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Cabled distribution systems for television and sound signals –

Part 10:
System performance of return path

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INTERNATIONAL ELECTROTECHNICAL COMMISSION
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CABLED DISTRIBUTION SYSTEMS FOR TELEVISION AND SOUND SIGNALS –

Part 10: System performance of return path

FOREWORD

1) The IEC (International Electrotechnical Commission) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of the 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, the IEC publishes International Standards. 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. The 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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6) Attention is drawn to the possibility that some of the elements of this International Standard may be the subject of patent rights. The IEC shall not be held responsible for identifying any or all such patent rights.

International Standard IEC 60728-10 has been prepared by TA 5: Cable networks for television signals, sound signals and interactive services, of IEC technical committee 100: Audio, video and multimedia systems and equipment.

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

FDIS	Report on voting
100/200/FDIS	100/224/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 3.

Annex A is for information only.

Annex B forms an integral part of this standard.

The committee has decided that the contents of this publication will remain unchanged until 2003. At this date, the publication will be

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- withdrawn;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

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

INTRODUCTION

Standards of the IEC 60728 series deal with cable networks for television signals, sound signals and interactive services including equipment for:

– head-end -reception, processing and distribution of television and sound signals and their associated data signals;

– processing, interfacing and transmitting all kinds of signals for interactive services using all applicable transmission media.

They apply to all kinds of networks such as:

– CATV-systems;

– MATV-systems and SMATV-systems;

– individual receiving systems and

– all kinds of equipment installed in such systems.

The extent of this standardization work is from the antennas and special signal source inputs to the head-end or other interface points to the network up to the system outlet or, where no system outlet exists, the terminal input.

The standardization of any user terminals (i.e. tuners, receivers, decoders, multimedia terminals, etc.) is excluded.

CABLED DISTRIBUTION SYSTEMS FOR TELEVISION AND SOUND SIGNALS –

Part 10: System performance of return path

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

This part of IEC 60728 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 have to 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 head-end but can also be at the node of the coaxial cell or at any other point of the network.
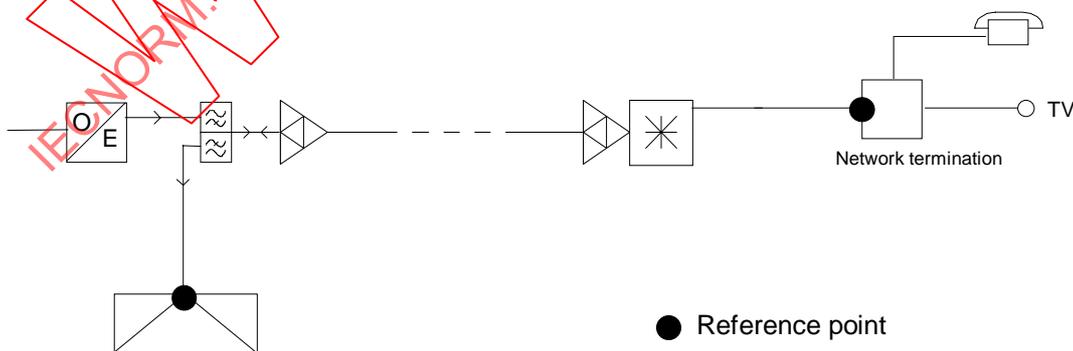
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Figure 1 – Reference points of an active return path system (example)

In addition to the system performance requirements for the transparent return path, system performance recommendations are laid down in this part of IEC 60728, 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 standardized in the relevant equipment standards, parts 3 to 6 of the IEC 60728 series.

Transmission systems are not within the scope of this part of IEC 60728.

2   Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of IEC 60728. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this part of IEC 60728 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of IEC and ISO maintain registers of currently valid International Standards.

IEC 60728-1, *Cabled distribution systems for television and sound signals – Part 1: Systems primarily intended for sound and television signals operating between 30 MHz and 1 GHz*

IEC 60728-3, *Cabled distribution systems for television and sound signals – Part 3: Active coaxial wideband distribution equipment*

IEC 60728-4, *Cabled distribution systems for television and sound signals – Part 4: Passive coaxial wideband distribution equipment*

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

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

IEC 60728-11, *Cabled distribution systems for television and sound signals – Part 11: Safety*

EN 50083, *Cable networks for television signals, sound signals and interactive services*

EN 50083-2, *Cable networks for television signals, sound signals and interactive services – Part 2: Electromagnetic compatibility for equipment*

ETS 300 800:July 1998, *Digital Video Broadcasting (DVB); Interaction channel for Cable TV distribution systems (CATV)*

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

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

3 Terms, definitions, symbols and abbreviations

For the purpose of this part of IEC 60728, the following terms, definitions, symbols and abbreviations apply.

3.1 Terms and definitions

3.1.1
broadcast signal
signal comprising video and/or audio and/or data content which is distributed to several receivers simultaneously

3.1.2
downstream direction
direction of signal flow in a cable network from the head-end or any other central point (node) of a cable network to the subscribers' area

3.1.3
forward path (downstream)
part of a cable network by which signals are distributed in the downstream direction from the head-end or any other central point (node) of a cable network to the subscribers' area

3.1.4
frequency error
quality of supply evaluated on the basis of the actual frequency of an electrical system compared to the nominal value. Frequency error consists of initial error, short term and long term frequency stability

3.1.5
head-end
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 head-end may, for example, comprise antenna amplifiers, frequency converters, combiners, separators and generators.

3.1.6
hybrid fibre coaxial (HFC) network
cable network which comprises optical equipment and cables and coaxial equipment and cables in different parts

3.1.7
impulse noise
noise caused by electromagnetic interference into cable networks. Impulse noise is characterized by pulses with a duration of typically <10 µs

3.1.8
ingress noise
noise 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

3.1.9
interaction path
part of a cable network by which interactive signals are transmitted in the downstream direction (from the head-end or node to the subscriber) and in the upstream direction (from the subscriber to the head-end or node)

3.1.10
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

3.1.11
multiple interference
interfering signal which consists of two or more signals which originate from two or more sources

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

3.1.12
multimedia signal
signal comprising two or more different media contents, for example video, audio, text, data, etc.

3.1.13
network management system (NMS)
software based system for controlling and supervising cable networks

3.1.14
network segment
part of a cable network comprising a set of functions and/or a specific extent of the complete cable network

3.1.15
network termination
electrical termination of a cable network at any outlet on subscribers' side and head-end or node side

3.1.16
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

3.1.17
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 head-end or any other central point (node) of a cable network

3.1.18
upstream direction
direction of signal flow in a cable network from a subscriber to the head-end or any other central point (node) of a cable network

3.2 Symbols

Symbol	Term	Symbol	Term
O / E	Optical receiver	BER	Bit error rate detector
⊓⊔	Test waveform generator	✳	Passive distribution network
SUT	System under test		Oscilloscope
	Demodulator		Low pass
	Amplifier with return path amplifier		High pass
			Modulator
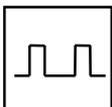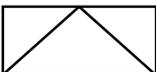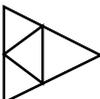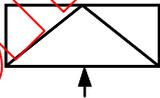
3.3 Abbreviations

BER	bit error rate
BW	bandwidth, equivalent noise bandwidth
CATV	community antenna television
CB	citizens' band
C/MI	carrier-to-multiple interference ratio
C/N	carrier-to-noise ratio
EMC	electromagnetic compatibility
FM	frequency modulation
FSK	frequency shift keying
HFC	hybrid fibre coaxial
IF	intermediate frequency
ISM	industrial, scientific, medical
MATV	master antenna television (network)
NMS	network management system
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
TS	transport stream
TV	television

4 Methods of measurement

4.1 Set-up of the network

Although the main purpose of this part of IEC 60728 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. The following set-up and operational procedures provide guidelines.

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

Table 1 – Characterization 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 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 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 the upstream properly

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

Network with fibre	Network without fibre

Network with fibre

1. Determine input level for all active equipment

2. Inject test signal to optical transmitter, input level: see step 1

3. Measure the level at the head end, adjust to planned value

4. Inject a signal to the amplifier closest to the optical transmitter, input level: see step 1

5. Measure the level at the optical transmitter input or at the head end

6. Adjust the output of the amplifier so that the input level at the optical transmitter or at the head end is according to step 1

7. Continue with the following amplifier in the downstream direction

Network without fibre

1. Determine input level for all active equipment

2. Inject a signal to the amplifier closest to the head end, input level: see step 1

3. Measure the level at the head end

4. Adjust the output of the amplifier so that the input level at the head end is according to step 1

5. Continue with the following amplifier in the downstream direction

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Figure 2 – Procedure for set-up and adjustment of the upstream system

4.2 Measurement of signal level

4.2.1 Introduction

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).

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 is to be performed by using a suitable connection lead. Ensure correct impedance matching.

4.2.4 Measurement procedure for RF signals without carriers

4.2.4.1 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.

4.2.4.2 Tune the spectrum analyzer to the channel that is to 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
16 QAM 12,8 Mbit/s	3,2000

4.2.4.3 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.

4.2.4.4 Measure the signal level (S) at the centre frequency of the channel in $dB(\mu V)$.

4.2.4.5 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.

4.2.4.6 Calculate the signal level (SL) by using the 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 dBm 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

4.3.1   Under consideration

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

4.4.1   Introduction

The C/N measurement of an analogue television channel is described in IEC 60728-1. The same method can also be used on the return path for signals which have a clear carrier. The noise bandwidth which is applicable for the channel under test shall be used.

This part of IEC 60728 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 minimize 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 is to be performed by using a suitable connection lead. Ensure correct impedance matching.

4.4.4   Measurement procedure

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

4.4.4.2   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.

4.4.4.3   Read the level of the signal (S) at the centre frequency of the channel.

4.4.4.4 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 4.4.4.2 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.

4.4.4.5 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 indicated in annex B.

4.4.4.6 Calculate the signal to noise ratio (S/N) by using the following formula:

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

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 Introduction

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 standalone 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 is to be performed by using a suitable connection lead. Ensure correct impedance matching.

To verify the quality of the return path, connect the measurement equipment to the reference point at the head-end 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 ETS 300 800 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. It is expressed as the percentage of time for which the C/MI ratio (in dB) of the channel fulfils the relevant performance requirement.

4.6   Measurement of impulse noise

4.6.1   Introduction

Impulse noise shall be measured with a digitizing 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 on 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 ($f_{-3\text{dB}}$ = 15 MHz, −12 dB/octave) 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 digitizing 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 standalone 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 is to be performed by using a suitable connection lead. Ensure correct impedance matching.

To verify the quality of the return path, connect the measurement equipment to the reference point at the head-end 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.

The trace length shall be 100 μs. The 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 the stored data pulse amplitude, pulse width and pulse interarrival time distributions are calculated. Whether an input filter was used shall be stated with the results.

4.7 Measurement of echo ratio

4.7.1 Introduction

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.

4.7.2 Equipment required

4.7.2.1 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 shall be in accordance with ITU-T Recommendation J.61.

4.7.2.2 A modulator having RF characteristics (excluding sound) appropriate to an analogue television system (see ITU-R Recommendation BT.470) and input characteristics to suit the generator in 4.7.2.1.

4.7.2.3 A synchronous demodulator having characteristics appropriate to the television system under consideration.

4.7.2.4 An oscilloscope of negligible distortion up to 5 MHz.

4.7.3 Connection of the equipment

The equipment shall be connected as in figure 3. The test waveform generator and modulator are connected to the reference point close to a subscriber. The demodulator and oscilloscope are connected to the head-end side reference point. The measuring equipment shall be connected taking care to maintain correct impedance matching.
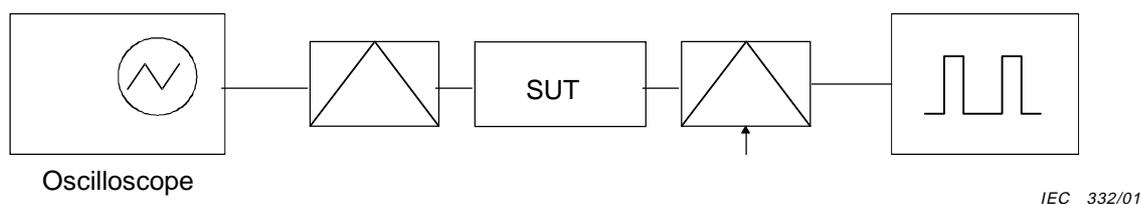
Figure 3 – Arrangement of test equipment for measurement of echo ratio

4.7.4   Measurement procedure

4.7.4.1   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 head-end has typically less echoes and that part is tested only to verify that the contribution to the total system echo ratio is negligible.

4.7.4.2   With the equipment connected as shown in figure 3, 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 ×5 or ×10 so that echoes become visible.

4.7.4.3   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 as a percentage.

4.7.5   Presentation of the results

The echo ratio is the amplitude of the strongest echo (positive or negative) compared to the peak amplitude of the 2T-pulse expressed as a percentage.

4.8   Measurement of group delay variation

Under consideration

4.9   Measurement of frequency error

4.9.1   Introduction

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).
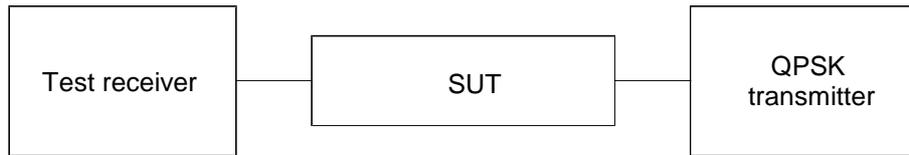
4.9.2   Equipment required

a) QPSK transmitter.

b) Test receiver.

4.9.3   Connection of the equipment

The measuring set-up for the frequency stability measurement is shown in figure 4.

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

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Figure 4 – Test set-up for frequency stability measurement

4.9.4   Measurement procedure

4.9.4.1   Modulate the QPSK transmitter with the PRBS signal.

4.9.4.2   Set the carrier frequency of the QPSK transmitter to the channel where the measurement is to be performed.

4.9.4.3   Adjust the carrier level of the QPSK transmitter to obtain the same level at the system output as in normal operation.

4.9.4.4   Tune the test receiver to the channel that is to be measured. After locking to the carrier frequency, the test receiver shows the regenerated carrier frequency.

4.9.4.5   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 minimize 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.

4.9.5   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.
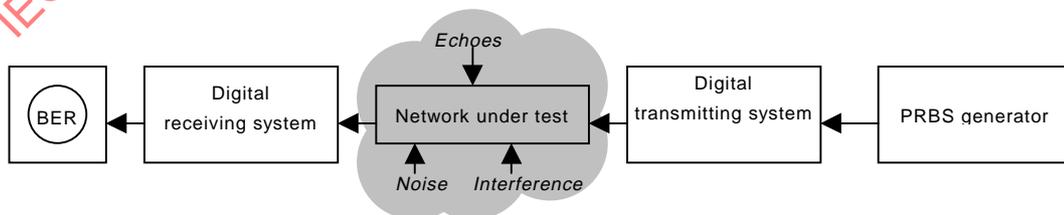
IEC   334/01

Figure 5 – Principle of BER measurement

4.10.2   Introduction

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 5. 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 synchronize 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.), BER also 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 modulator and demodulator are used.

4.10.3   Equipment 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 equalizer and a serial output interface for the PRBS data stream.
f) BER counter connected to the serial output interface of the demodulator.

4.10.4   Connection of the equipment

The measuring set-up for BER measurement is shown in figure 5. 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 to ensure correct impedance matching.

4.10.5   Measurement procedure

4.10.5.1   Apply the PBRS generator at the serial input interface of the modulator to obtain the QPSK modulation format.

4.10.5.2   Set the carrier frequency of the RF signal up-converter to the channel, where the measurement is to be performed.

4.10.5.3   Adjust the carrier level of the RF signal up-converter to obtain the same signal level as in normal operation.

4.10.5.4 Tune the RF signal tuner in the digital receiving system to the channel, at which the measurement is to be performed.

4.10.5.5 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.

4.10.5.6 Due to ingress of noise the BER measurement is repeated every 15 min for 24 h.

4.10.6 Presentation of the results

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

## 5 System performance requirements

5.1 Introduction

The requirements for the return path, laid down in this part of IEC 60728, are based on the existing parts of the IEC 60728 series and their 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.

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 6);

b) effects of downstream signals (e.g. intermodulation products) disturbing upstream signals (figure 7);

c) effects of upstream signals of service 1 (e.g. spurious signals) disturbing the upstream signals of a different service 2 (figure 8);

d) effects between upstream signals (e.g. intermodulation products) pertaining to the same service (figure 9).

For the first three cases the IEC 60728 series of standards set the limits so that interference will not occur. For case d) it is necessary to use system-inherent measures to manage interference.
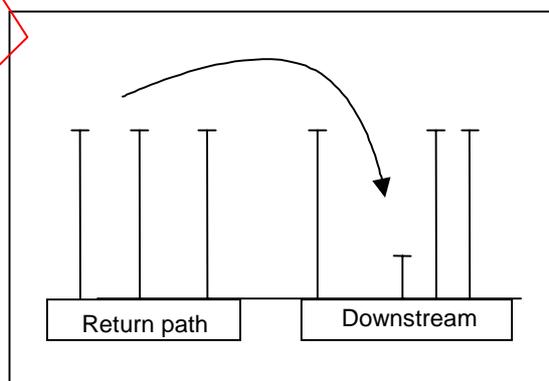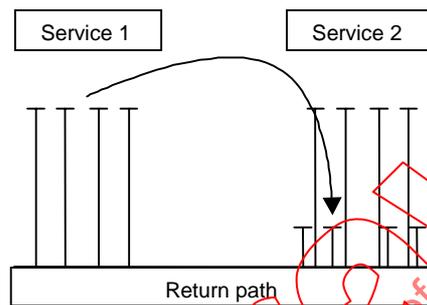
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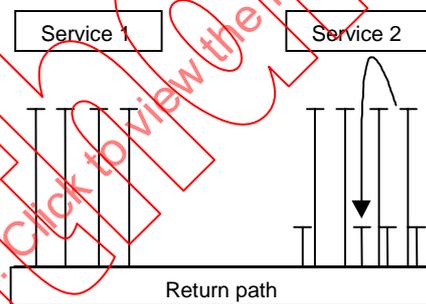**Figure 6 – Upstream signals affecting downstream signals**
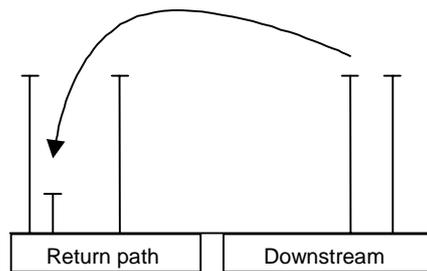
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Figure 7 – Downstream signals affecting upstream signals

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Figure 8 – Upstream signals of service 1 affecting upstream signals of a different service (e.g. service 2)

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Figure 9 – 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 the Reed-Solomon decoder is required for the reference signal, which is the 3,088 Mbit/s QPSK modulated signal specified in ETS 300 800. 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　inherent parameters 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 such as 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.

Establishing the requirements for the return path means finding the limiting values for the parameters mentioned above. This has been done 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 BER can result from several simultaneous distortions. Therefore sufficient margins have been added.

The main advantage in providing this link from BER 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 of 20 dB(pW) and the screening effectiveness according to EN 50083-2.

As an example, for a screening effectiveness of 75 dB and a single unmodulated 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   Digitally modulated signals are under consideration.

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

5.4 Specific system performance requirements

The return path system performance requirements for analogue parameters are listed in table 3. These requirements apply to the 3,088 Mbit/s QPSK signal, which is specified in ETS 300 800. Each of these values includes a safety margin taking into account the facts that all these parameters could occur simultaneously and that an overall BER of 10^{-4} shall be achieved.

If less robust types of signals (e.g. 16 QAM) are used, more stringent values shall be used. Annex A gives more information about the theoretical values for each parameter by which a BER of 10^{-4} can be achieved on condition that all the other parameters are ideal.

**Table 3 – System performance requirements using a reference signal
according to ETS 300 800 (QPSK grade C)**

Parameter	Requirement
Carrier to noise ratio	≥22 dB (BW = 1,544 MHz)
Amplitude response	≤2,5 dB/2 MHz
Carrier to multiple interference ratio	≥22 dB/1,544 MHz
Carrier to impulse noise	under consideration
Hum modulation	≤7 %
Echo ratio	≤15 %
Group delay variation	≤300 ns/2 MHz
Frequency error	±30 kHz

6   System performance recommendations

6.1   Proposal for the use of the return path bandwidth

6.1.1   Frequency allocation

Table 4 shows recommended frequency ranges for the return path assuming that the FM radio band starts at 87,5 MHz.

Table 4 – Return path frequency ranges

Upstream frequency range MHz	Upstream bandwidth MHz	Band I downstream	Band gap below FM radio band for narrowband services
5...30	25	yes	yes
5...50 [1]	45	no	yes
5...65	60	no	no
[1] or 5 MHz to 40 MHz, 5 MHz to 55 MHz, 5 MHz to 60 MHz, etc.			

6.1.2   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 10 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 5. Local transmitter stations can further impair the available bandwidth. Frequencies used for emergency services shall not be used for data transmission.

Table 5 – Reasons for quality reduction in sub-bands of the return path

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

5   10   15   30   50   60   65   f [MHz]

27   33,4   38,9

CB radio   TV IF

restricted usable
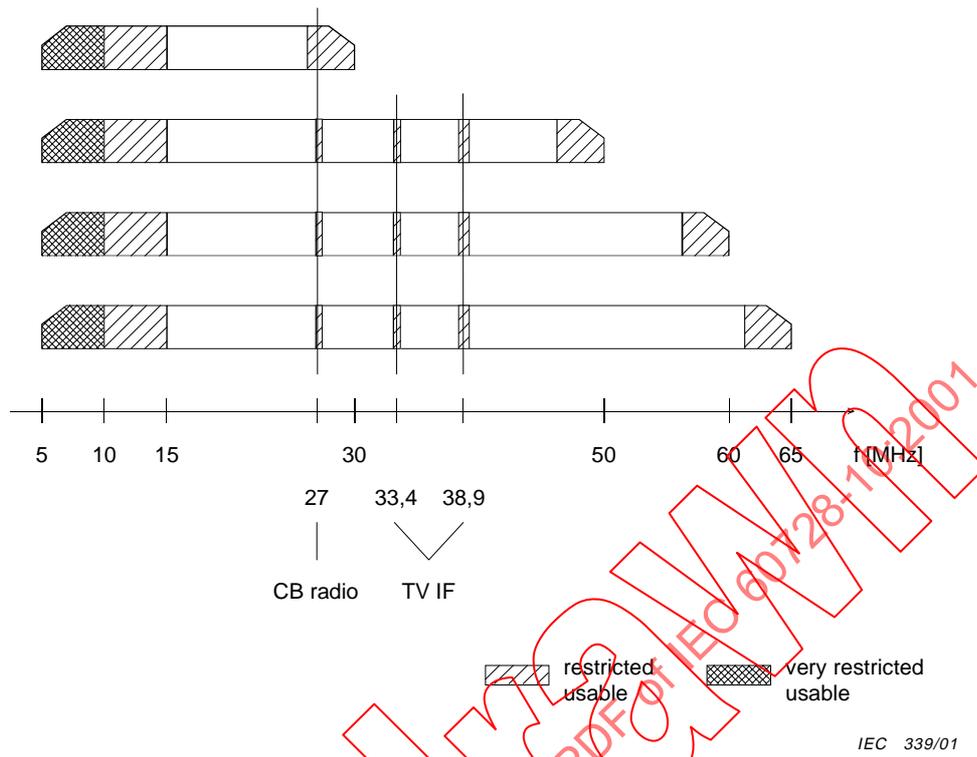
very restricted usable

IEC 339/01

**Figure 10 – Identification of the most common sub-bands within the return path band
with limited transmission quality**

Annex A
(informative)

System performance requirements for different modulation techniques

Table A.1 is not a list of requirements, but gives some information on how different parameters reduce BER to 10^{-4} for different modulation techniques. The parameter under consideration is the dominant one and the influences of all others are assumed to be minimal. Therefore sufficient margins should be added for practical conditions as may be seen for QPSK in table 3. An empty cell indicates that the parameter is not important or reliable information is not available.

Table A.1 – System performance requirements for different modulation techniques for BER = 10^{-4}

Modulation	C/N	Amplitude response	Group delay variation	Phase noise (reference carrier)	Frequency error	Echo ratio
FSK	7 dB					
QPSK	11 dB	3 dB		−70 dB(Hz^{-1}) at 3 kHz		
Burst QPSK	14 dB	3 dB		−70 dB(Hz^{-1}) at 3 kHz		
OFDM (16 QAM)	17 dB					
OFDM (64 QAM)	23 dB					
16 QAM	20 dB	3 dB	300 ns	−80 dB(Hz^{-1}) at 3 kHz	±200 kHz	15 dB at 0,5 µs 30 dB > 1,5 µs
64 QAM	26 dB	3 dB	200 ns	−85 dB(Hz^{-1}) at 3 kHz	±200 kHz	