INTERNATIONAL STANDARD

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Second edition
2005-06

Cable networks for television signals, sound signals and interactive services –

Part 10:
System performance of return paths

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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

Part 10: System performance for return paths

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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International Standard IEC 60728-10 has been prepared by technical area 5: Cable networks for television signals, sound signals and interactive services of IEC technical committee 100: Audio, video and multimedia systems and equipment.

This second edition cancels and replaces the first edition published in 2001 and constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

- New measurement method for amplitude response variation, 4.3
- Additional recommendations to documentation of measurement results in 4.5.6, 4.6.5.
- New subclause for measurement of group delay variation, 4.8

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

FDIS	Report on voting
100/948FDIS	100/978/RVD

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

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

IEC 60728 consists of the following parts, under the general title *Cable networks for television signals, sound signals and interactive services:*

Part 1: Methods of measurement and system performance
Part 2: Electromagnetic compatibility for equipment
Part 3: Active coaxial wideband distribution equipment (this publication)
Part 4: Passive coaxial wideband distribution equipment
Part 5: Headend equipment
Part 6: Optical equipment
Part 7-1: Hybrid fibre coax outside plant status monitoring – Physical (PHY) layer specification
Part 7-2: Hybrid fibre coax outside plant status monitoring – Media access control (MAC) layer specification
Part 7-3: Hybrid fibre coax outside plant status monitoring – Power supply to transponder interface bus (PSTIB) specification
Part 9: Interfaces for CATV/SMATV headends and similar professional equipment for DVB/MPEG-2 transport streams
Part 10: System performance of return path
Part 11: Safety
Part 12: Electromagnetic compatibility of systems

The committee has decided that the contents of this publication will remain unchanged until the maintenance result date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed;
- withdrawn;
- replaced by a revised edition, or
- amended.

A bilingual version of this publication may be issued at a later date.

INTRODUCTION

Standards of the IEC 60728 series deal with cable networks including equipment and associated methods of measurement for headend reception, processing and distribution of television signals, sound signals, interactive multimedia signals, interfaces and their associated data signals, using all applicable transmission media.

This includes:

– CATV-networks;

– MATV-networks and SMATV-networks;

– individual receiving networks,

and all kinds of equipment, systems and installations installed in such networks.

The extent of this standardisation work is from the antennas, special signal source inputs to the headend or other interface points to the network up to the terminal input.

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

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

Part 10: System performance for return paths

1 Scope

This part of IEC 60728 deals with the transparent return path of cable networks operated in the frequency range between 5 MHz and 65 MHz or parts thereof. 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.

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 close to the subscriber. It is the last point where all forward and return signals are present and carried on the same cable. If no network termination point exists, the reference point is the system outlet.

The other reference point is the input of the return signal receiver (or transceiver). 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.

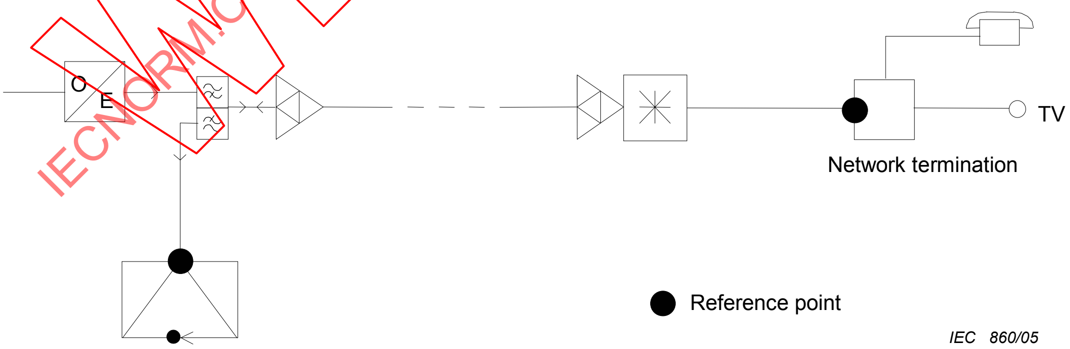


Figure 1 – Reference points of an active return path system (example)

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

Specific equipment installed in cable networks for the operation of such return paths is standardised in the relevant equipment standards, parts 3 to 6 of the IEC 60728 series.

Transmission systems are not within the scope of this standard.

2 Normative references

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

IEC 60728-1:2001, *Cable networks for television signals, sound signals and interactive services – Part 1: Methods of measurement and system performance*

IEC 60728-2:2002, *Cable networks for television signals, sound signals and interactive services – Part 2: Electromagnetic compatibility for equipment*

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

IEC 60728-4:2000, *Cable networks for television signals, sound signals and interactive services – Part 4: Passive coaxial wideband distribution equipment*

IEC 60728-5:2001, *Cable networks for television signals, sound signals and interactive services – Part 5: Headend equipment*

IEC 60728-6:2003, *Cable networks for television signals, sound signals and interactive services – Part 6 Optical equipment*

IEC 60728-11:2005, *Cable networks for television signals, sound signals and interactive services – Part 11: Safety*

IEC 60728-12:2001, *Cable networks for television signals, sound signals and interactive services – Part 12: Electromagnetic compatibility of systems*

ITU-R Recommendation BT.6/BL22: 2005, *Conventional analogue television systems*

ITU-T Recommendation J.61:1990, *Transmission performance of television circuits designed for use in international connections* (Published as ITU-R Rec. CMTT 567-3 in CCIR Recommendations, Volume XII, Düsseldorf, 1990)

ES 200 800 V1.3.1:2001, *Digital Video Broadcasting (DVB); DVB interaction channel for Cable TV distribution systems (CATV)*

3 Terms, definitions, symbols and abbreviations

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

3.1 Terms and definitions

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

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

3.1.3
channel availability
percentage of the time during which the channel fulfils all performance requirements. The duration of the observation time has to be published

3.1.4
downstream 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

3.1.5
forward path (downstream)
part of a cable network by which signals are distributed in the downstream direction from the headend or any other central point (node) of a cable network to the subscribers´ area

3.1.6
frequency error
quality of supply evaluated on the basis of the actual frequency of an electrical system compared to the nominal value. It consists of initial error, short term and long term frequency stability

3.1.7
headend
equipment which is connected between receiving antennas or other signal sources and the remainder of the cable network, to process the signals to be distributed

NOTE The headend may, for example, comprise antenna amplifiers, frequency converters, combiners, separators and generators.

3.1.8
hybrid fibre coaxial network
HFC
cable network which is comprised of optical equipment and cables and coaxial equipment and cables in different parts

3.1.9
impulse noise
noise which is caused by electromagnetic interference into cable networks. Impulse noise is characterised by pulses with a duration of typically <10 µs

3.1.10
ingress noise
noise which is caused by electromagnetic interference into cable networks. Its power decreases with increasing frequency. It is permanently present but slowly varies in its intensity as a function of time

3.1.11
interaction path
part of a cable network by which interactive signals are transmitted in the downstream direction (from the headend or node to the subscriber) and in the upstream direction (from the subscriber to the headend or node)

3.1.12
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

3.1.13
multiple interference
interfering signal which consists of at least two signals which are originated from at least two different sources

NOTE On return path the multiple interference consists of ingress noise and intermodulation distortion products.

3.1.14
multimedia signal
signal comprising of two or more different media contents, for example video, audio, text, data, etc.

3.1.15
network management system
NMS
software based system for controlling and supervising cable networks

3.1.16
network segment
part of a cable network comprising a set of functions and/or a specific extent of the complete cable network

3.1.17
network termination
electrical termination of a cable network at any outlet on subscribers' side and headend or node side

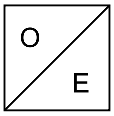
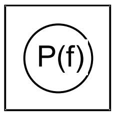
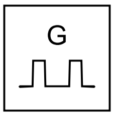
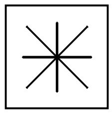
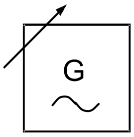
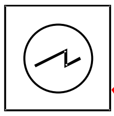
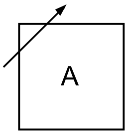
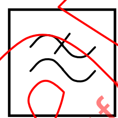
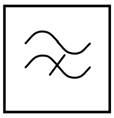
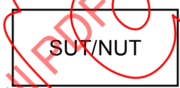
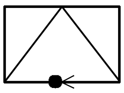
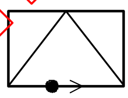
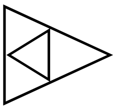
3.1.18
node
central point of a network segment at which signals could be fed into the forward path or could be gathered from a number of subscribers out of the return path

3.1.19
return path (upstream)
part of a cable network by which signals are transmitted in the upstream direction from any subscriber, connected to the network, to the headend or any other central point (node) of a cable network

3.1.20
upstream 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

3.2 Symbols

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

Symbols	Terms	Symbols	Terms
	Optical receiver [S00213]		Electrical spectrum analyzer [S00910]
	Test waveform generator [S01225]		Passive distribution network [S00910]
	Variable signal generator [S00899, S01403, S00081]		Oscilloscope [S00059, S00922]
	Variable attenuator [S01245]		Low pass filter [S01248]
	High pass filter [S01247]		System Under Test/ Network Under Test [S00060]
	Demodulator [IEC 60417-5260]		Modulator [IEC 60417-5261]
	Amplifier with return path amplifier [S00433]		Bit Error Rate detector [S00059, S00910]

3.3 Abbreviations

The following abbreviations are used in this standard:

BER	bit error rate
BW	bandwidth, equivalent noise bandwidth
CATV	community antenna television
CB	citizen band
C/MI	carrier-to-multiple interference ratio
C/N	carrier-to-noise ratio
DVB	digital video broadcasting
EMC	electromagnetic compatibility
FM	frequency modulation
FSK	frequency shift keying
HFC	hybrid fibre coaxial

IF	intermediate frequency
ISM	industrial, scientific, medical
LPF	low-pass filter
MATV	master antenna television (network)
NMS	network management system
NUT	network under test
OFDM	orthogonal frequency division multiplexing
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
SL	signal level (corrected)
SMATV	satellite master antenna television (network)
S/N	signal-to-noise ratio
SUT	system under test
TV	television

4 Methods of measurement

4.1 Set-up of the network

Even if the main target of this Clause 4 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. The following set-up and operational procedures is a guideline for that.

The return path differs in several ways from the forward path, even though they share mostly the same physical network. Table 1 gives some hints.

Table 1 – Characterisation criteria for downstream and upstream operations

Criteria	Downstream	Upstream
Signals present	continuously	intermittently or continuously
Power levels	well-defined	varying
Channel allocation	well-defined	may vary over time
Signal bandwidth	well-defined	application dependent
Modulation scheme	fixed	application dependent
Amplifier input	single	several inputs

As can be seen from the table, the variable factors require that the procedures used to operate the return path plant differ from those used in the downstream direction.

One major difference is that the amplifiers in the downstream direction are aligned by adjusting their output signals to predetermined levels and in the return direction, the network plant is adjusted so that the input signals from different sources are equalized at the amplifier input. Different types of signals may be at different levels.

4.1.1 Steps to set up properly the upstream plant

Figure 2 gives a rough procedure for the set-up.

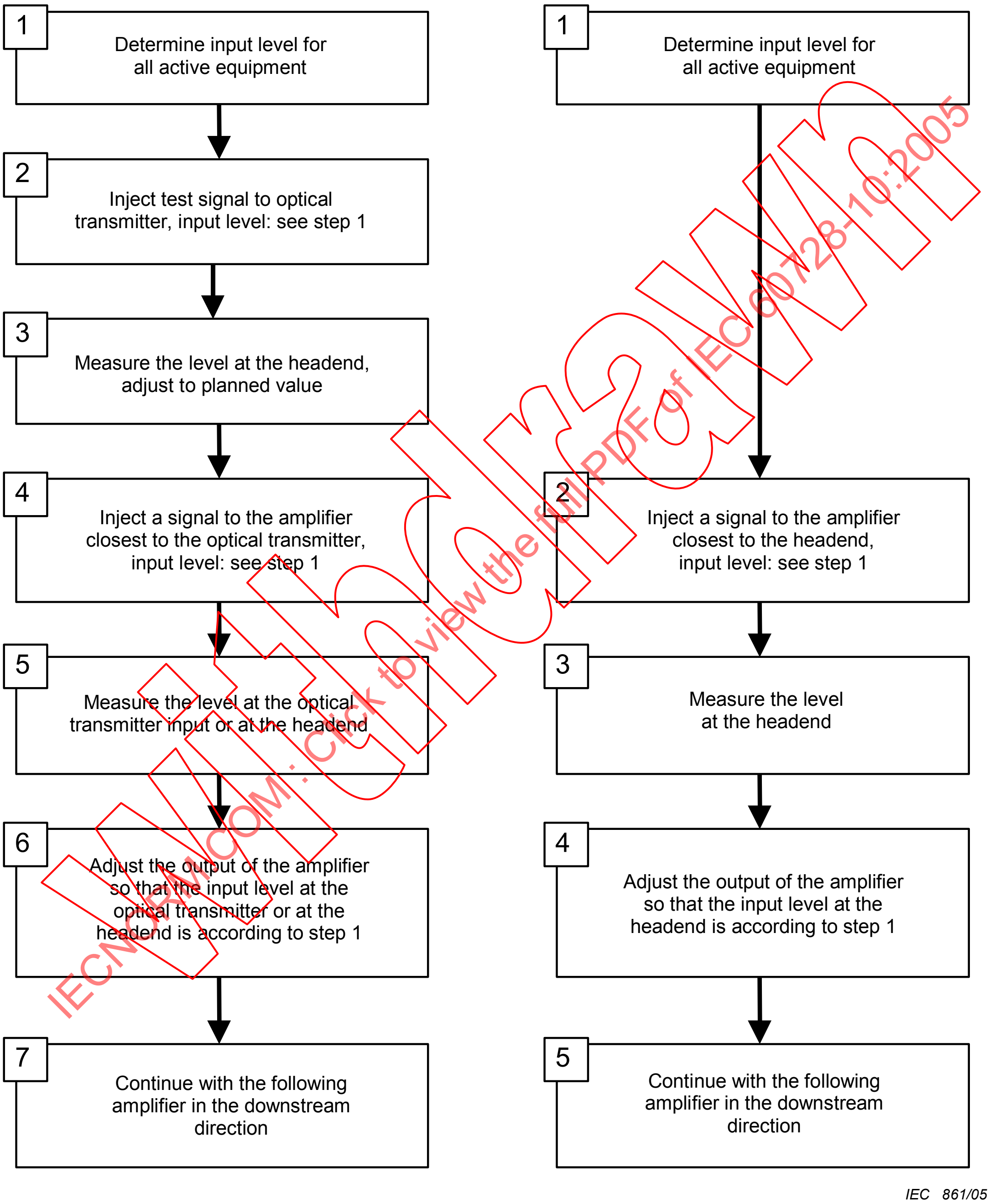


Figure 2 – Procedure for set-up and adjustment of an upstream plant

4.2 Measurement of signal level

4.2.1 General

The method described is applicable to the measurement of the level of RF signals which do not have a clear carrier (e.g. QPSK and QAM modulated carriers).

NOTE This method is not suitable for burst signals.

4.2.2 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.

4.2.3 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 of correct impedance matching.

4.2.4 Measurement procedure for RF signals without 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(ies) 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 2;

Table 2 – Examples of the Nyquist bandwidth of digitally modulated carriers

Type of digital channel	Nyquist bandwidth MHz
QPSK 0,256 Mbit/s	0,128
QPSK 0,288 Mbit/s	0,1875
QPSK 0,576 Mbit/s	0,375
QPSK 1,152 Mbit/s	0,750
QPSK 1,544 Mbit/s	0,772
QPSK 2,304 Mbit/s	1,5000
QPSK 3,088 Mbit/s	1,544
QPSK 4,608 Mbit/s	3,000
16QAM 12,8 Mbit/s	3,2000

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.

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 band is at least 15 dB lower than the measured level (S).

4.2.5 Presentation of the results

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

4.3 Measurement of amplitude response variation

4.3.1 Background

There is a number of propriety test equipment(s) available which are specifically designed for this purpose. However, since these may not be readily available, the method, which is described here, uses test equipment that is usually in service by CATV engineering staff.

NOTE The proposed method of measurement cannot be used in networks during normal operation.

4.3.2 Equipment required

The following equipment is 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 80 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.

4.3.3 Connection of the equipment

The equipment shall be connected as in Figure 3.

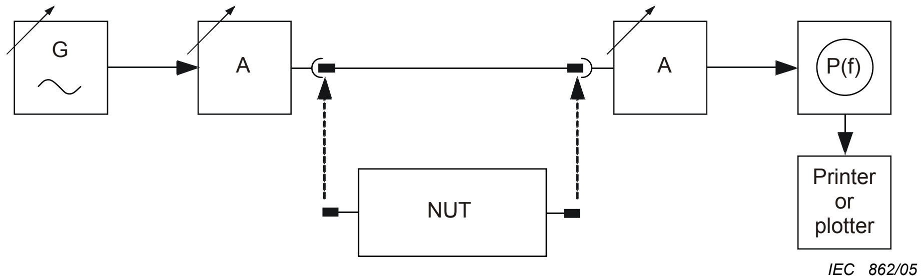


Figure 3 – Arrangement of test equipment for measurement of amplitude response variation

4.3.4 Calibration of the equipment

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).

4.3.5 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.

4.3.6 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.

4.4 Measurement of signal to noise ratio (S/N)

4.4.1 General

The C/N measurement of an analogue television channel is described in IEC 60728-1. The same method can be used also on the return path for signals, which have a clear carrier. 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 without a clear carrier (e.g. QPSK or QAM modulated channels). The S/N-ratio of such channels 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 C/N and S/N measurements. To minimise the influence of ingress noise C/N and S/N should be measured at frequencies above 15 MHz or at frequencies for which the return service is designed.

4.4.2 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.

4.4.3 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 of correct impedance matching.

4.4.4 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;

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). 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/N) by using the following formula:

$$(S/N)_{\mathrm{dB}} = S_{\mathrm{dB}(\mu V)} - N_{\mathrm{dB}(\mu V)}$$

4.4.5 Presentation of the results

The measured signal to noise ratio (S/N) shall be expressed in decibels.

4.5 Measurement of multiple interference

4.5.1 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 upstream 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.

4.5.2 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.

4.5.3 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 of 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.

4.5.4 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.

4.5.5 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 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.

4.5.6 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).

4.6 Measurement of impulse noise

4.6.1 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 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 an upstream 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.

4.6.2 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.

4.6.3 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 of 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

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).

4.6.5 Processing of the data and presentation of the results

By using stored impulse noise data, it is possible to analyse what is probability, for 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).

4.7 Measurement of echo ratio

This method is applicable to the measurement of the amplitude and time displacement of an echo at a specified point within a cable network. The method uses a 2T-sine-squared pulse.

4.7.1 Equipment required

The following equipment is required:

a) a test waveform generator providing a sine-squared pulse of half amplitude duration equal to 200 ns in PAL system or 250 ns in NTSC system. The test signal is in accordance with the ITU-T Recommendation J.61;

b) a modulator having RF characteristics (excluding sound) appropriate to an analogue television system (see ITU-R Recommendation BT.6/BL/22) and input characteristics to suit the generator in a);

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

d) an oscilloscope of negligible distortion up to 5 MHz.

4.7.2 Connection of the equipment

The equipment shall be connected as in Figure 4. The test waveform generator and modulator are connected to the reference point close to a subscriber. The demodulator and oscilloscope are connected to the headend side reference point. The measuring equipment shall be connected taking care to maintain correct impedance matching.

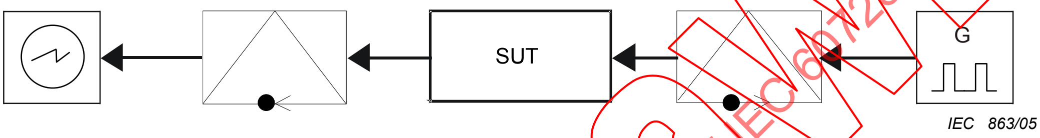


Figure 4 – Arrangement of test equipment for measurement of echo ratio

4.7.3 Measurement procedure

The measurement procedure comprises the following steps:

a) adjust the RF levels high enough to reach C/N > 40 dB at the demodulator input. If this is not possible, move the demodulator and the oscilloscope closer to the modulator and measure the network in two parts. The part closer to the headend has typically less echoes and that part is tested only to verify that the contribution to the total system echo ratio is negligible;

b) with the equipment connected as shown in Figure 4, adjust the oscilloscope time-base speed to 100 ns/div. Adjust the vertical gain and position controls so that the pulse is in the middle of the screen. Increase the vertical gain by x5 or x10 so that echoes become visible.

c) Search for echoes with the highest amplitude (≥10 %) using the horizontal shift control of the oscilloscope to slowly move the display to the left and to examine any long distance echoes. Note the level of the strongest echo in per cent.

4.7.4 Presentation of the results

Echo ratio is 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.

4.8 Measurement of group delay variation

It is technically difficult to measure group delay variation in a network. As 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 Defective components can cause additional group delay variation in a network. Such defective components can be found by using 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.

4.9 Measurement of frequency error

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).

4.9.1 Equipment required

The following equipment is required:

a) QPSK transmitter;
b) test receiver.

4.9.2 Connection of the equipment

The measuring set-up for the frequency stability measurement is shown in Figure 5.

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

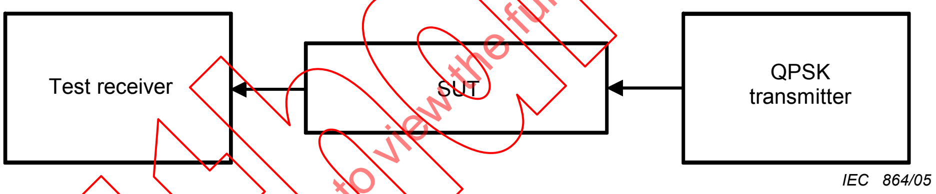


Figure 5 – Test set-up for frequency stability measurement

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

NOTE 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.

NOTE 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.

4.9.4 Presentation of the result

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

4.10 Measurement of bit error rate (BER)

4.10.1 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.

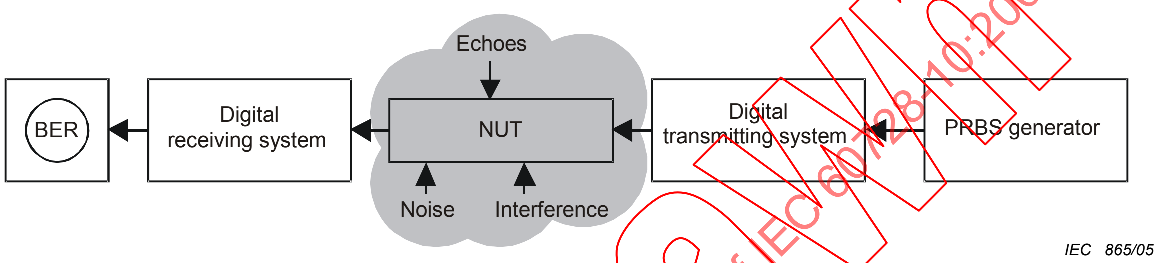


Figure 6 – Principle of BER measurement

This measuring method applies to the measurement of BER of digitally modulated signals using QPSK format. The measuring equipment consists of a generator which produces a pseudo random binary sequence (PRBS). This PRBS is fed to the digital transmitting system as a data stream as shown in Figure 6. 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 downstream or upstream 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 applicable also to other types of modulation if suitable types of modulator and demodulator are used.

4.10.2 Equipment required

The following equipment is required:

a) PRBS generator;
b) QPSK modulator with a serial input interface for the PRBS data stream;
c) RF signal up-converter;
d) RF signal tuner;
e) QPSK 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.

4.10.3 Connection of the equipment

The measuring set-up for BER measurement is shown in Figure 6. The digital transmitting system consists of the QPSK-modulator and the subsequent RF signal up-converter. The digital receiving system is composed of the RF signal tuner and the QPSK-demodulator.

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

4.10.4 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 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.

4.10.5 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.

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 material 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 downstream signals (Figure 7);
b) effects of downstream signals (e.g. intermodulation products) disturbing upstream signals (Figure 8);
c) effects of upstream signals of service 1 (e.g. spurious signals) disturbing the upstream signals of a different service 2 (Figure 9);
d) effects between upstream signals (e.g. intermodulation products) pertaining to the same service (Figure 10).

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.

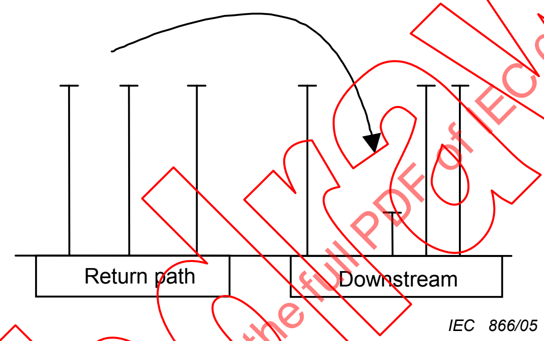


Figure 7 – Upstream signals affecting downstream signals

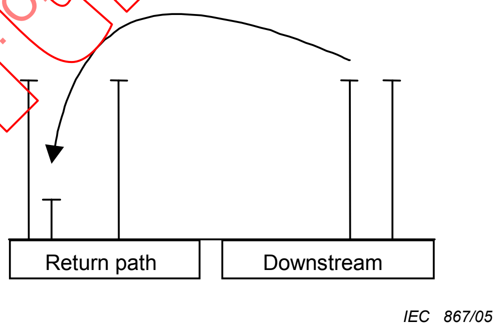


Figure 8 – Downstream signals affecting upstream signals

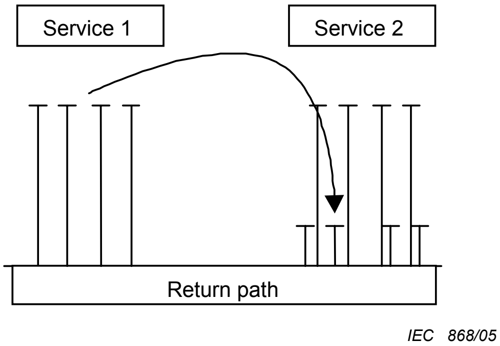


Figure 9 – Upstream signals of service 1 affecting upstream signals of a different service (e.g. service 2)

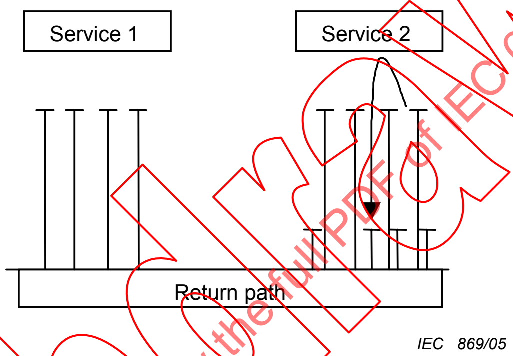


Figure 10 – Upstream signals of a specific service (e.g. service 2) affecting upstream signals of the same service

5.2 Analogue parameters influencing system performance

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, a BER of 10^{-4} before Reed-Solomon decoder is required for the reference signal which is the 3,088 Mbit/s QPSK modulated signal specified in ES 200 800. Other types of application may require a different BER.

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

1) parameters inherent of the return path (transmission properties);
2) parameters resulting from outside the return path;
3) 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 downstream and upstream signals exist simultaneously.