BS EN 60728-10:2014

BSI Standards Publication

Cable networks for television signals, sound signals and interactive services

Part 10: System performance for return paths

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National foreword

This British Standard is the UK implementation of EN 60728-10:2014. It is identical to IEC 60728-10:2014. It supersedes BS EN 60728-10:2006 which is withdrawn.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.

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Réseaux de distribution par câbles pour signaux de télévision, signaux de radiodiffusion sonore et services interactifs - Partie 10: Performances des systèmes de voie de retour (CEI 60728-10:2014)

Kabelnetze für Fernsehsignale, Tonsignale und interaktive Dienste - Teil 10: Rückweg-Systemanforderungen (IEC 60728-10:2014)

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Foreword

The text of document 100/2247/FDIS, future edition 3 of IEC 60728-10, 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 60728-10:2014.

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)	2015-01-15
• latest date by which the national standards conflicting with the document have to be withdrawn	(dow)	2017-04-15

This document supersedes EN 50083-10:2002 and EN 60728-10:2006.

EN 60728-10:2014 includes the following significant technical changes with respect to EN 60728-10:2006:

- update on the state-of-the-art of return path transmission in cable networks;
- provisions for DOCSIS 3.0 and EuroDOCSIS 3.0 transmission standards;
- revision of Subclause 4.3 on measurement of channel level;
- new Subclause 4.12 for method of measurement of noise power ratio (NPR) on return paths;
- new Subclause 4.13 for 10-tone measurements;
- new Subclause 4.14 for method of measurement of modulation error ratio (MER);
- revision of Subclause 5.2 on analogue parameters influencing system performance.

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 60728-10:2014 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 60728-3	NOTE	Harmonized as EN 60728-3.
IEC 60728-4	NOTE	Harmonized as EN 60728-4.
IEC 60728-6	NOTE	Harmonized as EN 60728-6.
IEC 60728-11	NOTE	Harmonized as EN 60728-11.

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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 1 When an International Publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

NOTE 2 Up-to-date information on the latest versions of the European Standards listed in this annex is available here: www.cenelec.eu

Publication	Year	Title	EN/HD	Year
		Cable networks for television signals, sound signals and interactive services - Part 10-1: Guidelines for the implementation of return paths in cable networks	CLC/TR 50083-10-1	2009 [1)]
IEC 60728	Series	Cable networks for television signals, sound signals and interactive services	EN 60728	Series
IEC 60728-1	-	Cable networks for television signals, sound signals and interactive services - Part 1: System performance of forward paths	EN 60728-1	-
IEC 60728-2	-	Cable networks for television signals, sound signals and interactive services - Part 2: Electromagnetic compatibility for equipment	EN 50083-2	-
IEC 60728-5	-	Cable networks for television signals, sound signals and interactive services - Part 5: Headend equipment	EN 60728-5	-
IEC 60728-12	-	Cabled distribution systems for television and sound signals - Part 12: Electromagnetic compatibility of systems	EN 50083-8	-
ISO/IEC 13818-1	2007 [2)]	Information technology - Generic coding of moving pictures and associated audio information: Systems	-	-
ITU-R Recommendation BT.470	-	Conventional analogue television systems	-	-
ETSI ES 200 800	-	Digital Video Broadcasting (DVB); DVB interaction channel for Cable TV distribution systems (CATV)	-	-

[1)] Superseded by CLC/TR 50083-10-1:2014.

[2)] Superseded by ISO/IEC 13818-1:2013.

ETSI EN 302 878-2	2011	Access, Terminals, Transmission and Multiplexing (ATTM); Third Generation Transmission Systems for Interactive Cable Television Services - IP Cable Modems; Part 2: Physical Layer; DOCSIS 3.0	-	-

CONTENTS

INTRODUCTION 8
1 Scope 9
2 Normative references 9
3 Terms, definitions, symbols and abbreviations 10
3.1 Terms and definitions 10
3.2 Symbols 13
3.3 Abbreviations 14
4 Methods of measurement 14
4.1 General 14
4.2 Set-up of the network 15
4.3 Measurement of channel level 15
4.3.1 General 15
4.3.2 Equipment required 15
4.3.3 Connection of the equipment 16
4.3.4 Measurement procedure for digitally modulated carriers 16
4.3.5 Measurement procedure for intermittent digitally modulated carriers 17
4.3.6 Presentation of the results 18
4.4 Measurement of amplitude response variation 18
4.4.1 Background 18
4.4.2 Equipment required 18
4.4.3 Connection of the equipment 18
4.4.4 Calibration of equipment 18
4.4.5 Method of measurement 19
4.4.6 Presentation of the results 19
4.5 Measurement of signal to noise ratio ($S_{D,RF}/N$) 19
4.5.1 General 19
4.5.2 Equipment required 19
4.5.3 Connection of the equipment 19
4.5.4 Measurement procedure 19
4.5.5 Presentation of the results 20
4.6 Measurement of multiple interference 20
4.6.1 General 20
4.6.2 Equipment required 21
4.6.3 Connection of the equipment 21
4.6.4 Measurement procedure 21
4.6.5 Processing of the data 21
4.6.6 Presentation of the results 21
4.7 Measurement of impulse noise 22
4.7.1 General 22
4.7.2 Equipment required 22
4.7.3 Connection of the equipment 22
4.7.4 Measurement procedure 22
4.7.5 Processing of the data and presentation of the results 23

4.8 Measurement of echo ratio ... 23
4.8.1 General ... 23
4.8.2 Equipment required ... 24
4.8.3 Connection of the equipment ... 25
4.8.4 Measurement procedure ... 25
4.8.5 Presentation of the results ... 25
4.9 Measurement of group delay variation ... 25
4.10 Measurement of frequency error ... 26
4.10.1 General ... 26
4.10.2 Equipment required ... 26
4.10.3 Connection of the equipment ... 26
4.10.4 Measurement procedure ... 26
4.10.5 Presentation of the result ... 27
4.11 Measurement of bit error ratio (BER) ... 27
4.11.1 General ... 27
4.11.2 Equipment required ... 27
4.11.3 Connection of the equipment ... 28
4.11.4 Measurement procedure ... 28
4.11.5 Presentation of the results ... 28
4.12 Noise power ratio (*NPR*) measurement on return path ... 28
4.12.1 General ... 28
4.12.2 Equipment required ... 29
4.12.3 Connection of the equipment ... 29
4.12.4 Measurement procedure ... 30
4.12.5 Presentation of the results ... 31
4.12.6 Recommended correction factors ... 31
4.12.7 Precautions during measurement ... 32
4.12.8 *NPR* dynamic range ... 32
4.13 10-Tone measurement ... 33
4.13.1 General ... 33
4.13.2 Measurement principle ... 34
4.13.3 Measurement procedure ... 34
4.14 Modulation error ratio (*MER*) measurement on return path ... 35
4.14.1 General ... 35
4.14.2 Equipment required ... 36
4.14.3 Connection of the equipment ... 36
4.14.4 Measurement procedure ... 36
4.14.5 Presentation of the results ... 37
5 System performance requirements ... 37
5.1 General ... 37
5.2 Analogue parameters that influence the system performance ... 40
5.3 General requirements ... 42
5.3.1 Impedance ... 42
5.3.2 Maximum signal level ... 42
5.4 Specific system performance requirements ... 42
6 System performance recommendations – Return path bandwidth ... 45
6.1 Frequency allocation ... 45
6.2 Transmission quality in the return path frequency ranges ... 45
Annex A (normative) Correction factors for noise ... 47

A.1 Signal level measurement 47
A.2 Noise level measurement 47
Annex B (normative) Correction factor for a spectrum analyser 49
Annex C (normative) Null packet and PRBS definitions 50
C.1 Null packet definition 50
C.2 PRBS definition 51
Bibliography 52

Figure 1 – Reference points of an active return path system (example) 15
Figure 2 – Time domain representation of an upstream burst with marker on the preamble of the DOCSIS signal 17
Figure 3 – Arrangement of test equipment for measurement of amplitude response variation 18
Figure 4 – Echo rating graticule 24
Figure 5 – Arrangement of test equipment for measurement of echo ratio 25
Figure 6 – Test set-up for frequency stability measurement 26
Figure 7 – Principle of BER measurement 27
Figure 8 – Band-pass and band-stop filters response 29
Figure 9 – *NPR* test set up 30
Figure 10 – *NPR* versus RF power density applied at input of optical transmitter and determination of *OMI* 100 % 31
Figure 11 – Example of the frequency response of the optional band-pass filter 31
Figure 12 – Example of *NPR* dynamic range 33
Figure 13 – Dynamic range plotted versus *NPR* 33
Figure 14 – Alternative *NPR* measurement principle 34
Figure 15 – Relationship between classical *NPR* method and multi-tone method 35
Figure 16 – Test set-up for modulation error ratio (*MER*) measurement 36
Figure 17 – Example of constellation diagram for a 64QAM modulation format 37
Figure 18 – Return path signals affecting forward path signals 38
Figure 19 – Forward path signals affecting return path signals 39
Figure 20 – Return path signals of service 1 affecting return path signals of a different service (e.g. service 2) 39
Figure 21 – Return path signals of a specific service (e.g. service 2) affecting return path signals of the same service 39
Figure 22 – Identification of the most common sub-bands within the return path band with limited transmission quality 46
Figure A.1 – Noise correction factor *CF* versus measured level difference *D* 48

Table 1 – Examples of the Nyquist bandwidth of digitally modulated carriers 16
Table 2 – Band-stop filter notch frequencies 29
Table 3 – Summary of the requirements for *MER* according to ETSI EN 302 878-2, V.1.1.1 (2011-11), (clause 6.2.22.3.2) 41
Table 4 – System performance requirements for different modulation techniques for $BER = 10^{-4}$ 43
Table 5 – Comparison of system performance parameters given in Table 4 with those given in ETSI EN 302 878-2, V.1.1.1 (2011-11), specifications 44

Table 6 – Return path frequency ranges 45
Table 7 – Reasons for quality reduction in sub-bands of the return path 45
Table A.1 – Noise correction factor 47
Table C.1 – Null transport stream packet definition 51

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.

Specific equipment installed in cable networks for the operation of such return paths is standardised in the relevant equipment standards. See IEC 60728-3, IEC 60728-4, IEC 60728-5, IEC 60728-6.

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

Part 10: System performance for return paths

1 Scope

This part of IEC 60728 specifies the transparent return path of cable networks operated in the frequency range between 5 MHz and 85 MHz or parts thereof. The upper frequency limit of the return path is reduced to 65 MHz where FM radio signals are transmitted in a cable network. Higher frequencies may be used in fibre based networks.

NOTE In addition, it is possible to use the frequency range from 0 MHz to 5 MHz for return path transmissions, for example for NMS or other control, monitoring and signalling purposes. Applications below 5 MHz are not covered by this standard.

Specifications of transmission systems (e.g. DOCSIS) are not within the scope of this standard.

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 60728 (all parts), *Cable networks for television signals, sound signals and interactive services*

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

IEC 60728-2, *Cable networks for television signals, sound signals and interactive services – Part 2: Electromagnetic compatibility for equipment*

IEC 60728-5, *Cable networks for television signals, sound signals and interactive services – Part 5: Headend equipment*

IEC 60728-12, *Cabled distribution systems for television and sound signals – Part 12: Electromagnetic compatibility of systems*

ISO/IEC 13818-1:2007, *Information technology − Generic coding of moving pictures and associated audio information − Part 1: Systems*

ITU-R BT.470, *Conventional analogue television systems*

CLC/TR 50083-10-1:2009, *Guidelines for the implementation of return paths in cable networks*

ETSI ES 200 800, *Digital Video Broadcasting (DVB); DVB interaction channel for Cable TV distribution systems (CATV)*

ETSI EN 302 878-2, V.1.1.1 (2011-11), *Access, Terminals, Transmission and Multiplexing (ATTM); Third Generation Transmission Systems for Interactive Cable Television Services – IP Cable Modems; Part 2: Physical Layer; DOCSIS 3.0*

3 Terms, definitions, symbols and abbreviations

3.1 Terms and definitions

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

3.1.1
amplitude response variation
peak-to-peak variation in frequency amplitude response of a specified signal path over a specified frequency band

Note 1 to entry: The amplitude response variation is expressed in dB.

3.1.2
broadcast signal
signal comprising video and/or audio and/or data content distributed to several receivers simultaneously

3.1.3
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.

3.1.4
channel availability
percentage of the time during which the channel fulfils all performance requirements

Note 1 to entry: The duration of the observation time shall be published.

3.1.5
extended satellite television distribution network or system
distribution network or system designed to provide sound and television signals received by satellite receiving antennas to households in one or more buildings

Note 1 to entry: This kind of network or system can possibly 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.

3.1.6
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 possibly 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.

3.1.7
forward path direction
direction of signal flow in a cable network from the headend or any other central point (node) of a cable network to the subscribers' area

3.1.8
forward path
part of a cable network by which signals are distributed in the forward path direction from the headend or any other central point (node) of a cable network to the subscribers' area

Note 1 to entry: The forward path was formerly referred to as downstream.

3.1.9
frequency error
quality of supply evaluated on the basis of the actual frequency of an electrical system compared to its nominal value

Note 1 to entry: Frequency error consists of initial error, and short term and long term frequency stability.

3.1.10
headend
equipment connected between receiving antennas or other signal sources and the remainder of the cable network, 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.

3.1.11
hybrid fibre coaxial network
HFC
cable network which is comprised of optical equipment and cables and coaxial equipment and cables in different parts

3.1.12
impulse noise
noise caused by electromagnetic interference into cable networks

Note 1 to entry: Impulse noise is characterised by pulses with a duration of typically $<10\ \mu s$.

3.1.13
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.

3.1.14
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 WiFi) in the return path direction.

3.1.15
ingress noise
noise caused by electromagnetic interference into cable networks

Note 1 to entry: The power of the ingress noise decreases with increasing frequency. It is permanently present but it varies slowly in its intensity as a function of time.

3.1.16
interaction path
part of a cable network by which interactive signals are transmitted in the forward path direction (from the headend or node to the subscriber) and in the return path direction (from the subscriber to the headend or node)

3.1.17
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)

3.1.18
location specific noise
noise which occurs at a specific area of a cable network or which occurs in a cable network located in a specific environment

3.1.19
MATV network
extended terrestrial television distribution networks or systems designed to provide sound and television signals received by terrestrial receiving antennas 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 possibly 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.

3.1.20
multiple interference
interfering signal which consists of at least two signals that originated from at least two different sources

Note 1 to entry: On return path the multiple interference consists of ingress noise and intermodulation distortion products.

3.1.21
multimedia signal
signal comprising two or more different media contents, for example, video, audio, text, data, etc.

3.1.22
network management system
NMS
software based system for controlling and supervising cable networks

3.1.23
network segment
part of a cable network comprising a set of functions and/or a specific extent of the complete cable network

3.1.24
network termination
electrical termination of a cable network at any outlet on subscribers' side and headend or node side

3.1.25
node
central point of a network segment at which signals can be fed into the forward path or can be gathered from a number of subscribers out of the return path

3.1.26
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

3.1.27
return path
part of a cable network by which signals are transmitted in the return path direction from any subscriber, connected to the network, to the headend or any other central point (node) of a cable network

Note 1 to entry: The return path was referred to as upstream before.

3.1.28
return path direction
direction of signal flow in a cable network from a subscriber to the headend or any other central point (node) of a cable network

3.1.29
SMATV network
extended distribution networks or systems designed to provide sound and television signals received by satellite receiving antennas to households in one or more buildings

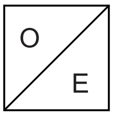
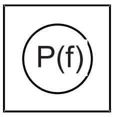
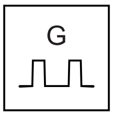
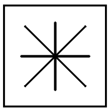
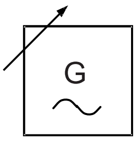
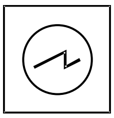
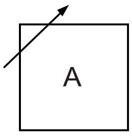
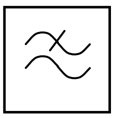
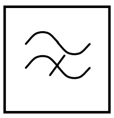
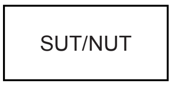
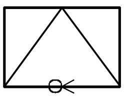
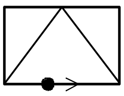
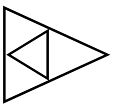
Note 1 to entry: Originally defined as satellite master antenna television network.

Note 2 to entry: This kind of network or system can possibly 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.

3.2 Symbols

The following graphical symbols are used in the figures of this standard. These symbols are either listed in IEC 60617, IEC 60417 or based on symbols defined in IEC 60617.

Symbols	Terms	Symbols	Terms
	Optical receiver [IEC 60617-S00213 (2001-07)]		Electrical spectrum analyzer [IEC 60617-S00910 (2001-07)]
	Test waveform generator [IEC 60617-S01225 (2001-07)]		Passive distribution network [IEC 60617-S00910 (2001-07)]
	Variable signal generator [IEC 60617-S00899 (2001-07), IEC 60617-S01403 (2001-09), IEC 60617-S00081 (2001-07)]		Oscilloscope [IEC 60617-S00059, IEC 60617-S00922 (2001-07)]
	Variable attenuator [IEC 60617-S01245 (2001-07)]		Low pass filter [IEC 60617-S01248 (2001-07)]
	High pass filter [IEC 60617-S01247 (2001-07)]		System under test/ Network under test [IEC 60617-S00060 (2007-07)]
	Demodulator [IEC 60417-5260 (2002-10)]		Modulator [IEC 60417-5261 (2002-10)]
	Amplifier with return path amplifier [IEC 60617-S00433 (2001-07)]		Bit error rate detector [IEC 60617-S00059, IEC 60617-S00910 (2001-07)]

3.3 Abbreviations

The following abbreviations are used in this standard:

BER	bit error ratio	BW	bandwidth, equivalent noise bandwidth
CATV	community antenna television	CB	citizen band
CIN	composite intermodulation noise	CM	cable modem
C/MI	carrier-to-multiple interference ratio	CMTS	cable modem termination system
C/N	carrier-to-noise ratio	DVB	digital video broadcasting
EMC	electromagnetic compatibility	FM	frequency modulation
FSK	frequency shift keying	HFC	hybrid fibre coaxial
HNI	home network interface	IF	intermediate frequency
ISM	industrial, scientific, medical	LPF	low-pass filter
MATV	master antenna television (network)	*MER*	modulation error ratio
MoCA	multimedia over cable alliance	NMS	network management system
NPR	noise power ratio	NUT	network under test
OFDM	orthogonal frequency division multiplexing	OMI	optical modulation index
PRBS	pseudo random binary sequence	QAM	quadrature amplitude modulation
QPSK	quaternary phase shift keying	RF	radio frequency
RMS	root mean square	RBW	resolution bandwidth
S	signal level, before corrections	SCDMA	synchronous code division multiple access
SL	signal level (corrected)	SMATV	satellite master antenna television (network)
S/N	signal-to-noise ratio	$S_{D,RF}/N$	signal-to-noise ratio (RF digital signal)
SUT	system under test	TDMA	time division multiple access
TV	television	WiFi	wireless fidelity

4 Methods of measurement

4.1 General

An active return path carries typically only return signals. A passive return path can be used for both return and forward signals.

This standard lays down the basic methods of measurement for signals typically used in the return path of cable networks in order to assess the performance of those signals and their performance limits.

All requirements refer to the performance limits, which shall be obtained between the reference points (Figure 1) of the return path system.

One reference point is the network termination unit (NTU) close to the home network interface HNI or to the subscriber system outlet (SO). It is the last point where all forward and return signals are present and carried on the same cable. If no network termination unit exists, the reference point is the HNI or the system outlet.

The other reference point is the input of the return signal receiver (or transceiver) in the CMTS. At this point, the transparent signal path ends and beyond this point, the signal is treated in a non-transparent way. The return signal receiver can be situated at the headend but can also be at the node of the coaxial cell or at any other point of the network (where the CMTS is located).

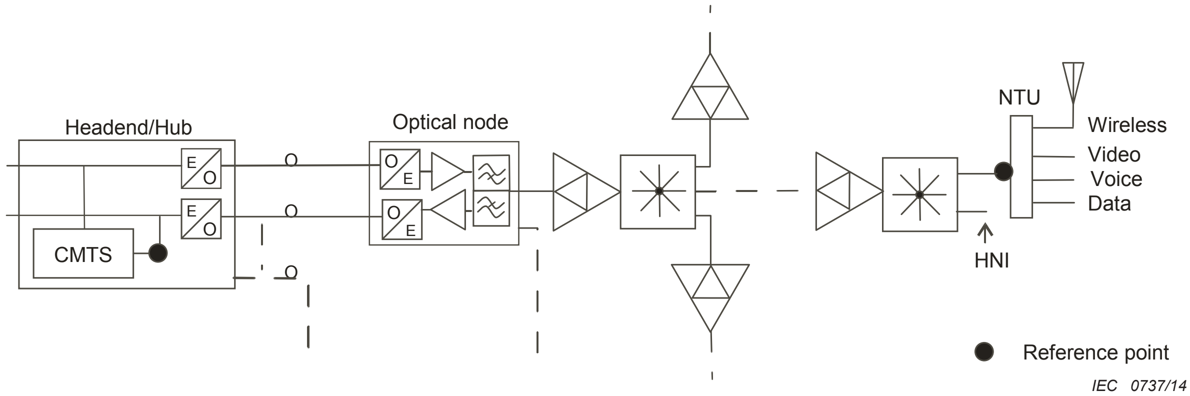


Figure 1 – Reference points of an active return path system (example)

In addition to the system performance requirements for the transparent return path, system performance recommendations were laid down in this standard. This includes, for example, the overall frequency allocation, the use of specific modulation techniques for different interactive multimedia services or different sub-bands within the return path frequency range, etc.

4.2 Set-up of the network

Although the main target of this clause is to describe the measurement methods for the performance of the return path, it is very important to do this on a properly aligned network plant. Clause 8 “Installation and maintenance” of CLC/TR 50083-10-1:2009 is referenced where the signal level adjustment is described in detail for the forward path and the return path directions.

4.3 Measurement of channel level

4.3.1 General

The method described is applicable to the measurement of the channel level of digitally modulated carriers and the channel level of intermittent digitally modulated carriers. The channel level of a digitally modulated carrier is the RMS voltage of a sinusoidal signal that would produce the same heating in a 75 Ω resistor as does the actual signal. For an intermittent digitally modulated channel, that occupies one assigned time slot in a time division multiple access (TDMA) sequence of time slots, the level to be considered shall be the equivalent level as if the signal being measured (any one of the multiple signals included in the total sequence) was transmitted continuously.

NOTE The terms “Signal level, carrier level, channel level, carrier power and channel power” are often used as synonyms. For a continuous wave signal the term “carrier level” is the most appropriate. When the carrier is modulated with digital information, the most suitable terms are “channel level” or “channel power”. Systems in the return path are loaded with modulated carriers, which in most cases are digitally modulated carriers.

4.3.2 Equipment required

The equipment required is a spectrum analyzer having a known noise bandwidth and a calibrated display. The calibration accuracy should be preferably within 0,5 dB.

4.3.3 Connection of the equipment

Connect the measuring equipment to the point where the measurement shall be performed by using a suitable connection lead. Take care to ensure correct impedance matching.

4.3.4 Measurement procedure for digitally modulated carriers

The measurement procedure comprises the following steps:

a) if a high level ambient field is present, check that the measuring equipment has no spurious readings. Connect a shielded termination to the connection lead, place the test equipment and the connection lead approximately in their measuring positions and check that there is a negligible reading at the frequency/frequencies and on the meter ranges to be used;

b) tune the spectrum analyzer to the channel that shall be measured (by selecting the centre frequency of the spectrum analyzer) and select the span and level settings to show the whole channel. Examples of the Nyquist bandwidth of digitally modulated carriers are given in Table 1;

Table 1 – Examples of the Nyquist bandwidth of digitally modulated carriers

Type of digital channel Mbit/s	**Nyquist bandwidth** MHz
QPSK 0,256	0,128
QPSK 0,288	0,187 5
QPSK 0,576	0,375
QPSK 1,152	0,750
QPSK 1,544	0,772
QPSK 2,304	1,500 0
QPSK 3,088	1,544
QPSK 4,608	3,000
16 QAM 12,8	3,200 0
64 QAM 30,7	6,400 0

c) set the resolution bandwidth (RBW) of the spectrum analyzer to 30 kHz (or lower than one tenth of the equivalent bandwidth) and the video bandwidth to 1 kHz (or lower to obtain a smooth display). Use an RMS-type detector;

d) measure the signal level (S) at the centre frequency of the channel in dB(μV);

e) measure the –3 dB frequencies of the channel. The difference between these two frequencies is assumed to be the equivalent signal bandwidth (BW);

NOTE This measurement is important for the QPSK modulation format where the equivalent signal bandwidth depends on the bit rate of the transmitted signal and the inner code rate used.

f) calculate the signal level (SL) by using formula:

$$SL = S + 10 \lg (BW / RBW) + K$$

The correction factor (K) depends on the measuring equipment used and shall be provided by the manufacturer of the measuring equipment or obtained by calibration. The value of the correction factor for a typical spectrum analyzer is about 1,7 dB (see Annex B).

If the measuring equipment can display the level in dB(mW/Hz), the correction factor K is not needed and the level (SL) in dB(mW) can be obtained from the measured level (S) by using the formula:

$$SL = S + 10 \lg (BW)$$

NOTE This measuring method actually measures the $S + N$ level. The contribution of noise is considered negligible if the level of noise outside the equivalent channel bandwidth is at least 15 dB lower than the measured level (S).

4.3.5 Measurement procedure for intermittent digitally modulated carriers

4.3.5.1 TDMA transmission

In the TDMA transmission mode, the amplitude of the upstream digitally modulated signal's preamble, which is equal to the signal's average power, shall be measured.

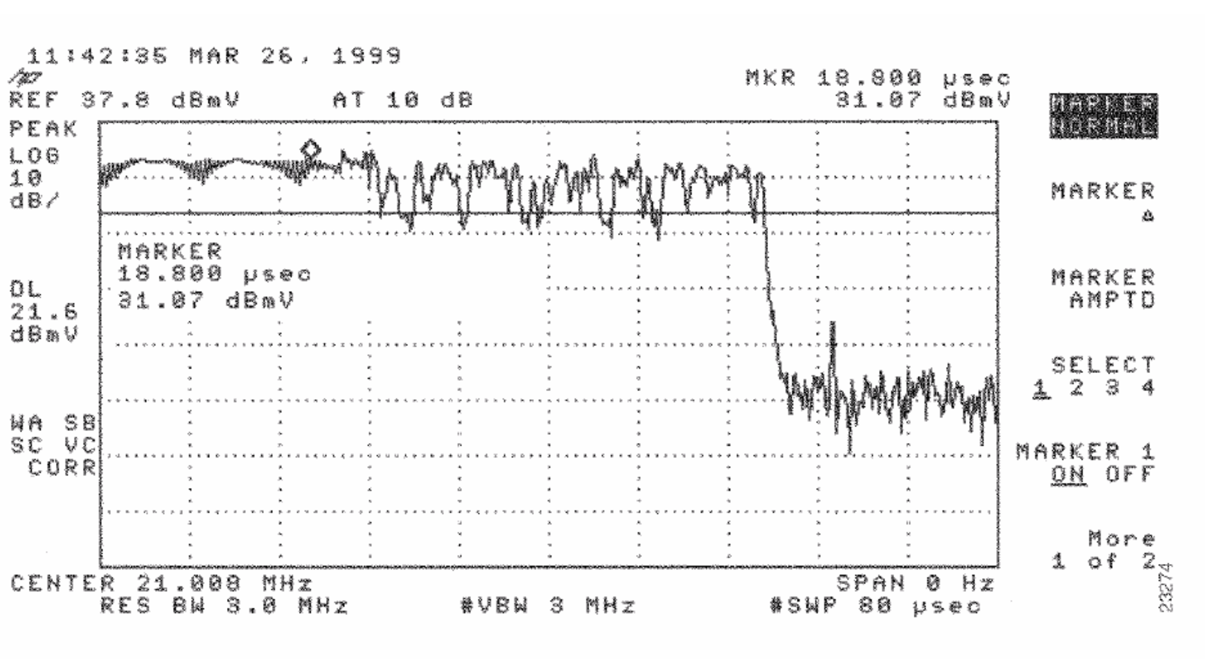
The spectrum analyser, tuned at the centre frequency of the channel, is set to the zero span mode and a display similar to that shown in Figure 2 is obtained.

The channel level is obtained reading the peak (marker) of the displayed envelope of the signal's preamble.

Due to the intermittent mode transmission, the Max Hold function shall be activated, in order to allow the spectrum analyser to catch transient signals such as cable modem return path channel bursts. The spectrum analyser displays the highest level measured and holds it until the trace is cleared. If different cable modems are transmitting on the same frequency with different levels, the highest channel level will be displayed.

4.3.5.2 SCDMA transmission

In the SCDMA transmission mode, data are transmitted using a spreading code. During one burst, spread signals from different codes are summed. The channel level of the composite signal depends on the number of codes used at the same time. A small number of codes results in a low channel power. An accurate measurement of the channel level can be obtained when all possible codes are used during the same burst. The Max Hold function on the spectrum analyser shall be activated in order to measure the channel level with reasonable accuracy, if all possible codes are used during the measured bursts.



IEC 0738/14

Figure 2 – Time domain representation of an upstream burst with marker on the preamble of the DOCSIS signal

4.3.6 Presentation of the results

The measured level shall be expressed in dB(μV) referred to 75 Ω.

4.4 Measurement of amplitude response variation

4.4.1 Background

There are a number of pieces of test equipment commercially available which are specifically designed for this purpose. However, since these may not be generally available, the generic method of measurement, which is described here, uses test equipment that is normally used in service by CATV engineering staff.

Note that the proposed method of measurement cannot be used in networks during normal operation.

4.4.2 Equipment required

The following pieces of equipment are required:

a) all equipment and cables needed for this method of measurement shall have 75 Ω impedance (with matching attenuators if required);
b) a signal generator covering at least 3 MHz to 90 MHz. This should have an output level of at least 114 dB(μV) and shall be capable of sweeping automatically;
c) a spectrum analyzer covering the frequency range of interest. This shall have a peak hold and storage facility and be capable of sweeping at a slow speed (greater than 30 s for a horizontal trace);
d) a calibrated attenuator, which can be changed in 1 dB steps. This shall be suitable for the frequency range of interest and may be built into the spectrum analyzer;
e) a plotter or printer, which can be used to store the spectrum analyzer screen trace. This is optional but desirable.

4.4.3 Connection of the equipment

Equipment shall be connected as shown in Figure 3.

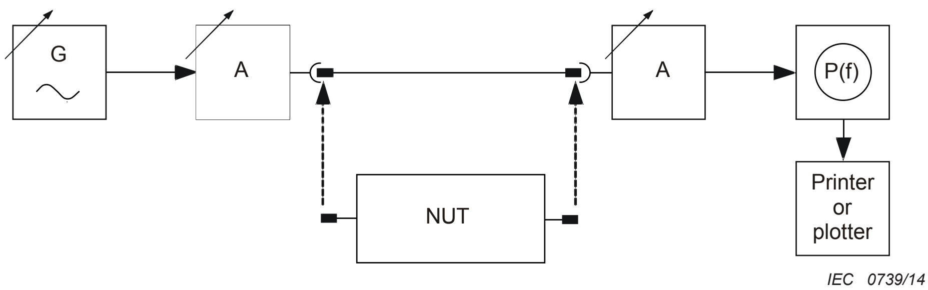


Figure 3 – Arrangement of test equipment for measurement of amplitude response variation

4.4.4 Calibration of equipment

The calibration procedure comprises the following steps.

a) Set the sweep generator to cover the frequency range to be measured and the output to the design reference level.
b) Set the sweep time to 50 ms or less.

c) Connect the sweep output from the generator to the input of the spectrum analyzer. Calibrated variable attenuators may be required if these are not built into the spectrum analyzer.
d) Adjust the analyzer display so that the sweep is on the screen with the vertical resolution set to 1 dB per division. The frequency span should be set to sweep at least 2 MHz above and below the range of interest.
e) Set the resolution bandwidth (RBW) of the spectrum analyzer to 1 MHz and the video bandwidth to 100 kHz. Adjust the analyzer sweep time to 50 s or greater.
f) Set the display to "maximum hold" and single sweep. Clear the screen.
g) Trigger the analyzer and capture the reference sweep on screen. Record the result. Where the spectrum analyzer has a “normalise” function this may be used at this point.
h) Increase the path loss by 1 dB and repeat step g). Repeat to obtain calibration lines from 0 dB to −10 dB.
i) Return the attenuator to the initial setting (0 dB calibration).

4.4.5 Method of measurement

Connect the analyzer and sweep generator to the network points to be measured. Ensure that both the sweep injection level and analyzer input levels are at the correct settings. Repeat the single sweep and plot the result. The amplitude response variation can be read from the final plot.

4.4.6 Presentation of the results

The amplitude response variation is expressed in dB as the maximum to minimum excursion. The injection and measurement points shall be stated together with the frequency limits.

4.5 Measurement of signal to noise ratio ($S_{D,RF}/N$)

4.5.1 General

The $S_{D,RF}/N$ measurement of a digital television channel is described in IEC 60728-1. The same method can be used also on the return path. A noise bandwidth, which is applicable for the channel under test, shall be used.

This standard describes a method of measurement for channels, which have a frequency spectrum with a suppressed carrier (e.g. QPSK or QAM modulated channels). The signal to noise ratio ($S_{D,RF}/N$) of such a channel is the modulated channel power divided by the channel noise power. The channel noise power is the power of the noise, which is present within the whole bandwidth of the modulated channel.

Ingress noise may interfere with $S_{D,RF}/N$ measurements. To minimise the influence of ingress noise $S_{D,RF}/N$ should be measured at frequencies above 15 MHz or at frequencies for which the return service is designed.

4.5.2 Equipment required

The equipment required is a spectrum analyzer having a known noise bandwidth and a calibrated display. The calibration accuracy should be preferably within 0,5 dB.

4.5.3 Connection of the equipment

Connect the measuring equipment to the point where the measurement shall be performed by using a suitable connection lead. Take care to ensure correct impedance matching.

4.5.4 Measurement procedure

The measurement procedure comprises the following steps.

a) Tune the spectrum analyzer to the channel that shall be measured (by selecting the centre frequency of the spectrum analyzer) and select the span and level settings to show the whole channel.

b) Set the resolution bandwidth (*RBW*) of the spectrum analyzer to 30 kHz (or lower than one tenth of the equivalent bandwidth) and the video bandwidth to 1 kHz (or lower to obtain a smooth display). Use an RMS-type detector.

c) Read the level of the signal (*S*) at the centre frequency of the channel in dB(μV) or in dB(mW) using the display line cursor if this feature is available.

d) Switch-off the channel at the input of the system or by terminating the input port with a matched impedance. If necessary, fine-tune the centre frequency of the spectrum analyzer to avoid ingress carriers. Otherwise, use the same settings of the spectrum analyzer as described in b) and read the noise level (*N*) in dB(μV) or in dB(mW). If the signal cannot be switched off during measurements, measure the noise level at a frequency which is close to the channel and includes only Gaussian noise.

e) The spectrum analyzer should have a noise level which is more than 10 dB lower than the measured noise level (*N*). Check it by terminating the input of the spectrum analyzer. If the difference between *N* and spectrum analyzer noise is 3 dB to 10 dB, correct the value of *N* as advised in Annex B.

f) Calculate the signal to noise ratio $S_{D,RF}/N$ by using the following formula:

$$S_{D,RF}/N = S - N$$

where

$S_{D,RF}/N$ is the signal-to-noise ratio in dB;

S is the signal level in dB(μV) or in dB(mW);

N is the noise level in dB(μV) or in dB(mW).

4.5.5 Presentation of the results

The measured signal to noise ratio $S_{D,RF}/N$ shall be expressed in decibels.

4.6 Measurement of multiple interference

4.6.1 General

The multiple-interference consists of ingress noise and intermodulation distortion products. It is measured with a spectrum analyzer. For 24 h, the interference spectrum is stored in a data memory every 10 s.

As forward path signals may cause distortion products in the return band, the measurement shall be made in a network, which has all the forward channels in operation and no signals on the return path. Alternatively (to verify that the distortion caused by the return path signals is insignificant), measure with all the forward and return channels, except the channel to be measured, in operation.

As field strength at the return band frequencies depends on many variables (e.g. weekday-weekend, summer-winter, sunspot cycles, etc.), one 24 h test may not give reliable results. It is recommended to repeat the measurement in different conditions.

In order to be able to compare multiple interference with impulse noise, both should be measured simultaneously.

CLC/TR 50083-10-1:2009, Annex A1 gives a brief overview of multiple interference causes, explains with more details the measurement procedure indicated below and gives ideas on how to extract information from the collected data. For example, the computation of the following graphs is described:

- spectrograms;
- average, minimum and maximum levels in the spectrum analyzer resolution bandwidth versus frequency;
- percentile analysis;
- temporal occurrence and frequency occurrence of threshold crossing.

4.6.2 Equipment required

A spectrum analyzer with a suitable data interface is used. The measurement set-up shall be stand-alone so that the measurement results are automatically stored during the measurement day.

4.6.3 Connection of the equipment

Connect the measuring equipment to the point where the measurement shall be performed by using a suitable connection lead. Take care to ensure correct impedance matching.

To verify the quality of the return path, connect the measurement equipment to the reference point at the headend or node side.

4.6.4 Measurement procedure

Every hour of the day, measure the frequency spectrum using the following settings:

- resolution bandwidth: 3 kHz;
- video bandwidth: 100 Hz;
- start and stop frequency: as required;
- detector type: peak.

Every 10 s of the day, measure the frequency spectrum using the following settings:

- resolution bandwidth: 30 kHz;
- video bandwidth: 10 kHz;
- start and stop frequency: as required;
- detector type: peak.

4.6.5 Processing of the data

To interpret the data, the spectral power density shall first be integrated over the selected modulation channels (e.g. 1,544 MHz according to ETSI ES 200 800 grade C). The power level in the channel is converted to a voltage level over 75 Ω.

Determine the signal level of each channel and calculate the percentage of samples, which fulfil the carrier-to-multiple interference ratio (*C/MI*) requirement for each channel.

4.6.6 Presentation of the results

The carrier-to-multiple interference ratio shall be determined for each channel separately. Good approximation of channel availability is expressed in percent of the time, during which the *C/MI* ratio (in dB) of the channel fulfils the relevant performance requirement.

In order to repeat measurements later and to be able to compare results, the following parameters should be stated together with the results:

- *C/MI* requirement used;
- channel centre frequency;

- channel bandwidth (integration BW);
- signal level;
- measurement site;
- network set-up;
- measurement date and start and stop time;
- duration of measurement;
- other parameters which are expected to affect the result (e.g. temperature).

4.7 Measurement of impulse noise

4.7.1 General

Impulse noise shall be measured with a digitising oscilloscope. For 24 h, samples of the impulse noise are collected and stored in a data memory. By using the collected samples, it is possible to calculate pulse amplitude, pulse width and interarrival distributions. These data are used to evaluate the influence of impulse noise to different services.

The impulse noise measurement shall be made when the return path is not in use.

Impulse noise is of wide bandwidth. A high-pass filter (f_{-3dB} = 15 MHz, –12 dB/octave, high-pass) can be used at the measurement set-up input to simulate the input filter of a return path signal receiver.

As impulse noise depends on many variables (e.g. weekday/weekend, summer/winter, etc.) one 24-h test may not give reliable results. It is recommended to repeat the measurement in different conditions.

In order to be able to compare impulse noise with multiple interference, both should be measured simultaneously.

4.7.2 Equipment required

A digitising oscilloscope of negligible distortion up to 50 MHz and equipped with a suitable data interface and input filter (as described in 4.6.1) is used. The measurement set-up shall be stand-alone so that the measurement results are automatically stored during the measurement day.

4.7.3 Connection of the equipment

Connect the measuring equipment to the point where the measurement shall be performed by using a suitable connection lead. Take care to ensure correct impedance matching.

To verify the quality of the return path, connect the measurement equipment to the reference point at the headend or node side.

4.7.4 Measurement procedure

The oscilloscope is triggered when the input signal reaches a threshold value. The threshold value shall be higher than the noise level of the oscilloscope and higher than the ingress noise level. A suitable threshold value triggers the oscilloscope every 2 s to 10 s. All impulse noise traces and starting times are stored in a data memory.

Trace length shall be 100 μs. Sample time shall be 10 ns (corresponding to an upper frequency limit of 50 MHz).

4.7.5 Processing of the data and presentation of the results

By using stored impulse noise data, it is possible to analyse what is the probability, that impulse noise causes an uncorrected error in transmission.

In order to repeat measurements later and to be able to compare results, the following parameters should be stated together with the results:

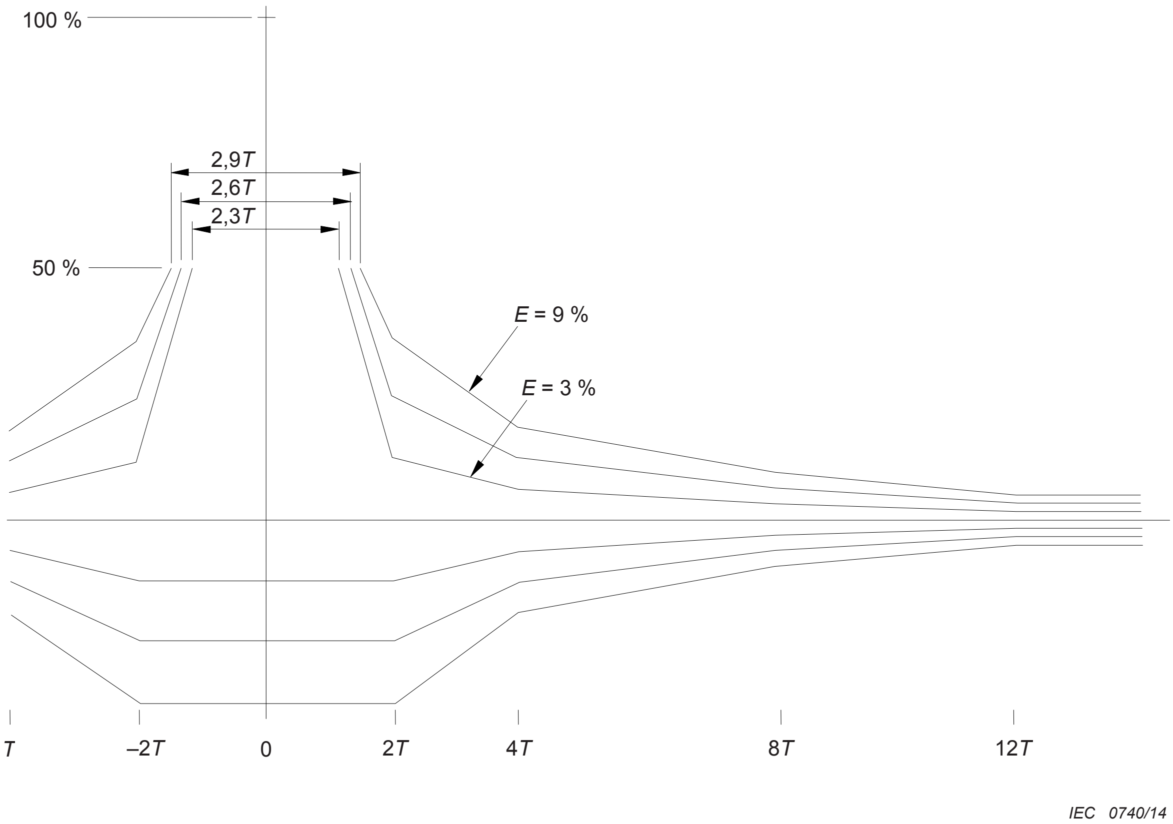
- algorithm which was used for calculating the error probability;
- any filter (if used at the measurement set-up input);
- signal level;
- measurement site;
- network set-up;
- measurement date and start and stop time;
- duration of measurement;
- other parameters which are expected to affect the result (e.g. temperature).

4.8 Measurement of echo ratio

4.8.1 General

The method described is applicable to the measurement of the amplitude and time displacement of an echo at a specified point within a cable network by the use of a 2T-sine-squared pulse with the graticule as shown in Figure 4. From these measurements, an "echo-rating" is derived.

NOTE This method of measurement is mainly applicable to cable networks where analogue signal transmission is used also in the return path.



±*T*	Maximum amplitude for a given *E* rating (%)		
	3	6	9
0	+100, –12	+100, –24	+100, –36
2	±12	±24	±36
4	±6	±12	±18
8	±3	±6	±9
12	±1,5	±3	±4,5

Figure 4 − Echo rating graticule

4.8.2 Equipment required

The test set-up shall be well-matched and shall consist of

a) a test waveform generator providing a sine-squared pulse of half amplitude duration equal to 2*T*, where *T* = 100 ns is the length of time; the test signals are in accordance with ITU-R BT.470,

b) a modulator having RF characteristics (excluding sound) appropriate to the television system under consideration (see ITU-R Recommendation BT.470) and input characteristics to suit the generator in item a),

c) a synchronous demodulator having characteristics appropriate to the television system is under consideration,

d) two attenuators variable in 1 dB steps,

e) an oscilloscope of negligible distortion up to 5 MHz, fitted with a graticule as shown in Figure 4.

4.8.3 Connection of the equipment

The equipment shall be connected as in Figure 5. The test waveform generator and modulator are connected to the reference point at the HNI (Figure 1) close to a subscriber. The demodulator and oscilloscope are connected to the headend side reference point at the input to the CMTS (Figure 1). The measuring equipment shall be connected taking care to maintain correct impedance matching.

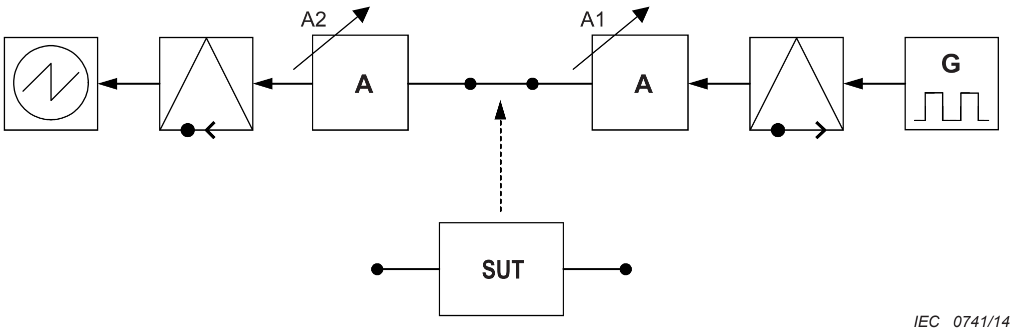


Figure 5 – Arrangement of test equipment for measurement of echo ratio

4.8.4 Measurement procedure

The measurement procedure comprises the steps as listed below.

a) Connect the test equipment to the system as shown in Figure 5.

b) Adjust the oscilloscope time-base speed to correspond with the T-scale on the graticule. Adjust the vertical gain and position controls to "fit" the pulse between the zero line and the pulse peak reference point. Examine the performance of the test equipment (control loop), which shall be such that an E-rating of not greater than 3 % is achieved.

c) Adjust the variable attenuator A1 to provide an input signal to the system at a level equal to that at which it normally operates. Adjust the attenuator A2 to provide an input signal to the demodulator equal to that used in step b) of this subclause.

d) Using the graticule as a reference, as before, determine the E-rating for each echo and note that of the echo with the highest rating.

e) Using the horizontal shift control of the oscilloscope slowly move the display to the left and examine any long-distance echoes. These should be rated using the parallel section of the graticule at the extreme right. Note the highest rating.

f) The E-rating for the system is the higher of the two figures noted in steps d) and e) of this subclause.

NOTE This result will not be that of the system alone. It is modified by the inherent distortion in the test equipment, usually due to group delay errors.

4.8.5 Presentation of the results

The result of the measurement of the echo shall be presented as echo ratio, expressed in percent. The value in percent is the amplitude of the strongest echo (positive or negative) compared to the peak amplitude of the 2T-pulse.

4.9 Measurement of group delay variation

It is technically difficult to measure the group delay variation in a network. As the group delay variation is caused by the return path band pass filters and other network components, a practical way to analyse a network is to analyse these components. Measuring the group delay variation of an individual component is described in IEC 60728-5. The combined effect of the components is the sum of the group delay variation in each component.

NOTE 1 Defect components can cause additional group delay variation in a network. Such defective components can be found by using an amplitude response measurement.

NOTE 2 If a measurement of group delay variation in a network is needed, a signal with known phase behaviour is sent over the network. A pulse train (pulse width of 15 ns for measurement up to 60 MHz) is a suitable test signal. The pulse is received with an oscilloscope and stored in a computer memory. To determine the relative group delay variation an FFT (Fast Fourier Transform) of both transmitted and received pulses is calculated.

4.10 Measurement of frequency error

4.10.1 General

If the frequency of the received signal is outside the capturing range of the receiver, the demodulator cannot lock to the signal. This measuring method is able to provide an indication of frequency error of an oscillator used in an equipment of the cable network (i.e. in a frequency converter).

4.10.2 Equipment required

The following equipment is required:

a) QPSK transmitter;

b) test receiver.

4.10.3 Connection of the equipment

The measuring set-up for the frequency stability measurement is shown in Figure 6.

The measuring equipment shall be connected taking care to ensure correct impedance matching.

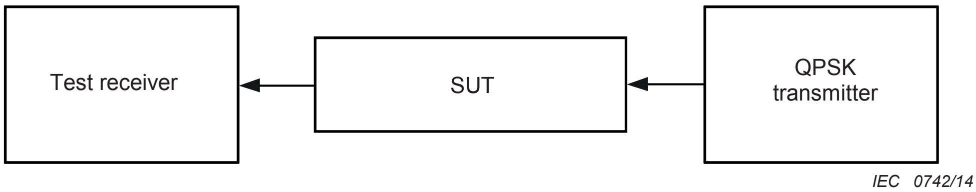


Figure 6 – Test set-up for frequency stability measurement

4.10.4 Measurement procedure

The measurement procedure comprises the following steps:

a) modulate the QPSK transmitter with the PRBS signal;

b) set the carrier frequency of the QPSK transmitter to the channel where the measurement shall be performed;

c) adjust the carrier level of the QPSK transmitter to obtain the same level at the system output as in normal operation;

d) tune the test receiver to the channel that shall be measured. After locking to the carrier frequency, the test receiver shows the regenerated carrier frequency;

e) the frequency error is the difference between the original carrier frequency of the modulator and the regenerated carrier frequency of the demodulator.

Remarks

1) If a frequency conversion causes frequency offset between the nominal input frequency and the nominal output frequency, the nominal value of the frequency offset has to be subtracted from the measured frequency difference.

2) To minimise errors in the frequency measurement, the measurement of the frequency error can be done by measuring the difference between the regenerated frequencies at the system input and output.
3) The above measuring method of frequency error can also by used for QAM modulated signals, replacing the QPSK transmitter with a QAM transmitter and using a test receiver able to demodulate QAM signals.

4.10.5 Presentation of the result

The measured frequency error is expressed in kilohertz (kHz) referred to the nominal carrier frequency.

4.11 Measurement of bit error ratio (BER)

4.11.1 General

BER is the primary parameter, which describes the quality of the digital transmission link. BER is defined as the ratio between the number of erroneous bits and the total number of transmitted bits during a determined elapsed time.

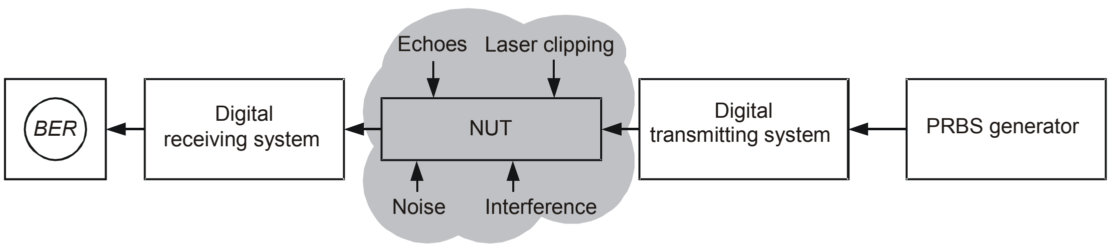


Figure 7 – Principle of BER measurement

This measuring method applies to the measurement of BER of digitally modulated signals using QPSK or QAM format. The measuring equipment consists of a generator which produces a pseudo random binary sequence (PRBS) (see Annex C). This PRBS is fed to the digital transmitting system as a data stream as shown in Figure 7. The interference, echoes and noise on the transmission link influence the signal demodulated and decoded by a digital receiver.

The pseudo random binary sequence should be as long as possible in order to provide a largely continuous spectrum for all data rates used. In digital transmission systems, sequences having the lengths $2^{15}-1$ or $2^{23}-1$ are generally used. The BER counter shall be able to synchronise itself to the PRBS used.

No error correction shall be used for this measurement.

Because any forward path or return path signal may interfere with the channel under test, all channels of the system shall be in normal use, except the channel under test.

As interference depends on many variables (e.g. weekday/weekend, summer/winter, etc.), also BER depends on those variables and one 24-h test may not give reliable results. It is recommended to repeat the measurement in different conditions.

NOTE This method of measurement is also applicable to other types of modulation if suitable types of modulators and demodulators are used.

4.11.2 Equipment required

The following equipment is required:

a) PRBS generator (see Annex C);
b) QPSK/QAM modulator with a serial input interface for the PRBS data stream;
c) RF signal up-converter;
d) RF signal tuner;
e) QPSK/QAM demodulator with a specified equaliser and a serial output interface for the PRBS data stream;
f) BER counter connected to the serial output interface of the demodulator.

4.11.3 Connection of the equipment

The measuring set-up for BER measurement is shown in Figure 7. The digital transmitting system consists of the QPSK-/QAM-modulator and the subsequent RF signal up-converter. The digital receiving system is composed of the RF signal tuner and the QPSK-/QAM-demodulator.

The measuring equipment shall be connected taking care to ensure correct impedance matching.

4.11.4 Measurement procedure

The measurement procedure comprises the following steps:

a) apply the PBRS generator at the serial input interface of the modulator to obtain the QPSK or QAM modulation format;
b) set the carrier frequency of the RF signal up-converter to the channel where the measurement shall be performed;
c) adjust the carrier level of the RF signal up-converter to obtain the same signal level as in normal operation;
d) tune the RF signal tuner in the digital receiving system to the channel at which the measurement shall be performed;
e) switch on the modulation and measure the BER counting the error bits for a sufficiently long time (to count at least 100 error bits) and divide the number of erroneous bits by the total number of the transmitted bits. The result is the BER;
f) due to ingress noise, the BER measurement is repeated every 15 min for 24 h.

4.11.5 Presentation of the results

The maximum measured BER is indicated. The types of the transmitter, receiver, demodulator and adaptive equaliser shall be stated with the result.

4.12 Noise power ratio (*NPR*) measurement on return path

4.12.1 General

The noise power ratio (*NPR*) testing is a valuable tool for the characterization of the non-linearity behaviour of the HFC return path components and sub-systems. The *NPR* is a measure for the amount of noise and intermodulation distortion in the return path of optical links between fibres nodes and headend/hubsite equipment. A test signal comprised of a flat Gaussian noise band limited to the frequency range of interest and with a narrow band (channel) of the noise deleted by a notch filter, is injected into the system under test (SUT). The *NPR* is measured at the output of the SUT as the test signal is swept across a power range.

This test is able to define the total amount of RF power that can be transferred in a linear fashion whilst maintaining sufficient noise performance margins.

NOTE This measuring method is similar to that described in IEC 60728-3 for equipment, where the composite intermodulation noise ratio (CINR) is considered instead of *NPR*.

4.12.2 Equipment required

The equipment required is:

a) a white Gaussian noise signal generator covering the return path frequency band;
b) a filter to shape the noise as shown in Figure 8 for frequencies as given in Table 2.

Table 2 – Band-stop filter notch frequencies

Frequency range f_{low} to f_{high}	Notch frequencies f			
MHz	MHz	MHz	MHz	MHz
5 to 30	12	17,5	22	–
5 to 50	22	27,5	35	–
5 to 65	27,5	35	48	–
5 to 85	27,5	35	48	66

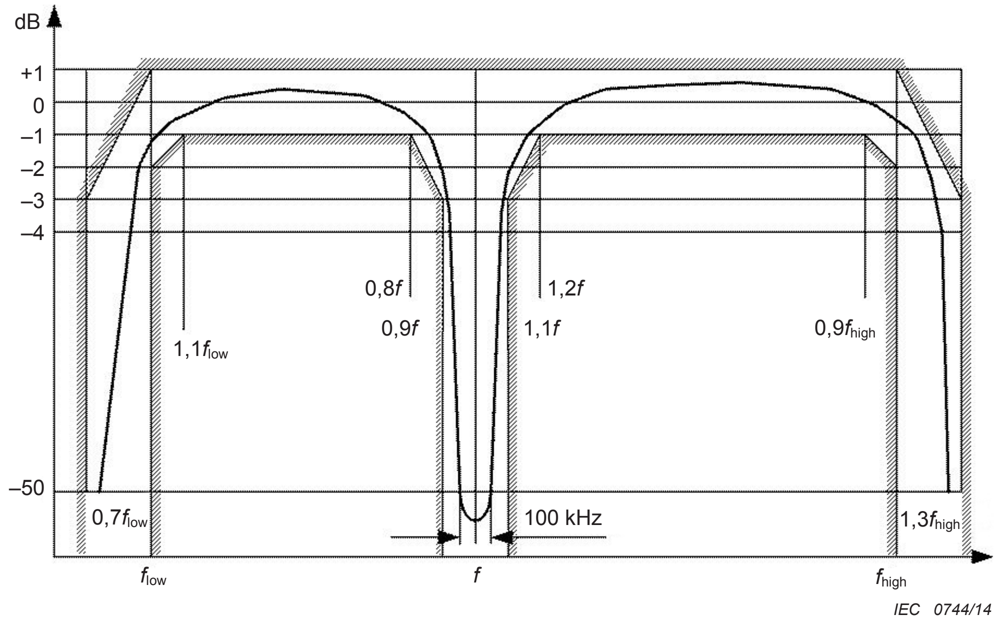


Figure 8 – Band-pass and band-stop filters response

One section of the filter (band-pass section) shall limit the noise bandwidth to the bandwidth of the return path. The second section of the filter (band-stop section) shall add a notch to the noise spectrum. The notch frequency shall be in the middle of the spectrum;

c) a variable 75 Ω attenuator, adjustable in 1 dB steps;
d) a band-pass filter (optional) to avoid overloading of the spectrum analyser;
e) a spectrum analyser having a calibrated display of the signals in the return path bandwidth.

4.12.3 Connection of the equipment

Connect the measuring equipment as indicated in Figure 9. The input signal is applied to the return path input reference point (fibre node) of the system under test (SUT) and the output signal is measured at the output reference point (headend/hubsite), using suitable cable and connectors, taking care to ensure correct impedance matching.

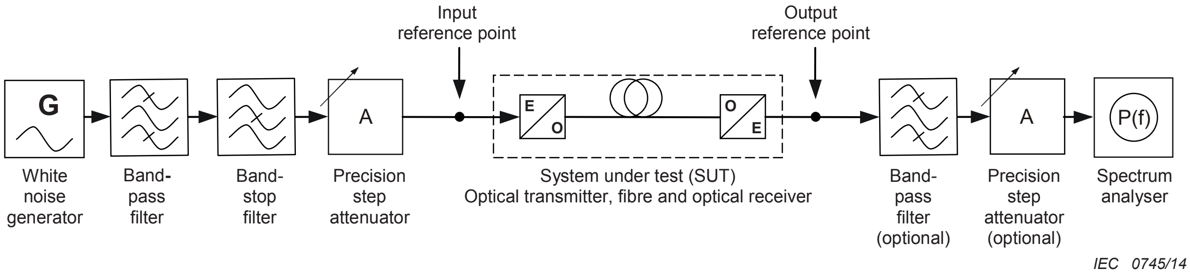


Figure 9 – *NPR* test set up

4.12.4 Measurement procedure

The Noise Power Ratio is defined as:

$$NPR = P - N$$

where

NPR is the Noise Power Ratio in dB;

P is the noise level in dB(mW) or in dB(mW/Hz) at the top of the displayed response;

N is the noise level in dB(mW) or in dB(mW/Hz) at the notch frequency.

The measurement procedure comprises the following steps:

a) Increase the drive level of the signal applied to the SUT in 1 dB steps.

b) Observe on the spectrum analyser the system noise floor and measure the difference relative to the top of the noise signal (difference between the top level and the noise level in the notch) and calculate the *NPR*.

c) Plot a graph of the *NPR* referred to the input signal level of the SUT.

When the RF power level of the noise input signal applied to the SUT approaches the upper limit of its transfer window, non-linear distortions appear and *CIN* (composite intermodulation noise) becomes the dominant component in the noise floor of the system, rising sharply in level.

An example of the plot of *NPR* versus input power of optical transmitter is shown in Figure 10 where the *NPR* of the return path link increases with increasing the RF power density applied to the optical transmitter (linear behaviour) up to a maximum point where a rapid decreasing is obtained (non-linear behaviour).

This point is the maximum optical modulation depth to be applied to the optical transmitter and is commonly referred to as 100 % *OMI* (Optical Modulation Index). When the RF power exceeds 100 % *OMI*, laser clipping can occur, which will result in actual signal loss.

The two slopes can define a point to be marked as the RF power density (P_i) at the input of the optical transmitter that corresponds to the *OMI* of 100 %.

If the effective total power (P_T) applied to the optical transmitter is to be calculated, the following formula is used:

$$P_T = P_i + 10 \lg (BW)$$

where

P_T is the total power (dB(mW)) applied to the optical transmitter;

P_i is the power density (dB(mW/Hz)) applied to the optical transmitter;

BW is the return path bandwidth in Hz.

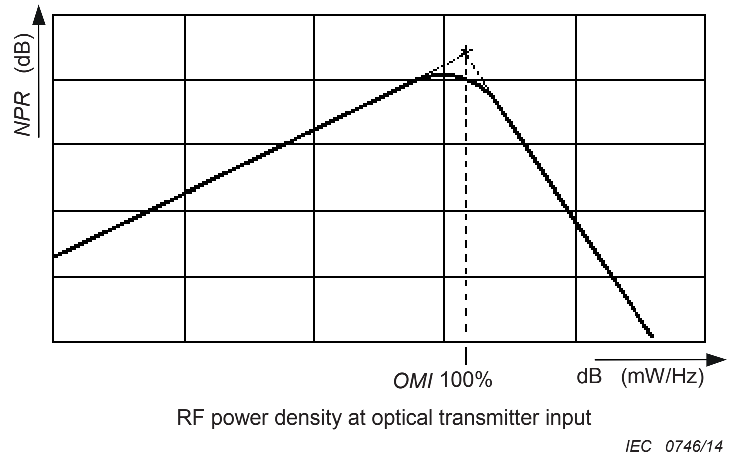


Figure 10 – *NPR* versus RF power density applied at input of optical transmitter and determination of *OMI* 100 %

To avoid overloading of the spectrum analyser, a band-pass filter can be inserted before it. An example of the frequency response of such a filter is indicated in Figure 11.

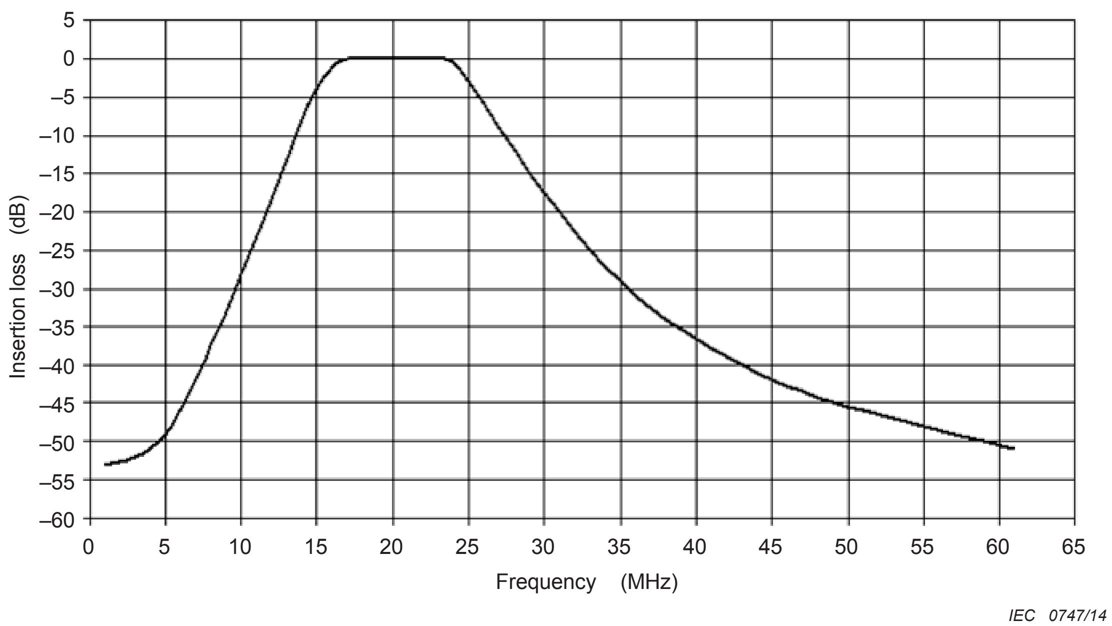


Figure 11 – Example of the frequency response of the optional band-pass filter

4.12.5 Presentation of the results

The measured noise power ratio (*NPR*) shall be expressed in decibel and plotted versus the applied noise input power to the optical transmitter. The intersection of the two slopes defines the input power to the optical transmitter that is taken as the 100 % OMI (optical modulation index).

4.12.6 Recommended correction factors

4.12.6.1 Correction factors for noise during signal and noise level measurements

The correction factors for noise during signal and noise level measurements are indicated in Annex A.

4.12.6.2 Correction factor for a spectrum analyser

The correction factor for a typical spectrum analyser is indicated in Annex B.

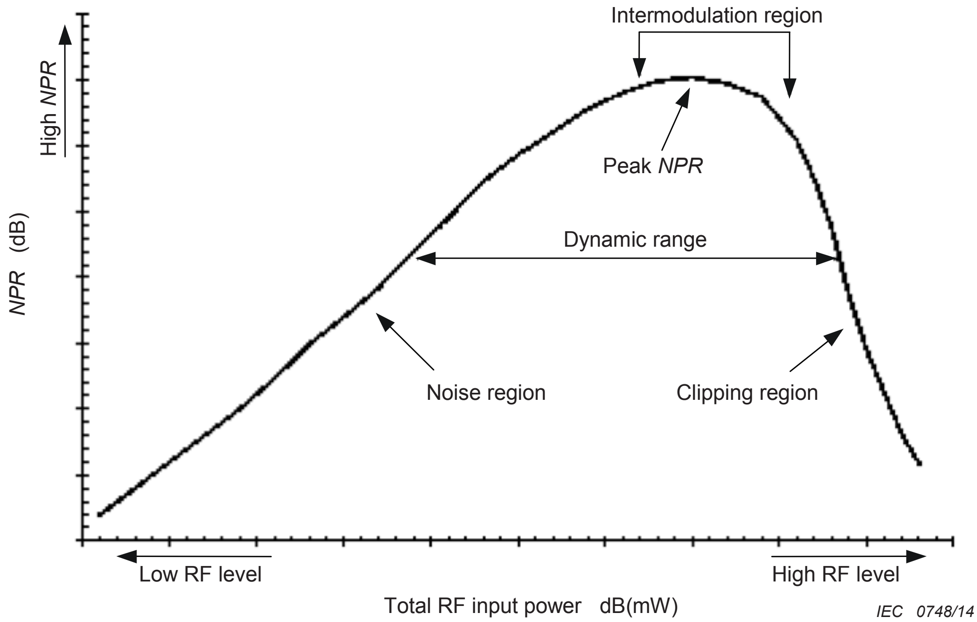
4.12.7 Precautions during measurement

Some precautions shall also be taken into account when using a spectrum analyser for noise signal measurement.

- Concerning the displaying detection mode of the spectrum, there are generally three detection modes: the 'peak detection', the 'negative peak detection' and the 'sample detection'. For noise measurement, the *'sample detection'* mode shall be used because it is the only mode that accurately indicates the random nature of noise.
- Also, given the random nature of noise, the displayed trace is changing at each sweep. A good average is thus necessary to reduce the amplitude variation of noise and to obtain the average noise level (the correction factor (see Annex B) of +2,5 dB is valuable only if a good averaging is realised by the spectrum). This average can be realised reducing the VBW filter or using the '*average*' function of the spectrum.
- Because the *NPR* is a measurement of distortions, the spectrum input mixer shall work without adding new distortions. So, an upper power limit at the input mixer shall be set in order to protect against distortions coming from the mixer. This maximum power level at the mixer input is about –10 dB(mW). To be sure those measurements are free of distortions coming from a mixer, a modification of the input attenuation value of the spectrum shall not induce a modification of the displayed noise level.
- The noise source shall conform to the following specifications. Its bandwidth shall cover the bandwidth of the system under test (5 MHz to 65 MHz for return path devices). Its flatness shall be lower than ±1 dB and its tilt has to be lower than 1 dB on the entire bandwidth. Concerning the noise source level, 0 dB(mW) is needed as total power. Thus, a density noise level of at least –80 dB(mW/Hz) is required. Finally, the probability density function of the noise source shall be absolutely Gaussian. So, if the noise source is realised by cascading several amplifiers, saturation of signal is not permitted in the cascade because it will lead to clipping and will thus reduce the peak-to-average ratio of the noise signal.
- The notch shall conform to the following specifications. Its band-pass bandwidth shall be greater than the noise source bandwidth to avoid any filtering. Its band-pass ripple shall be relatively low to keep a noise signal flatness lower than ±1 dB at the output of this notch filter. Moreover, the maximum *NPR* value is given by the maximum depth of the notch. Therefore, the minimum notch rejection shall be greater than the minimum *NPR* value to be measured.
- If an amplifier is required to obtain sufficient signal level, the amplifier should be placed between the band-pass and the notch filters. No amplifier should be used after the notch filter because its distortion will reduce the depth of the notch. The amplifier should have sufficient capability to produce the required level without compression.

4.12.8 *NPR* dynamic range

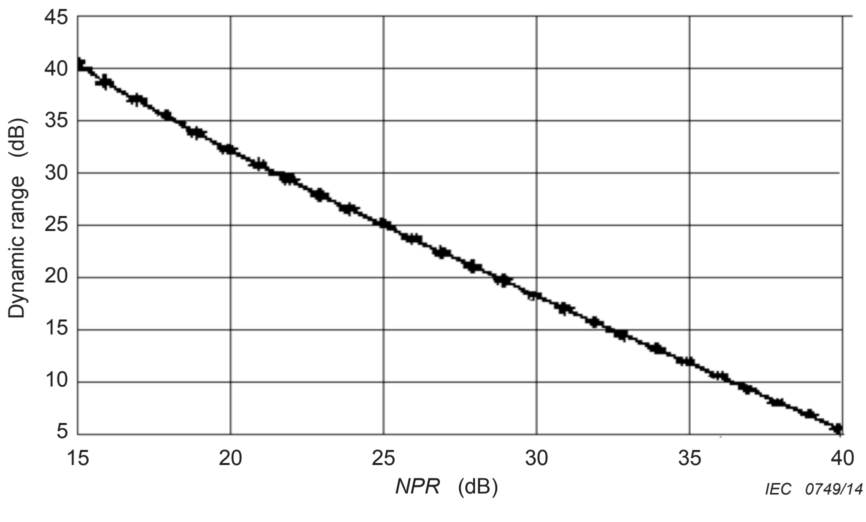
Representing the *NPR* values versus the total input power allows the determination of the power range where the *NPR* value is above a limit and where the performances are free of perturbations coming from both the intrinsic noise and distortion noise. In the dynamic range (or working range), the power is high enough with respect to the intrinsic noise of the equipment and the power is low enough to not produce important distortions (Figure 12).



The values both of the dynamic range and the *NPR* are in decibel.

Figure 12 – Example of *NPR* dynamic range

It is also possible to plot the dynamic range versus the *NPR* value (see Figure 13). This plot provides an indication of the margin of the used power level, given a *NPR* value.



The values both of the dynamic range and the *NPR* are in decibel.

Figure 13 – Dynamic range plotted versus *NPR*

4.13 10-Tone measurement

4.13.1 General

Instead of using a noise source and a set of filters to create the desired input signal (band-pass filtered noise with the notch), it is also possible to use an arbitrary waveform generator to synthesize a large number of CW-tones with equal amplitude and random phases. This signal will have approximately the same properties as the filtered noise with the advantage that the notch and the signal type can easily be controlled.

An approximation of this method is the use of a group of tones as input signal. Indeed the probability density function of a group of tones tends statistically to a Gaussian distribution when the number of tones increases in accordance with the statistical central limit theorem. This is already true with (5 to 10) tones. This statistical equivalence between noise signal and group of tones can be demonstrated also in terms of peak-to-average ratio. Thus, groups of tones can simulate statistically the load of the return path.

However, the spectral distribution of groups of tones is essentially different from noise. Thus, the spectral distribution of distortions coming from groups of tones and noise source are also different. Therefore, to obtain the same *NPR* curves in both cases, the distortion measurements realised from a group of tones input signal shall be interpreted and represented respecting some conditions.

4.13.2 Measurement principle

Two groups of (5 to 10) tones distant of some megahertz simulate the noise source and the notch. The intrinsic noise and the distortion can then be measured in the space created (Figure 14).

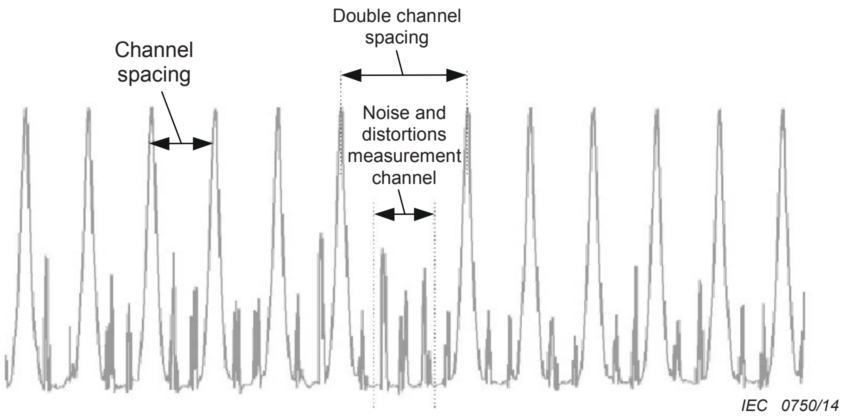


Figure 14 – Alternative *NPR* measurement principle

The classical *NPR* measurement realised with the noise source corresponds to the difference between the noise signal density level and the distortion noise density level present in the notch. But if both noise signal density level and distortion noise density are integrated into a QPSK/QAM channel bandwidth, the *NPR* value is unchanged. So, we can say that the *NPR* value represents the difference between the total power of a QPSK/QAM channel and the total power of both noise and distortion present in a free of load QPSK/QAM channel.

To compare classical *NPR* results and distortion measurements realised with groups of tones, the difference between the power of one channel carrier and the 'noise-plus-distortion' total power level present in a free load carrier channel spacing shall be represented.

4.13.3 Measurement procedure

Based on the principle described, the device under test is loaded with 2 groups of 6 tones equally spaced. The 'notch' is then realised by an empty channel position, resulting in double channel spacing in the middle of the spectrum. Measurements of total noise plus distortions are then realised in a channel bandwidth around the empty carrier (Figure 14) using the 'channel power' function of the spectrum analyser. So, all contributions of both noise and distortions are included in the measurement.

However, some corrections and precautions must be taken into account when noise is measured as a 'channel power' function. 'Channel power' function allows the measurement of the power within a frequency range. In the case of a classical spectrum analyser, the 'channel power' calculation realised by the spectrum analyser is:

$$P_{Ch} = 10 \cdot \lg\left(\frac{B_S}{B_N} \cdot \frac{1}{n} \sum_{i=1}^{n} 10^{\left(P_i/10\right)}\right) \qquad \text{dB(mW)}$$

where

P_{Ch} is the channel power;

B_S is the channel bandwidth;

B_N is the equivalent noise bandwidth of the RBW (see Annex B);

n is the number of data points in the summation;

P_i is the sample of the power in measurement cells *i* in dB(mW).

NOTE When the channel power function is activated, the sample mode detection is automatically used.

However, as shown in the previous method, to obtain the average noise density level, an averaging is necessary to measure the power in the channel bandwidth because both noise level and distortions vary with time. Nonetheless, the average cannot be realised with the spectrum analyzer. Indeed, spectrum averaging introduces an error which is known in the case of Gaussian noise (see Annex B) but not in the case of the alternative setup. So, the averaging is performed manually. To achieve this, several channel power measurements without averaging are realised, and the computation of the average channel power is carried out in the linear domain. Concerning low level of noise, the correction factor of Annex A shall also be applied.

Figure 15 gives the results of both classical *NPR* and the alternative method applied on an optical link. Both measurements were realised under the same condition of load. This confirms the validity of the proposed alternative method.

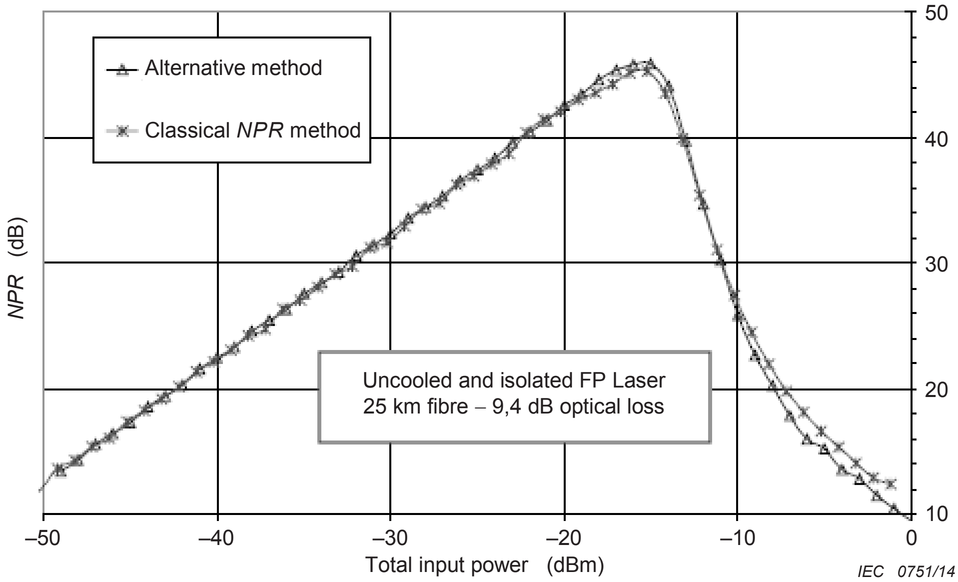


Figure 15 – Relationship between classical *NPR* method and multi-tone method

4.14 Modulation error ratio (*MER*) measurement on return path

4.14.1 General

This measuring method is able to provide a single "figure-of-merit" analysis of the received signal. This figure is computed to include the total signal degradation likely to be present at the input of a receiver's decision circuits and so give an indication of the ability of that receiver to correctly decode the signal.

This measurement is applied to return path links between cable modem (CM) and headend/hubsite equipment (CMTS).

The measurement is performed at the headend/hubsite return path receiver while the modulated signal with the appropriate format is applied at the system outlet (cable modem).

NOTE This measuring method shall be performed under out-of-service conditions.

4.14.2 Equipment required

The equipment required is listed below and shown in Figure 16:

a) *I/Q* baseband signal source for QPSK or QAM modulation format;

b) RF modulator for QPSK, or QAM modulation format;

c) reference receiver;

d) constellation analyser.

4.14.3 Connection of the equipment

The measuring set-up for the modulation error ratio (*MER*) measurement is shown in Figure 16.

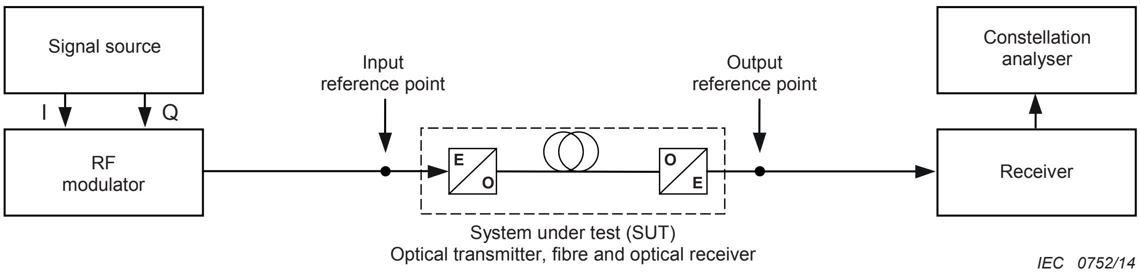


Figure 16 – Test set-up for modulation error ratio (*MER*) measurement

The measuring equipment shall be connected taking care to maintain correct impedance matching.

4.14.4 Measurement procedure

The measurement procedure comprises the steps as listed below.

a) Set the signal source (base band) to generate a sequence defined as the null transport stream packet in ISO/IEC 13818-1 with all bytes set to 0x00 (see Annex C). A sequence of four bytes followed by a PRBS can also be used.

NOTE The null transport stream packet is defined as the four-byte sequence 0x47, 0x1F, 0xFF, 0x10, followed by 184 zero bytes (0x00). This sequence can be available as an encoding system option.

b) Apply the signal source I and Q channels at the input of the modulator to obtain the desired QPSK or QAM modulation format.

c) Set the carrier frequency of the RF modulator to that of the channel where the measurement shall be performed.

d) Adjust the output carrier level of the RF modulator to obtain the same level at the headend receiver input as in normal operating conditions.

e) Tune the receiver to the channel where the measurement shall be performed. The measurement of the modulation error ratio (*MER*) does not assume the use of an equalizer. However, the measuring receiver may include a commercial quality equalizer to give more accurate results when the signal at the measurement point has linear impairments.

f) Connect the constellation analyser to the appropriate interface of the receiver. If the constellation analyser has its own tuner, the use of the receiver can be avoided.

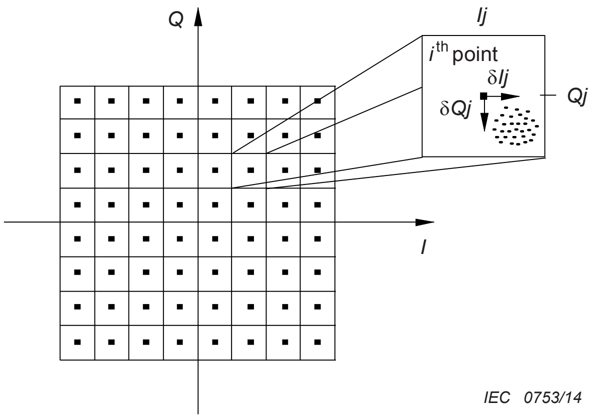
g) The carrier frequency and symbol timing are recovered, which removes frequency error and phase rotation. Origin offset (for example, caused by a residual carrier or DC offset), quadrature error and amplitude imbalance are not corrected.

h) A time record of *N* received symbol coordinate pairs (*Ij*, *Qj*) is captured by the constellation analyser. N shall be significantly larger than the *M* symbol points.

i) For each received symbol a decision is made as to which symbol was transmitted. The error vector is defined as the distance from the ideal position of the chosen symbol (the centre of the decision box) to the actual position of the received symbol.

j) The distance can be expressed as a vector (δ*Ij*, δ*Qj*).

An example of representation of the constellation diagram for a 64 QAM modulation format and the distance (δ*Ij,* δ*Qj*) for each of the *N* received symbols in the i^{th} point from the ideal position (*Ij, Qj*) is shown in Figure 17.



NOTE The i^{th} point has been enlarged to show the coordinates of the symbol error vector.

Figure 17 – Example of constellation diagram for a 64QAM modulation format

The sum of the squares of the magnitudes of the ideal symbol vectors is divided by the sum of the squares of the magnitude of the symbol error vectors. The result, expressed as a power ratio in decibel (dB), is defined as the modulation error ratio *MER*.

$$MER = 10 \cdot \lg \left\{ \frac{\sum_{j=1}^{N} \left(I_j^2 + Q_j^2 \right)}{\sum_{j=1}^{N} \left(\delta I_j^2 + \delta Q_j^2 \right)} \right\} \quad \text{in dB}$$

Before starting the measurement, check the modulator performance, connecting the receiver with the constellation analyser at the output of the signal generator modulated by the digital source. The displayed constellation diagram should be noted and assumed as the reference position for the measurement.

4.14.5 Presentation of the results

The measured modulation error ratio (*MER*) shall be expressed in dB. The interface of the receiver where the measurement has been performed shall be stated with the results.

5 System performance requirements

5.1 General

The requirements for the return path, laid down in this standard are based on the existing parts of the IEC 60728 series and its reference documents. In the return path, high levels of ingress and impulse noise call for a sufficiently high signal power. The highest admissible power level is limited by the maximum allowed radiation power of the network. IEC 60728-2 and IEC 60728-12 define the minimum requirements for EMC for the network equipment and for the cable network itself.

In a two-way system, the following four internal disturbing situations shall be taken into account:

a) unwanted effects from return path communication to TV, radio and other forward path signals (Figure 18);
b) effects of forward path signals (e.g. intermodulation products) disturbing return path signals (Figure 19);
c) effects of returm path signals of service 1 (e.g. spurious signals) disturbing the return path signals of a different service 2 (Figure 20);
d) effects between return path signals (e.g. intermodulation products) pertaining to the same service (Figure 21).

For the first three cases, the IEC 60728 series of standards sets the limits so that interference shall not occur. For case d), it is necessary to use system-inherent measures to manage interference.

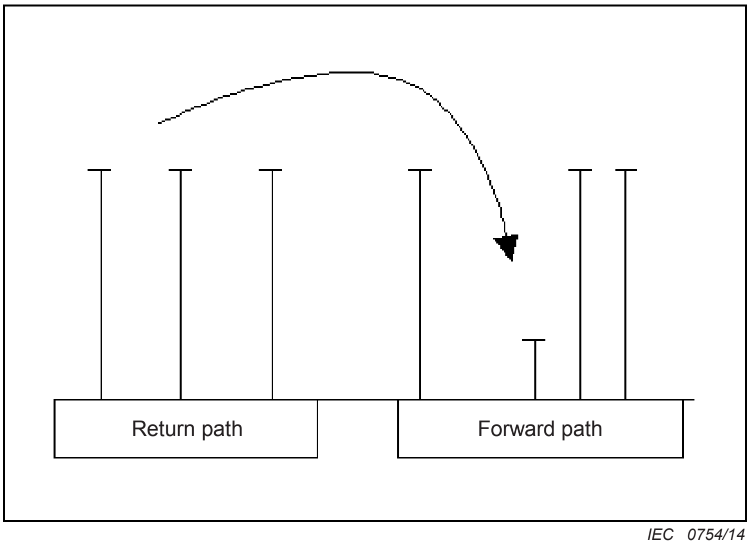
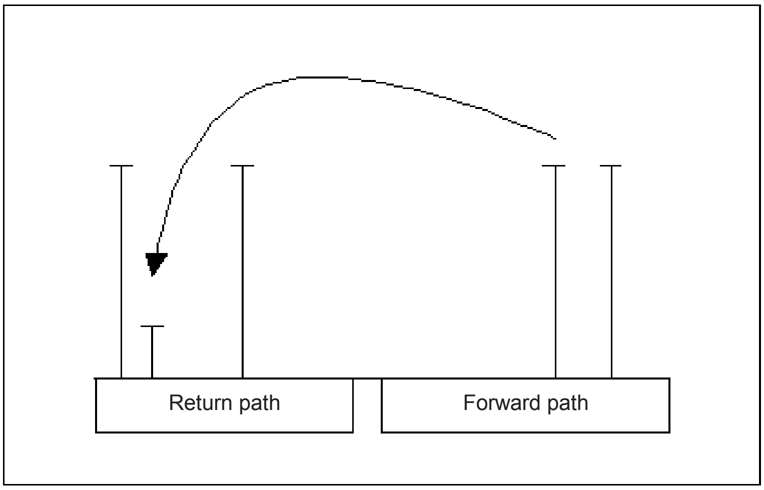


Figure 18 – Return path signals affecting forward path signals



IEC 0755/14

Figure 19 – Forward path signals affecting return path signals

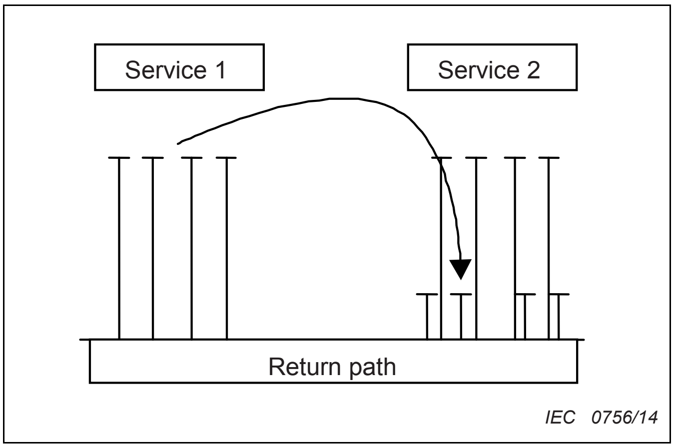


Figure 20 – Return path signals of service 1 affecting return path signals of a different service (e.g. service 2)

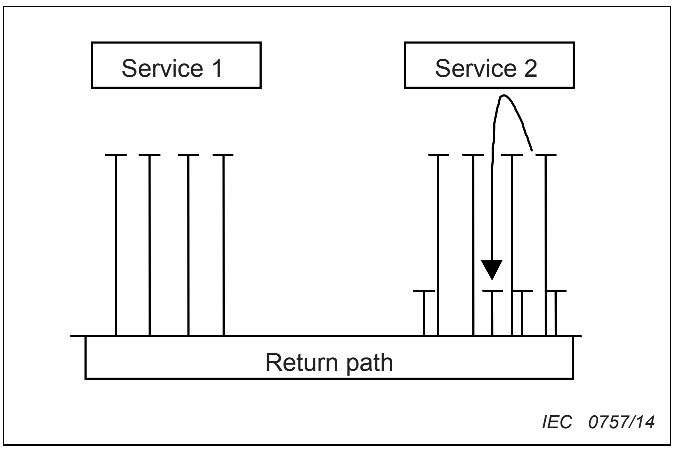


Figure 21 – Return path signals of a specific service (e.g. service 2) affecting return path signals of the same service

5.2 Analogue parameters that influence the system performance

The error probability in digital transmission systems depends on the degradation of the signal quality over the transmission path. For the return path of cable networks, performance is only evaluated in terms of *MER* according to DOCSIS 3.0 PHY, annex B, and can be summarized as presented in Table 3.

Table 3 – Summary of the requirements for *MER* according to ETSI EN 302 878-2, V.1.1.1 (2011-11), (clause 6.2.22.3.2)

Channel	Transmit Equalizer	Number of echoes [a]	Access method	Modulation rate kHz	*MERsymb* [c, d] dB									
					Operations up to 65 MHz					Operations up to 85 MHz				
					5-10 MHz	10-15 MHz	15-47 MHz	47-54 MHz	54-65 MHz	5-10 MHz	10-15 MHz	15-61 MHz	61-71 MHz	71-85 MHz
Flat	OFF	Not relevant	Not specified	160, 320, 640, 1 280, 2 560	≥26	≥27	≥30	≥27	≥26	≥26	≥27	≥30	≥27	≥26
				5 120	≥23	≥24	≥27	≥24	≥23	≥23	≥24	≥27	≥24	≥23
	ON	Not relevant	TDMA for QPSK only	Not specified	≥30									
			SCDMA [b] and all TDMA modulation formats		≥35									
Echo	ON	1	TDMA for QPSK only	Not specified	≥30									
			SCDMA and all TDMA modulation formats		≥33									
		2 or 3	Not specified	Not specified	≥29									

dBc = decibel referred to carrier signal level

[a] Echoes' values are chosen from the set of table B-3 of DOCSIS 3.0 CM-SP-PHYv3.0-I10-111117 (−10 dBc at ≤0,5 µs, −20 dBc at ≤1,0 µs and −31,5 dBc at >1,0 µs) – Since the table does not bind echo delay for the −30 dBc case, for testing purposes, it is assumed that the time span of the echo at this magnitude is ≤1,5 µs.

[b] In the case of the 'flat channel, transmit equalization ON', $MER_{chip} \geq 33$ dB is also defined.

[c] *MER* shall meet or exceed those limits over the full transmit power range of ETSI EN 302 878-2, V.1.1.1 (2011-11), (TDMA – QPSK: (+17 to +61) dB(mV) – 8 QAM & 16 QAM: (+17 to +58) dB(mV) – 32 QAM & 64 QAM: (+17 to +57) dB(mV)) (SCDMA – all modulations: (+17 to +56) dB(mV)), for each modulation, modulation rate and over the full carrier range and, for SCDMA, over any valid number of active and allocated codes.

[d] At the break points between regions, the higher *MER* specification applies.

The analogue parameters which influence the system performance of the return path can be classified in three categories:

a) parameters inherent of the return path (transmission properties);
b) parameters resulting from outside the return path;
c) influence from signals on the forward path.

Examples for the first category are properties like signal level, amplitude response, noise, intermodulation, group delay variation and echoes. Examples for the second type are ingress and impulse noise. Non-linear distortion according to the third category occurs typically in passive devices where both forward path and return path signals exist simultaneously.

Establishing the requirements for the return path means finding the limiting values for the parameters mentioned above. This has been carried out using theoretical and empirical methods supposing that the parameter under consideration is the dominant one and neglecting the influence of all the others. Of course, this approach does not reflect practical conditions where the *MER* can result from several simultaneous distortions. Therefore, sufficient margins have been added.

The main advantage in providing this link from *MER* to analogue parameters is that most of these parameters are well-known to the designers of cable networks and existing measurement equipment can be used.

5.3 General requirements

5.3.1 Impedance

The nominal impedance of the system shall be 75 Ω. This value applies to the coaxial cable part of the network. This nominal value shall be used as the reference impedance for all measurements.

5.3.2 Maximum signal level

The maximum allowable signal level injected into the network is based on the radiated power limit and the screening effectiveness according to IEC 60728-2.

As an example, for radiated power level of 20 dB(pW) and screening effectiveness of 75 dB and a single un-modulated carrier, the output level of any signal source within the cable network shall not exceed 114 dB(μV). If the screening effectiveness is higher, the allowable carrier level can be raised accordingly.

NOTE 1 When measuring the radiation of digitally modulated signals, the measuring bandwidth is:

- 9 kHz in the frequency range 5 MHz to 30 MHz, and
- 120 kHz in the frequency range 30 MHz to 950 MHz.

NOTE 2 High level of a return transmitter in the TV or radio IF band can interfere with a forward path signal if the mutual isolation between the return path transmitter and the forward path receiver is not sufficient.

5.4 Specific system performance requirements

The return path system performance requirements for different modulation techniques are listed in Table 4. These requirements apply to modulation techniques specified in the formerly used standard ETSI ES 200 800. Each of these values include a safety margin taking into account that all these parameters could occur simultaneously and that an overall *BER* of 10^{-4} shall be achieved under the condition that all the other parameters are ideal.

Table 4 – System performance requirements for different modulation techniques for *BER* = 10^{-4}

Parameters	Requirements						
	FSK	**QPSK**	**Burst QPSK**	**OFDM (16QAM)**	**OFDM (64QAM)**	**16QAM**	**64QAM**
Carrier-to-noise ratio $S_{D,RF}/N$	7 dB	11 dB	14 dB	17 dB	23 dB	20 dB	26 dB
Amplitude response variation, narrow band		3 dB	3 dB			3 dB	3 dB
Amplitude response variation, wide band		≤8 dB [a]					
Carrier-to-multiple interference ratio		≥22 dB/ 1,544 MHz					
Impulse noise distortion		Under consideration					
Hum modulation		≤7 %					
Echo ratio		≤15 %				15 dB at 0,5 µs 30 dB > 1,5 µs	
Group delay variation		≤300 ns/ 2 MHz					200 ns
Phase noise		–70 dBc/Hz at 3 kHz	–70 dBc/Hz at 3 kHz			–80 dBc/Hz at 3 kHz	–85 dBc/Hz at 3 kHz
Frequency error		±30 kHz				±200 kHz	±200 kHz
dBc = decibel referred to carrier signal level							
[a] For the frequency band from f_{min} +5 MHz to f_{max} −5 MHz, where f_{min} and f_{max} are the nominal minimum and respectively maximum frequency of the return path. The frequencies where ingress filters are used to attenuate interfering signals cannot be used for signal transmission and are excluded from this requirement.							

Table 5 compares some of the parameters given in Table 4 with those specified in the ETSI EN 302 878-2, V.1.1.1 (2011-11), specifications.

Table 5 – Comparison of system performance parameters given in Table 4 with those given in ETSI EN 302 878-2, V.1.1.1 (2011-11), specifications

Parameter	IEC 60728-10	ETSI EN 302 878-2, V.1.1.1 (2011-11),	ETSI EN 302 878-2, V.1.1.1 (2011-11),
Table number and title	Table 4 – System performance requirements using a reference signal according to ETSI ES 200 800 (QPSK Grade C)	Table 5–2 (page 22) – Assumed Upstream RF Channel Transmission Characteristics	Table B–3 (page 98) – Assumed Upstream RF Channel Transmission Characteristics
Carrier-to-noise ratio	≥22 dB (BW = 1,544 MHz)	Not available	Not less than 22 dB (in active bandwidth)
Amplitude response variation, narrow band	3,0 dB	No distinction between both: 0,5 dB/MHz	No distinction between both: maximum 2,5 dB in 2 MHz
Amplitude response variation, wide band	≤8 dB [a]		
Carrier-to-multiple interference ratio	≥22 dB / 1,544 MHz	Defined as Carrier-to-interference plus ingress (the sum of noise, distortion, common-path distortion and cross modulation and the sum of discrete and broadband ingress signals, impulse noise excluded) ratio: Not less than 25 dB	Two cases are considered: – Carrier-to-ingress power (the sum of discrete and broadband ingress signals) ratio in active channel – Carrier-to-interference (the sum of noise, distortion, common-path distortion and cross-modulation) ratio in active channel Both with a limit of 22 dB
Impulse noise distortion	Under consideration	Called ‘burst noise’: not longer than 10 µs at a 1 kHz average rate for most cases	Called ‘burst noise’: not longer than 10 µs at a 1 kHz average rate for most cases
Hum modulation	≤7 %	Not greater than –23 dBc (7,0 %)	Not greater than –23 dBc (7,0 %)
Echo ratio	≤15 %	Defined as Micro-reflections – single echo: –10 dBc at ≤0,5 µs; –20 dBc at ≤1,0 µs; –30 dBc at >1,0 µs	Defined as Micro-reflections (maximum) – single echo: –10 dBc at ≤0,5 µs; –20 dBc at ≤1,0µs; –31,5 dBc at >1,0 µs
Group delay variation	≤300 ns/2 MHz	200 ns/MHz	300 ns in 2 MHz
Frequency error	±30 kHz	Not available	Not available

dBc = decibel referred to carrier signal level

[a] For the frequency band from f_{min} + 5 MHz to f_{max} − 5 MHz, where f_{min} and f_{max} are the nominal minimum and respectively maximum frequency of the return path. The frequencies where ingress filters are used to attenuate interfering signals cannot be used for signal transmission and are excluded from this requirement.

6 System performance recommendations – Return path bandwidth

6.1 Frequency allocation

Table 6 shows recommended frequency ranges for the return path assuming that the FM radio band starts at 87,5 MHz.

Table 6 – Return path frequency ranges

Return path frequency range MHz	Return path bandwidth MHz	Recommended starting frequency of forward path MHz
5 to 30	25	47
5 to 50[a]	45	70
5 to 65	60	85
5 to 85	80	108
[a] or 5 MHz to 40 MHz, 5 MHz to 55 MHz, 5 MHz to 60 MHz, etc.		

6.2 Transmission quality in the return path frequency ranges

The whole bandwidth of the return path frequency range is not suitable for high quality transmission. Figure 22 shows some of the sub-bands with reduced transmission quality which are suitable only for slow data transmission. The reasons for quality reduction in sub-bands of the return path are shown in Table 7. Local transmitter stations can further impair the available bandwidth. Frequencies used for emergency services shall not be used for data transmission.

Table 7 – Reasons for quality reduction in sub-bands of the return path

Sub-band MHz	Reasons for quality reduction
5 to 15	Group delay variation, ingress noise, impulse noise, FM radio-IF
7, 10, 14, 18, 21, 24, 28	Radio amateur transmitters (exact frequency bands available at local radio authorities)
27	Terrestrial CB radio (ISM band)
38,9	TV – IF (other frequencies also used)
Close to band edge	Group delay variation

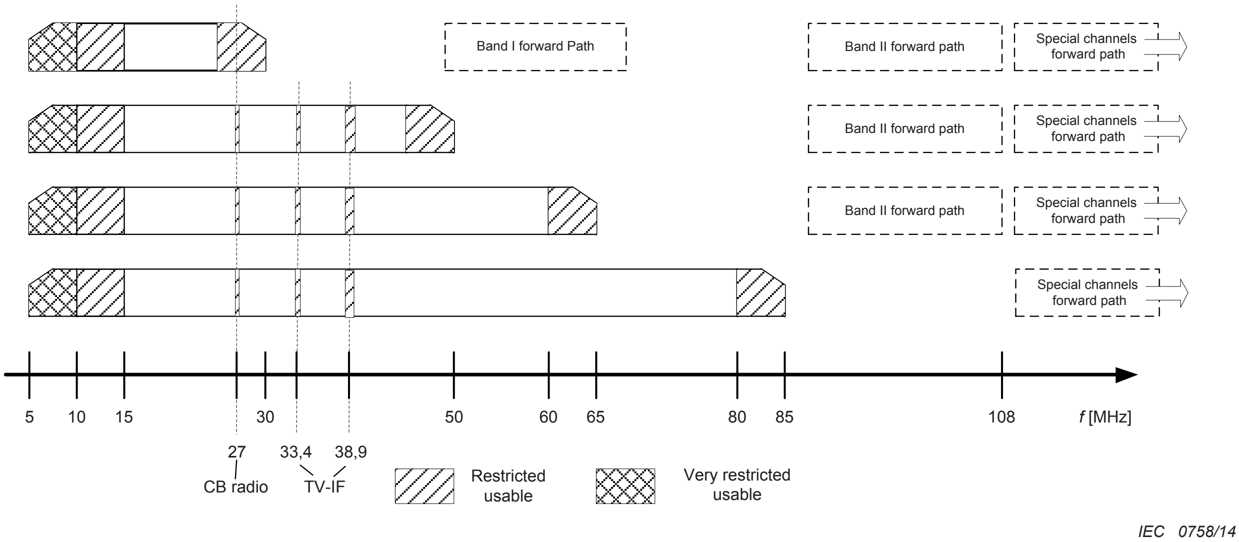


Figure 22 – Identification of the most common sub-bands within the return path band with limited transmission quality

Annex A
(normative)

Correction factors for noise

A.1 Signal level measurement

When measuring a signal level, the contribution of noise can be taken into account by reducing the measured signal level (S_m) by an amount (CF) that depends on the difference (D) between the measured signal (S_m) and noise (N_m) levels.

First calculate the difference D:

$$D = S_m - N_m$$

then from Table A.1 or Figure A.1, derive the correction factor (CF) and apply it to obtain the signal level (S) using the following formula:

$$S = S_m - CF$$

NOTE If the level difference (D) is lower than 2 dB, the reliability of the measurement becomes very low due to the big value of the correction factor (CF).

A.2 Noise level measurement

When measuring a noise level, the contribution of the measuring equipment noise can be taken into account by reducing the measured noise level by an amount given by the correction factor (CF) indicated in Table A.1 and in Figure A.1, that depends on the difference (D) between the noise level (N_m) measured when the measuring equipment is connected to the system or equipment under test and that (N_{eq}) measured when the input of the measuring equipment is terminated by its characteristic impedance.

First calculate the difference D:

$$D = N_m - N_{eq}$$

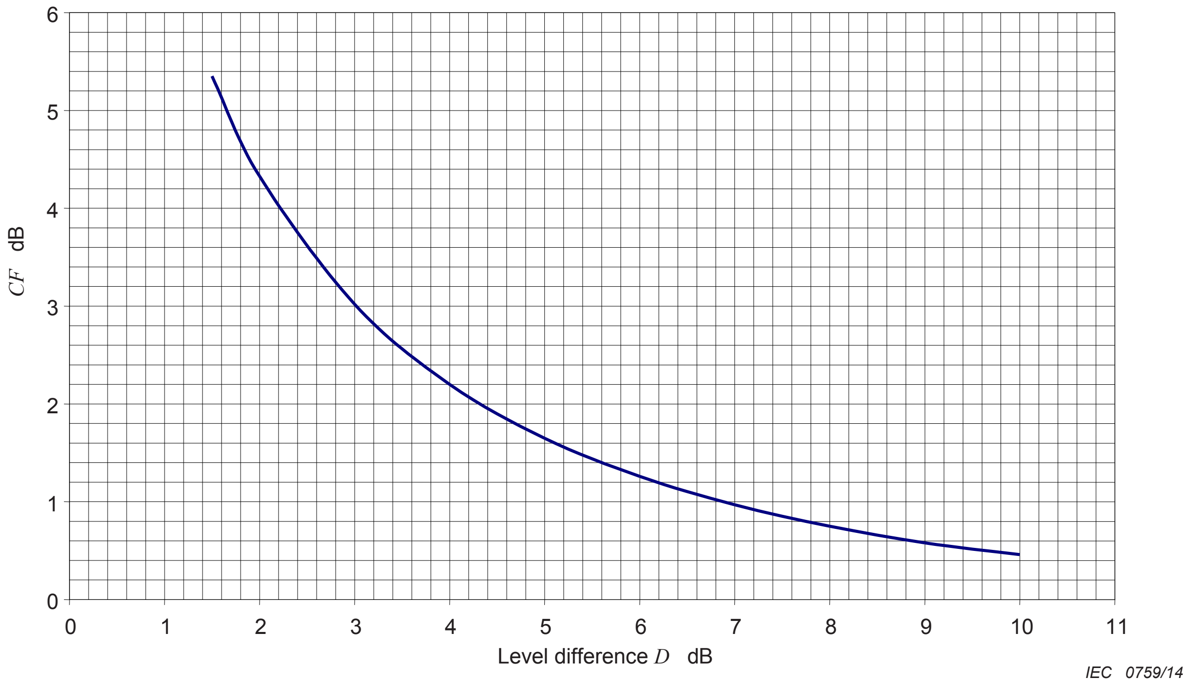
then from Table A.1 or Figure A.1, derive the correction factor (CF) and apply it to obtain the noise level (N) using the following formula:

$$N = N_m - CF$$

NOTE If the level difference (D) is lower than 2 dB the reliability of the measurement becomes very low due to the big value of the correction factor (CF).

Table A.1 – Noise correction factor

Level difference *D* dB	**Correctionfactor *CF*** dB	**Level difference *D*** dB	**Correctionfactor *CF*** dB
1,5	5,35	6,0	1,26
2,0	4,33	7,0	0,97
3,0	3,02	8,0	0,75
4,0	2,20	9,0	0,58
5,0	1,65	10,0	0,46



The values of both the noise correction factor and the level difference *D* are in decibel (dB).

Figure A.1 – Noise correction factor *CF* versus measured level difference *D*

Annex B
(normative)

Correction factor for a spectrum analyser

The correction factor (K_{sa}) for a typical spectrum analyser is about 1,7 dB and is due to two contributions:

- a +2,5 dB term for the effect of the detector/log amplifier (it accounts for the correction of 1,05 dB due to the narrowband envelope detection and the 1,45 dB due to the logarithmic amplifier);
- a –0,8 dB term that takes into account that the equivalent noise bandwidth of the IF filter of the spectrum analyser is greater than its nominal resolution bandwidth RSBW by a factor of 1,2.

Annex C
(normative)

Null packet and PRBS definitions

C.1 Null packet definition

The null packet definition from ISO/IEC 13818-1 is extended for the purpose of the recommended test mode.

ISO/IEC 13818-1 defines a null transport stream packet for the purpose of data rate stuffing.

Table C.1 shows the structure of a null transport stream packet using the method of describing bit stream syntax defined in 2.3 of ISO/IEC 13818-1:2007.

This description is derived from Table 2-2 in ISO/IEC 13818-1:2007. The abbreviation "bslbf" means "bit string, left bit first", and "uimsbf" means "unsigned integer, most significant bit first".

The column titled "Value" in Table C.1, gives the bit sequence for the recommended null packet.

A null packet is defined by ISO/IEC 13818-1 as having:

- **payload_unit_start_indicator** = '0';
- **PID** = 0x1FFF;
- **transport_scrambling_control** = '00';
- **adaptation_field_control** value = '01'. This corresponds to the case "no adaptation field, payload only".

The remaining fields in the null packet that shall be defined for testing purposes are:

- **transport_error_indicator** which is '0' unless the packet is corrupted: for testing purposes this bit is defined as '0' when the packet is generated;
- **transport_priority** which is not defined by ISO/IEC 13818-1 for null packet. For testing purposes this bit is defined as '0';
- **continuity_counter** which ISO/IEC 13818-1 states is undefined for a null packet. For testing purposes this bit field is defined as '0000';
- **data_byte** which ISO/IEC 13818-1 states may have any value in a null packet. For testing purposes this bit field is defined as '00000000'.

Table C.1 – Null transport stream packet definition

Syntax	No of bits	Identifier	Value
null_transport_packet(){			
sync_byte	8	bslbf	'01000111'
transport_error_indicator	1	bslbf	'0'
payload_unit_start_indicator	1	bslbf	'0'
transport_priority	1	bslbf	'0'
PID	13	uimsbf	'1111111111111'
transport_scrambling_control	2	bslbf	'00'
adaptation_field_control	2	bslbf	'01'
continuity_counter	4	uimsbf	'0000'
for (*i*=0;*i*<*N*;*i*++){**data_byte**}	8	bslbf	'00000000'
}			

C.2 PRBS definition

A PRBS (pseudo random bit sequence) generator can be used instead of a null packet generator. A PRBS of $10^{23} – 1$ inverted is recommended.

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