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Semiconductor devices –

Part 16-1: Microwave integrated circuits – Amplifiers

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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FOREWORD

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International Standard IEC 60747-16-1 has been prepared by subcommittee 47E: Discrete semiconductor devices, of IEC technical committee 47: Semiconductor devices.

This consolidated version of IEC 60747-16-1 consists of the first edition (2001) [documents 47E/200/FDIS and 47E/204/RVD] and its amendment 1 (2007) [documents 47E/305/FDIS and 47E/317/RVD].

The technical content is therefore identical to the base edition and its amendment and has been prepared for user convenience.

It bears the edition number 1.1.

A vertical line in the margin shows where the base publication has been modified by amendment 1.

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

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- withdrawn,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

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

SEMICONDUCTOR DEVICES –

Part 16-1: Microwave integrated circuits – Amplifiers

1 Scope

This part of IEC 60747 provides the terminology, the essential ratings and characteristics, as well as the measuring methods for integrated circuit microwave power amplifiers.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60617:2001, *Graphical symbols for diagrams*

IEC 60747-1:2006, *Semiconductor devices – Part 1: General*

IEC 60747-4:-, *Semiconductor devices – Discrete devices – Part 4: Microwave diodes and transistors*[1]

IEC 60747-7:2000, *Semiconductor devices – Part 7: Bipolar transistors*

IEC 60747-16-2:2001, *Semiconductor devices – Part 16-2: Microwave integrated circuits – Frequency prescalers*

IEC 60747-16-4:2004, *Semiconductor devices – Part 16-4: Microwave integrated circuits – Switches*

IEC 60748-2:1997, *Semiconductor devices – Integrated circuits – Part 2: Digital integrated circuits*

IEC 60748-3:1986, *Semiconductor devices – Integrated circuits – Part 3: Analogue integrated circuits*

IEC 60748-4:1997, *Semiconductor devices – Integrated circuits – Part 4: Interface integrated circuits*

IEC/TS 61340-5-1:1998, *Electrostatics - Part 5-1: Protection of electronic devices from electrostatic phenomena - General requirements*

IEC/TS 61340-5-2:1999, *Electrostatics - Part 5-2: Protection of electronic devices from electrostatic phenomena - User guide*

3 Terminology

3.1
linear (power) gain G_{lin}
power gain in the linear region of the power transfer curve P_o (dBm) = $f(P_i)$

NOTE In this region, ΔP_o (dBm) = ΔP_i (dBm).

———————

1 The second edition of IEC 60747-4, which is cited in this standard, and to which terms introduced in this amendment refer, is currently in preparation (ADIS).

3.2
linear (power) gain flatness ΔG_{lin}
power gain flatness when the operating point lies in the linear region of the power transfer curve

3.3
power gain G_p, G
ratio of the output power to the input power

NOTE Usually the power gain is expressed in decibels.

3.4
(power) gain flatness ΔG_p
difference between the maximum and minimum power gain for a specified input power in a specified frequency range

3.5
(maximum available) gain reduction ΔG_{red}
difference in decibels between the maximum and minimum power gains that can be provided by the gain control

3.6 Output power limiting

3.6.1
output power limiting range
range in which, for rising input power, the output power is limiting

NOTE For specification purposes, the limits of this range are specified by specified lower and upper limit values for the input power.

3.6.2
limiting output power $P_{o(ltg)}$
output power in the range where it is limiting

3.6.3
limiting output power flatness $\Delta P_{o(ltg)}$
difference between the maximum and minimum output power in the output power limiting range:

$$\Delta P_{o(ltg)} = P_{o(ltg,max)} - P_{o(ltg,min)}$$

3.7
intermodulation distortion P_1/P_n
ratio of the fundamental component of the output power to the nth order component of the output power, at a specified input power

3.8
power at the intercept point (for intermodulation products) $P_{n(IP)}$
output power at intersection between the extrapolated output powers of the fundamental component and the nth order intermodulation components, when the extrapolation is carried out in a diagram showing the output power of the components (in decibels) as a function of the input power (in decibels)

3.9
magnitude of the input reflection coefficient
(input return loss)
$|S_{11}|$
see 3.5.2.1 of IEC 60747-7

3.10
magnitude of the output reflection coefficient
(output return loss)
$|S_{22}|$
see 3.5.2.2 of IEC 60747-7

3.11
magnitude of the reverse transmission coefficient
(isolation)
$|S_{12}|$
see 3.5.2.4 of IEC 60747-7

3.12
conversion coefficient of amplitude modulation to phase modulation $\alpha_{(\mathrm{AM\text{-}PM})}$
quotient of

the phase deviation of the output signal (in degrees) by

the change in input power (in decibels) producing it

3.13
group delay time $t_{\mathrm{d(grp)}}$
ratio of the change, with angular frequency, of the phase shift through the amplifier

NOTE Usually group delay time is very close in value to input-to-output delay time.

3.14
***n*th order harmonic distortion ratio** P_1/P_{nth}
ratio of the power of the fundamental frequency measured at the output port of the device to the power of the *n*th order harmonic component measured at the output port for a specified output power

3.15
output noise power P_{N}
maximum noise power measured at the output port of the device within a specified bandwidth in a specified frequency range for a specified output power

3.16
spurious intensity under specified load VSWR $P_{\mathrm{o}}/P_{\mathrm{sp}}$
ratio of the power of the fundamental frequency measured at the output port of the device to the maximum spurious power measured at the output port under specified load VSWR

3.17
output power
P_{o}
see 3.3 of IEC 60747-16-2

3.18
output power at 1 dB gain compression
$P_{\mathrm{o(1dB)}}$
see 8.2.13 of IEC 60747-4

3.19
noise figure
F
see 702-08-57 of IEC 60050-702

3.20
power added efficiency
η_{add}
see 8.2.15 of IEC 60747-4

3.21
adjacent channel power ratio
$P_{o(mod)}/P_{adj}$
see 3.10 of IEC 60747-16-4

3.22
load mismatch tolerance
Ψ_L
see 7.2.20 of IEC 60747-4

3.23
source mismatch tolerance
Ψ_S
see 7.2.21 of IEC 60747-4

3.24
load mismatch ruggedness
Ψ_R
see 7.2.22 of IEC 60747-4

4 Essential ratings and characteristics

4.1 General

4.1.1 Circuit identification and types

4.1.1.1 Designation and types

The indication of type (device name), the category of the circuit and the technology applied should be given.

Microwave amplifiers are divided into four categories:

Type A: Low-noise type.

Type B: Auto-gain control type.

Type C: Limiting type.

Type D: Power type.

4.1.1.2 General function description

A general description of the function performed by the integrated circuit microwave amplifiers and the features for the application should be made.

4.1.1.3 Manufacturing technology

The manufacturing technology, for example, semiconductor monolithic integrated circuit, thin-film integrated circuit, micro-assembly, should be stated. This statement should include details of the semiconductor technologies such as MESFET, MISFET, Si bipolar transistor, HBT, etc.

4.1.1.4 Package identification

The following statements should be made:

a) IEC and/or national reference number of the outline drawing, or drawing of non-standard package including terminal numbering;
b) principal package material; for example, metal, ceramic, plastic.

4.1.1.5 Main application

The main application should be stated, if necessary. If the device has restrictive applications, these should be stated here.

4.2 Application related description

Information on the application of the integrated circuit and its relation to the associated devices should be given.

4.2.1 Conformance to system and/or interface information

It should be stated whether the integrated circuit conforms to an application system and/or interface standard or recommendation.

The detailed information about application systems, equipment and circuits such as VSAT systems, DBS receivers, microwave landing systems, etc., should also be given.

4.2.2 Overall block diagram

A block diagram of the applied systems should be given, if necessary.

4.2.3 Reference data

The most important properties to permit comparison between derivative types should be given.

4.2.4 Electrical compatibility

It should be stated whether the integrated circuit is electrically compatible with other particular integrated circuits or families of integrated circuits or whether special interfaces are required.

Details should be given of the type of the input and output circuits, for example, input/output impedances, d.c. block, open-drain, etc. Interchangeability with other devices, if any, should be given.

4.2.5 Associated devices

If applicable, the following should be stated here:

– devices necessary for correct operation (list with type number, name, and function);
– peripheral devices with direct interfacing (list with type number, name, and function).

4.3 Specification of the function

4.3.1 Detailed block diagram – Functional blocks

A detail block diagram or equivalent circuit information of the integrated circuit microwave amplifiers should be given. The block diagram should be composed of the following:

1) functional blocks;
2) mutual interconnections among the functional blocks;

3) individual functional units within the functional blocks;
4) mutual interconnections among the individual functional blocks;
5) function of each external connection;
6) interdependence between the separate functional blocks.

The block diagram should identify the function of each external connection and, where no ambiguity can arise, can also show the terminal symbols and/or numbers. If the encapsulation has metallic parts, any connection to them from external terminals should be indicated. The connections with any associated external electrical elements should be stated, where necessary.

As additional information, the complete electrical circuit diagram can be reproduced, but not necessarily with indications of the values of the circuit components. The graphical symbol for the function shall be given. This may be obtained from a catalogue of standards of graphical symbols or designed according to the rules of IEC 60617.

4.3.2 Identification and function of terminals

All terminals should be identified on the block diagram (supply terminals, input or output terminals, input/output terminals).

The terminal functions 1)-4) should be indicated in a table as follows:

Terminal number	**Terminal symbol**	**1) Terminal designation**	**2) Function**	**Function of terminal**	
				3) Input/output identification	**4) Type of input/output circuit**

1) Terminal name

   A terminal name to indicate the function terminal should be given. Supply terminals, ground terminals, blank terminals (with abbreviation NC), non-usable terminals (with abbreviation NU) should be distinguished.

2) Function

   A brief indication of the terminal function should be given.

   – Each function of multi-role terminals, that is terminals that have multiple functions.

   – Each function of the integrated circuit selected by mutual pin connections, programming and/or application of function selection data to the function selection pin, such as mode selection pin.

3) Input/output identification

   Input, output, input/output, and multiplex input/output terminals should be distinguished.

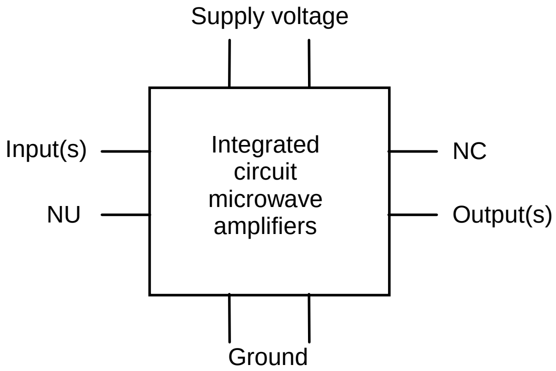
4) Type of input/output circuits

   The type of the input and output circuits, for example, input/output impedances, with or without d.c. block, etc., should be distinguished.

5) Type of ground

   If the baseplate of the package is used as ground, this should be stated.

Example:



4.3.3 Functional description

The function performed by the circuit should be specified, including the following information:

– basic function;
– relation to external terminals;
– operation mode (for example, set-up method, preference, etc.);
– interrupt handling.

4.3.4 Family-related characteristics

In this part, all the family-specific functional descriptions shall be stated (refer to IEC 60748-2, IEC 60748-3 and IEC 60748-4).

If ratings and characteristics and function characteristics exist for the family, the relevant part of IEC 60748 should be used (for example, for microprocessors, see IEC 60748-2, Chapter III, Section 3).

NOTE For each new device family, specific items shall be added in the relevant part of IEC 60748.

4.4 Limiting values (absolute maximum rating system)

The table of these values contains the following.

a) Any interdependence of limiting conditions shall be specified.
b) If externally connected and/or attached elements, for example heatsinks, have an influence on the values of the ratings, the ratings shall be prescribed for the integrated circuit with the elements connected and/or attached.
c) If limiting values are exceeded for transient overload, the permissible excess and their duration shall be specified.
d) Where minimum and maximum values differ during programming of the device, this should be stated.
e) All voltages are referenced to a specified reference terminal (V_{SS}, G_{ND}, etc.).
f) In satisfying the following clauses, if maximum and/or minimum values are quoted, the manufacturer must indicate whether he refers to the absolute magnitude or to the algebraic value of the quantity.
g) The ratings given must cover the operation of the multi-function integrated circuit over the specified range of operating temperatures. Where such ratings are temperature-dependent, this dependence should be indicated.

4.4.1 Electrical limiting values

Limiting values should be specified as follows.

Parameters		Min.	Max.
(1)	Power supply voltages	+	+
(2)	Power supply currents (where appropriate)		+
(3)	Input voltage(s) (where appropriate)	+	+
(4)	Output voltage(s) (where appropriate)	+	+
(5)	Input current(s) (where appropriate)		+
(6)	Output current(s) (where appropriate)		+
(7)	Other terminal voltage(s) (where appropriate)	+	+
(8)	Other terminal current(s) (where appropriate)		+
(9)	Voltage difference between input and output (where appropriate)	+	+
(10)	Power dissipation		+

The detail specification may indicate those values within the table including note 1 and note 2.

Parameters (Note 1, Note 2)	Symbols	Min.	Max.	Unit

NOTE 1 Where appropriate, in accordance with the type of circuit considered.

NOTE 2 For power supply voltage range:

– limiting value(s) of the continuous voltage(s) at the supply terminal(s) with respect to a special electrical reference point;

– where appropriate, limiting value between specified supply terminals;

– when more than one voltage supply is required, a statement should be made as to whether the sequence in which these supplies are applied is significant: if so, the sequence should be stated;

– when more than one supply is needed, it may be necessary to state the combinations of ratings for these supply voltages and currents.

4.4.2 Temperatures

1) Operating temperature
2) Storage temperature
3) Channel temperature (type C and type D only)
4) Lead temperature (for soldering).

The detail specification may indicate those values within the table including the note.

Parameters (Note)	Symbols	Min.	Max.	Unit

NOTE Where appropriate, in accordance with the type of circuit considered.

4.5 Operating conditions (within the specified operating temperature range)

They are not to be inspected but may be used for quality assessment purpose.

4.5.1 Power supplies positive and/or negative values

4.5.2 Initialization sequences (where appropriate)

If special initialization sequences are necessary, the power supply sequencing and the initialization procedure should be specified.

4.5.3 Input voltage(s) (where appropriate)

4.5.4 Output current(s) (where appropriate)

4.5.5 Voltage and/or current of other terminal(s)

4.5.6 External elements (where appropriate)

4.5.7 Operating temperature range

4.6 Electrical characteristics

The characteristics shall apply over the full operating temperature range, unless otherwise specified.

Each characteristic of 4.6.1 and 4.6.2 should be stated, either

a) over the specified range of operating temperatures, or

b) at a temperature of 25 °C, and at maximum and minimum operating temperatures.

4.6.1 Static characteristics

The parameters should be specified corresponding to the type as follows.

Parameters	Min.	Typ.[a]	Max.	Types			
				A	B	C	D
4.6.1.1 Power supply current	+	+	+	+	+	+	+
4.6.1.2 Thermal resistance			+			+	+
[a] Optional							

The detail specification may indicate those values within the table.

Characteristics	Symbols	Conditions	Min.	Typ.[a]	Max.	Unit
[a] Optional						

4.6.2 Dynamic or r.f. characteristics

Each dynamic or a.c. electrical characteristic should be stated under specified electrical worst-case conditions with respect to the recommended range of supply voltages, as stated in 4.5.1.

The parameters should be specified corresponding to the type as follows.

Parameters		Min.	Max.	Types			
				A	B	C	D
4.6.2.1	Linear gain	+		+	+		+
4.6.2.2	Linear gain flatness		+	+	+		+
4.6.2.3	Power gain	+			+		+
4.6.2.4	Power gain flatness		+		+		+
4.6.2.5	Gain reduction	+			+		
4.6.2.6	Output power	+			+		+
4.6.2.7	Output power at 1 dB gain compression	+			+		+
4.6.2.8	Limiting output power	+	+			+	
4.6.2.9	Limiting output power flatness		+			+	
4.6.2.10	Intermodulation distortion	+				+	+
4.6.2.11	Power at intercept point	+				+	+
4.6.2.12	Noise figure		+	+			
4.6.2.13	Magnitude of the input reflection coefficient (input return loss)	+		+	+	+	+
4.6.2.14	Magnitude of the output reflection coefficient (output return loss)	+		+	+		+[b]
4.6.2.15	Magnitude of the reverse transmission coefficient (isolation)	+		+	+	+	+
4.6.2.16	Conversion coefficient of amplitude modulation to phase modulation (where appropriate)		+			+	+
4.6.2.17	Group delay time (where appropriate)		+		+	+	+
4.6.2.18	Time constant for automatic gain control [a]						
4.6.2.19	Power added efficiency (where appropriate)	+					+
4.6.2.20	*n*th order harmonic distortion ratio (where appropriate) (note 2)	+					+
4.6.2.21	Output noise power (where appropriate)		+ +				+ +
4.6.2.22	Spurious intensity under specified load VSWR (where appropriate) (note 2)	+					+
4.6.2.23	Adjacent channel power ratio (where appropriate)	+					+
4.6.2.24	Load mismatch tolerance (where appropriate)		+				+
4.6.2.25	Source mismatch tolerance (where appropriate)		+				+
4.6.2.26	Load mismatch ruggedness (where appropriate)		+				+

NOTE 1 It is necessary for types B and D to select either the parameter set of 4.6.2.1, 4.6.2.2 and 4.6.2.7 or that of 4.6.2.3, 4.6.2.4 and 4.6.2.6.

NOTE 2 Generally expressed in dBc.

[a] Under consideration.

[b] Optional. For type D, the devices are sometimes required to specify under large signal operation instead of small signal operation. Although the definition is the same for both operating conditions, the different measuring method should be employed for the parameter under large signal operation from that under small signal operation.

The detail specification may indicate those values within the table.

Characteristics	Symbols	Conditions	Min.	Typ.[a]	Max.	Unit
[a] Optional						

4.7 Mechanical and environmental ratings, characteristics and data

Any specific mechanical and environmental ratings applicable should be stated (see also Subclause 5.10 and 5.11 of IEC 60747-1:2006).

4.8 Additional information

Where appropriate, the following information should be given.

4.8.1 Equivalent input and output circuit

Detailed information should be given regarding the type of the input and output circuits; for example, input/output impedances, d.c. block, open-drain, etc.

4.8.2 Internal protection

A statement should be given to indicate whether the integrated circuit contains internal protection against high static voltages or electrical fields.

4.8.3 Capacitors at terminals

If capacitors for the input/output d.c. block are needed, these capacitances should be stated.

4.8.4 Thermal resistance

4.8.5 Interconnections to other types of circuit

Where appropriate, details of the interconnections to other circuits, for example, detector circuit for AGC, sense amplifiers, buffer, should be given.

4.8.6 Effects of externally connected component(s)

Curves or data indicating the effect of externally connected component(s) that influence the characteristics may be given.

4.8.7 Recommendations for any associated device(s)

For example, decoupling of power supply to a high-frequency device should be stated.

4.8.8 Handling precautions

Where appropriate, handling precautions specific to the circuit should be stated (see also IEC 61340-5-1 and IEC 61340-5-2).

4.8.9 Application data

4.8.10 Other application information

4.8.11 Date of issue of the data sheet

5 Measuring methods

5.1 General

5.1.1 Characteristic impedances

The input and output characteristic impedances of the measurement system, shown in the circuit in this standard, are 50 Ω. If they are not 50 Ω, they should be specified.

5.1.2 General precautions

The general precautions listed in clause 6.3, 6.4 and 6.6 of IEC 60747-1:2006 apply. In addition, special care should be taken to use low-ripple d.c. supplies and to decouple adequately all bias supply voltages at the frequency of measurement. Also special care about the load impedance of the test circuit should be taken to measure the output power.

The power levels are indicated by using the unit "dBm". The unit "dBm" expresses decibel referred to 1 mW.

5.1.3 Handling precautions

When handling electrostatic-sensitive devices, the handling precautions given in IEC 61340-5-1 and IEC 61340-5-2, shall be observed.

5.1.4 Types

The devices in this standard are both package and chip types, measured using suitable test fixtures.

5.2 Linear (power) gain (G_{lin})

5.2.1 Purpose

To measure the linear gain under specified conditions.

5.2.2 Circuit diagram

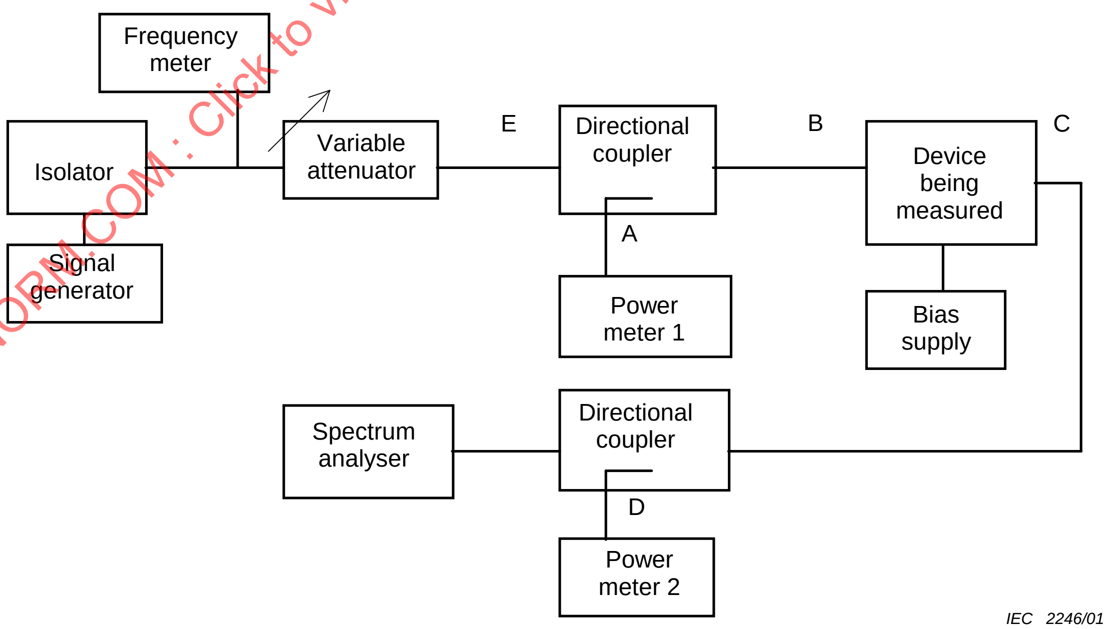


Figure 1 – Circuit for the measurements of linear gain

5.2.3 Principle of measurement

In the circuit diagram shown in figure 1, the input power P_i and the output power P_o of the device being measured are derived from the following equations:

$$P_i = P_1 + L_1 \quad (1)$$

$$P_o = P_2 + L_2 \quad (2)$$

where P_1 and P_2 are the value indicated by the power meters 1 and 2, respectively.

$$L_1 = L_A - L_B$$

where L_A is the loss from point E to point A and L_B is the loss from point E to point B shown in figure 1, respectively.

L_2 is the circuit loss from point C to point D shown in figure 1. P_i, P_o, P_1 and P_2 are expressed in dBm. L_1 and L_2 are expressed in decibels.

Power gain G_p in dB is derived from equation (1) and (2) as follows:

$$G_p = P_o - P_i \quad (3)$$

The linear gain G_{lin} is the power gain measured in the region where the change of the output power in dBm is the same as that of the input power.

5.2.4 Circuit description and requirements

The purpose of the isolator is to enable the power level to the device being measured to be kept constant irrespective of impedance mismatches at its input.

The circuit losses L_1 and L_2 should be measured beforehand.

5.2.5 Precautions to be observed

Oscillation, which is checked by a spectrum analyser, should be eliminated during these measurements. The termination must be capable of handling the power fed.

Harmonics or spurious responses of the signal generator should be reduced to negligible.

5.2.6 Measurement procedure

The frequency of the signal generator should be adjusted to the specified value.

The bias under specified conditions is applied.

An adequate input power is applied to the device being measured.

By varying input power, confirm that the change of the output power in dBm is the same as that of the input power.

The gain measured in the region where the change of output power is the same as that of input power is linear gain G_{lin}.

5.2.7 Specified conditions

– Ambient or reference-point temperature
– Bias conditions
– Frequency

5.3 Linear (power) gain flatness (ΔG_{lin})

5.3.1 Purpose

To measure the linear gain flatness under specified conditions.

5.3.2 Circuit diagram

See the circuit diagram shown in figure 1.

5.3.3 Principle of measurement

See the principle of measurements of 5.2.3.

Linear gain flatness is derived from the following equation.

$$\Delta G_{lin} = G_{linmax} - G_{linmin} \quad (4)$$

where G_{linmax} and G_{linmin} are maximum linear gain and minimum linear gain in the specified frequency band at the specified input power, respectively.

5.3.4 Circuit description and requirements

See the circuit description and requirements of 5.2.4.

5.3.5 Precautions to be observed

See the precautions to be observed of 5.2.5.

5.3.6 Measurement procedure

The frequency of the signal generator should be adjusted to the specified value.

The bias under specified conditions is applied.

An adequate input power level is applied to the device being measured.

By varying input power level, confirm that the change of output power in dBm is the same as that of input power.

Decide the suitable input power level for measuring linear gain.

Vary the frequency in the specified frequency band with the same input power level.

Obtain the maximum linear gain G_{linmax} and the minimum linear gain G_{linmin} in the specified frequency band.

Linear gain flatness ΔG_{lin} is derived from equation (4).

5.3.7 Specified conditions

- Ambient or reference-point temperature
- Bias conditions
- Frequency band

5.4 Power gain (G_p)

5.4.1 Purpose

To measure the power gain under specified conditions.

5.4.2 Circuit diagram

See the circuit diagram shown in figure 1.

5.4.3 Principle of measurement

See the principle of measurements of 5.2.3.

5.4.4 Circuit description and requirements

See the circuit description and requirements of 5.2.4.

5.4.5 Precautions to be observed

See the precautions to be observed of 5.2.5.

5.4.6 Measurement procedure

The frequency of the signal generator should be adjusted to the specified value.

The bias under specified conditions is applied.

The specified input power P_i is applied to the device being measured.

The output power P_o is measured.

5.4.7 Specified conditions

- Ambient or reference-point temperature
- Bias conditions
- Frequency
- Input power

5.5 (Power) gain flatness (ΔG_p)

5.5.1 Purpose

To measure the power gain flatness under specified conditions.

5.5.2 Circuit diagram

See the circuit diagram shown in figure 1.

5.5.3 Principle of measurement

See the principle of measurements of 5.2.3.

Power gain flatness is derived from the following equation.

$$\Delta G_p = G_{pmax} - G_{pmin} \quad (5)$$

where G_{pmax} and G_{pmin} are the maximum power gain and the minimum power gain in the specified frequency band at the specified input power, respectively.

5.5.4 Circuit description and requirements

See the circuit description and requirements of 5.2.4.

5.5.5 Precautions to be observed

See the precautions to be observed of 5.2.5.

5.5.6 Measurement procedure

The frequency of the signal generator should be adjusted to the specified value.

The bias under specified conditions is applied.

The input power P_i is applied to the device being measured.

The output power P_o is measured.

The power gain is calculated by equation (3).

The frequency in the specified band is varied continuously with the same input power level.

Obtain the maximum power gain G_{pmax} and the minimum power gain G_{pmin} in the specified frequency band.

Power gain flatness is derived from equation (5).

5.5.7 Specified conditions

- Ambient or reference-point temperature
- Bias conditions
- Frequency band
- Input power

5.6 (Maximum available) gain reduction (ΔG_{red})

5.6.1 Purpose

To measure the gain reduction of an AGC amplifier under specified conditions.

5.6.2 Circuit diagram

See the circuit diagram shown in figure 1, where bias supply contains AGC bias.

5.6.3 Principle of measurement

See the principle of measurements of 5.2.3.

5.6.4 Circuit description and requirements

See the circuit description and requirements of 5.2.4.

5.6.5 Precautions to be observed

See the precautions to be observed of 5.2.5.

5.6.6 Measurement procedure

The frequency of the signal generator should be adjusted to the specified value.

The bias under specified conditions is applied.

The AGC bias is set to specified values giving the maximum linear gain G_{linmax}.

An adequate input power is applied to the device being measured.

By varying input power, confirm the change of output power in dBm is the same as that of input power.

The gain, measured in the region where the change of output power is the same as that of input power, is maximum linear gain G_{linmax}.

The AGC bias is set to the specified value giving the minimum linear gain G_{linmin}.

The minimum linear gain G_{linmin} is measured in dB in the same way as above.

$$\Delta G_{\mathrm{red}} = G_{\mathrm{linmax}} - G_{\mathrm{linmin}} \tag{6}$$

5.6.7 Specified conditions

– Ambient or reference-point temperature
– Bias conditions
– Frequency
– AGC bias giving the maximum linear gain and the minimum linear gain

5.7 Limiting output power ($P_{\mathrm{o(ltg)}}$)

Limiting output power flatness ($\Delta P_{\mathrm{o(ltg)}}$)

5.7.1 Purpose

To measure the limiting output power and limiting output power flatness under specified conditions.

5.7.2 Circuit diagram

See the circuit diagram shown in figure 1.

5.7.3 Principle of measurement

See the principle of measurements of 5.2.3.

5.7.4 Circuit description and requirements

See the circuit description and requirements of 5.2.4.

5.7.5 Precautions to be observed

See the precautions to be observed of 5.2.5.

5.7.6 Measurement procedure

The frequency of the signal generator should be adjusted to the specified value.

The bias under specified conditions is applied.

The input power P_i is applied to the device being measured.

The output power P_o is measured.

By varying the input power between the lower and upper limits of limiting range, find the minimum and maximum output powers ($P_{o(ltg,min)}$ and $P_{o(ltg,max)}$).

The limiting output power ($P_{o(ltg)}$) and limiting output power flatness ($\Delta P_{o(ltg)}$) are derived from the following equations:

$$P_{o(ltg)} = P_{o(ltg,max)} \quad (7)$$

$$\Delta P_{o(ltg)} = P_{o(ltg,max)} - P_{o(ltg,min)} \quad (8)$$

5.7.7 Specified conditions

– Ambient or reference-point temperature
– Bias conditions
– Frequency
– Lower limit of limiting range
– Upper limit of limiting range

5.8 Output power (P_o)

5.8.1 Purpose

To measure the output power under specified conditions.

5.8.2 Circuit diagram

See the circuit diagram shown in figure 1.

5.8.3 Principle of measurement

See the principle of measurements of 5.2.3.

5.8.4 Circuit description and requirements

See the circuit description and requirements of 5.2.4.

5.8.5 Precautions to be observed

See the precautions to be observed of 5.2.5.

5.8.6 Measurement procedure

The frequency of the signal generator should be adjusted to the specified value.

The specified bias conditions are applied.

The input power with the specified value is applied to the device being measured.

The output power is measured.

5.8.7 Specified conditions

– Ambient or reference-point temperature
– Bias conditions
– Frequency band
– Input power

5.9 Output power at 1 dB gain compression ($P_{o(1dB)}$)

5.9.1 Purpose

To measure the output power at 1 dB gain compression under specified conditions.

5.9.2 Circuit diagram

See the circuit diagram shown in figure 1.

5.9.3 Principle of measurement

See the principle of measurements of 5.2.3.

The output power at 1 dB gain-compression $P_{o(1dB)}$ is the value where the gain decreases by 1 dB compared with the linear gain.

5.9.4 Circuit description and requirements

See the circuit description and requirements of 5.2.4.

5.9.5 Precautions to be observed

See the precautions to be observed of 5.2.5.

5.9.6 Measurement procedure

The frequency of the signal generator should be adjusted to the specified value.

The bias under specified conditions is applied.

An adequate input power is applied to the device being measured.

By varying input power, confirm that the change of output power in decibels is the same as that of input power.

The gain, measured in the region where the change of output power in decibels is the same as that of input power, is linear gain G_{lin}.

The input power is increased up to the power at which the gain decreases by 1 dB, compared with linear gain G_{lin}.

The output power is measured at 1 dB gain compression point.

5.9.7 Specified conditions

- Ambient or reference-point temperature
- Bias conditions
- Frequency

5.10 Noise figure (F)

5.10.1 Purpose

To measure the noise figure under specified conditions.

5.10.2 Circuit diagram

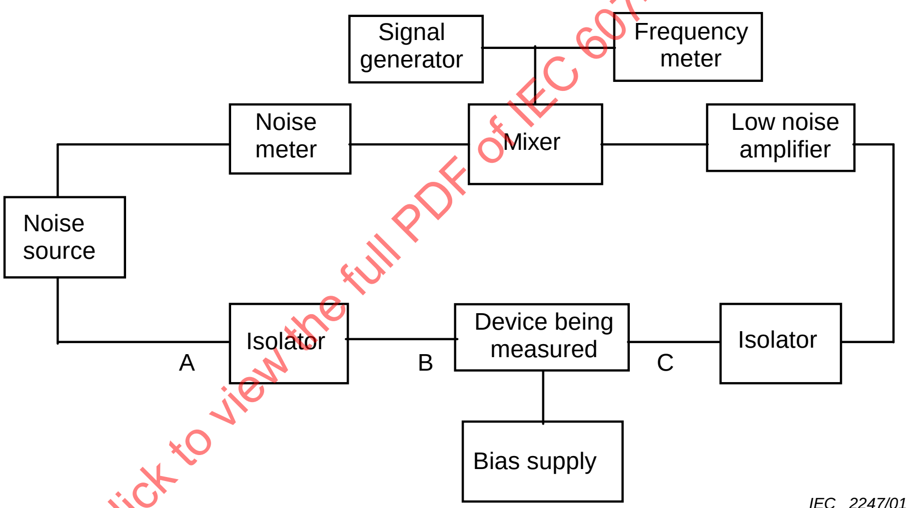


Figure 2 – Basic circuit for the measurement of the noise figure

5.10.3 Principle of measurement

The noise figure F of the device being measured is derived from the following equation:

$$F = 10\log\left[10^{(F_{12}-L_1)/10} - \frac{10^{(F_2/10)}-1}{10^{(G_{lin}/10)}}\right] \tag{9}$$

where

F_{12} is the overall noise figure;

L_1 is the circuit loss from point A to B;

F_2 is the noise figure after point C at the output stage;

G_{lin} is the linear gain of the device being measured;

F_{12}, F_2, G_{lin} and L_1 are expressed in dB.

The noise figure measurement is carried out by using the hot and cold measurement method.

F_{12}, F_2 and G_{lin} are calculated as follows.

$$F_{12} = 10\log\left(\frac{10^{ENR/10}}{(P_{N1}/P_{N2})-1}\right) \tag{10}$$

$$F_2 = 10\log\left(\frac{10^{ENR/10}}{(P_{N3}/P_{N4})-1}\right) \tag{11}$$

$$G_{lin} = 10\log\left(\frac{P_{N1}-P_{N2}}{P_{N3}-P_{N4}}\right) \tag{12}$$

where

ENR is the excess noise ratio of the noise source expressed in decibels;

P_{N1} and P_{N2} in W, are the measured noise powers under the hot and cold state of the noise source, respectively;

P_{N3} and P_{N4} in W, are the measured noise powers under the hot and cold state of the noise source, respectively, in the case of directly connecting point A to C in figure 2.

The temperature of the measurement is 290 K.

5.10.4 Circuit description and requirements

The circuit loss L_1 should be measured beforehand.

5.10.5 Precautions to be observed

The entire circuit must be shielded and earthed to prevent from undesired signals. For noise figure measurement under the SSB condition, careful attention must be paid to the image and other spurious responses which are generated by the mixer.

These spurious responses should be reduced to negligible.

5.10.6 Measurement procedure

The frequency of the signal generator is adjusted to the specified condition.

In order to measure the noise contribution of the measurement system, connect point A to C in figure 2 without the device being measured.

The noise power P_{N3} and P_{N4} corresponding to the noise source hot and cold, respectively, are measured.

The device being measured is inserted as shown in figure 2.

The bias under specified conditions is applied.

The noise power P_{N1} and P_{N2} corresponding to the noise source hot and cold, respectively, are measured.

The noise figure in decibels is calculated by equation (9).

NOTE Adjust to match the input and output impedance of the device being measured, when necessary.

5.10.7 Specified conditions

- Ambient or reference-point temperature
- Bias conditions
- Frequency
- Single-side band or double-side band

5.11 Intermodulation distortion (two-tone) (P_1/P_n)

5.11.1 Purpose

To measure the intermodulation distortion under specified conditions.

5.11.2 Circuit diagram

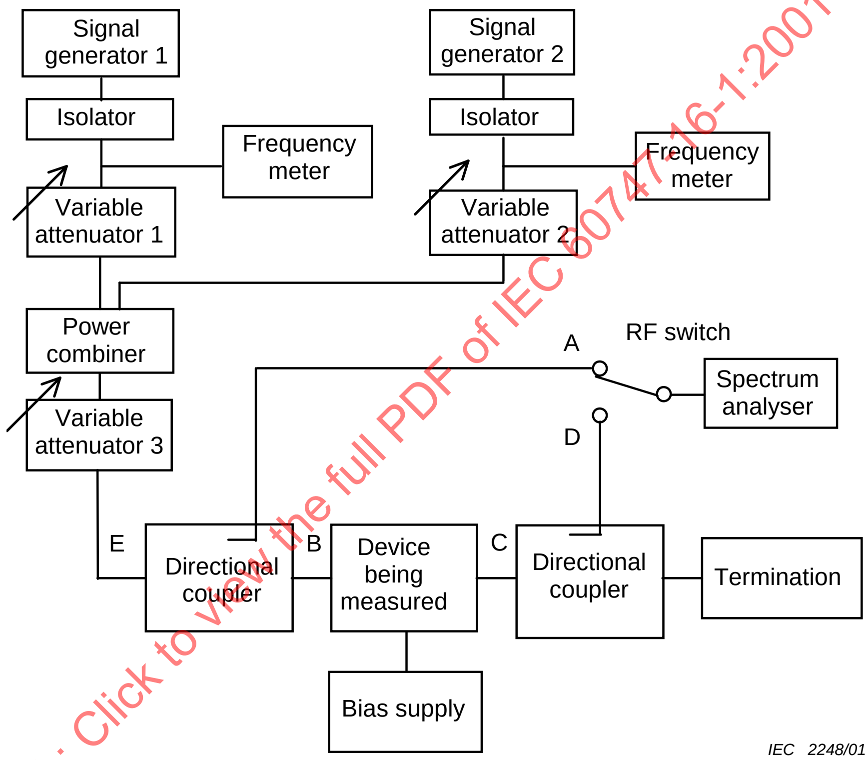


Figure 3 – Basic circuit for the measurements of two-tone intermodulation distortion

5.11.3 Principle of measurement

In the circuit diagram shown in figure 3 the input power P_i, the output powers P_1 and P_n of the device being measured are derived from the following equations:

$$P_i = P_a + L_1 \tag{13}$$

$$P_1 = P_b + L_2 \tag{14}$$

$$P_n = P_c + L_2 \tag{15}$$

where

P_1 and P_n are the powers of the fundamental signal and the intermodulation distortion, respectively;

P_a, P_b and P_c are the values indicated by the spectrum analyser corresponding to P_i, P_1 and P_n, respectively:

L_1 is the difference between the loss L_A and L_B where L_A is the loss from point E to point A and L_B is the loss from point E to point B shown in Figure 3, respectively. L_2 is the circuit loss from point C to point D shown in Figure 3. P_i, P_1, P_n, P_a, P_b and P_c are expressed in dBm. L_1 and L_2 are expressed in decibels.

The intermodulation distortion, P_1/P_n, which is expressed in dBc, is derived from Equations (14) and (15) as follows:

$$P_1/P_n = P_1 - P_n = P_b - P_c \tag{16}$$

5.11.4 Circuit description and requirements

See the circuit description and requirements of 5.2.4.

The variable attenuator 3 can be eliminated.

5.11.5 Precautions to be observed

See the precautions to be observed of 5.2.5.

It is better to terminate the port D, when the switch is connected to the position A, and vice versa.

5.11.6 Measurement procedure

The bias under specified conditions is applied.

The switch is connected to position A.

The signal generator 1 is turned on, and the fundamental signal is applied to the device being measured with the specified level P_i using the spectrum analyser and the variable attenuator 1.

The signal generator 2 is turned on, and another signal is added to the device being measured with the same level as the fundamental signal using the spectrum analyser and the variable attenuator 2.

The switch is connected to position D.

The output powers P_b and P_c in dB of the fundamental signal and the intermodulation products are measured using the spectrum analyser.

The intermodulation distortion on the specified input power P_i is derived from the equations (13) to (16).

5.11.7 Specified conditions

- Ambient or reference-point temperature
- Bias conditions
- Input power
- Frequencies

5.12 Power at the intercept point (for intermodulation products) ($P_{n(IP)}$)

5.12.1 Purpose

To measure the power at the intercept point for intermodulation products under specified conditions.

5.12.2 Circuit diagram

See the circuit diagram of 5.11.2.

5.12.3 Principle of measurement

Refer the principle of measurements of 5.11.3.

5.12.4 Circuit description and requirements

See the circuit description and requirements of 5.11.4.

5.12.5 Precautions to be observed

See the precautions to be observed of 5.11.5.

5.12.6 Measurement procedure

The bias under specified conditions is applied.

The switch is connected to position A.

The signal generator 1 is turned on, and the fundamental signal is applied to the device being measured with the specified level using the spectrum analyser and the variable attenuator 1.

The signal generator 2 is turned on, and another signal is applied to the device being measured with the same level as the fundamental signal using the spectrum analyser and the variable attenuator 2.

The switch is connected to position D.

The output powers of the fundamental signal and the specified intermodulation products are measured using the spectrum analyser.

Changing the power level of the input signals using the variable attenuator 3, the above procedure is repeated within the specified range.

The data obtained are plotted.

The straight lines of the fundamental signal and the inter-modulation products in the linear region are extended.

The output power at the intercept point of the two extended lines is the power at the intercept point for the intermodulation products, i.e. second order, third order etc., under the specified conditions required in 5.12.7.

5.12.7 Specified conditions

- Ambient or reference-point temperature
- Bias conditions
- Input power
- Frequencies
- Range of input power

5.13 Magnitude of the input reflection coefficient (input return loss) ($|S_{11}|$)

5.13.1 Purpose

To measure the magnitude of the input reflection coefficient (input return loss) under specified conditions.

5.13.2 Circuit diagram

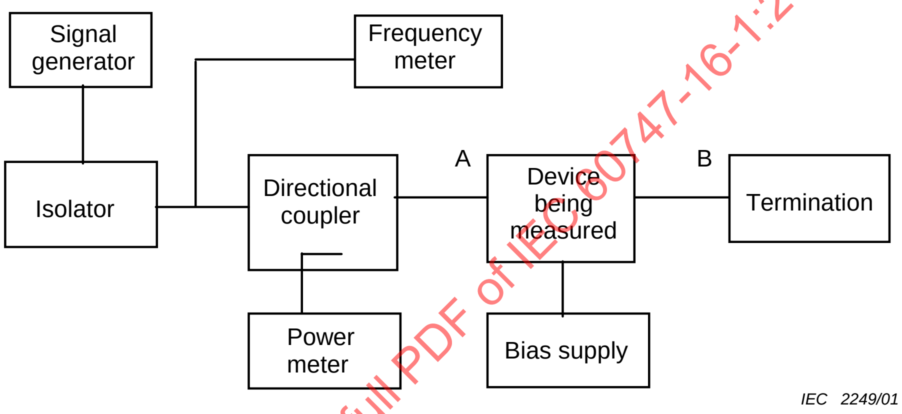


Figure 4 – Circuit for the measurements of magnitude of input/output reflection coefficient (input/output return loss)

NOTE A network analyser may be used to measure the magnitude of the reflection coefficient (input/output return loss).

5.13.3 Principle of measurement

In this measurement, the magnitude of the reflection coefficient is expressed in return loss, which is commonly in use. Thus, the sign of the return loss is opposite to that of the magnitude of the reflection coefficient in decibels.

The input return loss is derived from the following equation:

$$|S_{11}| \text{ (dB)} = P_1 \text{ (dBm)} - P_2 \text{ (dBm)} \qquad (17)$$

where

P_1 is the measured power when the line at point A is either short-circuited or made open-circuit;

P_2 is the measured power when the deviced being measured is inserted.

5.13.4 Circuit description and requirements

The purpose of the isolator is to enable the power level to the device being measured to be kept constant, irrespective of impedance mismatches at its input.

The input port of the device being measured is connected to directional coupler, and other r.f. ports are connected to the termination.

The directivity of the directional coupler shall be sufficient to avoid undue error in the value of the return loss of the device being measured.

5.13.5 Precautions to be observed

As specified in 5.1.2.

5.13.6 Measurement procedure

The frequency of the signal generator is adjusted to the specified value.

Points A and B are disconnected.

The line at point A is either short-circuited or made open-circuit.

The reading of the power meter is recorded as P_1.

The device being measured is inserted between points A and B.

The bias under specified conditions is applied.

The reading of the power meter is again recorded as P_2.

The input return loss is calculated by the equation (17).

5.13.7 Specified conditions

- Ambient or reference-point temperature
- Bias conditions
- Frequency
- Input power

5.14 Magnitude of the output reflection coefficient (output return loss) ($|S_{22}|$)

The definition of the parameter of the magnitude of the output reflection coefficient $|S_{22}|$ is the only one for all the operating condition of the devices; however, it is necessary to apply the different measuring methods according to the operating conditions. Note that the value of $|S_{22}|$ depends on the operating output power level.

The method described in 5.14.1 is for the measurement under the small-signal operating condition, whereas 5.14.2 is the measuring method for the large-signal operating condition.

5.14.1 Magnitude of the output reflection coefficient (output return loss) under small-signal operating condition

5.14.1.1 Purpose

To measure the magnitude of the output reflection coefficient (output return loss) under specified small-signal conditions.

5.14.1.2 Circuit diagram

See the circuit diagram shown in figure 4.

5.14.1.3 Principle of measurement

See the principle of measurements in 5.13.3.

The output return loss is derived from the following equation:

$$|S_{22}| \text{ (dB)} = P_1 \text{ (dBm)} - P_2 \text{ (dBm)} \tag{18}$$

where

P_1 is the measured power when the line at point A is either short-circuited or made open-circuit;

P_2 is the measured power when the device being measured is inserted.

5.14.1.4 Circuit description and requirements

The purpose of the isolator is to enable the power level to the device being measured to be kept constant irrespective of impedance mismatches at its input.

The output port of the device being measured is connected to directional coupler, and other r.f. ports are connected to the termination.

The directivity of the directional coupler shall be sufficient to avoid undue error in value of the return loss of the device being measured.

5.14.1.5 Precautions to be observed

As specified in 5.1.2.

5.14.1.6 Measurement procedure

The frequency of the signal generator should be adjusted to the specified value.

Points A and B are disconnected.

The line at point A is either short-circuited or made open-circuit.

The reading of the power meter is recorded as P_1.

The device being measured is inserted between points A and B.

The bias under specified conditions is applied.

The reading of the power meter is again recorded as P_2.

The output return loss is calculated by the equation (18).

5.14.1.7 Specified conditions

– Ambient or reference-point temperature
– Bias conditions
– Frequency
– Input power

5.14.2 Magnitude of the output reflection coefficient (output return loss) under large-signal operating condition

5.14.2.1 Purpose

To measure the magnitude of the output reflection coefficient (output return loss $|S_{22}|$) under the specified large-signal operation.

5.14.2.2 Circuit diagram

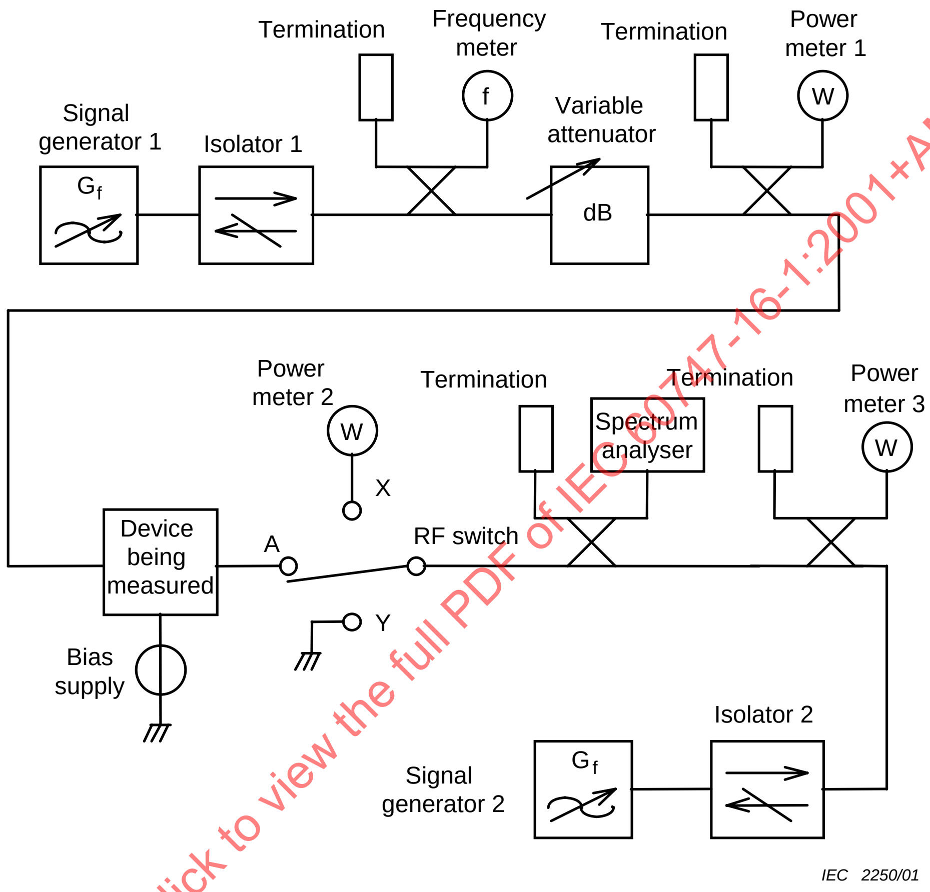


Figure 5 – Circuit for the measurement of output reflection coefficient

5.14.2.3 Principle of measurement

See the principle of measurements in 5.13.3.

The output return loss is derived from following equation:

$$|S_{22}|\ (\text{dB}) = P_1\ (\text{dBm}) - P_2\ (\text{dBm}) \qquad (19)$$

where

P_1 is the value indicated on the spectrum analyser when the r.f. switch is turned to Y, in dBm;

P_2 is the value indicated on the spectrum analyser when the r.f. switch is turned to A, in dBm.

5.14.2.4 Circuit description and requirements

The purposes of the isolators are to enable the power level to the device being measured to be kept constant irrespective of impedance mismatched at its input.

The signal generator 1 supplies specified power to the device being measured, and the generator 2 is signal source to measure the output reflection coefficient.

5.14.2.5 Precautions to be observed

Oscillation, which is checked by spectrum analyser, should be eliminated during measurement.

Harmonics or spurious responses of the signal generators should be reduced to be negligible.

Separate the frequency of signal generator 1 (f_1) and generator 2 (f_2) within the negligible of the frequency response of the device being measured.

5.14.2.6 Measurement procedure

The frequency of the signal generator 1 for input signal should be set to the specified value (f_1).

The frequency of the signal generator 2 for output reflection signal should be set to the specified value (f_2).

The r.f. switch is turned to X.

The power of signal generator 2 should be adjusted 20 dB less than the specified output power of the device being measured.

The r.f. switch is turned to Y.

The indicated power on the spectrum analyser should be recorded (P_1).

The r.f. switch is turned to A.

The biases under specified conditions are applied.

The specified power should be applied to the device being measured.

Record the indicated power on the spectrum analyser (P_2).

The output reflection coefficient is calculated from equation (19).

5.14.2.7 Specified conditions

- Ambient temperature or reference-point temperature
- Bias conditions
- Frequencies
- Input power
- Output power

5.15 Magnitude of the reverse transmission coefficient (isolation) ($|S_{12}|$)

5.15.1 Purpose

To measure the magnitude of the reverse transmission coefficient (isolation) under specified conditions.

5.15.2 Circuit diagram

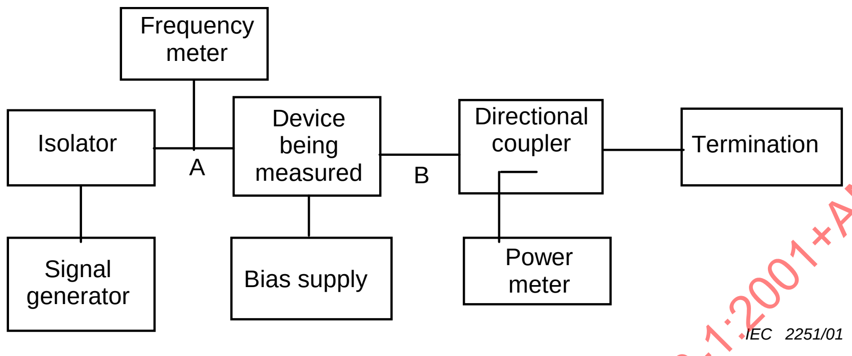


Figure 6 – Circuit for the measurement of isolation

NOTE A network analyser can also be used to measure the magnitude of the isolation.

5.15.3 Principle of measurement

The output port of the device being measured is connected to the isolator, and the input port is connected to the termination.

The input power at point A is P_1 and output power at point B is P_2.

The isolation is derived from equation (20) as follows:

$$|S_{12}| \text{ (dB)} = P_1 \text{ (dBm)} - P_2 \text{ (dBm)} \tag{20}$$

5.15.4 Circuit description and requirements

The purpose of the isolator is to enable the power level to the device being measured to be kept constant irrespective of impedance mismatches at its output ports.

The output port of the device being measured is connected to isolator, and input port is connected to the termination.

The dynamic range of the power meter shall be large in comparison to the reverse transmission coefficient of the device under measurement.

5.15.5 Precautions to be observed

As specified in 5.1.2.

5.15.6 Measurement procedure

The frequency of the signal generator should be adjusted to the specified value.

Points A and B are connected without inserting the device being measured.

The reading of the input power indicated by meters is recorded as P_1.

The device being measured is then inserted between points A and B.

The bias under specified conditions is applied.

The output power now recorded by the meter is noted as P_2.

The reverse transmission coefficient is derived from the equation (20).

5.15.7 Specified conditions

- Ambient or reference-point temperature
- Bias conditions
- Frequency
- Input power

5.16 Conversion coefficient of amplitude modulation to phase modulation ($\alpha_{(AM\text{-}PM)}$)

5.16.1 Purpose

To measure the conversion coefficient of amplitude modulation to phase modulation under specified conditions.

5.16.2 Circuit diagram

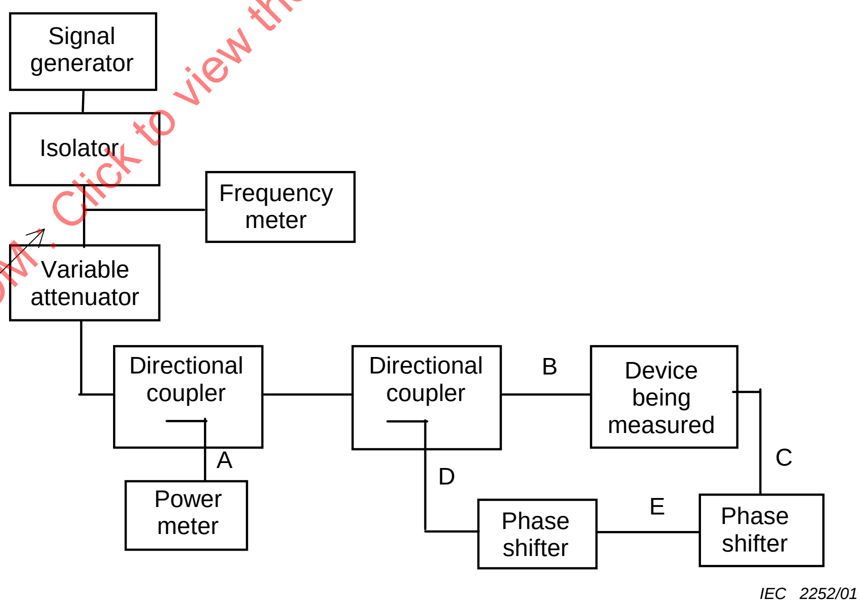


Figure 7 – Basic circuit for the measurement of $\alpha_{(AM\text{-}PM)}$

NOTE A network analyser can also be used to measure the conversion coefficient of amplitude modulation to phase modulation.

5.16.3 Principle of measurement

In the circuit diagram shown in figure 7, the input power P_i is derived from the following equation:

$$P_i = P_1 + L_1 \tag{21}$$

where

P_1 is the value indicated by the power meter;

L_1 is the circuit loss from point A to point B shown in figure 7.

The output signal-phase ϕ_0 in the circuit diagram is derived from the following equation:

$$\phi_0 = \phi_1 - \phi_2 \tag{22}$$

where

ϕ_1, ϕ_2 are the phase differences from point B to point C and from point D to point E shown in figure 7 at the specified input power P_i, respectively.

P_i, P_1 are expressed in dBm. L_1 is expressed in decibels. ϕ_0, ϕ_1, and ϕ_2 are expressed in degrees.

The conversion coefficient of amplitude modulation to phase modulation is derived from equations (21) and (22) as follows:

$$\alpha_{(AM-PM)} = \Delta\phi_0/\Delta P_1 \tag{23}$$

where

ΔP_1 is the input power change according to the modulation of variable attenuator;

$\Delta\phi_0$ is the signal-phase deviation corresponding to the change of input power.

5.16.4 Circuit description and requirements

See the circuit description and requirements of 5.2.4.

It is better that the through-circuitry signal phase is measured beforehand and the phase shifter shown in figure 7 adjusted to ϕ_0 = 0 for the convenience of the deviation calculation, before installing the device being measured.

5.16.5 Precautions to be observed

See the precautions to be observed in 5.2.5.

Harmonics or spurious responses of the signal generator and the device being measured should be reduced to a negligible level.

5.16.6 Measurement procedure

The frequency of the signal generator should be adjusted to the specified value.

The bias under specified conditions is applied.

A specified input power is applied to the device being measured.

Measure the signal-phase ϕ_1 and ϕ_2, then calculate ϕ_0 according to the equation (22).

By increasing input power, measure and calculate another ϕ_1, ϕ_2, and ϕ_0.

Conversion coefficient: $\alpha_{(AM\text{-}PM)}$ is determined from the equation (23) at the specified input power.

5.16.7 Specified conditions

– Ambient or reference-point temperature
– Bias conditions
– Input power
– Frequency
– Increment of input power

5.17 Group delay time ($t_{d(grp)}$)

5.17.1 Purpose

To measure the group delay time under specified conditions.

5.17.2 Circuit diagram

See the circuit diagram shown in figure 7.

NOTE A network analyser can also be used to measure the group delay time.

5.17.3 Principle of measurement

In the circuit diagram shown in figure 7, the output signal-phase ϕ_0 is derived from the following equation:

$$\phi_0 = \phi_1 - \phi_2 \tag{24}$$

where

ϕ_1, ϕ_2 are the phase differences from point B to point C and from point D to point E at the specified input signal angular frequency ω, respectively;

ϕ_0, ϕ_1 and ϕ_2 are expressed in radians;

ω is expressed in radians/second.

The group delay time is derived from equation (24) as follows:

$$t_{d(grp)} = -\Delta\phi_0/\Delta\omega \tag{25}$$

where

$\Delta\omega$ is the change of input signal angular frequency;

$\Delta\phi_0$ is the signal-phase deviation corresponding to the change of input frequency.

5.17.4 Circuit description and requirements

See the circuit description and requirements in 5.2.4.

The through-circuitry signal phase should be measured beforehand and the phase shifter shown in figure 7 adjusted to $\phi_0 = 0$ before installing the device being measured.

5.17.5 Precautions to be observed

See the precautions to be observed in 5.16.5.

5.17.6 Measurement procedure

The frequency of the signal generator should be adjusted to the specified value.

The bias under specified conditions is applied.

A specified input power is applied to the device being measured.

Measure the signal-phase ϕ_1 and ϕ_2, then calculate ϕ_0 according to equation (24).

By increasing input frequency, measure and calculate another ϕ_1, ϕ_2, and ϕ_0.

Group delay time: $t_{d(grp)}$ is determined from the equation (25) at the specified input angular frequency.

5.17.7 Specified conditions

- Ambient or reference-point temperature
- Bias conditions
- Input power
- Frequency
- Increment of input frequency

5.18 Power added efficiency

5.18.1 Purpose

To measure the power added efficiency under specified conditions.

5.18.2 Circuit diagram

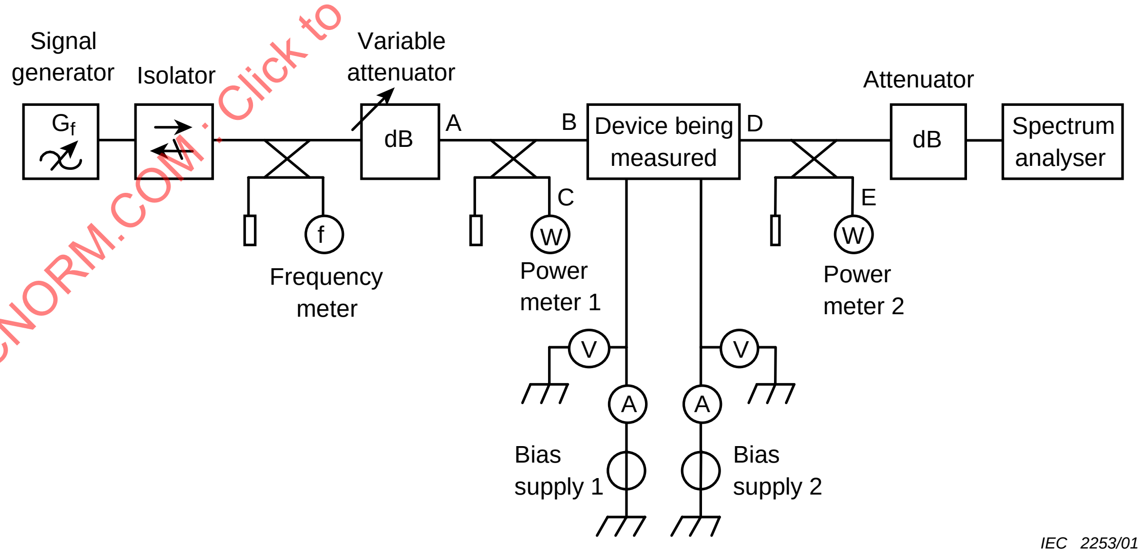


Figure 8 – Circuit for the measurement of the power added efficiency

5.18.3 Principle of measurement

In the circuit diagram shown in figure 8, input power P_i and output power P_o in dBm are derived from equations:

$$P_i = P_1 - L_1 \tag{26}$$
$$P_o = P_2 + L_2 \tag{27}$$

where

P_1 is the value indicated by the power meter 1, in dBm;

P_2 is the value indicated by the power meter 2, in dBm;

L_1 is the (loss from point A to point B, in dB) – (loss from point A to point C, in dB);

L_2 is the loss from point D to point E, in dB.

Power added efficiency η_{add} is derived from equation:

$$\eta_{add} = \frac{\left(10^{P_o/10} - 10^{P_i/10}\right)/1000}{|V_1 \cdot I_1| + |V_2 \cdot I_2|} \tag{28}$$

where

V_1 is the d.c. voltage, in V, applied to the device by the bias supply 1;

I_1 is the d.c. current, in A, supplied to the device by the bias supply 1;

V_2 is the control d.c. voltage, in V, applied to the device by the bias supply 2;

I_2 is the control d.c. current, in A, supplied to the device by the bias supply 2.

NOTE 1 Power added efficiency is normally expressed as a percentage; i.e. 100 × η_{add} from the equation (28).

NOTE 2 Sometimes P_i is neglected in the equation (28) because it is usually much smaller than P_o.

5.18.4 Circuit description and requirements

Bias supply 2 is for the gain control of the device being measured. L_1 and L_2 should be measured beforehand.

5.18.5 Precautions to be observed

The output signal and oscillation should be checked by spectrum analyser. Oscillation should be eliminated during these measurements. Harmonics or spurious responses of the signal generator should be reduced to be negligible.

5.18.6 Measurement procedure

The frequency of the signal generator is adjusted to the specified value.

The bias under specified conditions are applied.

Output power P_o is set to the specified value by adjusting V_2, I_2 or input power P_i.

DC bias currents and voltages are measured.

The power added efficiency η_{add} is calculated from equation (28).

5.18.7 Specified conditions

- Ambient or reference-point temperature
- Bias conditions
- Frequency
- Output power

5.19 *n*th order harmonic distortion ratio (P_1/P_{nth})

5.19.1 Purpose

To measure the *n*th order harmonic distortion ratio under specified conditions.

5.19.2 Circuit diagram

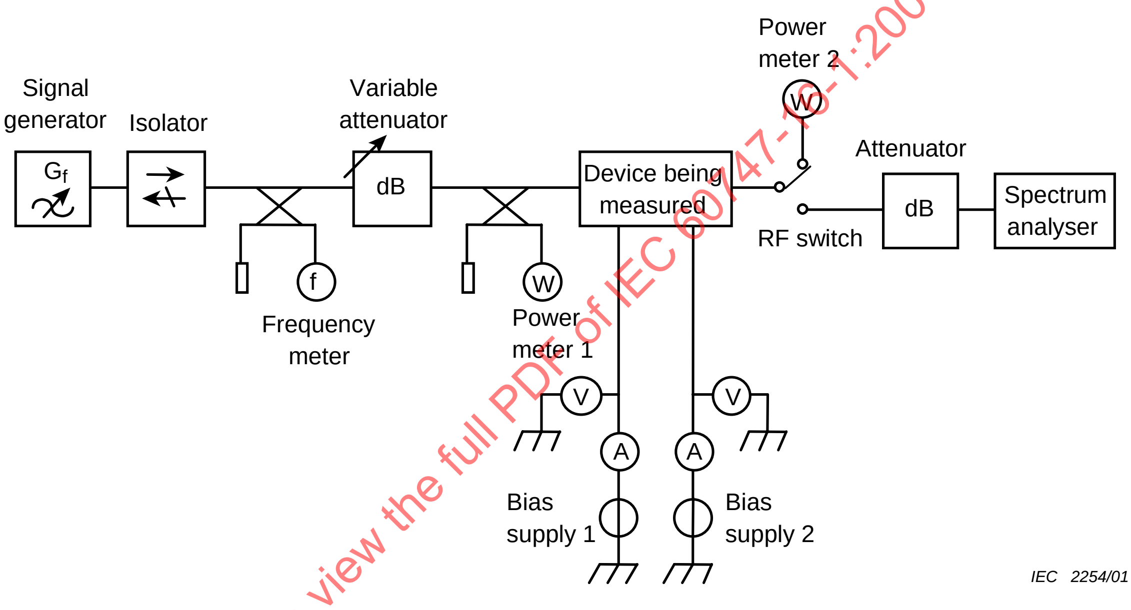


Figure 9 – Circuit for the measurements of the *n*th order harmonic distortion ratio

5.19.3 Principle of measurement

In the circuit diagram shown in figure 9, *n*th order harmonic distortion ratio P_1/P_{nth} are derived from equation

$$P_1/P_{nth} = P_1 - P_{nth} \tag{29}$$

where

P_1 is the power of the fundamental frequency measured by the spectrum analyser in dBm;

P_{nth} is the power of the *n*th order harmonic component measured by the spectrum analyser in dBm.

5.19.4 Circuit description and requirements

Bias supply 2 is for the gain control of the device being measured.

5.19.5 Precautions to be observed

The output signal and oscillation should be checked by spectrum analyser.

Oscillation should be eliminated during these measurements.

Harmonics or spurious responses of the signal generator should be reduced to be negligible.

5.19.6 Measurement procedure

The frequency of the signal generator is adjusted to the specified value.

The bias V_1 or I_1 under specified conditions is applied.

Output power P_o is set to the specified value by adjusting V_2, I_2 or input power P_i.

The power of the fundamental frequency P_1 and the power of the nth order harmonic component P_{nth} are measured by spectrum analyser.

The nth order harmonic distortion ratio is calculated from equation (29).

5.19.7 Specified conditions

– Ambient or reference-point temperature
– Bias conditions
– Frequency (fundamental)
– Input power
– Output power

5.20 Output noise power (P_N)

5.20.1 Purpose

To measure the output noise power under specified conditions.

5.20.2 Circuit diagram

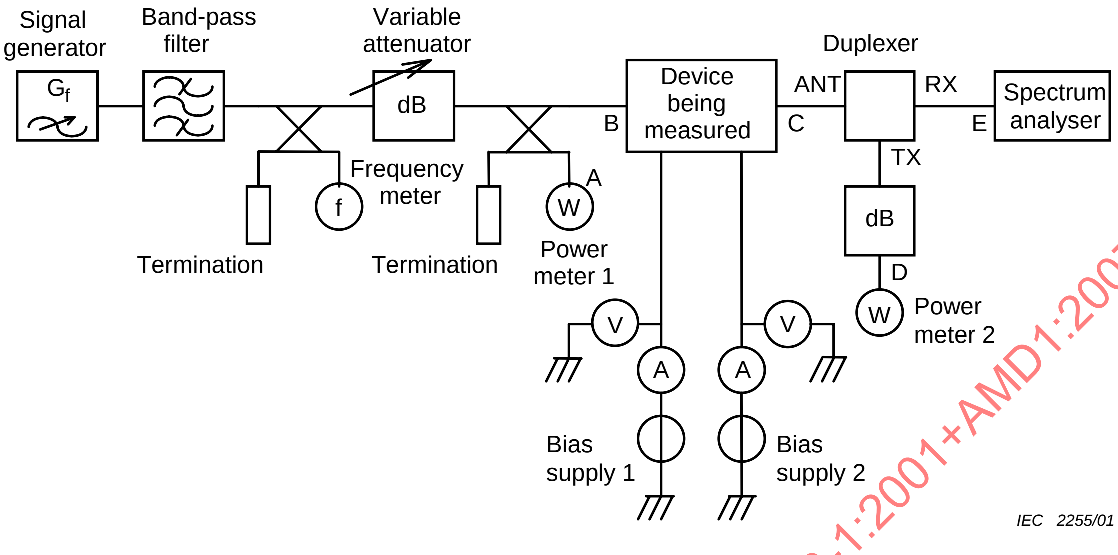


Figure 10 – Circuit diagram for the measurement of the output noise power

5.20.3 Principle of measurement

Output noise power P_N is the maximum output noise power delivered from the device being measured within the specified frequency range of noise measurement under the condition that the specified input power of the specified frequency P_i is applied and specified output power P_o is derived.

In the circuit diagram shown in figure 10 P_i, P_o, and P_N are obtained by following equations:

$$P_i = P_1 - L_1 \quad (30)$$

$$P_o = P_2 - L_2 \quad (31)$$

$$P_N = P_3 - L_3 \quad (32)$$

where

P_1 is the value indicated by power meter 1, in dBm;

P_2 is the value indicated by power meter 2, in dBm;

P_3 is the maximum value measured by the spectrum analyser in the specified frequency range for noise measurement;

L_1 is (the power at point A, in dBm) – (the power at point B, in dBm) for the fundamental frequency;

L_2 is (the power at point C, in dBm) – (the power at point D, in dBm) for the fundamental frequency;

L_3 is (the power at point C, in dBm) – (the power at point E, in dBm) for the noise power measurement frequency.

5.20.4 Circuit description and requirements

The pass band of band-pass filter is the fundamental frequency band (the frequency band for transmission) and the stop band is the noise power measurement frequency (the frequency band for reception). It should be inserted to reduce the noise from the signal generator.

ANT-TX path of duplexer passes the fundamental frequency signal and stops the noise power measurement frequency signal, and ANT-RX path passes the noise power measurement frequency signal and stops the fundamental frequency signal. The purpose of the duplexer is to prevent the spectrum analyser from saturation by the fundamental frequency signal.

Bias supply 2 is for gain control of the device being measured.

L_1, L_2, and L_3 should be measured beforehand.

5.20.5 Precautions to be observed

Oscillation should be eliminated during the measurement. Harmonics and spurious response of the signal generator should be reduced to negligible.

In order to enhance the sensitivity of the spectrum analyser if necessary, the amplifier is inserted between the duplexer and the spectrum analyser. The noise from the inserted amplifier should be negligibly small.

5.20.6 Measurement procedure

The frequency of the signal generator is adjusted to the specified value.

The biases under specified conditions are applied.

Output power P_o is set to the specified value by adjusting V_2, I_2 or input power P_i.

The maximum power in the specified noise measurement frequency band is measured by the spectrum analyser.

The noise power P_N is calculated from equation (32)

5.20.7 Specified conditions

– Ambient or reference point temperature
– Bias conditions
– Fundamental frequency
– Frequency band of noise measurement
– Input power
– Output power

5.21 Spurious intensity under specified load VSWR (P_o/P_{sp})

5.21.1 Purpose

To measure the spurious intensity under specified load VSWR to determine the stability under specified conditions.

5.21.2 Circuit diagram

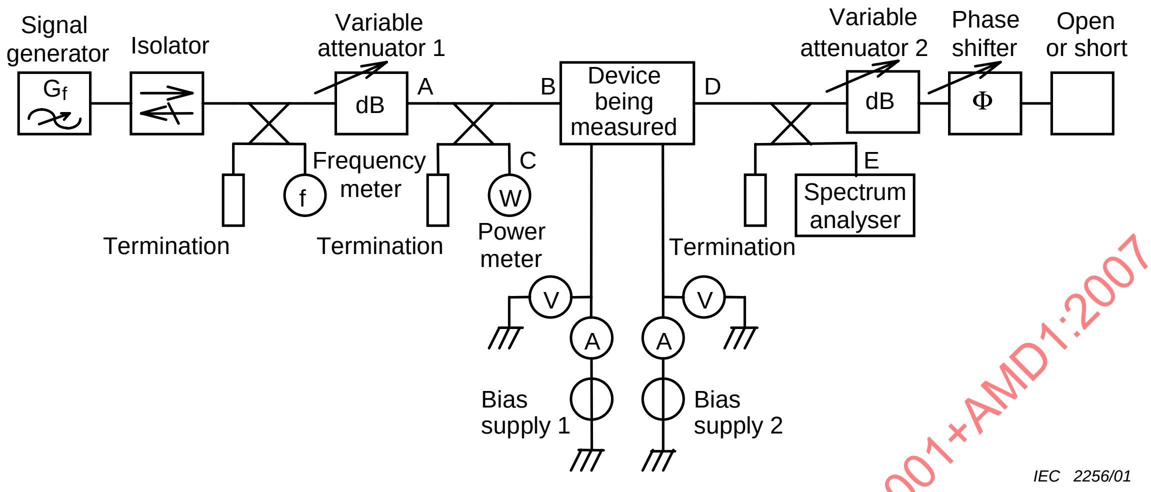


Figure 11 – Circuit diagram for the measurement of the spurious intensity

5.21.3 Principle of measurement

In the circuit diagram shown in figure 11, the output power P_o and the spurious output power P_{sp} are derived as follows:

$$P_o = P_1 - L_1 \tag{33}$$

$$P_{sp} = P_2 - L_2 \tag{34}$$

where P_1 is the value of the fundamental output indicated by the spectrum analyser in dBm, P_2 the value of the spurious output of the maximum power, except harmonic components, indicated by the spectrum analyser in dBm, and L_1 and L_2 are the circuit losses from point D to point E, in dB, at the frequency of P_1, at the frequency of P_2, respectively.

The spurious intensity P_o/P_{sp} in dBm is defined as follows:

$$P_o/P_{sp} = P_o - P_{sp} \tag{35}$$

5.21.4 Circuit description and requirements

Bias supply 2 is for gain control of the device being measured.

The variable attenuator 2 should be adjusted to get the specified load VSWR at point D beforehand.

L_1 and L_2 should be measured beforehand.

5.21.5 Precautions to be observed

Harmonics or spurious responses of the signal generator should be reduced to be negligible.

Oscillation will occur at the out-of-band frequency of the directional coupler.

5.21.6 Measurement procedure

The frequency of the signal generator is adjusted to the specified value.

The bias under specified conditions is applied.

The specified input power is applied.

By varying the phase of the phase shifter through the specified phase range, find the maximum spurious output.

While keeping the phase, measure the power of the fundamental frequency P_1 and the power of the spurious output P_{sp} with the spectrum analyser.

The spurious intensity is calculated from equation (35).

5.21.7 Specified conditions

- Ambient or reference point temperature
- Bias conditions
- Input frequency
- Input power
- Load VSWR
- Phase variation range of load

5.22 Adjacent channel power ratio ($P_{o(mod)}$ /P_{adj})

5.22.1 Purpose

To measure the adjacent channel power ratio under the specified conditions.