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INTERNATIONAL STANDARD

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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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PASSIVE RF AND MICROWAVE DEVICES, INTERMODULATION LEVEL MEASUREMENT –

Part 1: General requirements and measuring methods

FOREWORD

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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
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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.

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, 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.