

Radio equipment used in mobile services —

Part 8: Methods of measurement for antennas and ancillary equipment

ICS 33.070.01; 33.120.40; 33.120.99

Committees responsible for this British Standard

The preparation of this British Standard was entrusted by the Electronic Equipment Standards Policy Committee (EEL/-) to Technical Committee EEL/25, upon which the following bodies were represented:

- British Broadcasting Corporation
- British Radio and Electronic Equipment Manufacturers' Association
- British Telecommunications plc
- Independent Broadcasting Authority
- Institution of Electrical Engineers
- Radiocommunications Agency
- Radio Electrical and Television Retailers' Association

The following bodies were also represented in the drafting of the standard, through subcommittees and panels:

- British Approvals Board for Telecommunications
- EEA (the Electronics and Business Equipment Association)
- ERA Technology Ltd.
- GAMBICA (BEAMA Ltd.)
- OFTEL (Office of Telecommunications)
- Radio Society of Great Britain
- Telecommunication Engineering and Manufacturing Association

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National foreword

This part of BS 6160 has been prepared under the direction of the Electronic Equipment Standards Policy Committee. It is identical with IEC 60489-8:1984, *Methods of measurement for radio equipment used in the mobile services — Part 8: Methods of measurement for antennas and ancillary equipment*, including amendment 1:2000, published by the International Electrotechnical Commission (IEC).

The British Technical Committee EEL/25 implemented Harmonized Document HD 466.8 S1:1986, which was published by the European Committee for Electrotechnical Standardization and is identical with IEC 60489-8:1984, as BS 6160-8:1994. IEC amendment 1:2000 was exempted from parallel voting and is not harmonized in CENELEC, however, the British Technical Committee notified the 112 CENELEC BT [CLC/BT (GB) 408] that they would publish IEC amendment 1:2000 as an amendment to BS 6160-8:1994.

This Part of BS 6160 should be read, where applicable, in conjunction with BS 6160-1:1989.

The start and finish of text introduced by amendment is indicated in the text by tags **A1** **A1**. Tags indicating changes to IEC text carry the number of the IEC amendment. For example, text altered by IEC amendment 1 is indicated by **A1** **A1**.

Textual error

The textual error set out below was discovered when adopting the text of the international amendment. It has been reported to IEC in a proposal to amend the text of the international standard.

Errors have been noted in **13.4** and the corrections are under consideration.

For the purpose of this British Standard any references to IEC page numbers in the text should be ignored.

Cross references

The British Standards which implement international publications referred to in this document may be found in the *BSI catalogue* under the section entitled “International Standards Correspondence Index”, or by using the “Search” facility of the *BSI Electronic Catalogue* or of British Standards Online.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

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Summary of pages

This document comprises a front cover, an inside front cover, pages 1 to 29 and a back cover.

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1 Scope

This International Standard refers specifically to the antennas and ancillary equipment used in the mobile services.

This standard is intended to be used in conjunction with IEC 60489-1.

The supplementary terms and definitions and the conditions of measurement set forth in this standard are intended for type tests and may also be used for acceptable tests.

2 Object

The object of this standard is to standardize the definitions, the conditions and the methods of measurement used to ascertain the performance of antennas and ancillary equipment (e.g. duplexer) within the scope of this standard and to make possible a meaningful comparison of the results of measurements made by different observers on different equipment. ^(A1)

Section 1. Definitions and general conditions of measurement

3 Definitions

Definitions used in this standard generally conform to those given in the International Electrotechnical Vocabulary (IEV) and in other IEC publications on antennas. Where a term is not defined in this standard, the definition is that given in the IEV; in case of conflict, the definition given herein takes precedence.

Additional terms will be found in the measurement sections.

3.1

antenna

for the purpose of this standard, an antenna is defined as a device for coupling a transmission line to space for the purpose of radiating or receiving electromagnetic waves. It includes any matching, balancing, phasing or other coupling devices up to the point of connection of the transmission line

3.2

base station or fixed station antenna

an antenna intended to be used at a base station or fixed station

3.3

half-wave dipole antenna

a dipole whose electrical length is half a wavelength

3.4

omnidirectional antenna

an antenna having an essentially non-directional pattern in azimuth and a directional pattern in elevation

3.5

source antenna

an antenna which properly illuminates the antenna under test within specified conditions

3.6

transfer-standard antenna

a reference antenna of closely reproducible specified construction. Its gain and directivity can be calculated and, when necessary, confirmed by measurement. It is used for making antenna gain measurements (see Appendix B, Figure B.1, page 20)

3.7

antenna voltage rating

the maximum instantaneous peak voltage which may be applied repetitively to the antenna feed point without degrading its performance

3.8

antenna test site

the general vicinity of the antenna under test

3.9

antenna test range

the space enclosing the source antenna, the antenna under test, and their equipment for gain and radiation pattern measurement (see Appendix A, Figure A.1, page 18)

3.10

antenna gain

the ratio of the power radiated by the antenna in a stated direction to the maximum radiated power of a lossless half-wave reference dipole with identical power input

3.11

antenna power rating

the maximum continuous r.f. power which can be applied to the antenna continuously for a specified period of time under specified conditions without degrading its performance

3.12

effective antenna volume

the actual volume containing the antenna plus one-half wavelength all around the antenna, taking into account all appropriate positions of the antenna under test

3.13

nominal impedance

the resistive impedance specified as the reference for reflection coefficient measurement at the antenna terminals

3.14

wind loading

the sum of the forces caused by wind pressure on the antenna and its supporting structure

3.15

ice loading

the additional loading on the antenna and supporting structure due to ice

4 Conditions of measurement

4.1 Scale model measurements

In the lower frequency bands accurate results of measurements of radiation pattern and gain are difficult to obtain on a full-size antenna. Therefore, scale model techniques may be used.

4.2 Linear accuracy

The scale model shall be constructed to at least the following accuracy:

$$L_s = LR \pm 0.01 LR$$

where

R is the scale ratio

L_s is any significant linear dimension of the scale model, and

L is the corresponding linear dimension of the full-size antenna

4.3 Supporting structure

When the antenna supporting structure or the presence of ground will affect the electrical characteristics of the antenna, it also shall be taken into account where possible.

4.4 Materials

The parts of the scale model shall be constructed of materials which simulate the electrical characteristics of the corresponding parts of the full-size antenna.

NOTE Although this is not in strict conformance with scale model techniques, the errors introduced are small enough that the accuracy of the measurement will not be impaired noticeably, provided that the scaling factor is not too large.

Section 2. Base or fixed station antennas

5 General

This section deals only with linearly polarized antennas for use in the frequency range 25 MHz to 1 GHz. Tests for circularly polarized antennas, for active antennas and for frequencies below 25 MHz are under consideration.

Unless otherwise specified, the measurements detailed in this section shall be conducted on an appropriate test range (see Appendix A).

Terminology used generally conforms to that in the International Electrotechnical Vocabulary (IEV) and in other IEC publications on antennas. Other definitions will be found in Section 1 of this part.

6 Standing-wave ratio (SWR), impedance and antenna power and voltage rating

6.1 Test conditions

The antenna under test shall be located in a space relatively free from reflections and sufficiently far from the test equipment and personnel. The test site is considered satisfactory if the change in SWR is less than 10 % when the antenna is moved in a horizontal direction a minimum of $\lambda/2$ on each of eight azimuth directions, 45° apart, and up and down $\pm \lambda/2$.

For certain applications, such as side-mounted vertical antennas, the supporting structure is in the r.f. field. In this case, the supporting structure shall be included in the mounting of the antenna under test.

6.2 SWR measurement procedure

The antenna under test shall be connected to a suitably matched signal source at the desired frequency, through a SWR measuring device, that has a nominal impedance equal to that of the transmission line and a residual SWR of not more than 1.05 below 500 MHz and 1.10 above 500 MHz. This residual SWR should be measured with all connectors to be used in the measurement included and with the line terminated in a matched load with a SWR of not more than 1.01. The measurement shall be made at each frequency of interest.

The SWR, as read on the measuring device, will be the SWR of the antenna under test at the selected frequency. If the r.f. loss in the line connecting the antenna to the measuring device exceeds 0.5 dB, the measured SWR values shall be properly corrected to take account of the line loss.

6.2.1 Presentation of results

At least the maximum (corrected) SWR for each frequency of interest shall be provided, together with the nominal impedance of the measuring device.

6.3 Impedance measurement procedure

The antenna impedance may be measured with a r.f. impedance bridge or other suitable device at the specified frequency.

6.3.1 Presentation of results

Measured impedance shall be stated in the form $R \pm jX$ at frequency f MHz, or graphically.

6.4 Power rating test procedure

The stated power rating may be proven either by an analytical method or by physical measurements.

The antenna under test shall be connected to a r.f. signal source through a SWR measuring device, and a specified power at the specified frequency shall be applied for a period of 4 h, under specified temperature and humidity conditions. No damage or deformation shall be observed; the change in SWR shall be less than 10 %.

6.4.1 Presentation of results

The results shall state the power rating, the test frequency and the environmental temperature and humidity. Where the power rating is determined analytically, the method of analysis shall be shown.

6.5 Voltage rating test procedure

A r.f. signal of specified frequency and peak voltage shall be applied almost continuously, at least 10 times to the antenna under test during a period of five minutes. A suitable indicating device shall be provided to show whether a breakdown or a flashover has occurred. The average power applied shall not exceed the rated power.

7 Radiation pattern measurements

7.1 General

By the principle of reciprocity, test results obtained with the source antenna transmitting and the antenna under test receiving are the same as those obtained with the source antenna receiving and the antenna under test transmitting. For convenience, it will be assumed that the source antenna is the transmitting antenna.

The radiation pattern for either the horizontal plane or the vertical plane may be measured.

7.2 Test conditions

The antenna under test together with its mounting system shall be installed on a test range (see Appendix A), where:

- a) both antennas have the same polarization;
- b) the separation between the source antenna and the antenna under test shall be at least 10 wavelengths, or $\frac{2L^2}{\lambda}$

where L is the maximum dimension of the antenna under test and λ is the wavelength of the test frequency in metres, whichever is greater, and

- c) the antenna under test shall be placed in an area where the field is substantially uniform. The field shall previously be probed by a half-wave dipole over the effective antenna volume of the antenna under test. If the field-intensity variation exceeds 1.5 dB, the test site shall be considered unusable.

7.3 Measurement procedure

- 1) Mount the antenna under test in accordance with Figure A.1 of Appendix A, page 18.
- 2) Terminate the antenna under test with a resistive load equal to its nominal impedance.
- 3) Connect a r.f. signal generator, adjusted to the test frequency, to the source antenna.
- 4) Measure the signal level received across the resistive load with a selective voltmeter.
- 5) Rotate the antenna under test through 360° around the axis (shown in Figure A.1, of Appendix A) and record the signal level as a function of angle of rotation.
- 6) Repeat steps 3, 4 and 5 at each test frequency.
- 7) Repeat steps 1 to 6 for each plane of interest.

7.4 Presentation of results

The results for each test frequency should be plotted on a graph showing levels as a function of angle of rotation, expressed in decibels or voltage ratios relative to the maximum recorded value. All measured values to 20 dB below the maximum should be shown.

Test frequency and polarization shall be stated and the orientation of the antenna shall be shown by a diagram.

8 Gain

Unless otherwise specified, the “stated direction” (Sub-clause 3.10) of gain is in the horizontal plane.

8.1 Test conditions

The test conditions are as set forth in Sub-clause 7.2.

8.2 Method of measurement

- 1) Mount the antenna under test in accordance with Figure A.1 of Appendix A, page 18.
- 2) Terminate the antenna under test with a resistive load equal to its nominal impedance.
- 3) Connect a r.f. signal generator, adjusted to the test frequency, to the source antenna.
- 4) Measure the signal level received across the resistive load with a selective voltmeter.
- 5) Rotate the antenna under test through 360° around the axis (shown in Figure A.1 of Appendix A) and record the signal level as a function of angle of rotation.
- 6) Rotate the antenna to the direction of signal maximum (V_a).
- 7) Replace the antenna under test by a transfer standard antenna covering the frequency or frequencies of interest and repeat step 6 for maximum level. Add attenuation to change reading of level to the value V_a . Note the attenuation A_D . (See Appendix B for an example of a 50 Ω transfer standard antenna.)
- 8) Repeat the measurement for each frequency of interest.

8.3 Calculation of results

The gain of the antenna is:

$$G_a = A_D + G_s$$

where:

A_D is the attenuation (step 7, Sub-clause 8.2) and G_s is the gain of the transfer standard antenna; all the figures are expressed in decibels.

NOTE *Circularity correction*

If the antenna is intended for omnidirectional coverage in the horizontal plane, the measured gain shall be corrected to take into account the angular variations of gain and to give G_0 , which is the average antenna gain in decibels in azimuth with reference to a lossless half-wave dipole.

8.4 Presentation of results

- a) The gain of the antenna under test, with reference to a lossless half-wave dipole, shall be stated as a function of frequency in either tabular or graphical form. All measured values across the frequency range of the antenna under test shall be shown. Orientation of the transfer-standard antenna and the antenna under test shall be stated.
- b) Where the intended direction of radiation from the antenna under test differs from the direction of maximum radiation due to beamtilt, the measured gain G_a shall be replaced by G_b .
- c) Where the antenna under test has an irregular azimuth pattern, the value of G_a shall be replaced by G_0 .

NOTE *Beamtilt correction*

If the intended direction of maximum radiation from the antenna under test differs from the horizontal direction due to the beamtilt, then the corrected gain G_0 shall be further corrected to give

$$G_b = G_0 + L_b$$

where L_b is the increase in gain due to the intended beamtilt and G_b is the gain in the intended direction. The value L_b can be obtained from the vertical radiation pattern of the antenna.

A1 9 Measurement of duplexers

9.1 General

9.1.1 Supplementary terms and definitions

For the purposes of this standard, the following supplementary terms and definitions apply. **A1**

9.1.1.1**duplexer**

device allowing the same antenna to be used for simultaneous transmission and reception

[IEV 712-06-16]

NOTE There are three terminals which are connected to the transmitter, the receiver and the antenna respectively in a duplexer. The branch from the transmitting terminal to the terminal of the antenna is referred to as the transmitting branch. The branch from the terminal of the antenna to the receiving terminal is referred to as the receiving branch.

9.1.1.2**frequency stability (temperature)**

drift characteristic of the extreme frequency at which the specified duplexer performance is satisfied, with temperature. It is expressed as parts per million per centigrade ($10^{-6}/^{\circ}\text{C}$). The duplexer performance (e.g. transmitter noise suppression ability, transmitter-to-receiver isolation ability, insertion loss and SWR) should be measured under the condition of specified temperature range and more than specified frequency range

9.1.2**standard test condition**

unless otherwise specified, all measurements should be performed under the general test conditions as stated in IEC 60489-1 and the supplementary test conditions given below

9.1.3 Supplementary test conditions**9.1.3.1****test load**

non-radiating load with an impedance and power rating specified by the duplexer manufacturer

9.1.3.2**connections to the measuring equipment**

care must be taken to ensure that measuring equipment does not adversely affect the duplexer loading conditions

9.2 Transmitter noise suppression ability**9.2.1 Definition**

The ability of the duplexer to suppress the transmitter noise on the frequency band of the receiver, so as to prevent the desired performance of the receiver from degrading.

It is expressed by the minimum coupling attenuation value from the transmitting terminal to the receiving terminal of the duplexer in the above frequency band.

9.2.2 Method of measurement

- a) Connect the equipment as illustrated in Figure 1.
- b) Connect point P1 to P2. Adjust the frequency of the generator (1) to any one within the specified operating frequencies of the receiving branch.
Adjust the output of the generator (1) and attenuation of the attenuator (2) to provide a signal level within the linear range of the selective measuring device (4). Record the level and value of attenuation.
- c) If required, repeat step b) at another specified operating frequency.
- d) Connect point P1 to the transmitting terminal (Tx) of the duplexer, and point P2 to the receiving terminal (Rx) of the duplexer.

While maintaining the output of the generator (1) established in step b), vary the frequency over the specified operating range of the receiving branch and adjust the attenuator (2) to provide a signal level within the linear range of the selective measuring device (4). Record the level and the value of the attenuation at each frequency. **A1**

A1 9.2.3 Presentation of results

- a) Calculate the ratio, in dB, of the recorded level in step b) of **9.2.2** to recorded level in step d) of **9.2.2** and the difference, in dB, between the recorded attenuation in step b) of **9.2.2** and the recorded attenuation in step d) of **9.2.2**. Add the value of both the ratio and the difference. Record this coupling attenuation value, in dB.
- b) Plot the coupling attenuation value recorded in step a) on the linear ordinate of a graph versus the corresponding frequency on the linear abscissa
- c) The minimum coupling attenuation value in the graph is referred to as transmitter noise suppression ability of the duplexer.

9.3 Transmitter-to-receiver isolation ability**9.3.1 Definition**

The ability of the duplexer to isolate the transmitter output power level so as to prevent the desired performance of the receiver from degrading.

It is expressed by the minimum coupling attenuation value from the transmitting terminal to the receiving terminal of the duplexer in the transmitting frequency band.

9.3.2 Method of measurement

- a) Connect the equipment as illustrated in Figure 1.
- b) Connect point P1 to P2. Adjust the frequency of the generator (1) to any one within the specified operating frequencies of the transmitting branch.
Adjust the output of the generator (1) and attenuation of the attenuator (2) to provide a signal level within the linear range of the selective measuring device (4). Record the level and value of attenuation.
- c) If required, repeat step b) at another specified operating frequency.
- d) Connect point P1 to the transmitting terminal (Tx) of the duplexer, and point P2 to the receiving terminal (Rx) of the duplexer.

While maintaining the output of generator (1) established in step b), vary the frequency over the specified operating range of the transmitting branch and adjust the attenuation of attenuator (2) to provide a signal level within the linear range of the selective measuring device (4). Record the level and the value of attenuation at each frequency.

9.3.3 Presentation of results

- a) Calculate the ratio, in dB, of the recorded level in step b) of **9.3.2** to the recorded level in step d) of **9.3.2**, and the difference, in dB, between the recorded attenuation in step b) of **9.3.2** and the recorded attenuation in step d) of **9.3.2**. Add the values of both the ratio and difference. Record this coupling attenuation value, in dB.
- b) Plot the coupling attenuation value recorded in step a) on the linear ordinate of a graph versus the corresponding frequency on the linear abscissa.
- c) The minimum coupling attenuation value in the graph is referred to as transmitter-to-receiver isolation ability of the duplexer.

9.4 Insertion loss**9.4.1 Definition**

Transmission loss of the transmitter output power level and the receiver input signal level through the duplexer. **A1**