

Methods of measurement for equipment used in digital microwave radio transmission systems —

Part 3: Measurements on satellite earth stations —

Section 3.2 Antenna

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Contents

	Page
Committees responsible	Inside front cover
National foreword	ii
Foreword	2
Text of EN 60835-3-2	5
List of references	Inside back cover

National foreword

This British Standard has been prepared by Subcommittee EPL/12/5 and is the English language version of EN 60835-3-2:1996 *Methods of measurement for equipment used in digital microwave radio transmission systems — Part 3: Measurements on satellite earth stations — Section 3.2 Antenna*, published by the European Committee for Electrotechnical Standardization (CENELEC). It is identical with IEC 835-3-2:1995, published by the International Electrotechnical Commission (IEC).

BS EN 60835 is published in three Parts. The other Parts are:

- *Part 1: Measurements common to terrestrial radio-relay systems and satellite earth stations;*
- *Part 2: Measurements on terrestrial radio-relay systems.*

Some of the many Sections of the three Parts have appeared under the number BS 7573, of the same generic title.

This Section of BS EN 60835-3 gives definitions and methods of measurement of the electrical characteristics of satellite earth-station antennas for frequencies above about 1 GHz. The methods are applicable to reflector type antennas for digital and analogue signal transmission.

Additional information. In adopting the text of the International Standard the following typographical error was discovered. In clause 3, paragraph 2, line 2: “IEC 60” should read “IEC 50(60)”.

Cross-references

Publication referred to	Corresponding British Standard
IEC 50(712) 1992	BS 4727 <i>Glossary of electrotechnical, power, telecommunication, electronics, lighting and colour terms</i> Part 3: <i>Terms particular to telecommunications and electronics</i> Group 15:1992 <i>Antennas</i> BS EN 60835 <i>Methods of measurement for equipment used in digital microwave radio transmission systems</i>
EN 60835-1-2:1993 (IEC 835-1-2:1992)	Part 1 <i>Measurements common to terrestrial radio-relay systems and satellite earth stations</i> Section 1.2:1995 <i>Basic characteristics</i> Part 3 <i>Measurement on satellite earth stations</i>
EN 60835-3-4:1995 (IEC 835-3-4:1993)	Section 3.4:1996 <i>Low noise amplifier</i>
EN 60835-3-7:1995 (IEC 835-3-7:1995)	Section 3.7:1996 <i>Figure-of-merit of receiving system</i>

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Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, the EN title page, pages 2 to 44, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

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English version

Methods of measurement for equipment used in digital
microwave radio transmission systems
Part 3: Measurements on satellite earth stations
Section 2: Antenna

(IEC 835-3-2:1995)

Méthodes de mesure applicables au matériel
utilisé pour les systèmes de transmission
numérique en hyperfréquence
Partie 3: Mesures applicables aux stations
terriennes de télécommunications par satellite
Section 2: Antenne
(CEI 835-3-2:1995)

Meßverfahren für Geräte in digitalen
Mikrowellen-Funkübertragungssystemen
Teil 3: Messungen an Satelliten-Erdfunkstellen
Hauptabschnitt 2: Antenne
(IEC 835-3-2:1995)

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Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Central Secretariat or to any CENELEC member.

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European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
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Foreword

The text of document 12E/247/FDIS, future edition 1 of IEC 835-3-2, prepared by SC 12E, Radio-relay and fixed satellite communication systems, of IEC TC 12, Radiocommunications, was submitted to the IEC-CENELEC parallel vote and was approved by CENELEC as EN 60835-3-2 on 1996-03-05.

The following dates were fixed:

- latest date by which the EN has to be implemented at national level by publication of an identical national standard or by endorsement (dop) 1996-12-01
- latest date by which the national standards conflicting with the EN have to be withdrawn (dow) 1996-12-01

Annexes designated “normative” are part of the body of the standard. Annexes designated “informative” are given for information only. In this standard, Annex ZA is normative and Annex A is informative, Annex ZA has been added by CENELEC.

Contents

	Page
Foreword	2
1 Scope	5
2 Normative references	5
3 Definitions	5
4 Conditions of measurement	9
5 Antenna gain	9
5.1 General considerations	9
5.2 Methods of measurement	10
5.3 Presentation of results	14
5.4 Details to be specified	14
6 Antenna pattern	14
6.1 General considerations	14
6.2 Terrestrial bore-sight pattern measurements	15
6.3 Measurement of antenna pattern via satellite	16
6.4 Antenna monopulse pattern	17
6.5 Measurement accuracy	18
6.6 Presentation of results	18
6.7 Details to be specified	19
7 Polarization	19
7.1 Calculation of the polarization efficiency	19
7.2 Cross-polarization discrimination (XPD)	20
7.3 Two-port discrimination of dual polarized frequency re-use antennas	23
7.4 Presentation of results	26
7.5 Details to be specified	26
8 Receive figure of merit (G/T)	27
9 Antenna noise temperature	27
9.1 General considerations	27
9.2 Method of measurement	27
9.3 Presentation of results	28
9.4 Details to be specified	28
10 Antenna return loss	28
10.1 Method of measurement	28
10.2 Presentation of results	28
10.3 Details to be specified	28
11 Transmit-receive isolation	28
11.1 Method of measurement	28
11.2 Presentation of results	28
11.3 Details to be specified	28
Annex A (informative) Bibliography	44

	Page
Annex ZA (normative) Normative references to international publications with their corresponding European publications	44
Figure 1 — Antenna subsystem	29
Figure 2 — Measurement of antenna gain by comparison with a gain-reference antenna	30
Figure 3 — Receive antenna gain measurement set-up (satellite substitution method)	31
Figure 4 — Transmit antenna gain measurement set-up (satellite link power method)	32
Figure 5 — Antenna pattern measurement set-up — Receive band	33
Figure 6 — Example of measured near-in angle pattern of a 32 m antenna receive band	34
Figure 7 — Antenna pattern measurement set-up — Transmit band	35
Figure 8 — Example of measured transmit pattern of a 32 m antenna	36
Figure 9 — Antenna tracking pattern and sensitivity measurement set-up (example for a dual polarized frequency re-use antenna receiving a linear polarized beacon)	37
Figure 10 — Example of azimuth tracking channel pattern of 32 m antenna	38
Figure 11 — $(C + N)/N$ correction for signal measurements made near the noise level	39
Figure 12 — Typical arrangement for the measurement of cross-polarization discrimination using an operational satellite	40
Figure 13 — Example of antenna axial ratios measured via satellite (32 m antenna)	41
Figure 14 — Antenna noise temperature measurement set-up	42
Figure 15 — Transmit-receive port isolation measurement set-up	43

1 Scope

This section of IEC 835-3 gives definitions and methods of measurement of the electrical characteristics of satellite earth-station antennas for frequencies above about 1 GHz. The methods are applicable to reflector type antennas for digital and analog signal transmission.

The purpose of the measurements is mainly to confirm that earth-station antenna performance complies with the requirements generally given by the satellite system provider based on the Radio Regulations and applicable International Standards such as ITU-R Recommendation S.733-1 and the CCIR Recommendations 465-4, 580-3, 731 and 732. The measurement procedures are often prescribed by international satellite service organizations.

Measurements are performed under the condition that all antenna subsystem equipment is connected unless otherwise stated.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this section of IEC 835-3. At the time of publication, the editions indicated were valid. All normative documents are subject to revision, and parties to agreements based on this section of IEC 835-3 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

IEC 50(60):1970, *International Electrotechnical Vocabulary (IEV) — Chapter 60: Radio-communications*.

IEC 50(712):1992, *International Electrotechnical Vocabulary (IEV) — Chapter 712: Antennas*.

IEC 835-1-2:1992, *Methods of measurement for equipment used in digital microwave radio transmission systems — Part 1: Measurements common to terrestrial radio-relay systems and satellite earth stations — Section 2: Basic characteristics*.

IEC 835-3-4:1993, *Methods of measurement for equipment used in digital microwave radio transmission systems — Part 3: Measurements on satellite earth stations — Section 4: Low noise amplifier*.

IEC 835-3-7:1995, *Methods of measurement for equipment used in digital microwave radio transmission systems — Part 3: Measurements on satellite earth stations — Section 7: Figure-of-merit of receiving system*.

ITU-R S.465-5:1993, *Reference earth-station radiation pattern for use in coordination and interference assessment in the frequency range from 2 to about 30 GHz*.

ITU-R S.580-4:1993, *Radiation diagrams for use as design objectives for antennas of earth stations operating with geostationary satellites*.

ITU-R S.731:1992, *Reference earth-station cross-polarized radiation pattern for use in frequency coordination and interference assessment in the frequency range from 2 to about 30 GHz*.

ITU-R S.732:1992, *Method for statistical processing of earth-station antenna side-lobe peaks*.

ITU-R S.733-1:1993, *Determination of the G/T ratio for earth stations operating in the fixed-satellite service*.

3 Definitions

For the purpose of this section of IEC 835-3, the following definitions apply.

For definitions of the general terms used in this section, reference should be made to IEC 60 and IEC 50(712). In case of conflict, the definition given here takes precedence.

3.1

antenna subsystem

an antenna subsystem is that part of the earth-station communication equipment which comprises the antenna and the feed network, as shown in Figure 1. The antenna considered in this section is a reflector antenna consisting of the main reflector, secondary reflectors, if any, and the primary radiator. The feed network usually may contain frequency diplexers, transmit reject filters, hybrids, and a polarization diplexer (orthomode transducer) or a polarizer, to which are connected the waveguide feeders to the transmit and receive multiplexing and switching equipment and to the tracking receiver. The antenna subsystem may also include provisions for pointing the antenna. The terminals of the antenna subsystem should be specified for a given measurement

3.2

antenna port (antenna terminal)

an antenna port may be defined at any interface of the feed network where r.f. measurements are usually made. To separate antenna and feed network properties, sometimes the feed horn waveguide flange is defined as the antenna port, but in that case additional measurements including the whole feed network may be important

3.3

antenna gain

the gain of a transmitting antenna is the ratio of the power flux density produced in the far-field region, in a given direction and at a given distance from the antenna, to the power flux density which would be produced at the same distance by a loss-free isotropic antenna which accepts the same power from the same source as the antenna under test

for receiving antennas, a definition of gain can be derived from that of effective area A_e (see 3.5) by the equation:

$$G = \frac{4 \pi A_e}{\lambda^2} \quad (3-1)$$

where λ is the wavelength

for the same antenna used for transmitting and receiving on the same frequency and with the same terminals, the gains defined above for transmitting and for receiving will be equal, because of the reciprocity of the antenna

theoretically, gain does not include losses arising from polarization mismatches and from impedance mismatches at the gain-reference plane of the feed system. However, in practical measurements these effects normally are very small and may then be neglected. Nevertheless it may sometimes be necessary to give that part of the antenna gain (partial gain as defined in IEV 712-02-44) corresponding to a specified polarization. In this case the reference polarization should be indicated for example by “right-hand circular polarization gain” or “horizontal linear polarization gain”. The partial gain is the gain multiplied with the polarization efficiency corresponding to the specified polarization. It may be measured, for example, with a bore-sight antenna radiating with the specified polarization towards the antenna under test. If the antenna polarization is split into two orthogonal components (which is always possible), then the antenna gain is the sum of the partial gains corresponding to the polarizations of the components

NOTE Unless otherwise specified, gain will be defined as the gain in bore-sight direction (maximum gain).

3.4

antenna pattern

the antenna (radiation) pattern is an angular plot of the signal strength radiated from or received by the antenna with respect to a specified port. It normally corresponds to co- or cross-polarization

3.5

effective area of an antenna

for a specified direction, the effective (active) area of an antenna is the ratio between the power delivered to a matched load at the antenna terminals and the power flux density in a polarization matched plane wave incident on the antenna

NOTE The effective area is normally determined by a gain measurement using equation (3-1).

3.6

antenna efficiency

the antenna efficiency η is the ratio of the maximum effective area to the projected area A of the antenna in a plane perpendicular to the direction of maximum radiation. The maximum effective area is related to the maximum gain G as defined in 3.3. So:

$$\eta = \frac{A_e}{A} = \frac{G \lambda^2}{4 \pi A} \quad (3-2)$$

where λ is the wavelength

NOTE The reference plane for the efficiency should be the same as for the gain.

3.7

gain-reference antenna

an antenna with precisely known gain. The gain of the antenna under test may be compared with the gain of a reference antenna by switching between these antennas. The reference antenna is often much smaller than the antenna under test

3.8

bore-sight direction

for tracking antennas, the bore-sight direction is the direction of the tracking null. For non-tracking directive antennas, the bore-sight direction is the direction of the beam maximum

NOTE Bore-sight measurements are measurements with an ancillary antenna (bore-sight antenna) usually mounted on a tower (bore-sight tower), located at the bore-sight direction.

3.9

antenna polarization

the antenna polarization is the polarization of the electric far-field in a specified direction of a radiating antenna. It is also that polarization of a plane wave, incident from a given direction and having a given power flux density, which results in maximum available power at the antenna terminals

NOTE If not otherwise defined, the specified direction is the bore-sight direction. The polarization is characterized by the polarization ellipse, or by a sum of a co- and a cross-polarized component. Therefore, the polarization properties for all directions are also given by co- and cross-polarized antenna patterns.

3.10

axial ratio

axial ratio (or ellipticity ratio) r is defined as the ratio of the major axis to the minor axis of the polarization ellipse (linear polarization is given by $r = \infty$ circular polarization by $r = 1$)

3.11

co-polarization (nominal polarization)

co-polarization (of an antenna) is that polarization which the antenna is intended to radiate (or receive) in view of maximum power transfer under operational conditions the intended polarization for earth-station antennas is the co-polarization of the satellite antenna in the direction of this earth-station antenna. For linear polarization the direction of the satellite polarization depends on the positions of the earth station and the satellite and, to a small amount, on the polarization characteristic and direction stability of the satellite antenna

NOTE The co-polarization is normally exactly circular or linear. Linear co-polarization is usually specified with respect to the ground or the earth meridian plane belonging to the satellite position. In practice, an antenna is also called co-polarized, even if it is only approximately co-polarized with the intended polarization (for example, the far-field electric vector can move slightly with the frequency).

3.12

cross-polarization

cross-polarization (to a given co-polarization) is the polarization orthogonal to the co-polarization (with both waves having the same direction of propagation). Two polarizations are said to be orthogonal, if the polarization ellipses have opposite senses of rotation, the same axial ratios and orthogonal major axes two antennas are said to be cross-polarized, if their polarizations are orthogonal. Two antennas are said to be nominally cross-polarized if their co-polarizations (nominal polarizations) are orthogonal

NOTE In practice, two antennas are sometimes also called cross-polarized, if they are only approximately orthogonal.

3.13

cross-polarization discrimination (XPD)

for a given direction and a specified port, the cross-polarization discrimination XPD of an antenna is the power ratio in decibels of the co-polarized and cross-polarized component of the antenna polarization. The cross-polarization discrimination in decibels is given by $x = 10 \log X$. In the receive case, for example, this ratio may be measured by observing the power ratio, when the polarization of the transmitting antenna is switched over from co-polarization to the orthogonal cross-polarization, keeping the transmit power unchanged

NOTE Unless otherwise specified, the bore-sight direction is assumed. Cross-polarization is defined for each port of a multi-port antenna.

3.14**polarization efficiency**

the polarization efficiency η is a factor, of unity or less, which is employed in the following equation:

$$P_r(\Phi, \theta) = A_e(\Phi, \theta) \cdot S \cdot \eta \quad (3-3)$$

where

$A_e(\Phi, \theta)$ is the effective area of a receiving antenna in a given direction (Φ, θ) of incidence;

S is the power flux density of an incident plane wave from the direction (Φ, θ) ;

$P_r(\Phi, \theta)$ is the power delivered by a specified port of the receiving antenna to a matched termination.

3.15**dual-polarized antenna**

a dual-polarized antenna is an antenna designed for simultaneously transmitting and/or receiving signals having two orthogonal (cross-polarized) polarizations. If it has one receive and one transmit port, then the co-polarizations related to these ports are orthogonal. If it operates with frequency re-use and therefore has four communication signal ports, the co-polarizations related to the two receive and the two transmit ports are orthogonal in each case

NOTE If only one of the two received or transmitted operational polarizations is considered, sometimes the ports corresponding to the same signal propagation direction are called “co-polar” and “cross-polar” ports. But the antenna polarizations related to these ports, despite approximating the intended co- and cross-polarization, should then be distinguished from these polarizations.

3.16**two-port discrimination (TPD)**

the two-port discrimination (port-to-port discrimination, isolation) of a dual polarized frequency re-use earth-station antenna is defined for the two receive ports and the two transmit ports

if the satellite antenna radiates with one of the two operational polarizations, the receive two-port discrimination of the antenna under test related to this polarization is the ratio of the power received at the corresponding receive port to the power received at the other receive port (with both ports terminated with matched loads)

if the antenna under test radiates with one of the two operational polarizations to the satellite, the transmit two-port discrimination of the antenna under test related to this polarization is the ratio of the power received at the corresponding port of the satellite antenna to the power received at the same port when the power at the antenna under test is switched over from one to the other transmit port (satellite antenna ports terminated with matched loads)

the TPD depends on which of the two operational polarizations is transmitted or received respectively. It will also be affected by properties of the satellite or bore-sight antenna involved in the test and the transmission path. Therefore it is often not a sufficient measure of quality of the antenna under test, but it may be the only measurable quality in some practical situations

NOTE The two-port discrimination normally has to be distinguished from the transmit-receive isolation of a multi-port antenna (see 3.17), as well as from the cross-polarization discrimination (see 3.13, 7.2) defined for each of the antenna ports. Equal or approximately equal values for these quantities may exist only at special frequencies or for idealized antenna properties.

3.17**transmit-receive isolation (TRI)**

the transmit-receive isolation of an antenna is the power ratio of the power transmitted at a transmit port of the antenna to the power received at a receive port of the antenna (by coupling)

NOTE The transmit-receive isolation may include the contribution of a transmit reject filter in the receive line.

3.18

far-field (far-zone, Fraunhofer zone)

the far-field of an antenna begins at that distance L from the antenna, where the antenna pattern is approximately independent of the distance where it is measured. The far-field distance L is normally defined by the equation:

$$L = \frac{2 D^2}{\lambda} \quad (3-4)$$

where

D is the maximum aperture dimension of the antenna;

λ is the wavelength.

for far-field measurements the measurement distance will be greater than the maximum far-field distance resulting from the minimum operational wavelength

NOTE 1 When the maximum aperture dimension d of the opposite antenna is larger than approximately $0,64 D$, the following minimum distance may be required for measurement:

$$L = \frac{Dd}{0,32 \lambda} \quad (3-5)$$

If $D < 0,64 d$, then equation (3-4) should be used with d instead of D .

NOTE 2 For low sidelobe antennas, measurement distances longer than that of equation (3-4) may be required.

3.19

noise temperature of an antenna

the noise temperature of an antenna is the temperature of a resistor having an available power per unit bandwidth equal to that at the antenna output at a specified frequency

NOTE The noise temperature of an antenna depends on its coupling to all noise sources in its environment as well as noise generated within the antenna (for example, by ohmic losses).

4 Conditions of measurement

The measurements described in this standard shall be made as far as possible under realistic operational conditions. They shall be carried out within all the frequency bands given in the detailed equipment specification. The measurements may be made under different environmental conditions within the limits agreed between the parties concerned, for example:

- wind velocity;
- hail;
- ice;
- rain;
- snow;
- solar radiation;
- temperature range.

It should be recognized that mechanical deformations of the antenna geometry, due to the influence of gravity, wind and antenna pointing angle, can affect the results of the measurements, particularly those of gain, sidelobes, cross-polarization and two-port discrimination.

5 Antenna gain

5.1 General considerations

The antenna gain of a satellite earth station may be measured by one of the following four methods:

- a) comparison with a gain-reference antenna;
- b) satellite substitution method (receive band);
- c) satellite link power method (transmit band);
- d) radio star method.

The comparison with a gain-reference antenna (standard gain-horn method) is applicable if a terrestrial bore-sight range is available. The range shall have sufficient length and sufficiently low ground reflection for the measurement. This method may be carried out when the length of the range is greater than the far-field distance (see 3.18).

The satellite substitution method and satellite link power method are practical and convenient methods for antennas of all sizes, but are in general not very accurate. These methods are applicable when the bore-sight range is not available and when the antenna under test is not large enough for the radio star method.

The radio star method is feasible for large antennas. Practicality of the method depends on the radio star flux density, the antenna gain, system noise temperature and visibility of the radio star. This method is applicable when the Y-factor (the ratio of the received power from the radio star to the sky noise power) is greater than 2 dB (see IEC 835-3-7). The measurement is performed by the simultaneous measurement of G/T and the system noise temperature.

There are some small antennas whose feed includes a non-detachable low noise amplifier or transmit power amplifier. For these antennas, an equivalent alternative feed subsystem can be used for the measurement. The appropriate method is the standard gain-horn method using a terrestrial bore-sight range.

The reference points in the antenna subsystem at which the transmit and receive gains are to be measured or referred shall be specified. Also, the extent of filters, couplers, switches and other components in the transmission line, whose losses are to be included in the gain computation and measurement, should be specified.

5.2 Methods of measurement

5.2.1 Comparison with a gain-reference antenna

5.2.1.1 General considerations

Gain measurement by comparison with a gain-reference antenna involves the comparison of the signal level received by a gain-reference antenna and that received by the antenna under test from the same distant radiating source (bore-sight antenna).

It is preferable that the type of polarization (for example, linear or circular) of the source antenna and the gain-reference antenna is the same as that of the antenna under test. However, it is possible to use a linear polarized source antenna and/or gain-reference antenna for the measurement of a circular polarized antenna with correction (see 5.2.1.3).

NOTE Generally, the physical dimensions, and hence gain, of the antenna under test are greater than those of the gain-reference antenna.

5.2.1.2 Method of measurement

Figure 2 shows the block diagrams of two similar arrangements commonly used for the measurement of the antenna gain-by-gain comparison.

The r.f. receiver is successively connected to the antenna under test and to the gain-reference antenna, using either a flexible coaxial cable terminated by a coaxial-to-waveguide transition and an isolator or by a waveguide switch associated with two waveguide runs with known losses.

At the beginning of the measurement, both antennas, the gain-reference antenna and the antenna under test, shall be slightly de-pointed by a fraction of a beamwidth alternately in azimuth and elevation. The antennas are then panned or rotated in azimuth and/or elevation, through the point of maximum signal strength and then reset to that point in order to establish the bore-sight direction in azimuth and elevation for each antenna in turn for maximum received power. The azimuth and elevation settings of both the gain-reference antenna and the antenna under test are then maintained for the duration of the measurements. In addition, the exact polarization of the antennas should be checked and, if necessary, adjusted for maximum receive level.

Step 1: Connect the receiving equipment to the gain-reference antenna and note or record the indicated received power, P_r .

Step 2: Connect the receiving equipment to the antenna under test, increase the attenuation of the variable attenuator in order to receive the same order of magnitude of indicated received power, and note or record the received power, P_a , and the difference in the variable attenuator readings recorded in steps 1 and 2.

Step 3: Repeat steps 1 and 2 until an acceptable repeatability is achieved in the measurement of P_r and P_a . Lack of repeatability may be due to instability in the transmitting source, or in the receiving equipment, or in the test-range propagation path conditions.

The gain of the antenna under test can then be calculated by the following general expression:

$$G_a \text{ (dB)} = 10 \log \left(\frac{P_a}{P_r} \right) + L_{eq} + G_r \quad (5-1)$$

where

G_a is the calculated gain of the antenna under test at the gain-reference point;

G_r is the gain of the gain-reference antenna;

L_{eq} is the difference between the attenuator reading in step 2 and the reading in step 1 (generally, $L_{eq} > 0$ dB).

NOTE 1 To eliminate the influence of ground reflections, the power received by the gain-reference antenna should be recorded for different heights of the gain-reference antenna above ground. Interference of the ground reflections with the directly received wave cause a nearly periodic level variation with height. The amount of the variation of the gain-reference antenna height should be large enough to record one or more of these oscillations. (A separate construction for accurate moving of the gain-reference antenna is recommended.) The average level received by the gain reference antenna should be determined and used for the gain calculation. For a good test range, the peak-to-peak level variation with height may be less than 0,4 dB

NOTE 2 Most often, a swept-frequency measurement is used to measure P_r and P_a as a function of frequency. However, in the case of a fixed frequency measurement there will be less difficulty in adjusting P_a to exactly the same value as P_r which will then simplify the above equation and hence calculation of G_a .

5.2.1.3 Correction for a circularly polarized antenna measured by using a linearly polarized source and/or gain-reference antenna

Case 1: For an antenna under test with a good axial ratio

When the axial ratio of the antenna under test is less than about 2 dB, simple corrections described below can be applied:

a) a linearly polarized source antenna and a linearly polarized gain-reference antenna.

The measured gain of the antenna under test is 3 dB lower than the actual gain. Therefore, 3 dB shall be added to the measured gain.

b) a circularly polarized source antenna and a linearly polarized gain-reference antenna.

The received level by the gain-reference antenna is 3 dB lower than by a circularly polarized antenna of the same gain. Therefore, 3 dB shall be subtracted from the measured gain.

NOTE When a circularly polarized gain-reference antenna is used, no correction is necessary.

Case 2: For an antenna under test with a poor axial ratio using a linearly polarized source antenna

Firstly measure the antenna gain, G_0 (dB), with an appropriate polarization angle of the source antenna. Then rotate the polarization angle of the source antenna by 90° and measure the antenna gain, G_{90} (dB), again. Apply the same correction as for case 1 a) if a linear polarized gain-reference antenna is used. Then the antenna gain, G , can be derived as:

$$G = 10 \log \frac{10 \left(\frac{G_0}{10} \right) + 10 \left(\frac{G_{90}}{10} \right)}{2} \quad \text{(dB)} \quad (5-2)$$

NOTE When a circularly polarized source antenna is used, no correction is necessary other than the same correction as for case 1 b) above.