BS EN 60728-1-1:2014

BSI Standards Publication

Cable networks for television signals, sound signals and interactive services

Part 1-1: RF cabling for two way home networks

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National foreword

This British Standard is the UK implementation of EN 60728-1-1:2014. It is identical to IEC 60728-1-1:2014. It supersedes BS EN 60728-1-1:2010 which is withdrawn.

The UK participation in its preparation was entrusted by Technical Committee EPL/100, Audio, video and multimedia systems and equipment, to Subcommittee EPL/100/4, Cable distribution equipment and systems.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

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English Version

Cable networks for television signals, sound signals and interactive services - Part 1-1: RF cabling for two way home networks (IEC 60728-1-1:2014)

Réseaux de distribution par câbles pour signaux de télévision, signaux de radiodiffusion sonore et services interactifs - Partie 1-1: Câblage RF pour réseaux domestiques bidirectionnels (CEI 60728-1-1:2014)

Kabelnetze für Fernsehsignale, Tonsignale und interaktive Dienste - Teil 1-1: Zweiwege-HF-Wohnungsvernetzung (IEC 60728-1-1:2014)

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CENELEC

European Committee for Electrotechnical Standardization
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Europäisches Komitee für Elektrotechnische Normung

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Ref. No. EN 60728-1-1:2014 E

Foreword

The text of document 100/2249/FDIS, future edition 2 of IEC 60728-1-1, prepared by Technical Area 5 "Cable networks for television signals, sound signals and interactive services" of IEC/TC 100 "Audio, video and multimedia systems and equipment" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN 60728-1-1:2014.

The following dates are fixed:

• latest date by which the document has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2015-02-28
• latest date by which the national standards conflicting with the document have to be withdrawn	(dow)	2017-04-11

This document supersedes EN 60728-1-1:2010.

EN 60728-1-1:2014 includes the following significant technical changes with respect to EN 60728-1-1:2010:

- update of performance requirements in Clause 5 to include those for DVB-T2 signals.

This standard is to be used in conjunction with EN 60728-1:2014.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CENELEC [and/or CEN] shall not be held responsible for identifying any or all such patent rights.

Endorsement notice

The text of the International Standard IEC 60728-1-1:2014 was approved by CENELEC as a European Standard without any modification.

In the official version, for Bibliography, the following notes have to be added for the standards indicated:

IEC 61169-2	NOTE	Harmonized as EN 61169-2.
IEC 61169-24	NOTE	Harmonized as EN 61169-24.
IEC 61196-2	NOTE	Harmonized as EN 61196-2.

Annex ZA
(normative)

Normative references to international publications with their corresponding European publications

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

NOTE When an international publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

Publication	Year	Title	EN/HD	Year
		Coaxial cables - Part 2-4: Sectional specification for cables used in cabled distribution networks - Indoor drop cables for systems operating at 5 MHz - 3 000 MHz	EN 50117-2-4	-
IEC 60050-705	-	International Electrotechnical Vocabulary (IEV) - Chapter 705: Radio wave propagation	-	-
IEC 60050-712	-	International Electrotechnical Vocabulary (IEV) - Chapter 712: Antennas	-	-
IEC 60050-725	-	International Electrotechnical Vocabulary (IEV) - Chapter 725: Space radiocommunications	-	-
IEC 60728-1	2014	Cable networks for television signals, sound signals and interactive services - Part 1: System performance of forward paths	EN 60728-1	2014
IEC 60728-1-2	-	Cable networks for television signals, sound signals and interactive services - Part 1-2: Performance requirements or signals delivered at the system outlet in operation	EN 60728-1-2	-
IEC 60728-3	2010	Cable networks for television signals, sound signals and interactive services - Part 3: Active wideband equipment for cable networks	EN 60728-3	2011
IEC 60728-10	-	Cable networks for television signals, sound signals and interactive services - Part 10: System performance of return paths	EN 60728-10	-
IEC 60966	series	Radio frequency and coaxial cable assemblies	EN 60966	series
IEC 60966-2	series	Radio frequency and coaxial cable assemblies - Part 2: Sectional specification for flexible coaxial cable assemblies	EN 60966-2	series

Publication	Year	Title	EN/HD	Year
IEC 60966-2-4	-	Radio frequency and coaxial cable assemblies - Part 2-4: Detail specification for cable assemblies for radio and TV receivers - Frequency range 0 MHz to 3 000 MHz, IEC 61169-2 connectors	EN 60966-2-4	-
IEC 60966-2-5	-	Radio frequency and coaxial cable assemblies - Part 2-5: Detail specification for cable assemblies for radio and TV receivers - Frequency range 0 MHz to 1 000 MHz, IEC 61169-2 connectors	EN 60966-2-5	-
IEC 60966-2-6	-	Radio frequency and coaxial cable assemblies - Part 2-6: Detail specification for cable assemblies for radio and TV receivers - Frequency range 0 MHz to 3 000 MHz, IEC 61169-24 connectors	EN 60966-2-6	-
IEEE 802.11	-	IEEE Standard for Information Technology - Telecommunications and Information Exchange Between Systems - Local and Metropolitan Area Networks - Specific Requirements - Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications	-	-
IEEE 802.11a	-	IEEE Standard for Information technology - Telecommunications and information exchange between systems - Local and metropolitan area networks - Specific requirements - Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications - Amendment 1: High-speed Physical Layer in the 5 GHz band	-	-
IEEE 802.11b	-	Supplement to 802.11-1999, Wireless LAN MAC and PHY specifications: Higher speed Physical Layer (PHY) extension in the 2.4 GHz band	-	-
IEEE 802.11e	-	IEEE Standard for Information technology - Telecommunications and information exchange between systems - Local and metropolitan area networks - Specific requirements - Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications - Amendment 8: Medium Access Control (MAC) Quality of Service Enhancements	-	-

Publication	Year	Title	EN/HD	Year
IEEE 802.11g	-	IEEE Standard for Information technology - Telecommunications and information exchange between systems - Local and metropolitan area networks - Specific requirements - Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications - Amendment 4: Further Higher Data Rate Extension in the 2.4 GHz Band	-	-
IEEE 802.11h	-	IEEE Standard for Information technology - Telecommunications and Information Exchange Between Systems - LAN/MAN Specific Requirements - Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications: Spectrum and Transmit Power Management Extensions in the 5GHz band in Europe	-	-
IEEE 802.11n	-	IEEE Standard for Information Technology - Telecommunications and information exchange between systems-Local and metropolitan area networks-Specific requirements - Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications - Amendment 5: Enhancements for Higher Throughput	-	-
IEEE 802.16	-	IEEE Standard for Local and metropolitan area networks - Part 16: Air Interface for Fixed Broadband Wireless Access Systems (WiMax)	-	-
ITU-R Recommendation BT.500	-	Methodology for the subjective assessment of the quality of television pictures	-	-
ITU-T Recommendation J.61	-	Transmission performance of television circuits designed for use in international connections	-	-
ITU-T Recommendation J.63	-	Insertion of test signals in the field-blanking interval of monochrome and colour television signals	-	-
ETSI EN 300 421	-	Digital Video Broadcasting (DVB): Framing structure, channel coding and modulation for 11/12 GHz satellite services	-	-
ETSI EN 300 429	-	Digital Video Broadcasting (DVB): Framing structure, channel coding and modulation for cable systems	-	-
ETSI EN 300 473	-	Digital Video Broadcasting (DVB): Satellite Master Antenna Television (SMATV) distribution systems	-	-
ETSI EN 300 744	-	Digital Video Broadcasting (DVB): Framing structure, channel coding and modulation for digital terrestrial television	-	-

Publication	Year	Title	EN/HD	Year
ETSI EN 302 307	-	Digital Video Broadcasting (DVB);Second generation framing structure, channel coding and modulation systems for Broadcasting, Interactive Services, News Gathering and other broadband satellite applications (DVB-S2)	-	-
ETSI EN 302 755	-	Digital Video Broadcasting (DVB); Frame structure channel coding and modulation for a second generation digital terrestrial television broadcasting system (DVB-T2)	-	-

CONTENTS

INTRODUCTION

Standards and deliverables of IEC 60728 series deal with cable networks including equipment and associated methods of measurement for headend reception, processing and distribution of television and sound signals and for processing, interfacing and transmitting all kinds of data signals for interactive services using all applicable transmission media. These signals are typically transmitted in networks by frequency-multiplexing techniques.

This includes for instance

- regional and local broadband cable networks,
- extended satellite and terrestrial television distribution systems,
- individual satellite and terrestrial television receiving systems,

and all kinds of equipment, systems and installations used in such cable networks, distribution and receiving systems.

The extent of this standardization work is from the antennas and/or special signal source inputs to the headend or other interface points to the network up to the terminal input of the customer premises equipment.

The standardization work will consider coexistence with users of the RF spectrum in wired and wireless transmission systems.

The standardization of any user terminals (i.e. tuners, receivers, decoders, multimedia terminals, etc.) as well as of any coaxial, balanced and optical cables and accessories thereof is excluded.

The reception of television signals inside a building requires an outdoor antenna and a distribution network to convey the signal to the TV receivers.

This part of the IEC 60728 deals with the requirements and implementation guidelines for a home network that can be realised with different techniques. The following types of home networks (HN) are possible:

- passive coaxial home network;
- active coaxial home network;
- different home network types.

Figure 1 shows typical situations that are possible when considering RF home networks.

The RF home network can be realised using coaxial cables, balanced cables, optical cables or radio links.

Clause 5 defines the performance limits measured at system outlet or terminal input for an unimpaired (ideal) test signal applied at the HNI. Under normal operating conditions for any analogue channel and meeting these limits, the cumulative effect of the impairment of any single parameter at the HNI and that, due to the home network, will produce picture and sound signals not worse than grade four on the five-grade impairment scale contained in ITU-R BT.500. These requirements are given in IEC 60728-1-2. For digitally modulated signals the quality requirement is a QEF (Quasi Error Free) reception.

This standard describes the physical layer connection for home networks. Description of protocols required for Layer 2 and higher layers is out of the scope of this standard. Logical connections between devices within the home network are therefore not always guaranteed.

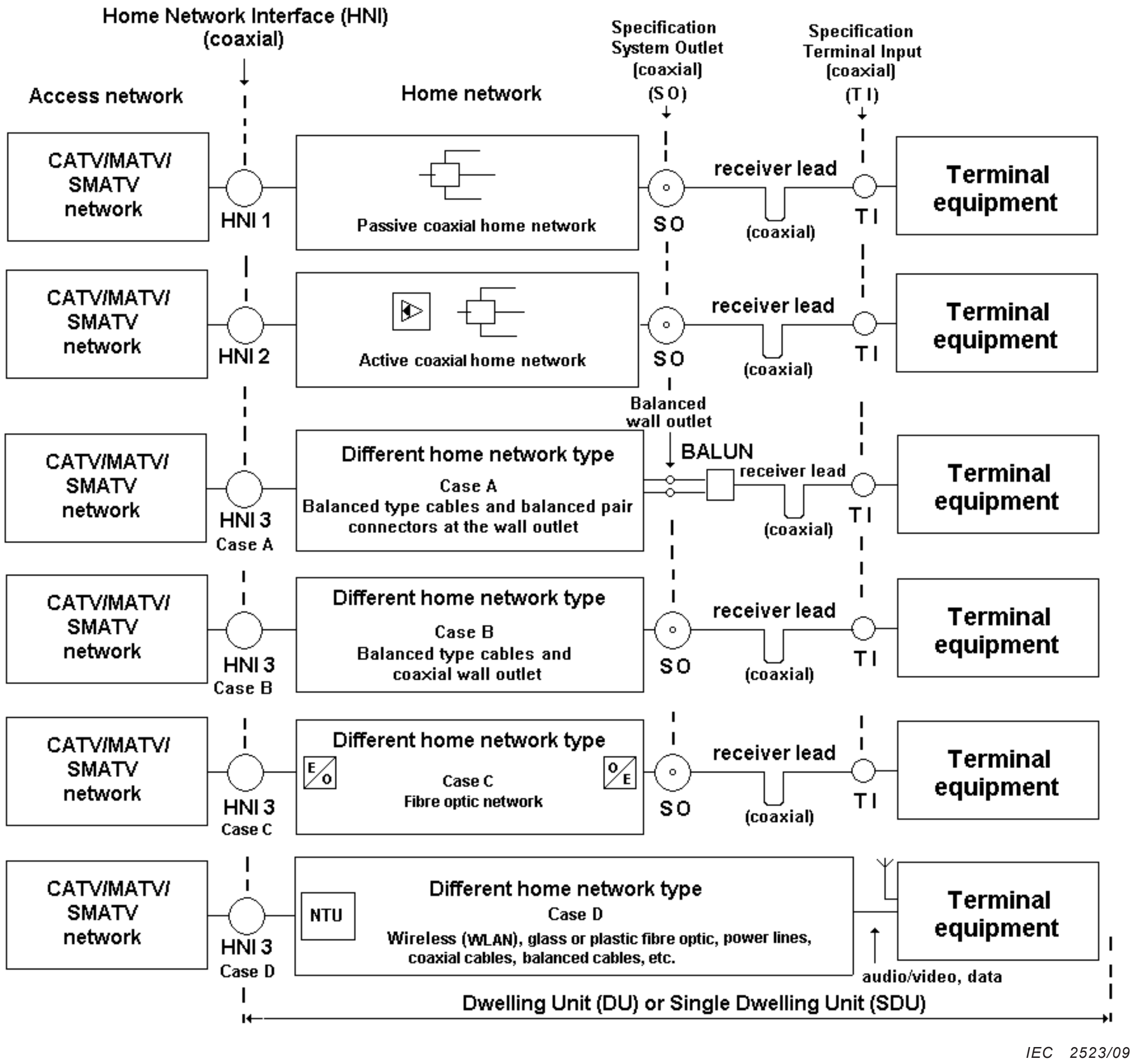

Figure 1 – Examples of RF home network types

CABLE NETWORKS FOR TELEVISION SIGNALS, SOUND SIGNALS AND INTERACTIVE SERVICES –

Part 1-1: RF cabling for two way home networks

1 Scope

This part of IEC 60728 provides the requirements and describes the implementation guidelines of RF cabling for two-way home networks. This standard is applicable to any home network that distributes signals provided by CATV/MATV/SMATV cable networks (including individual receiving systems) having a coaxial cable output. This standard also applies to home networks where some part of the distribution network uses wireless links, for example instead of the receiver cord.

This part of IEC 60728 is therefore applicable to RF cabling for two-way home networks with wired cords or wireless links inside a room and primarily intended for television and sound signals operating between about 5 MHz and 3 000 MHz. The frequency range is extended to 6 000 MHz for distribution techniques that replace wired cords with a wireless two-way communication inside a room (or a small number of adjacent rooms) that uses the 5 GHz to 6 GHz band.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60050-705, *International Electrotechnical Vocabulary – Chapter 705: Radio wave propagation*

IEC 60050-712, *International Electrotechnical Vocabulary – Chapter 712: Antennas*

IEC 60050-725, *International Electrotechnical Vocabulary – Chapter 725: Space radiocommunications*

IEC 60728-1:2014, *Cable networks for television signals, sound signals and interactive services – Part 1: System performance of forward paths*

IEC 60728-1-2, *Cable networks for television signals, sound signals and interactive services – Part 1-2: Performance requirements for signals delivered at system outlet in operation*

IEC 60728-3:2010, *Cable networks for television signals, sound signals and interactive services – Part 3: Active wideband equipment for coaxial cable networks*

IEC 60728-10, *Cable networks for television signals, sound signals and interactive services – Part 10: System performance of return paths*

IEC 60966 (all parts), *Radio frequency and coaxial cable assemblies*

IEC 60966-2 (all parts), *Radio frequency and coaxial cable assemblies – Part 2: Detail specification for cable assemblies for radio and TV receivers*

IEC 60966-2-4, *Radio frequency and coaxial cable assemblies – Part 2-4: Detail specification for cable assemblies for radio and TV receivers – Frequency range 0 MHz to 3 000 MHz, IEC 61169-2 connectors*

IEC 60966-2-5, *Radio frequency and coaxial cable assemblies – Part 2-5: Detail specification for cable assemblies for radio and TV receivers – Frequency range 0 MHz to 1 000 MHz, IEC 61169-2 connectors*

IEC 60966-2-6, *Radio frequency and coaxial cable assemblies – Part 2-6: Detail specification for cable assemblies for radio and TV receivers – Frequency range 0 MHz to 3 000 MHz, IEC 61169-24 connectors*

IEEE 802.11, *IEEE Standards for Information technology – Telecommunications and Information Exchange between Systems – Local and Metropolitan Area Network – Specific Requirements – Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications*[1]

IEEE 802.11a, *IEEE Standard for Information technology – Telecommunications and information exchange between systems – Local and metropolitan area networks – Specific requirements – Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications – Amendment 1: High-speed Physical Layer in the 5 GHz band*

IEEE 802.11b, Supplement to 802.11-1999, *Wireless LAN MAC and PHY specifications: Higher speed Physical Layer (PHY) extension in the 2.4 GHz band*

IEEE 802.11e, *IEEE Standard for Information technology – Telecommunications and information exchange between systems – Local and metropolitan area networks – Specific requirements Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications: Amendment 8: Medium Access Control (MAC) Quality of Service Enhancements*

IEEE 802.11g, *IEEE Standard for Information technology – Telecommunications and information exchange between systems – Local and metropolitan area networks – Specific requirements – Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications – Amendment 4: Further Higher-Speed Physical Layer Extension in the 2.4 GHz Band*

IEEE 802.11h, *IEEE Standard for Information technology – Telecommunications and Information Exchange Between Systems – LAN/MAN Specific Requirements – Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications: Spectrum and Transmit Power Management Extensions in the 5GHz band in Europe*

IEEE 802.11n, *IEEE Standard for Information Technology – Telecommunications and information exchange between systems-Local and metropolitan area networks-Specific requirements – Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications: Amendment 4: Enhancements for Higher Throughput*

IEEE 802.16, *IEEE Standard for Local and metropolitan area networks – Part 16: Air Interface for Fixed Broadband Wireless Access Systems (WiMax)*

ITU-R Recommendation BT.500, *Methodology for the subjective assessment of the quality of television pictures*

———————

[1] Parts of IEEE 802.11 are reproduced in ISO/IEC 8802-11:2005, *Information technology – Telecommunications and information exchange between systems – Local and metropolitan area networks – Specific requirements – Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specification*

ITU-T Recommendation J.61, *Transmission performance of television circuits designed for use in international connections*

ITU-T Recommendation J.63, *Insertion of test signals in the field-blanking interval of monochrome and colour television signals*

EN 50117-2-4, *Coaxial cables – Part 2-4: Sectional specification for cables used in cabled distribution networks – Indoor drop cables for systems operating at 5 MHz to 3 000 MHz*

ETSI EN 300 421, *Digital Video Broadcasting (DVB); Framing structure, channel coding and modulation for 11/12 GHz satellite services*

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ETSI EN 300 473, *Digital Video Broadcasting (DVB); Satellite Master Antenna Television (SMATV) distribution systems*

ETSI EN 300 744, *Digital Video Broadcasting (DVB); Framing structure, channel coding and modulation for digital terrestrial television*

ETSI EN 302 307, *Digital Video Broadcasting (DVB) – Second generation framing structure, channel coding and modulation systems for Broadcasting, Interactive Services, News Gathering and other broadband satellite appli*cations *(DVB-S2)*

ETSI EN 302 755, *Digital Video Broadcasting (DVB) – Frame structure, channel coding and modulation for a second generation digital terrestrial television broadcasting system (DVB-T2)*

3 Terms, definitions, symbols and abbreviations

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60050-705, IEC 60050-712 and IEC 60050-725, apply.

NOTE The most important definitions are repeated below.

3.1.1
active home network
home network that uses active equipment (for example, amplifiers) in addition to passive equipment like splitters, taps, system outlets, cables and connectors up to the coaxial RF interface (input and/or output) of the terminal equipment for distributing and combining RF signals

3.1.2
antenna
part of a radio transmitting or receiving system which is designed to provide the required coupling between a transmitter or receiver and the medium in which the radio wave propagates

Note 1 to entry: In practice, the terminals of the antenna or the points to be considered as the interface between the antenna and the transmitter or receiver should be specified.

Note 2 to entry: If the transmitter or receiver is connected to its antenna by a feeder line, the antenna may be considered to be a transducer between the guided radio waves of the feeder line and the radiated waves in space.

[SOURCE: IEC 60050-712:1992, 712-01-01, modified – The term feeder line instead of feed line has been used in note 2.]

3.1.3
attenuation
ratio of the input power to the output power of an equipment or system

Note 1 to entry: The ratio is expressed in decibels.

3.1.4
balun
device for transforming an unbalanced voltage to a balanced voltage or vice-versa

Note 1 to entry: The term is derived from balanced to unbalanced transformer.

3.1.5
bit error ratio
BER
ratio between erroneous bits and the total number of transmitted bits

3.1.6
broadcast and communication technologies
BCT
group of applications including RF distribution of sound signals and video signals

Note 1 to entry: For this standard, this is a group of applications using the HF band (3 MHz to 30 MHz), the VHF band (30 MHz to 300 MHz) and the UHF band (300 MHz to 3 000 MHz) for transmission of television signals, sound signals and interactive services, as well as for in-home inter-networking.

3.1.7
carrier-to-intermodulation ratio
C/I
difference between the carrier level at a specified point in a piece of equipment or a system and the level of a specified intermodulation product or combination of products

Note 1 to entry: The difference is given in decibels.

3.1.8
carrier-to-noise ratio
C/N
difference between the vision or sound carrier level at a given point in a piece of equipment or a system and the noise level at that point (measured within a bandwidth appropriate to the television or radio system in use)

Note 1 to entry: The difference is given in decibels.

3.1.9
CATV network
regional and local broadband cable networks designed to provide sound and television signals as well as signals for interactive services to a regional or local area

Note 1 to entry: Originally defined as Community Antenna Television network.

3.1.10
cross-modulation
undesired modulation of the carrier of a desired signal by the modulation of another signal as a result of equipment or system non-linearities

3.1.11
decibel ratio
ten times the logarithm to base 10 of the ratio of two quantities of power P_1 and P_2, i.e

$$10 \lg \frac{P_1}{P_2} \quad \text{in dB}$$

Note 1 to entry: May also be expressed in terms of voltages.

$$20 \lg \frac{U_1}{U_2} \quad \text{in dB}$$

3.1.12
designed receiving antenna
antenna that has the gain, the directivity and the polarization for receiving the wanted signal at the headend site with the required performance

3.1.13
directivity
attenuation between output port and interface or tap port minus the attenuation between input port and interface or tap port, of any equipment or system

3.1.14
DOCSIS
Euro-DOCSIS
standards defining interface specifications for cable modems and cable modem termination systems for high-speed data communication over RF cable networks

3.1.15
dwelling unit
DU
home or office where television and sound signals are distributed and that provides access to interactive services

3.1.16
echo rating
E
result of a system test with a 2*T* sine-squared pulse using the boundary line on a specified graticule within which all parts of the received pulse fall

EXAMPLE See Figure 25 of IEC 60728-1:2014.

Note 1 to entry: Echo rating is determined in ITU-T Recommendation J.61 and ITU-T Recommendation J.63.

Note 2 to entry: The object of the graticule design is to ensure that the subjective effect of an echo of rating *E* % is the same as that of a single echo, with displacement greater than 12*T*, of (*E*/2) % relative to the peak amplitude of the test pulse.

3.1.17
extended satellite television distribution network or system
distribution network or system designed to provide sound and television signals received by satellite receiving antenna to households in one or more buildings

Note 1 to entry: This kind of network or system can be combined with terrestrial antennas for the additional reception of TV and/or radio signals via terrestrial networks.

Note 2 to entry: This kind of network or system can also carry control signals for satellite switched systems or other signals for special transmission systems (e.g. MoCA or WiFi) in the return path direction.

3.1.18
extended terrestrial television distribution network or system
distribution network or system designed to provide sound and television signals received by terrestrial receiving antennas to households in one or more buildings

Note 1 to entry: This kind of network or system can be combined with a satellite antenna for the additional reception of TV and/or radio signals via satellite networks.

Note 2 to entry: This kind of network or system can also carry other signals for special transmission systems (e.g. MoCA or WiFi) in the return path direction.

3.1.19
feeder
transmission path forming part of a cable network

Note 1 to entry: Such a path may consist of a metallic cable, optical fibre, waveguide, or any combination of them.

Note 2 to entry: By extension, the term is also applied to paths containing one or more radio links.

3.1.20
gain
ratio of the output power to the input power of any equipment or system

Note 1 to entry: The ratio is expressed in decibels.

3.1.21
headend
equipment which is connected between receiving antennas or other signal sources and the remainder of the cable networks, to process the signals to be distributed

Note 1 to entry: The headend may, for example, comprise antenna amplifiers, frequency converters, combiners, separators and generators.

3.1.22
headend for individual reception
headend supplying an individual household

Note 1 to entry: This type of installation may include one or more system outlets.

3.1.23
headend input
interface of the headend where the signals received by antennas or individual feeder lines are applied for signal processing

3.1.24
home cable link
HCL
physical link (cable) between the home distributor (HD) and the system outlet or the terminal input

3.1.25
home distributor
HD
distributor within a home where cables terminate

3.1.26
home network
HN
RF cable network inside a single dwelling (one-family house or one unit of a multi-dwelling building) in the SOHO (Small Offices Home Offices) environments or in the rooms of hotels, and hospitals.

Note 1 to entry: The preferred topology of this network is a star.

Note 2 to entry: This network carries television signals, sound signals and interactive services up to the coaxial RF interface (input and/or output) of the terminal equipment. It may comprise active equipment, passive equipment, cables and connectors.

3.1.27
home network interface
HNI
interface for access to the network for transmission of television signals, sound signals and interactive services inside a home (single dwelling)

Note 1 to entry: It is the first accessible point after the entrance of the network into an individual home (see Figure 2).

Note 2 to entry: In some cases the home network interface may coincide with the system outlet. In this case the performance requirements for a system outlet apply.

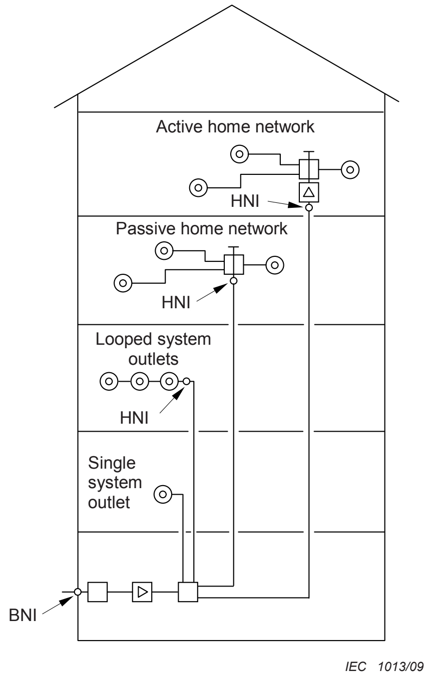


Figure 2 – Examples of location of HNI for various home network types

3.1.28
individual satellite television receiving system
system designed to provide sound and television signals received from satellite(s) to an individual household

Note 1 to entry: This kind of system can also carry control signals for satellite switched systems or other signals for special transmission systems (e.g. MoCA or WiFi) in the return path direction.

3.1.29
individual terrestrial television receiving system
system designed to provide sound and television signals received via terrestrial broadcast networks to an individual household

Note 1 to entry: This kind of system can also carry other signals for special transmission systems (e.g. MoCA or WiFi) in the return path direction.

3.1.30
intermodulation
process whereby non-linearity of equipment in a system produces output signals (called intermodulation products) at frequencies which are linear combinations of those of the input signals

3.1.31
isolation
attenuation between two output, tap or interface ports of any equipment or system

3.1.32
3.1.32.1
level
ratio of any power P_1 to the standard reference power P_0, i.e

$$10\lg \frac{P_1}{P_0} \quad \text{in dB}$$

Note 1 to entry: The ratio is given in decibel (dB).

Note 2 to entry: This may be expressed in decibels (relative to 1 μV in 75 Ω) or more simply in dB(μV) if there is no risk of ambiguity.

3.1.32.2
level
ratio of any voltage U_1 to the standard reference voltage U_0, i.e

$$20\lg \frac{U_1}{U_0} \quad \text{in dB}$$

Note 1 to entry: The ratio is given in decibel (dB).

Note 2 to entry: This may be expressed in decibels (relative to 1 μV in 75 Ω) or more simply in dB(μV) if there is no risk of ambiguity.

3.1.33
local broadband cable network
network designed to provide sound and television signals as well as signals for interactive services to a local area (e.g. one town or one village)

3.1.34
looped system outlet
device through which the spur feeder passes and to which is connected a receiver lead, without the use of a subscriber feeder

3.1.35
MATV headend
headend used in blocks of flats and in built-up sites to feed TV channels and FM radio channels into the house network or the spur network

3.1.36
MATV network
extended terrestrial television distribution networks or systems designed to provide sound and television signals received by terrestrial receiving antenna to households in one or more buildings

Note 1 to entry: Originally defined as Master Antenna Television network.

Note 2 to entry: This kind of network or system can be combined with a satellite antenna for the additional reception of TV and/or radio signals via satellite networks.

Note 3 to entry: This kind of network or system can also carry other signals for special transmission systems (e.g. MoCA or WiFi) in the return path direction.

3.1.37
multi dwelling unit
MDU
building with many homes or offices used by single owners where television signals, sound signals are distributed and with access to interactive services

3.1.38
multiplex
signals from several separate sources assembled into a single composite signal for transmission over a common transmission channel

[SOURCE: IEC 60050-701:1988, 701-03-10, modified – Term and definition have been changed to describe the result of the multiplexing process.]

3.1.39
mutual isolation
attenuation between two specified system outlets at any frequency within the range of the system under investigation which is always specified, for any particular installation, as the minimum value obtained within specified frequency limits

3.1.40
network interface
NI
interface to the network for transmission of television signals, sound signals and interactive services

3.1.41
network termination unit
NTU
equipment for access to the cable network for television signals, sound signals and interactive services

3.1.42
permanent link
transmission path between any two test interfaces within a cabling subsystem link including the connecting hardware at each end

3.1.43
receiver lead
lead which connects the system outlet to the subscriber's equipment

Note 1 to entry: A receiver lead may include filters and balun transformers in addition to the cable.

3.1.44
regional broadband cable network
network designed to provide sound and television signals as well as signals for interactive services to a regional area covering several towns and/or villages

3.1.45
SMATV network
extended distribution networks or systems designed to provide sound and television signals received by satellite receiving antenna to households in one or more buildings

Note 1 to entry: Originally defined as satellite master antenna television network.

Note 2 to entry: This kind of network or system can be combined with terrestrial antennas for the additional reception of TV and/or radio signals via terrestrial networks.

Note 3 to entry: This kind of network or system can also carry control signals for satellite switched systems or other signals for special transmission systems (e.g. MoCA or WiFi) in the return path direction

3.1.46
satellite master antenna television system
SMATV
system designed to provide sound and television signals to the outlets of a building or a group of buildings

Note 1 to entry: Two system configurations are defined in ETSI EN 300 473 as follows:

- SMATV system A, based on transparent transmodulation of QPSK satellite signals into QAM signals to be distributed to the user;
- SMATV system B, based on direct distribution of QPSK signals to the user, with two options:
  – SMATV-IF distribution in the satellite IF band (above 950 MHz);
  – SMATV-S distribution in the VHF/UHF band, for example in the extended S band (230 MHz to 470 MHz)

3.1.47
$S_{\mathbf{D,RF}}/N$
signal-to-noise ratio for a digitally modulated signal in the RF band

3.1.48
single dwelling unit
SDU
home or office used by a single owner where television signals and sound signals are distributed and with access to interactive services

3.1.49
slope
difference in gain or attenuation at two specified frequencies between any two points in a system

3.1.50
splitter
spur unit
device in which the signal power at the (input) port is divided equally or unequally between two or more (output) ports

Note 1 to entry: Some forms of this device may be used in the reverse direction for combining signal energy.

3.1.51
spur feeder
feeder to which splitters, subscriber taps, or looped system outlets are connected

3.1.52
standard reference power
$P_{\mathbf{0}}$
<in cable networks> 1/75 pW

Note 1 to entry: This is the power dissipated in a 75 Ω resistor with a voltage drop of 1 μV_{RMS} across it.

3.1.53
subscriber feeder
feeder connecting a subscriber tap to a system outlet or, where the latter is not used, directly to the subscriber equipment

Note 1 to entry: A subscriber feeder may include filters and balun transformers.

3.1.54
subscriber equipment
equipment at the subscriber premises such as receivers, tuners, decoders, video recorders

3.1.55
subscriber tap
device for connecting a subscriber feeder to a spur feeder

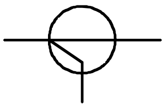
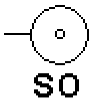
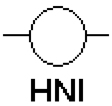
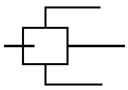
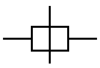
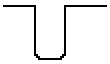
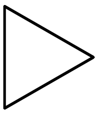
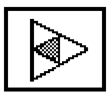
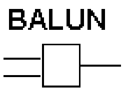
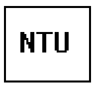
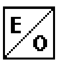
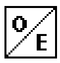
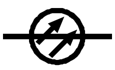
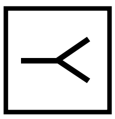
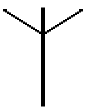
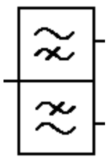
3.1.56
system outlet
SO
device for interconnecting a subscriber feeder and a receiver lead

3.1.57
terminal equipment
equipment (television receiver, radio receiver, set-top box, etc.) able to receive the distributed signals or to send (via a cable modem) return signals for interactive services

3.1.58
well-matched
matching condition when the return loss of the equipment complies with the requirements of Table 1 of IEC 60728-3:2010

3.2 Symbols

The following graphical symbols are used in the figures of this standard. These symbols are either listed in IEC 60617 or based on symbols defined in IEC 60617.

Symbols	Terms	Symbols	Terms
	Directional coupler [IEC 60617-S01340 (2001-07)]		System outlet (SO) [IEC 60617-S00438, modified (2001-07)]
	HNI: Home Network Interface		Splitter
	Subscriber tap		Receiver lead
	Amplifier [IEC 60617-S01239 (2001-07)]		Two-way amplifier
	Balun: Balanced to unbalanced transformer		NTU: Network Terminating Unit
	Optical transmitter based on [IEC 60617-S01231 (2001-07)]		Optical receiver based on [IEC 60617-S01231 (2001-07)]
	Optical fibre [IEC 60617-S01318 (2001-07)]		Coupler based on [IEC 60617-S00059 and IEC 60617-S01188 (2001-07)]
	Antenna [IEC 60617-S01102 (2001-07)]		Diplexer based on [IEC 60617-S01247 and IEC 60617-S01248 (2001-07)]

3.3 Abbreviations

ADSL	Asynchronous Digital Subscriber Line	AM	Amplitude Modulation
APSK	Amplitude and Phase Shift Keying	BCT	Broadcast and Communication Technologies
BER	Bit Error Ratio	BPSK	Binary Phase Shift Keying
BW	Bandwidth	*C/I*	Carrier-to-Interference ratio
C/N	Carrier-to-Noise ratio (ratio of RF or IF power to noise power)	CATV	Community Antenna Television
CCK	Complementary Code Keying	COFDM	Coded Orthogonal Frequency Division Multiplex
DAB	Digital Audio Broadcasting	DFS	Dynamic Frequency Selection
DOCSIS	Data Over Cable Service Interface Specification	DPC	Dynamic Power Control
DSSS	Direct Sequence Spread Spectrum	DU	Dwelling Unit
DVB	Digital Video Broadcasting	DVB-C	Digital Video Broadcasting baseline system for digital Cable television (ETSI EN 300 429)
DVB-S	Digital Video Broadcasting baseline system for digital Satellite television (ETSI EN 300 421)	DVB-S2	Digital Video Broadcasting baseline system for digital Satellite television Second generation (ETSI EN 302 307)
DVB-T	Digital Video Broadcasting baseline system for digital Terrestrial television (ETSI EN 300 744)	DVB-T2	digital video broadcasting baseline system for digital terrestrial television second generation (ETSI EN 302 755)
EIRP	Equivalent Isotropically Radiated Power	Euro DOCSIS	European Data Over Cable Service Interface Specification
FDM	Frequency Division Multiplex	FFT	Fast Fourier Transformation
FM	Frequency Modulation	HCL	Home Cable Link
HD	Home Distributor	HFC	Hybrid Fibre Coaxial
HN	Home Network	HNI	Home Network Interface
IF	Intermediate Frequency	IP	Internet Protocol
LAN	Local Area Network	LED	Light Emitting Diode
MAC	Medium Access Control	MAN	Metropolitan Area Network
MATV	Master Antenna Television (network)	MoCA	Multimedia over Cable Alliance
MCS	Modulation Coding Scheme	MDU	Multi-Dwelling Unit
MIMO	Multiple Input Multiple Output	MRC	Maximum Ratio Combining
NI	Network Interface	NICAM	Near-Instantaneously Companded Audio Multiplex
NTSC	National Television System Committee	NTU	Network Termination Unit
OFDM	Orthogonal Frequency Division Multiplex	PAL	Phase Alternation Line

PC	Personal Computer	PCMCIA	Personal Computer Memory Card International Association
PHY	Physical (layer)	PSK	Phase Shift Keying
PVR	Personal Video Recorder	QAM	Quadrature Amplitude Modulation
QEF	Quasi Error Free	QPSK	Quaternary Phase Shift Keying
RF	Radio Frequency	SDU	Single Dwelling Unit
SECAM	Séquenciel Couleur À Mémoire	SISO	Single Input Single Output
SMATV	Satellite Master Antenna Television	SO	System Outlet
SOHO	Small Office Home Office	TCP	Transmission Control Protocol
TC8PSK	Trellis Coded 8-Phase Shift Keying	TI	Terminal Input
TPC	Transmission Power Control	TV	Television
UDP	User Datagram Protocol	UHF	Ultra-High Frequency
USB	Universal Serial Bus	UWB	Ultra-Wide-Band
VHF	Very High Frequency	VSB	Vestigial Side Band
WLAN	Wireless Local Area Network	WiFi	Wireless Fidelity

4 Methods of measurement for the home network

The methods of measurement are related to the most important characteristics and requirements that the home network shall fulfil. The home network can be considered as a cabled bidirectional transmission network. Therefore the measuring methods described in IEC 60728-1 and in IEC 60728-10 for CATV/MATV/SMATV are applicable, although the network is much smaller in size. For the forward path the input of the network is in this case at the home network interface (HNI), while the output is still the system outlet (SO) or the terminal input (TI). The methods of measurement of the forward path for analogue and/or digitally modulated carriers are indicated in Table 1 with reference to the relevant clauses of IEC 60728-1:2014.

In a building divided into apartment blocks, the distribution of the signals inside the home starts from the home network interface (HNI) up to the system outlet or terminal input. The requirements at the system outlet are given in IEC 60728-1:2014, Clause 5 and the requirements at the HNI are given in IEC 60728-1:2014, Clause 7. In Clause 5 of this standard gives additional requirements.

This standard deals with various possibilities to distribute signals in a home network, using coaxial cables, balanced pair cables, fibre optic cables (glass or plastic) and also wireless links inside a room (or a small number of adjacent rooms) to replace wired cords.

This standard gives references to basic methods of measurement of the operational characteristics of the home cable network in order to assess its performance.

All requirements refer to the performance limits, which are obtained between the input(s) at the home network interface (HNI) and the output at any system outlet when terminated in a resistance equal to the nominal load impedance of the system, unless otherwise specified. Where system outlets are not used, the above applies to the terminal input.

If the home network is subdivided into a number of parts, using different transmission media (e.g. coaxial cabling, balanced cabling, optical cabling, wireless links) the accumulation of degradations should not exceed the figures given below.

NOTE Performance requirements of return paths as well as special methods of measurement for the use of the return paths in cable networks are described in IEC 60728-10.

Table 1 – Methods of measurement of IEC 60728-1:2014 applicable to the home network

Methods of measurement Subclause reference of IEC 60728-1:2014	Modulation of carriers									
	Analogue					Digital				
	Television				Radio FM	Television				
	Vision carrier AM-VSB			Vision and sound carriers	TV sound carrier	Vision and sound DVB			Sound	Radio
	NTSC	PAL	SECAM	FM	FM/AM	PSK, APSK	QAM	OFDM	NICAM	DAB
4.2 Mutual isolation between system outlets	X	X	X	X	X	X	X	X	X	X
4.3 Amplitude response within a channel	X	X	X	X	X	X	X	X	X	X
4.4 Chrominance luminance gain and delay inequalities		X	X							
4.5 Non-linear distortion	X	X	X	X	X		X			
4.6 Carrier-to-noise ratio	X	X	X	X	X					
4.7 Echoes	X	X	X							
4.8 AM-VSB television, FM radio and FM television signal level	X	X	X	X	X					
4.9 Data echo rating and data delay inequality	X	X	X							
4.10 Interference in FM sound channels					X					
4.11 Methods of measurement for digitally modulated signals						X	X	X		X
NOTE For non linearity (intermodulation) measurements of equipment used in the home network the reference method is described in IEC 60728-3:2010.										

5 Performance requirements of the home network

5.1 General

This clause defines the performance limits measured at system outlets or terminal inputs for an unimpaired (ideal) test signal applied at the HNI. In normal operating conditions for any analogue channel, the cumulative effect of the impairment of any single parameter at the HNI and that due to the home network will produce picture and sound signals not worse than Grade four on the five-grade impairment scale contained in ITU-R Recommendation BT.500 as given below:

5 – imperceptible;

4 – perceptible but not annoying;

3 – slightly annoying;

2 – annoying;

1 – very annoying.

The system parameters specified are mainly related to analogue frequency division multiplexed (FDM) signals. When different techniques are used, the overall quality requirements should be met.

The performance limits set out in this clause apply when the methods of measurement given in Clause 4 are employed, and, where appropriate, in the presence of all the signals for which the system was designed. The performance limits shall be met for those specified conditions of temperature, humidity, mains supply voltage and frequency, which apply to the location in which the home network is situated.

If a higher grade than 4 is desired at system outlet, the figures quoted in Clause 5 of IEC 60728-1:2014 should be modified accordingly. For instance, for grade 4,5, the figures quoted in 5.8 and 5.9 of IEC 60728-1:2014 shall be increased by 3 dB. The echo rating in 5.10.2 of IEC 60728-1:2014 shall be reduced to 3 %.

NOTE Performance requirements that are frequency dependent are specified up to 2 150 MHz. Requirements for the frequency range 2 150 MHz to 3 000 MHz (6 000 MHz) are under consideration.

For digital signals, the system performance limits ensure a service that is quasi-error-free, corresponding to a bit error ratio, before Reed-Solomon error correction, of 1×10^{-4} in a DVB signal.

When measuring the system parameters at the system outlet or terminal input in operation, the limit values indicated below can be exceeded, taking into account the contribution of the signal performance (quality) of each parameter present at the HNI.

EXAMPLE: The carrier-to-noise ratio measured at the system outlet in operation is lower than the values given at the HNI in Clause 7 of IEC 60728-1:2014. That is, for DVB-S or DVB-S2 the carrier to noise ratio will be impaired by up to 1 dB in respect to the HNI values given in Clause 7 of IEC 60728-1:2014.

5.2 Impedance

The nominal impedance of the home network shall be 75 Ω when coaxial cables are used or 100 Ω when twisted pair cables are used. It should be noted that the value of 75 Ω applies to all coaxial feeder cables and system outlets and shall be used as the reference impedance for all measurements.

5.3 Performance requirements at the terminal input

5.3.1 General

The following requirements apply when a receiver lead connects the system outlet directly to the “terminal input” (see 3.1.74 and 3.1.99 of IEC 60728-1:2014).

5.3.2 Signal level

The signal levels are those given in IEC 60728-1:2014 at the system outlet, reduced by the attenuation specified in IEC 60966-2-4, IEC 60966-2-5, IEC 60966-2-6. A receiver lead shorter than 3 m is not considered to affect the other quality parameters of the service provided by the terminal.

NOTE At the terminal input the signal level present at the system outlet is reduced by approximately 1,5 dB (at 1 000 MHz) by the receiver lead loss.

When balanced cables are used in the home network, the minimum signal levels at the terminal input are increased by 1 dB (see Table 45 of IEC 60728-1:2014).

5.3.3 Other parameters

The performance requirements given in IEC 60728-1:2014 at the system outlet remain unchanged at the terminal input.

5.4 Performance requirements at system outlets

5.4.1 Minimum and maximum carrier levels

The minimum and maximum carrier levels given in 5.4.1 of IEC 60728-1:2014 apply.

When balanced cables are used in the home network, the minimum signal levels at the system outlet are increased by 1 dB (see Table 45 of IEC 60728-1:2014).

5.4.2 Mutual isolation between system outlets

The minimum isolation at any frequency between any two system outlets connected separately to a spur feeder system shall be those given in 5.5.1 of IEC 60728-1:2014.

NOTE These requirements are relevant for the designer of the home network with respect to home networks installed in other households or dwelling units.

5.4.3 Isolation between individual outlets in one household

The minimum isolation between two individual outlets in one household shall be higher than 22 dB.

NOTE It may also be necessary to fulfil the requirements of 5.5.1 of IEC 60728-1:2014 for one household, if special conditions require it (e.g. if several analogue TV receivers are operated simultaneously).

5.4.4 Isolation between forward and return path

If system outlets are provided with return path inputs, the minimum isolation between return path input and any FM radio or television (analogue or digital: 64 QAM) output shall comply with 5.5.3 of IEC 60728-1:2014.

5.4.5 Long-term frequency stability of distributed carrier signals at any system outlet

The requirements given in 5.7 of IEC 60728-1:2014 shall apply, when frequency conversion is performed inside the active home network.

5.5 Performance requirements at the HNI

5.5.1 Minimum and maximum carrier levels at HNI1

The minimum and maximum signal levels at HNI1 shall not exceed those given in 7.2.2 of IEC 60728-1:2014.

5.5.2 Minimum and maximum carrier levels at HNI2 and HNI3

The minimum and maximum signal levels at HNI2 and HNI3 shall not exceed those given in 7.3.2 of IEC 60728-1:2014.

5.6 Carrier level differences in the home network from HNI to system outlet

The differences of carrier levels at system outlet shall not exceed 5 dB in the frequency range of 47 MHz to 862 MHz, 6 dB in the frequency range of 950 MHz to 2 150 MHz. The difference between adjacent channels shall not exceed 1,5 dB.

NOTE The limit of 5 dB or 6 dB can be exceeded only when the HNI slope is better than the worst case of −7 dB (e.g. when 0 dB or +7 dB applies).

5.7 Frequency response within a television channel in the home network

5.7.1 General

Taking into account the requirements given in 5.6 of IEC 60728-1:2014 the following limits are given, applicable to active home networks, from the HNI to the system outlet (SO) or terminal input (TI).

5.7.2 Amplitude response

The amplitude response variations within any television channel shall not exceed the values given in Table 2.

Table 2 – Amplitude response variation in the home network

Signal modulation	Occupied or channel bandwidth MHz	Maximum variation (peak-to-peak) dB	Maximum slope of variation dB/MHz
AM-VSB television	7 or 8	0,5	0,2
FM television	27 to 36	1	0,5
QPSK (DVB-S)	37,125	1	0,5
QPSK, 8PSK, 16APSK, 32APSK (DVB-S2)	37,125	u.c.	u.c.
TC8PSK (Japan)	34,5	–	–
64 QAM (DVB-C)	8	1[a]	0,2
64 QAM (Japan)	6	u.c.	u.c.
128 QAM (DVB-C)	8	0,75	u.c.
256 QAM (DVB-C)	8	0,5	u.c.
COFDM (DVB-T, DVB-T2)	8	0,2	0,2
OFDM (Japan)	6	u.c	u.c.
u.c. = under consideration.			
[a] Cable modems require a tighter amplitude response variation of less than 0,5 dB peak-to-peak in a 8 MHz channel bandwidth.			

5.7.3 Group delay

The group delay variation within any 8 MHz shall not exceed 10 ns. If the home network is designed only for a specific modulation scheme then the values given in Table 3 can be applied.

Table 3 – Group delay variation in the home network

Signal modulation	Frequency range MHz	Maximum group delay variation ns
AM-VSB television (PAL) with teletext	0,5 to 4,43	10
AM-VSB television (PAL) without teletext	0,5 to 4,43	10
QPSK	Signal bandwidth (see I.2.3 of IEC 60728-1:2014)	10
OFDM	Signal bandwidth (see I.2.3 of IEC 60728-1:2014)	10
QAM	Signal bandwidth (see I.2.3 of IEC 60728-1:2014)	10

5.8 Random noise produced in the home network

The level of noise voltage generated in the active home network, from the HNI to any SO or TI, in any channel shall be such that the carrier-to-noise ratio shall be at least 6 dB or 7 dB higher than the limits given in 5.8 of IEC 60728-1:2014, in order that the contributing impairment produced by the home network is not higher than 1,0 dB in regard to the carrier-to-noise ratio of the complete network.

This implies that the random noise contribution of the active home network shall be such that the *C/N* measured at any system outlet, with an unimpaired signal at the input of the home network (HNI), is higher than 51 dB (*BW* = 5 MHz) in the VHF/UHF bands (47 MHz to 862 MHz) and higher than 26 dB (*BW* = 27 MHz) in the first IF band (950 MHz to 2 150 MHz).

NOTE The maximum amplifier noise figure *NF* can be calculated considering the signal level *L* in dB(μV) at the HNI2 for VHF/UHF or first IF bands. The following formula can be applied:

$$NF = (C/N)_{in} - (C/N)_{out} = (L - N_{th}) - (C/N)_{out} \quad \text{[dB]} \qquad (1)$$

where N_{th} is the bandwidth dependent thermal noise voltage in dB(μV) (e.g. at T = 25 °C, N_{th} is 0,9 dB(μV) for *BW* = 4 MHz, 1,9 dB(μV) for *BW* = 5 MHz, 9,2 dB(μV) for *BW* = 27 MHz).

When the (worst case) signal level at HNI2 is L = 63 dB(μV) (VHF/UHF bands, AM-VSB PAL) or L = 48 dB(μV) (first IF band) the *NF* of the amplifier must not exceed 10,1 dB or 12,8 dB respectively.

5.9 Interference produced into downstream channels within a home network

5.9.1 General

These requirements apply when the home network contains active components.

This subclause considers only the multiple frequency intermodulation interference and the intermodulation noise generated in the active home network, from the HNI to any SO or TI.

NOTE Single frequency interference and single channel interference are not relevant for home networks.

5.9.2 Multiple frequency intermodulation interference

The level of the multiple frequency intermodulation interference generated in the active home network, from the HNI to any SO or TI, in any channel shall be sufficiently low in order that the contributing impairment produced by the home network is not higher than 2 dB with regard to the carrier-to-intermodulation ratio of the complete network.

This implies that the intermodulation contribution of the active coaxial home network shall be such that the carrier-to-multiple frequency interference ratio, in any wanted television channel, measured at any outlet, with an unimpaired signal at the input of the home network, is higher than 71 dB in the VHF/UHF bands (47 MHz to 862 MHz) and higher than 32 dB in the 1st IF band (950 MHz to 2 150 MHz). The equipment used in the forward path of the home network shall be specified according to the multicarrier measuring method described in IEC 60728-3:2010.

NOTE 1 If the carrier-to-intermodulation ratio of the active home network is higher than 76 dB in the VHF/UHF bands (47 MHz to 862 MHz) and higher than 35 dB in the first IF band (950 MHz to 2 150 MHz) the HNI2 values given in 7.3 of IEC 60728-1:2014 can be decreased by 1 dB.

NOTE 2 When coherent carriers are used lower limits are acceptable.

NOTE 3 Because intermodulation products between multiple, closely spaced, digital TV channels are similar to random noise, this intermodulation is taken into account in the carrier-to-noise measurements.

NOTE 4 The maximum output level of the amplifier may need to be adjusted to ensure it meets the 71 dB requirement in the VHF/UHF bands.

5.9.3 Intermodulation noise

The level of the intermodulation noise generated in the home network, from the HNI to any SO or TI, in any channel shall be sufficiently lower than the limits given for noise in 5.8 of IEC 60728-1:2014, so that the contribution of the impairment produced by the home network is not greater than 1 dB.

5.9.4 Crossmodulation

Under consideration.

6 Home network design and examples

6.1 General

The home network can be realised using coaxial cables, balanced cables, optical cables or radio links and requires a suitable design to fulfil the requirements given above.

6.2 Basic design considerations

6.2.1 General

The design of the home network starts from the following main specifications.

6.2.2 System outlet (SO) or terminal input (TI) specifications

The following subclauses and tables apply:

- minimum and maximum signal levels, as indicated in 5.3.2, 5.4.1 and Table 4 and Table 5 of IEC 60728-1:2014;
- maximum signal level differences allowed in the frequency range of interest, as indicated in 5.4.2 and in Table 6 of IEC 60728-1:2014 (e.g. 12 dB in the frequency range 47 MHz to 862 MHz for PAL, SECAM);
- when balanced cables are used in the home network, the minimum signal levels are increased by 1 dB (see Table 45 of IEC 60728-1:2014).

6.2.3 Home network interface (HNI) specifications

The following subclauses and tables apply:

- minimum and maximum signal levels at HNI1, as indicated in 7.2.2.1 and in Table 31 and Table 32 of IEC 60728-1:2014;

- minimum and maximum signal levels at HNI2 and HNI3, as indicated in 7.3.2.1 and in Table 37 and Table 38 of IEC 60728-1:2014;
- maximum signal level differences allowed in the frequency range of interest, as indicated in 7.2.2.2 and in Table 33 of IEC 60728-1:2014 for HNI1, in 7.3.2.2 and in Table 39 of IEC 60728-1:2014 for HNI2 and HNI3 (e.g. 7 dB in the frequency range 47 MHz to 862 MHz for PAL, SECAM).

Thus, the CATV/MATV/SMATV system provides, amongst others, television signals that, in the worst case, have a slope of −7 dB at the HNI. Hence the following requirements for the home network shall be taken into account.

NOTE The slope sign is considered:

a) negative when the attenuation increases with frequency (cables) or the gain (amplifiers) decreases with frequency;

b) positive when the gain (amplifiers) increases with frequency (compensating slope).

6.2.4 Requirements for the home network

6.2.4.1 Home network slope

The following requirements apply to the home network slope.

- The slope of the home cable link of the home network (between the HNI and the system outlet) shall be up to -5 dB (in the 47 MHz to 862 MHz frequency range), when the frequency response of the equipment, passive (splitter) or active (amplifier), is flat.
- The slope of the home cable link of the home network (between the HNI and the system outlet) can be lower than −5 dB (i.e. up to −11 dB), when the frequency response of the equipment, passive (splitter) or active (amplifier), has a compensating slope (i.e. up to +6 dB).
- The slope of the home cable link of the home network between the HNI and the terminal input (including a receiver lead 2 m long with characteristics according to the IEC 60966 series of standards) shall be up to –5,6 dB, when the frequency response of the equipment (passive (splitter) or active (amplifier)) is flat, or can be lower than –5,6 dB (i.e. up to –11,6 dB), when the frequency response of the equipment (passive (splitter) or active (amplifier)) has a compensating slope (i.e. up to +6 dB).

6.2.4.2 HNI signal level

The following requirements apply to the home network slope.

- The HNI1 interface level specification is up to 18 dB higher than the minimum system outlet specification (e.g. 78 dB(μV) for the analogue channels case with 60 dB(μV) minimum signal level at system outlet).
- The HNI2 and HNI3 interface minimum signal level specification is 3 dB to 6 dB higher than the minimum system outlet specification. The CATV/MATV/SMATV system may have at the HNI a positive slope ranging from 0 dB to +12 dB, when the HNI is near a CATV/MATV/SMATV amplifier. This is compatible with both types of standardized home-cabling (without or with a compensating slope up to +6 dB). However, taking the full benefit from the positive slope at the HNI would require a case by case analysis.

6.3 Implementation considerations

The implementation of a home network for BCT (Broadcast and Communication Technologies) signals requires special and appropriate installation criteria. Therefore, the following recommendations have to be fulfilled:

a) in coaxial cabling systems preference should be given to the interconnect model that avoids too many connections in series which may badly affect the signal quality;

b) jumpers and patch cords shall be avoided, by a direct connection of permanent link cables to the equipment;

As an installation rule half a meter of cable should be left hanging from the wall.

c) equipment connectors left unused shall be terminated with a matched load to minimize radiation, ingress and in-band ripples due to mismatches.

The following subclauses show some general examples of various types of home networks: coaxial and/or balanced cable networks, plastic or glass fibre optic networks, wireless links inside a home network, etc.

6.4 Home networks with coaxial and balanced cables

6.4.1 General

This subclause shows some basic design considerations for home networks based upon coaxial cabling and/or balanced cabling or other types of links used inside an apartment for carrying BCT signals provided by a CATV, MATV or SMATV cable network.

6.4.2 Network examples

Taking into account the above design and installation considerations, some examples of a home network implementation are indicated in Figure 3.

These examples show:

- the main requirement for signal level (maximum value) and slope (best and worst case) at the HNI and the total slope (worst case) allowed in the home network;
- the installation of a permanent link made with half a meter of cable left hanging from the wall, in order to allow direct connection to the equipment without jumpers or patch cords.

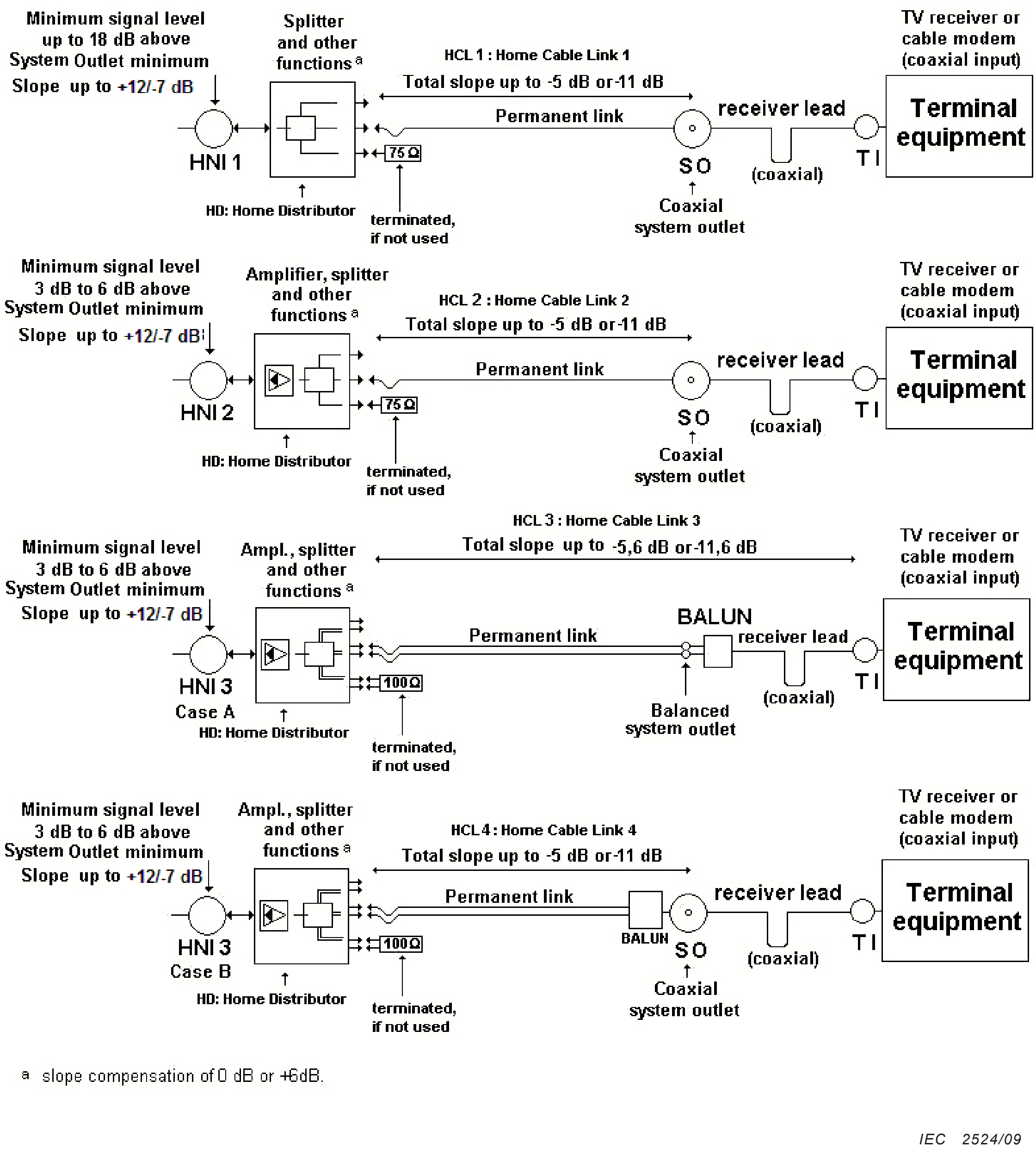


Figure 3 – Examples of home network implementation using coaxial or balanced cables

6.4.3 Calculation examples

6.4.3.1 General

The examples given in Table 4, Table 5, Table 6 and Table 7 show the maximum allowed insertion loss (or gain) of the home network between the HNI and system outlet (for HNI1, HNI2 and HNI3 case B) or the terminal input (HNI3 case A).

The home cable link (HCL) insertion loss is the addition of the losses of the fixed cabling (permanent link), of the equipment cords (receiver lead), of the system outlet and of any baluns used. The losses of the power splitter(s) and the gain of the amplifier near the HNI are not in the "HCL loss" and should be designed taking into account the number of system outlets to be connected and the type of the home network (passive or active, coaxial cable or balanced cables).

6.4.3.2 Passive or active coaxial home networks

The HNI1 and HNI2 specifications (7.2 and 7.3 of IEC 60728-1:2014) are related to a home network with coaxial cables and their connections, having a total length L_{PL} (permanent link length) which may be calculated, taking into account its attenuation and allowed slope.

The attenuation a_{PL} (dB), of the permanent link up to the system outlet, is given by the following formulae (this coaxial cable model is an example and corresponds to a specific attenuation of about 21,5 dB/100 m at 1 GHz (or 19,0 dB/100 m at 800 MHz according to EN 50117-2-4), assuming a direct connection of the cable to the equipment:

$$a_{PL} = (L_{PL}/100)\ (0{,}597\ \sqrt{f} + 0{,}002\,6\ f) + a_{SO} \quad [\text{dB}] \tag{2}$$

where

f is the frequency in MHz,

L_{PL} is the permanent link length in m,

a_{SO} is the loss of the system outlet in dB.

The values of Table 4 and Table 5 have been obtained assuming an attenuation of the system outlet (coaxial) of 0,5 dB.

NOTE The given values in Equation (2) and the tables are only examples and they can differ using other cable types with different specific parameters.

The insertion loss (dB) of the home cable links 1 and 2 (HCL1 and HCL2), including the receiver lead of length L_{RL} having characteristics according to the IEC 60966 series, but without jumpers or patch cords at the equipment, as stated in 6.3, is given by the following formula:

$$a_{HCL1,2} = a_{PL} + [0{,}08 + 0{,}4\ L_{RL}\ (f/1\,000)^{1/2}] \quad [\text{dB}] \tag{3}$$

6.4.3.3 Examples of signal levels in a home network with coaxial cables

6.4.3.3.1 General

In order to evaluate the behaviour of the HN when television signals are flowing in the forward path, signal levels at relevant points are obtained and shown at different frequencies taking into account the worst case for the HN with coaxial cables.

6.4.3.3.2 Passive home networks (HN) with coaxial cables

The evaluation of the signal levels in a passive home network requires that the following characteristics are known:

- the signal levels and slope at the home network interface (HNI1);
- the splitter attenuation due to the number of system outlets (SO) served, taking into account the mutual isolation required;
- the length of coaxial cables from the home distributor (HD) to the SO;
- the system outlet attenuation.

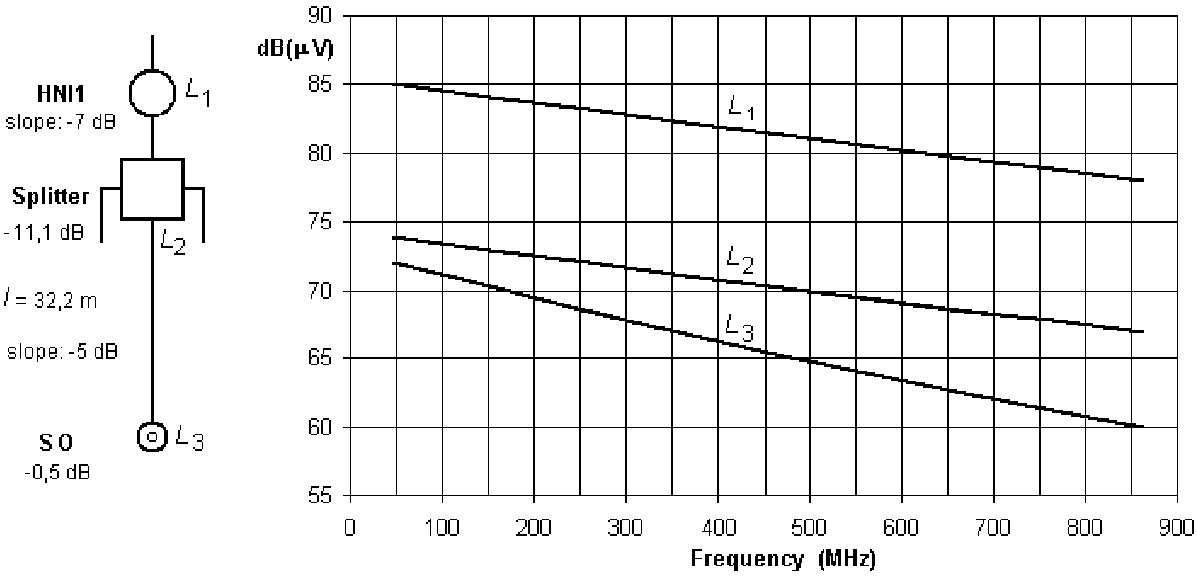
Assuming at the HNI1

- a slope of −7 dB (worst case),
- a signal level of 78 dB(μV) (+18 dB over the minimum SO level) at 862 MHz,

the maximum length of the coaxial cables is 32,2 m, as indicated in Table 5, in order to introduce a slope not higher than –5 dB and not to exceed the slope of –12 dB at SO. The splitter attenuation with a flat response is 11,1 dB, as also indicated in Table 5.

The signal levels at HNI1 (L_1), splitter output (L_2) and SO (L_3) are indicated in Figure 4.

It should be noted that the HNI1 maximum signal level is 85 dB(μV) at 47 MHz, according to the slope of –7 dB (worst case) and the signal level of 78 dB(μV) at 862 MHz.

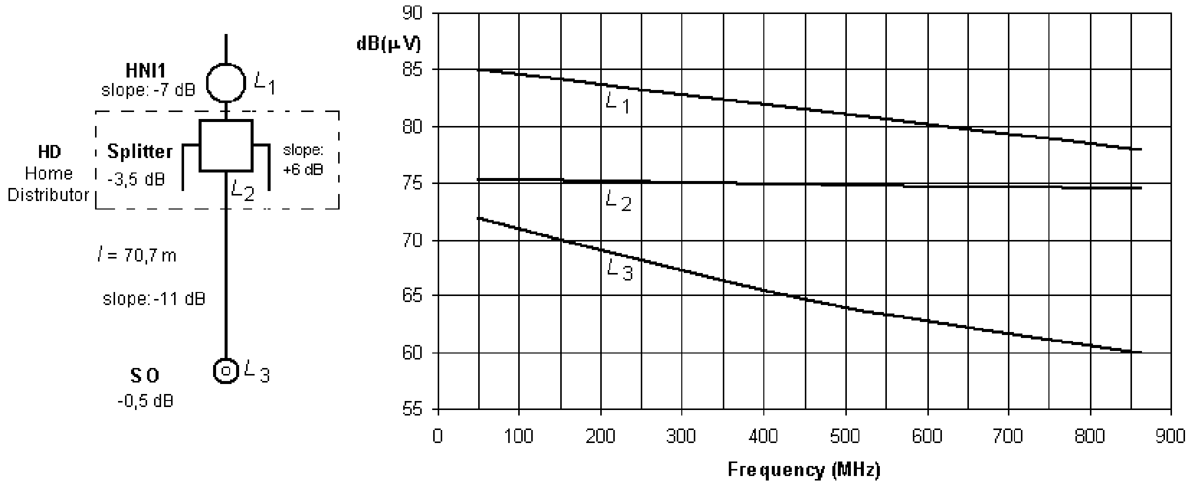


This diagram shows the signal levels at HNI1 (L_1), splitter output (L_2) and SO (L_3), assuming that the level delivered at HNI1 is +18 dB over the SO minimum at 862 MHz and the splitter has flat response over the frequency range.

Figure 4 – Signal levels at HNI1 (flat splitter response)

If the splitter has a compensating slope of +6 dB, the maximum splitter attenuation at 862 MHz should be not higher than 3,5 dB, but the maximum cable length is increased up to 70,7 m, as indicated in Table 6.

The signal levels at HNI1 (L_1), splitter output (L_2) and SO (L_3) are indicated in Figure 5.



This diagram shows the signal levels at HNI1 (L_1), splitter output (L_2) and SO (L_3), splitter output and SO, assuming that the level delivered at HNI1 is +18 dB over the SO minimum at 862 MHz and the splitter has a compensating slope of +6 dB over the frequency range.

Figure 5 – Signal levels at HNI1 (+6 dB compensating splitter slope)

6.4.3.3.3 Active home networks (HN) with coaxial cables

The evaluation of the signal levels in an active home network requires that the following characteristics are known:

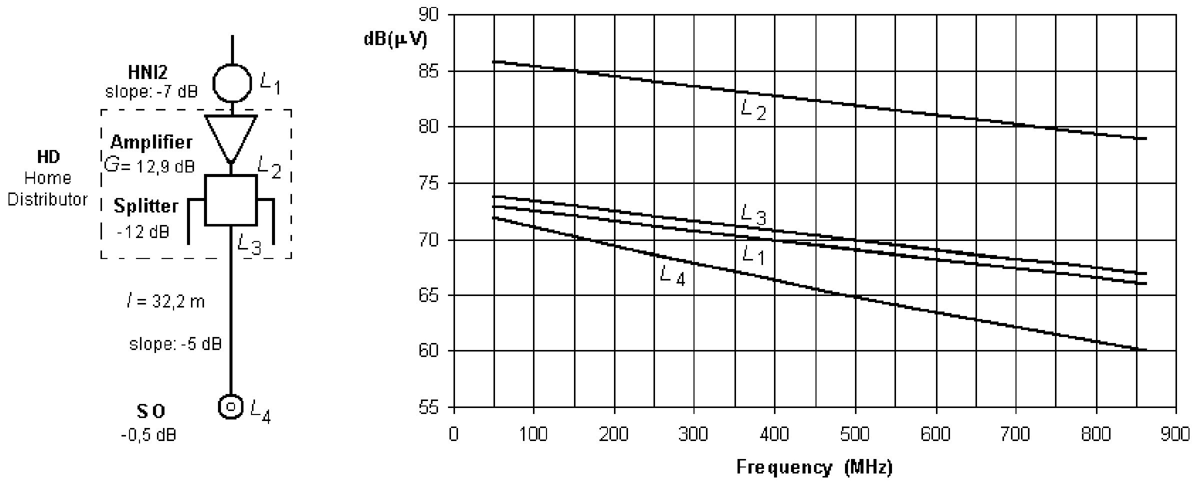
- the signal levels and slope at the home network interface (HNI2);
- the gain of the amplifier and splitter attenuation due to the number of system outlets (SO) served, taking into account the mutual isolation required;
- the length of coaxial cables from the home distributor (HD) to the SO;
- the system outlet attenuation.

Assuming at the HNI2

- a slope of −7 dB (worst case),
- a signal level of 66 dB(μV) (+6 dB over the minimum SO level) at 862 MHz,

the maximum length of the coaxial cables is 70,7 m, as indicated in Table 5, in order to introduce a slope not higher than –11 dB and does not exceed the slope of –12 dB at SO. The splitter attenuation, with a flat response, is of 12 dB and the gain of the amplifier is of 12,9 dB, as indicated in Table 5.

The signal levels at HNI2 (L_1), amplifier output (L_2), splitter output (L_3) and SO (L_4) are indicated in Figure 6.

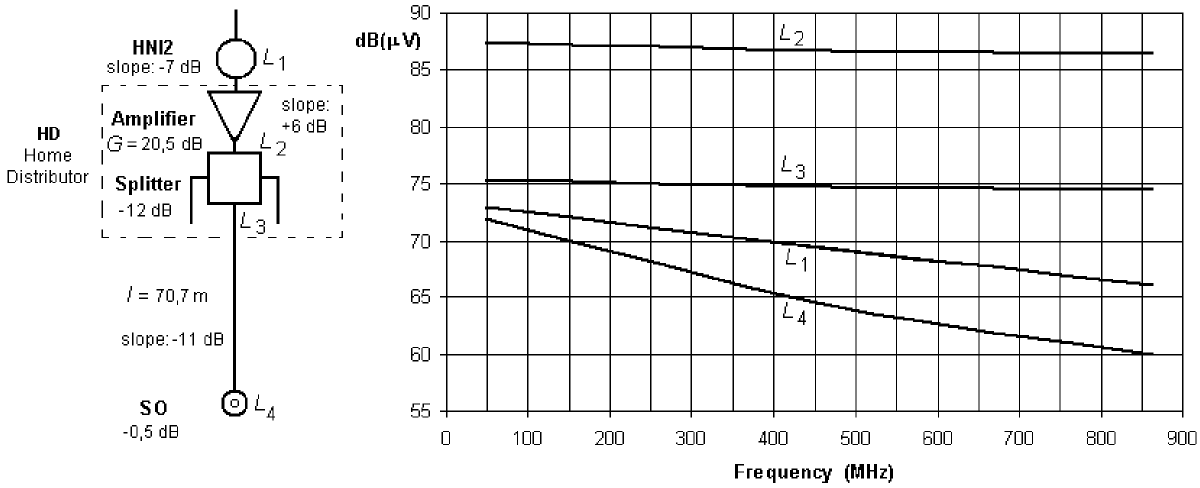


The diagram shows the signal levels at HNI2 (L_1), amplifier output (L_2), splitter output (L_3) and SO (L_4), assuming that the level delivered at HNI2 is +6 dB over the SO minimum at 862 MHz, the amplifier and the splitter have a flat response over the frequency range.

Figure 6 – Signal levels at HNI2 (L_1) (flat splitter/amplifier response)

If the amplifier and/or the splitter have a compensating slope of +6 dB (splitter attenuation of 12 dB and amplifier gain of 20,5 dB), the maximum cable length can be increased up to 70,7 m, as indicated in Table 5.

The signal levels at HNI2 (L_1), amplifier output (L_2), splitter output (L_3) and SO (L_4) are indicated in Figure 7.



This diagram shows the signal levels at HNI2 (L_1), amplifier output (L_2), splitter output (L_3) and SO (L_4), assuming that the level delivered at HNI2 is +6 dB over the SO minimum at 862 MHz, and that the amplifier and/or the splitter have a compensating slope of +6 dB over the frequency range.

Figure 7 – Signal levels at HNI2 (+6 dB compensating splitter/amplifier slope)

Table 4 – Example of home network implementation with coaxial cabling (passive) from HNI1 to system outlet

HNI1 Signal level above system outlet minimum	Splitter slope	Home distribution splitter attenuation	Maximum permanent link length L_{PL}	System outlet loss	Home cable link 1 (HCL1) insertion loss [a] dB					HCL1 Slope [a] 47 MHz to 862 MHz	HCL1 Slope [a] 950 MHz to 2 150 MHz
					47	**470**	**862**	**950**	**2 150**		
dB [b]	dB	dB	m	dB	MHz	MHz	MHz	MHz	MHz	dB	dB
18	0	11,1	32,2	0,5	1,9	5,1	6,9	7,2	11,2	−5,0	−4,0
18	+6	3,5	70,7	0,5	3,5	10,5	14,5	15,2	24,0	−11,0	−8,8

[a] Permanent link plus system outlet.

[b] In the rare case of a positive slope of +7 dB at the HNI1, the UHF (862 MHz) signal level at HNI1 has to be slightly above 80 dB(μV) for the Band I channels to meet the minimum level requirements, which are 60 dB(μV) (47 MHz at system outlet) +1,9 dB (permanent link) +11,1 dB (splitter) +7 dB (HNI1 positive slope) = 80 dB(μV)

Table 5 – Example of home network implementation with coaxial cabling (active) from HNI2 to system outlet

HNI2 Signal level above system outlet minimum	Amplifier gain	Amplifier or splitter slope	Home distribution splitter attenuation	Maximum permanent link length L_{PL}	System outlet loss	Home cable link 2 (HCL2) insertion loss [a] dB					HCL2 Slope [a] 47 MHz to 862 MHz	HCL2 Slope [a] 950 MHz to 2 150 MHz
						47	**470**	**862**	**950**	**2 150**		
dB	dB	dB	dB	m	dB	MHz	MHz	MHz	MHz	MHz	dB	dB
6	12,9	0	12,0	32,2	0,5	1,9	5,1	6,9	7,2	11,2	−5,0	-4,0
6	20,5	+6	12,0	70,7	0,5	3,5	10,5	14,5	15,2	24,0	−11,0	-8,8
3	15,8	0	12,0	32,2	0,5	1,9	5,1	6,9	7,2	11,2	−5,0	-4,0
3	23,5	+6	12,0	70,7	0,5	3,5	10,5	14,5	15,2	24,0	−11,0	-8,8

[a] Permanent link plus system outlet.

6.4.3.4 Different home network types (balanced type cables) (case A and case B)

The HNI3 specifications (7.4 of IEC 60728-1:2014) are related to a home network with balanced pair cables, having a total length L_{PL} (permanent link length) which may be calculated, taking into account its attenuation and the allowed slope.

In case A of Figure 3 there is not a coaxial system outlet (SO) but a balanced system outlet (e.g. RJ45 type connector) and a connection to the terminal input by a standardised (IEC 60966 series) receiver lead (coaxial) including a balun.

The receiver lead is assumed to comply with the specification given in 5.3.1. The length of this coaxial cable L_{RL} is assumed to be 2 m.

The attenuation (dB) of the home cable link 3 (HCL3) up to the terminal input, is given by the following formulae (the balanced cable model corresponds to a specific attenuation of about 62 dB/100 m at 1 GHz):

$$a_{HCL3A} = [L_{PL}/100]\ (1{,}645\ \sqrt{f} + 0{,}01\ f + 0{,}25/\sqrt{f}) + (0{,}04\ \sqrt{f}) + a_{BO} + a_{BAL} + (0{,}08 + 0{,}4\ L_{RL}\ (f/1\ 000)^{1/2})\ [\text{dB}] \quad (4)$$

where

f is the frequency in MHz,

L_{PL} is the permanent link length in m,

L_{RL} is the cable length of the coaxial receiver lead in m,

a_{BO} is the loss of the balanced system outlet in dB

a_{BAL} is the loss of the balun (in dB) included in the receiver lead.

The term: $0{,}08 + 0{,}4\ L_{RL}\ (f/1\ 000)^{1/2}$ is the attenuation model (see IEC 60966-2) for the receiver lead (coaxial) of length L_{RL}.

The values of Table 6 have been obtained assuming an attenuation of the system outlet (balanced) of 0,5 dB and of the balun of 0,5 dB.

The minimum signal level at terminal input shall comply with Table 45 of IEC 60728-1:2014 (i.e. at least 60 dB(μV) in this HNI3 case A).

NOTE 1 The 1 dB increase of minimum signal level at terminal input with respect to the all coaxial cases is a small provision against impairments due to a somewhat poorer return loss of balanced pair components.

NOTE 2 In this case the losses due to the balanced connectors (or connections) at both ends of the permanent link are assumed to be $0{,}04\sqrt{f}$.

For case B of Figure 3, where there is a coaxial system outlet (SO) and no patch cord or jumper in the connection to the equipment, the attenuation of the permanent link up to the system outlet is given by the following formula (the balanced cable model corresponds to a specific attenuation of about 62 dB/100 m at 1 GHz):

$$a_{HCL3B} = [L_{PL}/100]\ (1{,}645\ \sqrt{f} + 0{,}01\ f + 0{,}25/\sqrt{f}) + (0{,}04\ \sqrt{f}\ ) + a_{SO} + a_{BAL}\ \ [\text{dB}] \quad (5)$$

where

f is the frequency in MHz,

L_{PL} is the permanent link length in m,

A_{so} is the loss of the coaxial system outlet (SO) in dB,

a_{BAL} is the loss of the balun (in dB) included in the system outlet.

The values of Table 7 have been obtained assuming the attenuations of the system outlet (SO) (coaxial) and of its balun to be 0,5 dB each.

The minimum signal levels at system outlet shall comply with Table 45 of IEC 60728-1:2014 (i.e. at least 61 dB(μV) in this HNI3 case B).

NOTE 3 The 1 dB increase of minimum signal level at **system outlet** with respect to the all coaxial case is a small provision against impairments due to a somewhat poorer return loss of balanced pair components.

NOTE 4 In this case the losses (dB) due to the balanced connectors (or connections) at both ends of the permanent link are assumed to be 0,04 $\sqrt{f}$.

6.4.3.5 Examples of signal levels in a home network with balanced cables (case B)

In order to evaluate the behaviour of the HN when television signals are flowing in the forward path, the signal levels at relevant points are obtained and shown in the frequency domain, considering the worst case for the HN with balanced cables (case B).

NOTE For HN with balanced cables (case A) the signal levels are very similar and therefore are not shown here.

The evaluation of the signal levels in a home network requires that the following characteristics are known:

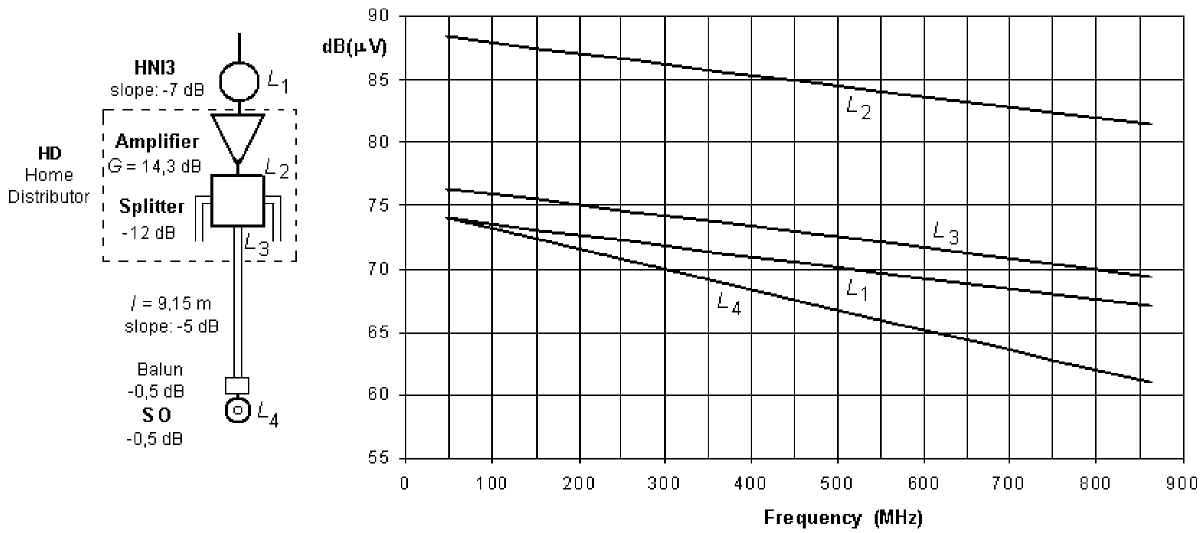
- the signal levels and slope at the home network interface (HNI3);
- the gain of the amplifier and splitter attenuation due to the number of system outlets (SO) served, taking into account the mutual isolation required;
- the length of balanced pair cables from the home distributor (HD) to the SO;
- the system outlet attenuation.

Assuming at the HNI3

- a slope of –7 dB (worst case),
- a signal level of 66 dB(μV) (+6 dB over the minimum SO level) at 862 MHz,

the maximum length of the balanced pair cables is 9,15 m, in order to introduce a slope not higher than –5 dB and not to exceed the slope of –12 dB at SO. The splitter attenuation with a flat response is of 12 dB and the gain of the amplifier is of 14,3 dB, as indicated in Table 5.

The signal levels at HNI3 (L_1), amplifier output (L_2), splitter output (L_3) and SO (L_4) are indicated in Figure 8.

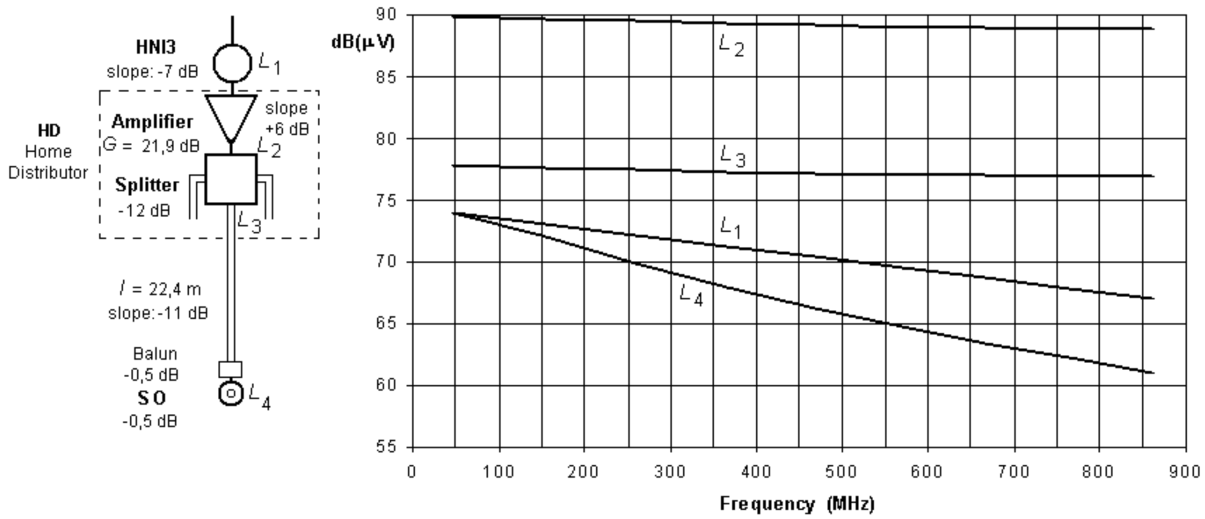


The diagram shows the signal levels at HNI3 (L_1), amplifier output (L_2), splitter output (L_3) and SO (L_4), assuming that the level delivered at HNI3 is +6 dB over the SO minimum at 862 MHz, and that the amplifier and/or the splitter have a flat response over the frequency range.

Figure 8 – Signal levels at HNI3 (flat splitter/amplifier response)

If the amplifier and/or the splitter have a compensating slope of +6 dB (splitter attenuation of 12 dB and amplifier gain of 21,9 dB), the maximum cable length can be increased up to 22,4 m as indicated in Table 7.

The signal levels at HNI3 (L_1), amplifier output (L_2), splitter output (L_3) and SO (L_4) are indicated in Figure 9.



This diagram shows the signal levels at HNI3 (L_1), amplifier output (L_2), splitter output (L_3) and SO (L_4), assuming that the level delivered at HNI3 is +6 dB over the SO minimum at 862 MHz, the amplifier and/or the splitter have a compensating slope of +6 dB over the frequency range.

Figure 9 – Signal levels at HNI3 (+6 dB compensating splitter/amplifier slope)

Table 6 – Example of home network implementation with balanced pair cables (active) from HNI3 to coaxial terminal input (case A)

HNI3 (case A) Minimum [a] signal level at HNI3 above minimum level at system outlet	Minimum amplifier gain	Amplifier or splitter slope	Home distribution splitter attenuation	Permanent link length L_{PL}	Receiver lead length L_{RL}	System outlet and baluns loss [b]	Home cable link 3 (HCL3) insertion loss dB			HCL3 slope 47 MHz to 862 MHz
							47	**470**	**862**	
dB	dB	dB	dB	m	m	dB	MHz	MHz	MHz	dB
6	14,2	0	12,0	9,15	2	1,0	2,6	6,2	8,2	−5,6
6	21,8	+6	12,0	22,5	2	1,0	4,2	11,5	15,8	−11,6
3	17,2	0	12,0	9,15	2	1,0	2,6	6,2	8,2	−5,6
3	24,8	+6	12,0	22,5	2	1,0	4,2	11,5	15,8	−11,6

[a] The HNI3 signal level can be significantly above the minimum. Some selectable or tunable attenuation may then be required at the input to the 25 dB gain amplifier (with 6 dB compensating slope) to meet the multiple frequency interference requirement (5.9.2) of 71 dB. In this HNI3-case A the terminal input level is at least 60 dB(μV).

[b] 1 dB for both together.

Table 7 – Example of home network implementation with balanced pair cables (active) from HNI3 to coaxial system outlet (case B)

HNI3 (case B) Minimum [a] signal level at HNI3 above minimum level at system outlet	Minimum amplifier gain [b]	Amplifier or splitter slope	Home distribution splitter attenuation	Permanent link length L_{PL}	System outlet and baluns loss	Home cable link 4 (HCL 4) insertion loss [c] dB			HCL4 slope [c] 47 MHz to 862 MHz
						47	**470**	**862**	
dB	dB	dB	dB	m	dB	MHz	MHz	MHz	dB
6	14,4	0	12,0	9,15	1,0	2,4	5,5	7,4	−5,0
6	21,9	+6	12,0	22,4	1,0	3,9	10,9	14,9	−11,0
3	17,4	0	12,0	9,15	1,0	2,4	5,5	7,4	−5,0
3	24,9	+6	12,0	22,4	1,0	3,9	10,9	14,9	−11,0

[a] The HNI3 signal level can be significantly above the minimum. Some selectable or tunable attenuation may then be required at the input to the 25 dB gain of the amplifier (with 6 dB compensating slope) to meet the multiple frequency interference requirement (5.9.2) of 71 dB.

[b] The gain of the amplifier for HNI3-case B is calculated to deliver at least 61 dB(μV) at the coaxial system outlet to reduce the effects of balanced pair component mismatches (in band ripple).

[c] Between the output of the balanced power splitter and the output of the coaxial system outlet.

6.4.4 General considerations

Table 4, Table 5, Table 6 and Table 7 clearly show that the cable length used for the home cable link depends on the type of cable used and also on the type and number of connectors, baluns, etc. introduced. These length values are mainly related to the maximum slope allowed in the cables. With cables of lower specific attenuation (dB/100 m) the lengths of the cables will be higher.

These tables also show the following.

- The maximum attenuation allowed for the splitter taking into account the signal delivered by the HNI1 (passive coaxial home network). The splitter attenuation with a flat response Table 4 can be up to about 11 dB (splitting up to 8 way), if the permanent link has a maximum length of 32 m. If one output of the splitter has a slope compensating response of +6 dB, with a 862 MHz attenuation of only about 3,5 dB, as for a two-way splitter, but 9,5 dB at 47 MHz, the permanent link connected to that output can be 70 m long.
- The required gain for the in-home amplifier is in the range between 12,8 dB and 24,9 dB (with or without slope), taking into account the signal delivered by the HNI2 (active coaxial home network) or by the HNI3 (active home network with balanced pair cables) and a splitter attenuation of 12 dB (Table 5, Table 6 and Table 7).

Typical losses for power splitters (F connectors, 22 dB isolation between outputs) are 3,6 dB for 2 outputs, 5,6 dB for 3 outputs and 7,4 dB for 4 outputs (0,4 dB should be added for the worst case loss at 862 MHz). Therefore, up to 8 system outlets could be installed within a total allocation of 11 dB to 12 dB for the home splitter(s) (see Table 4, Table 5, Table 6 and Table 7).

Therefore, the examples given can lead to the following general considerations.

- The HNI1 specifications allow passive in-home cablings with up to 8 system outlets inside the dwelling unit when the CATV/MATV network is optimized to deliver to the HNI1 at least 78 dB(μV) at 862 MHz (or 80 dB(μV) in the rare case of a +7 dB slope, where the 47 MHz carrier level is the limiting parameter). The required minimum mutual isolation of 22 dB between any two system outlets shall also be provided.
- The HNI2 and HNI3 specifications are compatible with several options of 13 dB to 25 dB in-home amplifiers for feeding in-home cablings with up to 8 to 10 system outlets inside the dwelling unit (the required minimum mutual isolation of 22 dB between any two system outlets shall also be provided)
- A +6 dB slope compensation built in the in-home splitter/amplifier extends the permissible lengths of the permanent link up to about 70 m for coaxial cables and up to about 22 m for the balanced cable cases.
- More complex cases, where the in-home cabling slope is below −11 dB, require case-specific design and engineering, with several slope compensations in cascade to match the effective home cable link (HCL) losses, and/or equalization at HNI considering the slope delivered by the CATV/MATV/SMATV network at the HNI of the dwelling unit.

The required minimum mutual isolation between any two TV receivers belonging to the same dwelling units is 22 dB (see 5.4.3). The actual value achieved for mutual isolation is obtained adding to the splitter isolation twice the VHF/UHF insertion loss of the permanent link. Thus, if the splitter itself has a 22 dB isolation, a value ranging from about 26 dB in VHF (lower frequency) to about 34 dB in UHF (upper frequency) can be achieved.

Asymmetrical power splitters (e.g. attenuations of 2 dB and 8 dB) may be useful when the lengths of the permanent links are very different (e.g. 10 m and 40 m). Combinations like a two-way splitter followed by a three-way splitter can support one "long" length up to 70 m (coaxial), and three shorter lengths up to 32 m (coaxial).

The upstream requirements on the two-way home amplifier are under consideration. A minimum gain of 10 dB to compensate for the insertion loss of the splitter is suggested.

6.4.5 Home network design in a MATV system

The case of a high signal level at HNI1 (e.g. 78 dB(μV) to 80 dB(μV) at 862 MHz) is that of an optimized MATV design when there are no in-home amplifiers, but a single collective amplifier (in the head end of the building's MATV system or in the staircase) enabling home habitants to install extensive passive in-home cabling. It may be the most convenient or most comfortable design for the habitants of flats.

NOTE With the availability of high power network amplifiers it is better practice to increase the level at the HNI to the maximum permissible HNI1 signal levels, with the aim of avoiding active elements in the home network.

6.4.6 Return path examples

Under consideration.

6.5 Different home network types (HNI3 case C) (glass or plastic fibre optic network)

This type of home network uses glass or plastic optical fibres. The optical transmitter (E/O) is placed at the HNI and the optical receiver (O/E), at the input of each terminal equipment.

The requirements of HNI2 (7.3 of IEC 60728-1:2014) with respect to the electrical signal level and to the other quality parameters (carrier level differences, frequency response, random noise, interference to television channels, etc.), also apply to HNI3, case C.

An example of a home network using optical fibres is shown in Figure 10.

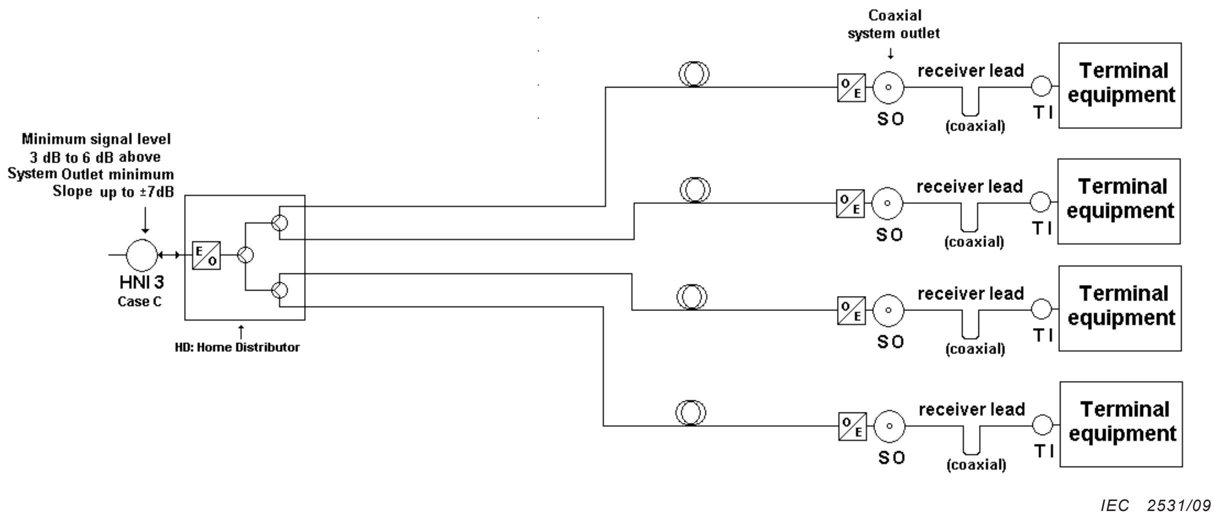


Figure 10 – Example of a home network using optical fibres

The length of the fibre and the number of splitters are designed taking into account the optical fibre attenuation characteristics, the optical power delivered by the optical source (LED, laser, etc.) of the optical transmitter and the required optical power at the optical receiver, either in front of each (coaxial) system outlet or at the input of each terminal equipment, usually in the range of −3 dB(mW) to −10 dB(mW).

The electrical signal level and quality delivered at each system outlet shall comply with the requirements indicated in IEC 60728-1. Two-way transmission can be obtained using two separate optical fibres or a WDM technique.

6.6 Different home network type (HNI3 case D)

6.6.1 General

This home network uses different link types to carry signals to and from the (digital) audio/video and data in-/output of a terminal equipment. Case D considers that in the downstream path the signals are transmitted from a terminating box (NTU, placed at the HNI) to the terminal equipment and in the upstream path from the terminal equipment (e.g. cable modem) to the NTU.

The requirements indicated for HNI2 (7.4 of IEC 60728-1:2014) with respect to the electrical signal level and the other quality parameters (carrier level differences, frequency response, random noise, interference to television channels, etc.), apply also to HNI3, case D.

6.6.2 Wireless links inside the home network

Case D also applies, amongst others, to the case where television signals and two way services are distributed inside the home using wireless links.

Usually a tree and branch coaxial cable network serves all the rooms where TV viewing is required. Digital in-home networking is desirable for most of the new digital audio and video appliances such as PVRs, PCs acting as PVRs, flat screens that have a network interface, flat screen TV sets, etc. But for these applications the installation of a Cat5/Cat6/Cat7 in-home network for twisted pair Ethernet has some practical drawbacks.

For this reason, radio networking using the IEEE 802.11 equipment (WLAN) has become very popular, with PCMCIA adapters on portable computers or installed inside, with WLAN hubs connected to or built in cable modems or ADSL modems.

The use of the IEEE 802.11 standard for the in-home audio and video service delivery and networking is, however, often limited by poor in-home radio coverage (concrete floors and ceilings, etc.) (see Annex A) limiting the available throughput to a few Mbit/s, suitable for data transmission and Internet access, but not for audio and video services that require a throughput of at least 10 Mbit/s.

The objective of the extension of the domestic coaxial cabling to 6 GHz is to enable a good quality unlicensed wireless bands coverage of the home with a hub and several wall antennas fed from the coaxial cabling, unlocking the full capability of the IEEE 802.11a/e standard (up to 54 Mbit/s) for carriage of digital audio, video and data (or sound and television signals and their associated data services), and providing service to IEEE 802.11b/g personal, portable and domestic appliances.

On this basis the coaxial in-home network can be used (see Figure 11):

a) between a home router (WLAN base station) (located at the HD and F-connector interface) and appliances (F-connector interface) such as set top boxes or digital TV sets. In this case the link is over the coaxial cable;
b) between a home router (WLAN base station) (located at the HD and F-connector interface) and microwave radiators located in selected rooms. In this case the link is in part over the coaxial network (the first twenty to thirty meters) and in part over the air (the last five meters) and possibly with a line of sight between the radiator and the portable IEEE 802.11 enabled appliance, connected to or included in the terminal equipment.

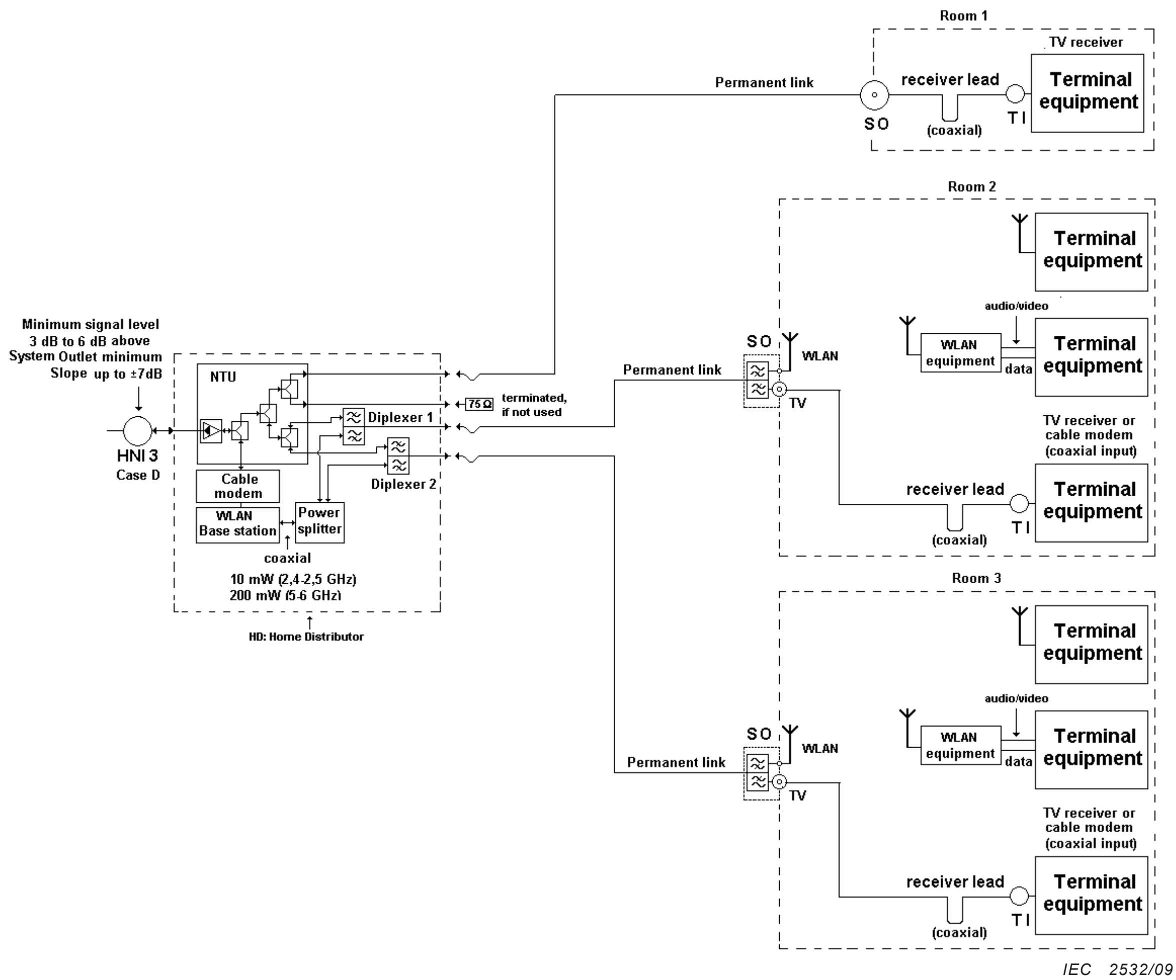


Figure 11 – Example of a home network using cable connection and cable/wireless connection

6.6.3 Applications of IEEE 802.11 (WLAN)

As there are only three non-interfering channels available in the 2 400 MHz to 2 483 MHz unlicensed band, the last Conférence Mondiale des Radiocommunications (2003) has allocated most of the 5 GHz to 6 GHz band to such unlicensed services with some requirements to limit possible impairments to radar reception, or to satellite reception.

The IEEE 802.11a/e provision in the 5 GHz to 6 GHz band, with quality of service, can be used for transmission of audio and video, as there are 10 to 20 channels (depending on national regulations) available. Co-channel interference from neighbors or from roaming users is much less likely than with the 3 channels of the IEEE 802.11b/g. A stable high bit rate error-free channel is required to carry live TV in the 2 Mbit/s to 10 Mbit/s range. However, there are concerns regarding the quality of service even in-home due to poor propagation through walls, floors and ceilings in the 5 GHz to 6 GHz band, as antenna gains are very small on most of the appliances marketed today.

Personal appliances like portable recorders or telephone sets may, in addition to their USB/Ethernet interface, provide a WLAN interface to insure cordless usage in the home or in the business premises. Authentication and security mechanisms are being developed for the business voice and data communication environment, including some world-wide IP based roaming capability.

Some improvement in the quality of the coverage could be achieved by the introduction of MIMO on bases and clients (IEEE 802.11n) (see Annex C).

6.6.4 Available bands in the 2 GHz to 6 GHz frequency range

The EIRP limit in the 2,4 GHz to 2,5 GHz band is limited to 100 mW and in the 5 GHz to 6 GHz band is limited to 1 000 mW indoor in most European countries, and sometimes 10 mW outdoor or even indoor. The limits recommended in the CEPT 70-03 are indicated in Table 8.

DFS (dynamic frequency selection) and TPC (transmission power control) are required for the protection of some radar bands and could as well be considered for avoiding interference with cordless networks in neighbouring homes.

Table 8 – Maximum EIRP according to CEPT ERC 70-03

Frequency band MHz	**EIRP** mW	**Other conditions**
2 400 to 2 454	100	Harmonized
2 400 to 2 483	100 10	Indoor Outdoor; national limits may apply
5 150 to 5 250	200	Indoor only
5 250 to 5 350	200	Indoor only; DFS and TPC
5 470 to 5 725	1 000	Indoor and outdoor; transmitter power <250 mW
5 725 to 5 875	25	National limits may apply

Sources of interference in those unlicensed bands may be

a) IEEE 802.16 (WiMax) that has been designed for wide area coverage and may use the outdoor allowed parts of the above mentioned bands (but they may be subject to the same power limitation),

b) UWB (ultra wide band) that is limited to −41 dB(mW/MHz) indoor (at the connector to the antenna) in the 3 100 MHz to 10 600 MHz range.

6.6.5 Main characteristics of a WLAN signal

Although a reference to the IEEE 802.11 standard is the most appropriate way to understand all its characteristics, a short summary is given below.

In the IEEE 802.11a/g standard the modulation is OFDM with 52 subcarriers, 64 points FFT (including pilots), convolution coding K = 7, R = 1/2, 2/3, 3/4, interleaving and Viterbi decoding; the required profiles are

- 6 Mbit/s (BPSK, R = 1/2),
- 12 Mbit/s (QPSK, R = 1/2),
- 24 Mbit/s (16-QAM, R = 1/2),
- 54 Mbits/s (CCK, OFDM).

Typical maximal transmit/minimal receive levels from/to chips are

- transmitted power: 16 dB(mW),
- received power: –88 dB(mW) or –93 dB(mW) (specififcation is –85 dB(mW)) for 6 Mbit/s
  –70 dB(mW) for 54 Mbit/s.

The available throughput with TCP or UDP for 1 500 byte packets and no errors is at most as indicated in Table 9.

Table 9 – Available throughput of the WLAN signal

WLAN signal IEEE standard	**Number of channels maximum**	**Modulation**	**Nominal** Mbit/s	**TCP** Mbit/s	**UDP** Mbit/s
802.11 b	3	CCK	11	5,9	7,1
802.11 b/g	3	CCK, OFDM	54	11,4	11,5
802.11 a	19	OFDM	54	24,4	30,5
802.11 n	–	DSSS, OFDM	<200	–	–

The values indicated in Table 9 are significantly degraded when the line of sight is no longer available and show a cut off in the 30 m to 70 m range (with maximum allowed up-stream transmitter power).

6.6.6 Main characteristics of coaxial cables

In-home coaxial cables are defined by EN 50117 where the main parameters are given. The loss per 100 m of cables can be 19 dB at 800 MHz, about 36 dB at 2 483 MHz and 62 dB at 5 875 MHz.

6.6.7 Characteristics of WLAN signals at system outlet

6.6.7.1 WLAN signal level

The WLAN signal level delivered at the system outlet (antenna) shall be not lower than the values given in Table 10, i.e. not lower than −30 dB(mW) in the 2,4 GHz to 2,5 GHz frequency band, and not lower than −23 dB(mW) in the 5 GHz to 6 GHz frequency band, in order to allow the minimum bit rate of 6 Mbit/s at a free space distance of 5 m. If a bit rate of 54 Mbit/s is required, the signal level shall be not lower than −16 dB(mW) in the 2,4 GHz to 2,5 GHz frequency band and not lower than −8 dB(mW) in the 5 GHz to 6 GHz frequency band. If the free space distance from the antenna is not greater than 1 m, the maximum bit rate of 54 Mbit/s can be obtained with a signal not lower than −30 dB(mW) in the 2,4 GHz to 2,5 GHz frequency band and not lower than −23 dB(mW) in the 5 GHz to 6 GHz frequency band.

Table 10 – Minimum signal level at system outlet (WLAN antenna)

Bit rate Mbit/s	**Free space distance** m	**Minimum signal level at system outlet (WLAN antenna)** dB(mW)	
		Frequency band 2,4 GHz to 2,483 GHz	**Frequency band** 5,150 GHz to 5,875 GHz
6	5	−30	−23
54	5	−16	−8
54	1	−30	−23
The minimum and maximum signal levels at the TV system outlet should comply with the requirements indicated in 5.4 of IEC 60728-1:2014.			

6.6.7.2 WLAN available bit rate

The minimum available bit rate shall be 6 Mbit/s. A bit rate of 54 Mbit/s should also be allowed at a reduced distance from the antenna. WLAN equipment can use dynamic power control (DPC) and dynamic frequency selection (DFS) as specified by IEEE 802.11h.

6.6.7.3 Isolation between WLAN outlet (antenna) and coaxial outlet

The minimum isolation between the WLAN and coaxial outlets shall be between 100 dB to 75 dB in the frequency range 47 MHz to 862 MHz (see Annex B). Higher values can be required if higher antenna gains are used to increase the radiated power (EIRP) of the antenna.

6.6.7.4 WLAN antenna specification

The antenna gain shall be not lower than −3 dB. If higher antenna gains are used, the isolation (6.6.7.3) should be raised accordingly. The maximum radiated power (EIRP) shall be in accordance with national or CEPT European regulations.

The output impedance of the equipment and that of the connector where the antenna is attached shall be designed to match the antenna impedance in the relevant frequency range.

6.6.8 Characteristics of signals at the TV system outlet

The signal level and signal quality delivered at each system outlet shall comply with the requirements indicated in IEC 60728-1:2014.

6.6.9 Example of diplexers and power splitters near the HNI

The diplexers and power splitters used to couple the WLAN interface into the home distribution network (Figure 11) can be obtained by a cascade of 3 dB couplers to provide a room to room direct connectivity. An example of such a coupler is indicated in Figure 12 where a tandem interconnection of two 8,34 dB symmetric tapered line couplers is used.

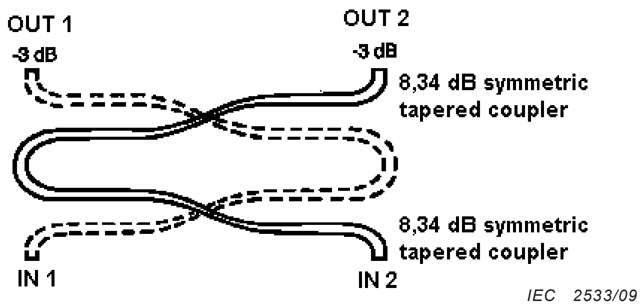


Figure 12 – Example of a coupler (tandem coupler) to insert WLAN signals into the home distribution network

6.6.10 Example of system outlet for coaxial TV connector and WLAN antenna

An example of a system outlet with a coaxial connector for direct TV connection (via receiver lead) and a connector for the WLAN antenna is shown in Figure 13.

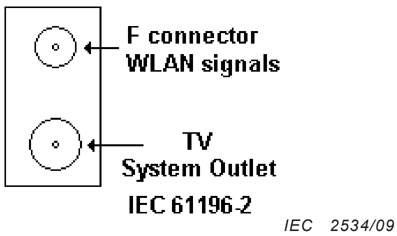


Figure 13 – Example of system outlet for coaxial TV connector and WLAN antenna

A possible way of implementation is a band-splitting filter made of a high-pass filter and a low-pass filter connected together at the 75 Ω coaxial cable port. The high-pass filter should have a strong attenuation (see Annex B) below 900 MHz, to make sure that the immunity of the whole home network is not reduced by the WLAN radiator. The F-connector for the WLAN bands is fully coupled to the waveguide and most of the power goes to the radiating device. The low-pass filter (below 862 MHz) connected to the TV system outlet, should introduce an attenuation in the 10 dB to 15 dB range in the WLAN bands, to allow connection of a set-top box with data in WLAN bands at the same connector as the TV set.

6.6.11 Examples of WLAN connection into home networks

6.6.11.1 General

Some examples of WLAN connections using home networks are presented in order to evaluate the maximum loss due either to the cable link part or also including the wireless part of these connections, based on the home network structure shown in Figure 11.

It is assumed that the system outlet, fed by a coaxial cable, splits the signals into the WLAN radiator (high-pass filter) and into the TV system outlet (low-pass filter). The main properties of the filters are indicated in Figure 14. The high-pass filter attenuation below 862 MHz is supposed above 65 dB (see also Annex B). The low-pass filter attenuation in the WLAN bands (2 300 MHz to 6 000 MHz) is assumed to be about 15 dB.

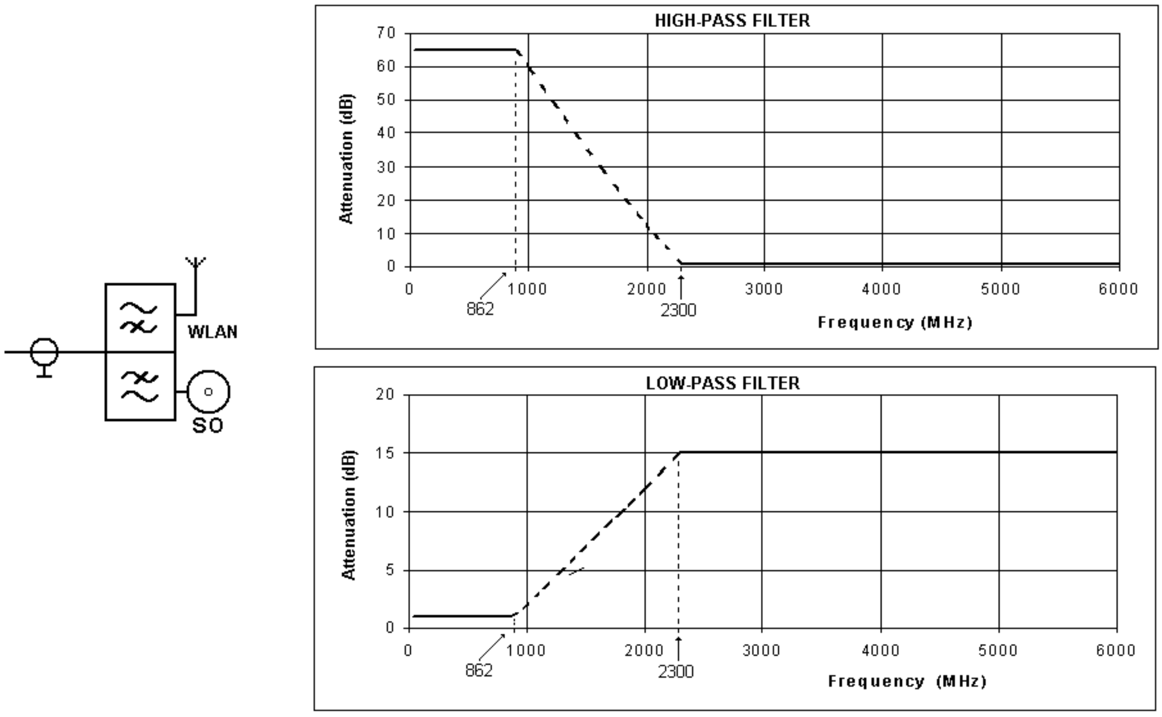


Figure 14 – Assumed properties of the filters in the system outlet

The following examples of WLAN connection to the home network are considered. These examples relate to the link between reference points (RP) indicated in Figure 15.

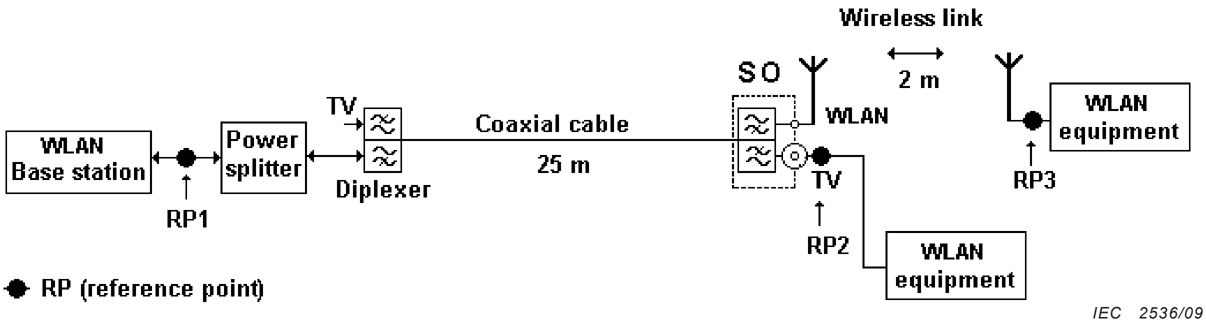


Figure 15 – Reference points for the examples of calculation of link loss or link budget

6.6.11.2 Loss from a system outlet (TV outlet) to the WLAN base station receiver

This example considers the loss from a WLAN equipment directly connected to the system outlet (TV outlet) (RP2 of Figure 15) to the WLAN base station receiver input (RP1 of Figure 15.

The loss from the system outlet (TV outlet) to the WLAN base station receiver input, can be calculated taking into account the sum of the attenuations due to the TV outlet, the coaxial cable (length of 25 m), the diplexer and power splitter of the “WLAN base station”, as indicated in Table 11, for both 2,4 GHz to 2,5 GHz and 5 GHz to 6 GHz frequency bands.

Table 11 – Loss from the system outlet to WLAN base station

Cascaded devices	Frequency band 2,4 GHz to 2,483 GHz	Frequency band 5,150 GHz to 5,875 GHz
TV outlet loss	15 dB	15 dB
Coaxial cable loss (25 m)	9,1 dB	15,5 dB
Diplexer and power splitter loss	10 dB	10 dB
Total loss	*34,1 dB*	*40,5 dB*

6.6.11.3 Direct connection between two system outlets (TV outlets)

This example considers two WLAN pieces of equipment operating in two different rooms and connected directly to a system outlet (TV outlet). In this case, it is supposed that the central WLAN base station works as a WLAN access point.

The total link is considered as consisting of two sub-links: one from the WLAN equipment transmitter (RP2 of Figure 15) to the WLAN base station receiver (RP1 of Figure 15), the second link from the WLAN base station transmitter (RP1 of Figure 15) to the WLAN equipment receiver (RP2 of Figure 15) in a different room.

The first link starts from a WLAN equipment and considers the WLAN equipment transmitter, the system outlet (TV outlet), the coaxial cable (length of 25 m), the diplexer and power splitter (loss of 10 dB) up to the WLAN base station receiver.

The second link starts from the WLAN base station and considers the WLAN base station transmitter, the diplexer and power splitter (loss of 10 dB) of the WLAN base station, the coaxial cable (length of 25 m), the system outlet (TV outlet) up to the WLAN receiver.

Each link budget is indicated in Table 12 for both 2,4 GHz to 2,5 GHz and 5 GHz to 6 GHz frequency bands.

Table 12 – Direct connection between two system outlets (TV outlets)

Cascaded devices	Frequency band 2,4 GHz to 2,483 GHz	Frequency band 5,150 GHz to 5,875 GHz
First link: system outlet to base station		
WLAN equipment transmitter power	+10 dB(mW)	+23 dB(mW) [a]
TV outlet loss	15 dB	15 dB
Coaxial cable loss (25 m)	9,1 dB	15,5 dB
Diplexer and power splitter loss	10 dB	10 dB
Base station received power	*−24,1 dB (mW)*	*−17,5 dB(mW)*
Second link: base station to system outlet		
Base station transmitter power	+10 dB(mW)	+23 dB(mW) [a]
Diplexer and power splitter loss	10 dB	10 dB
Coaxial cable loss (25 m)	9,1 dB	15,5 dB
TV outlet loss	15 dB	15 dB
WLAN equipment received power	*−24,1 dB (mW)*	*−17,5 dB(mW)*
[a] 1 W can be used in a restricted part of the band.		

6.6.11.4 Link budget from a WLAN equipment to the WLAN base station

This example considers the link budget from a WLAN equipment radiating towards the wall antenna to the WLAN base station receiver.

The link is considered from the WLAN equipment transmitter (RP3 of Figure 15) to the WLAN base station receiver (RP1 of Figure 15) considering the wireless link (2 m), the wall receiving antenna, the WLAN outlet, the coaxial cable (length of 25 m), the diplexer and power splitter in the WLAN base station.

The link budget is indicated in Table 13 for both 2,4 GHz to 2,5 GHz and 5 GHz to 6 GHz frequency bands.

Table 13 – Link budget between a WLAN equipment and the WLAN base station

Cascaded devices	Frequency band 2,4 GHz to 2,483 GHz	Frequency band 5,150 GHz to 5,875 GHz
WLAN equipment transmitter power	+10 dB(mW)	+23 dB(mW) [a]
Wireless link loss (2 m)	46,4 dB	53,8 dB
Receiving antenna loss	3 dB	3 dB
WLAN outlet loss	2 dB	2 dB
Coaxial cable loss (25 m)	9,1 dB	15,5 dB
Diplexer and power splitter loss	10 dB	10 dB
Base station received power	*−60,5 dB (mW)*	*−64,3 dB(mW)*
[a] 1 W can be used in a restricted part of the band.		

6.6.11.5 Wireless connection between two pieces of WLAN equipment

This example considers a connection of two pieces of WLAN equipment operating wireless in the same room or in two different rooms. In this case, it is supposed that the the WLAN base station works as a WLAN access point.

The link is considered as consisting of two sub-links: one from the WLAN equipment transmitter (RP3 of Figure 15) to the WLAN base station receiver (RP1 of Figure 15), the second link from the WLAN base station transmitter (RP1 of Figure 15) to a WLAN equipment receiver (RP3 of Figure 15) in the same room or in a different room.

The first link starts from a WLAN equipment and considers the WLAN equipment transmitter, the wireless link (2 m), the wall receiving antenna, the WLAN outlet, the coaxial cable (length of 25 m), the diplexer and power splitter (loss of 10 dB) up to the WLAN base station receiver.

The second link starts from the WLAN base station and considers the WLAN base station transmitter, the diplexer and power splitter (loss of 10 dB) of the WLAN base station, the coaxial cable (length of 25 m), the WLAN outlet, the wall transmitting antenna and the wireless link (2 m) up to the WLAN equipment receiver.

Each link budget is indicated in Table 14 for both 2,4 GHz to 2,5 GHz and 5 GHz to 6 GHz frequency bands.

Table 14 – Wireless connection between two WLAN equipment

Cascaded devices	Frequency band 2,4 GHz to 2,483 GHz	Frequency band 5,150 GHz to 5,875 GHz
First link: WLAN equipment to base station		
WLAN equipment transmitter power	+10 dB(mW)	+23 dB(mW) [a]
Wireless link loss (2 m)	46,3 dB	53,8 dB
Receiving antenna loss	3 dB	3 dB
WLAN outlet loss	2 dB	2 dB
Coaxial cable loss (25 m)	9,1 dB	15,5 dB
Diplexer, power splitter loss	10 dB	10 dB
Base station received power	*−60,5 dB (mW)*	*−64,3 dB(mW)*
Second link: base station to WLAN equipment		
Base station transmitter power	+10 dB(mW)	+23 dB(mW) [a]
Diplexer, power splitter loss	10 dB	10 dB
Coaxial cable loss (25 m)	9,1 dB	15,5 dB
WLAN outlet loss	2 dB	2 dB
Radiating antenna loss	3 dB	3 dB
Wireless link loss (2 m)	46,4 dB	53,8 dB
WLAN equipment received power	*−60,5 dB(mW)*	*−64,3 dB(mW)*
[a] 1 W can be used in a restricted part of the band.		

6.6.11.6 Connection from a system outlet (TV outlet) to a piece of WLAN equipment

This example considers a piece of WLAN equipment directly connected to a system outlet (TV outlet) to another piece of WLAN equipment operating wireless. In this case, it is assumed that the WLAN base station works as a WLAN access point.

The total link is considered as consisting of two sub-links: one from the WLAN equipment transmitter (RP3 of Figure 15) to the WLAN base station receiver (RP1 of Figure 15), the second link from the WLAN base station transmitter (RP1 of Figure 15) to a WLAN equipment receiver (RP3 of Figure 15) in the same room or in a different room.

The first link starts from a piece of WLAN equipment and considers the WLAN equipment transmitter, the system outlet (TV outlet), the coaxial cable (length of 25 m), the diplexer and power splitter (loss of 10 dB) up to the WLAN base station receiver.

The second link starts from the WLAN base station and considers the WLAN base station transmitter, the diplexer and power splitter (loss of 10 dB) of the WLAN base station, the coaxial cable (length of 25 m), the WLAN outlet, the wall transmitting antenna and the wireless link (2 m) up to the WLAN equipment receiver.

Each link budget is indicated in Table 15 for both 2,4 GHz to 2,5 GHz and 5 GHz to 6 GHz frequency bands.

Table 15 – Connection from a SO to a WLAN equipment

Cascaded devices	**Frequency band 2,4 GHz to 2,483 GHz**	**Frequency band 5,150 GHz to 5,875 GHz**
First link: system outlet to base station		
WLAN equipment transmitter power	+10 dB(mW)	+23 dB(mW) [a]
TV outlet loss	15 dB	15 dB
Coaxial cable loss (25 m)	9,1 dB	15,5 dB
Diplexer, power splitter loss	10 dB	10 dB
Base station received power	*−24,1 dB(mW)*	*−17,5 dB(mW)*
Second link: base station to WLAN equipment		
Base station transmitter power	+10 dB(mW)	+23 dB(mW) [a]
Diplexer, power splitter loss	10 dB	10 dB
Coaxial cable loss (25 m)	9,1 dB	15,5 dB
WLAN outlet loss	2 dB	2 dB
Radiating antenna loss	3 dB	3 dB
Wireless link loss (2 m)	46,4 dB	53,8 dB
WLAN equipment received power	*−60,5 dB(mW)*	*−64,3 dB(mW)*
[a] 1 W can be used in a restricted part of the band.		

Annex A
(informative)

Wireless links versus cable links

A.1 General

It is helpful to compare the link losses of a wireless link and a coaxial cable link, in order to understand the advantage of using mixed wireless and coaxial cable connections as opposed to only wireless connections.

A.2 Wireless links

The attenuation introduced by a wireless link (free space attenuation) can be calculated taking into account the following formula:

$$\frac{W_R}{W_T} = \frac{G_T\, G_R\, \lambda^2}{16\pi^2 R^2} \qquad \text{(A.1)}$$

where

W_R is the received power,

W_T is the transmitter power,

G_T is the transmitting antenna gain,

G_R is the receiving antenna gain,

λ is the wavelength of the radio link,

R is the distance between receiving and transmitting antennae.

This formula is valid when $R > 2\, D^2/\lambda$ where D is the dimension of the antenna.

The wireless link loss (*WLL*) between the antenna input on the transmitter side and the antenna output on the receiver side in free space can be calculated, in dB, considering the two contributions due to frequency ($f = v/\lambda$)) and distance (R):

$$WLL(\text{dB}) = 10\ \lg(W_T G_T) - 10\ \lg(W_R/G_R) = -20\ \lg(\lambda/4\pi) + 20\ \lg(R) \qquad \text{(A.2)}$$

at f = 2,483 GHz (λ = 0,12 m) is − 20 lg($\lambda/4\pi$) = +40,3 dB, while
at f = 5,875 GHz (λ = 0,05 m) is − 20 lg($\lambda/4\pi$) = +47,8 dB.

More generally, the values of the *WLL* can be evaluated using the following formulae:

$$WLL = 40{,}3\ \text{dB} + 10\ n\ \lg(R) \qquad \text{at 2,5 GHz} \qquad \text{(A.3)}$$

$$WLL = 47{,}8\ \text{dB} + 10\ n\ \lg(R) \qquad \text{at 5,875 GHz} \qquad \text{(A.4)}$$

where R is in meters and n is the propagation exponent, as follows:

n = 2 free space,

n = 4,5 in-house,

n = 3,3 open office.

For in home propagation at 5,875 GHz with R = 10 m, n = 4,5, the path loss is *WLL* = 92,8 dB.

Common values for the attenuation of walls and floors are

- plywood = 4 dB,
- concrete = 10 dB to15 dB.

This means that for a free space distance of 10 m the term +20 lg (R) is +20 dB, while inside a building this loss becomes: +35 dB to +45 dB if one or two walls or floors are placed across the wireless link connection.

Therefore the total loss of the wireless link could be in the range of 75 dB to 85 dB at 2,5 GHz and in the range of 83 dB to 93 dB at 5,875 GHz.

Considering a transmitted power (EIRP) of 10 mW (+10 dB(mW)) in the 2,4 GHz to 2,483 GHz band, respectively 200 mW (23 dB(mW)) in the 5,15 GHz to 5,875 GHz band and that the received power should be not lower than:

–85 dB(mW) at 6 Mbit/s

–70 dB(mW) at 54 Mbit/s

the maximum distance R can be calculated:

$$R = 10^{[(10+85-40,3)/10n]} \quad \text{at 6 Mbit/s and 2,483 GHz} \quad (A.5)$$

$$R = 10^{[(10+70-40,3)/10n]} \quad \text{at 54 Mbit/s and 2,483 GHz} \quad (A.6)$$

$$R = 10^{[(23+85-47,8)/10n]} \quad \text{at 6 Mbit/s and 5,875 GHz} \quad (A.7)$$

$$R = 10^{[(23+70-47,8)/10n]} \quad \text{at 54 Mbit/s and 5,875 GHz} \quad (A.8)$$

The maximum distances (R) covered by a wireless link in free space (n = 2) and inside a home (n = 4,5) are indicated in Table A.1.

Table A.1 – Maximum distance for a wireless link (WLAN) in free space or inside a home

Bit rate Mbit/s	**Maximum distance *R*** m			
	2,4 GHz to 2,483 GHz		**5,150 GHz to 5,875 GHz**	
	Free space n = 2	**Inside home** n = 4,5	**Free space** n = 2	**Inside home** n = 4,5
6	541	16,4	1 021	21,7
54	96,1	7,6	181,5	10,1

A.3 Cable links

If a combination of cable and wireless links is used, the maximum distance inside a home can be evaluated with the following considerations.

The wireless link loss inside a room can be evaluated considering a maximum distance of 5 m and a propagation in free space. Therefore the wireless link loss (WLL) at 5 m is:

WLL (5 m) = 54,3 dB at 2,483 GHz

WLL (5 m) = 61,8 dB at 5,875 GHz

Considering that the power injected in the cable by the WLAN device is 10 mW (10 dB(mW)) in the 2,4 GHz to 2,483 GHz band and 200 mW (23 dB(mW)) in the 5,15 GHz to 5,875 GHz band, but is reduced by 10 dB due to the the losses of WLAN power splitter and diplexer, the maximum value of the cable loss (*CL*) and antenna gain (G_a) can be evaluated as follows:

$$CL + G_a = 10 - 10 + 85 - 54{,}3 = 30{,}7 \text{ dB} \quad \text{at 6 Mbit/s and 2,483 GHz}$$

$$CL + G_a = 10 - 10 + 70 - 54{,}3 = 15{,}7 \text{ dB} \quad \text{at 54 Mbit/s and 2,483 GHz}$$

$$CL + G_a = 23 - 10 + 85 - 61{,}8 = 36{,}2 \text{ dB} \quad \text{at 6 Mbit/s and 5,875 GHz}$$

$$CL + G_a = 23 - 10 + 70 - 61{,}8 = 21{,}2 \text{ dB} \quad \text{at 54 Mbit/s and 5,875 GHz}$$

Assuming a coaxial cable attenuation of 21,5 dB/100 m at 1 GHz, 36,5 dB/100 m at 2,483 GHz, 62 dB/100 m at 5,875 GHz and an antenna gain (G_a) of −3 dB (loss of 3 dB), the maximum length of the cable in the home network can be calculated, as indicated in Table A.2.

Table A.2 – Maximum length of the cable

Bit rate Mbit/s	**Maximum length of cable** m	
	2,4 GHz to 2,483 GHz	**5,150 GHz to 5,875 GHz**
6	75,8	53,5
54	34,7	29,4

Annex B
(informative)

Isolation between radiating element and system outlet

For an ambient field of 106 dB(μV/m), the voltage due to coupling from any radiator to the coaxial system outlet for the terminal TV set shall be below 3 dB(μV).

NOTE The ambient field according to IEC 60728-12 is the maximum admissible field outside the building, with the implicit assumption of a minimum 10 dB building penetration loss. This is assumed to be the absolute worst case.

The injected voltage U from a field E with an antenna gain G (with respect to the isotropic antenna) is given by

$$U^2/75 = G\,[\lambda^2/(4\pi)]\,(E^2/120\pi) \qquad \text{(B.1)}$$

If f is in MHz, the field E in dB(μV/m) and the injected voltage U in dB(μV), then the following relation is derived:

$$U(\text{dB}(\mu\text{V})) = E\,(\text{dB}(\mu\text{V/m})) - 20\ \text{lg}\,(f/37{,}75) + 10\ \text{lg}(G) \qquad \text{(B.2)}$$

Taking into account that the field has a maximum value of 106 dB(μV/m) and the injected voltage into the coaxial system outlet shall be not higher than 3 dB(μV), the following condition shall be fulfilled, introducing a suitable filter attenuation (F_a):

$$106 - 20\ \text{lg}\,(f/37{,}75) + 10\ \text{lg}(G/F_a) < 3 \qquad \text{(B.3)}$$

or

$$-10\ \text{lg}(G/F_a) < +103 - 20\ \text{lg}\,(f/37{,}75) \qquad \text{(B.4)}$$

Therefore the required isolation (F_a/G) (filter loss and antenna gain) with respect to the coaxial system outlet, shall be between 101 dB and 75 dB in the frequency range 47 MHz to 862 MHz, as shown in Figure B.1.

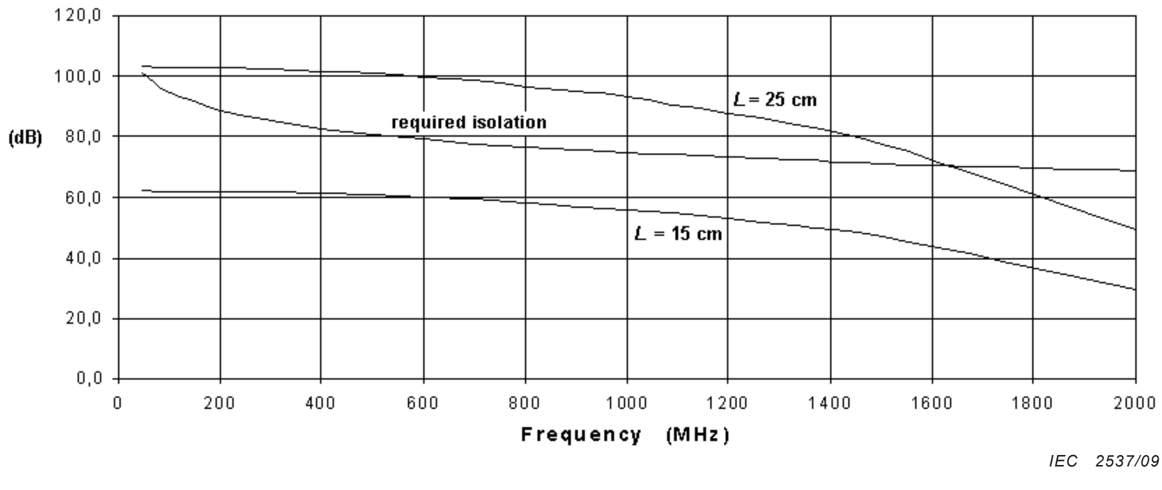


Figure B.1 – Required isolation and attenuation of a cut-off waveguide, with cut-off frequency of 2 275 MHz and a length (*L*) of 25 cm or 15 cm

If the filter is a waveguide, with a cut-off frequency (f_c), inserted between the WLAN outlet (antenna) and the coaxial system outlet, the propagation exponent

$$e^{-j2\pi L/\lambda}\sqrt{1-(\lambda/\lambda_c)^2} \quad (B.5)$$

of a waveguide having a cut-off wavelength λ_c at frequency f_c, becomes, in dB:

$$(8{,}68\ 2\pi/300)\ L\ f\ \sqrt{(f_c/f)^2-1}\ \text{(dB)} \quad (B.6)$$

where *f* is the frequency in MHz.

At 600 MHz a L = 25 cm length of cut-off waveguide (see Figure B.1) has an attenuation of about 100 dB for f_c = 2 275 MHz, significantly above the curve −103 + 20 lg(*f*/37,75).

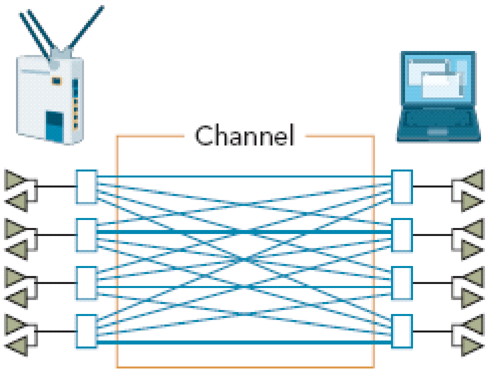
A radiating element in the WLAN bands (2,4 GHz to 2,483 GHz and 5,150 GHz to 5,875 GHz) provides at least a 20 dB loss in UHF bands IV and V (470 MHz to 862 MHz) and 40 dB in VHF bands I and III (47 MHz to 230 MHz). Thus the required isolation can also be obtained with a cut-off waveguide of only L = 15 cm length or even shorter.

Annex C
(informative)

MIMO techniques of IEEE 802.11n

C.1 General

MIMO (multi input multi output) techniques have introduced a true innovation in the area of wireless data transmission. Multipath is a common phenomenon in wireless channels, where the signal reflects from walls, furniture, and people. While radio systems according to IEEE 802.11 a, b, g work to overcome the effects of multipath, IEEE 802.11n MIMO radio systems take advantage of multiple paths to increase throughput by sending several data streams simultaneously. This requires multiple transmitters and receivers in the radio. An *N*x*M* MIMO system has *N* transmitters and *M* receivers (Figure C.1).



IEC 2538/09

Figure C.1 – Principle of MIMO techniques according to IEEE 802.11n

MIMO according to IEEE 802.11n specifies the operation with up to four transmitters and four receivers. Some products feature two transmitters and three receivers, and some have three transmitters and three receivers with other combinations possible.

Signals from each transmitter reach each receiver via a different path in the channel. MIMO works best if these paths are spatially distinct and each is capable of carrying its own data stream. If the radios are within line of sight of each other, MIMO can deteriorate into the traditional single-stream transmission, SISO (single input, single output).

C.2 MIMO techniques

The IEEE 802.11n standard incorporates two MIMO techniques: spatial multiplexing and beamforming.

Spatial multiplexing divides data into multiple streams and sends them simultaneously over multiple paths in the channel. These streams are recombined in the receiver to get the original data.

Beamforming is a technique that uses several directional antenna elements to spatially shape the emitted electromagnetic wave to beam the energy into the receiver over some optimum path. Beamforming requires the transmitting and receiving stations to perform channel sounding to optimize the shape and direction of the beam. Beamforming can be used in conjunction with spatial multiplexing or by itself when only a single path is available between the radios.

Beamforming at the transmitter can be augmented with Maximum Ratio Combining (MRC) at the receiver, a technique that phase-aligns and adds signals received by multiple antennas to optimize signal integrity. Multiple antennas or antenna elements can also be used for beamforming or for diversity.

NOTE Diversity is a technique of using two or more antennas for reception of the signal. Some diversity algorithms select the best signal from multiple antennas, and some algorithms may combine the signals.

The complexity of IEEE 802.11n rate adaptation has given birth to the concept of Modulation Coding Scheme (MCS). MCS includes variables such as the number of spatial streams, modulation, and the data rate on each stream. Radios establishing and maintaining a link shall automatically negotiate the optimum MCS based on channel conditions and then continuously adjust the selection of MCS as conditions change due to interference, motion, fading, and other events. Eight MCSs are mandatory for IEEE 802.11n compliance. Table C.1 shows an example of how MCSs are specified.

MIMO throughput, number of spatial streams, selection of MCSs, and beamforming techniques are highly dependent on the physical channel.

Table C.1 – MCSs that are mandatory in IEEE 802.11n

MCS index	Modulation	R	$N_{BPSC(iSS)}$	N_{SD}	N_{SP}	N_{CBPS}	N_{DBP}	Data rate Mbit/s	
								800 ns *GI* [a]	400 ns *G*
0	BPSK	1/2	1	108	6	108	54	13,5	15,0
1	QPSK	1/2	2	108	6	216	108	27,0	30,0
2	QPSK	3/4	2	108	6	216	162	40.5	45,0
3	16-QAM	1/2	4	108	6	432	216	54.0	60,0
4	16-QAM	3/4	4	108	6	432	324	81,0	90,0
5	64-QAM	2/3	6	108	6	648	432	108,0	120,0
6	64-QAM	3/4	6	108	6	648	486	121,5	135,0
7	64-QAM	5/6	6	108	6	648	540	135,0	150,0

Legend

N_{SS} number of spatial streams
R code rate
N_{BPSC} number of coded bits per single carrier
$N_{BPSC(iSS)}$ number of coded bits per single carrier for each spatial stream, iSS
N_{SD} number of data subcarriers
N_{SP} number of pilot subcarriers
N_{CBPS} number of coded bits per symbol
N_{DBPS} number of data bits per symbol
N_{ES} number of FEC encoders
N_{TBPS} number of total bits per subcarrier

NOTE These are rate-dependent parameters for mandatory 20 MHz channels, N_{SS} =1 MCS, N_{ES} = 1. IEEE 802.11n goes on to specify 77 different MCSs for 20 MHz and 40 MHz channels.

[a] Guard Interval (GI) is the time delay used by the receiver to let the reflections in the channel settle before sampling data bits.

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