RECOMMENDATIONS FOR BASE STATION ANTENNAS

V13.0

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Recommendations for Base Station Antennas

by NGMN Alliance

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1 Abstract

This publication addresses the performance criteria of Base Station Antennas (BSAs), by making recommendations on standards for electrical and mechanical parameters, by providing guidance on measurement and calculation practices in performance validation and production, and by recommending methods for electronic data exchange. It also addresses recommendations on applying existing environmental and reliability standards to BSAs.

This document is combining the earlier Passive Antenna System 12.0 (PAS)

[1] and Active Antenna System 3.0 (AAS)
[2] BASTA documents into a unified BASTA publication.

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2 Introduction and purpose of the document

2.1 Scope

The main scope of the present document is to describe and capture the electrical and mechanical key performance parameters of Passive Antenna Systems (PAS) and Active Antenna System (AAS) and how to exchange this data electronically.

The scope of this publication is limited to base station antennas. Even though antennas will not be categorised in performance-classes, this publication will address antennas built for different purposes. The document has been prepared for sub 6 GHz band antennas but any antenna working in any other band can be described with the parameters included in this publication, if necessary.

In addition, for the purpose of complying with RF-EMF exposure regulation requirements, mechanisms to monitor and limit the power radiated by AAS are described.

2.2 Preface

The performance of a BSA is a key factor in the overall performance and quality of the cellular communication link between a handset and the radio and, by extension, of the performance of a single cell, or of an entire cellular network. The BSA's influence on coverage, capacity, and QoS is extensive, and yet there exists no comprehensive, global, standard focusing on the base station antenna. The purpose of this publication is to address this gap. In particular, the following topics will be covered in various levels of detail:

- Definitions of common BSA electrical and mechanical parameters and specifications.
- Relevance of individual BSA parameters to network performance.
- Issues surrounding various parameters.
- Guidance on antenna measurement practices in design and production.
- Recommendations on:
    - Applying methods to the calculation and validation of specifications.
    - Applying existing environmental and reliability standards to BSA systems.
    - A format for the electronic transfer of BSA specifications from vendor to operator.

The Coordinate System approach has been revised. The Spherical Coordinate System (SPCS Polar) is adopted for descriptions and explanations in this Publication; other Coordinate Systems are described and allowed to be used, as an example for quantification of parameters or generation of the radiation patterns. The Coordinate System adopted for parameter quantification shall be indicated.

Information and data reported in this document are independent of frequency bands and duplex method (FDD/TDD). Reference to specific frequencies is indicated where relevant for the specification of the parameter or information to be reported.

This document is the result of joining the NGMN Passive Antenna Publication

[1] and the NGMN Active Antennas Publication
[2], including additional parameters valid for any type or specific to the typology of antenna.

2.3 Introduction for AAS

Space Division Multiplexing Access (SDMA) technologies are widely considered in the industry to be key enablers for coping with increasing capacity demand. AAS are key technologies for SDMA in next generation mobile communication networks. Such systems allow dynamic beam steering by using multiple technology options (e.g., MIMO, M-MIMO, or beamforming etc.) whose influence on coverage, capacity and QoS is extensive. The purpose of this publication is to provide a comprehensive hands-on document for operating, validating and measuring AAS base stations.

In particular, the following topics are covered:

- Definitions of relevant AAS electrical and mechanical parameters
- EMF monitoring parameters
- Recommended Test States that would allow operators to test antennas in lab or site

3 Generalities

3.1 Interpretation

For the scope of this document, certain words are used to indicate requirements, while others indicate directive enforcement. Key words used numerous times in the publication are:

- ***Shall:*** indicates requirements or directives strictly to be followed in order to conform to this publication and from which no deviation is permitted.
- ***Shall, if supported:*** indicates requirements or directives strictly to be followed in order to conform to this publication, if this requirement or directives are supported and from which no deviation is permitted.
- ***Should:*** indicates that among several possibilities, one is recommended as particularly suitable without mentioning or excluding others; or that a certain course of action is preferred but not necessarily required (*should* equals *is recommended*).
- ***May:*** is used to indicate a course of action permissible within the limits of this publication
- ***Can:*** is used for statements of capability.
- ***Mandatory:*** indicates compulsory or required information, parameter or element.
- ***Optional:*** indicates elective or possible information, parameter or element.

Only three specific methods to deliver antennas technical parameters and information to the customers are hereby taken into consideration:

- **BASTA antenna XML datasheet:**
  - Describes a golden sample of a specific BSA through its technical parameters and additional information.
  - Is an electronic file strictly intended for computer processing.
  - Must be compliant with the XSD schema files for Antennas or RET stored on the NGMN workspace
  - Must adhere to the format and comply with the BASTA Antenna XML rules, which are both specified in this document and in the BASTA Antenna schema file stored in the NGMN web space.
  - Must contain all "required" parameters applicable to the described BSA.
  - May contain "optional" parameters applicable to the described BSA.
  - Must contain a reference to the publication release used.

- **BASTA antenna Datasheet:**
  - Describes the golden sample or of a specific BSA through its technical parameters and additional information.
  - May either be printed or delivered in a humanly readable electronic format.
  - Is not intended for computer processing and does not require following any specific format.
  - Must contain all "required" parameters applicable to the described BSA.
  - May contain "optional" parameters applicable to the described BSA.
  - Must comply with the rules specified in this document.
  - Must contain a reference to the BASTA Antenna Publication release.
- **3D Radiation Pattern File format:**
  - For details see Section 14.

A golden sample is a version of the product in which the vendor specifies the development stage of the product, see section 7.2.1.

3.2 NGMN BASTA data files repository

XML description of parameters, XML schema and XML example can be found in https://ngmn.org/schema/ubastav13/

3DRP file format examples can be found in https://ngmn.org/schema/ubastav13/

3.3 References

This publication incorporates provisions from other publications. These are cited in the text and the referenced publications are listed below. Where references are listed with a specific version or release, subsequent amendments or revisions of these publications apply only when specifically incorporated by amendment or revision of this publication.

For references listed without a version or release, the latest edition of the publication referred to applies.

[1] NGMN "Recommendations on Base Station Antenna Standards v12.0", https://www.ngmn.org/wp-content/uploads/BASTA-Passive-Antennas-WP12.0.pdf, 24/01/2022.

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[3] IEEE Std. 145-2013 Standard definitions of Terms for Antennas
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[9] 3GPP TS 38.141-2 Base Station (BS) conformance testing. Part 2: Radiated conformance testing
[10] IEC TR 62232: 2022, Edition 3.0 - Determination of RF field strength, power density and SAR in the vicinity of radiocommunication base stations for the purpose of evaluating human exposure (106/511/CD of 2019-12-20)
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[23] EIA/TIA 222-G Structural Standard for Antenna Supporting Structures and Antennas.
[24] EN 1991-1-4 Eurocode 1: Actions on structures - Part 1-4: General actions - Windloads.
[25] ETSI EN300019-1-1 Environmental Engineering (EE); Environmental conditions and environmental tests for telecommunications equipment. Part 1-1: Classification of environmental conditions.
[26] ETSI EN 300019-1-2 Equipment Engineering Environmental conditions and environmental tests for telecommunications equipment. Part 1-2: Classification of environmental conditions Transportation.
[27] ETSI EN 300019-1-4 Equipment Engineering (EE); Environmental conditions and environmental test for telecommunications equipment. Part 1-4: Classification of environmental conditions Stationary use at non-weather protected locations.
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[29] IEC 60068-2-2 Environmental testing – Part 2-2: Tests – Test B: Dry heat.

[30] IEC 60068-2-6 Environmental testing – Part 2-6: Tests – Test Fc: Vibration (sinusoidal).
[31] IEC 60068-2-11 Basic Environmental Testing Procedures, Part 2: Test Ka: Salt Mist.
[32] IEC 60068-2-14 Environmental testing – Part 2-14: Tests – Test N: Change of temperature.
[33] IEC 60068-2-18 Environmental testing – Part 2-18: Tests – Test R and guidance: Water.
[34] IEC 60068-2-27 Environmental testing – Part 2-27: Tests – Test Ea and guidance: Shock.
[35] IEC 60068-2-30 Environmental testing – Part 2-30: Tests – Test Db: Damp heat, cyclic (12 h + 12 h cycle).
[36] IEC 60068-2-31 Environmental testing – Part 2-31: Tests – Test Ec: Rough handling shocks, primarily for equipment-type specimen.
[37] IEC 60068-2-56 Environmental testing - Part 2: Tests. Test Cb: Damp heat, steady state, primarily for equipment.
[38] IEC 60068-2-64 Environmental testing – Part 2-64: Tests – Test Fh: Vibration, broadband random and guidance.
[39] IEC 60068-2-68 Environmental Testing - Part 2: Tests - Test L: Dust and Sand.
[40] IEC 60529 Degrees of Protection Provided By Enclosures (IP CODE).
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[45] IEC 61754 series
[46] IEC 61755 series

3.4 Abbreviations

The abbreviations used in this publication are explained in the following table:

Table 3-1: Acronyms and abbreviations table.

Abbreviation	Definition
3GPP	3rd Generation Partnership Project
AAS	Active Antenna System
AIR	Azimuth Interference Ratio
AISG	Antenna Interface Standards Group
AR	Angular Region
AUT	Antenna Under Test
AVG	Average
AZ	Azimuth
BERP	Broadcast Envelope Radiation Pattern
BBU	Base Band Unit
BF	Beamforming
BSA	Base Station Antenna
BS	Base Station
CBB	Code Book-Based Beamforming
Co-Pol	Co-Polar
CPD	Cross-Polar Discrimination. XPD or XPR are also used

CPI	Cross-Polar Isolation
Cr-Pol (or X-Pol)	Cross-Polar
CW	Continuous Wave
dBc	Decibel referred to Carrier
DL	DownLink
E-UTRA	Evolved UMTS Terrestrial Radio access
EBB	Eigen Based Beamforming
EIRP	Equivalent Isotropic Radiated Power
EL	Elevation
EMF	Electromagnetic Field
ETSI	European Telecommunication Standards Institute
F/B or FBR or F2B	Front-to-Back ratio
FF	Far-Field
FFT	Fast Fourier Transform
FDD	Frequency Division Duplex
GoB	Grid of Beams
H_HPBW	Horizontal HPBW
HPAA	Hybrid Passive and Active Antenna
HPBW	Half-Power Beamwidth
HOS	Higher Order Sectorization
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical & Electronic Engineers
LHCP	Left-Handed Circular Polarization OR Circularly Polarized
M-MIMO	Massive MIMO
MIMO	Multiple Input/Multiple Output
MSR	Multi Standard Radio
MTBF	Mean Time Between Failures
MU-MIMO	Multi-User MIMO
N/A or NA	Not Available or Not Applicable
NF	Near Field
NGMN	Next Generation Mobile Network Alliance
NR	New Radio
N/S or NS	Not Specified
O&M	Operation and Maintenance
OEWG	Open-Ended WaveGuide
P-BASTA	Project Base Station Antennas
PAS	Passive Antenna System
PBCA	Passive Beamforming Capable Antenna
PCF	Polarization Correlation Factor
PDF	Probability Distribution Function
PIM	Passive Inter Modulation
QoS	Quality of Service
R&D	Research and Development
RDN	Radio Distribution Network
RAT	Radio Access Technology
RET	Remote Electrical Tilt
RF	Radio Frequency
RFQ	Request For Quotation

RHCP	Right-Handed Circular Polarization OR Circularly Polarized
RL	Return Loss
RXU	Receiver Unit
SDMA	Space Division Multiplexing Access
SI	System International
SLS	SideLobe Suppression
SPCS	SPherical Coordinate System
SPCS_Geo	SPherical Coordinate System Geographics
SPCS_CW	SPherical Coordinate System Clockwise
SPCS_CCW	SPherical Coordinate System Counterclockwise
SPCS_Polar	SPherical Coordinate System Polar
SU-MIMO	Single user MIMO
TAB	Transceiver Array Boundary
TDD	Time Division Duplex
TEM	Transverse Electric and Magnetic
TERP	Traffic Envelope Radiation Pattern
TR	Technical Report
TRX	Transceiver
TRXUA	Transceiver Unit Array
TXU	Transmitter Unit
TS	Technical Specification
UE	User Equipment
UL	Up Link
UMTS	Universal Mobile Telecommunications System
USLS	Upper SideLobe Suppression
V_HPBW	Vertical HPBW
VNA	Vector Network Analyzer
WP	Publication
VSWR	Voltage Standing Wave Ratio
XML	eXtensible Markup Language
XSD	XML Schema Definition
ZFB	Zero Forcing-Based Beamforming

4 Passive and Active Antenna Systems

Unless otherwise stated, definitions from [3] apply.

The scope of this Section is to contribute to give a functional description of antenna systems for mobile cellular networks, setting the boundary between passive and active antenna systems.

3GPP [4], in base station type BS-Type 1-C, clearly defines the interface between BTS and passive antenna namely as radio frequency (RF)-interface, Figure 4.1. However, a definition of passive antenna is not given, and the antenna block is not shown in the diagram.

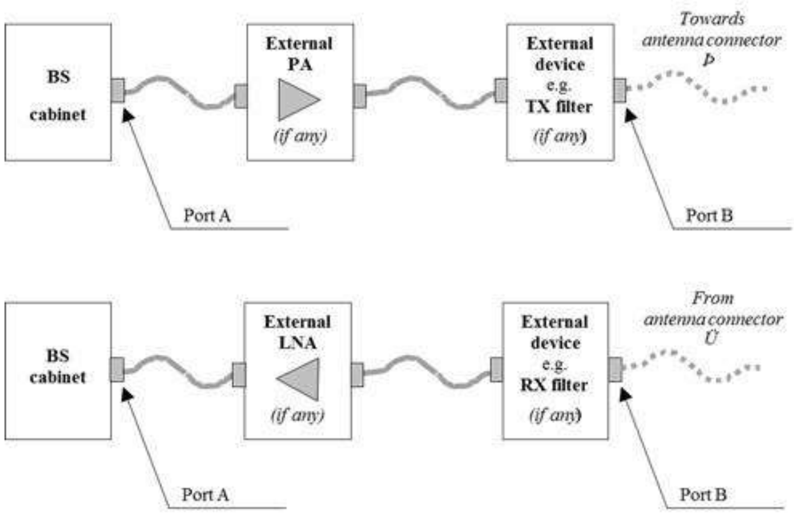


Figure 4.1: 3GPP BS-Type 1-C

A Passive Antenna is a device which performs the function to transform conducted RF signals to electromagnetic field over the air and vice versa, with assigned phases and amplitudes. It is composed of:

- NxM Antenna Array, with N≥1, M≥1
- Radio Distribution Network (RDN), optionally including Remote Electrical Tilt (RET) device

For instance, for the purpose of network planning, passive BTS antennas offer the possibility to setup a so called down tilt

[1]. This means that PAS has the capability to point the radiation pattern within a range in the elevation plane for the purpose of coverage optimisation. The down tilt adjustment is performed by sending commands remotely through the AISG interface [5]. Those drive Remote Electrical Tilt devices installed in the passive antenna which allow electromechanical adjustment of the phase shifter a few times over the whole antenna lifetime [6].

The mechanical adjustment of the phase path is performed in the Radio Distribution Network (RDN) which is not defined in BS-Type 1-C. This is defined in BS-Type 1-H, Figure 4.2, as "the RDN is a linear passive network which distributes the RF power generated by the transceiver unit array to the antenna array, and/or distributes the radio signals collected by the antenna array to the transceiver unit array, in an implementation specific way".
The simplest implementation consists in a one-to-one Transceiver Array Boundary (TAB) port to single antenna element connection.

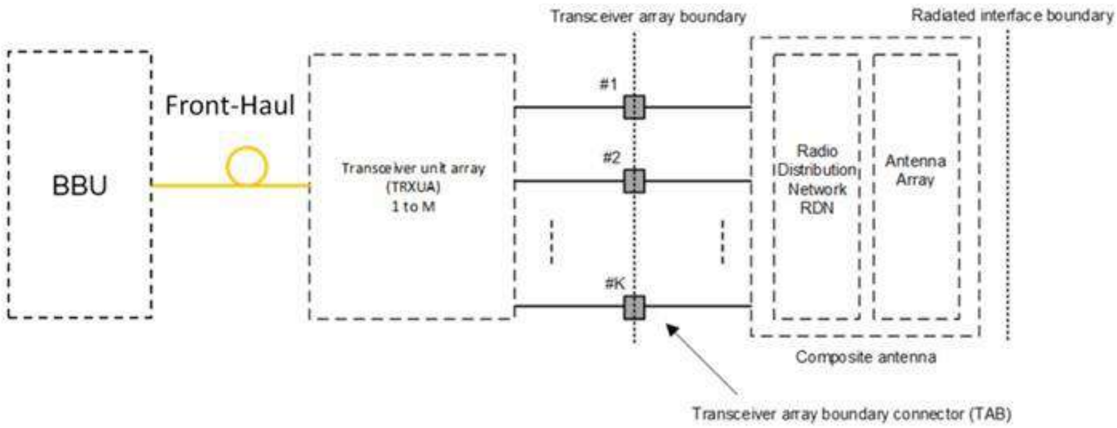


Figure 4.2: BS-Type 1-H and BBU

The RDN is passive, see Figure 4.2, and the RDN and Antenna Array form the so-called Composite antenna which can be still accessible via a radio frequency (RF)–Interface through the TAB connector.

Following this definition path, the Composite antenna is a passive antenna. For instance, at the TAB conducted measurements of the Composite antenna can be performed. Through the TAB, the Composite antenna supports real time beam steering to enable SDMA applications.
Indeed, through the TRXUA the composite antenna can be fed with assigned phases and amplitudes at TAB resulting in different radiation patterns.

Precisely, the Base Band Unit (BBU) can handle multiple users by calculating the optimal phases and amplitudes also known as pre-coders in real time. The goal is to optimise network performance by load control and advanced interference management. This means that the BBU represents the core intelligence, the TRXUA and Composite antenna the supporting devices.

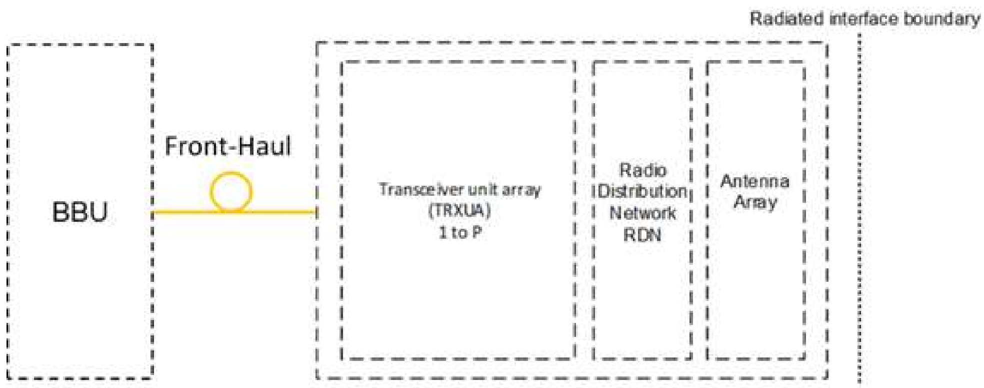


Figure 4.3: BS-Type 1-O and 2.O combined with BBU

In 3GPP BS-Type 1-O (at least 8 TRXUA) and 2-O, see Figure 4.3, TRXUA, RDN and AA are fully integrated. In this case conducted measurements for the Composite antenna are not possible. Only Over the Air (OTA) measurements through the Radiated interface boundary are possible as the RF-Interface is no longer available.

This is an AAS, which integrates TRXUA, RDN and Antenna Array together, and the interface to BBU is via a Front-Haul.
Similarly, to the BS-Type 1-H the AAS is the supporting device and the BBU is the core intelligence, Figure 4.3.

Summarizing, in BS-Type 1-C and 1-H, there is no passive antenna definition where the concept of Composite antenna as combination of RDN and Antenna Array is introduced. In BS-Type 1-O and 2-O, AAS is defined.

Here below a comprehensive definition of a Passive Antenna (PA) will be introduced, derived from the functional blocks introduced by 3GPP: Antenna Array, RDN and RET.
Basic concepts of passive antenna element and their combinations in Arrays will be reviewed and their functional relations discussed.

Passive Antennas basic definitions
Specifically considering radio waves, which are a type of electromagnetic (EM) radiation with wavelengths in the electromagnetic spectrum longer than infrared light (3 kHz to 300 GHz), one can derive a more practical definition of passive antenna element for telecommunication industry: a passive antenna element is a device which transforms radio frequency (RF) signals to radio waves and vice versa. The RF-Signals generator – TRXUA - is connected to the passive antenna element by an RF-interface. Figure 4.4 shows a function schematic of a passive antenna.

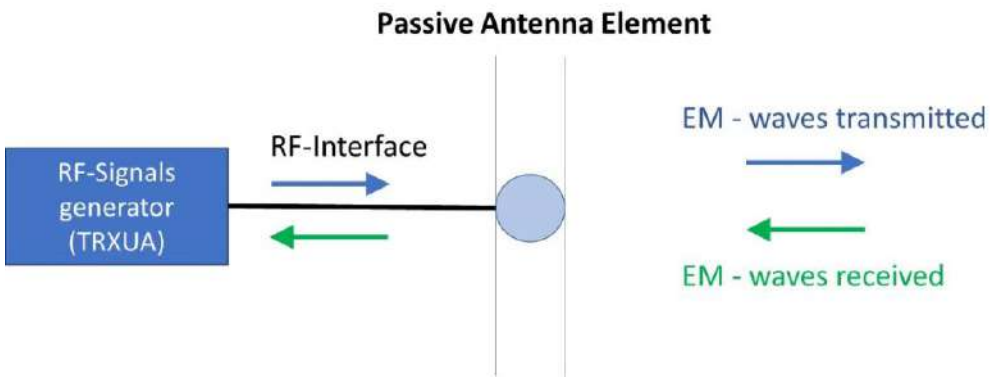


Figure 4.4: Passive antenna element functional block

Radio waves can be combined in patterns produced by multiple passive antenna elements properly distributed in space. For this reason, this definition is easily extendible to groups of passive antenna elements which are best represented by means of NxM-matrixes also called in common technical language "Array". Matrixes are linear operators which also transform the state of a system to another state.
This means that Arrays, have the capability to transform RF-signals distributed over all elements (Matrixes entries) to radio waves to form combined radiation patterns. Similarly, to the single passive element, the passive Array is connected to the RF-Signals generation via an RF-interface. Also, in this case the RF-Signals are distributed over the passive antenna elements via a RDN, Figure 4.3.
Arrays can be best described by classical antenna theory [7]. For the purpose of a functional description and without losing on generality – radio waves are linear - we consider a uniform linear Array [7], Figure 4.5. By observing the antenna radiation pattern in the far field region, waves from antenna element can be treated as plane waves, and the rays theory applies.
In this setup N is the number of elements, d the spacing between the elements, θ the radiation pattern direction which can be changed by properly choosing the phase difference between the radiating elements and superimposing the elements patterns into the far-field region [7], Figure 4.5 (a). As an example, in Figure 4.5

(b), it is shown the change of radiation pattern when increasing linearly the number of elements when all the passive antenna elements use the same phase/amplitude.

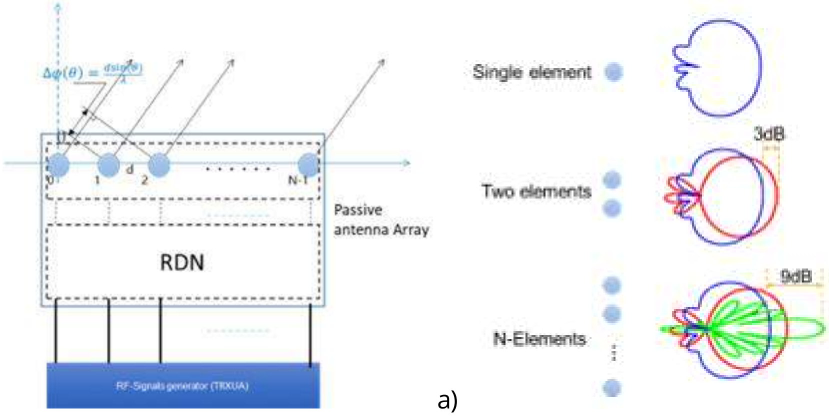


Figure 4.5: (a) Passive Antenna Array. (b) Example of radiation pattern changing when increasing the number of radiating elements

From the functional view point the passive antenna array is composed by the antenna array and RDN. In the case shown in Figure 4.5(a) then, the RDN is simply composed by RF- transmission lines connecting one to one the passive antenna elements of the array to the RF-signals from/to the TRXUA thought an RF-Interface. This concept, considering the linearity, can be extended to more complex RDN architectures in which, for design purposes, hardware coded phase and amplitudes distribution can be implemented, multiple antenna elements can be grouped, etc. Also, in this case the RDN functionality is identical, linear and reciprocal.
Along this path a passive antenna array is device which supports the function to transform the RF-signals from/to the TRXUA through an RF-interface with assigned phases and amplitudes to radiation patterns and vice versa. Similarly, to BS-Types discussed above, the BBU handles multiple users and calculates phase and amplitudes in real time to minimize the interference in the network, Figure 4.6.

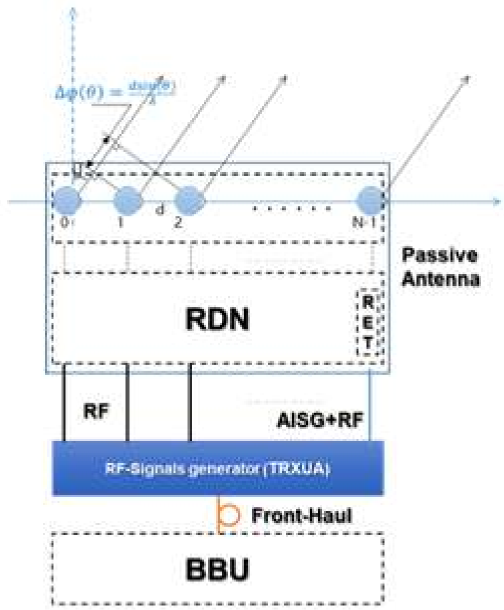
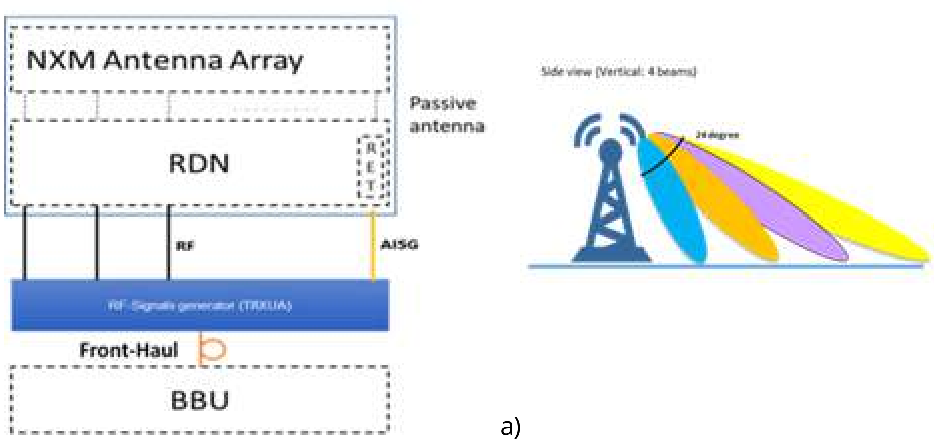


Figure 4.6: Passive Array with TRXUA and BBU



a) b)

Figure 4.7: (a) Passive Antenna with integrated RET device. (b) Down Tilt example

As was mentioned in the introduction, for the case of passive BTS antennas, it is convenient to offer the possibility to change the down tilt value for the goal of optimising network performance [6], Figure 4.7 (b). The down tilt adjustment is implemented by Remote Electrical Tilt devices controlled over the AISG interface [5]. The RET is controlling the phase shifters according to AISG input - see Figure 4.7 (a).
The RET device, combined with the RDN, supports the functionality to change the effective physical path of the RF-signals, affecting therefore the elevation beam pointing direction to allow coverage planning. This is a hardware functionality which enables the RDN to be reconfigured for several coverage scenarios.

5 Antenna Reference Coordinate Systems

5.1 Cartesian Coordinate Reference System (CCRS_Cartesian) and Antenna Reference Coordinate System

The Cartesian Coordinate Reference System (CRS) adopted in this Publication is shown in Figure 5.1.

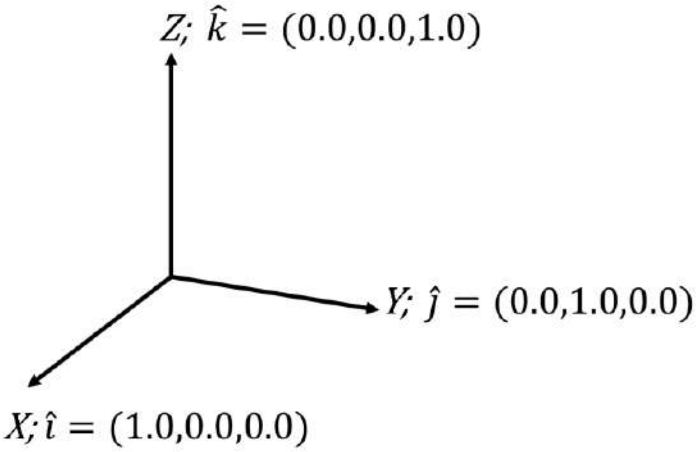


Figure 5.1: The Cartesian Coordinate System (CCRS) adopted in this Publication

Relations between vectors of the coordinate system are:

$$\hat{\imath} \cdot \hat{\jmath} = \hat{\imath} \cdot \hat{k} = \hat{\jmath} \cdot \hat{k} = 0 \tag{5.1}$$
$$\hat{\imath} \times \hat{\jmath} = \hat{k} \tag{5.2}$$
$$\hat{\imath} \times \hat{k} = -\hat{\jmath} \tag{5.3}$$
$$\hat{\jmath} \times \hat{k} = \hat{\imath} \tag{5.4}$$

The antenna is oriented to the CCRS_Cartesian as shown in Figure 5.2.

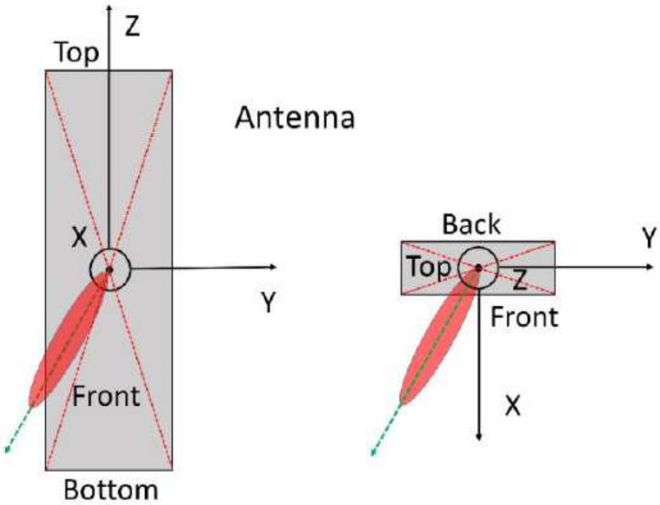


Figure 5.2: Antenna Positioning and Orientation in the CCRS_Cartesian

By considering the minimum parallelepiped including the antenna, with the front side corresponding to the half space where is located the maximum of the radiation, then:

- The top of the antenna corresponds to the positive Z axis
- The bottom of the antenna corresponds to the negative Z axis
- The front of the antenna is directed toward the positive X Axis
- The back of the antenna is directed toward the negative X Axis
- The sides of the antenna are directed toward the Y axis

Unless specified, the mechanical boresight corresponds to the X axis in Figure 5.2. For antenna geometries different from Figure 5.2, the vendor can define the mechanical boresight.

5.2 Spherical Coordinate Systems

5.2.1 General

Associated to the CCRS_Cartesian there is a spherical coordinate system for representing points on a spherical surface for describing parameters and properties of the antenna. There can be multiple options to represent the angular coordinates, each one has pros and cons depending on the usage. The following criteria are adopted for describing angles in this Publication:

- The Spherical Polar Coordinate System (SPCS_Polar) is adopted in the body of this Publication, Section 5.2.2.
- Other Spherical Coordinate System are available, described in the following sections, that can be adopted for specific uses, like the representation of the antenna's radiation pattern, see Section 14.
- The Spherical Coordinate System CRS for describing specific parameter or features in the Radiation Pattern file format (see Section 14) and XML data file must be declared, see Section 7.2.3.

To avoid ambiguities in the usage of different coordinate system, the following terminology convention is adopted:

- With the term "Elevation" or "Elevation Coordinate" is intended the angular coordinate that scans the sphere, on a half-circle, from the Positive Z axis to the Negative Z axis or vice versa, see Sections 5.2.2, 5.2.3, 5.2.4, 5.2.5. The positive direction and limits are specific of the adopted SPCS. The symbol used for identifying the elevation direction is the Greek symbol ϑ or Θ or the term "Theta" or "theta"; where required the symbol or the term is complemented with a subscript indicating univocally the SCPS at which symbol or term is referred to.
- With the term "Azimuth" or "Azimuthal Coordinate" is intended the angular coordinate that scans the sphere on a circle at constant Z. The positive direction and limits are specific of the adopted SPCS, see Sections 5.2.2, 5.2.3, 5.2.4, 5.2.5. The symbol used for identifying the azimuth direction is the Greek symbol φ or Φ or the term "Phy" or "phy"; where required the symbol or the term is complemented with a subscript indicating univocally the SPCS at which symbol or term is referred to.
- With the term "radius" is intended the radius of the sphere centred at the origin of the SPCS. The radius starts from the centre of the SPCS and ends to the point on the sphere's surface, see Sections 5.2.2, 5.2.3, 5.2.4, 5.2.5. The symbol used for identifying the radius direction is the symbol r or R or the term "Radius" or "radius"; where required the symbol or the term is complemented with a subscript indicating univocally the SPCS at which symbol or term is referred to.
- A point P(x,y,z) on the sphere's surface is represented by its elevation and azimuthal coordinates and radius: P(x,y,z) = P(r,ϑ, φ) = P(Radius, Θ, Φ) = P(radius,Theta,Phy) or any combination of symbols and terms. The same point can have different values for radius, elevation and azimuthal coordinates depending on the convention used by the adopted SPCS.

- Angles are expressed in degrees: a number followed by the symbol "°". If the symbol or the term is missing the angle is intended in degrees.
- Metric quantities are expressed in terms of meters, like radius, x,y,z coordinates; if the unit is missing, meters are intended
- Other information relevant to specific usages of the adopted SPCS can be included in the XML or 3drp.json (see Section 14).

In this Publication the adopted SPCS is the Polar Coordinate System [7] [8], as explained in Section 5.2.2, indicated with the term SPCS_Polar, for describing angles in the body of this document.

5.2.2 Spherical Polar Coordinate System (SPCS_Polar)

The centre of the SCS_Polar is placed at the (0.0, 0.0, 0.0) position of the CCRS_Cartesian, as shown in Figure 5.3.

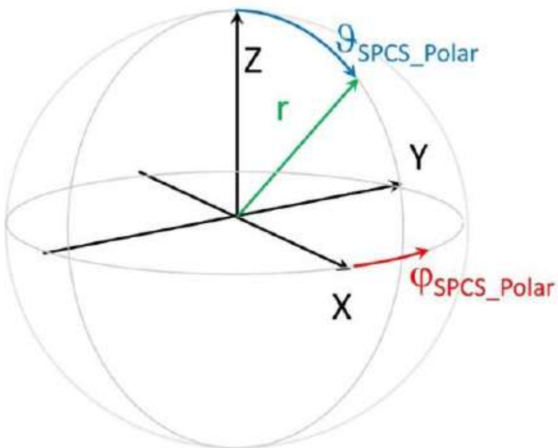


Figure 5.3: The Polar Coordinate System SPCS_Polar

In the SCS_Polar system

- r is the distance from the CRS centre to the point on the sphere, see the green arrow in Figure 5.3
- the ϑ_{SPCS_Polar} angular coordinate ranges from 0.0° to 180.0° starting from the Positive Z axis toward the Negative Z axis (see the blue arrow in Figure 5.3). This coordinate is referenced as elevation.
- The φ_{SPCS_Polar} angular coordinate ranges from 0° to < 360° starting from the X axis counterclockwise looking downward from the Z Positive Axis (see the red arrow in Figure 5.3). This coordinate is referenced as azimuth.

Note: for convenience, azimuth angles from 180° to 360° may be indicated as difference from 360°: for example 270° may be indicated as -90°; 350° may be indicated as -10°.

The cartesian coordinates of a point on the sphere are given by

$$x = r\ sin\vartheta\ cos\varphi \qquad y = r\ sin\vartheta\ sin\varphi \qquad z = r\ cos\vartheta \tag{5.5}$$

5.2.3 Spherical Polar Coordinate System Clockwise (SPCS_CW)

The SPCS_CW is shown in Figure 5.4, it has the centre at the (0.0, 0.0, 0.0) position of the CCRS_Cartesian.

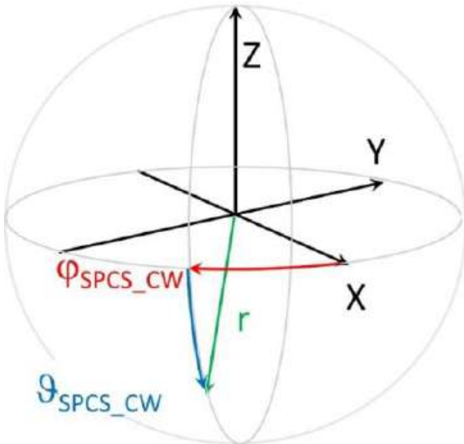


Figure 5.4: Antenna Reference Coordinate System SPCS_CW

In the SPCS_CW system:

- r is the distance from the SPCS_CW centre (see the green arrow in Figure 5.4)
- the ϑ_{SPCS_CW} angular coordinate ranges from -90.0° to 90.0° starting from the Positive Z axis toward the Negative Z axis (see the blue arrow in Figure 5.4). This coordinate is referenced as elevation; the elevation coordinate assumes the value 0° on the XY plane at Z = 0.
- The φ_{SPCS_CW} angular coordinate ranges from 0° to < 360° starting from the X axis clockwise looking downward from the Z Positive Axis (see the red arrow in Figure 5.4).

Note: for convenience, azimuth angles from 180° to 360° may be indicated as difference from 360°: for example 270° may be indicated as -90°; 350° may be indicated as -10°. The cartesian coordinates of a point are given by

$$x = r \sin{(\vartheta + 90.0)} \cos{(360.0 - \varphi)}$$
$$y = r\, sin(\vartheta + 90.0)\, sin(360.0 - \varphi)$$
$$z = r\, cos\, (\vartheta + 90.0)$$

(5.6)

5.2.4 Spherical Polar Coordinate System Counterclockwise (SPCS_CCW)

The SPCS_CCW is shown in Figure 5.5, it has the centre at the (0.0, 0.0, 0.0) position of the CCRS_Cartesian.

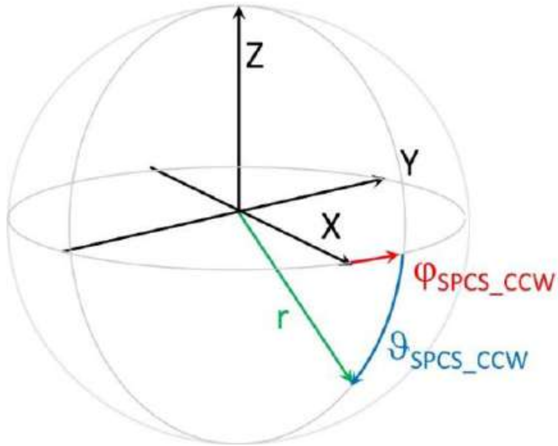


Figure 5.5: Antenna Reference Coordinate System SPCS_CCW

In the SPCS_CCW system

- r is the distance from the SPCS_CCW centre (see the green arrow in Figure 5.5)
- The ϑ_{SPCS_CCW} angular coordinate ranges from -90.0° to 90.0° starting from the Positive Z axis toward the Negative Z axis (see the blue arrow in Figure 5.5). This coordinate is referenced as elevation; the elevation coordinate assumes the value 0° on the XY plane at Z = 0.
- The φ_{SPCS_CCW} angular coordinate ranges from 0° to < 360° starting from the X axis counterclockwise looking downward from the Z Positive Axis (see the red arrow in Figure 5.5).

Note: for convenience, azimuth angles from 180° to 360° may be indicated as difference from 360°: for example 270° may be indicated as -90°; 350° may be indicated as -10°.

The cartesian coordinates of a point are given by

$$x = r \sin(\vartheta + 90.0) \cos \varphi$$
$$y = r\ sin(\vartheta + 90.0)\ sin\varphi$$
$$z = r\ cos\ (\vartheta + 90.0)$$

(5.7)

Note – This Coordinate System is used in [9] [10].

5.2.5 Spherical Polar Coordinate Geographical (SPCS_GEO)

The SPCS_Geo is shown in Figure 5.6, it has the centre at the (0.0, 0.0, 0.0) position of the CCRS_Cartesian.

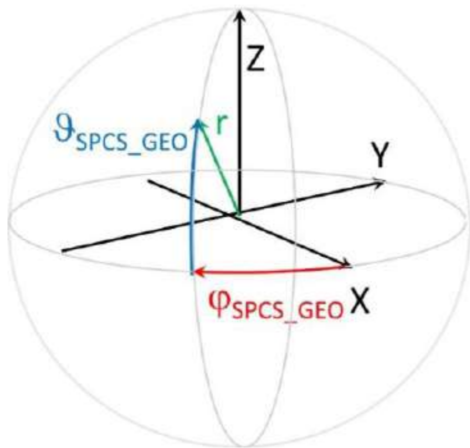


Figure 5.6: Antenna Reference Coordinate System SPCS_Geo

In the SPCS_Geo system

- r is the distance from the SPCS_Geo centre (see the green arrow in Figure 5.6)
- the ϑ_{SPCS_GEO} angular coordinate ranges from 90.0° to -90.0° starting from the Positive Z axis toward the Negative Z axis (see the blue arrow in Figure 5.6). This coordinate is referenced as elevation; the elevation coordinate assumes the value 0° on the XY plane at Z = 0.
- the φ_{SPCS_GEO} angular coordinate ranges from 0° to < 360° starting from the X axis clockwise looking downward from the Z Positive Axis (see the red arrow in Figure 5.6).

Note: for convenience, azimuth angles from 180° to 360° may be indicated as difference from 360°: for example 270° may be indicated as -90°; 350° may be indicated as -10°.

The cartesian coordinates of a point are given by

$$x = r \sin (90.0 - \vartheta) \cos (360.0 - \varphi)$$
$$y = r\, sin(90.0 - \vartheta)\, sin(360.0 - \varphi)$$
$$z = r\, cos\, (90.0 - \vartheta)$$

(5.8)

5.3 Relation between SPCS

Table 5-1: Relation between angles among SPCSs described in Section 5.2

	SPCS_Polar	SPCS_CW	SPCS_CCW	SPCS_Geo
SPCS_Polar	-	$\vartheta_{SPCS\_Polar} = \vartheta_{SPCS\_CW} + 90$ $\varphi_{SPCS\_Polar} = 360 - \varphi_{SPCS\_CW}$	$\vartheta_{SPCS\_Polar} = \vartheta_{SPCS\_CCW} + 90$ $\varphi_{SPCS\_Polar} = \varphi_{SPCS\_CCW}$	$\vartheta_{SPCS\_Polar} = 90 - \vartheta_{SPCS\_Geo}$ $\varphi_{SPCS\_Polar} = 360 - \varphi_{SPCS\_Geo}$
SPCS_CW	$\vartheta_{SPCS\_CW} = \vartheta_{SPCS\_Polar} - 90$ $\varphi_{SPCS\_CW} = 360 - \varphi_{SPCS\_Polar}$	-	$\vartheta_{SPCS\_CW} = \vartheta_{SPCS\_CCW}$ $\varphi_{SPCS\_CW} = 360 - \varphi_{SPCS\_CCW}$	$\vartheta_{SPCS\_CW} = \vartheta_{SPCS\_Geo}$ $\varphi_{SPCS\_CW} = \varphi_{SPCS\_Geo}$
SPCS_CCW	$\vartheta_{SPCS\_CCW} = \vartheta_{SPCS\_Polar} - 90$ $\varphi_{SPCS\_CCW} = \varphi_{SPCS\_Polar}$	$\vartheta_{SPCS\_CCW} = \vartheta_{SPCS\_CW}$ $\varphi_{SPCS\_CCW} = 360 - \varphi_{SPCS\_CW}$	-	$\vartheta_{SPCS\_CCW} = -\vartheta_{SPCS\_Geo}$ $\varphi_{SPCS\_CCW} = 360 - \varphi_{SPCS\_Geo}$
SPCS_Geo	$\vartheta_{SPCS\_Geo} = 90 - \vartheta_{SPCS\_Polar}$ $\varphi_{SPCS\_Geo} = 360 - \varphi_{SPCS\_Polar}$	$\vartheta_{SPCS\_Geo} = -\vartheta_{SPCS\_CW}$ $\varphi_{SPCS\_Geo} = \varphi_{SPCS\_CW}$	$\vartheta_{SPCS\_Geo} = -\vartheta_{SPCS\_CCW}$ $\varphi_{SPCS\_Geo} = 360 - \varphi_{SPCS\_CCW}$	-

Table 5-2: Summary of symbol back compatibility with BASTA PA WP12.0

[1]

Angle Name	mathematical symbol	Definition	Identifier for use in data files	Value along X Axis (degrees)	Direction from X-axis as seen from coordinate origin (Antenna backside)
3GPP Phi	Φ or φ	CCW around z-axis	Phi	0	Left
3GPP Theta or elevation downtilt	Θ	Downwards from xy plane at constant 3GPP-Phi	Theta	0	Down
Azimuth	$\mathrm{AZ} = \Phi$	$\mathrm{AZ} = \Phi = -\phi$	Azimuth or Phi	0	Right

Elevation	EL	$\mathrm{EL} = -\Theta$	Elevation	0	Up
Phi	$\Phi\ or\ \varphi$	Identical to 3GPP-Phi	phi	0	Left
theta	ϑ	$\vartheta = 90 + \Theta$	theta	90	Down

6 Antenna Terms and Definitions

6.1 General for Antennas

6.1.1 Angular Region

An Angular Region (AR) is defined as an elevation aperture and an azimuth aperture. Within the AR, the spherical angles vary as follows:

$$\vartheta_{start} \leq \vartheta \leq \vartheta_{end}$$
$$\varphi_{start} \leq \varphi \leq \varphi_{end}$$

NOTE: in other contexts, outside this current document the AR concept can also be denoted as “Segment” or “Angular Segment” [10].

An example on how to divide the served sector into ARs is shown in Figure 6.1, and in Table 6-1, for an AAS covering a sector from 300° to 60° in azimuth range and from 85° to 110° in elevation range.

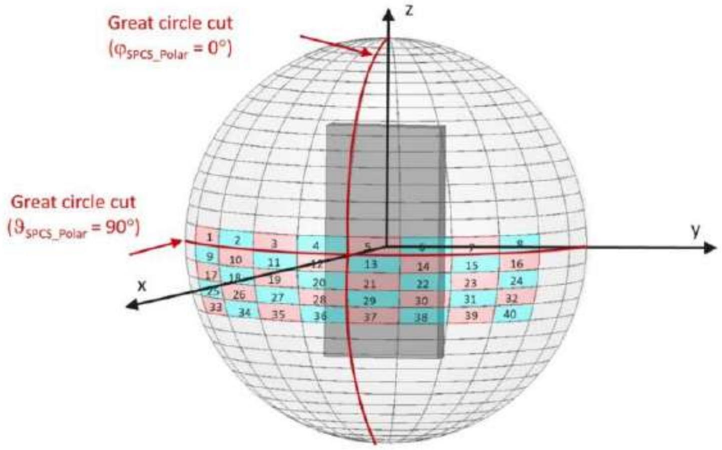


Figure 6.1: Example of sector divided into ARs

Note: As an example, in Figure 6.1 $\vartheta_{SPCS\_Polar} = 90°$ corresponds to $\vartheta_{SPCS\_CW} = 0°, \vartheta_{SPCS\_CCW} = 0°, \vartheta_{SPCS\_GEO} = 0°$.

Table 6-1: AR tabular description of the example given in Figure 6.1

	SPCS_Polar				SPCS_CW				SPCS_CCW				SPCS_Geo			
AR ID	Azimuth Range		Elevation Range		Azimuth Range		Elevation Range		Azimuth Range		Elevation Range		Azimuth Range		Elevation Range	
	Start	End	Start	End	Start	End	Start	End	Start	End	Start	End	Start	End	Start	End
1	300	315	85	90	45	60	-5	0	300	315	-5	0	45	60	90	95
2	315	330	85	90	30	45	-5	0	315	330	-5	0	30	45	90	95
3	330	345	85	90	15	30	-5	0	330	345	-5	0	15	30	90	95
4	345	360	85	90	0	15	-5	0	345	360	-5	0	0	15	90	95
5	0	15	85	90	345	360	-5	0	0	15	-5	0	345	360	90	95
6	15	30	85	90	330	345	-5	0	15	30	-5	0	330	345	90	95
7	30	45	85	90	315	330	-5	0	30	45	-5	0	315	330	90	95
8	45	60	85	90	300	315	-5	0	45	60	-5	0	300	315	90	95

9	300	315	90	95	45	60	0	5	300	315	0	5	45	60	85	90
10	315	330	90	95	30	45	0	5	315	330	0	5	30	45	85	90
11	330	345	90	95	15	30	0	5	330	345	0	5	15	30	85	90
12	345	360	90	95	0	15	0	5	345	360	0	5	0	15	85	90
13	0	15	90	95	345	360	0	5	0	15	0	5	345	360	85	90
14	15	30	90	95	330	345	0	5	15	30	0	5	330	345	85	90
15	30	45	90	95	315	330	0	5	30	45	0	5	315	330	85	90
16	45	60	90	95	300	315	0	5	45	60	0	5	300	315	85	90
17	300	315	95	100	45	60	5	10	300	315	5	10	45	60	80	85
18	315	330	95	100	30	45	5	10	315	330	5	10	30	45	80	85
19	330	345	95	100	15	30	5	10	330	345	5	10	15	30	80	85
20	345	360	95	100	0	15	5	10	345	360	5	10	0	15	80	85
21	0	15	95	100	345	360	5	10	0	15	5	10	345	360	80	85
22	15	30	95	100	330	345	5	10	15	30	5	10	330	345	80	85
23	30	45	95	100	315	330	5	10	30	45	5	10	315	330	80	85
24	45	60	95	100	300	315	5	10	45	60	5	10	300	315	80	85
25	300	315	100	105	45	60	10	15	300	315	10	15	45	60	75	80
26	315	330	100	105	30	45	10	15	315	330	10	15	30	45	75	80
27	330	345	100	105	15	30	10	15	330	345	10	15	15	30	75	80
28	345	360	100	105	0	15	10	15	345	360	10	15	0	15	75	80
29	0	15	100	105	345	360	10	15	0	15	10	15	345	360	75	80
30	15	30	100	105	330	345	10	15	15	30	10	15	330	345	75	80
31	30	45	100	105	315	330	10	15	30	45	10	15	315	330	75	80
32	45	60	100	105	300	315	10	15	45	60	10	15	300	315	75	80
33	300	315	105	110	45	60	15	20	300	315	15	20	45	60	70	75
34	315	330	105	110	30	45	15	20	315	330	15	20	30	45	70	75
35	330	345	105	110	15	30	15	20	330	345	15	20	15	30	70	75
36	345	360	105	110	0	15	15	20	345	360	15	20	0	15	70	75
37	0	15	105	110	345	360	15	20	0	15	15	20	345	360	70	75
38	15	30	105	110	330	345	15	20	15	30	15	20	330	345	70	75
39	30	45	105	110	315	330	15	20	30	45	15	20	315	330	70	75
40	45	60	105	110	300	315	15	20	45	60	15	20	300	315	70	75

NOTE: In general, if irregular or more complex shapes of ARs are used, appropriate textual description and an elevation-azimuth plane drawing is required.

6.1.2 Array and Cluster

A radiator is a component of a BSA whose purpose is to transform a guided electromagnetic wave into on-air traveling electromagnetic waves and vice versa.

A cluster is a logical group of single or dual polarised radiators, which are connected to a single port (for single-polarised radiators) or to a pair of ports (for dual-polarised radiators). More than one cluster can belong to a single array.

An array is a logical group of clusters located side-by-side, supporting a common frequency band, a similar beam shape and a common tilt e.g., four clusters in case of an PBCA antenna with beamforming capabilities.

In this publication it is recommended that the clusters shall follow the same naming rules as for the arrays in the latest version of AISG Standard for port colour coding.
The manufacturer shall indicate the association between port and corresponding name inside the XML datasheet.

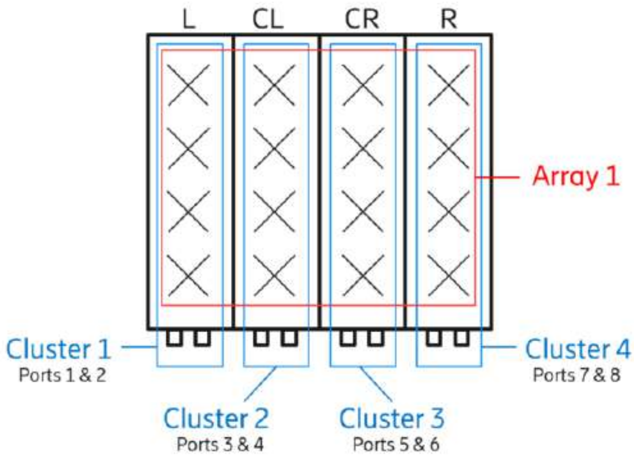


Figure 6.2: Possible difference between array and clusters.

Note: More information about radiator polarization can be found in Section 7.2.12.

6.1.3 Beam Centre

The X dB Beam Centre is, for a given far-field radiation pattern, the average of the two directions closest to the beam peak, in azimuth and elevation, in which the Radiation Intensity is X dB below the maximum value (if X = 3 dB the HPBW is intended).

Note – for a symmetrical, single peak beam, the Beam Centre corresponds to the Beam Direction, see Section 6.1.4. The same does not hold for a not symmetrical beam, see Figure 6.3.
Note – the definition well adapts to radiation patterns where a peak could not be univocally identified, as an example for envelope radiation patterns.

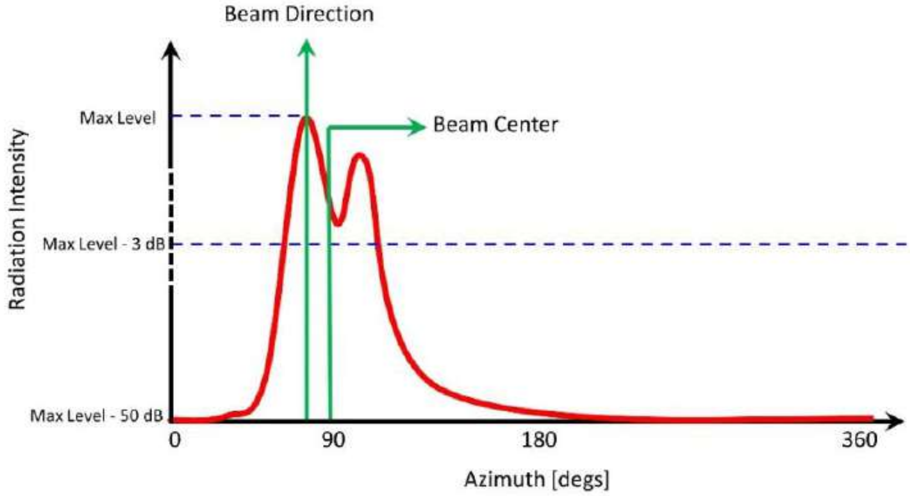


Figure 6.3: Beam Centre and Beam Direction

6.1.4 Beam Direction

The direction of the maximum radiation intensity of the radiation pattern, the direction could be derived from a cut on the radiation pattern, see Figure 6.8.

6.1.5 Beams and Antenna Classes

The main beam is defined as the major lobe of the radiation pattern of an antenna. The main beam peak axis is the direction, within the main beam, along which the radiation intensity is maximum. All the other lobes are called sidelobes or grating lobes.

In this document, for Passive Antennas, several classes of antennas will be addressed:

- Omnidirectional antennas (also known as omni-antennas) are those able to irradiate, at all their supported frequencies, a "donut-shaped" main beam, which exhibits for the whole turn (360°) in the azimuth plane low fluctuations of radiation intensity in comparison to the main beam peak.
- Directional single-beam antennas are those able to irradiate, at all their supported frequencies, only one main beam, which has also the peculiarity to be the only beam containing all the points in the antenna's patterns that lie between the main beam peak and its half-power boundaries.
- Directional multi-beam antennas are those able to radiate more than one main beam at the same frequency and at the same time on the azimuth plane; each of these beams is typically associated with a couple of ports (one for each polarization). There are two kinds of multi-beam antennas:
    - Those whose main beams are each physically due to a single cluster; in this case the specifications of each beam coincide with the ones of the cluster. These antennas will be from now on indicated as multi-beam type I.
    - Those whose set of beams can be formed by properly feeding each port and combining each contribution (e.g.: planar phased-array antennas). In this case there is no physical correspondence between beam and cluster, and generally each beam is conceptually paired with a pair of ports. Since it is useful to have specifications for each beam, only as a device those shall be indicated by associating a cluster to each pair of ports, therefore to each relevant beam. These antennas will be from now on indicated as multi-beam type II.

- Additionally, there is a particular case of multi-beam type II antennas, whose pair of ports cannot be associated 1:1 to each one of their main beams in the azimuth plane, because a single cluster radiates more than one of them. Those will be from now on indicated as multi-beam type III.
- Array Antennas with Beamforming capabilities are those able to create different beams by feeding the corresponding RF ports with RF signals based on special complex weights (different phases and amplitudes) created in a remote radio head with beamforming capabilities.

In this document, in order to identify a common reference to relate antenna parameters to, the axis perpendicular to the antenna aperture will be called mechanical boresight and will be used to fulfil that very purpose. For the purpose of this publication, omni-directional antennas shall have no mechanical boresight. Parameters normally referring to it will, instead, have the horizon (great circle cut $\vartheta_{SPCS\_Polar} = 90°$) as reference. Should the antenna mechanical boresight or horizon not be unmistakably discernible (e.g.: spherical antenna), a common reference shall be both indicated onto the antenna and specified in its datasheet (see Section 5.2).

Note: Omnidirectional and directional single-beam antennas are basically defined by their properties, while multi-beam antennas are defined by their use.
Note: Multi-beam antennas can have only a single mounting orientation, but more mechanical boresights, which may be distinct for each aperture, may not point to the mounting orientation and may also point to different directions. Those mechanical boresights should always be visually recognizable.
Note: Each beam of multi-beam antennas type II has a nominal direction which can differ from that beam's peak axis, its mounting orientation and/or its mechanical boresight. Those nominal directions are defined by a specific parameter (see Section 7.3.2).

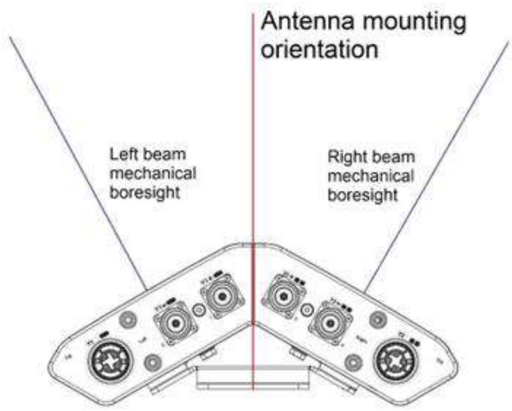


Figure 6.4: Example of a dual-beam antenna. Its mounting orientation is aligned along 0°. Left and right mechanical boresights are respectively pointed to -30° and +30°.

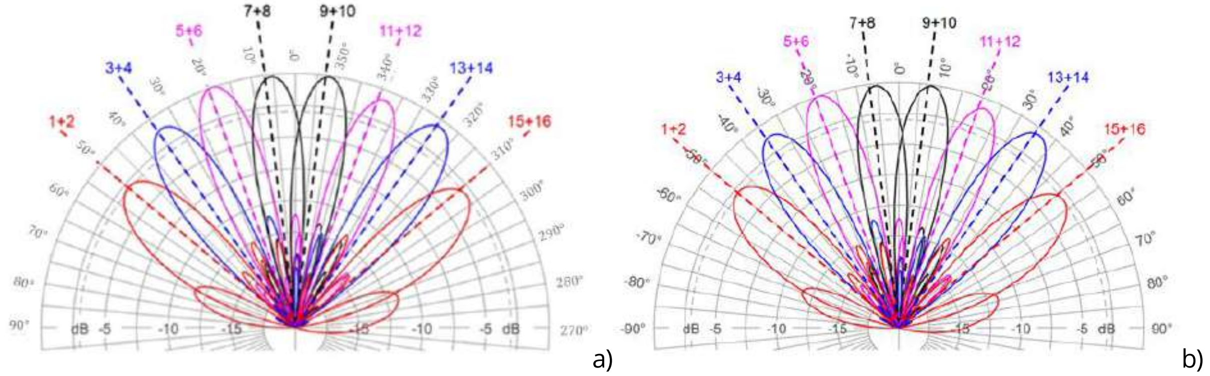


Figure 6.5: Azimuth pattern of a multi-beam antenna type II. Mounting orientation and mechanical boresight are aligned along 0°. Nominal directions are noted with dotted lines. Each beam is associated to a pair of ports only as a device. All the 16 ports collaborate to produce the pattern are shown. a) SPCS_Polar, b) SPCS_CW

6.1.6 Beamwidth

The X dB beamwidth is, for a given far-field radiation pattern cut (see section 6.1.11.1) the angle between the two directions in which the Radiation Intensity is X dB below the maximum value. The pattern may be Total Radiated Power, Co-polar, or any other specified polarization. In this publication, the parameter is considered a property of the patterns considered, so the choice of Total Power or co-polar is typically clear form the context. It is still recommended to explicitly state which type of pattern is considered for the beamwidth.

6.1.6.1 Half-Power Beamwidth

When X is equal to 3 dB, then the term half-power beamwidth (HPBW) is used.

Principal half-power beamwidths (of the antenna beam) are, for a pattern whose beam has a half-power contour that is essentially elliptical, the half-power beamwidths in the two pattern cuts that contain the major and minor axes of the ellipse. In this publication the principal half-power beamwidths are the half-power beamwidth in the azimuth cut and elevation cut.

The nominal horizontal HPBW (HPBW of the azimuth cut), is a coarse approximation of half the area covered by the BSA and is normally used to classify different types of antennas.

Note: For omnidirectional antennas, the HPBW shall not be given.

Figure 6.4 a-d show examples of HPBW for azimuth- and elevation cuts of the radiation pattern. The distance between the HPBW points (red) are used for HPBW calculations. Also shown (green point) is the Beam Direction of each cut.

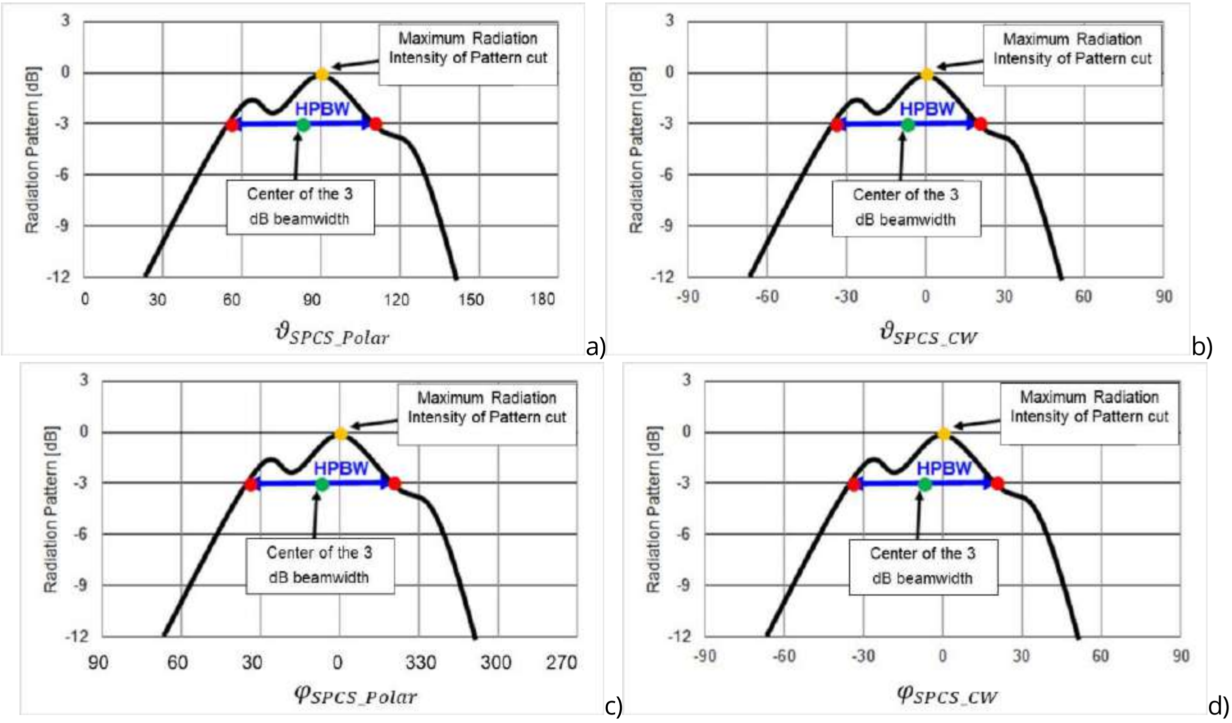


Figure 6.6: HPBW Beam Centre and Beam Direction derived from Beamwidth definition and assuming 3 dB reduction for the radiation intensity. a) and c) SPCS_Polar; b) and d) SPCS_CW.

6.1.6.2 Azimuth Beamwidth

The Azimuth Beamwidth of the antenna is defined in the Azimuth Cut (see Section 6.1.11.1) as the angular width including the direction of maximum co-polar Radiation Intensity, which extends between the only two points at a beam level X dB lower than the maximum of the co-polar Radiation Intensity.

The azimuth beamwidth is determined on the azimuth radiation pattern conical cut containing the main beam peak. Such a cut is obtained over a path in which ϑ is constant and is φ a variable.

6.1.6.3 Elevation Beamwidth

The Elevation Beamwidth of the antenna is defined in the Elevation Cut (see Section 6.1.11.1) as the angular width including the direction of maximum co-polar Radiation Intensity, which extends between the only two points at a beam level X dB lower than the maximum of the co-polar Radiation Intensity in said cut.

The elevation beamwidth is determined on the elevation radiation pattern great circle cut containing the main beam peak. Such a cut is obtained over a path in which φ is constant and ϑ is a variable.

6.1.6.4 Envelope azimuthal beamwidth and pan direction

The Envelope Azimuthal Beamwidth of the Envelope Radiation Pattern is defined as the angle between the two directions A and B in which the Radiation Intensity is X dB below the maximum value in the Azimuth Cut (see Section 6.1.11.1) as shown in Figure 6.5.

The Envelope azimuthal beamwidth is by default calculated with X equal to 3 (i.e. envelope azimuthal half-power beamwidth) but other values may be chosen, e.g. X equal to 10 is typically used for coverage calculation purposes.

The Pan direction of the Azimuthal Envelope Radiation Pattern is the midpoint between angles A and B.

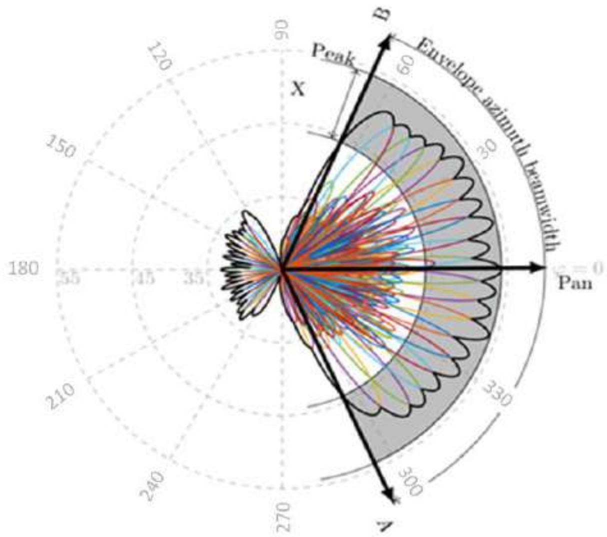


Figure 6.7: Envelope Azimuthal Radiation Pattern and related parameters example

6.1.6.5 Envelope elevation beamwidth and tilt direction

The Elevation Beamwidth of the Envelope Radiation Pattern is defined as the angle between directions C and D, in which the Radiation Intensity is X dB below the maximum value in the Elevation Cut (see Section 6.1.11.1) as shown in Figure 6.8.

The envelope elevation beamwidth is by default calculated with X equal to 3 but other values may be chosen, e.g. X equal to 10 is typically used for coverage calculation purposes.

The Tilt direction of the Elevation Envelope Radiation Pattern is the midpoint between angles C and D.

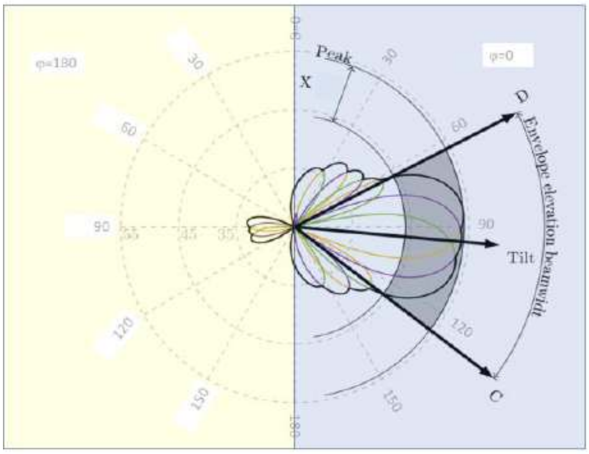


Figure 6.8: Envelope elevation beamwidth and Tilt direction and related parameters example

6.1.7 EIRP

Equivalent (or Effective) Isotopically Radiated Power (EIRP), in a direction, is the total radiated power if the radiation intensity (see Section 48) the device produces in that direction would be radiated isotopically. Hence, EIRP is a far field parameter like the radiation intensity. In the System International (SI) unit of EIRP is W.

EIRP, in each direction, is defined as the directive antenna gain (G) in the direction multiplied by the net power accepted by the antenna ($P_{accepted}$),

$$EIRP(\vartheta, \varphi) = 4\pi I(\vartheta, \varphi) = G(\vartheta, \varphi) P_{accepted} \qquad 6.1$$

where the solid angle of the full sphere (4π sr) is used.

Note that in the first part of equation in 6.1 the definition of EIRP has the advantage of being independent of accepted power and gain which are not measurable for tightly integrated AASs, such as in 3GPP AAS types 1-O and 2-O [4]. From equation 6.1

$$G(\vartheta, \varphi) = \frac{I(\vartheta, \varphi)}{\frac{P_{accepted}}{4\pi}} \qquad 6.2$$

Moreover, the radiation intensity is related to the effective value of the electric field strength in the Far-field region as

$$I(\vartheta, \varphi) = lim_{r \to \infty} \frac{|E(r, \vartheta, \varphi)|^2}{Z_0} r^2 \qquad 6.3$$

Here, $Z_0 \approx 377\ \Omega$ is the impedance of vaccuum. Hence, EIRP can be obtained by measuring the electric field strength in a single point in the Far-Field region.

Relations to other parameters

$$EIRP(\vartheta, \varphi) = S(r, \vartheta, \varphi) 4\pi r^2 \qquad 6.4$$

where r is the distance from the antenna and $S(r, \vartheta, \varphi)$ is the radial power flux per unit area.

$$EIRP(\vartheta, \varphi) = D(\vartheta, \varphi)\ TRP \qquad 6.5$$

where TRP is the Total radiated Power and D is directivity.

Note: For AAS see Gain definition in Section 6.1.12.

Note: For AAS, The meaning of "Configured Output Power" is to be defined and provided by the manufacturer.

Attributes applied to EIRP, radiation intensity and related parameters are summarized here for completeness:

- **Total** denotes the sum (in linear scale) of two partial EIRP values corresponding to two orthogonal polarisations of the electromagnetic field
- **Partial** denotes a value corresponding to a specific polarization
- **Peak** denotes the highest value with respect to angular directions.
- If no attribute is used and no direction is specified, then "Peak Total" is intended.

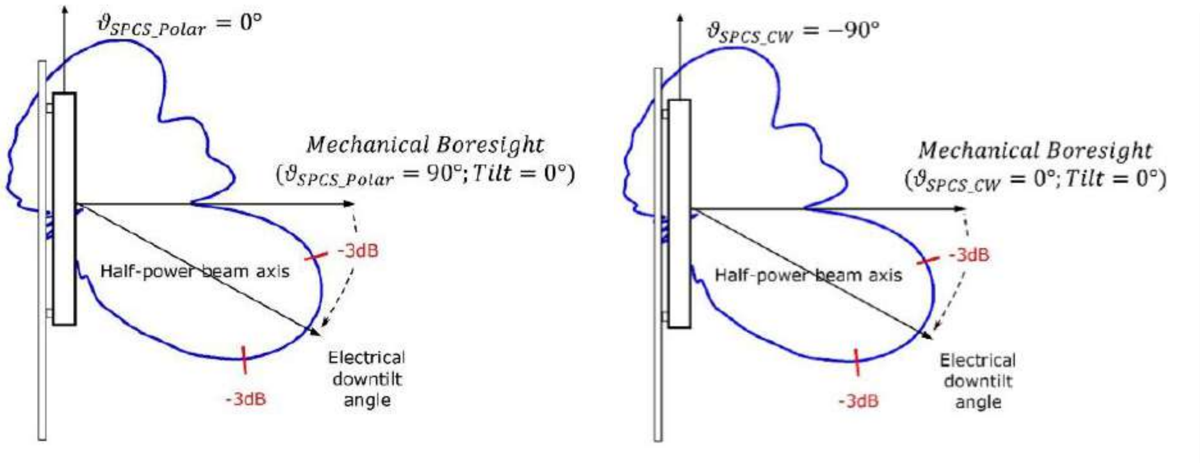
Example:

The statement "EIRP = 50 dBm", means that the Peak Total EIRP is 50 dBm.

An EIRP is a Total EIRP if not otherwise stated. If only one polarization component is measured e.g. +45° slanted polarization, then "Partial EIRP +45" shall be used.

6.1.8 Electrical Downtilt Angle

The electrical downtilt angle is, in the elevation cut, the angle between the antenna mechanical boresight and the half-power beam axis (Figure 6.9). An electrical downtilt is achieved by tuning the feeding-phase of the radiating elements of an antenna, and not by mechanically tilting the antenna itself.



a) b)

Figure 6.9: Electrical downtilt angle. A) picture in SPCS_Polar b) Picture in SPCS_CW

Note: for sake of clarity, In Figure 6.9 $\vartheta_{SPCS\_Polar} = 0$ corresponds to $\vartheta_{SPCS\_CW} = -90$; $\vartheta_{SPCS\_CCW} = -90$, $\vartheta_{SPCS\_GEO} = 90$ while $\vartheta_{SPCS\_Polar} = 90$ corresponds to to $\vartheta_{SPCS\_CW} = 0$; $\vartheta_{SPCS\_CCW} = 0, \vartheta_{SPCS\_GEO} = 0$.

The electrical tilt value coincides with the value of ϑ_{SPCS_CW} and ϑ_{SPCS_CCW} or the half power beam axis. A negative tilt means that the half-power beam axis lies in the hemisphere above the horizontal cut.

Since omnidirectional antennas have (as specified in Section 6.1.5) no boresight, their electrical downtilt angle shall be calculated in the appropriate elevation cut with the whole horizontal cut ($\vartheta_{SPCS\_Polar} = 90$) as a zero reference. In this case the half-power beam axis might lie along an angle enclosed by è $\varphi_{SPCS\_Polar} = 180°$ and $\varphi_{SPCS\_Polar} = 360°$. Should this happen, in order to have consistent data, the electrical downtilt angle to consider shall be one mirrored around the $\varphi_{SPCS\_Polar} = 0°$ (or $\varphi_{SPCS\_Polar} = \pm 180°$) axis instead.

In addition to the beamforming capabilities of the AAS, that are achieved by modifying the feeding weights (amplitude and phases) applied to each radiator or group of radiators connected to a TRX, the AAS might have the additional capability to apply an offset in elevation to the whole set of patterns that the AAS can generate, which is not attributed to mechanical tilting of the antenna.

Unlike the feeding weights of each TRX that are adjusted dynamically during the normal operation of the AAS, the electrical downtilt angle is intended to be a parameter that is set when the AAS is deployed, and it is modified only during network planning and optimisation activities.

6.1.9 Efficiency

The antenna efficiency is the ratio of the power radiated by an antenna (i.e., the power that is effectively converted into electromagnetic waves) to the power input to the antenna.
Efficiency can be expressed in dB taking the linear values of the Gain (G) and directivity (D) at the angle of maximum radiation by the formula.

$$Efficency = 10\ log_{10}\left(\frac{G_{max}}{D_{max}}\right) \tag{6.6}$$

According to the measured D in dB and G in dBi, the Efficiency η can be calculated by the formula

$$Efficency = G_{max}(dBi) - D_{max}(dB) \tag{6.7}$$

6.1.10 Envelope Radiation Pattern

The Envelope Radiation Pattern is a non-physical radiation pattern obtained by taking, for each direction in azimuth and elevation, the maximum of the absolute, not peak normalized to its own peak, radiation pattern among the radiation patterns that the AAS can generate for a given operating condition (deployment/coverage scenario). More details on envelope radiation patterns can be found in Section 19.

Radiation pattern parameters also apply to envelope radiation patterns, with the exception of the changes described in the following sub-sections.

6.1.10.1 Envelope Radiation Pattern Ripple

The Radiation Pattern Ripple is defined, for omnidirectional antennas or for envelope radiation patterns of AAS or PBCA antennas, as the difference between the highest and the lowest radiation pattern levels per AR and it is expressed in dB. For envelope radiation patterns of AAS or PBCA antennas, if no AR is defined, it is intended an AR corresponding to the Envelope azimuthal and elevation scanning ranges.

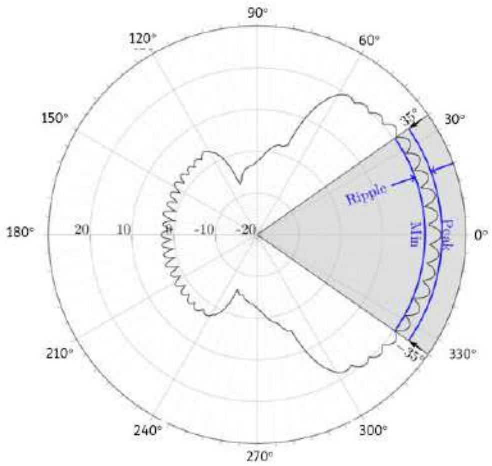


Figure 6.10: Ripple example of envelope radiation pattern in the azimuth cut. The grey area illustrates the AR.

6.1.11 Far-Field Radiation Pattern or Beam

The Far Field (FF) radiation pattern (or antenna pattern) (or beam pattern) is the spatial distribution of the normalized radiation intensity generated by an antenna in the far-field region, see also Section 6.1.13. For base station antennas, this region coincides with the Fraunhofer zone.

A radiation pattern can be characterized by:

- The half-power beamwidth (HPBW) along two orthogonal directions, see Section 6.1.6.1
- The Beam Direction
- The Beam Centre.
- The ripple, see Section 6.1.10.1

In general, for symmetrical beams, the Beam Direction and the Beam Centre are the same but in case of asymmetrical beams, or beams with strong ripple the beam peak and the beam centre directions might be different, see Sections 6.1.4 6.1.3.

Note: An AAS can generate, at the same time, one or more beams with various time-dependent shapes (different HPBW) and pointing to different directions using the same frequency band.

6.1.11.1 Far-Field Radiation Pattern Cut

The far-field radiation pattern cut is any path on the radiation sphere over which a radiation pattern is obtained. The path formed by the locus of points for which the elevation is a specified constant and azimuth is variable is a conical cut. The conical cut containing the main beam peak is called azimuth cut, while the cut with $\vartheta_{SPCS\_Polar} = 90°$ is called horizontal cut. In this document the azimuth cut will also be referred to as azimuth pattern.

The path formed by the locus of points for which φ is a specified constant and ϑ is a variable is called a great circle cut. The great circle cut containing the main beam peak is called elevation cut or vertical cut. In this document the elevation cut will also be referred to as elevation pattern.

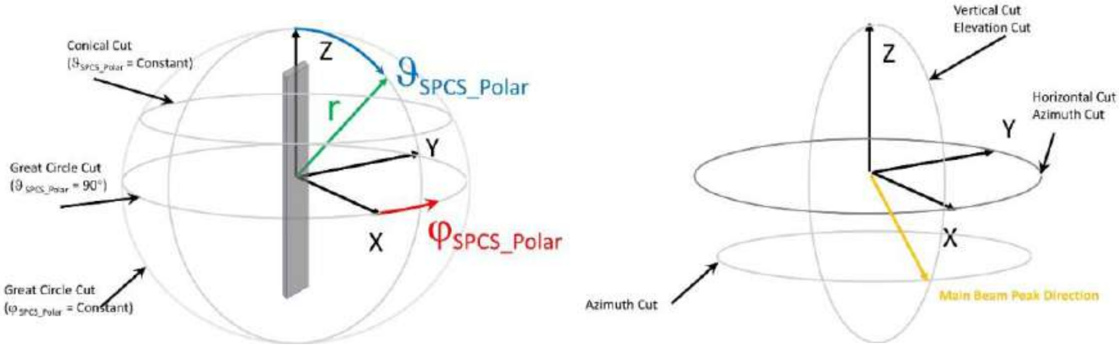


Figure 6.11: Cuts over the radiation sphere

The total power radiation pattern cut is obtained by measuring in far-field two orthogonal components of the radiation intensity generated by the antenna on a specific pattern cut. Let LV and LH are the values of those components. The total power radiation pattern cut is computed by adding the two as follows:

$$L_{total} = 10log_{10}\left(10^{\frac{L_V}{10}} + 10^{\frac{L_H}{10}}\right) \quad (6.8)$$

Far Field Radiation Pattern Cut could be normalized to maximum.

6.1.12 Gain

According to the definitions provided by [3], the antenna gain (in a given direction) is the ratio of the radiation intensity (see Section 6.1.13) (the power radiated per unit solid angle), in the direction of the main beam peak axis, to the radiation intensity that would be obtained if the power accepted by the antenna were radiated isotopically.

In general, it is not always possible to measure $P_{accepted}$ in integrated AAS products as there is not a connector where the RF power can be measured. In such situations, the AAS Gain is introduced which can be derived as the EIRP in the specific direction divided by the “Configured Output Power” – which is the power that can be set on the O&M system.

6.1.13 Radiation Intensity

Radiation intensity is the power radiated from an antenna per unit solid angle in a given direction.

$$\boldsymbol{U} = \frac{\boldsymbol{dP_{rad}}}{\boldsymbol{d\Omega}} \quad \text{[W/sr]} \quad (6.9)$$

In far field

$$U(\vartheta, \varphi) = \frac{r^2}{2\eta}|E(r, \vartheta, \varphi)|^2 \quad \text{[W/sr]} \quad (6.10)$$

6.1.14 Radiation Pattern File Format

Main elevation and azimuth cuts of the radiation pattern shall be provided.

If required, beam radiation patterns generated by antenna are made available in 3D format, preferably via a web link.

The file format for 3D patterns is described in Annex 14.

6.1.15 Realized Gain

A realized gain is the gain (see Section 6.1.12) of an antenna reduced by the losses due to the mismatch of the antenna input impedance to a specified impedance.
Merely in the interests of simplification, in this document from here on the realized gain will be addressed as gain.

6.1.16 Up Link (UL) Radiation Pattern

The UL pattern is obtained for each direction in azimuth and elevation from the combined RX power received by the antenna for a specific constant configuration in response to a constant reference stimulus signal.

6.2 Specific for Active Antennas

6.2.1 AAS Beam-types definition

A passive antenna has a radiation pattern whose shape and direction are fixed in time (not including the effect of the tilt change). The radiation pattern of an AAS in general is dynamic.

By exploiting the processing capabilities of an AAS, the beams it radiates can be of two different types depending on their usage: broadcast beams and traffic beams. They are described in detail in the following sections.

6.2.1.1 Broadcast Beams

Broadcast beams (also named cell-specific beams) are beams used for providing the served cell with coverage. They are intrinsically non-user-based, so they are independent of UE presence.

It is useful to introduce the following definitions:

- **broadcast beam set** is the collection of all broadcast beams that can be radiated by the AAS;
- **broadcast beam configuration** is a sub-set of broadcast beams within a broadcast beam set; it identifies the overall radiating behaviour of the AAS suitable for serving a certain deployment/coverage scenario.

Broadcast beams in a given broadcast beam configuration could be selected sequentially in a loop over time.

For backward compatibility, in case of passive antennas, there is only one broadcast beam in the set (not including the effect of the tilt change), which also behaves as a traffic beam.

6.2.1.2 Traffic Beams

Traffic beams are beams activated only if a traffic channel is assigned to a UE to deliver the required service, hence they are intrinsically user-based.

It is useful to define different traffic beam implementations: Grid of Beams (GoB), Codebook Based Beamforming and Eigen-Based Beamforming (EBB).

6.2.1.3 Grid of Beams

In GoB implementation, traffic beams are selected among a finite number of pre-configured beams. This includes e.g. the so-called Codebook implementation [11][12]. An AAS may have more than one GoB configuration to adapt to the cell scenario. An example of a GoB configuration is shown in Figure 6.12.

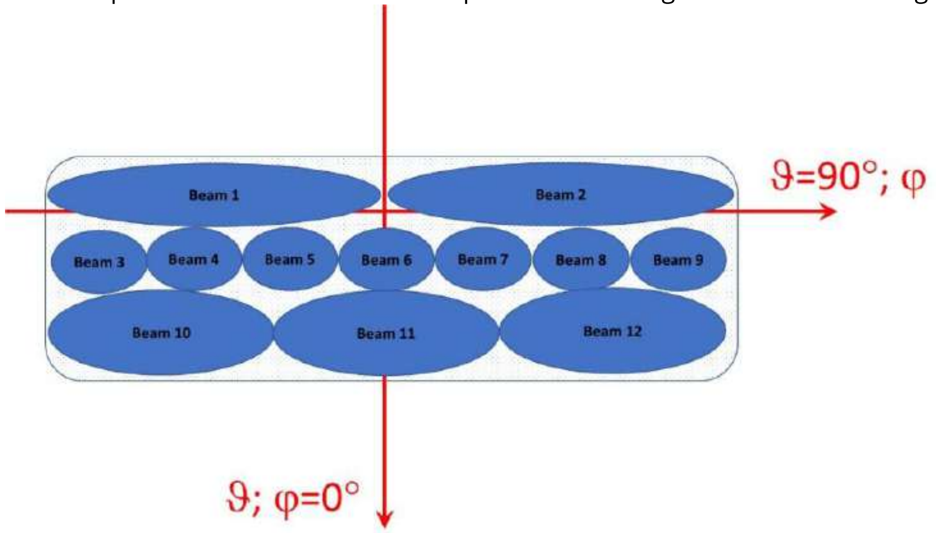


Figure 6.12: GoB Example; beam traces seen from the front

6.2.1.4 Eigen-Based Beamforming (EBB)

In Eigen-Based Beamforming (EBB) configuration, the calculation of the traffic beam (i.e. the array weights applied to each Array Element) is done adaptively in real-time to compensate for the variations of the propagation channel.

6.2.1.5 Codebook-Based Beamforming (CBB)

In Grid of Beam or Codebook-Based Beamforming (GoB or CBB) configuration, the calculation of the traffic beam (i.e. the array weights applied to each Array Element) is done adaptively in real-time selecting in a set of predetermined beams, even containing an high number of beams, ex: some hundreds.

6.2.1.6 Zero Forcing Beamforming (ZFB)

In Zero Forcing Beamforming (ZFB) configuration, the calculation of the traffic beam (i.e. the array weights applied to each Array Element) is done adaptively in real-time so that a minimum of reception is set in a specific direction, as an example to minimize interference.

6.2.2 AAS Frequency range and bandwidth

The following definitions are mainly taken from 3GPP terminology. See [4], [12] for more details and additional parameters.

6.2.2.1 Operating band and supported frequency range

The operating band defined here follows [4] for New Radio (NR) and [13] for Multi Standard Radio (MSR) definition.
The supported frequency range is a specific band within the operating band and defined by a continuous range between two frequencies.

6.2.2.2 Occupied bandwidth

The definition of Occupied Bandwidth (OBW) used e.g. in [4] and [13] applies. This refers to 99% symmetric power utilization, i.e., 0.5% relative power leakage outside each band edge.

6.2.2.3 Aggregated Occupied Bandwidth

The Aggregated Occupied Bandwidth (Aggregated OBW) indicates the bandwidth occupied by multiple carriers and is the sum of the OBWs of signals that can be output at the same time.

6.2.2.4 Instantaneous Bandwidth

The Instantaneous Bandwidth (IBW) is the span between the highest frequency and the lowest frequency of the signals that can be output at the same time. The IBW is always greater or equal to the Aggregated OBW. IBW is identical to “Maximum radiated Base Station RF Bandwidth for non-contiguous operation.” (D9.19) Sec. 4 in [14].

Figure 6.13 shows an example of calculation of IBW and Aggregated OBW.

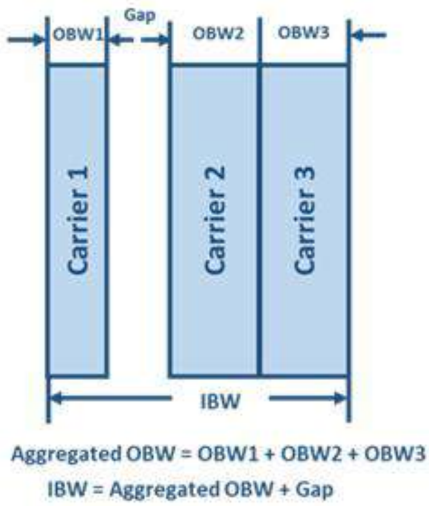


Figure 6.13: IBW and Aggregated OBW calculation example

7 RF Parameters and Recommendations

A BSA can be indicated as "BASTA Antenna compliant" only if:

- Its BASTA antenna XML datasheet or its BASTA antenna datasheet is publicly available.
- Its far-field (possibly tri-dimensional in the format specified in Section 14) pattern files data is publicly available.
- The definitions of the parameters contained in its BASTA antenna XML datasheet or its BASTA antenna datasheet coincide with the ones given by this publication.
- The values associated to each required parameter contained in its BASTA antenna XML datasheet or its BASTA antenna datasheet is calculated with the methods explained in this publication.

7.1 Format

In this publication the parameters will be classified as required or optional. The following format will be used for specifications:

Parameter Definition

A description of the parameter in terms of the antenna properties using standard antenna and cellular communications terminology.

Note: If for any reason it is not possible to describe a particular case with a parameter, due to the impossibility to fully identify the case within the parameter's definition, that very parameter is said to be not applicable.

Specification Definition

- A definition for each element of the specification and associated unit of measure.
- The specification, if not absolute, will be identified as a nominal or distribution-based
- A description of the specification's area of validity.
- The specification's measurement unit.

Note: A note specifying topics, if required.

Specification Example

An example of the full specification.

Relevance

A short description of the impact of the parameter to the antenna performance and/or communication network performance. Supplementary information may be provided in the additional topics section of the publication. If needed, an elaboration on issues surrounding the parameter and its specification will be addressed here or in the additional topics section of the publication.

Note: A note specifying topics, if required.

7.2 Mandatory Parameters and Recommendations for all Antennas

7.2.1 Product Reference

Parameter Definition

The parameter indicates the product version, or the product code given by the manufacturer or vendor.

Specification Definition
The parameter, described by a string as defined by the manufacturer or vendor, describes the type or version or whatever status of the product represented in the XML datasheet.

Specification Example
- Product Reference: Prototype No. 21
- Product Reference: Version No. 21

Relevance
NA

7.2.2 Reference Date

Parameter Definition
Reference date for data contained in the XML datasheet.

Specification Definition
Reference date is reported as 4 digits for the year, 2 digits for the month (01 to 12) and 2 digits for the day (01 to 31) separated by the dash symbol "-", see [15]

Specification Example
- Reference Date: 2021-12-31 for December 31, 2021
- Reference Date: 2021-01-01 for January 01, 2021

Relevance
NA

7.2.3 Adopted Coordinate System

Parameter Definition
Coordinate System used through the XML datasheet for those parameters where there are coordinate system related values.

Specification Definition
The Coordinate Systems adopted in this Publication are:
  - SPCS_Polar
  - SPCS_CW
  - SPCS_CCW
  - SPCS_Geo

described in Section 5.2.

Specification Example
Adopted Coordinate System: SPCS_Polar

Relevance
- The parameter allows to univocally indicate the coordinate systems adopted to describe parameter through all the electronic datasheet

- Mandatory parameter for the correct representation of data through the XML datasheet.

7.2.4 Angular Region Efficiency (ARE)

Parameter Definition

The Angular Region Efficiency (ARE) is defined as the integral of the radiation intensity over a specific AR (see Section 6.1.1) with respect to the integral of the radiation intensity over an AR taken as reference. Since its definition, ARE is a property of the radiation pattern. ARE is expressed in percentage as

$$ARE = 100\frac{\int_{AR} I(\vartheta,\varphi)dS}{\int_{AR_{reference}} I(\vartheta,\varphi)dS} = 100\frac{\int_{\vartheta_{Start}}^{\vartheta_{End}}\int_{\varphi_{Start}}^{\varphi_{End}} I(\vartheta,\varphi)r^2 sin\vartheta d\vartheta d\varphi}{\int_{\vartheta_{referenceStart}}^{\vartheta_{referenceEnd}}\int_{\varphi_{ReferenceStart}}^{\varphi_{referenceEnd}} I(\vartheta,\varphi)r^2 sin\vartheta d\vartheta d\varphi} \qquad (7.1)$$

and depends on the size, shape, and the position on the sphere of the AR including the portion of the radiation intensity. Once the ARs are defined, ARE is used to give a measure of the radiation intensity spatial distribution for a specific beam or for an envelope radiation pattern.

For the purposes of this section the following subdivision of the whole sphere is adopted, see Figure 7.1.

- Upper AR: is a rectangular shaped AR ranging from $0° \le \vartheta < \vartheta_1;\ 0° \le \varphi \le 360°$
- Interference AR: is a shaped AR defined by the following borders:
- $\{(\vartheta_1;\varphi_0),(\vartheta_3;\varphi_0),(\vartheta_3;\varphi_1),(\vartheta_2;\varphi_1),(\vartheta_2;\varphi_2),(\vartheta_3;\varphi_2),(\vartheta_3;\varphi_3),(\vartheta_1;\varphi_3)\}$
- Service AR: is a rectangular shaped AR ranging from $\vartheta_2 \le \vartheta \le \vartheta_3;\ \varphi_1 \le \varphi \le \varphi_2$
- Lower AR: is a rectangular shaped AR ranging from $\vartheta_3 < \vartheta \le \vartheta_4; \varphi_0 \le \varphi \le \varphi_3$

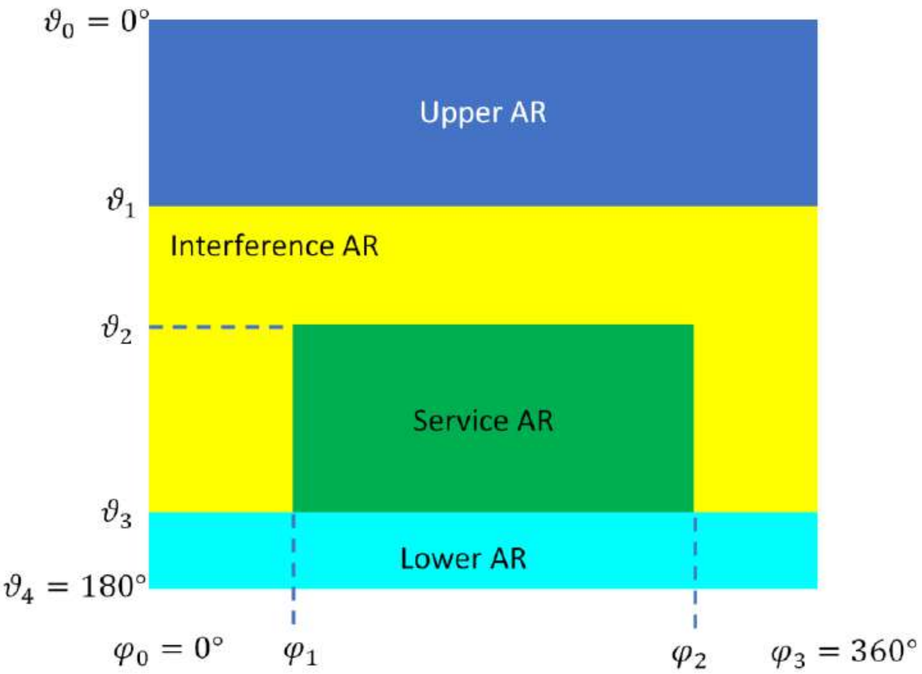


Figure 7.1: The shape of the ARs for computation of ARE.

ARE includes the following 3 quantities:

Sector Efficiency: $\mathbf{100}\,\dfrac{\int_{\boldsymbol{Service\ AR}} \boldsymbol{I(\vartheta,\varphi)dS}}{\int_{\boldsymbol{Whole\ Sphere}} \boldsymbol{I(\vartheta,\varphi)dS}}$ 7.2

Spatial Efficiency: $100\,\dfrac{\int_{Service\ AR} I(\vartheta,\varphi)dS}{\int_{Interference\ AR} I(\vartheta,\varphi)dS+\int_{Service\ AR} I(\vartheta,\varphi)dS}$ 7.3

Lower AR Ratio: $\mathbf{100}\,\dfrac{\int_{\boldsymbol{Lower\ AR}} \boldsymbol{I(\vartheta,\varphi)dS}}{\int_{\boldsymbol{Whole\ Sphere}} \boldsymbol{I(\vartheta,\varphi)dS}}$ 7.4

Note: in formulas 6.2, 6.3 and 6.4 the element $dS = r^2 sin\vartheta d\vartheta d\varphi$, as indicated in formula (6.1). The elementary surface dS depends on the adopted coordinate reference system.

The position and size of ARs are reported in Table 7-1

Table 7-1: Shape and size of the ARs arrangement shown in Figure YYY, per beam

Type A: Macro BS Beam; $\mathbf{0.5° \le HPBW_\vartheta \le 25°; 50° \le HPBW_\varphi \le 130°}$	
$\vartheta_0 = 0°$	$\varphi_0 = 0$
$\vartheta_1 = \min(90°, \vartheta_{Beam\ Peak} - HPBW_\vartheta)$	$\varphi_1 = \varphi_{Nominal\ Direction} - \dfrac{Nominal\ Sector_\varphi}{2}$
$\vartheta_2 = \vartheta_{Beam\ Peak} - \dfrac{HPBW_\vartheta}{2}$	$\varphi_2 = \varphi_{Nominal\ Direction} + \dfrac{Nominal\ Sector_\varphi}{2}$
$\vartheta_3 = 165°$	$\varphi_3 = 360°$
$\vartheta_4 = 180°$	
Type B: Ground to Air Beam; Tilt - 4° to 16°	
$\vartheta_0 = 0°$	$\varphi_0 = 0$
$\vartheta_1 = \min(90°, \vartheta_{Beam\ Peak} - HPBW_\vartheta)$	$\varphi_1 = \varphi_{Nominal\ Direction} - \dfrac{Nominal\ Sector_\varphi}{2}$
$\vartheta_2 = \vartheta_{Beam\ Peak} - \dfrac{HPBW_\vartheta}{2}$	$\varphi_2 = \varphi_{Nominal\ Direction} + \dfrac{Nominal\ Sector_\varphi}{2}$
$\vartheta_3 = \vartheta_{Beam\ Peak} + \dfrac{HPBW_\vartheta}{2}$	$\varphi_3 = 360°$
$\vartheta_4 = 180°$	
Type C: Macro Split Beam	
$\vartheta_0 = 0°$	$\varphi_0 = 0$
$\vartheta_1 = 0°$	$\varphi_1 = \varphi_{Nominal\ Direction} - \varphi Beamwidth_{-10\ dB}$
$\vartheta_2 = \vartheta_{Beam\ Peak} - HPBW_\vartheta$	$\varphi_2 = \varphi_{Nominal\ Direction} + \varphi Beamwidth_{-10\ dB}$
$\vartheta_3 = \vartheta_{Beam\ Peak} + HPBW_\vartheta$	$\varphi_3 = 360°$
$\vartheta_4 = 180°$	
Type D: Generic Multi Beam	
$\vartheta_0 = 0°$	$\varphi_0 = 0$
$\vartheta_1 = 0°$	$\varphi_1 = \varphi_{Nominal\ Direction} - \varphi Beamwidth_{-10\ dB}$
$\vartheta_2 = \vartheta_{Beam\ Peak} - \vartheta Beamwidth_{-10\ dB}$	$\varphi_2 = \varphi_{Nominal\ Direction} + \varphi Beamwidth_{-10\ dB}$
$\vartheta_3 = \vartheta_{Beam\ Peak} + \vartheta Beamwidth_{-10\ dB}$	$\varphi_3 = 360°$
$\vartheta_4 = 180°$	
Type E: Active Antenna Envelope	
$\vartheta_0 = 0°$	$\varphi_0 = 0$

$\vartheta_1 = \min(90°, \vartheta_{Beam\ Peak} - HPBW_{\vartheta})$	$\varphi_1 = \varphi_{Nominal\ Direction} - \frac{Nominal\ Sector_{\varphi}}{2}$
$\vartheta_2 = \vartheta_{Beam\ Peak} - \frac{HPBW_{\vartheta}}{2}$	$\varphi_2 = \varphi_{Nominal\ Direction} + \frac{Nominal\ Sector_{\varphi}}{2}$
$\vartheta_3 = \vartheta_{Beam\ Peak} + \frac{HPBW_{\vartheta}}{2}$	$\varphi_3 = 360°$
$\vartheta_4 = 180°$	
Type Free	
$\vartheta_0 = 0°;\ \vartheta_4 = 180°$	$\varphi_0 = 0;\ \varphi_3 = 360$
$\vartheta_1; \vartheta_2; \vartheta_3\ tbd$	$\varphi_1\ and\ \varphi_2 tbd$

Interpolation may be needed to find the required accuracy on the boundaries.

Specification Definition

ARE is the application of formulas **7.2**, 7.3a and **7.4** to an AR arrangement as described in Table 7-1

For a single beam ARE is reported as

- The beam ID
- The frequency
- The port, if applicable
- The Sector Efficiency
- The Spatial Efficiency
- The Lower AR Ratio
- The AR arrangement type as reported in Table 7-1
- In the case of Type Free AR, the AR shapes

For a set of beams

- The list of beam IDs
- The band in MHz
- The port, if applicable
- The Sector Efficiency as the mean of the Sector Efficiencies among all the beams and related double-sided deviation as specified in Section 12.4.2
- The Spatial Efficiency as the mean of the Sector Efficiencies among all the beams and related double-sided deviation as specified in Section 12.4.2
- The Lower AR Ratio as the mean of the Sector Efficiencies among all the beams and related double-sided deviation as specified in Section 12.4.2
- The AR arrangement type as reported in Table 7-1
- In the case of Type Free AR, the shape of the AR

Specification Example

For a single beam

Beam ID	Beam123
Frequency	900 MHz
Port	XXX
Sector Efficiency [%]	75 %
Spatial Efficiency [%]	90 %
Lower AR Ratio [%]	5 %
AR Arrangement	Type A
AR Shapes	NA

For a set of beams

Beam ID List	Beam123, Beam 124, Beam 125, Beam 126
Band	900 MHz
Port	TheNameOfThePort
Sector Efficiency and deviation [%]	75 %, tolerance ± 3 %
Spatial Efficiency and deviation [%]	90 %, tolerance ± 3 %
Lower AR Ratio and deviation [%]	5 %, tolerance ± 3%
AR Arrangement	Type A
AR Shapes	NA

Relevance

ARE is a parameter that indicates power distribution in the space.

7.2.5 Azimuth related parameters

7.2.5.1 Azimuth Beamwidth

Parameter definition

The parameter reports the Azimuth Beamwidth on the Azimuth Cut between the only two points at a beam level 3 dB lower than the maximum of the co-polar Radiation Intensity of said Azimuth Cut.

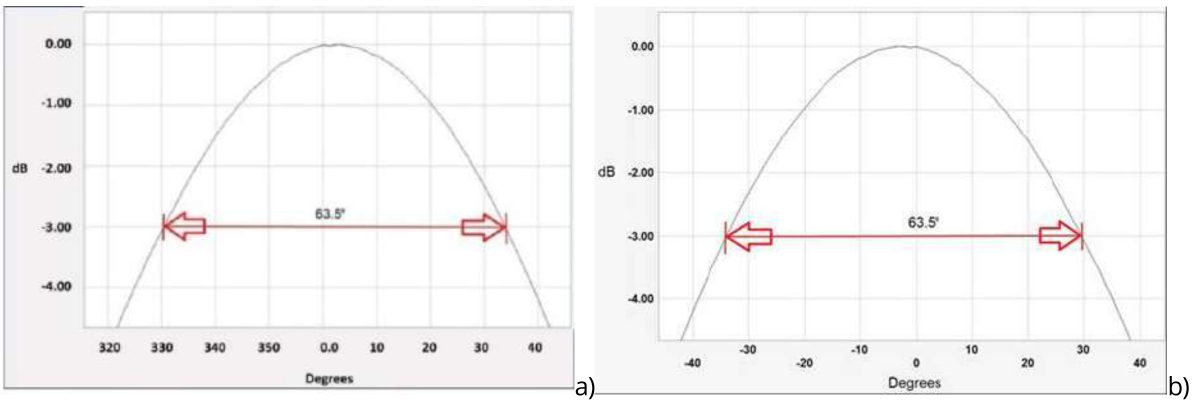


Figure 7.2: Calculation of azimuth beamwidth. a) SPCS_Polar, b) SPCS_CW

Specification Definition

- Typical (mean) value in degrees.
- Tolerance in degrees.
- This is a double-sided distribution-based parameter.
- The beamwidth is calculated from the co-polar pattern.
- This parameter is to be defined for the nominal sub-bands in a broadband antenna. It will be assumed that the specification is valid for the full electrical downtilt range, and for all the ports associated with each frequency sub-band of the antenna.

- For omnidirectional antennas, this parameter shall not be given.

Specification Example

Type: Distribution-based	1710-1880 MHz	1850-1990 MHz	1920-2170 MHz
Azimuth Beamwidth:	67.9° Tolerance ± 1.9°	65.0° Tolerance ± 1.6°	63.5° Tolerance ± 2.3°

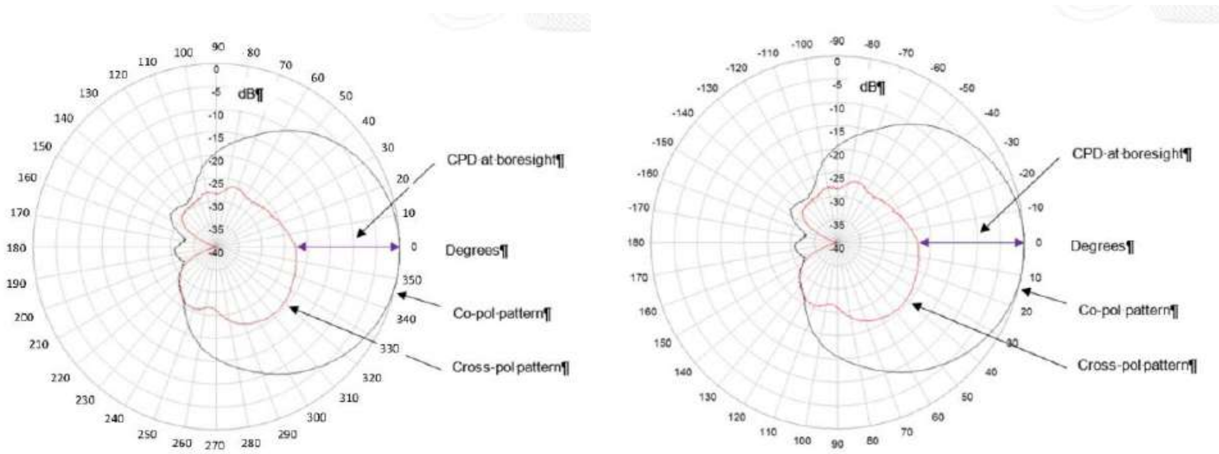
Relevance

- This beam parameter indicates the sector coverage provided by a BSA.
- BSAs are typically referred to by their nominal azimuth beamwidth, for example, a 65° BSA.
- Nominal requirements are usually but not limited to, 90° or 65° for 3 sector cell sites, and 45° or 33° for 6 sector sites.

7.2.6 Cross-Polar Discrimination (CPD) at Mechanical Boresight

Parameter Definition

The CPD at mechanical boresight is defined as the ratio of the azimuthal Co-Pol component of a specific polarization to the orthogonal Cr-Pol component (typically +45° to -45° or vice versa) along the projection of the mechanical boresight onto the azimuth cut.



a) b)

Figure 7.3: Cross-polar discrimination at mechanical boresight. A) SPCS_Polar, b) SPCS_CW

Specification Definition

- CPD at mechanical boresight is specified as a minimum value in dB in 84th percentile of the test samples.
- It is subject to a distribution-based validation for a single-sided parameter.
- This parameter is to be defined for the nominal sub-bands in a broadband antenna. It will be assumed that the specification is valid for the full electrical downtilt range, and for all the ports associated with each frequency sub-band of the antenna.
- For multi-beam antennas type II, this parameter shall be instead defined for each beam, as the CPD of the analysed beam in respect to the projection of its nominal direction onto the azimuth cut.
- For omnidirectional antennas, this parameter shall not be given.

Specification Example

Type: Distribution-based	1710-1880 MHz	1850-1990 MHz	1920-2170 MHz
Cross Polar Discrimination at Mechanical boresight	> 25.4 dB	> 22.1 dB	> 26.3 dB

Relevance

CPD is important for a low level of correlation between the orthogonally polarised propagation channels. Correlation generated by the antenna can negatively affect receive diversity and MIMO downlink performance of the system.

7.2.7 Electrical downtilt range

Parameter Definition

For an antenna capable of variable electrical tilt, the nominal range of angles defined by the minimum and maximum electrical tilt settings.
For a fixed electrical tilt antenna, the only possible nominal angle.

Specification Definition

- For a fixed electrical tilt antenna, the nominal value in degrees.
- For a variable electrical tilt antenna, the nominal range of values in degrees.
- For omni directional antennas, this parameter shall be referenced to the nominal angle between the horizontal cut and the main beam peak axis.

Specification Example

- For a variable tilt antenna:
  Type: Nominal 1710-2170 MHz
  Electrical downtilt 0-10°

- For a fixed tilt antenna:
  Type: Nominal 1710-2170 MHz
  Electrical downtilt 4°

Relevance

- One of the parameters contributing to the characteristics and extent of the cell sector coverage.
- The setting of electrical tilt is commonly adjusted for RF coverage and interference optimisation.
- Electrical downtilt can be used for cell load balancing.

7.2.8 Elevation Related Parameters

7.2.8.1 Elevation Beamwidth

Parameter Definition

The Elevation Beamwidth of the antenna is defined in the Elevation Cut (see Section 5.1.5.1) as the angular width including the direction of maximum co-polar Radiation Intensity, which extends between the only two points at a beam level 3 dB lower than the maximum of the co-polar Radiation Intensity in said cut.

Specification Definition

- Typical (mean) value in degrees.
- Tolerance in degrees.
- This is a double-sided distribution-based parameter.
- The beamwidth is calculated from the co-polar pattern.
- This parameter is to be defined for the nominal sub-bands in a broadband antenna. It will be assumed that the specification is valid for the full electrical downtilt range, and for all the ports associated with each frequency sub-band of the antenna.

Specification Example

Type: Distribution-based	1710-1880 MHz	1850-1990 MHz	1920-2170 MHz
Elevation Beamwidth	7.6° Tolerance ± 0.4°	7.0° Tolerance ± 0.3°	6.6° Tolerance ± 0.5°

Relevance

One of the parameters contributing to the characteristics and extent of the cell sector coverage.

7.2.8.2 Elevation Downtilt Deviation

Parameter Definition

Maximum deviation of the actual elevation downtilt from the nominal elevation downtilt value.

Specification Definition

- Specified as a maximum value in degrees referenced to nominal tilt value.
- This is a single-sided distribution-based parameter – its validation is a special case.
- It is measured from the Co-Pol pattern.
- The reference for the elevation beam peak is the mechanical boresight.
- The reference for the nominal tilt setting the elevation downtilt indicator.
- Section 12.7 addresses the distribution-based validation of the electrical downtilt deviation.
- This parameter is to be defined for the nominal sub-bands in a broadband antenna. It will be assumed that the specification is valid for the full electrical downtilt range, and for all the ports associated with each frequency sub-band of the antenna.
- For omnidirectional antennas, this parameter shall be referenced to the difference between nominal and actual angle between the horizontal cut and the beam peak axis.

Specification Example

Type: Distribution-based	1710-1880 MHz	1850-1990 MHz	1920-2170 MHz
Elevation Downtilt Deviation	< 0.5°	< 0.4°	< 0.4°

Relevance

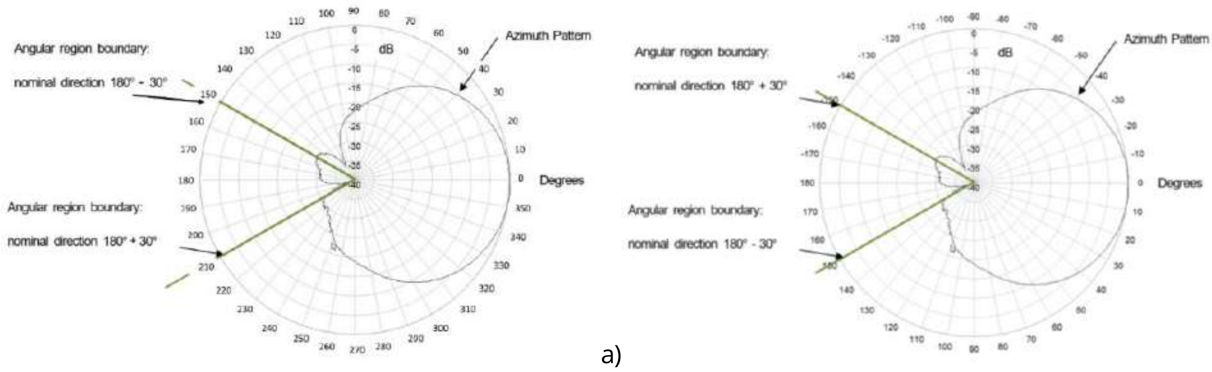
A measure of the accuracy of electrical tilt settings.

7.2.9 Front to Back Ratio

7.2.9.1 Front-to-Back Ratio of the 2D Radiation Pattern, Total Power, ± 30°

Parameter Definition

The F/B total power ± 30° is defined as the ratio of power between the main beam peak level and the highest total power level in the 60° angular region of the azimuth cut contained between two boundaries, each 30° distant from the axis corresponding to the nominal direction ± 180°.



a) b)

Figure 7.4: Angular region for front-to-back, total power ± 30° of a 0° nominal direction antenna. A) SPCS_Polar, b) SPCS_CW

Specification Definition

- F/B total power ± 30° is specified as a minimum value in dB.
- It is subject to a distribution-based validation for a single-sided parameter.
- This parameter is to be defined for the nominal sub-bands in a broadband antenna. It will be assumed that the specification is valid for the full electrical downtilt range, and for all the ports associated with each frequency sub-band of the antenna.
- Section 6.1.11.1 addresses the total power calculation.
- For omnidirectional antennas, this parameter shall not be given.

Specification Example

Type: Distribution-based	**1710-1880 MHz**	**1850-1990 MHz**	**1920-2170 MHz**
Front-to-Back Ratio, Total Power, ± 30°	> 25.0 dB	> 26.4 dB	> 25.8 dB

Relevance

- A measure of the interference radiated backwards by the antenna into neighbouring cells.
- Total power is the root square sum of the linear values of the co-polarised and cross-polarised radiation from an antenna port.

7.2.9.2 Front-to-Back Ratio of the 3D Total Power radiation pattern ± 30°

Parameter Definition

The Front-to-Back Ratio of the 3D Total Power radiation pattern, +/-30° is defined as the ratio between the radiation intensity on the main beam peak and the maximum radiation intensity in an Angular

Region +/-30° wide (60° in total) in elevation and azimuth, in the back radiation side of the antenna. This is abbreviated by FB_3D_TPpm30.

Specification Definition

$$FB\_3D\_TP|_{AR} = 10\ log_{10}\frac{I(\vartheta,\varphi)|_{main\ beam\ peak}}{Max(I(\vartheta,\varphi)|_{AR})}\ [dB] \quad (7.5)$$

FB_3D_TP can be computed even as

$$FB\_3D\_TP|_{AR} = \left[G(\vartheta,\varphi)_{main\ beam\ peak}\left.\right|_{dBi} - Max(G(\vartheta,\varphi)_{dBi})|_{AR}\right]\ [dB] \quad (7.6)$$

The mandatory FB_3D_TP is:

- FB_3D_TP_pm30RS with respect to the Reference System: it is the FB_3D_TP evaluated on an AR, ± 30° wide (60°) in both elevation and azimuth. The centre of the AR is the opposite of the antenna reference (the mechanical boresight direction), i.e., it is centred on the negative X-axis as seen in Figure X1.
- The AR includes the azimuth region of the 2D parameter Front-to-Back Ratio (section 7.2.9.1), Total Power, ±30° when φ_p= 0. It covers the expected direction of maximum back radiation for most practical base station antenna applications.

$$AR = \begin{cases} 60° \leq \vartheta \leq 120° \\ 150° \leq \varphi \leq 210° \end{cases}$$

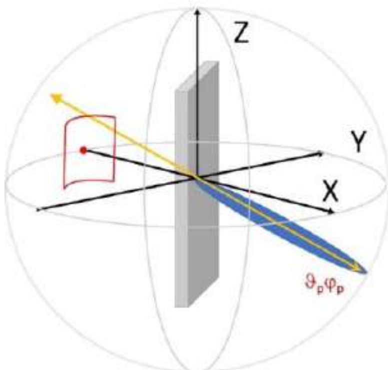


Figure 7.5: Position of the AR on the sphere for the F/B 3D +/-30RS

Additional Optional FB_3D_TP definitions are

- FB_TP_3D_pm30PD with respect to the Peak Direction: it is the FB_3D_TP evaluated on an AR, ± 30° wide (60°) in both elevation and azimuth directions. The centre of the AR corresponds to the intersection point between the back radiation hemisphere and the line crossing the centre of the coordinate system and the main beam peak (assuming the latter is included in the front radiation hemisphere), see Figure 7.6.
  It aims to characterize the maximum interference in the reverse region with respect to the peak position.

$$AR = \begin{cases} 150° - \vartheta_p \leq \vartheta \leq 210° - \vartheta_p \\ \varphi_p + 150° \leq \varphi \leq \varphi_p + 210° \end{cases}$$

Note: in the case ϑ_p is greater than 150°, coordinate shifting is required.

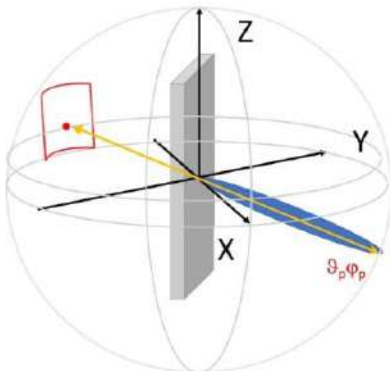


Figure 7.6: Area of the AR (delimited in red on the sphere) for the F/B 3D +/-30PD

- FB_3D_TP_pm30EFP in Elevation Fixed Position: it is the FB_3D_TP evaluated on an AR, ± 30° wide (60°) in both elevation and azimuth directions. The AR is centred at an elevation angle $\vartheta = 90°$ and azimuth position corresponding to $\varphi_p + 180°$, see Figure 7.7.
- It aims to characterize the maximum interference in an AR in the back of the antenna, negative X direction, at fixed elevation while the main beam peak is steered in azimuth and elevation.

$$AR = \begin{cases} 60° \leq \vartheta \leq 120° \\ \varphi_p + 150° \leq \varphi \leq \varphi_p + 210° \end{cases}$$

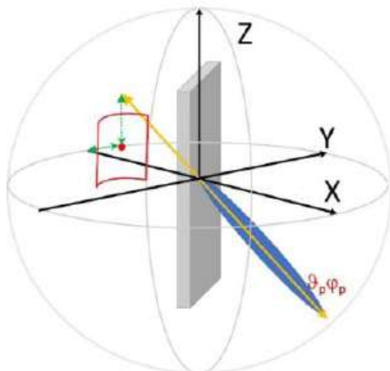


Figure 7.7: Position of the AR on the sphere for the F/B 3D +/-30EFP

- FB_3D_TP_pm30AFP in Azimuth Fixed Position: it is the FB_3D_TP evaluated on an AR, ± 30° wide (60°) in both elevation and azimuth directions. The centre of the AR is the point having azimuth position equal 180° and elevation position corresponding to 180-ϑ_p where ϑ_p is the elevation angle of the main beam peak, see Figure 7.8.
- It aims to characterize the maximum interference in the reverse region according to the tilt, regardless to if it's downtilt or uptilt.

$$AR = \begin{cases} 150° - \vartheta_p \leq \vartheta \leq 210° - \vartheta_p \\ 150° \leq \varphi \leq 210° \end{cases}$$

Note: in the case ϑ_p is greater than 150°, coordinate shifting is required.

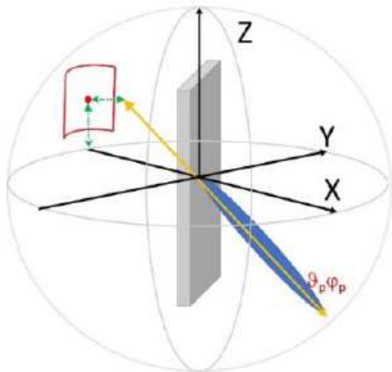


Figure 7.8: Position of the AR on the sphere for the F/B 3D +/-30AFP

FB_3D_TP is:

- specified as a minimum value in dB.
- defined for all the nominal sub-bands of a broadband antenna.
- for PAs, it is valid for the full electrical tilt range, and for all the ports associated to each frequency sub-band of the antenna
- for AAs, it is valid for the nominal direction of a specific configuration envelope radiation pattern
- subject to a distribution-based validation for a single-sided parameter.
- associated to a single beam or to a set of beams
  - for a specific beam, the beam ID shall be indicated
  - for a set of beams, the list of beam IDs is not required.
- For omnidirectional antennas, F/B 3D 30 shall not be given.

Specification Example

	Band	Port	Beam ID	F/B 3D 30
FB_3D_TP_pm30RS	1710-1880 MHz	ThePort	NA	>30.0 dB
FB_3D_TP_pm30RS	N78	NA	EnvelopeConfiguration1	>30.0 dB
FB_3D_TP_pm30RS	1710-1880 MHz	NA	Beam1234	>30.0 dB
FB_3D_TP_pm30PD	1710-1880 MHz	ThePort	NA	>30.0 dB
FB_3D_TP_pm30PD	N78	NA	EnvelopeConfiguration1	>30.0 dB
FB_3D_TP_pm30PD	1710-1880 MHz	NA	Beam1234	>30.0 dB
FB_3D_TP_pm30EFP	1710-1880 MHZ	ThePort	NA	>30.0 dB
FB_3D_TP_pm30EFP	N78	NA	EnvelopeConfiguration1	>30.0 dB
FB_3D_TP_pm30EFP	1710-1880 MHz	NA	Beam1234	>30.0 dB
FB_3D_TP_pm30AFP	1710-1880 MHz	ThePort	NA	>30.0 dB
FB_3D_TP_pm30AFP	N78	NA	EnvelopeConfiguration1	>30.0 dB
FB_3D_TP_pm30AFP	1710-1880 MHz	NA	Beam1234	>30.0 dB

Relevance

A measure of the interference radiated backwards by the antenna

7.2.10 Antenna Gain

Parameter Definition

The maximum gain associated to the beam.

Note: see Section 6.1.12 for AAS gain.

Specification Definition

- Gain is a typical (mean) value in dBi.
- It is specified for the specific lowest (minimum), middle, and highest (maximum) downtilt angles of the whole tilt range for each frequency sub-band.
- The gain specified at a certain downtilt angle shall be calculated as the maximum gain of the antenna, when its downtilt is set to that nominal angle.
- In addition, the "over all tilts" gain is specified by a mean value and a tolerance, both over the whole tilt range and for each frequency sub-band. This is a double-sided distribution-based parameter. Tolerance is in dB.
- Gain validation is determined by the distribution-based methodology described in Section 12.6.
- This parameter is to be defined for each frequency sub-band in a broadband antenna. It will be assumed that the specification is valid for all the ports associated with each frequency sub-band of the antenna.
- The repeatability margin associated with a specified mean gain is defined Section 12.6.
- A discussion of guidelines for a gain measurement is presented in Section 11.1.1 and a discussion of the measurement accuracy that can be expected when measuring gain on a far-field range is discussed in Section 11.1.3.

Specification Example

Type: Distribution-based	1710-1880 MHz	1850-1990 MHz	1920-2170 MHz
Gain at 0° Tilt	17.1 dBi	17.4 dBi	17.7 dBi
Gain at 5° Tilt	17.3 dBi	17.5 dBi	17.7 dBi
Gain at 10° Tilt	17.0 dBi	17.0 dBi	17.2 dBi
Over all tilts (0°-10°)	17.2 dBi Tolerance ± 0.2 dB	17.4 dBi Tolerance ± 0.3 dB	17.5 dBi Tolerance ± 0.3 dB

Relevance

- Primary specification used in the calculation of a link budget.
- The gain specified in radiation pattern data files is used by radio planning software to predict coverage and capacity performance of a cell.

7.2.11 Side Lobe Suppression

Parameter Definition

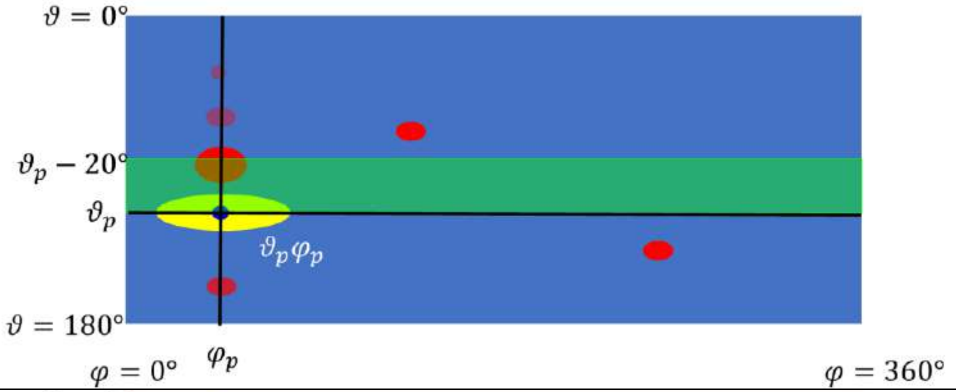
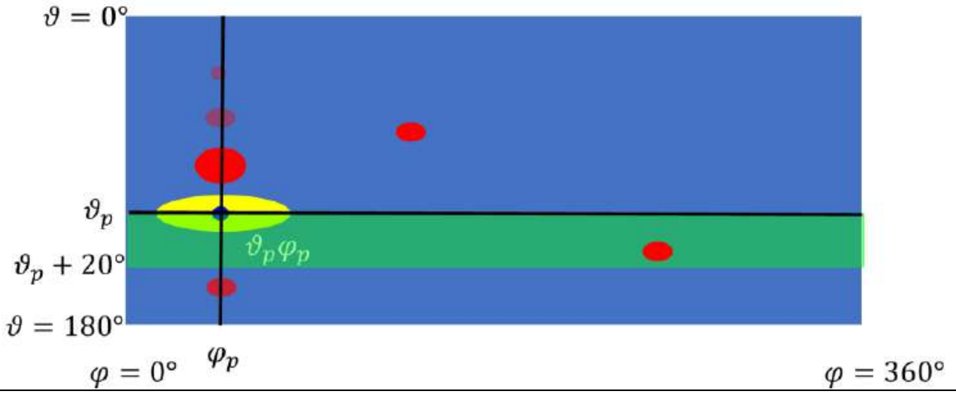
The Sidelobe Suppression (SLS) is defined as the ratio between the radiation intensity of the main beam peak of the 3D radiation pattern and the maximum radiation intensity of a sidelobe that can be found within a specific Angular Region.
Depending on the AR choice and the sidelobe selection, different SLS definitions can be obtained. In current WP, the ARs defined in table Table 7-2 and the corresponding SLS definitions apply:

Table 7-2: AR position and shape for the computation of the SLS

Description	Acronym	AR	Comment

Sidelobe Suppression Above Peak 20°	SLSAP20	$\vartheta_{main\ peak} - 20° \leq \vartheta \leq \vartheta_{main\ peak}$ $0° \leq \varphi < 360°$	See Figure Figure 7.9
Sidelobe Suppression Below Peak 20°	SLSBP20	$\vartheta_{main\ peak} \leq \vartheta \leq \vartheta_{main\ peak} + 20°$ $0° \leq \varphi < 360°$	
Sidelobe Suppression Above Peak	SLSAP	$0° \leq \vartheta \leq \vartheta_{main\ peak}$ $0° \leq \varphi < 360°$	
Sidelobe Suppression Below Peak	SLSBP	$\vartheta_{main\ peak} \leq \vartheta \leq 180°$ $0° \leq \varphi < 360°$	
First Upper Sidelobe Suppression	FUSLS	$0° \leq \vartheta \leq \vartheta_{main\ peak}$ $0° \leq \varphi < 360°$	The first secondary lobe peak above the main peak within the specified AR
First Lower Sidelobe Suppression	FLSLS	$\vartheta_{main\ peak} \leq \vartheta \leq 180°$ $0° \leq \varphi < 360°$	The first secondary lobe peak below the main peak within the specified AR

Note: the definition of this parameter is derived from analogous definitions for the 2D radiations patterns.

SLSAP20	
SLSBP20	

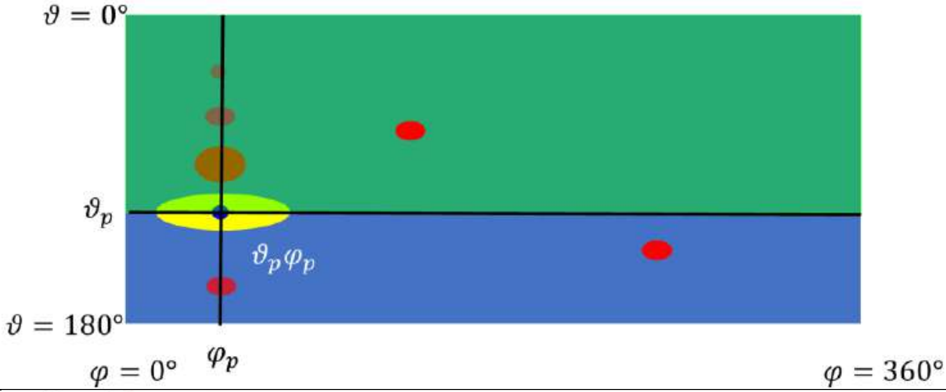
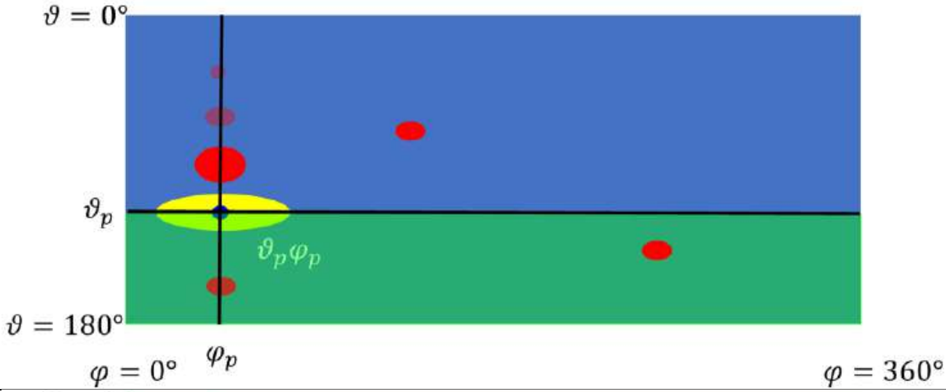
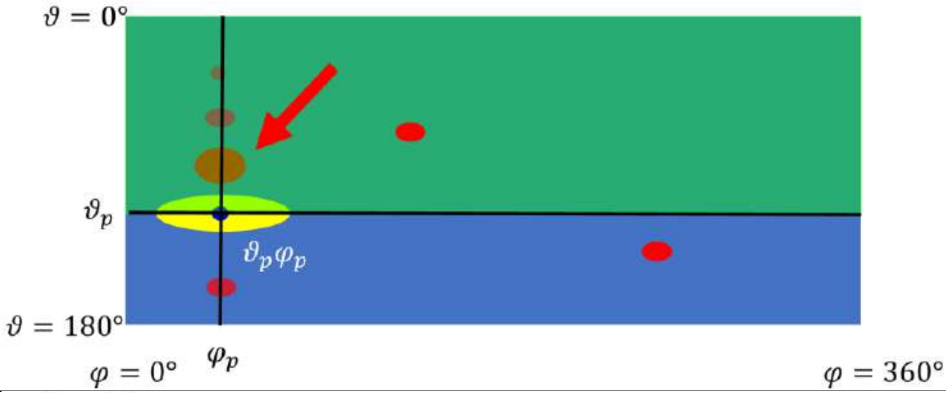
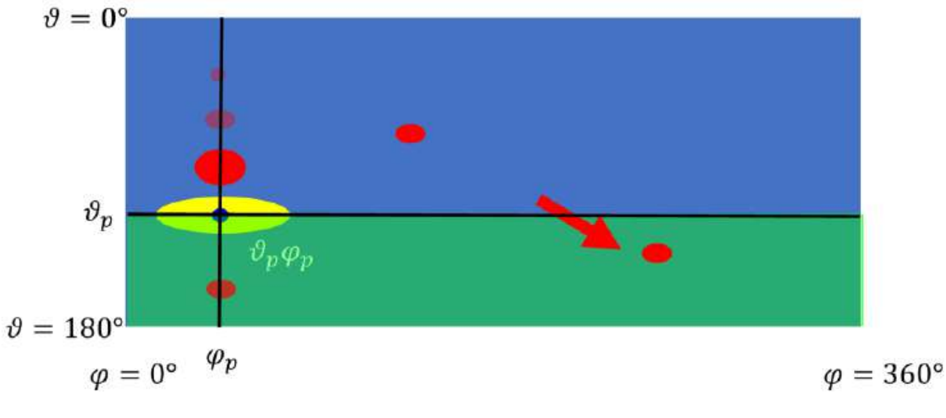
SLSAP	
SLSBP	
FUSLS	
FLSLS	

Figure 7.9: Graphical representation of the ARs for the computations of SLS.

SLS can be determined even as:

$$G_{main\ beam\ peak\ dBi}(\vartheta,\varphi) - Max(G(\vartheta,\varphi)_{dBi})|_{AR} \quad (7.7)$$

Specification Definition

- SLS is specified as a minimum value in dB.
- It is subject to a distribution-based validation for a single-sided parameter.
- This parameter is to be defined for the nominal sub-bands in a broadband antenna. It will be assumed that the specification is valid for the full electrical tilt range, and for all the ports associated to each frequency sub-band of the antenna.
- The parameter is applicable even to the Envelope radiation patterns
- For omnidirectional antennas, this parameter shall be referenced to the cut by the beam peak axis.
- If SLS is evaluated for a specific beam, the beam ID of that specific beam shall be indicated.
- If SLS is evaluated for a set of beams, the list of beam IDs is not required.

Specification Example

Type: Distribution-based	**Port**	**Beam ID**	**1710-1880 MHz**	**1850-1990 MHz**	**1920-2170 MHz**	**N78**
SLS	The Port	NA	> 18.6 dB	> 17.8 dB	> 16.2 dB	NA
SLS	NA	B12345	18.6 dB	17.8 dB	16.2 dB	NA
SLS	NA	EnvelopeConfiguration1	NA	NA	NA	> 20.0 dB

Note – the row SLS is repeated for any of the SLSAP20, SLSBP20, SLSAP, SLSBP, FUSLS, FLSLS.

Relevance

Parameter indicating the amount of neighbouring direction interference generated by the sidelobes.

7.2.12 Polarization

Parameter Definition

The nominal polarization associated to the antenna port whose related radiators generate a wave polarised (nominally) along the same plane.

Specification Definition

- The nominal value as a type and direction for the reference polarization of the antenna.
- Horizontal and vertical linear polarizations are typically defined as H and V.
- Slant linear polarizations are typically defined as +45 and -45.
- Circular polarizations are typically defined as RHCP and LHCP.

Specification Example

Type: Nominal	1710-2690 MHz	
Cluster name	Y1+	Y1-
Port number	1	2
Polarization	+45	-45

Relevance

- Two orthogonal polarizations are often radiated from an antenna to provide diversity. This is typically used in uplink and MIMO applications.

Antennas that provide two orthogonal polarizations are typically called “dual-pol”.

- A recommended vendor reference to the polarization labelling convention is described in Section 11.1.3.7.

7.2.13 Mean Time Between Failure (MTBF)

Introduction

What follows is specifically thought to calculate MTBF, not demonstrated or observed MTBF.
Today there are two popular methods to calculate MTBF, reported in [16] [17].

Telcordia is often used by Telecom industry and is more suitable for passive antennas. The Telcordia method is targeted for electronic products. There are no accepted and demonstrated standards for including passive RF/electromechanical components.

Telcordia method requires the user to make several assumptions. These assumptions have a significant impact on calculated MTBF value. Two identical products with different assumptions are not comparable, and one cannot adjust an MTBF number for a certain assumption without having access to the original calculation.
This means that for the purpose of BASTA, which is to have published specifications that are comparable, BASTA recommendations would have to set the assumptions to be used. The resulting MTBF figures could be very different from manufacturer’s previously published MTBF figures, but they would be at least somewhat comparable between the manufacturers.

Parameter Definition

The parameter indicates the MTBF for the antenna unit.

Specification Definition

- MTBF is reported
  - indicating the time unit, typically hours or years
  - The methodology used to determine the MTBF

Specification Example

- Example 1:
  - MTBF: 200000 h
  - MTBF methodology: methodology X
- Example 1:
  - MTBF: 20 y
  - MTBF methodology: methodology Y

Relevance

NA

7.3 Mandatory Parameters and Recommendations for Passive Antennas

7.3.1 Frequency Range and Frequency Sub-Range

Parameter Definition

The frequency range is the main operating bandwidth of a cluster that is defined by a continuous range between two limiting frequencies f_{START} and f_{STOP}.
The frequency sub-range (or sub-band) is a specific operating bandwidth included in a frequency range and defined by a continuous range between two limiting frequencies f_{START} and f_{STOP}.

Specification Definition

Ranges are specified in MHz.

Specification Example

- Type: Absolute
  - Frequency Range: 1710-2170 MHz
  - Frequency Sub-Range: 1710-1880 MHz

Relevance

- On a datasheet, all specifications valid for the stated frequency range are also valid for its included frequency sub-bands. Vice versa all specifications valid for the stated frequency sub-range are not valid outside that very range.
- Most BSAs are broadband, and they cover one or more frequency sub-range.
- See Section 11.2.4 for an example of cellular frequency sub-bands.

7.3.2 Antenna Reference, Nominal Sector and Nominal Directions

Parameter Definition

The antenna reference of standard base station antennas is the mechanical boresight direction. The axis along which an antenna is supposed to concentrate the highest peak of radiation is identified by two angles: the Downtilt Angle in the elevation cut, already defined in Section 6.1.8, and the Nominal Direction in the azimuth cut. A nominal sector is identified as an angular region which is covered by the main beam in the azimuth cut. These nominal parameters could be different for different clusters and shall be referred to each cluster.

Specification Definition

- As stated in section 6.1.8, for the purpose of this publication the mechanical boresight will be used where possible to fill the role of antenna reference. Omni-directional antennas shall have no mechanical boresight, therefore parameters normally referring to it shall, instead, have the horizon (great circle cut $\vartheta_{SPCS\_Polar} = 90°, \vartheta_{SPCS\_CW} = 0°, \vartheta_{SPCS\_CCW} = 0°, \vartheta_{SPCS\_GEO} = 0°$) as reference. Should the antenna mechanical boresight or horizon not be unmistakably discernible (e.g.: spherical antenna), a reference shall be both indicated onto the antenna and specified in its datasheet (see Section 5.2).

- With respect to the antenna reference, the nominal direction is the direction identified in degrees along the azimuth cut, which the antenna is supposed to concentrate its radiation maximum(s). For a multi-beam BSA, this parameter shall designate the angles of each beam's nominal direction.
- The antenna sector coarsely defines, in the azimuth cut, the angular aperture in degrees of the area illuminated by the antenna main beam, or one of the antenna's main beams covered in one of the antenna clusters.
- The attribute 'Nominal Direction' is defined for each cluster as an integer in the range of 0° to 360° in SPCS_Polar or the correspondent range in the other SPCS.
- The attribute 'Nominal Half Power Beamwidth' is defined for each cluster as an integer in the range of 0° to 360° in SPCS_Polar or the correspondent range in the other SPCS.
- The attribute 'Nominal Sector' is defined for each cluster as an integer in the range of 0° to 360° in SPCS_Polar or the correspondent range in the other SPCS.

Specification Example for Directional single-beam antennas

Type: Nominal: R1
Nominal Direction: 0°
Nominal Horizontal Half Power Beamwidth: 65°
Nominal Sector: 120°

Specification Example for Directional Multi-Beam Antennas

Type: Nominal: Y1 Y2
Nominal Direction: -30° +30°
Nominal Horizontal Half Power Beamwidth: 30° +30°
Nominal Sector: -60° +60°

Relevance

- On a datasheet, these specifications are valid for one single cluster.
- A 65° nominal horizontal HPBW BSA is expected to have more or less a coverage up to 60° clockwise and up to 60° counterclockwise in respect to the nominal direction. The 120° angle included in those boundaries is the nominal sector.

7.3.3 Impedance

Parameter Definition

The characteristic impedance is the ratio between voltage and current flowing into an infinite length transmission line. Validity of this definition is limited to TEM modes (i.e., fundamental modes of coaxial cable). For an antenna the impedance is defined at its inputs (typically its ports).

Specification Definition

The characteristic impedance nominal value in Ohms.

Specification Example

Type: Nominal	1710-2170 MHz
Impedance	50.0 Ω

Relevance

- Base station antennas are typically specified to have a characteristic impedance of 50 Ohm.

- The VSWR (see below) specification parameter measures the antenna mismatch with respect to characteristic impedance.

7.3.4 Maximum Effective Power per Port

Parameter Definition

The maximum power, which can be transmitted into one antenna port, and does not cause any damage to the antenna or negatively affect the antenna mechanical or electrical integrity and performance (hence subject to parameters' alteration).

Specification Definition

- Power is defined as effective CW power.
- This is an absolute, maximum parameter specified is either Watt or dBm.
- It is valid for the operational environmental conditions specified for the antenna.
- Specification shall reference the full frequency range, full electrical downtilt range, and associated ports of the antenna.

Specification Example

Type: Absolute	1710-2170 MHz
Maximum Effective Power per Port	250.0 W
	54.0 dBm

Relevance

Exceeding the specified power rating can damage the antenna.

7.3.5 Maximum Effective Power Whole Antenna

Parameter Definition

The maximum power, which can be transmitted into the antenna, and does not cause any damage to the antenna or negatively affect the antenna mechanical or electrical integrity and performance (hence subject to parameters' alteration).

Specification Definition

- Power is defined as effective CW power.
- This is an absolute, maximum parameter specified is either Watt or dBm.
- It is valid for the operational environmental conditions specified for the antenna.
- Specification shall reference all the frequency ranges, the full electrical downtilt range, and all the ports of the antenna.

Specification Example

Type: Absolute	
Maximum Effective Power Whole Antenna	1200.0 W
	60.8 dBm

Relevance
Exceeding the specified power rating can damage the antenna.

7.3.6 Inter-Cluster Isolation

Parameter Definition
The worst coupling case between a port of a specific cluster and any other port of another cluster in a multiple band, or broad band antenna.

Specification Definition
- Inter-cluster isolation is an absolute minimum parameter specified in dB.
- Coupling between individual ports is best described in terms of “S parameters”. For example, the magnitude in dB of the coupling from port 1 to port 3 is signified by S_{13}.
- For passive devices, coupling is reciprocal, that is, $S_{13} = S_{31}$.
- Specification shall reference the full frequency range, full electrical downtilt range, and associated ports of the antenna.

Specification Example

Type: Absolute	1710-2170 MHz
Inter-cluster Isolation	> 20 dB

Relevance
Coupling between antenna ports can influence the level of filtering required for a given site configuration.

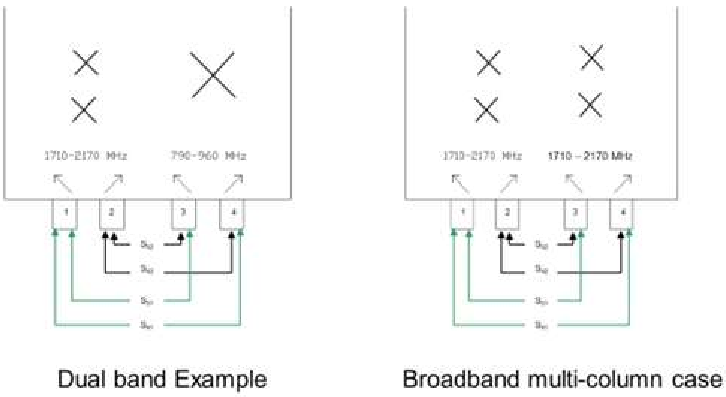


Figure 7.10: Inter-Cluster isolation examples.

In this example, the inter-cluster isolation is the worst case of S41, S31, S42 and S32.

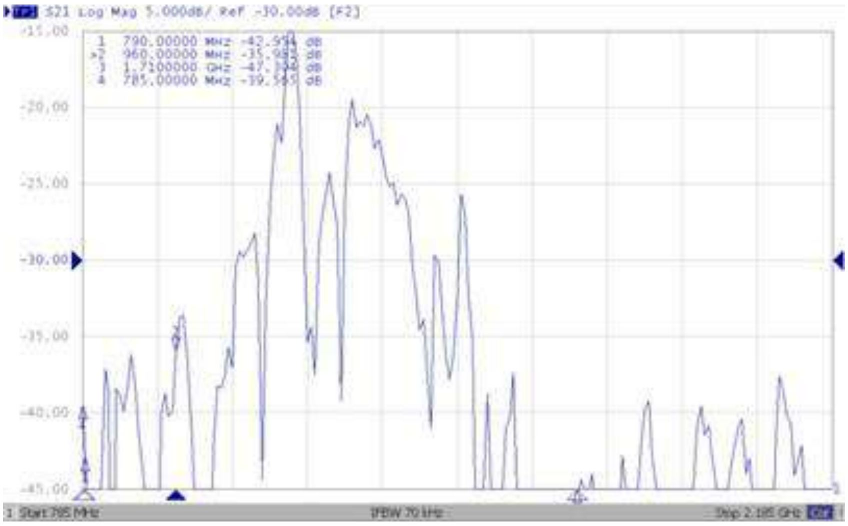


Figure 7.11: Inter-cluster isolation vs. frequency on a single pair of ports.

7.3.7 Intra-Cluster Isolation

Parameter Definition

It is within a cluster the ratio of the power injected in one of the ports associated to a specific polarization, and the power detected from the other port associated to the polarization orthogonal to the first one.

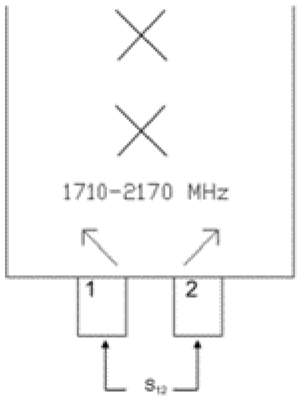
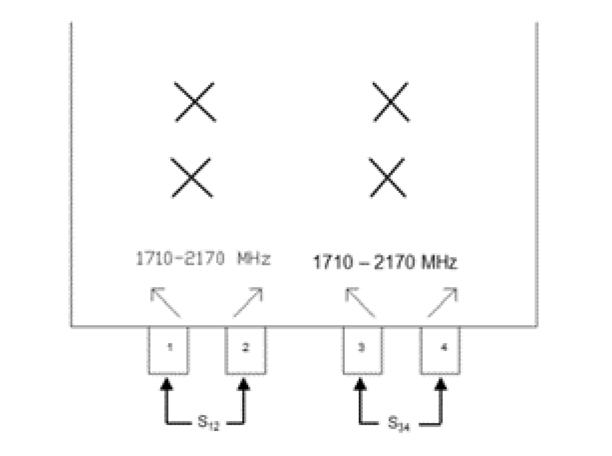


Figure 7.12: Intra-Cluster isolation example: single cluster antenna.



In this dual cluster example, the cross-polar isolation is the S_{12} for the first cluster and S_{34} for the second cluster.

Figure 7.13: Intra-Cluster isolation example: dual cluster antenna.

Specification Definition

- Intra-Cluster Isolation is a minimum absolute parameter.
- Specified in dB.
- This parameter is to be defined for all the sub-bands in a broadband antenna. It will be assumed the specification is for the full electrical downtilt range, and for all the ports associated with each frequency sub-band of the antenna.
- For antennas with multiple dual-pol clusters, the specification applies to each cluster individually and does not address coupling between them.
- Coupling between individual ports is best described in terms of "S parameters". For example, the magnitude in dB of the coupling from port 1 to port 2 is signified by S_{12}.
- For passive BSAs, coupling is reciprocal, i.e., $S_{12} = S_{21}$.

Specification Example

Type: Absolute	1710-1880 MHz	1850-1990 MHz	1920-2170 MHz
Intra-Cluster Isolation	> 30 dB	> 28 dB	> 26 dB

Relevance

Coupling between antenna ports can influence the level of filtering required for a given site configuration.

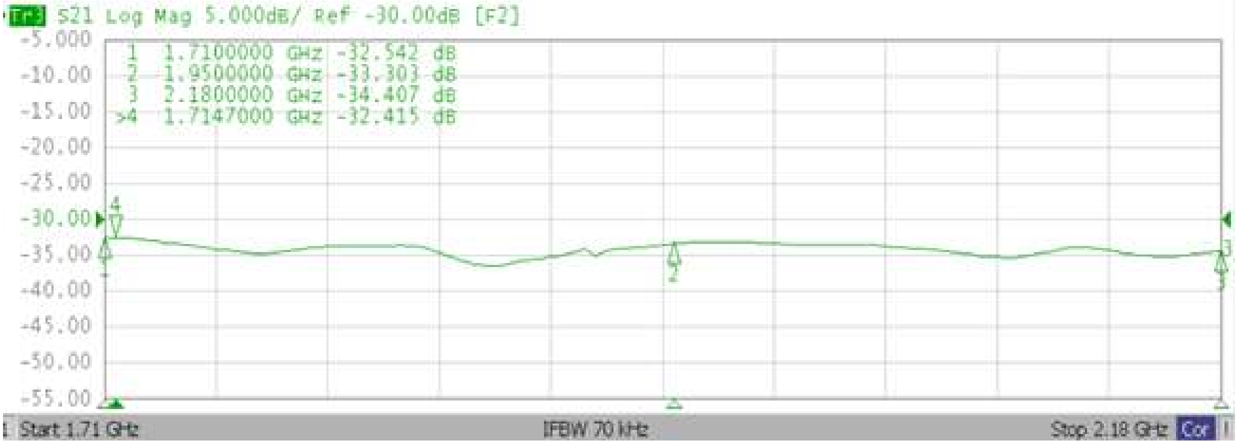


Figure 7.14: Example of an intra-cluster isolation measurement between two antenna ports.

7.3.8 Passive Intermodulation

Parameter Definition

The PIM is the low-level signal created as the result of multiple high power transmit signals in an antenna. This relatively low power signal is generated at distinct frequencies and has the potential to inject interference in the receive band thereby degrading the uplink reception.

Specification Definition

- PIM is an absolute parameter.
- It is specified as a maximum in-band negative value in dBc.
- 3rd order passive intermodulation products measured using 2 x 20 W (2 x 43 dBm) carriers (F1 and F2).
- 3rd order products are defined at frequencies of (F1 ± 2*F2) and (F2 ± 2*F1) falling within the receive band when transmit frequencies F1 and F2 are used as the input carriers.
- Specification shall reference the full frequency range, full electrical downtilt range, and associated ports of the antenna.
- PIM measurement practices are discussed in Section 11.1.3.7

PIM measurement values shall refer to measurement at the connector in accordance with [18] .

Specification Example

Type: Absolute	1710-2170 MHz
Passive Intermodulation	< -150.0 dBc

Relevance

The specification defines a limit to the PIM generated in the antenna, which under the right conditions, causes receive band interference that degrades uplink system sensitivity.

7.3.9 Return Loss

Parameter Definition

The RL is the ratio (in linear unit) between forward and reflected power measured at the antenna port over the stated operating band.

Specification Definition

- Return loss is an absolute parameter.
- Specified as a minimum in-band value in dB.
- Specification shall reference the full frequency range, full electrical downtilt range, and associated ports of the antenna.

Specification Example

Type: Absolute	1710-2170 MHz
Return Loss	> 14 dB

Relevance

- One of the indicators of the effectiveness of the power delivery from an antenna's input to an antenna's radiated output (a higher RL value represents less reflections from the antenna).
- Return loss and VSWR both characterize the mismatch between the transmission line and the antenna's radiators and are mathematically related though the following formula:

$$RL = 20\ log_{10}\left(\frac{VSWR+1}{VSWR-1}\right)\ [dB] \qquad (7.8)$$

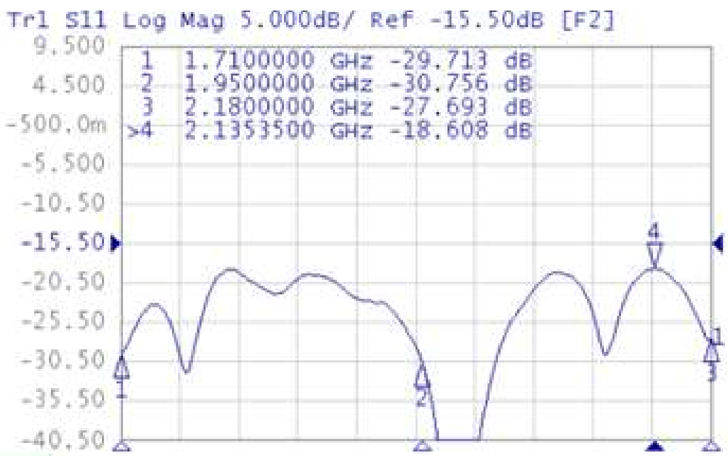


Figure 7.15: Example of a return loss measurement on a single antenna port.

7.3.10 Voltage Standing Wave Ratio

Parameter Definition

The VSWR is defined as the highest ratio between the cluster ports of the maximum and minimum amplitudes of the voltage standing wave measured at the input ports of an antenna.

Specification Definition

- VSWR is an absolute parameter.
- Specified as a maximum in-band value without measurement unit. All the possible values are between 1 (no reflection) and infinite (total reflection). The reference wave impedance is 50 Ohms.

- Specification shall reference the full frequency range, full electrical downtilt range, and associated ports of the antenna.

Specification Example

Type: Absolute	1710-2170 MHz
Voltage Standing Wave Ratio	< 1.5

Relevance
- Base station antennas are typically specified to have a VSWR of less than 1.5 which corresponds to a return loss of 14dB.
- The VSWR is a measure of the matching of the antenna's radiators to its source and feeder cables. A low VSWR will minimize reflections from the antenna.

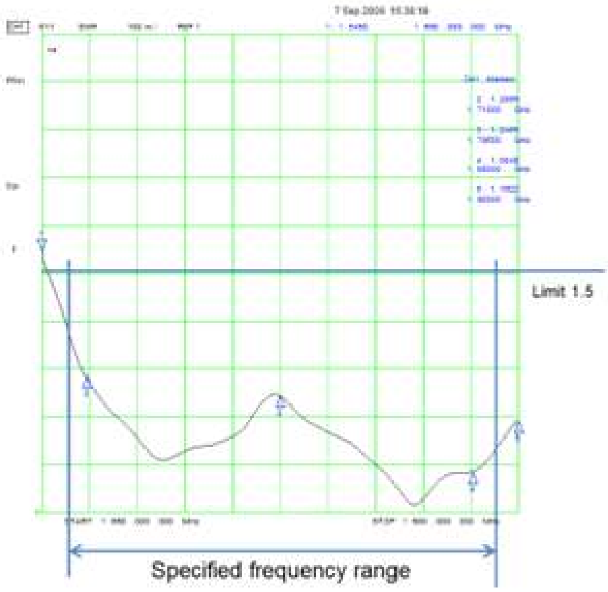


Figure 7.16: Example of VSWR measurement of an antenna port.

7.4 Mandatory Parameters and Recommendations for Active Antennas

7.4.1 Frequency Range and Bandwidth

Parameter Definition
Supported frequency band configuration(s), expressed in the terms defined in Section 2.13

Specification Definition
- The frequency range(s) are specified in MHz.
- If the AAS supports more than one Operating Band, the supported frequency range(s) shall be specified for each Operating Band

Specification Example

- Operating Band: n78
- Supported Frequency Range: 3400-3600 MHz
- Aggregated OBW: 160 MHz
- IBW: 200 MHz

Relevance
NA

7.4.2 Active Antenna System Test State (TS)

The Test State (TS) is a state of an AAS in which some specific operations for testing purposes are performed, accessed, and managed by means of a tool (hardware and/or software) made available by the manufacturer. The TS is used for in lab, in situ and for pre-operation testing.

Note: In the TS the AAS, preferably, can be operated without any need to connect it to a commercial core network.

Parameter definition
- The purpose of this section is to describe Test States (TS). TS implementation and availability are optional.
- The manufacturer/supplier is expected to support the operator to conduct the corresponding test, if needed.
- The following Test States are defined:
    - TS01: Broadcast Beam radiation pattern measurement
    - This TS enables the radiation pattern testing of beams (for each applicable nominal polarization as per section 3.2.3) in the broadcast beam set.
    - In case a broadcast configuration is composed of sweeping beams (see section 7.4.8), TS01 allows individual beams to be locked in time, see Section 19.
    - TS02: Traffic Envelope Radiation Pattern (TERP) measurement associated to a specific Broadcast configuration.
    - This TS enables the measurement of TERP for a specific BERP configuration (for each applicable nominal polarization as per Section 7.4.15) at a Configured Output Power given by the AAS datasheet, see Section 19.
    - TS03: Radiation pattern measurement of Traffic Beams in GoB configuration
    - This TS enables the radiation pattern testing of traffic beams in a GoB configuration (for each applicable nominal polarization as per Section 7.4.15) at Configured Output Power given by the AAS datasheet by locking each beam in time. The beam is selected among the available Beam Set as defined in Section 7.4.17, see Section 19.
    - TS04: Radiation pattern measurement of Traffic Beams in EBB configuration
    - This TS enables the radiation pattern testing of traffic beams in an EBB configuration (for each applicable nominal polarization as per Section 7.4.15) at Configured Output Power given by the AAS datasheet by locking each beam in time. The selected beam may be defined by means of a specific pan and tilt direction and HPBWs, see Section 19.
    - TS05: UL Pattern measurements
    - This TS enables the UL pattern testing by selecting a specific configuration (as an example: beam ID, set of weights, manufacturer specific code) locked in time during the measurement with a constant reference stimulus signal.

NOTE: for the reference signal the 3GPP test signal could be used [14]. Alternatively, a UE with UL test signal could be used.

Specification definition

- The manufacturer/supplier should provide information related to each TS listed below according to the following structure:

- TS Available: [Yes/No], if Yes then provide the following:
    - Description:
        - Test objective and procedure, test limitations and any other relevant information
    - Test State: TS01, TS02, TS03, TS04, TS05
    - Additional items: if Yes then provide further details
        - Core Network need: [Yes/No]
        - AAS related HW: [Yes/No]
        - Test equipment: [Yes/No]
        - Dedicated SW: [Yes/No]
    - Test environment: [Lab and/or on site]

Specification Example

- Test State Available: Yes
- Description: This is the description
- Test State: TS01
- Additional Items: Dedicated SW
- Test Environment: Laboratory and Onsite

Relevance

NA

7.4.3 Azimuth Scanning Range

Parameter Definition

Range of angles in azimuth in which the AAS is optimised and intended to be operated. It is a subset of the OTA peak direction set defined in 3GPP, see [4][14].

Specification Definition

The nominal range of values in degrees.

Specification Example

Azimuth Scanning Range = 300° to 60° (-60° to 60 ° in SPCS_CW or SPCS_CCW)

Relevance

NA

7.4.4 Elevation Scanning Range

Parameter Definition

Angular range in elevation in which the AAS is optimised and intended to be operated. It is a subset of the OTA peak direction set defined in 3GPP, see [14].

Specification Definition
The nominal range of values in degrees.

Specification Example
Elevation Scanning Range = 75° to 105° (-15° to 15° in SPCS_CW or SPCS_CCW)

Relevance
NA

7.4.5 Maximum Number of Layers

Parameter Definition
Maximum number of data streams (layers) sharing time and frequency resources that the AAS can handle simultaneously, in uplink and downlink. As an example, the layers can be associated to multiple users (MU-MIMO), one single user (SU-MIMO) or a combination of both, i.e., multiple users having each of them one or multiple layers associated.

Specification Definition
- Maximum Number of downlink Layers
- Maximum Number of downlink layers per user
- Maximum Number of uplink Layer
- Maximum number of uplink layer per user

Specification Example
- Maximum Number of downlink Layers: 16
- Maximum Number of downlink layers per user: 4
- Maximum Number of uplink Layer: 4
- Maximum number of uplink layer per user: 2

Relevance
NA

7.4.6 Number of TRX

Parameter Definition
Number of independent TRX in the AAS. For each TRX branch there can be one or more radiating elements connected to it.

Specification Definition
mTnR: Where m is the number of TX and n is the number of RX

Specification Example
Number of TRX = 64T64R

Relevance
NA

7.4.7 Power of an Active Antenna System

7.4.7.1 Maximum Total Output RF Power

Parameter Definition

The Maximum Total Output RF power is the maximum power achievable by the AAS during the transmitter ON period, typically when all power amplifiers have the (same) maximum power at their outputs. Maximum Total Output RF power is identical to "OTA BS Output Power" Sec 9.3 in [4] [14], this is a TRP value declared by the vendor.
Power values are intended to be RMS with respect to time.

Specification Definition

- Maximum Total Output RF power is specified is either Watt or dBm.
- Unit shall be indicated.

Specification Example

Type: Absolute
Maximum Total Output RF Power: 200 W
Maximum Total Output RF Power: 53 dBm

Relevance

NA

7.4.7.2 Minimum Configurable Total Output RF power

Parameter Definition

The Minimum Configurable Total Output RF power is the minimum power achievable by the AAS, typically when all power amplifiers have the (same) minimum power at their outputs. Minimum Configurable Total Output RF power is a TRP value declared by the vendor. At the Minimum Configurable Total Output power the performances declared by the vendor may not be achieved.
Power values are intended to be RMS with respect to time.

Specification Definition

- Minimum Configurable Total Output RF power is specified either in W or dBm.
- Unit shall be indicated

Specification Example

Type: Absolute
Minimum Configurable Total Output RF Power: 1 W
Minimum Configurable Total Output RF Power: 30 dBm

Relevance

NA

7.4.7.3 Output RF Power Dynamic Range

Parameter Definition

The Output RF Power Dynamic Range defines the maximum reduction of the nominal Maximum Total Output RF radiated power while maintaining the performances within the range declared by the vendor.

Specification Definition
Output RF Power Dynamic Range is specified in dB.

Specification Example
- Type: Relative
- Output RF Power Dynamic Range: 10 dB

Relevance
NA

7.4.8 Broadcast Beams

7.4.8.1 Broadcast Beam Set

Parameter Definition
A broadcast beam set is defined as the collection of all the preconfigured broadcast beams (see section 7.4.8). Each beam is declared according to the table below. The configured output power associated to the given EIRP shall be reported.

Specification Definition

Beam ID	Frequency Band	EIRP	Nominal Polarization	Azimuth		Elevation	
				HPBW	Pan	HPBW	Tilt
		[dBm]		[degrees]	[degrees]	[degrees]	[degrees]

Specification Example

Beam ID	Frequency Band	EIRP [dBm]	Nominal Polarization [degrees]	Azimuth		Elevation	
				HPBW [degrees]	Pan [degrees]	HPBW [degrees]	Tilt [degrees]
1	n78	75.5	+45	15.0°	307.5°	6.0°	96.0°
2		76.0	-45		322.5°		
3		76.5	0		337.5°		
4		77.0	+90		352.5°		
5		77.0	+45		+7.5°		
6		76.5	-45		+22.5°		
7		76.0	0		+37.5°		
8		75.5	+90		+52.5°		

The configured power was 50 dBm

Relevance
NA

7.4.8.2 Broadcast Beam Configuration

Parameter Definition
A broadcast beam configuration is defined as the overall radiating behaviour for a given deployment/coverage scenario (see Section 7.4.8) obtained by radiating one or more beams selected from the ones belonging to the broadcast beam set.

- The broadcast beam configuration can be:
    - Composed by just one of the beams of the broadcast beam set;
    - Composed by a number of broadcast beams of the broadcast beam set selected in a way for solving specific coverage needs. There can be a different number of available broadcast beam configuration implemented by the AAS, each one composed by beams belonging to the broadcast beam set.
    - Sweeping across beams type, Section 7.4.8.
- The broadcast beam configuration can:
    - Have an associated envelope radiation pattern as described in Section 6.1.10
    - Refer to a single beam ID. In the case this section is not relevant

Example of configuration:
A possible configuration may comprise 8 beams, with the same elevation pointing direction ($\vartheta_{SPCS\_Polar} = 0°$ for example) and equally distributed in azimuth from 300° to 60°. The following figure illustrates this example. Each single beam is depicted in green; the red curves (H65) correspond to a traditional coverage beam of a passive antenna.

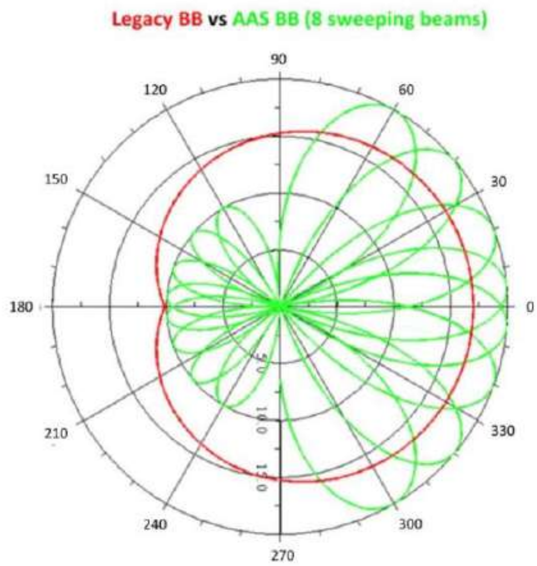


Figure 7.17: Broadcast beams configuration example (8 beams).

Other possible examples are depicted in the following figures.

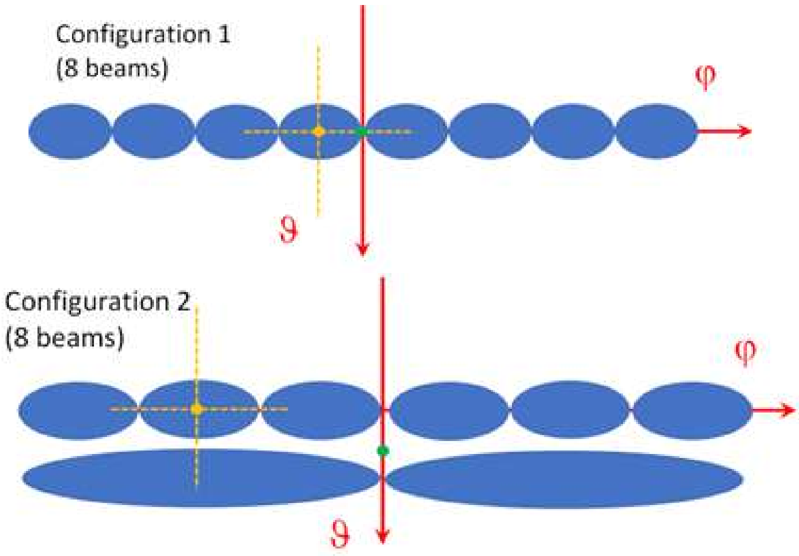


Figure 7.18: Broadcast beams configuration examples, using 8 beams where the green and orange dots indicate the envelope centre and peak direction

Specification Definition

For each configuration ID, the main characteristics of the corresponding envelope radiation pattern are to be provided according to the following table format. For the values of Pan, Tilt and Beamwidth, either a single value or a set of values can be stated. If there is more than one beam, by default it is assumed that sweeping across beams is applied, see Section 6.2.1.1. The Configured Output Power associated to the given EIRP shall be reported (exactly as for broadcast beam set).

Config. ID	Frequency Band	EIRP	Nominal Polarizatio	Envelope Azimuth			Envelope Elevation		
		dBm		HPBW	Pan	Conical Cut Direction	HPBW	Tilt	Great Circle Cut Direction
				[degrees]	[degrees]	[degrees]	[degrees]	[degrees]	[degrees]

Specification Example

Config. ID	Frequency Band	EIRP [dBm]	Nominal Polarizatio	Envelope Azimuth	Envelope Elevation

				HPBW	Pan	Conical Cut Direction	HPBW	Tilt	Great Circle Cut Direction
1	n78	77.0	+45°	60°	0°	90°,95°,100°	6°	90°,95°,100°	7.5°
2	n78	74.0	-45°	60°	0°	90° 93°,96°	12°	90°,93°,96°	7.5°

The configured power was 50 dBm

Relevance
NA

7.4.9 Minimum Azimuth HPBW

Parameter Definition
The minimum azimuth HPBW that can be achieved when all the radiators in the AAS are active and fed with uniform phase and amplitude.

Specification Definition
- Range of values over frequency in degrees.
- The HPBW is calculated from the Total radiated power radiation pattern.

Specification Example
Minimum Azimuth HPBW = 12° to 16°

Relevance
NA

7.4.10 Minimum Elevation HPBW

Specification Definition
The minimum elevation HPBW that can be achieved when all the radiators in the AAS are active and fed with uniform phase and amplitude.
Range of values over frequency in degrees.
The HPBW is calculated from the Total radiated power radiation pattern.

Specification Example
Minimum Elevation HPBW = 5.5° to 7.5°

Relevance
NA

7.4.11 Number of Carriers

Parameter Definition
Number of carriers supported by the AAS.

Specification Definition

- For defining the number of carriers, it is recommended to follow 3GPP documents: [4] for New Radio (NR) and [14] for Multi Standard Radio (MSR)
- If the AAS supports more than one Operating Band, the supported number of carriers shall be specified for each Operating Band

Relevance
NA

7.4.12 Supported Carrier Bandwidths

Parameter Definition
The parameter indicates the bandwidths the AAS supports within the declared IBW. The Supported Carriers Bandwidths is reported as list. The unit is MHz.

This parameter does not apply to PBCA Antennas.

Specification Definition
List of Supported Carrier Bandwidth

Specification Example
Supported Carrier Bandwidth: 10 MHz, 20 MHz, 50 MHz, 100 MHz, 200 MHz

Relevance
NA

7.4.13 Supported RATs

Parameter Definition
The parameter reports the list of the RATs supported by the AAS

Specification Definition
List of supported RATs, as follows:

- 5GNR_n# where # indicates the specific band as reported in [4]
- LTE_B#, where # indicates the specific band as reported in [4]
- Free format: description of the RAT if not included in the list.

Specification Example
Supported RAT: 5GNR_n78, LTE_B43

Relevance
NA

7.4.14 Supported TDD Patterns

Parameter Definition

The parameter indicates the TDD pattern supported by the AAS, by using the following character coding for slots:

- the letter "D" stands for Downlink slot
- the letter "U" stands for uplink slot
- the letter "S" stands for Special slot.

Specification Definition

List of supported TDD Patterns

Specification Example

List of supported TDD Patterns: DDDDDDDSUU, DDDSUUDDDD, DDDSU

Relevance

NA

7.4.15 Optical Connection

Parameter Definition

The parameter describes the characteristics of the optical connection to/from the AAS.

Specification Definition

The optical connection to/from the AAS should be described by the following elements:

- the number of the optical transceivers to be plugged into the AAS: an integer number ≥ 1
- the form factor of the optical transceivers as specified by MOPA Alliance [44]: a string
- the number of the optical fibres per optical transceiver: an integer number ≥ 1
- the connector type of the optical fibres as specified in [45][46]: a string.

The parameter should be given for each optical connection type supported by the AAS, if more than one is available.

Specification Example

- Optical connection type 1
    - number of optical transceivers: 4
    - optical transceiver form factor: SFP28
    - number of optical fibres per optical transceiver: 2
    - optical fibre connector type: LC
- Optical connection type 2
    - number of optical transceivers: 2
    - optical transceiver form factor: SFP56
    - number of optical fibres per optical transceiver: 2
    - optical fibre connector type: LC

Relevance

NA

7.4.16 Polarization

Parameter Definition

The nominal polarization associated to the radiating elements of the AAS.

Specification Definition

- Linear polarizations are declared as: H and V, +45 and -45, etc
- Circular polarizations are typically declared as RHCP and LHCP.
- If the polarization is expressed in terms of angle (number), the unit is degrees

Specification Example

Polarization: +45 and -45

Relevance

NA

7.4.17 Traffic Beams

The following two mutually exclusive parameter definitions apply according to the traffic beam types defined in Section 6.2.1.3, Section, 6.2.1.4 and Section 6.2.1.5.

7.4.17.1 GoB Configuration

Parameter Definition

The characteristics of each beam in a traffic GoB set (Section 6.2.1.3) shall be specified according to the table given below. Beams having different Pan and Tilt are considered different, so a specific Beam_Id is associated to each beam.

When the number of beams in a traffic GoB is so large that it can be difficult, time consuming or inefficient to describe the characteristics of each beam in the set, the manufacturer can describe the traffic performances of the GoB AAS with one or more envelope patterns, as defined in Section 6.1.10.

- The configured output power associated to the given EIRP shall be reported.

Specification Definition

<table>
<tr><th rowspan="3">Beam ID</th><th rowspan="3">Frequency Band</th><th rowspan="2">EIRP</th><th rowspan="3">Nominal Polarization</th><th colspan="2">Azimuth</th><th colspan="2">Elevation</th></tr>
<tr><th>HPBW</th><th>Pan</th><th>HPBW</th><th>Tilt</th></tr>
<tr><th>[dBm]</th><th>[degrees]</th><th>[degrees]</th><th>[degrees]</th><th>[degrees]</th></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

Specification Example

<table>
<tr><th rowspan="2">Beam ID</th><th rowspan="2">Frequency Band</th><th rowspan="2">EIRP</th><th rowspan="2">Nominal Polarization</th><th colspan="2">Azimuth</th><th colspan="2">Elevation</th></tr>
<tr><th>HPBW</th><th>Pan</th><th>HPBW</th><th>Tilt</th></tr>
<tr><td>1</td><td rowspan="4">n78</td><td>73.0</td><td>+45°</td><td rowspan="4">30°</td><td>315°</td><td rowspan="4">6°</td><td rowspan="4">93°</td></tr>
<tr><td>2</td><td>74.0</td><td>-45°</td><td>345°</td></tr>
<tr><td>3</td><td>74.0</td><td>0°</td><td>15°</td></tr>
<tr><td>4</td><td>73.0</td><td>+90°</td><td>45°</td></tr>
</table>

5		73.0	+45°		315°		
6		74.0	-45°		345°		99°
7		74.0	0°		15°		
8		73.0	+90°		45°		

The configured power was 50 dBm

Relevance
NA

7.4.17.2 EBB Approach

Parameter Definition
An AAS implementing traffic beams by using the EBB approach generates, in real time, radiation patterns whose shape depends on traffic conditions. For such systems, the radiating performance is summarized by the envelope radiation pattern as defined in Section 6.1.10.
The configured output power associated to the given EIRP shall be reported.

Specification Definition
The EBB envelope radiation pattern characteristics are described according to the following table:

Envelope ID	Frequency Band	EIRP [dBm]	Nominal Polarization	Ripple	Azimuth		Elevation	
					HPBW	Pan	HPBW	Tilt
				[dB]	[degrees]	[degrees]	[degrees]	[degrees]

The maximum EIRP and the associated envelope radiation pattern correspond to an unlikely situation in which all the power is assigned to a single beam, to one user only, and in LoS (Line of Sight) conditions. However, this situation is important in the context of EMF, since it gives the absolute maximum EIRP in a given direction.

NOTE: For EBB, as the number of patterns that can be generated is unlimited, the envelope radiation pattern can be created by means of software taking as input the tested radiation pattern of each TRX, the array factor and weights calculated for each direction.

Specification Example

Envelope ID	Frequency Band	EIRP	Nominal Polarization	Ripple	Azimuth		Elevation	
					HPBW	Pan	HPBW	Tilt
1	n78	77 dBm	+45	3 dB	60°	0°	12°	96°

The configured power was 50 dBm

Relevance
NA

7.4.18 Monitoring Counters

Parameter definition

The parameter indicates if power counters are available on the AAS unit. Descriptions of counters can be found in sections 7.4.18.1 to 7.4.18.2.2.

In the context of RF-EMF exposure assessment [19], [20] and [21], it is required that antenna manufacturers make available to operators a certain number of counters (see [10] [19] and Section 13.3.3.3 in [22]). In line with those requirements, the following power monitoring counters are defined:

- Total radiated power counter
- Directional radiated power counters

Specification Definition

The following characteristics mandatorily apply to such counters:

- counters names and formats are declared by AAS manufacturer;
- counters are made available to the operator's Network Management System;
- the averaging process is performed over a 6-minute time interval or its sub-multiple (e.g. 10 s, 30 s, 60 s, etc.), in line with what is specified in the applicable RF-EMF exposure regulations;
- the time-averaging methodology is described (e.g. moving window).

The availability of monitoring counters is required.

Specification Example

- Total Radiated Power Counter: Available
- AR Radiated Power Counter: Available
- Beam Radiated Power Counter: Not Available

If radiation control mechanisms are implemented, see Section7.4.19, the corresponding counters are required.

NOTE: Counter reporting time interval may not correspond to average time interval

Relevance

NA

7.4.18.1 Total radiated power counter

The counter that monitors the total radiated power over the full sphere shall report:

- the time-averaged power level;
- as an option, its Probability Distribution Function (PDF).

7.4.18.2 Directional radiated power counters

- Directional radiated power counters are introduced to monitor the time-averaged radiated power delivered to specific directions where exposure issues can happen.
- Directional power counters can be associated to either an AR (per-AR radiated power counter) or a specific beam (per-beam radiated power counter).

- AR radiated power counter can be used for both GoB and EBB traffic beam implementation choices while per-beam radiated power counter might be more straightforwardly applicable to GoB solutions. Anyway, it is not necessary to have both types of counters implemented and it is up to the AAS's manufacturer to decide which type of counter is more suitable for its own AAS product.

7.4.18.2.1 Angular region radiated power counter

The power radiated through an AR (AR TRP) is defined as:

$$AR\ TRP = \frac{1}{4\pi}\iint_S \ EIRP(\vartheta,\varphi)\,dS \qquad (7.9)$$

In the SPCS_Polar, equation (7.1) is expressed as

$$AR\ TRP = \frac{1}{4\pi}\int_{\vartheta_{min}}^{\vartheta_{max}}\int_{\varphi_{min}}^{\varphi_{max}} EIRP(\vartheta,\varphi) r^2 sin\vartheta\ d\vartheta\ d\varphi \qquad (7.10)$$

being ϑ_{min}, ϑ_{max}, φ_{min}, φ_{max} the limits of the AR.

The AR radiated power counter monitors the time-averaged power radiated through each AR the served sector is divided into (AR definition and example is given in section 2.4).

Each AR needs to be described and identified with an ID, as specified in 2.4.

For each AR, the AR radiated power counter shall report:

  - the AR ID it is associated to;
  - the time-averaged power level;
  - and optionally, the Probability Distribution Function (PDF) of the monitored power levels.

Similar counter reporting EIRP can also be provided.

NOTE: The power reported in each AR is the whole power radiated by the AAS in that region.

7.4.18.2.2 Beam radiated power counter

The beam radiated power counter monitors the time-averaged power radiated by each beam in the beam set the antenna is configured to use.

For each beam, the beam radiated power counter shall report:

- the beam ID it is associated to;
- the time-averaged power value;
- and optionally, the Probability Distribution Function (PDF) of the monitored power levels.

Similar counter reporting EIRP can also be provided.

7.4.19 Radiated Power Limiting Mechanisms

Parameter definition

In this section the capability of controlling the AAS radiated power [10], either statically or dynamically depending on the scenario where it is operated, is addressed.
The availability of radiated power control mechanisms is required.
The purpose of such mechanisms is to limit the power radiated by an AAS, either in general or towards specific directions (e.g. to comply with RF-EMF exposure limits).
Power limiting mechanisms are always associated to the corresponding power monitoring counters described in [10], which allow the operator to monitor the evolution of the power radiated by the AAS over time.
Following Sections7.4.19.1 to 7.4.19.4 ,contain a description of the features.

Specification Definition

- Total Radiated Power Control: Available/Not Available
- AR Radiated Power Control: Available/Not Available
- Beam Radiated Power Control: Available/Not Available

Specification Example

- Total Radiated Power Control: Available
- AR Radiated Power Control: Available
- Beam Radiated Power Control: Not Available

Relevance

NA

7.4.19.1 Total radiated power limiting mechanism

The total radiated power limiting mechanism indicates the capability to limit the Total radiated power radiated by an AAS. Implementation-dependent options are to limit:

- the peak power level;
- the time-averaged power level.

If such mechanism is supported, whatever option is implemented, the vendor shall provide:

- a description of the mechanism, by explicitly indicating whether the implemented mechanism is either static or dynamic;
- the range and the steps used to limit the power.

7.4.19.2 Directional radiated power limiting mechanism

The directional radiated power limiting mechanism indicates the capability to limit the power radiated by an AAS towards specific directions. Implementation-dependent options are to limit:

- the peak power level;
- the time-averaged power level.

If such mechanism is supported, whatever option is implemented, the vendor shall provide:

- a description of the mechanism, by explicitly indicating whether the implemented mechanism is either static or dynamic;

- the range and the steps used to limit the power per direction.

A direction can be defined either by the AR it refers to or by the beam associated to it in case of GoB approach. Whatever choice is made, two different directional power limiting mechanisms can be defined (associated to the corresponding directional power monitoring counters of Sections 7.4.19.3 and **7.4.19.4**), which are described in the two following two sections.

7.4.19.3 AR radiated power limiting mechanism

The AR radiated power limiting mechanism indicates the capability to limit the power radiated by an AAS towards a specific AR. Implementation-dependent options are to limit:

- the peak power level;
- the time-averaged power level.

If such mechanism is supported, whatever option is implemented, the vendor shall provide:

- the identification of the AR where the power limiting mechanism is operated;
- a description of the mechanism, by explicitly indicating whether the implemented mechanism is either static or dynamic;
- the range and the steps used to limit the power per-AR.

7.4.19.4 Beam radiated power limiting mechanism

The beam radiated power limiting mechanism indicates the capability to limit the power of a specific beam radiated by an AAS. Implementation-dependent options are to limit:

- the peak power level;
- the time-averaged power level.

If such mechanism is supported, whatever option is implemented, the vendor shall provide:

- Beam ID (Section 7.4.8.1) where the power limiting mechanism is operated;
- a description of the mechanism, by explicitly indicating whether the implemented mechanism is either static or dynamic;
- the range and the steps used to limit the power per beam.

7.5 Mandatory Parameters and Recommendations for Hybrid Passive Active Antennas (HPAA)

The term Hybrid Passive and Active Antenna (HPAA) refers to a radiating system made of two or more passive and active antenna systems placed in a defined mechanical layout, maybe but not necessarily placed inside the same enclosure.
AAS and PAS can be separated units or can form a single functional entity. Different layouts are possible depending on the specific HPAA implementation, see details in Section 15.

In case of separated antenna systems placed inside the same enclosure, performance of each antenna in the HPAA configuration with respect to its performance when operated in standalone configuration may be impacted.

7.5.1 HPAA

Parameter definition
The parameter specifies if the antenna is an HPAA

Specification Definition
Hybrid Passive and Active Antenna system or Not Hybrid Passive and Active Antenna system

Specification Example
HPAA: Hybrid Passive Active Antenna system
Not HPAA

Relevance
NA

7.5.2 Modularity of Antenna Units Inside the Same Enclosure in HPAA configuration

Parameter Definition
The parameter indicates if the antenna unit can be arranged in a HPAA arrangement configuration, see description in Section 15.

Specification Definition
Modular arrangement in HPAA configuration can be described as follows:
- Not Modular Arrangement in HPAA, abbreviated as NMAHPAA
- Modular Arrangement in HPAA
    - An antenna unit that can be included as is in the common enclosure, abbreviated as MAHPAA-SA
    - An antenna unit that can be included in the common enclosure without its own enclosure, abbreviated as MAHPAA-NU
- Not Applicable: abbreviated as NA

Note: Modular Arrangement in HPAA of a standalone antenna unit means the antenna can be included in the common enclosure without any modification to the unit

Note: Modular Arrangement in HPAA of a naked antenna unit means the antenna can be included in the common enclosure removing its own enclosure.

Specification Example
- NMAHPAA
- MAHPAA-SA
- MAHPAA-NU
- NA

Relevance
NA

7.5.3 HPAA Type

Parameter definition

HPAA layout is made of two components:

- HPAA layout
- HPAA enclosure type

The definition of this parameter is relevant only to the layout of the HPAA systems and it is independent if the AAS and PAS are single or separated functional entities, modality of connection, typology and arrangement of connectors.

Table 7-3: List of acronyms for HPAA

Acronym	Layout
VS	Vertical Stacked
HIL	Horizontal Inline Layout
OL	Overlay Layout
IL	Interleaved
NS	Not Specified
NA	None of the Above

Configuration Description

Depending on the HPAA implementation, possible layouts are (see Section 15):

- Not HPAA
- VS, Top PAS, Bottom AAS
- VS, Top AAS, Bottom PAS
- VS, Top PAS, Bottom empty
- VS, Top Empty, Bottom PAS
- VS, Top AAS, Bottom Empty
- VS, Top Empty, Bottom AAS
- HIL, Left PAS, Right AAS
- HIL, Left AAS, Right PAS
- HIL, Left PAS, Right Empty
- HIL, Left Empty, Right PAS
- HIL, Left AAS, Right Empty
- HIL, Left Empty, AAS Right
- OL, Front AAS Back PAS
- OL, Front PAS Back AAS
- OL Front AAS, Back Empty
- OL front PAS, Back empty
- IL, Front PAS, Back AAS
- IL, Front AAS, Back PAS
- NS, Not Specified
- NA: none of the above - Description needed. NA apply also to describe HPAA including more than 2 antenna systems.

- According to the HPAA layout, possible enclosure types are (see Section 15 for details):
  - Standalone: two separated standalone antenna systems are placed inside the same enclosure.

- Naked: two separated naked antenna systems (naked antenna is intended an antenna system without the enclosure or with its original enclosure removed) are placed inside the same enclosure.
- Separated: two separated antenna systems are arranged in an HPAA layout as described by the previous item list 1, but they are not placed inside the same enclosure (each antenna systems uses its own enclosure)
- NS: Not specified
- NA: no one of the above – Description needed

<u>Specification Examples</u>

HPAA Type

Layout: VS, Top Empty, Bottom AAS
Enclosure type: Standalone"

HPAA Type

Layout: VS, Top Empty, Bottom AAS
Enclosure type: NA. "Describe here the implementation.

HPAA Type

Layout: Not Specified
Enclosure type: Not Specified

HPAA Type

Layout: NA. "Describe here the implementation
Enclosure type: NA. "Describe here the implementation

<u>Relevance</u>

NA

7.5.4 HPAA Performance Changes

7.5.4.1 General

An antenna used in either a Stand Alone (SA) or an HPAA configuration in general shows different behaviour. To evaluate such different behaviour, averaged Gain and EIRP are chosen, together with the methodology used to measure them. If antenna arrays behaviour should be compared, the set of array weights used in the measurements should be specified.

<u>Broadcast/Traffic/Service Beam</u>: The beam is formed by exciting multiple ports simultaneously. Therefore, the mutual-coupling needs to be characterized and compensated before applying the formula of Gain change. Example of methods are:

- Method 1: Measuring the scattering parameters and individual patterns. Then use a simple algorithm to perform calculation.
- Method 2: Use a power splitter board (1xN). The board needs to have a good matching, lower amplitude & phase variation between the N-input ports.
- Other methods are not precluded.

Note: the same methodology used to evaluate the parameter for the standalone unit and for the unit in HPAA configuration shall be used.

Note: the previous is applicable to antenna units where a port can be defined

7.5.4.2 HPAA Average Gain Change (HPAA AGC)

Parameter Definition

HPAA Average Gain Change (HPAA AGC), when applicable, indicates the change of the average Gain over an Angular Region of the antenna unit arranged in a Hybrid Passive Active Antenna configuration, with respect to the average Gain of the very same antenna unit arranged in a standalone configuration. The parameter applies to Option2 of HPAA as described in Section 15.3.

Note for AAs: Test condition shall be specified (ex: centre frequency, bandwidth, configuration, etc). If 3GPP test model is used it shall be indicated. If no 3GGP test model is used, then it is required to specify test conditions.

Specification Definition

- HPAA AGC is composed by two terms:

  The maximum gain change

$$GC_{max} = G_{HPAA\ configuration}(\vartheta_p, \varphi_p) - G_{Standalone\ Unit}(\vartheta_p, \varphi_p) \qquad (7.11)$$

The HPAA Average Gain change in an Angular Region centred on the beam peak is determined as

$$AGC = \frac{\int_{\varphi_{start}}^{\varphi_{end}} \int_{\vartheta_{start}}^{\vartheta_{end}} G_{HPAA}(\vartheta,\varphi) r^2 sin\vartheta d\vartheta d\varphi}{\int_{\varphi_{start}}^{\varphi_{end}} \int_{\vartheta_{start}}^{\vartheta_{end}} G_{standalone}(\vartheta,\varphi) r^2 sin\vartheta d\vartheta d\varphi} \qquad (7.12)$$

In the AR

$$AR = \begin{cases} \vartheta_p - 10° \leq \vartheta \leq \vartheta_p + 10° \\ \varphi_p - 45° \leq \varphi \leq \varphi_p + 45° \end{cases}$$

Note: the r^2 term in (7.12) can be removed since numerator and denominator integrals do not depend on distance in far field.

HPAA AGC is

- is specified as a mean value and reported in dB.
- is defined for all the nominal sub-bands of a broadband antenna.
- is valid for the full electrical tilt range, and for all the ports associated with each frequency sub-band of the antenna.
- is associated to a single beam or to a set of beams; in the case HPAA AGC is associated to a set of beams, it is constituted by two parameters:
  - Value: it is the mean value obtained by averaging over the HPAA AGC values of all beams in the set
  - Deviation: is the double-sided deviation as specified in Section 12.4.2.
- If it is evaluated for a specific beam, the beam ID of that specific beam shall be indicated while the Deviation shall not be indicated.
- If it is evaluated for a set of beams, the list of beam IDs it is not required.

Note – the specific enclosure shall be indicated.

Specification Example

Band	Port	Beam ID	HPAA Gain Max Change	HPAA Gain Max change Deviation	HPAA AGC	HPAA AGC Deviation
1710-1880	ThePort	NA	2.0 dB	0.5 dB	1.0 dB	0.3 dB
1710-1880	ThePort	NA	2.0 dB	0.5 dB	1.0 dB	0.3 dB
N78	NA	EnvelopeConfiguration1	2.0 dB	0.5 dB	1.0 dB	0.3 dB
N78	NA	Beam1234	2.0 dB	0.5 dB	1.0 dB	0.3 dB
N78	NA	Beam1234	2.0 dB	0.5 dB	1.0 dB	0.3 dB
N78	NA	BroadcastBeam1	2.0 dB	0.5 dB	1.0 dB	0.3 dB

Enclosure: “Model of the Enclosure”

Relevance
If HPAA AGC is reported then HPAA AEC could not be reported, in the case indicate NS (Not Specified)

7.5.4.3 HPAA Beam Forming Gain Change (HPAA BFGC)

Parameter Definition
HPAA Beam Forming Gain Change (HPAA BFGC), when applicable, indicates the change of the maximum Beamforming Gain of the antenna unit arranged in a Hybrid Passive Active Antenna configuration, with respect to the maximum Beamforming Gain of the very same antenna unit arranged in a standalone configuration.

It applies to a specific beam including but not restricted traffic beams.

Specification Definition
The maximum gain change is calculated at the nominal beam peak (ϑ_p, φ_p) as:

$$BFGC(\vartheta_p, \varphi_p) = BFG_{HPAA}(\vartheta_p, \varphi_p) - BFG_{Standalone}(\vartheta_p, \varphi_p) \quad (7.13)$$

BF Gain may be calculated in different ways, for example by
- digital post-processing of sub-array patterns, or
- using an analogue RF combining circuit applied to said sub-arrays.

It is required that the same method is used for both the HPAA and the Standalone case.

HPAA BFGC is
- specified as a mean value and reported in dB.
- defined for all the nominal sub-bands of a broadband antenna.
- valid for the full electrical tilt range, and for with each frequency sub-band of the antenna.
- associated to a single beam,
- constituted by two parameters:
    - Value: it is the mean value of BFGC
    - Deviation: is the double-sided deviation as specified in Section 12.4.2.
    - Weight change: YES/NO/NA
- the beam ID of that specific beam shall be indicated.

Specification Example

Band	Beam ID	BFGC Value	BFGC Deviation	Weight Change
1710-1880	NA	2.0 dB	0.5 dB	YES/NO/NA
1710-1880	NA	2.0 dB	0.5 dB	YES/NO/NA
N78	EnvelopeConfiguration1	2.0 dB	0.5 dB	YES/NO/NA
N78	Beam1234	2.0 dB	0.5 dB	YES/NO/NA
N78	Beam1234	2.0 dB	0.5 dB	YES/NO/NA
N78	BroadcastBeam1	2.0 dB	0.5 dB	YES/NO/NA

Enclosure: "Model of the Enclosure"

Relevance
If HPAA GC is reported then HPAA EC could not be reported, in the case indicate NS (Not Specified)

7.5.4.4 HPAA Average EIRP Change (HPAA AEC)

Parameter Definition
HPAA Average EIRP Change (HPAA AEC), when applicable, indicates the change of the maximum EIRP of the antenna unit arranged in a Hybrid Passive Active Antenna configuration, with respect to the maximum EIRP of the very same antenna unit arranged in a standalone configuration.
The parameter applies to Option2 of HPAA as described in Section 15.3.
Note for AAs: Test condition shall be specified (ex: centre frequency, bandwidth, configuration, etc). If 3GPP test model is used it shall be indicated. If no 3GGP test model is used, then it is required to specify test conditions.

Note: the reference power shall be indicated.

Specification Definition
HPAA AEC is composed by two terms:

The maximum EIRP change

$$EC_{max} = EIRP_{HPAA\ configuration}\left(\vartheta_p, \varphi_p\right) - EIRP_{Standalone\ Unit}\left(\vartheta_p, \varphi_p\right) \tag{7.14}$$

The Average Gain change in an Angular Region centred on the beam peak

$$AEC = \frac{\int_{\varphi_{start}}^{\varphi_{end}} \int_{\vartheta_{start}}^{\vartheta_{end}} EIRP_{HPAA}(\vartheta,\varphi) r^2 sin\vartheta d\vartheta d\varphi}{\int_{\varphi_{start}}^{\varphi_{end}} \int_{\vartheta_{start}}^{\vartheta_{end}} EIRP_{standalone}(\vartheta,\varphi) r^2 sin\vartheta d\vartheta d\varphi} \tag{7.15}$$

Note: the r^2 term in (7.15) can be removed since numerator and denominator integrals do not depend on distance in far field.
In the AR

$$AR = \begin{cases} \vartheta_p - 10° \leq \vartheta \leq \vartheta_p + 10° \\ \varphi_p - 45° \leq \varphi \leq \varphi_p + 45° \end{cases}$$

HPAA AEC is

- is specified as a mean value and reported in dB.
- is defined for all the nominal sub-bands of a broadband antenna.
- is valid for the full electrical tilt range, and for all the ports associated with each frequency sub-band of the antenna.
- is associated to a single beam or to a set of beams; in the case HPAA AEC is associated to a set of beams, it is constituted by two parameters:
    - o Value: it is the mean value obtained by averaging over the HPAA AEC values of all beams in the set
    - o Deviation: is the double-sided deviation as specified in Section 12.4.2.
- If it is evaluated for a specific beam, the beam ID of that specific beam shall be indicated while the Deviation shall not be indicated.
- If it is evaluated for a set of beams, the list of beam IDs it is not required.

Note – the specific enclosure shall be indicated.
Note: the same reference power is used to define the parameter when the antenna unit is in standalone configuration or placed inside the enclosure.

Specification Example

Band	Port	Beam ID	HPAA EC_{Max}	HPAA EC_{Max} Deviation	HPAA AEC	HPAA AEC Deviation
1710-1880	ThePort	NA	2.0 dB	0.5 dB	1.0 dB	0.3 dB
1710-1880	ThePort	NA	2.0 dB	0.5 dB	1.0 dB	0.3 dB
N78	NA	EnvelopeConfiguration1	2.0 dB	0.5 dB	1.0 dB	0.3 dB
N78	NA	Beam1234	2.0 dB	0.5 dB	1.0 dB	0.3 dB
N78	NA	Beam1234	2.0 dB	0.5 dB	1.0 dB	0.3 dB
N78	NA	BroadcastBeam1	2.0 dB	0.5 dB	1.0 dB	0.3 dB

Enclosure: Model XXXX

Relevance
If HPAA AEC is reported then HPAA AGC could not be reported, in the case indicate NS (Not Specified)

7.5.4.5 HPAA Beam Forming EIRP Change (HPAA BFEC)

Parameter Definition
HPAA Beam Forming EIRP Change (HPAA BFEC), when applicable, indicates the change of the maximum Beamforming EIRP of the antenna unit arranged in a Hybrid Passive Active Antenna configuration, with respect to the maximum Beamforming EIRP of the very same antenna unit arranged in a standalone configuration.

It applies to a specific beam including but not restricted traffic beams.

Specification Definition

The maximum EIRP change is calculated at the nominal beam peak (ϑ_p, φ_p) as:

$$BFEC(\vartheta_p, \varphi_p) = BFE_{HPAA}(\vartheta_p, \varphi_p) - BFE_{Standalone}(\vartheta_p, \varphi_p) \quad (7.16)$$

BF EIRP may be calculated in different ways, for example by

- digital post-processing of sub-array patterns, or
- using an analogue RF combining circuit applied to said sub-arrays.

It is required that the same method is used for both the HPAA and the Standalone case.

HPAA BFEC is

- specified as a mean value and reported in dB.
- defined for all the nominal sub-bands of a broadband antenna.
- valid for the full electrical tilt range, and for with each frequency sub-band of the antenna.
- associated to a single beam,
- constituted by two parameters:
  - Value: it is the mean value of BFGC
  - Deviation: is the double-sided deviation as specified in Section 12.4.2.
  - Weight change: YES/NO/NA
- the beam ID of that specific beam shall be indicated.

Specification Example

Band	Beam ID	BFEC Value	BFEC Deviation	Weight Change
1710-1880	NA	2.0 dB	0.5 dB	YES/NO/NA
1710-1880	NA	2.0 dB	0.5 dB	YES/NO/NA
N78	EnvelopeConfiguration1	2.0 dB	0.5 dB	YES/NO/NA
N78	Beam1234	2.0 dB	0.5 dB	YES/NO/NA
N78	Beam1234	2.0 dB	0.5 dB	YES/NO/NA
N78	BroadcastBeam1	2.0 dB	0.5 dB	YES/NO/NA

Enclosure: Model XXXX

Relevance

If HPAA EC is reported then HPAA GC could not be reported, in the case indicate NS (Not Specified)

7.6 Mandatory Parameters and Recommendations for Passive Beamforming Capable Antennas (PBCA)

7.6.1 General

This section applies to antennas that are not capable of beamforming by themselves but only when they are connected to an external radio unit capable of beamforming.

Antennas supporting beamforming usually consist of a set of dual polarised columns (e.g., four columns, see Figure 7.19) with typical half wave spacing and a calibration network. According to AISG [41] single clusters (columns) are marked with letters from left to right (e.g.: L-left, CL-centre left, CR-centre right and R-right).

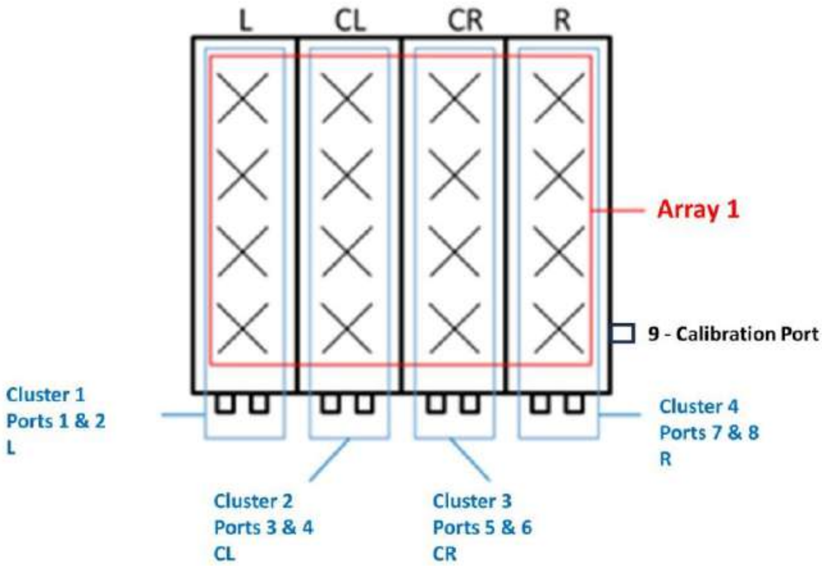


Figure 7.19: Example of PBCA antenna array with four dual polarised columns (Front view)

The performance of PBCA antenna beamforming is based on the antenna design and can be characterized by different beams that are generated feeding the different antenna ports with a proper phase and amplitude (feeding weights):

- Single column beam (single cluster)
- Broadcast beam
- Traffic beam 0° (service beam)
- Traffic beam +/-30° (service beam)
- Soft split beam (multibeam application)

The feeding weights are optimised by the antenna manufacturer or vendor to get optimal performance for each type of beam. The feeding weights can be exchanged between the antenna and radio unit, so the radio unit can load this information and 'know' how to feed the antenna to get the optimal beam shape. The format of the feeding weights and the process to exchange the files and load them into the radio unit is out of the scope of this document.

The different beams can be measured by using external RF devices (e.g. power dividers) that are connected to the individual antenna RF-ports. Typical antenna parameters like Gain, beamwidth, sidelobe suppression, etc., can be calculated for each type of beam. In the final deployment scenario, these RF devices will not be present, and the antenna will be fed directly from the external radio unit.

For all the beams defined in this section, except for the single column beams, the radiated power is highly dependent on the feeding weights. The performance of the calibration network can be described by the parameters listed below and they will be also covered in this section of the publication:

- Coupling factor between each antenna port and calibration port
- Maximum amplitude deviation between coupling factors
- Maximum phase deviation between coupling factors

All other parameters typical of AAS, like OBW, IBW, EIRP, Monitoring counters are not specific for PBCA Antenna but depends on the external radio unit, so are not considered in this section.

7.6.2 Coordinate Reference System associated to the PBCA antenna array

Parameter Definition

The reference system of a PBCA antenna is associated to the antenna array, not to each single column. The centre of the reference system associated to the antenna array is as indicated in Section 5.1; if different, it shall be specified and described:

Specification Definition

Reference System associated to the PBCA antenna array

Specification Example

- Specification example for reference system conforming to Section 5.1
    - Reference System associated to the PBCA antenna array: NA
- Specification example for reference system not conforming to Section 5.1
    - The centre is placed is the upper left corner of the antenna array;
    - Axis are aligned as described in section 5.1

Relevance

NA

7.6.3 Required Beams

7.6.3.1 Single Column Beam

Description

The characteristic of a single column beam of an antenna array (e.g., PBCA with four dual polarised columns) is based on all single columns and must be specified comparable to clusters of standard base station antennas.

The single column beam must be described by required parameters of

- Frequency Range in MHz
- Gain (see Section 6.1.12 6.1.13) in dBi
- Azimuth beamwidth (see Section 6.1.6.2) in degrees
- Elevation beamwidth (see Section 6.1.6.3) in degrees
- Front-to-Back Ratio, Total Power, ± 30° (see Section 7.2.9) in dB
- First Upper Sidelobe Suppression (see Section 7.2.11) in dB
- Azimuth Beam Roll-Off (see Section 7.8.1.4) in dB
- Cross-Polar Discrimination at mechanical boresight (see Section 7.2.6) in dB

These parameters have to be obtained by an average of the measurements of each cluster (single column) (e.g., for PBCA with L, CL, CR, R).

Parameter Definition
Single column beam describes the representative characteristics of all single clusters which belong to the beamforming array.

Specification Definition
- The definition of each parameter is described in the related chapters.
- Each parameter is based on an averaging over all clusters of the beamforming array, all measured frequency points and all downtilt angles.
- The parameters shall be defined for the nominal sub-bands in a broadband antenna array.

Specification Example

	Value
Frequency Range	3300-3800 MHz
Gain over all tilts	15.1° , tolerance ±0.5°
Azimuth Beamwidth over all tilts	88.1°, tolrerance ±1.5°
Elevation Beamwidth over all tilts	7.0°, tolerance ±0.3°
Front-to-Back Ratio, Total Power, ± 30°	> 26.4 dB
Cross-Polar Discrimination at mechanical boresight	> 8.4 dB
First Upper SidelobeSuppression	> 17.8 dB
Azimuth Beam Roll-Off	10.0 dB, tolerance ±1.0 dB

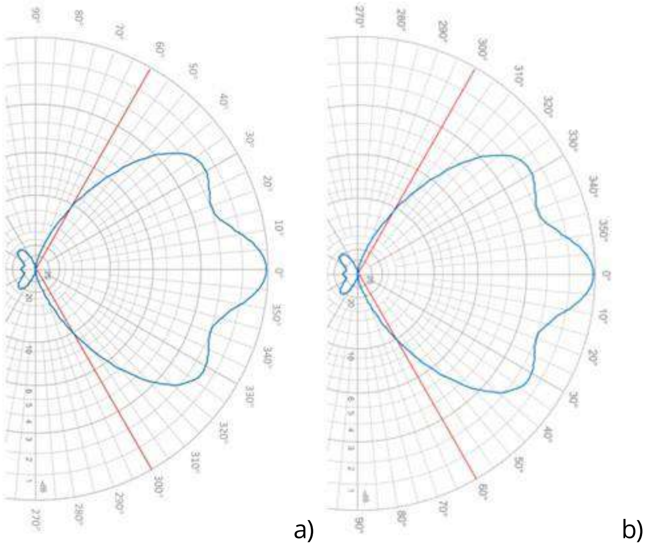
Relevance
Single column beam might be useful to compare single column behaviour.

7.6.3.2 Broadcast Beam

Description
In this section, Broadcast Beam refers to a Broadcast Beam Configuration as defined in Section 7.4.8.2 with a single Broadcast Beam designed to cover the whole sector.

Broadcast beam must be described by parameters of
- Frequency Range in MHz
- Gain (see Section 6.1.12 6.1.13) in dBi
- Azimuth beamwidth (see Section7.2.5) in degrees
- Elevation beamwidth (see Section7.2.8) in degrees
- Front-to-Back Ratio, Total Power, ± 30° (see Section 7.2.9) in dB
- First Upper Sidelobe Suppression (see Section 7.8.4.2) in dB
- Azimuth Beam Roll-Off (see Section 7.8.1.4) in dB
- Cross-Polar Discrimination at mechanical boresight (see Section 7.2.6) in dB

Parameter Definition
Broadcast beam is a set of parameters which describes the characteristics of a broadcast beam.



a) b)

Figure 7.20: Example of Broadcast Beam, e.g. PBCA-8T8R antenna with four columns separated half wavelength and fed with amplitudes 1/2/2/1 and phase 120/0/0/120 distribution. A) SPC_Polar, b) SPCS_CW

Specification Definition

- The definition of each parameter is described in the related chapters.
- These sets of parameters are to be defined for the nominal sub-bands in a broadband antenna array.

Specification Example

	Value
Frequency Range	3300-3800 MHz
Gain over all tilts	17.8 dBi, tolerance ±0.5 dBi
Azimuth Beamwidth over all tilts	65.1°, tolerance ±1.5°
Elevation Beamwidth over all tilts	7.0°, tolerance ±0.3°
Front-to-Back Ratio, Total Power, ± 30°	> 26.4 dB
Cross-Polar Discrimination at mechanical boresight	> 12.4 dB
First Upper Sidelobe Suppression	> 17.8 dB
Azimuth Beam Roll-Off	10.0 dB, tolerance ±1.0

Relevance

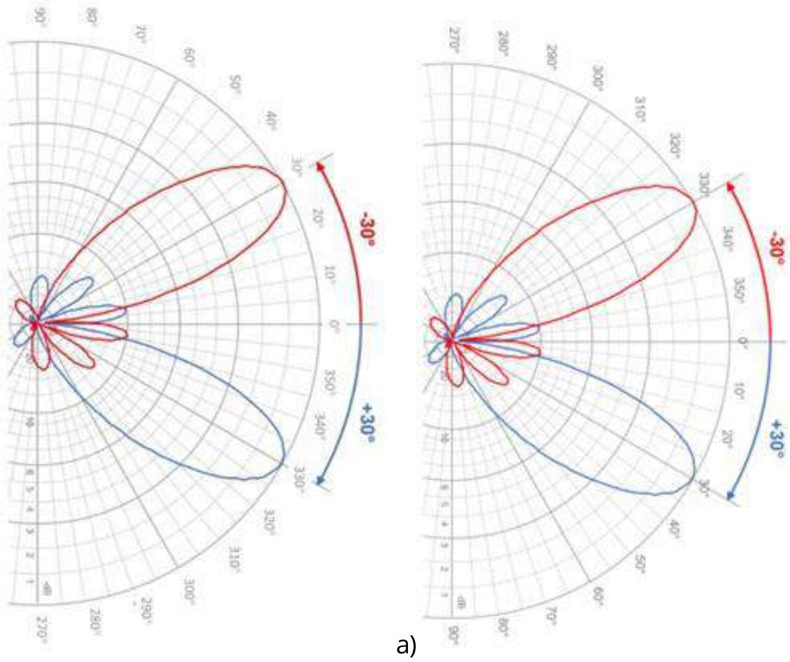
- Describes the coverage footprint of the antenna.
- In 5G NR, the broadcast radiation can be composed of a configuration of beams swept along the coverage range, in that case the envelope of these beams is provided for coverage planning purposes. The parameters related to the envelope of the broadcast beam are already described in the document Section 6.1.10.

7.6.3.3 Traffic Beam 30

Description
Traffic beam 30 describes a beam characteristic of two traffic beams in +/- 30° direction and must be described by required parameters of

- Frequency Range in MHz
- Gain (see Section 6.1.12 6.1.13) in dBi
- Azimuth beamwidth (see Section7.2.5) in degrees
- Front-to-Back Ratio, Total Power, ± 30° (see Section 7.2.9) in dB
- Maximum Horizontal Sidelobe Suppression (see Section 7.8.4.1)
- Cross-Polar Discrimination over 3 dB Azimuth Beamwidth (see Section 7.8.2.1) in dB

Parameter Definition
Traffic beam 30 is a set of parameters which describes the common characteristic of two traffic beams directed to azimuth direction +/- 30°.



a) b)

Figure 7.21: Example of Traffic Beam 30, e.g., PBCA 8T8R antenna with four columns separated half wavelength and fed with amplitudes 1/1/1/1 and phase -150/-50/50/150 (SPCS_Polar = 330°, SPCSCW = -30°) or 150/50/-50/-150 (SPCS_Polar = +30°, SPCS_CCW=+30°) distribution. A) SPCS_Polar, b) SPCS_CCW.

Specification Definition
- The definition of each parameter is described in the related chapters.
- Traffic Beam 30 describes the representative characteristics of two traffic beams directed to azimuth direction +/- 30°.
- These sets of parameters are to be defined for the nominal sub-bands in a broadband antenna array.
- It is based on two measurements (+/- 30°) and averaged over all the measured values

Specification Example

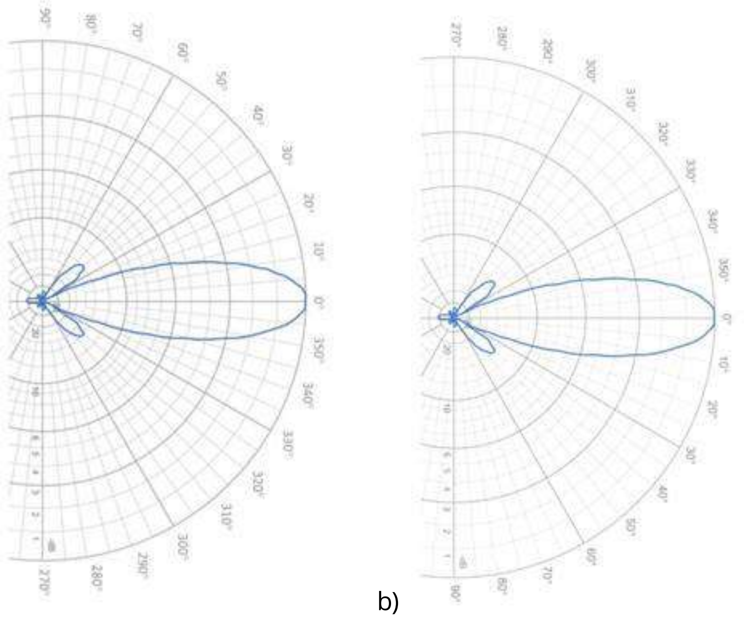
	Value
Frequency Range	3300-3800 Mhz
Gain over all tilts	21.8 dBi, tolerance ±0.5dBi
Azimuth Beamwidth	19.1°, tolerance ±1.5°
Front-to-Back Ratio, Total Power, ± 30°	> 26.4 dB
Cross-Polar Discrimination over 3 dB Azimuth Beamwidth	> 12.4 dB
Maximum Horizontal Sidelobe Suppression	> 17.8 dB

Relevance
This parameter provides guidance of what the antenna supporting beamforming is capable of steering a traffic beam to +30° or -30° azimuth direction.

7.6.3.4 Traffic Beam Zero

Description
Traffic beam zero is a traffic beam in 0° direction and must be described by required parameters of
- Frequency Range in MHz
- Gain (see Section 6.1.12 6.1.13) in dBi
- Azimuth beamwidth (see Section7.2.5) in degrees
- Front-to-Back Ratio, Total Power, ± 30° (see Section 7.2.9) in dB
- Maximum Horizontal Sidelobe Suppression (see Section 7.8.4.1)
- Cross-Polar Discrimination over 3 dB Azimuth Beamwidth (see Section 7.8.2.1) in dB

Parameter Definition
Traffic beam zero is a set of parameters which describes the characteristics of a traffic beam directed to azimuth direction 0°.



a) b)

Figure 7.22: Example of Traffic Beam Zero, e.g. PBCA 8T8R antenna with four columns separated half wavelength and fed with uniform amplitude and phase distribution.

a) SPCS_Polar, b) SPCS_CW

Specification Definition

- The definition of each parameter is described in the related chapters.
- These sets of parameters are to be defined for the nominal sub-bands in a broadband antenna array.

Specification Example

	Value
Frequency Range	3300-3800 MHz
Gain over all tilts	21.8 dBi, tolerance ±0.5 dBi
Azimuth Beamwidth	19.1°, tolerance ± 1.5°
Front-to-Back Ratio, Total Power, ± 30°	> 26.4 dB
Cross-Polar Discrimination over 3 dB Azimuth Beamwidth	> 12.4 dB
Maximum Horizontal Sidelobe Suppression	> 17.8 dB

Relevance

Describes the performance of the antenna supporting beamforming when all the radiators are fed with weights to achieve the best compromise of maximum gain and maximum horizontal sidelobe suppression.

7.6.3.5 Optional Beams

Description

In this case, the antenna is fed to radiate multiple beams simultaneously in the sector. Each beam would cover a part of the sector, splitting the sector and increasing the level of sectorization.

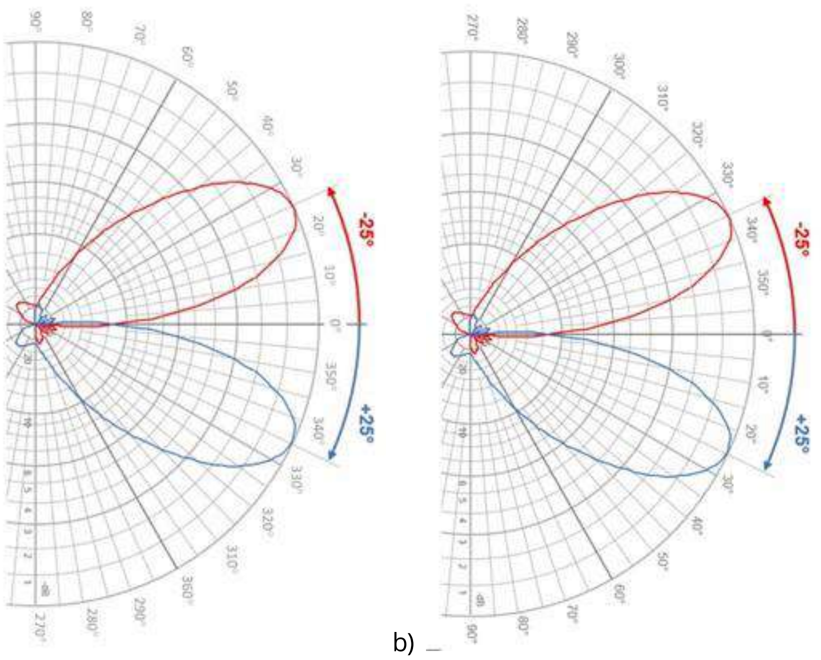
The antenna is typically fed with amplitude tapering and progressive phase to provide low horizontal sidelobes and reduce the interference between the beams.

Soft split beam must be described by required parameters of:

- Frequency Range in MHz
- Beam ID
- Azimuth Nominal Beam Directions
- Gain (see Section 6.1.12 6.1.13) in dBi
- Azimuth beamwidth (see Section 7.2.5) in degrees
- Front-to-Back Ratio, Total Power, ± 30° (see Section 7.2.9) in dB
- Maximum Horizontal Sidelobe Suppression (see Section 7.8.4.1)
- Cross-Polar Discrimination over 3 dB Azimuth Beamwidth (see Section 7.8.2.1) in dB

Parameter Definition

Soft split beams are sets of parameters which describes the characteristics of each soft split beam.



a) b)

Figure 7.23: Example of Soft Split Beams, e.g., PBCA 8T8R antenna with four columns separated half wavelength and fed with amplitudes 0.25/1/1/0.25 and phase -127/-42.5/42.5/127 (Beam 1) or 127/42.5/-42.5/-127 (Beam 2) distribution.

a) SPCS_Polar, b) SPCS_CW

Specification Definition

- The definition of each parameter is described in the related chapters.
- These sets of parameters are to be defined for the nominal sub-bands in a broadband antenna array.

Specification Example

	Value	
Frequency Range	3300-3800 MHz	3300-3800 MHz
Beam ID	1	2
Azimuth Nominal Beam Directions	-25°	+25°
Gain over all tilts	15.1 dBi, tolerance ± 0.5 dBi	15.2 dBi, tolerance ± 0.4 dBi
Azimuth Beamwidth	31.1°, tolerance ± 1.5°	30.8°, tolerance ± 1.4°
Front-to-Back Ratio, Total Power, ± 30°	> 26.4 dB	> 26.7 dB
Cross-Polar Discrimination over 3 dB Azimuth Beamwidth	> 9.7 dB	> 9.4 dB
Maximum Horizontal Sidelobe Suppression	> 21.3 dB	> 22.1 dB

Relevance
This parameter could be used with special weight sets for virtual Higher Order Sectorization (HOS)

7.6.3.6 Traffic Envelope Radiation Pattern

For envelope radiation pattern description use the same requirements as described in Section 7.4.17.

7.6.4 Azimuth Nominal Beam Direction

Parameter Definition
For an antenna with beamforming capabilities which soft split beams pointed in the azimuth plane, the nominal directions of all the main beams shall be defined.

Specification Definition
The azimuth nominal beam direction is the nominal value in degrees of the beam directions with respect to the mechanical boresight.

Specification Example

Type: Nominal		
Beam name	Beam1	Beam2
Nominal Direction	-25°	25°

Relevance
- A specification defining the geometry of the site and sectors.
- One of the parameters contributing to the characteristics and extent of the cell sector coverage.

7.6.5 Calibration network

The performance of the calibration network can be described by the parameters listed in this section.

7.6.5.1 Coupling factor between each antenna port and calibration port

Parameter Definition

It describes a range of all ratios between the power detected at the calibration port and the power injected in each of the antenna ports.

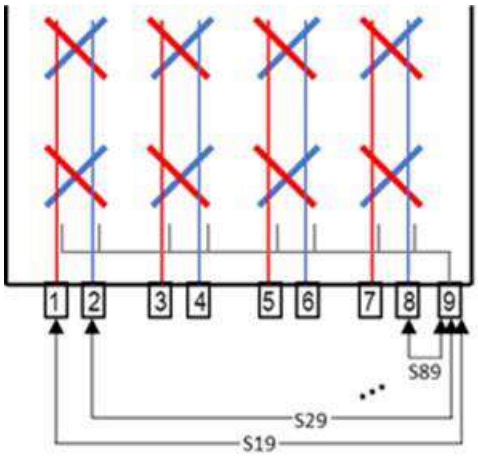


Figure 7.24: Coupling factor between each antenna port and calibration port, i.e. PBCA antenna with RF ports 1 to 8 and calibration port 9.

Specification Definition

- Coupling factor between each antenna port and calibration port is an absolute parameter.
- Specified as a range between minimum (lower limit) and maximum (upper limit) in-band values in dB, e.g. for PBCA antenna all measured values of S19-S89.
- Specification shall reference the full frequency range, full electrical downtilt range, and for all the ports associated to the calibration port.

Specification Example

Type: Absolute	3300-3800 MHz
Coupling factor between each antenna port and calibration port	-26 dB Tolerance ± 2 dB

Relevance

- Coupling factor between each antenna port and calibration port is used to calibrate the magnitude of each RF branch between an array antenna and RRU connected over jumper cables.
- This parameter could affect the link budget for RRU calibration.
- If the level is too high, the amplifier of the RRU may be saturated.
- If the level is too low, the SNR is small and can impact the accuracy of the calibration.

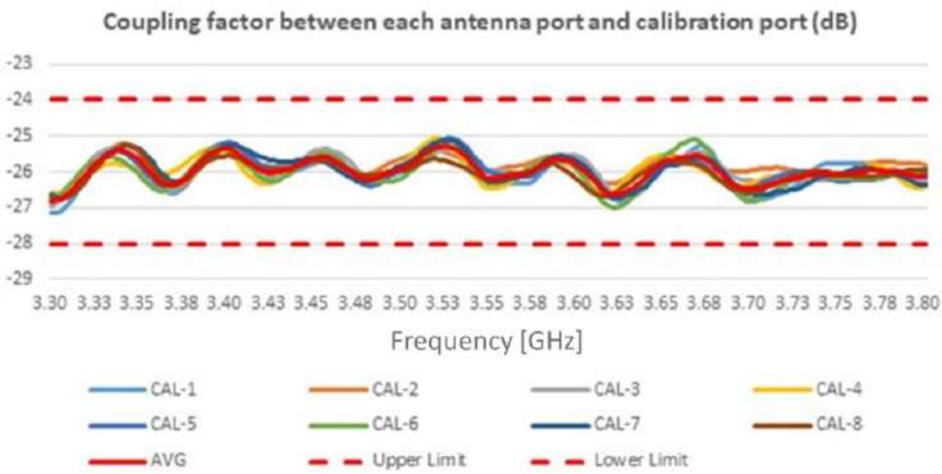


Figure 7.25: Example of measured coupling factor between each antenna port and calibration port, i.e. PBCA-8T8R antenna with RF ports 1 to 8 and calibration port 9, including lower and upper limit as well as an average curve (AVG) at each frequency point over of all measurements

7.6.5.2 Maximum amplitude deviation between coupling factors

Parameter Definition

Defines the amplitude deviation between all coupling factors and the averaged reference coupling factor (AVG).

Specification Definition

- Maximum amplitude deviation between coupling factors is an absolute value, in dB.
- This parameter should be evaluated by the following procedure:
    - For a certain value of electrical downtilt, measure the amplitude of coupling factor between each antenna port and calibration port, i.e., S19-S89 for an PBCA antenna.
    - Calculate the average amplitude per frequency of all the coupling factors S19-S89. This will be the reference for the maximum amplitude deviation.
    - For each frequency, calculate the difference between the amplitude of each coupling factor and the average level (AVG) resulting in a set of deviation curves versus frequency (eight curves in the case of the PBCA antenna of the example). This corresponds to the normalized amplitude deviation with reference to the average.
    - Maximum amplitude deviation between coupling factors is defined as the largest magnitude among the full set of normalized amplitude deviation curves
- Specification shall reference the full frequency range
- If applicable, the specification shall be guaranteed for the full downtilt range

Specification Example

Type: Absolute	3300-3800 MHz
Maximum amplitude deviation between coupling factors	< 0.7 dB

Relevance

The Maximum amplitude deviation between coupling factors indicates the calibration network accuracy, affecting the beamforming performance.

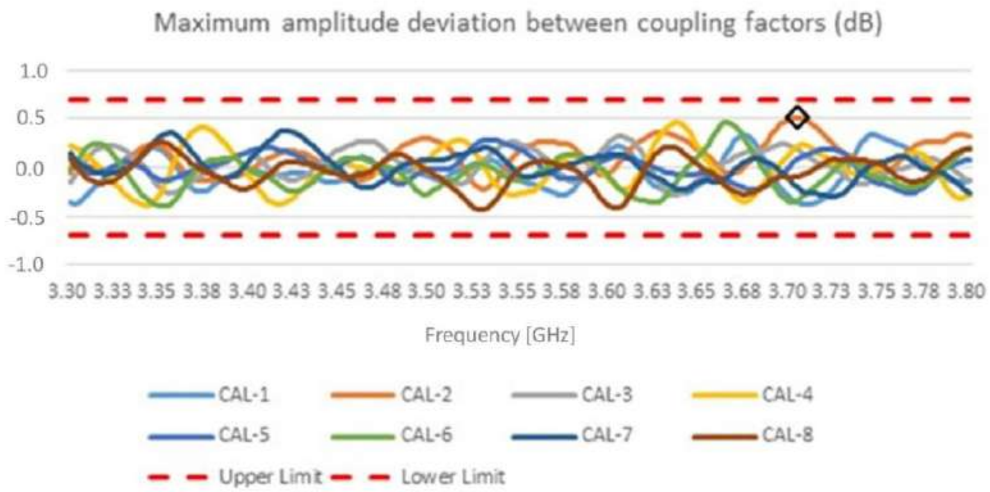


Figure 7.26: Calculated difference between the amplitude of each coupling factor and the average level (AVG) shown in Figure 7.25.

The point marked with a diamond in the Figure 7.26 corresponds to the Maximum amplitude deviation between coupling factors, as it represents the largest magnitude among the normalized amplitude deviation curves. In the example, the antenna fulfils the specification as the largest magnitude is within the upper and lower limits.

7.6.5.3 Maximum phase deviation between coupling factors

Parameter Definition

Defines the phase deviation between all coupling factors and the averaged reference coupling factor (AVG).

Specification Definition

- Maximum phase deviation between coupling factors is an absolute value, in degrees.
- This parameter should be evaluated by the following procedure:
    - For a certain value of electrical downtilt, measure the phase of coupling factor between each antenna port and calibration port, i.e., S19-S89 for an PBCA antenna.
    - Calculate the average phase per frequency of all the coupling factors S19-S89. This will be the reference for the maximum phase deviation.
    - For each frequency, calculate the difference between the phase of each coupling factor and the average phase (AVG) resulting in a set of deviation curves versus frequency (eight curves in the case of the PBCA antenna of the example). This corresponds to the normalized phase deviation with reference to the average.
    - Maximum phase deviation between coupling factors is defined as the largest magnitude among the full set of normalized phase deviation curves
- Specification shall reference the full frequency range
- If applicable, the specification shall be guaranteed for the full downtilt range

Specification Example

Type: Absolute	3300-3800 MHz
Maximum phase deviation between coupling factors	<0.7°

Relevance
The Maximum amplitude deviation between coupling factors indicates the calibration network accuracy, affecting the beamforming performance.

7.6.5.4 Connector Type

For connector type description, use the same requirements as described in Section 8.1.2.

7.7 Optional Parameters and Recommendations for all Antennas

7.7.1 Radome

7.7.1.1 Radome Colour

Parameter Definition
The radome colour is a simple statement about the colour of the radome. This is commonly related to the material used to build it.
Colour options for BSA radomes are uncommon.

Specification Definition
RAL colour code.

Note: RAL is a numeric code to univocally identify a colour.

Specification Example
Radome Colour: RAL7005.

Relevance
The radome colour might be of interest to minimize obtrusiveness of an antenna installation.

7.7.1.2 Radome Material

Parameter Definition
The radome material provides high level information about the material the antenna radome is made of. This information will not be detailed to certain composition variants and/or supplier references.

Specification Definition
The material of which the radome is made of.

Specification Example
Radome Material: PVC

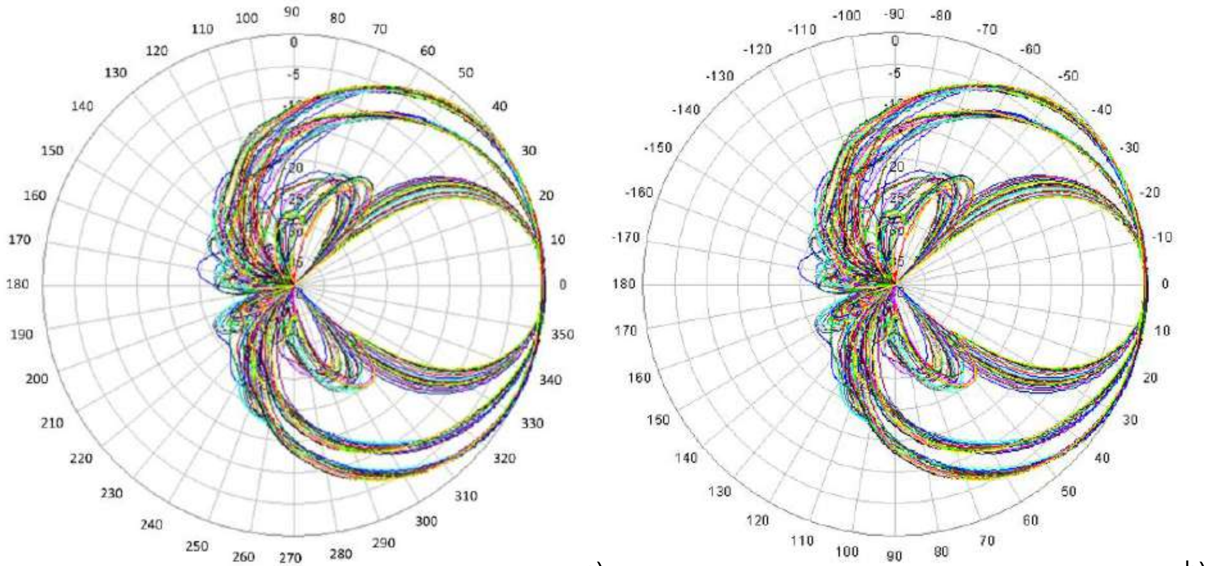
Relevance
The material of the radome contributes to the overall antenna environmental compliance.

7.8 Optional Parameters and Recommendations for Passive Antennas

7.8.1 Azimuth Related Parameters

7.8.1.1 Azimuth Beamwidth Fan

Parameter Definition
For an electrically variable azimuth beamwidth antenna, the azimuth beamwidth fan is the list of nominal azimuth half-power beamwidths that the antenna can be set to exhibit by electrically altering its beam.



a) b)

Figure 7.27: Patterns of a variable azimuth beamwidth BSA (35°/65°/105° pattern overlays). a) SPCS_Polar, b) SPCS_CW.

Specification Definition

- For the purpose of this publication, a fan angle is defined as the nominal H_HPBW (Section 6.1.6.1) of one of the possible azimuth patterns of an electrically variable azimuth beamwidth antenna.
- It is a list of relevant fan angles.
- The values in the list are nominal ones in degrees.
- Since different fan angles produce different antenna patterns, the antenna's parameters shall be described for each fan angle by a single XML datasheet.

- The parameters of antennas that are not able to vary their beam continuously shall be described by a single XML datasheet for each fan angle possibility.
- The parameters of antennas that are able to vary their beam continuously shall be described by a single XML datasheet for each relevant fan angle. The recommendations on the relevant fan angles are similar to those specified for the electrical downtilt (see Section 12.2), except that the angular resolution shall in this case be at least 10°. The lowest fan angle shall be the reference for the all the other ones.

Specification Example

- List of XML datasheets of the same datasheet version of an antenna "XYZ" capable of varying its H_HPBW only to 35°, 65° and 105°:

  BASTA10-0_MANUFACTURER_XYZ,FAN035_2007-05-01_V02_P.xml
  BASTA10-0_MANUFACTURER_XYZ,FAN065_2007-05-01_V02_P.xml
  BASTA10-0_MANUFACTURER_XYZ,FAN105_2007-05-01_V02_P.xml

List of XML datasheets of the same datasheet version of an antenna "XYZ" capable of varying its H_HPBW continuously between 65° and 90°:

  BASTA10-0_MANUFACTURER_XYZ,FAN065_2007-05-01_V02_P.xml
  BASTA10-0_MANUFACTURER_XYZ,FAN070_2007-05-01_V02_P.xml
  BASTA10-0_MANUFACTURER_XYZ,FAN080_2007-05-01_V02_P.xml
  BASTA10-0_MANUFACTURER_XYZ,FAN090_2007-05-01_V02_P.xml

Relevance

- This is one of the parameters contributing to the characteristics and extent of the cell sector coverage.
- It is a parameter that can be adjusted for:
  - Sector alignment and hand-off optimisation.
  - RF coverage and interference optimisation.
  - Sector load balancing.

7.8.1.2 Azimuth Beam H/V Tracking

Parameter Definition

The azimuth beam H/V tracking is the highest ratio between the signal level of the horizontal and vertical polarization for each port within the sector boundaries.

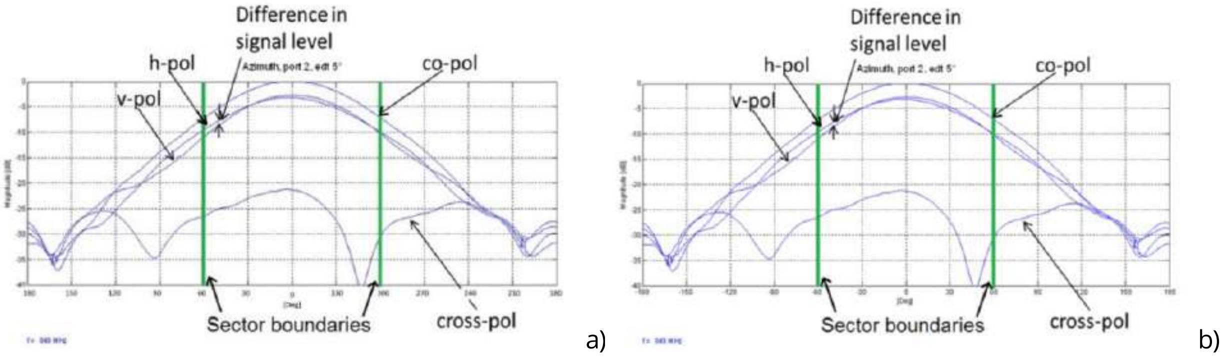


Figure 7.28: Azimuth beam H/V tracking. a) SPCS_Polar, b) SPCS_CW

Specification Definition

- Azimuth beam H/V tracking is measured within the sector around the projection of the mechanical boresight onto the azimuth pattern. It is a Co-Pol pattern measurement.
- Azimuth beam H/V tracking is specified as a maximum value in dB.
- It is subject to a distribution-based validation for a single-sided parameter.
- This parameter is to be defined for the nominal sub-bands in a broadband antenna. It will be assumed that the specification is valid for the full electrical downtilt range, and for all the ports associated with each frequency sub-band of the antenna.
- For multi-beam antennas type II, this parameter shall be instead defined for each beam, as the worst-case ratio between the signal levels of the horizontal and vertical polarization for each port within its nominal beamwidth boundaries (in respect to the projection of mechanical boresight onto the azimuth pattern).
- For omnidirectional antennas, this parameter shall be referenced to the whole turn. This parameter shall then represent the worst possible case.

Specification Example

Type: Distribution-based	1710-1880 MHz	1850-1990 MHz	1920-2170 MHz
Azimuth H/V Tracking	< 1.8 dB	< 2.2 dB	< 1.6 dB

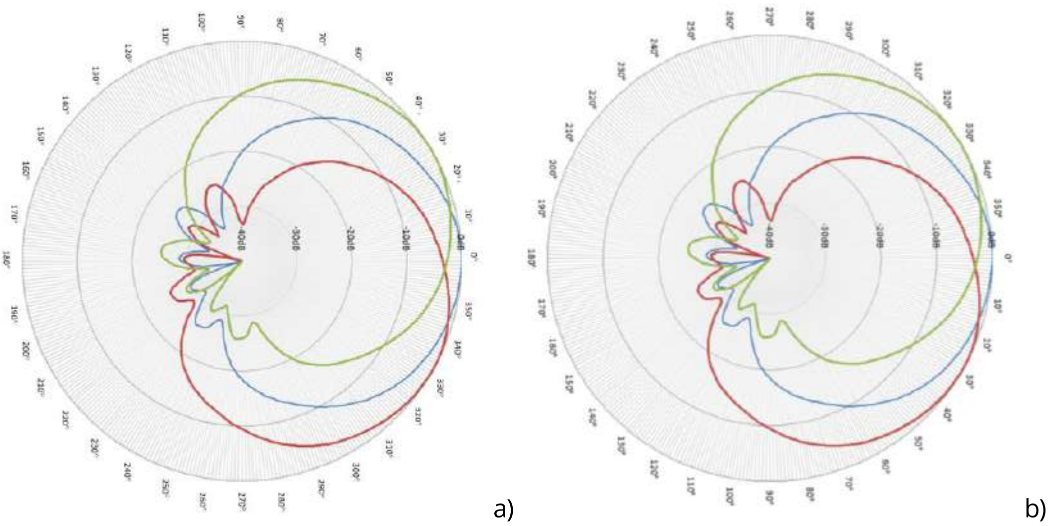
Relevance

This parameter gives an overview on the behaviour of an antenna's polarization over the sector. H and V signal levels are equal when the polarization is exactly ±45°. Their difference should be minimized in order to maximize polarization diversity gain.

7.8.1.3 Azimuth Beam Pan Angles

Parameter Definition

The azimuth beam pan angles are the nominal beam directions in the azimuth plane, which the antenna can point to, when its beam is electrically steered.



a) b)

Figure 7.29: Some patterns of an azimuth beam steering antenna (pan angles: -30°; 0°; +30°). a) SPCS_Polar, b) SPCS_CW

Specification Definition

- It is a list of relevant pan angles with respect to the antenna mechanical boresight (pan = 0°).
- The values in the list are nominal ones in degrees.
- Negative values shall indicate counterclockwise beam panning, vice versa positive values shall indicate clockwise beam panning.
- Since electrical beam panning in the azimuth plane is conceptually similar to electrical tilting in the elevation plane, the recommendations on the relevant pan angles are the same as those specified for the electrical downtilt (see Section 12.2), except that the angular resolution shall in this case be at least 10°. Pan = 0° shall be the reference for all the other angles.
- Since different pan angles produce different antenna patterns, the antenna's parameters shall be described for each pan angle by a single XML datasheet.

Specification Example

List of XML datasheets of the same datasheet version of an antenna "XYZ" capable of steering between -30° and +30°:

BASTA10-0_MANUFACTURER_XYZ,PANM030_1999-12-30_V00_F.xml
BASTA10-0_MANUFACTURER_XYZ,PANM020_1999-12-30_V00_F.xml
BASTA10-0_MANUFACTURER_XYZ,PANM010_1999-12-30_V00_F.xml
BASTA10-0_MANUFACTURER_XYZ,PANP000_1999-12-30_V00_F.xml
BASTA10-0_MANUFACTURER_XYZ,PANP010_1999-12-30_V00_F.xml
BASTA10-0_MANUFACTURER_XYZ,PANP020_1999-12-30_V00_F.xml
BASTA10-0_MANUFACTURER_XYZ,PANP030_1999-12-30_V00_F.xml

Relevance

- This is one of the parameters contributing to the characteristics and extent of the cell sector coverage.
- It is a parameter that can be adjusted for:
    - Sector alignment and hand-off optimisation.
    - RF coverage and interference optimisation.
    - Sector load balancing.

7.8.1.4 Azimuth Beam Roll-Off

Parameter Definition

The azimuth beam roll-off is the highest difference of the Co-Pol signal levels at the sector edges in respect to the one at the main beam peak.

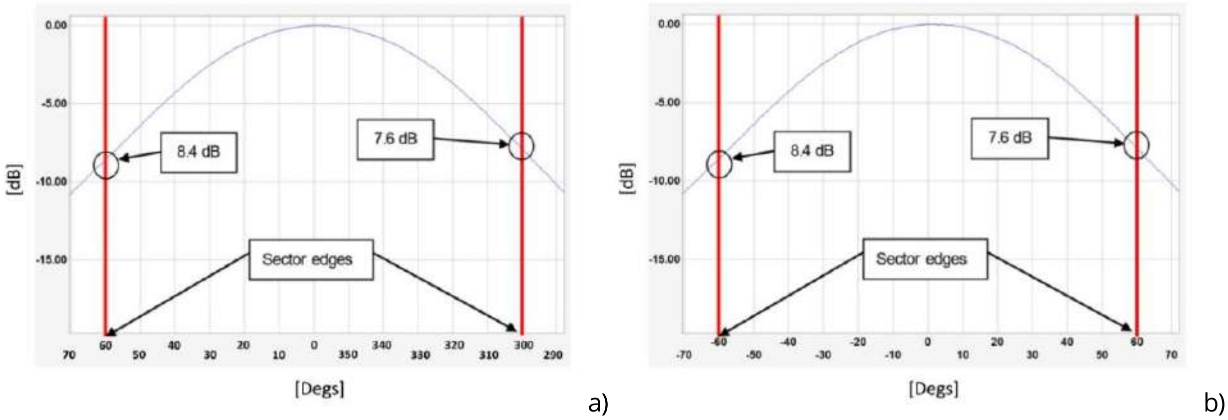


Figure 7.30: Azimuth beam roll-off. a) SPCS_Polar, b) SPCS_CW

Specification Definition

- Azimuth beam roll-off is defined as the combination of a typical (mean) value and a tolerance, both in dB.
- It is subject to a distribution-based validation for a double-sided parameter.
- It is measured at the sector edges around the projection of the mechanical boresight onto the azimuth pattern. It is a Co-Pol pattern measurement.
- This parameter is to be defined for the nominal sub-bands in a broadband antenna. It will be assumed that the specification is valid for the full electrical downtilt range, for all the ports associated with each frequency sub-band of the antenna and for both the sector edges.
- For multi-beam antennas type II, this parameter shall be instead defined for each beam, the signal level at the nominal beamwidth edges (in respect to the projection of mechanical boresight onto the azimuth pattern) of the two antenna Co-Pol polarization branches of the analysed beam.
- For omnidirectional antennas, this parameter shall not be given.

Specification Example

Type: Distribution-based	1710-1880 MHz	1850-1990 MHz	1920-2170 MHz
Azimuth Beam Roll-Off	8.1 dB Tolerance ± 0.6 dB	9.8 dB Tolerance ± 2.3 dB	11.3 dB Tolerance ± 2.1 dB

Relevance

- This parameter gives an estimate of the power radiated at the sector edges of a cell.
- For a BSA with a given sector, the higher the sector roll-off value, the less interference that is radiated into the adjacent sectors.

7.8.1.5 Azimuth Beam Squint

Parameter Definition

The azimuth beam squint is the difference in the azimuth cut between the pointing direction of the main beam and the antenna's nominal direction. The pointing direction of the main beam is defined as the half-power beamwidth bisect.

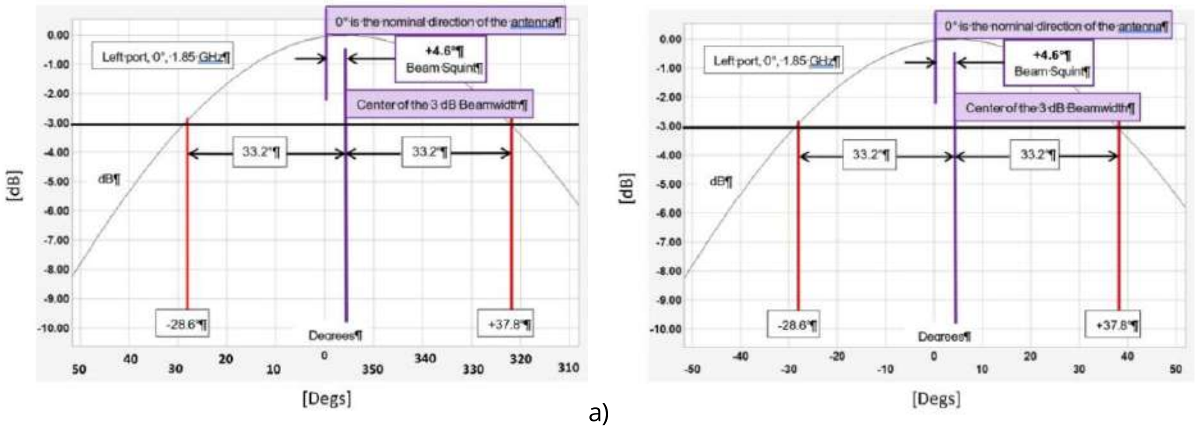


Figure 7.31: Illustration of beam squint calculation for a given frequency, tilt and port. a) SPCS_Polar, b) SPCS_CW

Specification Definition

- Typical (mean) value in degrees.
- Tolerance in degrees.
- It is subject to a distribution-based validation for a double-sided parameter.
- Squint is measured from the co-polar pattern.
- This parameter is to be defined for the nominal sub-bands in a broadband antenna. It will be assumed that the specification is valid for the full electrical downtilt range, and for all the ports associated with each frequency sub-band of the antenna.
- For multi-beam antennas type II, this parameter shall be instead defined for each beam, as the difference in the azimuth cut between the pointing direction (defined as the half-power beamwidth bisect) of the analysed beam and its nominal direction.
- For omnidirectional antennas, this parameter shall not be given.

Specification Example

Type: Distribution-based	1710-1880 MHz	1850-1990 MHz	1920-2170 MHz
Azimuth Beam Squint	1.1° Tolerance ± 2.4°	2.7° Tolerance ± 2.7°	2.6° Tolerance ± 2.6°

Relevance

- The half-power beamwidth bisect approach for defining the squint is, in many cases, a better metric than using the beam peak axis, as the first one outlines the centring of the whole half power region of the antenna beam. This is especially relevant for asymmetrical beams. Also, for a beam that has ripples across the centre, its axis can be difficult to identify. Beam ripples and asymmetry can especially occur on multi-cluster antennas.
- Excessive azimuth beam squint can impact cell performance near its sectors' boundaries.

- Beams may squint as a function of electrical downtilt.
- Beams may squint due to asymmetries in the antenna architecture, for example, asymmetries in multi-cluster antennas.

7.8.1.6 Azimuth Interference Ratio

Parameter Definition

AIR is defined as the ratio of the integrated radiation intensity inside the antenna's sector edges to its integrated interfering radiation. The sector is in this case referenced to the projection of the mechanical boresight onto the azimuth pattern.

Specification Definition

- It is subject to a distribution-based validation for a double-sided parameter.
- The AIR is defined as the combination of a typical (mean) value and a tolerance, both in dB.
- It is calculated from both the Co-pol pattern and the Cr-pol pattern in the form of:

$$AIR = 10\ log_{10}\left(\frac{P_d}{P_u}\right) \tag{7.17}$$

Where:

- P_d is defined as the integrated in sector radiation intensity calculated as the square root of sum of copolar gain squared and x-polar gain squared, summed over all directions inside the sector.
- P_u is defined as the corresponding sum outside the sector.

Note: the angular resolution of the gain measurements must be the same in the entire azimuth pattern

- This parameter is to be defined for the nominal sub-bands in a broadband antenna. It will be assumed that the specification is valid for the full electrical downtilt range, and for all the ports associated with each frequency sub-band of the antenna.
- For multi-beam antennas type II, this parameter shall not be given.
- For omnidirectional antennas, this parameter shall not be given.

Specification Example

Type: Distribution-based	1710-1880 MHz	1850-1990 MHz	1920-2170 MHz
Azimuth Interference Ratio	11.0 dB Tolerance ± 0.5 dB	11.5 dB Tolerance ± 0.6 dB	11.8 dB Tolerance ± 0.7 dB

Relevance

It is a parameter that allows comparison of various antennas' rejection of interference to cells illuminated from the same site.

7.8.2 Cross Polar Related Parameters

7.8.2.1 Cross-Polar Discrimination over 3 dB Azimuth Beamwidth

Parameter Definition

The CPD over 3 dB azimuth beamwidth is defined as the lowest ratio between the co-polar component of a specific polarization and the orthogonal cross-polar component (typically +45° to -45° or vice versa) within the half-power angular region (between the -3 dB levels of the antenna pattern nearest to the beam peak) in the azimuth cut.

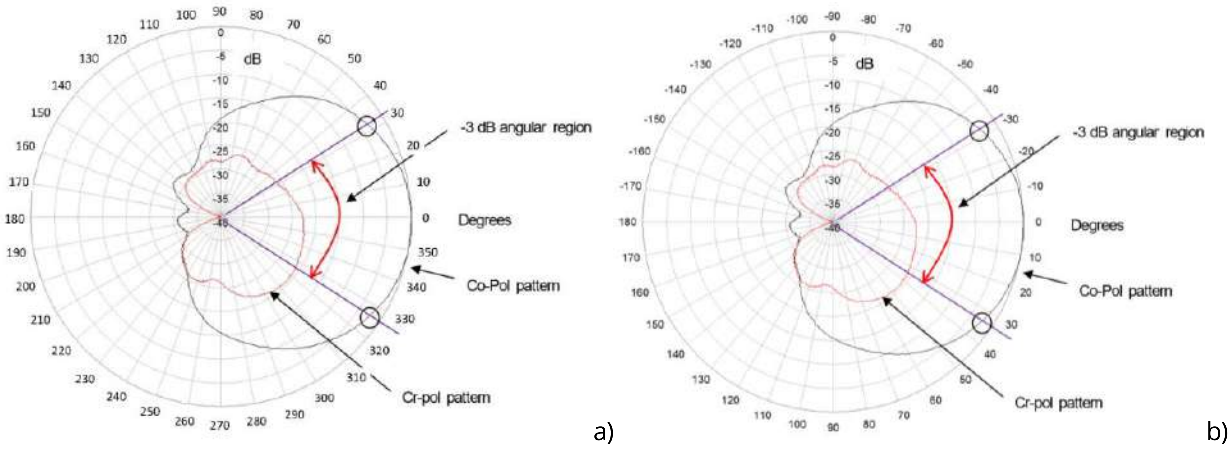


Figure 7.32: Cross pol discrimination over 3 dB azimuth beamwidth. a) SPCS_Polar, b) SPCS_CW

Specification Definition

- CPD over 3 dB azimuth beamwidth is specified as a minimum value in dB.
- It is subject to a distribution-based validation for a single-sided parameter.
- This parameter is to be defined for the nominal sub-bands in a broadband antenna. It will be assumed that the specification is valid for the full electrical downtilt range, and for all the ports associated with each frequency sub-band of the antenna.
- For omnidirectional antennas, this parameter shall not be given.

Specification Example

Type: Distribution-based	1710-1880 MHz	1850-1990 MHz	1920-2170 MHz
Cross-Polar Discrimination over 3 dB Azimuth Beamwidth	> 11.8 dB	> 16.3 dB	> 14.6 dB

Relevance

CPD is important for a low level of correlation between the orthogonally polarised propagation channels. Correlation generated by the antenna can negatively affect receive diversity and MIMO downlink performance of the system.

7.8.2.2 Cross-Polar Discrimination over 10 dB Azimuth Beamwidth

Parameter Definition

The CPD over 10 dB azimuth beamwidth is defined as the lowest ratio between the co-polar component of a specific polarization and the orthogonal cross-polar component (typically +45° to -45° or vice versa) within the -10dB angular region (between the -10 dB levels of the antenna pattern nearest to the beam peak) in the azimuth cut.

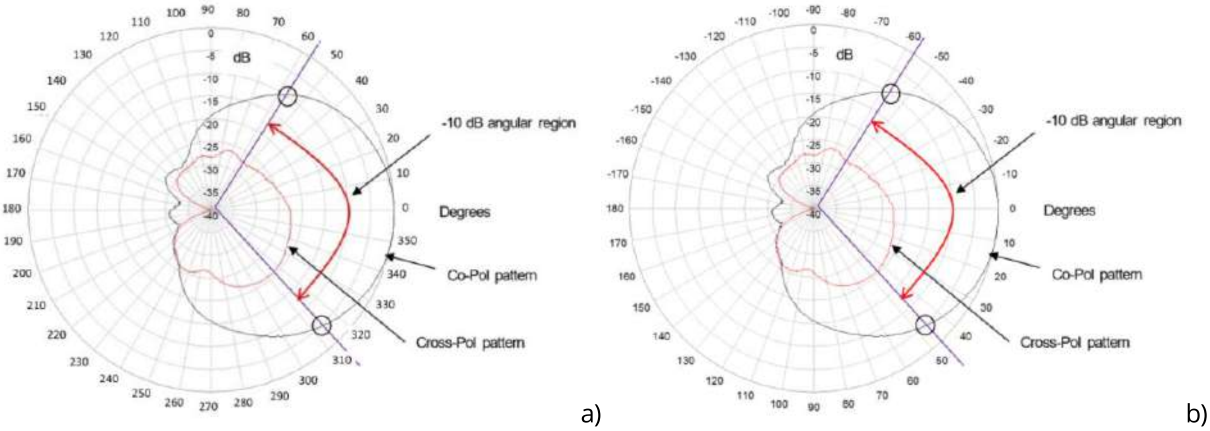


Figure 7.33: Cross pol discrimination over 10 dB azimuth beamwidth. a) SPCS_Polar, b) SPCS_CW

Specification Definition

- CPD over 10 dB azimuth beamwidth is specified as a minimum value in dB.
- It is subject to a distribution-based validation for a single-sided parameter.
- This parameter is to be defined for the nominal sub-bands in a broadband antenna. It will be assumed that the specification is valid for the full electrical downtilt range, and for all the ports associated with each frequency sub-band of the antenna.
- For omnidirectional antennas, this parameter shall not be given.

Specification Example

Type: Distribution-based	1710-1880 MHz	1850-1990 MHz	1920-2170 MHz
Cross Polar Discrimination over 10 dB Beamwidth	> 11.8 dB	> 13.4 dB	> 12.2 dB

Relevance

CPD is important for a low level of correlation between the orthogonally polarised propagation channels. Correlation generated by the antenna can negatively affect receive diversity and MIMO downlink performance of the system.

7.8.2.3 Cross Polar Discrimination over 3 dB Elevation Beamwidth

Parameter Definition

The CPD over 3 dB elevation beamwidth is defined as the lowest ratio between the co-polar component of a specific polarization and the orthogonal cross-polar component (typically +45° to -45°

or vice versa) within the half-power angular region (between the -3 dB levels of the antenna pattern nearest to the beam peak) in the elevation cut.

Specification Definition

- CPD over the 3 dB elevation beamwidth is specified as a minimum value in dB.
- It is subject to a distribution-based validation for a single-sided parameter.
- This parameter is to be defined for the nominal sub-bands in a broadband antenna. It will be assumed that the specification is valid for the full electrical downtilt range, and for all the ports associated with each frequency sub-band of the antenna.
- For omnidirectional antennas, this parameter shall be referenced to the cut by the beam peak axis.

Specification Example

Type: Distribution-based	1710-1880 MHz	1850-1990 MHz	1920-2170 MHz
Cross Polar Discrimination over the 3 dB Elevation Beamwidth	> 11.3 dB	> 10.7 dB	> 9.8 dB

Relevance

CPD is important for a low level of correlation between the orthogonally polarised propagation channels. Correlation generated by the antenna can negatively affect receive diversity and MIMO downlink performance of the system.

7.8.2.4 Cross Polar Discrimination over 10 dB Elevation Beamwidth

Parameter Definition

The CPD over 10 dB elevation beamwidth is defined as the lowest ratio between the co-polar component of a specific polarization and the orthogonal cross-polar component (typically +45° to -45° or vice versa) within the -10dB angular region (between the -10 dB levels of the antenna pattern nearest to the beam peak) in the elevation cut.

Specification Definition

- CPD over the 10 dB elevation beamwidth is specified as a minimum value in dB.
- It is subject to a distribution-based validation for a single-sided parameter.
- This parameter is to be defined for the nominal sub-bands in a broadband antenna. It will be assumed that the specification is valid for the full electrical downtilt range, and for all the ports associated with each frequency sub-band of the antenna.
- For omnidirectional antennas, this parameter shall be referenced to the cut by the beam peak axis.

Specification Example

Type: Distribution-based	1710-1880 MHz	1850-1990 MHz	1920-2170 MHz
Cross Polar Discrimination over the 10 dB Elevation Beamwidth	> 11.0 dB	> 10.2 dB	> 9.8 dB

Relevance

CPD is important for a low level of correlation between the orthogonally polarised propagation channels. Correlation generated by the antenna can negatively affect receive diversity and MIMO downlink performance of the system.

7.8.2.5 Cross-Polar Discrimination over Sector

Parameter Definition

The CPD over sector is defined as the lowest ratio between the co-polar component of a specific polarization and the orthogonal cross-polar component (typically +45° to -45° or vice versa) within the left and right sector boundaries in respect to the projection of the mechanical boresight onto the azimuth cut.

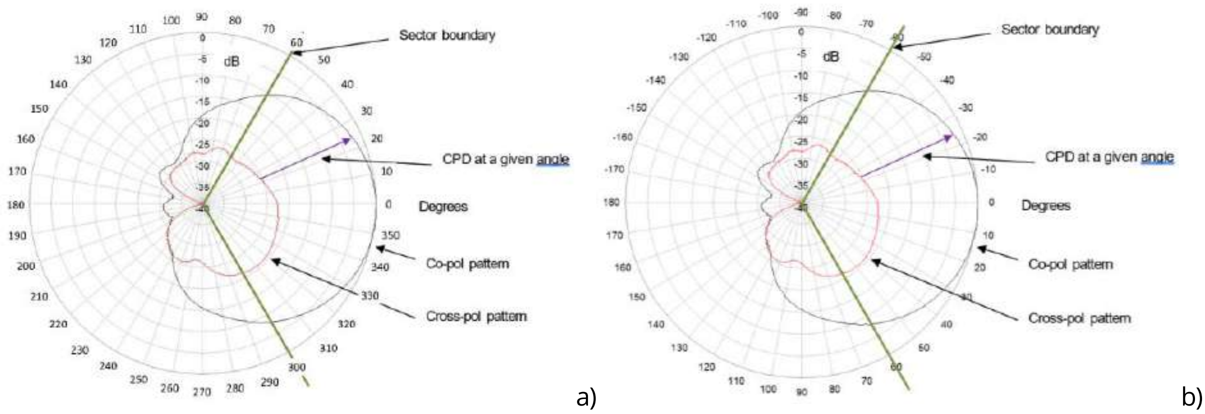


Figure 7.34: Cross-polar discrimination over 120° sector of a 0° mechanical boresight. a) SPCS_Polar, b) SPCS_CW

Specification Definition

- CPD over sector is specified as a minimum value in dB.
- It is subject to a distribution-based validation for a single-sided parameter.
- CPD is the magnitude of the relative power of the Co-Pol pattern with respect to the Cr-Pol pattern at a given angle.
- The CPD over the sector is the worst case measured in a defined angular deviation from the main beam direction. It will be assumed that the parameter is referenced to the nominal sector associated with the antenna.
- For a three-sector application the nominal sector is normally defined as 120°. For a six-sector application the nominal sector is normally defined 60°.
- This parameter is to be defined for the nominal sub-bands in a broadband antenna. It will be assumed that the specification is valid for the full electrical downtilt range, and for all the ports associated with each frequency sub-band of the antenna.
- For multi-beam antennas type II, this parameter shall be instead defined for each beam as the CPD over the nominal beamwidth of the analysed beam around the projection of its nominal direction onto the azimuth cut.
- For omnidirectional antennas, this parameter shall be referenced to the whole turn. It shall then be the worst possible case.

Specification Example

Type: Distribution-based	1710-1880 MHz	1850-1990 MHz	1920-2170 MHz
Cross Polar Discrimination Over Sector	> 10.8 dB	> 9.4 dB	> 8.5 dB

Relevance

CPD is important for a low level of correlation between the orthogonally polarised propagation channels. Correlation generated by the antenna can negatively affect receive diversity and MIMO performance of the system.

7.8.3 Null Fill

Parameter Definition

The null fill is the pattern level of the first relative minimum below the main beam. This "null" is defined as the point of minimum between the main beam and the first sidelobe below it.

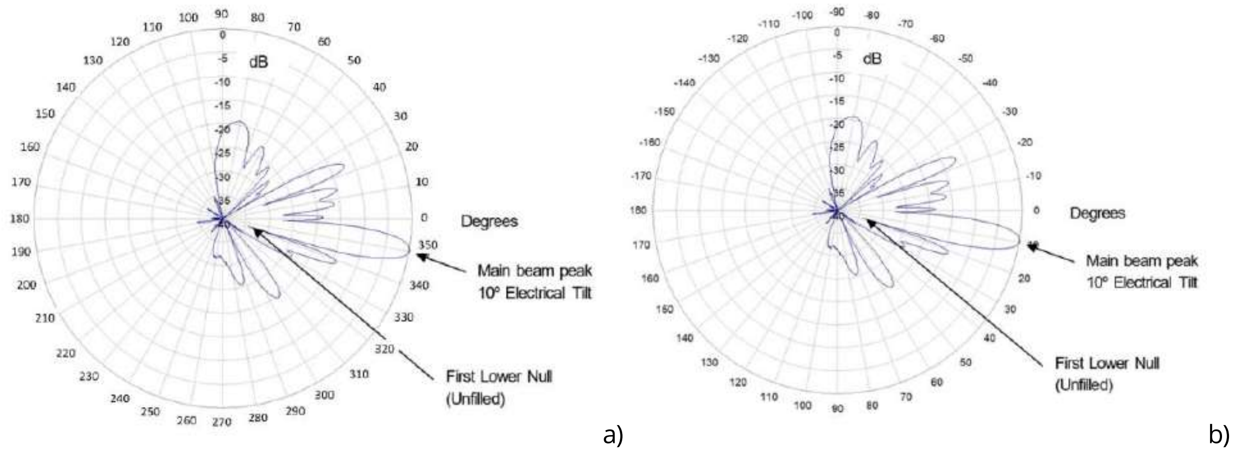


Figure 7.35: Identification of the lower first null. a) SPCS_Polar, b) SPCS_CW

Specification Definition

- Null fill is a minimum value in dB.
- It is subject to a distribution-based validation for a single-sided parameter.
- This parameter is to be defined for the nominal sub-bands in a broadband antenna. It will be assumed that the specification is valid for the full electrical downtilt range, and for all the ports associated with each frequency sub-band of the antenna.
- Since the null fill depends on the first lower sidelobe, its detection routines are discussed with the sidelobes' ones in Section 11.1.3.7.
- For omnidirectional antennas, this parameter shall be referenced to the cut by the beam peak axis.

Specification Example

Type: Distribution-based	1710-1880 MHz	1850-1990 MHz	1920-2170 MHz
Null Fill	< 30.2 dB	< 30.3 dB	< 30.3 dB

Relevance

- Null fill is, in most BSA site scenarios, a non-critical parameter due to multipath signal propagation in the environment and power levels near the cell site.
- Pattern shaping methods are sometimes applied to fill the lower null.
- It can affect the coverage close to base stations with high antenna positions where the null illumination may fall on distances from the antenna where the path loss is sufficient to create coverage holes, and scattering is insufficient to create secondary illumination from the lobes.

7.8.4 Radiation Pattern Sidelobe Suppression

7.8.4.1 2D Maximum Horizontal Sidelobe Suppression

Parameter Definition

The maximum horizontal sidelobe suppression is in the azimuth cut the gain difference between the main beam peak and the highest level amidst all the horizontal sidelobes of an azimuth pattern of a beamforming array antenna within the left and right sector boundaries.

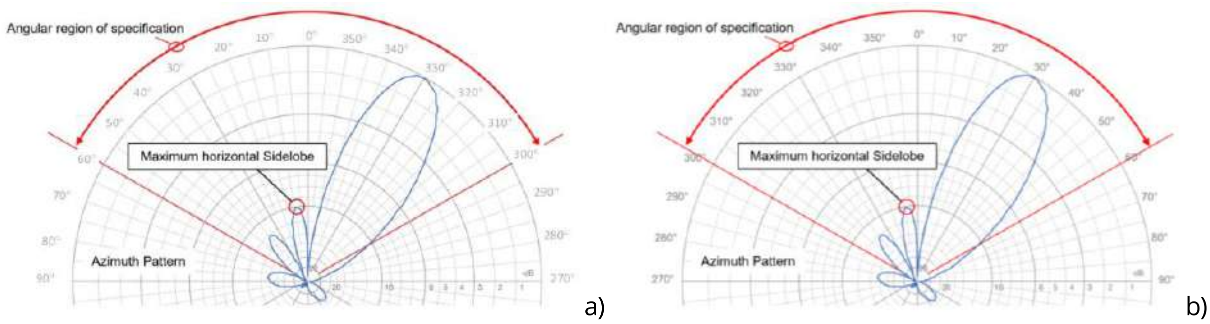


Figure 7.36: Maximum Horizontal Sidelobe Suppression, e.g. PBCA 8T8R antenna with four columns. a) SPCS_Polar, b) SPCS_CW

Specification Definition

- The ratio of the main beam peak and the maximum of the horizontal sidelobe level must be greater than value in xxdB in 84th Percentile of the test samples.
- The angular region of specification shall be within the left and right sector boundaries.
- For a three-sector application the nominal sector is normally defined as 120°. For a six-sector application the nominal sector is normally defined 60°.
- It is subject to a distribution-based validation for a single-sided parameter.
- This parameter is to be defined for the nominal sub-bands in a broadband beamforming array antenna. It will be assumed that the specification is valid for the full electrical downtilt range, and for all the ports associated with each frequency sub-band of the beamforming antenna.

Specification Example

Type: Absolute	3300-3800 MHz
Maximum Horizontal Sidelobe Suppression	> 10.5 dB

Relevance
Horizontal sidelobes of a beamforming antenna might create interference to other beams and might reduce the beamforming gain. Consequently, a high value of maximum horizontal sidelobe suppression is beneficial.

7.8.4.2 First Upper Sidelobe Suppression

Parameter Definition
The first upper sidelobe suppression is the gain difference between the main beam peak and the peak of the closest sidelobe above it.

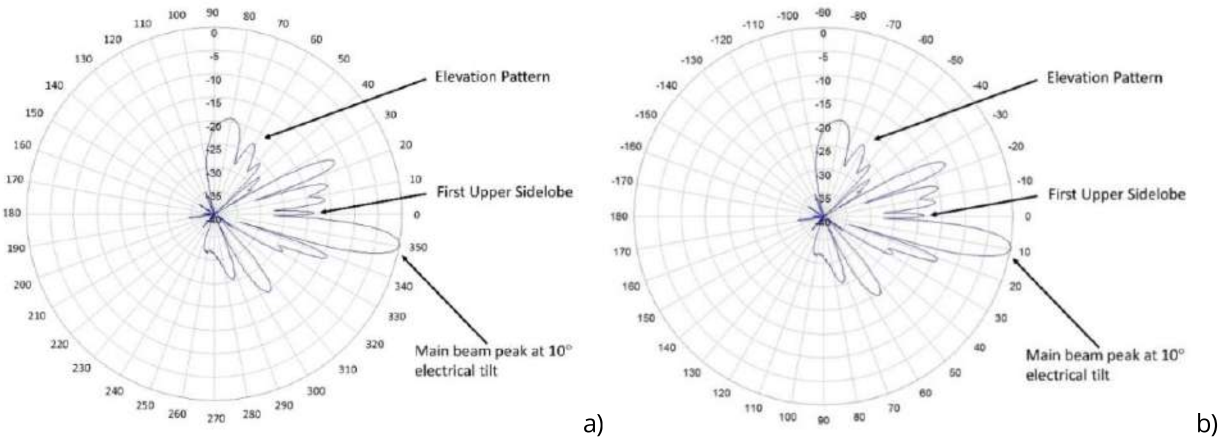


Figure 7.37: First upper sidelobe suppression. Aa) SPCS_Polar, b) SPCS_CW

Specification Definition
- First upper sidelobe suppression is specified as a minimum value in dB.
- It is subject to a distribution-based validation for a single-sided parameter.
- This parameter is to be defined for the nominal sub-bands in a broadband antenna. It will be assumed that the specification is valid for the full electrical downtilt range, and for all the ports associated with each frequency sub-band of the antenna.
- Sidelobe detection routines are discussed in Section 12.5.
- For omnidirectional antennas, this parameter shall be referenced to the cut by the beam peak axis.

Specification Example

Type: Distribution-based	1710-1880 MHz	1850-1990 MHz	1920-2170 MHz
First Upper Sidelobe Suppression	> 18.6 dB	> 17.8 dB	> 16.2 dB

Relevance
- Parameter indicating the amount of neighbouring cell interference generated by the first sidelobe.
- Positioning of the suppressed upper sidelobe using variable electrical tilt can minimize adjacent cell interference.

7.8.4.3 Upper Sidelobe Suppression, Peak to 20°

Parameter Definition

The USLS peak to 20° is the difference between the main beam peak level and the maximum of the sidelobes levels in the angular region delimited by the main beam peak and 20° above it.

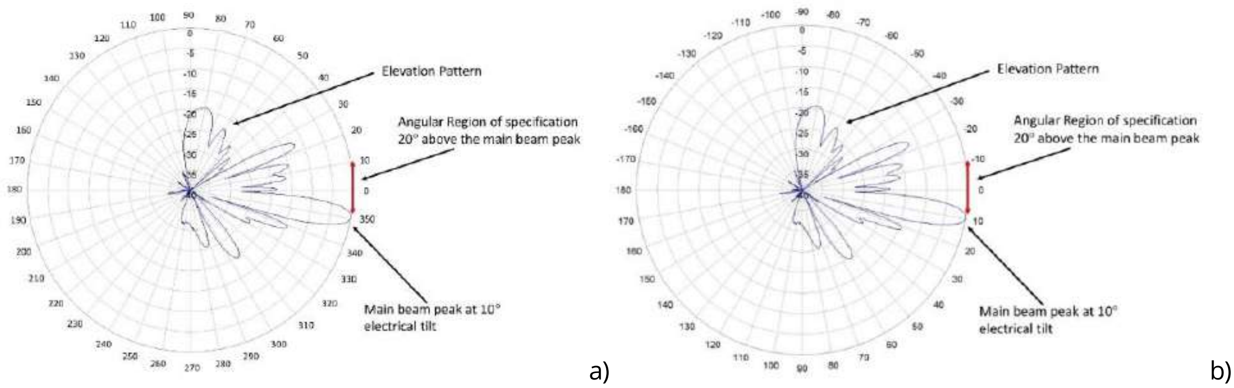


Figure 7.38: Upper sidelobe suppression, peak to 20º. a) SPCS_Polar, b) SPCS_CW

Specification Definition

- Upper SLS from main beam peak to 20° above the main peak is specified as a minimum value in dB.
- This parameter must be less than value in xxdB in 84th percentile of the test samples.
- It is subject to a distribution-based validation for a single-sided parameter.
- This parameter is to be defined for the nominal sub-bands in a broadband antenna. It will be assumed that the specification is valid for the full electrical downtilt range, and for all the ports associated with each frequency sub-band of the antenna.
- Sidelobe detection routines are discussed in Section 12.5.
- For omnidirectional antennas, this parameter shall be referenced to the cut by the beam peak axis.

Specification Example

Type: Distribution-based	1710-1880 MHz	1850-1990 MHz	1920-2170 MHz
Upper Sidelobe Suppression, Peak to 20°	> 18.6 dB	> 17.8 dB	> 16.2 dB

Relevance

- Parameter indicating the amount of neighbouring cell interference generated by the upper sidelobes.
- Positioning of the suppressed upper sidelobes using variable electrical tilt can minimize adjacent-cell interference.

7.8.4.4 2D Maximum Upper Sidelobe Suppression

Parameter Definition

The maximum upper sidelobe suppression is in the elevation cut the gain difference between the main beam peak and the highest level amidst all the sidelobes above the main beam peak and up to the zenith.

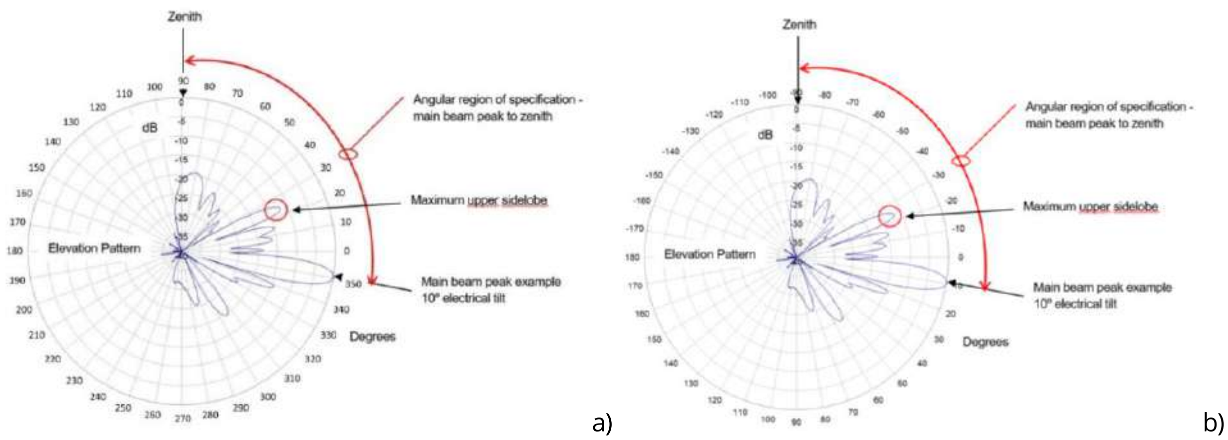


Figure 7.39: Maximum Upper Sidelobe Suppression. a) SPCS_Polar, b) SPCS_CW

Specification Definition

- The ratio of the main beam peak and any upper sidelobe level must be greater than value in xxdB in 84th Percentile of the test samples
- The angular region of specification elongates from the main beam peak to the zenith.
- It is subject to a distribution-based validation for a single-sided parameter.
- This parameter is to be defined for the nominal sub-bands in a broadband antenna. It will be assumed that the specification is valid for the full electrical downtilt range, and for all the ports associated with each frequency sub-band of the antenna.
- For omnidirectional antennas, this parameter shall be referenced to the cut by the beam peak axis.

Specification Example

Type: Distribution-based	1710-1880 MHz	1850-1990 MHz	1920-2170 MHz
Maximum Upper Sidelobe Suppression	> 14.3 dB	> 15.1 dB	> 15.6 dB

Relevance

Upper sidelobes are generally undesirable, considering that even if they do not create interference, they represent energy radiated in unwanted directions and therefore lost to the system. Consequently, a low value of maximum upper sidelobe suppression is beneficial.

7.8.4.5 2D Upper Sidelobe Suppression, Horizon to 20°

Parameter Definition

The USLS, horizon to 20° is the gain difference between the main beam peak and the maximum of the sidelobes levels in the angular region delimited by the horizontal cut (antenna horizon) and the angular direction 20° above it.

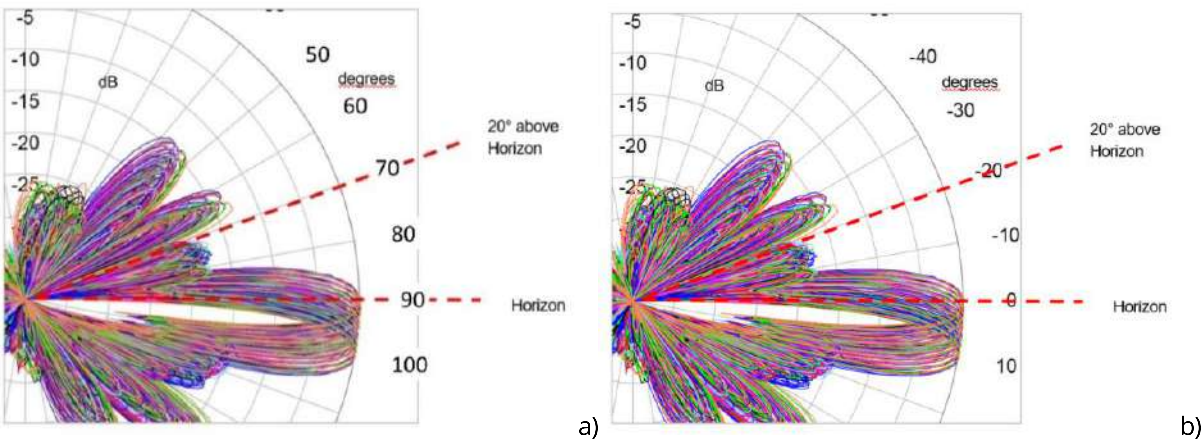


Figure 7.40: Upper sidelobe suppression, horizon to 20º. a) SPCS_Polar, b) SPCS_CW

Specification Definition

- The 84th percentile of the USLS, horizon to 20° is specified as a minimum value in dB.
- It is subject to a distribution-based validation for a single-sided parameter.
- This parameter is to be defined for the nominal sub-bands in a broadband antenna. It will be assumed that the specification is valid for the full electrical downtilt range, and for all the ports associated with each frequency sub-band of the antenna.
- Sidelobe detection routines are discussed in Section 12.5.
- For omnidirectional antennas, this parameter shall be referenced to the cut by the beam peak axis.

Specification Example

Type: Distribution-based	1710-1880 MHz	1850-1990 MHz	1920-2170 MHz
Upper Sidelobe Suppression, horizon to 20°	> 17.6 dB	> 16.6 dB	> 18.4 dB

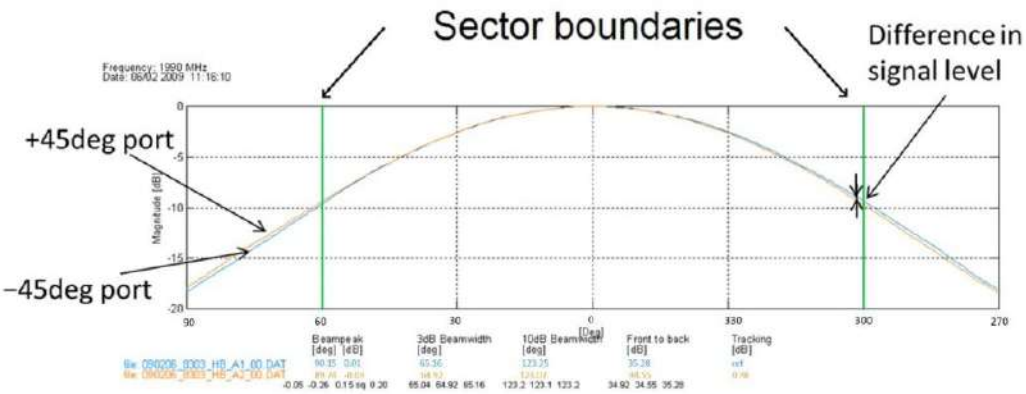
Relevance

- This parameter indicates the amount of interfering signal radiated above the horizon due to the upper sidelobes presence.
- It also indicates the minimum suppression level of the sidelobes above the main beam in a 20° sector above the horizon.

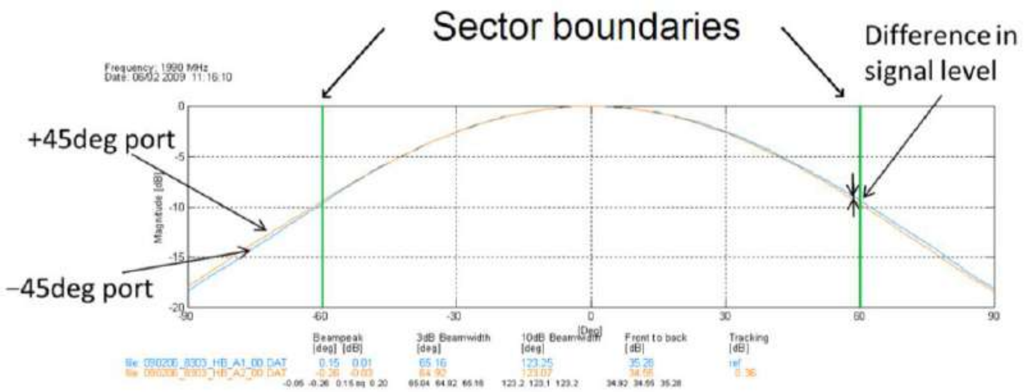
7.8.5 Azimuth Beam Port-to-Port Tracking

Parameter Definition

Azimuth beam port-to-port tracking is the highest ratio between the amplitude of the two antenna Co-Pol polarization branches (e.g.: +45° by port 1 to -45° by port 2) within the sector boundaries.



a)



b)

Figure 7.41: Azimuth beam port-to-port tracking. a) SPCS_Polar, b) SPCS_CW

Specification Definition

- Azimuth port-to-port tracking is measured within the sector around the projection of mechanical boresight onto the azimuth pattern. It is a Co-Pol pattern measurement.
- Port-to-port tracking is specified as a maximum value in dB.
- It is subject to a distribution-based validation for a single-sided parameter.
- This parameter is to be defined for the nominal sub-bands in a broadband antenna. It will be assumed that the specification is valid for the full electrical downtilt range, and for all the ports associated with each frequency sub-band of the antenna.
- For omnidirectional antennas, this parameter shall be referenced to the whole turn. This parameter shall then represent the worst possible case.

Specification Example

Type: Distribution-based	1710-1880 MHz	1850-1990 MHz	1920-2170 MHz
Azimuth Port-to-Port Tracking	< 1.1 dB	< 1.5 dB	< 1.6 dB

Relevance
This parameter characterizes the difference in illumination of the cell between two ports of a dual-pol antenna. This difference should be minimized in order to maximize potential diversity gain.

7.8.6 Antenna Radiation Efficiency

Parameter Definition
The efficiency of the antenna, see Section 6.1.9.

- Efficiency is directly related to the overall losses in an antenna expressed in dB.
- In a practical case, the Gain of a passive antenna is always lower than its directivity and the efficiency will always be a negative value.

Specification Definition

- Efficiency is a typical (mean) value in dB.
- It is specified by a mean value and a tolerance, both over the whole tilt range and for each frequency sub-band. It is a double-sided distribution-based parameter. Tolerance is in dB.
- Directivity and Gain measurements are described in Section 11.1.2.
- The calculation of efficiency of antennas with low losses (i.e., short antennas) might lead to positive values if the accuracy of the gain measurement is lower than the overall losses.
- According to Section 11.1.2.2 the Efficiency can be calculated by efficiency = - $a_{antenna}$, whereby $a_{antenna}$ represents the antenna losses.

Specification Example

Type: Distribution-based	1695-1990 MHz	1920-2200 MHz	2200-2490 MHz	2490-2690 MHz
Efficiency	-1.19 dB Tolerance ±0.29 dB	-1.12 dB Tolerance ±0.31 dB	-1.31db Tolerance ±0.38 dB	-1.27 dB Tolerance ±0.25 dB

Relevance

- Antenna efficiency reflects the ability of antennas of the same dimensions to effectively transmit RF signals.
- For a given dimension, an antenna with a higher efficiency can be used to improve the coverage (maintaining the same input power) or allow a reduction of the input power (maintaining the same coverage area).
- In the ideal case of an antenna without losses (Gain equals Directivity, i.e., 100% of the input power is radiated), the efficiency would be equal to 0 dB.

7.8.7 Maximum Effective Power of Cluster

Parameter Definition
The maximum power, which can be transmitted into one antenna cluster, and which shall be withstood by the antenna without it suffering permanent damage or being mechanically or electrically affected (hence subject to parameters' alteration).

Specification Definition

- Power is defined as effective CW power.

- This is an absolute, maximum parameter specified is either Watt or dBm.
- It is specified at sea level over the environmental conditions specified for the antenna.
- Specification shall reference the full frequency range, full electrical downtilt range, and the associated ports of the cluster.

Specification Example

Type: Absolute	1710-2170 MHz
Maximum Effective Power of Cluster	500.0 W
	57 dBm

Relevance
Exceeding the specified power rating can damage the antenna.

7.9 Optional Parameters and Recommendations for Active Antennas

7.9.1 AAS Unit Power consumption

Parameter Definition
The power consumption for operating the AAS according to traffic conditions according to [43].

Specification Definition
Nominal values in Watt.

Specification Example

Traffic load	Power consumption
10 %	450 W
30 %	550 W
50 %	700 W
100 %	900 W

NOTE: The manufacturers may specify environmental conditions in which the power consumptions are given (example 100% Traffic load @ 55℃).

Relevance
NA

7.9.2 Ripple

7.9.2.1 Ripple on the Azimuth Cut – 2D (2DRAC)

Parameter Definition
- This parameter is required only for omnidirectional antennas or for envelope radiation patterns of AAS or PBCA.

- Gain ripple is the ratio between the maximum and the minimum levels of the azimuth cut in a specified azimuth interval. If the azimuth interval is not specified, then the HPBW interval is intended.

Note: If the antenna is a single-beam or multi-beam or, for any single beam of an AAS or PBCA Antenna, this parameter shall not be given.

Specification Definition
- Gain ripple is a maximum value in dB.
- It is the difference between maximum and minimum levels in the azimuth cut, if both are in dB.
- Pattern levels for this parameter shall be taken, at least, with a 1° angular resolution.
- It is subject to a distribution-based validation for a single-sided parameter.
- For AAS or PBCA the configuration (beam ID) shall be specified.

- 2DRAC Ripple is composed by the following values
- The 2DRAC value
- The band
- The Angular Region Interval, in degrees
- The ID of the beams

Specification Example

Type: Distribution-based	1710-1880 MHz	1850-1990 MHz	1920-2170 MHz	N78
2DRAC Ripple	< 3.0 dB	< 4.1 dB	< 3.9 dB	-2.0 dB
AR Interval	NA	-30° to +30°	-35° to +20°	NA
Beam ID	Beam1	Beam2	Beam3	Envelope1

Relevance
- This parameter gives an estimation of the “roundness” of the azimuth pattern.
- An ideal antenna, which radiates perfectly in every direction in the azimuth, would have a gain ripple of 0.0 dB.

7.9.2.2 Ripple on Vertical Cut – 2D (2DRVC)

Parameter Definition
- This parameter is required only for omnidirectional antennas or for envelope radiation patterns of AAS or PBCA.
- Gain ripple is the ratio between the maximum and the minimum levels of the elevation cut in a specified elevation interval. If the elevation interval is not specified, then the HPBW interval is intended.

Note: If the antenna is a single-beam or multi-beam or, for any single beam of an AAS or PBCA Antenna, this parameter shall not be given.

Specification Definition
- Gain ripple is a maximum value in dB.
- It is the difference between maximum and minimum levels in the elevation cut, if both are considered in dB.

- Pattern levels for this parameter shall be taken, at least, with a 1° angular resolution.
- It is subject to a distribution-based validation for a single-sided parameter.
- For AAS or PBCA the configuration (beam ID) shall be specified.

- 2DRVC Ripple is composed by the following values
- The 2DRVC value
- The band
- The Angular Region Interval, in degrees
- The ID of the beams

Specification Example

Type: Distribution-based	1710-1880 MHz	1850-1990 MHz	1920-2170 MHz	N78
2DRVC Ripple	< 3.0 dB	< 4.1 dB	< 3.9 dB	< 2.0 dB
AR Interval	NA	-10° to +10°	-15° to +20°	NA
ID	Beam1	Beam2	Beam3	Envelope1

Relevance

- This parameter gives an estimation of the "roundness" of the elevation pattern.
- An ideal antenna, which radiates perfectly in every direction in the elevation plane, would have a gain ripple of 0.0 dB.

7.9.2.3 Ripple on 3D Envelope Radiation Pattern

Parameter Definition

- This parameter is required only for envelope radiation patterns of AAS or PBCA.
- Gain ripple is the ratio between the maximum and the minimum levels of the radiation pattern in a specified Angular Region around the peak. If the AR is not specified, then the AR sized as the scanning range interval is intended.

Note: For any single beam of an AAS or PBCA Antenna, this parameter shall not be given.

Specification Definition

- Gain ripple is a maximum value in dB.
- It is the difference between the maximum and the minimum levels within the specified AR, considered in dB.

- 3D Ripple is composed by the following values
- The 3D Ripple value
- The band
- The angular Region Interval, in degrees
- The ID of the beam

Specification Example

Type: Distribution-based	
3D Ripple	<2.0 dB
AR	-10°≤ ϑ ≤10°;-50° ≤ φ ≤45°

Band	N78
ID	Envelope1

Relevance

This parameter gives an estimation of the “roundness” of the 3D Radiation pattern in the peak direction.

8 Mechanical and Environmental Parameters and Recommendations

In this publication the mechanical parameters and the environmental specifications will always be, when not specifically otherwise written, intended as required.

The format used for the mechanical parameters will be the same used for electrical specifications.

8.1 Mechanical Parameters

8.1.1 Antenna Dimension

Parameter Definition
The outer antenna dimensions without additional antenna system components (e.g.: the mount or the RET unit).
The dimensions are defined along the three axis of a Cartesian coordinate system defining the height (H), the width (W) and the depth (D) of the product (see Figure 8.1).

Specification Definition
- The antenna dimensions are its nominal values specified in millimetres.
- Height is measured along the vertical direction of the antenna in its intended mounting position (typically this is also the largest dimension).
- Width is measured along the horizontal direction of the antenna.
- Depth is measured perpendicular to the plane spanned by vertical and horizontal direction.
- The antenna RET installation reference plane is described by the H, W, or D dimension, but is actually the plane normal (or most normal) to it.

Specification Example
- Antenna without RET support:
  - H x W x D: 1391 mm x 183 mm x 118 mm.
  - A RET actuator cannot be attached to the antenna.
- Antenna with RET support:
  - H x W x D: 1391 mm x 183 mm x 118 mm.
  - A RET actuator interface is present on the bottom of the antenna along the plane normal to its height.

Relevance
- The antenna dimensions are relevant to plan detailed antenna installations regarding required space, required fixation points and visual impact.
- The antenna dimensions also impact the windload at a rated wind speed.

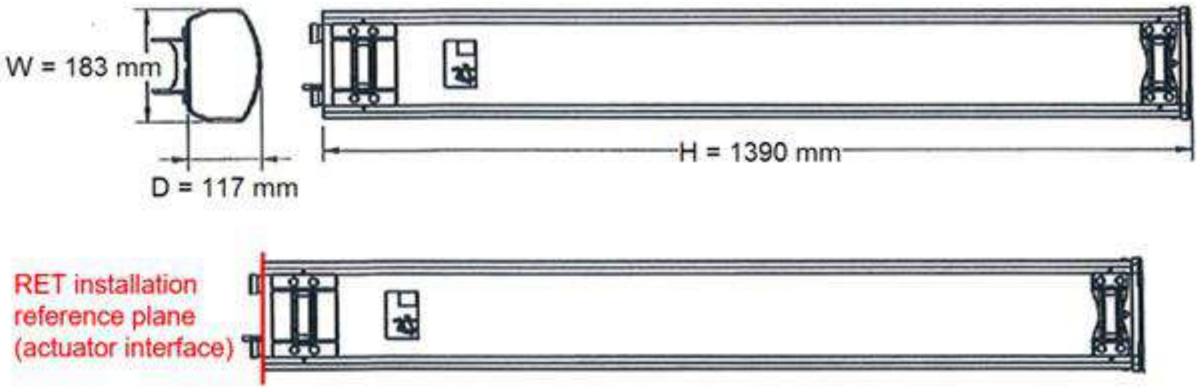


Figure 8.1: Antenna dimensions example.

8.1.2 Connector

8.1.2.1 Connector Position

Parameter Definition

This parameter defines the position of the different RF connectors together with a marking of the corresponding required input (frequency band, polarization).

The detailed position of the individual connector will vary by the antenna manufacturer design. Minimum generic information to be provided is the side where the connectors are located in (top, back, bottom).

Specification Definition

- The same reference axis used to calculate the antenna's mechanical dimensions shall be used to define the "top", "back" and "bottom" of the antenna.
- For the purpose of this publication, the only possibilities are "top", "back" and "bottom".

Specification Example

Port Y3- (-45°) is a "4.3-10 male" port that is located at the bottom of the antenna.

Relevance

Knowledge of the connector position is required for proper antenna operation. It also supports upfront planning of antenna system cabling for the individual installation site.

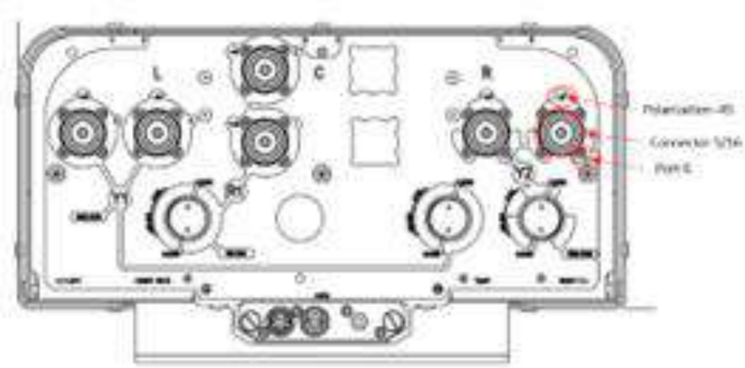


Figure 8.2: Antenna Bottom with connector position

8.1.2.2 Connector Quantity

Parameter Definition

The connector quantity specifies the number of RF connector ports of the antenna, which directly depends on the number of bands and polarizations that are supported by the antenna itself.

Specification Definition

The quantity is defined by the number of times that each unique port tag appears under each cluster.

Specification Example

There are 2 “4.3-10 female” connectors at the bottom of the antenna and 2 “4.3-10 female” at its back, for a total of 4 RF connectors.

```
<cluster name="R1" beam_forming="false" nominal_direction="0°" nominal_sector="120°"
        nominal_horizontal_half_power_beamwidth="65°">
<port name="R1+" number="1" polarization="+45" location=”bottom”
        connector_type="4.3-10 female "/>
<port name="R1-" number="2" polarization="-45" location=”bottom”
        connector_type="4.3-10 female "/>
[. . .]
</cluster>
<cluster name="Y1" beam_forming="false" nominal_direction="0°" nominal_sector="120°"
        nominal_horizontal_half_power_beamwidth="65°">
<port name="Y1+" number="3" polarization="+45" location=”back”
        connector_type="4.3-10 female"/>
<port name="Y1-" number="4" polarization="-45" location=”back”
        connector_type="4.3-10 female"/>
[. . .]
</cluster>
```

Relevance

The antenna connectors define the input interfaces to connect the antenna to the rest of the systems. This is relevant for the operators to ensure that their system design matches the antenna input needs regarding the connections and different inputs.

8.1.2.3 Connector Type

Parameter Definition
The antenna connector type specifies the RF connectors of the antenna, which can be attached to other system components (e.g.: feeder cables).

Specification Definition
RF connectors follow standard nomenclature regarding their size and detail it with the male/female information. Selected options as long/short neck are also specified.

Specification Example
Port Y2+ is a "4.3-10 female long neck" RF connector.

Relevance
The antenna connector types are relevant for the operators to ensure the system components can be connected with the antenna in an efficient way without the need for additional connectors or adapters.

8.1.3 Mechanical Distance between Antenna Mounting Points

Parameter Definition
The mechanical distance between antenna mounting points defines the vertical distance between the fixation points of the antenna to its mounting hardware.

Specification Definition
Nominal values in millimetres.

Specification Example
Example: S1 = 1274 mm (see points". Figure)

Relevance

This value is of interest for installation site planning to ensure the corresponding tower provides sufficient clearance, and for the installation teams in order to mount the antenna correctly.

8.1.4 Mechanical Distance between Pole Mounting Points

Parameter Definition
The mechanical distance between pole mounting points defines the vertical distance between the mounting brackets of an antenna at the pole.
This might be in line with the mechanical distance between antenna mounting points.

Specification Definition
Nominal values in millimetres.

Specification Example
Example: S2 = 1019 mm (see Figure 8.3)

Relevance
This value is of interest for the installation site planning to ensure that the corresponding tower provides sufficient clearance, and for the installation teams in order to be able to mount the antenna correctly.

Bracket Separation 'S', in millimetres

Kits	Separation
Direct	S1
Azimuth	
Scissor	S2
Scissor + Azimuth	
Beam	Variable with tilt
Beam + Azimuth	
S1 = Refer to antenna mount bracket separation for distance **S2** = (S1 - 255) mm	

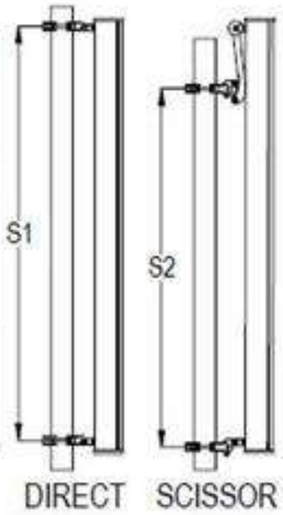


Figure 8.3: Potential differences between “distance between antenna mounting points” and “distance between pole mounting points”.

8.1.5 Net Weight

Parameter Definition
The net weight of an antenna without mounting hardware or accessories or other options.
The net weight of the individual antenna options as, for example, antenna mounting hardware (including all nuts, bolts and brackets of the corresponding variant) or the RET.

Specification Definition
- Nominal values in kilograms.
- Providing the individual values for both antenna and accessories provides all information on the weight required and avoids missing clarity of different kits or options.

Specification Example
- Weight without accessories = 14.5 kg.
- Weight of accessories only = 3.4 kg.

Relevance

The antenna weight is relevant to plan detailed antenna installations regarding pole loading, transportation and installation work.

8.1.6 Packing Size

Parameter Definition

The outer dimensions of the packaged antenna.
The dimensions are defined along the three axis of a Cartesian coordinate system defining the height (H), the width (W) and the depth (D) of the package.

Specification Definition

- The packaged antenna dimensions are its nominal values specified in millimetres.
- H, W and D shall be specified along the same directions of the unpacked antenna dimensions, irrespective of the orientation of the package during transport or storage.

Specification Example

H x W x D - 1391 mm x 350 mm x 110 mm.

Relevance

The packaged antenna dimensions are relevant to plan and optimize transport and storage of the antenna.
The package includes ordered components as mounting hardware, the accessories (e.g.: RET) or other options.

8.1.7 Shipping Weight

Parameter Definition

The shipping weight of an antenna includes the antenna, its packaging and all other options put into the package (e.g.: the selected mount).

Specification Definition

Nominal values in kilograms.

Specification Example

Shipping weight = 3.4 kg.

Relevance

The antenna shipping weight is required for the logistics to manage shipping and storage of antennas.

8.2 Environmental Parameters

8.2.1 General for Antennas

8.2.1.1 Lightning Protection

Parameter Definition:
It is a simple statement on the equipment whether the equipment supplier considers the equipment lightning protected.

Specification Definition:
Protected or not protected.

Specification Example
The manufacturer considers the equipment lightning protected.

Relevance

According to good practice and relevant national standards, it is always assumed that an antenna supporting structure or pole is grounded and/or connected to a lightning protection system.

8.2.1.2 Ingress Protection Index

Parameter Definition
The ingress protection index is classification according to [22] in which the AAS is designed to operate.

Specification Definition
IP index

Specification Example
IP 65

Relevance
NA

8.2.1.3 Operational temperature

Parameter Definition
The operational temperature is the temperature range in which the antenna is designed to operate.

Specification Definition
- Nominal values in Celsius degrees.
- Minimum and Maximum operating temperatures.

Specification Example
Minimum temperature = -20°C; Maximum temperature = +60°C.

Relevance
NA

8.2.1.4 Relevant humidity

Parameter Definition
The relative humidity is the relative humidity range in which the antenna is designed to operate.

Specification Definition
- Nominal value in % RH.
- Minimum and Maximum relative humidity values.

Specification Example
Minimum relative humidity = 5% RH; Maximum relative humidity = 100% RH

Relevance
NA

8.2.1.5 Product Environmental Compliance

Parameter Definition
- Overall the environmental compliance is the combination of all individual environmental compliance statements declared for the product (see Section 10.1.1.3).
- Recyclability of the product falls also under the environmental compliance term.
- A variety of different standards with different contents and focuses exist across the globe.
- Compliance requirements for the product depend on the country where the antenna is to be shipped to or installed in. The product shall fulfil these requirements.
- The necessity to state the environmental compliance in the datasheet depends on the individual needs. Nevertheless it can be done for marketing purposes.
- The compliance information shall be provided as part of the product documentation and/or shipping papers in order to ensure that the import/export of the product from/into countries is possible.
- Specific product marking requirements (if any) are defined by the corresponding environmental standard.

- The parameter indicates the list of the standards the antenna unit is compliant to. See 10.1.

Specification Definition
- It is the list of standards for which the antenna unit achieved the compliance. The parameter is reported as a description, followed by the name of the Standard or its numeric code and then followed by the compliance. If none of the descriptions, as indicated in the list below, apply the generic description term "Vendor Specific" is used. The term can be repeated as many times as required for describing standards that are not supported by the following list.
- The list of the description is as follows:
    - General Environmental RoHS
    - Environmental Conditions
    - Transportation

- Storage
- Packed Storage
- Environmental testing
- IP CODE
- IM Testing of Passive Antennas
- Actions on structures – Windloads
- AISG, if applicable
- The Radio Equipment Directive
- RoHS Directive
- REACH
- WEEE
- Packaging
- Batteries and accumulators
- Exposure to EMF
- Vendor Specific: use this description in the case no one of the previous apply.

Specification Example

Description	Name of the Standard	Compliance
General Environmental	AAA.BBB.CCC	x.y.z
RoHS	DDD.EEE.FFF	
Vendor Specific	XXX.YYY.ZZZ	

Relevance

The compliance to individual environmental standards might be required by law, can be an industry wide accepted “best practice” or might be requested by the individual customer.

8.2.2 Specific for Passive Antennas

8.2.2.1 Passive Antenna Product Compliance

Parameter Definition

The parameter specifies the standards listed in 10.1.1.1 to 10.1.1.19 the antenna is compliant to

Specification Definition

It is the list of standards for which the antenna unit achieved the compliance. The parameter is reported as a description, followed by the name of the Standard or its numeric code and then followed by the compliance. If none of the descriptions, as indicated in the list below, apply the generic description term “Vendor Specific” is used. The term can be repeated as many times as required for describing standards that are not supported by the following list.

Specification Example

Description	Name of the Standard	Compliance
Environmental Test Approach	AAA.BBB.CCC	x.y.z
Humidity exposure	DDD.EEE.FFF	
Rain	XXX.YYY.ZZZ	

Relevance
NA

8.2.3 Specific for Active antennas

8.2.3.1 Heat Dissipation

Parameter Definition
Maximum Heat Dissipation

Specification Definition
Nominal values in kilowatt

Specification Example
Maximum Heat Dissipation = 0.47 kW

NOTE: The manufacturers may specify the cooling type e.g. natural cooling

Relevance
NA

8.3 Wind Load

8.3.1 Definition of the Drag, Lift, and Resultant Force

In the context of this Publication, windload is defined as the resultant force based on the forces lift and drag.

These forces are described by

- Definition of the force drag:
    - The fluid resistance imposed on a body (antenna) due to relative motion between the fluid and the body.
    - Total drag is the sum of parasitic drag (skin friction drag+ pressure drag) and lift inducted drag.
    - Skin friction drag is the vector component of fluid force applied parallel to each element of surface, summed over the surface of the body, and resolved to the direction of relative motion.
    - Pressure drag is the vector component of the fluid force applied normal to each element of the surface, summed over the surface of the body, and resolved to the direction of the relative motion.
    - Lift induced drag is the vector component of the fluid force related to the amount of induced down wash in the vicinity of the antenna.

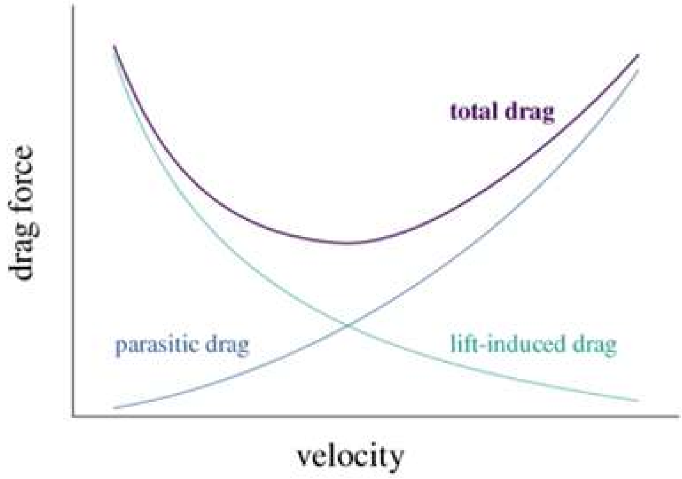


Figure 8.4: Drag force over velocity

- Definition of the force lift:
    - The component of fluid force exerted on a body in a steady fluid flow which acts perpendicular to the motion.
- Resultant force (total force):
    - A single force that can be obtained by combining a system of forces acting on a body (antenna).
    - The resultant force can be calculated by vector addition from the drag and lift components.

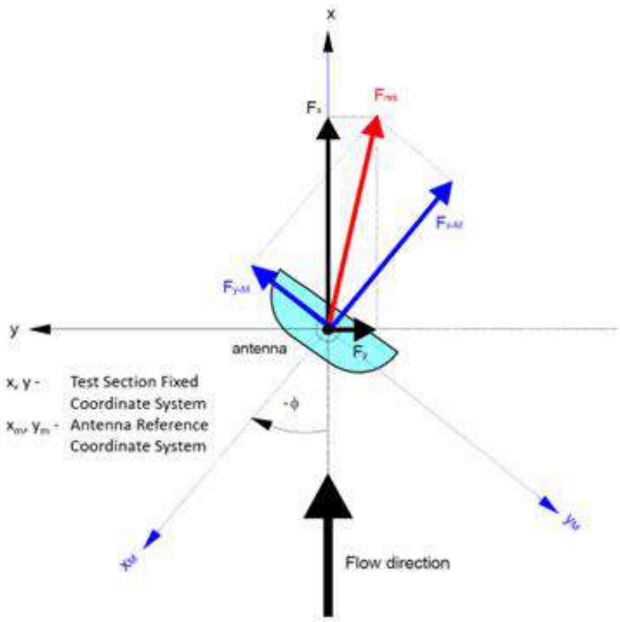


Figure 8.5: Illustration of an antenna in test configuration

The 2D coordinate system in blue represents the coordinate system of the balance which measure the forces during the test.
The 2D coordinate system in black represents the coordinate system of the wind tunnel. It is in this coordinate system that the drag and the lift are expressed.

Formula for the change of reference frame:

Drag $$F_x = F_{Drag} = F_{x-M}cos\varphi + F_{y-M}sin\varphi \tag{8.1}$$

Lift $$F_y = F_{Lift} = -F_{x-M}sin\varphi + F_{y-M}cos\varphi \tag{8.2}$$

Resultant $$F_{Resultant} = F_{Total} = \sqrt{F_{x-M}^2 + F_{y-M}^2} = \sqrt{F_x^2 + F_y^2} \tag{8.3}$$

The angle φ describes the angle between the flow direction of the wind and the plain that is perpendicular to the bore sight of the antenna.

8.3.2 Windload – Calculation Guideline

Antenna providers generally use wind tunnel testing to determine the windload of antennas. Two different standards are used for reference; [23] provides guidance for windload determination in North America and [24] is used for windload guidance in Europe and Asia.

Based on the two standards this publication defines the best practice for the reliability of the results by specifying the following requirements:

- The standard used for the determination, either [23] or [24], should be quoted.
- Windload measurement shall be performed in a wind tunnel test laboratory. For the sake of measurement repeatability antenna producers shall provide upon request information such as the laboratory name, its location and which tunnel in particular was used.
- Since there are a plethora of different antennas and mounting arrangements, windload measurements shall be performed with the antenna attached to a pipe/mast whose minimum external diameter measures between 60 mm and 100, recommend is 80mm. The mounting hardware used shall be that recommended by the antenna provider.
- The minimum distance between the edge of the pipe/mast mounted antenna (connectors and other appendices included) and the wind tunnel floor/ceiling shall be the largest of the antenna's second largest dimension (height, width or depth) or 300 mm. An influence of the wind flow due to the test set up is not permitted.
- Windload measurements shall be performed with the antenna set at minimum or at 0° of mechanical tilt.
- Measurements can be performed with downtilt kit or brackets only. The vendor shall state in the datasheet, whether measurements are performed with downtilt kit or without it.
- The measurement shall be performed with the wind velocity set to 150 km/h. Should this condition cause the antenna to resonate mechanically, the test shall be repeated with a lower wind velocity and its results shall be used to extrapolate the windload at 150 km/h by projection. The minimum test wind speed should be within 10% of the intended wind speed. This extrapolation must be calculated with the following formula:

$$F_2 = F_1 \left(\frac{v_2^2}{v_1^2}\right) \tag{8.4}$$

- The wind velocity used during testing shall be stated and the extrapolation to 150 km/h shall be noted.
- The windload is measured at an interval of no more than 10° in the range of 0° to 360°. (If the antenna is symmetrical, measure the antenna at an angle ranging from 0° to 180°.)

- Force coefficients shall be derived from the wind tunnel testing to adjust the formulas provided in the above-mentioned standards.
- Antennas must be tested in real dimension. Length scaling for same cross section is allowed as described below. Scaled models are not allowed.

Note: The maximum windload is not necessarily the frontal or lateral one. Due to the aerodynamic lift and drag effects the maximum value may be at any angle in between.

8.3.3 Length extrapolation

For antennas with different lengths but with the same cross section linear extrapolation can be used. This way no standard is required for the extrapolation.

Following formula shall be applied:

$$F_{Resultant\ with\ length\ x} = F_{Resultant\ with\ length\ measured} \cdot \frac{L_{antenna\ x}}{L_{antenna\ measured}} \tag{8.5}$$

With $L_{antenna\ x}$ representing the length of the new unknown antenna and $L_{antenna}$ measured the original measured antenna.

The limits of the length extrapolation are from 0.5 to 2 times the length of the measured antenna.

An overall Formula for an antenna with a given length $L_{antenna\ x}$ is:

$$F_{Resultant\ antenna-pole} = \left(\sqrt{F^2_{Drag\ antenna+pole\ measured} + F^2_{Lift\ antenna+pole\ measured}} - L_{Visible} \cdot F_{Drag\ pole\ measured}\right) \cdot \frac{L_{antenna\ x}}{L_{antenna\ measured}} \tag{8.6}$$

With $L_{visible}$ see equation (8.8).

8.3.4 Pole deduction

Wind tunnel test are performed with a pole mounted antenna. To calculate the actual windload of the antenna the windload of the pole must be deducted. This is done according to the following method.

Basis for the calculation is the windload of the pole only measured in the same wind tunnel and same conditions as the antenna.

The mast will be deducted as follows. In direction where the mast is fully visible and not shading the antenna the whole mast force shall be deducted (Figure 8.6 and Figure 8.7).

In direction where the antenna is shielding the mast fully or partly only the mast sections above and below the antenna shall be deducted (Figure 8.7)

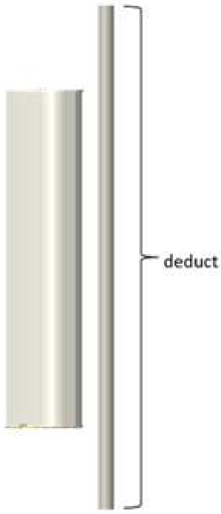


Figure 8.6: Full pole deduction

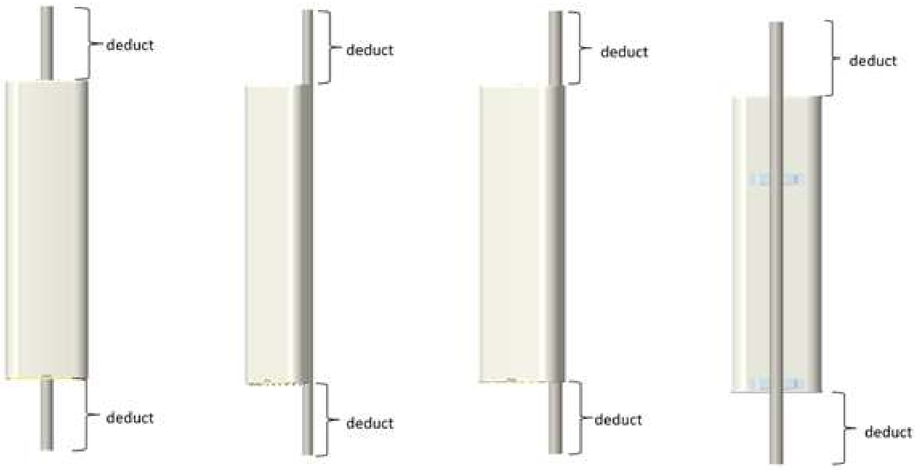


Figure 8.7: Partly pole deduction

Following formula shall be applied:

$$F_{Resultant\ antenna-pole} = \sqrt{F^2_{Drag\ antenna+pole\ measured} + F^2_{Lift\ antenna+pole\ measured}} - L_{Visible} \cdot F_{Drag\ antenna+pole\ measured} \quad (8.7)$$

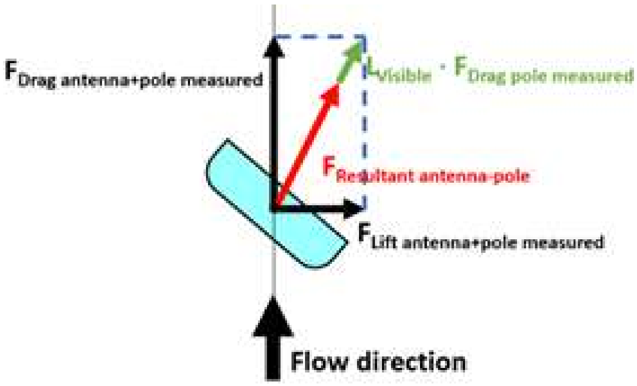


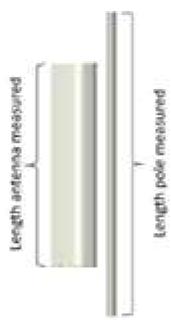
Figure 8.8: to be described

$F_{Resultant\ antenna\text{-}pole}$	N or LB	Resultant force of the antenna with pole deduction
$F_{Drag\ antenna+pole\ measured}$	N or LB	Drag component of the measured antenna force
$F_{Lift\ antenna+pole\ measured}$	N or LB	Lift component of the measured antenna force
$L_{Visible}$	-	Factor dependent on the visible length of the pole - Definition see formula (equation (8.8))
$F_{Drag\ pole\ measured}$	N or LB	Measured force of the standalone pole – due to the cylindrical shape the resultant force is the drag force

As shown before the visible length of the pole $L_{visible}$ is dependent on the wind direction. If the mast is fully visible the visible length $L_{visible}$ is equal to 1. That means that the pole force can be fully deducted.
In all other cases $L_{visible}$ shall be $1\text{-}L_{antenna}/L_{pole}$ shown in Figure 8.7.

$$L_{Visible} = \begin{cases} 1; \textit{if the pole is fully visible} \\ 1 - \frac{L_{antenna\ measured}}{L_{pole\ measured}}; \textit{if antenna or pole are shielding each other} \end{cases} \quad (8.8)$$

$L_{Visible}$	-	Factor dependent on the visible length of the pole
$L_{antenna\ measured}$	m or ft	Length of the measured antenna
$L_{pole\ measured}$	m or ft	Overall length of the used pole



8.3.5 Box Like Enclosure

8.3.5.1 Polar Chart

Specification Definition

- The polar chart gives the resultant force of the windload measured in 10° steps for 360° at 150km/h in a spider web chart.
- 0° refers to the bore sight of the antenna.
- 0° shall be pointing up in the diagram.
- The angles increase in clockwise direction.
- The chart has linear scaling that starts from 0 and shows the unit (either N or LB or LBF)

Specification Example

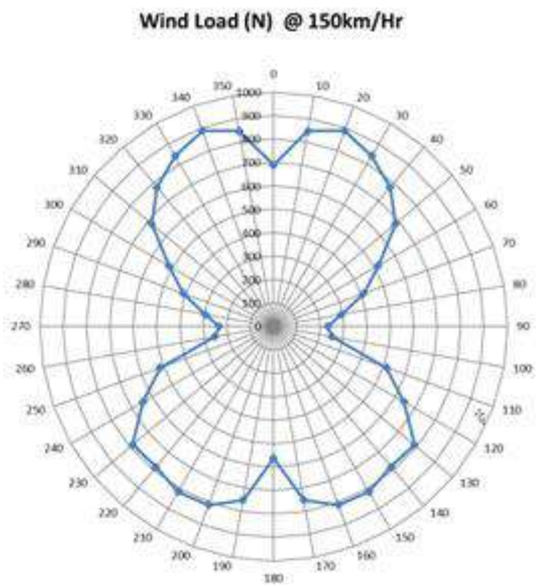


Figure 8.9: Example of Polar Chart

Relevance

Windload values are required to calculate resulting tower loads in order to dimension the towers appropriately, and to ensure safety.

8.3.5.2 Survival Wind Speed

Parameter Definition

The survival wind speed defines the maximum wind velocity the BSA can withstand without suffering permanent damage.

Specification Definition

Nominal value in kilometres per hour.

Specification Example

The antenna can withstand 200 km/h without being damaged.

Relevance

- The survival wind speed marks one limiting factor in the network viability against the influence of the wind.
- For the operators it is relevant that the product as well as the existing network installation remains safe for the public.
- In some countries there are legal requirements to ensure communication systems availability after natural catastrophes such as hurricanes or tornados.

8.3.5.3 Windload – Frontal

Parameter Definition

The windload – frontal defines the resultant force on the antenna frontal surface resulting at 150 km/h wind velocity. The incoming angle of the wind is therefore the same of the antenna mounting orientation

Specification Definition

- The windload – frontal is an absolute value in N.
- For the evaluation of this parameter the pipe/mast has a minor influence due to it being hidden to the wind by the antenna's body. The drag of the pipe/mast below and/or above the antenna, which is exposed directly to the wind, shall be subtracted by assuming a pipe/mast in undisturbed flow.

Specification Example

- Windload – frontal = 500 N.
- This parameter was measured in the "xy" laboratory, in the "z" closed-loop tunnel.
- The value was not extrapolated (extrapolation velocity = 0 km/h).

Relevance

Windload values are required to calculate resulting tower loads to dimension the towers appropriately, and to ensure safety.

8.3.5.4 Windload – Lateral

Parameter Definition

- The windload – lateral defines the resultant force on the antenna side surface resulting at 150 km/h wind velocity. The incoming angle of the wind is therefore perpendicular to the antenna mounting orientation (see Figure 6.4)
- For the evaluation of this parameter the windload of the pole shall be deducted as described in section 8.3.4.

Specification Definition

The windload – lateral is an absolute value in N.

Specification Example

- Windload – lateral = 370 N.

- This parameter was measured in the “xy” laboratory, in the “z” closed-loop tunnel.
- The value was extrapolated to 150 km/h after measuring at 140 km/h wind velocity.

Relevance
Windload values are required to calculate resulting tower loads to dimension the towers appropriately, and to ensure safety.

8.3.5.5 Windload – Maximum360

Parameter Definition
- The windload maximum 360 is the maximum resultant force of all measured values as provided in the polar chart at 150 km/h wind velocity.
- For the evaluation of this parameter the windload of the pole shall be deducted as described in Section 8.3.4

Specification Definition
The windload polar maximum – is an absolute value in N.

Specification Example
- Windload maximum360 = 850 N.
- This parameter was measured in the “xy” laboratory, in the “z” closed-loop tunnel.
- The value was extrapolated to 150 km/h after measuring at 140 km/h wind velocity.

Relevance
Windload values are required to calculate resulting tower loads in order to dimension the towers appropriately, and to ensure safety.

9 Remote Electrical Tilt System - RET

A remote electrical tilt is a device capable of adjusting an antenna's electrical downtilt by receiving appropriate commands from a remote user or system. RET units consist of two elements: controller and actuator. A controller contains the logical unit that receives and interprets the commands, while the actuator is a transducer that can alter mechanically or electrically the phase of the antenna's feed signal in order to achieve a certain electrical downtilt angle. Since controllers can be positioned relatively far away from the antenna, from now on only the part immediately attached to or integrated in the antenna will be referred to as RET. RETs are categorised in fact in three branches: internal, external and partially external. The first ones are embedded into antennas, while the second ones are typically but not exclusively attached to the bottom of antennas. The third ones are a particular subset of the external RETs and are characterized by being partially inserted into the antenna and partially protruding outside it.

General RET requirements are specified in the framework of the Antenna Interface Standards Group [41] where specifications for the control interface of antenna devices are defined. RET systems have to operate in accordance with the AISG standards and with all the relevant part of the 3GPP (Third Generation Partnership Project) specifications.

9.1 Actuator Size

Parameter Definition

- The RET stand-alone dimensions.
- The RET installed dimensions.
- The stand-alone dimensions are defined along the three axis of a Cartesian coordinate system defining the height (H), the width (W) and the depth (D) of the product (see Figure 9.1).
- The installed dimensions are defined along the three axis of a Cartesian coordinate system defining the height (H), the width (W) and the depth (D) of the product. Installed dimensions are the part of the RET protruding outside from the RET installation reference plane defined in the antenna datasheet in the antenna dimensions chapter. (see Figure 9.2).

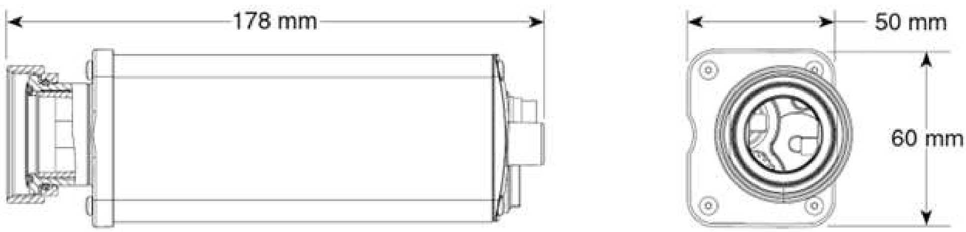


Figure 9.1: Example of an external RET.

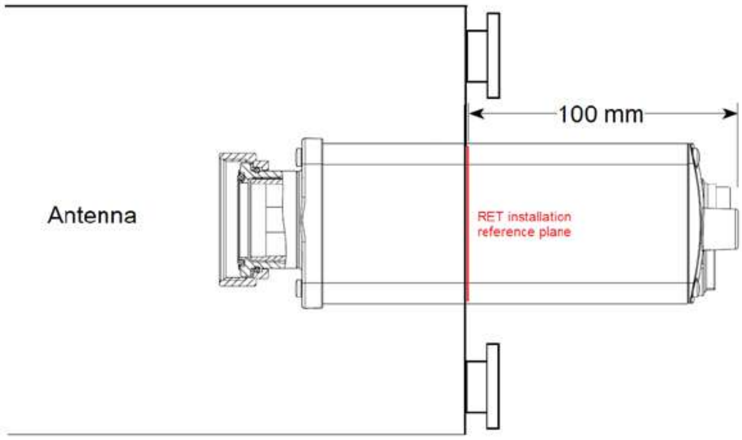


Figure 9.2: Example of the height dimension of an installed partially external RET. Its protrusion out of the antenna lies along the antenna height plane (H).

Specification Definition

- The RET stand-alone dimensions are its nominal values specified in millimetres.
- The RET installed dimensions are its protrusion dimensions beyond the RET installation reference plane.
- With the RET oriented similar to antenna alignment on the tower prior any antenna tilting:
    - Height is measured along the vertical direction of the RET (typically this is also the largest dimension).
    - Width is measured along the horizontal direction of the RET.
    - Depth is measured perpendicular to the plane spanned by vertical and horizontal direction.
- For partially external RET actuators H x W x D refers to the protrusion dimensions beyond the antenna RET installation reference plane.
- The RET installation reference plane is described by the H, W, or D dimension, but is actually the plane normal (or most normal) to it.
- The length, width and depth shall have the same orientation when describing the protrusion dimensions.
- The RET unit installation reference plane is described by the normal (or most normal) direction to H, W, or D.
- If when installed the RET does not protrude beyond the RET installation reference plane the RET actuator installed dimensions must be 0mm x 0mm x 0mm

Specification Example

- Stand-alone dimensions:
    - External RET - H x W x D: 178 mm x 60 mm x 50 mm (see Figure 9.1).
    - Partially external RET - H x W x D: 178 mm x 60 mm x 50 mm (see Figure 9.2).

- Installed dimensions:
    - External RET - H x W x D: 178 mm x 60 mm x 50 mm (see figure 6.1-1).
    - Partially external RET - H x W x D: 100 mm x 60 mm x 50 mm (see figure 6.1-2).
    - Integrated RET - H x W x D: 0 mm x 0 mm x 0 mm.

Relevance

- The RET actuator dimensions are relevant to plan detailed antenna installations regarding required space, required fixation points and visual impact.
- The RET dimensions may also impact the windload at a rated wind speed.

9.2 Antenna Configuration File Availability

Parameter Definition

This parameter defines whether the configuration file for a specific antenna is available or not. For specific antennas the manufacturer provides (when available) the antenna configuration file. This typically happens during the delivery process or during operation.

Specification Definition

Value: True / False.

Specification Example

Configuration file is not available.

Relevance

This parameter is only relevant for a specific antenna model. As an example, in case of need to substitute the antenna, the manufacturer should be able to provide the relevant configuration file.

9.3 Antenna Configuration File Upgradability

Parameter Definition

- This parameter defines whether the configuration file for a specific antenna is upgradable or not.
- In case of upgradability 'info' specifies how.
- This parameter typically applies to external RETs and RETs that require configuration in the field.

Specification Definition

- Value is of type Boolean and could be true or false.
- Examples of attribute info of type string:
    - "Yes, by base station only"
    - "Yes, by proprietary portable controller only"
    - "Yes, by base station and proprietary portable controller"
    - "No"

Specification Example

RET configuration file can be updated both from the base station and from the proprietary portable controller.

Relevance

RETs that can be installed and/or configured for an antenna in the field might require configuration per one of these methods.

9.4 Compatible Standards

Parameter Definition
List of standards which the RET is fully compliant to.

Specification Definition
- Standards names can be written in multiple fashions (e.g.: upper- or lower-case letters, version specification beginning with "v" or nothing at all). It is the task of the datasheet's provider to write the name and version of the standards understandably, while it is the end-user's task to correctly interpret them.
- Each compliant standard shall be referenced in an additional 'standard'-Tag.

Specification Example
RET is compliant with AISG v1.1, v2.x, v3.1.3 and 3GPP Release 17.

Relevance
Compliance to standards is relevant for RET installation and controlling.

9.5 Compatible Proprietary Protocols

Parameter Definition
List of proprietary protocols which the RET is fully compliant to.

Specification Definition
- Protocols names can be written in multiple fashions (e.g.: upper- or lower-case letters, version specification beginning with "v" or nothing at all). It is the task of the datasheet's provider to write the name and version of the protocols understandably, while it is the end-user's task to correctly interpret them.
- Each compatible protocol shall be referenced in an additional 'protocol'-Tag.

Specification Example
RET is compliant with the proprietary protocols of the companies A and B.

Relevance
Important to handle the refarming of the sites where the old RET systems are maintained with proprietary protocols.

9.6 Configuration Management

Parameter Definition
- This parameter defines how the RET configuration is managed. It is applicable to all RETs, internal and external.
- The applicable values are specific to internal or external RETs.
- It is possible that some internal RETs might require field configuration, while some internal RETs might be fixed (not field replaceable).

- RETs may be delivered with configuration already loaded (pre-configured). If "not pre-configured" is noted, then configuration is required (loading the configuration file) before the RET can be operational.
- Pre-configured means the RET comes from factory equipped with the appropriate configuration file, no configuration process is required.
- Automatically configuring means the RET will detect the antenna to which it will be connected and automatically configure itself to work with that antenna, no configuration process is required.

Specification Definition

- Only one of the following values are accepted (case sensitive):
    - "External RET, not pre-configured"
    - "External RET, pre-configured"
    - "External RET, automatically configured"
    - "Integrated RET, not pre-configured"
    - "Integrated RET, pre-configured"
    - "Integrated RET, automatically configured"

Specification Example

RET is internal and pre-configured.

Relevance

This parameter is relevant to the operators involved in setting and configuring the RET to a specific antenna mode for RET position movement.

9.7 Daisy Chain Available

Parameter Definition

This parameter defines whether it is possible to connect the RET to another one via daisy chain.

Specification Definition

Value: True / False.

Specification Example

Daisy chain is possible

Relevance

This parameter is relevant to the operators involved in the installation of RETs and to those responsible for the correct functioning of a whole cell.

9.8 Loss of Position on Power Failure

Parameter Definition

This parameter defines, in accordance with the relevant part of AISG standard, whether the RET loses its position in the event of a power failure during the movement of its motor.

Specification Definition

Value: True / False.

Specification Example
True

Relevance
In case the position is lost, it is necessary to first reference the RET and then set the electrical tilt of the RET again whenever the power is re-established.

9.9 RET Power Consumption

Parameter Definition
The RET's consumption of energy.

Specification Definition
- Nominal values in Watt.
- Values specified for low- and high-power modes.
- Definitions of low- and high-power modes according to the relevant 3GPP and AISG specification.

Specification Example
Low power consumption = 0.5 W; High power consumption = 5 W.

Relevance
The RET power consumption is relevant to estimate a correct overall energy economy.

9.10 Replaceability in Field

Parameter Definition
- This parameter defines whether the RET is replaceable (can be mounted/dismounted) in the same environment where the antenna is operating or not replaceable.
- In case of value='true' it specifies if it is possible only by removing the antenna from its support, or if this activity may take place without this operation.

Specification Definition
- Value is of type Boolean and could be true or false.
- Only one of the following 'info' is accepted (case sensitive):
    - "Yes, without removing antenna"
    - "Yes, only removing antenna"
    - "No"

Specification Example
RET can be replaced in the field, but in order to be able to do it, the antenna to be removed from its support.

Relevance
This parameter is relevant to the operators involved in maintenance and installation of RETs.

9.11 Smart Bias-T Available and Smart Bias-T Assigned Port

Parameter Definition

- Smart Bias-T Available defines whether the antenna is configured with a Smart Bias-T.
- Smart Bias-T Assigned Port defines on which port the Bias-T is located

Specification Definition

- Smart Bias-T available is defined as type Boolean (true / false).
- Smart Bias-T assigned RF port is defined as integer and related to the number in the corresponding port definition of a cluster. This parameter has to be mentioned for each port which has a Bias-T included.

Specification Example

- False, if no port has a Bias-T included.
- Yes, if one or more ports have Bias-T included
  - Port numbers with Bias-T included are 1, 3 and 5.

Relevance

- This parameter is relevant to the operators involved in the installation of RETs and to those responsible for the correct functioning of a whole cell.
- IN AISG 3.0 a pinging function is defined for testing the connection between each a radio port and an antenna port. In this case each RF port needs to be assigned with a Bias-T.

9.12 Software Upgradability

Parameter Definition

- This parameter defines whether the RET operative system software is upgradable or not
- In case of yes 'info' specifies how.

Specification Definition

- Value is of type Boolean and could be true or false.
- Examples of attribute info of type string:
  - "Yes, by base station only"
  - "Yes, by proprietary portable controller only"
  - "Yes, by base station and proprietary portable controller"
  - "No"

Specification Example

- RET software can be upgradable by base station and proprietary portable controller
- RET software cannot be upgraded.

Relevance

For a RET that allows the software to be upgraded in the field, this defines the available methods for upgrading the software.

9.13 Visual Indicator Available on Tilt Change

Parameter Definition

- This parameter defines whether operators within a reasonable distance to the RET are able to be visually notified when a change of downtilt takes place.
- The beginning and the end of the procedure shall be recognizable.
- If the RET is not integrated, the visual indicator shall be visible by looking at its external surface.
- If the RET is integrated, the visual indicator shall be visible by looking at the external surface of the RET or of the antenna.
- For some antenna models, the visual indicator may be part of the antenna and thus associated with the antenna.

Specification Definition

Value: True / False.

Specification Example

A visible indicator of tilt change is not implemented.

Relevance

This parameter is relevant to the operators involved in maintenance and testing of RETs.

9.14 Working Temperature Range

Parameter Definition

The temperature range in which the RET can operate properly, without suffering permanent damage. It shall also survive without being mechanically or electrically affected due to temperature in any way that would require service maintenance at the site.

Specification Definition

- Nominal values in Celsius degrees.
- Minimum and Maximum operating temperatures.

Specification Example

Minimum temperature = -20°C; Maximum temperature = +60°C.

Relevance

The RET working temperature range is relevant to evaluate the overall operational working temperature of the RET system and ensure its correct operation.

10 Annex A: Certifications and Standards

10.1 Environmental standards

10.1.1 Specific for Passive antennas

10.1.1.1 Base Station Antenna Environmental Criteria

The operating environment of base station antennas is classified as remote, stationary, outdoor, uncontrolled and not weather-protected. The electromagnetic environment includes close proximity to intentionally radiating devices and installation on structures prone to lightning strikes. The systems are expected to operate in this environment for an extended period of time. This, together with storage, transport and installation conditions, defines the "mission profile" for antennas and other tower top systems – a key factor needed to their determine reliability.

ETSI defined climatic classifications to describe the operating environment for tower top systems. Considering that installation environments vary, an antenna cannot fit in only one group, because those depend highly on the installation area. A summary of these classifications is given in the following table:

- Class 4.1 represents a nominal uncontrolled outdoor environment.
- Class 4.1E extends temperature and humidity ranges to the average minimum and maximum temperatures in the 5 European climatic zones.
- Classes 4.2L and 4.2H represent more extreme climates addressed by ETSI, but these are also further extended in regions outside of Europe.

For example, high temperature operation at +70ºC is a common requirement for base station antennas.

Table 10-1: ETSI 300 019-1-4 [27] stationary, non-weather protected environmental classes.

Environmental Parameter	Classes			
	4.1	4.1E	4.2L	4.3H
Minimum air temperature	-33°C	-45°C	-65°C	-20°C
Maximum air temperature	40°C	45°C	35°C	55°C
Minimum relative humidity	15 %RH	8 %RH	20 %RH	4 %RH
Maximum relative humidity	100 %RH	100 %RH	100 %RH	100 %RH
Minimum absolute humidity	0.26 g/m3	0.03 g/m3	0.003 g/m3	0.09 g/m3
Maximum absolute humidity	25 g/m3	30 g/m3	22 g/m3	36 g/m3
Rain intensity	6 mm/min	15 mm/min	15 mm/min	15 mm/min
Maximum temperature change rate	0.5 ºC/min	0.5 ºC/min	0.5 ºC/min	0.5 ºC/min

Minimum air pressure	70 kPa	70 kPa	70 kPa	70 kPa
Maximum air pressure	106 kPa	106 kPa	106 kPa	106 kPa
Solar radiation	1120 W/m2	1120 W/m2	1120 W/m2	1120 W/m2
Maximum wind speed	50 m/s	50 m/s	50 m/s	50 m/s

The standard BSA product complies to the [27] standard for environmental conditions: Class 4.1 E but, as already mentioned, customer requirements and application scenarios might call for more rigid environmental class compliance such as 4.2L or 4.2H. The specific design changes and material selections required for that compliance is out of the scope of this publication.
Standard BSAs comply also with [25] for storage: Class 1.2 (see Section 6.3.1) and [26] for transportation: Class 2.3.

Note: Should the standards be updated, or should better standards be available, the recommendation is to use those instead.

10.1.1.2 Environmental Test Approach

The generic test approach for qualifying BSA products is similar to other technical qualification best practice rules. Overall target is to demonstrate compliance to the applicable standard and one of its environmental classes.
This qualification requires for each of the environmental parameters (see table above):

- A defined test setup: this serves as instruction to set the test up in a defined reproducible way using certified test equipment. It consists typically of a plan or block diagram identifying the components and devices of the whole setup, their serial numbers and a wiring diagram. The start settings and/or calibration procedure of the above-mentioned equipment shall also be included.
- The definition of standard atmospheric conditions (see [28] to [39]) in which the tests take place (even if during test the specimen might be subject to strongly deviating conditions). These are defined as ranges to enable testing in environments not completely climatic controlled.
- A uniform and reproducible method of environmental test: the procedures of IEC 60068 (see [28] to [39]) cover the different environmental parameters applicable to BSA.
- Trained test operator(s) proficient in the usage of test equipment and measurement devices.
- A defined number of test specimens. This is rarely prescribed by IEC 60068 (see [28] to [39]), but the testing team should consider this in relation to the test reproducibility: the test might fail or pass by cause of different devices production techniques, materials, number of suppliers, etc. In case the test effects have some statistic behaviour, the number of test specimen should be selected accordingly (under consideration of test efforts in time and budget).
- A defined set of acceptance criteria. The test specimen shall comply to the defined acceptance criteria prior and after the test. These criteria are also to be observed and rated during the test itself. Available test equipment might limit the "during the test" assessment, so a practical but also documented approach on what is required and what can be done is necessary. The list of acceptance criteria differs by parameter: for environmental performance ones it typically includes functional tests, electrical measurements and visual inspection.
- A test documentation. This consists of the raw test data and protocols rating the actual measured values against the test criteria, the identification of the tested specimen (e.g.: by model number and serial number) and finally the test report. It documents the compliance of the tested devices prior the tests, specific test events, observations, consolidated data of the test itself and the device compliance to the acceptance criteria after the test was performed. The report is then concluded by an assessment of the test results, a compliance statement and a conclusion.

10.1.1.3 Environmental Test Methods

The following criteria are used to demonstrate that base station antennas can operate as needed (hence all the parameters given in the datasheet are valid) in the environments in which they will be typically set in operation. These tests alone cannot, though, determine an antenna's reliability, which is the probability over time that it will continue to operate as needed in these environments. However, they can establish the initial reliability and indicate a measure of an antenna's service life. The aforementioned criteria are based on publicly available and widely accepted test methods (generally on ETSI Class 4.1 for common performance needs under nominal conditions or Class 4.1E for extended use – 10 or more years – in harsher environments).

Comparing the standard ETS300019-2-4 [27] with the IEC60068 (see [28] to [39]) it is clear that the characteristic severities of the ETS might deviate from the corresponding ones of the IEC. Due to this fact and because in general the definitions of the standards should be sanity-checked considering the BSA application, this publication recommends test limits that may deviate from corresponding ETSI and IEC recommendations.

10.1.1.4 Packaged Storage

While packaged, transported and stored, antennas shall tolerate non-temperature-controlled-weather-protected-environments without degradation (Baseline: ETS 300 019-1-1 [25] Class 1.2; -25 to +55°C; 10% to 100% Relative Air Humidity). The conditions for water from sources other than rain are the limiting factor for the environmental class of packaged storage. The higher ETS 300 019-1-1 [25] classes 1.3 and 1.3E include splashing water also from side or bottom directions, but since the antennas are packed in cardboard boxes that normally draw water, get wet and soften up until they rip apart, the packaged storage class shall be limited to the class 1.2.

10.1.1.5 Cold Temperature Survival

Antennas shall operate within their specifications after exposure to cold air temperature following IEC 60068-2-1 [28] test methods (Baseline: ETS 300 019-1-4 [27] Class 4.1; 16 hours at -33°C / Extended: ETS 300 019-1-4 [27] Class 4.1E – further extended to 16 hours at -40°C). Due to test equipment limitations, it is not possible to demonstrate the proper antenna operation and/or the behaviour of all antenna parameters during the cold temperature survival test. The operation of the device is verified prior and following to the test.

10.1.1.6 Hot Temperature Survival

Antennas shall operate within their specifications after exposure to hot air temperature following IEC 60068-2-2 [29] test methods (Baseline: ETS 300 019-1-4 [27] Class 4.1; 16 hours at +40/55°C / Extended: ETS 300 019-1-4 [27] Class 4.1E – further extended to 16 hours at +60°C). Due to test equipment limitations, it is not possible to demonstrate the proper antenna operation and/or the behaviour of all antenna parameters during the cold temperature survival test. The operation of the device is verified prior and following to the test.

10.1.1.7 Temperature Cycling

Antennas shall operate within their specifications after exposure to temperature cycling following IEC 60068-2-14 [32] test methods (Baseline: ETS 300 019-2-4 [27] Class T4.1; 2 cycles with T1 = 3h and 0.5 °C/min from -10°C to +40°C / Extended: ETS 300 019-2-4 Class T4.1E; 2 cycles with T1 = 3h and 0.5 °C/min from -10°C to +45°C).

The characteristic severity of the lower temperature of ETS300019-2-4 [27] strongly differs from the one defined in the cycle testing of IEC 60068-2-14 [32], but considered that technically the risk for failures increases in the lower end of the temperature range, and having acknowledged the testing capabilities, this publication recommends, as a proper compromise between the ETSI and the IEC requirements, applying 5 cycles from -25 to +45 °C allowing temperature change rates of 1 °C/min.

10.1.1.8 Sinusoidal

Antennas shall operate within their specifications after (non-operating) exposure to sinusoidal vibration following IEC 60068-2-6 [30] test methods (Baseline: Five 2-200 Hz sweeps in each X, Y and Z axis, limited to 0.5g / Extended: Five 2-200 Hz sweeps in each X, Y and Z axis, limited to 1.0 g). This publication recommends 5 Hz as minimum frequency due to test equipment limitations.

10.1.1.9 Humidity Exposure

Antennas shall operate within their specifications after (non-operating) exposure to humidity exposure following the IEC 60068-2-30 [35] test methods (Baseline: 2 cycles between 25 and 40°C in 24 hours at 90-98% relative humidity / Extended: 2 cycles at 30°C in 24 hours at 90-98% relative humidity) or their equivalent.

The joint experience is that no failures have been ever observed for these tests. Thus, it is considered to be a low-risk parameter that could be verified with a shorter standard test of 2 cycles/8 hours. In the case where a new design with major design changes and/or different materials is tested, the experts teams shall instead apply the more rigid 6 cycles/24 hours testing.

10.1.1.10 Rain

Antennas shall operate within their specifications after (non-operating) exposure to simulated rain following the IEC 60068-2-18 test methods (Baseline: ETS 300 019-1-4 [27] Class 4.1: 6 mm/minute for 30 min / Extended: ETS 300 019-1-4 Class 4.1E: 15 mm/minute for 30 min).

Requirements of 10 mm/min for 30 minutes are in this publication considered an acceptable compromise between the ETS and IEC characteristic severities.

10.1.1.11 Water Ingress

Antennas electronics and RF path interconnections potentially exposed to water shall be protected against splashed, sprayed or windblown ingress to a rating of IPX6 as defined by IEC 60529 [40] “degrees of protection provided by enclosures (IP Code)”.

This publication recommends the value not to be stated in the technical customer documentation and datasheets, because only very rarely a customer inquires on this. It is seldom tested, and the applicable class might be directly limited by design features (e.g.: rain drop holes).

10.1.1.12 Dust and Sand Ingress

Antenna components potentially harmed from dust or sand exposure shall be protected from their ingress to a rating of IP5X as defined by IEC 60529 [40] “degrees of protection provided by enclosures (IP Code)” (Baseline:

an IP5X dust ingress rating may be assumed without testing based on demonstration of an IPX6 water ingress rating / Extended: IEC 60068-2-68 [39] Test Lc1 or the equivalent).

Overall, this is not considered to be a problem. It is extremely rarely tested, and if inquired, the figure might be deducted from the water Ingress test figure. This publication recommends the value not to be stated in the technical customer documentation and datasheets.

10.1.1.13 Survival Wind Speed

Antennas shall survive exposure to forces simulating the effects of strong winds according to the definition in Section 5.8. It is calculated using methods consistent with latest revision of Eurocode 1 "Actions on structures" – Part 1-4 "General actions" – "Wind actions" (EN 1991-1-4 [24]) and/or EIA/TIA 222 [23]. The detailed reference to be used might vary by country and has to be checked accordingly.

The maximum wind velocities cited in ETS 300019 [25][26][27] not considered to be sufficient for BSA applications. Consequently and in line with the customer requirements a standard survival wind speed of 200 km/h is defined. For higher windload designs typically 240 km/h is realized although individual customer tailored design solutions might be required. It is acceptable to demonstrate compliance to this survival wind speed by:

- Dynamic testing.
- Static testing.
- FEM modelling & simulation.
- Similarity to existing verified products.
- Analytics applying best structural engineering practices.

This publication recommends: 55.6 meter/sec; 200 km/h (124 mph) for standard duty antennas, 66.6 meters/sec 240 km/h (150 mph) for heavy duty antennas.

10.1.1.14 Solar/Weather Exposure

Antenna materials shall not degrade significantly after simulated solar exposure following the IEC 60068-2-56 [37] test methods or their equivalent. The IEC defines three different methods with two cyclic (cycle of light and dark) and one continuous radiation exposure. The cyclic tests are considered to be more aggressive, especially the procedure B that has 20 hours light and only 4 hours dark time (Baseline: 20 hours on / 4 hours off at 55°C for 56 cycles/56 days = 1344 hours).

In order to save time, shortening the test duration was discussed. Experience is that test duration of at least 1000 hours shows the material failures and that the test samples have to be visually inspected. Moreover, some mechanical tests (tensile and/or bending) have to be performed to ensure the materials keep at least 60% their initial properties and do not get brittle. The standards define detailed lists of light sources qualified for the test with resulting impact on test conditions (typically the wavelength of the UV is applied). Any light source compatible with the above-mentioned cycling procedure B is acceptable.

Crack, chalking or permanent dimensional change might appear in any intermediate test or final inspection. The individual material changes that might be tolerated depend on the material and where it is used: this is to be risk assessed by the mechanical designer on a case-by-case basis; therefore no generic applicable guidance can be provided in this publication. As an example, these material specific limits could be defined considering following behaviour as a failure of the material:

- Mean tensile strength change > 10%
- Mean elastic modulus change > 30%
- Mean elongation change > 30%
- Mean impact strength change > 30%

Remark: Significant colour changes completely changing the visual aspect of the antenna could become an issue for customer acceptance even if they would not negatively impact the environmental reliability of the antenna.

10.1.1.15 Corrosion Resistance

Antenna materials and surface finishes shall be corrosion resistant for the intended service lifetime. The system, or its components and materials, shall be tested for corrosion resistance following the IEC 60068-2-11 [31], test Ka method (a.k.a. B117) using a salt fog (mist) from a neutral, 5% weight sodium chloride solution for 28 days = 720 hours (Standard Baseline: 10 days = 240 hours / Extended: “Procedure B” with 20 hours on / 4 hours off at 40°C for 28 days = 672 hours).

Functional tests shall be done prior to and after the corrosion exposure. The visual acceptance criteria are many and require some definition. While it is jointly agreed that after 28 days of salt spray testing there are always some ‘salt’ remains on the device (which is acceptable), corrosion starting at metal parts is not acceptable.
Due to limitations of test equipment it is not feasible to test complete antenna products in all cases. Suitable test samples are typically selected to demonstrate the viability versus salt corrosion of the antenna including all connectors, sealings, materials, joints and moving parts. This publication recommends the test duration defined in IEC 60068-2-11 [31] ranges from 16 hours to 672 hours = 28 days, but individual customer inquiries asking for even longer test durations might occur.

Acceptance criteria (visual inspection shall be done before and after test):

- Excessive corrosion in critical areas.
- Salt deposits in electrical critical areas.
- Corrosion of insulating materials and metals.
- Clogging or binding of movable parts.

After completing the test, the exposed materials may be washed with warm water and lightly brushed to remove the salt deposits and expose the base material under the salt.
The following are indications of material failure:

- The base material has been attacked by the salt deposits.
- In the case of plating, bubbling, lifting or the plating has been eaten through.
- For assemblies with working mechanical pieces, failures of thread, seals, etc.
- Leakages.
- Illegibility of marking and nameplate.

Moreover, electrical measurements have to be done before and after test (if applicable) to assess:

- VSWR.
- Isolation.
- Intermodulation.

10.1.1.16 Shock & Bump

An antenna shall survive shocks and/or bumps without suffering any permanent damage that can alter its electrical and/or mechanical features, compromising its service efficiency. Visual and operational checks are to be done prior to and after the shock & bump trial in order to verify whether the antenna has maintained its characteristics. The test method is indicated by IEC 60068-2-27 [34] “Test Eb: Bump” (Baseline: antenna without packaging, half-sine bumps from 6 directions, 100 bumps in each direction).

This publication recommends applying, irrespective of the product weight, the test specifications below:

Antenna Weight	Input Acceleration	Duration
<50kg	100 m/s^2	6 ms
>50kg	50 m/s^2	11 ms

10.1.1.17 Free Fall (Packaged Product)

An antenna shall survive free falls without suffering any permanent damage that can alter its electrical and/or mechanical features, compromising its service efficiency. Visual and operational checks are to be done prior to and after the free fall trial in order to verify whether the antenna has maintained its characteristics. The test method is indicated by IEC 60068-2-31 [36] (Baseline: packaged antenna, 1 fall per face or 2 falls, altitude specified in Table 10-2).

Table 10-2: Free fall test heights.

Mass	Free fall test height Class T 2.2	Free fall test height Class T 2.3
< 10 kg	0.8 m	1.0 m
< 20 kg	0.6 m	0.8 m
< 30 kg	0.5 m	0.6 m
< 40 kg	0.4 m	0.5 m
< 50 kg	0.3 m	0.4 m
< 100 kg	0.2 m	0.3 m
> 100 kg	0.1 m	0.1 m

This publication recommends this either to be tested, or to declare the compliance referring to existing test results of products with similar packaging design. The test shall also be only applied for the 6 flat sides of the package (no corner drop test is applied).

10.1.1.18 Broadband Random Vibration

An antenna shall survive random vibration within a broad spectrum without suffering any permanent damage that can alter its electrical and/or mechanical features, compromising its service efficiency. Visual and operational checks are to be done prior to and after the vibration trial in order to verify whether the antenna has maintained its characteristics. The test method is indicated by IEC 60068-2-64 [38] “Test Fh: Vibration broadband”.

This publication recommends the tested frequency spectrum for broadband random vibration to be aligned with the one applied for the sinusoidal testing.

10.1.1.19 Steady State Humidity

Antenna materials and surface finishes shall be humidity resistant for the intended service lifetime. The system, or its components and materials, shall be tested for steady state humidity following the test method designated by IEC 60068-2-56 [37] "Test Cab: Damp Heat, Steady state" (Baseline: 93% relative humidity, with a temperature of +40°C ± 2°C and a duration of 21 days = 504 hours).

The steady state humidity test according to IEC 60068-56 [37] allows different combinations of temperature and relative humidity and test durations in a range from 12 hours to 1344 hours = 56 days. The selected parameters above define a very stringent (highest temperature combined with highest relative humidity, second longest test duration) test condition, which is recommended by this publication too.

10.2 Reliability Standards for Passive Antennas

Reliability is the probability that a product or service will perform as needed for a specified time and under specified operating conditions. It deals with the knowledge of the physics of failure and with the design to reduce it throughout the product's service life or, for complex systems such as antennas, to make them tolerant to failures when they do happen. Acceptance and qualification tests address initial quality by showing that no failures occur under certain operating and environmental conditions. While these conditions may include "reliability demonstrations" (such as corrosion tests run for a fixed time), these tests cannot determine a product's reliability.

By contrast, reliability tests are meant to actually cause failures, usually by "accelerating product aging", so that realistic failures happen quickly. These tests are designed to measure failure rates (or MTBF values) and operating lifetimes. While there are many references for general reliability test methods (the IEC 60605 family of standards is one example), in practice most reliability tests and predictions are customized around product features and dominant failure mechanisms. As a result failure rates, MTBF values and lifetimes are always approximations under several assumptions, which shall be known and understood to properly compare predictions from different sources.

11 Annex B: Additional Topics

11.1 General for Antennas

11.1.1 Guidance on Pattern and Gain Measurements

A general guideline is that all equipment used for measurements of antennas patterns and gain should be calibrated with a visible proof of the latest calibration date. The following section give recommendations on the methodology to observe in order to correctly execute an antenna's measurement.

11.1.1.1 Mechanical Alignment of Test System

The mechanical boresight of the antenna and measurement system shall be calibrated by testing the antenna elevation pattern two times: once with the typical operating setup, while the second time the antenna mounting shall be rotated by 180° or, if possible, the antenna mounting axis shall be flipped (recommended). In both cases the value of the measured antenna electrical tilt should be the same; contrarily, mechanics shall be realigned and tested again.

11.1.1.2 Phase Centre Check

The antenna shall be rotated around its own phase centre. To ensure that it happens, a pattern test on the middle frequency of each cluster shall be run to acknowledge the phase response over the azimuth. The outcome is a phase curve, which shall be flat in the angular region corresponding to the main beam of the antenna. If not, the antenna shall be positioned away from or towards the mechanical rotation centre of the system, until it is aligned with the antenna phase centre.

11.1.1.3 Antenna Pattern Testing

The system shall be set up to measure the antenna's patterns by the frequencies identified through the rules described in 11.2.4. A unique calibration shall be used for all the antenna's ports, and the test shall start from the minimum frequency supported by each cluster of the antenna and shall end with its supported maximum one. The azimuth and elevation patterns, Co-Pol and Cross-Pol shall be measured for each port and electrical downtilt of interest (see Section 4.2). These consist in the set of signal levels measured respectively by every azimuth and elevation angle of interest (see Section 4.2), which appear respectively in the same elevation and azimuth cuts where the absolute signal maximum lays. Signal levels can be in this way easily compared and evaluated relatively to each other. The resulting patterns shall have the antenna's mechanical boresight as an angular "zero-reference".

11.1.1.4 Pattern Accuracy Estimation

The following quick tests shall be performed before any measurement.

- When possible, a golden unit antenna with known performance (from another range) shall be tested.
- A pattern sweep (360°) shall be run, and the signal level by -180º and +180º shall be checked. The signal levels should be identical since those point coincide, but they are measured with a time difference between them. If the signal level is not the same, this shall be taken as an indication of instability in the measurement setup, or of the surrounding environment. This issue should be further investigated (loose connections, signal interference, stability in instruments) before starting a measurement.

- A second pattern sweep shall be run with the antenna mounting rotated by 180º. At the end both patterns shall be checked for symmetry issues (right hand side of pattern in test 1 should look the same as left hand side of pattern in test 2). This test can give information of asymmetries in the measurement range (reflections or interfering signals from one direction).
- The two steps above are worth to be taken for both azimuth and elevation patterns.

11.1.2 Gain Measurement

In the following sections two methods to calculate the gain of an antenna will be described.

11.1.2.1 Gain by Substitution Method

The gain by substitution (also known as gain by comparison) method consists in a procedure that allows to measure an antenna's gain by using a reference antenna whose gain is already known, which is then compared with the AUT. The gain reference antenna is typically a calibrated standard gain horn.

- The first step in this procedure consists in calibrating the test range using the gain reference antenna by positioning it in its phase centre and main beam direction, hence giving the system a "zero reference". This shall be done for each individual polarization of interest, since the transfer function of the range can be different for each polarization.
- The second step consists in measuring the antenna under test in its phase centre and main beam direction.

The gain of the AUT is finally found by taking the measured values (step two), and adding the known gain of the reference antenna, which is typically found in a document delivered with it.

11.1.2.2 Gain by Directivity/Loss Method

An alternative gain measurement procedure is the gain by directivity/loss method. This procedure allows to measure an antenna's gain by measuring the directivity of an antenna and then considering its losses. Gain (G) and directivity (D) are in fact linked by the formula:

$$G = kD \tag{11.1}$$

with k representing the antenna efficiency factor ($0 \leq k \leq 1$), which describes the overall losses of the antenna ($k = 1$ means that the antenna is lossless). Therefore the antenna gain can be calculated by:

$$G[dB] = D[dB] - a_{antenna}[dB] \tag{11.2}$$

where a is the sum of all the antenna's losses.

<u>Measuring the Directivity of an Antenna</u>

To calculate the directivity, the field irradiated from an antenna shall be measured in every direction through the interaction of the Antenna Under Test (AUT) and a probe. This procedure is better performed with the entire system placed in an anechoic chamber (typically in near-field conditions) that allows the rotation of the AUT in both the spherical axis (ϑ – elevation and φ - azimuth).

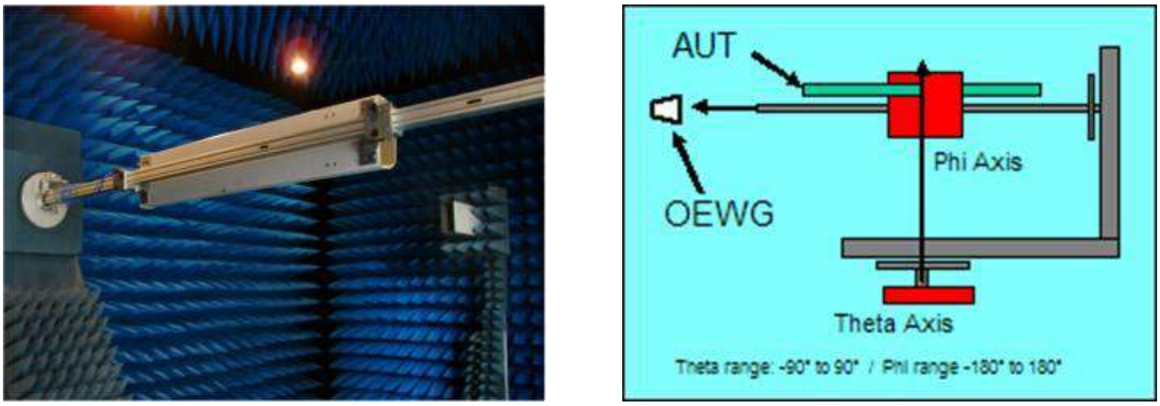


Figure 11.1: Spherical near-field system.

The directivity cannot be measured directly, but shall be computed from the far-field power pattern normalized to its maximum value:

$$D = \frac{4\pi P_n(\varphi_m, \vartheta_m)}{\oiint P_n(\varphi, \vartheta) sin\vartheta \; d\varphi d\vartheta} \tag{11.3}$$

where D is once again the directivity and P_n the tridimensional power pattern.

In substance the directivity is calculated from a full tridimensional pattern measurement:

$$D[dB] = MaxFF[dB] - Powersum[dB] + 10 \log (4\pi) \tag{11.4}$$

where:

- MaxFF = Overall peak of the measured and computed FF.
- Powersum = Sum of all measured and computed far-field points (3D).

During the calculation of the directivity the following faults can cause problems:

- Shadowing effects of the scanner, which unavoidably cause a wrong Powersum to be calculated.
- Probe correction error, which causes the software to perform wrong NF to FF transformations.
- Insufficient FFT density (sampling criteria should be carefully chosen during scanning and the near-to-far-field transformation), which causes aliasing.
- Wrong FF reference polarization, which causes false patterns to be measured.
- High Cr-Pol level in the measurement probe.

<u>Measuring the Internal Losses of an Antenna</u>

The antenna losses are the sum of the ohmic and dielectric losses between the input connector and the outer surface of the radome plus the loss due to the impedance mismatch:

$$a_{antenna} = a_{network} + a_{antenna\ mismatch} + a_{radome} \tag{11.5}$$

The feeding loss $\alpha_{network}$ can be measured with a network analyzer as shown in the following picture:

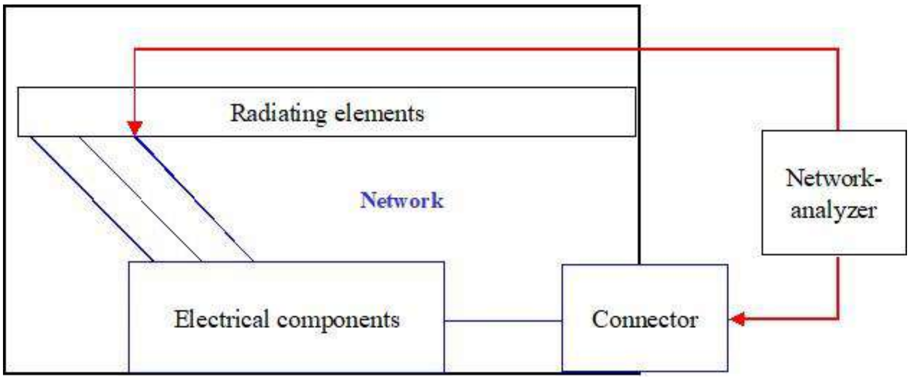


Figure 11.2: Block diagram of loss measurement.

This measurement shall be executed in four steps:

- Radiating elements shall be detached from the network.
- The transmission of each input-to-output path shall be measured.
- All the transmission losses of each path shall be summed.
- $\alpha_{network}$ shall be calculated as the average of the total transmission losses for each path.

The antenna mismatch has to be calculated with the formula:

$$a_{mismatch} = -10\ log_{10}\left(1 - e^{-\frac{RL}{10}}\right)[dB] \tag{11.6}$$

where RL is the return loss.

In the end, the overall network loss is:

$$a_{network} = a_{cables} + a_{componets} + a_{network\ mismatch} \tag{11.7}$$

The dielectric losses of the radome depend on its loss factor $tan\delta$, which differs for each material. Under the assumption that the radome is normally thin, the value of tanδ is less than 0.05dB and therefore can be neglected.

11.1.3 On the Accuracy of Gain Measurements

The following sections will detail potential sources of errors occurring during an antenna's gain measurement and will give recommendations in order to minimize these errors. This discussion will be mainly focused on gain measurements done using the method of substitution and by means of far-field ranges (but its validity is extended to near-field gain measurements).

As a general rule it is strongly advised that all instruments have reached their working temperature before a calibration or a measurement, and that the measurement equipment is calibrated with the reference antenna as close in time as possible prior to the gain measurements. After the gain measurements have been performed, the reference antenna should be mounted and measured again against the previous calibration; should any deviation from it be observed, this shall be taken as an indication of instability in the measurement setup, or of the surrounding environment. This issue should be further investigated (loose connections, signal interference, stability in instruments) before repeating the measurement.

11.1.3.1 Antenna Mismatch between Reference Antenna and AUT

The measurement system is typically calibrated by the interface of the receiver (network analyser) and not by the interface of antenna under test; under this assumption a difference between the VSWR of the reference antenna and the one under test is expected. This will result in an unavoidable (due to different reflections in the measurements) calibration error Divergently from the IEEE gain definition, the power reflected due to mismatch is not compensated for, and the above-mentioned error is estimated to be ~0.1dB. In order to minimize it, though, it is recommended that long measurement cables are used, and that the measurement of their RL towards the network analyser is < -20 dB.

11.1.3.2 Size Difference between Reference Antenna and AUT

In condition of far-field an antenna's quiet zone is never ideal but instead characterized by amplitude and phase variations that are dependent on the size of the antenna's aperture. Considering that the aperture of an AUT typically differs from the one associated to a reference antenna (normally a standard gain horn), a measurement error between 0.1 dB and 0.2 dB can typically be taken into account.

Theoretically, if for each frequency the AUT would be moved in a plane perpendicular to a planar wave coming from the probe and defined by the averages of both the antennas lengths and widths (also oriented along the same antennas' axis), the gain would be obtained as a function of AUT's displacement. Integrating the gain found in the whole area (basically the average aperture) would minimize the above-mentioned error, as the differences in the quiet zones would be minimized too. Doing this, though, is unpractical and very time-consuming, so the mentioned error is accepted instead.

11.1.3.3 Temperature and Humidity Drift in Instruments

The signal level measured at the receiver (network analyser) depends on the surrounding environment conditions. To avoid temperature and/or humidity drifts, the measurement equipment shall be placed in a controlled environment (see Section 10.1).

11.1.3.4 Polarization

In the measurement chamber the transfer function is not the same for different polarizations, therefore in order to avoid errors each polarization shall be individually calibrated.

11.1.3.5 Direct Gain Comparison Between Two Antennas

The gain difference between two similar (shape, sizes, frequencies, tilt) antennas can be quite accurately determined by using the gain by comparison method. In this case the power level difference between the AUT and the reference antenna (which in this case is not a standard gain horn, but an already measured antenna) corresponds to the difference in gain between the two.

11.1.3.6 Reference Antennas

Reference antennas should be absolutely calibrated and shall periodically be checked/recalibrated. Due to errors in the absolute calibration method a deviation of ~0.2 dB from the published values shall always be estimated.

11.1.3.7 Efficiency Measurement

The antenna efficiency is defined in Section 3.3.17. In a measurement system, the efficiency can be calculated after the gain calibration. The following formula is used after the measurement and gain calibration

$$Efficiency = 10\log\left(\frac{P_{rad}}{P_{in}}\right) = 10\log\left(\frac{\oiint G_{calibrated}(\vartheta,\varphi)sin\vartheta\ d\vartheta d\varphi}{4\pi}\right) \tag{11.8}$$

Where P_{rad} is the radiated power and P_{in} is the input power of the antenna.

To calculate the efficiency, the field irradiated from an antenna shall be measured in every direction through the interaction of the Antenna Under Test (AUT) and a probe. This procedure is better performed with the entire system placed in an anechoic chamber that allows the rotation of the AUT in both the spherical axis (theta θ and phi ϕ). The following steps in test procedures are recommended to calculate the efficiency.

11.1.3.7.1 Near-Field Efficiency Measurement

- Using the calibration reference antenna for gain calibration.
- It is recommended that for the Antenna installation: The phase centre of the antenna shall be aligned with the system laser positioning.
- Connect cables, adjust the downtilt of the antenna RET, and start the test.
- Rotate the antenna as many times as needed, in order to measure the near-field in all directions, then the near-field 3D pattern is obtained.
- The far-field 3D pattern is obtained through the NF to FF transformation.
- Efficiency can be directly calculated according to the far-field 3D pattern data

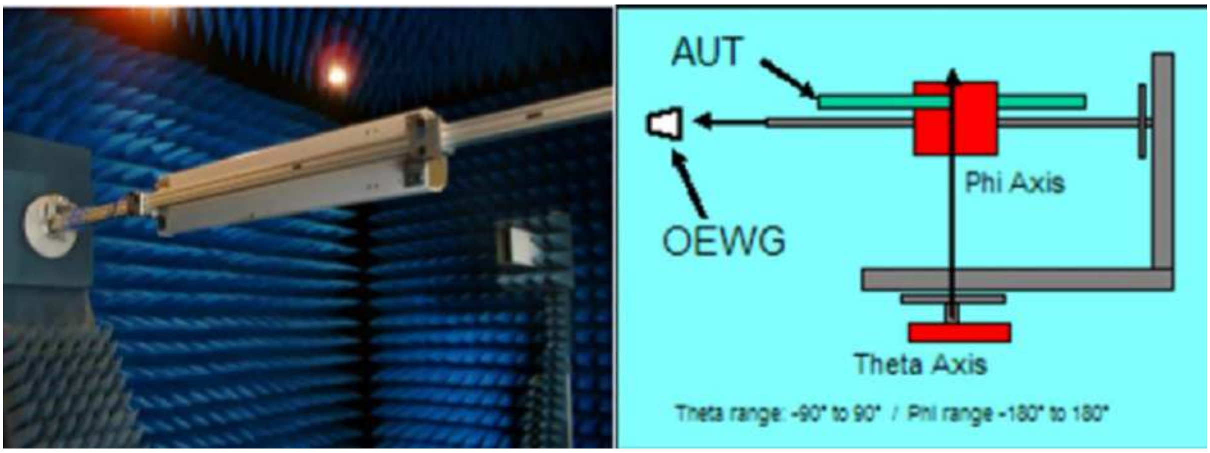


Figure 11.3: Example of a spherical near-field system

11.1.3.7.2 Far-Field Efficiency Measurement

- Using the calibration reference antenna for gain calibration.
- Antenna installation: The beam direction and polarization are aligned with the source antenna.
- Start the test, fix the Theta angle, rotate the Phi from 0° to 360°, and record the corresponding angle and receive level.
- Based on a fixed step, Rotate Theta to the next angle and repeat previous step.

- Until Theta completes 180° rotation so that the test data form a complete, equal-spaced 3D sphere, and obtain the co-polarised antenna data.
- Rotate the source antenna 90° and repeat the preceding four steps, the cross-polarization data can be obtained. Efficiency can be directly calculated according to the 3D pattern data.

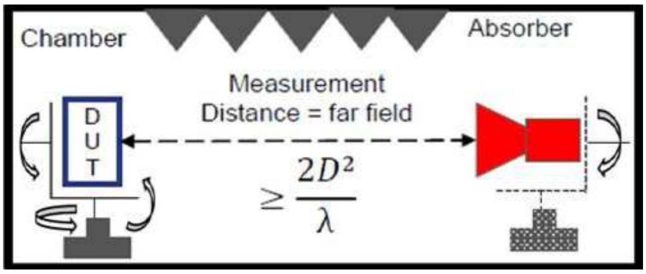


Figure 11.4: Calculated difference between the phase of each coupling factor and the average phase of all coupling factors for each frequency point

11.1.3.7.3 Efficiency calculated by Loss Measurement

Alternatively, to the described methods above, the efficiency can be obtained by directly measuring the losses of the antenna as presented in 11.1.2.2.

In this case, the efficiency would be calculated by the formula

$$Efficieny = -a_{antenna} \qquad (11.9)$$

where $a_{antenna}$ represents the antenna losses.

11.1.3.7.4 Efficiency in Percentage

The parameter Efficiency is defined in dB in a mean value and a tolerance based on an average over all downtilts and measured frequency points within a sub-band.

In other industries efficiency is defined in percentage. With the following formula the efficiency could be calculated from dB into percentage easily.

$$Efficieny[\%] = 10^{\frac{Efficiency[dB]}{10}} \cdot 100 \qquad (11.10)$$

The following table shows the results in percentage.

Table 11-1: Efficiency in dB and percentage.

dB	0,0	-0,1	-0,2	-0,3	-0,4	-0,5	-0,6	-0,7	-0,8	-0,9	-1,0	-1,1	-1,2	-1,3	-1,4	-1,5
Relative	100,0%	97,7%	95,5%	93,3%	91,2%	89,1%	87,1%	85,1%	83,2%	81,3%	79,4%	77,6%	75,9%	74,1%	72,4%	70,8%

11.2 Specific for Passive antennas

11.2.1 Compatibility with old publication versions and use of non-BASTA frequencies

When a new frequency table is released and the frequency samples accordingly calculated, there can be two issues yet to deal with:

- The calculated frequency samples are not exactly those used by operators all over the world.
- Older antennas cannot be exactly compared to newer ones, due to difference in measured frequency samples.

In case of need, a specific non-BASTA frequency sample and the all the values (parameters, pattern level, etc.) associated to it can be calculated by linear interpolation between two frequency samples compliant with the latest version of this publication. The proportion to use are the following:

(Sample A - Sample B) : 100 = (Sample A - Non-BASTA frequency sample) : (100 – x)
(Value by sample A - Value by sample B) : 100 = (Value by sample A - Value by interpolated sample) : x

This option shall be valid only for structures that are non-resonant between the selected frequencies. A maximum distance of 34 MHz between two frequency samples implicitly defined in this publication guarantees (antenna's patterns are different in this neighbourhood, but not extremely) a sufficient fidelity of the values obtained by interpolation to those that would be through a real measurement. Samples obtained through interpolation shall not be used but for internal purposes, and shall

11.2.2 Frequency Ranges Choice Method

The first steps of this algorithm consist in:

- Finding the most recent frequency table (see previous Section 11.2.1).
- Copying the UL range in the DL column when the DL is marked by "N/A" (Table 11-2) and vice versa.
- Approximating the frequency ranges to the nearest unit of megahertz.
- Sorting the table "horizontally", by defining "lowest" and "highest" portion of sub-bands, regardless of UL or DL.
- Sorting the table "vertically" in ascending fashion, giving priority to the lower start-frequency and, in the case of match, to the narrower band (total broadness of lowest + highest portions), and finally to the order of appearance (band number) in the original frequency table.

With reference to Table 11-2, the following should be obtained as results here:

Table 11-2: Sorted frequency table.

Sorted Table				
	Lowest Portion		Highest Portion	
Band No.	Start	Stop	Start	Stop
87	410 MHz	415 MHz	420 MHz	425 MHz
88	412 MHz	417 MHz	422 MHz	427 MHz
73	450 MHz	455 MHz	460 MHz	465 MHz
72	451 MHz	456 MHz	461 MHz	466 MHz
31	452.5 MHz	457.5 MHz	462.5 MHz	467.5 MHz
71	617 MHz	652 MHz	663 MHz	698 MHz
68	698 MHz	728 MHz	753 MHz	783 MHz
85	698 MHz	716 MHz	728 MHz	746 MHz
12	699 MHz	716 MHz	729 MHz	746 MHz
28	703 MHz	748 MHz	758 MHz	803 MHz
44	703 MHz	803 MHz	703 MHz	803 MHz
17	704 MHz	716 MHz	734 MHz	746 MHz
29	717 MHz	728 MHz	717 MHz	728 MHz
67	738 MHz	758 MHz	738 MHz	758 MHz
13	777 MHz	787 MHz	746 MHz	756 MHz
14	788 MHz	798 MHz	758 MHz	768 MHz
20	791 MHz	821 MHz	832 MHz	862 MHz
27	807 MHz	824 MHz	852 MHz	869 MHz
26	814 MHz	849 MHz	859 MHz	894 MHz
18	815 MHz	830 MHz	860 MHz	875 MHz
5	824 MHz	849 MHz	869 MHz	894MHz
6	830 MHz	840 MHz	875 MHz	885 MHz
19	830 MHz	845 MHz	875 MHz	890 MHz
8	880 MHz	915 MHz	925 MHz	960 MHz
74	1427 MHz	1470 MHz	1475 MHz	1518 MHz
76	1427 MHz	1432 MHz	1427 MHz	1432 MHz
51	1427 MHz	1432 MHz	1427 MHz	1432 MHz
11	1427.9 MHz	1447.9 MHz	1475.9 MHz	1495.9 MHz
75	1432 MHz	1517 MHz	1432 MHz	1517 MHz
50	1432 MHz	1517 MHz	1432 MHz	1517 MHz
45	1447 MHz	1467 MHz	1447 MHz	1467 MHz
21	1447.9 MHz	1462.9 MHz	1495.9 MHz	1510.9 MHz
32	1452 MHz	1496 MHz	1452 MHz	1496 MHz

Sorted Table				
	Lowest Portion		Highest Portion	
Band No.	Start	Stop	Start	Stop
24	1626.5 MHz	1660.5 MHz	1525 MHz	1559 MHz
70	1695 MHz	1710 MHz	1995 MHz	2020 MHz
3	1710 MHz	1785 MHz	1805 MHz	1880 MHz
4	1710 MHz	1755 MHz	2110 MHz	2155 MHz
10	1710 MHz	1770 MHz	2110 MHz	2170 MHz
66	1710 MHz	1780 MHz	2110 MHz	2200 MHz
9	1749.9 MHz	1784.9 MHz	1844.9 MHz	1879.9 MHz
2	1850 MHz	1910 MHz	1930 MHz	1990 MHz
25	1850 MHz	1915 MHz	1930 MHz	1995 MHz
35	1850 MHz	1910 MHz	1850 MHz	1910 MHz
39	1880 MHz	1920 MHz	1880 MHz	1920 MHz
33	1900 MHz	1920 MHz	1900 MHz	1920 MHz
37	1910 MHz	1930 MHz	1910 MHz	1930 MHz
1	1920 MHz	1980 MHz	2110 MHz	2170 MHz
65	1920 MHz	2010 MHz	2110 MHz	2200 MHz
36	1930 MHz	1990 MHz	1930 MHz	1990 MHz
238	2000 MHz	2020 MHz	2180 MHz	2200 MHz
34	2010 MHz	2025 MHz	2010 MHz	2025 MHz
40	2300 MHz	2400 MHz	2300 MHz	2400 MHz
30	2305 MHz	2315 MHz	2350 MHz	2360 MHz
53	2483.5 MHz	2495 MHz	2483.5 MHz	2495 MHz
41	2496 MHz	2690 MHz	2496 MHz	2690 MHz
7	2500 MHz	2570 MHz	2620 MHz	2690 MHz
69	2570 MHz	2620 MHz	2570 MHz	2620 MHz
38	2570 MHz	2620 MHz	2570 MHz	2620 MHz
77	3300 MHz	4200 MHz	3300 MHz	4200 MHz
78	3300 MHz	3800 MHz	3300 MHz	3800 MHz
52	3300 MHz	3400 MHz	3300 MHz	3400 MHz
42	3400 MHz	3600 MHz	3400 MHz	3600 MHz
22	3410 MHz	3490 MHz	3510 MHz	3590 MHz
48	3550 MHz	3700 MHz	3550 MHz	3700 MHz
43	3600 MHz	3800 MHz	3600 MHz	3800 MHz

At this point a deeper analysis of the table is necessary. Before selecting each sub-band's representative samples, it should be noticed that some of these sub-bands are contained in others and some overlap each other. In these cases, the method proposed in this publication contemplates a unification of the sub-bands in accordance with the following set of rules:

- Each sub-band in the sorted table shall be compared with the immediately following one.
- Should the application of these rules result in a "merged" band, this one shall be immediately considered for the next comparison.
- If a band is completely contained in another one, the broader will represent them both and keep all its characteristics. Exceptions to this rule are sub-bands, which are only contained in another's band-gap (between the lowest and highest portions of the sub-band), and those whose total bandwidth is narrower than half the other's width.

Example: sub-band 44 and 17 are compared. The first one has no band gap, while the second one has a gap between 716 MHz and 734 MHz; the total bandwidth of sub-band 17 is 90 MHz, while band 44 is 100 MHz broad (sub-band 17 is >= 50% of band 44's width). Sub-band 44 contains sub-band 17 totally and none of the exceptions are verified. A new sub-band called "17+44" will take place of the two merged ones and will extend from 703 MHz to 803 MHz. Per the second point, the sub-band 17+44 shall then be compared to sub-band 29.

- If at least the 70% of a sub-band is contained in another, a new one will represent them both. In this case its start frequency shall be the lowest amongst the two analysed sub-bands, by analogy the stop frequency shall be the highest instead. If both the merged sub-bands contain a band-gap, the new sub-band will contain a gap, which will split the sub-band in lowest and highest portion. This new gap shall be the "common gap", that is the spectrum that does not contain any bit of any portion of any of the two analysed sub-bands.

Example: Sub-Band 18 overlaps with sub-band 5. The overlapping ranges are 824-830 MHz in the lower portion and 869-875 MHz in the higher portion of the sub-bands. The total overlapping spectrum is 12 MHz, which is the 40% of the sub-band 18 and 13.3% of sub-band 5. In this case the sub-bands are not merged (none of them reaches 70%), but if they were, the common gap would have been 849-860 MHz and the new sub-band would have been the "18+5", whose portions would have been 815-849 MHz and 860-894 MHz.

- Finally, if the total width of a sub-band is lower or equal than 30 MHz, and it has a difference from another sub-band of no more than 10 MHz between start frequencies and/or end frequencies of both the portions, the narrower sub-band shall be merged with the broader one. In this case, regardless of the overlapping percent, the procedure to follow is described in the previous point.
- These rules shall be applied over again, until no bands can be merged anymore.

After this process, the frequency table is shown in Table 11-3:

Table 11-3: Frequency table after sub-bands unifications.

Band No.	Lowest Portion		Highest Portion		B-Width Low	B-Width High	Gap
	Start	Stop	Start	Stop			
87+88	410	417	420	427	7	7	3
31+72+73	450	458	460	468	8	8	2
71	617	652	663	698	35	35	11
12+28+44+68+85	698	803	698	803	105	105	0
17	704	716	734	746	12	12	18
29	717	728	717	728	11	11	0
67	738	758	738	758	20	20	0
13	746	756	777	787	10	10	21
14	758	768	788	798	10	10	20
20	791	821	832	862	30	30	11
27	807	824	852	869	17	17	28
5+6+18+19+26	814	849	859	894	35	35	10
8	880	915	925	960	35	35	10
74	1427	1470	1475	1518	43	43	5
51+76	1427	1432	1427	1432	5	5	0
11	1428	1448	1476	1496	20	20	28
50	1432	1517	1432	1517	85	85	0
21+45	1447	1467	1447	1467	20	20	0
32	1452	1496	1452	1496	44	44	0
24	1525	1559	1626	1660	34	34	67
70	1695	1710	1995	2020	15	25	285
3	1710	1785	1805	1880	75	75	20
4+10	1710	1770	2110	2170	60	60	340
66	1710	1780	2110	2200	70	90	330
9	1749,9	1784,9	1844,9	1879,9	35	35	60
2+25+35	1850	1995	1850	1995	145	145	0
33+39	1880	1920	1880	1920	40	40	0
37	1910	1930	1910	1930	20	20	0
1	1920	1980	2110	2170	60	60	130
65	1920	2010	2110	2200	90	90	100
36	1930	1990	1930	1990	60	60	0
23	2000	2020	2180	2200	20	20	160
34	2010	2025	2010	2025	15	15	0
40	2300	2400	2300	2400	100	100	0
30	2305	2315	2350	2360	10	10	35
53	2483	2495	2483	2495	12	12	0
41+7	2496	2690	2496	2690	194	194	0
38+69	2570	2620	2570	2620	50	50	0
77	3300	4200	3300	4200	900	900	0
78	3300	3800	3300	3800	500	500	0
52	3300	3400	3300	3400	100	100	0
42+22	3400	3600	3400	3600	200	200	0
48	3550	3700	3550	3700	150	150	0
43	3600	3800	3600	3800	200	200	0

As it is possible to notice in the table above, sub-bands have very different bandwidths and gaps. The broader ones and those that contain a wide gap represent a concern to the precision of the parameters' specifications:

selecting samples that are frequency-wise distant one from another means dealing with a dataset containing very different values (the difference between antennas pattern is proportional to the space between the frequencies they belong to). From a statistical point of view this would mean having weak averages and strong deviations. In order to address this issue, sub-bands shall be splitted into:

- Two new ones when the gap between the lowest and highest portion of sub-band is wider than 50 MHz. In this case the new sub-bands will coincide with the previous lower portion and higher portion. Those are now treated as “stand alone” sub-bands.
- A number of new, equally broad ones, if a portion (typically this happens for bands whose lower portion coincides with the higher one) is broader than 120 MHz. This number shall depend on the width of the new sub-bands, which shall be the broadest possible, but maximum 120 MHz wide. In case of asymmetric bands (case highlighted in yellow in Table 11-4)

Table 11-4if they have to be divided, the portions nearest to the gap shall be kept as a sub-band. The resulting sub-bands can, in this case, also be asymmetric.

Example: Sub-Band 4+10 contains a gap of 340 MHz between its lower and higher portions. It will then be divided in sub-band “(4+10)a” and “(4+10)b”, whose frequency ranges are respectively: 1710-1770 MHz and 2110-2170 MHz.

Example: Assume sub-band 66 to be 1650-1780 MHz / 2110-2200 MHz. Since its lower portion would be 130 MHz wide and its higher portion 90 MHz wide, the lowest one should be split into two sub-bands: 1650-1715 MHz and 1715-1780 MHz / 2110-2200 MHz. The second sub-band would be, in fact, the combination of sub-band 66’s portions nearest to its frequency gap.

Cases in which these divisions take place are highlighted in orange in Table 11-4. After this process, the frequency table shall be sorted again (see beginning of this section) and should look as in the table below:

Table 11-4: Frequency table after sub-bands divisions.

After division (sorted again)				
Band No.	Lowest Portion		Highest Portion	
	Start	Stop	Start	Stop
87+88	410	417	420	427
31+72+73	450	458	460	468
71	617	652	663	698
12+28+44+68+85	698	803	698	803
17	704	716	734	746
29	717	728	717	728
67	738	758	738	758
13	746	756	777	787
14	758	768	788	798
20	791	821	832	862
27	807	824	852	869
5+6+18+19+26	814	849	859	894
8	880	915	925	960
74	1427	1470	1475	1518
51+76	1427	1432	1427	1432
11	1428	1448	1476	1496
50	1432	1517	1432	1517
21+45	1447	1467	1447	1467
32	1452	1496	1452	1496
(24)a	1525	1559	1525	1559
(24)b	1626	1660	1626	1660
(70)a	1695	1710	1695	1710
3	1710	1785	1805	1880
(4+10)a	1710	1770	1710	1770
(66)a	1710	1780	1710	1780
(9)a	1749,9	1784,9	1749,9	1784,9
(9)b	1844,9	1879,9	1844,9	1879,9
(2+25+35)a	1850	1922	1850	1922
33+39	1880	1920	1880	1920
37	1910	1930	1910	1930
(1)a	1920	1980	1920	1980
(65)a	1920	2010	1920	2010
(2+25+35)b	1922	1995	1922	1995
36	1930	1990	1930	1990
70b	1995	2020	1995	2020

After division (sorted again)				
Band No.	Lowest Portion		Highest Portion	
	Start	Stop	Start	Stop
(23)a	2000	2020	2000	2020
34	2010	2025	2010	2025
(4+10)b	2110	2170	2110	2170
(66)b	2110	2200	2110	2200
(1)b	2110	2170	2110	2170
(65)b	2110	2200	2110	2200
(23)b	2180	2200	2180	2200
40	2300	2400	2300	2400
30	2305	2315	2350	2360
53	2483	2495	2483	2495
(41+7)a	2496	2593	2496	2593
38+69	2570	2620	2570	2620
(41+7)b	2593	2690	2593	2690
(77)a	3300	3400	3300	3400
(78)a	3300	3400	3300	3400
52	3300	3400	3300	3400
(77)b	3400	3500	3400	3500
(78)b	3400	3500	3400	3500
(42+22)a	3400	3500	3400	3500
(77)c	3500	3600	3500	3600
(78)c	3500	3600	3500	3600
(42+22)b	3500	3600	3500	3600
(48)a	3550	3650	3550	3650
(77)d	3600	3700	3600	3700
(78)d	3600	3700	3600	3700
(43)a	3600	3700	3600	3700
(48)b	3650	3700	3650	3700
(77)e	3700	3800	3700	3800
(78)e	3700	3800	3700	3800
(43)b	3700	3800	3700	3800
(77)f	3800	3900	3800	3900
(77)g	3900	4000	3900	4000
(77)h	4000	4100	4000	4100
(77)i	4100	4200	4100	4200

The listed sub-bands shall eventually be merged, splitted and sorted again by applying all the previously described rules, until no change to the table is possible anymore. Finally the frequency table should look as Table 11-5:

Table 11-5: Frequency table at the end of the merging/splitting/sorting processes.

Band No.	Lowest Portion		Highest Portion		B-Width Low	B-Width High	Gap
	Start	Stop	Start	Stop			
87+88	410	417	420	427	7	7	3
31+72+73	450	458	460	468	8	8	2
71	617	652	663	698	35	35	11
12+28+44+68+85	698	803	698	803	105	105	0
17	704	716	734	746	12	12	18
29	717	728	717	728	11	11	0
67	738	758	738	758	20	20	0
13	746	756	777	787	10	10	21
14	758	768	788	798	10	10	20
20	791	821	832	862	30	30	11
27	807	824	852	869	17	17	28
5+6+18+19+26	814	849	859	894	35	35	10
8	880	915	925	960	35	35	10
51+76	1427	1432	1427	1432	5	5	0
74	1427	1470	1475	1518	43	43	5
11	1428	1448	1476	1496	20	20	28
50	1432	1517	1432	1517	85	85	0
21+45	1447	1467	1447	1467	20	20	0
32	1452	1496	1452	1496	44	44	0
(24)a	1525	1559	1525	1559	34	34	0
(24)b	1626	1660	1626	1660	34	34	0
(70)a	1695	1710	1695	1710	15	15	0
(4+10)a+(66)a	1710	1780	1710	1780	70	70	0
3	1710	1785	1805	1880	75	75	20
(9)a	1749,9	1784,9	1749,9	1784,9	35	35	0
(9)b	1844,9	1879,9	1844,9	1879,9	35	35	0
(2+25+35)a+33+39	1850	1922	1850	1922	72	72	0
37	1910	1930	1910	1930	20	20	0
(1)a+(65)a+(2+25+35)b+36+(70)b	1920	2020	1920	2020	100	100	0
(23)a+34	2000	2025	2000	2025	25	25	0
(4+10)b+(1)b+(65)b+(66)b	2110	2200	2110	2200	90	90	0
(23)b	2180	2200	2180	2200	20	20	0
40	2300	2400	2300	2400	100	100	0
30	2305	2315	2350	2360	10	10	35
53	2483	2495	2483	2495	12	12	0
(41+7)a	2496	2593	2496	2593	97	97	0
38+69	2570	2620	2570	2620	50	50	0
(41+7)b	2593	2690	2593	2690	97	97	0
(77)a+(78)a+52	3300	3400	3300	3400	100	100	0
(77)b+(78)b+(42+22)a	3400	3500	3400	3500	100	100	0
(77)c+(78)c+(42+22)b	3500	3600	3500	3600	100	100	0
(48)a	3550	3650	3550	3650	100	100	0
(77)d+(78)d+(43)a+(48)b	3600	3700	3600	3700	100	100	0
(77)e+(78)b+(43)b	3700	3800	3700	3800	100	100	0
(77)f	3800	3900	3800	3900	100	100	0
(77)g	3900	4000	3900	4000	100	100	0
(77)h	4000	4100	4000	4100	100	100	0
(77)i	4100	4200	4100	4200	100	100	0

None of the sub-bands listed above can be merged or splitted. At this time another issue should be considered: the algorithm described until now works with respect to a frequency table that is already standardised, but what just stated does not fully comply with the needs of the research & development, which generally cannot wait the amount of time essential to the processes that result in a standardization of the frequencies (therefore to a frequency table). Thus, extensions to the sub-bands are here contemplated, that is an appendix up to 15

MHz wide may be added to a single portion of the sub-bands, whether before its start frequency or after its stop frequency. Notice that at this point no merging or splitting is possible anymore, which means that from now on a sub-band may be maximum 135 MHz wide, and/or that a sub-band may overlap with (hardly contain) another one. For the sake of comprehension, in the table above the lower portion of the sub-band "(4+10)a+(66)a" will be extended to 1695-1780 MHz:

Band number	Lowest portion		Highest portion		B-width Low	B-width High	Gap
	start	stop	start	stop			
[3]*	1695 MHz	1785 MHz	1805 MHz	1880 MHz	90 MHz	75 MHz	20 MHz

Figure 11.5: Band lowest portion and highest portion example

Understandably, appendices cannot be enough if an antenna has to be measured within brand-new frequency ranges. The enlargement of the frequency table by inclusion of not yet standardised new sub-bands is permitted, supposing that a new "R&D" sub-band:

- Is not intended as a way to get around the application of all the rules described in Section 8.1 and its sub-sections.
- Has a gap narrower than 50 MHz.
- Has a bandwidth of maximum 120 MHz in its lower portion and 120 MHz in its higher portion.

11.2.3 Frequency Samples Choice Method

After having determined the frequency table with the algorithm described in Section 9.1.1, the representative frequency samples for each sub-band shall be calculated by means of the following procedure. The number of samples for each one shall be variable and proportional to width of each sub-band's portions. A portion will be represented by:

- One sample if its width is less than 10 MHz. In this case the sample shall be the middle frequency, that is between the start and stop frequencies of the portion.
- Two samples if its width is at least 10 MHz and less than 30 MHz. In this case the samples shall be the start and stop frequencies of the portion.
- Three samples if its width is at least 30 MHz and less than 60 MHz. In this case the samples shall be the start, middle and stop frequencies of the portion.
- Four samples if its width is at least 60 MHz. In this case the samples shall be the start frequency of the portion, the sample found by adding a third of the portion's bandwidth to the start frequency, the sample found by subtracting a third of the portion's bandwidth to the stop frequency, and the stop frequency itself.

Table 11-6: Frequency sampling.

Width [MHz]	Number of frequency samples	Samples
W < 10	1	fstart + W/2
10 ≤ W < 30	2	fstart fstop
30 ≤ W < 60	3	fstart fstart + W/2 fstop
W ≥ 60	4	fstart fstart + W/3 fstop - W/3 fstop

All the samples calculated this way shall be approximated to the nearest unit of megahertz. Below, in Table 11-7, the list of frequency samples associated to each sub-band:

Table 11-7: Samples associated to sub-bands' portions.

Band No.	Lowest Portion		Highest Portion		B-Width	B-Width	Samples	Samples	Lowest Portion				Highest Portion			
	Start	Stop	Start	Stop	Low	High	Low	High								
87+88	410	417	420	427	7	7	1	1	414				424			
31+72+73	450	458	460	468	8	8	1	1	455				465			
71	617	652	663	698	35	35	3	3	617	635	652		663	681	698	
12+28+44+68+85	698	803	698	803	105	105	4	4	698	733	768	803	698	733	768	803
17	704	716	734	746	12	12	2	2	704	716			734	746		
29	717	728	717	728	11	11	2	2	717	728			717	728		
67	738	758	738	758	20	20	2	2	738	758			738	758		
13	746	756	777	787	10	10	2	2	746	756			777	787		
14	758	768	788	798	10	10	2	2	758	768			788	798		
20	791	821	832	862	30	30	3	3	791	806	821		832	847	862	
27	807	824	852	869	17	17	2	2	807	824			852	869		
5+6+18+19+26	814	849	859	894	35	35	3	3	814	832	849		859	877	894	
8	880	915	925	960	35	35	3	3	880	898	915		925	943	960	
51+76	1427	1432	1427	1432	5	5	1	1	1430				1430			
74	1427	1470	1475	1518	43	43	3	3	1427	1449	1470		1475	1497	1518	
11	1428	1448	1476	1496	20	20	2	2	1428	1448			1476	1496		
50	1432	1517	1432	1517	85	85	4	4	1432	1460	1489	1517	1432	1460	1489	1517
21+45	1447	1467	1447	1467	20	20	2	2	1447	1467			1447	1467		
32	1452	1496	1452	1496	44	44	3	3	1452	1474	1496		1452	1474	1496	
(24)a	1525	1559	1525	1559	34	34	3	3	1525	1542	1559		1525	1542	1559	
(24)b	1626	1660	1626	1660	34	34	3	3	1626	1643	1660		1626	1643	1660	
(70)a	1695	1710	1695	1710	15	15	2	2	1695	1710			1695	1710		
(4+10)a+(66)a	1710	1780	1710	1780	70	70	4	4	1710	1733	1757	1780	1710	1733	1757	1780
3*	1695	1785	1805	1880	90	75	4	4	1695	1725	1755	1785	1805	1830	1855	1880
(9)a	1749.9	1784.9	1749.9	1784.9	35	35	3	3	1750	1767	1785		1750	1767	1785	
(9)b	1844.9	1879.9	1844.9	1879.9	35	35	3	3	1845	1862	1880		1845	1862	1880	
(2+25+35)a+33+39	1850	1922	1850	1922	72	72	4	4	1850	1874	1898	1922	1850	1874	1898	1922
37	1910	1930	1910	1930	20	20	2	2	1910	1930			1910	1930		
(1)a+(65)a+(2+25+35)b+36+(70)b	1920	2020	1920	2020	100	100	4	4	1920	1953	1987	2020	1920	1953	1987	2020
(23)a+34	2000	2025	2000	2025	25	25	2	2	2000	2025			2000	2025		
(4+10)b+(1)b+(65)b+(66)b	2110	2200	2110	2200	90	90	4	4	2110	2140	2170	2200	2110	2140	2170	2200
(23)b	2180	2200	2180	2200	20	20	2	2	2180	2200			2180	2200		
40	2300	2400	2300	2400	100	100	4	4	2300	2333	2367	2400	2300	2333	2367	2400
30	2305	2315	2350	2360	10	10	2	2	2305	2315			2350	2360		
53	2483	2495	2483	2495	12	12	2	2	2483	2495			2483	2495		
(41+7)a	2496	2593	2496	2593	97	97	4	4	2496	2528	2561	2593	2496	2528	2561	2593
38+69	2570	2620	2570	2620	50	50	3	3	2570	2595	2620		2570	2595	2620	
(41+7)b	2593	2690	2593	2690	97	97	4	4	2593	2625	2658	2690	2593	2625	2658	2690
(77)a+(78)a+52	3300	3400	3300	3400	100	100	4	4	3300	3333	3367	3400	3300	3333	3367	3400
(77)b+(78)b+(42+22)a	3400	3500	3400	3500	100	100	4	4	3400	3433	3467	3500	3400	3433	3467	3500
(77)c+(78)c+(42+22)b	3500	3600	3500	3600	100	100	4	4	3500	3533	3567	3600	3500	3533	3567	3600
(48)a	3550	3650	3550	3650	100	100	4	4	3550	3583	3617	3650	3550	3583	3617	3650
(77)d+(78)d+(43)a+(48)b	3600	3700	3600	3700	100	100	4	4	3600	3633	3667	3700	3600	3633	3667	3700
(77)e+(78)b+(43)b	3700	3800	3700	3800	100	100	4	4	3700	3733	3767	3800	3700	3733	3767	3800
(77)f	3800	3900	3800	3900	100	100	4	4	3800	3833	3867	3900	3800	3833	3867	3900
(77)g	3900	4000	3900	4000	100	100	4	4	3900	3933	3967	4000	3900	3933	3967	4000
(77)h	4000	4100	4000	4100	100	100	4	4	4000	4033	4067	4100	4000	4033	4067	4100
(77)i	4100	4200	4100	4200	100	100	4	4	4100	4133	4167	4200	4100	4133	4167	4200

When the lower and higher portions coincide, it means that there is actually only a single "block" of spectrum occupied by the associated sub-band, hence the samples appearing in both the portions columns are doubles, and only one occurrence of each one shall be taken into consideration when building the dataset whose distribution will be analysed. In this example, the list of frequency samples counts 166 unique frequencies to measure, in order to be able to evaluate the performances of a hypothetical antenna between 414 MHz and 4200 MHz in 48 different sub-bands.

Though, not every sample is needed. In the table above (and by extension in all the tables built following the procedures described until now) there are some samples that are very close one another, which means that there is a certain level of redundancy that can be reduced through optimisation. This shall be achieved by applying the following rules in their presented order:

- Each sample shall be compared to the following ones, after the list of samples is sorted in ascending fashion.
- Frequency samples belonging to "R&D sub-bands" shall always be removed from the list if there is already a sample 3 MHz or less (see third point) or 10 MHz or less (see fourth point) distant. Those shall be used instead. This is not applied to "appendices".
- Under 1000 MHz:
    - If three or more (the maximum is obviously four) adjacent frequency samples are 3 MHz or less distant one from each other, and the farthest ones have a difference of exactly 3 MHz, the samples in the middle shall be removed from the list.
    - If, instead, the difference is greater than 3 MHz, the last amongst the adjacent samples shall be preserved, and another one shall be chosen through a new comparison: if the distance between the preserved sample and the average between the first two adjacent ones is less than 3 MHz, the first sample shall be preserved too. Otherwise, a new sample shall replace the first two ones, and its frequency will be equal to their average.
    - If two or more (the maximum is obviously three) adjacent frequency samples are less than 3 MHz distant one from each other, they shall be replaced by a single sample, whose frequency will be equal to the average of the two farthest replaced ones.
- If the cases described in the third point are verified for comparisons between frequency samples under 1000 MHz and above or exactly 1000 MHz, the rules of the third point shall be applied too.
- 1000 MHz and above:
    - If three or more adjacent frequency samples are 10 MHz or less distant one from each other, and the farthest ones have a difference of exactly 10 MHz, the samples in the middle shall be removed from the list.
    - If, instead, the difference is greater than 10 MHz, the last amongst the adjacent samples shall be preserved, and another one shall be chosen through a new comparison: if the distance between the preserved sample and the average between the first two adjacent ones is less than 10 MHz, the first sample shall be preserved too. Otherwise a new sample shall replace the first two ones, and its frequency will be equal to their average.
    - If two or more adjacent frequency samples are less than 10 MHz distant one from each other, they shall be replaced by a single sample.
- Once samples have been replaced, they shall be rounded to the nearest unit of megahertz. The replaced ones shall be compared to the next ones in the list.

Below some examples:

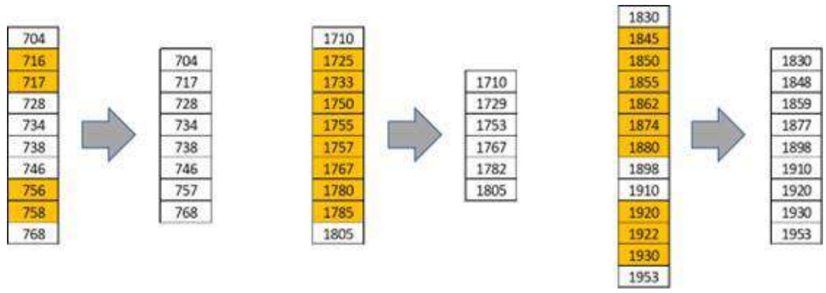


Figure 11.6: Examples of frequency samples redundancy optimisation.

On the left there are two cases where the highlighted frequency-samples are simply averaged. In the centre there are a couple of “blocks” of samples to optimize one after the other: the first one goes from 1725 MHz to 1750 MHz. Since 1725 MHz and 1733 MHz averaged are more than 10 MHz distant from 1750 MHz, 1729 MHz and 1750 MHz appear in the “final samples” list. The second one goes from 1750 MHz (because it has been preserved) to 1768 MHz; the rules applied are the same. The third block with 1780 MHz and 1785 Mhz is simply averaged. On the right there are also cases where only the middle sample is eliminated because the distance between 2 samples is exactly 10 MHz.

At this point, the only thing to do left is to replace the samples listed in Table 11-8 with the optimised ones. To do this, each frequency sample nearest to those to be replaced shall take their place. In case two samples are equally distant from the one to replace, the priority shall be given to the one inside the sub-frequency, and finally, if both are, to the higher one.

Table 11-8: Final frequency table. Samples undergoing optimisation (orange) as well as new samples compared to WP11.1 (blue) are highlighted.

Band No.	Lowest Portion		Highest Portion		Sampling before Optimization								Sampling after Optimization							
	Start	Stop	Start	Stop																
87+88	410	417	420	427	414	424							414	424						
31+72+73	450	458	460	468	455	465							455	465						
71	617	652	663	698	617	635	652	663	681	698			617	635	652	663	681	698		
12+28+44+68+85	698	803	698	803	698	734	768	803					698	734	768	803				
17	704	716	734	746	704	716	734	746					704	717	734	746				
29	717	728	717	728	717	728							717	728						
67	738	758	738	758	738	758							738	757						
13	746	756	777	787	746	756	777	787					746	757	777	788				
14	758	768	788	798	758	768	788	798					757	768	788	798				
20	791	821	832	862	791	806	821	832	847	862			791	807	821	832	848	862		
27	807	824	852	869	807	824	852	869					807	824	852	869				
5+6+18+19+26	814	849	859	894	814	832	849	859	877	894			814	832	848	859	877	894		
8	880	915	925	960	880	898	915	925	943	960			880	898	915	925	943	960		
51+76	1427	1432	1427	1432	1430								1428							
74	1427	1470	1475	1518	1427	1449	1470	1475	1497	1518			1428	1450	1475	1475	1496	1517		
11	1428	1448	1476	1496	1428	1448	1476	1496					1428	1450	1475	1496				
50	1432	1517	1432	1517	1432	1460	1489	1517					1428	1463	1489	1517				
21+45	1447	1467	1496	1511	1447	1467	1496	1511					1450	1463	1496	1511				
32	1452	1496	1452	1496	1452	1474	1496						1450	1475	1496					
(24)a	1525	1559	1525	1559	1525	1542	1559						1525	1542	1559					
(24)b	1626	1660	1626	1660	1626	1643	1660						1626	1643	1660					
(70)a	1695	1710	1695	1710	1695	1710							1695	1710						
(4+10)a+(66)a	1710	1780	1710	1780	1710	1733	1757	1780					1710	1729	1753	1782				
3*	1695	1785	1805	1880	1695	1725	1755	1785	1805	1830	1855	1880	1695	1729	1753	1782	1805	1830	1859	1880
(9)a	1749.9	1784.9	1749.9	1784.9	1750	1768	1785						1753	1768	1782					
(9)b	1844.9	1879.9	1844.9	1879.9	1845	1862	1880						1848	1859	1880					
(2+25+35)a+33+39	1850	1922	1850	1922	1850	1874	1898	1922					1848	1880	1898	1920				
37	1910	1930	1910	1930	1910	1930							1910	1930						
(1)a+(65)a+(2+25+35)b+36+(70)b	1920	2020	1920	2020	1920	1953	1987	2020					1920	1953	1987	2020				
(23)a+34	2000	2025	2000	2025	2000	2025							2000	2020						
(4+10)b+(1)b+(65)b+(66)b	2110	2200	2110	2200	2110	2140	2170	2200					2110	2140	2170	2200				
(23)b	2180	2200	2180	2200	2180	2200							2180	2200						
40	2300	2400	2300	2400	2300	2333	2367	2400					2302	2333	2364	2400				
30	2305	2315	2350	2360	2305	2315	2350	2360					2302	2315	2350	2364				
53	2483	2495	2483	2495	2483	2495							2483	2496						
(41+7)a	2496	2593	2496	2593	2496	2528	2561	2593					2496	2528	2566	2594				
38+69	2570	2620	2570	2620	2570	2595	2620						2566	2594	2622					
(41+7)b	2593	2690	2593	2690	2593	2625	2658	2690					2594	2622	2658	2690				
(77)a+(78)a+52	3300	3400	3300	3400	3300	3333	3367	3400					3300	3333	3367	3400				
(77)b+(78)b+(42+22)a	3400	3500	3400	3500	3400	3433	3467	3500					3400	3433	3467	3500				
(77)c+(78)c+(42+22)b	3500	3600	3500	3600	3500	3533	3567	3600					3500	3533	3567	3600				
(48)a	3550	3650	3550	3650	3550	3583	3617	3650					3550	3583	3617	3650				
(77)d+(78)d+(43)a+(48)b	3600	3700	3600	3700	3600	3633	3667	3700					3600	3633	3667	3700				
(77)e+(78)e+(43)b	3700	3800	3700	3800	3700	3733	3767	3800					3700	3733	3767	3800				
(77)f	3800	3900	3800	3900	3800	3833	3867	3900					3800	3833	3867	3900				
(77)g	3900	4000	3900	4000	3900	3933	3967	4000					3900	3933	3967	4000				
(77)h	4000	4100	4000	4100	4000	4033	4067	4100					4000	4033	4067	4100				
(77)i	4100	4200	4100	4200	4100	4133	4167	4200					4100	4133	4167	4200				

11.2.4 Recommended Sub-bands and Associated Frequency List

From the operators' point of view it is an ordinary procedure to require that antennas produced by vendors are measured by very specific frequencies of interest. This routine represents a huge problem in the economy of the vendors, which ultimately results in longer wait times and higher costs for everyone. It also denies an accurate comparison between antennas, since there is no assurance that similar antennas from different vendors are measured by the same frequency points. Thus it is critical that all the parties involved in the evaluation of antennas use an agreed upon set of frequencies for the calculation of antennas' parameters.

Frequency bands for mobile telecommunications are highly standardised by organizations such as ETSI and 3GPP, hence here it will not be necessary to define them anew. This publication will in fact refer to the latest operating bands table (at the time of this document's writing it was contained in section 4.5 of the 3GPP TS 37.104, v17.2.0, 2021-06), an adaptation of which will also be used in the following sections as an example, or an equivalent one (should the original table not be available or applicable anymore).

Table 11-9: Paired bands in NR, E-UTRA, UTRA and GSM/EDGE (3GPP TS 37.104 V17.2.0, 2021-06)

MSR and E-UTRA Band number	NR Band number	Uplink (UL) BS receive UE transmit			Downlink (DL) BS transmit UE receive			Duplex Mode
1	n1	1920 MHz	–	1980 MHz	2110 MHz	–	2170 MHz	FDD
2	n2	1850 MHz	–	1910 MHz	1930 MHz	–	1990 MHz	FDD
3	n3	1710 MHz	–	1785 MHz	1805 MHz	–	1880 MHz	FDD
4		1710 MHz	–	1755 MHz	2110 MHz	–	2155 MHz	FDD
5	n5	824 MHz	–	849 MHz	869 MHz	–	894MHz	FDD
6		830 MHz	–	840 MHz	875 MHz	–	885 MHz	FDD
7	n7	2500 MHz	–	2570 MHz	2620 MHz	–	2690 MHz	FDD
8	n8	880 MHz	–	915 MHz	925 MHz	–	960 MHz	FDD
9		1749.9 MHz	–	1784.9 MHz	1844.9 MHz	–	1879.9 MHz	FDD
10		1710 MHz	–	1770 MHz	2110 MHz	–	2170 MHz	FDD
11		1427.9 MHz	–	1447.9 MHz	1475.9 MHz	–	1495.9 MHz	FDD
12	n12	699 MHz	–	716 MHz	729 MHz	–	746 MHz	FDD
13	n13	777 MHz	–	787 MHz	746 MHz	–	756 MHz	FDD
14	n14	788 MHz	–	798 MHz	758 MHz	–	768 MHz	FDD
17		704 MHz	–	716 MHz	734 MHz	–	746 MHz	FDD
18	n18	815 MHz	–	830 MHz	860 MHz	–	875 MHz	FDD
19		830 MHz	–	845 MHz	875 MHz	–	890 MHz	FDD
20	n20	832 MHz	–	862 MHz	791 MHz	–	821 MHz	FDD
21		1447.9 MHz	–	1462.9 MHz	1495.9 MHz	–	1510.9 MHz	FDD
22		3410 MHz	–	3490 MHz	3510 MHz	–	3590 MHz	FDD
238		2000 MHz	–	2020 MHz	2180 MHz	–	2200 MHz	FDD
24	n24	1626.5 MHz	–	1660.5 MHz	1525 MHz	–	1559 MHz	FDD
25	n25	1850 MHz	–	1915 MHz	1930 MHz	–	1995 MHz	FDD
26	n26	814 MHz	–	849 MHz	859 MHz	–	894 MHz	FDD
27		807 MHz	–	824 MHz	852 MHz	–	869 MHz	FDD
28	n28	703 MHz	–	748 MHz	758 MHz	–	803 MHz	FDD
29	n29		N/A		717 MHz	–	728 MHz	FDD/CA
30	n30	2305 MHz	–	2315 MHz	2350 MHz	–	2360 MHz	FDD
31		452.5 MHz	–	457.5 MHz	462.5 MHz	–	467.5 MHz	FDD
32			N/A		1452 MHz	–	1496 MHz	FDD/CA
65	n65	1920 MHz	–	2010 MHz	2110 MHz	–	2200 MHz	FDD
66	n66	1710 MHz	–	1780 MHz	2110 MHz	–	2200 MHz	FDD
67	n67		N/A		738 MHz	-	758 MHz	FDD/CA
68		698 MHz	–	728 MHz	753 MHz	–	783 MHz	FDD
69			N/A		2570 MHz	–	2620 MHz	FDD/CA
70	n70	1695 MHz	–	1710 MHz	1995 MHz	–	2020 MHz	FDD
71	n71	663 MHz	–	698 MHz	617 MHz	–	652 MHz	FDD
72		451 MHz	–	456 MHz	461 MHz	–	466 MHz	FDD
73		450 MHz	–	455 MHz	460 MHz	–	465 MHz	FDD
74	n74	1427 MHz	–	1470 MHz	1475 MHz	–	1518 MHz	FDD
75	n75		N/A		1432 MHz	–	1517 MHz	FDD/CA
76	n76		N/A		1427 MHz	–	1432 MHz	FDD/CA
85	n85	698 MHz	–	716 MHz	728 MHz	–	746 MHz	FDD
87		410 MHz	–	415 MHz	420 MHz	–	425 MHz	FDD
88		412 MHz	–	417 MHz	422 MHz	–	427 MHz	FDD

Table 11-10: Unpaired bands in NR, E-UTRA, UTRA (3GPP TS 37.104 V17.2.0, 2021-06)

MSR and E-UTRA Band number	NR Band number	UTRA Band number	Uplink (UL) BS receive UE transmit			Downlink (DL) BS transmit UE receive			Duplex Mode
33		a)	1900 MHz	–	1920 MHz	1900 MHz	–	1920 MHz	TDD
34	n34	a)	2010 MHz	–	2025 MHz	2010 MHz	–	2025 MHz	TDD
35		b)	1850 MHz	–	1910 MHz	1850 MHz	–	1910 MHz	TDD
36		b)	1930 MHz	–	1990 MHz	1930 MHz	–	1990 MHz	TDD
37		c)	1910 MHz	–	1930 MHz	1910 MHz	–	1930 MHz	TDD
38	n38	d)	2570 MHz	–	2620 MHz	2570 MHz	–	2620 MHz	TDD
39	n39	f)	1880 MHz	–	1920 MHz	1880 MHz	–	1920 MHz	TDD
40	n40	e)	2300 MHz	–	2400 MHz	2300 MHz	–	2400 MHz	TDD
41	n41	-	2496 MHz	–	2690 MHz	2496 MHz	–	2690 MHz	TDD
42		-	3400 MHz	–	3600 MHz	3400 MHz	–	3600 MHz	TDD
43		-	3600 MHz	–	3800 MHz	3600 MHz	–	3800 MHz	TDD
44		-	703 MHz	–	803 MHz	703 MHz	–	803 MHz	TDD
45		-	1447 MHz	–	1467 MHz	1447 MHz	–	1467 MHz	TDD
48	n48	-	3550 MHz	–	3700 MHz	3550 MHz	–	3700 MHz	TDD
50	n50	-	1432 MHz	-	1517 MHz	1432 MHz	-	1517 MHz	TDD
51	n51	-	1427 MHz	-	1432 MHz	1427 MHz	-	1432 MHz	TDD
52		-	3300 MHz	–	3400 MHz	3300 MHz	–	3400 MHz	TDD
53	n53	-	2483.5 MHz	–	2495 MHz	2483.5 MHz	–	2495 MHz	TDD
77	n77	-	3300 MHz	-	4200 MHz	3300 MHz	-	4200 MHz	TDD
78	n78	-	3300 MHz	-	3800 MHz	3300 MHz	-	3800 MHz	TDD

Each frequency range (including UL + DL in case of FDD) specified in a table like the ones above corresponds to one of the antennas' sub-bands and shall be described by a series of frequency samples that characterize the range itself, and identify, along with the electrical downtilt angle and the polarizations, the "coordinates", where the electrical parameters' specifications shall be measured.

As an example, let an antenna's electrical downtilt range from 0° to 2°, two polarizations (+45° and -45°), and let the E-UTRA operating band 31 of previous table be the sub-band to be analysed. The values constituting the dataset of the particular 452.5-467.5 MHz sub-band shall then be measured by:

- 455 MHz, 0° tilt, +45° polarization
- 465 MHz, 0° tilt, -45° polarization
- 455 MHz, 1° tilt, +45° polarization
- 465 MHz, 1° tilt, -45° polarization
- 455 MHz, 2° tilt, +45° polarization
- 465 MHz, 2° tilt, -45° polarization

Where 455 MHz and 465 MHz were chosen as characteristic frequency samples to describe the E-UTRA operating band 31 (the choice method will be elaborated in the following sections).

It is critical to acknowledge that the spectrum "evolves" and that a frequency table is very unlikely to remain unchanged throughout the time. Considering that at the time of this document's writing there was no standard or technical guideline defining a method to measure antennas through the use of specific frequency samples for each sub-band, it is impossible here to refer to another source or recommend a list of fixed frequencies, without having to update it each time a new table is published. In order to keep this document's adaptability to all the frequency tables to come, a "frequency ranges choice algorithm" and a "frequency samples choice algorithm" have been developed to be here recommended.

The proposed algorithms is a dynamic (innovation-resistant) one, and it was built around constraints defined by the fact that it is either very expensive, time-consuming and equipment-dependent to measure broadband antennas with simpler techniques, or very inaccurate to do it. For example, using a fixed "frequency step" (e.g.: measuring a 1710-2690 MHz band every 10 MHz), could require either too many (98 in this case) frequency samples – this would mean using expensive equipment and waiting longer for a measurement to end –, or only a few (e.g.: 25 samples, which is a much more reasonable number, would require a sample every 39.2 MHz), with the risk of representing antennas with a single "weak" or "strong" pattern for a broad specific frequency neighbourhood (antennas' patterns change already in 20 MHz, in this case a single frequency would be used to be representative of almost two times the width).

11.2.5 Guidance on Production Electrical Testing

In order to validate the performance and quality of each antenna produced, the following best practices for the production testing of each BSA should be observed by manufacturers:

- VSWR (or RL) and isolation:
  - Measurement shall be performed under condition such that radiated power is not reflected back into the antenna, and that other radiated power cannot be received through the antenna.
  - VNA calibration shall be performed at least once per day (once per shift).
  - For variable downtilt antennas, the RL and isolation shall be measured through the full tilt range and the worst-case value shall be recorded.
  - Final test plots shall be provided with the antenna upon request.
- PIM:
  - IEC 62037-6 Passive RF and microwave devices, intermodulation level measurement - Part 6: Measurement of passive intermodulation in antennas defines the test fixtures and procedures for testing PIM.
  - Measurement shall be performed under condition such that radiated power is not reflected back into the antenna, and that other radiated power cannot be received through the antenna.
  - Connectors shall be clear of debris and void of damage.
  - Power shall be verified at the end of the test cable to ensure appropriate carrier power is fed to the antenna under test. If not done, the test cable loss could mask the true PIM levels.
  - Equipment noise floor shall be validated/calibrated using a low-PIM load.
  - Measurement shall be performed in swept mode (with one of the two tests tones sweeping in frequency).
  - Dynamic stress shall be placed on the antenna during PIM testing.
  - For variable downtilt antennas, the PIM shall be measured through the full tilt range and the worst-case value shall be recorded.
  - Measuring PIM performance in the sub-band nearest to the middle frequency of the entire bandwidth is generally sufficient to characterize the PIM performance for the whole cluster.
  - Final test plots shall be provided with the antenna upon request.
- For antennas with cabled corporate feed networks, a quality check process shall be implemented to assure that the cables are wired properly.
- General Comments:
  - Valid equipment calibration stickers should be visible on production equipment.
  - Test technicians should be properly trained.

11.2.6 Recommend Vendor's Reference Polarization Labelling Convention

Given the legacy issue of vendors having defined slant 45° polarizations using different naming conventions and geometries, a labelling convention approach is recommended as opposed to harmonizing vendors on a common polarization naming convention. This will avoid inconsistency with an existing installed base of antennas; it does, however, require installers' attention to interpreting and comparing the labels of different vendors.

The labelling convention requires vendors to define the polarization geometry and naming convention they have adopted for their antenna products and to depict this information clearly on a label placed on the antenna. The convention is then applied to each antenna port, which must be also labelled to allow the identification of its polarization.

Below an example of a vendor label defining a polarization geometry and naming convention, and picture illustrating an example of labelling on the rear side of an antenna:

Figure 11.7: Example of polarization conventional label.

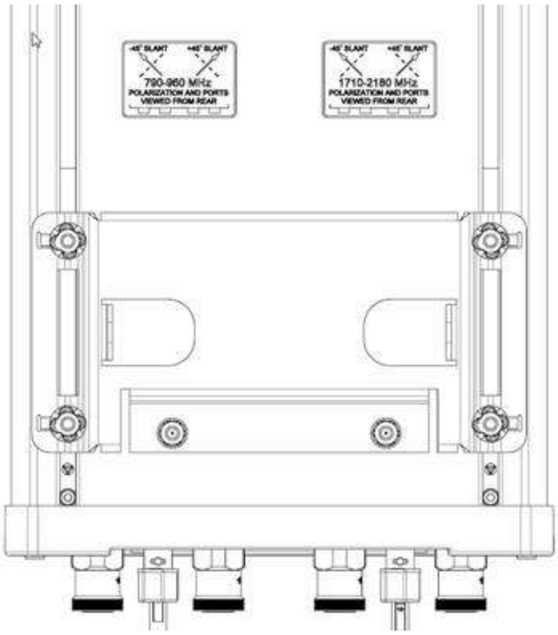


Figure 11.8: Polarization conventional label affixed on the antenna back.

Finally, an example of the ports labelling per the convention described on the antenna:

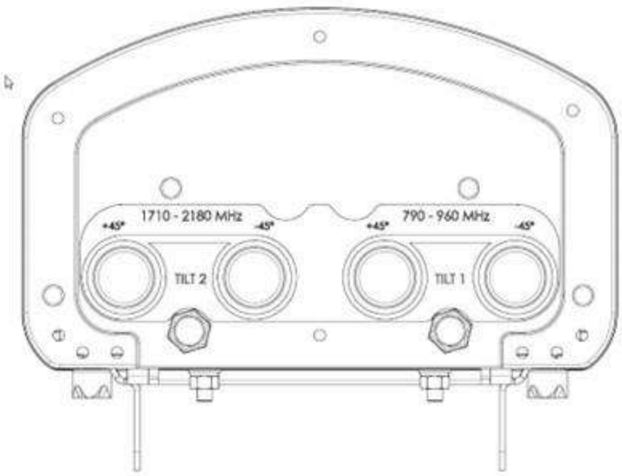


Figure 11.9: Ports identified by polarization.

12 Annex C: Validation and Specification of RF Parameters

12.1 Industry Practice for Base Station Antennas

In a commercial RFQ process cellular operators specify the expected performance of the antennas that need to be purchased for deployment in their networks. Detailed specifications are provided to antenna vendors, who respond with specification datasheets or other documentation that compares how the performance of their products complies with the RFQ requirements. In order to accurately compare the properties of one antenna vendor's product with another's, all parties in the supply chain shall have a common understanding of the antenna parameters definitions, and just as critically, of the methodology used to calculate and validate the associated specifications. This section of the publication addresses the calculation and validation of the RF specifications.

12.2 General Guidance

- For the validation and the specification of radiation pattern derived parameters, the NGMN guidelines require a specific set of sub-bands and associated frequencies to be measured and analysed. See Section 9.1 for details.
- Parameters are classified as **absolute** or **distribution-based**. Distribution-based parameters are further classified as **single-sided parameters** or **double-sided parameters**.
- In general, **absolute parameters** are defined for the full frequency range of an antenna and are based on swept frequency measurements of the input ports. For these parameters, unless otherwise noted, it will be assumed that the specification is valid for the full frequency range, full electrical downtilt range, and all the associated ports of the antenna. E.g.: 1710-2170 MHz; 0°-10°; +45 and -45 ports.
- In general, **distribution-based parameters** are defined in sub-bands of the full frequency range of an antenna and are based on radiation pattern measurements. For these parameters, unless otherwise noted, it will be assumed that the specification is valid for the full sub-band frequency range, full electrical downtilt range, and all associated ports of the antenna. E.g.: 1710-1880 MHz; 0°-10°; +45 and -45 ports.
- **Typical parameters** are distribution-based parameters that are defined by a mean value and a tolerance. If the specification's measured values constituted a normal (Gaussian) probability distribution, the tolerance would be defined as ± 1.5 standard deviations. The reason why these parameters are also called **double-sided lies** in the fact that typical parameters are validated by a set of measured data points revolving around the mean value, both to its "left side" (- tolerance) and to the "right side" (+ tolerance) in the distribution function.
    - Gain is a special case of a typical parameter. It is specified for each of the sub-bands included in the frequency range of the antenna, for the associated ports and for the specific lowest, middle, and highest tilt values over the electrical tilt range of the antenna. In addition, an "over all tilts" (all the electrical tilt angles are included in the calculation) gain is specified as a standard typical parameter.
- **Maximum or minimum parameters** are distribution-based parameters that are defined by a threshold value. If the specification's measured values constituted a normal (Gaussian) probability distribution, the maximum threshold value would be determined by their mean value plus one standard deviation, while the minimum threshold value would be determined by their mean value minus one standard deviation. The reason why these parameters are called **single-sided** lies in the fact that these parameters are validated by a set of measured data points, respectively only to

the "left side" (for "maximum" parameters) or only to the "right side" (for "minimum" parameters) of a threshold in the distribution function.

  - Elevation downtilt deviation is a special case of a maximum parameter. The absolute maximum differences between the real tilt values (calculated as specified in Section 7.2.7) and the nominal tilt angle shall be calculated, and with those the parameter shall be specified for each of the sub-bands included in the frequency range of the antenna, for the associated ports and for the whole tilt range.
- For the single-sided parameters that use decibels as measurement unit there shall be no more than 3 dB excursion beyond the specified value. For example, if the threshold for the first upper sidelobe suppression was specified as 15.2 dB, there should be no value lower than 12.2 dB in the whole set of measured values. If that happens, the parameter specified value shall be adjusted so that the excursion is exactly 3 dB
- Some parameters require the measurement of Co-Pol as well as Cr-Pol patterns, both of which require a scrupulous alignment of the whole measurement system. A misalignment can lead to sub-optimal figures, due to the decrease of Co-Pol amplitudes and increase of the Cr-Pol ones.
- Pattern data shall be extracted at a minimum of 1° angular resolution if the pattern has an average HPBW equal to 20° or broader. Vice versa if the pattern has an average HPBW of less than 20°, it can happen that the patterns exhibit some "spikes": under these circumstances, these sudden changes of pattern level shall be handled by extracting pattern data with 0.5° angular resolution. This rule applies only for the sake of parameters' precision and shall not affect any other information that the vendors provide to the operators (radio planning files, etc.).
- Pattern data for antennas capable of electrical downtilt shall be taken with the same step at least every 1° over the entire specified tilt range. Antennas whose tilt-range starts and/or stops with half a degree follow the same principle, except that if the chosen step is 1°, the first and/or last tilt shall be measured with a step of 0.5° (e.g.: 2.5° to 10° downtilting antenna's pattern data will be taken at: 2.5°; 3°; …; 10°. 2.5° to 10.5° downtilting antenna's pattern data will be taken at: 2.5°; 3°; …; 10°; 10.5°.).
- Pattern data shall be given for the elevation and azimuth pattern cuts.
- Legacy vendor specification datasheets and legacy NGMN datasheets shall not be required to be updated as a whole. It is foreseen that operators might request NGMN compliance for new RFQs and new products, therefore the recommendations present in this document shall be only applied to antennas that are developed after the date of its publication. Legacy NGMN datasheet shall therefore keep their validity for legacy products.

12.3 Absolute RF Parameters

For absolute parameters, 100% of the measured data falls below a maximum value or above a minimum value and distribution-based analysis is not necessary. In those cases there shall be no data points excursions beyond the specified value.

Typically these parameters are specified for the full frequency range, full electrical downtilt range, and associated ports of the antenna (for example: 1710-2170 MHz; 0°-10°; +45 and -45 ports).

12.4 Distribution-based RF Parameters

Considering that antennas' patterns change with frequency, tilt and polarization, for certain parameters it is not suitable to use absolute maxima or minima as metrics to evaluate an antenna's performance. In fact, by using them, a misrepresentation of the antenna could be likely. A very limited set of values (worst case: a single one) amongst the entire dataset of measured ones would characterize a parameter, even though all the other values are sensibly higher or lower. In these cases a distribution-based analysis excluding worst and best values is necessary to give a better overview of the aforementioned performances.

12.4.1 General methodology

For a given antenna model, its radiation patterns are measured at the recommended frequencies (see Section 11.2.4) for each of the required sub-bands in the full antenna bandwidth.

A full antenna bandwidth (or main frequency range) that is used only as an example in this section of the publication is: 1710-2170 MHz. The specified sub-bands that are used only as an example in this section of the publication are the following three:

Band	1710-2170 MHz		
Sub-Bands	1710-1880 MHz	1850-1990 MHz	1920-2170 MHz

Recommendation on sub-bands can be found in Section 11.2.4.

For antennas with variable electrical downtilt, each individual pattern is measured (as specified in Section 12.2), analysed, and finally a value is calculated according to the definition of the chosen parameter. The distribution of the resulting dataset of values is then analysed, so that a single value that represents the specification of that very parameter can be obtained.

In the table below it is shown an example of a full dataset of the azimuth beamwidth parameter for the sub-band 1710-1880 MHz:

Table 12-1: Parameter dataset – single sub-band, all tilts, all ports.

Az -3 dB beamwidth									
1710 - 1880 MHz	**1.71**	**1.73**	**1.75**	**1.76**	**1.79**	**1.81**	**1.84**	**1.85**	**1.88**
L-PORT DEG:0	68.84	69.01	68.94	68.80	67.98	67.06	66.98	66.37	65.75
R-PORT DEG:0	69.86	70.02	69.75	69.34	66.91	67.28	66.52	65.71	66.15
L-PORT DEG:2	69.79	68.90	68.47	68.35	67.60	67.21	66.82	66.54	65.62
R-PORT DEG:2	70.51	69.21	68.59	68.45	67.83	68.08	66.30	65.69	65.51
L-PORT DEG:4	69.50	69.12	68.91	68.82	68.37	67.74	66.38	66.74	66.02
R-PORT DEG:4	69.16	69.05	68.91	68.62	67.32	67.91	66.19	66.36	65.52
L-PORT DEG:6	69.17	68.79	68.63	68.59	68.31	67.31	66.81	66.54	65.85
R-PORT DEG:6	69.42	69.02	68.65	68.56	68.18	68.27	67.62	67.03	65.92
L-PORT DEG:8	69.64	69.55	69.33	69.12	67.67	67.16	66.52	66.56	66.65
R-PORT DEG:8	70.23	69.27	68.71	68.37	67.37	68.00	67.56	67.09	66.35
L-PORT DEG:10	69.80	69.23	68.93	68.76	67.87	68.08	67.12	66.49	66.12
R-PORT DEG:10	70.03	68.93	68.55	68.37	67.44	67.91	67.50	67.21	66.29
L-PORT DEG:1	69.54	68.94	68.58	68.44	67.60	67.13	66.90	66.50	65.58
L-PORT DEG:3	69.86	69.02	68.69	68.58	68.04	67.60	66.56	66.75	65.89
L-PORT DEG:7	69.39	69.18	68.99	68.85	68.04	67.02	66.63	66.47	66.23
L-PORT DEG:9	69.77	69.57	69.39	69.15	67.64	67.40	66.67	66.49	66.61
L-PORT DEG:5	69.26	68.92	68.74	68.68	68.35	67.61	66.62	66.67	66.00
R-PORT DEG:1	70.44	69.39	68.90	68.68	67.60	67.87	66.38	65.59	65.69
R-PORT DEG:3	69.79	69.07	68.69	68.51	67.54	68.04	66.02	65.98	65.41
R-PORT DEG:5	69.27	69.01	68.77	68.59	67.81	68.13	66.88	66.78	65.71
R-PORT DEG:7	69.96	69.17	68.68	68.52	67.89	68.23	67.77	67.07	66.22
R-PORT DEG:9	70.11	69.24	68.57	68.35	67.27	67.88	67.56	67.18	66.41
	Min	**Max**	**Mean**	**Stdv**					
Overall	65.41	70.51	67.90	1.26					

12.4.2 Double-Sided Specifications

For some parameters, their relevance is best captured by how the whole calculated dataset revolves around a typical value; therefore, these are designated as double-sided parameters (see also Section 12.2). Their distribution-based validation is applied in the measurement units identified within their specification definition.

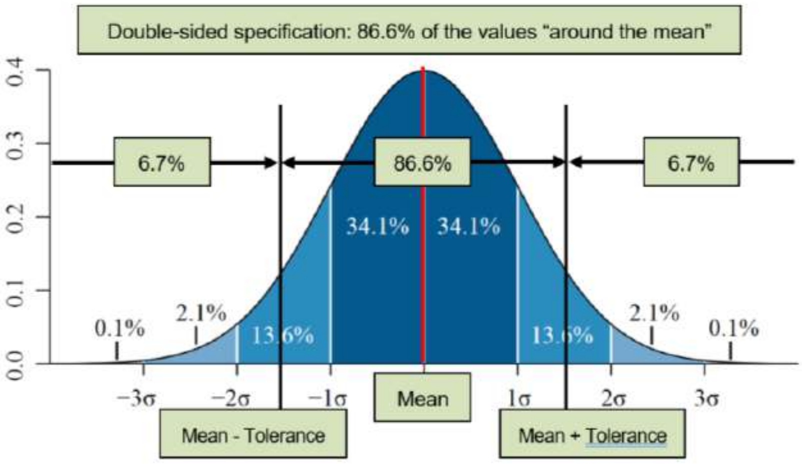


Figure 12.1: Double-sided specification for a normal distribution.

Even though the definition of double-sided parameters is inspired by Gaussian statistic, in reality most of the parameters' probability distribution are questionably a Gaussian curve. Even if the definition of mean (μ) is obviously the same (it is **the average of the values in the distribution as linear numbers**), the tolerance definitions do not coincide: for a normal distribution would simply be equal to ± 1.5 * standard deviation (σ); for a real one instead, it is defined as **the average of the distances from the mean of the two values, both of which exclude from the distribution the 6.7% of the measured values, that is respectively its far left side (from 0% to 6.7%) and its far right side (from 93.3% to 100%).**

A normal distribution is also a continuous curve, but in the real world it is possible only to approximate a probability distribution function using a sorted array of measured values (one value for each frequency, polarization and tilt angle). Thus it is possible that the threshold values "mean - tolerance" (6.7th percentile) and "mean + tolerance" (93.3rd percentile) are not values that were actually measured. Below it is shown a block chart describing the algorithm to correctly find those:

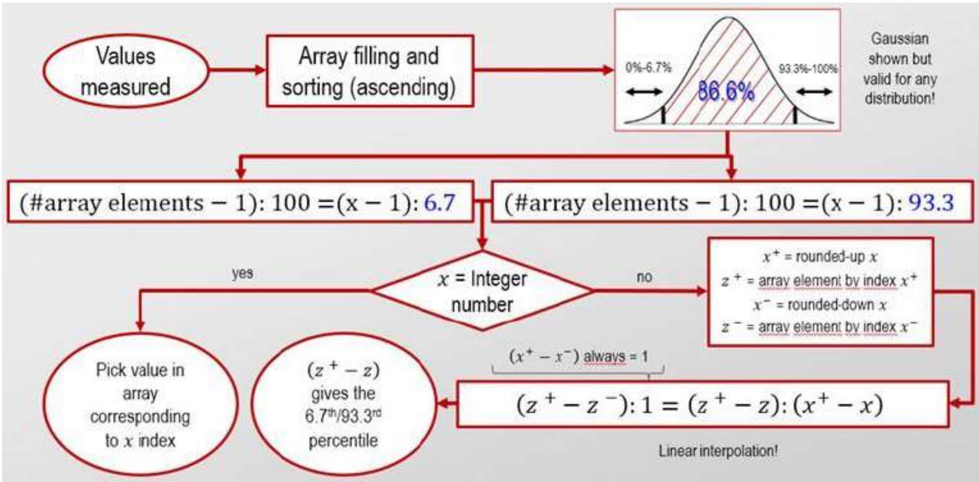


Figure 12.2: Algorithm to find "mean - tolerance" and "mean + tolerance"

Once the two percentiles are found, the modulus of their differences from the mean value shall be averaged in order to obtain a single number hence designated as tolerance.

12.4.3 Double-Sided Specification Example–Azimuth HPBW Validation

For this example of validation process, the calculation of the azimuth HPBW specification in the 1710-1880 MHz sub-band will be used.
First of all, the antennas radiation patterns for the sub-band are analysed according to the parameter definition (see Section 7.2.5.1):

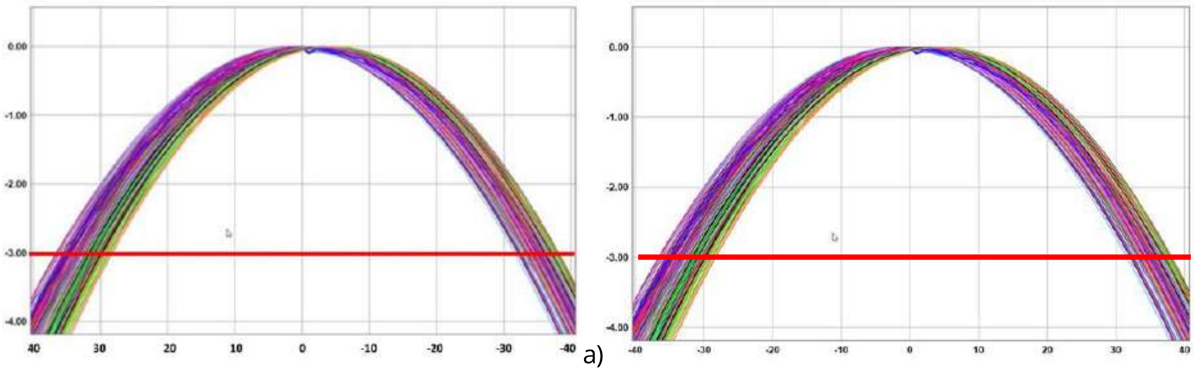


Figure 12.3: Azimuth beam-peak patterns plots - 1710-1880 MHz, all ports, and all tilts. a) SPCS_Polar, b) SPCS_CW

The values for azimuth beamwidth are calculated for each frequency in the sub-band, each port, and each downtilt setting:

Table 12-2: Complete dataset of azimuth HPBWs.

El. Tilt	2.5	2.5	3.0	3.0	4.0	4.0	5.0	5.0	6.0	6.0	7.0	7.0	8.0	8.0
Polarization	+45°	-45°	+45°	-45°	+45°	-45°	+45°	-45°	+45°	-45°	+45°	-45°	+45°	-45°
1710 MHz	68.2	69.4	66.9	68.7	68.0	68.7	68.7	68.9	69.8	68.8	69.6	68.6	70.8	68.8
1733 MHz	66.0	69.0	65.9	69.0	65.0	68.3	65.1	67.9	66.2	68.4	67.0	69.0	69.4	69.5
1748 MHz	64.3	68.6	65.6	69.4	64.2	69.0	63.5	68.3	63.5	68.1	65.3	68.3	68.6	68.9
1755 MHz	64.0	68.6	64.0	69.9	63.0	69.9	62.5	69.5	62.9	68.8	64.2	68.5	67.8	68.8
1785 MHz	64.9	64.4	63.5	64.2	62.8	64.7	62.1	64.8	60.9	64.5	60.7	64.1	60.7	63.6
1805 MHz	62.1	61.9	61.1	62.6	60.4	62.7	60.0	62.8	59.3	62.6	59.0	62.4	58.8	62.1
1843 MHz	66.2	62.9	65.0	63.0	64.1	62.2	63.6	61.8	62.9	61.9	63.2	62.6	63.4	63.5
1850 MHz	66.4	62.6	65.1	62.9	64.1	62.4	63.6	62.3	63.4	62.7	63.7	63.4	64.1	64.1
1880 MHz	66.0	65.5	64.9	64.3	64.5	64.1	64.2	64.0	64.2	64.4	64.6	65.2	65.5	66.6

The distribution of the set of measured values is finally analysed to determine the specification:

- The array containing all the values above counts 126 elements (9 frequencies x 7 tilts x 2 polarizations).
- The minimum value is 58.8° and the maximum is 70.8°. The mean is the sum of all the elements (degree values do not need the conversion in linear numbers), divided by 126.

The proportion **(126 – 1) : 100 = (x – 1) : 6.7** solved by x, returns **x = 9.4**. Where x is the array index of the 6.7th percentile.

The proportion **(126 – 1) : 100 = (x – 1) : 93.3** solved by x, returns **x = 117.6**. Where x is the array index of the 93.3rd percentile.

- Once the array is sorted in ascending fashion, it can be seen that the 9th element (index = 9) is 61.1°, the 10th is 61.8, the 117th and 118th are both 69.4°.
- Clearly, the **"mean + tolerance" value is 69.4°**, while for the "mean – tolerance" a linear interpolation between 61.1° and 61.8° is necessary.
- Using the following equivalences: z+ = 61.8°; z- = 61.1°; x+ = 10; x- = 9; the value of "mean - tolerance" can be obtained: (z+-z) = 61.4°.
- The modulus of the differences of the two values from the mean is respectively: 3.7° and 4.3°, therefore **the tolerance is their average, which is 4.0°.**

Table 12-3: Summary of azimuth HPBW statistics.

Azimuth beamwidth	# Array elements	Min	Max	Mean	Tolerance
1710-1880 MHz	126	58.8°	70.8°	65.1°	4.0°

The specification is set as:

Type: Distribution-based	1710-1880 MHz
Azimuth HPBW	65.1°, tolerance ± 4.0°

As previously stated, in this example, the azimuth HPBW has only been calculated for one sub-band (1710-1880 MHz).

This procedure has to be repeated two additional times to populate the full specification table for the parameter:

Type: Distribution-based	1710-1880 MHz	1850-1990 MHz	1920-2170 MHz
Azimuth HPBW	65.1° Tolerance ± 4.0°	64.8° Tolerance ± 1.6°	63.4° Tolerance ± 2.3°

For the purpose of this publication, it is instructive to show the plotted the azimuth HPBW values as a function of frequency, and the distribution of the calculated values in a histogram. These plots are shown below:

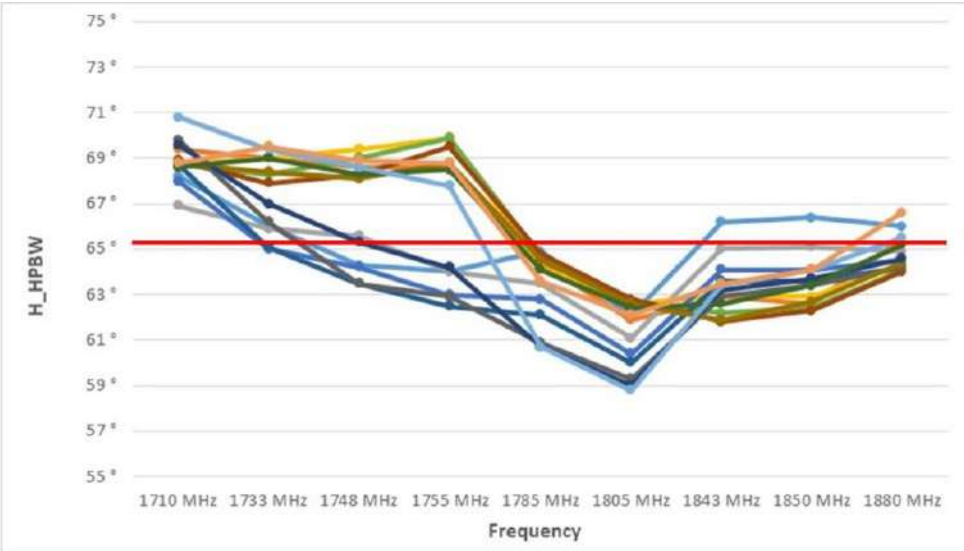


Figure 12.4: Azimuth HPBW for each tilt and port as a function of the frequency.

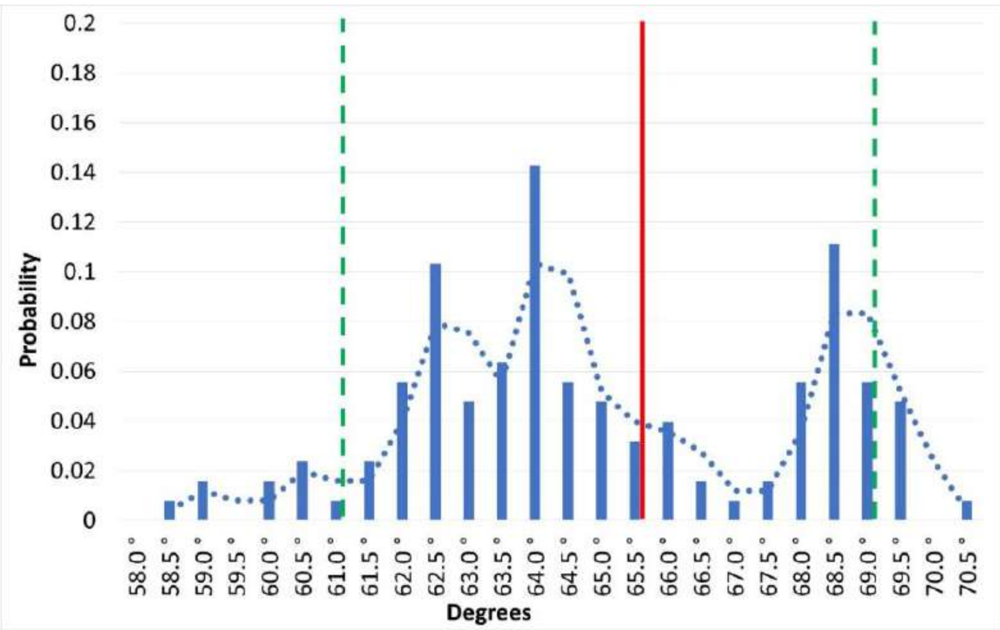


Figure 12.5: Histogram of azimuth HPBW values.

The histogram above shows well that the distribution of the values is not Gaussian. In fact, if the tolerance would have been incorrectly calculated as 1.5 * σ, it would have been equal to 4.3°.

12.4.4 Single-sided Specifications

For some parameters, their relevance is best captured by how the dataset of calculated values fall above or below a threshold value; therefore, they are designated as single-sided parameters (see also Section 12.2). The distribution-based validation is applied in the units identified within the specification definition.

A "maximum" specification for a parameter is defined when the above-mentioned dataset is mostly "below" a specified value: this does not strictly mean that the values must be lower than it, since the physical meaning of the parameter and its associated sign play an important role in the meaning of "below".
For Gaussian statistics, the "maximum" would be a threshold value defined by the mean plus the standard deviation, both calculated on the dataset used to validate the specification. Since μ+σ serves as limit for the lower 84% of the values in a normal probability distribution, and since in reality the parameters' distributions are hardly Gaussian, a "maximum" will be generally defined as the value that demarcate the lower 84% of the entire dataset. In other words, 84% of the measured values will fall below the given specification (threshold).

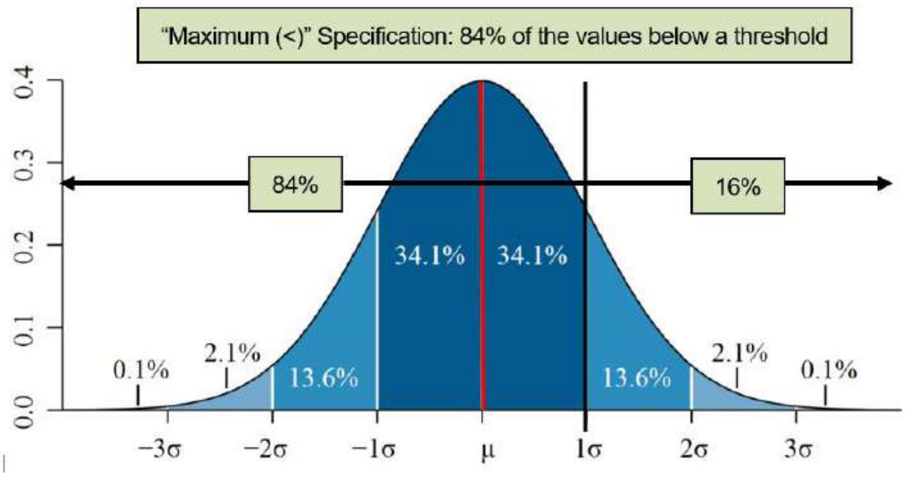


Figure 12.6: Single-sided specification (maximum).

A "minimum" specification for a parameter is defined when the above-mentioned dataset is mostly "above" a specified value: this does not strictly mean that the values must be higher than it, since the physical meaning of the parameter and its associated sign play an important role in the meaning of "above".
For Gaussian statistics, the "minimum" would be a threshold value defined by the mean minus the standard deviation, both calculated on the dataset used to validate the specification. Since μ-σ serves as limit for the higher 84% of the values in a normal probability distribution, and since in reality the parameters' distributions are hardly Gaussian, a "minimum" will be generally defined as the value that demarcate the higher 84% of the entire dataset. In other words, 84% of the measured values will fall above the given specification (threshold).

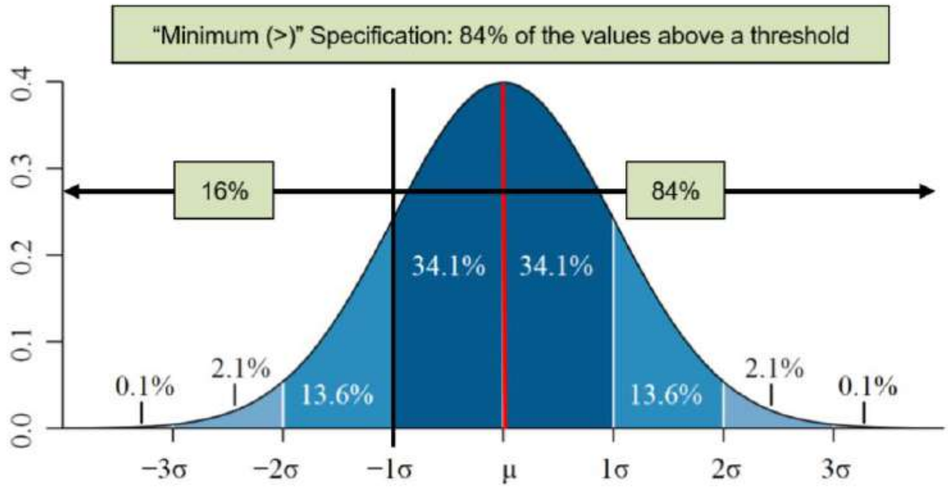


Figure 12.7: Single-sided specification (minimum).

A normal distribution is also a continuous curve, but in the real world it is possible only to approximate a probability distribution function using a sorted array of measured values (one value for each frequency, polarization and tilt angle). Thus it is possible that the threshold values "maximum" (84th percentile) and "minimum" (16th percentile) are not values that were actually measured. Below it is shown a block chart describing the algorithm to correctly find those:

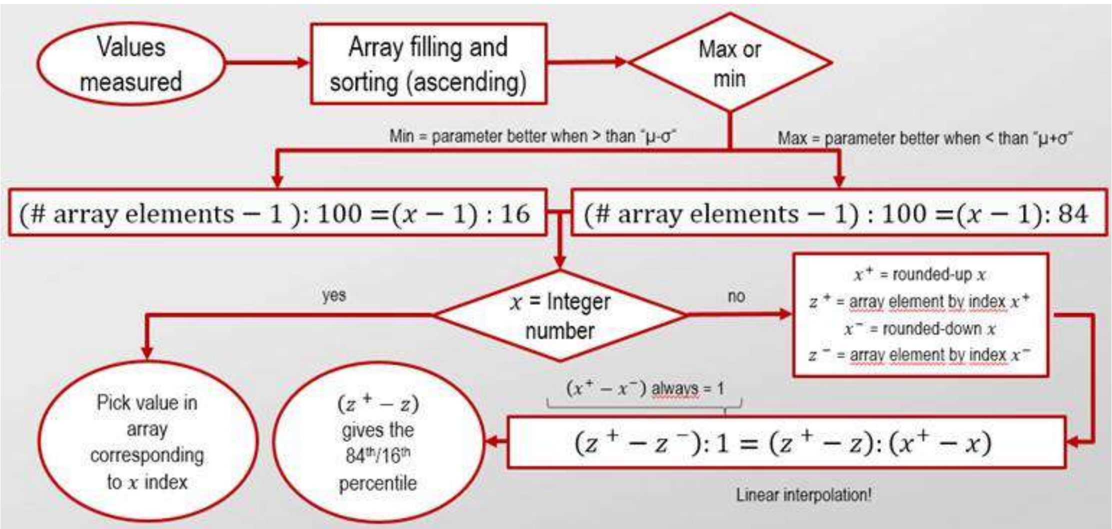


Figure 12.8: Algorithm to find "maximum" and "minimum".

12.4.5 Single-sided Specification Example – Azimuth Beam Port-to-Port Tracking Validation

For this example of validation process, the calculation of the azimuth beam port-to-port tracking specification in the 1710-1880 MHz sub-band will be used.

First, the antennas' radiation patterns for the sub-band are analysed according to the parameter definition (see Section 7.8.1):

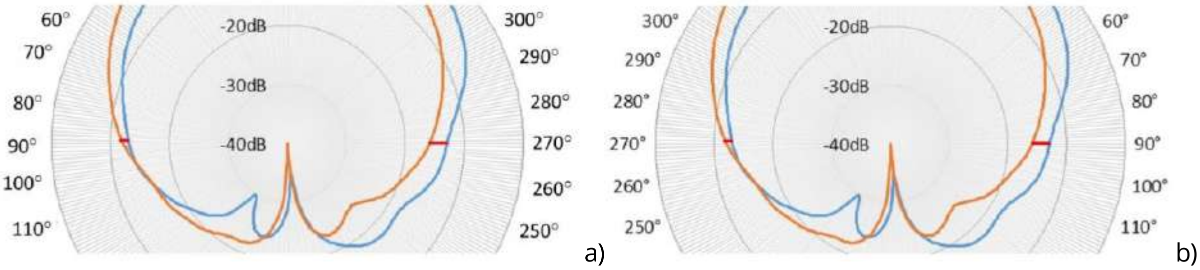


Figure 12.9: Polarizations pattern level difference of a 90° sector antenna for one frequency and a single downtilt angle. a) SPCS_Polar, b) SPCS_CW.

Table 12-4: Complete dataset azimuth beam port-to-port tracking.

El. Tilt	2.0		3.0		4.0		5.0		6.0		7.0		8.0		9.0		10.0	
Sector	-90°	+90°	-90°	+90°	-90°	+90°	-90°	+90°	-90°	+90°	-90°	+90°	-90°	+90°	-90°	+90°	-90°	+90°
1710 MHz	0.0	0.5	0.3	0.1	0.2	0.1	0.1	0.1	0.2	0.1	0.2	0.1	0.2	0.1	0.3	0.1	0.5	0.1
1733 MHz	0.3	0.5	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.3	0.1	0.1	0.0	0.1	0.1	0.4	0.3
1748 MHz	0.4	0.9	0.2	0.4	0.2	0.3	0.2	0.3	0.5	0.3	0.7	0.1	0.5	0.1	0.3	0.1	0.4	0.4
1755 MHz	0.5	1.2	0.4	0.7	0.4	0.6	0.5	0.5	0.8	0.4	1.0	0.1	0.9	0.0	0.8	0.2	0.8	0.5
1785 MHz	0.5	2.1	0.6	2.3	0.5	2.4	0.4	2.2	0.6	2.3	0.7	2.3	0.7	2.3	0.6	2.3	0.6	2.5
1805 MHz	0.4	0.7	0.0	1.0	0.1	1.2	0.2	1.0	0.1	0.7	0.0	0.6	0.1	0.6	0.2	0.8	0.5	1.0
1843 MHz	2.3	2.6	2.4	2.9	2.4	3.0	2.4	2.9	2.4	2.8	2.3	2.8	2.2	2.8	2.1	2.6	2.0	2.2
1850 MHz	2.5	3.0	2.6	3.4	2.8	3.6	2.9	3.5	3.0	3.3	2.9	3.4	2.8	3.4	2.7	3.3	2.6	3.0
1880 MHz	1.9	2.7	1.9	2.5	2.1	2.5	2.2	2.5	2.3	2.6	2.7	2.7	2.9	3.0	2.9	3.3	2.9	3.3

The distribution of the set of measured values is finally analysed to determine the specification:

- The array containing all the values in the table above counts 162 elements (9 frequencies x 9 tilts x 2 directions).
- The minimum value is 0 dB, and the maximum is 3.6 dB. The mean is the sum of all the elements (as linear numbers) divided by 162.
- In the table above the higher the number, the worse the signal difference, the worse the antenna's performance. To define the parameter 16% of the worst cases (higher values) are ruled out.

The proportion (162 – 1) : 100 = (x – 1) : 84 solved by x, returns x = 136.24. Where x is the array index of the 84th percentile.

- Since 136.24 is not an integer number, an interpolation is necessary.
- Once the array is sorted in ascending fashion, it can be seen that the value lies between the 136th element (index = 136), which is 2.7 dB, and the 137th element (index = 137) of the array, which is 2.8 dB.
- The interpolation formula becomes: 0.1 : 1 = (2.8 – z) : (137-136.24) and ultimately gives a result of 2.7 dB.

Table 12-5: Summary of azimuth beam port-to-port tracking statistics.

Azimuth Beam Port-to-Port Tracking	# Array elements	Min = Best	Max = Worst	84%
1710-1880 MHz	162	0 dB	3.6 dB	2.7 dB

The specification is set as:

Type: Distribution-based	1710-1880 MHz
Azimuth Beam Port-to-Port Tracking	**< 2.7 dB**

Note that the specification values are never more than 3 dB higher than the maximum found through the algorithm.
As previously state, in this example, azimuth beam port-to-port tracking has only been calculated for one sub-band (1710-1880 MHz).
This procedure has to be repeated two additional times to populate the full specification table for the azimuth beam port-to-port tracking parameter:

Type: Distribution-based	1710-1880 MHz	1850-1990 MHz	1920-2170 MHz
Azimuth Beam Port-to-Port Tracking	< 2.7 dB	< 1.8 dB	< 2.2 dB

For the purpose of this publication, it is instructive to show the plotted azimuth beam port-to-port tracking values as a function of frequency, and the distribution of the calculated values in a histogram. These plots are shown below:

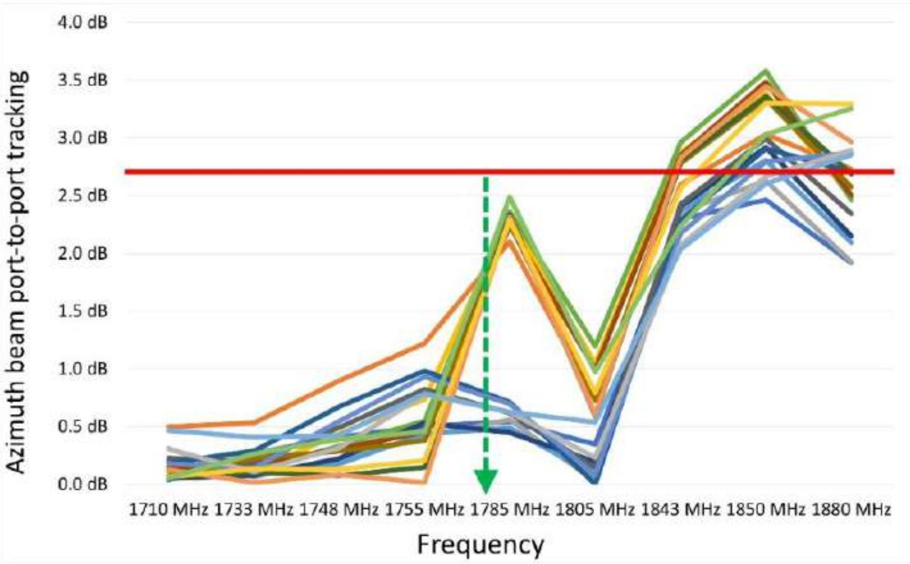


Figure 12.10: Azimuth beam port-to-port tracking for each tilt and port as a function of the frequency.

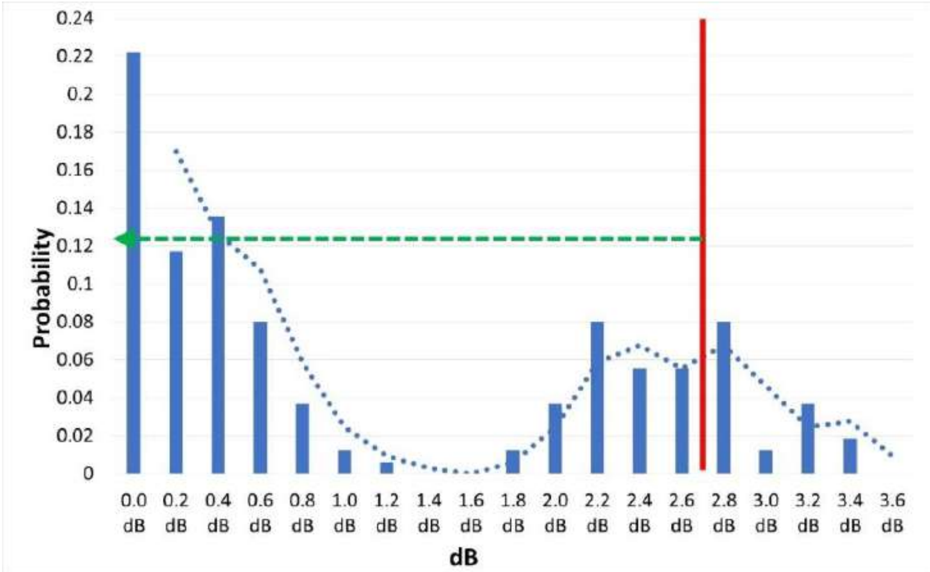


Figure 12.11: Histogram azimuth beam port-to-port tracking.

The histogram above shows well that the distribution of the values is not Gaussian. In fact, if the parameter would have been incorrectly calculated as μ+σ, it would have been equal to 2.5 dB.

12.4.6 Single-sided Specification Example – Upper Sidelobe Suppression, Peak to 20° Validation

For this example of validation process, the calculation of the upper sidelobe suppression, peak to 20° specification in the 1710-1880 MHz sub-band will be used.
First, the antennas' radiation patterns for the sub-band are analysed according to the parameter definition (see Section 3.2.15):

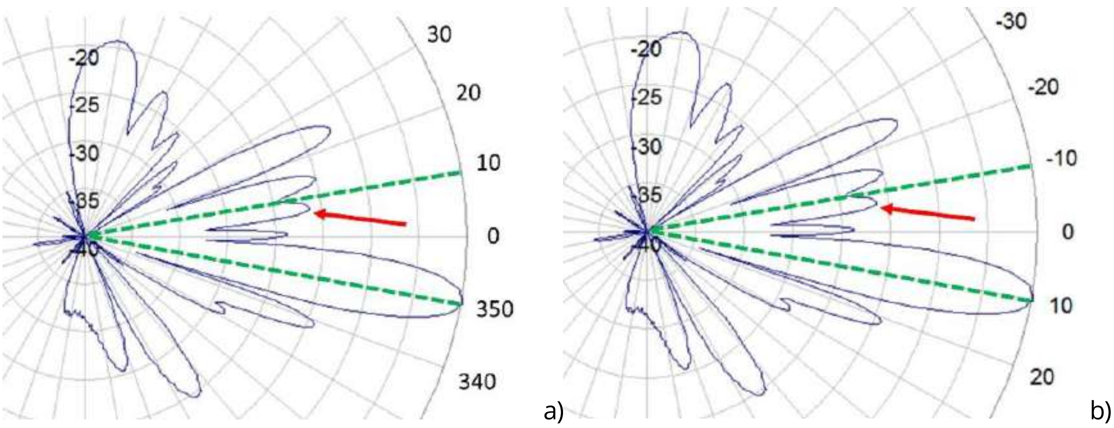


Figure 12.12: Worst sidelobe peak 20° above the main beam peak for one frequency, a single port and a single downtilt angle. a) SPCS_Polar, b) SPCS_CW

Table 12-6: Complete dataset upper sidelobe suppression, peak to 20°.

El. Tilt	2.5	2.5	3.0	3.0	4.0	4.0	5.0	5.0	6.0	6.0	7.0	7.0	8.0	8.0
Polarization	+45°	-45°	+45°	-45°	+45°	-45°	+45°	-45°	+45°	-45°	+45°	-45°	+45°	-45°
1710 MHz	17.1	17.9	16.8	17.5	15.4	15.4	15.5	15.0	17.1	16.3	18.1	16.7	17.7	15.3
1733 MHz	16.0	16.7	15.6	16.4	15.2	16.0	15.4	15.5	15.7	15.2	16.6	16.2	17.0	16.2
1748 MHz	17.1	17.0	16.7	16.3	15.8	15.1	15.9	15.0	16.8	15.9	16.5	17.0	16.3	17.1
1755 MHz	18.5	17.8	17.7	16.6	16.5	15.1	16.5	14.9	17.3	15.5	17.3	16.7	16.4	17.4
1785 MHz	19.0	17.6	18.4	17.4	17.8	16.6	17.4	16.0	16.9	16.0	16.7	16.2	16.2	16.6
1805 MHz	16.1	17.0	15.9	16.8	15.8	16.7	15.8	16.2	15.8	15.6	15.8	15.3	15.8	15.3
1843 MHz	17.0	16.8	16.8	16.2	16.7	16.5	17.2	17.6	17.5	18.6	17.5	18.6	16.9	17.4
1850 MHz	17.6	17.0	17.4	16.4	17.1	16.2	17.6	17.0	18.2	18.5	18.3	18.6	17.7	17.6
1880 MHz	17.6	16.3	17.4	16.4	18.9	17.7	19.8	19.7	18.6	18.5	17.9	17.6	16.7	16.6

The distribution of the set of measured values is finally analysed to determine the specification:

- The array containing all the values in the table above counts 126 elements (9 frequencies x 7 tilts x 2 polarizations).
- The minimum value is 14.9 dB, and the maximum is 19.8 dB. The mean is the sum of all the elements (as linear numbers) divided by 126.
- In the table above the higher the number, the smaller the sidelobe, the better the antenna's performance. To define the parameter 16% of the worst cases (lower values) are ruled out.

The proportion (126 – 1) : 100 = (x – 1) : 16 solved by x, returns x = 21. Where x is the array index of the 16th percentile.

- Since 21 is an integer number, no interpolation is necessary.
- Once the array is sorted in ascending fashion, it can be seen that the 21st element (index = 21) is 15.8 dB.

Table 12-7: Summary of upper sidelobe suppression, peak to 20° statistics.

Upper sidelobe suppression, peak to 20°	**# Array elements**	**Min = Worst**	**Max = Best**	**16%**
1710-1880 MHz	126	14.9 dB	19.8 dB	15.8 dB

The specification is set as:

Type: Distribution-based	**1710-1880 MHz**
Upper sidelobe suppression, peak to 20°	> 15.8 dB

Note that the specification values are never lower than 3 dB higher than the minimum found through the algorithm.
As previously state, in this example, the Upper sidelobe suppression, peak to 20° has only been calculated for one sub-band (1710-1880 MHz).
This procedure has to be repeated two additional times to populate the full specification table for the Upper sidelobe suppression, peak to 20° parameter:

Type: Distribution-based	**1710-1880 MHz**	**1850-1990 MHz**	**1920-2170 MHz**
Upper sidelobe suppression, peak to 20°	> 15.8 dB	> 16.1 dB	> 17.9 dB

For the purpose of this publication, it is instructive to show the plotted the Upper sidelobe suppression, peak to 20° values as a function of frequency, and the distribution of the calculated values in a histogram. These plots are shown below:

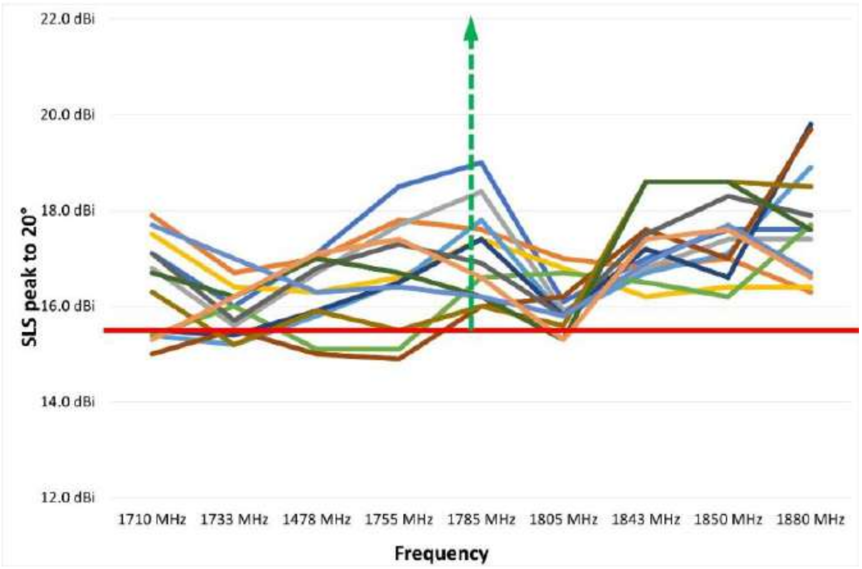


Figure 12.13: Upper sidelobe suppression, peak to 20° for each tilt and port as a function of the frequency.

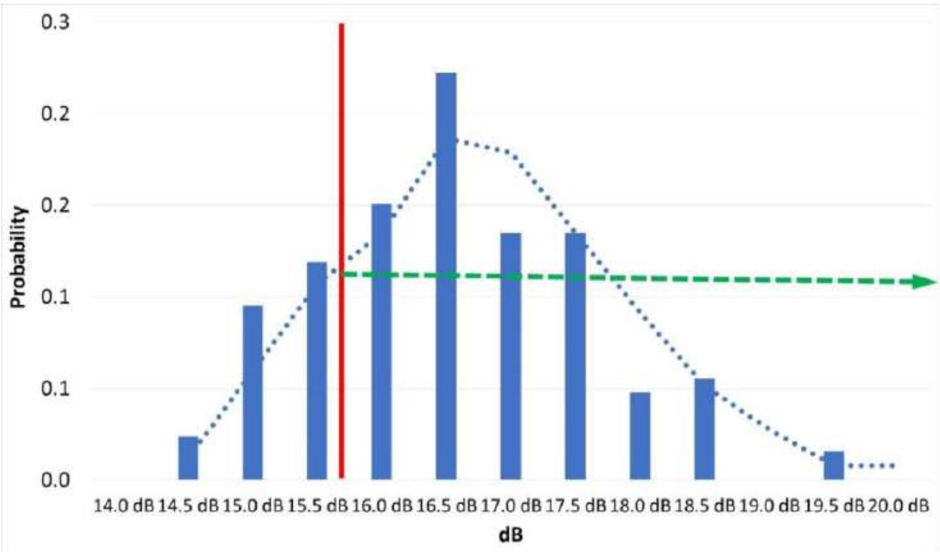


Figure 12.14: Histogram Upper sidelobe suppression, peak to 20°.

The histogram above shows well that the distribution of the values is not Gaussian. If the parameter would have been incorrectly calculated as μ-σ, it would have been equal to 15.7 dB.

12.5 Sidelobe Suppression Calculation and Validation

The calculation of all the parameters related to the sidelobes (in this publication: "first sidelobe suppression", "null fill", "upper sidelobe suppression, peak to 20°" and "upper sidelobe suppression, horizon to 20°") is only apparently uncomplicated, due to the fact that not all the sidelobes' peaks are displayed as relative maxima in the elevation pattern. It is in fact possible that some of them (especially the first sidelobe above and/or below the main beam) are "merged" to another one (rare) or to the main beam (common). Should this eventuality occur, the sidelobe peak would at best be visible as an inflection point, but it could alternatively not be visible at all.

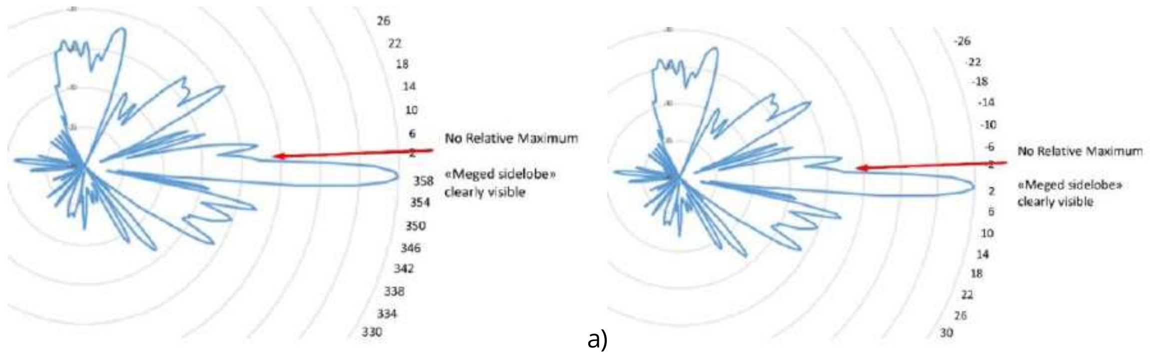


Figure 12.15: First upper sidelobe merged into main beam. a) SPCS_Polar, b) SPCS_CW

It is necessary to address this issue from the perspective of an automated calculation process, rather than relying on a visual analysis of the elevation pattern. On this wise some algorithms for the correct calculation of the above-mentioned parameters will be described in the forthcoming sections.

12.5.1 First Sidelobe Suppression

Several empirical tests were conducted amongst a number of antennas with different performances and characteristics, and those suggested that the first sidelobe above (counterclockwise in the elevation pattern) the main beam commonly appeared as a relative maximum in a sector equal to the V_HPBW multiplied by 1.78 above the main beam peak. For all the remaining cases where the elevation pattern did not exhibit any relative maximum in that sector, the tests showed a very high probability that the peak of a merged sidelobe could be found by, or immediately in proximity to, the angular direction corresponding to V_HPBW * 1.55° above the main beam peak.

Consequently, the first sidelobe peak shall be determined by executing the following steps for each frequency, tilt and polarization involved in the calculation:

- Locate main beam's maximum in the elevation pattern.
- Locate the first relative minimum above main beam's maximum.
- Locate the first relative maximum above the first relative minimum.
- Calculate the V_HPBW.
- If the angular position of the first relative maximum lies in the range delimited by the main beam peak and the angular direction represented by 1.78 * V_HPBW degrees above it, then the corresponding pattern level shall be selected as the peak of the first sidelobe above the main beam peak.
- If the angular position of the first relative maximum lies above the sector defined in the previous point, then the pattern level corresponding to the angular position marked by 1.55 * V_HPBW degrees above the main beam peak shall represent the level of the (merged) first sidelobe above the main beam peak.

Note: The above-mentioned tests were conducted using a resolution of 0.5° in the elevation pattern, and with a set of antennas, whose V_HPBW never exceeded a broadness of 20°.

12.5.2 Null fill

According to the definition in Section 128, the null fill parameter estimates the pattern level of the first relative minimum below (clockwise in the elevation pattern) the main beam. Comparably to what happens for the first sidelobe suppression (see previous section), it is possible that merged sidelobes show up in the section of the elevation pattern situated below the main beam peak. In this case the first null does not appear as a relative minimum, but coincides with the peak of the merged sidelobe, as its angular position matches the end of the main beam. The aforementioned tests within the same conditions (see previous section and the note at its foot), have proven to be valid for the first sidelobe below the main beam peak too, consequently the steps to execute in order to determine the null fill are the following ones:

- Locate main beam's maximum in the elevation pattern.
- Locate the first relative minimum below main beam's maximum.
- Locate the first relative maximum above the first relative minimum.
- Calculate the V_HPBW.
- If the angular position of the first relative maximum lies in the range delimited by the main beam peak and the angular direction represented by 1.78 * V_HPBW degrees below it, then the corresponding pattern level shall represent the peak of the first sidelobe below the main beam peak. In this case the null fill shall correspond to the relative minimum found before (second point of this list).
- If the angular position of the first relative maximum lies outside the sector defined in the previous point, then the beam level corresponding to the angular position marked by 1.55 * V_HPBW degrees below the main beam peak shall represent the level of the (merged) first sidelobe below the main beam peak. The null fill shall have, in this case, the same value of the peak of the first sidelobe below the main beam peak.

12.5.3 Upper Sidelobe Suppression, Peak to 20° / Horizon to 20°

As stated in Section 7.8.4.2 and Section 7.8.4.5, the "upper sidelobe suppression, peak to 20°" and the "upper sidelobe suppression, horizon to 20°" estimate the worst level of a sidelobe inside their appropriate sectors defined in the elevation pattern.

Yet, especially for antenna beams that have a very broad V_HPBW (e.g.: mechanically short antennas at low frequencies), it can happen that there is no sidelobe peak in the sector delimited by the main beam peak and 20° above (counterclockwise in the elevation pattern) it or by the horizon and 20° above (counterclockwise in the elevation pattern) it.

In these cases, only one of the following three circumstances can occur:

- In the analysed sector there is only the first merged sidelobe peak.
- In the analysed sector there is only a portion of a sidelobe.
- In the analysed sector there only the main beam is contained.

For each of these circumstances there is an appropriate method to calculate the correct value for the parameter to evaluate. Respectively:

- The first merged sidelobe peak is treated as any other sidelobe peak. Since it does lie in the sector under observation, the specification of the studied parameter shall be in fact equal to the first merged sidelobe peak value.
- The specification of the studied parameter shall be equal to the highest level of the portion of the sidelobe included in the sector under observation.
- The specification of the studied parameter shall be temporarily set to "not available".

A deeper analysis is required in case one or more measurement points appear as "not available". After having calculated the specification for all the measurement points (one for each combination of frequency, tilt and polarization), it is necessary to determine the quantity of “not available” data in respect to the one that has been associated to a numeric value instead. If the “not available” are more than 50% of the whole dataset, then the distribution-based evaluation of the parameter is skipped, and its specification shall be instead set to “not applicable”. On the contrary, if there are at least 50% of numeric values in the above-mentioned dataset, then all the “not available” shall be substituted by 22 dB and the distribution-based evaluation of the parameter is performed as usual.

Note: The value of 22 dB has been selected after a research on the “upper sidelobe suppression, peak to 20°” and “upper sidelobe suppression, horizon to 20°” specifications. This value appeared to be the one most of the measurement points lean to. It has also been proven, that the substitutions of 22 dB to the “not applicable” don’t polarize much the single-sided distribution-based evaluation of the above-mentioned parameters, which means that this value lets the performance of the antenna remain accurate enough.

12.6 Gain Validation

Gain values are typically determined by the “gain by substitution” method, or the “gain by directivity / loss” method (see Section 11.1.2 for their description). Both can be used to validate the specification of the gain, and the validation process described below is applicable to the dataset of the parameter generated by either method.

The gain specification is based on the values measured on all relevant ports, over the specified sub-band frequency ranges, and at the low, mid, and high electrical downtilt settings. A “gain over all tilts” is also specified, and it is calculated using measurements over all the antenna electrical downtilt values. In other words, gain is to be specified in two ways:

- At the specific minimum, middle, and maximum values of an antenna’s tilt range. In this case, the validation data for each specified tilt is analysed only at that tilt, not within a tilt range.
- Over all tilts of an antenna’s tilt range. In this case, the validation data is analysed over the entire tilt range as measured in specific increments of electrical downtilt (see Section 12.2).

Gain measurements shall be carried out carefully to ensure their certainty. They can be difficult to be precisely repeated, because the accuracy and repeatability of those measurements is determined by a number of factors (this is better described in Section 11.1.3). Industry experts outline the discrepancy between gain measurements as a number that oscillates between 0.5 dB and 1.0 dB. The repeatability margin specification recommended for gain in this publication is 0.8 dB, which is a value based on the experience of the above-mentioned experts and is applied to all the antennas covered by this document, measured on all calibrated antenna ranges, at any time, in good environmental conditions.

12.6.1 Gain Validation for a Single Tilt Value

For this example of validation process, the calculation of the gain specification in the 1710-1880 MHz sub-band and by 0° of electrical tilt will be used.

Gain			
Type: Distribution-based	**1710-1880 MHz**	**1850-1990 MHz**	**1920-2170 MHz**
0° Tilt	17.1 dB	17.4 dB	17.7 dB
5° Tilt	17.3 dB	17.5 dB	17.7 dB
10° Tilt	17.0 dB	17.0 dB	17.2 dB

First of all, the antennas radiation patterns for the sub-band are analysed according to the parameter definition (see Sections 6.1.12 and 6.1.13). The values for gain are measured for each frequency in the sub-band, each port, and 0° of electrical downtilt:

Table 12-8: Complete dataset for gain (1710-1880 MHz, 0° tilt).

Total Gain, dBi									
	1.71	**1.733**	**1.748**	**1.755**	**1.785**	**1.805**	**1.843**	**1.85**	**1.88**
L-PORT DEG:0	17.44	17.22	17.08	17.08	17.20	17.08	16.85	16.85	16.97
R-PORT DEG:0	16.88	16.91	16.93	16.98	17.25	17.14	17.20	17.29	17.30
Overall	**Min**	**Max**	**Mean**						
1710 - 1880 MHz	16.85	17.44	17.09						

The distribution of the set of measured values is finally analysed to determine the specification (in this case the mean, which shall be calculated over the magnitude and then reconverted in dBi):

Table 12-9: Summary of gain statistics (1710 – 1880 MHz, 0° tilt).

Total Gain	Min	Max	Mean
1710-1880 MHz	16.9 dBi	17.4 dBi	17.1 dBi

The specification is finally set to 17.1 dBi.

As previously state, in this example, the gain has only been calculated for one sub-band (1710-1880 MHz). This procedure has to be repeated two additional times to populate the full specification table for the gain parameter by 0° of electrical downtilt:

Type: Distribution-based	**All ports**	**1710-1880 MHz**	**1850-1990 MHz**	**1920-2170 MHz**
Gain	0°Tilt	17.1 dBi	17.4 dBi	17.7 dBi

The same has to be done for the other two tilts (middle and maximum, being 0° the minimum):

Type: Distribution-based	**All ports**	**1710-1880 MHz**	**1850-1990 MHz**	**1920-2170 MHz**
Gain	0° Tilt	17.1 dBi	17.4 dBi	17.7 dBi
	5° Tilt	17.3 dBi	17.5 dBi	17.7 dBi
	10° Tilt	17.0 dBi	17.0 dBi	17.2 dBi

Per this publication's guidelines, the repeatability margin associated with a 17.1 dBi gain specification is 17.1 dBi – 0.8 dB, or 16.3 dBi.

For the purpose of this publication, it is instructive to show the plotted the gain values as a function of frequency, the distribution of the calculated values in a histogram, and the gain with its repeatability margin.

These plots are shown below:

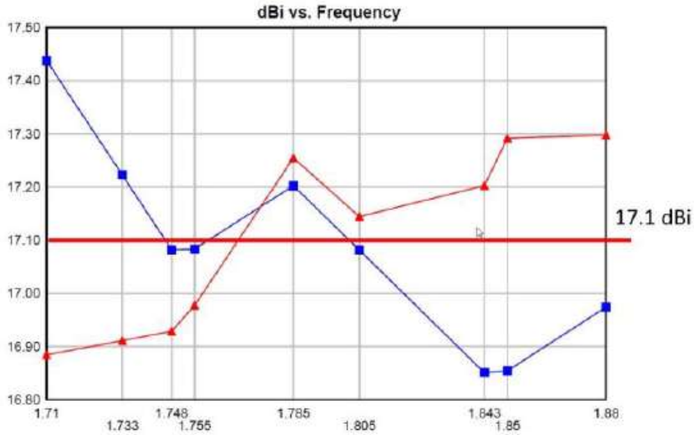


Figure 12.16: Gain plot for 0º tilt, both ports.

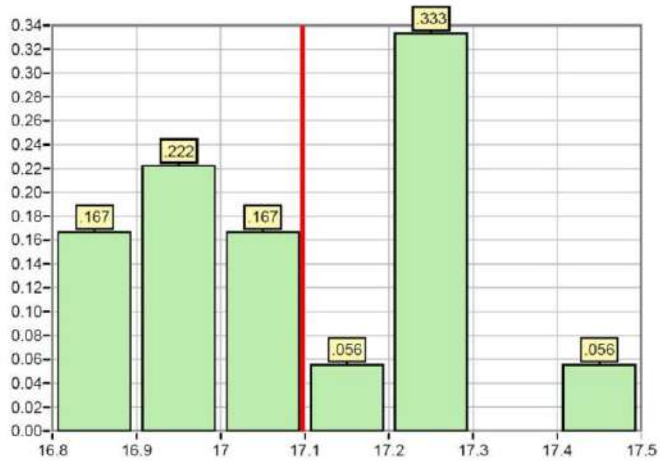


Figure 12.17: Gain histogram.

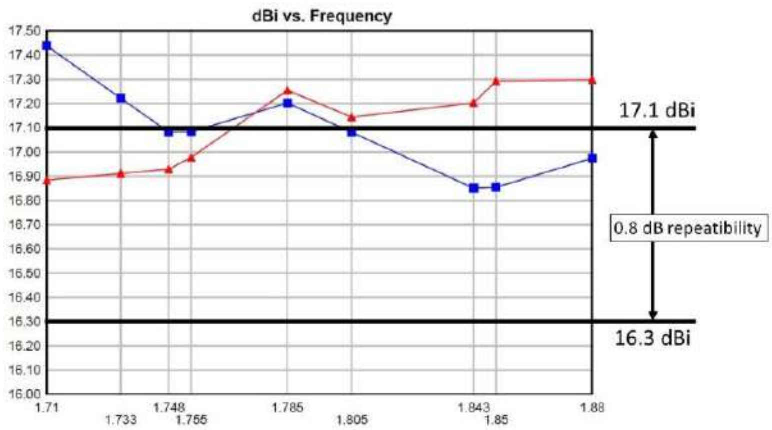


Figure 12.18: Gain plot with repeatability margin.

12.6.2 Gain Over All Tilts Validation

In this specification the gain is averaged for all values of the tilt range (see Sections 6.1.12 and 6.1.13 for an explanation of “all values of the tilt range”). For this example of validation process, the calculation of the “gain over all tilts” specification in the 1850-1990 MHz sub-band will be used.

First of all, the antennas radiation patterns for the sub-band are analysed according to the parameter definition (see Sections 6.1.12 and 6.1.13). The values for gain are measured for each frequency in the sub-band, each port, and the whole range of electrical downtilt.

Table 12-10: Complete dataset of gain.

El. Tilt	2.5	2.5	3.0	3.0	4.0	4.0	5.0	5.0	6.0	6.0	7.0	7.0	8.0	8.0	9.0	9.0	10.0	10.0	11.0	11.0	12.0	12.0
Polarization	+45°	-45°	+45°	-45°	+45°	-45°	+45°	-45°	+45°	-45°	+45°	-45°	+45°	-45°	+45°	-45°	+45°	-45°	+45°	-45°	+45°	-45°
1850 MHz	17.7	17.4	17.7	17.4	17.7	17.4	17.7	17.5	17.7	17.5	17.7	17.5	17.6	17.4	17.5	17.3	17.4	17.3	17.3	17.2	17.1	17.1
1880 MHz	17.7	17.6	17.8	17.7	17.8	17.7	17.8	17.6	17.8	17.6	17.7	17.5	17.5	17.4	17.4	17.3	17.3	17.3	17.2	17.2	17.1	17.1
1910 MHz	17.5	17.5	17.5	17.5	17.5	17.4	17.5	17.3	17.5	17.2	17.4	17.2	17.4	17.2	17.4	17.2	17.4	17.2	17.3	17.1	17.3	17.1
1920 MHz	17.5	17.5	17.5	17.4	17.5	17.3	17.5	17.3	17.5	17.2	17.6	17.2	17.6	17.3	17.5	17.2	17.5	17.2	17.4	17.1	17.4	17.1
1930 MHz	17.6	17.4	17.6	17.4	17.6	17.3	17.6	17.3	17.6	17.3	17.7	17.3	17.7	17.3	17.6	17.3	17.6	17.2	17.5	17.2	17.5	17.2
1950 MHz	17.6	17.4	17.6	17.4	17.7	17.4	17.8	17.4	17.8	17.4	17.9	17.4	17.8	17.4	17.8	17.3	17.7	17.2	17.7	17.2	17.5	17.1
1960 MHz	17.6	17.5	17.6	17.5	17.7	17.5	17.8	17.5	17.8	17.5	17.8	17.5	17.8	17.5	17.8	17.4	17.7	17.3	17.6	17.2	17.4	17.1
1980 MHz	17.7	17.7	17.7	17.6	17.7	17.6	17.7	17.6	17.7	17.5	17.7	17.5	17.6	17.5	17.6	17.4	17.5	17.3	17.3	17.1	17.0	16.9
1990 MHz	17.8	17.7	17.7	17.7	17.7	17.6	17.7	17.6	17.6	17.5	17.5	17.5	17.5	17.4	17.4	17.3	17.3	17.2	17.1	17.0	17.0	16.9

The distribution of the set of measured values is finally analysed to determine the specification:

- The array containing all the values above counts 198 elements (9 frequencies x 11 tilts x 2 polarizations).
- The minimum value is 16.9 dBi and the maximum is 17.9 dBi. The mean is the sum of all the elements in magnitude divided by 198 and then reconverted in dB.

The proportion **(198 – 1) : 100 = (x – 1) : 6.7** solved by x, returns **x = 14.2**. Where x is the array index of the 6.7th percentile.

The proportion **(198 – 1) : 100 = (x – 1) : 93.3** solved by x, returns **x = 184.8**. Where x is the array index of the 93.3rd percentile.

- Once the array is sorted in ascending fashion, it can be seen that the 14th (index = 14) and 15th elements are both is 17.1 dBi, while the 184th and 185th are both 17.8 dBi.
- Clearly, the “mean + tolerance” value is 17.8 dBi, while “mean - tolerance” value is 17.1 dBi.
- The modulus of the differences of the two values from the mean is respectively: 0.3 dB and 0.4 dB, **therefore the tolerance is their average, which is 0.3 dB**.

Table 12-11: Summary of gain statistics, over all tilts, 1850-1990 MHz.

Gain over all tilts	# Array elements	Min	Max	Mean	Tolerance
1850-1990 MHz	198	16.9 dBi	17.9 dBi	17.5 dBi	0.3 dBi

The specification is set by the rounding of the mean value to 17.5 dBi and the rounding of the tolerance to 0.3 dB:

Type: Distribution-based	**All ports**	**1850-1990 MHz**
Gain	**Over all tilts**	17.5 dBi, tolerance ± 0.3 dBi

As previously state, in this example, the gain over all tilts has only been calculated for one sub-band (1850-1990 MHz).
This procedure has to be repeated two additional times to populate the full specification table for the parameter:

Type: Distribution-based	All ports	1710-1880 MHz	1850-1990 MHz	1920-2170 MHz
Gain	**Over all tilts**	17.4 dBi Tolerance ± 0.2 dBi	17.5 dBi Tolerance ± 0.3 dBi	17.9 dBi Tolerance ± 0.3 dBi

Below a table of the whole gain specification:

Type: Distribution-based	All ports	1710-1880 MHz	1850-1990 MHz	1920-2170 MHz
Gain	**0° Tilt**	17.1 dBi	17.4 dBi	17.7 dBi
	5° Tilt	17.3 dBi	17.5 dBi	17.7 dBi
	10° Tilt	17.0 dBi	17.0 dBi	17.2 dBi
	Over all tilts	17.4 dBi Tolerance ± 0.2 dBi	17.5 dBi Tolerance ± 0.3 dBi	17.9 dBi Tolerance ± 0.3 dBi

For the purpose of this publication, it is instructive to show the plotted gain over all tilts values as a function of frequency, and the distribution of the calculated values in a histogram. These plots are shown below:

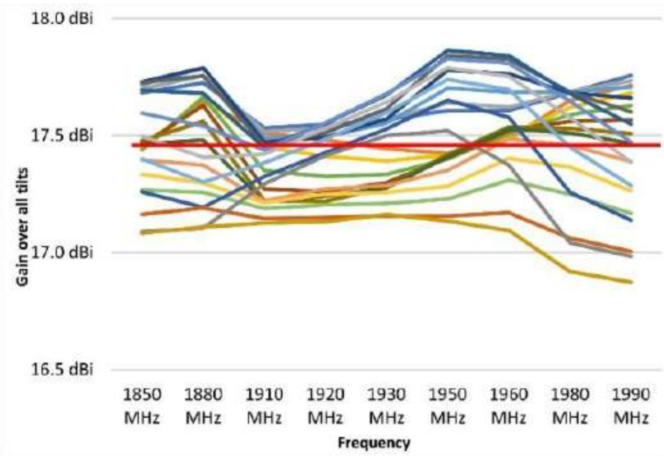


Figure 12.19: Gain for each tilt and port as a function of the frequency.

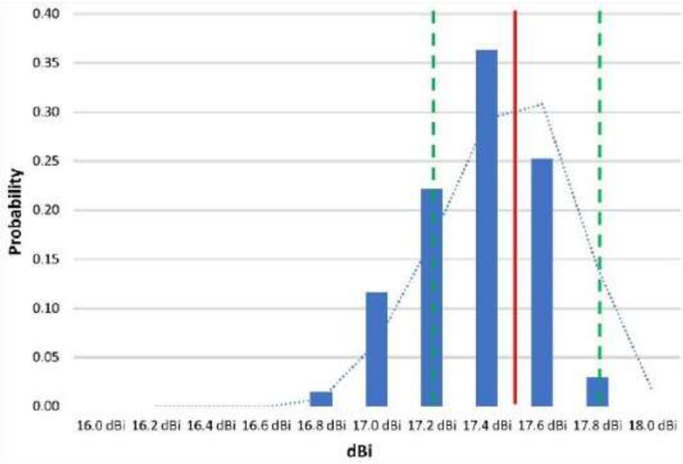


Figure 12.20: Gain histogram.

The repeatability margin value of 0.8 dB is graphed below:

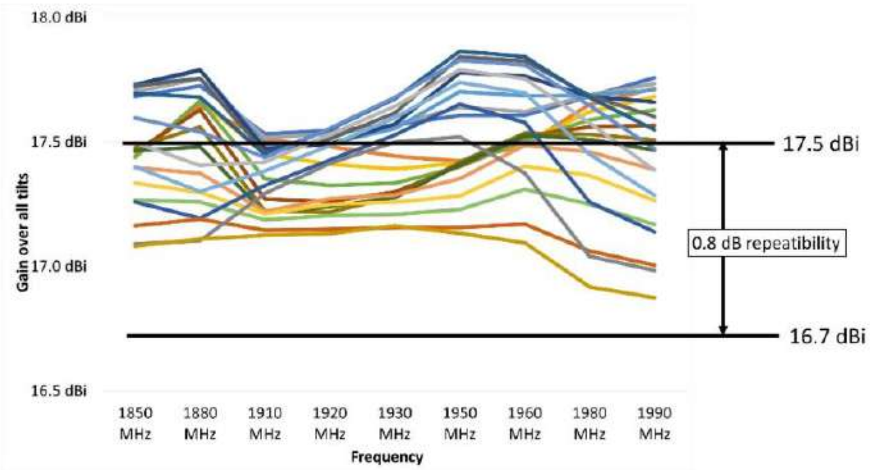


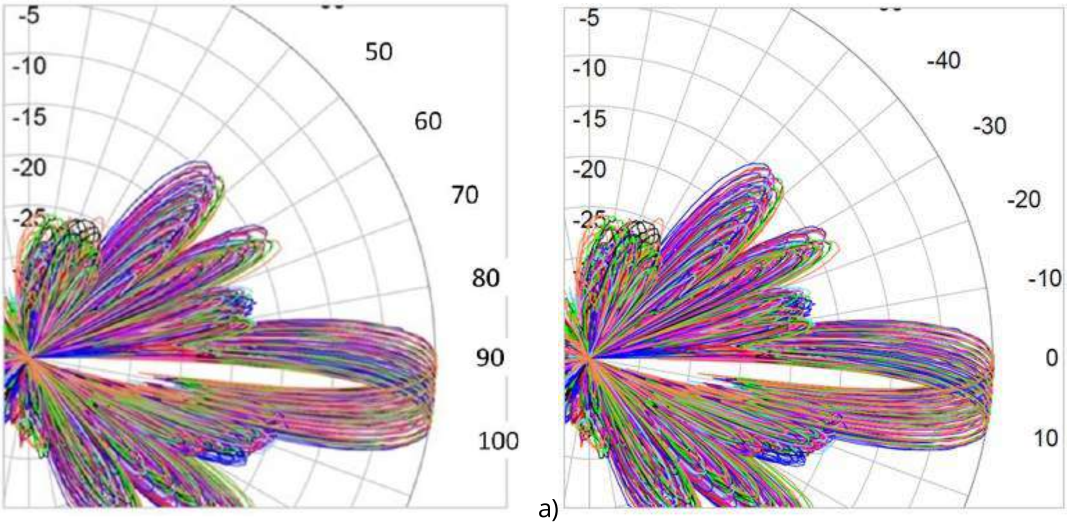
Figure 12.21: Gain plot with repeatability margin.

The histogram above shows well that the distribution of the values is not Gaussian, even if the tolerance incorrectly calculated as 1.5 * σ would have had the same value of 0.3 dB.

12.7 Validation of Elevation Downtilt Deviation

For this example of the validation process, the calculation of the elevation downtilt deviation specification in the antenna sub-bands of 1710-1880 MHz, 1850-1990 MHz, and 1920-2170 MHz will be used.

First of all, the antennas radiation patterns for the sub-bands are analysed according to the parameter definition (see Section 7.2.8.2). The values for the real electrical downtilt are measured (see Section 7.2.7) for each frequency in the sub-band, each port, and the whole range of electrical downtilt.



a) b)

Figure 12.22: Elevation pattern plots – 1710-1880 MHz, all ports, and all tilts. a) SPCS_Polar, b) SPCS_CW

For each tilt angle, the real elevation electrical downtilt is compared to its nominal value, and the absolute maximum differences (deviations) between those two are calculated:

Table 12-12: Complete dataset elevation downtilt deviation.

Measured beam peak value

Absolute deviation from nominal tilt setting

	1710 MHz	1732,5 MHz	1747,5 MHz	1755 MHz	1785 MHz	1805 MHz	1842,5 MHz	1850 MHz	1880 MHz	1910 MHz	1920 MHz	1930 MHz	1950 MHz	1960 MHz	1980 MHz	1990 MHz	2110 MHz	2132,5 MHz	2140 MHz	2155 MHz	2170 MHz
Electrical tilt [°], port 1																					
EDT 0°	-0,3	-0,3	-0,3	-0,3	-0,3	-0,4	-0,3	-0,4	-0,4	-0,4	-0,3	-0,3	-0,3	-0,5	-0,5	-0,5	-0,4	-0,4	-0,4	-0,4	-0,4
Nominal dev.	0,3	0,3	0,3	0,3	0,3	0,4	0,3	0,4	0,4	0,4	0,3	0,3	0,3	0,5	0,5	0,5	0,4	0,4	0,4	0,4	0,4
EDT 1°	-1,4	-1,5	-1,5	-1,7	-1,7	-1,5	-1,4	-1,6	-1,6	-1,3	-1,2	-1,2	-1,2	-1,5	-1,5	-1,3	-1,2	-1,3	-1,4	-1,4	-1,4
Nominal dev.	0,4	0,5	0,5	0,7	0,7	0,5	0,4	0,6	0,6	0,3	0,2	0,2	0,2	0,5	0,5	0,3	0,2	0,3	0,4	0,4	0,4
EDT 2°	-2,3	-2,4	-2,4	-2,7	-2,7	-2,5	-2,4	-2,6	-2,6	-2,2	-2,2	-2,2	-2,2	-2,5	-2,5	-2,3	-2,2	-2,2	-2,2	-2,2	-2,0
Nominal dev.	0,3	0,4	0,4	0,7	0,7	0,5	0,4	0,6	0,6	0,2	0,2	0,2	0,2	0,5	0,5	0,3	0,2	0,2	0,2	0,2	0,0
EDT 3°	-3,1	-3,2	-3,2	-3,4	-3,4	-3,3	-3,2	-3,5	-3,5	-3,1	-3,3	-3,3	-3,3	-3,4	-3,4	-3,3	-3,3	-3,3	-3,3	-3,3	-3,1
Nominal dev.	0,1	0,2	0,2	0,4	0,4	0,3	0,2	0,5	0,5	0,1	0,3	0,3	0,3	0,4	0,4	0,3	0,3	0,3	0,3	0,3	0,1
EDT 4°	-4,1	-4,3	-4,3	-4,4	-4,4	-4,4	-4,3	-4,4	-4,4	-4,2	-4,3	-4,3	-4,3	-4,2	-4,2	-4,2	-4,3	-4,3	-4,2	-4,2	-4,3
Nominal dev.	0,1	0,3	0,3	0,4	0,4	0,4	0,3	0,4	0,4	0,2	0,3	0,3	0,3	0,2	0,2	0,2	0,3	0,3	0,2	0,2	0,3
EDT 5°	-5,1	-5,3	-5,3	-5,2	-5,2	-5,3	-5,3	-5,2	-5,2	-5,3	-5,4	-5,4	-5,4	-5,1	-5,1	-5,1	-5,2	-5,1	-4,9	-4,9	-5,2
Nominal dev.	0,1	0,3	0,3	0,2	0,2	0,3	0,3	0,2	0,2	0,3	0,4	0,4	0,4	0,1	0,1	0,1	0,2	0,1	0,1	0,1	0,2
EDT 6°	-5,9	-6,0	-6,0	-5,9	-5,9	-6,0	-6,2	-6,0	-6,0	-6,2	-6,3	-6,3	-6,3	-5,9	-5,9	-6,0	-6,1	-6,2	-6,0	-6,0	-6,3
Nominal dev.	0,1	0,0	0,0	0,1	0,1	0,0	0,2	0,0	0,0	0,2	0,3	0,3	0,3	0,1	0,1	0,0	0,1	0,2	0,0	0,0	0,3
EDT 7°	-6,8	-6,8	-6,8	-6,7	-6,7	-6,9	-7,0	-6,9	-6,9	-7,1	-7,2	-7,2	-7,2	-6,8	-6,8	-6,9	-7,0	-7,1	-6,9	-6,9	-7,1
Nominal dev.	0,2	0,2	0,2	0,3	0,3	0,1	0,0	0,1	0,1	0,1	0,2	0,2	0,2	0,2	0,2	0,1	0,0	0,1	0,1	0,1	0,1
EDT 8°	-8,0	-8,0	-8,0	-7,8	-7,8	-8,0	-8,1	-8,0	-8,0	-8,1	-8,0	-8,0	-8,0	-7,8	-7,8	-7,8	-7,9	-8,0	-7,8	-7,8	-7,9
Nominal dev.	0,0	0,0	0,0	0,2	0,2	0,0	0,1	0,0	0,0	0,1	0,0	0,0	0,0	0,2	0,2	0,2	0,1	0,0	0,2	0,2	0,1
Electrical tilt [°], port 2																					
EDT 0°	-0,3	-0,3	-0,3	-0,3	-0,3	-0,4	-0,3	-0,3	-0,3	-0,2	-0,2	-0,2	-0,2	-0,4	-0,4	-0,3	-0,3	-0,3	-0,3	-0,3	-0,3
Nominal dev.	0,3	0,3	0,3	0,3	0,3	0,4	0,3	0,3	0,3	0,2	0,2	0,2	0,2	0,4	0,4	0,3	0,3	0,3	0,3	0,3	0,3
EDT 1°	-1,3	-1,4	-1,4	-1,7	-1,7	-1,5	-1,3	-1,3	-1,3	-1,0	-1,2	-1,2	-1,2	-1,5	-1,5	-1,2	-1,1	-1,2	-1,2	-1,2	-1,1
Nominal dev.	0,3	0,4	0,4	0,7	0,7	0,5	0,3	0,3	0,3	0,0	0,2	0,2	0,2	0,5	0,5	0,2	0,1	0,2	0,2	0,2	0,1
EDT 2°	-2,1	-2,3	-2,3	-2,6	-2,6	-2,4	-2,3	-2,3	-2,3	-1,9	-2,1	-2,1	-2,1	-2,4	-2,4	-2,1	-2,0	-2,0	-2,1	-2,1	-1,9
Nominal dev.	0,1	0,3	0,3	0,6	0,6	0,4	0,3	0,3	0,3	0,1	0,1	0,1	0,1	0,4	0,4	0,1	0,0	0,0	0,1	0,1	0,1
EDT 3°	-2,8	-3,0	-3,0	-3,3	-3,3	-3,2	-3,1	-3,1	-3,1	-2,8	-3,1	-3,1	-3,1	-3,2	-3,2	-3,0	-3,0	-3,0	-3,1	-3,1	-2,9
Nominal dev.	0,2	0,0	0,0	0,3	0,3	0,2	0,1	0,1	0,1	0,2	0,1	0,1	0,1	0,2	0,2	0,0	0,0	0,0	0,1	0,1	0,1
EDT 4°	-4,0	-4,2	-4,2	-4,3	-4,3	-4,3	-4,2	-4,2	-4,2	-4,1	-4,2	-4,2	-4,2	-4,1	-4,1	-4,1	-4,2	-4,2	-4,1	-4,1	-4,1
Nominal dev.	0,0	0,2	0,2	0,3	0,3	0,3	0,2	0,2	0,2	0,1	0,2	0,2	0,2	0,1	0,1	0,1	0,2	0,2	0,1	0,1	0,1
EDT 5°	-5,0	-5,1	-5,1	-5,1	-5,1	-5,3	-5,3	-5,2	-5,2	-5,3	-5,2	-5,2	-5,2	-4,9	-4,9	-5,0	-5,2	-5,1	-4,9	-4,9	-5,1
Nominal dev.	0,0	0,1	0,1	0,1	0,1	0,3	0,3	0,2	0,2	0,3	0,2	0,2	0,2	0,1	0,1	0,0	0,2	0,1	0,1	0,1	0,1
EDT 6°	-5,8	-5,9	-5,9	-5,9	-5,9	-6,0	-6,2	-6,0	-6,0	-6,2	-6,2	-6,2	-6,2	-5,8	-5,8	-6,0	-6,2	-6,2	-6,0	-6,0	-6,1
Nominal dev.	0,2	0,1	0,1	0,1	0,1	0,0	0,2	0,0	0,0	0,2	0,2	0,2	0,2	0,2	0,2	0,0	0,2	0,2	0,0	0,0	0,1
EDT 7°	-6,8	-6,9	-6,9	-6,8	-6,8	-7,0	-7,1	-7,0	-7,0	-7,1	-7,1	-7,1	-7,1	-6,8	-6,8	-7,0	-7,1	-7,1	-7,0	-7,0	-7,1
Nominal dev.	0,2	0,1	0,1	0,2	0,2	0,0	0,1	0,0	0,0	0,1	0,1	0,1	0,1	0,2	0,2	0,0	0,1	0,1	0,0	0,0	0,1
EDT 8°	-8,0	-8,1	-8,1	-7,9	-7,9	-8,0	-8,1	-8,0	-8,0	-8,1	-8,0	-8,0	-8,0	-7,9	-7,9	-7,8	-7,9	-8,0	-7,9	-7,9	-7,9
Nominal dev.	0,0	0,1	0,1	0,1	0,1	0,0	0,1	0,0	0,0	0,1	0,0	0,0	0,0	0,1	0,1	0,2	0,1	0,0	0,1	0,1	0,1

Note that the downtilts (real ones are those not marked in grey in the table above, nominal ones are those in the first column beside the "EDT" labels) shall be referenced to the mechanical boresight.
Below an example on how to calculate the deviation of a tilt from its nominal value:

EDT 7°	-6,8
Nominal dev.	0,2

At the 7° nominal electrical downtilt setting (EDT), the beam peak measures 6.8° (the minus indicates, in this table, only the fact that the beam is tilting down in respect to the horizon). Thus the deviation of the beam tilt is:

$$| \text{Nominal tilt} - \text{Real tilt} | = | 7° - 6.8° | = | 0.2° | = 0.2°$$

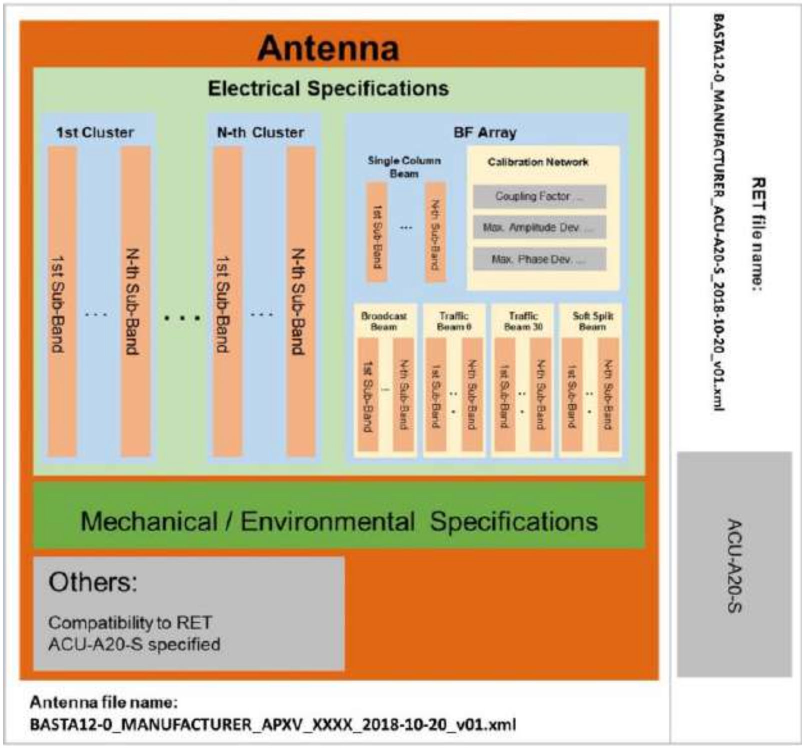
Once the complete dataset of deviations is obtained, the distribution of the parameter is analysed to calculate the specification. This is done no differently than the example in Section 4.4.6 for single-sided maximum parameters.

Type: Distribution-based	**1710-1880 MHz**	**1850-1990 MHz**	**1920-2170 MHz**
Elevation Downtilt Deviation	< 0.5°	< 0.4°	< 0.4°

12.8 Guidance on Specifications Provided in Radio Planning Files

RF planning tool data file formats shall follow the same frequency and downtilt recommendations illustrated in this document, preferably to the recommended frequencies specified in Section11.2.1. The gain parameter present in each pattern's data file shall be equal to the actual measured gain determined when the pattern was taken. Note that this procedure is different from what already specified for the gain parameter.

13 Annex D: Logical Block Structure (Antenna+RET)



14 Annex E: File Format for 3D Radiation Patterns

This section describes the file format for interchanging the antenna radiation pattern data. The file format is thought to represent the antenna radiation pattern independently by the antenna typology, passive or active. The file format described here is also suitable for describing the envelope radiation pattern.
The available coordinate systems for using this radiation pattern file format are described in Section 4; the adopted Coordinate System shall be declared in the header section - see Section 14.2.
Any deviation shall be reported in the headers of radiation pattern file format in the optional set of information – see Section 14.2.

Radiation pattern data is coded into file by using the JSON data-interchange format (see https://www.json.org/json-en.html).

14.1 File naming

The file name is constructed by fields separated by the symbol underscore "_". Each field shall contain only the characters: alphanumeric (0-9, a-z, A-Z), hash (ASCII 35), dash (ASCII 45), dot (ASCII 46). The following set of fields shall be included in the file name for easy file selection, according to the order given in the bulleted list below:

- Manufacturer: the name of the Manufacturer of the Antenna (example: TheCompanyName)
- Antenna Model: the name the Manufacturer has given to the antenna (example: Antenna1)
- Frequency: frequency is reported in units of MHz (example: 3700 for 3.7 GHz, 2569.8 for 2.5698 GHz, 0.1 for 100 kHz). No limits on the decimals.
- Beam identification for the radiation pattern, a selection of:
  - Letter "E" for Envelope Radiation Pattern followed by the beam ID (example: E123 is an envelope pattern whose ID is 123)
  - Letter "B" for Beam Radiation Pattern followed by the beam ID (example: B456 is a beam whose ID is 456)
  - Code "A-" (reference to the AISG Colour Code – see [41]) for a Passive Antenna Radiation Pattern then followed by
    - the ARRAY ID built as a concatenated string which consists of the first letter of the appropriate colour (R, Y, G, B, P) and a unique number within each colour.
    - the RF port number as defined in [41] RFp followed by 2 digits for port number

    Example:
    - A-Y1_RFp07
    - A-R3_RFp02
- Tilt coded as T followed by 2 digits tilt followed by a p (p stands for plus – downtilt) or m (m stands for minus - uptilt) followed by 1 digit for decimals (example: T02p1 stands for 2.1° downtilt, T02m1 stands for 2.1° uptilt).
  Note – downtilt means the direction down from the horizon.
- Pan – [Optional information] - coded as Pan followed by 2 digits followed by p or m (plus or minus, according to the respective coordinate system), followed by 1 digit for decimal (example: Pan12p6 stands for 12.6° Pan).
  Note – Pan means the left and right direction in horizontal plane.
- Nominal Polarization: allowed codification for polarization is listed below (corresponding to Table 14-1: Mandatory Information Lines at row "Nominal_Polarization")
  - Total: in the case the pattern is not related to a specific polarization
  - P45: for Positive 45 angles
  - M45: for Negative 45 angles

- P45M45: for Positive 45 angles and Negative 45 angles
- M45P45: for Negative 45 angles and Positive 45 angles
- H: for Linear Horizontal
- V: for Linear Vertical
- HV: for Linear Horizontal and Linear Vertical
- VH: for Linear Vertical and Linear Horizontal
- RHC: for Right Hand Circular
- LHC: for Left Hand Circular
- P###: for Positive ### angles
- M###: for Negative ### angles
- P###-M###: for Positive ### angles and Negative ### angles
- M###-P### for Negative ### angles and Positive ### angles

"Note - ### stands for any integer value of angles in degrees (max. 3 digits)"

- Optional Information
    - PeakPosition:
        - the code "Th" for elevation followed by
        - the integer elevation position followed by
        - the character "p" for positive or "m" for negative followed by
        - 1 decimal digit followed by
        - "-" followed by
        - the code "Ph" for azimuth followed by
        - the integer azimuth position followed by
        - the character "p" for positive or "m" for negative followed by
        - 1 decimal digit

      example Peak position at Theta = 91.5, Phi 340.7 is coded as
      Th91p5-Ph340p7 in SPCS Polar
      Th1p5-Ph19m3 in SPCS_CW
    - Extra Information (optional): optional field the manufacturer may add to provide extra information (example: ThisIsAnExtraInformation)

  File extension: "_3drp.json".

Note – Double polarization codes (e.g. M45P45, P45M45, HV, VH, P###M### and M###P###) could be used for Active Antenna systems in the case there is not confusion in the description of the polarization in the Radiation Pattern data file. For Passive Antenna Systems each polarization is described in a specific radiation pattern data file.

Examples:

- An active antenna working at 700.5 MHz, Envelope Radiation Pattern ID 123, both +45° and -45° polarizations

TheCompanyName_Antenna1_700.5_E123_P45M45_3drp.json

- The same as in example 1) with an extra optional information,

TheCompanyName_Antenna1_700.5_E123_P45M45_ThisIsAnExtraInformation_3drp.json

- An active antenna working at 2.5 GHz, Beam Radiation Pattern ID 123, total pattern not related to a specific polarization, including an optional extra information

TheCompanyName_Antenna1_2500_B123_Total_ThisIsAnExtraInformation_3drp.json

- A passive antenna working at 934.7 MHz, Array ID no. R5, RF port no. 7, 3.5° uptilt, RHC polarization, including an optional extra information

TheCompanyName_Antenna1_934.7_A-R5_RFp07_T03m5_RHC_ThisIsAnExtraInformation_3drp.json

- A passive antenna working at 934.7 MHz, Array ID no. R5, RF port no. 7, 3.5° uptilt, Pan -45.4°, , including an optional extra information

TheCompanyName_Antenna1_934.70_A-R5_RFp07_T03m5_Pan45m4_ThisIsAnExtraInformation_3drp.json

- A passive antenna working at 934.7 MHz, Array ID no. R5, RF port no. 7, 3.5° uptilt, Pan -45.4°, including an optional extra information and beam peak position

TheCompanyName_Antenna1_934.70_A-R5_RFp07_T03m5_Pan45m4_ThisIsAnExtraInformation_Th91p5-Ph340p7**_3drp.json**

14.2 File content

File content consists of an unordered set of information lines:

- each information line consists of a name/value pair;
- an information line can be either mandatory or optional:
    - the name of a mandatory information line (see Table 14-1, first column) cannot be changed
    - a mandatory information line shall be present even if its value, in the name/value pair, is empty
    - empty values shall be coded with the keyword null according to the JSON format.
    - optional name/value pair can be added by the manufacturer

Optional_Comment	Any comment the manufacturer wants to include	String or numerical data	"Optional_Comment": "any comment"

- o the name of an optional information line shall be different than the names of any mandatory information lines
- o any optional information line shall be placed before the "Data_Set_Row_Structure" mandatory information line, see Table 14-1: Mandatory Information Lines

- names in the name/value pairs are case-sensitive.

Each information line is mapped into an object consisting of a name/value pair according to the JSON (JavaScript Object Notation) data-interchange format (https://www.json.org/).

The radiation pattern data are given in the angular coordinates depending on the selected SPCS as defined in Section 2.2. For brevity, these are here forth referred to by their symbol names Theta and Phi.

Table 14-1: Mandatory Information Lines

Name	Description	Type	JSON example
BASTA_WP_version	BASTA WP version in which the .3drp format is referred to. This is useful for maintaining the coherence of the file content to the relevant WP version	String	"BASTA_WP_version": "3.0"
Supplier	The name of the manufacturer or supplier	String	"Supplier": "ACME Inc."
Antenna_Model	The model of the antenna as defined by the manufacturer	String	"Antenna_Model": "BeepBeep"
Antenna_Type	Allowed values are: Active, Passive, Hybrid	String	"Antenna_Type": "Active"
Revision_Version	The version of the file as defined by the antenna manufacturer	String	"Revision_Version": "1.2.3a"
Released_Date	The release date of the file. The date is reported in [15] format: 4 digits for the year followed by a dash, 2 digits for the month (01 to 12) followed by a dash and 2 digits for the day (01 to 31)	String	"Released_Date": "2021-12-31"
Coordinate_System	The adopted Coordinate System for the representation of angles in the file format as defined in Section 2.2 Allowed keywords are: • SPCS_Polar • SPCS_CW • SPCS_CCW • SPCS_Geo	String	"Coordinate_System": "SPCS_CCW"
Pattern_Name	The name the manufacturer gives to the pattern. 'null' in case of passive antennas	String	"Pattern_Name": "BB_01" "Pattern_Name": null
Beam_ID	Beam Identification code the manufacturer gives to the beam. If there is no ID use the keyword null	String	"Beam_ID": "ID12345" "Beam_ID": null
Pattern_Type	Allowed values are: Broadcast Beam Broadcast Configuration Envelope Traffic Beam	String	"Pattern_Type": "Traffic Envelope" "Pattern_Type": "Generic"

	Traffic Envelope Uplink Generic (it is used for non-specific radiation patterns, as an example for passive antennas)		

Frequency	The pattern frequency and the associated unit.
	Allowed units are:
	Hz
	kHz
	MHz
	GHz
	THz
		Object:
		Float (value)
		String (unit)
			"Frequency": {
			"value": 3.126,
			"unit": "GHz"
			}

Frequency_Range	The frequency range (lower bound, the frequency upper bound and the associated unit) within which data in the file are valid.
	Allowed units are:
	Hz
	kHz
	MHz
	GHz
	THz
	If Frequency_Range is not present null shall be used.
		Object:
		Float (lower)
		Float (upper)
		String (unit)
			"Frequency_Range": {
			"lower": 2145.8,
			"upper": 3280.0,
			"unit": "MHz"
			}
			"Frequency_Range": null

EIRP	The maximum EIRP value and the associated unit.
	Allowed units are:
	mW
	W
	dBW
	dBm
	If populated, the Configured_Output_Power shall be populated with the power whose EIRP is referred to.
	If EIRP cannot be indicated (e.g. for Passive Antennas) null shall be used
		Object:
		Float (value)
		String (unit)
			"EIRP": {
			"value": 5.0,
			"unit": "W"
			}
			"EIRP": null

Configured_Output_Power	The configured output power the EIRP is referred to. Allowed units are:	Object:	"Configured_Output_Power": {

	mW W dBW dBm If EIRP is not populated, null shall be used	Float (value) String (unit)	"value": 5.0, "unit": "dBm" } "Configured_Output_Power": null

Gain	The gain and the associated unit.
	Allowed units are:
	dBi
	dBd
	If not populated null shall be used, and both EIRP and Configured_Output_Power shall be populated
		Object:
		Float (value)
		String (unit)
			"Gain": {
			"value": 5.0,
			"unit": "dBi"
			}
			"Gain": null

Peak_Position	The position of the peak, for single peak radiation pattern, or the positions of the peaks for multi peak radiation pattern, on the elevation and azimuth directions. Values depend on the adopted Coordinate System. Exact peak position(s) could not be included in the radiation Pattern data set depending on the sampling step used.
	
	The values of peak position are provided as object, while these corresponds to the highest peak values of theta and phi, in elevation and azimuth.
	
	When values are provided for multi peak antennas, where more than one peak position is identified, values are provided as object, and the order of the peak values in theta and phi related to each peak position in the radiation pattern, are correctly identified according to the coordinate system. The unit is in degrees.
	
	- If the Data_Set_Row_Structure mandatory field (see below) contains:
	o the keyword "MagAttenuationTP" then the position on the Total Power radiation pattern is intended.
	o Both the keywords "MagAttenuationCo" and "MagAttenuationCR", then the position on the Total Power radiation pattern is intended.
		Object	Single peak radiation pattern:
			"Peak_Position":{
			"Theta": [92.5],
			"Phi": [15.1]
			},
			
			Multi peak radiation pattern:
			"Peak_Position": {
			"Theta": [92.5, 93.5],
			"Phi": [15.1, 105.7]
			},

	 ○ Only the keyword "MagAttenuationCo" then the position on the CoPolar Radiation Pattern is intended. ○ Only the keyword "MagAttenuationCr" then the position on the CrossPolar Radiation Pattern is intended.		
Configuration	The configuration of the Active Antenna which the radiation pattern refers to. Use null for Passive Antennas	String	"Configuration": "TNT_01" "Configuration": null
RF_Port	The RF port name given by the manufacturer, according to the AISG Standard [41] Use null for Active Antennas	String	"RF_Port": "5" "RF_Port": null
Array_ID	Codification of the Array ID according to the AISG Standard. Use null for Active Antennas	String	"Array_ID": "Y1" "Array_ID": null
Array_Position	Codification of the Array Position according to the AISG Standard [41] Use null for Active Antennas or single column passive	String	"Array_Position": "CR" "Array_Position": null
Phi_HPBW	Half-Power BeamWidth on the azimut plane at the maximum gain position. Unit: degrees	Float	"Phi_HPBW": 65.0
Theta_HPBW	Half-Power BeamWidth on the elevation plane at the maximum gain position. Unit: degrees	Float	"Theta_HPBW": 5.0
Front_to_Back	Minimum attenuation relative to “Gain” along the backside direction, in Theta angle range +/-30° and in Phi angle range +/-30°. Unit: dB	Float	"Front_to_Back": 10.0
Phi_Pan	The pan on the azimuth plane; value depends on the adopted Coordinate System, see Section 4. Unit: degrees If Phi_Pan is not present null shall be used.	Float	"Phi_Pan": 30.0 "Phi_Pan": null
Theta_Tilt	The tilt on the elevation plane with respect to the horizontal direction. Value depends on the adopted Coordinate System Unit: degrees	Float	"Theta_Tilt": 10.0 "Theta_Tilt": null

	If Theta_Tilt is not present null shall be used.		
Nominal_Polarization	The nominal polarization(s) the pattern is referred to. Depending on how many polarizations are contained in the data section, the following values are allowed: Total: in the case the pattern is not related to a specific polarization P45: for Positive 45° M45: for Negative 45° P45M45: for Positive 45° and Negative 45° M45P45: for Negative 45° and Positive 45° H: for Linear Horizontal V: for Linear Vertical HV: for Linear Horizontal and Linear Vertical VH: for Linear Vertical and Linear Horizontal RHC: for Right Hand Circular LHC: for Left Hand Circular P###: for Positive ### angles M###: for Negative ### angles P###M###: for Positive ### angles and Negative ### angles M###P### for Negative ### angles and Positive ### angles Note ### stands for any integer value of angles in degrees (max. 3 digits)”	String	"Nominal_Polarization": "P45"
Theta_Sampling	Theta angles the pattern is sampled at. The format is as follows, according to sampling format: uniform sampling: start angle, step angle, stop angle; values are in degrees. non-uniform sampling: null; Theta angle must be provided in Data_Set; Phi_Sampling shall be null as well. Value depends on the adopted Coordinate System, see Section 5 Unit: degrees	3-element float array	Theta_Sampling": [-90.0, 1.0, 90.0] "Theta_Sampling": null

Phi_Sampling	Phi angles the pattern is sampled at. The format is as follows, according to sampling format:: uniform sampling: start angle, step angle, stop angle; values are in degrees. non-uniform sampling: null; Phi angle must be provided in Data_Set; Theta_Sampling shall be null as well. Value depends on the adopted Coordinate System, see Section 5 Unit: degrees	3-element float array	"Phi_Sampling": [0.0, 1.0, 359.0] "Phi_Sampling": null
Nominal_Sector_Phi	See Definition in Section 7.3.2 Unit: degrees	Float	"Nominal_Sector_Phi": 120.0
Nominal_Direction	A two-value array in which the first value is the elevation nominal direction and the second value is the azimuth Nominal direction. Value depends on the adopted Coordinate System, see Section 5. Units: degrees	2-element array	"Nominal_Direction": [92.0,30.0] "Nominal_Direction": null
Data_Set_Row_Structure	The list of elements in each row of Data_Set: angular elements if Theta_Sampling and Phi_Sampling are null: "Theta","Phi" if Theta_Sampling and Phi_Sampling are not null angles can be omitted radiation pattern elements - a selection of position-independent strings: "MagAttenuationTP" for Total Power magnitude "MagAttenuationCo" for CoPolar component magnitude "MagAttenuationCr" for CrossPolar component magnitude "PhaseCo" for CoPolar component phase "PhaseCr" for CrossPolar component phase Attenuation is given in dB (positive with respect to maximum EIRP or Gain) and phase is given in degrees (see Note 1).	Array of strings	If Theta_Sampling and phi_Sampling are null: ["Theta", "Phi", "MagAttenuationCo", "PhaseCo"] If Theta_Sampling and Phi_Sampling are not null: ["MagAttenuationCo", "PhaseCo"]

Data_Set	Radiation Pattern matrix built as follows:
	[
	[data set row 1],
	[data set row 2]
	…
	]
	
	where the content of each row is described by Data_Set_Row_Structure.
	
	If angles Theta and phi are omitted in the data set row, radiation pattern elements shall be provided by scanning the sphere according to the following rule:
	for (Theta=start;step;stop){
	for (Phi=start;step;stop){
	radiation pattern elements
	}
	}
	where start, step and stop are given by Theta_Sampling and Phi_Sampling.
	
	Note: Any order for angle representation, uniform or not, is allowed. Ordered data as in the side example is recommended, if possible.
		Array of arrays	If Theta_Sampling and Phi_Sampling are null and with reference to the Data_Set_Row_Structure example given above:
			[
			[-90.,0.,0.1,10.],
			[-90.,3.,0.6,15.],
			…
			[-86.,0.,0.1,10.],
			[-86.,9.,0.6,15.],
			[-86.,10.,0.6,15.],
			]
			
			If Theta_Sampling and Phi_Sampling are not null and with reference to the Data_Set_Row_Structure example given above:
			[
			[0.1,10.],
			[0.6,15.],
			…
			]

NOTE 1: To convert from MagAttenuation and Phase to linear relative Far Field (FF) use $F = 10^{-MagAttenuation/10} e^{j\,Phase\,\pi/180}$ where is the $|FF|^2$ | the relative gain.

14.3 JSON File Format Examples

Numerical data contained in the following examples and in the accompanying data files (include here the link to BASTA repository) are only for showing the _3drp.json file format, so not corresponding to real or realistic radiation patterns.

14.3.1 Passive Antenna Uniform Sampling Example

File Name : VENDOR_ANTMODEL2_2100_A-Y1_RFp01_T00p0_P45_UniformSampling_3drp.json


```
{
 "BASTA_WP_version": "13.0",
 "Supplier": "VENDOR",
 "Antenna_Model": "ANTMODEL2",
 "Antenna_Type": "Passive",
 "Revision_Version": "1.0",
 "Released_Date": "2023-05-05",
 "Coordinate_System": "SPCS_CW",
 "Pattern_Name": null,
 "Beam_ID": null,
 "Pattern_Type": "Generic",
 "Frequency": {
  "value": 2100,
  "unit": "MHz"
 },
 "Frequency_Range": null,
 "EIRP": null,
 "Configured_Output_Power": null,
 "Gain": {
  "value": 15.11,
  "unit": "dBi"
 },
 "Peak_Position": {
   “Theta”: [92.5, 93.5],
   “Phi”: [15.1, 105.7]
 },
 "Configuration": null,
 "RF_Port": "01",
 "Array_ID": "Y1",
 "Array_Position": "L",
 "Phi_HPBW": 91.64,
 "Theta_HPBW": 10.8,
 "Front_to_Back": 21.72,
 "Phi_Pan": null,
 "Theta_Tilt": 0,
 "Nominal_Polarization": "P45",
 "Theta_Sampling": [-90.0, 1.0, 90.0],
 "Phi_Sampling": [0.0, 1.0, 359.0],
 “Nominal_Sector_Phi”: 120.0,
```

"Nominal_Direction": [92.0,30.0],
"Optional_Comments": "example of passive antenna; theta and phi of radiation pattern are omitted in Data_Set (uniform sampling)",
"Data_Set_Row_Structure": [
"MagAttenuationCo",
"MagAttenuationCr"
],
"Data_Set": [
[
65.63973311055209,
112.76348938213428
],
[
65.64120737221384,
106.04556131402066
],
[
65.64563443576502,
102.2783015522732
],
[
65.65301291621606,
99.6665197293747
],
[
65.66334051866878,
97.67415975082629
],
[
65.67661406007106,
96.06978747488755
],
......
......
}

14.3.2 Passive Antenna Not Uniform Sampling Example

File Name: VENDOR_ANTMODEL1_2100_A-Y1_RFp01_T00p0_P45_NonUniformSampling_3drp.json

{
"BASTA_WP_version": "13.0",
"Supplier": "VENDOR",
"Antenna_Model": "ANTMODEL1",
"Antenna_Type": "Passive",
"Revision_Version": "1.0",
"Released_Date": "2023-05-05",
"Coordinate_System": "SPCS_CW",

"Pattern_Name": null,
"Beam_ID": null,
"Pattern_Type": "Generic",
"Frequency": {
"value": 2100,
"unit": "MHz"
},
"Frequency_Range": null,
"EIRP": null,
"Configured_Output_Power": null,
"Gain": {
"value": 15.11,
"unit": "dBi"
},
"Peak_Position": {
“Theta”: [92.5, 93.5],
“Phi”: [15.1, 105.7]
},
"Configuration": null,
"RF_Port": "01",
"Array_ID": "Y1",
"Array_Position": "L",
"Phi_HPBW": 91.64,
"Theta_HPBW": 10.80,
"Front_to_Back": 21.72,
"Phi_Pan": null,
"Theta_Tilt": 0.0,
"Nominal_Polarization": "P45",
"Theta_Sampling": null,
"Phi_Sampling": null,
“Nominal_Sector_Phi”: 120.0,
“Nominal_Direction": [92.0,30.0],
"Optional_Comments": "example of passive antenna; theta and phi of radiation pattern are provided in Data_Set (non-uniform sampling)",
"Data_Set_Row_Structure": [
"Theta",
"Phi",
"MagAttenuationCo",
"MagAttenuationCr"
],
"Data_Set": [
[
-90,
0,
65.63973311055209,
112.76348938213428
],
[
-90,
1,

```
    65.64120737221384,
    106.04556131402066
  ],
  [
    -90,
    2,
    65.64563443576502,
    102.2783015522732
  ],
  [
    -90,
    3,
    65.65301291621606,
    99.6665197293747
  ],

......
......
}
```

14.3.3 Active Antenna Uniform Sampling Example

File Name: VENDOR_ANTMODEL4_3700_BID67890_T00p0_P45_UniformSampling_3drp.json

```
{
 "BASTA_WP_version": "13.0",
 "Supplier": "VENDOR",
 "Antenna_Model": "ANTMODEL4",
 "Antenna_Type": "Active",
 "Revision_Version": "1.0",
 "Released_Date": "2023-05-05",
 "Coordinate_System": "SPCS_CW",
 "Pattern_Name": "ThePatternName",
 "Beam_ID": "ID67890",
 "Pattern_Type": "Broadcast Beam",
 "Frequency": {
  "value": 3700,
  "unit": "MHz"
 },
 "Frequency_Range": null,
 "EIRP": null,
 "Configured_Output_Power": null,
 "Gain": {
  "value": 15.11,
  "unit": "dBi"
 },
 "Peak_Position": {
   "Theta": [92.5, 93.5],
```

    “Phi”: [15.1, 105.7]
  },
  "Configuration": null,
  "RF_Port": null,
  "Array_ID": null,
  "Array_Position": null,
  "Phi_HPBW": 91.64,
  "Theta_HPBW": 10.8,
  "Front_to_Back": 21.72,
  "Phi_Pan": 0.0,
  "Theta_Tilt": 0,
  "Nominal_Polarization": "P45",
  "Theta_Sampling": [-90.0, 1.0, 90.0],
  “Nominal_Sector_Phi”: 120.0,
  “Nominal_Direction": [92.0,30.0],
  "Optional_Comments": "example of active antenna; theta and phi of radiation pattern are omitted in Data_Set (uniform sampling)",
  "Data_Set_Row_Structure": [
    "MagAttenuationCo",
    "MagAttenuationCr"
  ],
  "Data_Set": [
    [
      65.63973311055209,
      112.76348938213428
    ],
    [
      65.64120737221384,
      106.04556131402066
    ],
    [
      65.64563443576502,
      102.2783015522732
    ],
    [
      65.65301291621606,
      99.6665197293747
    ],
    [
      65.66334051866878,
      97.67415975082629
    ],
...
}

14.3.4 Active Antenna Not Uniform Sampling Example

FileName: VENDOR_ANTMODEL3_3700_EID12345_T00p0_P45_NonUniformSampling_3drp.json

{
"BASTA_WP_version": "13.0",
"Supplier": "VENDOR",
"Antenna_Model": "ANTMODEL3",
"Antenna_Type": "Active",
"Revision_Version": "1.0",
"Released_Date": "2023-05-05",
"Coordinate_System": "SPCS_CW",
"Pattern_Name": "ThePatternName",
"Beam_ID": "ID12345",
"Pattern_Type": "Traffic Envelope",
"Frequency": {
"value": 3700,
"unit": "MHz"
},
"Frequency_Range": null,
"EIRP": null,
"Configured_Output_Power": null,
"Gain": {
"value": 15.11,
"unit": "dBi"
},
"Peak_Position": {
“Theta”: [92.5, 93.5],
“Phi”: [15.1, 105.7]
},
"Configuration": null,
"RF_Port": null,
"Array_ID": null,
"Array_Position": null,
"Phi_HPBW": 91.64,
"Theta_HPBW": 10.80,
"Front_to_Back": 21.72,
"Phi_Pan": 0.0,
"Theta_Tilt": 0.0,
"Nominal_Polarization": "P45",
"Theta_Sampling": null,
"Phi_Sampling": null,
“Nominal_Sector_Phi”: 120.0,
“Nominal_Direction": [92.0,30.0],
"Optional_Comments": "example of active antenna; theta and phi of radiation pattern are provided in Data_Set (non-uniform sampling)",
"Data_Set_Row_Structure": [
"Theta",
"Phi",
"MagAttenuationCo",
"MagAttenuationCr"
],
"Data_Set": [

```
  [
    -90,
    0,
    65.63973311055209,
    112.76348938213428
  ],
  [
    -90,
    1,
    65.64120737221384,
    106.04556131402066
  ],
  [
    -90,
    2,
    65.64563443576502,
    102.2783015522732
  ],
...
}
```

14.3.5 JSON Schema

The JSON file format used for exchanging the 3D radiation pattern data must comply with both ordinary JSON syntax rules (see https://www.json.org/json-en.html) and the specific NGMN BASTA rules described in Section 14.2.
In order to help validating the formal correctness of a JSON file it is useful to introduce a JSON Schema, which is a declarative language that allows to annotate and validate JSON documents so as to enable the confident and reliable use of the JSON data format (see https://json-schema.org/).
The NGMN BASTA JSON Schema to be used for validating JSON files which describe 3D radiation patterns compliant with the rules detailed in section 15 of current document is made available by NGMN at the following link:

https://ngmn.org/schema/ubastav13/NGMN_BASTA_3drp_schema_WP13_0_latest.json

Among different implementations of JSON file validation against a given schema listed in JSON Schema reference web page (see https://json-schema.org/implementations.html#validators), for convenience an example is presented here for a JSON file whose name is taken from the second example of Section 14.1. It is an example based on the Python Command-Line Interface command check-jsonschema (full documentation can be found at https://check-jsonschema.readthedocs.io/) where the abovementioned NGMN BASTA JSON Schema may be specified as either a local file:

check-jsonschema --schemafile "NGMN_BASTA_3drp_schema_WP13_0_latest.json"
TheCompanyName_Antenna1_700.5_E123_P45M45_ThisIsAnExtraInformation_3drp.json[1]

or as a remote file (HTTP or HTTPS; remote files are automatically downloaded and cached if possible):

[1] check-jsonschema can be installed under basic Python environment with pip install check-jsonschema.

check-jsonschema --no-cache --schemafile
https://ngmn.org/schema/ubastav13/NGMN_BASTA_3drp_schema_WP3_0_latest.json
TheCompanyName_Antenna1_700.5_E123_P45M45_ThisIsAnExtraInformation_3drp.json2[2]

If errors are found, details are provided to help identifying them, if not the output is

ok -- validation done.

14.3.5.1 JSON Schema File Example

The latest release of the JSON Schema can be found in:
https://ngmn.org/schema/ubastav13/NGMN_BASTA_3drp_schema_WP3_0_latest.json

```
{
 "$schema": "http://json-schema.org/draft/2020-12/schema#",

 "type": "object",
 "properties": {
  "BASTA_AA_WP_version": {
   "type": "string"
  },
  "Supplier": {
   "type": "string"
  },
  "Antenna_Model": {
   "type": "string"
  },
  "Antenna_Type": {
   "type": "string"
  },
  "Revision_Version": {
   "type": "string"
  },
  "Released_Date": {
   "type": "string",
   "format": "date"
  },
  "Coordinate_System": {
   "type": "string",
   "enum": [
    "SPCS_Polar",
    "SPCS_CW",
    "SPCS_CCW",
    "SPCS_Geo"
   ]
  },
  "Pattern_Name": {
```

[2] Command to be given on one line only

```
  "type": [
    "string",
    "null"
  ]
},
"Beam_ID": {
  "type": [
    "string",
    "null"
  ]
},
"Pattern_Type": {
  "type": "string",
  "enum": [
    "Broadcast Beam",
    "Broadcast Configuration Envelope",
    "Traffic Beam",
    "Traffic Envelope",
    "Uplink",
    "Generic"
  ]
},
"Frequency": {
  "type": "object",
  "properties": {
    "value": {
      "type": "number",
      "minimum": 0
    },
    "unit": {
      "type": "string",
      "enum": [
        "Hz",
        "kHz",
        "MHz",
        "GHz",
        "THz"
      ]
    }
  },
  "required": [
    "value",
    "unit"
  ]
},
"Frequency_Range": {
  "type": [
    "object",
    "null"
  ],
```

```
  "properties": {
    "lower": {
      "type": "number",
      "minimum": 0
    },
    "upper": {
      "type": "number",
      "minimum": 0
    },
    "unit": {
      "type": "string",
      "enum": [
        "Hz",
        "kHz",
        "MHz",
        "GHz",
        "THz"
      ]
    }
  },
  "required": [
    "lower",
    "upper",
    "unit"
  ]
},
"EIRP": {
  "type": [
    "object",
    "null"
  ],
  "properties": {
    "value": {
      "type": "number"
    },
    "unit": {
      "type": "string",
      "enum": [
        "mW",
        "W",
        "dBW",
        "dBm"
      ]
    }
  },
  "required": [
    "value",
    "unit"
  ]
},
```

"Configured_Output_Power": {
  "type": [
    "object",
    "null"
  ],
  "properties": {
    "value": {
      "type": "number"
    },
    "unit": {
      "type": "string",
      "enum": [
        "mW",
        "W",
        "dBW",
        "dBm"
      ]
    }
  },
  "required": [
    "value",
    "unit"
  ]
},
"Gain": {
  "type": [
    "object",
    "null"
  ],
  "properties": {
    "value": {
      "type": "number"
    },
    "unit": {
      "type": "string",
      "enum": [
        "dBi",
        "dBd"
      ]
    }
  },
  "required": [
    "value",
    "unit"
  ]
},
"Peak_Position": {
  "type": [
    "object",
    "null"

],
"properties": {
"Theta": {
"type": "array",
"minItems": 1,
"items": {
"type": "number"
}
},
"Phi": {
"type": "array",
"minItems": 1,
"items": {
"type": "number"
}
}
},
"required": [
"Theta",
"Phi"
]
},
"Configuration": {
"type": [
"string",
"null"
]
},
"RF_Port": {
"type": [
"string",
"null"
]
},
"Array_ID": {
"type": [
"string",
"null"
]
},
"Array_Position": {
"type": [
"string",
"null"
]
},
"Phi_HPBW": {
"type": "number",
"exclusiveMinimum": 0
},

```
"Theta_HPBW": {
  "type": "number",
  "exclusiveMinimum": 0
},
"Front_to_Back": {
  "type": "number",
  "exclusiveMinimum": 0
},
"Phi_Pan": {
   "type": [
     "number",
     "null"
   ]
},
"Theta_Tilt": {
   "type": [
     "number",
     "null"
   ]
},
"Nominal_Polarization": {
  "anyOf": [
   {
     "type": "string",
     "enum": [
       "Total",
       "P45",
       "M45",
       "P45M45",
       "M45P45",
       "H",
       "V",
       "HV",
       "VH",
       "RHC",
       "LHC"
     ]
   },
   {
     "$comment": "M### or P###M### for Negative|Positive ### angles (### is an integer, max. 3 digits)",
     "type": "string",
     "pattern": "^(P[0-9]{1,3})?M[0-9]{1,3}$"
   },
   {
     "$comment": "P### or M###P### for Positive|Negative ### angles (### is an integer, max. 3 digits)",
     "type": "string",
     "pattern": "^(M[0-9]{1,3})?P[0-9]{1,3}$"
   }
  ]
},
```

```
    "Theta_Sampling": {
      "type": [
        "array",
        "null"
      ],
      "minItems": 3,
      "maxItems": 3,
      "items": {
        "type": "number"
      }
    },
    "Phi_Sampling": {
      "type": [
        "array",
        "null"
      ],
      "minItems": 3,
      "maxItems": 3,
      "items": {
        "type": "number"
      }
    },
  “Nominal_Sector_Phi”: {
  "type": "number",
      "exclusiveMinimum": 0
    },
“Nominal_Direction": {
      "type": [
        "array",
        "null"
      ],
      "minItems": 2,
      "maxItems": 2,
      "items": {
        "type": "number"
      }
},
    "Data_Set_Row_Structure": {
      "type": "array",
      "minItems": 1,
      "maxItems": 7,
      "items": {
        "type": "string",
        "enum": [
          "Theta",
          "Phi",
          "MagAttenuationTP",
          "MagAttenuationCo",
          "MagAttenuationCr",
          "PhaseCo",
```

```
        "PhaseCr"
      ]
    }
  },
  "Data_Set": {
    "type": "array",
    "items": {
      "type": "array",
      "minItems": 1,
      "maxItems": 7,
      "items": {
        "type": "number"
      }
    }
  }
},
"required": [
  "BASTA_AA_WP_version",
  "Supplier",
  "Antenna_Model",
  "Antenna_Type",
  "Revision_Version",
  "Released_Date",
  "Coordinate_System",
  "Pattern_Name",
  "Beam_ID",
  "Pattern_Type",
  "Frequency",
  "Frequency_Range",
  "EIRP",
  "Configured_Output_Power",
  "Gain",
  "Configuration",
  "RF_Port",
  "Array_ID",
  "Array_Position",
  "Phi_HPBW",
  "Theta_HPBW",
  "Front_to_Back",
  "Phi_Pan_Setting",
  "Theta_Tilt_Setting",
  "Nominal_Polarization",
  "Theta_Sampling",
  "Phi_Sampling",
  "Data_Set_Row_Structure",
  "Data_Set"
 ]
}
```

15 Annex F: Mixed Passive Active Antenna

15.1 General

AAS can be deployed in the same sites as the legacy (2G/3G/4G) PAS; in some installations the AAS can be arranged in a layout with a PAS in order to solve installations issues, i.e. available space on the pole hosting other antenna systems.

AAS arranged together with PAS systems are commonly referenced to as HPAA (Hybrid Passive Active Antenna), meaning that the same enclosure includes one or more AAS system and one more PAS system in a specific layout.

The following four arrangements are considered (see Figure 15.1):

- Option 1: AAS and PAS systems arranged in a Side-by-Side or Top Bottom configuration and physically separated;
- Option 2: AAS and PAS systems arranged in a stacked configuration and both are inside the same enclosure;
- Option 3: AAS and PAS systems interleaved in a common enclosure;
- Option 4: AAS deployed behind the PAS or vice versa.

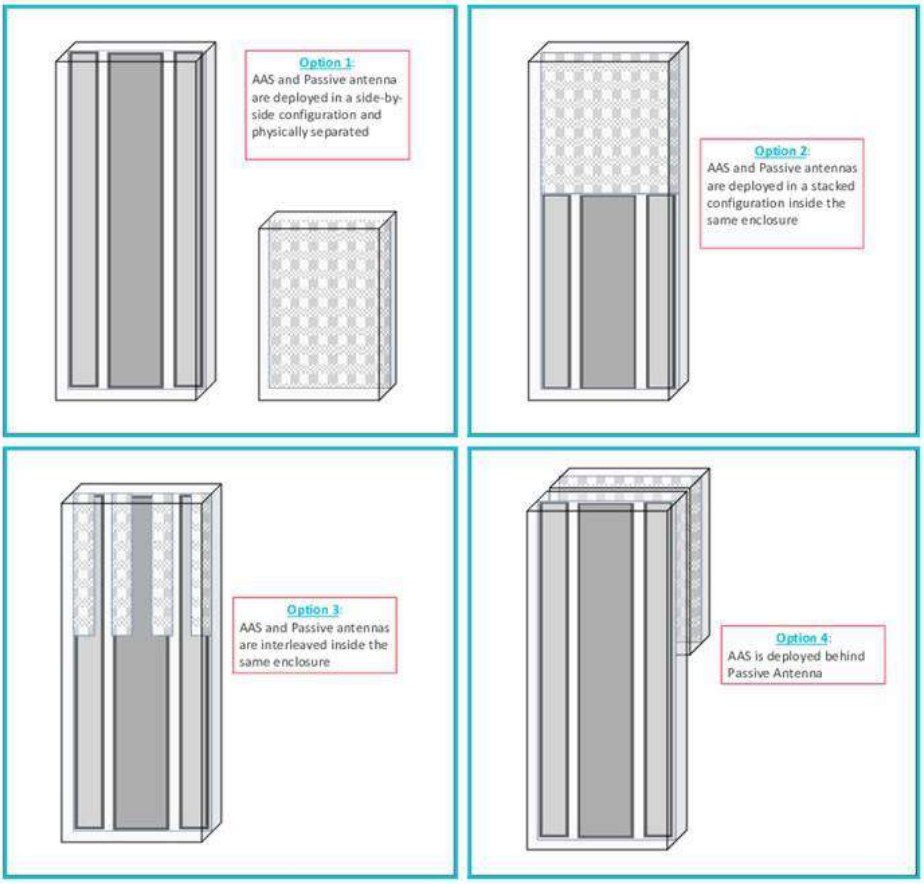


Figure 15.1: Hybrid Antennas Layout Options

15.2 Option 1: AAS and PAS arranged in a side-by-side or top-bottom configuration and physically separated

In Option 1 PAS and AAS are two distinct units, totally independent of each other (see Figure 15.2). Azimuth and mechanical tilt of the two systems may be set separately and independently of each other.

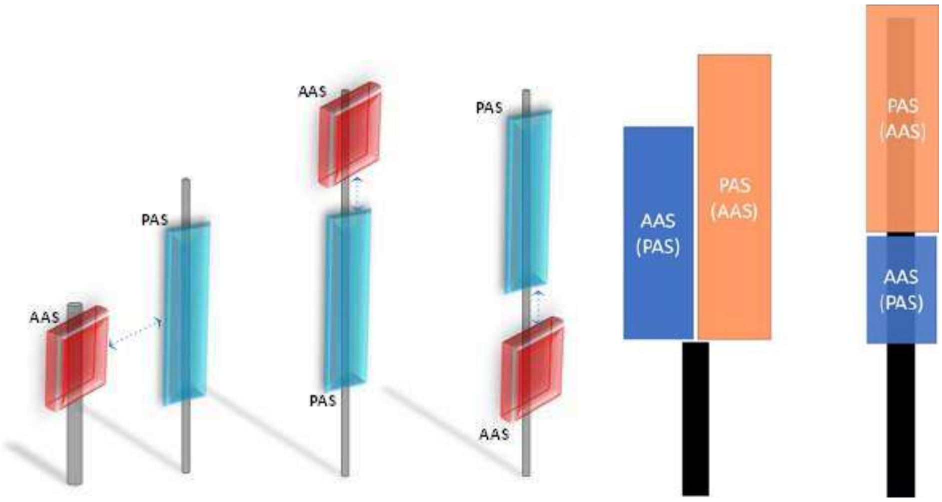


Figure 15.2: Schematic representations for Option 1: Side-by-Side or top-bottom

This is the simplest solution for site upgrade, as the AAS can be simply added either side-by-side or below/above the PAS.
Since the active and passive antennas are two separate entities, either antenna may be swapped without having to replace the other, offering a longer lifespan for each individual system.
From an operational point of view, some factors have to be taken into account:

- Mechanical constraints: arrangement and length of the cable tray
- Thermal constraints: spacing between elements to allow free cooling of the AAS.

15.3 Option 2: AAS and PAS arranged in a stacked configuration and both antennas are inside the same enclosure

In Option 2 AAS and the PAS are arranged in the same enclosure, either one on the top of the other or side by side (see Figure 15.3).

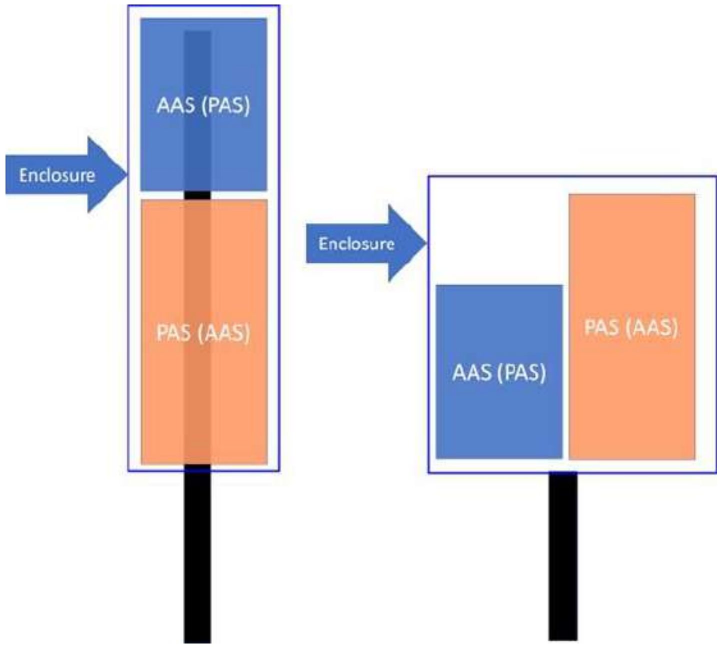


Figure 15.3: Schematic representations for Option 2

The antenna enclosure is a container capable to arrange the PAS and the AAS inside of it. The AAS and the PAS are installed inside such enclosure.

The active and passive antennas are still two separate entities. After opening or removal of the enclosure either antenna may be swapped without having to replace the other.
From an operational point of view, the same factors have to be taken into account than for option 1:

- Mechanical constraints: arrangement and length of the cable tray
- Thermal constraints: spacing between elements to allow free cooling for the AAS.

15.4 Option 3: AAS and PAS interleaved in a common enclosure

In option 3 (designated as interleaved configuration) passive and active modules are developed as a whole and placed within a common enclosure, by the same vendor (see Figure 15.4).

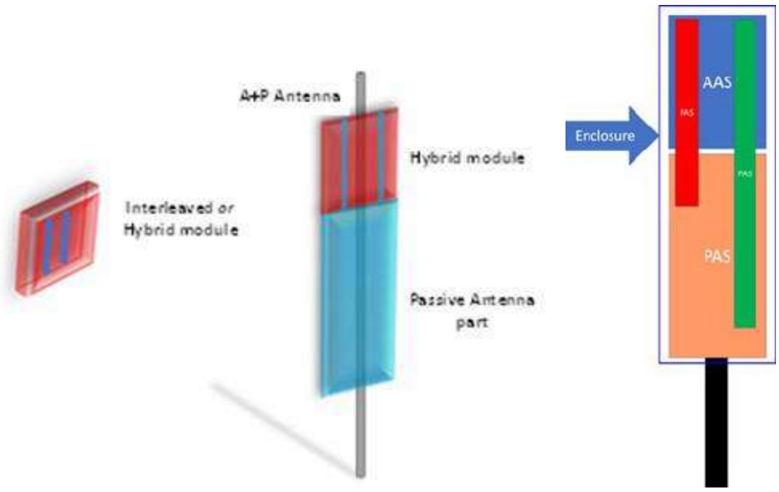


Figure 15.4: Schematic representation for Option 3: Interleaved concept

In general, the solution consists of:

- a hybrid module (Interleaved antenna in which m-MIMO elements are interleaved with passive antennas sub-arrays;
- a PAS with mid-band and low-band arrays.

The two antenna system elements are closely aligned to appear as an all-in-one radiating system and electrically interconnected, in order to guarantee "continuity" for the lowest frequencies.
Since the PAS requires the presence of the hybrid part to perform "as designed", a common development in the design of the two parts is required.
The advantage of this implementation is that the hybrid module can be easily replaced in case of failure or for upgrading the m-MIMO unit (i.e. 32T32R to 64T64R swap).

15.5 Option 4: AAS deployed behind the PAS

In option 4 the PAS and the AAS are two distinct standalone units that can operate independently of each other. The passive antenna shows an RF-transparent window larger than the m-MIMO antenna radiating aperture that allows the AAS to be placed behind it (see Figure 15.5). As a result, RF signals from the AAS can pass through the PAS without any major impact on the overall antenna performance.

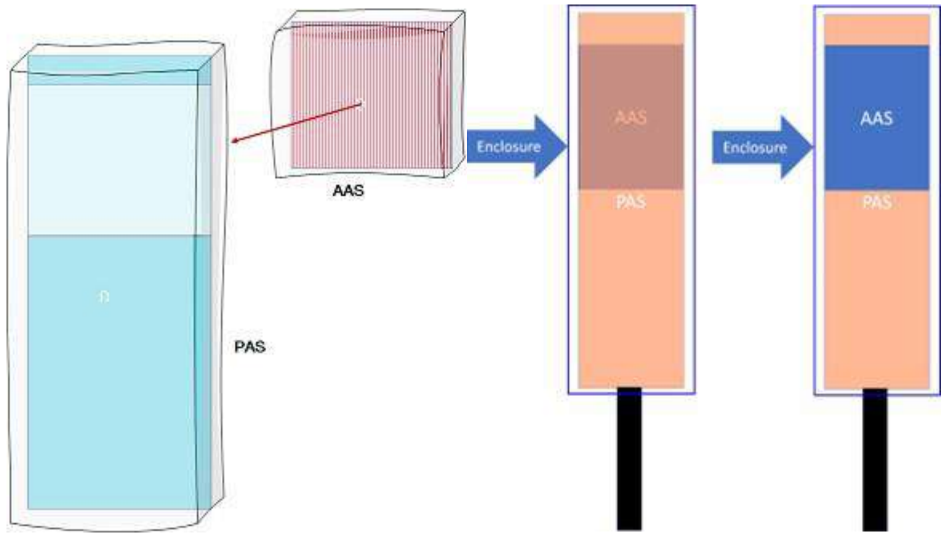


Figure 15.5: Schematic representation Option 4

With this approach, the evolution and lifespan of the AAS and the PAS are decoupled. AAS and PAS from either a single vendor or different vendors can coexist and be upgraded independently of each other.

16 Annex G: EMF Scenarios, Assumptions and Examples [Informative]

In order to better understand the behaviour of EMF in several relevant scenarios' simulations have been performed. By monitoring EIRP in all directions of the antenna and defining a power grid, statistics have been collected. The model is based on a cluster of 21 cells using 3D-Uma 3GPP model. Three different scenarios have been evaluated; evenly distributed users, fully centralized users and single user.

Table 16-1: Simulation Scenarios

Scenarios (S#i)	Description
S#1: Normal MU	21 cells, 50UE evenly distributed per cell
S#2: Extreme MU	21 cells, 50UE fully centralized per cell
S#3: Single UE	21 cells, single UE distributed per cell

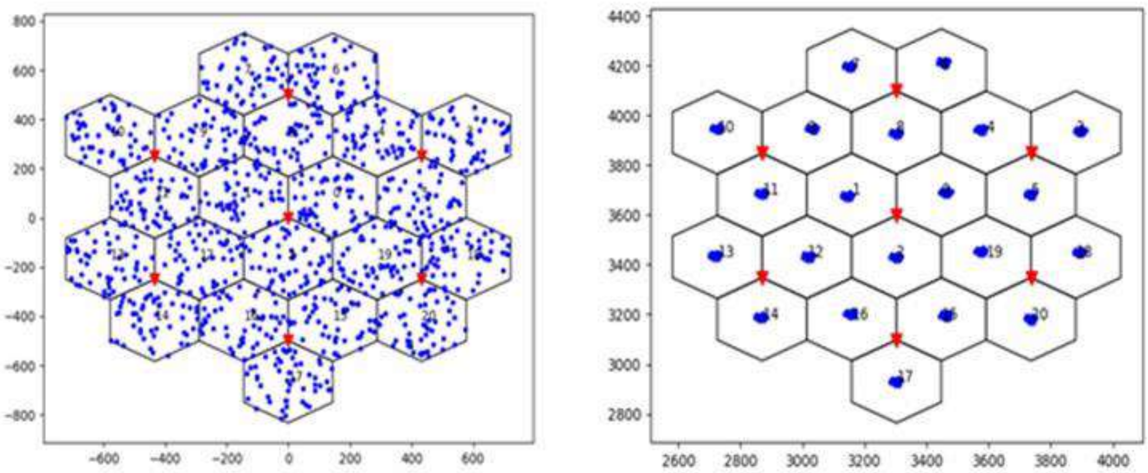


Figure 16.1: Example of UEs distribution for S#1 and S#2 – see left and right figure

Table 16-2: Simulation Assumptions

General Parameters	Description	Values
Scenarios		3D-Uma
Layout		Hexagonal grid 7macro sites 3 sectors per sit ISD 500 m
UE Rx configuration		4T4R
UE mobility		3 km/h
BS antenna height		29 m
Total BS Tx Power		43 dBm for 10 MHz(50 PRBs)
Carrier frequency		3.5 GHz
Min. UE-eNB 2D		distance 35 m
UE height (hUT) in meters	General equation	hUT=3 (nfl – 1) + 1.5
	nfl for outdoor UEs	1

	nfl for indoor UEs nfl	~ uniform(1,Nfl) where Nfl ~ uniform(4,8)
Indoor UE fraction		80%
UE distribution (in x-y plane)	Outdoor UEs	Uniform in cell
	Indoor UEs	Uniform in cell
Traffic Model		Fullbuffer（2/4/8 layer

Each grid point represents an AR. Then the EIRP value is recorded in each point.

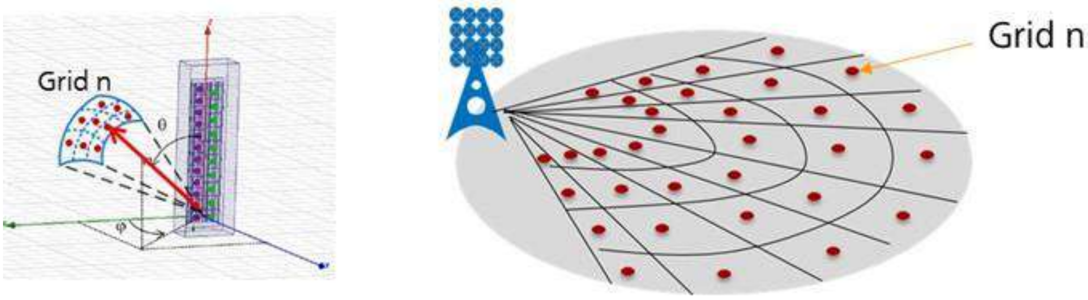


Figure 16.2: Grid points of the antenna

Scenario 1: Evenly Distributed Users

When looking at the instantaneous probability of exceeding a threshold of -6 dB backoff, one can notice that for 2 layers, the probability is close to 10% in some grid points. For 4 layers, the probability is almost zero. The CDF for all grid points, shows a 95% probability, that the output power of the antenna is 9-11dB less than peak power.

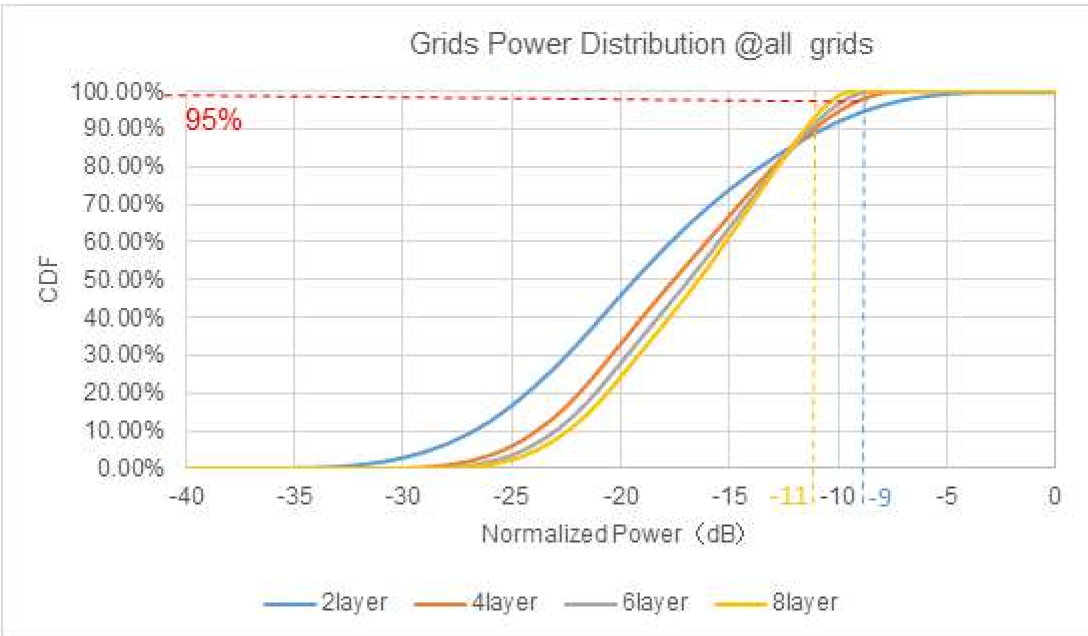


Figure 16.3: Grids Power distribution (Scenario 1)

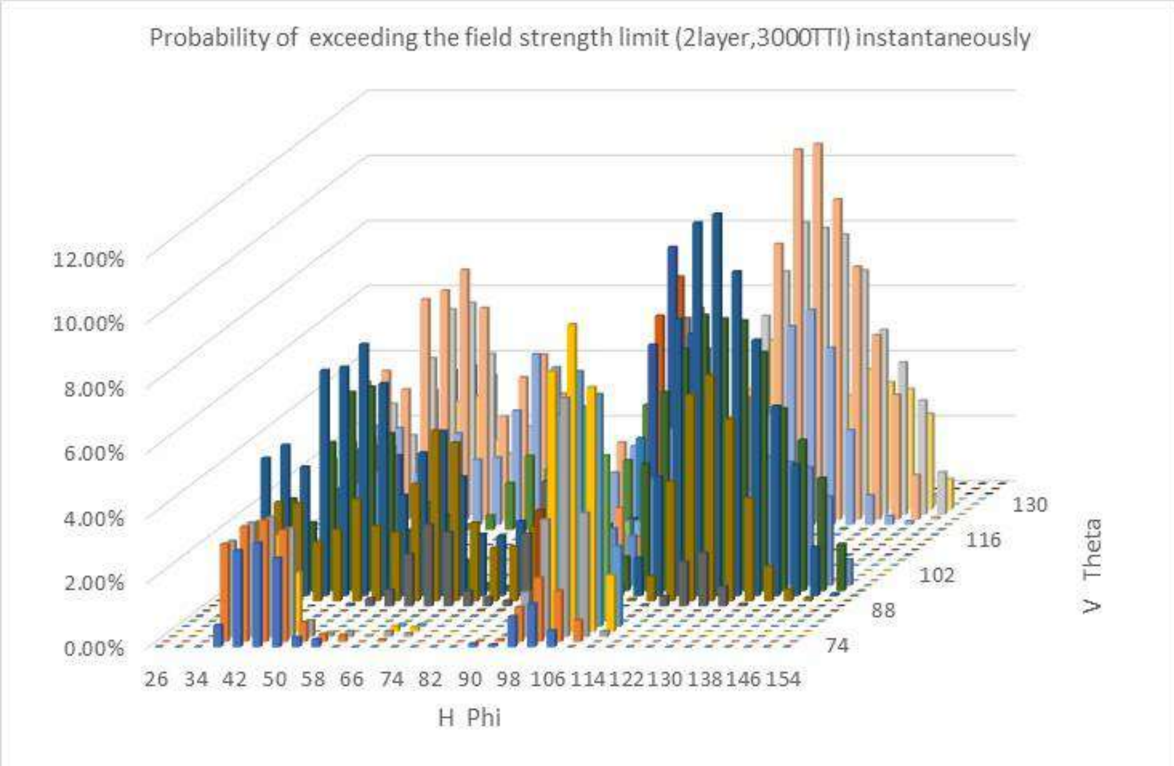


Figure 16.4: Probability of exceeding the field strength limit (2 layers, scenario 1)

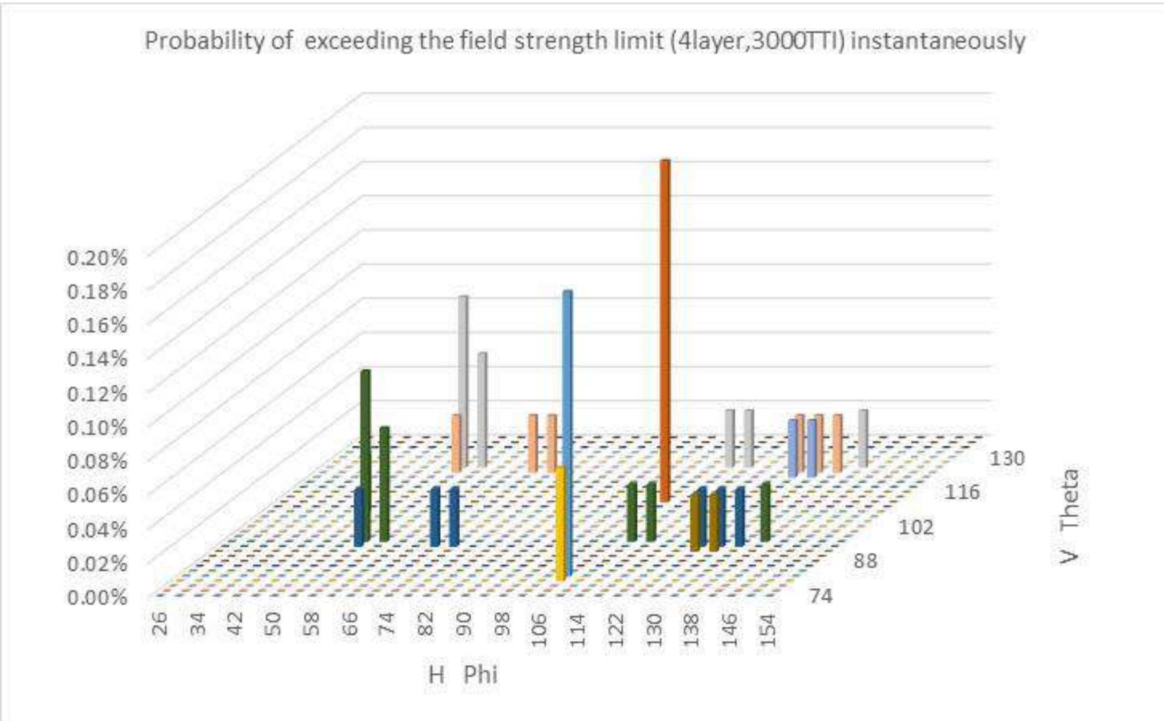


Figure 16.5: Probability of exceeding the field strength limit (4 layers, scenario 1)

If the averaged power is studied in each grid point, it is found that the level is always less than the -6 dB threshold (Pn=0.25). The averaging is here done over three seconds but similar result is expected using a longer filtering time such as 6 minutes as defined by ICNIRP.

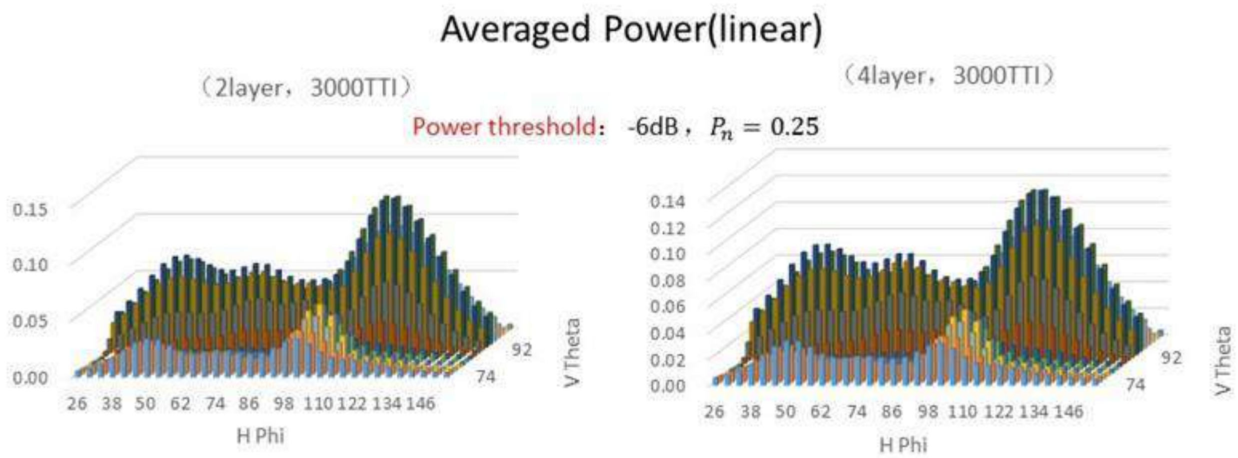


Figure 16.6: Grid points for averaged power (scenario 1)

The conclusion is that thanks to multi paths, multi user and user distribution, it is clear that the average power levels of a massive MIMO antenna system will be much lower than the peak levels.

Scenario 2: Centralized Users

In this scenario, all users are close to the antenna, it can be seen that the instantaneous probability that the power level exceed the -6 dB threshold will be significantly higher. The CDF for all grid points, shows a 95% probability, that the output power of the antenna is 8-10 dB less than peak power i.e. 1 dB more compared to scenario 1.

Figure 16.7: Grids Power distribution (Scenario 2)

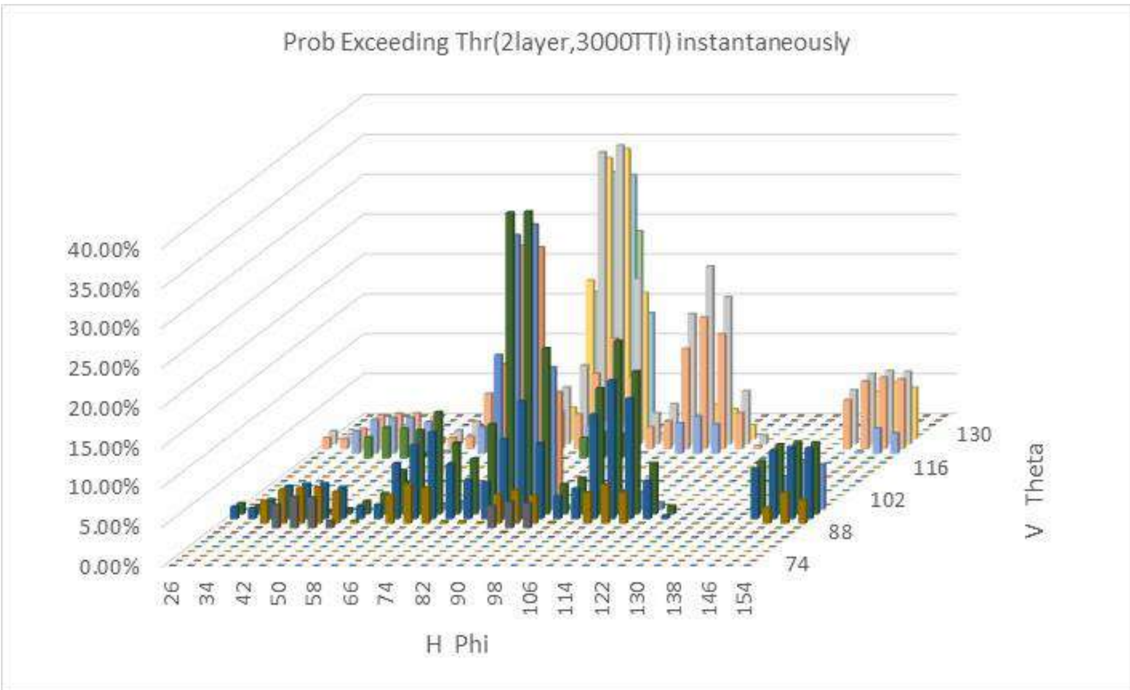


Figure 16.8: Probability of exceeding the field strength limit (2 layers, scenario 2)

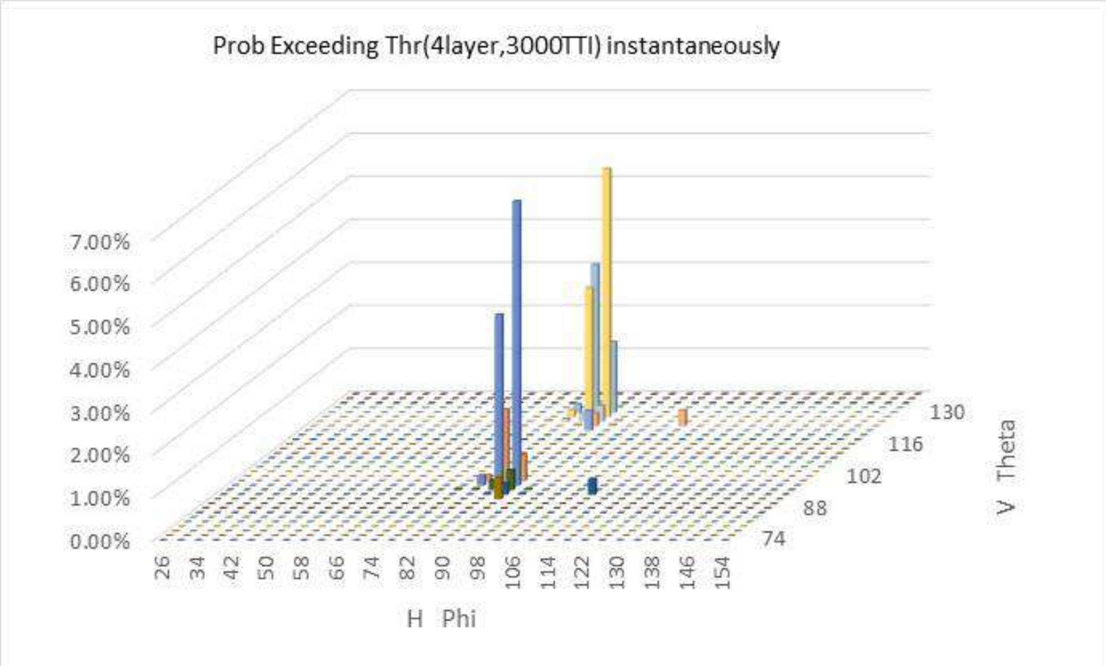


Figure 16.9: Probability of exceeding the field strength limit (4 layers, scenario 2)

If the averaged power is studied in each grid point, it can be found that the levels are very similar to those in scenario 1, i.e. always less than the -6 dB threshold (Pn=0.25). It is clear that beamforming can create spatial separation between different users even though the users are close to each other.

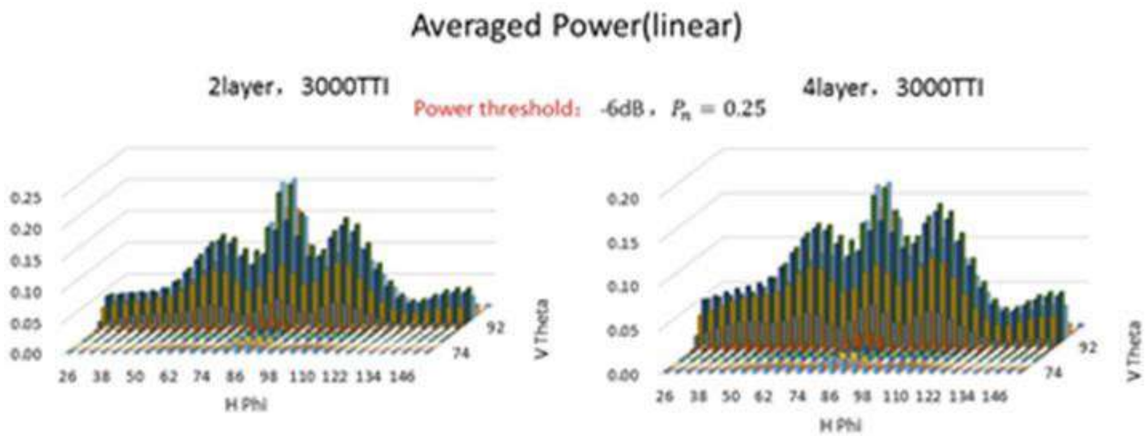


Figure 16.10: Averaged power per grid point (scenario 2)

Scenario 3: Single User

In case of a single user, the CDF for all grid points will be similar to scenario 1 and 2 and the probability to exceed the -6 dB level will be low. However, since all the power is transmitted to a single user there will be no back-off when averaging the power. This is a case that needs to be mitigated.

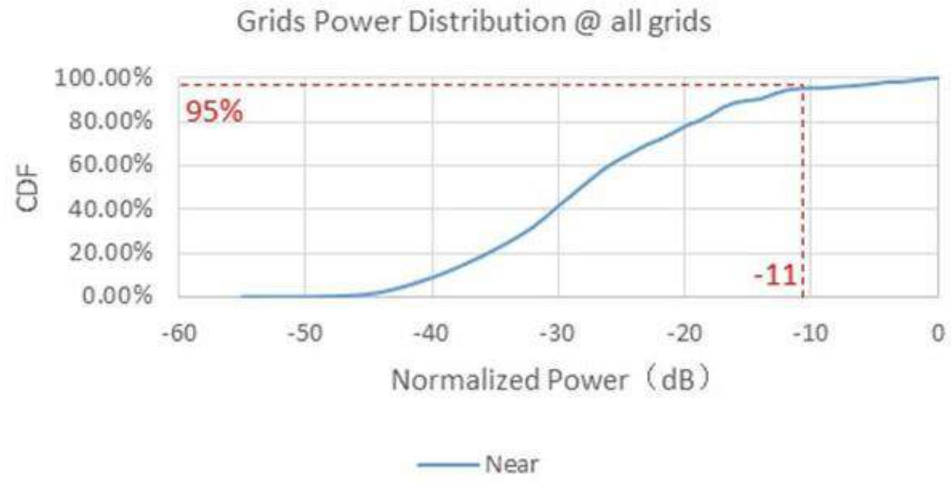


Figure 16.11: Grids Power distribution (Scenario 3)

Additional Examples

Additional examples of implementation of EMF compliance based on actual maximum transmitted power or EIRP can be found in [42] as well as in [20] and [21].

17 Annex H: Basics for Counters

This appendix outlines some relations between power flux density, radiation intensity and EIRP relevant for EMF counters. The basic quantity is the radiated power per area, i.e., the power flux density

$$S(r, \vartheta, \varphi) = \frac{\left|\vec{E}\right|^2}{Z_0} \tag{17.1}$$

Here, $\left|\vec{E}\right|$ is the RMS value over time and $Z_0 \approx 377\ \Omega$ is the free space impedance. In the farfield region, the power density can be expressed in terms of radiation intensity (radiated power per solid angle) or EIRP. The relations to power flux density are [2]

$$S(\vartheta, \varphi) = \frac{I(\vartheta,\varphi)}{r^2} = \frac{EIRP(\vartheta,\varphi)}{4\pi\, r^2} \tag{17.2}$$

$$\mathrm{d}P_{rad}(\vartheta, \varphi) = I(\vartheta, \varphi)\sin\vartheta \mathrm{d}\vartheta \mathrm{d}\varphi = \frac{EIRP(\vartheta,\varphi)}{4\pi}\sin\vartheta \mathrm{d}\vartheta \mathrm{d}\varphi \tag{17.3}$$

The power radiated in an angular sector, given by the intervals $\vartheta \in [\vartheta_{start}, \vartheta_{stop}]$ and $\varphi \in [\varphi_{start}, \varphi_{stop}]$, is then

$$P_{sector} = \int_{\vartheta_{START}}^{\vartheta_{STOP}} \int_{\varphi_{START}}^{\varphi_{STOP}} I(\vartheta, \varphi) sin\vartheta d\vartheta d\varphi = \frac{1}{4\pi} \int_{\vartheta_{Start}}^{\vartheta_{Stop}} \int_{\varphi_{Start}}^{\varphi_{Stop}} EIRP(\vartheta, \varphi) sin\vartheta d\vartheta d\varphi \tag{17.4}$$

NOTE: If EIRP is integrated over an angular region, a scaling factor of $\frac{1}{4\pi}$ is required to get the power radiated in the angular region.

The reverse action is to estimate the field strength at a distance and in a given angular region from a given power level P_{sector}. Since P_{sector} is retrieved from an integrated value, only the average EIRP or Radiation Intensity is possible to estimate. The angular average of the radiation intensity is

$$I_{av} = \frac{1}{\Omega_{sector}} \int_{\vartheta_{START}}^{\vartheta_{STOP}} \int_{\varphi_{START}}^{\varphi_{STOP}} I(\vartheta, \varphi) sin\vartheta d\vartheta d\varphi = \frac{P_{sector}}{\Omega_{sector}} \tag{17.5}$$

Here,

$$\Omega_{sector} = \int_{\vartheta_{START}}^{\vartheta_{STOP}} \int_{\varphi_{START}}^{\varphi_{STOP}} sin\vartheta d\vartheta d\varphi = (\sin\vartheta_{STOP} - \sin\vartheta_{START})(\varphi_{STOP} - \varphi_{START}) \tag{17.6}$$

is the solid angle of the angular sector. At a fixed distance r, the angular average of the power flux density is

$$S_{av} = \frac{1}{r^2}\frac{P_{sector}}{\Omega_{sector}} \tag{17.7}$$

Finally, the angular average RMS E-field strength is calculated as

$$\left|\vec{E}\right| = \frac{1}{r}\sqrt{\frac{Z_0 P_{sector}}{\Omega_{sector}}} \tag{17.8}$$

18 Annex I: Polarization Correlation Factor

For a dual polarised system Polarization Correlation Factor (PCF) is defined as:

$$\mathrm{PCF}(\vartheta,\varphi) = \frac{\left|\overrightarrow{\mathrm{E}_1}(\vartheta,\varphi)\cdot\overrightarrow{\mathrm{E}_2^*}((\vartheta,\varphi))\right|^2}{\left|\overrightarrow{\mathrm{E}_1}((\vartheta,\varphi))\right|^2\left|\overrightarrow{\mathrm{E}_2}((\vartheta,\varphi))\right|^2} \tag{18.1}$$

This is a directional metric and the far fields $\overrightarrow{\mathrm{E}_1}(\vartheta,\varphi)$ and $\overrightarrow{\mathrm{E}_2}(\vartheta,\varphi)$ are

- Generated by two beams serving the same direction for GoB systems
- Not yet defined, in the EEB case

PCF generalizes the concept of Cross Polar Discrimination wherein one of the fields has a constant polarization.
NOTE: In the case of orthogonal polarizations PCF = 0 and for equal polarizations PCF = 1 or equivalently 100%.
This definition is related to the IEEE definition of Polarization Mismatch Factor [2].

Synonym to PCF is "Polarization Parallelity"

The following table illustrates PCF and may be used for reference calculations.

Table 18-1: Examples of Polarization Correlation Factors (PCFs)

Polarization 1	$\overrightarrow{\mathrm{E}_1}(\vartheta,\varphi)$	$\overrightarrow{\mathrm{E}_1}(\vartheta,\varphi)^2$	Polarization 2	$\overrightarrow{\mathrm{E}_2}(\vartheta,\varphi)$	$\overrightarrow{\mathrm{E}_2}(\vartheta,\varphi)^2$	$\left\|\overrightarrow{\mathrm{E}_1}\cdot\vec{E}_2^*\right\|$	PCF (%)
V	$\hat{\vartheta}$	1	H	$\hat{\varphi}$	1	0	0%
V	$\hat{\vartheta}$	1	V	$\hat{\vartheta}$	1	1	100%
V	$\hat{\vartheta}$	1	+45/-45	$\hat{\vartheta}\pm\hat{\varphi}$	2	1	50%
V	$\hat{\vartheta}$	1	LHCP/RHCP	$\hat{\vartheta}\pm\hat{\varphi}$	2	1	50%
Elliptical	$\hat{\vartheta}+2\hat{\varphi}$	5	Elliptical	$\hat{\vartheta}-\hat{\varphi}$	2	1	10%
Elliptical	$\hat{\vartheta}+2\hat{\varphi}$	5	Elliptical	$\widehat{2j\vartheta}-\hat{\varphi}$	5	0	0%
Elliptical	$\hat{\vartheta}+2\hat{\varphi}$	5	Elliptical	$\hat{\vartheta}-2j\hat{\varphi}$	5	3	36%

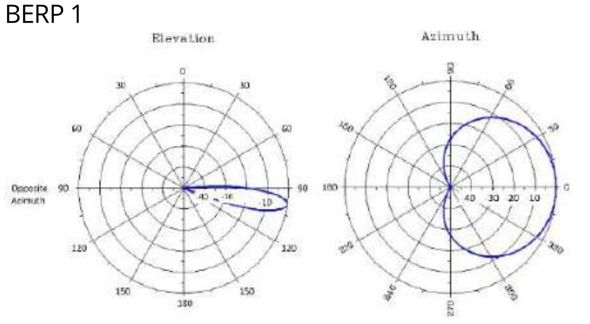
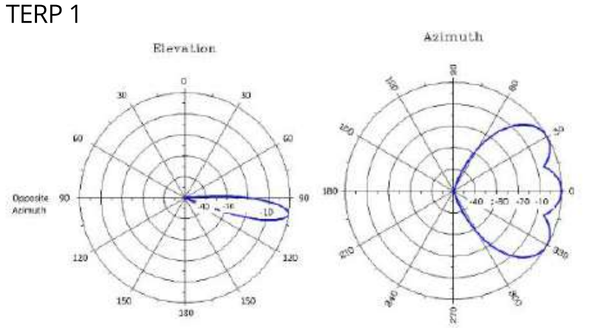
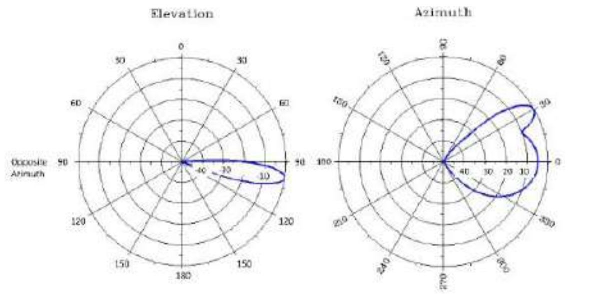
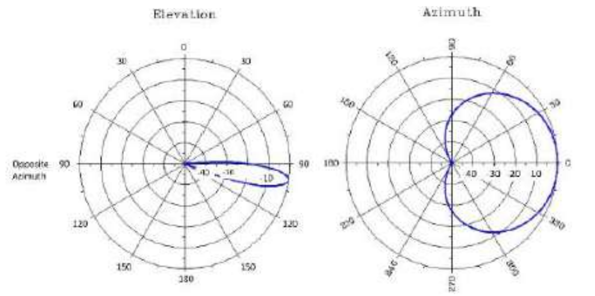
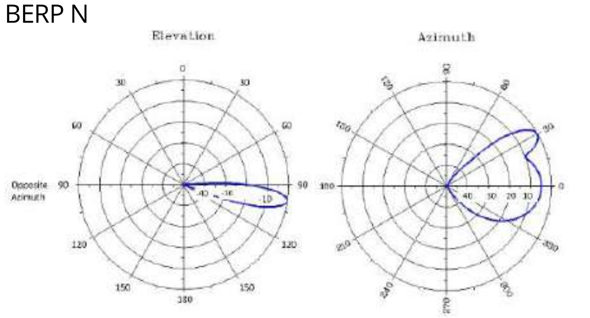
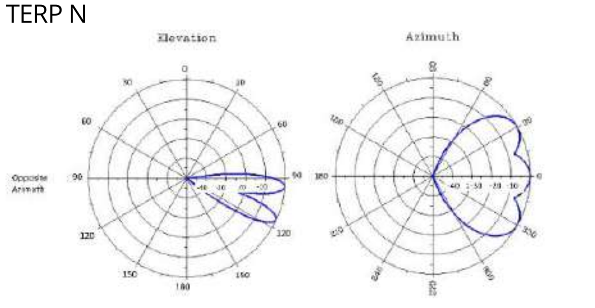
19 Annex J: Envelope Radiation Patterns

It might be convenient to distinguish between Broadcast and Traffic envelopes. An AAS has the following set of envelope radiation patterns:

- Broadcast Envelope Radiation Pattern (BERP): is the envelope pattern of each Broadcast Beam Configuration. Since the AAS can have different broadcast configurations available for specific coverage requirements, there are as many BERP as the number of configurations implemented by the AAS. In case the configuration is made of just one beam, the BERP corresponds to the radiation pattern of that beam;
- Traffic Envelope Radiation Pattern (TERP): is the envelope pattern of the traffic beams associated with a Broadcast Configuration. TERP could be associated to more than one Broadcast Configuration.

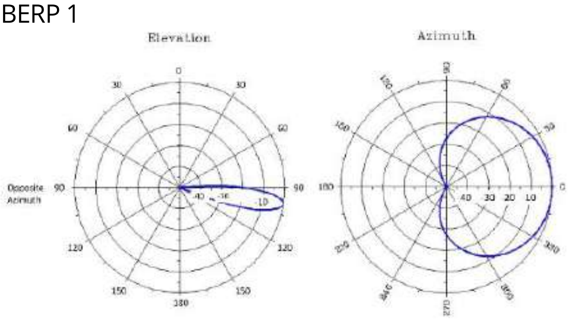
The following examples show different combinations of BERP and TERP:

A. AAS implementing some configurations for BERP, each one having a corresponding TERP:

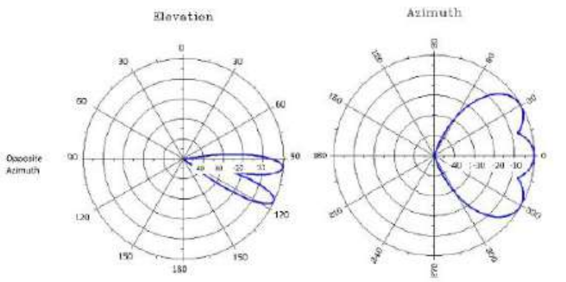
<table>
<tr><td>BERP 1
</td><td>TERP 1
</td></tr>
<tr><td>BERP 2
</td><td>TERP
</td></tr>
<tr><td>…</td><td>…</td></tr>
<tr><td>BERP N
</td><td>TERP N
</td></tr>
</table>

B. AAS implementing some configurations for BERP, each one has the same TERP:

BERP 1

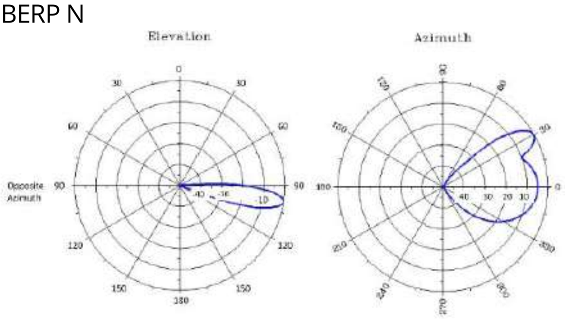


BERP 2

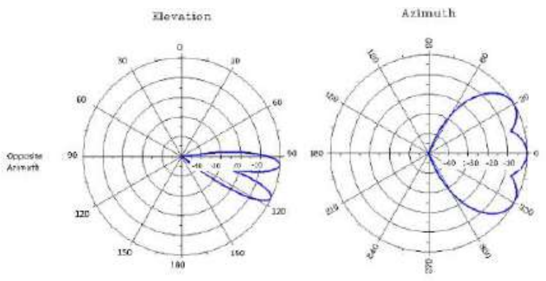


...

BERP N

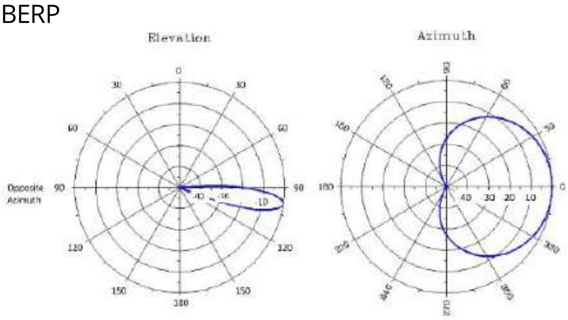


TERP

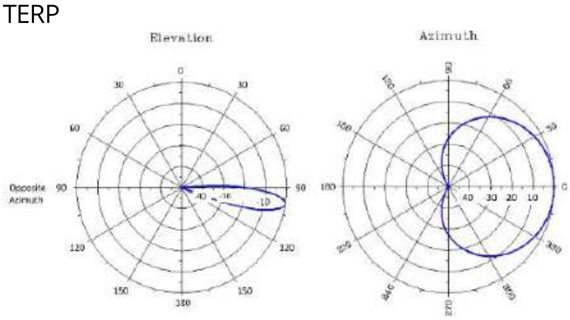


C. AAS implementing one BERP and TERP, which are the same pattern:

BERP



TERP



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- To evaluate and drive technology evolution towards the three **Strategic Focus Topics**:
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    Leading in the development of open, disaggregated, virtualised and cloud native solutions
  - **Green Future Networks:**

    Developing sustainable and environmentally conscious solutions
  - **6G:**

    Providing guidance and requirements related to design considerations and network architecture evolution
- To define precise functional and non-functional requirements for the next generation of mobile networks
- To provide guidance to equipment developers, standardisation bodies, and collaborative partners, leading to the implementation of a cost-effective network evolution
- To serve as a platform for information exchange within the industry, addressing urgent concerns, sharing experiences, and learning from technological challenges

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