 111	9	78	46
GMSK indoor Sinsenveien 91	9	Not measured	55
OFDM Vestre Sandslimarka 40	17	75	45
OFDM Vestre Sandslimarka 52	17	95	60
DSSS Marieroparken 12	10 V peak to peak.	85	55

Table 8.1.1.2: PLT measurement results in Norway

GMSK - outdoor Gaussian minimum shift keying.
Bandwidth 2 MHz at 10 dB down, center frequency 2,4 MHz.

GMSK - indoor Gaussian minimun shift keying.
Bandwidth 2 MHz at 10 dB down, center frequency 19,8 or 22,8 MHz.

OFDM - Orthogonal frequency division multiplex.
Using frequencies in the band 2 MHz to 3 MHz..

DSSS - Direct sequence spread spectrum.
Using frequencies from 3,8 MHz to 18 MHz at 10 dB down.

For practical reasons the conducted measurements have not been done directly on PLT equipment. There have been some metres of mains network cable between the PLT equipment and the measuring point. This means there has been some dB of attenuation in the cable before the signal reached the measuring site. The exception from this is the first measurement in the table. This is done directly on the PLT equipment. It is reasonable to expect an average attenuation due to the cable of 10 dB for the highest frequencies (around 20 MHz), and 5 dB for the lowest frequencies (around 2 MHz). The measurements then shows an average coupling factor between PhE levels from the PLT equipment and EM field levels in 3 m distance of -40 dB for the highest frequencies, and -35 dB for the lowest frequencies. All the measurements in the table are referred to houses made of wood. Other measurements show that power cables in the access network hanging in free air between poles, radiate the PLT signal about as much as the cabling inside the building. Power cables put into the ground do not contribute very much to the radiation. Streetlights connected to power cables in the ground, will to a large extent increase the radiation from such cables.

8.1.1.3 Listening test with a radio receiver

Listening tests with a shortwave radio receiver showed that radiation from the powerline systems gave an embarrassing noise in the frequency area 1,4 MHz to 3,750 MHz from the GMSK outdoor system, and 18,4 MHz to 21,3 MHz from the GMSK indoor system (center frequency 19,8 MHz). It was very much the same situation for the OFDM system i the frequency range 2 –3 MHz. The DSSS system created a real wide band noise, covering large parts of the short wave range. For example, the noise was audible at the nominal frequency 19,8 MHz at a distance of 350 meters in free space from the nearest indoor controller unit of the GMSK system.

8.1.1.4 Conclusion

What has been seen during these measurements is that the conducted levels due to the PLT equipment are far higher than EMC regulation allow. General EMC requirements for the mains port is 56 dBμV QP (PhE) in the frequency range 0,5 MHz – 5 MHz, and 60 dBμV QP for 5 MHz – 30 MHz. QP means measured with a quasi-peak detector. The values listed in the table are peak values, but the QP correction is just a few dB for the different types of PLT signals. There should be compatibility between existing conducted EMC requirements, and new requirements defining maximum allowed EM field levels from electric power cables carrying PLT signals.

Combining conducted EMC requirements with the coupling factor described earlier in this report, will give as result the extent of field emission that can be expected from equipment complying with EMC requirements for the mains port. Houses made of wood represent a worst case situation regarding unwanted EM field emission from the mains cabling. The compatibility between requirements must also be valid for houses made of wood, therefore this kind of building is a good reference. Based on this philosophy, equipment complying with EMC requirements for the mains port should on average give a maximum field emission of 20 dBμV/m QP measured at a distance of 3 metres from the cable structure.

Measurements on PLT pilot projects show EM field levels 20–40 dB higher than 20 dBμV/m. This clearly indicates the need for a significant reduction in the spectral power density of the PLT signal to achieve compatibility with existing EMC standards. When considering maximum permitted field emission from PLT, it should be taken into account that the PLT signal might be an "always on" signal, and that the geographical concentration of PLT units within a certain area might be fairly high. The field emission requirements for PLT should therefore be somewhat more restrictive than the 20 dBμV/m QP limit.

8.1.2 Germany – System A

System A is designed for Outdoor and Indoor-Communication in several frequency bands. The outdoor-section begins at a transformer station and ends in the cellar of several houses, mostly in front of the power meter. At the same location the indoor section begins using another frequency range and ends at the plugs in the rooms.

8.1.2.1 Measurement configuration

In the field trial, where the measurements were done, the injection point was not the transformer station, because there was not enough space in there. The main injection point was situated in a cellar of one house. The PLT signal was distributed to the transformer and further to another house. In the cellars of these two houses outdoor slaves and indoor masters were installed. Both units were in one box. Every unit could be set-up in several frequency ranges, power level and operation modes. According to each measurement point, the system was configured in a kind of worst-case status, e.g. in front of the second house the outdoor slave was set-up in continuous mode at 10 dBm in the lowest frequency range (2.4MHz) and the outdoor master was turned off.

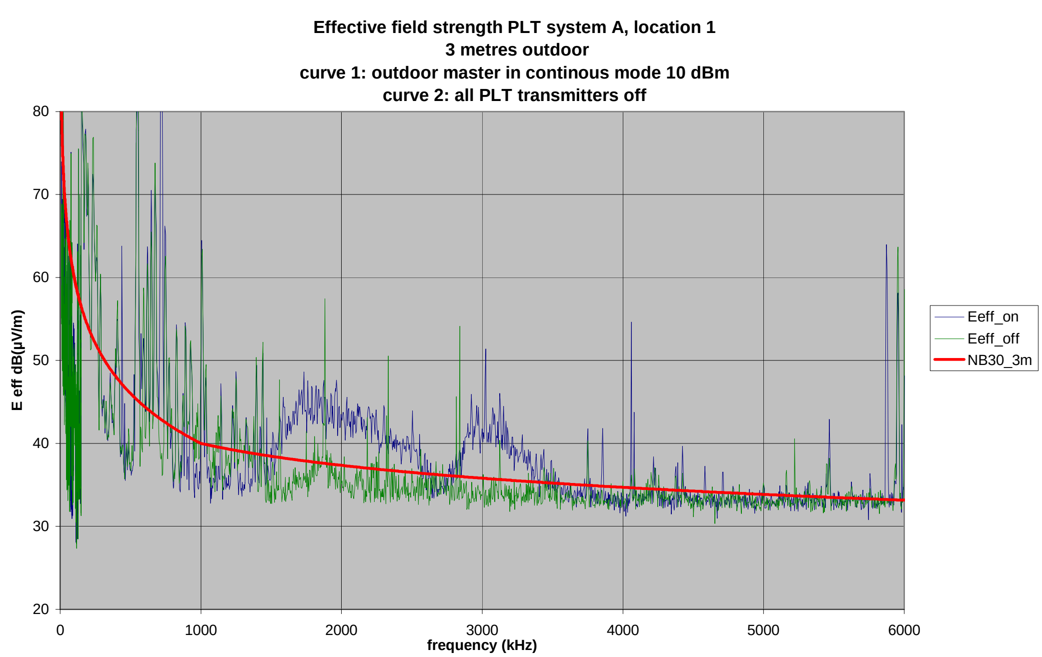
8.1.2.2 Fingerprint of the signal

The "fingerprint" of the PLT signal was determined in measurements made in the cellar of the first house. The unsymmetrical, asymmetrical and symmetrical current was measured using a current clamp connected behind the outdoor master. Additionally the voltage was measured at the same injection point by using a voltage probe.

8.1.2.3 Field strength results

The measurements were made using a CISPR loop antenna at 3 metres from the wall of the first house, at ground level, fixed on a tripod with a special mechanism for turning the antenna around the same centre point in all three directions.

The antenna was connected to an EMI receiver. For every direction (X, Y, Z) a scan was made from 9 kHz to 30 MHz, with a bandwidth of 200 Hz in the range from 9 kHz to 150 kHz and a bandwidth of 9 kHz in the range from 150 kHz to 30 MHz. All the scans were made using a peak detector. For comparative reasons also one scan was made using quasi-peak-detector. The results of the X/Y/Z scans were stored on a floppy disk and transformed into an Excel spreadsheet to calculate the effective field strength.



8.1.2.4 Conclusions

The characteristics of a PLT signal can be determined by using either a voltage probe or a current clamp at the injection point. However, the best way is to switch off the PLT system, and compare the scans made with the system on and off. With an injected power level of +10 dBm, the PLT signal in the field trial exceeded the example n°1 limit (German "Usage Provision 30").

However, it should be noted that the field trial covered only one injection point (outdoor master) and only less than three households, and therefore is not representative. This field trial provides some first results based on two examples of cabling and using PLT equipment which is still under development.

8.1.3 Germany - System B

System B is designed for Outdoor and Indoor-Communication in the same frequency bands. The outdoor-section begins at a transformer station and ends in the cellar of several houses, mostly in front of the power meter. The indoor section begins at the same location using the same frequency range and ends at the plugs in the rooms. Between Outdoor slave and Indoor Master, a filter is inserted to suppress influence.

8.1.3.1 Measurement configuration

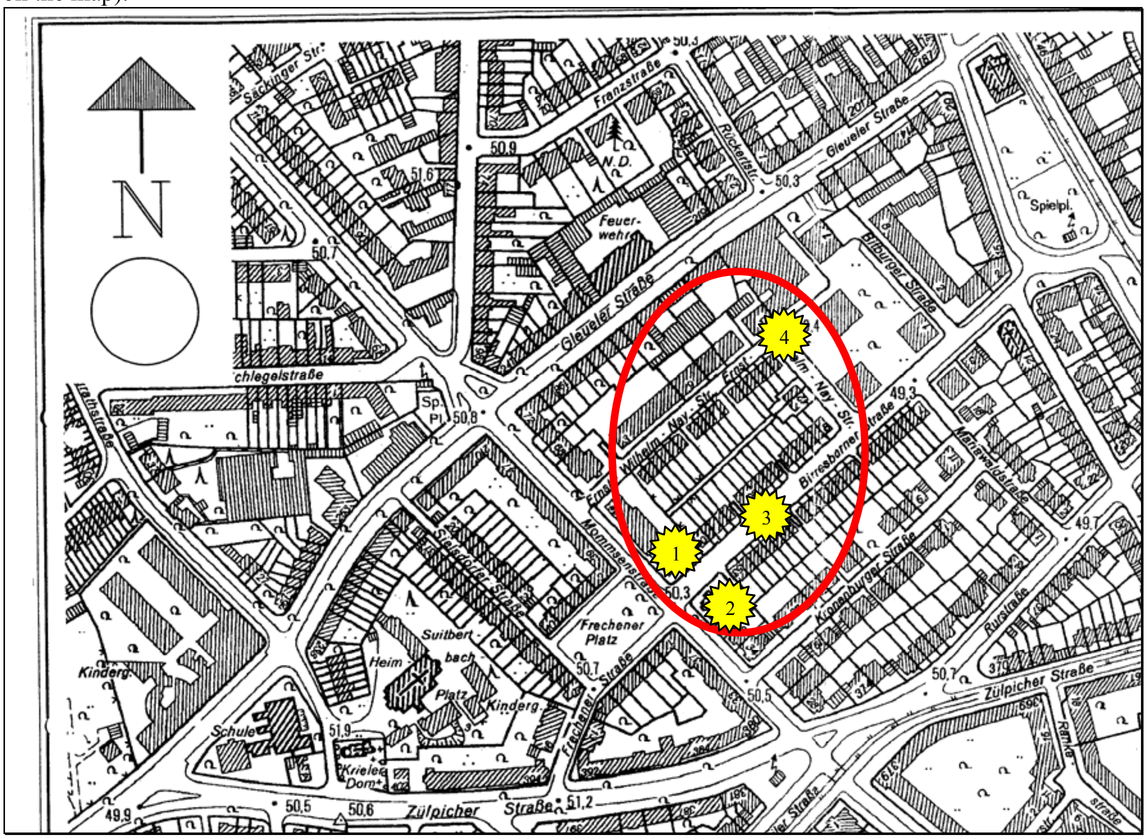
A transformer (no 1 on the map) is located in an underground room next to an underground car park. The outdoor master is located in the same room, and the PLT signal injected between L2 and L3.

The signal is distributed via the mains of the street. The cable ends at no 4 on the map.

The two households under test are houses 12 and 55 (no 2 on the map). The two households have outdoor slaves in the rooms themselves. Each slave is connected to a PC.

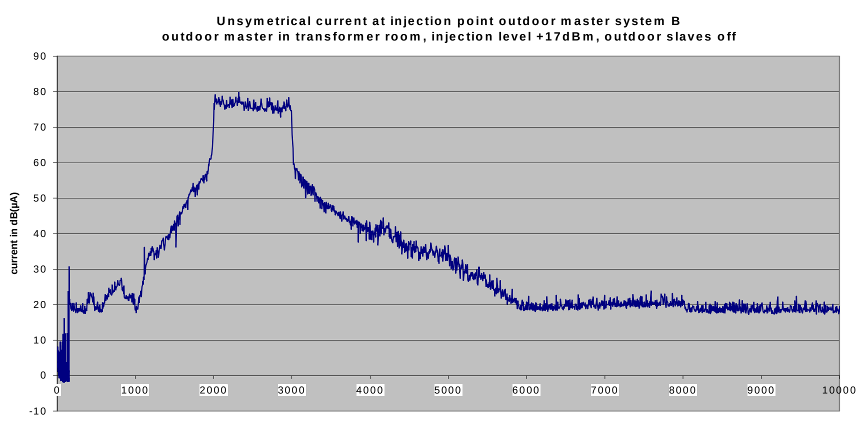
In the case of house no 28 (no 3 on the map), the outdoor slave and the indoor master are installed in the cellar. They use the same frequency, and therefore a filter is inserted in the mains to decouple the signals. Both the slave and the master are connected via an Ethernet cable. The indoor slave is installed and connected with the PC in a room on the first floor.

The map shows the four measurement points. The results presented are from the measurements at the transformer (no 1 on the map).



8.1.3.2 *Fingerprint of the signal*

The "fingerprint" of the PLT signal was determined in measurements made at the transformer: the unsymmetrical, asymmetrical and symmetrical current was measured using a current clamp connected behind the balun. The measurement result is shown below.

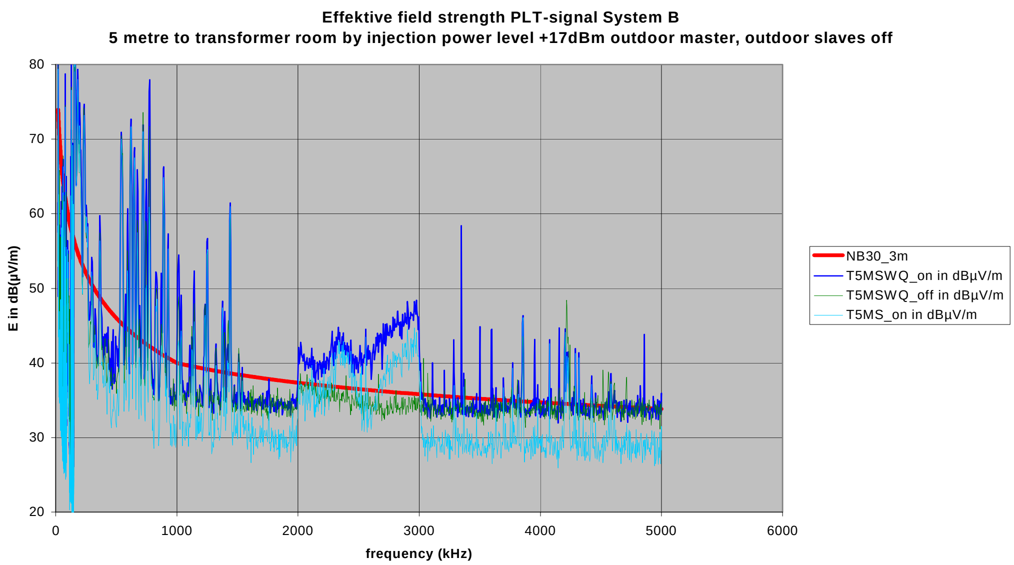


8.1.3.3 *Field strength results*

Outside the transformer room was the entrance to the underground car park. This meant that the measurement distance was greater than 3 metres. The measurements were made using a CISPR-conform loop antenna fixed on a tripod with a special mechanism for turning the antenna around the same centre point in all three directions. The antenna was connected to an EMI receiver. For every direction (X, Y, Z) a scan was made from 9 kHz to 30 MHz, with a bandwidth of 200 Hz in the range from 9 kHz to 150 kHz and a bandwidth of 9 kHz in the range from 150 kHz to 30 MHz. All the scans were made using a peak detector.

The results of the X/Y/Z scans were stored on a floppy disk and transferred onto an Excel spreadsheet to calculate the effective field strength.

The following diagram shows the measurement point and results:



8.1.3.4 Conclusions

The characteristics of a PLT signal can be determined by using either a voltage probe or a current clamp at the injection point. Additionally, the best way is to switch off the PLT system, and compare the scans made with the system on and off. With an injected power level of +17 dBm, the PLT signal in the field trial exceeded the example n°1 limit (German "Usage Provision 30").

However, it should be noted that the trial covered only one injection point and only three households, and therefore is not representative. The trial provides some first results based on one example of cabling and using PLT equipment which is still under development.

8.1.4 Germany - System C

The company that developed System C is convinced that no compatibility problems regarding radio services arise if a system concept is used which provides for a low wanted signal level on the distribution cable. For this reason the company has firmly committed itself to the threshold values specified in example n°1 limit.

In the field trial, the system is installed between the injection points at the transformer. The transmit/receive signal is coupled via a balun. The latter is a passive device with a coupling ratio of 1:1 which is not adapted to the injection point by network analysis. The signals are fed into the system by means of the bus bars of two phases in such a way that not only the house or the settled area, but the entire low-voltage network segment is supplied with the downstream signals.

The two injection points are located approximately 200 to 250 m apart. According to System C representatives the power input at the transformer as measured with a bidirectional coupler (T joint) at the BNC output of the PLT system is -11 dBm. No up-to-date measurement value for the remote end was available, but a lower power level seems to be used.

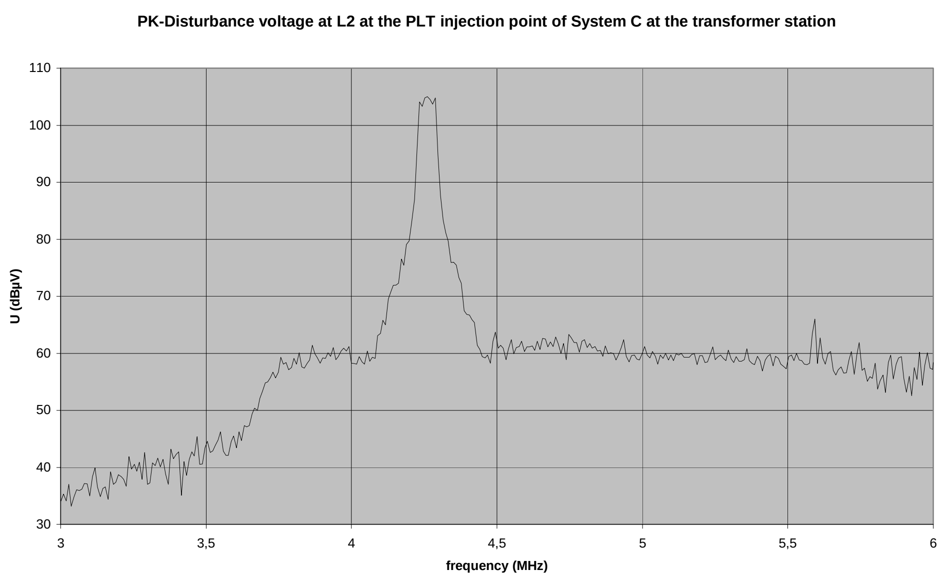
For trial purposes an additional device amplifying the signals by 22 dB was inserted at MP 3 for the measurements carried out on 14 March 2000. However, this amplifier turned out not only to be superfluous but to deteriorate the quality. To compensate for this effect 20 dB attenuation were inserted. The adverse effects caused by the amplifier were observable in a substantial increase in the noise level, which was easily demonstrated by the probe measurements.

For modulation, OFDM is used. At the time of the measurements, the field trial was carried out with a bandwidth of 65 kHz on the distribution cable. The system is equipped with an inband service channel providing continuous communication between the connected PLT devices. The connection is constantly in operation, irrespective of whether or not the PLT system is being used. The power level is controlled either by the PLT devices or centrally.

The system enables different modes of operation to be used. On 14 March 2000 the measurements were carried out in the operating mode „dedicated line“. The use of different transmission rates does not lead to any spectrum changes („load sensitivity“). Operation of the test connection is currently limited to the stretch between the transformer station and the house. In the house itself, the signals are transmitted over specially installed lines and not along the 230-V circuits.

Different coupling scenarios were tested with the PLT system. Prior to the first measurements on 14 March 2000 the signals were applied via „N“ and „L3“ of the distribution network. In the presence of two representatives of the Regulatory Authority the two couplers were changed and the signals applied via „L1“ and „L2“. Changing the coupling mode aimed at examining the effect of coupling on radiation.

On the stretch from the transformer station to the customer, the signals are conveyed on 4.26 MHz and on 2.38 MHz in the reverse direction.



8.1.4.1 Measurement configuration

In addition, the surrounding field strengths were determined at measurement points 1 and 2. To this end the antenna was mounted in a tripod at a height of about 1.5 metres. The peak field strengths in the aforementioned frequency range were measured in the scan mode with automatic attenuation. The values measured in this way represent the radiation pattern of the loop antenna used and hence do not constitute omnidirectional reception.

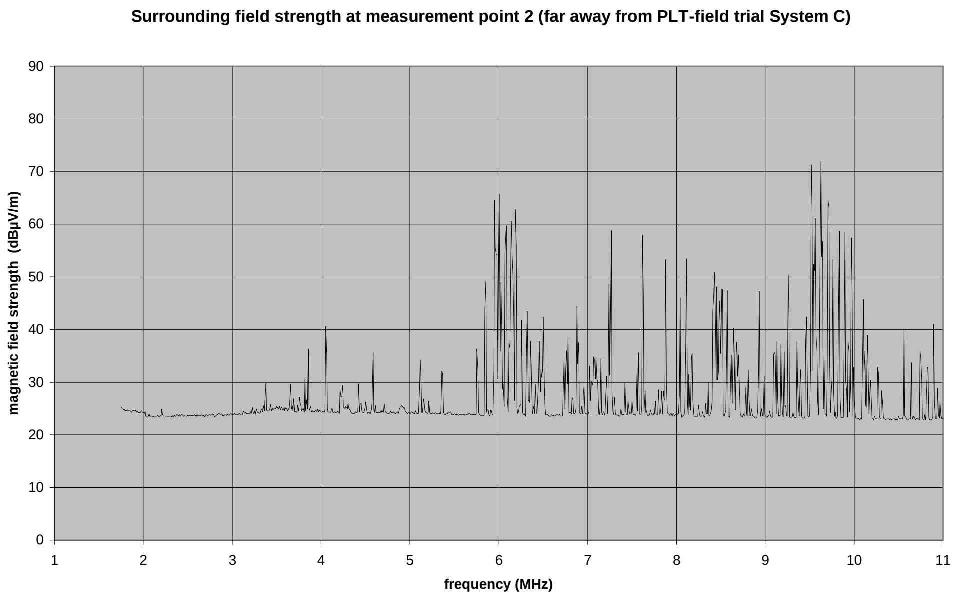
This measurement technique allows emissions in the powerline spectrum to be identified which are not generated by the spectrum itself.

8.1.4.2 Environment field strength

The field strengths measured at one antenna orientation only are shown below. The system setting is not known as no representatives of System C attended the measurements on 6 March 2000.

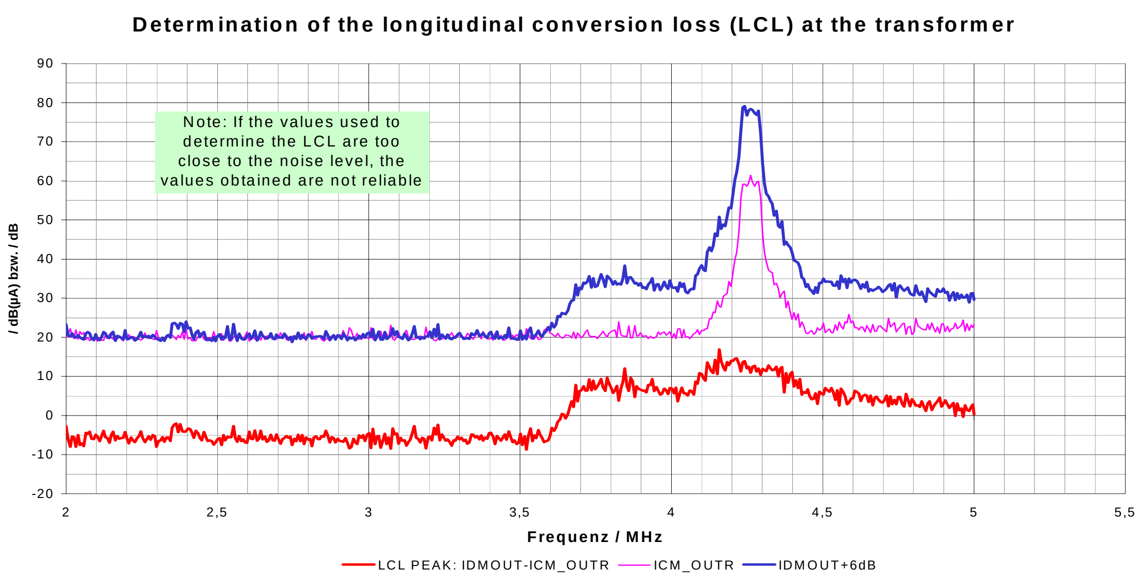
8.1.4.3 Fingerprint of the signal

The measured voltage is shown below:



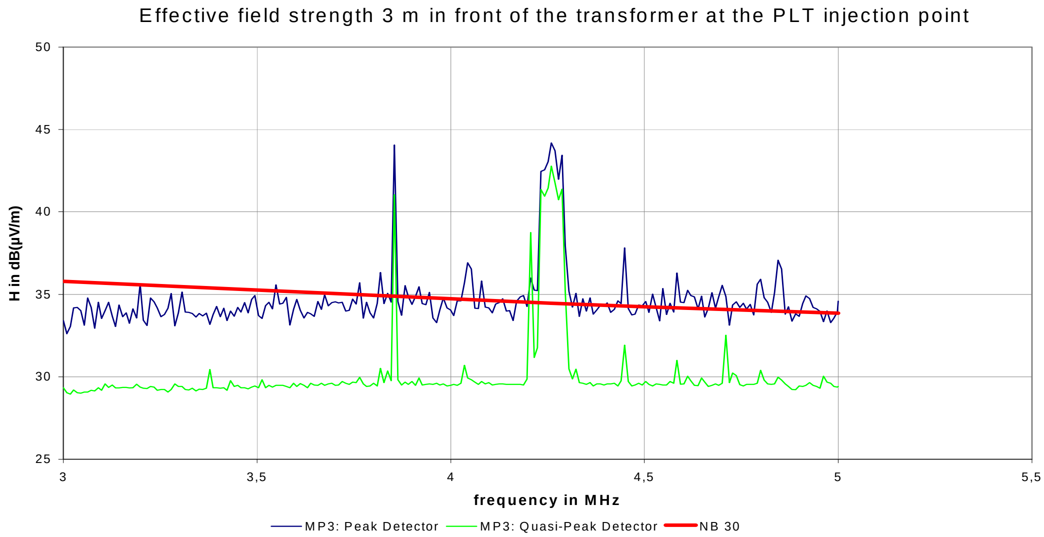
During the measurement of the symmetrical voltage and symmetrical current both signals (up- and downstream) were clearly observable. The symmetry of the cables assessed by the current measurement matched expectations.

The diagram below depicts the longitudinal conversion loss (LCL) at the transformer, based on the measurement of the symmetrical and asymmetrical disturbance current.



8.1.4.4 Field strength results

In the course of the field strength measurement carried out on 26 April 2000 all three orthogonal directions were scanned with a peak and quasi-peak detector to obtain data about the effective field strength. System C Company had removed the additional amplifier described prior to 26 April 2000. The transmit power was not optimised with regard to radiation. The results obtained are shown below:



The field strength value at virtually the same measurement point was of the same order of magnitude as at the last measurement. When comparing the field strength patterns of 14 March and 26 April it should be borne in mind that the effective field strength is based on the calculation of the three components whereas diagram MP3QP2 only represents one component. Measurement uncertainties have not been taken into account in either of the two diagrams.

8.1.4.5 Conclusions

The field strengths generated by the PLT signals are detectable using the measurement method described in Measurement Specification 322MV05 both inside and outside of buildings supplied with PLT.

In the case of a disturbance voltage of about 105 dBµV as measured at the injection point the field strength at a distance of 3 metres was close to the threshold values in example n°1 (NB30). An exact investigation revealed that example n°1 was exceeded at the measurement point „transformer station“.

8.1.5 Finland

8.1.5.1 Background

In Finland, there have been two access PLT trial networks involving two electricity companies using equipment from two PLT manufacturers. In October 2001, FICORA made field measurements in one of the two PLT trial networks.

8.1.5.2 Measured PLT system

PLT interface was connected to electricity outlets of 17 households of a block of flats under a single transformer station using underground cables.

8.1.5.3 Measurements

Radiated field strength was measured; 1) at 3 meters distance from the wall of the transformer cabinet and 2) inside the house on the ground floor in a staircase approx. 1 m from the mains cabling.

Subjective listening tests were also done using two portable SW broadcast receivers. The received interference audio was also recorded on tape.

Measuring equipment was compliant with CISPR requirements: measuring receiver using a peak detector, spectrum analyser and loop antenna.

First the background noise was recorded with PLT totally off. Then the PLT noise was measured with the PLT system on and loaded with full capacity by downloading a big data file from a local server. Interference levels were noted to be dependent on the loading of the PLT system.

8.1.5.4 Results

Measured PLT interference exceeded the example n°1 limit (NB30) considerably. Maximum indoor levels were about 15 ... 20 dB higher than outdoor values. Power spectrum of the interference occurred between 3 ... 23 MHz. Maximum outdoor PLT radiation occurred on the band 14 ...18 MHz. PLT interference values, measured by the Finnish Radio Administration, were declared confidential by the PLT manufacturer and operator, so detailed values cannot be given.

Subjective analysis using an HF broadcast receiver revealed that the PLT interference practically masked the broadcast bands which fell under the PLT spectrum, and it was almost impossible even to listen to any of the strongest HF broadcast stations indoors and outdoors roughly within 10 meters from buildings or underground cables. The PLT interference was characterised by a slow repetition rate impulse type noise. PLT interference decreased quite quickly while moving away > 30 meters from the building wall and underground cables.

8.2 Measurement results on DSL and LAN systems

8.2.1 ADSL measurements in Germany

8.2.1.1 Measurement configuration

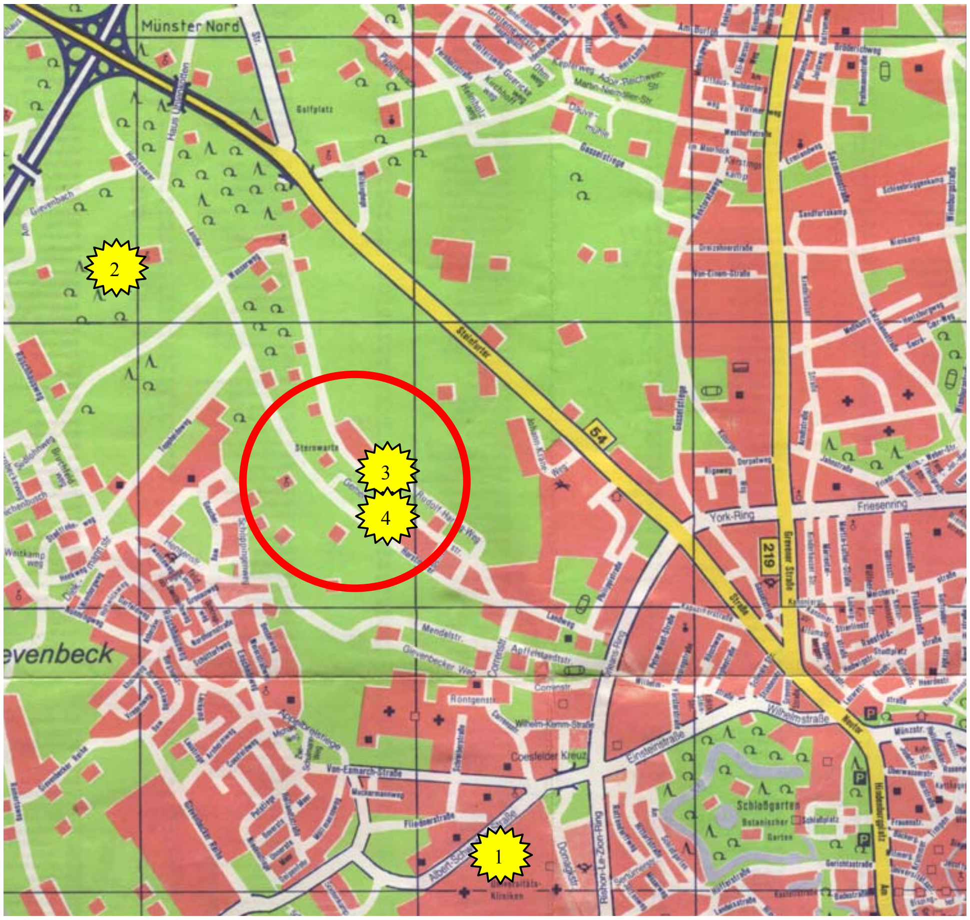
The following measurement campaign was done with a view to determining disturbance problems like radiating disturbance power. In the area where the field trial took place, were about 67 ADSL-Modems installed in a housing area of students.

Of course, it should be noted, that the system which was examined (ADSL over POTS), is not the final version for use in Germany. The difference is in using a shifted-up frequency spectrum so as not to have any interference in the ISDN Systems on the same Copper wire (ADSL over ISDN). The advantage of the field trial was the high density of ADSL-modems in one area. For example, this offered the possibility to switch off seven modems in one house and keep the other 60 modems in the area on.

The measurement locations followed the signal path in the downstream. The equipment used was CISPR-compliant : measurement-receiver, loop antenna, current clamp and voltage probe. At all locations, a scan was made in the frequency range by using the bandwidth 200 Hz in the range from 9 kHz to 150 kHz and a bandwidth of 9 kHz in the range from 150 kHz to 30 MHz. All the scans were made using a peak detector. The results of the X/Y/Z scans were stored on a floppy disk and transferred onto an Excel spreadsheet to calculate the effective field strength. The approach was in line with the measurement specification of the 1st draft of RegTP322MV05, May 1999.

8.2.1.2 Field trial

The trial was based in a student area of Münster.



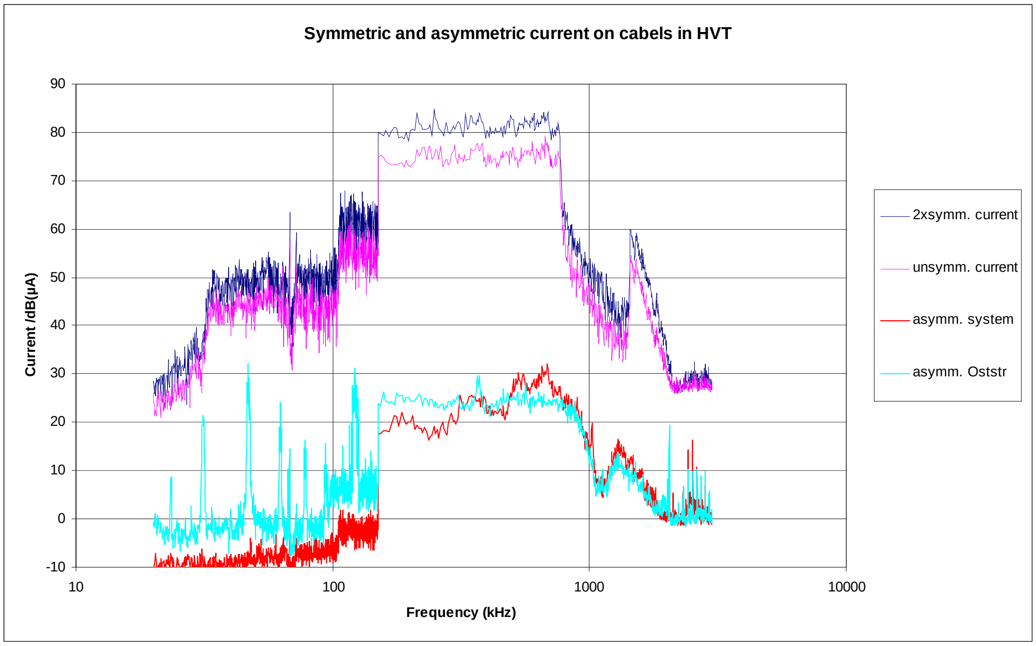
The signal was injected at a main switching unit at point 1 on the map. The meadow measuring point is located point 2 on the map. The housing area where all the 67 ADSL-modems were installed is no. 3.

Additionally there was a measuring point no. 4 in front of a switching box in the street. Of course, the results of this point were not inserted in this short report because the results do not deviate from the other values.

8.2.1.3 Fingerprint of the signal

The "fingerprint" of the ADSL signal was determined in measurements made at the OVSt. The unsymmetrical, asymmetrical and symmetrical current was measured using a current clamp.

The measurement result is shown below:



8.2.1.4 Environment field strength

To take the field strength without any disturbance, a measurement performed at a meadow using a CISPR loop antenna. A scan was made using peak detector in max hold in the frequency range 9 kHz to 30 MHz. On reaching 30 MHz, the scan was interrupted and the antenna was turned 45 degrees. Afterwards the scan was continued. Finally 4 scans were made and all signals were added. As a result, the values are independent of the direction.

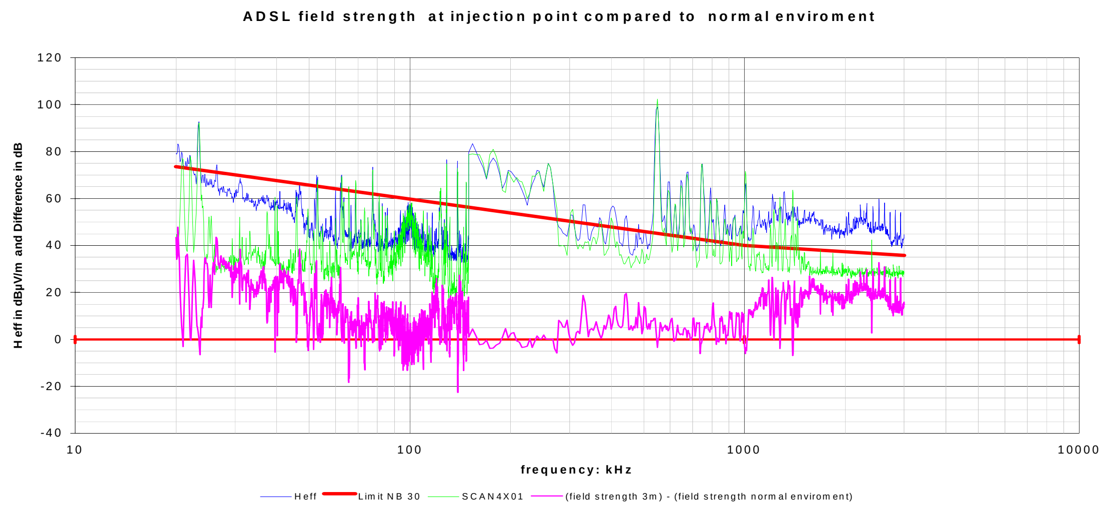
The measurement result is shown below on the curve called SCAN4X01 on the next paragraph's figure.

The radio broadcast frequencies can be very clearly identified. The change in the spectrum at 150 kHz depends on changing the bandwidth of the detector from 200 Hz to 9 kHz. In the vicinity of 100 kHz there are some easily noticeable signals that are due to the Loran C radionavigation system.

8.2.1.5 Field strength at main switching unit

The field strength was measured in three orthogonal directions (X/Y/Z) In this case, it was different to the results at the meadow. After transferring the values onto an Excel sheet, the effective field strength was calculated. The calculated field strength was compared to the meadow field strength by doing a subtraction. The difference shows in the range from 20 kHz to 90 kHz about 20 dB above the “meadow-level”. By comparing with the fingerprint, it was not reasonable coming from the ADSL-System.

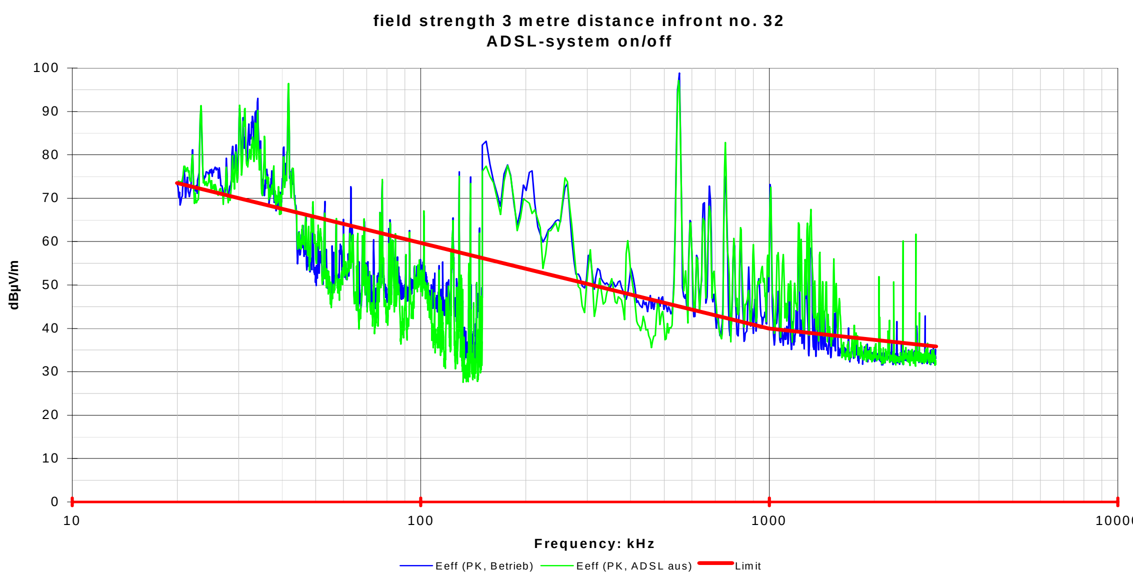
In the range 100 kHz to 1 MHz (downstream) there are field-strength levels which exceed the noise floor on the meadow (reference environment) by about 5 dB. The conclusion is, that the man-made noise in front of the local exchange (originating from all the equipment located inside the building incl. ADSL) has nearly the same level as the reference environment. The peaks exceeding the limit do not arise from the ADSL-System. The increase above 1 MHz is produced by luminescent lamps. To summarise, the exceeding levels are not produced by the ADSL system.



8.2.1.6 Field strength outside building

The following diagram has been obtained using the same procedure as described above.

In the evaluation phase after the measurements, it was recognised that this measurement point was directly above the telecommunication underground cable leading into the building. Therefore the distance to the installation was not 3m as prescribed in the measurement specification RegTP 322 MV 05. Consequently, the measured field strength levels cannot be used directly to verify compliance with example n°1 (NB30).



It should also be noticed, that there was a lot of man made noise. In this house there were 7 ADSL-modems in use. And every student, of course, uses a computer to have a connection to the ADSL modem.

8.2.1.7 Conclusions

The characteristics of an ADSL signal can be determined by using a current clamp at the injection point.

There was no possibility to compare the ADSL field strength directly with the example n°1 limit (NB30). The reason was the environment field strength of radio stations (e.g. LW,MW broadcasting) and, of course, electronic devices which produces disturbance field strength. Instead of comparing directly, the ADSL-System was shut down completely and scans were made in this turned off state. To eliminate the man made noise, there was made a second scan outside the city on a meadow. All scans were compared with these two reference graphics.

As a result of the comparing procedure described before, the fields from the ADSL-System comply with the example n°1 limit. However, it should be noticed, that the measurement procedure does not permit the ADSL-System to have higher disturbance field strength.

8.2.2 Measurements on DSL, LANs and other sources performed in the UK

Figure 8.2.2-1 shows in pink the radiation from ADSL on a short line, compared with the radiation emitted by lighting equipment, against the examples for limits n°3 (MPT 1570) and n°4 (BBC).

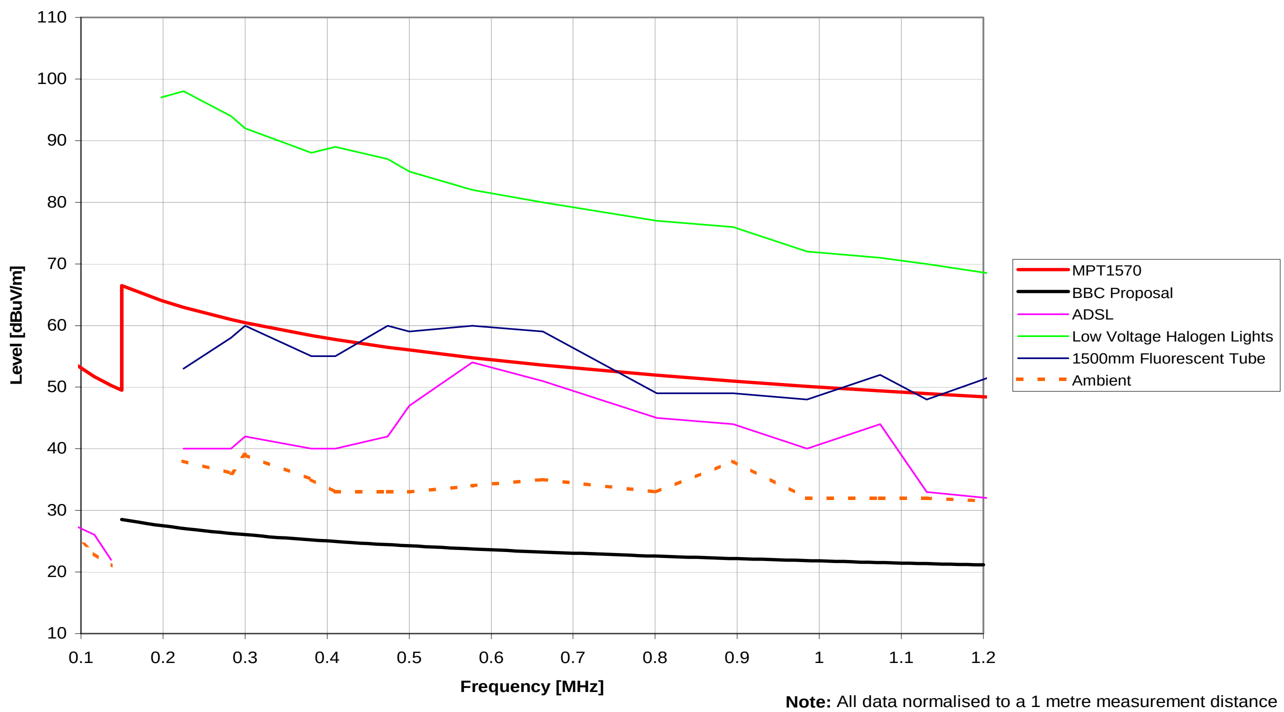


Figure 8.2.2-1: radiation from ADSL compared with radiation produced by lighting equipment

Figure 8.2.2-2 shows in orange the radiation from VDSL, compared with other wide spread cable protocols such as USB, Ethernet protocols 10BaseT and 100 Base T… against the examples for limits n°1 (NB30) and n°4 (BBC).

It can be seen that LANs emit at significantly high levels. However, such sources of interference are important in an office environment but are less widespread in a residential environment where typical levels are generally lower.

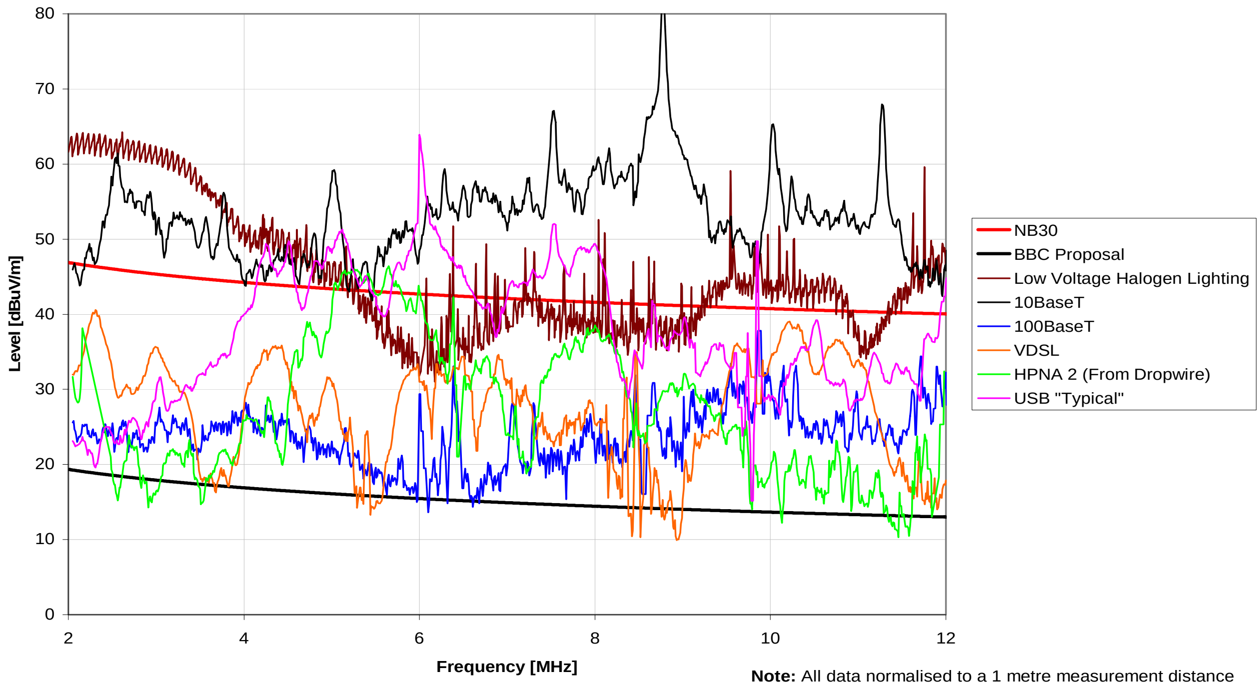


Figure 8.2.2-2: radiation from VDSL compared with other cable protocols and lights

8.3 Measurement results on cable TV networks

8.3.1 Ground Measurement results in Germany

8.3.1.1 Introduction

In view of the interference caused to the aeronautical service a pilot project was defined to evaluate 1000 households in a typical developed area served by cabled distribution systems.

8.3.1.2 Objectives

The project was to pursue the following goals:

1. Localisation of cable home wiring exceeding the standard limit of **20 dB(pW)**.
2. Determination of the reason for the deviation from the limit, classed according to network level 3 (NL 3), NL 4 and/or NL 5 (household unit-related distribution/final customer).
3. To gain experience regarding the complaints procedure in the case of non-compliant cable home wiring to be used in connection with the operator of the interfering network level (NL 3, NL 4 and/or NL 5).
4. Investigation of the remedies open to the operator of NL 3 in the case of severe degradations of NL 4 and 5 (disconnection of the subscriber's premises (i.e. NL 4) or of individual channels at the demarcation point).
5. Clarification of the intervention rights of NL 3 operators.
6. Fault rectification at NL 3, NL 4 and/or NL 5.
7. Verification of fault rectification after notification of work completion by the operator of the home wiring.
8. Overall cost assessment on the basis of 1000 households.
9. Overall assessment of the time required for country-wide rectification.
10. Statistical evaluation of the deviation in 10-dB steps.

8.3.1.3 Order of the work

The pilot project was carried out in the urban part of Hanover.

The following collateral conditions were determined:

- The 1000 households to be investigated should be located within an area at the edge of the VOR service area of the VOR transmitter Brünkendorf (identification code BKD and frequency 117.70 MHz) in the western/northwestern part of Hanover.
- If possible, the area to be selected should have an urban structure characterised by 55 % 1-2 household units, 37 % 3-5 household units, 6 % 6-25 household units and 2 % 26-100 household units and served primarily by DT AG cabled distribution systems.
- The measurements were to be carried out on the vision carrier frequency carrying a PAL signal on a special channel in the range S 4 to S 6. If possible, one of the special channels (S 4 to S 6) evincing the highest radiated disturbance power should be selected for the measurement of the individual vision carriers.
- During the individual measurements the interference source contributing to the deviation should be identified and the operator of the relevant network level identified so that an administrative order requesting rectification could be sent to it.
- The project was limited to a maximum of three months.

8.3.1.4 Time schedule

The project was split up into six phases, to be carried out either in parallel or sequentially, depending on the progress made.

The following phases had originally been defined:

- Phase 1 Location identification tour
- Phase 2 Individual measurements
- Phase 3 Administrative measures
- Phase 4 Fault rectification verification
- Phase 5 Location identification tour (performance assessment)
- Phase 6 Compilation of results.

Six weeks were allocated for phases 1 and 2. If it proved not possible to identify the required 1000 households the attempt to do so was to be aborted after 8 weeks and the results obtained adapted to 1000 households.

Contrary to the original plan fault rectification verification took place in parallel with the individual measurements in those cases where the faults could be rectified during the measurement. This was possible whenever an inadequately screened connecting cord had to be replaced.

The second location identification tour was cancelled because not all locations identified during the first tour were investigated. As agreed, the individual measurements were terminated on 27 October 1999.

8.3.1.5 Measurement

8.3.1.5.1 Location identification tour

During the location identification tour a short stop was made in front of each house to determine the field strength on the vision carrier frequency of special channel S6 by means of the measurement antenna FT-01. The field strength value and the distance to the house were registered. The distance and field strength were then used to calculate the interference power associated with the house.

When no data was available as to the actual number of household units in a building, this number was determined, inter alia, by counting the number of letterboxes.

8.3.1.5.2 Individual measurements

After the first location identification tour, those locations evincing the highest levels of interference were to be investigated first, by identifying the source and cause locally.

The measurements were to be carried out in the following sequence:

a) Identification of the interference source by disconnecting the demarcation point for a short time.
b) Registration of the contact persons for the individual household units.
c) Disconnection of the subscribers' premises.
d) Accurate registration of the radiated disturbance power in special channel 6.
e) Identification of the source of interference in the cable home wiring and documentation in the form of a photograph, if possible.

8.3.1.6 Results

8.3.1.6.1 Location identification tour

During the location identification tour a total of 715 buildings comprising 2368 household units were investigated.

This means that the area investigated was much larger than initially envisaged but that a suitable mix of building types had been found. The results are shown in Table 8.3.1.6.1-1.

	Total	1-2 HH	3-5 HH	6-20 HH	21-100 HH	> 100 HH
Building	715	544	74	77	20	0
	100.0%	76.1%	10.3%	10.8%	2.8%	0.0%
HH	2368	691	274	676	727	0
	100.0%	29.2%	11.6%	28.5%	30.7%	0.0%

Table 8.3.1.6.1-1: buildings characteristics

The interference powers registered during the location identification tour were divided into interference power classes as shown in Table 8.3.1.6.1-2. As can be seen from the figures, 277 buildings did not exceed the limit of 20 dBpW, implying that individual measurements had to be carried out in 438 buildings.

Any	I <= 20	20 < I <= 30	30 < I <=40	40 < I <= 50	50 < I <=60	I > 60
715	277	292	122	22	2	0
100.0%	38.7%	40.8%	17.1%	3.1%	0.3%	0.0%

Table 8.3.1.6.1-2: general measurement results

It was noticeable that the number of serious cases involving faulty home wiring, i.e. with more than 40 dBpW, was very low compared with the findings in previous measurement campaigns and that no values exceeding 60 dBpW were found.

8.3.1.6.2 Individual measurements

A total of 170 values were measured during the individual measurements. They are shown in Table 8.3.1.6.2-1.

Table 8.3.1.6.2-1: individual measurement results

Each measurement value represents responsibility for the faults at a network level. This means that multiple errors in a network level were not counted more than once. However, a fault at NL 4 and a fault at NL 5 were counted twice, even if it involved only one particular owner.

By way of example, the five highest interference levels were discovered in the following buildings:

1. First street 16H
2. First street 16H
3. Second street 5
4. Third street 18
5. Fourth street 30

The fact that *First street 16H* is listed twice indicates a fault both at NL 4 and NL 5.

A comparison between Table 8.3.1.6.1-2 and Table 8.3.1.6.2-1 reveals a shift in the individual interference power classes between the location identification tour and the individual measurements. These shifts are due to the measurement uncertainty of the identification tour and do not systematically point in a particular direction.

Cases also occurred in which buildings classed as "suspect" during the tour did not suffer from increased interference.

In Table 8.3.1.6.2-2 the measurement values are classified according to household type. Individual measurements hence revealed faults primarily in one- and two-family houses.

Associated household units (HH)					
Any	**1-2 HH**	**3-5 HH**	**6-20 HH**	**21-100 HH**	**> 100 HH**
132	**83**	**13**	**27**	**9**	**0**
100%	62.9%	9.8%	20.5%	6.8%	0.0%

Table 8.3.1.6.2-2: measurement results according to household type

The fault distribution revealed a relatively high number of faults at NL 5 (see Chart 1).

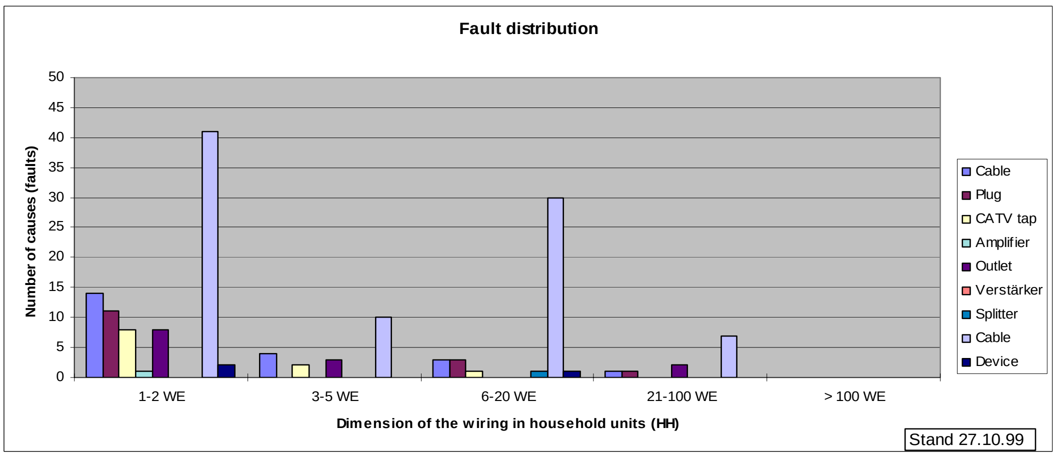


Figure 8.3.1.6.2: fault distribution repartition

As can be seen from this figure, 1-2 household units revealed the highest number of faults.

8.3.1.7 Summary

Measurements carried out in 1000 households in Hanover revealed cases in which the cable home wiring is faulty. In spite of numerous "simple" defects, such as unsuitable connecting cords, and in view of the decision to dispense with time-consuming substitution measurements for the individual measurements it was not possible to eliminate interference in the area entirely in the time available.

However, it should be noted that the area investigated exceeded the specified number of 1000 households. It is difficult to estimate the extent to which the pilot project may be deemed representative. The building types admittedly covered a wide range, yet no severe interferers were found.

All demarcation points in the area are made available by one provider which also offers customers the provision of NL 4 by reliable companies. It is not possible to state whether this may have affected the measurement results.

8.3.2 Aerial leakage measurement results in Germany

8.3.2.1 Summary

Some flight measurements were performed over the cities of Berlin (3,4 Mio inhabitants), Hannover (0,516 Mio inhab.), Neustrelitz (0,024 Mio inhab.) and Neubrandenburg (0,079 Mio inhab.).

The maximum field strength of CATV network radiation on 133,250 MHz (PAL image carrier), RMS, in 12 kHz and 7,5 kHz bandwidth, are as shown in the following Table 8.3.2.1.

The plane used for the measurements was a small Cessna with two piston engines. The antenna used for the measurements was a commercial λ/4 whip airborne antenna, commonly used in general aviation.

	E/dBµV/m, RMS		
	height 400m, BW 7,5 kHz	height 550 m, BW 12 kHz	height 6000 m, BW 12 kHz
Berlin	-	32,7	24,8
Hannover	32,0	-	-
Neustrelitz	-	21,2	-
Neubrandenburg	-	18,1	-

Table 8.3.2.1: maximum measured field strength in the air

The measurement results are described in more details in the following sub-sections, but no analysis of the data is made here. This analysis is made in Annex 9 where these measurement results have been used to calculate input parameters for the cumulative effect models described in this Annex.

8.3.2.2 Flight Measurement Results over Berlin

The results of the flight measurements over Berlin are contained in Table 8.3.2.2. The location of the points P1 to P11 can be seen in section 4.3.1 of Annex 9.

h = 550 m				
Points	measured E/dBµV/m	equivalent Eeq/dBµV/m	equivalent Eeq/µV/m	mean value of Eeq/µV/m
P 1	32,7	36,2	64,6	**45,2** (33,1 dBµV/m)
P 2	25,9	29,4	29,5	
P 3	31,1	34,6	53,7	
P 4	26,9	30,4	33,1	
h = 6000 m				
P 8	24,8	28,3	26,0	**23,5** (27,4 dBµV/m)
P 9	24,3	27,8	24,6	
P 10	23,5	27,0	22,4	
P 11	23,0	26,5	21,1	

Table 8.3.2.2: flight measurement results over Berlin

The measured field strength values in Table 8.3.2.2 are RMS in a 12 kHz bandwidth. The image carrier of the CATV channel S5, 133,250 MHz, was measured. While the measured field strength values for the lower height have great variation due to local areas without flats, the measured field strength values for the higher height is rather stable, because the measured field strength is smoothed due to the larger distance to the local areas without flats.

8.3.2.3 Flight Measurement Results over Neustrelitz

The flight measurement results for Neustrelitz are given in Table 8.3.2.3. There are only results for a height of 550 metres. Neustrelitz was not over flew directly at a height of 6000 m, and only a perceptible field strength in the Neustrelitz area was taken around 9 km aside of Neustrelitz, over an almost unpopulated area near a small village. If the town of Neustrelitz had generated this field strength, an equivalent leak density of around 9000/km^2 would have been necessary. Since this is an unrealistically high figure, another reason for this emission must exist. Therefore this measured field strength was not taken into account.

The measured field strength is RMS in a 12 kHz bandwidth, and the image carrier of channel S5, 133,250 MHz, was measured.

Points	measured E/dBµV/m	equivalent Eeq/dBµV/m	equivalent Eeq/µV/m
P 1	18,4	21,9	12,45
P 2	21,2	24,7	17,18

Table 8.3.2.3: flight measurement results over Neustrelitz at 550 m height

The situation of the measurement points is shown section 4.3.2 of Annex 9.

8.3.2.4 Flight Measurement Results over Neubrandenburg

The flight measurement results are shown in Table 8.3.2.4. There are only results for a height of 550 m. For a height of 6000 m, there is a maximum, but small measured field strength 5 km aside of the town of Neubrandenburg. Calculation showed that an effective leak density of 5000/km² would be necessary to generate the measured field strength. Since this figure is unreasonably high and is not in line with the results for 550 m height, there must be another reason for the measured value.

The measured values are RMS in a 12 kHz bandwidth, and the image carrier of S5, 133,250 MHz was measured.

Point	measured E/dBµV/m	equivalent Eeq/dBµV/m	equivalent Eeq/µV/m
P 1	18,1	21,6	12,02

Table 8.3.2.4: flight measurement results over Neubrandenburg, 550 m height

8.3.2.5 Flight Measurement Results over Hanover

The Hanover flight measurements were conducted in 1999, unfortunately not over the same part of Hanover, where RegTP did their measurements, but here one of the two measurement points is in an area similar to that RegTP used. The measurements were done in a height of 400 m. The results are given in Table 8.3.2.5, and are RMS over 7,5 kHz bandwidth. The image carrier of S4 (126,250 MHz) was measured.

Points	measured E/dBµV/m	equivalent Eeq/dBµV/m	equivalent Eeq/µV/m
1	30	33,5	47,32
2	32	35,5	59,57

Table 8.3.2.5: flight measurement results for Hannover, height 400 m

The location of the measurement points and the distribution of the parts of the radiating areas are shown in section 4.3.4 of Annex 9.

8.3.3 Measurement results in France

Three measurement campaigns on three cable networks in three different cities have carried out in France using the EN 50083-8 method and limit. In terms of limits, EN 50083-8 corresponds to the NB30 limit (example n°1) except that NB30 specifies a peak measurement and EN 50083-8 a quasi-peak measurement, this latter being therefore a slightly more relaxed requirement. Some typical results obtained during this measurement campaign are given in Annex 5, with the following conclusions:

- It is extremely difficult to distinguish between emissions from the cable network and emissions due to the radio transmitters or other sources received locally. In practise, a leakage location tool has been used together with measurements before and after intervention on the network (see figures in Annex 5) at places where the tool indicated some significant leakage, and it's only under these circumstances that it is relatively easy to identify radiation from the network;
- Even with the use of a 25 dB preamplifier in front of the spectrum analyser, the 27 dBµV/m limit of EN 50083-8 lies most of the time below the measurement system noise level, so that it is not possible to assess whether after intervention the network comply with the limit or not. Increasing the gain of the receiver would lead to saturation problems due to the high ambients and would require the use of notch filters that would make the measurement over the whole frequency band at one location extremely time-consuming, so that a complete verification of a network with this protocol is not realistic;
- The specified measuring distance of 3 m leads generally to a location of the measurement vehicle in the middle of the street, which is definitely not possible in big towns. Most measurements have therefore been performed at distances between 5 and 10 meters, with a corresponding decrease of the measured cable radiation level, and with even more sensitivity problems;
- All measurements have been made using a peak detector and a quasi-peak verification at each of the frequencies over the limit would be very time-consuming to perform;

As a conclusion, this measurement campaign points out the practical difficulties in applying the measurement method and limit defined in EN 50083-8.

8.3.4 Aerial leakage survey in Ireland

8.3.4.1 Background

Ireland has had cable television networks since the late 1960s. At the time these were managed and run by local operators or by community groups. In 1974 the Department of Posts and Telegraphs introduced a licensing scheme to regularise and introduce minimum standards to these operations.

In 1996 an act of the Oireachtas (parliament) led to the delegation of regulatory powers in the Telecoms sector from the Minister of Transport Energy and Communications to an independent body established by the act and in 1997 the Office of the Director of Telecommunications Regulation (ODTR) was formed to perform these duties. In 2003, ODTR changed its name to become ComReg.

At the start of 2001 at the request of the ODTR/ComReg, a cable operator arranged for the first aerial leakage surveys of cable networks in Ireland. The survey was to take place on all three networks and was to be performed during late July. The operator contracted this task to a company from Florida, USA.

Special permission had to be obtained from the Irish Aviation Authority including a new certificate of airworthiness for the aircraft after the equipment had been installed. Additional clearances had to be sought from the Gardai (Police) and the Department of Defence. The formal results of the survey were received by the ODTR/ComReg on the 10th of December 2001.

8.3.4.2 Procedure

The aircraft was flown at 1500ft (457.2m) at a speed of 120knots (222.2kmph). A 1 km square grid pattern was used to cover all of each licensed area. This was arranged in advance and the proposed flight plan was submitted to the appropriate authorities.
The data was sampled twice a second, with the GPS and signal level readings being combined in custom software. Each high sample point is valid for all signals emitting from the cable plant within a half mile radius (804.7 m).
A ground based leakage survey was carried out simultaneously with the flyover. Each ground survey covered two random 1 km squared areas of which one is presented here.
The frequency used was 139.25MHz, the leakage limit in Ireland for this frequency is 4dBμV/m.

8.3.4.3 Results (Ground Based, averaged by location, all results in dBμV/m)

Ardbeg			Kilmore Road	35.7
Crescent	23.5			
Drive	30.5		Malahide Road	45.7
Park	21			
Road	30.5		Maryfield Crescent	33.1
Ardcolum Ave	29.9		Mask	
			Avenue	27
Ardlea Rd	26.4		Drive	26
			Green	30
Brookville Park	26.7		Road	31.7
Brookwood			Pinewood	
Avenue	33		Grove	31.5
Drive	21.5		Rise	50
Road	23.9		School Avenue	35
Castleview	38		St. Brendans	
			Avenue	38.1
Chanel			Drive	29
Avenue	34.5			
Road	28.1		St. Brighids	
			Close	33
Craigford Avenue	33		Crescent	31
			Grove	26.4
Danieli Drive	31.2		Road	26.7
Gracefield Road	30.6		St. Davids Wood	30
Hazelwood			Rosemount Avenue	30
Drive	49			
Park	30			

Table 8.3.4.3: aerial leakage results in Ireland

Notes:
- The network in this area is overhead and the homes are typically two stories with the Distribution being suspended from the eaves at a height of around 5m.
- The results for the ground based survey have been averaged on a per street basis and corrected for a distance from the network of 10m. The field strengths were measured using a horizontally polarised calibrated antenna. Only the peak readings opposite taps or amplifiers have been counted.
- One Hundred and one test points were out of compliance in the one square kilometre area.
- These are arithmetic averages and do not take into account cumulative or phased array effects.

8.3.4.4 Aerial Survey Results

42.3dBµV/m at 457.2m at the centre of the 1 km square area.

8.3.4.5 Conclusions

From this survey it is clear that there is some cumulative addition of the signals emanating from the network.

Further analysis needs to be carried out possibly modelling the network as an array of point sources each with a respective phase shift dependent on their position in the network and the theoretical phase response of the components in the chain at that frequency.

8.4 Radiation from equipment below 30 MHz

A measurement campaign has been performed in France to determine the radiation level produced by various types of equipment, some being part or being connected to the telecommunication networks (computer, TV…) and some being outside the field of telecommunications.

In order to clearly identify emissions produced by the evaluated devices from the radio signals present in the electromagnetic environment, a first series of measurements has been done in a Faraday cage and a second series has been done in real life conditions. The complete measurement results are given in Annex 6.

They have been done according to the method defined in the draft CEPT ECC Recommendation, i.e. using measuring equipment compliant with the CISPR 16-1 and CISPR 16-2 standards.

The main measurement parameters are as follows:
- 9 kHz <f< 150 kHz: standard CISPR resolution bandwidth of 200 Hz ;
- 150 kHz<f<30 MHz: standard CISPR resolution bandwidth of 9 kHz (10 kHz used in practise on spectrum analysers) ;
- Measurements with a peak detector as most of the proposed limits are defined in peak;
- As some limits are defined at 1 meter (examples n°3 and n°4 for example) and some other at 3 meters (example n°1, n°2 and n°5), measurements have been done as far as possible at these two distances.

The main results of these measurements are the following:
- Using standard CISPR instrumentation, measurements with sufficient margin with regard to the limit to be checked is not possible, particularly for example n°2 and n°4 limits;
- When doing in-situ measurements, the wanted signals from the radio services received on site is generally higher than most of the proposed limits, making it difficult in practise to determine whether the evaluated device or system meets or not the limit;
- Many equipment that can be connected to a cable transmission network (computer, TV set…) currently radiate at or above the example n°1 and n°3 limit and largely exceed the example n°2 and n°4 limits; they however generally meet example n°5 limit;
- Non-telecommunication equipment such as microwave ovens… exceed example n°1, n°2, n°3 and n°4 limits and even example n°5 in the case of a grinding machine;
- Inside a telecommunication centre, radiation largely exceed all example n°1, n°2, n°3, n°4 and n°5 limits.

8.5 Sensitivity issues

One of the points of discussion is the ability to measure low interference levels. As generally is known, the normally used EMI field strength measuring equipment is rather insensitive and is showing a relatively high level of internal generated noise.

An example of that equipment is the CISPR loop antenna. In a screened room we measured the noise floor of this antenna in combination with the CISPR-16 measuring receiver. Three sets of measurements were performed, the first one using the average detector and a bandwidth of 10 kHz, the second one using the quasi-peak detector and a 9 kHz

bandwidth (as defined in CISPR 16), and the third measurement using the peak detector in combination with a bandwidth of 10 kHz.
The results has were plotted in figure 8.5-1, together with the limit examples: Example n°1 (NB30) at 3 m distance, example n° 2 (Norwegian example) at 3 m distance, example n° 2 converted to 1 m distance, and example n° 4 at 1 m distance. In this way a comparison is possible with the measurement noise floor.

A far more sensitive measuring antenna has been described by Mr David Lauder and James Moritz of the University of Hertfordshire[22]. Noise data from their report were plotted in figure 8.5-2, together with the same limit curves as in figure 8.5-1.

From figure 8.5-2, it can be concluded that the noise floor in the peak detector mode of the described field strength measurement system is below all proposed limits.

As far as known the measuring system is not commercially available by now. But this could change when a standard is agreed, which gives a need for this equipment.

[22]"Design of a portable measuring system capable of quantifying the LF and HF spectral emissions from telecommunications transmission networks at field strengths of 1 µV/metre and below". Report prepared for the Radiocommunications Agency, RA ref: AY3430 (51000 2080). http://www.radio.gov.uk/rahome.htm

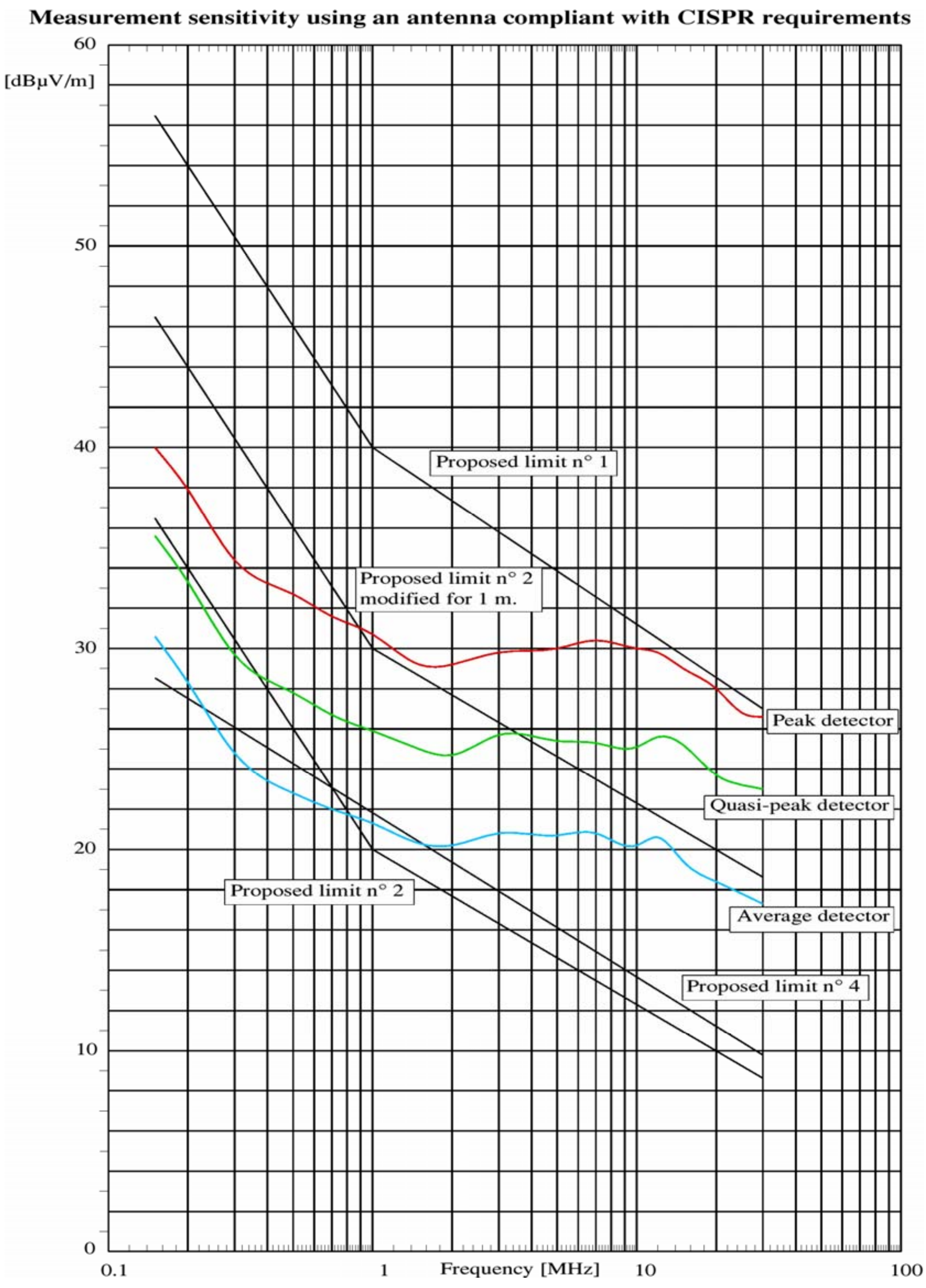


Figure 8.5-1: measurement sensitivity using a CISPR compliant antenna

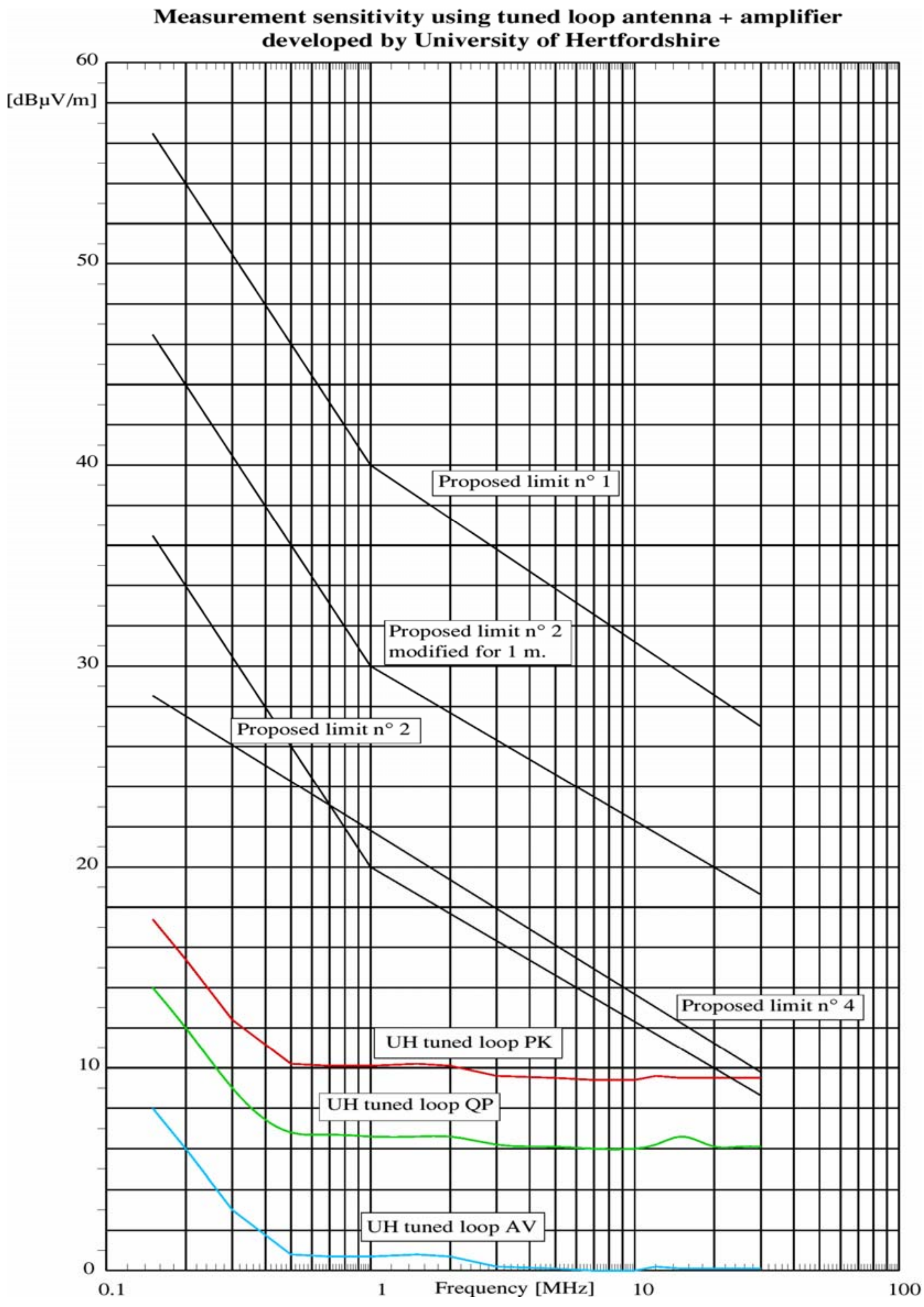


Figure 8.5-2: measurement sensitivity using antennas develop in the UK

8.6 Electric cables characteristics

Low-voltage power-line networks are designed for transmission of electrical power at low frequency (50 or 60 Hz), where the wavelength is several thousands kilometres and the lines can be of mixed mesh and star types and tapped without any transmission problems because even big cities remain electrically short. This kind of construction leads to multi-path propagation at frequencies when the lines become electrical long. At 20 MHz the wavelength is about 10 m and even a home is electrically long. Multi-path propagation leads to forward echoes, which complicate high capacity digital transmission. The measurements made demonstrate clearly these difficulties. The main principle of line-transmission is that the transmitted signals should be kept inside the cables. This is not followed because the power-lines are unsymmetrical, unscreened and the line can be regarded as a broadband antenna system which electromagnetically pollutes its surroundings. Looking from the telecommunications point of view power-line are unbalanced, unscreened, radiating, noisy, time variant, and multi-path transmission media.

Several measurements of typical parameters (attenuation, insertion loss, return loss) of electric cables from actual installations have been carried out. The following example shows the influence of the fuses at the meter.

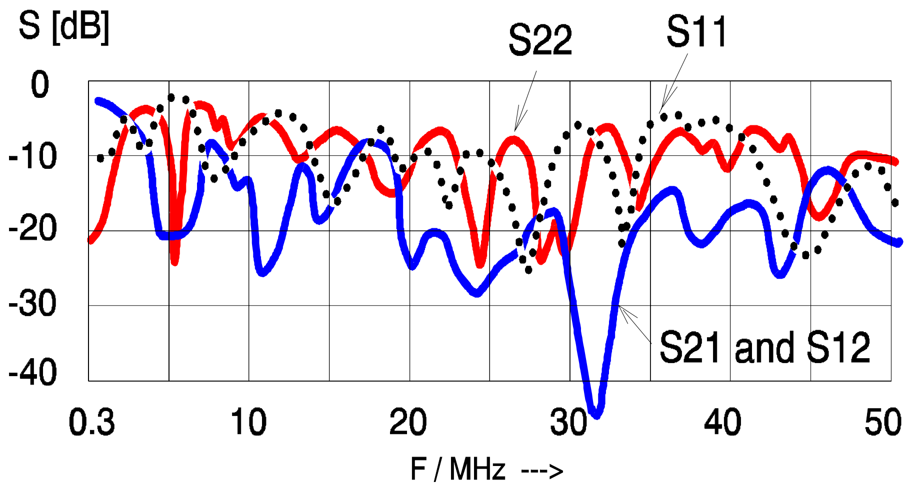


Figure 8.6: operational insertion loss and return losses of a Home fuse Group Supply (HGS) circuit

These results show that the power-line network should be more regarded as a broadband antenna system with many resonance frequencies than a line transmission network.

The real measured network is very complicated and includes large capacitors. The quality of a power line telecommunication transmission channel is far below a class D or SOHO data channel (100 MHz). For a maximum 100 meter channel the maximum attenuation is 24 dB, the minimum return loss is 10 dB and the minimum equal level far-end crosstalk attenuation is 17.4 dB.

9 COMPATIBILITY STUDIES

This chapter presents the results of the compatibility studies between cable transmission systems and radio services that have been performed. At frequencies below 30 MHz, the following cases are studied:

- Cumulative effect of broadband PLT using the HF frequency band ;
- Compatibility between Short Range Devices and cable transmission systems ;
- Impact of cable transmissions on the planning of a radio service ;
- Interference calculations based on the noise floor in the HF band ;
- Relationship between the received interference from Power Line Communication by an amateur radio station and the various proposed limits.

At frequencies above 30 MHz, the compatibility between cable TV and aeronautical navigation systems has been studied.

9.1 Cumulative effect of broadband PLT using frequencies below 30 MHz

A summary of the studies done under this topic is presented in Annex 7.

Calculations of potential cumulative effect from PLT systems towards radiocommunications services have been performed assuming four interference scenarios:

- Victim radio receiver in the sky with a directly received interference (free space propagation);
- Victim radio receiver in the sky with an interference received by skywave propagation;
- Victim radio receiver on the ground with an interference received by groundwave propagation;
- Victim radio receiver on the ground with an interference received by skywave propagation;

The input parameters for the PLT systems vary as follows:

- Injected power between –40 dBm/Hz to –70 dBm/Hz;
- Equivalent gain of the electrical cabling between –20 dBi to –50 dBi;
- Density of interferers from 3 to 100 / km².

Depending on the chosen value for each of these parameters, the overall EIRP density of all interference sources ranges from –170 dBW/m^2/10 kHz (no cumulative effect problem) to –80 dBW/m^2/10 kHz (definite cumulative effect problem).

9.2 Compatibility between Short Range Devices and cable transmission systems below 30 MHz

The position of installed EAS/RFID equipment is mostly close to entrances, walls, and ceiling. So a well-estimated distance between mains wiring in the building and antennas of an EAS/RFID system is 1 meter. This means that in case of PLT the interference field at a distance of 1 m from the mains wiring must not exceed 38 / 35 dBµV/m if interference to EAS/RFID system is to be prevented.

Although EAS/RFID systems generally use far field cancelling techniques like quadropole antennas, this will only cancel the reception of signals and noise with a nearly homogeneous field close to the antenna. The field, generated by mains wiring, is far from homogeneous and will not reduce the noise from radiated PLT signals.

Besides direct coupling from mains wiring to EAS system antennas, there is also an indirect path from the mains wiring inducing RF currents into close coupled metal structures. Those structures again closely couple with the EAS antennas. In this way a complex EM space can exist inside buildings. Some EAS companies have more than 20 years of experience with this kind of phenomena which can result in extra coupling effects of more than 10 dB.

The result is that the earlier mentioned level of 38 / 35 dBµV/m must be lowered to **28 / 25 dBµV/m a**t a measuring distance of 1 m. This means that at the proposed measuring distance of 3 m the limit should be 1**8 dBµV/m** for 8 MHz and 1**5 dBµV/m** for 13.56 MHz systems.
In the next table the requirements of the EAS and RFID industry is compared with the proposed radiation limits.

Frequency band	Usage	Industry requirement	Example n°1	Example n°2
119 – 148.5 kHz	EAS/RFID	35	58.1	
1.65-2.1 MHz	EAS	24	37.7	18.0
3.155-3.4 MHz	EAS/RFID	21	35.5	16.1
4.75-8.815 MHz	EAS/RFID	18	31.9	13.1
9.1 - 11.0 MHz	EAS	17	31.2	12.3
11.56 - 15.56 MHz	RFID (+EAS)	15	30.0	11.3
All field strength numbers in dBµV/m at a measuring distance of 3 meter.				

Table 9.2: all field strength numbers in dBµV/m at a measuring distance of 10 meters.

9.3 Impact of cable transmissions limits on the planning of a radio service

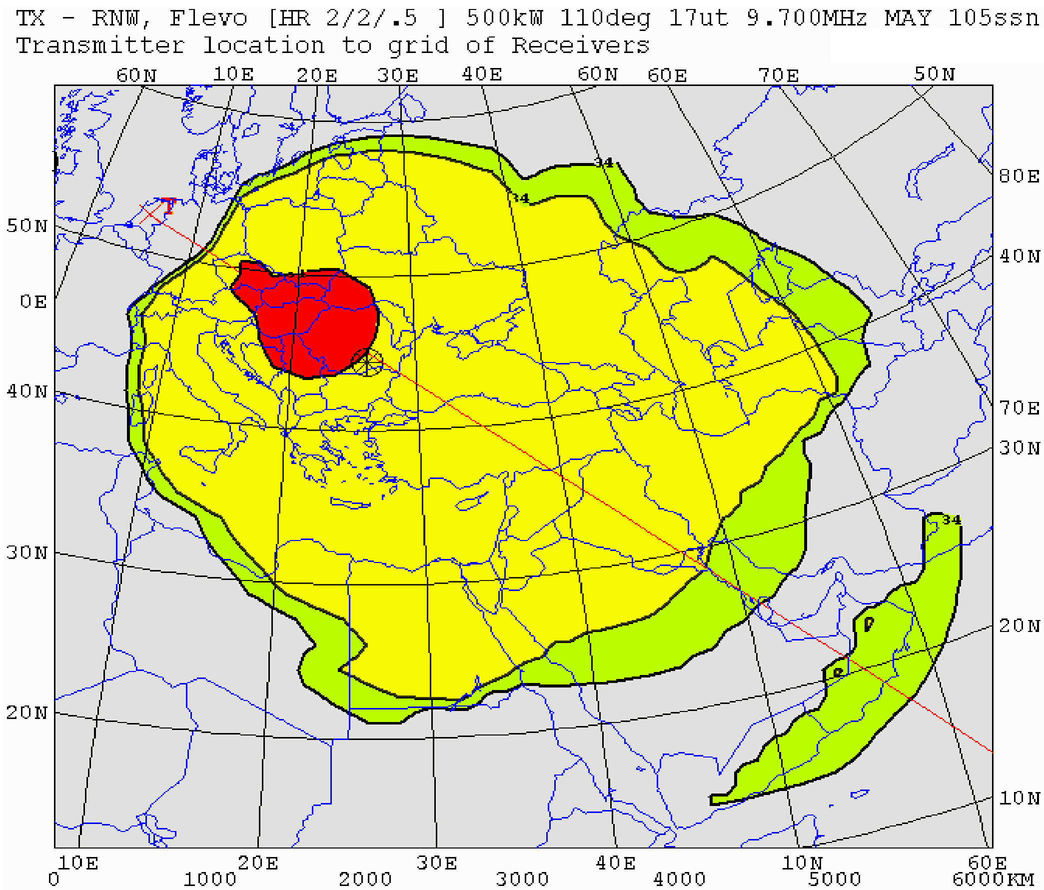


Figure 9.3: impact of proposed national emission limits for PLT, DSL and cable communications on the coverage area of HF broadcast transmissions.

Size of coverage area in case of:

- Residential environment man-made noise only
- Increased noise floor imposed by the example n°2 limit
- Increased noise floor imposed by the example n°1 limit (NB30).

The figure illustrates the impact of emissions on broadcast reception, assuming that reception takes place indoors at a distance of 1 meter from a cable, and that emissions from the cable at that point are at the level that would be permitted by the example[23] as specified in the legend of figure 1.

To still cover the intended (green) area, a considerable increase of transmitter power is necessary, or more transmitter stations are required. It's obvious that this is impossible with respect to costs and frequency availability.

In the future, with high emission levels corresponding to example n°1 limit, reception of shortwave radiosignals will be very difficult. The example n°2 example already shows a better compromise but still results in a significant reduction of the area coverage size.

The example n°4 on the other hand will present shortwave broadcasting with very reasonable protection. Although it protects the reference scenario well (with the reference scenario being outdoor reception, 10 meters away from a potentially-interfering cable), indoor reception with a small proximity to interfering cables has to accept greater compromise. This applies generally to shortwave broadcast listeners.

[23] Limit levels have been corrected for a distance of 1 meter to cables, assuming field varies as 1/r.

The example transmission chosen for this calculation is still quite optimistic, since the increase in noise level would be even greater compared to rural and quiet rural environments. Also a distance of 1 meter from any potentially-interfering cable will be hard to accomplish for an in-house reception and even outdoors in a residential or business environment.

In case of high emission levels, quality of existing services will deteriorate to such a level that reliable reception will be nearly impossible to achieve with current broadcast telecommunications systems in use. Only a considerable increase of transmitter power can provide the same reliability again. It's obvious that this is impossible, neither technically nor financially.

9.4 Interference calculations based on the noise floor in the HF band

In this section are given calculations results on the impact on the noise floor of interference produced by cable transmission systems and other sources.

9.4.1 Protection Criteria

The protection criteria used in the present calculations is defined in Section 3.6.5.1 of this report (0.5 dB sensitivity degradation with regard to the noise floor defined in Section 3.2.3).

9.4.2 Separation distances between cable transmission and radio systems

Based on the above-mentioned parameters and assuming a free space propagation model, the following tables and figures show the separation distances between cable transmission systems and victim HF receivers, for four of the five proposed radiation limits for cable transmission systems.

Note: a minimum separation distance equal to 0.0 m means that the victim at any separation distance would not suffer sensitivity degradation of more than 0.5 dB.

9.4.2.1 Separation distances in the case of the example n°1 limit (NB30)

		Quiet Rural			Rural			Residential			Business		
Frequency (MHz)	Limit at 3 m (dBuV/m)	Max Interference Level Quiet Rural (dBm/Hz)	Max Interference Level Quiet Rural (dBuV/m)	Min Separation Quiet Rural (m)	Max Interference Level Rural (dBm/Hz)	Max Interference Level Rural (dBuV/m)	Min Separation Rural (m)	Max Interference Level Residential (dBm/Hz)	Max Interference Level Residential (dBuV/m)	Min Separation Residential (m)	Max Interference Level Business (dBm/Hz)	Max Interference Level Business (dBuV/m)	Min Separation Business (m)
1,5	38,5	-134,6	-14,3	920,7	-120,8	-0,5	188,9	-115,5	4,8	102,6	-111,2	9,1	62,6
2	37,4	-138,1	-15,4	917,7	-124,3	-1,5	185,9	-119,0	3,8	101,0	-114,7	8,1	61,6
3	35,8	-143,1	-16,9	910,9	-129,2	-2,9	181,8	-123,9	2,4	98,8	-119,6	6,7	60,2
4	34,7	-146,6	-17,8	896,0	-132,6	-3,8	178,9	-127,3	1,5	97,2	-123,0	5,8	59,3
5	33,8	-149,0	-18,3	860,0	-135,3	-4,6	176,4	-130,0	0,7	96,0	-125,7	5,0	58,5
6	33,2	-150,6	-18,3	794,5	-137,4	-5,1	174,1	-132,2	0,1	94,9	-127,9	4,4	57,9
7	32,6	-151,6	-18,0	711,8	-139,2	-5,6	171,6	-134,0	-0,4	94,0	-129,7	3,9	57,4
8	32,1	-152,3	-17,5	637,2	-140,8	-6,0	169,2	-135,6	-0,8	93,1	-131,3	3,5	56,9
10	31,2	-154,2	-17,4	571,6	-143,4	-6,7	165,8	-138,3	-1,5	91,7	-134,0	2,7	56,2
10	31,2	-150,6	-13,9	380,5	-143,0	-6,2	157,7	-138,1	-1,4	90,3	-134,0	2,8	55,9
12	30,5	-153,0	-14,6	383,4	-145,2	-6,9	156,6	-140,3	-2,0	89,5	-136,2	2,2	55,3
14	29,9	-154,9	-15,2	383,6	-147,1	-7,4	155,4	-142,2	-2,5	88,8	-138,0	1,7	54,9
16	29,4	-156,6	-15,7	383,5	-148,7	-7,8	154,5	-143,8	-3,0	88,1	-139,6	1,2	54,5
18	29,0	-157,9	-16,1	378,1	-150,1	-8,2	153,2	-145,2	-3,4	87,5	-141,0	0,8	54,1
20	28,6	-159,0	-16,3	369,0	-151,3	-8,6	151,9	-146,5	-3,7	86,9	-142,3	0,5	53,8
22	28,2	-160,0	-16,4	359,3	-152,4	-8,8	150,5	-147,6	-4,0	86,4	-143,4	0,2	53,5
24	27,9	-160,8	-16,5	349,9	-153,4	-9,1	149,2	-148,6	-4,3	85,8	-144,5	-0,1	53,2
26	27,5	-161,6	-16,6	341,0	-154,4	-9,3	147,9	-149,6	-4,5	85,3	-145,4	-0,4	52,9
28	27,3	-162,3	-16,6	332,6	-155,2	-9,5	146,7	-150,5	-4,8	84,9	-146,3	-0,6	52,7
30	27,0	-163,0	-16,7	324,6	-156,0	-9,7	145,6	-151,3	-5,0	84,4	-147,2	-0,9	52,4

Table 9.4.2.1: separation distances in the case of the example n°1 limit

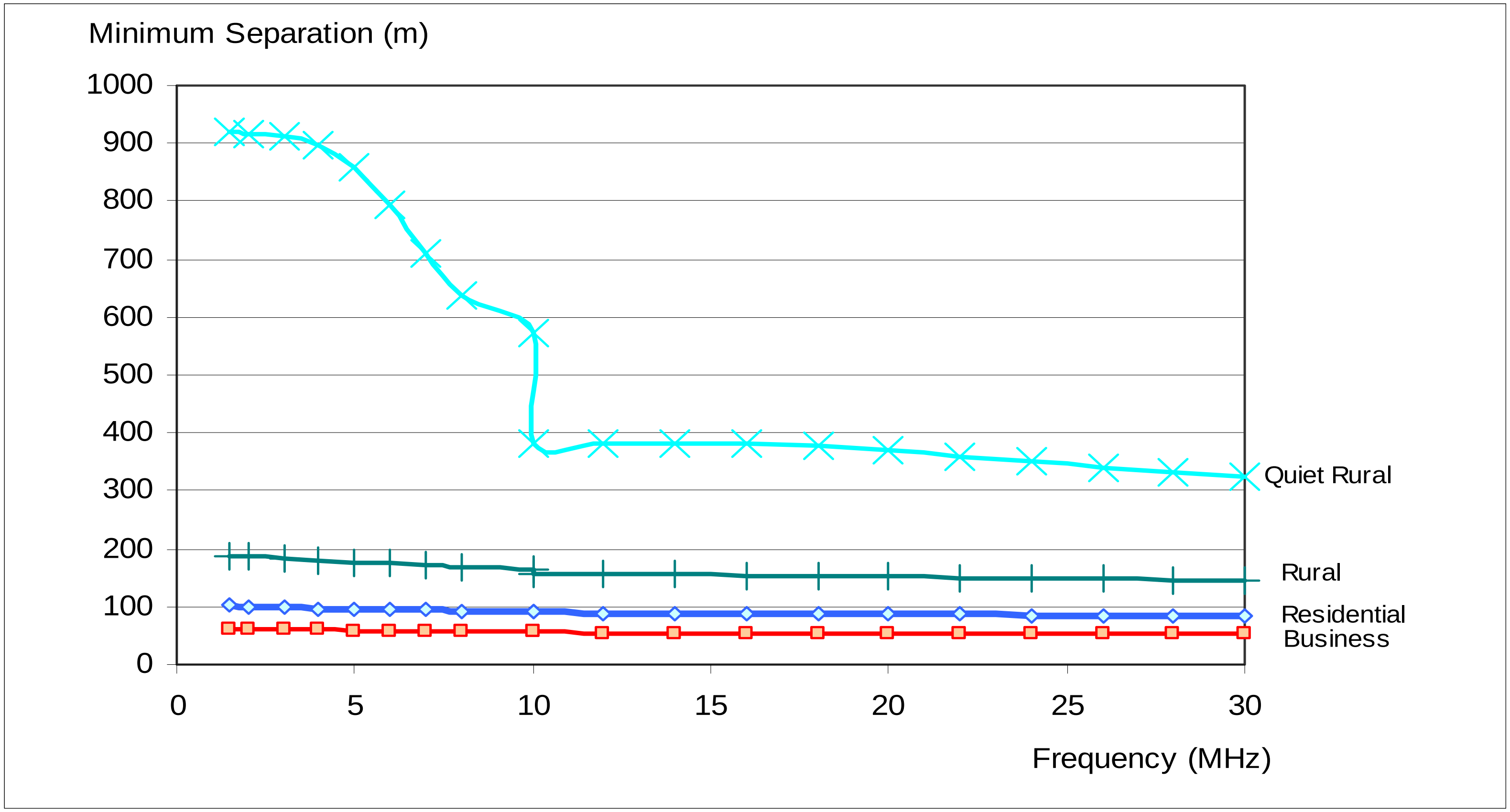


Figure 9.4.2.1: separation distances between cable transmission and radio systems in the case of Example n°1 limit

9.4.2.2 Separation distances in the case of the example N°2 limit

		Quiet Rural			Rural			Residential			Business		
Frequency (MHz)	Limit at 3 m (dBuV/m)	Max Interference Level Quiet Rural (dBm/Hz)	Max Interference Level Quiet Rural (dBuV/m)	Min Separation Quiet Rural (m)	Max Interference Level Rural (dBm/Hz)	Max Interference Level Rural (dBuV/m)	Min Separation Rural (m)	Max Interference Level Residential (dBm/Hz)	Max Interference Level Residential (dBuV/m)	Min Separation Residential (m)	Max Interference Level Business (dBm/Hz)	Max Interference Level Business (dBuV/m)	Min Separation Business (m)
1,5	18,6	-134,6	-14,3	94,1	-120,8	-0,5	19,3	-115,5	4,8	0,0	-111,2	9,1	0,0
2	17,7	-138,1	-15,4	95,3	-124,3	-1,5	19,3	-119,0	3,8	0,0	-114,7	8,1	0,0
3	16,3	-143,1	-16,9	96,8	-129,2	-2,9	19,3	-123,9	2,4	10,5	-119,6	6,7	0,0
4	15,4	-146,6	-17,8	96,7	-132,6	-3,8	19,3	-127,3	1,5	10,5	-123,0	5,8	6,4
5	14,6	-149,0	-18,3	94,0	-135,3	-4,6	19,3	-130,0	0,7	10,5	-125,7	5,0	6,4
6	14,0	-150,6	-18,3	87,7	-137,4	-5,1	19,2	-132,2	0,1	10,5	-127,9	4,4	6,4
7	13,5	-151,6	-18,0	79,2	-139,2	-5,6	19,1	-134,0	-0,4	10,5	-129,7	3,9	6,4
8	13,0	-152,3	-17,5	71,4	-140,8	-6,0	19,0	-135,6	-0,8	10,4	-131,3	3,5	6,4
10	12,3	-154,2	-17,4	64,9	-143,4	-6,7	18,8	-138,3	-1,5	10,4	-134,0	2,7	6,4
10	12,3	-150,6	-13,9	43,2	-143,0	-6,2	17,9	-138,1	-1,4	10,2	-134,0	2,8	6,3
12	11,7	-153,0	-14,6	44,0	-145,2	-6,9	17,9	-140,3	-2,0	10,3	-136,2	2,2	6,3
14	11,2	-154,9	-15,2	44,4	-147,1	-7,4	18,0	-142,2	-2,5	10,3	-138,0	1,7	6,3
16	10,7	-156,6	-15,7	44,7	-148,7	-7,8	18,0	-143,8	-3,0	10,3	-139,6	1,2	6,3
18	10,3	-157,9	-16,1	44,3	-150,1	-8,2	18,0	-145,2	-3,4	10,3	-141,0	0,8	6,3
20	10,0	-159,0	-16,3	43,5	-151,3	-8,6	17,9	-146,5	-3,7	10,2	-142,3	0,5	6,3
22	9,7	-160,0	-16,4	42,6	-152,4	-8,8	17,8	-147,6	-4,0	10,2	-143,4	0,2	6,3
24	9,4	-160,8	-16,5	41,7	-153,4	-9,1	17,8	-148,6	-4,3	10,2	-144,5	-0,1	6,3
26	9,1	-161,6	-16,6	40,8	-154,4	-9,3	17,7	-149,6	-4,5	10,2	-145,4	-0,4	6,3
28	8,9	-162,3	-16,6	40,0	-155,2	-9,5	17,6	-150,5	-4,8	10,2	-146,3	-0,6	6,3
30	8,6	-163,0	-16,7	39,1	-156,0	-9,7	17,6	-151,3	-5,0	10,2	-147,2	-0,9	6,3

Table 9.4.2.2: separation distances in the case of the example n°2 limit

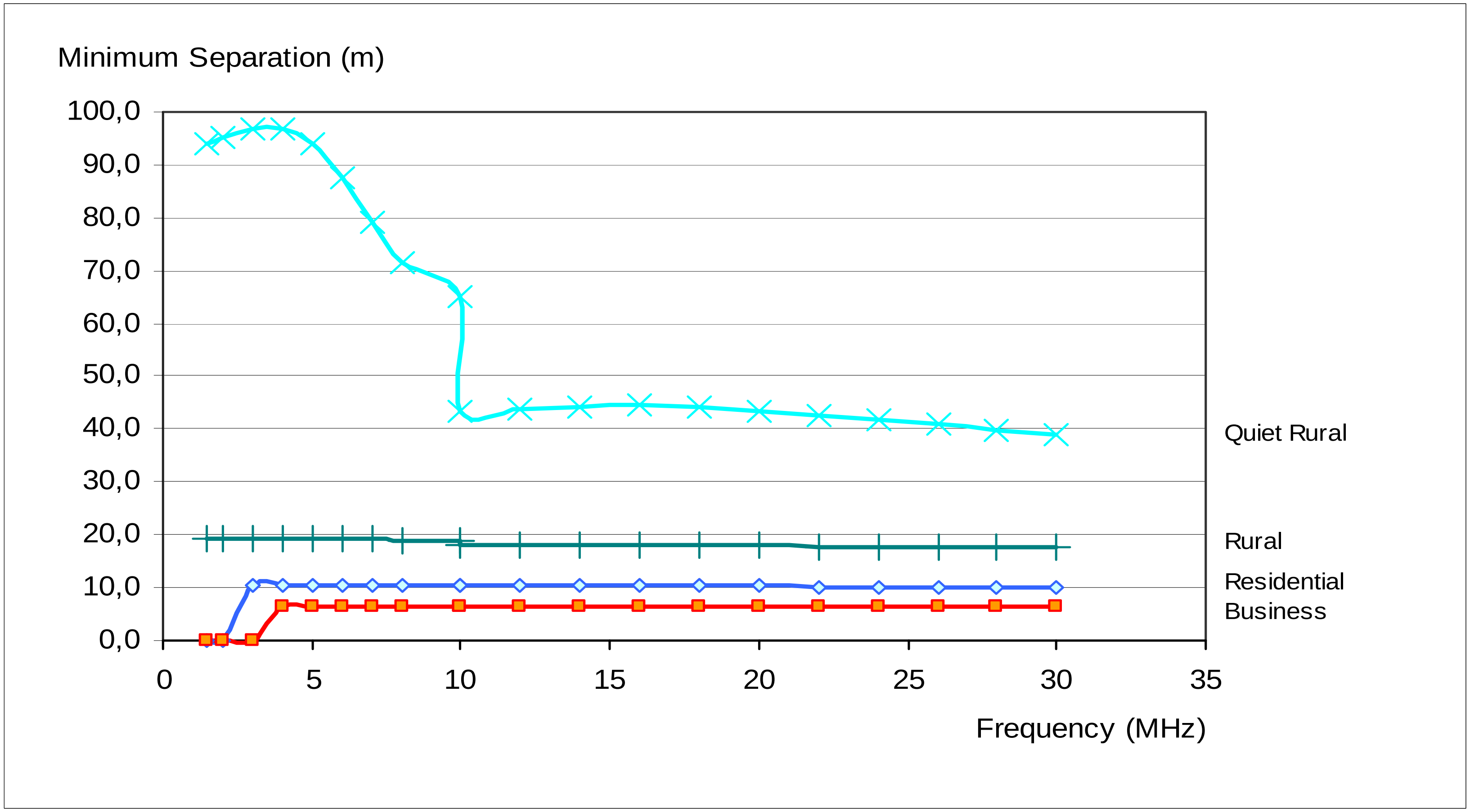


Figure 9.4.2.2: separation distances between cable transmission and radio systems in the case of Example n°2 limit

9.4.2.3 Separation distances in the case of the example N°4 limit

		Quiet Rural			**Rural**			**Residential**			**Business**		
Frequency (MHz)	**Limit at 3 m (dBuV/m)**	**Max Interference Level Quiet Rural (dBm/Hz)**	**Max Interference Level Quiet Rural (dBuV/m)**	**Min Separation Quiet Rural (m)**	**Max Interference Level Rural (dBm/Hz)**	**Max Interference Level Rural (dBuV/m)**	**Min Separation Rural (m)**	**Max Interference Level Residential (dBm/Hz)**	**Max Interference Level Residential (dBuV/m)**	**Min Separation Residential (m)**	**Max Interference Level Business (dBm/Hz)**	**Max Interference Level Business (dBuV/m)**	**Min Separation Business (m)**
1,5	10,8	-134,6	-14,3	38,3	-120,8	-0,5	0,0	-115,5	4,8	0,0	-111,2	9,1	0,0
2	9,8	-138,1	-15,4	38,5	-124,3	-1,5	0,0	-119,0	3,8	0,0	-114,7	8,1	0,0
3	8,4	-143,1	-16,9	38,7	-129,2	-2,9	0,0	-123,9	2,4	0,0	-119,6	6,7	0,0
4	7,4	-146,6	-17,8	38,4	-132,6	-3,8	7,7	-127,3	1,5	0,0	-123,0	5,8	0,0
5	6,6	-149,0	-18,3	37,2	-135,3	-4,6	7,6	-130,0	0,7	0,0	-125,7	5,0	0,0
6	5,9	-150,6	-18,3	34,5	-137,4	-5,1	7,6	-132,2	0,1	4,1	-127,9	4,4	0,0
7	5,4	-151,6	-18,0	31,1	-139,2	-5,6	7,5	-134,0	-0,4	4,1	-129,7	3,9	0,0
8	4,9	-152,3	-17,5	28,0	-140,8	-6,0	7,4	-135,6	-0,8	4,1	-131,3	3,5	0,0
10	4,1	-154,2	-17,4	25,3	-143,4	-6,7	7,3	-138,3	-1,5	4,1	-134,0	2,7	2,5
10	4,1	-150,6	-13,9	16,8	-143,0	-6,2	7,0	-138,1	-1,4	4,0	-134,0	2,8	2,5
12	3,5	-153,0	-14,6	17,0	-145,2	-6,9	7,0	-140,3	-2,0	4,0	-136,2	2,2	2,5
14	2,9	-154,9	-15,2	17,1	-147,1	-7,4	6,9	-142,2	-2,5	4,0	-138,0	1,7	2,5
16	2,4	-156,6	-15,7	17,2	-148,7	-7,8	6,9	-143,8	-3,0	4,0	-139,6	1,2	2,4
18	2,0	-157,9	-16,1	17,0	-150,1	-8,2	6,9	-145,2	-3,4	3,9	-141,0	0,8	2,4
20	1,7	-159,0	-16,3	16,7	-151,3	-8,6	6,9	-146,5	-3,7	3,9	-142,3	0,5	2,4
22	1,3	-160,0	-16,4	16,3	-152,4	-8,8	6,8	-147,6	-4,0	3,9	-143,4	0,2	2,4
24	1,0	-160,8	-16,5	15,9	-153,4	-9,1	6,8	-148,6	-4,3	3,9	-144,5	-0,1	2,4
26	0,7	-161,6	-16,6	15,5	-154,4	-9,3	6,7	-149,6	-4,5	3,9	-145,4	-0,4	2,4
28	0,5	-162,3	-16,6	15,2	-155,2	-9,5	6,7	-150,5	-4,8	3,9	-146,3	-0,6	2,4
30	0,2	-163,0	-16,7	14,9	-156,0	-9,7	6,7	-151,3	-5,0	3,9	-147,2	-0,9	2,4

Table 9.4.2.3: separation distances in the case of the example n°4 limit

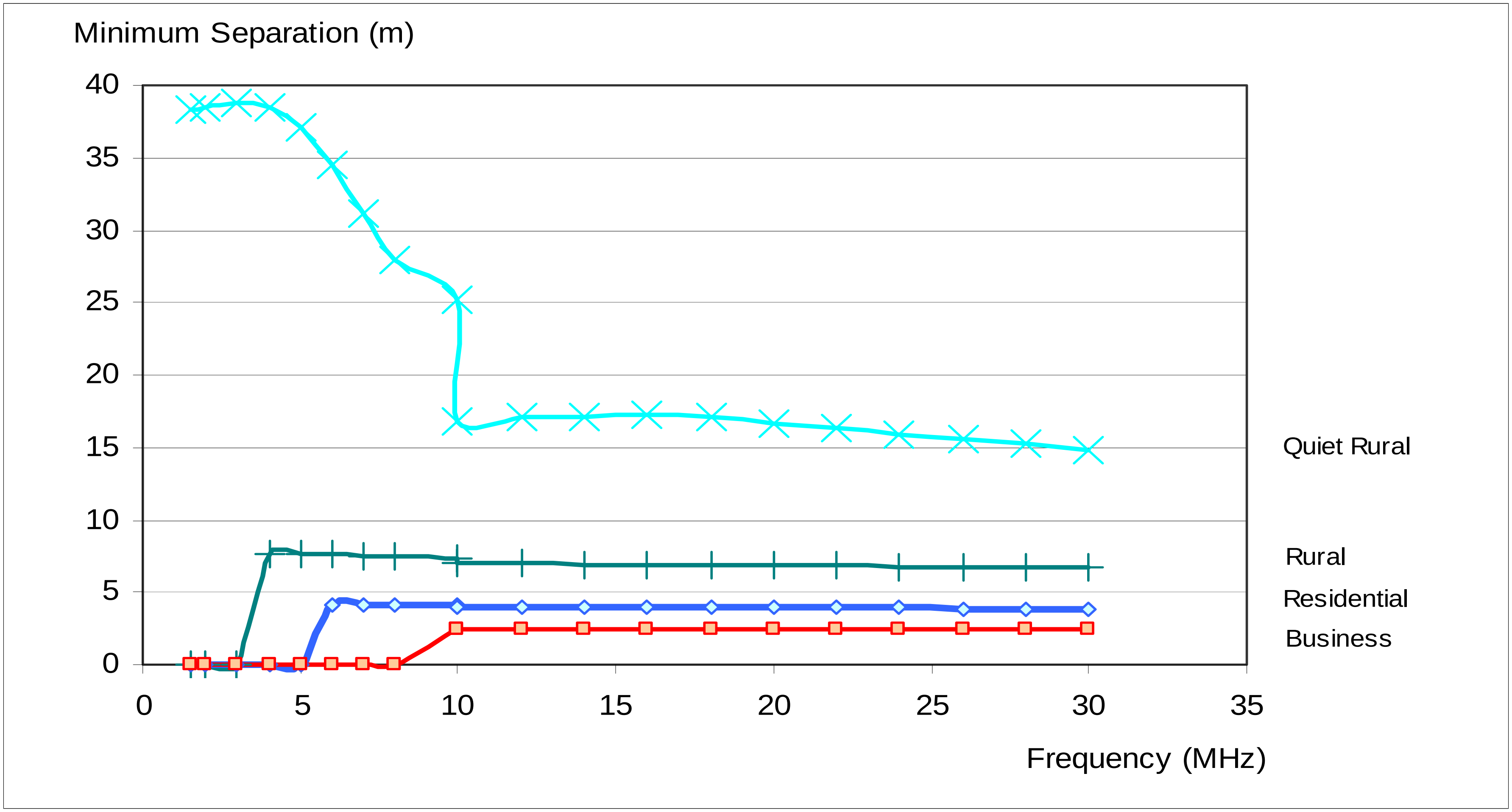


Figure 9.4.2.3: separation distances between cable transmission and radio systems in the case of Example n°4 limit

Separation distances in the case of the example N°5 limit

		Quiet Rural			Rural			Residential			Business		
Frequency (MHz)	**Limit at 3 m (dBuV/m)**	**Max Interference Level Quiet Rural (dBm/Hz)**	**Max Interference Level Quiet Rural (dBuV/m)**	**Min Separation Quiet Rural (m)**	**Max Interference Level Rural (dBm/Hz)**	**Max Interference Level Rural (dBuV/m)**	**Min Separation Rural (m)**	**Max Interference Level Residential (dBm/Hz)**	**Max Interference Level Residential (dBuV/m)**	**Min Separation Residential (m)**	**Max Interference Level Business (dBm/Hz)**	**Max Interference Level Business (dBuV/m)**	**Min Separation Business (m)**
1.5	70.0	-134.6	-14.3	34802	-120.8	-0.5	7141	-115.5	4.8	3879	-111.2	9.1	2365
2	70.0	-138.1	-15.4	39369	-124.3	-1.5	7977	-119.0	3.8	4334	-114.7	8.1	2642
3	70.0	-143.1	-16.9	46711	-129.2	-2.9	9324	-123.9	2.4	5066	-119.6	6.7	3088
4	70.0	-146.6	-17.8	52146	-132.6	-3.8	10410	-127.3	1.5	5658	-123.0	5.8	3449
5	70.0	-149.0	-18.3	55213	-135.3	-4.6	11326	-130.0	0.7	6163	-125.7	5.0	3758
6	70.0	-150.6	-18.3	55270	-137.4	-5.1	12109	-132.2	0.1	6604	-127.9	4.4	4030
7	70.0	-151.6	-18.0	52988	-139.2	-5.6	12777	-134.0	-0.4	6996	-129.7	3.9	4273
8	70.0	-152.3	-17.5	50305	-140.8	-6.0	13359	-135.6	-0.8	7350	-131.3	3.5	4495
10	70.0	-154.2	-17.4	49781	-143.4	-6.7	14445	-138.3	-1.5	7991	-134.0	2.7	4894
10	70.0	-150.6	-13.9	33140	-143.0	-6.2	13736	-138.1	-1.4	7864	-134.0	2.8	4865
12	70.0	-153.0	-14.6	36183	-145.2	-6.9	14776	-140.3	-2.0	8444	-136.2	2.2	5221
14	70.0	-154.9	-15.2	38740	-147.1	-7.4	15699	-142.2	-2.5	8964	-138.0	1.7	5541
16	70.0	-156.6	-15.7	41078	-148.7	-7.8	16544	-143.8	-3.0	9440	-139.6	1.2	5834
18	70.0	-157.9	-16.1	42652	-150.1	-8.2	17287	-145.2	-3.4	9873	-141.0	0.8	6103
20	70.0	-159.0	-16.3	43596	-151.3	-8.6	17944	-146.5	-3.7	10271	-142.3	0.5	6353
22	70.0	-160.0	-16.4	44270	-152.4	-8.8	18544	-147.6	-4.0	10641	-143.4	0.2	6588
24	70.0	-160.8	-16.5	44800	-153.4	-9.1	19100	-148.6	-4.3	10990	-144.5	-0.1	6809
26	70.0	-161.6	-16.6	45227	-154.4	-9.3	19618	-149.6	-4.5	11318	-145.4	-0.4	7018
28	70.0	-162.3	-16.6	45570	-155.2	-9.5	20103	-150.5	-4.8	11630	-146.3	-0.6	7217
30	70.0	-163.0	-16.7	45837	-156.0	-9.7	20558	-151.3	-5.0	11926	-147.2	-0.9	7408

Table 9.4.2.4: separation distances in the case of the example n°5 limit

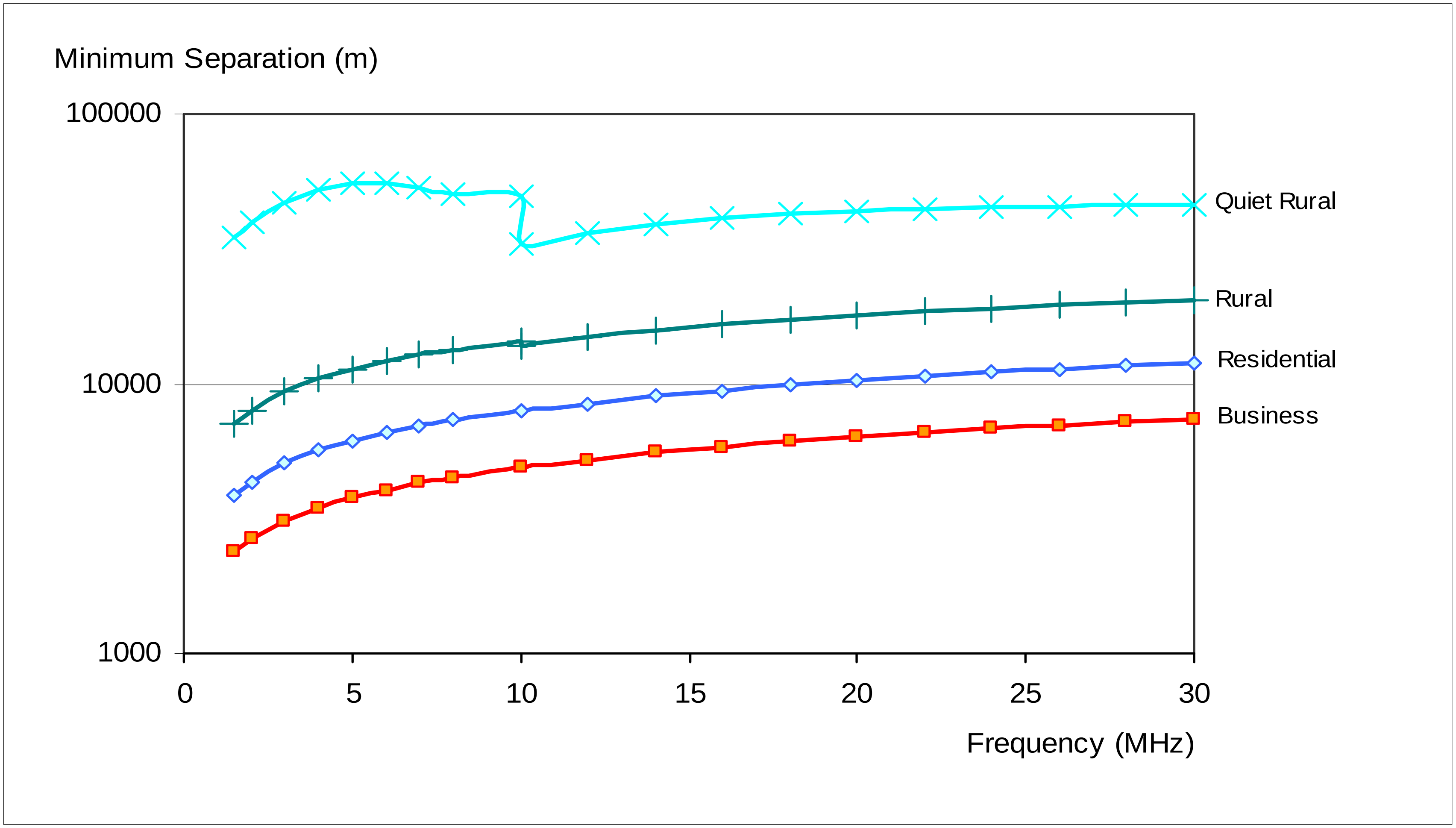


Figure 9.4.2.4: separation distances between cable transmission and radio systems in the case of Example n°5 limit

9.4.3 Noise floor degradation induced by existing limits

As a complement to the theoretical calculations presented in 4.4.1 and 4.4.2, we try in the present section to evaluate how they can be correlated to existing limits and compatibility situations. Some EMC standards applicable to numerous products like lighting equipment, ISM apparatus, trains… define radiated limits below 30 MHz. The corresponding limits are given in Section 6.

In the following tables 9.4.3-1 and 9.4.3-2, we have calculated the raise of the noise floor in dBs induced by equipment just meeting their EMC radiated limits below 30 MHz ; in Table 9.4.3-1 the ITU-R quiet rural levels are used as reference and in Table 9.4.3-2, the reference is the business noise level.

Frequency (MHz)	**1,5**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**10**	**12**	**14**	**16**	**18**	**20**	**22**	**24**	**26**	**28**	**30**
CISPR 11 (Tab3b) induction cooking appliance	79,5	77,5	74,5	72,3	72,8	72,8	72,5	72	68,4	69,1	69,7	70,2	70,6	70,8	70,9	71	71,1	71,1	71,2
CISPR 11 (Tab4) group 2 Class B	89,2	88,3	87,1	86	85	83,7	82,4	81	75,9	75,3	74,9	74,5	74,1	73,5	73	72,5	72,1	71,6	71,2
CISPR 11 (Tab5) group 2 Class A	109,3	115,4	111,9	97,8	98,3	98,3	98	97,5	93,9	94,6	95,2	95,7	96,1	86,3	86,4	86,5	86,6	86,6	86,7
CISPR 15 Tab 4							128,5				125,7							127,1	
EN 50121 stationary test	99,1	97,5	95,1	93,3	91,7	90	88,2	86,5	80,8	79,8	78,9	78,1	77,4	76,6	75,8	75,1	74,45	73,7	73,2
EN 50121 slow moving test	136,4	112,5	110,1	108,3	106,7	105	103,2	101,5	95,8	94,8	93,9	93,1	92,4	91,6	90,8	90,1	89,4	88,7	88,2

Table 9.4.3-1: raise of the ITU-R quiet rural noise floor in dBs induced by existing EMC emission limits

Conclusion: the difference between the ITU-R quiet rural noise level and EMC emission limits lies between 68 dB and 136 dB.

Frequency (MHz)	**1,5**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**10**	**12**	**14**	**16**	**18**	**20**	**22**	**24**	**26**	**28**	**30**
CISPR 11 (Tab 3b) induction cooking appliance	56,12	54	50,9	48,7	49,5	50,1	50,6	51	51	52,3	52,8	53,3	53,7	54	54,3	54,6	54,9	55,1	55,4
CISPR 11 (Tab4) group 2 Class B	65,7	64,8	63,4	62,4	61,7	61	60,5	60	59,1	58,5	58	57,6	57,2	57,7	56,4	56,1	56	55,6	55,4
CISPR 11 (Tab 5) group 2 class A	85,9	91,9	88,3	74,2	75	75,6	76,1	76,5	72,2	77,8	78,3	78,8	79,2	69,5	69,8	70,1	70,4	70,6	70,9
CISPR 15 Tab 4							106,6				108,8							111,1	
EN50121 stationary test	75,7	74	71,5	69,7	68,4	67,3	63,3	65,5	64,1	62,9	62	61,2	60,5	59,8	59,2	58,7	58,2	57,7	57,4
EN50121 slow moving test	113	89	86,5	84,7	83,4	82,3	81,3	80,5	79,1	77,9	77	76,2	75,5	74,8	74,2	73,7	73,2	72,7	72,4

Table 9.4.3-2: raise of the ITU-R business noise floor in dBs induced by existing EMC emission limits

Conclusion : the difference between the ITU-R quiet rural noise level and EMC emission limits lies between 48 dB and 113 dB.

9.4.4 Effect of various emission standards on HF radio reception

9.4.4.1 Calculation model: Fieldstrength into receiver input voltage

Chapters 4 and 5 of this report contain a collection of standards and regulations for the limitation of unwanted emissions, based mostly on fieldstrength limits. This study will try to give an overview of how these standards, if applied to limits for the radiation of modern digital broadband transmissions, would affect radio reception in the HF bands.

The small amateur radio bands are taken as examples because they are spread all over the HF spectrum. The resulting unwanted receiver input signals are given in microvolts across 50 Ohms, and in typical radio amateur "S" units (S9 equalling 50 µV across 50 ohms, each S step below S9 equalling 6 dB, figures above S9 are in dB over S9).

The calculation model is based on a half wave receiving antenna located at a **distance of 10 meters** from a house, in which cables for different purposes would radiate according to these standards or regulations. Conversion factors are needed to take into account different measuring distances in these regulations and different receiving bandwidths.

The BASIC calculation programme employed contains the following functions:

- Conversion of dB(µV/m) into µV/m;
- Conversion of µV/m into power received by a half wave dipole;
- Possibility to change this power by a dB factor to correct the influence of different measuring distances and receiver bandwidths;
- Conversion of received antenna power into µV across 50 ohms;
- Conversion of µV across 50 ohms into a typical S-meter indication.

Five noise-limiting curves have been investigated:

1. The ITU-R Report 258 on the present noise situation, mixed residential and rural areas;
2. The example n°2 limit
3. The example n°1 limit (NB30)
4. The radiated CISPR 11 limits
5. The example n°5 limit (FCC Part 15).

Table 9.4.4.1-1 shows the relevant fieldstrengths which would develop in the six classical amateur bands.

Limits B=9 kHz dB(µV/m)	MHz						distance	Correction for 10 m
	1.8	3.6	7	14	21	28		
ITU-R Report 258 B = 9 kHz	+2.4	-0.1	-2.4	-4.9	-6.3	-7.4	-	-
Example n°2	18	15.7	13.5	11.2	9.8	8.9	3 m	-10.46 dB
Example n°1 (NB30)	37.8	35.1	32.6	29.9	28.4	27.3	3 m	-10.46 dB
CISPR 11 radiated limit	70	65	50	50	40	40	30 m	+9.54 dB
Example n°5 (FCC Section.15.209)	29.5	29.5	29.5	29.5	29.5	29.5	30 m	+9.54 dB

Table 9.4.4.1-1: fieldstrength limits of the regulations considered

Regulations considered	MHz						Bandw.	Correction
	1.8	3.6	7	14	21	28		
ITU-R Report 258 SSB	11.6 µV	4 µV	1.8 µV	0.6 µV	0.34 µV	0.23 µV	2.5 kHz	-5.56 dB
	S 6-7	S 5-6	S 4	S 2-3	S 2	S 1		
Example n°2 SSB	19 µV	7.5 µV	3 µV	1.1 µV	0.65 µV	0.44 µV	2.5 kHz	-5.56 dB
	S 7-8	S 6-7	S 5	S 3-4	S 2-3	S 2		-10.46 dB
Example N°1 (NB30) SSB	190µV	70µV	27µV	9.9µV	5.5µV	3.7µV	2.5 kHz	-5.56 dB
	S9+12	S9+3	S 8	S 6-7	S 5-6	S 5		-10.46 dB
CISPR radiated	78 mV	22 mV	2 mV	1 mV	210µV	160µV	2.5 kHz	-5.56 dB
	S9+64	S9+53	S9+32	S9+26	S9+12	S9+10		+9.54 dB
Example n°5 (FCC Section 15.209)	730µV	370µV	190µV	94 µV	63 µV	47 µV	2.5 kHz	-5.56 dB
	S9+23	S9+17	S9+12	S9+6	S9+2	S9		+9.54 dB

Table 9.4.4.1-2: receiver input voltages and S values caused by the regulations considered

9.4.4.2 Assessment of the Results in Table 9.4.4.1-2

For the time being all radio services are still operating on the conditions of ITU-R-Report 258, with the exception, of course, that in towns and large cities the man-made noise level may be higher, especially below 5 MHz. Example n°2 would have caused a minimal increase in noise level only, even weak and low power stations would be captured with a minimum of extra effort. The introduction of example n°1, however, would mask a considerable portion of the typical receiving levels of amateur radio signals with broadband noise. This would make communications over long distances difficult, if not impossible, especially when using low power. Amateur radio in residential areas would be forced to rely on maximum permissible power, accompanied by all kinds of immunity and environmental problems. The only way the present low power activity in amateur radio could be continued would be by portable or mobile stations, leaving the residential areas.

The application of example n°5 limits or the CISPR radiated limits would mask the level of amateur radio operation almost completely or even obliterate it. These limits may be justified in certain cases for small-band emissions, typical for analogue equipment only.

9.4.4.3 Real input voltages of practical receivers

This paragraph has been added to draw attention to a problem related to modern receiver design. The relatively low receiver input voltages in Table 9.4.4.4.1-2 should not mislead the reader in one respect: These figures would be the input voltages if the bandwidth of 2.5 kHz (SSB) were effective already at the receiver input. In reality, however, the front-end bandwidth of receivers is much wider, especially since the concept of sub-octave bandwidth input filters was introduced about two decades ago.

Calculating the case of a receiver covering the HF range 1.5 – 30 MHz in six sub-octave sub-ranges has shown that in general, with one exception, the input voltages are not dangerously high. The exception is the radiated CISPR standard delivering up to 1.4 volts to the receiver input (+16 dBm) which would drive many receivers into blocking.

9.4.4.4 Summary

These calculations show that example n°1 or example n°5 limits are not appropriate for the protection of amateur radio operations against interference from all kinds of broadband cable transmission systems.

9.5 Effects on amateur radio of the use of power lines for broadband data communications (PLT)

A detailed study has been conducted on this matter and is enclosed in Annex 8.

The perception of the noise from his receiver is finally what counts for the radio amateur. For that not only the absolute signal strength in dBµV is important, but also the background noise. This composite noise, from several sources, like man made noise, atmospheric noise and galactic noise is received by the station antennas.
By injecting a test signal into the 230 V grid of a house in the Netherlands, a series of preliminary measurements were carried out for the EM radiation as result of the injected RF interference signal on the 230 V mains.
For this experiment alternately the measurement receiver and the station receiver were connected to one of the three antennas and was listened to the received injected interference signal. The signal generator was set to different output levels.

These levels are equal to:

1 0 dBm, available output power of the generator.
2 So much output power that the average of the measured field strength at the measurement points 1 and 2 is equal to the example N°1 limit value for that frequency.
3 So much output power that the average of the measured field strength at the measurement points 1 and 2 corresponds with the field strength which is related to a mains interference voltage in accordance with the CISPR 22 Class B limit values (see section 4.1) for that frequency.
4 So much output power that the average of the measured field strength at the measurement points 1 and 2 is equal to the example n°2 limit values for that frequency.
5 So much output power that the average of the measured field strength at the measurement points 1 and 2 is equal to the example n°4 limit values for that frequency.

In case of experiment number one where power was injected in the Neutral line, the averages of the field strength computed from the measurements at MP1 and MP2, respective $E_{3m,0dBm,MP1}$ and $E_{3m,0dBm,MP2}$ and are displayed in table 9.5 as $E_{3m,0dBm}$. Additionally the limit values were computed for the examples n°1, n°2 and n°4 limit values, and reflected in table 9.5 as respective $E_{3m,NB30}$, $E_{3m,Norway}$, $E_{3m,BBC}$.
Also field strength $E_{3m,CISPR}$ was defined, which is equal to the average of the field strength levels measured at MP1 and MP2, where the Neutral injected voltage at the injection point is equal to the CISPR 22 Class B quasi-peak limit on the mains port (see section 4.1).

The corresponding injected power levels for these limits, IP_{NB30}, IP_{CISPR}, IP_{Norway}, IP_{BBC}, were determined from:

$$IP_{limit} = E_{limit} - E_{0dBm}$$

The results as shown in table 9.5 are used to set the output level of the generator for the measurements. The antenna voltage was measured with the measurement receiver. Then was listened with the radioamateur receiver and the reception of the injected “interference” assessed against the IARU defined S- units. For a strong received interference signal the S-meter read out (the NRD 525 meets the IARU specification fairly well) was translated to the IARU description. For a weak signal the level was determined in relation to the background noise.

Calculation of injected power levels in experiments 2 - 5											
Frequency [MHz]	$E_{3m,0dBm,MP1}$ [dBµV/m]	$E_{3m,0dBm,MP2}$ [dBµV/m]	$E_{3m,0dBm}$ [dBµV/m]	$E_{3m,NB30}$ [dBµV/m]	$E_{3m,CISPR}$ [dBµV/m]	$E_{3m,Norway}$ [dBµV/m]	$E_{3m,BBC}$ [dBµV/m]	IP_{NB30} [dBm]	IP_{CISPR} [dBm]	IP_{Norway} [dBm]	IP_{BBC} [dBm]
1.84	73.4	86.4	79.9	37.7	31.7	18.0	9.3	-42.2	-48.2	-61.9	-70.6
3.58	79.4	78.4	78.9	35.1	30.4	15.7	6.9	-43.8	-48.5	-63.2	-72.0
7.03	77.4	71.4	74.4	32.5	31.2	13.5	4.6	-41.9	-43.2	-60.9	-69.8
10.12	71.4	64.4	67.9	31.2	18.1	12.3	3.3	-36.7	-49.8	-55.6	-64.6
14.06	69.4	67.4	68.4	29.9	19.8	11.2	2.1	-38.5	-48.6	-57.2	-66.3
18.1	68.4	58.4	63.4	28.9	12.4	10.3	1.2	-34.5	-51.0	-53.1	-62.2
21.1	63.4	56.4	59.9	28.3	7.9	9.8	0.7	-31.6	-52.0	-50.1	-59.2
24.9	66.4	56.4	61.4	27.7	13.0	9.2	0.1	-33.7	-48.4	-52.2	-61.3
28.4	66.4	63.4	64.9	27.2	18.1	8.8	-0.4	-37.7	-46.8	-56.1	-65.3

Table 9.5: calculation of injected power levels

From the in this way found values for the interference we can clearly see what the effects are for the Amateur service when these limits are enforced. The results are shown in table 9.5.1.

9.5.1 Background noise

Background noise was also measured. For this purpose the measurement receiver was set to “average” and further averaging was done on the face of the reading. The values were then normalized to a bandwidth of 2.7 kHz for the purpose of comparing the values in ERC Report 69.

However, only for 21/28 MHz an antenna factor k could be determined, using an antenna gain of 8 dBi. To define the noise field strength, the value of k is first converted in dB/m and than added to the noise voltage.

ERC Report 69 gives for the noise field strength at 21 MHz: -19 dBµV/m, and for 28 MHz: -20.0 dBµV/m in "Quiet Rural Area". These are values valid for a short monopole receiving antenna over a perfect conducting ground. For a half wave dipole in free space we must subtract 3.5 dB[24], so we arrive at -22.5 resp. -23.5 dBµV/m. The measured values are about these same levels.

Evaluation table of Amateur radio reception, interfered by powerline communication								
Receive antenna:		German Quad: a square loop of 20 by 20 m, 10 m high. The smallest distance to the house is **12 m**. Connected via balun trafo and matching circuit. Full matching only on 3.5 and 14 MHz band. [ ]: Inverted L receive_only antenna, 30m horizontal, 10 m height, **40 m** distance to house. Connected via broadband trafo.				Duo bander, 2 x 4 elements beam. Positioned at mast **2 m** from house, **21 m** above ground.		
Experiment:	Frequency:	1.84	3.575	7.03	14.09	21.1	28.4	MHz
1. $E=E_0$	**Injected power:**	**0**	**0**	**0**	**0**	**0**	**0**	dBm
	E@3m:	79.9	78.9	74.4	68.4	59.9	64.9	dBµV/m
	$V_{antenna}$:	49 [39]	62 [43]	55 [55]	49 [35]	56	56	dBµV
	Experience of interference: (on rx: NRD525)	Very strong [very strong]	Very strong [very strong]	Very strong [very strong]	Very strong [very strong]	Very strong	Very strong	
2. $E=E_{NB30}$	**Injected power:**	-42.2	-43.8	-41.9	-38.5	-31.6	-37.7	dBm
	E@3m:	37.7	35.1	32.5	29.9	28.3	27.2	dBµV
	$V_{antenna}$:	8 [0]	19 [0]	14 [14]	10 [-4]	23	19	dBµV
	Interference:	Reasonable [weak]	Rather strong [reasonable]	Well [well]	Reasonable [very weak]	Rather strong	Rather strong	
3. $E=E_{CISPR22}$	**Injected power:**	-48.2	-48.5	-43.2	-48.6	-52.0	-46.8	dBm
	E@3m:	31.7	30.4	31.2	19.8	7.9	18.1	dBµV/m
	$V_{antenna}$:	1 [-6]	13 [-]	12 [12]	1 [-14]	3	9	dBµV
	Interference:	Weak [very weak]	Reasonable well [hardly perceptible]	Well [well]	Hardly perceptible [no]	Reasonable	Rather strong	
4. $E=E_{Norway}$	**Injected power:**	-61.9	-63.2	-60.9	-57.2	-50.1	-56.1	dBm
	E@3m@	18.0	15.7	13.5	11.2	9.8	8.8	dBµV/m
	$V_{antenna}$:	-13 [-]	-1 [-]	- [-]	-7 [-]	6	0	dBµV
	Interference:	Hardly perceptible [no]	Hardly perceptible [no]	No	No	Reasonable	Weak	
5. $E=E_{BBC}$	**Injected power:**	-70.6	-72.0	-69.8	-66.3	-59.2	-65.3	dBm
	E@3m:	9.3	6.9	4.6	2.1	0.7	-0.4	dBµV/m
	$V_{antenna}$:	- [-]	- [-]	- [-]	- [-]	-3	-7	dBµV
	Interference:	No	No	No	No	Very weak	Very weak	
6. Amb. noise	B = 500 Hz:	-12 [-6]	3 [-4]	3 [1]	-4 [-9]	-20	-21	dBµV
	B = 2.7 kHz:	-3 [1]	10 [3]	10 [8]	3 [-2]	-13	-14	dBµV
	Antenna factor:	Unknown	Unknown	Unknown	Unknown	-11.2	-8.7	dB/m
	Noise field strength:					-24.2	-22.7	dBµV/m

Table 9.5.1: evaluation of amateur radio reception interfered by powerline communication

9.5.2 Conclusions

- For an antenna location as is common for most amateurs, close to or above the house, the reception of interference radiating from the mains is very serious for field strength levels equal to the example n°1 (NB 30) limit or the equivalent field strength level of the CISPR 22 Class B limit.
- Even the example n°4 (BBC) limit is inadequate to avoid interference in the above-mentioned situation, in particular on the higher amateur bands.

9.6 Compatibility between cable TV and aeronautical navigation systems above 30 MHz

This compatibility study is contained in Annex 9. Two models to calculate the cumulative effect are described and calculations have been made of the cumulative interference created in the sky by a cable TV network over a large city (Berlin has been taken as a representative example). Both models produced very similar results.

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[24]According Rec. ITU-R PI.372-6. The relationship between the noise field strength and the type of antenna is addressed in CCIR Report 670 and in the therein mentioned reference: LAUBER, W.R. [1977] Preliminary urban UHF/VHF radio noise measurements in Ottawa, Canada. Proceedings of 2nd Symposium on EMC, Montreux, Switzerland, June 28-30,357-362.

In the case of analogue TV signals, a first calculation has been made assuming:

- Either that leakage on the ground follow a lognormal distribution with values coming from a ground measurement campaign performed in 1999 in Hannover);
- or that all leakage values are equal to the EN 50083-8 limit of 20 dB(pW) quasi-peak in a 120 kHz bandwidth.

For the digital Cable TV network, the assumption that has been made is that the digital power over 7 MHz is equal to the analogue power over 7 MHz (this equality over the whole bandwidth corresponds to a 16 dB difference for the quasi-peak values over 120 kHz). In the case of the EN 50083-8 constant distribution, this assumption means that the maximum leakage level is equal to 4 dBpW quasi-peak in a 120 kHz bandwidth.

In the case of the lognormal distributions, under the scenarios assumed here, the calculations led to the conclusions that:

- such an analogue cable TV network over a large city is not compatible with ILS LOC, VOR, VHF COM, UHF COM, but is compatible with ILS GP;
- such a digital cable TV network over a large city is not compatible with ILS LOC and VHF COM, but is compatible with VOR, UHF COM and ILS GP.

In the case of the constant distributions, under the scenarios assumed here, the calculations led to the conclusions that:

- such an analogue cable TV network over a large city is not compatible with ILS LOC, VHF COM, is compatible with VOR and ILS GP; and is only partly compatible with UHF COM;
- such a digital cable TV network over a large city is compatible with ILS LOC, VOR, VHF COM,UHF COM and ILS GP.

These numerical results should be taken as the first examples of such compatibility results and a more general analysis of the situation should be made taking into account the following elements:

- A risk assessment analysis should in any case be conducted, bearing in mind the safety of life function (in addition to the "aviation safety factor" already considered in the calculations) of the radio services of concern here;
- Input values for the models have been defined taking into account a limited number of measurement results and it would be useful to base the analysis on additional measurement data;
- Some parameters, such as phase cancellation and summation effects at the arrival point or the possibility of additional attenuations would have merit further studies.

10 CONCLUSIONS

General conclusions of the report

- There should be a harmonised radiation limit and a common EMC-standard for Europe and preferably a worldwide agreement on the same limits for cable transmissions systems because:
    - Europe has a common market and trade develops towards global markets;
    - Propagation conditions (in the frequency range up to 30 MHz) are such that the risk of interference to radio services cannot be limited to a national or regional scale (cumulative effect, reflection by the ionosphere of wanted signals as well as interfering radiation originating from cable systems).
- The radio spectrum is a unique resource. In particular, the frequency range below 30 MHz has extremely favourable propagation conditions allowing economic long range as well as low power communication for important security and non-security radio services. Thus this part of the electromagnetic spectrum needs special protection by choosing an appropriate interfering radiation limit;
- Total protection of radio services is not possible due to the fact that this would require very low radiation limits which would prohibit high data rate telecommunication services using copper cable technologies in the local loop. Furthermore it has to be recognised that electronic equipment of any kind is an already existing source of interference, which would make any decision in favour of very tight radiation limits unrealistic and uneconomical;
- A radiation limit to be generally applied to all cable systems should take into account the interests of the radio users. This radiation limit is an environmental parameter being decisive for the future development of systems and services;
- Safety of life radio services used to safeguard human life and property must be protected on a priority basis, regardless of any limit met or not by the cable transmission system;

- Manufacturers should develop and cable operators should employ technologies and procedures enabling reduction of emissions in cases of interference (e.g. reduction of power levels in general or for specific frequencies or frequency ranges);
- The risk of interference to radio services depends not only on the compliance with a radiation limit but also on different network structures and technologies as well as on the frequency ranges used. For example, owing to the type and properties of cables installed, the frequency ranges used and the structure of the network, the risk of interference for the same radiation level caused by high frequency Power Line systems (i.e. using frequencies in the range 1.6 to 30 MHz) is much higher than with DSL or Cable TV systems;
- Given the high densities of deployment foreseen for PLT networks including in-house applications, there is a risk of significant rise in overall noise level even in rural areas. Every radiation limit to be developed for networks or output power values of individual PLT products should be judged on the cumulative interference effect using the models described in Annex 7;
- Special attention needs to be paid to the in-house part of the networks that are self-installed by private persons who generally don't have EMC expertise;
- The issue of monitoring of networks, which is outside the scope of the present EMC Directive but may be undertaken by national administrations, is addressed in Section 5.2.5;
- The frequency range covered by this report is from 9 kHz to 3 GHz, although in many sections, emphasis is put on frequencies below 30 MHz.
- In the frequency range above 30 MHz, the analysis has mostly concentrated on the issue of the compatibility between cable TV networks and aeronautical radio services that is addressed in details in Annex 9. Two calculation models have been established and calibrated based on the available ground and aerial measurements performed on existing cable TV networks. They led to the following conclusions:
  - an existing analogue cable TV network over a large city is not compatible with ILS LOC, VOR, UHF COM and VHF COM but is compatible with ILS GP;
  - an existing digital cable TV network over a large city is not compatible with UHF COM, but is compatible with ILS LOC, VOR, UVHF COM and ILS GP. Concerning VHF COM, the result depends on the modulation scheme and aircraft height (see Annex 9);
  - Assuming all leakage values can be reduced below a given value, the limit that should be set to the leakage levels to ensure compatibility for each of the radio services and types of cable TV network (analogue or digital) studied here is given in Annex 9.

Evaluation of radiation limit examples

Section 9.4.2 of the report presents some calculations of the separation distances between cable transmission and radio systems assuming;

- That the cable system is at the proposed limits level (examples n°1 to 5);
- That the noise level is at the ITU-R Rec 372 noise levels (quiet rural, rural, residential and business);
- That the protection requirement of the radio services is that cable systems should not increase this noise level by more than 0.5 dB (quiet rural, rural, residential and business);
- Free space propagation between the two.

The following table summarises these results by giving the corresponding separation distances at two spot frequencies and for the two extreme ITU-R environments:

Separation distance	1.5 MHz quiet rural	30 MHz quiet rural	1.5 MHz business	30 MHz business
Example n°1 limit	920 m	320 m	63 m	52 m
Example n°2 limit	94 m	39 m	0 m	6 m
Example n°3 limit	770 m	Not applicable	53 m	Not applicable
Example n°4 limit	38 m	15 m	0 m	2 m
Example n°5 limit	35 km	46 km	2,4 km	7,4 km

Note: a minimum separation distance equal to 0 m means that the victim at any separation distance would not suffer sensitivity degradation of more than 0.5 dB.

- Concerning radiation from cable transmission systems, the setting of a general limit (flat or slowly varying) across the bands between 9 kHz and 3000 MHz is required;
- The example n°1 limit (see Section 7.1) puts great constraints on radio services and users and it is expected that there will be numerous cases of interference to be resolved. These levels are considered as maximum tolerable levels as far as radio services protection is concerned.
- The example n°2 limit (see Section 7.2; this limit is approximately 20 dB below the example n°1 limit quoted above) may be regarded as sufficient to protect radio services in the majority of cases;
- For safety of life radio services, the emissions must be at a level such that interference to these services is prevented in advance with a very high probability.

GLOSSARY

ADSL	Asymmetric Digital Subscriber Line
ALE	Automatic Link Establishment
AM	Amplitude Modulation
ATC	Air Traffic Control
BBC	British Broadcasting Corporation
BLOS	Beyond Line of Sight
CATV	Community Antenna Television
CCS	Carrier Current System
CEN	European Standardisation Committee
CENELEC	European Committee for Electrotechnical Standardisation
CEPT	European Postal and Telecommunications Administrations Conference
CIS	Control Infra Structure
CISPR	International Special Committee on Radio Interference
CLC	Abbreviation for CENELEC
CNO	Cable Network Operator
CTN	Cable Transmission Network
DM	Differential Mode
DME	Distance Measuring Equipment
DOC	Designated Operation Coverage
DRM	Digital Radio Mondiale
DSC	Digital Selective Calling
DSL	Digital Subscriber Line
DSP	Digital Signal Processing
DSSS	Direct Sequence Spread Spectrum
EAS	Electronic Article Surveillance
ECA	European Common Allocation
ECC	Electronic Communications Committee
ECCA	European Cable Communications Association
EIC	Engineer in Charge
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
EN	European Norm
EPIRB	Emergency Position Indicating Radio Beacon
ERC	European Radiocommunication Committee
ERO	European Radiocommunication Office
ETSI	European Telecommunications Standards Institute
EU	European Union
EUT	Equipment Under Test
FCC	Federal Communications Commission
FDD	Frequency Division Duplexing
FSAN	Full Service Access Network
FTTCab	Fibre To The Cabinet
GBAS	Great Britain Amateur Society
GMDSS	Global Maritime Distress and Safety System
GMSK	Gaussian Minimum Shift Keying
GPS	Global Positioning System
HDSL	High bit rate Digital Subscriber Line
HF	High Frequencies
HRC	Harmonically Related Carriers
HVT	High Voltage Transformer
IARU	International Amateur Radio Union
ICAO	International Civil Aviation Authority
IEC	International Electrotechnical Commission
ILS	International Landing System
ISDN	Integrated Services Digital Network
ISDN-BA	Integrated Services Digital Network – Basic Access
ISM	Industrial Scientific and Medical

ISO	International Standards Organisation
ITE	Information Technology Equipment
ITU	International Telecommunications Union
ITU-R	International Telecommunications Union – Radiocommunications sector
LAN	Local Area Network
LCL	Longitudinal Conversion Loss
LF	Low Frequencies
LORAN	Long Range Navigation System
MATV	Master Antenna Television
MCD	Mains Connector Device
MF	Medium Frequencies
MSI	Maritime Safety Information
MVPD	Multi Channel Video Programming Distributor
NATO	North Atlantic Treaty Organisation
NB	Usage Provision
NBDP	Narrow Band Direct Printing Telegraphy
NDB	Non Directional Beacon
ODTR	Office of the Director of Telecommunications Regulation
OFDM	Orthogonal Frequency Division Multiplex
OIRT	International Radio and Television Organization
OVSt	Outdoor Voltage Station
PfP	Partner for Peace
PhE	Phase and the earthing
PLT	Power Line Telecommunications
POTS	Plain Old Telephony Service
PSK	Phase Shift Keying
QAM	Quadrature Amplitude Modulation
QPSK	Quadrature Phase Shift Keying
RFI	Radio Frequency Ingress
RFID	Radio Frequency Identification
RHD	Radio Horizon Distance
RR	Radio Regulations
RSGB	Radio Society of Great Britain
RTP	Radio Telephony
R&TTE	Radio and Telecommunications Terminal Equipment
SAR	Search And Rescue
SDH	Synchronous Digital Hierarchy
SDSL	Symmetric Digital Subscriber Line
SHDSL	Symmetrical High bit rate DSL
SIGINT	SIGnal INTelligence
SMATV	Satellite MATV
SNR	Signal to Noise Ratio
SOHO	Small Office – Home Office
SRD	Short Range Device
SSB	Single Side Band
SSR	Secondary Surveillance Radar
TLX	Telex
USB	Universal Serial Bus
VDSL	Very high-speed Digital Subscriber Line
VOR	VHF Radiocommunication Range
WG-SE	Working Group Spectrum Engineering
WRC	World Radiocommunications Conference