

INTERNATIONAL STANDARD

NORME INTERNATIONALE



**Cable networks for television signals, sound signals and interactive services –
Part 3: Active wideband equipment for cable networks**

**Réseaux de distribution par câbles pour signaux de télévision, signaux de
radiodiffusion sonore et services interactifs –
Partie 3: Matériel actif à large bande pour réseaux de distribution par câbles**



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INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

COMMISSION
ELECTROTECHNIQUE
INTERNATIONALE

PRICE CODE
CODE PRIX

XB

ICS 33.060.40; 33.170

ISBN 978-2-88912-576-0

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Withdrawn

INTERNATIONAL ELECTROTECHNICAL COMMISSION

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

Part 3: Active wideband equipment for cable networks

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International Standard IEC 60728-3 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 fourth edition cancels and replaces the third edition published in 2005 of which it constitutes a technical revision.

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

- extension of upper frequency range limit for cable network equipment from 862 MHz to 1 000 MHz;
- method of measurement and requirements for immunity to surge voltages;
- extension of scope to equipment using symmetrical ports;
- additional normative references;

- additional terms and definitions and abbreviations.

This bilingual version, published in 2011-07, corresponds to the English version.

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

FDIS	Report on voting
100/1746/FDIS	100/1766/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.

The French version of this standard has not been voted upon.

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

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

The committee has decided that the contents of this publication will remain unchanged until the stability 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.

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

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

This includes

- CATV¹-networks;
- MATV-networks and SMATV-networks;
- individual receiving networks;

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

For active equipment with balanced RF signal ports this standard applies to those ports which carry RF broadband signals for services as described in the scope of this standard.

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

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

¹ This word encompasses the HFC (Hybrid Fibre Cable) networks used nowadays to provide telecommunications services, voice, data, audio and video both broadcast and narrowcast.

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

Part 3: Active wideband equipment for cable networks

1 Scope

This part of IEC 60728 lays down the measuring methods, performance requirements and data publication requirements for active wideband equipment of cable networks for television signals, sound signals and interactive services.

This standard

- applies to all broadband amplifiers used in cable networks;
- covers the frequency range 5 MHz to 3 000 MHz;

NOTE The upper limit of 3 000 MHz is an example, but not a strict value. The frequency range, or ranges, over which the equipment is specified, should be published.

- applies to one-way and two-way equipment;
- lays down the basic methods of measurement of the operational characteristics of the active equipment in order to assess the performance of this equipment;
- identifies the performance specifications to be published by the manufacturers;
- states the minimum performance requirements of certain parameters.

Amplifiers are divided into the following two quality levels:

Grade 1: amplifiers typically intended to be cascaded;

Grade 2: amplifiers for use typically within an apartment block, or within a single residence, to feed a few outlets.

Practical experience has shown that these types meet most of the technical requirements necessary for supplying a minimum signal quality to the subscribers. This classification is not a requirement but is provided to users and manufacturers for information about minimum quality criteria of the material required to install networks of different sizes. The system operator has to select appropriate material to meet the minimum signal quality at the subscriber's outlet, and to optimise cost/performance, taking into account the size of the network and local circumstances.

All requirements and published data are understood as guaranteed values within the specified frequency range and in well-matched conditions.

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 60065, *Audio, video and similar electronic apparatus – Safety requirements*

IEC 60068-1:1998, *Environmental testing – Part 1: General and guidance*

IEC 60068-2-1, *Environmental testing – Part 2-1: Tests – Tests A: Cold*

- IEC 60068-2-2, *Environmental testing – Part 2-2: Tests – Tests B: Dry heat*
- IEC 60068-2-6, *Environmental testing – Part 2-6: Tests – Test Fc: Vibration (sinusoidal)*
- IEC 60068-2-14, *Environmental testing – Part 2-14: Tests – Test N: Change of temperature*
- IEC 60068-2-27, *Environmental testing – Part 2-27: Tests – Test Ea and guidance: Shock*
- IEC 60068-2-29, *Basic environmental testing procedures – Part 2-29: Tests – Test Eb and guidance: Bump*
- IEC 60068-2-30, *Environmental testing – Part 2-30: Tests – Test dB: Damp heat, cyclic (12 h + 12 h cycle)*
- IEC 60068-2-31, *Environmental testing – Part 2-31: Tests – Test Ec: Rough handling shocks, primarily for equipment-type specimens*
- IEC 60068-2-32, *Basic environmental testing procedures – Part 2-32: Tests – Test Ed: Free fall*
- IEC 60068-2-40, *Basic environmental testing procedures – Part 2-40: Tests – Test Z/AM: Combined cold/low air pressure tests*
- IEC 60068-2-48, *Basic environmental testing procedures – Part 2-48: Tests – Guidance on the application of the tests of IEC publication 60068 to simulate the effects of storage*
- IEC 60529, *Degrees of protection provided by enclosures (IP Code)*
- IEC 60728-1, *Cable networks for television signals, sound signals and interactive services – Part 1: System performance of forward paths*
- IEC 60728-2, *Cable networks for television signals, sound signals and interactive services – Part 2: Electromagnetic compatibility for equipment*
- IEC 60728-4, *Cable networks for television signals, sound signals and interactive services – Part 4: Passive wideband equipment for coaxial cable networks*
- IEC 60728-5, *Cable networks for television signals, sound signals and interactive services – Part 5: Headend equipment*
- IEC 60728-11, *Cable networks for television signals, sound signals and interactive services – Part 11: Safety*
- IEC 60950-1, *Information technology equipment – Safety – Part 1: General requirements*
- IEC 61000-4-5, *Electromagnetic compatibility (EMC) – Part 4-5: Testing and measurement techniques – Surge immunity test*
- IEC 61319-1, *Interconnections of satellite receiving equipment – Part 1: Europe*
- IEC 61319-2, *Interconnections of satellite receiving equipment – Part 2: Japan*
- ITU-T Recommendation G.117, *Transmission systems and media – Digital systems and networks – International telephone connections and circuits – General recommendations on the transmission quality for an entire international telephone connection – Transmission aspects of unbalance about earth*
- ITU-T Recommendation O.9, *Specifications of measuring equipment – General – Measuring arrangements to assess the degree of unbalance about earth*

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 frequency response

gain or loss of an equipment or system plotted against frequency

3.1.2

attenuation

ratio of the input power to the output power of an equipment or system, usually expressed in decibels

3.1.3

balun

device to match symmetrical impedance $100\ \Omega$ (balanced) to un-symmetrical impedance $75\ \Omega$ (unbalanced) and vice-versa

3.1.4

carrier-to-noise ratio

difference in decibels between the vision or sound carrier level at a given point in an equipment or system and the noise level at that point (measured within a bandwidth appropriate to the television or radio system in use)

3.1.5

chrominance-luminance delay inequality

difference in transmission delay of chrominance and luminance signals, which results in the spilling of colour to left or right of the area of corresponding luminance

[IEC 60050-723:1997, 723-06-61]

3.1.6

composite intermodulation noise

CIN

sum of noise and intermodulation products from digital modulated signals

3.1.7

composite intermodulation noise ratio

CINR

ratio of the signal level and the CIN level

3.1.8

crossmodulation

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

3.1.9

crosstalk attenuation

unwanted signals beside the wanted signal on a lead caused by electromagnetic coupling between leads; ratio of the wanted signal power to the unwanted signal power, while equal signal powers are applied to the leads

NOTE Crosstalk attenuation is usually expressed in decibels.

3.1.10

decibel ratio

ten times the logarithm of the ratio of two quantities of power P_1 and P_2 , i.e.

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

3.1.11

equaliser

device designed to compensate over a certain frequency range for the amplitude/frequency distortion or phase/frequency distortion introduced by feeders or equipment

NOTE This device is for the compensation of linear distortions only.

3.1.12

feeder

transmission path forming part of a cable network

NOTE Such a path may consist of a metallic cable, optical fibre, waveguide or any combination of them. By extension, the term is also applied to paths containing one or more radio links.

3.1.13

gain

ratio of the output power to the input power, usually expressed in decibels

3.1.14

ideal thermal noise

noise generated in a resistive component due to the thermal agitation of electrons

NOTE The thermal power generated is given by

$$P = 4 \cdot B \cdot k \cdot T$$

where

P is the noise power in watts;

B is the bandwidth in hertz;

k is the Boltzmann's constant = $1,38 \cdot 10^{-23}$ J/K;

T is the absolute temperature in kelvins.

It follows that

$$\frac{U^2}{R} = 4 \cdot B \cdot k \cdot T$$

and

$$U = \sqrt{4 \cdot R \cdot B \cdot k \cdot T}$$

where

U is the noise voltage (e.m.f.);

R is the resistance in ohms.

In practice, it is normal for the source to be terminated with a load equal to the internal resistance value, the noise voltage at the input is then $U/2$.

3.1.15

level

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

$$10 \lg \frac{P_1}{P_0}$$

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

$$20 \lg \frac{U_1}{U_0}$$

NOTE The power level may be expressed in decibels relative to $P_0 = (U_0^2/R) = (1/75) \text{ pW}$, i.e. in $\text{dB}(P_0)$, taking into account that the level of P_0 corresponds to 0 $\text{dB}(P_0)$ or, as more usually, in $\text{dB}(\text{pW})$, taking into account that the level of P_0 corresponds to $-18,75 \text{ dB}(\text{pW})$. The voltage level is expressed in decibels relative to 1 μV (across 75 Ω), i.e. in $\text{dB}(\mu\text{V})$.

3.1.16

modulation error ratio

MER

sum of the squares of the magnitudes of the ideal symbol vectors is divided by the sum of the squares of the magnitudes of the symbol error vectors of a sequence of symbols, the result being expressed as a power ratio in dB

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

3.1.17

multi-switch

equipment used in distribution systems for signals that are received from satellites and converted to a suitable IF

NOTE The IF signals that are received from different polarisations, frequency bands and orbital positions are input signals to the multi-switch. Subscriber feeders are connected to the multi-switch output ports. Each output port is switched to one of the input ports, depending on control signals that are transmitted from the subscriber equipment to the multi-switch. Besides a splitter for each input port and a switch for each output port, a multi-switch can contain amplifiers to compensate for distribution or cable losses.

3.1.18

multi-switch loop through port

one or more ports to loop through the input signals through a multi-switch

NOTE This enables larger networks with multiple multi-switches, each one installed close to a group of subscribers. The multi-switches are connected in a loop through manner. The IF signals that are received by an outdoor unit from different polarisations, frequency bands and orbital positions are input signals to a first multi-switch. Cables connect the loop through ports of this multi-switch to the input ports of a second multi-switch and so on.

3.1.19

multi-switch port for terrestrial signals

port in a multi-switch used to distribute terrestrial signals in addition to the signals received from satellites

3.1.20

noise factor/noise figure

used as figures of merit describing the internally generated noise of an active device

NOTE The noise factor, F , is the ratio of the carrier-to-noise ratio at the input, to the carrier-to-noise ratio at the output of an active device.

$$F = \frac{C_1/N_1}{C_2/N_2}$$

where

- C_1 is the signal power at the input;
- C_2 is the signal power at the output;
- N_1 is the noise power at the input (ideal thermal noise);
- N_2 is the noise power at the output.

In other words, the noise factor is the ratio of noise power at the output of an active device to the noise power at the same point if the device had been ideal and added no noise.

$$F = \frac{N_{2\text{actual}}}{N_{2\text{ideal}}}$$

The noise factor is dimensionless and is often expressed as noise figure, NF , in dB

$$NF = 10 \lg F \quad \text{in dB}$$

3.1.21

slope

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

NOTE The slope sign is considered

- a) negative when the attenuation increases with frequency (cables) or the gain (amplifiers) decreases with frequency,
- b) positive when the gain (amplifiers) increases with frequency (compensating slope).

3.1.22

standard reference power and voltage

in cable networks, the standard reference power, P_0 , is (1/75) pW

NOTE 1 This is the power dissipated in a 75 Ω resistor with an RMS voltage drop of 1 μV across it.

NOTE 2 The standard reference voltage, U_0 , is 1 μV .

3.1.23

surge voltage

produced by a direct or indirect lightning stroke

3.1.24

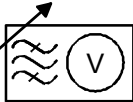
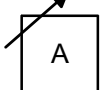
well-matched

matching condition when the return loss of the equipment complies with the requirements of Table 3

NOTE Through mismatching of measurement instruments and the measurement object, measurement errors are possible. Comments to the estimation of such errors are given in Annex E.

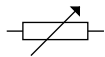
3.2 Symbols

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
	Amperemeter based on [IEC 60617-S00910 (2001-07)]		Voltmeter based on [IEC 60617-S00910 (2001-07)]
	Selective voltmeter		Power meter based on [IEC 60617-S00910 (2001-07)]
	Equipment Under Test based on [IEC 60617-S00059 (2001-07)]		Signal generator based on [IEC 60617-S00899, IEC 60617-S01403 (2001-07)]
	Noise generator [IEC 60617-S01230 (2001-07)]		Variable signal genera- tor based on [IEC 60617-S00081, IEC 60617-S00899, IEC 60617-S01403 (2001-09)]
	Surge generator [IEC 60617-S01228 (2001-07)]		VSWR-bridge
	High-pass filter [IEC 60617-S01247 (2001-07)]		Low-pass filter [IEC 60617-S01248 (2001-07)]
	Band-stop filter [IEC 60617-S01250 (2001-07)]		Band-pass filter [IEC 60617-S01249 (2001-07)]
	Oscilloscope based on [IEC 60617-S00059, and IEC 60617-S00922 (2001-07)]		Spectrum analyzer (electrical) based on [IEC 60617-S00910 (2001-07)]
	Attenuator based on [IEC 60617-S01244 (2001-07)]		Variable attenuator [IEC 60617-S01245 (2001-07)]
	Combiner based on [IEC 60617-S00059 (2001-07)]		Tap-off-box
	Double tap-off-box		Optical receiver [IEC 60617-S00213 (2001-07)]

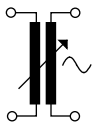
Symbols

Terms

	Amplifier with return path amplifier [IEC 60617-S00433 (2001-07)]
	Functional equipotential bonding [IEC 60617-S01410 (2001-11)]
	Variable resistor [IEC 60617-S00557 (2001-07)]
	RF choke [IEC 60617-S00583 (2001-07)]

Symbols

Terms

	Detector with LF-amplifier
	Adjustable AC voltage source
	Capacitor [IEC 60617-S00567 (2001-07)]

3.3 Abbreviations

AC	alternating current
AF	audio frequency
AGC	automatic gain control
AM	amplitude modulation
BER	bit error ratio
CATV	community antenna television (system)
CIN	composite intermodulation noise
CINR	composite intermodulation noise ratio
CSO	composite second order
CTB	composite triple beat
CW	continuous wave
CXM	composite crossmodulation
DC	direct current
EMC	electromagnetic compatibility
EUT	equipment under test
HP	high pass
IF	intermediate frequency
IP	international protection
LF	low frequency
LP	low pass
MATV	master antenna television (system)
MER	modulation error ratio
MTBF	meantime between failure
OMI	optimum modulation index
PAL	phase alternating line
PID	packet identifier
PRBS	pseudo-random bit sequence

QAM	quadrature amplitude modulation
QPSK	quadrature phase shift keying
RF	radio frequency
RMS	root mean square
RS	rotary switch
SECAM	sequential colour with memory (séquentiel couleur à mémoire)
SG	signal generator
SMATV	satellite master antenna television (system)
TV	television
UHF	ultra-high frequency
VHF	very-high frequency
VSWR	voltage standing wave ratio
XM	crossmodulation

4 Methods of measurement

4.1 General

This clause defines basic methods of measurement. Any equivalent method that ensures the same accuracy may be used for assessing performance.

Unless stated otherwise, all measurements shall be carried out with 0 dB plug-in attenuators and equalisers. The position of variable controls used during the measurements shall be published.

The test set-up shall be well-matched over the specified frequency band.

A network can be used to distribute terrestrial signals in addition to the signals received from satellites. The terrestrial antennas are connected to an optional terrestrial input port of a multi-switch. On each output port the terrestrial signals are available in addition to the satellite IF signals. Since the usual frequency ranges for terrestrial signals and satellite IF signals do not overlap, both can be carried on the same cable.

For large networks with loop through connected multi-switches, two possibilities exist to carry the terrestrial signals from one multi-switch to another multi-switch:

- to use a specialised cable for the terrestrial signal, in addition with the cables used for the satellite IF signals and then, on each output port the terrestrial signal is combined with the selected satellite IF signal;
- to combine the terrestrial signal with each satellite IF signal before the first multi-switch in order to minimise the number of cables between multi-switches.

NOTE The signal coming from an outdoor unit for satellite reception may contain unwanted signal-components with frequencies below the foreseen satellite IF frequency range. These signal-components overlap with the frequency range of terrestrial signals. For example, an outdoor unit that converts the frequency band 11,7 GHz to 12,75 GHz to the satellite IF frequency range may convert signals in the 10,7 GHz to 11,7 GHz band to frequencies below the satellite IF frequency range. These frequencies have to be filtered out sufficiently to avoid interference with terrestrial signals on the same cable.

For measurements on multi-switches, it is necessary that control signals be fed to the output ports that are involved in the measurement. Therefore, a bias-tee has to be connected between the multi-switch output port and the measurement set. The DC port of the bias-tee is connected to a standard receiver that generates the required control signals. Care has to be taken that the influence of the bias-tee on the measurement result is insignificant. This can be

achieved by including it into the calibration or using a network analyzer with a built in bias-tee.

Measurements on active equipment with symmetrical ports shall be performed using a measurement balun. The symmetry (common mode suppression) of the output signal of such a measurement balun shall be >30 dB for 100 MHz to 1 000 MHz and >50 dB for 30 MHz to 100 MHz. The common mode suppression shall be measured according to ITU-T Rec. G.117 and ITU-T Rec. O.9. The return loss of the measurement balun shall be 10 dB higher than the return loss of the EUT to which the coaxial measurement equipment is connected via the measurement balun.

4.2 Linear distortion

4.2.1 Return loss

4.2.1.1 General

The method described is applicable to the measurement of the return loss of equipment operating in the frequency range 5 MHz to 3 000 MHz.

All input and output ports of the unit shall meet the specification under all conditions of automatic and manual gain controls and with any combination of plug-in equalisers and attenuators fitted.

4.2.1.2 Equipment required

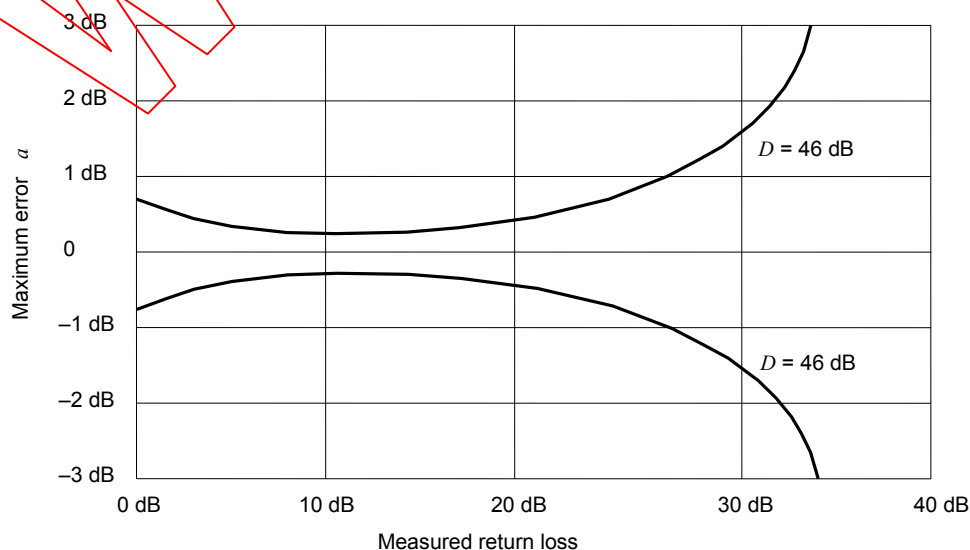
The following equipment is required.

- A signal generator or sweep generator, adjustable over the frequency range of the equipment to be tested.

Care shall be taken to ensure that the signal generator or sweep generator output does not have a high harmonic content as this can cause serious inaccuracy.

- A voltage standing wave ratio bridge with built-in or separate RF detector.

The accuracy of measurement is dependent on the quality of the bridge. In particular on the directivity and on the return loss of the test port of the bridge. For example Figure 1 shows the maximum accuracy achieved by a bridge with 46 dB directivity and 26 dB return loss.



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Figure 1 – Maximum error α for measurement of return loss using VSWR-bridge with directivity $D = 46$ dB and 26 dB test port return loss

- c) An oscilloscope.
- d) Calibrated mismatches.

NOTE The signal generator and the oscilloscope can be replaced by a spectrum analyzer and a tracking generator or by a network analyzer connected directly to the EUT.

4.2.1.3 Connection of equipment

The equipment shall be connected as in Figure 2.

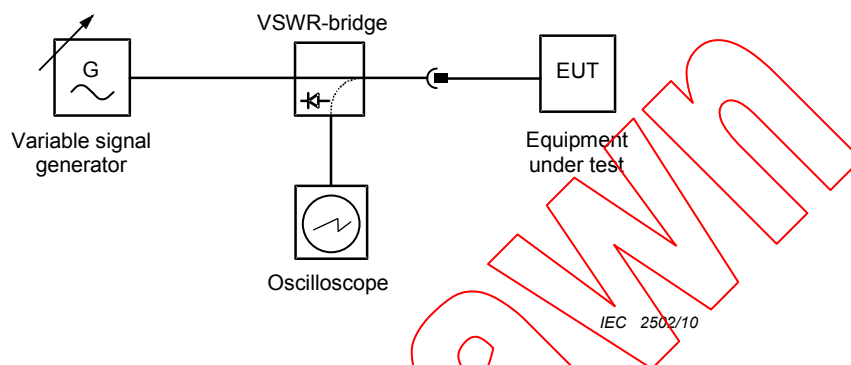


Figure 2 – Measurement of return loss

4.2.1.4 Measurement procedure

All coaxial input and output ports, other than those under test, shall be terminated in $75\ \Omega$.

Ensure that there is no supply voltage on the port being measured as this could damage the bridge. If it is necessary to use a voltage blocking device, use one with a good return loss (10 dB above requirement).

Only good quality calibrated connectors, adaptors and cables shall be used.

The measurement procedure comprises the following steps:

- a) connect the equipment as shown in Figure 2;
- b) set the signal generator output level so that the equipment under test is not overloaded;
- c) use calibrated mismatches to calibrate the display on the oscilloscope;
- d) connect the equipment under test as shown in Figure 2 and check the return loss over the specified frequency range.

4.2.2 Flatness

Methods of measurement are well-known and a full description of the procedure is not necessary.

Measurement is commonly made with a $75\ \Omega$ scalar or vector network analyzer. Care shall be taken that all equipment used (connectors, adaptors, cable, etc.) are well-matched.

4.2.3 Chrominance/luminance delay inequality for PAL/SECAM only

The well-known 20T pulse method of measurement is used as described in IEC 60728-5.

4.3 Non-linear distortion

4.3.1 General

In a non-linear device, the expression for the output signal will, in general, have an infinity of terms, each generated from one or more of the (assumed sinusoidal) terms in the input, and particularly by the interaction of two or more terms. A detailed derivation is described in the Annex A.

A method of measurement of non-linearity for pure digital channel load is under consideration.

4.3.2 Types of measurements

Measurements related to the following phenomena are described:

- intermodulation between two or three single frequency signals;
- composite beats produced by a number of single frequency signals;
- composite crossmodulation between a number of single frequency signals.

A proper specification shall include at least the following details:

- a) the particular effect that is measured;
- b) the required signal to distortion ratio.

The result of the measurement shall be given as the worst-case maximum signal level at the equipment output that allows the required signal to distortion ratio to be met. If the output level is sloped with frequency, this shall be defined.

The effect shall be defined as being of a particular order (e.g. "third-order intermodulation").

4.3.3 Intermodulation

4.3.3.1 General

The two equal carrier and the three equal carrier methods described are applicable to the measurement of the ratio of the carrier to a single intermodulation product at a specified point within the cable network. The methods can also be used to determine the intermodulation performance of individual items of equipment.

NOTE 1 It should be especially noted that the simultaneous use of many channels spaced by the same frequency interval results in a large number of intermodulation products (particularly those of the third-order) falling near the vision carrier of a wanted television channel.

In these cases, the resultant interference is of an extremely complex nature and an alternative measurement procedure will be needed. This is covered in 4.3.4 and 4.3.5.

Examples of second-order and third-order intermodulation products are given in Annex B.

Second-order products are encountered only in wideband equipment and systems, covering more than one octave, and shall be measured using two signals (see Clause B.1).

Third-order products are encountered in wideband and narrowband equipment and systems and shall be measured using three signals (see Clause B.2).

NOTE 2 If the unequal carrier method of measurement, as described in IEC 60728-5, is used, the output level giving the appropriate signal to distortion ratio must be decreased by 6 dB to obtain the correct result for the equal carrier method described here.

4.3.3.2 Equipment required

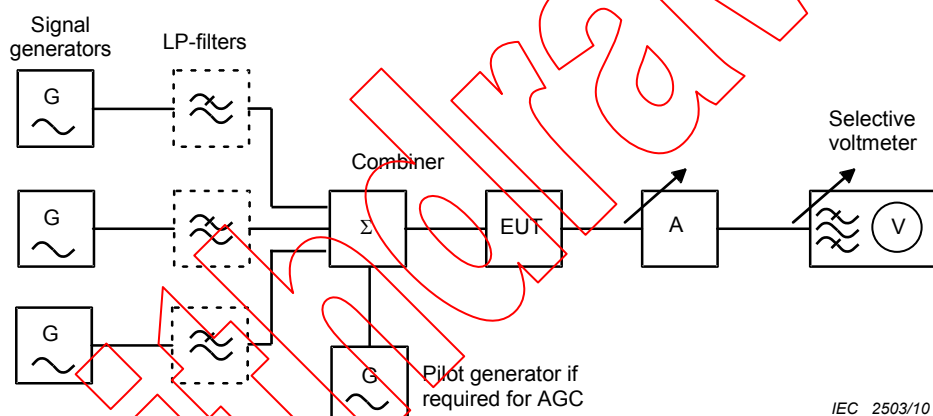
The following equipment is required.

- A selective voltmeter covering the frequency range of the equipment or system to be tested. This may be a spectrum analyzer.
- The appropriate number of signal generators covering the frequencies at which the tests are to be carried out.
- A variable attenuator with a range greater than the signal to intermodulation ratio expected, if not incorporated in the voltmeter described in 4.3.3.2 a).
- A combiner will be required for tests on equipment and systems with a single input (Figure 3).

NOTE Additional items may be necessary, for example to ensure that the measurements are not affected by spurious signals generated in the test equipment itself (Annex C).

4.3.3.3 Connection of equipment

The equipment shall be connected as shown in Figure 3.



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NOTE 1 The requirement for the items of test equipment indicated by dotted lines depends on the results of checks given in Annex C. The filters at the signal generator outputs may be needed to suppress spurious signals. The selective voltmeter input filter may be required to prevent intermodulation in the meter. If a filter is used, then the possible mismatch should be avoided by not reducing the attenuator value below 10 dB.

NOTE 2 To avoid intermodulation between the signal generators, it may be necessary for the combiner to be in the form of one or more directional couplers (see Annex C).

Figure 3 – Basic arrangement of test equipment for evaluation of the ratio of signal to intermodulation product

4.3.3.4 Measurement procedure

The measurement procedure comprises the following steps.

a) General

Unless otherwise required, the reference output levels used in the measurements shall be the nominal output levels for the equipment. It shall be quoted whether the signal output levels are constant over the frequency range or not. If the specified output levels are not constant over frequency range then the output levels of all the test signals shall be quoted in the results.

Measurements of both second order and third order products shall be carried out with the test signals widely and closely spaced over each band of interest at frequencies capable of producing significant products within the overall frequency range.

Where the equipment to be measured includes automatic gain control, tests shall be carried out at the nominal operating signal input levels.

b) Calibration and checks

A check shall be made to determine if the harmonics and other spurious signals at the outputs of the signal generators are likely to affect materially the results of the measurements (see Annex C).

The selective voltmeter shall be calibrated and checked for satisfactory operation (see Annex C).

A check shall be made for possible intermodulation between the signal generators at the output levels to be used for the tests (see Annex C).

c) Measurement

Set the signal generators, in CW mode, to the frequencies of the test signals (see 4.3.3.4 a) and Annex B) and adjust their outputs and that of the different points of the system as far as the point of measurement to obtain the specified system operating levels throughout.

Connect the variable attenuator and selective voltmeter and other items if required (see Annex C) to the output of the equipment under test. Tune the meter to each test signal and note the attenuator value a_1 required to obtain a convenient meter reading R for the reference signal. The attenuator value a_1 should be slightly greater than the signal to intermodulation ratio expected at the point of measurement.

Tune the meter to the intermodulation product to be measured and reduce the setting of the variable attenuator to the value a_2 required to obtain the same meter reading R .

NOTE When measuring levels of intermodulation products, it may be necessary to insert a filter at the input to the meter (see Annex C). In such instances the insertion loss (in dB) of the filter at the frequency of the products shall be added to the attenuator value.

The signal to intermodulation product ratio in dB is given by

$$S/I = a_1 - a_2$$

where

a_1 is the attenuator value for the test signal used as a reference in dB;

a_2 is the attenuator value for the intermodulation product in dB.

4.3.4 Composite triple beat

4.3.4.1 General

The method of measurement of composite triple beat using CW signals is applicable to the measurement of the ratio of the carrier to composite triple beat at a specified point in a cable network. The method can also be used to determine the composite triple beat intermodulation performance of individual items of equipment.

When the input signals are at regularly spaced intervals (as is common in most allocations for TV channels), the various distortion products tend to cluster in groups, close to the TV channels. The number of different products in each cluster increases rapidly with the number of

channels, and they combine in different ways, depending on the degree of coherence between generating signals, and the relative phases of the different distortion products.

The method described in this subclause measures the non-linear distortion of a device or system by the composite effect of all the beats clustered within ± 15 kHz of the vision carrier of a TV channel. During the measurement, the vision carrier of that channel shall be turned off, so that the composite triple beat measured is that generated by all the carriers except that of the measured channel.

The method is used to support a specification of the following general format:

"The composite triple beat ratio for groups of carriers in channel (A) at (B) dB(μ V) is (C) dB."

where

- (A) designates the channel in which the test is made. If omitted, the specification is understood to be a minimum specification for measurements at all the channels specified by the list of carriers;
- (B) is the reference level at which all the carriers should be set during the measurement, unless otherwise specified. If all the carriers are not at the same level, the specification should clearly indicate the level of each carrier relative to the reference level;
- (C) is the composite triple beat ratio, usually given as a minimum specification.

Because of the large variety of frequency plans in use throughout the world and the need to compare readily performance specifications of different manufacturer's equipment, the measurement should be made with the carriers listed in Annex D (the carriers are all in an 8 MHz raster, except for the special case of 48,25 MHz).

The vision carrier frequencies are arranged in groups and only complete groups shall be used, except as stated below. If an amplifier is specified up to 450 MHz, group A shall be used. If specified up to 550 MHz, groups A and B shall be used. If specified up to 862 MHz, all groups A, B, C, D and E shall be used.

If an amplifier is specified up to 1 000 MHz the method of measurement for pure digital channel load should be used. This method of measurement is currently under consideration.

Group A can also be used in part, dependent on the specified bandwidth of the equipment under test. The frequencies deleted shall be stated. If the carrier 48,25 MHz is not used in case where the forward path starts with 85 MHz, then the results of measurements shall be published including the notice "without Band I". If the equipment can operate at all frequencies in group A this result shall be quoted together with the result where only a part of group A is used.

For all pass bands, the performance shall be quoted for the maximum possible number of complete groups. The manufacturer may, in addition, provide a performance figure for a larger number of carriers. The frequencies deleted shall be stated.

4.3.4.2 Equipment required

The following equipment is required:

- a) a spectrum analyzer with 30 kHz intermediate frequency (IF) bandwidth and 10 Hz video bandwidth capability;

NOTE When using a spectrum analyzer with minimum video filtering capabilities greater than 10 Hz, the composite third-order distortion may be noisy and should be read at the middle of the trace.

- b) a variable 75 Ω attenuator, adjustable in 1 dB steps;

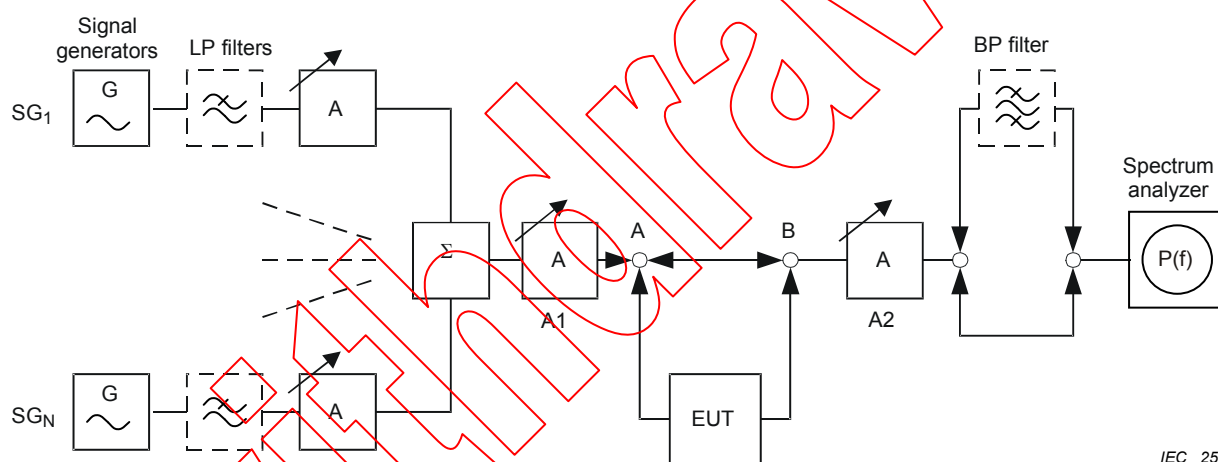
- c) a bandpass filter for each channel to be tested or a tunable bandpass filter. This filter shall attenuate the other channels present on the system to be tested sufficiently to ensure that the products generated by non-linearity in the spectrum analyzer itself do not contribute significantly to the composite beat products to be measured.

The passband of this filter shall be flat, at least to within 1 dB over the frequency range of interest, and shall be well-matched over the complete frequency band. If necessary, a fixed attenuator shall be connected at the input to the filter;

- d) CW generators, operating at the frequencies of the vision carriers used in the system to be tested; The tuning accuracy and stability shall be better than ± 5 kHz. The number of generators needed is governed by the number of groups of frequencies used for the tests (see 4.3.4.1);
- e) a combiner for the signals from the generators;
- f) matching devices, attenuators and filters, etc. to obtain the correct signal levels, matching conditions and reduction of spurious signals at the input of the system.

4.3.4.3 Connection of equipment

The equipment shall be connected as shown in Figure 4.



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Figure 4 – Connection of test equipment for the measurement of non-linear distortion by composite beat

4.3.4.4 Measurement procedure

The measurement procedure comprises the following steps:

- a) connect point A directly to point B and disconnect the bandpass filter (see Figure 4). Adjust the level of each generator for an output level at point A equal to that which will be present when the system or equipment under test is connected;
- b) adjust the spectrum analyzer as follows:
- | | |
|-----------------|-------------|
| IF bandwidth | 30 kHz |
| video bandwidth | 10 Hz |
| scan width | 50 kHz/div. |
| vertical scale | 10 dB/div. |
| scan time | 0,5 s/div |
- c) tune the spectrum analyzer so that the vision carrier of the channel in which the measurement is to be made is centred on the display screen;

- d) adjust the sensitivity of the spectrum analyzer together with its internal and external input attenuator in such a way that the response to the vision carrier corresponds to a full scale reference. At the same time, the noise level shall be at least 10 dB lower than the distortion level expected;
- e) insert the bandpass filter corresponding to the channel to be measured and adjust the input attenuator to correct for the attenuation of the filter;
- f) disconnect the generator for the channel to be measured and terminate the combiner with its nominal impedance;
- g) verify that the intermodulation products generated in the spectrum analyzer over the entire channel are at least 20 dB below the distortion ratio required. If this is not the case, disconnect the bandpass filter and repeat the steps d) to g) of this procedure with decreased sensitivity of the spectrum analyzer;
- h) note the setting of the sensitivity control;
- i) connect the signal generator again and repeat steps c) to h) of this procedure for all channels;
- j) connect the device to be tested between points A and B and reset the signal generators to obtain the required output levels at point B;
- k) adjust the centre frequency of the spectrum analyzer as in step c) and insert the appropriate bandpass filter;
- l) adjust the input attenuator (internal or external) to return the response of the spectrum analyzer to the vision carrier to full scale with the appropriate setting of its sensitivity control (see step h);
- m) disconnect the generator for the channel to be measured and terminate the combiner with its nominal impedance;
- n) the composite triple beats are clustered within ± 15 kHz of the vision carrier, so the signal/composite triple beat ratio can be read directly off the screen of the spectrum analyzer;
- o) adjust the attenuator A1 of Figure 4 to obtain the required signal/composite triple beat ratio and compensate for the change in output level by using attenuator A2;
- p) measure the signal level at the output of the equipment under test;
- q) repeat the steps k) to p) of this procedure for every channel used in this test;
- r) the worst case maximum output level giving the required signal to composite triple beat ratio shall be noted for publication.

4.3.5 Composite second order beat

4.3.5.1 General

The test equipment required, connection of equipment and measurement procedure are as for the composite triple beat measurement but with the following differences.

4.3.5.2 Equipment required

The test equipment required is the same as described in 4.3.4.2.

4.3.5.3 Measurement procedure

The procedure is as for composite triple beat except that the second order beats are not clustered (± 15 kHz) about the exact carrier frequencies but may be clustered (± 10 kHz) at $\pm 0,75$ MHz or $\pm 0,25$ MHz from them. The carrier/composite second order distortion ratio can be read directly off the screen of the spectrum analyzer.

For composite second order, it is also necessary to measure the beats close to the channel at 48,25 MHz or, where this is not possible with the equipment under test, at the lowest frequency available. Although it is not essential to have the carrier present at this frequency, it may

be useful for reference purposes. In this case, the second order beats are clustered around 48,00 MHz ± 10 kHz and so again may be read directly off the screen of the spectrum analyzer.

The worst case maximum output level giving the required signal to composite second order distortion ratio shall be noted for publication.

4.3.6 Composite crossmodulation

4.3.6.1 General

The multi-signal method of measurement is used. The equipment output signal levels that produce the required composite amplitude crossmodulation ratio and the composite total crossmodulation ratio are measured.

The method described is applicable to the measurement of crossmodulation by the transfer of modulation from multiple interfering modulated signals on to an unmodulated wanted signal. Measurements are made using the same carrier frequencies as for composite second order, i.e. as shown in the Table D.1.

The method uses multiple interfering signals synchronously modulated so that the voltage at the peak of the modulation envelope is equal to the reference level L , which is also the level of the unmodulated wanted signal.

A correction factor is included to allow for the use of modulation depths less than 100 % (see Table 1).

Table 1 – Correction factors where the modulation used is other than 100 %

Modulation (AC coupled) %	Correction to be added to measured ratio dB
100	0
90	0,4
80	0,9
70	1,4
60	1,9
50	2,5
40	3,1
30	3,7

Composite amplitude crossmodulation is defined as the transfer of amplitude modulation from a number of modulated signals to the wanted carrier, and can be expressed as follows:

$$20 \lg \frac{\text{p - p voltage of wanted amplitude modulation}}{\text{p - p voltage of transferred amplitude modulation}}$$

Composite total crossmodulation is defined as the transfer of total modulation, i.e. the vector sum of amplitude and phase modulation, from a number of modulated signals to the wanted carrier, and can be expressed as follows:

$$20 \lg \frac{\text{p - p voltage of wanted sideband}}{\text{p - p voltage of transferred sideband}}$$

The measurement results obtained at the chosen depth of modulation are corrected to those which would be obtained with 100 % modulation (see Table 1).

The equipment under test is measured at the maximum output signal level that will allow a particular wanted modulation/composite crossmodulation ratio to be achieved (usually 60 dB).

4.3.6.2 Conditions of measurement

The following measurement conditions apply.

- a) The measurements shall be carried out with all the input signals present. These shall be appropriate to the frequency range of the particular equipment under test and in accordance with the Table D.1.
- b) Where the equipment to be measured includes AGC, the tests shall be made at the input signal's nominal levels.
- c) All levels shall be expressed in RMS values.

4.3.6.3 Equipment required

The following equipment is required:

- a) an RF selective voltmeter covering the frequency range of the system or equipment to be tested having linear demodulated output facilities at the depths of modulation to be used and a bandwidth adequate to pass the desired AF sidebands without attenuation. If the selectivity and linearity of the voltmeter are not adequate to prevent the generation of spurious signals, it is essential that the bandpass filter shown in Figure 5 is inserted.

The RF selective voltmeter shall indicate the RMS value of its input signal at the peaks of the modulation envelope;

- b) signal generators covering the appropriate vision carrier frequencies as listed in Annex D, all having the required modulation facilities, and linear at the depth of modulation to be used.

NOTE It is recommended that the modulation frequency approximates the line scan frequency of the TV signals in order to include effects which may be caused by the low frequency circuits (e.g. decoupling) in the equipment to be tested. The modulation frequency should not be a multiple of the power supply frequency.

Any symmetrical modulation waveform (excluding pulse modulation) may be used providing the same signal generator is used for both calibration and measurement, and the modulation depth and waveform remain the same;

- c) a modulating voltage generator of sufficient output to provide common modulation of the signal generators in b);
- d) an AF selective voltmeter covering the modulation frequency to be used and having a calibrated input level range exceeding the expected crossmodulation ratio;
- e) a combiner, matching devices, attenuators, filters, etc. to obtain the correct signal levels, matching and reduction of spurious signals;
- f) a spectrum analyzer with 1 kHz IF bandwidth and 10 Hz video bandwidth capability;
- g) a bandpass filter for each channel to be tested or a tunable bandpass filter. This filter shall attenuate the other channels present on the system to be tested sufficiently to ensure that the products generated by non-linearity in the spectrum analyzer itself do not contribute significantly to the crossmodulation products to be measured. The passband of this filter shall be flat at least to within 1 dB over the frequency range of interest, and shall be well-matched over the complete frequency band. If necessary, a fixed attenuator shall be connected to the input of the filter.

4.3.6.4 Connection of equipment

Connect the equipment as shown in Figure 5.

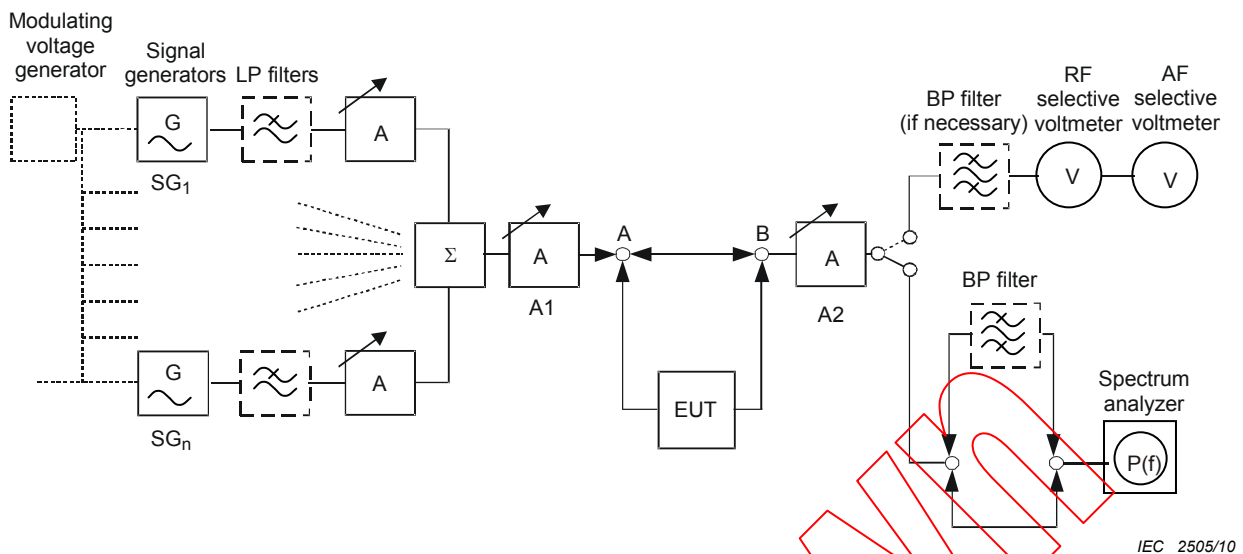


Figure 5 – Connection of test equipment for the measurement of composite crossmodulation

4.3.6.5 Measurement procedure

The measurement procedure comprises the following steps:

- Composite amplitude crossmodulation
 - a) connect the output of the equipment under test to the RF selective voltmeter;
 - b) select each signal generator in turn, set the modulation depth and adjust the output to give the desired RF peak level L at the output of the equipment to be tested using the RF selective voltmeter;
 - c) tune the selective voltmeter to the frequency of the carrier selected as the wanted signal. Switch off all the unwanted signals. Adjust the AF selective voltmeter for a convenient reading of the demodulated signal. Note this reading;
 - d) switch off the modulation on the selected wanted signal. Adjust its unmodulated output to give the desired RF level L at the output of the equipment to be tested, using the RF selective voltmeter;
 - e) switch on all the modulated signals and, with the RF selective voltmeter tuned to the wanted carrier frequency, note the level of the demodulated amplitude crossmodulation signal on the AF selective voltmeter;
 - f) the difference in decibel between the levels obtained in steps c) and e), corrected as in Table 1, is the amplitude crossmodulation ratio referred to 100 % modulation. Adjust the attenuator A1 of Figure 5 and compensate for the change in output level using attenuator A2 in order to obtain the required composite amplitude crossmodulation ratio;
 - g) the worst case maximum output level giving the required signal to composite amplitude crossmodulation ratio shall be noted for publication.
- Composite total crossmodulation
 - h) connect the output of the system or equipment under test to the spectrum analyzer;
 - i) adjust the spectrum analyzer as follows:

IF bandwidth	1 kHz;
video bandwidth	10 Hz;
scan width	5 kHz/div.;
vertical scale	10 dB/div.;

scan time 2 s/div.;

- j) tune the spectrum analyzer to the channel on which the measurement is to be made so as to display the vision carrier and a frequency range of 25 kHz on either side of the carrier;
- k) switch off all other channels and switch on the modulation of the channel to be measured;
- l) insert the bandpass filter corresponding to the channel to be measured and adjust the input attenuator to correct for the attenuation of the filter;

NOTE When using a spectrum analyzer with minimum video filtering capabilities greater than 10 Hz, the composite crossmodulation may be noisy and should be read at the middle of the trace.

- m) adjust the sensitivity of the spectrum analyzer together with its internal and/or external input attenuator in such a way that the responses to the first sidebands, approximately 15 kHz on either side of the vision carrier, correspond to a full scale reference; At the same time, the noise level shall be at least 10 dB lower than the distortion level expected;
- n) switch off the modulation of the wanted carrier and switch on all the other modulated carriers;
- o) measure the amplitude of the sidebands on either side of the wanted carrier caused by the total composite crossmodulation transfer; The difference in dB between the full scale reference and the largest of the sidebands, corrected as in Table 1, is the total crossmodulation ratio referred to 100% modulation.

Adjust attenuator A1 of Figure 5 and compensate for the change in output level by using the attenuator A2 in order to obtain the required total composite crossmodulation;

- p) repeat steps a) to n) of this procedure, each time selecting a different wanted signal, until all channels used in this test have been selected;
- q) the worst case maximum output level giving the required signal to composite total crossmodulation ratio shall be noted for publication.

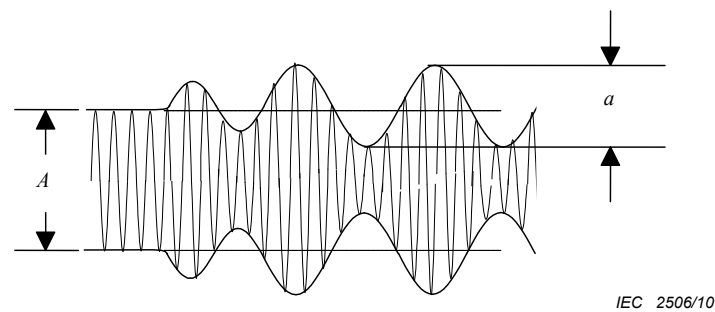
4.3.7 Method of measurement of non-linearity for pure digital channel load

Under consideration.

4.3.8 Hum modulation of carrier

4.3.8.1 Definition

The interference ratio for hum modulation is given by the ratio, expressed in dB, between the peak-to-peak value (A) of the unmodulated carrier and the peak-to-peak value, a , of one of the two envelopes caused by the hum modulated to this carrier (see Figure 6).



$$\text{Carrier/hum ratio} = 20 \lg \frac{A}{a} \text{ dB}$$

Figure 6 – Carrier/hum ratio

4.3.8.2 Description of the method of measurement

4.3.8.2.1 General

This method of measurement is valid for radio and TV signal equipment within a cable network that are supplied with alternating current, 50 Hz.

For measuring purposes sinusoidal voltages from a source with sufficient low output impedance are used. Taking into account the maximum admissible voltage or the maximum admissible current, the worst value for the operating frequency range shall be published.

NOTE For cable networks the peak value of the supply voltage or of the supply current can be higher than the value resulting from calculation using the corresponding waveform factor.

To measure the test object an oscilloscope method is used.

4.3.8.2.2 Test equipment required

The following test equipment is required:

- adjustable voltage source;
- variable load resistor;
- power inserter;
- variable attenuator;
- oscilloscope;
- voltmeter (RMS);
- ampere meter;
- tunable RF signal generator with sufficient phase noise and hum modulation ratio, including AM capability (400 Hz);
- detector including (battery powered) LF-amplifier and 1 kHz LP-filter in the output, to suppress low frequency distortion (A HP-filter shall be used at the input).

4.3.8.2.3 Connection of test equipment

The connection scheme for local-powered test objects is shown in Figure 7. The connection scheme for remote-powered test objects is shown in Figure 8.

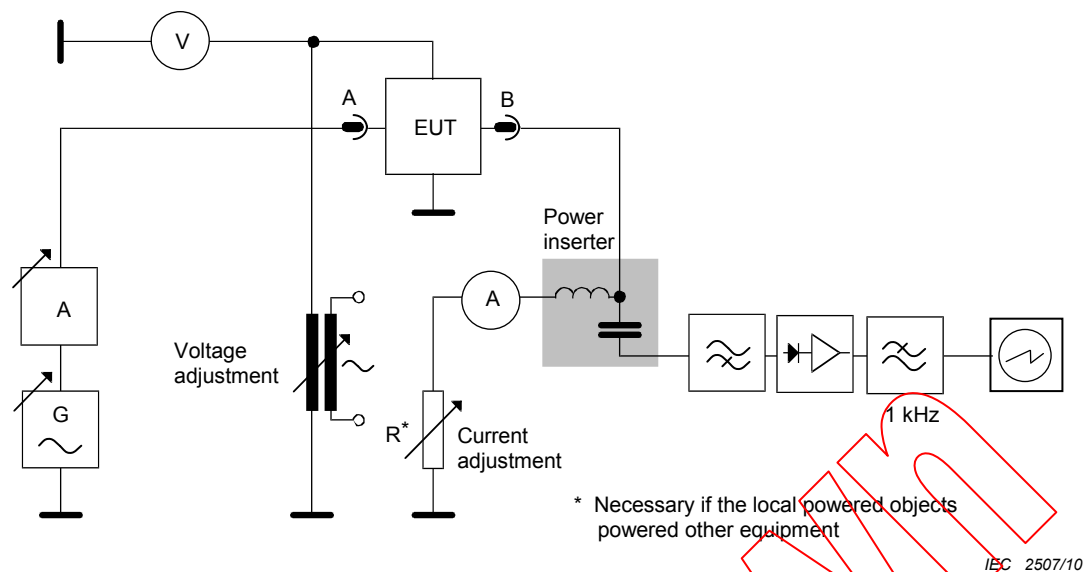


Figure 7 – Test set-up for local-powered objects

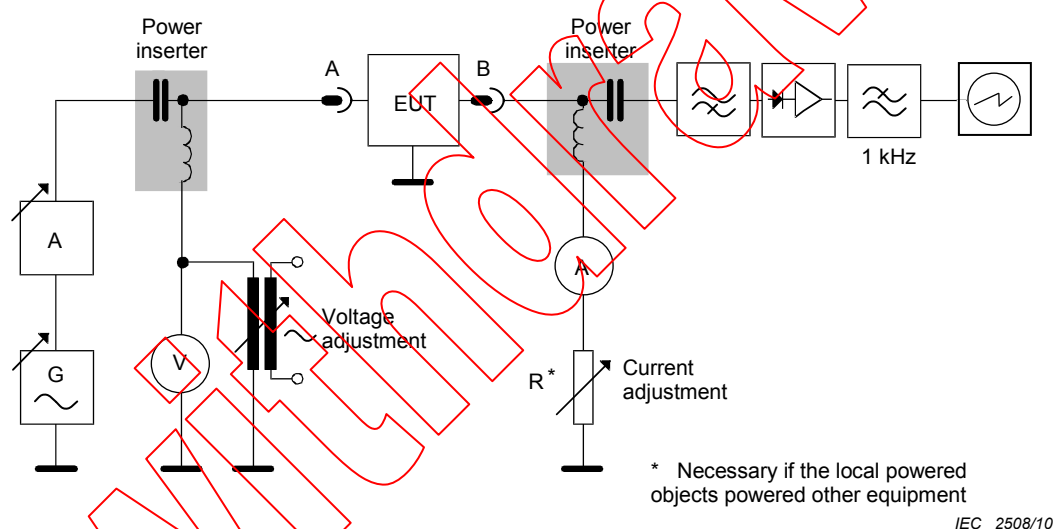


Figure 8 – Test set-up for remote-powered objects

4.3.8.3 Measuring procedure

4.3.8.3.1 Set-up of calibration

The reference signal is generated by means of the RF signal generator shown in Figure 7 and Figure 8. Select an RF carrier frequency that suits the TV channel under consideration and modulate it to a depth of 1 % at a frequency of 400 Hz. Adjust the RF signal generator to an appropriate level and read the peak-to-peak value of the demodulated AM signal ("c" in Figure 9) on the oscilloscope. This is the reference signal. With 1 % modulation this value is

$$-20 \lg (0,01) = 40 \text{ dB}.$$

The modulation of the signal generator has to be switched off. The remaining value "m" in Figure 9 is the value to be measured.

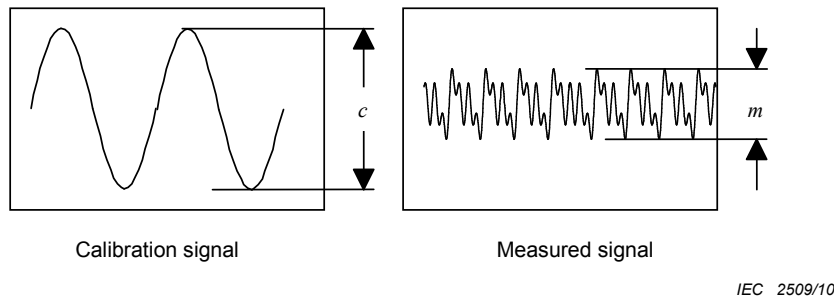


Figure 9 – Oscilloscope display

Check the suitability of the measuring set-up by connecting points A and B together and measuring the set-ups inherent hum. The calculation of the hum modulation ratio is given in 4.3.8.4. This value should be at least 10 dB better than the values to be measured for the equipment under test. For measurements with set-ups for local powered objects, use the set-up shown in Figure 7 to check. The subsequent measurements shall be carried out in suitable increments through the entire operating frequency range. The measured value is independent of the RF level, however, the RF level should be at least the magnitude of the test object's operating level.

4.3.8.3.2 Local-powered test objects

Adjust the test object to maximum or minimum operating voltage using the transformer. The supply current depends on the power requirement of the test object. Modulate the signal generator with the reference signal and adjust the level at point B by means of an attenuator so that neither the measuring object is overdriven nor the detector is within a non-admissible operating range. Note down the peak-to-peak amplitude "c" of the demodulated reference signal which is displayed on the oscilloscope. Then switch off the reference signal and measure the peak-to-peak value "m" of the remaining signal.

In addition, for test objects with remote supply terminals, adjust the maximum admissible current for the respective terminal by means of resistor R.

4.3.8.3.3 Remote-powered test objects

For remotely supplied test objects, generally proceed as described in the paragraphs above on "Local-powered test objects". The only difference is that the supply energy is routed to the equipment via an RF terminal. In case there are several RF interfaces available for power insertion, each of these interfaces shall be included in the measurement procedure in a suitable manner.

4.3.8.4 Calculating the hum modulation ratio

4.3.8.4.1 Frequency range

The considered frequency range for the hum is from 50 Hz to 1 kHz.

4.3.8.4.2 Individual object

Hum modulation ratio $_{[EUT]} = 40 + 20 \lg(c/m)[\text{dB}]$ for 1 % reference modulation depth.

For other chosen reference modulation depth, the value 40 dB has to be replaced by the result of the term: $-20 \lg(\text{modulation depth})$.

4.3.8.4.3 Cascaded test objects

For high hum modulation ratios it can be useful to cascade several test objects for better determination of the measuring values. Then, for calculating the individual object, use the following formula:

$$\text{Hum modulation ratio}_{[EUT]} = \text{Hum modulation ratio}_{[cascaded]} + 20 \lg n \text{ [dB]}$$

where n = number of cascaded test objects.

4.3.8.4.4 Loop value correction

In case a set-up calibration correction is required use the following formula:

$$\text{Hum modulation ratio}_{[EUT]} = -20 \lg \left(10^{\frac{\text{measured value}}{20}} - 10^{\frac{\text{calibration correction}}{20}} \right) \text{ dB}$$

4.4 Automatic gain and slope control step response

4.4.1 Definitions

In cable networks using broadband amplifiers having automatic gain and slope controls, it is important to have carefully chosen control time constants to prevent instability when amplifiers are cascaded. Moreover, correctly chosen time constants are an advantage during measurements with CATV systems analyzers.

The control time constant T_c is the time in which the effect on the output of an instantaneous change in level at the input of an amplifier is reduced to 50 % of the instantaneous change.

NOTE It is assumed that the control curve follows an exponential function. Contrary to the normal definition of a time constant, the 50 % value has been chosen as it is more easily read on the display of a spectrum analyzer, (see Figure 10).

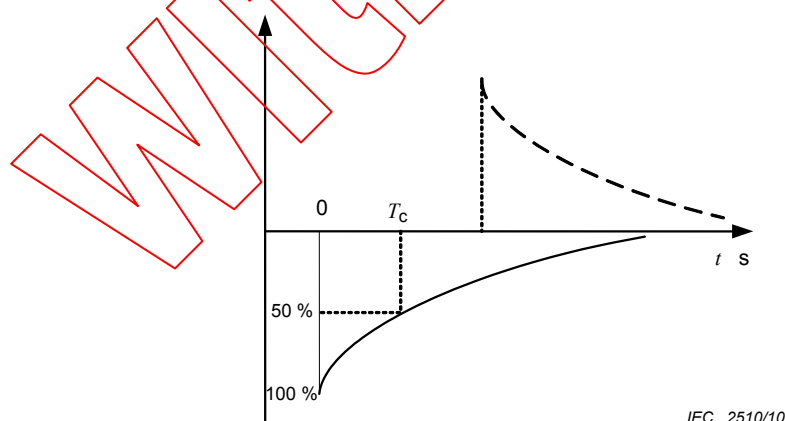


Figure 10 – Time constant T_c

The following procedure is used on equipment using pilots.

4.4.2 Equipment required

The following equipment is required:

- a) two pilot frequency generators (or one if only one pilot frequency is used);

- b) a combiner for the two pilot frequency generators;
- c) one switched attenuator;
- d) two rotary switches (make-before-break);
- e) two cables with attenuation of 2 dB at the highest frequency of the amplifier range;
- f) a spectrum analyzer with storage display.

4.4.3 Connection of equipment

The equipment is connected as shown in Figure 11.

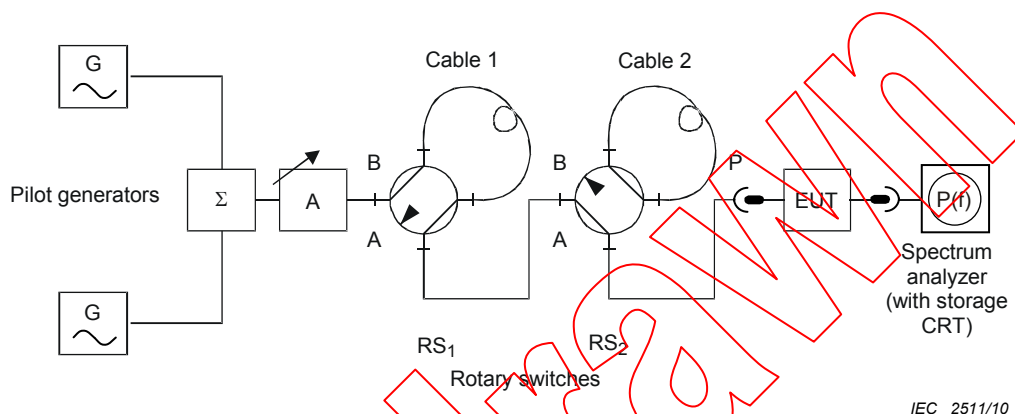


Figure 11 – Measurement of AGC step response

4.4.4 Measurement procedure

The measurement procedure comprises the following steps:

- a) with the rotary switches RS_1 and RS_2 in position B, (no cables), ensure that the pilot signals at the point P have the same value and that the input levels are in the normal operating range of the equipment under test;
- b) turn the rotary switch RS_1 to position A (cable 1) and connect the equipment under test. With a 2 dB plug-in equaliser (or an additional 2 dB cable equaliser in front of the equipment under test), the pilot signals will have the same level at the first stage of the amplifier;
- c) switch the equipment under test to automatic gain control. The two pilot frequencies on the spectrum analyzer should have the normal level;
- d) tune to the upper pilot frequency using the spectrum analyzer on the following settings:

frequency span	0 MHz
IF bandwidth	3 MHz
scan time	0,5 s/div.
vertical scale	1 dB/div.
- e) turn the rotary switch RS_2 to position A (negative step) shortly after the start of the spectrum analyzer scan. See Figure 11. Measure the control time constant T_C ;
- f) repeat the procedure with the rotary switches in the same start positions (RS_1 at A, RS_2 at B) and turn RS_1 to position B (no cable), (positive step);
- g) repeat the procedure for the lower pilot frequency.

4.5 Noise figure

4.5.1 General

Normally the noise figure is measured using either a calibrated noise generator suitable for the required frequency range or, more conveniently, with an automatic noise figure meter using an excess noise source.

The following clauses describe the "twice power" method of measurement using a calibrated noise generator.

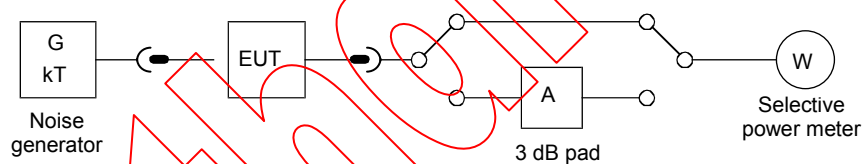
4.5.2 Equipment required

The following equipment is required:

- a noise generator (excess noise source) suitable for the frequency range in use with dB, or kT_0 , calibration.
- a 3 dB attenuator.
- a frequency selective power meter (voltmeter).

4.5.3 Connection of equipment

The equipment is connected as in Figure 12. The connection between the noise generator and the equipment under test should be short. The impedance of all equipment should be $75\ \Omega$.



IEC 2512/10

Figure 12 – Measurement of noise figure

4.5.4 Measurement procedure

The measurement procedure comprises the following steps:

- set a convenient reference on the power meter at the wanted frequency without the 3 dB attenuator and without additional noise at the input port of the equipment under test (noise generator turned off); The measured noise level should be at least 10 dB higher than the indication of the power meter if its input is terminated in $75\ \Omega$. The bandwidth of the power meter should be adjusted to obtain a stable reading;
- insert the 3 dB attenuator and increase the noise generator output level until the power meter returns to the original reference level;
- read the noise figure from the noise generator;
- repeat steps a) to c) at different frequencies across the band. The worst case shall be stated.

4.6 Crosstalk attenuation

4.6.1 Crosstalk attenuation for loop through ports

4.6.1.1 General

Each loop through port corresponds to one input port. Due to crosstalk a loop through port of a multi-switch carries besides the corresponding input signal interfering signals from other input ports. Therefore, the crosstalk attenuation between input ports is an important parameter.

4.6.1.2 Equipment required

A network analyzer is required.

4.6.1.3 Measurement procedure over the operating satellite IF frequency range

The measurement procedure comprises the following steps:

- a) connect the network analyzer reflection port to multi-switch input port 1 (see Figure 13);
- b) connect the multi-switch loop through port 1 to the network analyzer transmission port. Loop through port 1 corresponds to input port 1;
- c) terminate all unused ports;
- d) measure the attenuation between the input port 1 and the loop through port 1. Let a_1 be the attenuation in decibels over the operating frequency range;
- e) connect the network analyzer reflection port to another multi-switch-input port, for example input port 2;
- f) terminate all unused ports;
- g) measure the attenuation between the input port 2 and the loop through port 1. Let a_2 be the attenuation in decibel over the operating frequency range.

The worst-case crosstalk attenuation in decibels is the minimum of $a_2 - a_1$ over the operating satellite IF frequency range.

4.6.2 Crosstalk attenuation for output ports

4.6.2.1 General

Due to crosstalk an output port of a multi-switch carries, besides the selected input signal, interfering signals from other input ports. Therefore, the crosstalk attenuation between input ports is an important parameter.

In addition to electromagnetic coupling between leads, unwanted signals at the output port are due to imperfect isolation performance of the switches. Crosstalk attenuation for output ports is the combination of both.

4.6.2.2 Equipment required

The following equipment is required:

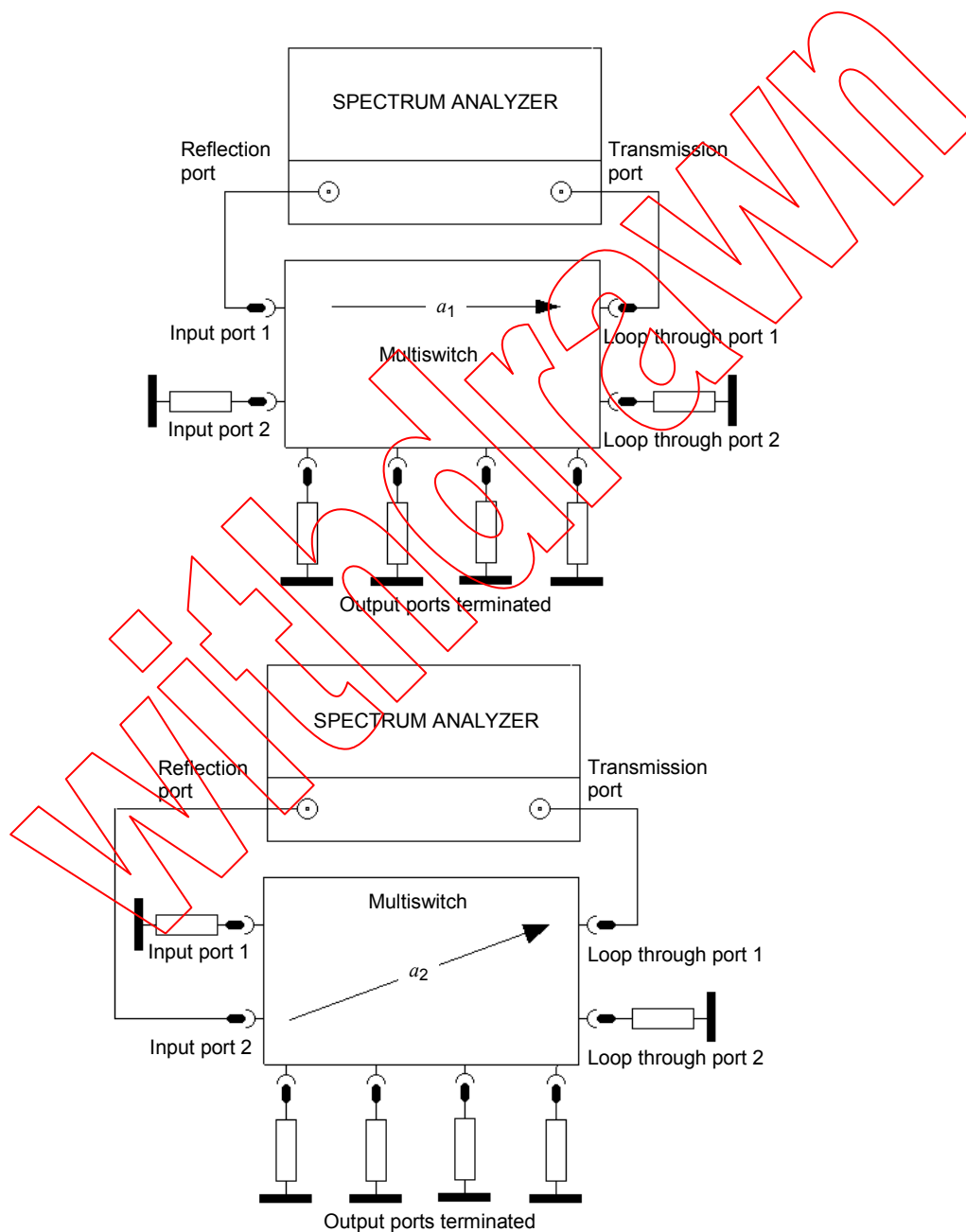
- a) network analyzer;
- b) bias-tee (see Figure 8);
- c) standard satellite receiver.

4.6.2.3 Measurement procedure over the operating satellite IF frequency range

The measurement procedure comprises the following steps:

- a) connect the multi-switch output port to the bias-tee RF and DC port;

- b) connect the bias-tee RF port to the network analyzer transmission port;
- c) connect the bias-tee DC port to the satellite receiver;
- d) set the satellite receiver to generate control signals that select input port 1 of the multi-switch;
- e) connect the network analyzer reflection port to multi-switch input port 1;
- f) terminate all unused ports;
- g) measure the attenuation between the selected input port 1 and the output port. Let a_1 be the attenuation in decibels over the operating frequency range;



IEC 2513/10

Figure 13 – Measurement of crosstalk attenuation for loop through ports of multi-switches

- h) connect the network analyzer reflection port to another multi-switch input port, for example port 2;
- i) terminate all unused ports;
- j) measure the attenuation between the not selected input port 2 and the output port. Let a_2 be the attenuation in decibels over the operating frequency range.

The worst-case crosstalk attenuation in decibels is the minimum of $a_2 - a_1$ over the operating satellite IF frequency range.

4.7 Signal level for digitally modulated signals

The method to measure the signal level for digitally modulated signals is described in IEC 60728-1.

4.8 Measurement of composite intermodulation noise ratio (CINR)

4.8.1 General

Non-linearity of return path equipment carrying only digital modulated signals can be measured using different methods. The most prevalent methods are:

a) Bit Error Ratio (BER)

This method involves sending modulated, pseudo-random, bit streams on many channels to fill the return band. The BER is measured while changing the level of the RF signal.

b) The noise in gap measurement

Distortion caused by noise is also noise. The measurement of distortion noise is possible, if a small gap of the noise is removed before the noise enters the equipment under test. The equipment is loaded with wideband noise and a small gap of the noise is removed before the noise enters the equipment under test. While changing the level of the loading noise, the gap is more or less filled with distortion noise. The ratio between the original loading signal (noise) and the distortion noise is measured and plotted.

c) The multi-tone measurement

In this method two groups of more than ten CW tones are presented at the input of the equipment under test. The tones in each group are phase-locked to simulate the peak-to-average ratio of the digital channel. The signal level is varied, while measuring the ratio between the total power of the two groups of CW tones and the noise plus distortion power in the upper and lower third order products.

The result of plotting the BER or the power ratios versus the signal level is a bathtub curve. When the signal level is low thermal noise (or other constant noise such as RIN of lasers) will dominate. When the signal is high enough, intermodulation noise will dominate. All these methods can not differentiate between the two, since both appear as noise.

4.8.2 Equipment required

The following equipment is required:

- a) a source of white Gaussian noise covering the frequency band of the equipment to be tested;
- b) a filter to shape the noise as shown in Figure 14 for frequencies as given in Table 2.

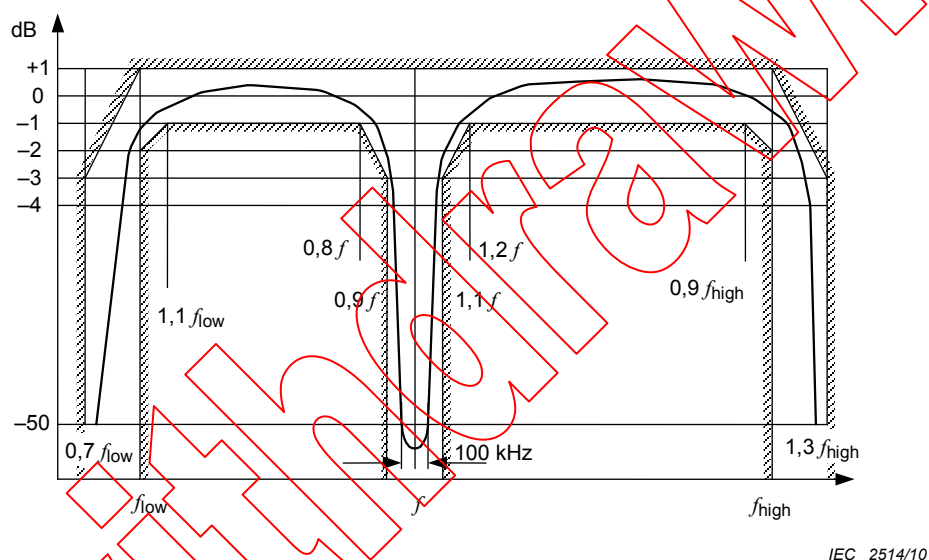
Table 2 – Notch filter frequencies

Frequency range f_{low} to f_{high}	Notch filter frequency f		
5 MHz to 30 MHz	12 MHz	17,5 MHz	22 MHz
5 MHz to 50 MHz	22 MHz	27,5 MHz	35 MHz
5 MHz to 65 MHz	27,5 MHz	35 MHz	48 MHz

The filter shall limit the noise bandwidth to the bandwidth of the EUT. It shall also add a notch to the noise spectrum. The notch frequency shall be in the middle of the spectrum;

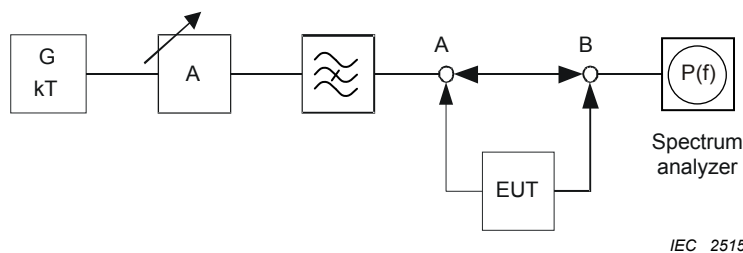
c) a spectrum analyzer;

d) a variable $75\ \Omega$ attenuator, adjustable in 1 dB steps.

**Figure 14 – Characteristic of the noise filter**

4.8.3 Connection of equipment

The equipment shall be connected as in Figure 15. The filter can alternatively consist of several cascaded filter modules. Take care of correct impedance matching.

**Figure 15 – Test setup for the non-linearity measurement**