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Technical Report

Fixed Radio Systems;
Point-to-point and point-to-multipoint equipment;
Use of circular polarization in multipoint systems;
Part 2: Antenna parameters

Reference

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Contents

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Foreword

This Technical Report has been produced by the ETSI Technical Committee Transmission and Multiplexing (TM).

The present document is part 2 of a multipart deliverable covering the Fixed Radio Systems; Point-to-point and point-to-multipoint equipment; Use of circular polarization in multipoint systems as identified below:

Part 1: "Systems aspects";

Part 2: "Antenna parameters";

Part 3: "Antennas for multipoint fixed radio systems in the 1 GHz to 11 GHz band".

The purpose of the present document is to set out the format of a standard for the use of circularly polarized antennas in conjunction with MultiPoint (MP) systems in the frequency bands 1 GHz to 3 GHz and 3 GHz to 11 GHz. This suggested standard forms the third part of a report on the use of circular polarization which is divided as follows:

Part 1 examines the systems aspects of using circular polarization in environments where linear polarization is in use.

Part 2 examines the electrical/mechanical characteristics required for circularly polarized antennas, and the related conformance testing. The requirements for linearly polarized antennas are covered by EN 301 525 [5] and EN 302 085 [6].

Part 3 defines the antenna characteristics necessary to ensure optimum frequency co-ordination between systems and/or different services by the Regulatory Authorities, and specifies the required conformance testing.

Antennas as components for radio relay systems may need to meet environmental, mechanical and electrical characteristics not covered by the present document, in order that the systems will operate as intended. Characteristics to be considered are provided as guidance.

1 Scope

The present document examines the electrical and mechanical characteristics required for circularly polarized antennas, and the related conformance testing. The requirements for linearly polarized antennas are covered by EN 301 525 [5] and EN 302 085 [6]. Electronically steerable antennas, and linearly polarized antennas are not considered under the present document.

2 References

For the purposes of this Technical Report (TR), the following references apply:

[1] Evans, G.E.: "Antenna Measurement Techniques", Artech House 1990".

[2] Hollis, J.S., Lyon, T.J., Clayton, L.: "Microwave Antenna Measurements", Scientific-Atlanta Inc., 1970".

[3] Hollis, J.S., Clayton, L.: "Antenna Polarization Analysis by Amplitude Measurement of Multiple Components" Microwave Journal, January 1965".

[4] Lo, Y.T., Lee, S.W.: "Antenna handbook: theory, applications and design", 1988 Van Nostrand Reinhold Company".

[5] ETSI EN 301 525: "Fixed Radio Systems; Point-to-Multipoint Antennas; Antennas for Point-to-Multipoint fixed radio systems in the 1 GHz to 3 GHz band".

[6] ETSI EN 302 085: "Fixed Radio Systems; Point-to-Multipoint Antennas; Antennas for point-to-multipoint fixed radio systems in the 3 GHz to 11 GHz band".

[7] IEC 835-2-2: "Methods of measurement for equipment used in digital microwave transmission systems - Part 2: Measurements on terrestrial radio-relay systems - Section 2: Antenna".

3 Definitions, symbols and abbreviations

3.1 Definitions

For the purposes of the present document, the following terms and definitions apply:

antenna: part of the transmitting or receiving system that is designed to radiate or receive electromagnetic waves

axial ratio: ratio of maximum to minimum power contained in the field components of the polarization ellipse

radiation pattern: diagram relating power flux density at a constant distance from the antenna to the direction relative to the antenna main beam axis

Radiation Pattern Envelope (RPE): envelope below which the radiation pattern shall fit

3.2 Symbols

For the purposes of the present document, the following symbols apply:

dB	DeciBels
GHz	GigaHertz
τ	tilt angle

3.3 Abbreviations

For the purposes of the present document, the following abbreviations apply:

AR	Axial Ratio
CP	Circularly Polarized
CPR	Circular Polarization Ratio
CS	Central Station
MP	MultiPoint
RHCP	Right Hand Circular Polarization
LHCP	Left Hand Circular Polarization
RPE	Radiation Pattern Envelope
XPD	cross Polar Discrimination

4 Circular polarization testing

Consider an elliptical polarized electromagnetic plane wave. The tip of the rotating vector E(t) traces out an ellipse.

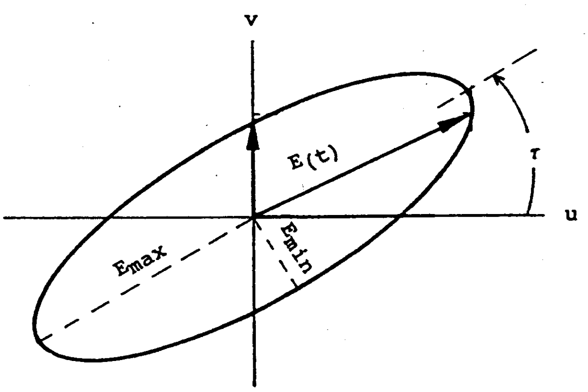


Figure 1: Polarization ellipse

The polarization ellipse in figure 1 is characterized by three parameters described as follows:

a) the axial ratio AR is defined by the ratio of maximum length and minimum length of E(t), or the ratio of the semimajor and semiminor axes of the polarization ellipse;

b) the tilt angle τ;

c) the sense of rotation of E(t).

It can be shown that this field can be resolved into left-circular and right-circular components of appropriate magnitudes and relative phases. If we denote the right hand circular component E_{RHCP} and the left hand component by E_{LHCP} the minor and the major axes of the polarization ellipse are defined as:

$$E_{min} = E_{LHCP} - E_{RHCP}$$

$$E_{max} = E_{LHCP} + E_{RHCP}$$

respectively.

Observe that the sense of rotation is that of the larger circular component; that is, if E_{LHCP} larger than E_{RHCP}, the sense is left hand.

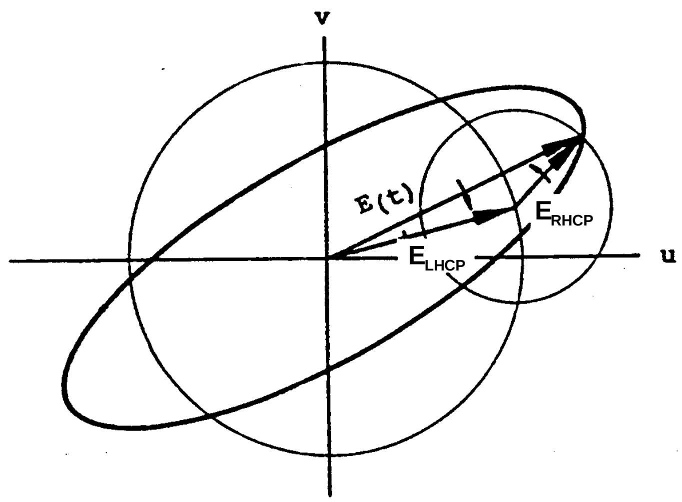


Figure 2: Polarization ellipse resolved into two circular components

The axial ratio can be calculated from:

$$AR = \frac{|E_{RHCP}| + |E_{LHCP}|}{|E_{RHCP}| - |E_{LHCP}|} = \frac{U_{\max}}{U_{\min}}$$

The axial ratio is often expressed in decibels, by the relation:

$$ar_{[dB]} = 20\,x\log(ar)$$

Note that the absolute value of AR is required. The sense of rotation must be indicated separately.

The crosspolar discrimination XPD or circular polarization ratio CPR [2] will defined by:

$$XPD = \frac{|E_{RHCP}|}{|E_{LHCP}|}$$ expressed in decibels $$XPD_{[dB]} = 20\,x\log\frac{ar+1}{ar-1}$$

5 Polarization conversion

Table 1 below lists the relationships between the axial ratio AR and the crosspolar discrimination XPD.

Table 1: Cross Polar discrimination as a function of Axial Ratio

AR	AR [dB]	XPD [dB]
1,01	0,09	46,06
1,02	0,17	40,09
1,03	0,26	36,61
1,04	0,34	34,15
1,05	0,42	32,26
1,06	0,51	30,71
1,07	0,59	29,42
1,08	0,67	28,30
1,09	0,75	27,32
1,10	0,83	26,44
1,11	0,91	25,66
1,12	0,98	24,94
1,13	1,06	24,29
1,14	1,14	23,69
1,15	1,21	23,13
1,16	1,29	22,61
1,17	1,36	22,12
1,18	1,44	21,66
1,19	1,51	21,23
1,20	1,58	20,83
1,21	1,66	20,44
1,22	1,73	20,08
1,23	1,80	19,73
1,24	1,87	19,40
1,25	1,94	19,08
1,26	2,01	18,78
1,27	2,08	18,49
1,28	2,14	18,22
1,29	2,21	17,95
1,30	2,28	17,69
1,40	2,92	15,56
1,50	3,52	13,98
1,60	4,08	12,74
1,70	4,61	11,73

AR	AR [dB]	XPD [dB]
1,80	5,11	10,88
1,90	5,58	10,16
2,00	6,02	9,54
2,10	6,44	9,00
2,20	6,85	8,52
2,30	7,23	8,09
2,40	7,60	7,71
2,50	7,96	7,36
2,60	8,30	7,04
2,70	8,63	6,76
2,80	8,94	6,49
2,90	9,25	6,25
3,00	9,54	6,02
3,10	9,83	5,81
3,20	10,10	5,62
3,30	10,37	5,43
3,40	10,63	5,26
3,50	10,88	5,11
3,60	11,13	4,96
3,70	11,36	4,81
3,80	11,60	4,68
3,90	11,82	4,56
4,00	12,04	4,44
4,10	12,26	4,32
4,20	12,46	4,22
4,30	12,67	4,12
4,40	12,87	4,02
4,50	13,06	3,93
4,60	13,26	3,84
4,70	13,44	3,75
4,80	13,62	3,67
4,90	13,80	3,60
5,00	13,98	3,52

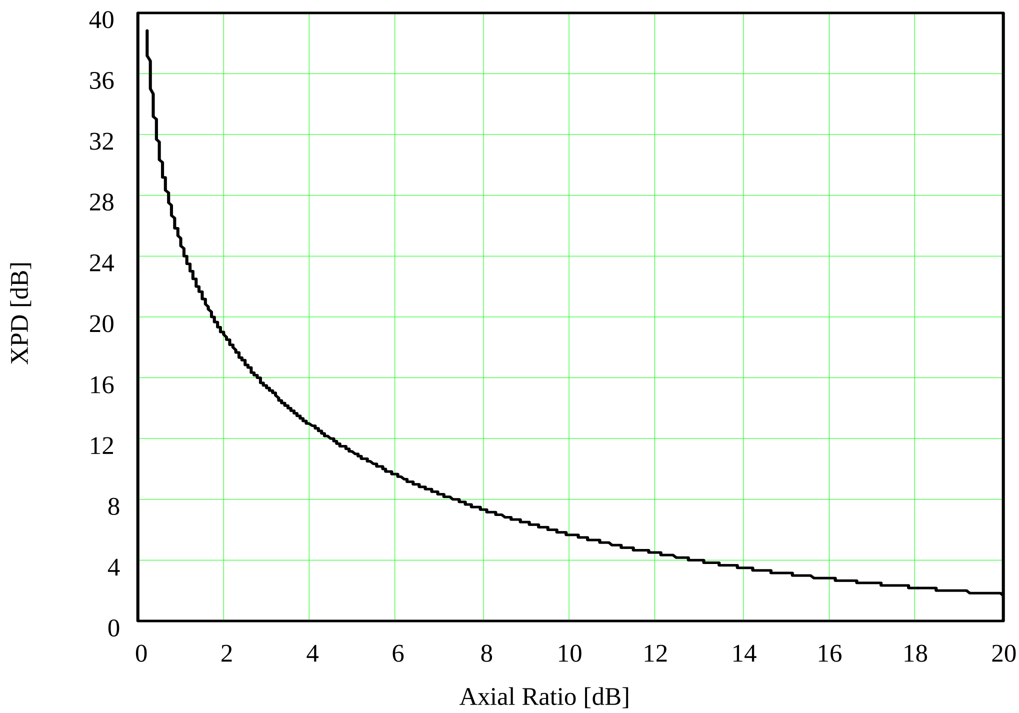


Figure 3: Graphical representation XPD vs axial ratio

6 Pattern Measurement

For circular polarization testing four methods can be used as illustrated in figure 4 [1]. The reference antenna must be either rotatable linear or circular with very small axial ratio:

a) measure phase and amplitude of two linear components;

b) measure amplitude of three or four linear components [3];

c) rotating linear reference antenna;

d) switchable-sense circular polarized reference antenna.

See references for further explanation of the different methods.

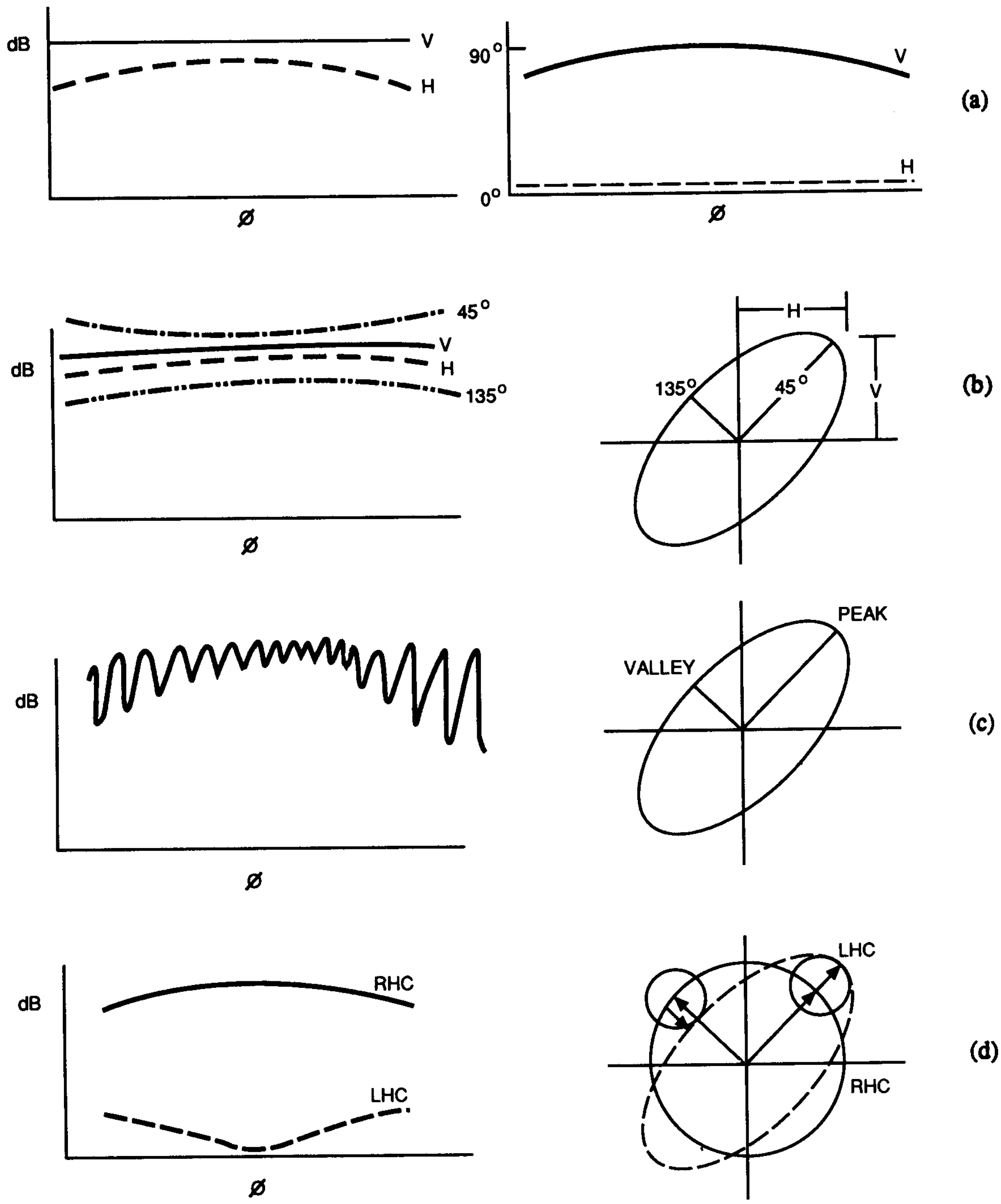


Figure 4: Circular polarization testing methods [1]

7 Examples and comparison of measurement methods

7.1 Comparison of circular vs multiple linear components

Radiation pattern of a circular polarized satellite antenna feed horn measured by using a circular polarized reference antenna with very small axial ratio. The reference antenna is rotated to show the minimum and maximum of cross-polar level.

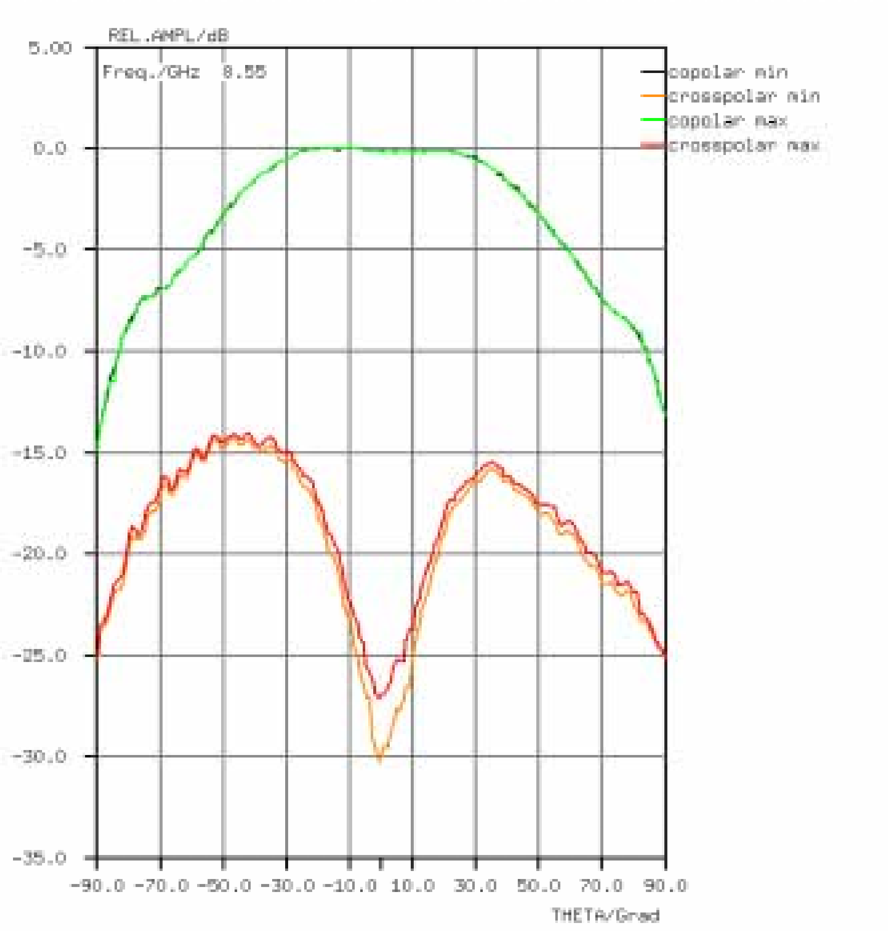


Figure 5: Radiation pattern of a CP antenna

Pattern cuts at 10, 70, 130, 210 degree using a linear reference antenna. Based on these multiple amplitude components the circular pattern can be calculated [3].

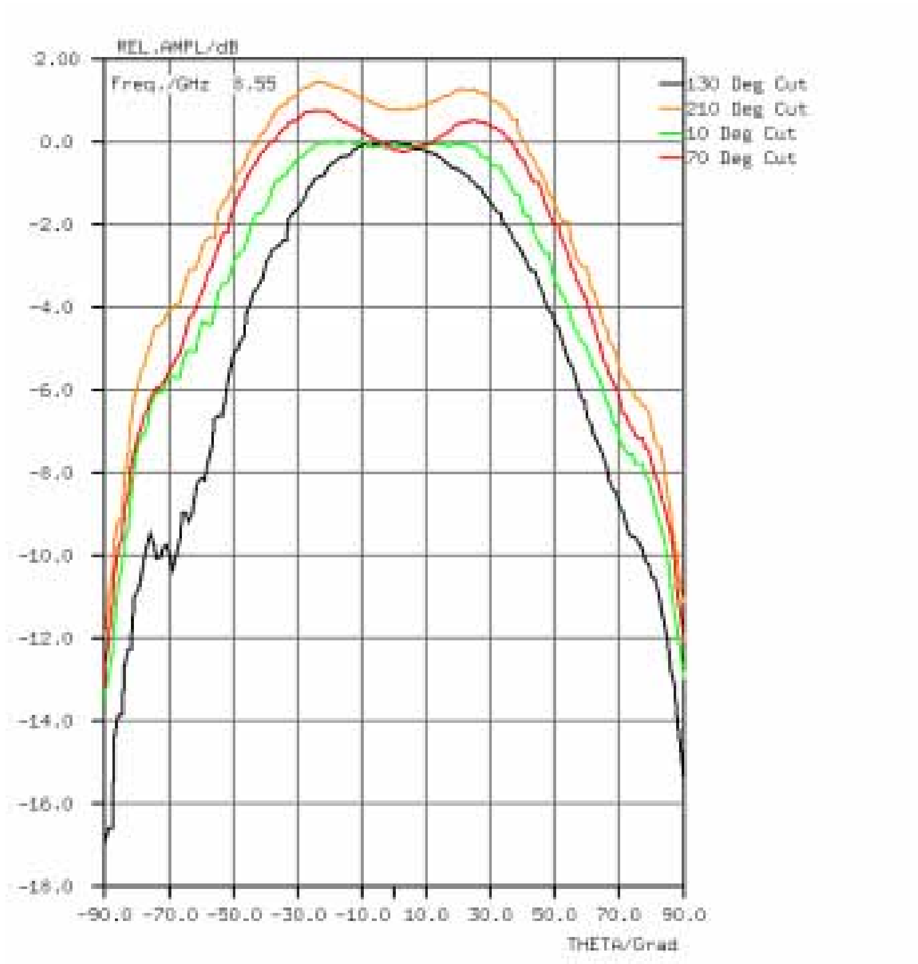


Figure 6: Pattern cuts at 10, 70, 130 and 210 degree using a linear reference anntenna

Comparison of method b) and d) of clause 6. It can be shown that calculated circular pattern is very similar to the measured circular one.

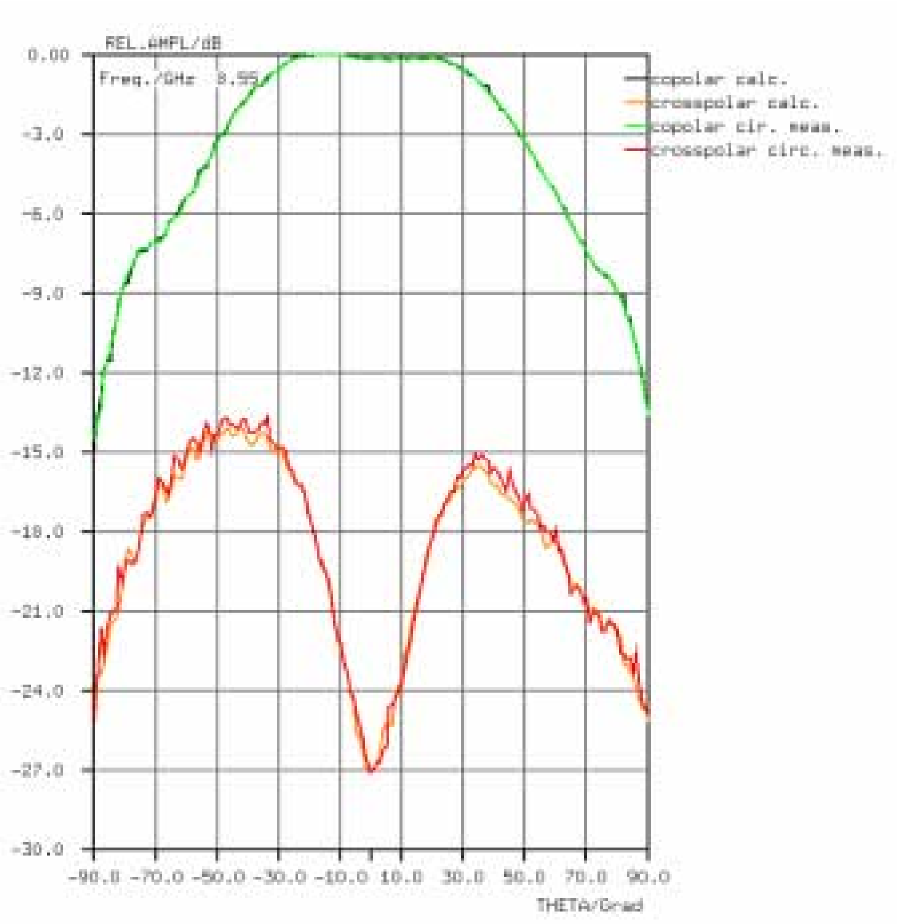


Figure 7: Comparisonn of calculated and measured circular pattern

7.2 Rotating linear polarized reference antenna

This method does not yield either tilt angle or sense of polarization.

The axial ratio over an entire pattern cut can be accomplished by rotating the tilt angle of a linearly polarized transmit antenna while a pattern cut of the antenna under test is being recorded. The rate of rotation of the transmit antenna must be much greater than the angular rate of rotation of the positioner orientating the antenna under test. An axial ratio pattern results. A typical pattern is shown in figure 8. At any given angle the axial ratio can be determined, it being the ratio of the outer to the inner response levels.

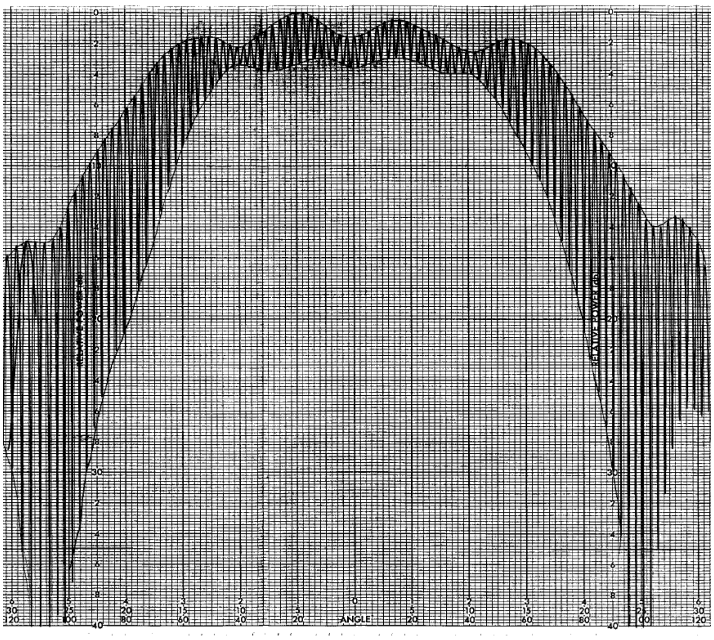


Figure 8: Typical example of an axial ratio pattern measured at ±120 deg.

The antenna under test is a low gain S-band antenna.

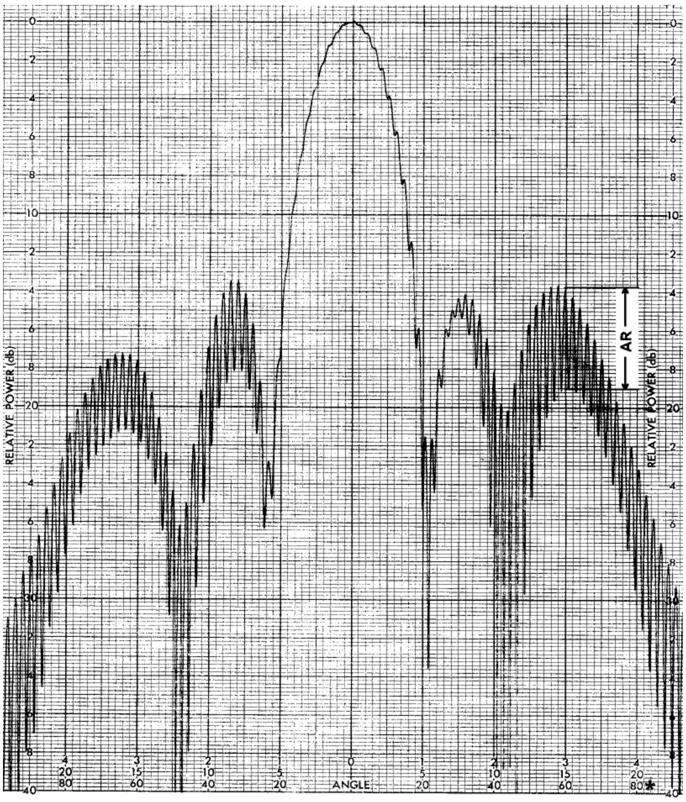


Figure 9: The antenna under test is a 2 x element array using the sequential rotation technique to obtain good axial ratio

8 Typical measurements of a circularly polarized sector antenna

In the following measurement examples of a circularly polarized sector antenna (i.e. CS type) is shown.

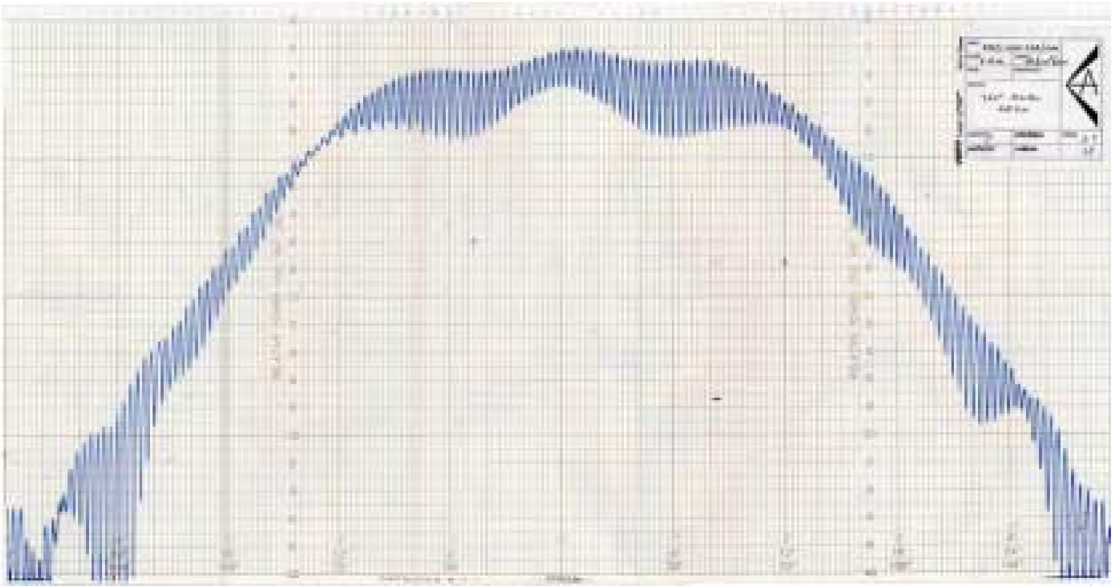


Figure 10: Axial ratio as a function of azimuth angle

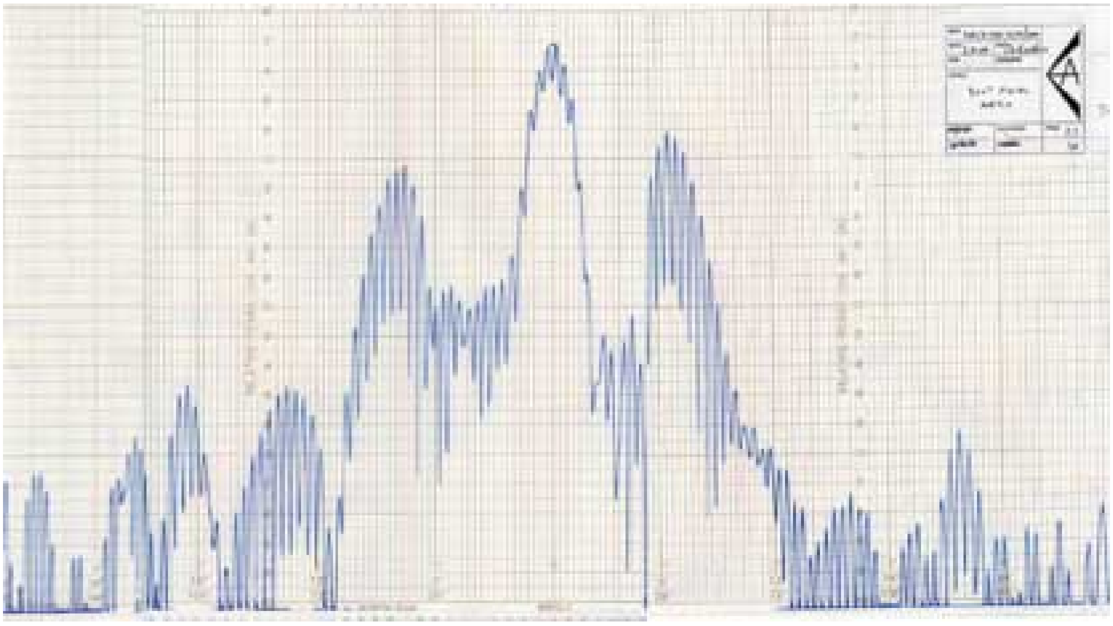


Figure 11: Axial ratio as a function of elevation angle

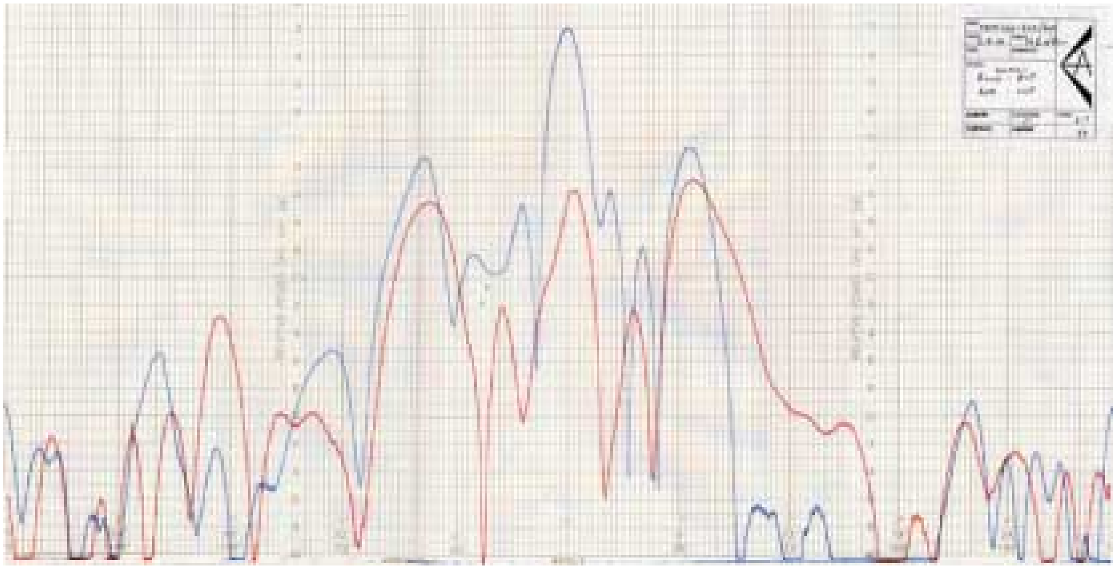


Figure 12: Co and crosspolar signal levels measured to spiral probes as a function of elevation

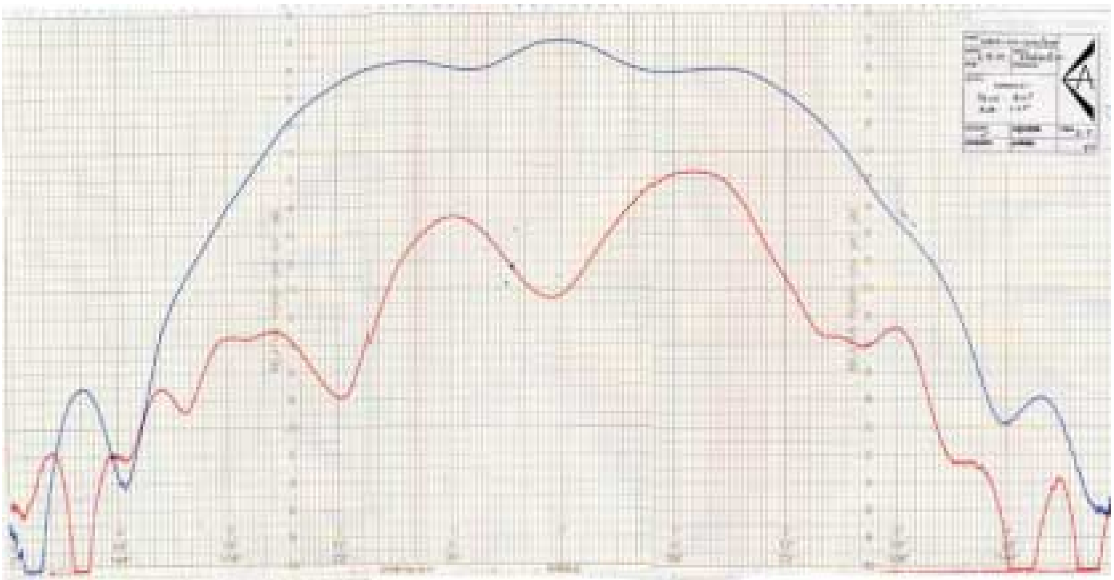


Figure 13: Co and cross-polar signal levels measured to spiral probes as a function of azimuth

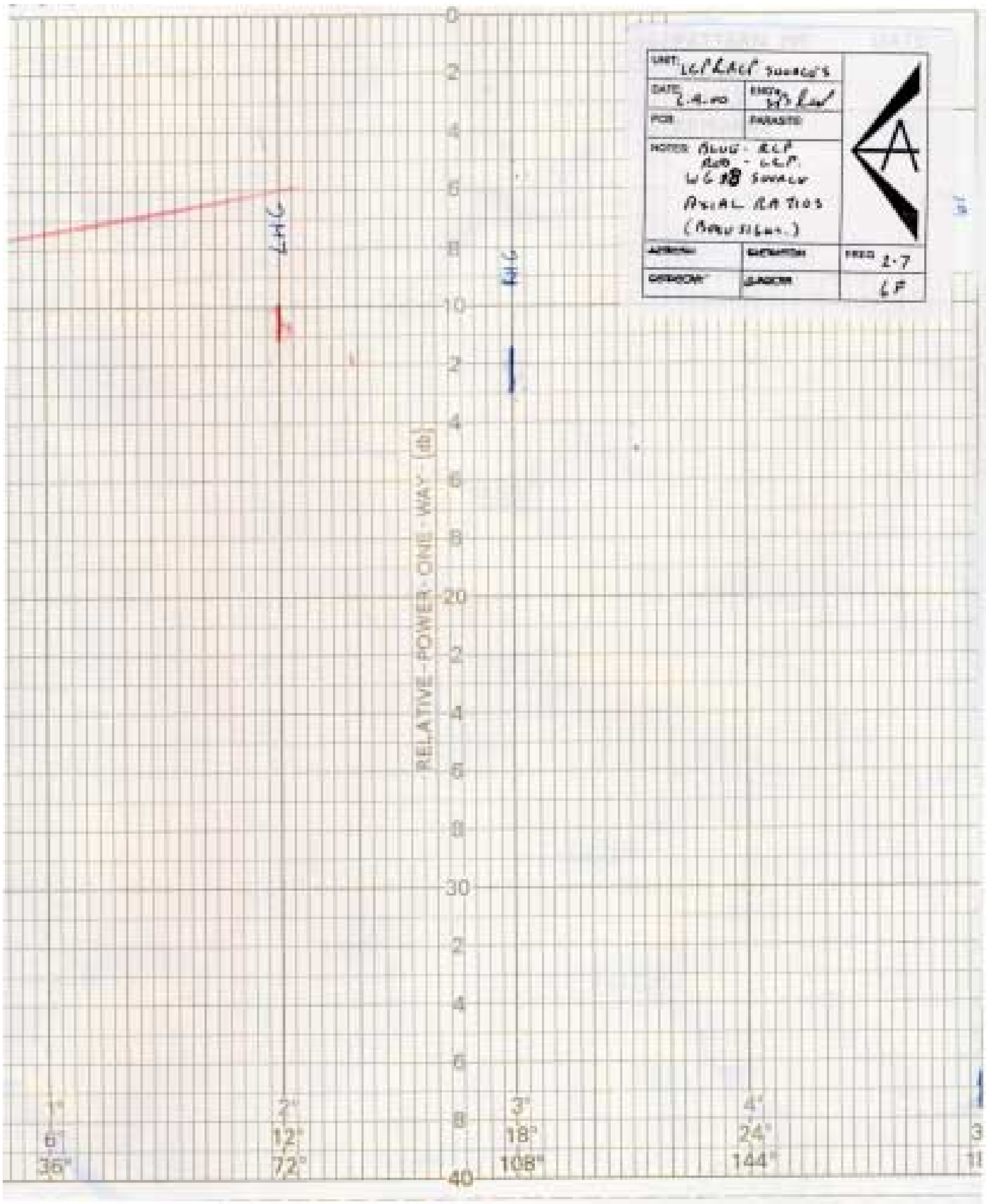


Figure 14: Axial ratio measurements on spiral probes used for figures 10 to 13

The existing conformance testing standard needs to be extended to deal with CP antennas. In the following clause some preliminary information is reported.

9 Radiation Pattern Envelope (RPE)

9.1 Objective

To verify that the antenna radiation pattern, for the declared class and frequency range, is contained within the limits of the stated RPE from the relevant standard. This covers both azimuth and elevation, as applicable.

9.2 Test instruments and set-up

Figure 15 shows a typical test set-up.

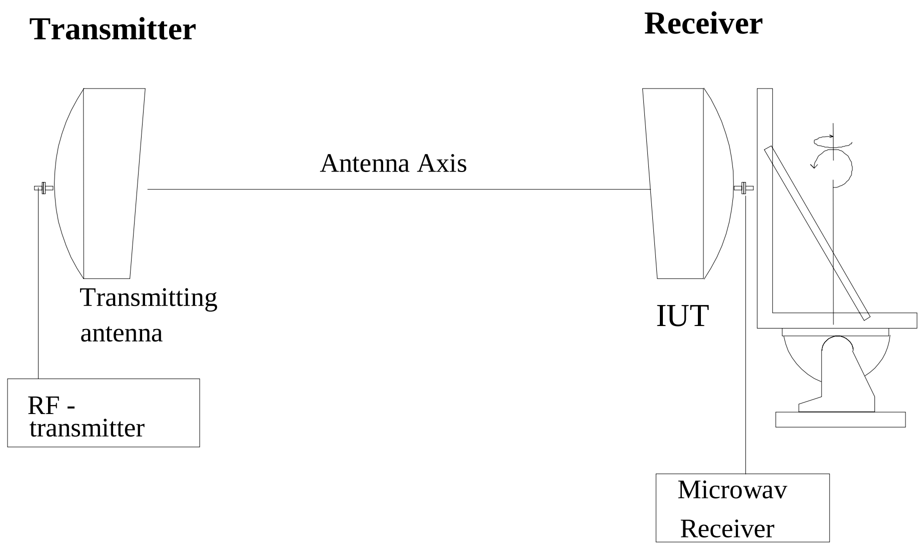


Figure 15: Example of arrangement for the measurement of the radiation pattern

9.3 Test procedure

The test methods described in IEC 835-2-2 [7] are generally applicable. The antenna shall be measured as a minimum at the lowest, middle and highest of the declared frequency band.

The cross-polar radiation patterns shall be recorded after an alignment procedure based on the minimization of the cross-polar level in the frequency band of the antenna. This mechanical setting shall be maintained for all the cross-polar measurements at all frequencies.

Test procedure example (alternative test procedures could be used)- circularly polarized antennas:

1) Initial adjustments are made at the centre frequency of the declared frequency band.

   a) For co-polar patterns, ensure that a circularly polarized transmit antenna, with the same sense (RHCP or LHCP) of polarization is being used.

   b) Align the azimuth and elevation of the transmit antenna and test antenna for maximum signal.

   c) Perform co polar measurements at lower, mid-band and upper frequency in the declared frequency band(s), in the planes of interest.

2) For circularly polarized antennas, axial ratio measurements are made as follows. Alternatively, traditional co- and cross-polar measurements may be performed with circularly polarized transmit antennas.

   a) Using a linearly polarized transmit antenna set in an arbitrary plane of polarization, align the azimuth and elevation of the transmit antennas and test antenna for maximum signal.

   b) With the transmit antenna spinning about the link axis, perform the axial ratio ("spinning dipole") measurements on the test antenna.

10 Antenna gain

10.1 Objective

To verify that the measured gain, for the declared class, category gain and frequency range, satisfies the minimum gain stated in the relevant standard and to use the measured gain to normalize the RPE.

10.2 Test instruments and set-up

Figures 16 to 19 show typical examples of gain measurement test set-ups; in these examples the antenna is taken as having a coaxial or waveguide port respectively.

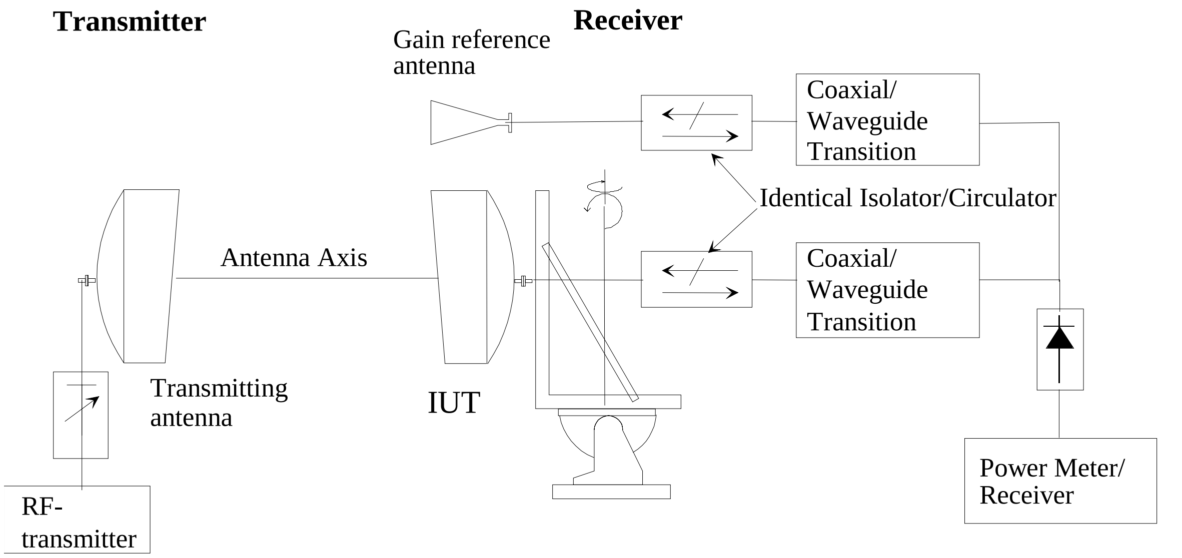


Figure 16: Test set-up for gain measurement by comparison with a gain reference antenna, using coaxial cable

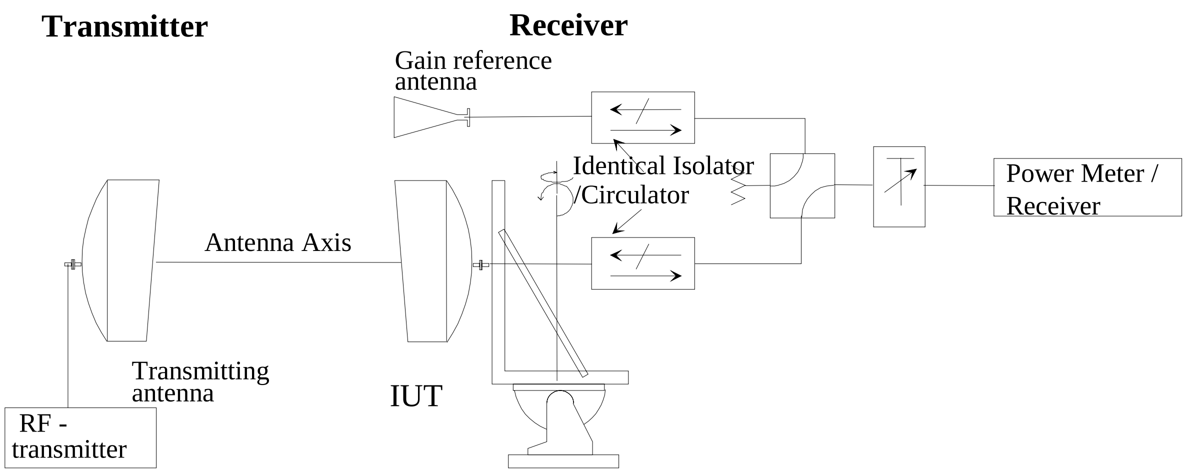
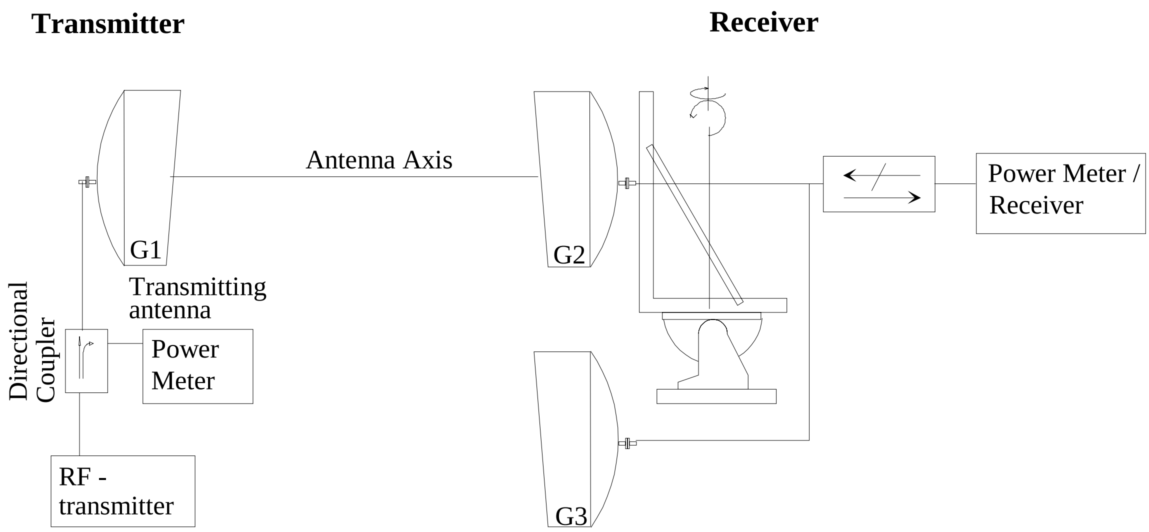


Figure 17: Test set-up for gain measurement by comparison with a gain reference antenna, using waveguides



NOTE: Interchange G1, G2 and G3 in sequence

Figure 18: Test set-up for gain measurement with three antenna method

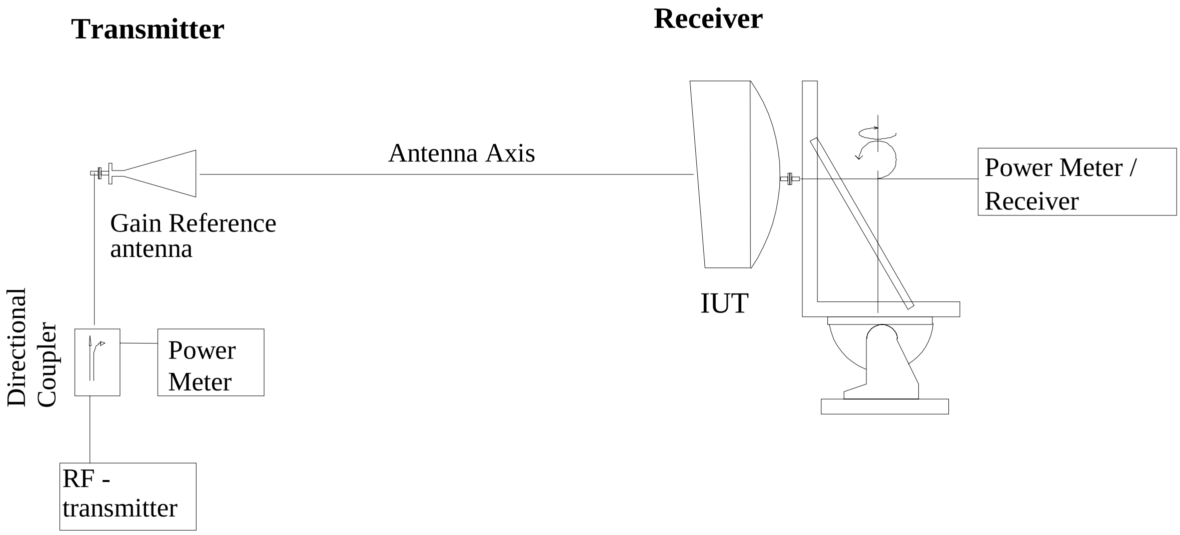


Figure 19: Test set-up for gain measurement with direct method

10.3 Test procedure (alternative test procedures could be used)

The test methods described in IEC 835-2-2 [7] are generally applicable. The antenna gain shall be measured as a minimum at the lowest, middle and highest of the declared frequency band.

For nominally circularly polarized antennas, the method of partial gains may conveniently be used to determine the circularly polarized gain (dBiC). This can be achieved using a test arrangement similar to those shown in figure 16 or figure 17, using a linearly polarized source and a linearly polarized gain reference antenna.

Measure the (linearly polarized) gains for the vertical and horizontally polarized components of the circularly polarized. IUT, by treating the measurements as two linearly polarized gain measurements. Convert these (dB) gains to linear numbers, sum them and convert back to dB to give the resultant CP gain in dBiC.

NOTE: Any two perpendicular orientations can be used, as it can be shown that the total power in any elliptically polarized wave is contained in the sum of any two orthogonal polarizations.

History

Document history		
V1.1.1	January 2002	Publication