INTERNATIONAL STANDARD

IEC 60747-4

1991

AMENDMENT 2
1999-04

Amendment 2

Semiconductor devices – Discrete devices

Part 4:
Microwave devices

Amendement 2

Dispositifs à semiconducteurs –
Dispositifs discrets

Quatrième partie:
Diodes et transistors hyperfréquences

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FOREWORD

This amendment has been prepared by subcommittee 47E: Discrete semiconductor devices, of IEC technical committee 47: Semiconductor devices.

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

FDIS	Report on voting
47E/123/FDIS	47E/124/RVD

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

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

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Amend the title of this standard on the cover page, the title page, and on pages 7 and 11 as follows:

SEMICONDUCTOR DEVICES – DISCRETE DEVICES –

Part 4: Microwave devices

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CONTENTS

Add the title of Chapter VIII as follows and renumber chapter VIII as chapter IX:

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CHAPTER VII: FIELD EFFECT TRANSISTORS

2.1.4 Powers

Replace this subclause by the following new subclause:

2.1.4 Powers

Output power at 1 dB gain compression	$P_{o(1dB)}$
or:	
Output power at specified input power	P_o
Power gain at 1 dB gain compression	$G_{p(1dB)}$
Power added efficiency	η_{add}
Associated (power) gain	G_{as}
Maximum available gain (Note 1)	$G_{a(max)}$
Minimum noise figure	F_{min}
Source reflection factor for minimum noise figure (Notes 2 and 3)	r_{GFmin}
Equivalent input noise resistance	R_n

NOTE 1 – The abbreviation "MAG" is still in common use for maximum available gain.

NOTE 2 – For source reflection coefficient (factor), see 5.3.3 of IEC 60747-7, Chapter II*.

NOTE 3 – The symbol "Γ_{opt}" is still in common use for the source reflection factor for minimum noise figure.

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2.2.3 Power

Add the following definitions:

Minimum noise figure
The minimum value of the noise figure that can be obtained through adjustment of the source impedance under specified bias condition and a specified frequency.

Equivalent input noise resistance
The quotient of the equivalent input noise voltage and the equivalent input noise current (see 5.4.9 and 5.4.10 of IEC 60747-1, Chapter IV**).

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* IEC 60747-7 (all parts), *Semiconductor devices – Discrete devices – Part 7: Bipolar transistors*

** IEC 60747-1:1983, *Semiconductor devices – Discrete devices – Part 1: General*

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3.2.2 RF characteristics

Add the following new essential ratings and characteristics:

Subclause	Categories A	Categories B
3.2.2.8		+
3.2.2.9		+
3.2.2.10		+

3.2.2.8 Minimum noise figure

Maximum value under specified conditions

3.2.2.9 Source reflection factor for minimum noise figure

Maximum and minimum values under specified conditions

NOTE – Maximum and minimum values respectively should be prescribed for magnitude and angle.

3.2.2.10 Equivalent input noise resistance

Maximum and minimum values under specified conditions

4 Measurement methods

Replace subclauses 4.10 and 4.11 by the following new subclause 4.10:

4.10 Noise figure (F) and associated gain (G_{as})

4.10.1 Purpose

To measure the noise figure of a microwave field-effect transistor under specified conditions.

4.10.2 Circuit diagram

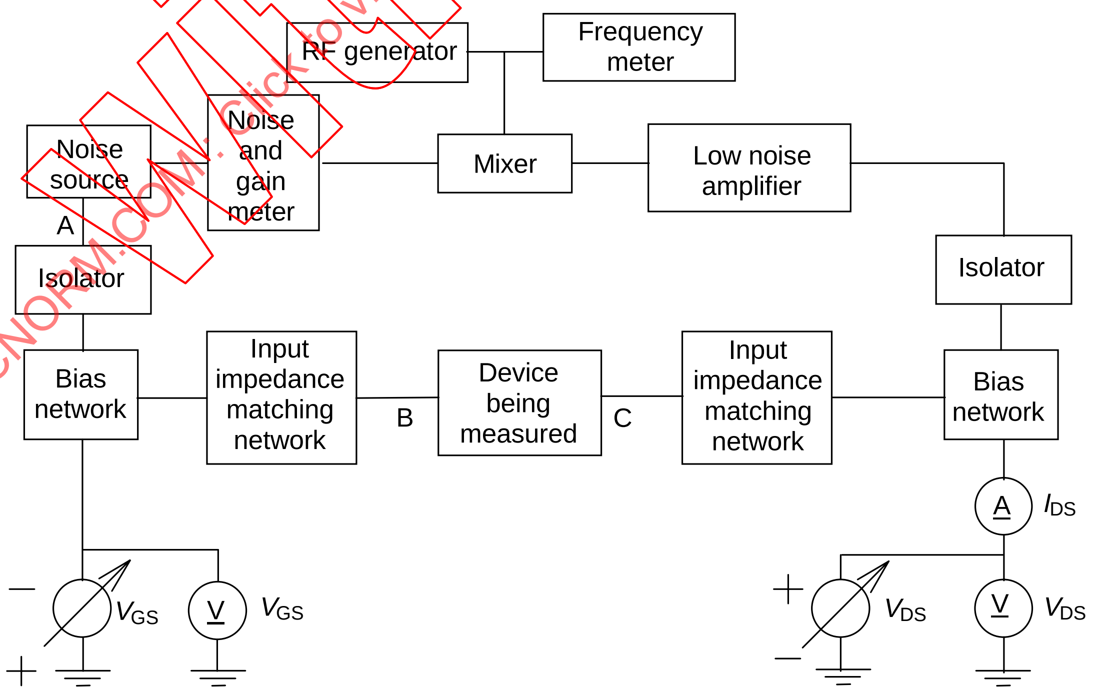

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Figure 46 – Basic circuit for the measurement of the noise figure

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4.10.3 Principle of measurements

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

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

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, and

G_{as} is the associated gain of the device being measured.

F, F_{12}, F_2, L_1 and G_{as} are expressed in decibels. The noise figure measurement is carried out by using the hot and cold measurement method. F_{12}, F_2 and G_{as} are calculated as follows:

$$F_{12} = 10\log\left(\frac{10^{ENR/10}}{(P_{N1}/P_{N2})-1}\right) \tag{2}$$

$$F_2 = 10\log\left(\frac{10^{ENR/10}}{(P_{N3}/P_{N4})-1}\right) \tag{3}$$

$$G_{as} = 10\log\left(\frac{P_{N1}-P_{N2}}{P_{N3}-P_{N4}}\right) \tag{4}$$

where

ENR is the excess noise ratio of the noise source;

P_{N1} and P_{N2} in W are the measured noise power 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 B to C in figure 46.

The temperature of the measurement is 290 K.

4.10.4 Circuit description and requirements

The circuit loss L_1 from point A to B should be measured beforehand.

4.10.5 Precautions to be observed

The entire circuit shall be shielded and grounded to prevent undesired signals. For noise figure measurement under the single-side-band (SSB) condition, careful attention shall be paid to the image and other spurious responses which are generated by the mixer. These spurious responses should be reduced so as to be negligible.

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4.10.6 Measurement procedure

The frequency of the r.f. generator is adjusted to the specified condition.

In order to measure the noise contribution of the measurement system, connect point B to C in figure 46 without the device being measured and set the input and output impedance matching networks to 50 Ω.

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

The noise figure F_2 in decibels is calculated by equation (3).

The device being measured is inserted as shown in figure 46.

The gate-source voltage V_{GS} (near the gate-source cut-off voltage) is applied.

The specified drain-source voltage V_{DS} is applied.

The drain current I_{DS} is adjusted to the specified value by varying V_{GS}.

During the adjustment of the input and output matching networks, the noise power P_{N1} and P_{N2} corresponding to the noise source hot and cold, respectively, are measured.

The noise figure F_{12} in decibels is calculated by equation (2).

The associated gain G_{as} in decibels is calculated by equation (4).

The noise figure F in decibels is calculated by equation (1).

The input impedance matching network is adjusted to the minimum value of F.

The output impedance matching network is adjusted to the maximum value of G_{as}.

Repeat the above two steps until no further reduction in noise figure F is possible.

4.10.7 Specified conditions

– Ambient or reference point temperature
– Drain source voltage
– Drain current
– Frequency
– Single-side band or double-side band.

Renumber subclauses 4.12 as 4.11 and 4.13 as 4.12 and add the following new subclause 4.13:

4.13 Minimum noise figure (F_{min}), equivalent input noise resistance (R_n) and source reflection factor for minimum noise figure (r_{GFmin})

4.13.1 Purpose

To measure the minimum noise figure, equivalent input noise resistance and source reflection factor for the minimum noise figure of a microwave field-effect transistor under specified conditions.

4.13.2 Circuit diagram

See the circuit diagram in 4.10.2.

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4.13.3 Principle of measurements

See the principle of measurements in 4.10.3.

The noise figure dependence on the source admittance can be expressed as:

$$F = F_{min} + \frac{R_n}{G_s}\left\{(G_s - G_0)^2 + (B_s - B_0)^2\right\} \qquad (1)$$

where

F	is the noise figure
F_{min}	is the minimum noise figure
R_n	is the equivalent input noise resistance
G_s	is the source conductance
B_s	is the source susceptance
G_0	is the source conductance for F_{min}
B_0	is the source susceptance for F_{min}

To determine the four parameters, F_{min}, R_n, G_0 and B_0, four dimensional simultaneous equations should be solved.

From equation (1)

$$F = F_{min} + \frac{R_n|Y_0|^2}{G_s} - 2\,R_n G_0 + \frac{R_n|Y_s|^2}{G_s} - 2\,R_n B_0\left(\frac{B_s}{G_s}\right) \qquad (2)$$

where

$$Y_0 = G_0 + \mathrm{j}B_0 \qquad (3)$$

$$Y_s = G_s + \mathrm{j}B_s \qquad (4)$$

In equation (2), X_1, X_2, X_3 and X_4 are defined as

$$X_1 = F_{min} - 2\,R_n G_0$$
$$X_2 = R_n|Y_0|^2$$
$$X_3 = R_n \qquad (5)$$
$$X_4 = R_n\,B_0$$

Then, equation (2) leads to the following equations for *n* different Y_s

$$F_{(1)} = X_1 + \frac{1}{G_{s(1)}}X_2 + \frac{|Y_{s(1)}|^2}{G_{s(1)}}X_3 - 2\left(\frac{B_{s(1)}}{G_{s(1)}}\right)X_4$$

•
•
•

$$F_{(n)} = X_1 + \frac{1}{G_{s(n)}}X_2 + \frac{|Y_{s(n)}|^2}{G_{s(n)}}X_3 - 2\left(\frac{B_{s(n)}}{G_{s(n)}}\right)X_4 \qquad (6)$$

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Substituting X_1, X_2, X_3 and X_4 obtained from equation (6) into equation (5), the four parameters are determined as follows:

$$F_{min} = X_1 + 2\sqrt{X_2 X_3 - X_4{}^2} \quad (7)$$

$$R_n = X_3 \quad (8)$$

$$G_0 = \sqrt{X_2 / X_3 - (X_4 / X_3)^2} \quad (9)$$

$$B_0 = X_4 / X_3 \quad (10)$$

Γ_{Fmin}, source reflection factor for F_{min}, is determined from the above G_0 and B_0.

4.13.4 Circuit description and requirements

See the circuit description and requirements in 4.10.4.

4.13.5 Precautions to be observed

See the precaution to be observed in 4.10.5.

4.13.6 Measurement procedure

The frequency of the r.f. generator is adjusted to the specified condition.

The device being measured is inserted as shown in figure 46.

The gate-source voltage V_{GS} (near gate-source cut-off voltage) is applied.

The specified drain-source voltage V_{DS} is applied.

The drain current I_{DS} is adjusted to the specified value by varying V_{GS}.

The input impedance matching network is adjusted so that the source admittance becomes ($G_{s(1)}$, $B_{s(1)}$).

The output impedance matching network is adjusted so that the maximum power gain is achieved.

The noise figure $F_{(1)}$ is measured in accordance with the procedure described in 4.10.6.

Repeating the above procedure n times, $F_{(1)-(n)}$ are determined for the n source admittance ($G_{s(1)-(n)}$, $B_{s(1)-(n)}$).

The noise parameters: F_{min}, R_n and Γ_{Fmin} are determined from the equations (6) to (10).

4.13.7 Specified conditions

– Ambient or reference point temperature
– Drain source voltage
– Drain current
– Frequency
– Single-side band or double-side band.

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Add the following new chapter and renumber chapter VIII as chapter IX:

CHAPTER VIII – INTEGRATED CIRCUIT MICROWAVE AMPLIFIERS

1 Terminology

1.1 Linear (power) gain G_{lin}

The 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).

1.2 Linear (power) gain flatness ΔG_{lin}

The power gain flatness when the operating point lies in the linear region of the power transfer curve.

1.3 Power gain G_p, G

The ratio of the output power to the input power.

NOTE – Usually the power gain is expressed in decibels.

1.4 (Power) gain flatness ΔG_p

The difference between the maximum and minimum power gain for a specified input power in a specified frequency range.

1.5 (Maximum available) gain reduction, ΔG_{red}

The difference in decibels between the maximum and minimum power gains that can be provided by the gain control.

1.6 Output power limiting

1.6.1 Output power limiting range

The 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.

1.6.2 Limiting output power $P_{o(ltg)}$

The output power in the range where it is limiting.

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

The difference between the maximum and minimum output power in the output power limiting range:

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

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1.7 Intermodulation distortion P_n/P_i

The ratio of

the output power of the *n*th order component to

the output power of the fundamental component,

at a specified input power.

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

The output power at intersection between the extrapolated output powers of the fundamental component and the *n*th 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).

1.9 Magnitude of the input reflection coefficient (input return loss) $|s_{11}|$

See 5.2.1 of IEC 60747-7, Chapter II.

1.10 Magnitude of the output reflection coefficient (output return loss) $|s_{22}|$

See 5.2.2 of IEC 60747-7, Chapter II.

1.11 Magnitude of the reverse transmission coefficient (isolation) $|s_{12}|$

See 5.2.4 of IEC 60747-7, Chapter II.

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

The quotient of

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

the change in input power (in decibels) producing it.

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

The 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.

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2 Essential ratings and characteristics for integrated circuit microwave amplifiers

2.1 General

2.1.1 Circuit identification and types

2.1.1.1 Designation and types

Indication of type (device name), category of circuit and 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.

2.1.1.2 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.

2.1.1.3 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.

2.1.1.4 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.

2.1.1.5 Main application

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

2.2 Application related description

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

2.2.1 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., also should be given.

2.2.2 Overall block diagram

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

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2.2.3 Reference data

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

2.2.4 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.

2.2.5 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).

2.3 Specification of the function

2.3.1 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 60617-12 or IEC 60617-13*.

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* IEC 60617-12:1997, *Graphical symbols for diagrams – Part 12: Binary logic elements*

IEC 60617-13:1993, *Graphical symbols for diagrams – Part 13: Analogue elements*

2.3.2 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.

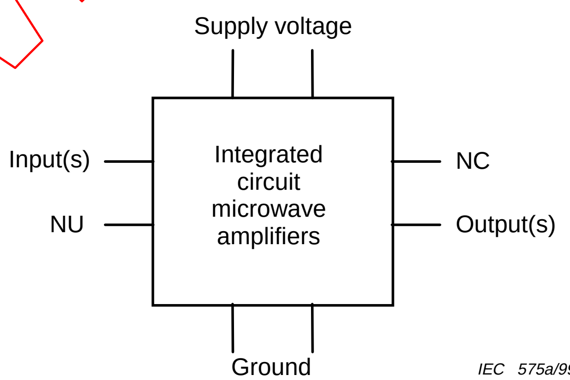
4) Type of input/output circuits

   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:



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2.3.3 Functional description

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

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

2.3.4 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.

2.4 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.

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* IEC 60748-2 (all parts), *Semiconductor devices – Integrated circuits – Part 2: Digital integrated circuits*

IEC 60748-3 (all parts), *Semiconductor devices – Integrated circuits – Part 3: Analogue integrated circuits*

IEC 60748-4 (all parts), *Semiconductor devices – Integrated circuits – Part 4: Inteface integrated circuits*

2.4.1 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 considered circuit.

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.

2.4.2 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 considered circuit.

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2.5 Operating conditions (within the specified operating temperature range)

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

2.5.1 Power supplies positive and /or negative values

2.5.2 Initialization sequences (where appropriate)

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

2.5.3 Input voltage(s) (where appropriate)

2.5.4 Output current(s) (where appropriate)

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

2.5.6 External elements (where appropriate)

2.5.7 Operating temperature range

2.6 Electrical characteristics

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

Each characteristic of 2.6.1 and 2.6.2 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.

2.6.1 Static characteristics

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

Parameters		Min.	Typ.*	Max.	Types			
					A	B	C	D
2.6.1.1	Power supply current	+	+	+	+	+	+	+
2.6.1.2	Thermal resistance			+			+	+
* Optional								

The detail specification may indicate those values within the table.

Characteristics	Symbols	Conditions	Min.	Typ.*	Max.	Unit
* Optional						

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2.6.2 Dynamic or a.c. 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 2.5.1.

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

Parameters		Min.	Max.	Types			
				A	B	C	D
2.6.2.1	Linear gain	+		+	+		+
2.6.2.2	Linear gain flatness		+	+	+		+
2.6.2.3	Power gain	+			+		+
2.6.2.4	Power gain flatness		+		+		+
2.6.2.5	Gain reduction	+			+		
2.6.2.6	Output power	+			+		+
2.6.2.7	Output power at 1 dB gain compression	+			+		+
2.6.2.8	Limiting output power	+	+			+	
2.6.2.9	Limiting output power flatness		+			+	
2.6.2.10	Intermodulation distortion		+			+	+
2.6.2.11	Power at intercept point	+				+	+
2.6.2.12	Noise figure		+	+			
2.6.2.13	Magnitude of the input reflection coefficient (input return loss)	+		+	+	+	+
2.6.2.14	Magnitude of the output reflection coefficient (output return loss)	+		+	+		
2.6.2.15	Magnitude of the reverse transmission coefficient (isolation)	+		+	+	+	+
2.6.2.16	Conversion coefficient of amplitude modulation to phase modulation (where appropriate)		+			+	+
2.6.2.17	Group delay time (where appropriate)		+		+	+	+
2.6.2.18	Time constant for automatic gain control *						

* Under consideration

NOTE – It is necessary for types B and D to select either the parameter set of 2.6.2.1, 2.6.2.2 and 2.6.2.7 or that of 2.6.2.3, 2.6.2.4 and 2.6.2.6.

The detail specification may indicate those values within the table.

Characteristics	Symbols	Conditions	Min.	Typ.*	Max.	Unit

* Optional

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2.7 Mechanical and environmental ratings, characteristics and data

Any specific mechanical and environmental ratings applicable should be stated (see also IEC 60747-1, Chapter VI, clause 7)

2.8 Additional information

Where appropriate, the following information should be given.

2.8.1 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.

2.8.2 Internal protection

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

2.8.3 Capacitors at terminals

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

2.8.4 Thermal resistance

2.8.5 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.

2.8.6 Effects of externally connected component(s)

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

2.8.7 Recommendations for any associated device(s)

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

2.8.8 Handling precautions

Where appropriate, handling precautions specific to the circuit should be stated (see also IEC 60747-1, Chapter IX).

2.8.9 Application data

2.8.10 Other application information

2.8.11 Date of issue of the data sheet

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3 Measuring methods

3.1 General

3.1.1 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.

3.1.2 General precautions

The general precautions listed in clause 1 of IEC 60747-1, Chapter VII, 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. And also special care about the load impedance of the test circuit should be taken to measure the output power.

3.1.3 Handling precautions

When handling electrostatic-sensitive devices, the handling precautions given in IEC 60747-1, Chapter IX, clause 1, shall be observed.

3.1.4 Types

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

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

3.2.1 Purpose

To measure the linear gain under specified conditions.

3.2.2 Circuit diagram

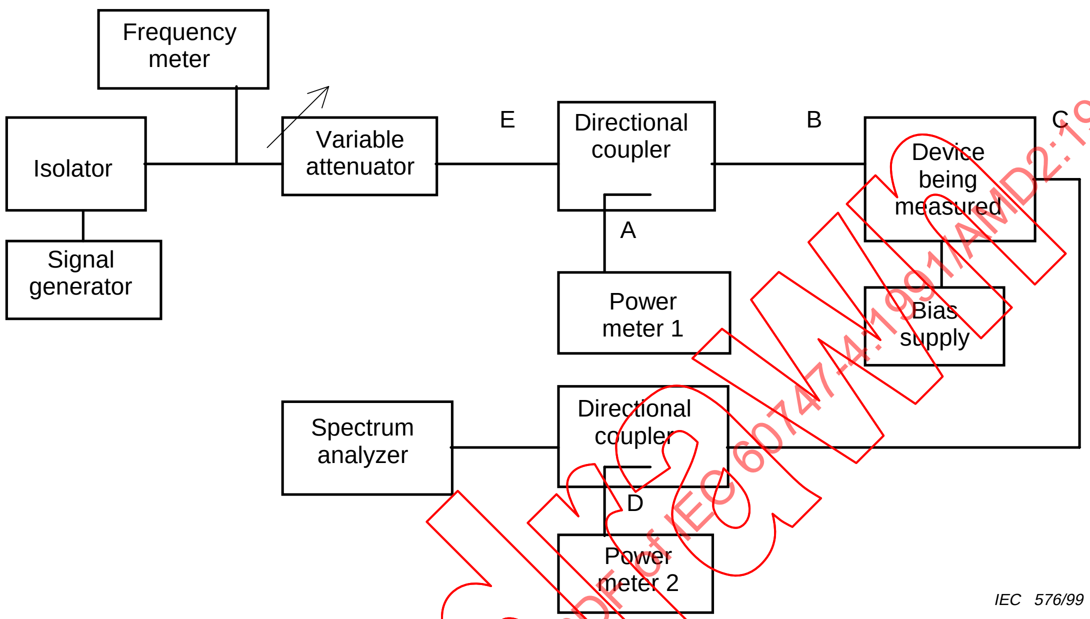

Figure 47 – Circuit for the measurements of linear gain

3.2.3 Principle of measurements

In the circuit diagram shown in figure 47, the input power P_i and the output power P_o of the device being measured are derived from the following equation:

$$P_i = P_1 + L_1 \qquad (2\text{-}1)$$

$$P_o = P_2 + L_2 \qquad (2\text{-}2)$$

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 47, respectively.

L_2 is the circuit loss from point C to point D shown in figure 47. 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 (2-1) and (2-2) as follows:

$$G_p = P_o - P_i \qquad (2\text{-}3)$$

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.

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3.2.4 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.

3.2.5 Precautions to be observed

Oscillation, which is checked by a spectrum analyzer, 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.

3.2.6 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}.

3.2.7 Specified conditions

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

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

3.3.1 Purpose

To measure the linear gain flatness under specified conditions.

3.3.2 Circuit diagram

See the circuit diagram shown in figure 47.

3.3.3 Principle of measurements

See the principle of measurements of 3.2.3.

Linear gain flatness is derived from following equation.

$$\Delta G_{lin} = G_{linmax} - G_{linmin} \quad (3\text{-}1)$$

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

3.3.4 Circuit description and requirements

See the circuit description and requirements of 3.2.4.

3.3.5 Precaution to be observed

See the precaution to be observed of 3.2.5.

3.3.6 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 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 (3-1).

3.3.7 Specified conditions

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

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3.4 Power gain (G_p)

3.4.1 Purpose

To measure the power gain under specified conditions.

3.4.2 Circuit diagram

See the circuit diagram shown in figure 47.

3.4.3 Principle of measurements

See the principle of measurements of 3.2.3.

3.4.4 Circuit description and requirements

See the circuit description and requirements of 3.2.4.

3.4.5 Precaution to be observed

See the precaution to be observed of 3.2.5.

3.4.6 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.

3.4.7 Specified conditions

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

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3.5 (Power) gain flatness (ΔG_p)

3.5.1 Purpose

To measure the power gain flatness under specified conditions.

3.5.2 Circuit diagram

See the circuit diagram shown in figure 47.

3.5.3 Principle of measurements

See the principle of measurements of 3.2.3.

Power gain flatness is derived from the following equation.

$$\Delta G_p = G_{pmax} - G_{pmin} \quad (5\text{-}1)$$

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.

3.5.4 Circuit description and requirements

See the circuit description and requirements of 3.2.4.

3.5.5 Precaution to be observed

See the precaution to be observed of 3.2.5.

3.5.6 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 (2-3).

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 (5-1).

3.5.7 Specified conditions

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

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

3.6.1 Purpose

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

3.6.2 Circuit diagram

See the circuit diagram shown in figure 47, where bias supply contains AGC bias.

3.6.3 Principle of measurements

See the principle of measurements of 3.2.3.

3.6.4 Circuit description and requirements

See the circuit description and requirements of 3.2.4.

3.6.5 Precaution to be observed

See the precaution to be observed of 3.2.5.

3.6.6 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 by the same way with the above.

$$\Delta G_{red} = G_{linmax} - G_{linmin} \tag{6-1}$$

3.6.7 Specified conditions

– Ambient or reference-point temperature

– Bias conditions

– Frequency

– AGC bias giving the maximum linear gain and the minimum linear gain.

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3.7 Limiting output power ($P_{o(ltg)}$)

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

3.7.1 Purpose

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

3.7.2 Circuit diagram

See the circuit diagram shown in figure 47.

3.7.3 Principle of measurements

See the principle of measurements of 3.2.3.

3.7.4 Circuit description and requirements

See the circuit description and requirements of 3.2.4.

3.7.5 Precaution to be observed

See the precaution to be observed of 3.2.5.

3.7.6 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 following equations:

$$P_{o(ltg)} = P_{o(ltg,max)} \qquad (7\text{-}1)$$

$$\Delta P_{o(ltg)} = P_{o(ltg,max)} - P_{o(ltg,min)} \qquad (7\text{-}2)$$

3.7.7 Specified conditions

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

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3.8 Output power (P_o)

3.8.1 Purpose

To measure the output power under specified conditions.

3.8.2 Circuit diagram

See the circuit diagram shown in figure 47.

3.8.3 Principle of measurements

See the principle of measurements of 3.2.3.

3.8.4 Circuit description and requirements

See the circuit description and requirements of 3.2.4.

3.8.5 Precaution to be observed

See the precaution to be observed of 3.2.5.

3.8.6 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.

3.8.7 Specified conditions

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

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

3.9.1 Purpose

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

3.9.2 Circuit diagram

See the circuit diagram shown in figure 47.

3.9.3 Principle of measurements

See the principle of measurements of 3.2.3.

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.

3.9.4 Circuit description and requirements

See the circuit description and requirements of 3.2.4.

3.9.5 Precaution to be observed

See the precaution to be observed of 3.2.5.

3.9.6 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.

3.9.7 Specified conditions

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

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3.10 Noise figure (*F*)

3.10.1 Purpose

To measure the noise figure under specified conditions.

3.10.2 Circuit diagram

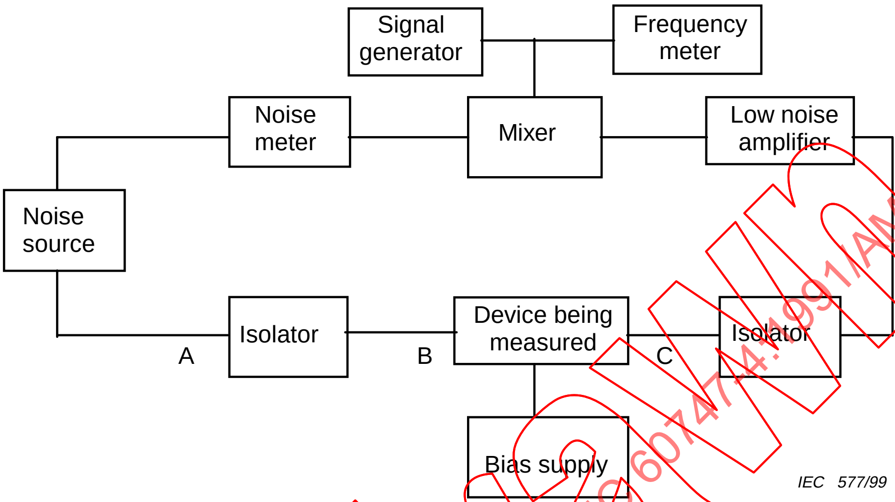

Figure 48 – Basic circuit for the measurement of the noise figure

3.10.3 Principle of measurement

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

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

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.

$$F_{12} = 10\log\left(\frac{10^{ENR/10}}{(P_{N1}/P_{N2}) - 1}\right) \tag{10-2}$$

$$F_2 = 10\log\left(\frac{10^{ENR/10}}{(P_{N3}/P_{N4}) - 1}\right) \tag{10-3}$$

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$$G_{lin} = 10 \log\left(\frac{P_{N1} - P_{N2}}{P_{N3} - P_{N4}}\right) \quad (10\text{-}4)$$

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 48.

The temperature of the measurement is 290 K.

3.10.4 Circuit description and requirements

The circuit loss L_1 should be measured beforehand.

3.10.5 Precaution to be observed

The entire circuit must be shielded and earthed to prevent to 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.

3.10.6 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 48 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 48.

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 (10-1).

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

3.10.7 Specified conditions

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

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3.11 Intermodulation distortion (P_n/P_1) (two tone)

3.11.1 Purpose

To measure the intermodulation distortion under specified conditions.

3.11.2 Circuit diagram

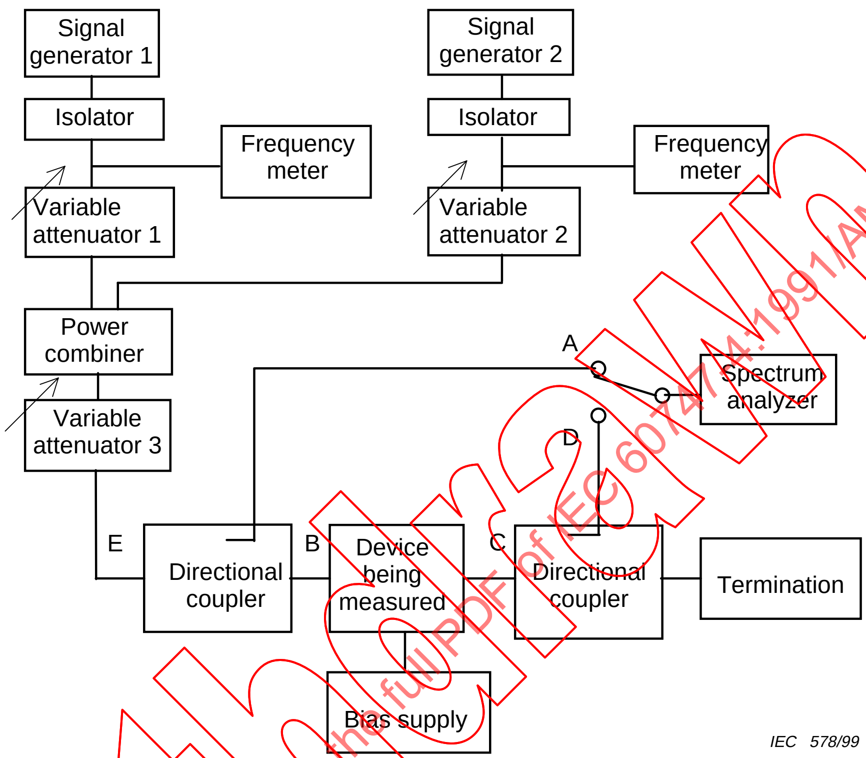

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Figure 49 – Basic circuit for the measurements of two-tone intermodulation distortion

3.11.3 Principle of measurements

In the circuit diagram shown in figure 49 the input power P_i, the output powers P_o and P_n of the device being measured are derived from the following equations:

$$P_i = P_a + L_1 \quad (11\text{-}1)$$

$$P_o = P_b + L_2 \quad (11\text{-}2)$$

$$P_n = P_c + L_2 \quad (11\text{-}3)$$

where

P_o and P_n are the output powers of the fundamental signal and the intermodulation distortion, respectively.

P_a, P_b and P_c are the values indicated by the spectrum analyzer and corresponding to P_i, P_o 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 49, respectively. L_2 is the circuit loss from point C to point D shown in figure 49. P_i, P_o, 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_n/P_1, which is expressed in dBc, is derived from equations (11-2) and (11-3) as follows:

$$P_n/P_1 = P_n - P_o = P_c - P_b \quad (11\text{-}4)$$

3.11.4 Circuit description and requirements

See the circuit description and requirements of 3.2.4.

The variable attenuator 3 can be eliminated.

3.11.5 Precaution to be observed

See the precaution to be observed of 3.2.5.

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

3.11.6 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 analyzer 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 analyzer 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 analyzer.

The intermodulation distortion on the specified input power P_i is derived from the equations (11-1) to (11-4).

3.11.7 Specified conditions

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

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

3.12.1 Purpose

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

3.12.2 Circuit diagram

See the circuit diagram of 3.11.2.

3.12.3 Principle of measurements

Refer the principle of measurements of 3.11.3.

3.12.4 Circuit description and requirements

See the circuit description and requirements of 3.11.4.

3.12.5 Precaution to be observed

See the precaution to be observed of 3.11.5.

3.12.6 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 analyzer 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 analyzer 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 analyzer.

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 3.12.7.

3.12.7 Specified conditions

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

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3.13 Magnitude of the input reflection coefficient (input return loss) ($|s_{11}|$)

3.13.1 Purpose

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

3.13.2 Circuit diagram

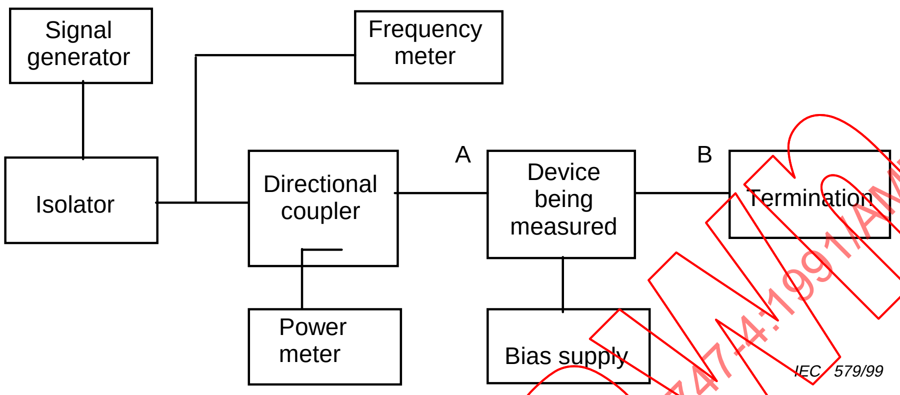

Figure 50 – Circuit for the measurements of magnitude of input/output reflection coefficient (input/output return loss)

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

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3.13.3 Principle of measurements

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 following equation:

$$|s_{11}| \text{ (dB)} = P_1 \text{ (dBm)} - P_2 \text{ (dBm)} \tag{13-1}$$

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.

3.13.4 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.

3.13.5 Precaution to be observed

As specified in 3.1.2.

3.13.6 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 (13-1).

3.13.7 Specified conditions

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

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