

INTERNATIONAL STANDARD

NORME INTERNATIONALE



**Cable networks for television signals, sound signals and interactive services –
Part 101-1: RF cabling for two-way home networks with all-digital channels load**

**Réseaux de distribution par câbles pour signaux de télévision, signaux de
radiodiffusion sonore et services interactifs –
Partie 101-1: Câblage RF pour réseaux domestiques bidirectionnels soumis à
une charge de porteuses exclusivement numériques**



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INTERNATIONAL ELECTROTECHNICAL COMMISSION

**CABLE NETWORKS FOR TELEVISION SIGNALS,
SOUND SIGNALS AND INTERACTIVE SERVICES –****Part 101-1: RF cabling for two-way home networks
with all-digital channels load**

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IEC 60728-101-1 has been prepared by technical area 5: Cable networks for television signals, sound signals and interactive services, of IEC technical committee 100: Audio, video and multimedia systems and equipment. It is an International Standard.

This International Standard is to be used in conjunction with IEC 60728-101:2016.

The text of this standard is based on the following documents:

Draft	Report on voting
100/3904/FDIS	100/3945/RVD

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this International Standard is English.



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A list of all parts of the IEC 60728 series, under the general title *Cable networks for television signals, sound signals and interactive services*, can be found on the IEC website.

The reader's attention is drawn to the fact that Annex F lists all of the "in-some-country" clauses on differing practices of a less permanent nature relating to the subject of this document.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

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INTRODUCTION

Standards and deliverables of the 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 (cases A to D shown in Figure 1).

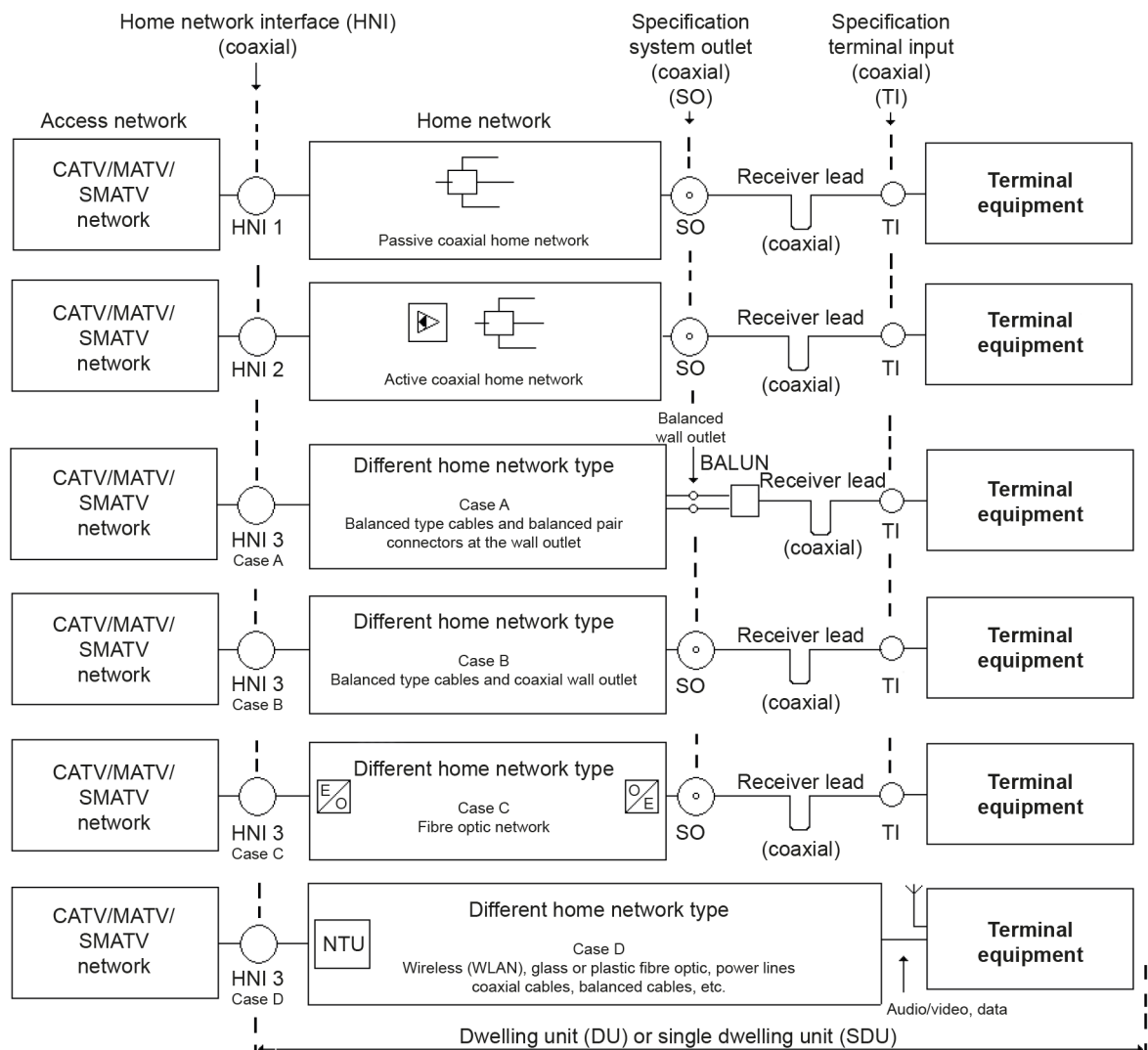
Figure 1 shows typical situations that are possible when considering RF home networks.

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

This document considers digital signals only and is based on IEC 60728-101 dealing with system performance of forward paths loaded with digital channels only. For RF cable systems loaded with analogue and digital signals, refer to IEC 60728-1-1 ED2.

Figure 4 to Figure 9 have been amended to take into account the level requirement for digital signals only.

Although the upper frequency range of terrestrial broadcast signals depends on the allocation frequency plan of each region (e.g. in Europe it is 694 MHz, the 700 MHz and 800 MHz bands being assigned to telecommunication services), the upper frequency range into the cable networks can be maintained at 862 MHz in order to maximise the number of channels to be distributed in the cable networks, assuming that sufficient immunity (screening efficiency) to signals radiated in the 700 MHz and 800 MHz bands is provided.



IEC

Figure 1 – Examples of RF home network types

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

Part 101-1: RF cabling for two-way home networks with all-digital channels load

1 Scope

This part of IEC 60728-101 provides the requirements and describes the implementation guidelines of RF cabling for two-way home networks; it 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. It is also applicable to home networks where some part of the distribution network uses wireless links, for example in place 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 3 300 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.

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 60728-101:2016, Clause 5 and the requirements at the HNI are given in IEC 60728-101:2016, Clause 7. In Clause 5 of this document, additional requirements are given.

This document 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 document 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.

The present document also provides limits for the accumulation of degradations 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).

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.

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 digital 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 produces signals not worse than the requirements given in IEC 60728-101-2. For digitally modulated signals, the quality requirement is a QEF (quasi error-free) reception.

This document 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 document. Logical connections between devices within the home network are therefore not always guaranteed.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

IEC 60728-101:2016, *Cable networks for television signals sound signals and interactive services – Part 101: System performance of forward paths loaded with digital channels only*

IEC 60728-3:2017, *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*

ISO/IEC/IEEE 8802-11, *Information technology – Telecommunications and exchange between information technology systems – Requirements for local and metropolitan area networks – Part 11: Wireless LAN medium access control (MAC) and physical layer (PHY) specifications*

3 Terms, definitions, symbols and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- IEC Electropedia: available at <https://www.electropedia.org/>
- ISO Online browsing platform: available at <https://www.iso.org/obp>

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

[SOURCE: IEC 60728-1:2014, 3.1.2]

3.1.2**antenna**

part of a radio transmitting or receiving system which is designed to provide the required coupling between a transmitter or a 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 are specified.

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

Note 3 to entry: See also IEC 60728-1:2014, 3.1.3, IEC 60728-1-1:2014, 3.1.2 and IEC 60728-1-2:2014, 3.1.2.

[SOURCE: IEC 60050-712:1992, 712-01-01, modified – The deprecated term "aerial" has been deleted, in Note 1 "should be specified" has been replaced by "are specified", Note 2 has been clarified and a Note 3 giving additional references has been added.]

3.1.3**attenuation**

ratio of the input power to the output power of a piece of equipment or a system

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

[SOURCE: IEC 60728-1:2014, 3.1.5]

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

[SOURCE: IEC 60728-1:2014, 3.1.9]

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 document, 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.

[SOURCE: IEC 60728-1:2014, 3.1.13]

3.1.7**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.

[SOURCE: IEC 60728-1-1:2014, 3.1.9]

3.1.8**decibel ratio**

ten times the logarithm to the 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: This ratio may also be expressed in terms of voltages, on the condition that the impedances of U_1 and U_2 are the same (e.g. 75 Ω).

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

[SOURCE: IEC 60728-1:2014, 3.1.24, modified – Note 1 to entry clarified.]

3.1.9**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

[SOURCE: IEC 60728-1:2014, 3.1.27]

3.1.10**dwelling unit****DU**

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

[SOURCE: IEC 60728-1:2014, 3.1.31]

3.1.11**extended satellite television distribution network or system**

distribution network or system designed to provide sound and television signals received by a 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 Wi-Fi) in the return path direction.

[SOURCE: IEC 60728-1:2014, 3.1.35]

3.1.12**extended terrestrial television distribution network or system**

distribution network or system designed to provide sound and television signals received by terrestrial receiving antenna 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 Wi-Fi) in the return path direction.

[SOURCE: IEC 60728-1:2014, 3.1.36]

3.1.13**feeder**

transmission path forming part of a cable network

Note 1 to entry: Such a path can 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.

[SOURCE: IEC 60728-1:2014, 3.1.38]

3.1.14**gain**

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

Note 1 to entry: Gain is expressed in decibels.

[SOURCE: IEC 60728-1:2014, 3.1.42]

3.1.15**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 can, for example, comprise antenna amplifiers, frequency converters, combiners, separators and generators.

[SOURCE: IEC 60728-1:2014, 3.1.43]

3.1.16**home cable link****HCL**

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

3.1.17**home distributor****HD**

distributor within a home where cables terminate

3.1.18**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, 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 can comprise active equipment, passive equipment, cables, and connectors.

[SOURCE: IEC 60728-1:2014, 3.1.48]

3.1.19 home network interface HNI

interface for access to the network for transmission of television signal, 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 can coincide with the system outlet. In this case, the performance requirements for a system outlet apply.

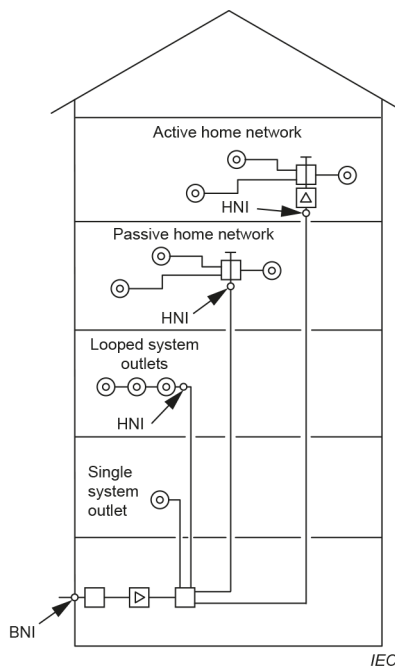


Figure 2 – Examples of location of HNI for various home network types

[SOURCE: IEC 60728-1:2014, 3.1.49, modified – Notes to entry and Figure 2 added.]

3.1.20 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 could also carry control signals for satellite switched systems or other signals for special transmission systems (e.g. MoCA or Wi-Fi) in the return path direction.

[SOURCE: IEC 60728-1:2014, 3.1.51]

3.1.21 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 could also carry other signals for special transmission systems (e.g. MoCA or Wi-Fi) in the return path direction.

[SOURCE: IEC 60728-1:2014, 3.1.52]

3.1.22**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

[SOURCE: IEC 60728-1:2014, 3.1.53]

3.1.23**isolation**

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

[SOURCE: IEC 60728-1:2014, 3.1.54]

3.1.24**level**

<power> decibel ratio of any power P_1 to the standard reference power P_0 , i.e.

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

[SOURCE: IEC 60728-1:2014, 3.1.55.1, modified – Notes 1 and 2 have been deleted.]

3.1.25**level**

<voltage> decibel 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: This can be expressed in decibels (relative to 1 μV in 75 Ω) or more simply in dB(μV) if there is no risk of ambiguity.

[SOURCE: IEC 60728-1:2014, 3.1.55.2, modified – Note 1 to entry has been deleted and former Note 2 to entry has become Note 1 to entry.]

3.1.26**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)

[SOURCE: IEC 60728-1:2014, 3.1.56]

3.1.27**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

[SOURCE: IEC 60728-1:2014, 3.1.58]

3.1.28

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 Wi-Fi) in the return path direction.

[SOURCE: IEC 60728-1:2014, 3.1.60]

3.1.29

multi-dwelling unit

MDU

building with many homes or offices used by single owners where television signals, sound signals are distributed and where is access to interactive services

[SOURCE: IEC 60728-1:2014, 3.1.64]

3.1.30

multiplex

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

Note 1 to entry: See also IEC 60728-1:2014, 3.1.65.

[SOURCE: IEC 60050-701:2016, 701-03-09, modified – The term and the definition have been changed to describe the result of the multiplexing process, and Note 1 to entry has been added.]

3.1.31

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

[SOURCE: IEC 60728-1:2014, 3.1.66]

3.1.32

network interface

NI

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

[SOURCE: IEC 60728-1:2014, 3.1.67]

3.1.33

network termination unit

NTU

equipment for access to the cable network for television signal, sound signals and interactive services

[SOURCE: IEC 60728-1:2014, 3.1.68]

3.1.34**permanent link**

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

3.1.35**receiver lead**

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

Note 1 to entry: The definition of a receiver lead includes any filters and/or balun transformers in addition to the cable.

[SOURCE: IEC 60728-1:2014, 3.1.74, modified – Note 1 to entry has been refined.]

3.1.36**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

[SOURCE: IEC 60728-1:2014, 3.1.75]

3.1.37**satellite master antenna television system****SMATV**

system which is 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).

[SOURCE: IEC 60728-1:2014, 3.1.77]

3.1.38**S/IN**

signal-to-intermodulation and noise ratio for a digitally modulated signal in the RF band

[SOURCE: IEC 60728-101:2016, 3.1.67]

3.1.39**single dwelling unit****SDU**

home, office or one-family house used by a single owner where television signals and sound signals are distributed and there is access to interactive services

[SOURCE: IEC 60728-1:2014, 3.1.81]

3.1.40**slope**

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

[SOURCE: IEC 60728-1:2014, 3.1.85]

3.1.41

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 Wi-Fi) in the return path direction.

[SOURCE: IEC 60728-1:2014, 3.1.87]

3.1.42

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 can be used in the reverse direction for combining signal energy.

[SOURCE: IEC 60728-1:2014, 3.1.88]

3.1.43

spur feeder

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

[SOURCE: IEC 60728-1:2014, 3.1.90]

3.1.44

standard reference power

P_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 μ V RMS across it.

[SOURCE: IEC 60728-1:2014, 3.1.92]

3.1.45

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 can include filters and balun transformers.

[SOURCE: IEC 60728-1:2014, 3.1.93]

3.1.46

subscriber equipment

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

[SOURCE: IEC 60728-1:2014, 3.1.94]

3.1.47

subscriber tap

device for connecting a subscriber feeder to a spur feeder

[SOURCE: IEC 60728-1:2014, 3.1.95]

3.1.48**system outlet****SO**

device for interconnecting a subscriber feeder and a receiver lead

[SOURCE: IEC 60728-1:2014, 3.1.99]

3.1.49**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

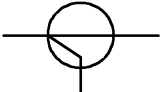
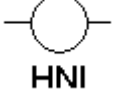
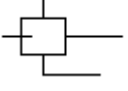
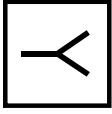
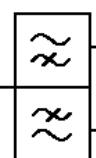
3.1.50**well-matched**, adj

matching condition when the return loss of the equipment complies with the requirements of IEC 60728-3:2017, Table 3

[SOURCE: IEC 60728-1:2014, 3.1.105, modified – IEC 60728-3:2017 referenced]

3.2 Symbols

The following graphical symbols are used in the figures of this document. 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 Abbreviated terms

ADSL	asynchronous digital subscriber line	AP	access point
APSK	amplitude and phase shift keying	BCH	Bose-Chaudhuri-Hocquenghem (codes)
BCT	broadcast and communication technologies	BER	bit error ratio
BPSK	binary phase shift keying	BW	bandwidth
CATV	community antenna television	CCK	complementary code keying
CEPT	European Conference of Postal and Telecommunications Administrations	COFDM	coded orthogonal frequency division multiplex
CSMA/CA	carrier sense multiple access with collision avoidance	DAB	digital audio broadcasting
DFS	dynamic frequency selection	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-C2	digital video broadcasting baseline system for digital cable television Second generation (ETSI EN 302 769)
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	FDM	frequency division multiplex
FFT	fast Fourier transformation	HCL	home cable link
HD	home distributor	HFC	hybrid fibre coaxial
HN	home network	HNI	home network interface
IF	intermediate frequency	IP	internet protocol
ISDB-C	integrated services digital broadcasting – cable	ISDB-S	integrated services digital broadcasting – satellite
ISDB-S3	integrated services digital broadcasting – satellite third generation	ISDB-T	integrated services digital broadcasting – terrestrial
LAN	local area network	LDPC	low-density parity-check (codes)
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	NTU	network termination unit
OFDM	orthogonal frequency division multiplex	PBA	Padovan sequence based backoff algorithm
PC	personal computer	PCMCIA	Personal Computer Memory Card International Association
PER	packet error ratio	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	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	WDM	Wavelength Division Multiplexing
Wi-Fi	wireless fidelity	WLAN	wireless local area network

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 60728-101 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 digitally modulated signals are indicated in Table 1 with reference to the relevant clauses of IEC 60728-101:2016.

Table 1 – Methods of measurement of IEC 60728-101 applicable to the home network

Methods of measurement Subclause reference of IEC 60728-101:2016		Television				Radio
		Vision and sound			Sound	
		DVB				
		PSK, APSK	QAM	OFDM	NICAM	DAB
4.11	Mutual isolation between system outlets	x	x	x	x	x
4.12	Amplitude response within a channel	x	x	x	x	x
4.13	Non-linear distortion	x	x	x	x	X
x Method of measurement is applicable						

5 Performance requirements of the home network

5.1 General

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

For DVB-S2, DVB-C2 and DVB-T2 digital signals, the service that is quasi-free of interruption is intended for a packet error ratio (PER) of 10^{-7} after LDPC and BCH decoders.

NOTE 1 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.

When measuring the system parameters at the system outlet or terminal input in operation, the limit values indicated in 5.2 to 5.9 can be exceeded, taking into account the contribution of the signal performance (quality) of each parameter present at the HNI.

EXAMPLE: The signal-to-noise ratio measured at the system outlet in operation is lower than the values given at the HNI in Clause 7 of IEC 60728-101; i.e., for DVB-S or DVB-S2, the signal-to-noise ratio will be impaired by up to 1 dB with respect to the HNI values given in IEC 60728-101:2016, Clause 7.

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. 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 IEC 60728-101:2016, 3.1.62 and IEC 60728-101:2016, 3.1.83).

5.3.2 Signal level

The signal levels are those given in IEC 60728-101 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 IEC 60728-101:2016, Table 3).

5.3.3 Other parameters

The performance requirements given in IEC 60728-101 at the system outlet remain unchanged at the terminal input.

5.4 Performance requirements at system outlets

5.4.1 Minimum and maximum RF signal levels

The minimum and maximum RF signal levels given in IEC 60728-101:2016, 5.5.1 apply.

When balanced cables are used in the home network, the minimum signal levels at the system outlet are increased by 1 dB (see IEC 60728-101:2016, Table 3).

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 IEC 60728-101:2016, 5.6.1.

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 can also be necessary to fulfil the requirements of IEC 60728-101:2016, 5.6.1 for one household, if special conditions require it (e.g. if several 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 (digital: 64 QAM) output shall comply with IEC 60728-101:2016, 5.6.3.

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

The requirements given in IEC 60728-101:2016, 5.8 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 signal levels at HNI1

The minimum and maximum signal levels at HNI1 shall not exceed those given in IEC 60728-101:2016, 7.2.2.1.

5.5.2 Minimum and maximum RF signal levels at HNI2 and HNI3

The minimum and maximum signal levels at HNI2 and HNI3 shall not exceed those given in IEC 60728-101:2016, 7.3.2.1.

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

The differences of signal 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.

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 IEC 60728-101:2016, 5.7, 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 ^c dB/MHz
QPSK (DVB-S)	37,125	1	0,5
QPSK, 8PSK, 16 APSK, 32 APSK (DVB-S2)	37,125	u.c.	u.c.
TC 8 PSK (ISDB-S)	34,5	2	–
16 APSK (ISDB-S3)	34,5	2	–
64 QAM (DVB-C)	8	1 ^a	0,2
64 QAM (ISDB-C)	6	2 ^b	–
128 QAM (DVB-C)	8	0,75	u.c.
256 QAM (DVB-C)	8	0,5	u.c.
256 QAM (ISDB-C)	6	2 ^b	–
COFDM (DVB-T, DVB-T2)	8	0,2	0,2
OFDM (ISDB-T)	5,7	2 ^b	–
^a Cable modems require a tighter amplitude response variation of less than 0,5 dB peak-to-peak in a 8 MHz channel bandwidth. ^b Cable modems require a tighter amplitude response variation of less than 0,5 dB peak-to-peak in a 6 MHz channel bandwidth. ^c The value of "maximum slope of variation" is not specified in Japan.			

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
QPSK	Signal bandwidth (see IEC 60728-101:2016, Clause C.3)	10
OFDM	Signal bandwidth (see IEC 60728-101:2016, Clause C.3)	10
QAM	Signal bandwidth (see IEC 60728-101:2016, Clause C.3)	10

5.8 Random noise produced in the home network

5.8.1 General

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 signal-to-noise ratio shall be at least 6 dB or 7 dB higher than the limits given in IEC 60728-101:2016, 5.9, so that the contributing impairment produced by the home network is not higher than 1,0 dB in regard to the signal-to-noise ratio of the complete network.

This implies that the random noise contribution of the active home network shall be such that, in a typical case, the S/IN measured at any system outlet, with an unimpaired signal at the input of the home network (HNI), is higher than 42 dB in the VHF/UHF bands (47 MHz to 862 MHz) and higher than 26 dB in the first IF band (950 MHz to 2 150 MHz).

5.8.2 Maximum amplifier noise figure

The maximum amplifier noise figure F_N 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:

$$F_N = R_{\text{SIN},\text{in}} - R_{\text{SIN},\text{out}} = (L - N_{\text{th}}) - R_{\text{SIN},\text{out}} \quad [\text{dB}] \quad (1)$$

where N_{th} is the bandwidth-dependent thermal noise voltage in dB(μV) (e.g. at $T = 25^\circ\text{C}$, N_{th} is 3,3 dB(μV) for $B_W = 7$ MHz, 3,9 dB(μV) for $B_W = 8$ MHz, 9,2 dB(μV) for $B_W = 27$ MHz).

When the (worst case) signal level at HNI2 is $L = 57$ dB(μV) (VHF/UHF bands) or $L = 48$ dB(μV) (first IF band), the F_N of the amplifier shall not exceed 11,1 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.

Subclause 5.9 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 for the contributing impairment produced by the home network to be not higher than 2 dB with regard to the signal-to-intermodulation ratio of the complete network, in accordance with IEC 60728-101:2016, 5.10.2 and IEC 60728-101:2016, 7.3.7.

This implies that the intermodulation contribution of the active coaxial home network shall be such that the signal-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 in accordance with the multicarrier measuring method described in IEC 60728-3.

NOTE 1 If the signal-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 IEC 60728-101:2016, 7.3.6 can be decreased by 1 dB.

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

Because intermodulation products between multiple, closely spaced, digital TV channels are similar to random noise, this intermodulation should be taken into account in the signal-to-noise measurements.

NOTE 3 It can be necessary to adjust the maximum output level of the amplifier 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 IEC 60728-101:2016, 5.9, so that the contribution of the impairment produced by the home network is not greater than 1 dB.

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 specifications given in 6.2.2, 6.2.3 and 6.2.4.

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 IEC 60728-101:2016, 5.5.1 and IEC 60728-101:2016, Table 3;
- maximum signal level differences allowed in the frequency range of interest, as indicated in IEC 60728-101:2016, 5.5.2 and IEC 60728-101:2016, Table 4 (e.g. 12 dB in the frequency range 47 MHz to 862 MHz);
- when balanced cables are used in the home network, the minimum signal levels are increased by 1 dB (see IEC 60728-101:2016, Table 27).

6.2.3 Home network interface (HNI) specifications

The following subclauses and tables apply:

- minimum and maximum signal levels at HNI1, as indicated in IEC 60728-101:2016, 7.2.2.1 and in IEC 60728-101:2016, Table 18;
- minimum and maximum signal levels at HNI2 and HNI3, as indicated in IEC 60728-101:2016, 7.3.2.1 and in IEC 60728-101:2016, Table 22;
- maximum signal level differences allowed in the frequency range of interest, for HNI1, HNI2 and HNI3 (e.g. 7 dB in the frequency range 47 MHz to 862 MHz).

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 requirements of 6.2.4 for home networks 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) 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 HNI signal level.

- The HNI1 interface level specification is up to 18 dB higher than the minimum system outlet specification (e.g., 68 dB(μV) for digital channels with 50 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), but 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 shall be met:

- a) in coaxial cabling systems, an interconnection model shall be chosen that minimizes the number of connections in series in order to not degrade the signal quality;
- b) jumpers and patch cords shall be avoided, by a direct connection of permanent link cables to the equipment;

NOTE As an installation rule, 0,5 m of cable is left hanging from the wall.

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

Subclauses 6.4, 6.5 and 6.6 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

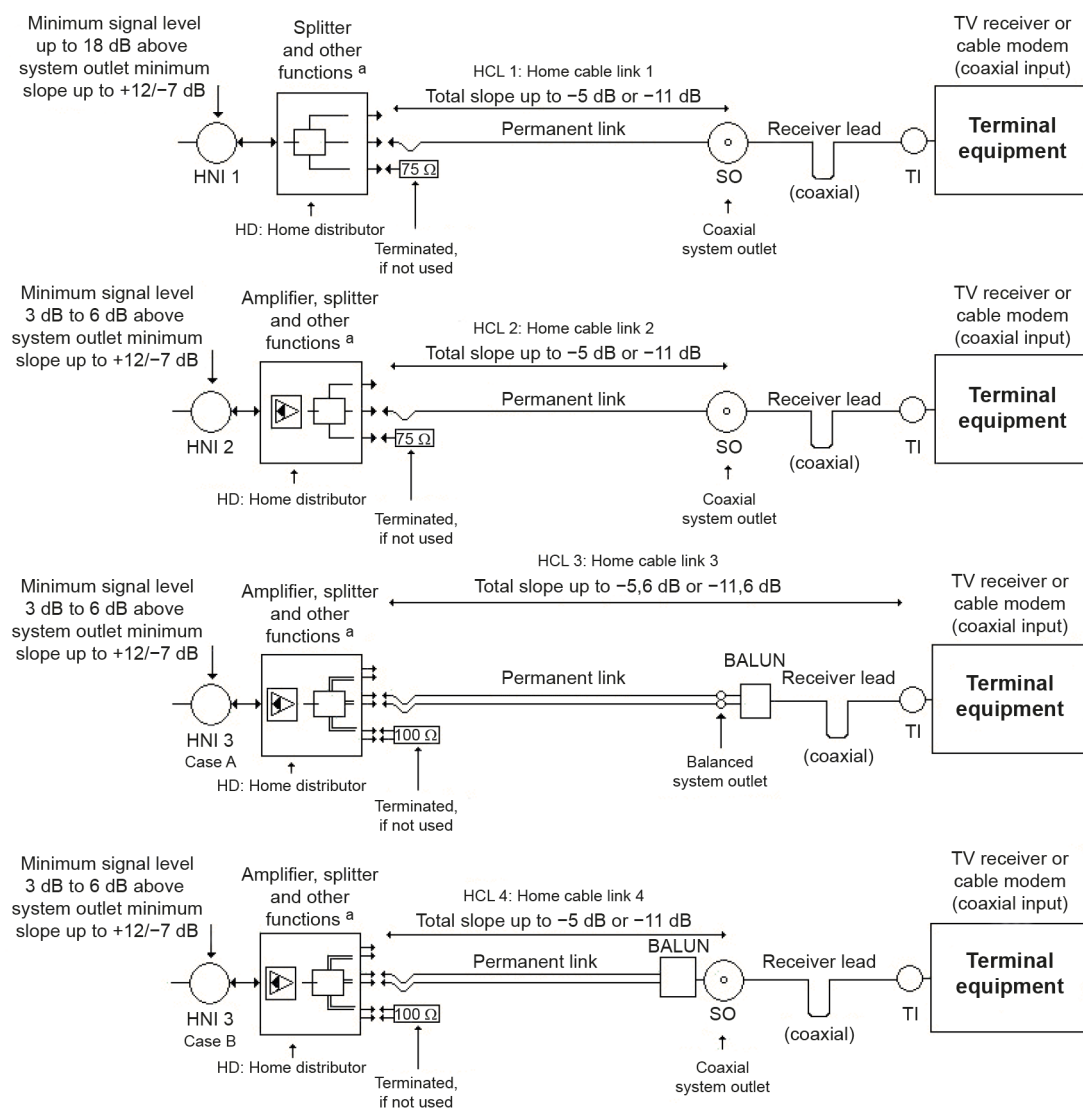
Subclause 6.4 shows some basic design considerations for home networks based upon coaxial cabling and/or balanced cabling or other types of links used inside an apartment for carrying BCT signals provided by CATV, MATV or SMATV cable networks.

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 0,5 m of cable left hanging from the wall, in order to allow direct connection to the equipment without jumpers or patch cords.



^a Slope compensation of 0 dB or +6 dB

IEC

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 (IEC 60728-101:2016, 7.2 and IEC 60728-101:2016, 7.3) 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 Formula (2) (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/100m at 800 MHz) according to EN 50117-2-4), assuming a direct connection of the cable to the equipment:

$$a_{PL} = (L_{PL} / 100) (0,597 \sqrt{f} + 0,0026 f) + a_{SO} \quad [\text{dB}] \quad (2)$$

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 values given in Formula (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 conforming to the IEC 60966 series, but without jumpers or patch cords at the equipment, as stated in 6.3 above, is given by Formula (3):

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

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 the 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 knowing the following characteristics:

- 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.

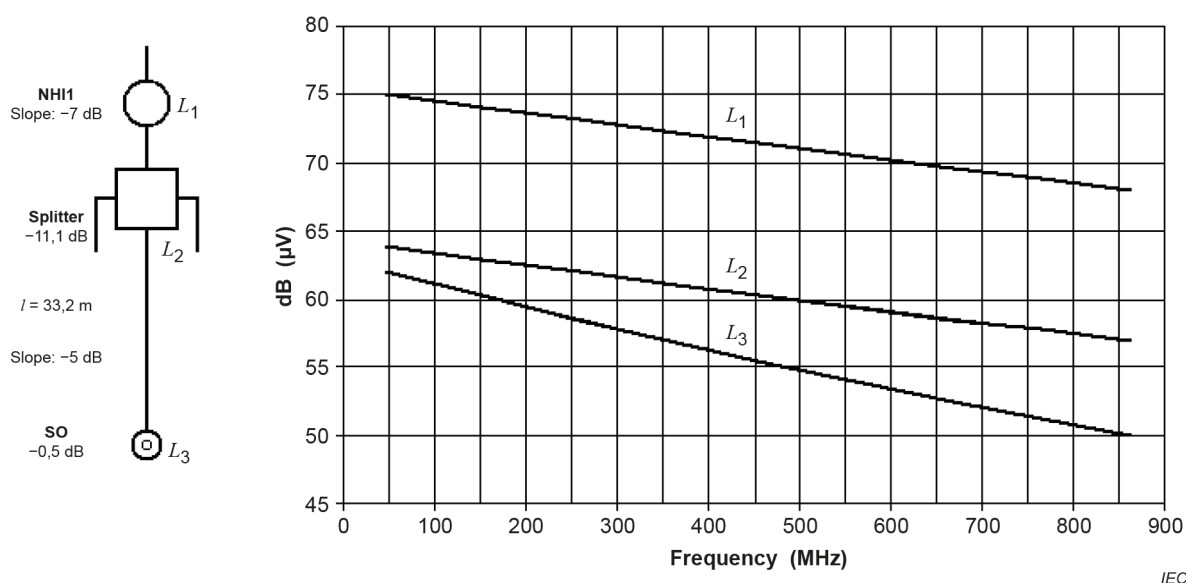
Assuming at the HNI1

- a slope of -7 dB,
- a signal level of 68 dB(μ V) (+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 of $11,1$ dB, as also indicated in Table 4.

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(μ V) at 47 MHz, in accordance with the slope of -7 dB (worst case) and the signal level of 68 dB(μ V) at 862 MHz.

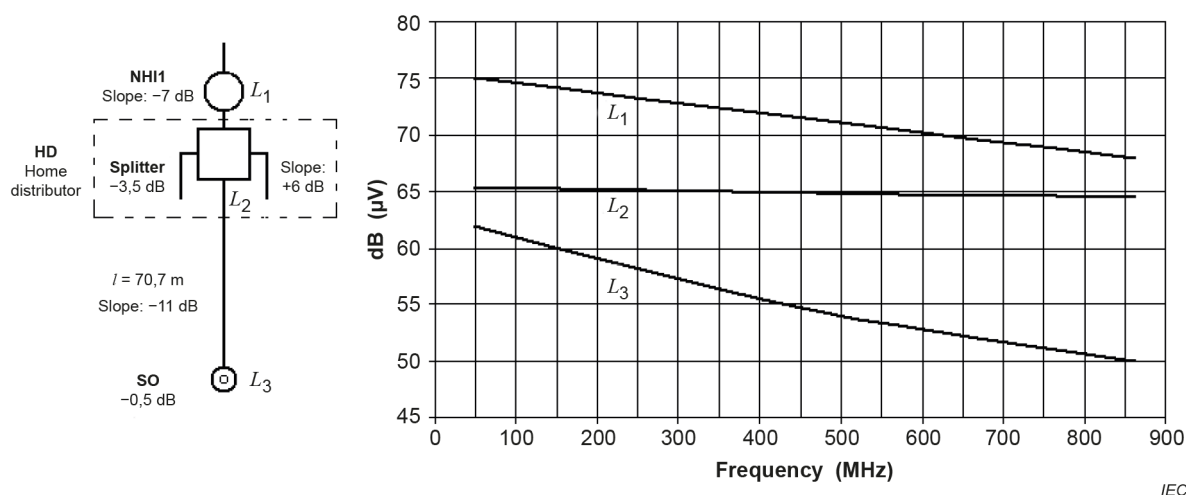


This diagram shows the signal levels at HNI1 (L_1), splitter output (L_2) and SO (L_3), assuming that the level delivered at HNI1 is +18 dB over the SO minimum at 862 MHz and the splitter has flat response over the frequency range.

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 4.

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), 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 knowing the following characteristics:

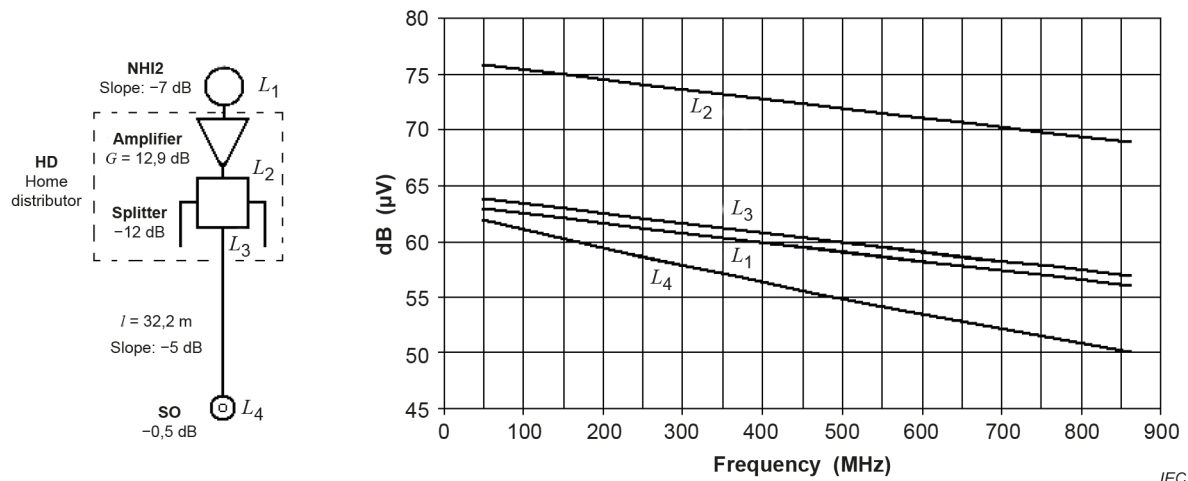
- the signal levels and slope at the home network interface (HNI2);
- the gain of the amplifier and splitter attenuation due to the number of system outlets (SO) served, taking into account the mutual isolation required;
- the length of coaxial cables from the home distributor (HD) to the SO;
- the system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

Assuming at the HNI2

- a slope of -7 dB,
- a signal level of 56 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 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 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.

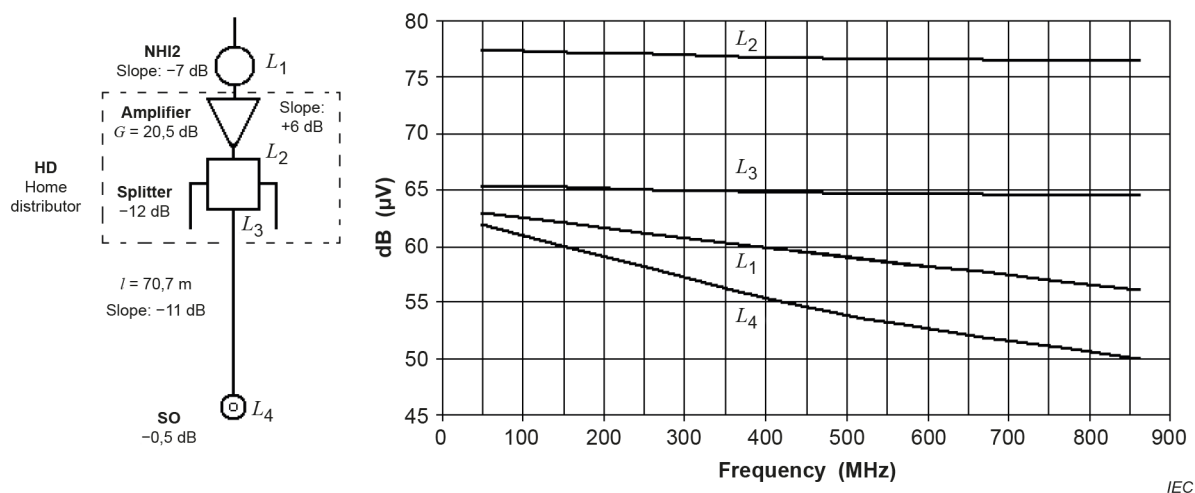


The diagram shows the signal levels at HNI2 (L_1), amplifier output (L_2), splitter output (L_3) and SO (L_4), assuming that the level delivered at HNI2 is +6 dB over the SO minimum at 862 MHz, the amplifier and the splitter have a flat response over the frequency range.

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 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 dB ^b	Splitter slope dB	Home distribution splitter attenuation dB	Maximum permanent link length L_{PL} m	System outlet loss dB	Home cable link 1 (HCL1) insertion loss ^a dB				HCL1 Slope ^a 47 MHz to 862 MHz dB	HCL1 Slope ^a 950 MHz to 2 150 MHz dB
18	0	11,1	32,2	0,5	47 MHz	470 MHz	862 MHz	950 MHz	2 150 MHz	
18	+6	3,5	70,7	0,5	1,9	5,1	6,9	7,2	11,2	-4,0
^a Permanent link plus system outlet.					3,5	10,5	14,5	15,2	24,0	-8,8
^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 50 dB(µV) (47 MHz at system outlet) +1,9 dB (permanent link) +11,1 dB (splitter) +7 dB (HNI1 positive slope) = 70 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 dB	Amplifier gain dB	Amplifier or splitter slope dB	Home distribution splitter attenuation dB	Maximum permanent link length L_{PL} m	System outlet loss dB	Home cable link 2 (HCL2) insertion loss ^a dB				HCL2 Slope ^a 47 MHz to 862 MHz dB	HCL2 Slope ^a 950 MHz to 2 150 MHz dB
6	12,9	0	12,0	32,2	0,5	47 MHz	470 MHz	862 MHz	950 MHz	2 150 MHz	
6	20,5	+6	12,0	70,7	0,5	1,9	5,1	6,9	7,2	11,2	-4,0
3	15,8	0	12,0	32,2	0,5	3,5	10,5	14,5	15,2	24,0	-8,8
3	23,5	+6	12,0	70,7	0,5	1,9	5,1	6,9	7,2	11,2	-4,0
^a Permanent link plus system outlet.						3,5	10,5	14,5	15,2	24,0	-8,8

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

The HNI3 specifications (IEC 60728-101:2016, 7.4) are related to a home network with balanced pair cables, having a total length L_{PL} (permanent link length) which can 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) that includes a balun.

The receiver lead is assumed to comply with the specification given in 5.3. 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 Formula (4) (the balanced cable model corresponds to a specific attenuation of about 62 dB/100 m at 1 GHz):

$$a_{HCL3A} = [L_{PL}/100] (1,645 \sqrt{f} + 0,01 f + 0,25/\sqrt{f}) + (0,04 \sqrt{f}) + a_{BO} + a_{BAL} + (0,08 + 0,4 L_{RL} (f/1000)^{1/2}) \text{ [dB]} \quad (4)$$

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: $0,08 + 0,4 L_{RL} (f/1000)^{1/2}$ 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 IEC 60728-1:2014, Table 39 (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 case 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 Formula (5) (the balanced cable model corresponds to a specific attenuation of about 62 dB/100m 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 IEC 60728-101:2016, Table 27 (i.e. at least 51 dB(μV) in case B of HNI3 for digital channels with a 50 dB(μV) minimum signal level in case A).

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 the 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 a HN with balanced cables (Case B).

NOTE For a 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 knowing the following characteristics:

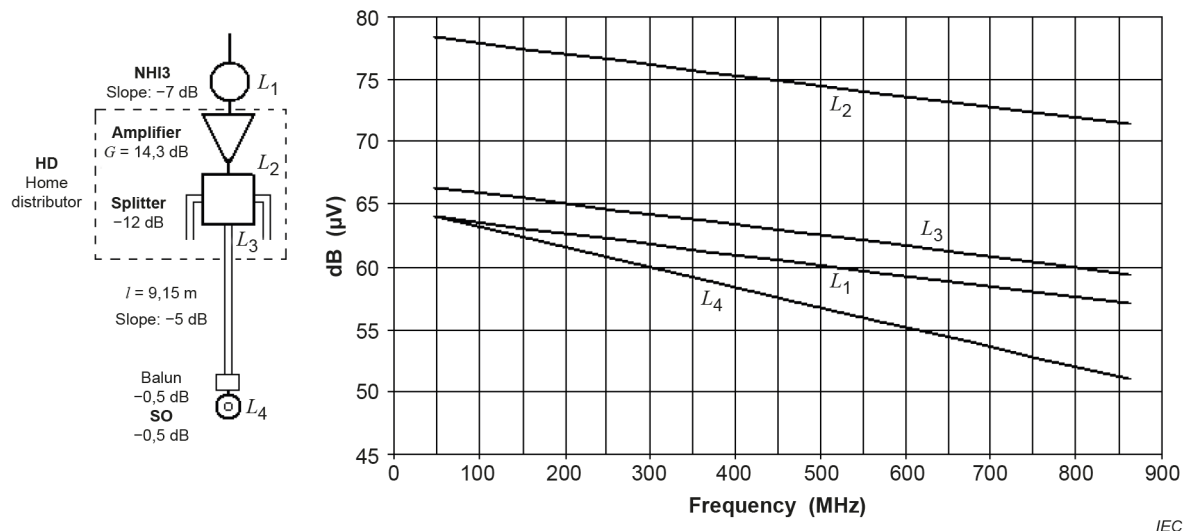
- the signal levels and slope at the home network interface (HNI3);
- the gain of the amplifier and splitter attenuation due to the number of system outlets (SO) served, taking into account the mutual isolation required;
- the length of balanced pair cables from the home distributor (HD) to the SO;
-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

Assuming at the HNI3

- a slope of –7 dB,
- a signal level of 57 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.



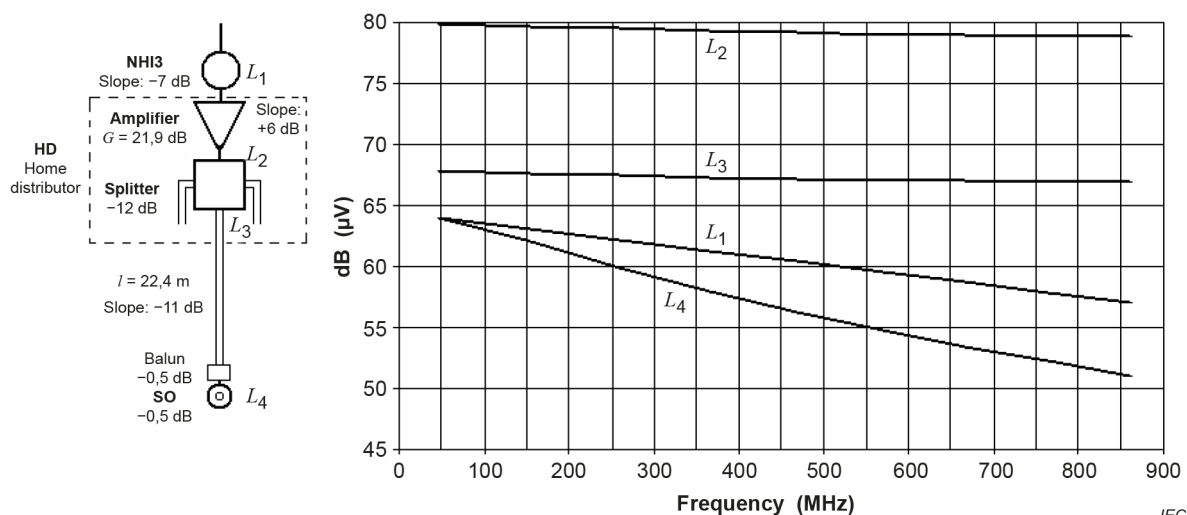
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The diagram shows the signal levels at HNI3 (L_1), amplifier output (L_2), splitter output (L_3) and SO (L_4), assuming that the level delivered at HNI3 is +6 dB over the SO minimum at 862 MHz, and the amplifier and/or the splitter have a flat response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



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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, and 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 dB	Minimum amplifier gain dB	Amplifier or splitter slope dB	Home distribution splitter attenuation dB	Permanent link length L_{PL} m	Receiver lead length L_{RL} m	System outlet and baluns loss ^b dB	Home cable link 3 (HCL3) insertion loss dB			HCL3 slope 47 MHz to 862 MHz dB
							47 MHz	470 MHz	862 MHz	
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 tuneable attenuation might 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 50 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 dB	Minimum amplifier gain ^b dB	Amplifier or splitter slope dB	Home distribution splitter attenuation dB	Permanent link length L_{PL} m	System outlet and baluns loss dB	Home cable link 4 (HCL 4) insertion loss ^c dB			HCL4 slope ^c 47 MHz to 862 MHz dB
						47 MHz	470 MHz	862 MHz	
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 tuneable attenuation might 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 51 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 ways), if the permanent link has the maximum length of 32 m. If one output of the splitter has a slope compensating response of +6 dB, with an attenuation of only about 3,5 dB at 862 MHz (like 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 68 dB(μ V) at 862 MHz (or 70 dB(μ V) in the rare case of a +7 dB slope, where the 47 MHz signal 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 balanced cables.
- 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) can 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 for two-way home amplifiers 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. 68 dB(μ V) to 70 dB(μ V) 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 can be "the most convenient" or "most comfortable" design for the habitants of the 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 type (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 (IEC 60728-101:2016, 7.3) with respect to the electrical signal level and to the other quality parameters (signal levels differences, frequency response, random noise, interference to television channels, etc.), apply also for HNI3, case C.

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

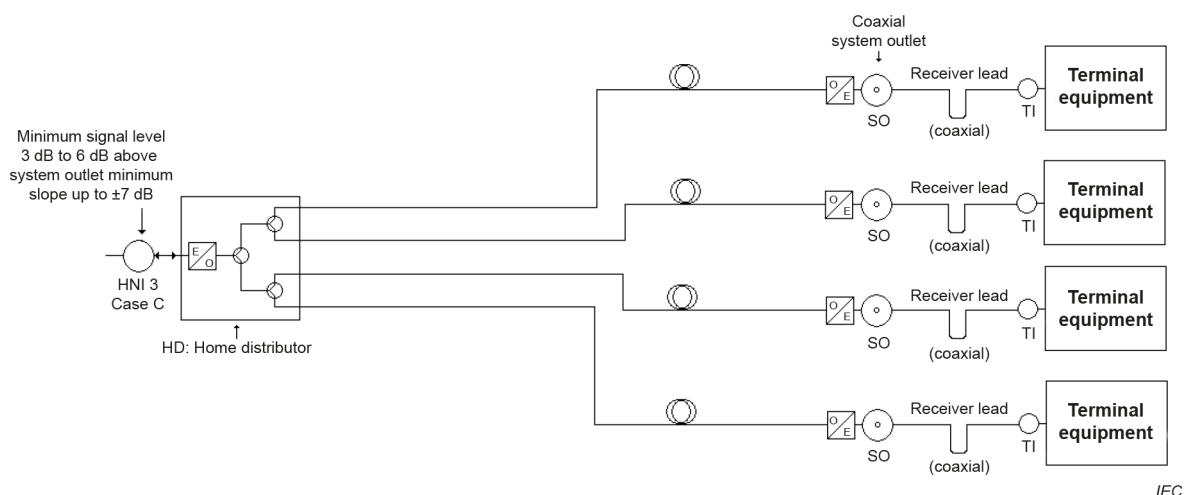


Figure 10 – Example of a home network using optical fibres

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), or -1 dB(mW) to $+7$ dB(mW) for Japan.

The electrical signal level and quality delivered at each system outlet shall comply with the requirements indicated in IEC 60728-101. 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 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 HNI3 (IEC 60728-101:2016, 7.4) in respect to the electrical signal level and the other quality parameters (signal levels differences, frequency response, random noise, interference to television channels, etc.), apply also for 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, and flatscreen TV sets. But for these applications, the installation of a twisted pair in-home network with Category 5/Category 6/Category 7 cables has some practical drawbacks.

For this reason, radio networking using ISO/IEC/IEEE 8802-11 equipment (WLAN) has become very popular, with WLAN hubs connected to or built into cable modems or ADSL modems.

The use of ISO/IEC/IEEE 8802-11 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.

The objective of the extension of the domestic coaxial cabling 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 ISO/IEC/IEEE 8802-11 (IEEE 802.11n/ac) standard.

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 which 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 WLAN antennas located in selected rooms: in this case the link is in part over the coaxial network (e.g. the first 20 m to 30 m) and in part over the air (e.g. the last 5 m) and possibly with a line of sight between the WLAN antenna and the portable ISO/IEC/IEEE 8802-11-enabled appliance, connected to or included in the terminal equipment.