INTERNATIONAL STANDARD

IEC 60728-3

Third edition
2005-06

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

Part 3: Active wideband equipment for coaxial cable networks

Reference number
IEC 60728-3:2005(E)

Publication numbering

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Commission Electrotechnique Internationale
International Electrotechnical Commission
Международная Электротехническая Комиссия

PRICE CODE XA

For price, see current catalogue

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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

Part 3: Active wideband equipment for coaxial cable networks

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
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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 third edition cancels and replaces the second edition published in 2000 of which it constitutes a technical revision.

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

– New methods of measurement:
  - crosstalk attenuation, 4.5,
  - signal level for digitally modulated signals, 4.6,

  - method of measurement for non-linearity of return path equipment carrying only digital modulated signals [Measurement of composite intermodulation noise ratio (CINR)], 4.7;
- New requirements for multi-switches, 5.18;
- New informative Annex E: Examples of signals, methods of measurement and network design for return paths

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

FDIS	Report on voting
100/946/FDIS	100/976/RVD

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

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

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

Part 1: Methods of measurement and system performance Part 2: Electromagnetic compatibility for equipment

Part 3: Active wideband equipment for coaxial cable networks

Part 4: Passive coaxial wideband distribution equipment (under consideration)

Part 5: Headend equipment

Part 6: Optical equipment

Part 7-1: Hybrid fibre coax outside plant status monitoring – Physical (PHY) layer specification

Part 7-2: Hybrid fibre coax outside plant status monitoring – Media access control (MAC) layer specification

Part 7-3: Hybrid fibre coax outside plant status monitoring – Power supply to transponder interface bus (PSTIB) specification

Part 9: Interfaces for CATV/SMATV headends and similar professional equipment for DVB/MPEG-2 transport streams

Part 10: System performance of return path

Part 11: Safety

Part 12: Electromagnetic compatibility of systems

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

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

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

INTRODUCTION

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

This includes:

- CATV networks;
- MATV networks and SMATV networks;
- individual receiving networks,

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

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

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

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

Part 3: Active wideband equipment for coaxial cable networks

1 Scope

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

This standard applies to all broadband amplifiers used in cable networks and covers the frequency range 5 MHz to 3 000 MHz. It also applies to one-way and two-way equipment.

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.

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

This standard

- applies to all broadband amplifiers used in cable networks;
- covers the frequency range 5 MHz to 3 000 MHz;
- 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 that shall 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 these types meet most of the technical requirements necessary for supplying a minimum signal quality to the subscribers. This classification shall not be considered as a requirement but as the information for users and manufacturers on the 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 60068-1:1988, *Environmental testing – Part 1: General and guidance*
Amendment 1 (1992)

IEC 60068-2-1:1990), *Environmental testing – Part 2: Tests. Tests A: Cold*
Amendment 1 (1993)
Amendment 2 (1994)

IEC 60068-2-2:1974, *Environmental testing – Part 2: Tests. Tests B: Dry heat*
Amendment 1 (1993)
Amendment 2 (1994)

IEC 60068-2-6:1995, *Environmental testing – Part 2: Tests – Test Fc: Vibration (sinusoidal)*

IEC 60068-2-14:1984, *Environmental testing – Part 2: Tests. Test N: Change of temperature*
Amendment 1 (1986)

IEC 60068-2-27:1987, *Environmental testing – Part 2: Tests. Test Ea and guidance: Shock*

IEC 60068-2-29:1987, *Environmental testing – Part 2: Tests. Test Eb and guidance: Bump*

IEC 60068-2-30:1980, *Environmental testing – Part 2: Tests. Test Db and guidance: Damp heat, cyclic (12 + 12-hour cycle)*
Amendment 1 (1985)

IEC 60068-2-31:1969, *Environmental testing –. Part 2: Tests. Test Ec: Drop and topple, primarily for equipment-type specimens*
Amendment 1 (1982)

IEC 60068-2-32:1975, *Environmental testing – Part 2: Tests. Test Ed: Free fall (Procedure 1)*
Amendment 2 (1990)

IEC 60068-2-40:1976, *Environmental testing – Part 2: Tests. Test Z/AM: Combined cold/low air pressure tests*
Amendment 1 (1983)

IEC 60068-2-48:1982, *Environmental testing – Part 2: Tests. Guidance on the application of the tests of IEC 68 to simulate the effects of storage*

IEC 60169-2:1965, *Radio-frequency connectors. Part 2: Coaxial unmatched connector*
Amendment 1 (1982)

IEC 60169-24:1991, *Radio frequency connectors – Part 24: Radio frequency coaxial connectors with screw coupling, typically for use in 75 ohm cable distribution systems (Type F)*

IEC 60417-DB:2002[1] *Graphical symbols for use on equipment*

IEC 60529:1989, *Degrees of protection provided by enclosures (IP Code)*
Amendment 1 (1999)

[1] "DB" refers to the IEC on-line database.

IEC 60617-DB, 2001[2] *Graphical symbols for diagrams – database comprising parts 2 to 13 of IEC 60617*

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

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

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

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

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

IEC 60728-10:2001, *Cable networks for television signals, sound signals and interactive services – Part 10: System performance of return path*

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

IEC 61319-1:1995, *Interconnections of satellite receiving equipment – Part 1: Europe*

IEC 61319-2:1997 *Interconnections of satellite receiving equipment – Part 2: Japan*

IEC 80416 (series), *Basic principles for graphical symbols for use on equipment*

ES 200 800 V1.3.12001, *Digital Video Broadcasting (DVB); DVB interaction channel for Cable TV distribution systems (CATV)*

3 Terms, definitions, symbols and abbreviations

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

3.1 Terms and definitions

3.1.1
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.

3.1.2
feeder
transmission path forming part of a cable network. 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

[2] "DB" refers to the IEC on-line database.

3.1.3
decibel ratio
ten times the logarithm of the ratio of two quantities of power P_1 and P_2, i.e.

$$10\lg\frac{P_1}{P_2} \qquad \text{(dB)}$$

3.1.4
standard reference power and voltage
in cable networks, the standard reference power, P_0, is (1/75) pW

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

the standard reference voltage, U_0, is 1 µV

3.1.5
level
of any power P_1 it is the decibel ratio of that power to the standard reference power P_0, i.e.

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

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

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

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

3.1.6
attenuation
ratio of the input power to the output power of an equipment or system, usually expressed in decibels

3.1.7
gain
ratio of the output power to the input power, usually expressed in decibels

3.1.8
amplitude frequency response
gain or loss of an equipment or system plotted against frequency

3.1.9
slope
difference in gain or attenuation at two specified frequencies between any two points in an equipment or system

3.1.10
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

3.1.11
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)

3.1.12
noise factor/noise figure
used as figures of merit describing the internally generated noise of an active device

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

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

3.1.13
ideal thermal noise
noise generated in a resistive component due to the thermal agitation of electrons

The thermal power generated is given by

$$P = 4 \cdot B \cdot \text{k} \cdot T$$

where

P is the noise power in watts;

B is the bandwidth in hertz;

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

T is the absolute temperature in kelvins.

It follows that

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

and

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

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 $U/2$.

3.1.14
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

[IEV 723-06-61]

3.1.15
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 D.

3.1.16
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.

3.1.17
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.

3.1.18
multi-switch port for terrestrial signals
port in a multi-switch used to distribute terrestrial signals in addition to the signals received from satellites

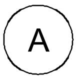
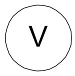
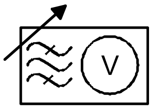
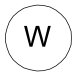
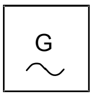
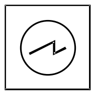
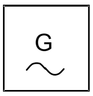
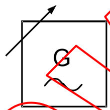
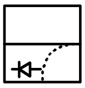
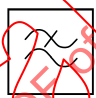
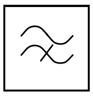
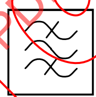
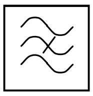
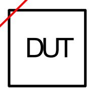
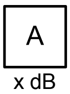
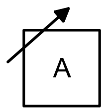
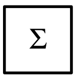
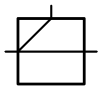
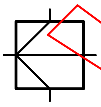
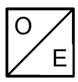
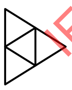
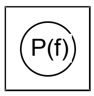
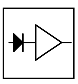
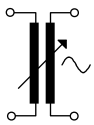
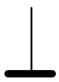
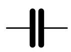
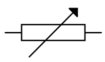
3.1.19
crosstalk attenuation
unwanted signals beside the wanted signal on a lead caused by electromagnetic coupling between leads. It is the ratio of the wanted signal power to the unwanted signal power, while equal signal powers are applied to the leads and is usually expressed in decibels

3.1.20
composite intermodulation noise (CIN)
sum of noise and intermodulation products from digital modulated signals

3.1.21
composite intermodulation noise ratio (CINR)
ratio of the signal level and the CIN level

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
	Ammeter [S00910]		Voltmeter [S00910]
	Selective voltmeter		Power meter [S00910]
	Signal generator [S00899, S01403]		Oscilloscope [S00059, S00922]
	Noise generator [S01230]		Variable signal generator [S00081, S00899, S01403]
	VSWR-bridge		Low-pass filter [S01248]
	High-pass filter [S01247]		Band-pass filter [S01249]
	Band-stop filter [S01250]		Device Under Test [S00059]
	Attenuator [S01244]		Variable attenuator [S01245]
	Combiner [S00059]		Tap-off-box
	Double tap-off-box		Optical receiver [S00213]
	Amplifier with return path amplifier [S00433]		Spectrum analyzer (electrical) [S00910]
	Detector with LF-amplifier		Adjustable AC voltage source
	(Functional equipotential bonding) [S01410]		Capacitor [S00567]
	RF choke [S00583]		Variable resistor [S00557]

3.3 Abbreviations

AC	alternating current
AF	audio frequency
AGC	automatic gain control
AM	amplitude modulation
BER	bit error rate
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
DC	direct current
DUT	device under test
EMC	electromagnetic compatibility
HP	high pass
IF	intermediate frequency
IP	international protection
LF	low frequency
LP	low pass
MATV	master antenna television (system)
MTBF	meantime between failure
OMI	optimum modulation index
PAL	phase alternating line
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
VSWR	voltage standing wave ratio
XM	crossmodulation

4 Methods of measurement

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 signa;.
- 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.

4.1 Linear distortion

4.1.1 Return loss

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.

4.1.1.1 Equipment required

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

   Care must 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.

b) 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.

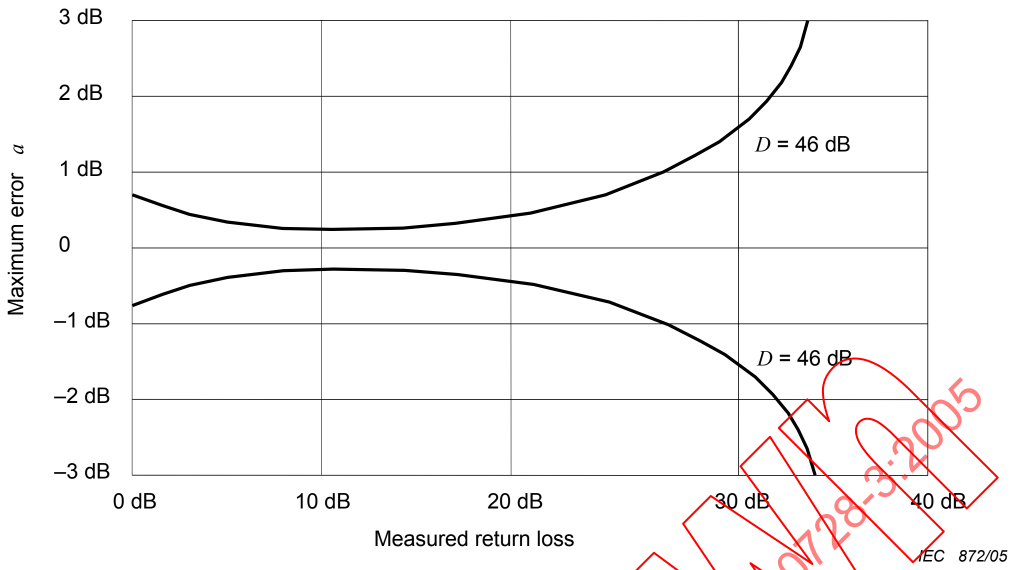


Figure 1 – Maximum error *a* for measurement of return loss using VSWR-bridge with directivity D = 46 dB and 26 dB test port return loss

c) An oscilloscope.

d) Calibrated mismatches.

4.1.1.2 Connection of equipment

The equipment shall be connected as in Figure 2.

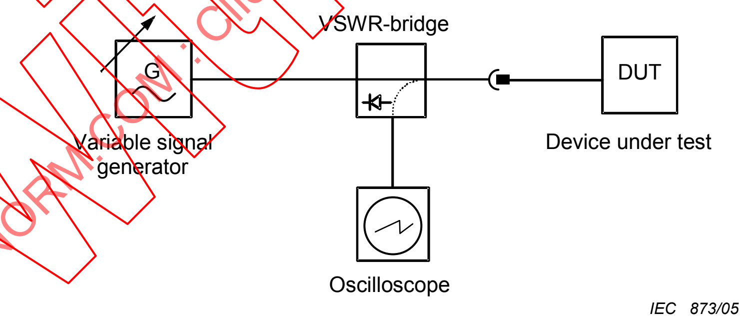


Figure 2 – Measurement of return loss

4.1.1.3 Measurement procedure

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

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 device under test is not overloaded;

c) use calibrated mismatches to calibrate the display on the oscilloscope;

d) connect the device under test as shown in Figure 2 and check the return loss over the specified frequency range.

4.1.2 Flatness

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

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

4.1.3 Chrominance/luminance delay inequality for PAL/SECAM only

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

4.2 Non-linear distortion

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. The transfer function of the device can be expressed as£:

$$V_{out} = a_0 + a_1 V_{in} + a_2 V^2_{in} + a_3 V^3_{in} + ...a_n V^n_{in} + ..., \text{etc.}$$

If the input signal V_{in} has m sinusoidal terms, then this can be expressed as:

$$V_{in} = V_1 \sin(\omega_1 t + \Phi_1) + V_2 \sin(\omega_2 t + \Phi_2) + ...V_m \sin(\omega_m t + \Phi_m)$$

The output signal is then a series of terms each of which can be expressed in the general form:

$$CV_i\, a_n \sin(\omega_i t + \Phi_i)$$

where ω_i is the sum or difference of integral positive multiples of one or more of the input frequencies, for example:

$$4\omega_2,\ 2\omega_1 - \omega_3,\ 4\omega_1 + \omega_2,\ 2\omega_1 + \omega_2 + \omega_3.$$

This may be written in a general form as:

$$\omega_i = p_1\omega_1 \pm p_2\omega_2 \pm p_3\omega_3 \pm .....p_m\omega_m$$

where

ω_i	is the angular velocity $2\pi f_i$;
$p_1, p_2, ...p_m$	are positive integers (including 0);
Φ_i	is the relative phase of the output signals;

a_n is a coefficient of the transfer function;

V_i is a term dependent on the product of powers of the amplitudes of the input signals (V_1, V_2, etc.) where the sum of the powers equals n;

C is a numerical multiplier.

It should be noted that terms at the same frequency may arise from several different terms in the transfer function, i.e. for several different values of n.

Each component of the output signal represented by such an expression with $n > 1$ is a non-linear distortion product, where ω_i is an integral multiple of a single term in the input signal, for example $4\omega_2$, the product is regarded as a harmonic distortion product. If it is formed from two or more terms, for example $2\omega_1 - \omega_3$, it is known as an intermodulation distortion product.

Since the values of a_1, a_2, a_3, etc., usually decrease relatively rapidly with increasing values of n, it is found that the predominant non-linear output signals arise from the terms in the transfer function in such a way that the sum $p_1+p_2+\dots p_m = n$, and n is defined as the order of the non-linear distortion product, for example $3\omega_1 - 2\omega_3$ is a fifth order product arising from the term $a_5 V_{in}^5$.

The m input signals represented in the expression are not necessarily distinct signals. Any periodic signal may be represented by a series of sinusoidal terms as in the expression for V_{in}. For the predominant non-linear output signals it is found that:

$$V_i = V_1^{p_1} \cdot V_2^{p_2} \cdot V_3^{p_3} \cdot \ldots \cdot V_m^{p_m}$$

so that if the amplitudes of all the input signals are multiplied by a common factor K, the amplitude of the n^th^ order distortion products will be multiplied by K^n (*since* $p_1 + p_2 + p_3 + \dots p_m = n$). When the levels of all input signals are raised by 1 dB, the level of any signal n^th^ order distortion product will increase by n dB, and the resultant signal/distortion ratio will decrease by $(n - 1)$ dB. This relationship will be referred to as the "standard level variation" of a distortion product.

If a distortion product is due to components of different order, and/or different order products occur within the bandwidth of the device used to measure the level of distortion products, then the measured level will not follow a standard level variation.

In principle, an infinite number of terms is necessary for a complete description of a non-linear characteristic. However, considering the standard level variation of terms of different order, the relative contribution of higher-order terms increases with the level of input signals. Conversely, if signal levels are low enough, only a few of the lowest order terms will produce significant contributions at the output.

If all input signals are limited to a frequency band of less than one octave, the frequencies of all second-order terms will fall outside the band limits. Signal frequencies can also be allocated in two or more non-contiguous bands in a manner that will place all second-order products outside the bands.

Third-order distortion products, in particular some of the products that occur at frequencies represented by $\omega_1 \pm \omega_2 \pm \omega_3$ cannot be kept out of the band that contains the input signals. The accumulation of third-order distortion products may therefore be a limiting factor in the performance of a wideband multi-channel distribution system.

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").

4.2.1 Intermodulation

4.2.1.1 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 4.2.3 and 4.2.4.

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

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 A.1).

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

4.2.1.2 Equipment required

a) A selective voltmeter covering the frequency range of the equipment or system to be tested. This may be a spectrum analyzer.

b) The appropriate number of signal generators covering the frequencies at which the tests are to be carried out.

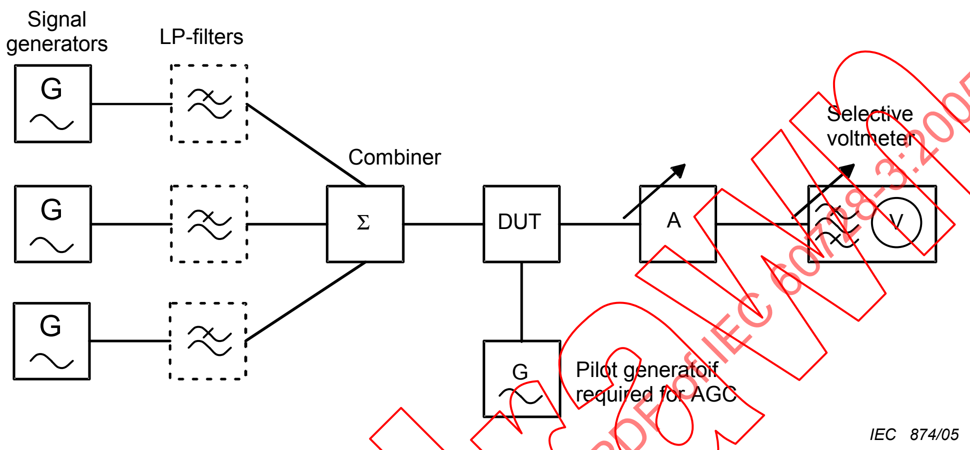
c) A variable attenuator with a range greater than the signal to intermodulation ratio expected, if not incorporated in the voltmeter described in 4.2.2.2 a).

d) 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 B).

4.2.1.3 Connection of equipment

The equipment shall be connected as shown in Figure 3.



NOTE 1 The requirement for the items of test equipment indicated by dotted lines depends on the results of checks given in Annex B. 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 B).

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

4.2.1.4 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 off 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 B).

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

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

c) Measurement

Set the signal generators, in CW mode, to the frequencies of the test signals (see 4.2.2.4 a) and Annex A) 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 B) to the output of the device 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 B). 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.

4.2.2 Composite triple beat

4.2.2.1 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(µV) 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 C (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.

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.

4.2.2.2 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 4.2.3.1);

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.

4.2.2.3 Connection of equipment

The equipment shall be connected as shown in Figure 4.

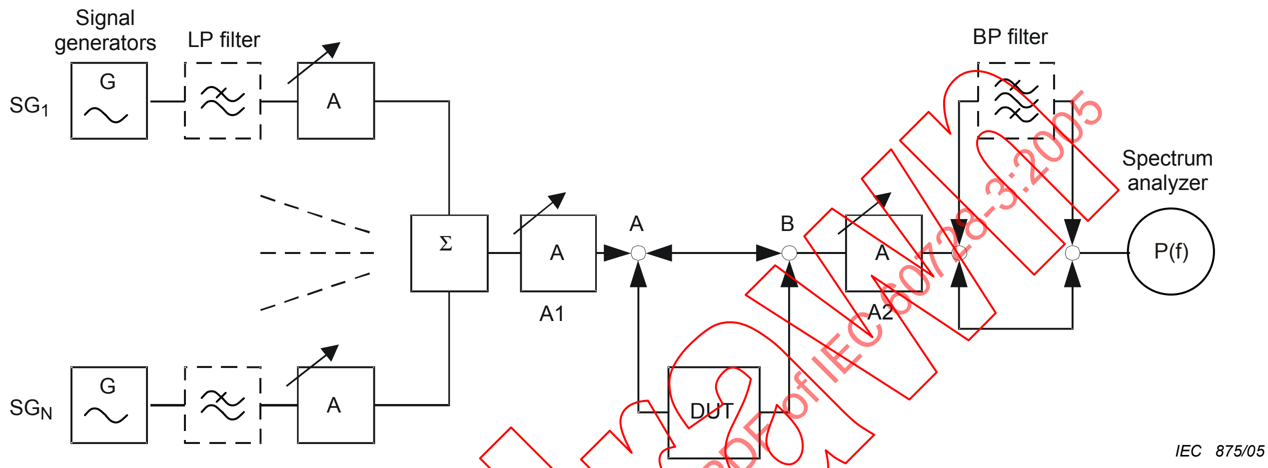


Figure 4 – Connection of test equipment for the measurement of non-linear distortion by composite beat

4.2.2.4 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 device 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 device 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.

4.2.3 Composite second order beat

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

4.2.3.1 Equipment required

The test equipment required is the same as described in 4.2.3.2.

4.2.3.2 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 ±0,75 MHz or ±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.

4.2.4 Composite crossmodulation

4.2.4.1 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 C1.

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 device 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).

4.2.4.2 Conditions of measurement

a) The measurements shall be carried out with all the input signals present. These shall be appropriate to the frequency range of the particular device under test and in accordance with the Table C1.

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 r.m.s. values.

4.2.4.3 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 r.m.s. 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 C, 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.

4.2.4.4 Connection of equipment

Connect the equipment as shown in Figure 5.

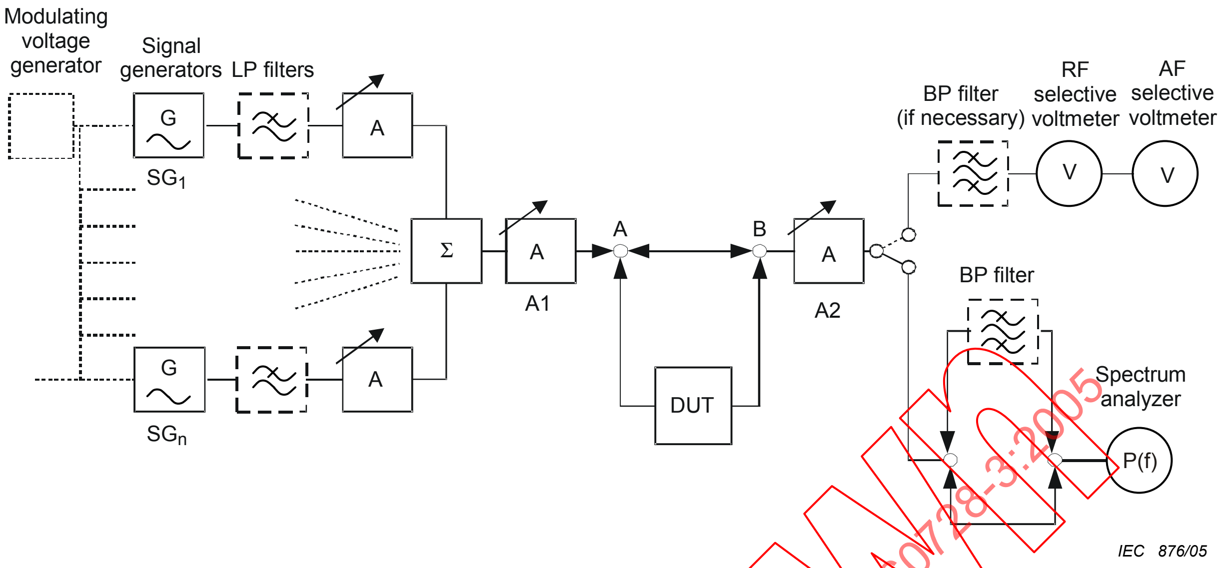


Figure 5 – Connection of test equipment for the measurement of composite crossmodulation

4.2.4.5 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.

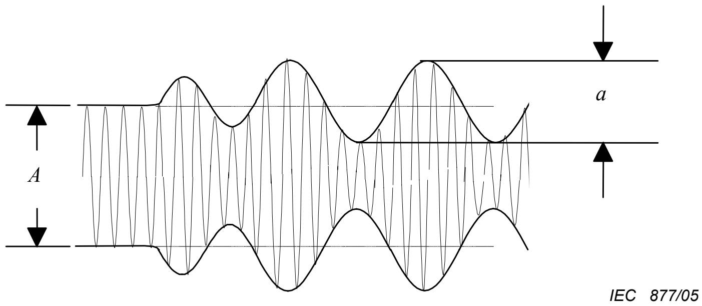
Adjust attenuator A1 of Figure 5 and compensate for the change in output level by using the attenuator A2 in order to obtain the required total composite cross-modulation;

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.

4.2.5 Hum modulation of carrier

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).



$$\text{Carrier/hum ratio} = 20 \cdot \log \frac{A}{a} [dB]$$

Figure 6 – Carrier/hum ratio

4.2.5.1 Description of the method of measurement

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.

4.2.5.1.1 Test equipment required

The following test equipment is required:

- adjustable voltage source;
- variable load resistor;
- power inserter;
- variable attenuator;
- oscilloscope;
- voltmeter (RMS);
- ammeter;
- 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).

4.2.5.1.2 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.

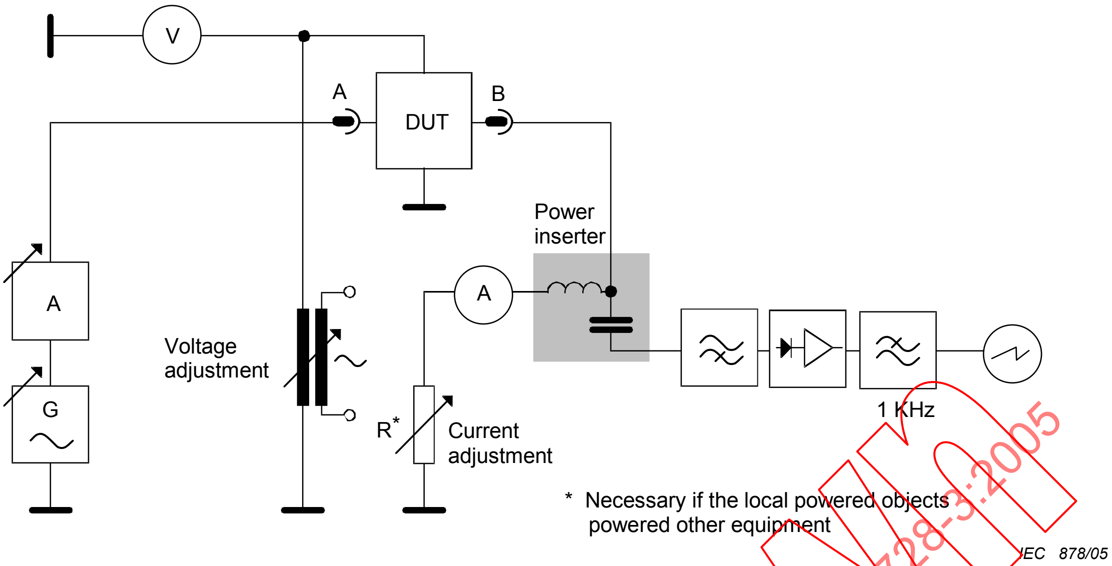


Figure 7 – Test set-up for local-powered objects

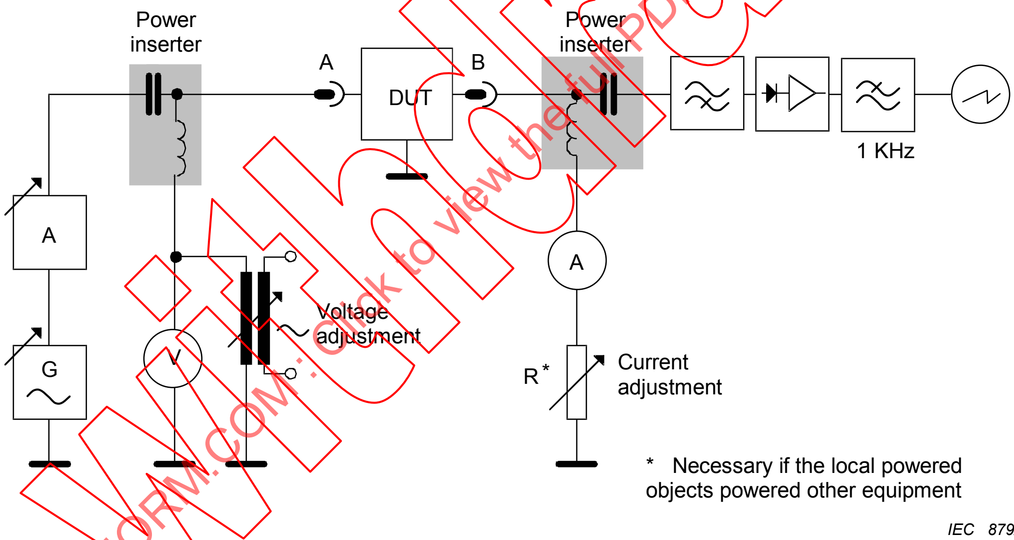


Figure 8 – Test set-up for remote-powered objects

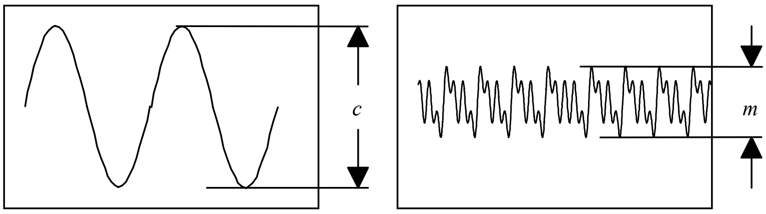
4.2.5.2 Measuring procedure

4.2.5.2.1 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.



Calibration signal Measured signal

IEC 880/05

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 4.2.5.3. 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.

4.2.5.2.2 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.

4.2.5.2.3 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.

4.2.5.3 Calculating the hum modulation ratio

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

4.2.5.3.1 Individual object

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

For other chosen reference modulation depth, the value 40 dB has to be replaced by the result of the term: –20 lg(modulation depth).

4.2.5.3.2 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:

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

where: n = number of cascaded test objects

4.2.5.3.3 Loop value correction

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

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

4.3 Automatic gain and slope control step response

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).

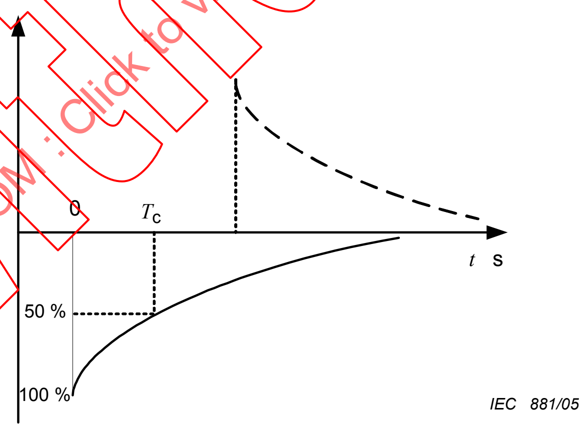


Figure 10 – Time constant T_c

The following procedure is used on equipment using pilots.

4.3.1 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.

4.3.2 Connection of equipment

The equipment is connected as shown in Figure 11.

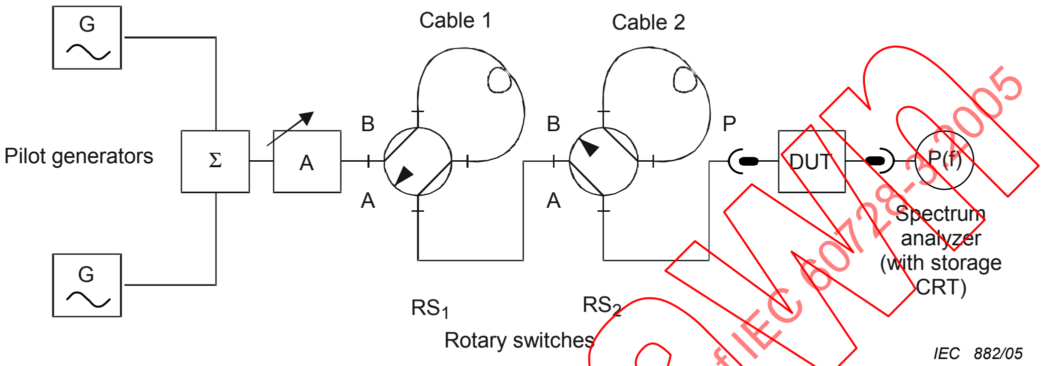


Figure 11 – Measurement of AGC step response

4.3.3 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 device under test;

b) turn the rotary switch RS_1 to position A (cable 1) and connect the device under test; With a 2 dB plug-in equaliser (or an additional 2 dB cable equaliser in front of the device under test), the pilot signals will have the same level at the first stage of the amplifier;

c) switch the device 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.

4.4 Noise figure

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.

4.4.1 Equipment required

a) A noise generator (excess noise source) suitable for the frequency range in use with dB, or kT_0, calibration.

b) A 3 dB attenuator.

c) A frequency selective power meter (voltmeter).

4.4.2 Connection of equipment

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

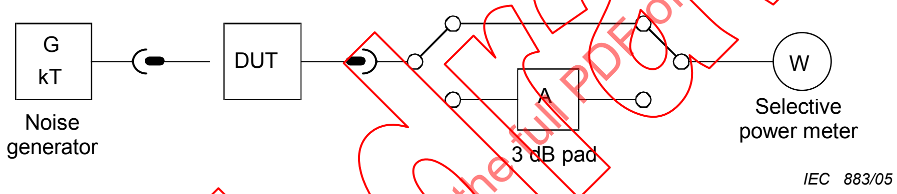


Figure 12 – Measurement of noise figure

4.4.3 Measurement procedure

The measurement procedure comprises the following steps:

a) 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 device 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 Ω. The bandwidth of the power meter should be adjusted to obtain a stable reading;

b) insert the 3 dB attenuator and increase the noise generator output level until the power meter returns to the original reference level;

c) read the noise figure from the noise generator;

d) repeat steps a) to c) at different frequencies across the band; The worst case shall be stated.

4.5 Crosstalk attenuation

4.5.1 Crosstalk attenuation for loop through ports

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.

4.5.1.1 Equipment required

Network analyzer.

4.5.1.2 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 port 2;
f) terminate all unused ports;
g) measure the attenuation between the input port 2 and the loop trough 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.

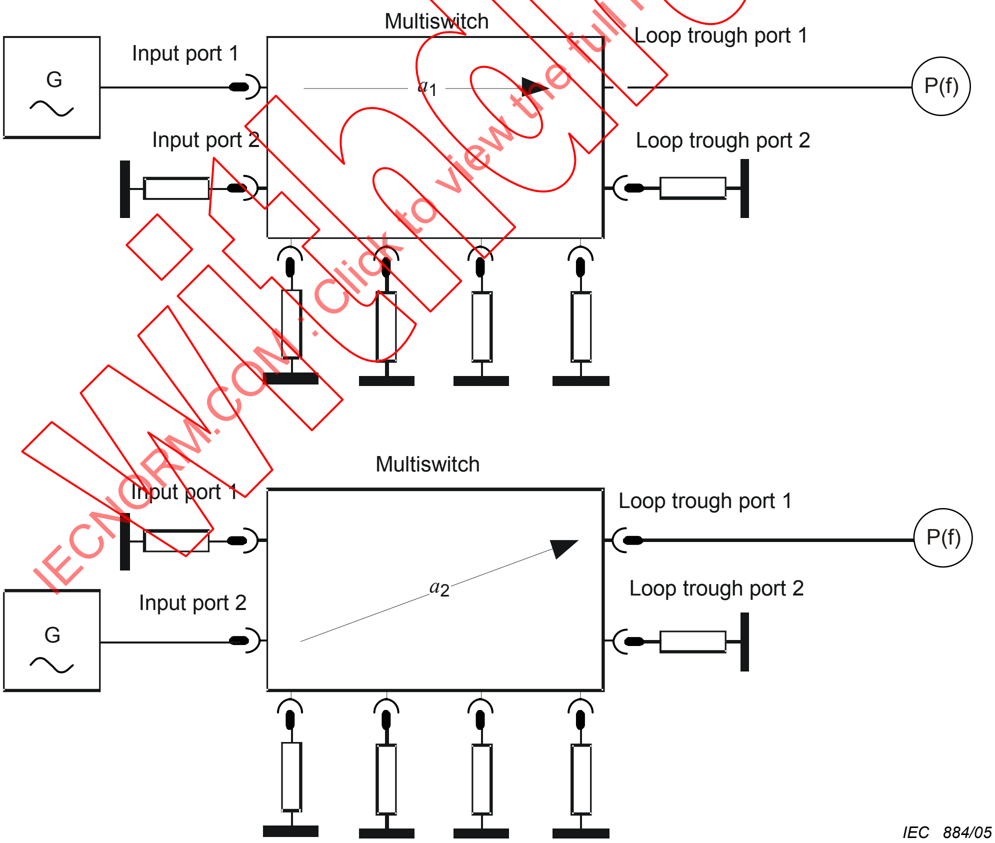


Figure 13 – Measurement of crosstalk attenuation for loop trough ports of multi-switches

4.5.2 Crosstalk attenuation for output ports

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.

4.5.2.1 Equipment required

The following equipment is required:

a) network analyzer;
b) bias-tee, see Clause 4;
c) standard satellite receiver.

4.5.2.2 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+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;
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.

4.6 Signal level for digitally modulated signals

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

4.7 Method of measurement for non-linearity of return path equipment carrying only digital modulated signals [Measurement of composite intermodulation noise ratio (CINR)]

Non-linear distortion of equipment carrying digital channels could be measured using different methods. The most prevalent methods are:

a) Bit Error Rate (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 device under test. The equipment is loaded with wideband noise and a small gap of the noise is removed before the noise enters the device 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.

4.7.1 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 DUT. 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 Ω attenuator, adjustable in 1 dB steps.

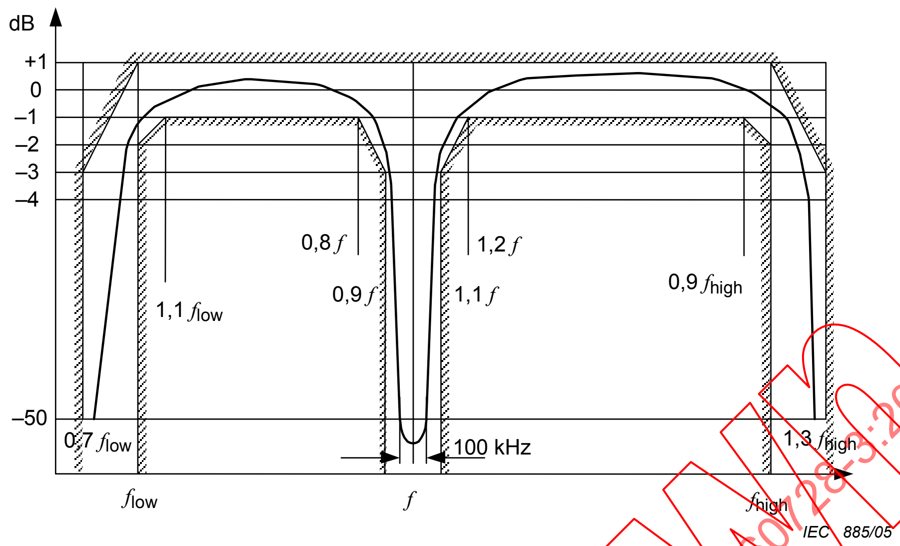


Figure 14 – Characteristic of the noise filter

4.7.2 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.

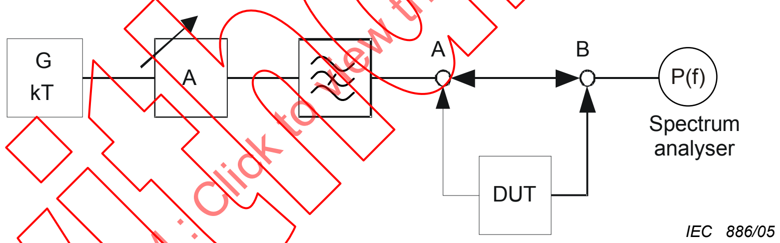


Figure 15 – Test setup for the non-linearity measurement

4.7.3 Measurement procedure

Because the digitally modulated signal is similar in characteristics to white noise, an accurate power density measurement can be performed using the marker noise function of a spectrum analyzer:

a) connect point A directly to point B;

b) adjust the spectrum analyzer as follows:
   - resolution bandwidth: 30 kHz,
   - video bandwidth: 1 kHz (or lower to obtain a smooth display),
   - start and stop frequency: as required,
   - detector type: r.m.s. vertical scale 5 dB/div;

c) adjust the sensitivity of the spectrum analyzer to maximise the dynamic range. If the spectrum analyzer does not provide enough dynamic range to measure a high notch depth, a bandpass filter may be added in front of the spectrum analyzer which should pass enough of the signal and the notch so that both signal and notch level could be measured. The signal level for maximum dynamic range should be fixed as reference level;.

d) connect the device under test between points A and B, adjust the gain of the device for maximum gain and readjust the input attenuator of the spectrum analyzer to the reference level;

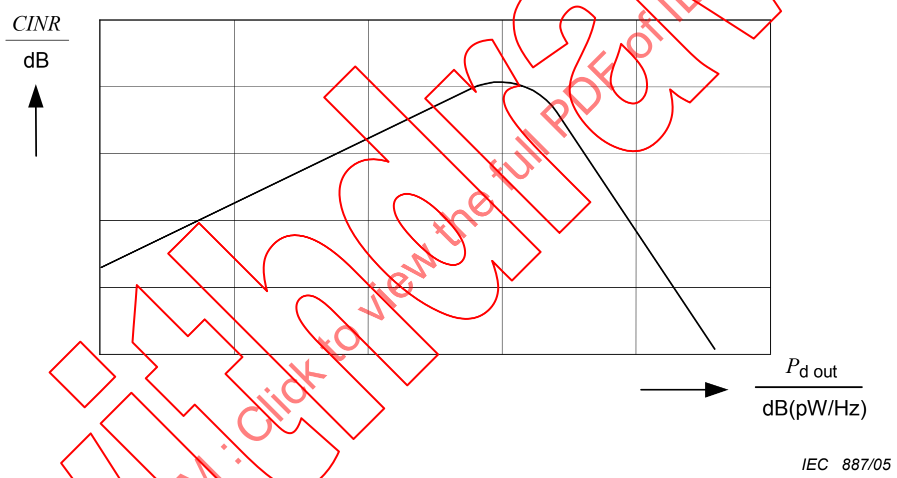
e) while adjusting the variable attenuator always make sure to readjust the input attenuator of the spectrum analyzer to the reference level for maximum dynamic range. Verify that the analyzer noise floor is sufficiently (>10 dB) below notch level, otherwise use a noise-near-correction table. Verify that the analyzer's contribution to the intermodulation is negligible;

f) measure the level of the wideband noise density in dB(mW/Hz) at point B. Measure CINR as the difference of the values of the noise inside and outside of the gap of the notch filter;

g) the measurement has to be done at the three given frequencies.

4.7.4 Presentation of the results

The worst case of the results shall be plotted in dB of the composite intermodulation noise ratio (*CINR*) at the considered notch frequency versus the output power density P_d in dB(pW/Hz) (Figure 16).



$P_d = P - 10\ \lg\ (B_w)$

where

P is the power in dB(pW);

B_w is the bandwidth in Hz.

Figure 16 – Presentation of the result of *CINR*

The indication of the best possible notch depth leads to incorrect data about intermodulation performance of the equipment, because at this signal level distortion noise does not dominate thermal noise. The results are highly dependent on the thermal noise performance of the equipment. For this reason, it is very useful to plot depths of the notch at its centre frequency versus several high output levels, to be sure reaching the signal levels were distortion noise dominates.

NOTE 1 If it is not possible to measure the full curve due to the dynamic range of the equipment, parts of the curve can be presented. See also Clause E.5

NOTE 2 For a given bandwidth, there is a precise relationship between power and level. For impedance of 75 Ω, the relationship is:

$$P\ [\mathrm{dB(pW)}] = L\ [\mathrm{dB(\mu V)}] - 18{,}75\ \mathrm{dB}$$

where

L is the level in dB(μV);

P is the power in dB(pW).

18,75 dB(μV) = 0 dB(pW)

5 Equipment requirements

5.1 General requirements

Where the standard calls for performance figures to be published, these shall be stated, if appropriate, for each input and output port.

Published performance figures shall apply when the methods of measurement given in Clause 4, or equivalent methods are used.

Service and installation instructions should be available.

5.1.1 Connectors

The following types of connectors are required:

d) for equipment used below 950 MHz: connectors according to IEC 60169-2:1965 and amendment 1:1982 or IEC 60169-24;

e) for equipment used above 950 MHz: connectors according to IEC 60169-24.

NOTE Inside equipment, other types of connectors are allowed.

5.2 Safety

The relevant safety requirements as laid down in IEC 60728-11 shall be met.

5.3 Electromagnetic compatibility (EMC)

The relevant EMC requirements as laid down in IEC 60728-2 shall be met.

5.4 Frequency range

The frequency range or ranges, over which the equipment is specified, shall be published.

5.5 Impedance and return loss

The nominal impedance shall be 75 Ω.

Amplifier return loss requirements are dependent on its position and purpose in the system. All input and output ports of the unit shall meet the specification under all specified conditions of automatic and manual gain and slope controls and with any combination of plug-in equalisers and attenuators fitted.

For amplifier quality grade 1, the return loss shall be category B and for amplifier quality grade 2, the return loss shall be category C.

The performance requirement for each return loss category is given in Table 3.

Table 3 – Return loss requirements for all equipment

Category	Frequency range MHz	Requirement
A	5 to 40	≥ 22 dB
	40 to 1750	≥ 22 dB – 1,5 dB/octave but ≥ 14 dB
	1750 to 3000	14 dB decreasing linear to 10 dB
B	5 to 40	≥ 18 dB
	40 to 1750	≥ 18 dB – 1,5 dB/octave but ≥ 10 dB
	1750 to 3000	10 dB decreasing linear to 6 dB
C	5 to 40	≥ 14 dB
	40 to 1750	≥ 14 dB – 1,5 dB/octave but ≥ 10 dB
	1750 to 3000	10 dB decreasing linear to 6 dB
D	5 to 1750	≥ 10 dB
	1750 to 3000	10 dB decreasing linear to 6 dB

Manufacturers shall state the return loss category of each amplifier.

NOTE For amplifiers of quality grades other than 1 or 2, manufacturers must specify minimum return loss ratio using the method of measurement described in 4.1.1 and presentation as Table 3. Some amplifiers may have different return loss ratio categories for different ports.

5.6 Gain

The minimum and maximum guaranteed gain of the amplifier, in dB, at the highest specified frequency shall be published.

5.6.1 Gain control

The range, in dB, of any gain control shall be published.

5.6.2 Slope and slope control

The characteristic of any fixed slope, if fitted, and cable characteristic for that slope, shall be published. This shall be in the form of a formula showing the relationship between attenuation, in dB, and frequency, or, the particular test cable used for the factory test shall be stated.

The range, in dB, of any variable slope control, relative to the mean value, shall be published.

5.7 Flatness

The flatness of the amplitude frequency response from the input to the output ports shall be published. Slope is assumed to be eliminated either by calculation or by cable.

Narrowband flatness to the output ports shall be within 0,2 dB peak-to-peak/0,5 MHz and 0,5 dB peak-to-peak/7 MHz.

The flatness specification shall be achieved in all specified conditions of automatic and manual gain controls and also with any combination of plug-in equalisers and attenuators specified for the device.

5.8 Test points

Test points shall be 75 Ω or adapted to 75 Ω through a test probe. The return loss shall correspond to that of the quality grade of the amplifier according to Table 3. The attenuation and flatness shall be published.

5.9 Group delay

5.9.1 Chrominance/luminance delay inequality

The worst-case delay inequality, in nanoseconds, between the luminance signal and chrominance sub-carrier (4,43 MHz) within a single PAL/SECAM television channel shall be published. The worst-case channel shall be identified by frequency.

5.9.2 Chrominance/luminance delay inequality for other television standards and modulation systems

These shall be measured over the relevant channel bandwidth and the worst case figure shall be published, if relevant.

5.10 Noise figure

The maximum noise figure over the specified frequency range shall be published.

5.11 Non-linear distortion

If the amplifier is designed for sloped operation, measurements shall be carried out with sloped output.

The tests outlined are applicable to various categories of amplifiers as follows:

a) for wideband amplifiers intended for operation with more than 10 television channels in the range below 862 MHz: composite triple beat, composite second order and composite crossmodulation;

   NOTE Manufacturers may also publish second order and third order intermodulation performance.

b) for amplifiers intended for operation with less than 10 television channels in the range below 862 MHz, including return path amplifiers below 70 MHz: second order and third order distortion;

   NOTE The maximum number of channels must be clearly stated in the specification.

c) for amplifiers operating in the range above 862 MHz, usually with only FM signals: second order and third order distortion;

   NOTE Composite distortion measurements for these amplifiers remain under consideration.

5.11.1 Second order distortion

The worst case value shall be published as the output level in dB(μV), that gives 60 dB signal to distortion ratio, or 35 dB for amplifiers carrying only FM signals in the pass band.

NOTE For some amplifiers (e.g. feedforward), it may not be possible to measure 60 dB signal to distortion ratio. In these cases, the output level for a greater signal to distortion ratio may be stated.

5.11.2 Third order distortion

The worst-case value shall be published as the output level in dB(μV), that gives 60 dB signal to distortion ratio, or 35 dB for amplifiers carrying only FM signals in the pass band.

NOTE For some amplifiers (e.g. feedforward), it may not be possible to measure 60 dB signal to distortion ratio. In these cases, the output level for a greater signal to distortion ratio may be stated.

5.11.3 Composite triple beat

The worst case value over all channels shall be published as the output level in dB(μV), that gives 60 dB signal to distortion ratio.

NOTE For some amplifiers (e.g. feedforward), it may not be possible to measure 60 dB signal to distortion ratio. In these cases, the output level for a greater signal to distortion ratio may be stated.

5.11.4 Composite second order

The worst case value over all channels shall be published as the output level in dB(μV), that gives 60 dB signal to distortion ratio.

NOTE For some amplifiers (e.g. feedforward), it may not be possible to measure 60 dB signal to distortion ratio. In these cases, the output level for a greater signal to distortion ratio may be stated.

5.11.5 Composite crossmodulation

The worst case value over all channels shall be published as the output level in dB(μV), that gives 60 dB signal to distortion ratio.

Two output level values shall be published. These correspond to the transfer of amplitude modulation only, as measured by amplitude demodulation, and to total modulation transfer as measured on a spectrum analyzer.

NOTE For some amplifiers (e.g. feedforward), it may not be possible to measure 60 dB signal to distortion ratio. In these cases, the output level for a greater signal to distortion ratio may be stated.

5.12 Automatic gain and slope control

The pilot frequencies and the dynamic range shall be published. Dynamic range is, in this case, defined as the minimum and maximum input level variations, in dB, which can be compensated for by the amplifier, at the highest and lowest frequencies. Maximum variation in the output level at the highest and lowest frequencies, corresponding to the input level variations for the specified dynamic range and over the specified temperature range, shall be published.

NOTE This may not correspond to the variation at the pilot frequencies if the pilots are not close to the highest and lowest frequencies.

The control time constant of the step response shall be published.

5.13 Hum modulation

The value of the hum modulation shall be published in dB at the worst case of voltage and specified peak-current of the equipment.

5.14 Power supply

The following shall be published:

- input AC_{RMS} voltage and frequency range;
- power consumption to complete amplifier assembly or to each active module;
- for modular amplifiers, the DC current and voltage required for, or given by, each active module;
- the worst-case peak-to-peak ripple voltage, if the supply voltage is available for external use.

5.15 Environmental

Manufacturers shall publish relevant environmental information on their products in accordance with the requirements of the following publications:

5.15.1 Storage (simulated effects of)

	IEC 60068-2-48

5.15.2 Transportation

Air freight (combined cold and low pressure)	IEC 60068-2-40
Road transport (bump test)	IEC 60068-2-29
Road transport (shock test)	IEC 60068-2-27

5.15.3 Installation or maintenance

Topple or drop test	IEC 60068-2-31
Free fall test	IEC 60068-2-32

5.15.4 Operation

IP class. Protection provided by enclosures		IEC 60529+A1
Climatic category of component or equipment for storage and operation as defined in	Appendix A of	IEC 60068-1
Cold		IEC 60068-2-1
Dry heat		IEC 60068-2-2+A1
Damp heat		IEC 60068-2-30
Change of temperature (test Nb)		IEC 60068-2-14
Vibration (sinusoidal)	Appendix B of	IEC 60068-2-6

This will enable users to judge their suitability with regards to four main requirements: storage, transportation, installation and operation.

5.16 Marking

5.16.1 Marking of equipment

All equipment shall be legibly and durably marked with the manufacturers name and type number.

5.16.2 Marking of ports

It is recommended that symbols in accordance with the series IEC 60417 and IEC 80416 should be used when marking ports.

5.17 Mean operating time between failure (MTBF)

Under consideration.

5.18 Requirements for multi-switches

5.18.1 Control signals for multi-switches

Control signals shall be compliant with the control signals for low-noise block converters as specified in IEC 61319-1 and IEC 61319-2.

5.18.2 Amplitude frequency response flatness

The flatness of the amplitude frequency response from input to output ports, from input to loop through ports and from terrestrial input to output ports shall be according to the requirements for splitters in IEC 60728-4

5.18.3 Return loss

The return loss on all input, output, loop through and terrestrial input ports shall be according to the requirements for splitters in IEC 60728-4.

5.18.4 Through loss

The through loss from input to output ports, from input to loop through ports and from terrestrial input to output ports shall be published for the appropriate frequency ranges.

5.18.5 Isolation

The isolation between input ports and between loop through ports shall be published.

The isolation between output ports that are switched to the same input port shall be according to the requirements for splitters in IEC 60728-4.

The isolation between output ports that are switched to different input ports shall be published.

NOTE Performance requirements can be derived from system parameters given in IEC 60728-1.

5.18.6 Crosstalk attenuation

At an output the crosstalk attenuation between the selected input and another input shall be measured. The minimum value of all combinations of output ports, input ports and switch positions shall be published. The method of measurement is given in 4.5.

NOTE Performance requirements can be derived from system parameters given in IEC 60728-1.

5.18.7 Satellite IF to terrestrial signal isolation

If the multi-switch includes a coupling function for terrestrial signals, then the minimum value of the attenuation from satellite IF input ports to output ports in the frequency range of the terrestrial signals shall be published.

NOTE Performance requirements can be derived from system parameters given in IEC 60728-1.

Annex A
(normative)

Test carriers, levels and intermodulation products

A.1 Two signal tests for second and third order products

A.1.1 Intermodulation products with test signals at frequencies f_a and f_b

Second order (see note):	$P2_a = f_b - f_a$	
	$P2_b = f_a + f_b$	
Third order:	$P3_a = 2f_a - f_b$	where $2f_a > f_b$
	$P3_a = f_b - 2f_a$	where $2f_a < f_b$
	$P3_b = 2f_b - f_a$	
	$P3_c = 2f_a + f_b$	
	$P3_d = 2f_b + f_a$	

NOTE Not applicable to narrow-band equipment unless the frequency range covered by the equipment is such that $2f_{min} < f_{max}$.

A.1.2 Signal levels

The two test carriers shall be set to the reference level.

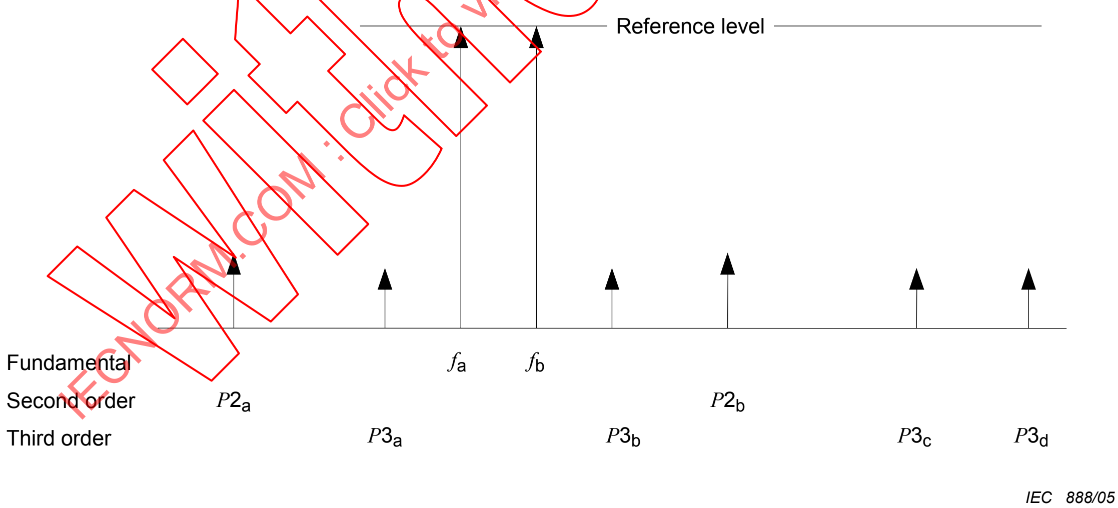


Figure A.1 – An example showing products formed when $2f_a > f_b$

NOTE The sequence of the intermodulation products will depend on the fundamental frequencies chosen.

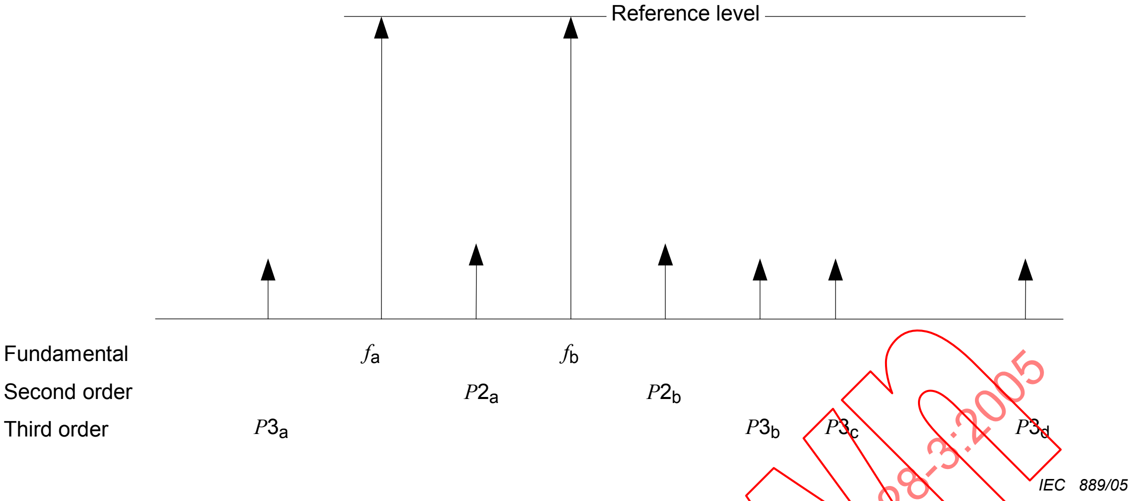


Figure A.2 – An example showing products formed when $2f_a < f_b$

NOTE The sequence of the intermodulation products will depend on the fundamental frequencies chosen.

A.2 Three signal tests for third order products

A.2.1 Intermodulation products with test signals at frequencies f_a, f_b and f_c.

Third order:	$P3_f = f_a + f_b - f_c$
	$P3_g = f_a + f_c - f_b$
	$P3_h = f_b + f_c - f_a$
	$P3_i = f_a + f_b + f_c$

NOTE Second and third order products due to any two of the test carriers will also be present if they fall within the frequency range of the equipment or system to be tested.

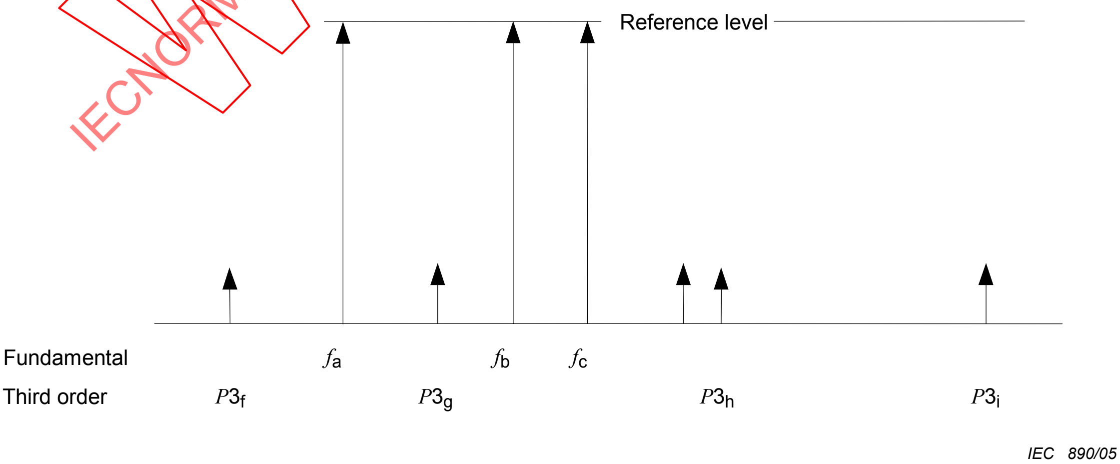


Figure A.3 – Products of the form $f_a \pm f_b \pm f_c$