भारतीय मानक

Indian Standard

IS/IEC 62037-1 : 2021

निष्क्रिय आरएफ और माइक्रोवेव उपकरण का इंटरमॉड्यूलेशन स्तर माप

भाग 1 सामान्य अपेक्षाएँ और मापने के तरीके

(पहला पुनरीक्षण)

Passive RF and Microwave Devices, Intermodulation Level Measurement

Part 1 General Requirements and Measuring Methods

(First Revision)

ICS 33.040.20

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NATIONAL FOREWORD

This Indian Standard (Part1) (First Revision) which is identical to IEC 62037-1 : 2021 'Passive RF and microwave devices, intermodulation level measurement — Part 1: Generalrequirements and measuring methods' issued by the International Electrotechnical Commission (IEC) was adopted by the Bureau of Indian Standards on the recommendations of the Wires, Cables, Waveguides & AccessoriesSectional Committee and approval of the Electronics and Information Technology Division Council.

This standard was first published in 2021 and identical to IEC 62037-1 : 2012. The first revision of this standard has been undertaken to align it with the latest version of IEC 62037-1: 2021.

The text of IEC standard has been approved as suitable for publication as an Indian Standard without deviations. Certain conventions and terminologies are, however, not identical to those used in Indian Standards. Attention is particularly drawn to the following:

a) Wherever the words 'International Standard' appear referring to this standard, they should be read as 'Indian Standard'; and

b) Comma (,) has been used as a decimal marker while in Indian Standards, the current practice is to use a point (.) as the decimal marker.

In this adopted standard, reference appears to certain International Standards for which Indian Standards also exist. The corresponding Indian Standards, which are to be substituted in their respective places, are listed below along with their degree of equivalence for the editions indicated. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies:

International Standards	*Corresponding Indian Standard*	*Degree of Equivalence*
IEC 62037 (all parts) Passive RF and microwave devices, intermodulation level measurement	IS/IEC 62037-1 : 2012 Passive RF and microwave devicesintermodulation level measurement — Part 1: General requirements and measuring methods	Identical

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 2022 'Rules for rounding off numerical values (*second revision*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

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Indian Standard

PASSIVE RF AND MICROWAVE DEVICES, INTERMODULATION LEVEL MEASUREMENT

PART 1 GENERAL REQUIREMENTS AND MEASURING METHODS

(First Revision)

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.

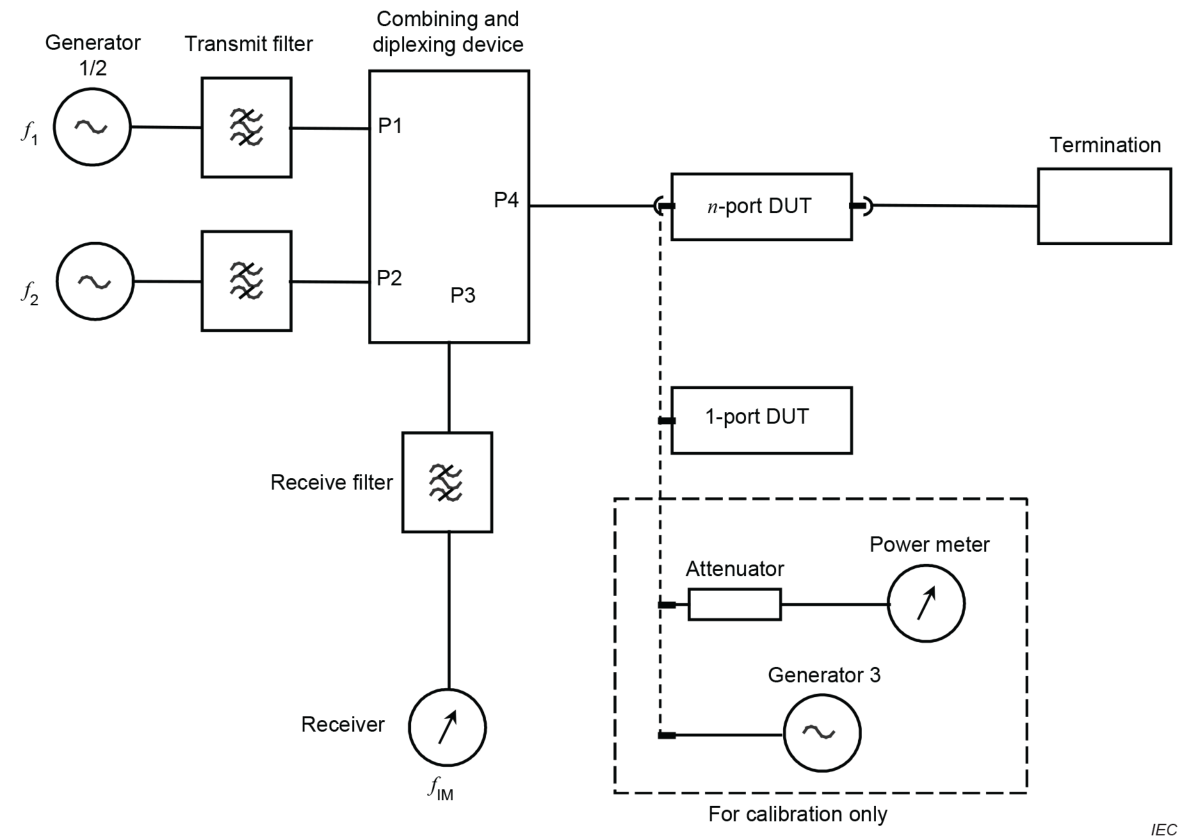

Figure 1 – Set-up 1: reverse IM-test set-up

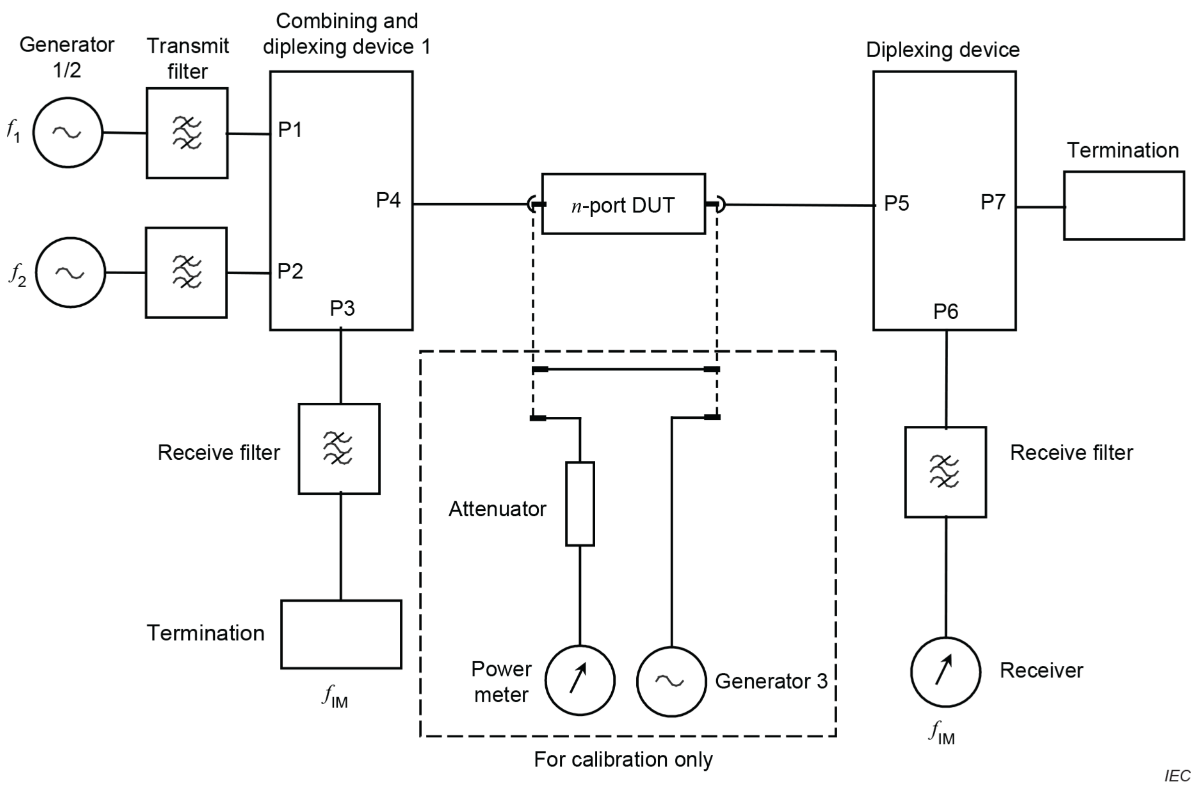

Figure 2 – Set-up 2: forward IM-test set-up

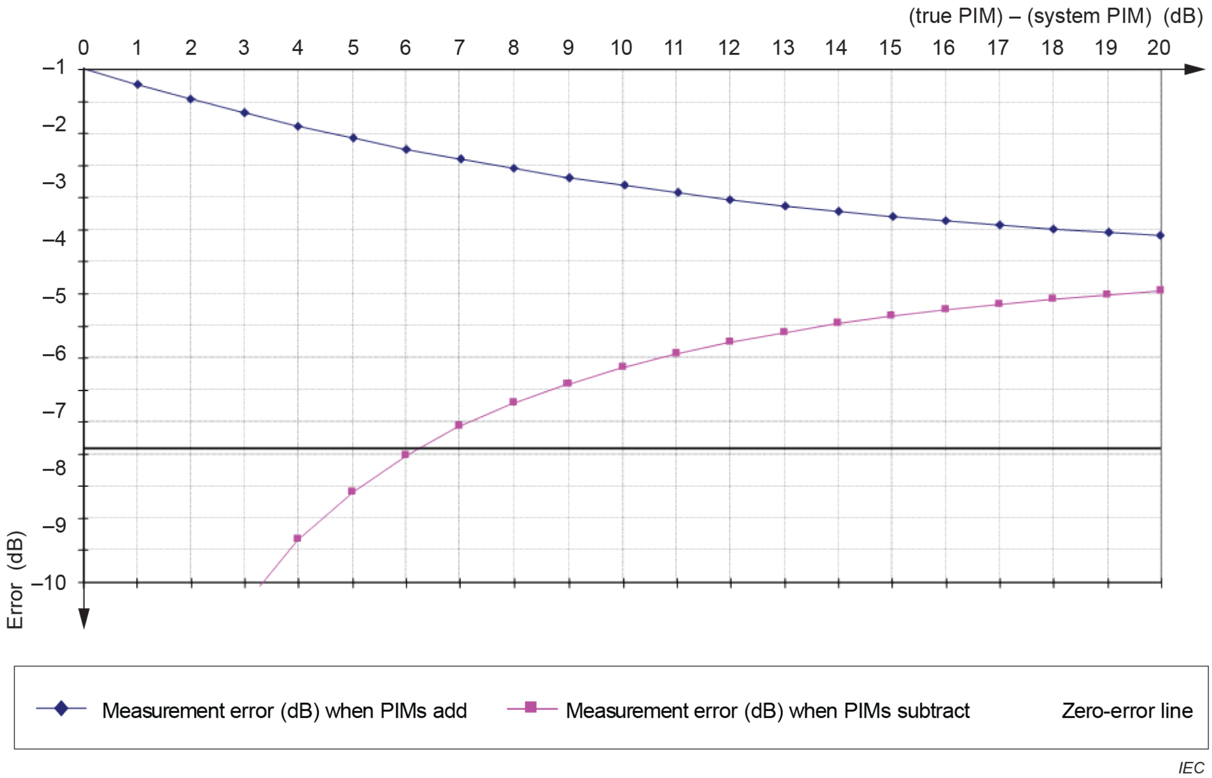

Figure 3 – Passive intermodulation (PIM) measurement error caused by residual system error

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.

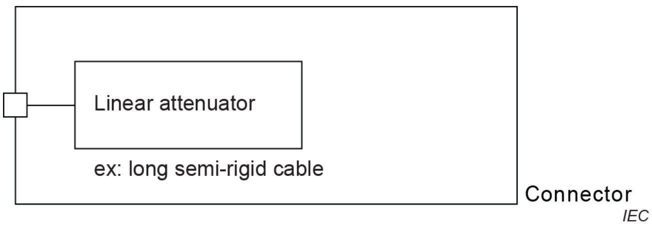

Figure A.1 – Long cable termination

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.

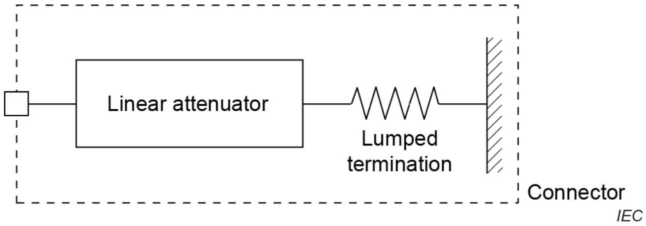

Figure A.2 – Lumped termination with a linear attenuator

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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