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Passive RF and microwave devices, intermodulation level measurement – Part 1: General requirements and measuring methods

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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PASSIVE RF AND MICROWAVE DEVICES, INTERMODULATION LEVEL MEASUREMENT –

Part 1: General requirements and measuring methods

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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This redline version of the official IEC Standard allows the user to identify the changes made to the previous edition IEC 62037-1:2012. A vertical bar appears in the margin wherever a change has been made. Additions are in green text, deletions are in strikethrough red text.

IEC 62037-1 has been prepared by IEC technical committee 46: Cables, wires, waveguides, RF connectors, RF and microwave passive components and accessories. It is an International Standard.

This second edition cancels and replaces the first edition published in 2012. This edition constitutes a technical revision.

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

a) clarification added that test equipment may utilize pulsed generators to reduce power consumption;
b) heating effect differences in the device under test noted in Annex B for tests conducted using pulsed generators;
c) guidance added in Annex B to improve probability of detection of short duration PIM events while dynamic testing.

The text of this International Standard is based on the following documents:

Draft	Report on voting
46/834/FDIS	46/855/RVD

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

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/standardsdev/publications.

This International Standard is to be used in conjunction with IEC 62037 (all parts).

A list of all the parts in the IEC 62037 series, published under the general title *Passive RF and microwave devices, intermodulation level measurement*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

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- withdrawn,
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PASSIVE RF AND MICROWAVE DEVICES, INTERMODULATION LEVEL MEASUREMENT –

Part 1: General requirements and measuring methods

1 Scope

This part of IEC 62037 deals with the general requirements and measuring methods for intermodulation (IM) level measurement of passive RF and microwave components, which can be caused by the presence of two or more transmitting signals.

The test procedures given in this document give the general requirements and measurement methods required to characterize the level of unwanted IM signals using two transmitting signals.

The IEC 62037 series addresses the measurement of PIM, but does not cover the long-term reliability of a product with reference to its performance.

~~This standard is to be used in conjunction with other appropriate part(s) of IEC 62037.~~

2 Normative references

~~None.~~

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 62037 (all parts), *Passive RF and microwave devices, intermodulation level measurement*

3 Terms, definitions and abbreviated terms

3.1 Terms and definitions

No terms and definitions are listed in this document.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

3.2 Abbreviated terms

CATV Community antenna television

CFEC Carbon fibre epoxy composite

CW Continuous wave

DUT Device under test

IM Intermodulation

PCB Printed circuit board

PIM Passive intermodulation

RBW Resolution bandwidth

VDA Vacuum deposited aluminium

4 Characteristics of intermodulation products

PIM interference is caused by sources of non-linearity of mostly unknown nature, location and behaviour. A few examples are inter-metallic contacts, choice of materials, corrosion products, dirt, etc. Most of these effects are subject to changes over time due to mechanical stress, temperature changes, variations in material characteristics (cold flow, etc.) and climatic changes~~, etc~~.

The generation of intermodulation products originates from point sources inside a DUT and propagates equally in all available directions.

The generation of passive intermodulation (PIM) products does not necessarily follow the law of the usual non-linear equation of quadratic form. Therefore, accurate calculation to other power levels causing the intermodulation is not possible and PIM comparisons should be made at the same power level.

Furthermore, PIM generation can be frequency dependent. When PIM generation is frequency dependent, the PIM performance shall be investigated over the specified frequency band.

5 Principle of test procedure

Test signals of frequencies f_1 and f_2 with equal specified test port power levels are combined and fed to the DUT. The test signals should contain a harmonic or self-intermodulation signal level at least 10 dB lower than the expected level generated in the DUT.

The PIM is measured over the specified frequency range. The intermodulation products of order $(2f_1 \pm f_2)$, $(2f_2 \pm f_1)$, etc., are measured.

In most cases, the third order intermodulation signals represent the worst-case condition of unwanted signals generated; therefore, the measurement of these signals characterizes the DUT in a sufficient way. However, the test set-ups given in Clause 6 are suitable for measuring other intermodulation products.

In other systems (such as CATV), the third order may not be as applicable in characterizing the DUT.

Intermodulation can be measured in the reverse and forward direction. Reverse and forward refer to the direction of propagation of the most powerful carrier.

6 Test set-up

6.1 General

Experience shows that the generation of intermodulation products originates from point sources inside a device under test (DUT) and propagates equally in all available directions. Therefore, either the reverse (reflected) or the forward (transmitted) intermodulation signal can be measured.

Two different test set-ups are described in Figure 1 and Figure 2 and are for reference only. Other topologies are possible.

Set-up 1 is for measuring the reverse (reflected) intermodulation signal only, and set-up 2 is for measuring the forward (transmitted) intermodulation signal. The measurement method (reverse or forward) is dependent upon the DUT. The set-ups may be assembled from standard microwave or radio link hardware selected for this particular application. All components shall be checked for lowest self-intermodulation generation.

Experience shows that devices containing magnetic materials (circulators, isolators, etc.) can be prominent sources of intermodulation signal generation.

See Annex B for additional set-up considerations.

6.2 Test equipment

6.2.1 General

Two signal sources or signal generators with power amplifiers are required to reach the specified test port power. The combining and diplexing device ~~may~~ can comprise a circulator, hybrid junction, coupler or filter network.

The test set-up self-intermodulation generated (including contribution of the load) should be at least 10 dB below the level to be measured on the DUT. The associated error may be obtained from the graph in Figure 3.

The DUT shall be terminated by a load for the specified power if necessary. The receiving bandpass filter, tuned for the desired intermodulation signal, is followed by a low noise amplifier (if required) and a receiver.

See Annex B for additional set-up considerations.

6.2.2 Set-up 1

This set-up is for measuring the reverse (reflected) IM-product and is therefore suitable for one-port and multi-port DUTs. On multi-port DUTs, the unused ports shall be connected to a linear termination. See Annex A for information on low PIM terminations.

a) Generators

The generators shall provide continuous wave (CW) signals of the specified test port power. They shall have sufficient frequency stability to ~~make sure~~ ensure that the IM-product can be detected properly by the receiver. The generators may be pulsed on and off while testing to reduce power consumption.

Some limitations apply when using pulsed generators. See Annex B for test procedure considerations when using equipment with pulsed generators.

b) Transmit-filters

The filters are bandpass filters tuned to the particular frequencies. They isolate the generators from each other and filter out the harmonics of f_1 and f_2.

c) Combining and diplexing device

This device is used for combining the signals f_1 and f_2, delivering them to the test port and provides a port for the extraction of the reverse (reflected) signal f_{IM}.

d) Receive-filter

This filter is used for isolating the input of the receiver from the signals f_1 and f_2 to the extent that IM-products are not generated within the receiver.

e) Test port

The DUT is connected to P4. The specified input power shall be at the DUT, with any set-up loss between the receiver and the DUT compensated for.

f) Termination

When a multi-port DUT is measured, the DUT shall be connected to a sufficiently linear termination (low intermodulation) of suitable power handling capability.

g) Receiver

The receiver shall be sensitive enough to detect a signal of the expected power level.

The receiver response time shall be sufficiently short to allow acquisition of rapid changes in amplitude. Sensitivity can be increased by a low noise preamplifier. Frequency stability shall be sufficient for the proper detection of the IM-signal.

When the PIM measurement result is close to the thermal noise floor of the receiver, the receiver sensitivity can be improved by reducing the resolution bandwidth (RBW). Furthermore, by using the averaging mode rather than the max-hold mode, a further improvement can be achieved, since the max-hold mode essentially measures the maximum thermal noise peak, while the averaging mode results in a measurement that is closer to the RMS value.

6.2.3 Set-up 2

This set-up is for measuring the forward (transmitted) IM-product and is therefore suitable only for two- or multi-port DUTs.

All components are the same as those of set-up 1, except for those as noted below:

a) Combining and diplexing device

The extraction-port P3 on this device shall be terminated to prevent reflection of the IM-signals.

b) Diplexing device

The signals f_1, f_2 and f_{IM} are split to P6 and P7. This device, together with an additional receive-filter, is used for the extraction of the intermodulation signals.

7 Preparation of DUT and test equipment

7.1 General

The DUT and test equipment shall be carefully checked for proper power handling range, frequency range, cleanliness and correct interconnection dimensions. All connector interfaces shall be tightened to the applicable IEC specification or, if none exists, to the manufacturer's recommended specification.

See Annex B for additional set-up considerations.

7.2 Guidelines for minimizing generation of passive intermodulation

The following guidelines and Table 1 should be considered and adhered to wherever possible.

a) Non-linear materials should not be used in or near the current paths.

b) Current densities should be minimized in the conduction paths (e.g. Tx channel), by using larger conductors.

c) Minimize metallic junctions, avoid loose contacts and rotating joints.

d) Minimize the exposure of loose contacts, rough surfaces and sharp edges to RF power.

e) Keep thermal variations to a minimum, as the expansion and contraction of metals can create non-linear contacts.

f) Use brazed, soldered or welded joints if possible, but ensure these joints are good and have no non-linear materials, cracks, contamination or corrosion.

g) Avoid having tuning screws or moving parts in the high current paths; if necessary, ensure all joints are tight and clean, and preferably, free from vibration.

h) Cable lengths in general should be minimized and the use of high quality, low-IM cable is essential.

i) Minimize the use of non-linear components such as high-PIM loads, circulators, isolators and semiconductor devices.

j) Achieve good isolation between the high-power transmit signals and the low power receive signals by filtering and physical separation.

Table 1 – Guide for the design, selection of materials and handling of components that ~~may~~ can be ~~susceptive~~ susceptible to PIM generation

Part, material or procedure	Recommendations
Interfaces	Minimize the total number.
Connectors	Minimize the number of connectors used. Use high quality, low-PIM connectors mated with proper torque.
Inter-metallic connections	Each inter-metallic connection should be evaluated in terms of criticality for the total PIM level. Methods of controlling the performance are high contact pressure, insulation, soldering, brazing, etc.
Ferromagnetic materials	Not recommended (non-linear).
Non-magnetic stainless steel	Not recommended (contains iron).
Circulators, isolators and other ferrite devices	Not recommended.
Sharp edges	Avoid if it results in high current density.
Terminations or attenuators	Should be evaluated before use.
Hermetic seals / gaskets	Evaluate before use and avoid ferromagnetic materials.
Printed circuit boards (PCBs)	Materials, processes and design should all be considered and evaluated. Use low-PIM materials; be careful with material impurities, contamination and etching residuals. The copper trace should be finished to prevent corrosion.
Dissimilar metals	Not recommended (risk of galvanic corrosion).
Dielectric material	Use clean, high quality material. Ensure it does not contain electrically conductive particles.
Machined dielectric materials	Use clean non-contaminated tools for machining.
Welded, soldered or brazed joints	Well executed and thoroughly cleaned, they provide satisfactory results. Shall be carefully inspected.
Carbon fibre epoxy composite (CFEC)	Generally acceptable for use in reflector and support structures, provided the fibres are not damaged. Should be evaluated if high flux density (e.g. > 10 mW /cm^2) is expected.
Standard multilayer thermal blankets made of vacuum deposited aluminium (VDA) on biaxially-oriented polyethylene terephthalate film or polyimide film	Special design required.
Cleanliness	Maintain clean and dry surfaces.
Plating	The thickness of the plating should be at least three times greater than the skin depth of the wave resulting from the skin effect at the lowest relevant frequency.

8 Test procedure

Table 2 gives certain conditions for test set-up 1 and test set-up 2.

Table 2 – Test set-up conditions

Test set-up 1	Test set-up 2
The set-up shall be verified for correct signal levels applied to the DUT. For mobile communication systems, it is generally recommended to use 2 × 20 W (43 dBm) at the test port of the DUT, unless otherwise specified. Other systems ~~may~~ can require different power levels (higher or lower). See Annex B for heating effect considerations.	
The minimum number of test frequencies and/or frequency spacing shall be specified.	
For lowest measurement uncertainty, the receiver shall be calibrated at the expected IM-level with a calibrated signal-source as indicated in Figure 1 and Figure 2.	
The termination shall be connected directly to the test port P4 and the self-intermodulation level of the set-up recorded.	P5 of the diplexing device shall be connected directly to P4 of the combining and summing device and the self-intermodulation level of the set-up recorded.
For low measurement uncertainties, the level of self-intermodulation should be at least 10 dB below the specified value for the DUT.	
Test the DUT as given in the specific set-up and procedure in the appropriate test set-up.	
An additional mechanical shock test may be carried out during the test sequence.	

9 Reporting

9.1 Results

The input power at individual frequencies should be specified. The values of f_1 and f_2 should be specified.

The PIM level and frequency should be specified.

9.2 Example of results

The result is expressed as an absolute magnitude in dBm or relative magnitude in dBc, referenced to the power of a single carrier.

The relationship between a measured IM_3 value of –120 dBm can be converted to dBc as follows:

EXAMPLE:

f_1 = 936 MHz, f_2 = 958 MHz, f_{IM_3} = 914 MHz

$P(f_1) = P(f_2)$ = 20 W (+43 dBm) IM_3 = –163 dBc (–120 dBm)

10 Measurement error

The measurement uncertainty can be calculated by the following formula:

$$RSS = \sqrt{\left[(\delta A)^2 + (\delta P_m)^2 + (\delta P_g)^2 + (\delta D)^2 \right]}$$

where

δA is the uncertainty of the attenuator;

δP_m is the uncertainty of the power meter;

δP_g is the uncertainty of the generator 3;

δD is the uncertainty due to the difference between self-intermodulation of the test bench and intermodulation of the DUT (taken from Figure 3).

Mismatch errors are not included in the given formula.

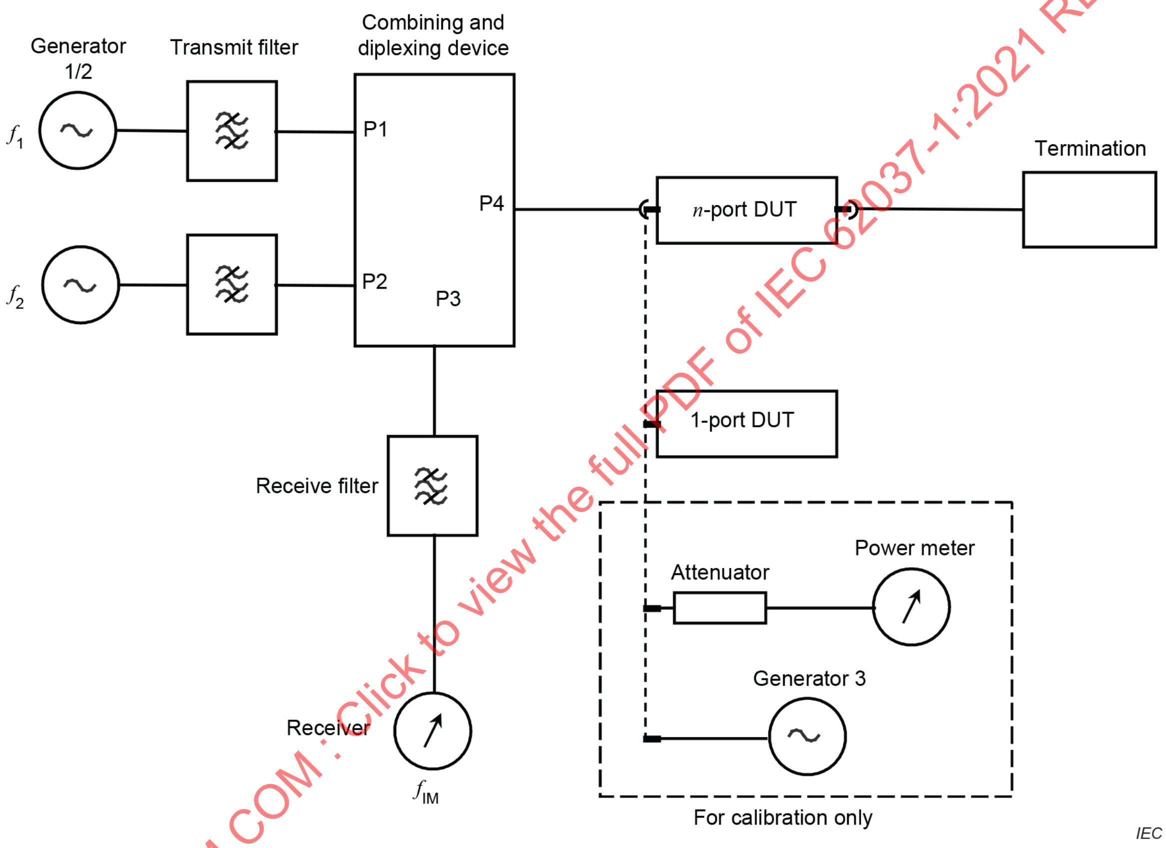


Figure 1 – Set-up 1: reverse IM-test set-up

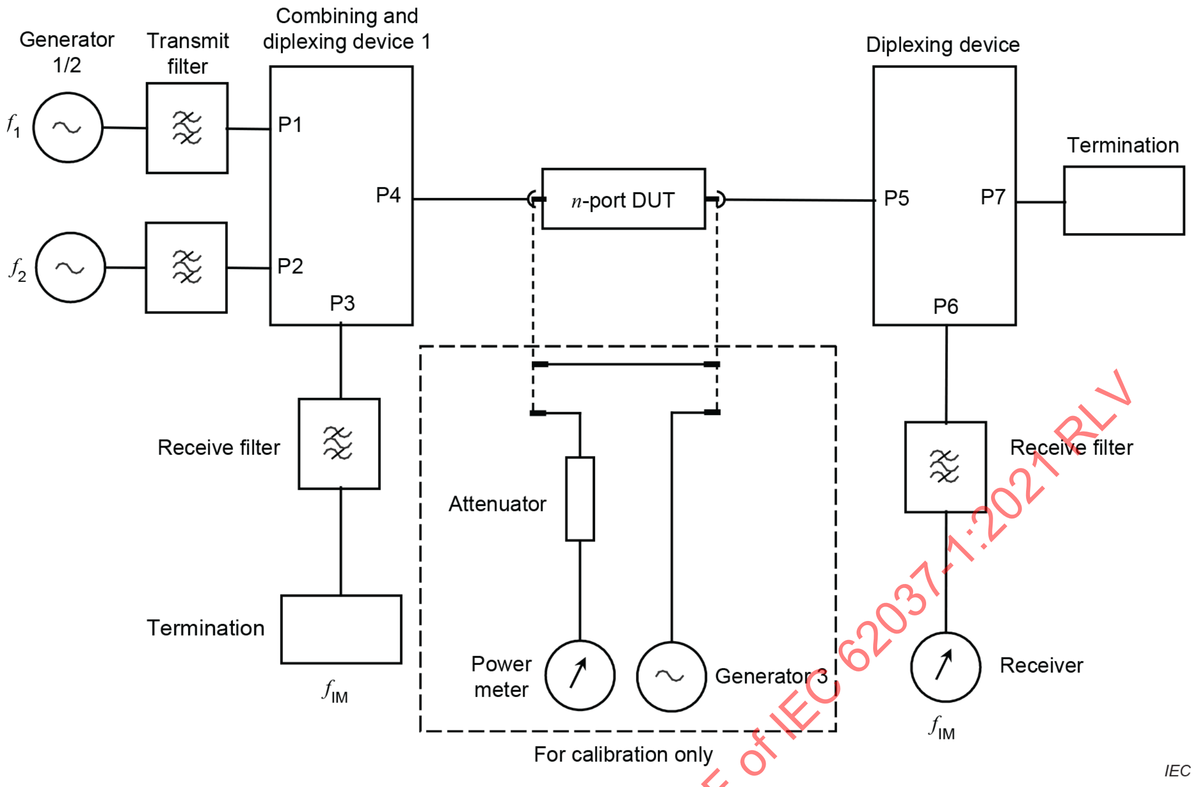
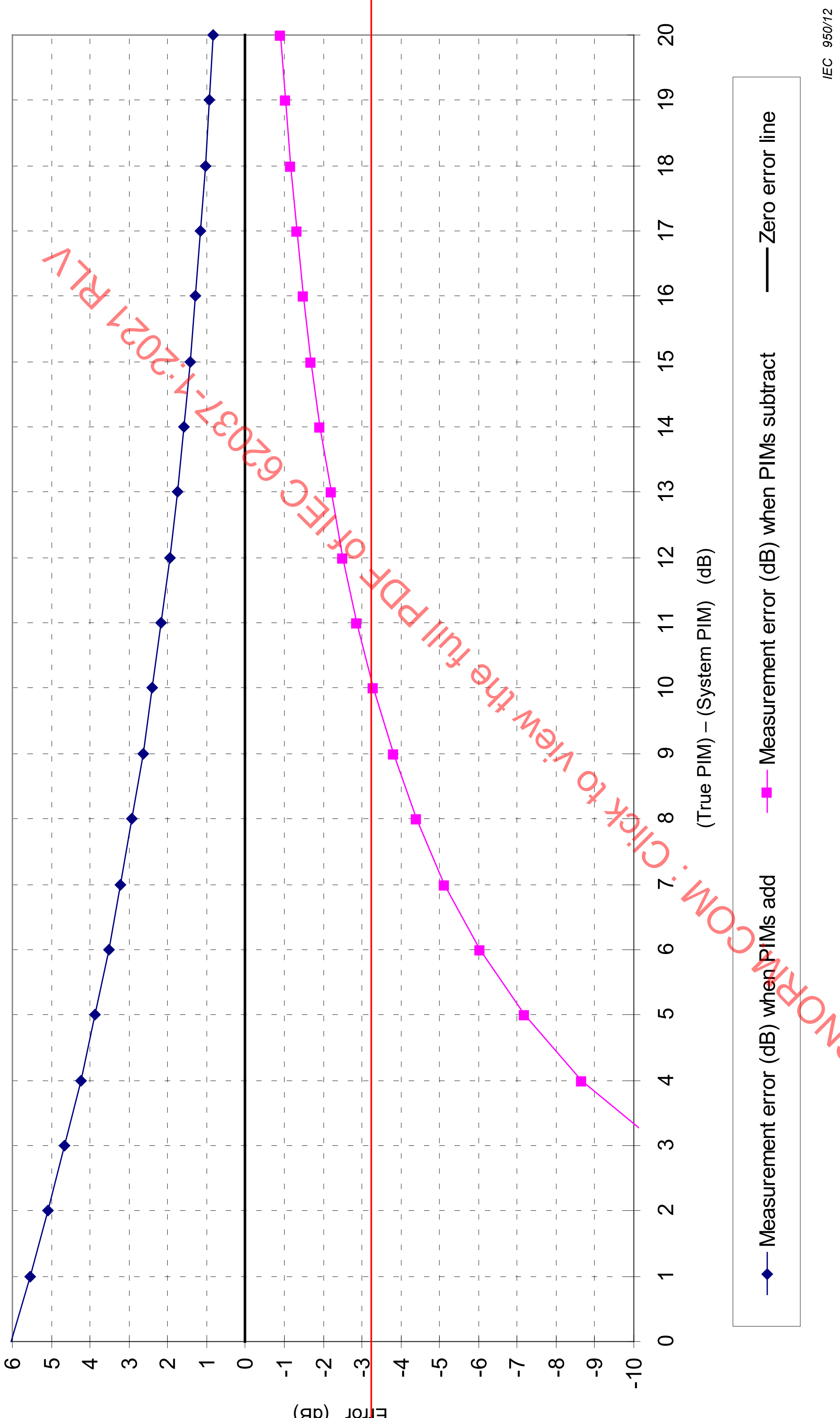


Figure 2 – Set-up 2: forward IM-test set-up


Error (dB)
(True PIM) – (System PIM) (dB)
Measurement error (dB) when PIMs add
Measurement error (dB) when PIMs subtract
Zero error line
IEC 950/12

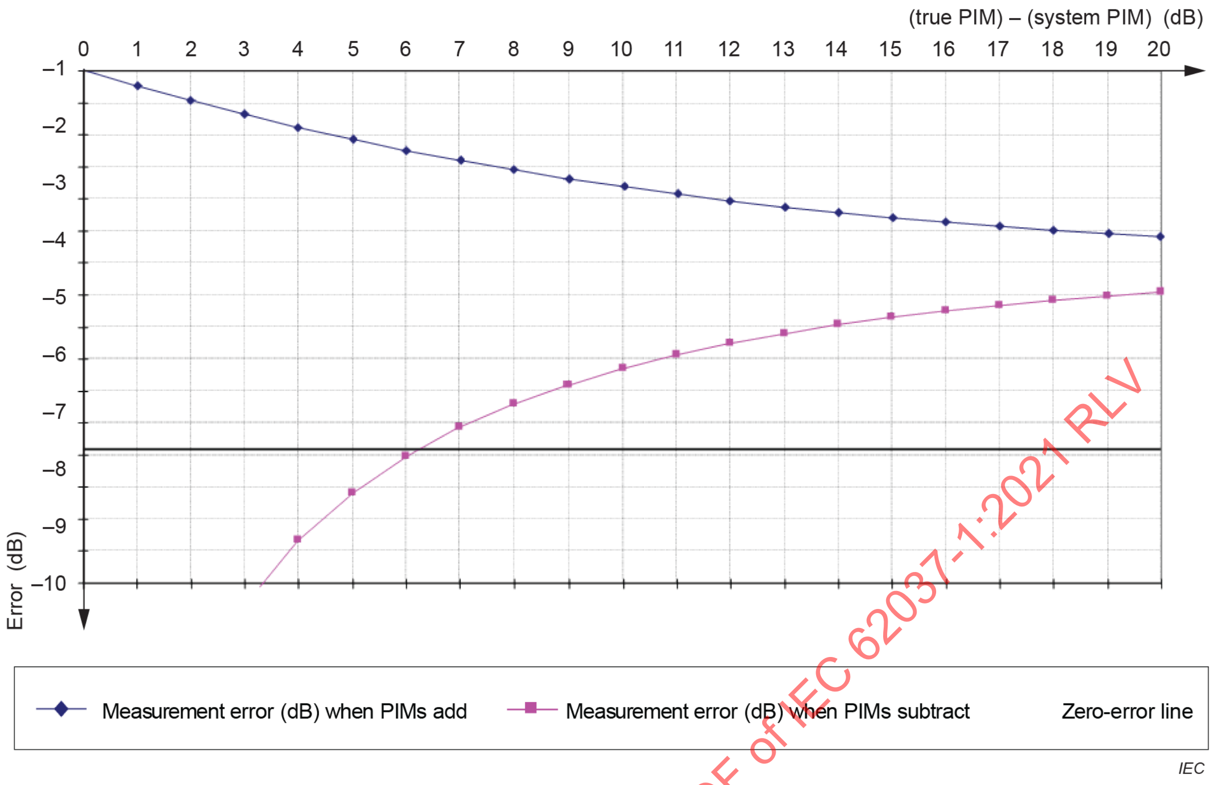


Figure 3 – Passive intermodulation (PIM) measurement error caused by residual system error

Annex A
(informative)

Configuration of low-PIM termination

A.1 General

Annex A provides information on low-PIM terminations.

A.2 Configuration of low-PIM terminations

A.2.1 Long cable termination

High-PIM terminations ~~may~~ can often consist of resistive materials. Therefore, long coaxial cables are used as a low-PIM termination (see Figure A.1). The following guidelines are in no particular order of significance but should be considered and adhered to wherever possible.

a) Avoid braided cables. Cables with a single centre conductor should be used. Semi-rigid cables would be a good choice from the practical viewpoint.

b) Avoid using cables with high-PIM materials and high-PIM plating. Plating with silver and tin would be a good choice. Plating should be sufficiently thicker than the skin depth at the lowest fundamental frequency.

c) A seamless cable configuration is the best for terminations because minimizing cable-connection is essential to achieve low-PIM. When the termination is composed of several short cables, the longest one should be used at the nearest side to the DUT.

d) Choose the cable with sufficient power-handling capability.

e) Choose the cable length sufficient for power absorption at the lowest fundamental frequency considering the isolation performance between the receive signals and transmit signals.

f) Use a connector with low-PIM characteristics.

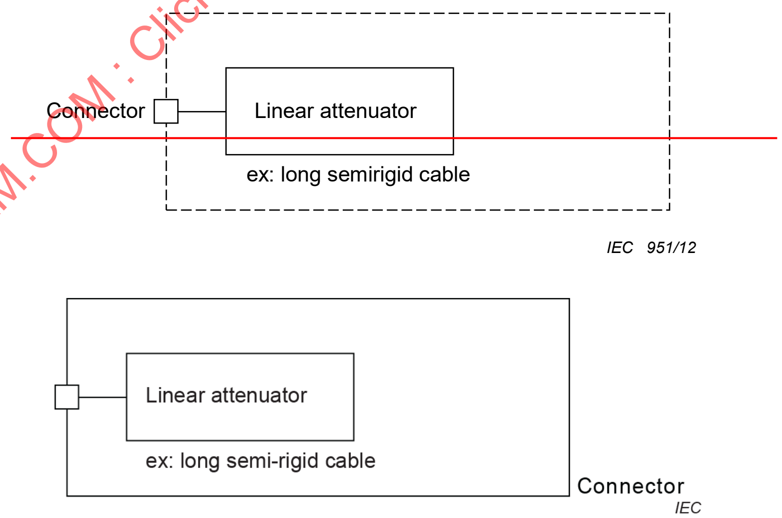


Figure A.1 – Long cable termination

A.2.2 Lumped termination with a linear attenuator

A low-PIM cable can be considered as a linear attenuator. The combination of the linear attenuator and a high-PIM lumped load as shown in Figure A.2 may be used as a low-PIM termination. The following procedure is presented for designing a low-PIM termination.

a) Measure the PIM characteristics of the lumped termination as a function of the fundamental power and determine the PIM-increase ratio X[dB].

b) Determine the required attenuation of the linear attenuator X_c[dB] using the formula:

$$PIM_{term} = PIM_{RDL} - (X+1)X_c$$

$$Y_{term} = Y_{RDL} - (X+1)X_c$$

c) Design the required length of the cable for the linear attenuator using the following formula:

$$X_c = \alpha \times l_m$$

where

PIM_{RDL} Y_{RDL} is the PIM of the lumped termination for P_{in}, in dBm;

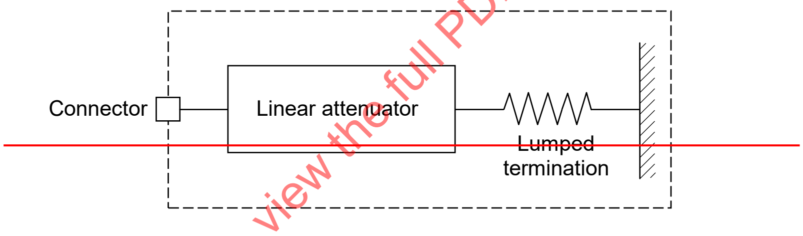
PIM_{term} Y_{term} is the PIM level required for the low-PIM termination in dBm;

X is the PIM increase against the 1 dB increase of each input tone, in dB;

X_c is the attenuation of the linear attenuator, in dB;

α is the attenuation ratio of the cable, in dB/m;

l_m is the cable length, in m.



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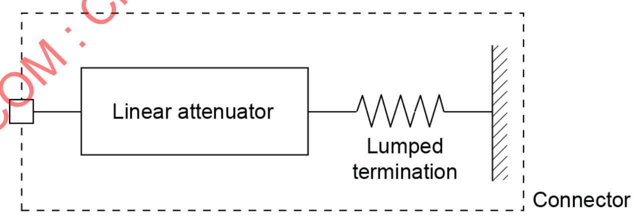

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Figure A.2 – Lumped termination with a linear attenuator

Annex B
(informative)

Test procedure considerations

B.1 ~~General~~ PIM variation versus frequency

Due to the phase interaction of the connectors and the length of the transmission line when measured in the reverse (reflected) mode, the frequency at which maximum PIM occurs within the band can vary ~~and shall be determined~~. The following methods may be used to determine maximum PIM.

B.2 Stepped frequency sweep method

An accepted method of sweeping is to fix f_1 at the low end of the transmit band and step ~~F2~~ f_1 down, starting at the top of the band for all combination of frequencies that result in IM in the receive band. If desired, this procedure can be reversed by fixing ~~F1~~ f_2 at the highest frequency in the transmit band and then stepping ~~F2~~ f_1 up, starting at the bottom of the band.

B.3 Fixed frequency method

Assemblies of varying lengths ~~shall~~ can be made to ensure that the PIM adds in phase. Assemble two additional DUTs. The first one is to be λ6 longer and the second one is to be λ/3 longer at the receive frequency of test. The PIM of the three assemblies is measured to determine which DUT exhibits maximum PIM. ~~The impact test is to be performed on this DUT.~~

A multiple fixed frequency may be used in lieu of varying the cable length.

B.4 Dynamic PIM testing

A fixed frequency, non-pulsed PIM test equipment provides the highest probability of detection of short duration PIM events when performing dynamic tests. Multiple dynamic impacts are recommended when using pulsed PIM test equipment or when sweeping the test generators to improve the probability of PIM event detection.

B.5 Heating effects

The magnitude of PIM generated by a PIM source can change as the temperature of the DUT changes. The PIM magnitude can increase or can decrease depending on the physical characteristic of the PIM source. Utilizing non-pulsed PIM analyzers, implementing longer test durations and testing at higher power levels will impart higher average power into the DUT and can more accurately simulate heating effects in high-power mobile communications systems.

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Passive RF and microwave devices, intermodulation level measurement –
Part 1: General requirements and measuring methods

Dispositifs RF et à micro-ondes passifs, mesure du niveau d'intermodulation –
Partie 1: Exigences générales et méthodes de mesure

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IEC 62037-1 has been prepared by IEC technical committee 46: Cables, wires, waveguides, RF connectors, RF and microwave passive components and accessories. It is an International Standard.

This second edition cancels and replaces the first edition published in 2012. This edition constitutes a technical revision.

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

a) clarification added that test equipment may utilize pulsed generators to reduce power consumption;
b) heating effect differences in the device under test noted in Annex B for tests conducted using pulsed generators;
c) guidance added in Annex B to improve probability of detection of short duration PIM events while dynamic testing.

The text of this International Standard is based on the following documents:

Draft	Report on voting
46/834/FDIS	46/855/RVD

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

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/standardsdev/publications.

This International Standard is to be used in conjunction with IEC 62037 (all parts).

A list of all the parts in the IEC 62037 series, published under the general title *Passive RF and microwave devices, intermodulation level measurement*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

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

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

PASSIVE RF AND MICROWAVE DEVICES, INTERMODULATION LEVEL MEASUREMENT –

Part 1: General requirements and measuring methods

1 Scope

This part of IEC 62037 deals with the general requirements and measuring methods for intermodulation (IM) level measurement of passive RF and microwave components, which can be caused by the presence of two or more transmitting signals.

The test procedures given in this document give the general requirements and measurement methods required to characterize the level of unwanted IM signals using two transmitting signals.

The IEC 62037 series addresses the measurement of PIM, but does not cover the long-term reliability of a product with reference to its performance.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 62037 (all parts), *Passive RF and microwave devices, intermodulation level measurement*

3 Terms, definitions and abbreviated terms

3.1 Terms and definitions

No terms and definitions are listed in this document.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

3.2 Abbreviated terms

CATV Community antenna television

CFEC Carbon fibre epoxy composite

CW Continuous wave

DUT Device under test

IM Intermodulation

PCB Printed circuit board

PIM Passive intermodulation

RBW Resolution bandwidth

VDA Vacuum deposited aluminium

4 Characteristics of intermodulation products

PIM interference is caused by sources of non-linearity of mostly unknown nature, location and behaviour. A few examples are inter-metallic contacts, choice of materials, corrosion products, dirt, etc. Most of these effects are subject to changes over time due to mechanical stress, temperature changes, variations in material characteristics (cold flow, etc.) and climatic changes.

The generation of intermodulation products originates from point sources inside a DUT and propagates equally in all available directions.

The generation of passive intermodulation (PIM) products does not necessarily follow the law of the usual non-linear equation of quadratic form. Therefore, accurate calculation to other power levels causing the intermodulation is not possible and PIM comparisons should be made at the same power level.

Furthermore, PIM generation can be frequency dependent. When PIM generation is frequency dependent, the PIM performance shall be investigated over the specified frequency band.

5 Principle of test procedure

Test signals of frequencies f_1 and f_2 with equal specified test port power levels are combined and fed to the DUT. The test signals should contain a harmonic or self-intermodulation signal level at least 10 dB lower than the expected level generated in the DUT.

The PIM is measured over the specified frequency range. The intermodulation products of order $(2f_1 \pm f_2)$, $(2f_2 \pm f_1)$, etc., are measured.

In most cases, the third order intermodulation signals represent the worst-case condition of unwanted signals generated; therefore, the measurement of these signals characterizes the DUT in a sufficient way. However, the test set-ups given in Clause 6 are suitable for measuring other intermodulation products.

In other systems (such as CATV), the third order may not be as applicable in characterizing the DUT.

Intermodulation can be measured in the reverse and forward direction. Reverse and forward refer to the direction of propagation of the most powerful carrier.

6 Test set-up

6.1 General

Experience shows that the generation of intermodulation products originates from point sources inside a device under test (DUT) and propagates equally in all available directions. Therefore, either the reverse (reflected) or the forward (transmitted) intermodulation signal can be measured.

Two different test set-ups are described in Figure 1 and Figure 2 and are for reference only. Other topologies are possible.

Set-up 1 is for measuring the reverse (reflected) intermodulation signal only, and set-up 2 is for measuring the forward (transmitted) intermodulation signal. The measurement method (reverse or forward) is dependent upon the DUT. The set-ups may be assembled from standard microwave or radio link hardware selected for this particular application. All components shall be checked for lowest self-intermodulation generation.

Experience shows that devices containing magnetic materials (circulators, isolators, etc.) can be prominent sources of intermodulation signal generation.

See Annex B for additional set-up considerations.

6.2 Test equipment

6.2.1 General

Two signal sources or signal generators with power amplifiers are required to reach the specified test port power. The combining and diplexing device can comprise a circulator, hybrid junction, coupler or filter network.

The test set-up self-intermodulation generated (including contribution of the load) should be at least 10 dB below the level to be measured on the DUT. The associated error may be obtained from the graph in Figure 3.

The DUT shall be terminated by a load for the specified power if necessary. The receiving bandpass filter, tuned for the desired intermodulation signal, is followed by a low noise amplifier (if required) and a receiver.

See Annex B for additional set-up considerations.

6.2.2 Set-up 1

This set-up is for measuring the reverse (reflected) IM-product and is therefore suitable for one-port and multi-port DUTs. On multi-port DUTs, the unused ports shall be connected to a linear termination. See Annex A for information on low PIM terminations.

a) Generators

   The generators shall provide continuous wave (CW) signals of the specified test port power. They shall have sufficient frequency stability to ensure that the IM-product can be detected properly by the receiver. The generators may be pulsed on and off while testing to reduce power consumption.

   Some limitations apply when using pulsed generators. See Annex B for test procedure considerations when using equipment with pulsed generators.

b) Transmit-filters

   The filters are bandpass filters tuned to the particular frequencies. They isolate the generators from each other and filter out the harmonics of f_1 and f_2.

c) Combining and diplexing device

   This device is used for combining the signals f_1 and f_2, delivering them to the test port and provides a port for the extraction of the reverse (reflected) signal f_{IM}.

d) Receive-filter

   This filter is used for isolating the input of the receiver from the signals f_1 and f_2 to the extent that IM-products are not generated within the receiver.

e) Test port

   The DUT is connected to P4. The specified input power shall be at the DUT, with any set-up loss between the receiver and the DUT compensated for.

f) Termination

   When a multi-port DUT is measured, the DUT shall be connected to a sufficiently linear termination (low intermodulation) of suitable power handling capability.

g) Receiver

The receiver shall be sensitive enough to detect a signal of the expected power level.

The receiver response time shall be sufficiently short to allow acquisition of rapid changes in amplitude. Sensitivity can be increased by a low noise preamplifier. Frequency stability shall be sufficient for the proper detection of the IM-signal.

When the PIM measurement result is close to the thermal noise floor of the receiver, the receiver sensitivity can be improved by reducing the resolution bandwidth (RBW). Furthermore, by using the averaging mode rather than the max-hold mode, a further improvement can be achieved, since the max-hold mode essentially measures the maximum thermal noise peak, while the averaging mode results in a measurement that is closer to the RMS value.

6.2.3 Set-up 2

This set-up is for measuring the forward (transmitted) IM-product and is therefore suitable only for two- or multi-port DUTs.

All components are the same as those of set-up 1, except for those as noted below:

a) Combining and diplexing device

The extraction-port P3 on this device shall be terminated to prevent reflection of the IM-signals.

b) Diplexing device

The signals f_1, f_2 and f_{IM} are split to P6 and P7. This device, together with an additional receive-filter, is used for the extraction of the intermodulation signals.

7 Preparation of DUT and test equipment

7.1 General

The DUT and test equipment shall be carefully checked for proper power handling range, frequency range, cleanliness and correct interconnection dimensions. All connector interfaces shall be tightened to the applicable IEC specification or, if none exists, to the manufacturer's recommended specification.

See Annex B for additional set-up considerations.

7.2 Guidelines for minimizing generation of passive intermodulation

The following guidelines and Table 1 should be considered and adhered to wherever possible.

a) Non-linear materials should not be used in or near the current paths.
b) Current densities should be minimized in the conduction paths (e.g. Tx channel), by using larger conductors.
c) Minimize metallic junctions, avoid loose contacts and rotating joints.
d) Minimize the exposure of loose contacts, rough surfaces and sharp edges to RF power.
e) Keep thermal variations to a minimum, as the expansion and contraction of metals can create non-linear contacts.
f) Use brazed, soldered or welded joints if possible, but ensure these joints are good and have no non-linear materials, cracks, contamination or corrosion.
g) Avoid having tuning screws or moving parts in the high current paths; if necessary, ensure all joints are tight and clean, and preferably, free from vibration.
h) Cable lengths in general should be minimized and the use of high quality, low-IM cable is essential.

i) Minimize the use of non-linear components such as high-PIM loads, circulators, isolators and semiconductor devices.

j) Achieve good isolation between the high-power transmit signals and the low power receive signals by filtering and physical separation.

Table 1 – Guide for the design, selection of materials and handling of components that can be susceptible to PIM generation

Part, material or procedure	Recommendations
Interfaces	Minimize the total number.
Connectors	Minimize the number of connectors used. Use high quality, low-PIM connectors mated with proper torque.
Inter-metallic connections	Each inter-metallic connection should be evaluated in terms of criticality for the total PIM level. Methods of controlling the performance are high contact pressure, insulation, soldering, brazing, etc.
Ferromagnetic materials	Not recommended (non-linear).
Non-magnetic stainless steel	Not recommended (contains iron).
Circulators, isolators and other ferrite devices	Not recommended.
Sharp edges	Avoid if it results in high current density.
Terminations or attenuators	Should be evaluated before use.
Hermetic seals / gaskets	Evaluate before use and avoid ferromagnetic materials.
Printed circuit boards (PCBs)	Materials, processes and design should all be considered and evaluated. Use low-PIM materials; be careful with material impurities, contamination and etching residuals. The copper trace should be finished to prevent corrosion.
Dissimilar metals	Not recommended (risk of galvanic corrosion).
Dielectric material	Use clean, high quality material. Ensure it does not contain electrically conductive particles.
Machined dielectric materials	Use clean non-contaminated tools for machining.
Welded, soldered or brazed joints	Well executed and thoroughly cleaned, they provide satisfactory results. Shall be carefully inspected.
Carbon fibre epoxy composite (CFEC)	Generally acceptable for use in reflector and support structures, provided the fibres are not damaged. Should be evaluated if high flux density (e.g. > 10 mW /cm^2) is expected.
Standard multilayer thermal blankets made of vacuum deposited aluminium (VDA) on biaxially-oriented polyethylene terephthalate film or polyimide film	Special design required.
Cleanliness	Maintain clean and dry surfaces.
Plating	The thickness of the plating should be at least three times greater than the skin depth of the wave resulting from the skin effect at the lowest relevant frequency.

8 Test procedure

Table 2 gives certain conditions for test set-up 1 and test set-up 2.

Table 2 – Test set-up conditions

Test set-up 1	Test set-up 2
The set-up shall be verified for correct signal levels applied to the DUT. For mobile communication systems, it is generally recommended to use 2 × 20 W (43 dBm) at the test port of the DUT, unless otherwise specified. Other systems can require different power levels (higher or lower). See Annex B for heating effect considerations.	
The minimum number of test frequencies and/or frequency spacing shall be specified.	
For lowest measurement uncertainty, the receiver shall be calibrated at the expected IM-level with a calibrated signal-source as indicated in Figure 1 and Figure 2.	
The termination shall be connected directly to the test port P4 and the self-intermodulation level of the set-up recorded.	P5 of the diplexing device shall be connected directly to P4 of the combining and summing device and the self-intermodulation level of the set-up recorded.
For low measurement uncertainties, the level of self-intermodulation should be at least 10 dB below the specified value for the DUT.	
Test the DUT as given in the specific set-up and procedure in the appropriate test set-up.	
An additional mechanical shock test may be carried out during the test sequence.	

9 Reporting

9.1 Results

The input power at individual frequencies should be specified. The values of f_1 and f_2 should be specified.

The PIM level and frequency should be specified.

9.2 Example of results

The result is expressed as an absolute magnitude in dBm or relative magnitude in dBc, referenced to the power of a single carrier.

The relationship between a measured IM_3 value of –120 dBm can be converted to dBc as follows:

EXAMPLE:

f_1 = 936 MHz, f_2 = 958 MHz, fIM_3 = 914 MHz

$P(f_1) = P(f_2)$ = 20 W (+43 dBm) IM_3 = –163 dBc (–120 dBm)

10 Measurement error

The measurement uncertainty can be calculated by the following formula:

$$RSS = \sqrt{\left[(\delta A)^2 + (\delta P_\mathrm{m})^2 + (\delta P_\mathrm{g})^2 + (\delta D)^2\right]}$$

where

δA is the uncertainty of the attenuator;

δP_m is the uncertainty of the power meter;

δP_g is the uncertainty of the generator 3;

δD is the uncertainty due to the difference between self-intermodulation of the test bench and intermodulation of the DUT (taken from Figure 3).

Mismatch errors are not included in the given formula.

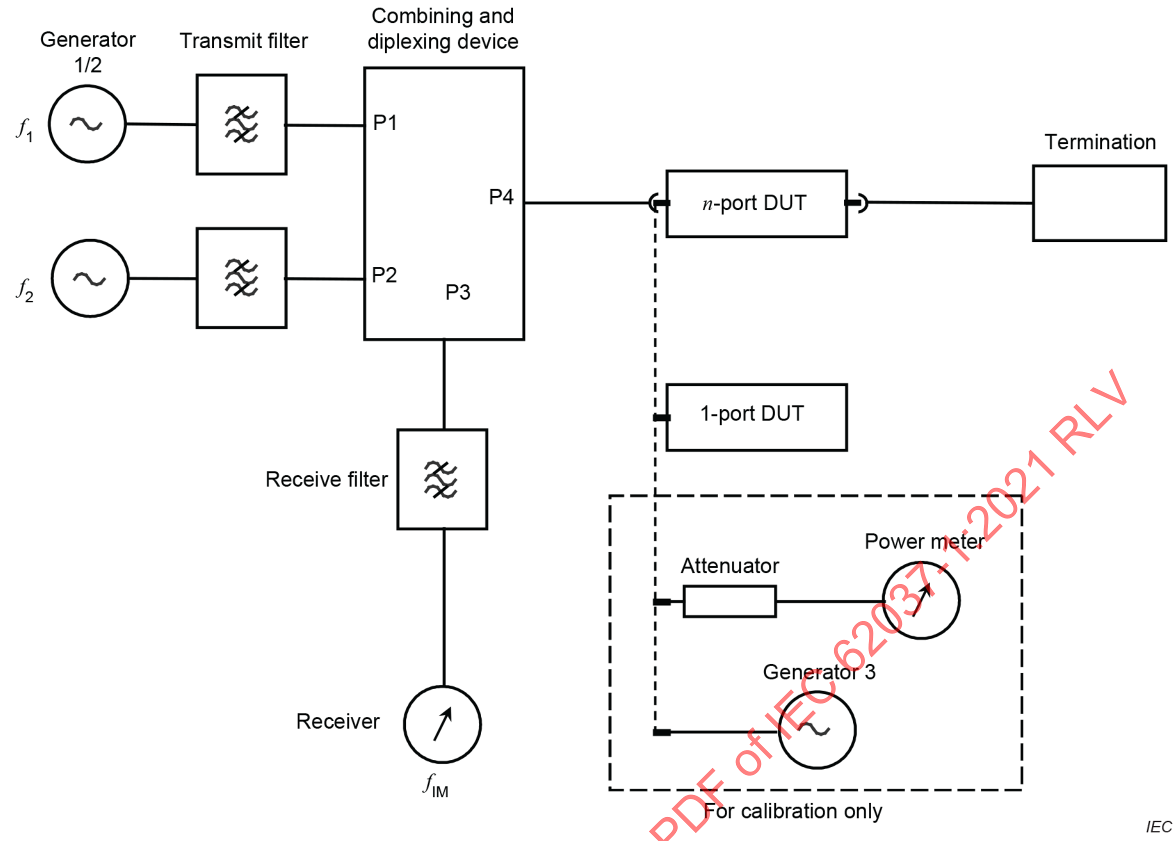

Figure 1 – Set-up 1: reverse IM-test set-up

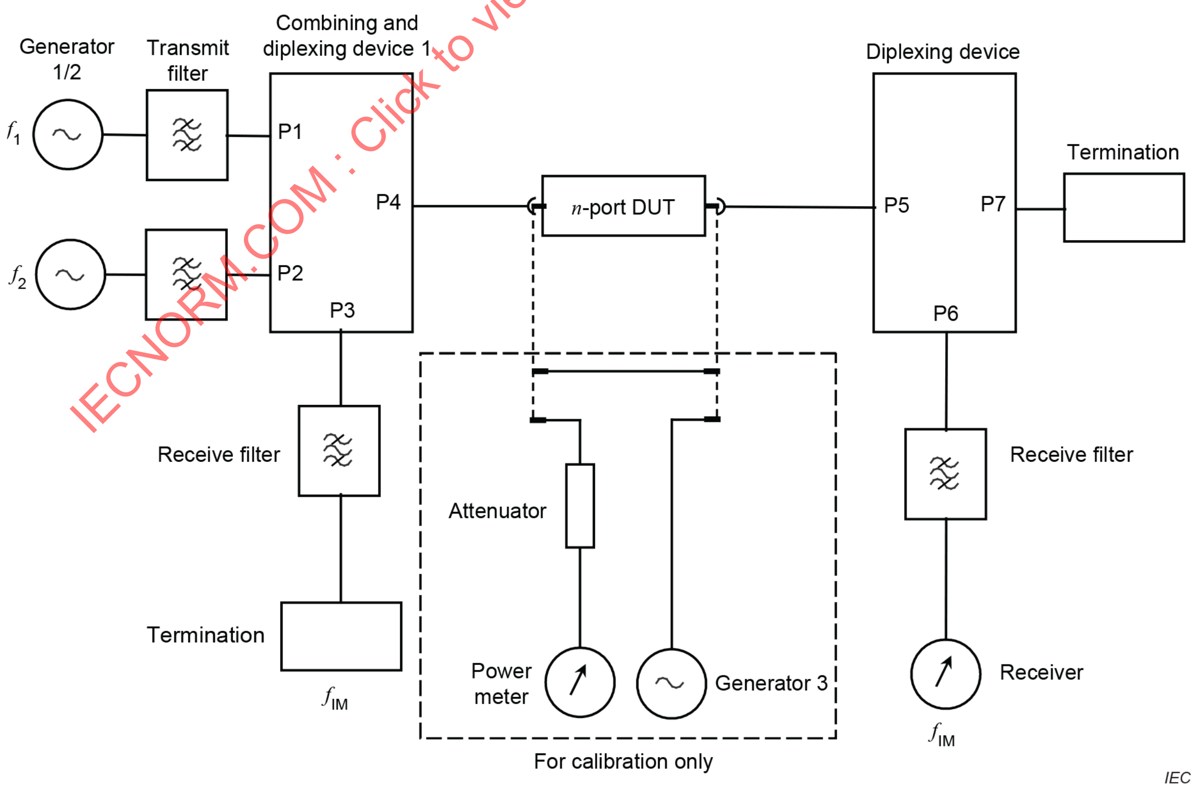

Figure 2 – Set-up 2: forward IM-test set-up

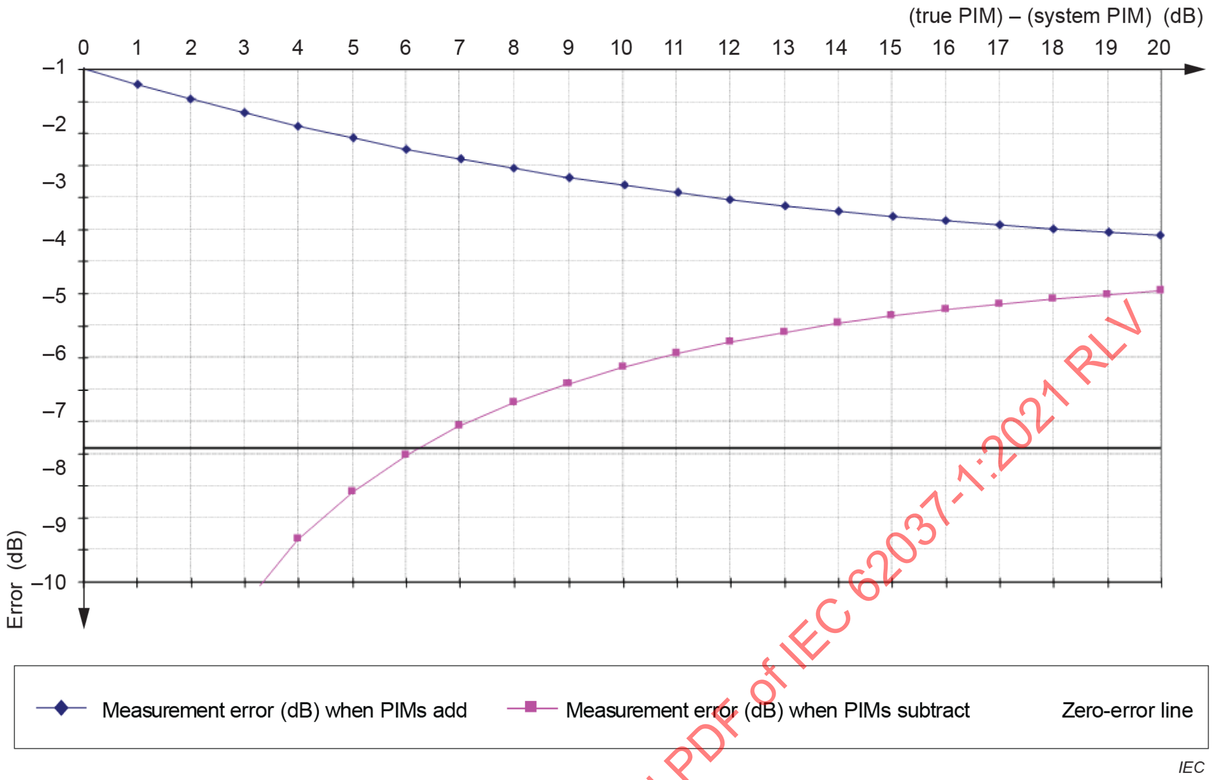

Figure 3 – Passive intermodulation (PIM) measurement error caused by residual system error

Annex A
(informative)

Configuration of low-PIM termination

A.1 General

Annex A provides information on low-PIM terminations.

A.2 Configuration of low-PIM terminations

A.2.1 Long cable termination

High-PIM terminations can often consist of resistive materials. Therefore, long coaxial cables are used as a low-PIM termination (see Figure A.1). The following guidelines are in no particular order of significance but should be considered and adhered to wherever possible.

a) Avoid braided cables. Cables with a single centre conductor should be used. Semi-rigid cables would be a good choice from the practical viewpoint.
b) Avoid using cables with high-PIM materials and high-PIM plating. Plating with silver and tin would be a good choice. Plating should be sufficiently thicker than the skin depth at the lowest fundamental frequency.
c) A seamless cable configuration is the best for terminations because minimizing cable-connection is essential to achieve low-PIM. When the termination is composed of several short cables, the longest one should be used at the nearest side to the DUT.
d) Choose the cable with sufficient power-handling capability.
e) Choose the cable length sufficient for power absorption at the lowest fundamental frequency considering the isolation performance between the receive signals and transmit signals.
f) Use a connector with low-PIM characteristics.

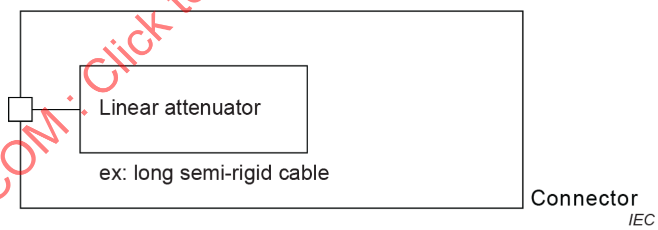

Figure A.1 – Long cable termination

A.2.2 Lumped termination with a linear attenuator

A low-PIM cable can be considered as a linear attenuator. The combination of the linear attenuator and a high-PIM lumped load as shown in Figure A.2 may be used as a low-PIM termination. The following procedure is presented for designing a low-PIM termination.

a) Measure the PIM characteristics of the lumped termination as a function of the fundamental power and determine the PIM-increase ratio X[dB].
b) Determine the required attenuation of the linear attenuator X_c[dB] using the formula:

$$Y_{term} = Y_{RDL} - (X+1)X_c$$

c) Design the required length of the cable for the linear attenuator using the following formula:

$$X_c = \alpha \times l_m$$

where

Y_{RDL} is the PIM of the lumped termination for P_{in}, in dBm;

Y_{term} is the PIM level required for the low-PIM termination in dBm;

X is the PIM increase against the 1 dB increase of each input tone, in dB;

X_c is the attenuation of the linear attenuator, in dB;

α is the attenuation ratio of the cable, in dB/m;

l_m is the cable length, in m.

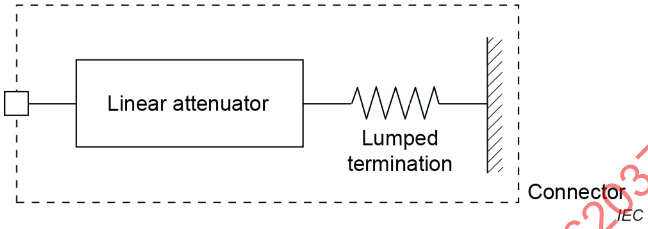

Figure A.2 – Lumped termination with a linear attenuator

Annex B
(informative)

Test procedure considerations

B.1 PIM variation versus frequency

Due to the phase interaction of the connectors and the length of the transmission line when measured in the reverse (reflected) mode, the frequency at which maximum PIM occurs within the band can vary. The following methods may be used to determine maximum PIM.

B.2 Stepped frequency sweep method

An accepted method of sweeping is to fix f_1 at the low end of the transmit band and step f_1 down, starting at the top of the band for all combination of frequencies that result in IM in the receive band. If desired, this procedure can be reversed by fixing f_2 at the highest frequency in the transmit band and then stepping f_1 up, starting at the bottom of the band.

B.3 Fixed frequency method

Assemblies of varying lengths can be made to ensure that the PIM adds in phase. Assemble two additional DUTs. The first one is to be λ6 longer and the second one is to be $\lambda/3$ longer at the receive frequency of test. The PIM of the three assemblies is measured to determine which DUT exhibits maximum PIM.

A multiple fixed frequency may be used in lieu of varying the cable length.

B.4 Dynamic PIM testing

A fixed frequency, non-pulsed PIM test equipment provides the highest probability of detection of short duration PIM events when performing dynamic tests. Multiple dynamic impacts are recommended when using pulsed PIM test equipment or when sweeping the test generators to improve the probability of PIM event detection.

B.5 Heating effects

The magnitude of PIM generated by a PIM source can change as the temperature of the DUT changes. The PIM magnitude can increase or can decrease depending on the physical characteristic of the PIM source. Utilizing non-pulsed PIM analyzers, implementing longer test durations and testing at higher power levels will impart higher average power into the DUT and can more accurately simulate heating effects in high-power mobile communications systems.

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SOMMAIRE

COMMISSION ÉLECTROTECHNIQUE INTERNATIONALE

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DISPOSITIFS RF ET À MICRO-ONDES PASSIFS, MESURE DU NIVEAU D'INTERMODULATION –

Partie 1: Exigences générales et méthodes de mesure

AVANT-PROPOS

1) La Commission Electrotechnique Internationale (IEC) est une organisation mondiale de normalisation composée de l'ensemble des comités électrotechniques nationaux (Comités nationaux de l'IEC). L'IEC a pour objet de favoriser la coopération internationale pour toutes les questions de normalisation dans les domaines de l'électricité et de l'électronique. A cet effet, l'IEC – entre autres activités – publie des Normes internationales, des Spécifications techniques, des Rapports techniques, des Spécifications accessibles au public (PAS) et des Guides (ci-après dénommés "Publication(s) de l'IEC"). Leur élaboration est confiée à des comités d'études, aux travaux desquels tout Comité national intéressé par le sujet traité peut participer. Les organisations internationales, gouvernementales et non gouvernementales, en liaison avec l'IEC, participent également aux travaux. L'IEC collabore étroitement avec l'Organisation Internationale de Normalisation (ISO), selon des conditions fixées par accord entre les deux organisations.
2) Les décisions ou accords officiels de l'IEC concernant les questions techniques représentent, dans la mesure du possible, un accord international sur les sujets étudiés, étant donné que les Comités nationaux de l'IEC intéressés sont représentés dans chaque comité d'études.
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8) L'attention est attirée sur les références normatives citées dans cette publication. L'utilisation de publications référencées est obligatoire pour une application correcte de la présente publication.
9) L'attention est attirée sur le fait que certains des éléments du présent document de l'IEC peuvent faire l'objet de droits de brevet. L'IEC ne saurait être tenue pour responsable de ne pas avoir identifié de tels droits de brevets.

L'IEC 62037-1 a été établie par le comité d'études 46 de l'IEC: Câbles, fils, guides d'ondes, connecteurs, composants passifs pour micro-onde et accessoires. Il s'agit d'une Norme internationale.

Cette seconde édition annule et remplace la première édition parue en 2012. Cette édition constitue une révision technique.

Cette édition inclut les modifications techniques majeures suivantes par rapport à l'édition précédente:

a) ajout d'une clarification au fait que le matériel d'essai peut utiliser des générateurs à impulsions pour réduire la consommation de puissance;
b) description des différences d'effet de chauffage sur le dispositif en essai à l'Annexe B dans les essais réalisés avec des générateurs à impulsions;
c) ajout de recommandations à l'Annexe B pour améliorer la probabilité de détection d'événements d'intermodulation passive de courte durée lors des essais dynamiques.

Le texte de cette Norme internationale est issu des documents suivants:

Projet	Rapport de vote
46/834/FDIS	46/855/RVD

Le rapport de vote indiqué dans le tableau ci-dessus donne toute information sur le vote ayant abouti à son approbation.

La langue utilisée pour l'élaboration de la présente Norme internationale est l'anglais.

Ce document a été rédigé selon les Directives ISO/IEC, Partie 2, il a été développé selon les Directives ISO/IEC, Partie 1 et les Directives ISO/IEC, Supplément IEC, disponibles sous www.iec.ch/members_experts/refdocs. Les principaux types de documents développés par l'IEC sont décrits plus en détail sous www.iec.ch/standardsdev/publications.

La présente Norme internationale doit être utilisée conjointement avec l'IEC 62037 (toutes les parties).

Une liste de toutes les parties de la série IEC 62037, publiées sous le titre général *Dispositifs RF et à micro-ondes passifs, mesure du niveau d'intermodulation*, est disponible sur le site web de l'IEC.

Le comité a décidé que le contenu de ce document ne sera pas modifié avant la date de stabilité indiquée sur le site web de l'IEC sous webstore.iec.ch dans les données relatives au document recherché. À cette date, le document sera

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- amendé.

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DISPOSITIFS RF ET À MICRO-ONDES PASSIFS, MESURE DU NIVEAU D'INTERMODULATION –

Partie 1: Exigences générales et méthodes de mesure

1 Domaine d'application

La présente partie de l'IEC 62037 est applicable aux exigences générales et aux méthodes de mesure du niveau d'intermodulation (IM) des composants RF et à micro-ondes passifs, qui peut être provoquée par la présence de deux ou plusieurs signaux d'émission.

Les procédures d'essai présentées dans le présent document donnent les exigences générales et les méthodes de mesure exigées pour caractériser le niveau des signaux d'intermodulation indésirables à l'aide de deux signaux d'émission.

La série IEC 62037 porte sur la mesure de l'intermodulation passive (PIM), mais ne couvre pas la fiabilité à long terme des produits par rapport à ses performances.

2 Références normatives

Les documents suivants sont cités dans le texte de sorte qu'ils constituent, pour tout ou partie de leur contenu, des exigences du présent document. Pour les références datées, seule l'édition citée s'applique. Pour les références non datées, la dernière édition du document de référence s'applique (y compris les éventuels amendements).

IEC 62037 (toutes les parties), *Dispositifs RF et à micro-ondes passifs, mesure du niveau d'intermodulation*

3 Termes, définitions et termes abrégés

3.1 Termes et définitions

Aucun terme n'est défini dans le présent document.

L'ISO et l'IEC tiennent à jour des bases de données terminologiques destinées à être utilisées en normalisation, consultables aux adresses suivantes:

- IEC Electropedia: disponible à l'adresse http://www.electropedia.org/
- ISO Online browsing platform: disponible à l'adresse http://www.iso.org/obp

3.2 Termes abrégés

CATV Community antenna television (antenne communautaire)

CFEC Carbon fibre epoxy composite (composite époxy en fibres de carbone)

CW Continuous wave (onde entretenue)

DUT Device under test (dispositif en essai)

IM Intermodulation

PCB Printed circuit board (carte à circuit imprimé)

PIM Passive intermodulation (intermodulation passive)

RBW Resolution bandwidth (largeur de bande de résolution)

VDA Vacuum deposited aluminium (aluminium déposé sous vide)

4 Caractéristiques des produits d'intermodulation

Les perturbations dues à l'intermodulation passive sont provoquées par des sources de non-linéarité de nature, d'emplacement et de comportement le plus souvent inconnus, par exemple les contacts intermétalliques, le choix des matériaux, les produits corrosifs, la saleté, etc. La plupart de ces effets sont sujets à des modifications dans le temps du fait de contraintes mécaniques, de variations de température, de modifications des caractéristiques des matériaux (fluage à froid, etc.), de variations climatiques, etc.

La génération de produits d'intermodulation provient de sources ponctuelles situées à l'intérieur d'un dispositif en essai, et ces produits se propagent de façon uniforme dans toutes les directions disponibles.

La génération de produits d'intermodulation passive (PIM) ne suit pas nécessairement la loi de l'équation non linéaire habituelle de forme quadratique. De ce fait, un calcul précis à d'autres niveaux de puissance provoquant l'intermodulation n'est pas possible, et il convient d'effectuer des comparaisons de l'intermodulation passive au même niveau de puissance.

De plus, la génération de l'intermodulation passive peut dépendre de la fréquence. Lorsque la génération de l'intermodulation passive dépend de la fréquence, la performance de l'intermodulation passive doit être examinée sur la bande de fréquences spécifiée.

5 Principe de procédure d'essai

Les signaux d'essai de fréquences f_1 et f_2 à des niveaux de puissance au niveau du port d'essai spécifiés égaux sont combinés et délivrés au dispositif en essai. Il convient que les signaux d'essai contiennent au moins un niveau de signal d'auto-intermodulation ou d'harmonique de 10 dB inférieur au niveau prévu généré dans le dispositif en essai.

L'intermodulation passive est mesurée sur la plage de fréquences spécifiée. Les produits d'intermodulation d'ordre $(2f_1 \pm f_2)$, $(2f_2 \pm f_1)$ etc., sont mesurés.

Dans la plupart des cas, les signaux d'intermodulation de troisième ordre représentent la condition la plus défavorable des signaux indésirables générés; de ce fait, la mesure de ces signaux caractérise le dispositif en essai de manière suffisante. Cependant, les montages d'essai présentés à l'Article 6 sont adaptés aux mesures d'autres produits d'intermodulation.

Dans d'autres systèmes (tels que CATV), le 3^{e} ordre peut ne pas être approprié dans la caractérisation du dispositif en essai.

L'intermodulation peut être mesurée dans le sens inverse et dans le sens direct. Le sens inverse et le sens direct font référence au sens de propagation de la porteuse la plus puissante.

6 Montage d'essai

6.1 Généralités

L'expérience montre que la génération de produits d'intermodulation provient de sources ponctuelles situées à l'intérieur d'un dispositif en essai (DUT), et que ces produits se propagent de façon uniforme dans toutes les directions disponibles. Par conséquent, il est possible de mesurer le signal d'intermodulation, soit inverse (réfléchi), soit direct (émis).

Deux différents montages d'essai sont décrits à la Figure 1 et à la Figure 2, et servent uniquement de référence. D'autres topologies sont possibles.

Le montage 1 a pour but de mesurer uniquement le signal d'intermodulation inverse (réfléchi), et le montage 2 a pour but de mesurer le signal d'intermodulation direct (émis). La méthode de mesure (inverse ou directe) dépend du dispositif en essai. Les montages peuvent être assemblés à partir d'un matériel normalisé pour une liaison radioélectrique ou pour un faisceau hertzien sélectionné pour cette application spécifique. Tous les composants doivent faire l'objet d'une vérification ayant trait à la génération d'auto-intermodulation la plus faible.

L'expérience prouve que les dispositifs contenant des matériaux magnétiques (circulateurs, isolateurs, etc.) peuvent être des sources prédominantes de génération de signaux d'intermodulation.

L'Annexe B donne des considérations de montage supplémentaires.

6.2 Équipement d'essai

6.2.1 Généralités

Deux sources de signaux ou générateurs de signaux à amplificateurs de puissance sont exigées pour atteindre la puissance d'essai spécifiée au niveau du port. Le dispositif mélangeur et diplexeur peut comprendre un circulateur, une jonction hybride, un coupleur ou un réseau de filtres.

Il convient que l'auto-intermodulation générée par le montage d'essai (y compris la contribution de la charge) soit d'au moins 10 dB en dessous du niveau à mesurer sur le dispositif en essai. L'erreur associée peut être obtenue à partir du graphique de la Figure 3.

Le dispositif en essai doit être terminé par une charge pour la puissance spécifiée, si nécessaire. Le filtre passe-bande de réception, accordé pour le signal d'intermodulation désiré, est suivi par un amplificateur de faible bruit (si cela est exigé) et un récepteur.

L'Annexe B donne des considérations de montage supplémentaires.

6.2.2 Montage 1

Ce montage sert à mesurer le produit d'intermodulation inverse (réfléchie) et il est, de ce fait, adapté pour des dispositifs en essai à un port et à plusieurs ports. Sur les dispositifs en essai à plusieurs ports, les ports non utilisés doivent être connectés à une terminaison linéaire. Voir l'Annexe A pour des informations sur des terminaisons de faible intermodulation passive.

a) Générateurs

   Les générateurs doivent fournir des signaux à onde entretenue (CW) de la puissance d'essai spécifiée au niveau du port. Ils doivent avoir une stabilité de fréquence suffisante pour s'assurer que le produit d'intermodulation peut être correctement détecté par le récepteur. Les générateurs à impulsions peuvent être activés et désactivés pendant les essais pour réduire la consommation de puissance.

   Certaines limitations s'appliquent lorsque des générateurs à impulsions sont utilisés. L'Annexe B donne des considérations sur les procédures d'essai lorsqu'un équipement est utilisé avec un générateur à impulsions.

b) Filtres émetteurs

   Les filtres sont des filtres passe-bande accordés sur des fréquences particulières. Ils isolent entre eux les générateurs et séparent par filtration les harmoniques de f_1 et f_2.

c) Dispositif mélangeur et diplexeur

   Ce dispositif est utilisé pour combiner les signaux f_1 et f_2, en les délivrant au port d'essai, et il fournit un port pour l'extraction du signal inverse (réfléchi) f_{IM}.

d) Filtre récepteur