Recommendation on Standards for Passive Base Station Antenna Systems

v 12.0

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Recommendation on Standards for Passive Base Station Antennas

by NGMN Alliance

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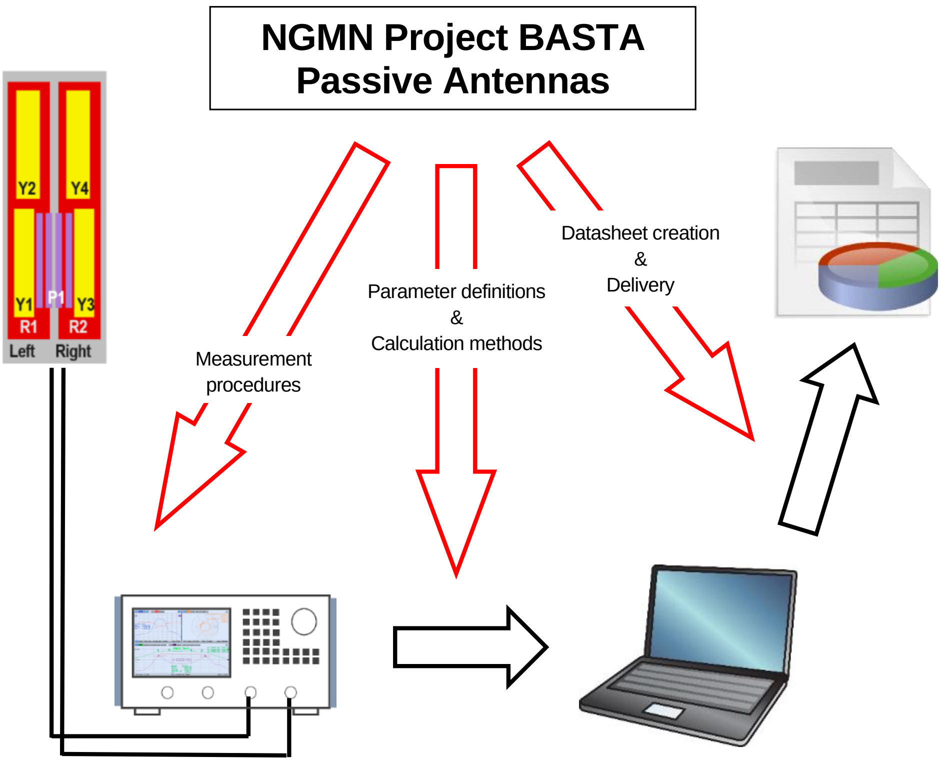
Project:	BASTA Passive Antennas
Editor / Submitter:	**Johan Obermaier (Huawei)** **Juergen Rumold (Ericsson)**
Contributors:	**Amphenol Antenna Solutions** **Commscope** **Comba** **Deutsche Telekom** **Ericsson** **Huawei** **Nokia (RFS)** **Orange** **Rosenberger** **Telecom Italia** **Telefonica** **Vodafone**
Approved by / Date:	NGMN Board, 24th January 2022

NGMN e. V.
Großer Hasenpfad 30 • 60598 Frankfurt • Germany
Phone +49 69/9 07 49 98-0 • office@ngmn.org

Abstract

This White Paper addresses the performance criteria of passive 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 passive BSAs.



Changes from version 11.1

- Harmonization and error correction
- Several changes in XML tags to improve automatic processing (avoid nested ComplexTypes and enumerations, introduce boolean attributes and use numbers instead of strings)
- Updated figure 2.3.1 to consider 8T8R array antennas
- XML topics updated
- Section 2.5, 2.6 and 2.7 updated the text and figures to align with BASTA Active Antennas
- Section 3.2.1: added new examples of Nominal Sector & Nominal Directions to handle different type of passive antennas
- Section 3.2.3: change in examples adding a port number to the XML tag 'port'
- Section 3.2.22: change to use this parameter only for antennas with beamforming capabilities.
- Section 3.3.17: new optional parameter for antenna efficiency
- Section 3.3.18: new optional parameter for Maximum Horizontal Sidelobe Suppression used for BF antennas
- Section 3.4: new section with parameter definitions for antennas with beam forming (BF) capabilities
- Section 5.2: updated figure 5.1-1 defining the same RET reference plane shown in figure 6.1-2.
- Sections 5.5,5.6,5.7: new examples and tags with added number in XML tag 'port'
- Section 5.9 Added: Definition of Drag, Lift and Resultant force
- Section 5.10 completely reworked for wind tunnel measurement, add polar chart and describe pole deduction and length extrapolation.
- Section 6.1: change XML tag 'RET_unit_installation…' to 'uni_installation…'
- Section 6.14: change title to cover both specified parameters in this section
- Section 7.3.10 Changes referenced standards to latest version
- Section 9.1.x was updated with new frequency list according to 3GPP TS 37.104 v17.2.0
- Section 10.1 XML block scheme updated to consider beamforming antennas
- Section 10.1.5 adding figure 10.1-2 as an example for clusters and arrays including ports
- Section 10.1.6: update of tables with XML tag
- Section 10.1.7: added table with XML tags for beamforming
- Section 10.1.8: update of tables with XML tag
- Section 10.1.9: updated XML tags to avoid enumerations
- Removed APPENDIX A – EXAMPLE OF ANTENNA DATASHEET
- Removed APPENDIX B – EXAMPLE OF RET DATASHEET
- Updated APPENDIX C – LOGICAL BLOCK STRUCTURE (ANTENNA+RET)
- Removed APPENDIX D – EXAMPLE OF ANTENNA XML FILE
- Removed APPENDIX E – EXAMPLE OF RET XML FILE
- Removed APPENDIX F – TEST CONFIG. & WIND LOAD EXTRAPOLATION

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1 Introduction and Purpose of Document

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 White Paper is to address this gap. In particular, the following topics will be covered in various degrees 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 scope of this paper is limited **to passive base station antennas**. Even though antennas will not be categorized in performance-classes, this paper will address antennas built for different purposes. **The operating range of the addressed antennas shall be limited within the 400 MHz - 6000 MHz spectrum**.

1.1 Interpretation

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

- ***Shall:*** indicates requirements or directives strictly to be followed in order to conform to this paper and from which no deviation is permitted.
- ***Shall, if supported:*** indicates requirements or directives strictly to be followed in order to conform to this White Paper, 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 White Paper
- ***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.

Moreover, only two specific methods to deliver antennas technical parameters and information to the customers are hereby taken into consideration:

- **BASTA antenna XML file:**
  - 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 public website (Link to NGMN)

- Must adhere to the format and comply with the BASTA Passive Antenna XML rules, which are both specified in this document and in the BASTA Passive 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 white paper release used

- **BASTA antenna Datasheet:**
  - Describes the golden sample 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 Passive Antenna white paper release

A golden sample is a finalized version of the product that was built on the production line and built to the product definition standards. The golden sample is the perfect product used as the benchmark for all of the product units.

Additionally, an antenna's far-field radiation pattern file:

- Describes numerically the far-field radiation pattern (see paragraph 2.6).
- Shall contain at least the co-polar azimuth cut and elevation cut data (see paragraph 2.7).
- Shall specify the field level at least with a resolution of one degree of azimuth per one degree of elevation.

Is an electronic file strictly intended for computer processing.

1.2 References

This white paper 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 White Paper. For references listed without a version or release, the latest edition of the publication referred to applies.

1. IEEE Std. 145-1993 or following versions Standard definitions of Terms for Antennas.
2. ETSI EN300019-1-1 Environmental Engineering (EE); Environmental conditions and environmental tests for telecommunications equipment. Part 1-1: Classification of environmental conditions;
3. ETSI EN 300019-1-2" Equipment Engineering Environmental conditions and environmental tests for telecommunications equipment. Part 1-2: Classification of environmental conditions Transportation.
4. 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.

5. 3GPP TS 37.104, v17.2.0, 2021-06 Digital cellular telecommunications system (Phase 2+); Universal Mobile Telecommunications System (UMTS); LTE; E-UTRA, UTRA and GSM/EDGE; Multi-Standard Radio (MSR) Base Station (BS) radio transmission and reception.
6. IEC 60068-2-1 Environmental testing Part 2-1 Tests – Test A: Cold.
7. IEC 60068-2-2 Environmental testing – Part 2-2: Tests – Test B: Dry heat.
8. IEC 60068-2-6 Environmental testing – Part 2-6: Tests – Test Fc: Vibration (sinusoidal).
9. IEC 60068-2-11 Basic Environmental Testing Procedures, Part 2: Test Ka: Salt Mist.
10. IEC 60068-2-14 Environmental testing – Part 2-14: Tests – Test N: Change of temperature.
11. IEC 60068-2-18 Environmental testing – Part 2-18: Tests – Test R and guidance: Water.
12. IEC 60068-2-27 Environmental testing – Part 2-27: Tests – Test Ea and guidance: Shock.
13. IEC 60068-2-30 Environmental testing – Part 2-30: Tests – Test Db: Damp heat, cyclic (12 h + 12 h cycle).
14. IEC 60068-2-31 Environmental testing – Part 2-31: Tests – Test Ec: Rough handling shocks, primarily for equipment-type specimen.
15. IEC 60068-2-56 Environmental testing - Part 2: Tests. Test Cb: Damp heat, steady state, primarily for equipment.
16. IEC 60068-2-64 Environmental testing – Part 2-64: Tests – Test Fh: Vibration, broadband random and guidance.
17. IEC 60068-2-68 Environmental Testing - Part 2: Tests - Test L: Dust and Sand.
18. IEC 60529 Degrees of Protection Provided By Enclosures (IP CODE).
19. IEC 62037-6 Passive RF and microwave devices, intermodulation level measurement - Part 6: Measurement of passive intermodulation in antennas
20. EN 1991-1-4 Eurocode 1: Actions on structures - Part 1-4: General actions - Windloads.
21. EIA/TIA 222-G Structural Standard for Antenna Supporting Structures and Antennas.
22. AISG v1.1 Antenna Interface Standards Group Version 1.1.
23. AISG V2.0 Antenna Interface Standards Group Version 2.0.
24. AISG V3.0 Antenna Interface Standards Group Version 3.0.
25. NGMN Recommendation on Base Station Active Antenna System Standards
26. NGMN RF Cluster Connector

2 Abbreviations and Antenna Terms Definitions

2.1 Abbreviations

The abbreviations used in this White Paper are explained in the following table:

Abbreviation	Definition
3GPP	3rd Generation Partnership Project
AIR	Azimuth Interference Ratio
AISG	Antenna Interface Standards Group
AUT	Antenna Under Test
AZ	Azimuth
BF	Beamforming
BSA	Base Station Antenna
Co-Pol	Co-Polar
CPD (or XPD)	Cross-Polar Discrimination (see: CPR)
CPI	Cross-Polar Isolation
CPR	Cross-Polar Ratio (see: CPD)
Cr-Pol (or X-Pol)	Cross-Polar
CW	Continuous Wave
DL	DownLink
E-UTRA	Evolved UMTS Terrestrial Radio access
EL	ELevation
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
H_HPBW	Horizontal HPBW
HPBW	Half-Power Beamwidth
IEC	International Electrotechnical Commission
LHCP	Left-Handed Circular Polarization OR Circularly Polarized
MIMO	Multiple Input/Multiple Output
MTBF	Mean Time Between Failures
N/A or n/a	Not Available or Not Applicable
NF	Near Field
NGMN	Next Generation Mobile Network Alliance
OEWG	Open-Ended WaveGuide
P-BASTA	Project Base Station Antennas
PIM	Passive Inter Modulation
QoS	Quality of Service
R&D	Research and Development
RET	Remote Electrical Tilt
RF	Radio Frequency
RFQ	Request For Quotation
RHCP	Right-Handed Circular Polarization OR Circularly Polarized

RL	Return Loss
SLS	SideLobe Suppression
TDD	Time Division Duplex
TEM	Transverse Electric and Magnetic
UMTS	Universal Mobile Telecommunications System
USLS	Upper SideLobe Suppression
V_HPBW	Vertical HPBW
VNA	Vector Network Analyzer
VSWR	Voltage Standing Wave Ratio
XML	eXtensible Markup Language
XSD	XML Schema Definition

Table 2.1-1—Acronyms and abbreviations table.

2.2 Antenna terms

The following section reports the definition of commonly used antenna terms. Most definitions are based on the IEEE Standard (*IEEE Standard definitions of Terms for Antennas, IEEE Std. 145-1993 or following versions*), tailored to the class of antennas under test by means of notes. Definitions in IEEE std 145 apply unless otherwise stated.

Antenna Terms	Definition location
Antenna mounting orientation	Section 2.9
Array	Section 2.3
Azimuth pattern	Section 2.7
Cluster	Section 2.3
Directional single beam antenna	Section 2.9
Directional multi beam antenna	Section 2.9
Electrical down tilt angle	Section 2.11
Elevation pattern	Section 2.7
Far field radiation pattern	Section 2.6
Far field radiation pattern cut	Section 2.7
Half power beam width	Section 2.10
Half power beam axis	Section 2.10
Horizontal cut	Section 2.7
Main beam	Section 2.9
Main beam peak axis	Section 2.9
Nominal direction	Section 2.9
Mechanical boresight	Section 2.9
Omni-directional antenna	Section 2.9
Principal half power beam width	Section 2.10
Radiation intensity	Section 2.4
Radiation sphere	Section 2.5
Radiator	Section 2.3
Sidelobe / Grating lobe	Section 2.9
Total power radiation pattern cut	Section 2.8
Beamforming & Calibration	Section 3.4

Table 2.2-1—Antenna terms reference table.

2.3 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 polarized radiators inside the antenna radome, which are connected to a single port (for single-polarized radiators) or to a pair of ports (for dual-polarized 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 8T8R antenna with beamforming capabilities.

In this paper 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 color coding.
The manufacturer shall indicate the association between port and corresponding name inside the xml file.

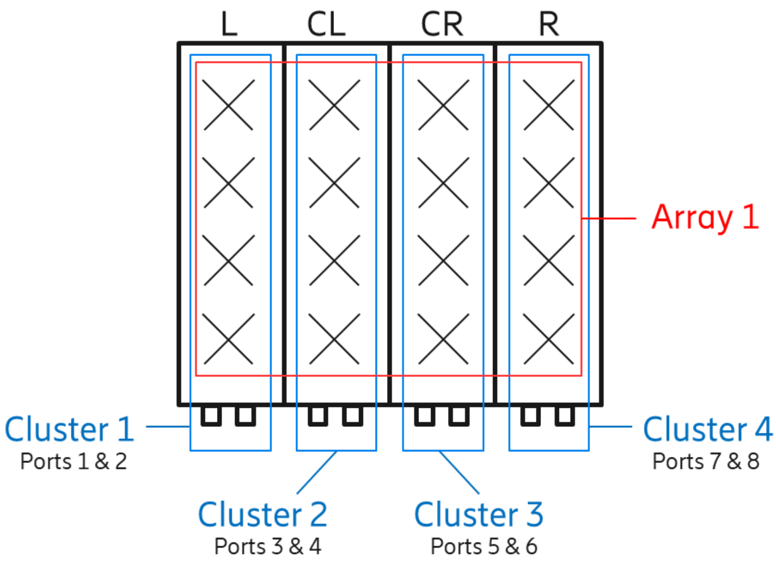


Figure 2.3-1—Possible difference between array and clusters.

Note 2.3.1: *More information about radiator polarization can be found in Section 3.2.2.*

2.4 Radiation Intensity

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

2.5 Antenna Reference Coordinate System

In this White Paper the antenna reference coordinate system is identified by a right-handed set of three orthogonal axis $(\bar{x}, \bar{y}, \bar{z})$ whose origin coincides with the center of an antenna's FF radiation sphere, whose spherical angles (Θ, ϕ) are defined as in Fig. 2.5. Also shown are the normal spherical coordinates (θ, ϕ) as well as the Azimuth (AZ) and Elevation (EL) angles.

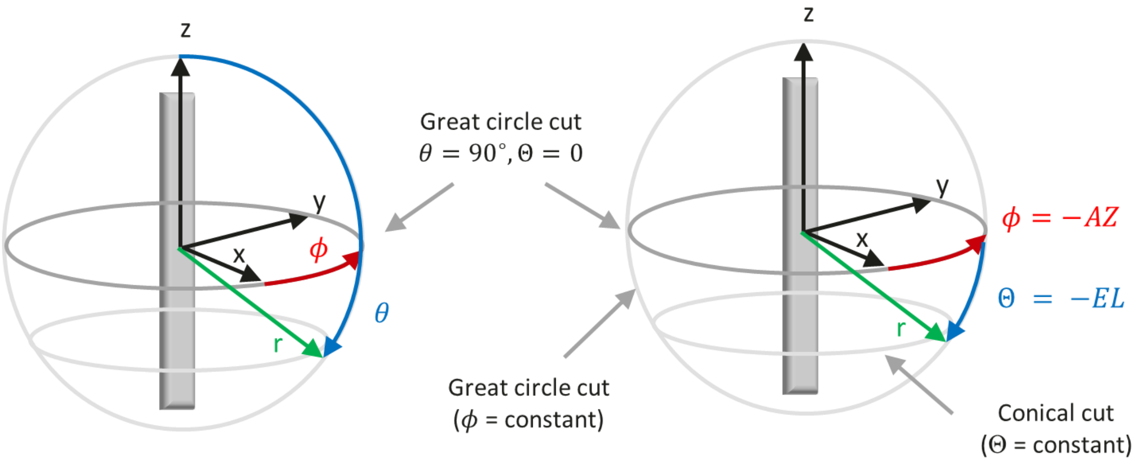


Figure 2.5-1—Antenna Reference Coordinate System.

As shown in the figure, there are several definitions of angles used for antenna patterns. For vertical patterns, we have:

$\theta =$ spherical angle measured from vertical z-axis

or

$\Theta = elevation\ downtilt$ measured down from the horizontal xy-plane

or

$EL = elevation$ measured up from the horizontal plane

where

$\Theta = -EL = \theta - 90°.$

For patterns in the horizontal plane, or in conical cuts (see below), we have:

$\phi =$ spherical angle measured from the x-axis towards the y-axis

or

$AZ = -\phi = azimuth$ measured CW from x-axis towards negative y-axis

These different angles are part of three different coordinate systems, which all can be defined from the (x,y,z) cartesian coordinate system:

Spherical coordinate definition:

$$x = r \sin\theta \cos\phi$$
$$y = r \sin\theta \sin\phi$$
$$z = r \cos\theta$$

Standard azimuth (AZ) and elevation (EL) definition:

$$x = r \cos EL \cos AZ$$
$$y = -r \cos EL \sin AZ$$
$$z = r \sin EL$$

3GPP coordinate definition:

$$x = r\cos\Theta\cos\phi$$
$$y = r\cos\Theta\sin\phi$$
$$z = -r\sin\Theta$$

In the radiation pattern plots in this paper we will use the angles elevation downtilt Θ and azimuth (AZ) angles.

2.6 Far-Field Radiation Pattern

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

2.7 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 Θ is a specified constant and *AZ* or ϕ is a variable used in a conical cut. The conical cut containing the main beam peak is called azimuth cut, while the cut with Θ equal to 0° 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 *AZ* or 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**.

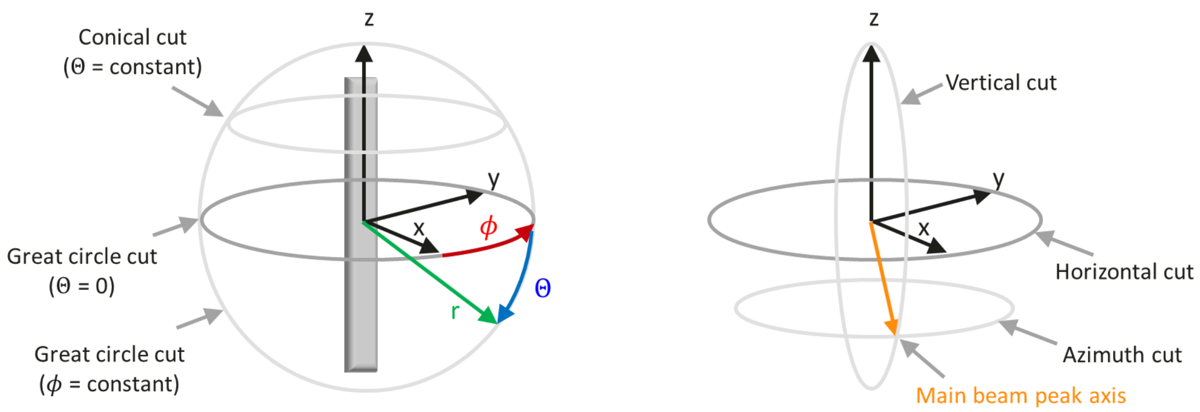


Figure 2.7-1—Cuts over the radiation sphere.

2.8 Total Power Radiation Pattern Cut

The total power radiation pattern cut is obtained by measuring in far-field two orthogonal polarization components of the electric field radiated by the antenna on a specific pattern cut. Let L_V and L_H the values in dB of those components. The total power radiation pattern cut is computed in dB by adding the two as follows:

$$L_{total}[dB] = 10 \cdot \log_{10}(10^{L_V/10} + 10^{L_H/10})$$

and by normalizing it with respect to the maximum.

2.9 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 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 beam 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 fulfill that very purpose. For the purpose of this White Paper, omni-directional antennas shall have no mechanical boresight. Parameters normally referring to it will, instead, have the horizon (great circle cut $\theta = \pi/2$) 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 2.5).

Note 2.9.1: *Omnidirectional and directional single-beam antennas are basically defined by their properties, while multi-beam antennas are defined by their use.*

Note 2.9.2: *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 2.9.3: *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 3.2.1).*

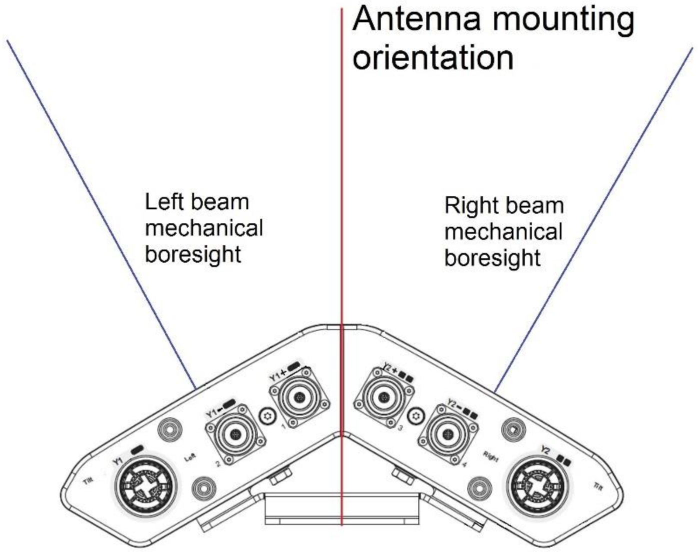


Figure 2.9-1—Example of a dual-beam antenna.

Its mounting orientation is aligned along 0°. Left and right mechanical boresights are respectively pointed to -30° and +30°.

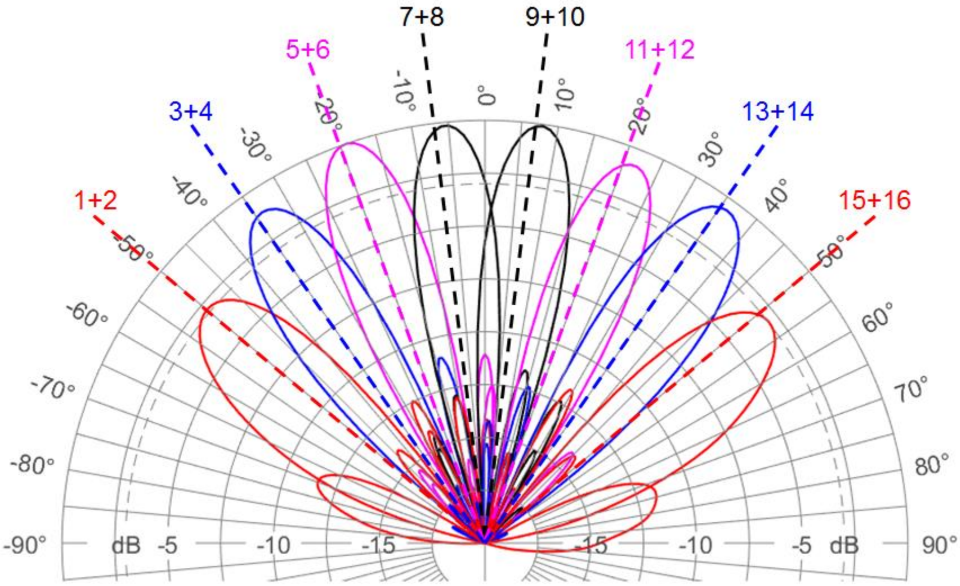


Figure 2.9-2—Azimuth pattern of a multi-beam antenna type II.
Mounting orientation and mechanical boresight are aligned along 0°. Nominal directions are noted with dotted lines. Each beam is associated to a pair of ports only as a device. All the 16 ports collaborate to produce the pattern shown.

2.10 Half-Power Beamwidth

The HPBW is, in a radiation pattern cut containing the beam peak axis, the angle between the two closest directions in which the radiation intensity is one-half the maximum value; its bisect will be here called half-power beam axis. 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 paper 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 2.10.1: *For omnidirectional antennas, the H_HPBW shall not be given.*

2.11 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 (Fig. 2.11-1). 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.

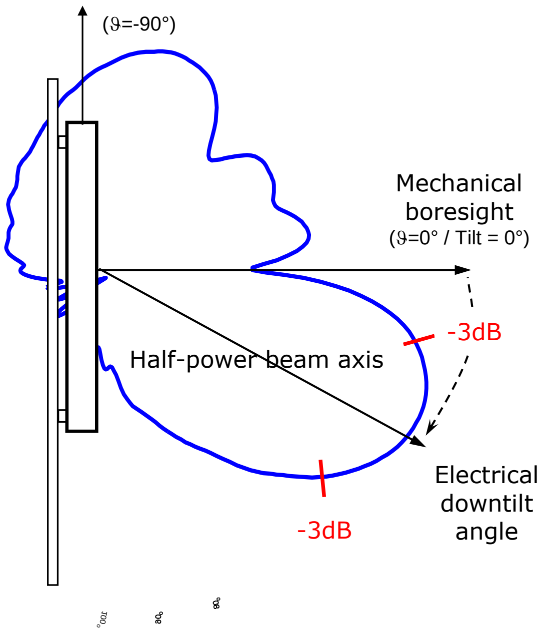


Figure 2.11-1—Electrical downtilt angle.

The electrical tilt value coincides with the value of J for 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 2.7) no boresight, their electrical downtilt angle shall be calculated in the appropriate elevation cut with the whole horizontal cut (J = 0°) as a zero reference. In this case the half-power beam axis might lie along an angle enclosed by J = 180° and J = 360°. Should this happen, in order to have consistent data, the electrical downtilt angle to consider shall be one mirrored around the J = 0° (or J = ±180°) axis instead.

A negative tilt means that the half-power beam axis lies in the hemisphere above the horizontal cut.

3 Parameter and Specifications

A passive BSA can be indicated as "BASTA Passive Antenna compliant" only if (see section 1.1):

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

3.1 Format

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

Parameter Name

Parameter Definition

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

Note 3.1.1: *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 (see Sections 4.3 and 4.4).
- A description of the specification's area of validity.
- The specification's measurement unit.

Note 3.1.2: *For the purpose of this document, the numeric values associated to each parameter shall be always positive when not otherwise specified.*

Specification Example

- An example of the full specification.

XML - Tag Example

- Provides an example for the XML tag, in order to show its uniqueness.
- If a certain value is only valid in a certain range of the antenna (e.g., frequency range) this is specified in the cluster section of the XML file.
- May provide additional information for the application of the tag.

Note 3.1.3: *See also Chapter 10.*

Note 3.1.4: *For the purpose of this document, the precision of the values associated to each parameter shall mostly be limited to a single decimal number, even though in some cases an integer number will suffice. The "XML – Tag Example" sections will always contain an example written with the correct precision to use in each case.*

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 White Paper.
- If needed, an elaboration on issues surrounding the parameter and its specification will be addressed here or in the additional topics section of the White Paper.

Note 3.1.5: *A figure illustrating the parameter and specification will be provided where applicable.*

3.2 Required RF Parameters

3.2.1 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 2.11, 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 2.9, for the purpose of this White Paper 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 $\theta = \pi/2$) 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 2.5).

- 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 -180 degree to +180 degree.
- The attribute 'Nominal Half Power Beamwidth' is defined for each cluster as an integer in the range of 0 degree to +359 degree.
- The attribute 'Nominal Sector' is defined for each cluster as an integer in the range of 0 degree to +359 degree.

Specification Example for Directional single-beam antennas

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

XML - Tag Example for Directional single-beam antennas

<cluster name="R1" beam_forming="false" nominal_direction="0" nominal_sector="120" nominal_horizontal_half_power_beamwidth =”65”>

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°

XML - Tag Example for Directional Multi-Beam Antennas

<cluster name="Y1" beam_forming="false" nominal_direction="-30" nominal_sector="60" nominal_horizontal_half_power_beamwidth =”30”>

<cluster name="Y2" beam_forming="false" nominal_direction="30" nominal_sector="60" nominal_horizontal_half_power_beamwidth =”30”>

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.

3.2.2 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

XML - Tag Example

<frequency_range start="1710" stop="2170"/>

<frequency_sub_range start="1710" stop="1880">

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 9.1 for an example of cellular frequency sub-bands.

3.2.3 Polarization

Parameter Definition

- The nominal polarization associated to the antenna port whose related radiators generate a wave polarized (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

XML - Tag Example

<port name="Y1+" number="1" polarization="+45" location="bottom" connector_type="4.3-10 female" />

<port name="Y1-" number="2" polarization="-45" location="bottom" connector_type="4.3-10 female" />

The polarization is provided as a value for a single port and associated to a port's name.

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 labeling convention is described in Section 9.5.

3.2.4 Gain

Parameter Definition

- According to the definitions provided by IEEE-145 (1993):
  - The antenna gain (in a given direction) is the ratio of the radiation intensity (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 isotropically.
  - A realized gain is the gain 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**.

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 4.6.
- 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 in Section 4.6 .
- A discussion of guidelines for a gain measurement is presented in Section 9.2 and a discussion of the measurement accuracy that can be expected when measuring gain on a far-field range is discussed in Section 9.4.

Specification Example

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

XML - Tag Example

<gain_at_tilt min="17.4" mid="17.5" max="17.0"/>

<gain_over_all_tilts value="17.4" tolerance="0.3"/>

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.

3.2.5 Gain Ripple

Parameter Definition

- This parameter is required only for omnidirectional antenna.
- Gain ripple is the ratio between the peak and the lowest level of the azimuth pattern.

Note 3.2.1: *If the antenna is a single-beam or multi-beam, this parameter shall not be given. Vice versa, it shall be treated as required for omnidirectional antennas.*

Specification Definition

- Gain ripple is a maximum value in dB.

- It is the difference between the highest and lowest azimuth pattern level, if both are considered in dB.
- Pattern levels for this parameter shall be taken with a 1° angular resolution.
- 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.

Specification Example

Type: Distribution-based	**1710-1880 MHz**	**1850-1990 MHz**	**1920-2170 MHz**
Gain Ripple	< 3.0	< 4.1	< 3.9

XML - Tag Example

<gain_ripple value="3.2"/>

Relevance

- This parameter gives an estimation of the "roundness" of the azimuth pattern.
- It is the most characterizing parameter for omni antennas' radiation in the azimuth plane.
- An ideal antenna, which radiates perfectly in every direction in the azimuth plane, would have a gain ripple of 0.0 dB.

3.2.6 Azimuth Beamwidth

Parameter Definition

- The 3 dB (or half-power) azimuth beamwidth of the antenna is defined in the azimuth radiation pattern as the angular width including the main beam peak, which extends between the only two points at a beam level 3 dB lower than the maximum of radiation, which are also the nearest to the main beam peak.

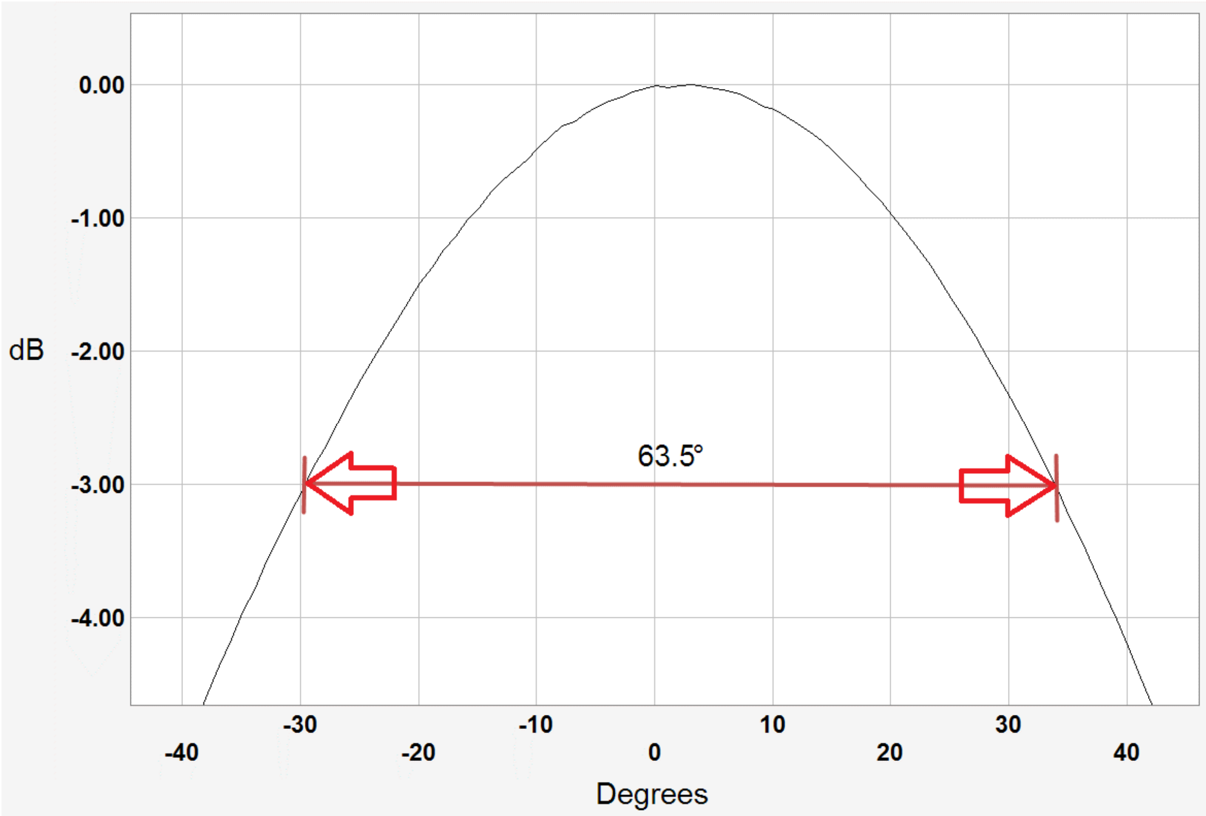


Figure 3.2-1—Calculation of azimuth beamwidth.

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 ± 1.9	65.0 ± 1.6	63.5 ± 2.3

XML - Tag Example

<azimuth_beamwidth value="67.9" tolerance="1.9"/>

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.

3.2.7 Elevation Beamwidth

Parameter Definition

- The 3 dB (or half-power) elevation beamwidth of the antenna is defined in the elevation radiation pattern as the angular width including the main beam peak, which extends between the only two points at a beam level 3 dB lower than the maximum of radiation, which are also the nearest to the main beam peak.

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 ± 0.4	7.0 ± 0.3	6.6 ± 0.5

XML - Tag Example

<elevation_beamwidth value="6.6" tolerance="0.5"/>

Relevance

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

3.2.8 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

XML - Tag Example

<electrical_downtilt start="0" stop="10"/>

<electrical_downtilt start="4" stop="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 optimization.
- Electrical downtilt can be used for cell load balancing.

3.2.9 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 4.7 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

XML - Tag Example

<elevation_downtilt_deviation value="0.5"/>

Relevance

- A measure of the accuracy of electrical tilt settings.

3.2.10 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

XML - Tag Example

<impedance value="50"/>

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.

3.2.11 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

XML - Tag Example

<vswr value="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.

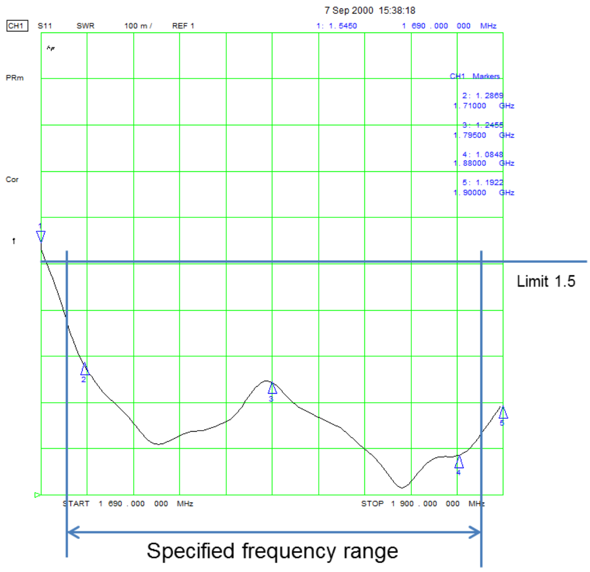


Figure 3.2-2—Example of VSWR measurement of an antenna port.

3.2.12 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

XML - Tag Example

<return_loss value="14.0"/>

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:

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

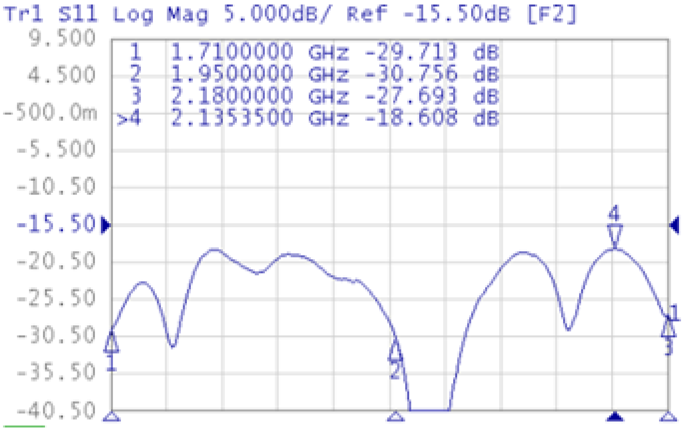


Figure 3.2-3—Example of a return loss measurement on a single antenna port.

3.2.13 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.

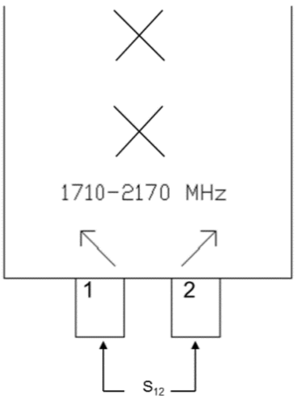


Figure 3.2-4—Intra-Cluster isolation example: single cluster antenna.

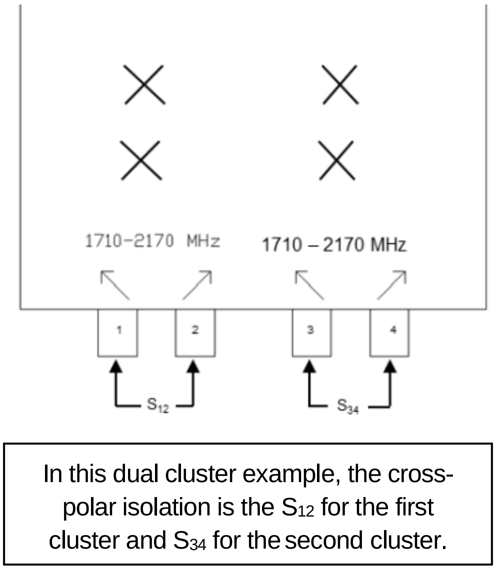


Figure 3.2-5—Intra-Cluster isolation example: dual cluster antenna.

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	> 28	> 26

XML - Tag Example

<isolation_intra_cluster value="26"/>

Relevance

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

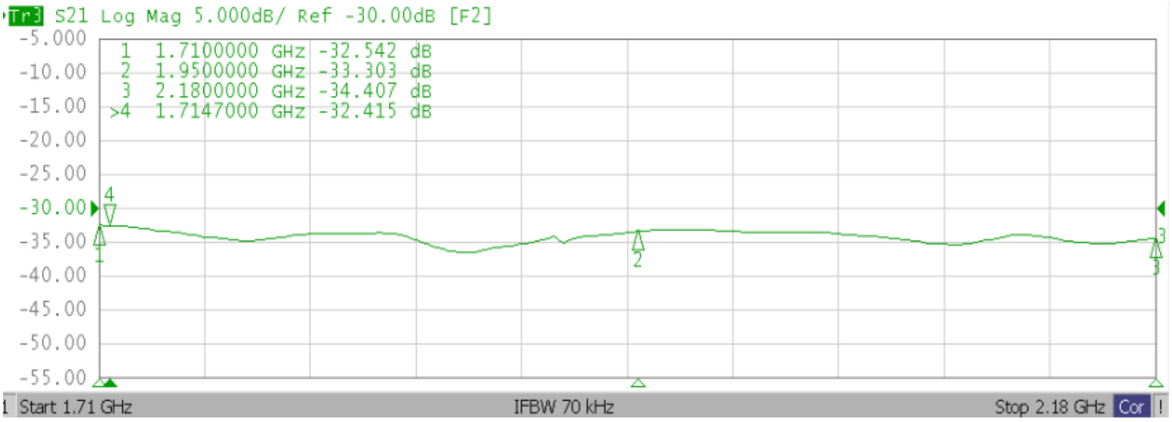


Figure 3.2-6—Example of an intra-cluster isolation measurement between two antenna ports.

3.2.14 **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 20W (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 9.5 .
- PIM measurement values shall refer to measurement at the connector in accordance with IEC 62037-6, Passive RF and microwave devices, intermodulation level measurement – Part 6: Measurement of passive intermodulation in antennas.

Specification Example

Type: Absolute	**1710-2170 MHz**
Passive Intermodulation	< -150

XML - Tag Example

<passive_intermodulation value="-150"/>

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.

3.2.15 **Front-to-Back Ratio, 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°.

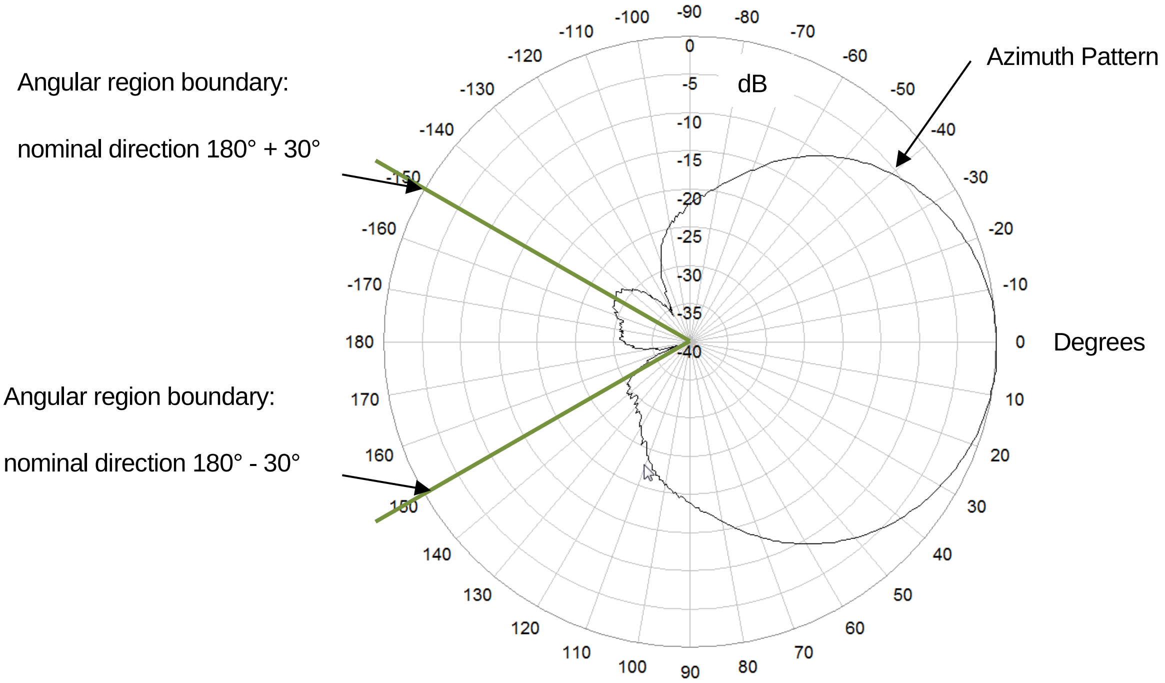


Figure 3.2-7—Angular region for front-to-back, total power ± 30° of a 0° nominal direction antenna.

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 2.8 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	> 26.4	> 25.8

XML - Tag Example

<front_to_back_ratio_total_power_pm30 value="26.4"/>

Relevance

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

3.2.16 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.

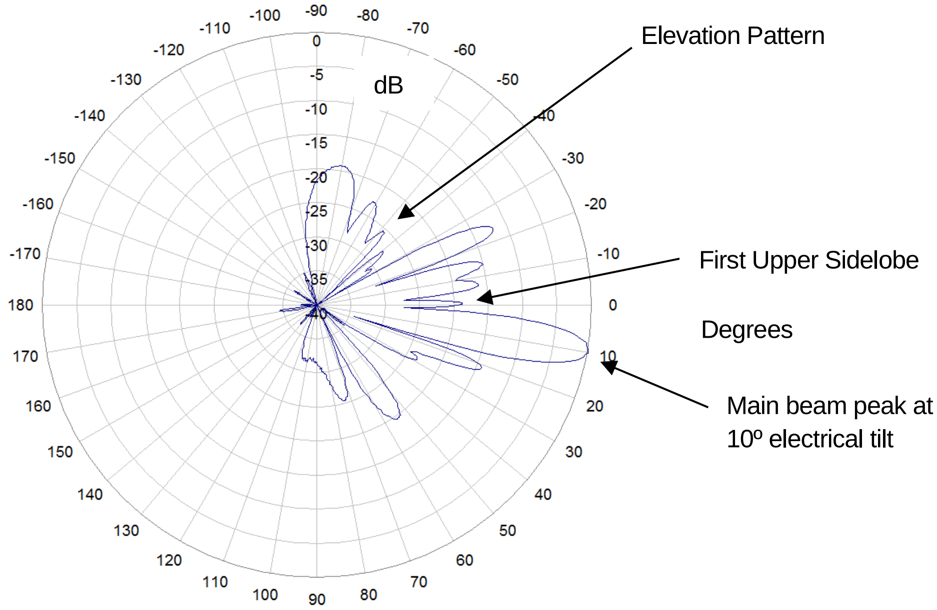


Figure 3.2-8—First upper sidelobe suppression.

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 9.5 .
- For omnidirectional antennas, this parameter shall be referenced to the cut by the beam peak axis.

<u>Specification Example</u>

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

<u>XML - Tag Example</u>

```
<upper_sidelobe_suppression_first value="18.6"/>
```

<u>Relevance</u>

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

3.2.17 Upper Sidelobe Suppression, Peak to 20°

<u>Parameter Definition</u>

- 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 degrees above it.

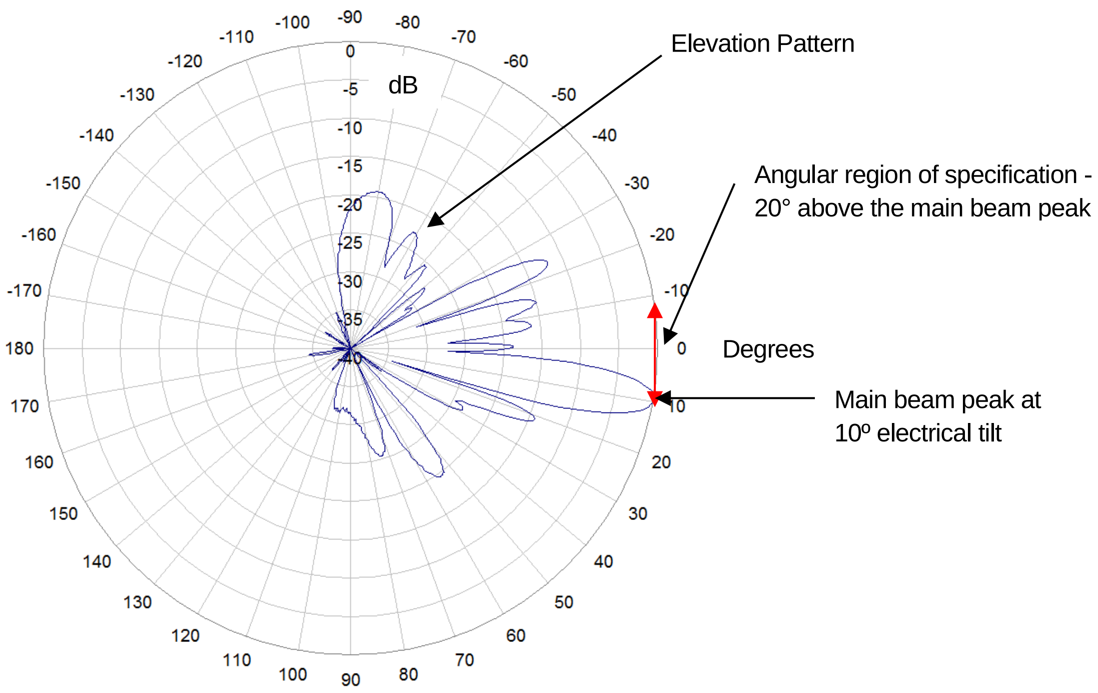


Figure 3.2-9—Upper sidelobe suppression, peak to 20º.

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 9.5 .
- 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	> 17.8	> 16.2

XML - Tag Example

<upper_sidelobe_suppression_peak_to_20 value="16.2"/>

Relevance

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

3.2.18 **Cross-Polar Discrimination 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.

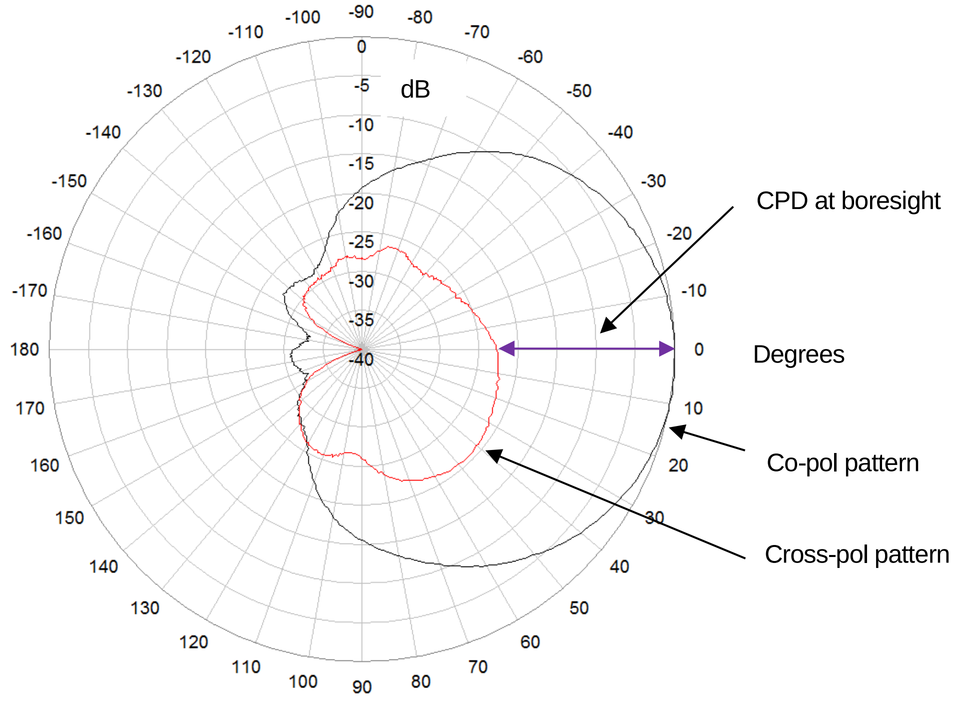


Figure 3.2-10—Cross-polar discrimination at mechanical boresight.

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 CPR of the analyzed 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	> 22.1	> 26.3

XML - Tag Example

<cross_polar_discrimination_at_mechanical_boresight value="25.4"/>

Relevance

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

3.2.19 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 in Watts.
- 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

XML - Tag Example

<maximum_effective_power_per_port value="250"/>

Relevance

- Exceeding the specified power rating can damage the antenna.

3.2.20 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 in Watts.
- 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

XML - Tag Example

<maximum_effective_power_antenna value="1200"/>

Relevance

- Exceeding the specified power rating can damage the antenna.

3.2.21 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

XML - Tag Example

<isolation_inter_cluster value="20"/>

Relevance

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

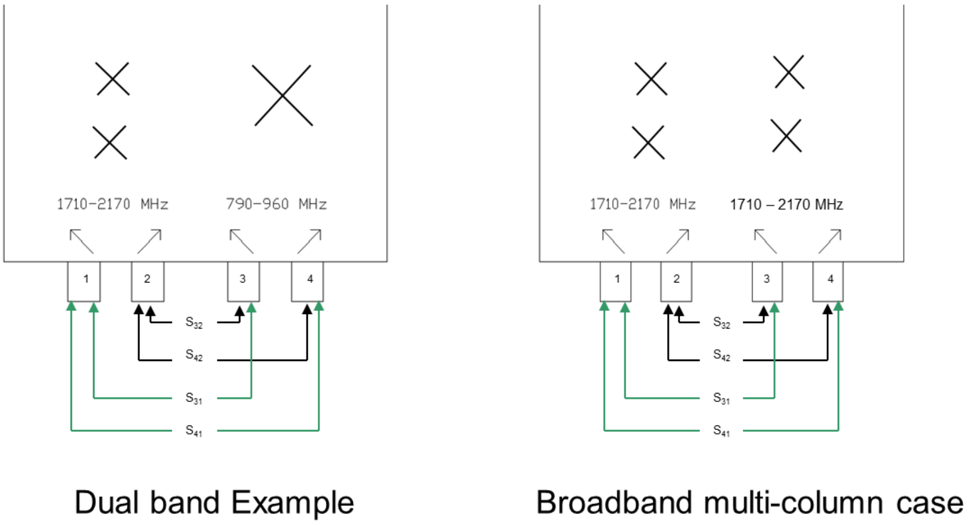


Figure 3.2-11—Inter-Cluster isolation examples.

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

Figure 3.2-12—Inter-cluster isolation vs. frequency on a single pair of ports.

3.2.22 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.

Note: This parameter is set as optional, in fact if the antenna has no beamforming capabilities it shall not be given.

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	**1**	**2**
Nominal Direction	-25°	25°

XML - Tag Example

```
<soft_split_beam name="1">
        <azimuth_nominal_beam_direction value="-25"/>
</soft_split_beam >
<soft_split_beam name="2">
        <azimuth_nominal_beam_direction value="25"/>
</soft_split_beam >
```

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.

3.3 Optional RF Parameters

3.3.1 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.

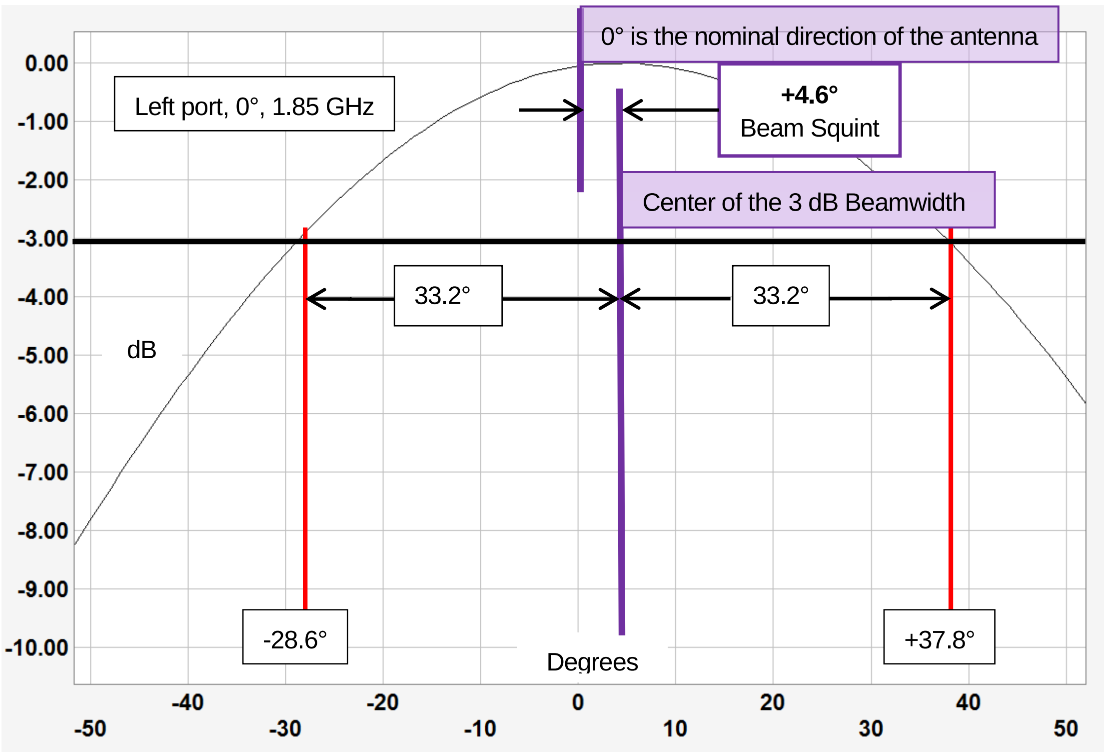


Figure 3.3-1—Illustration of beam squint calculation for a given frequency, tilt and port.

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 analyzed 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 ± 2.4	2.7 ± 2.7	2.6 ± 2.6

XML - Tag Example

<azimuth_beam_squint value="2.7" tolerance="2.7"/>

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 centering 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 center, 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.

3.3.2 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.

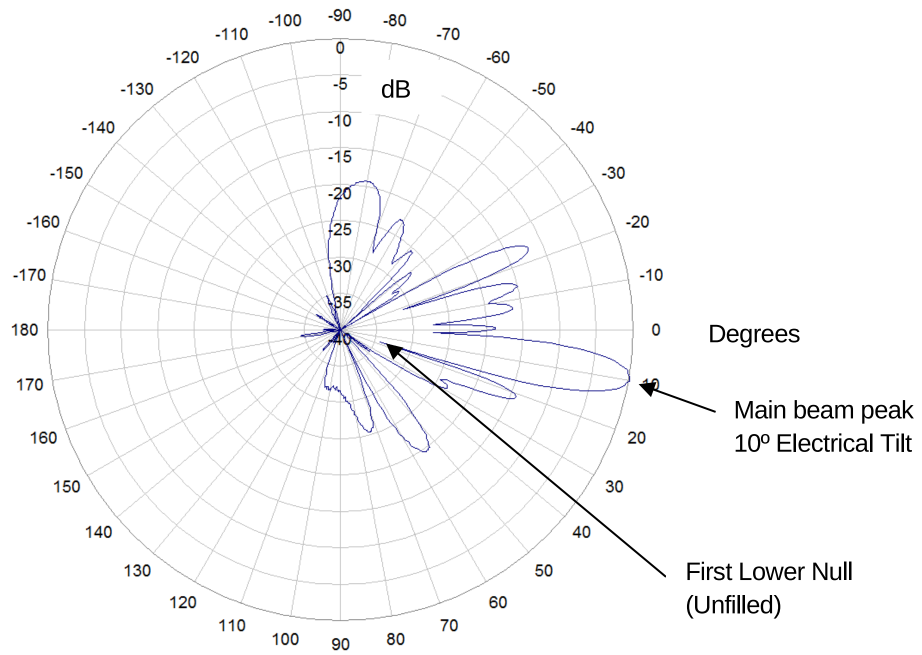


Figure 3.3-2—Identification of the lower first null.

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 9.5 .
- 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**
Null Fill	< 30.2	< 30.3	< 30.3

XML - Tag Example

<null_fill value="30.2"/>

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.

3.3.3 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.

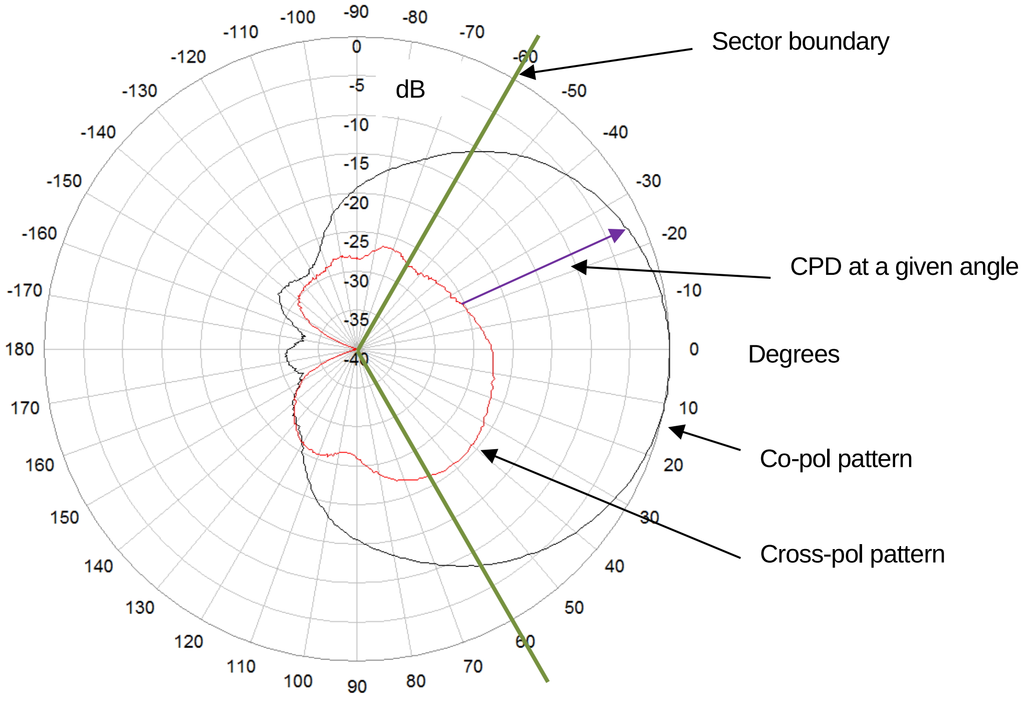


Figure 3.3-3—Cross-polar discrimination over 120° sector of a 0° mechanical boresight.

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 CPR over the nominal beamwidth of the analyzed 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	> 9.4	> 8.5

XML - Tag Example

<cross_polar_discrimination_over_sector value="10.8"/>

Relevance

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

3.3.4 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.

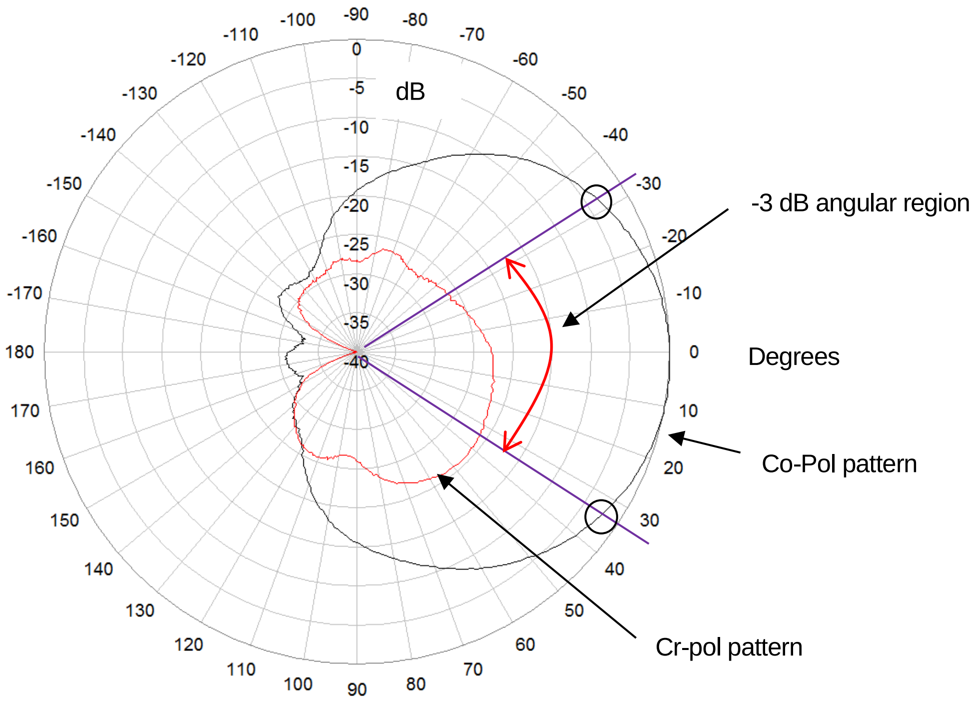


Figure 3.3-4—Cross pol discrimination over 3 dB azimuth beamwidth.

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	> 16.3	> 14.6

XML - Tag Example

<cross_polar_discrimination_over_3_db_azimuth_beamwidth value="11.8"/>

Relevance

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

3.3.5 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.

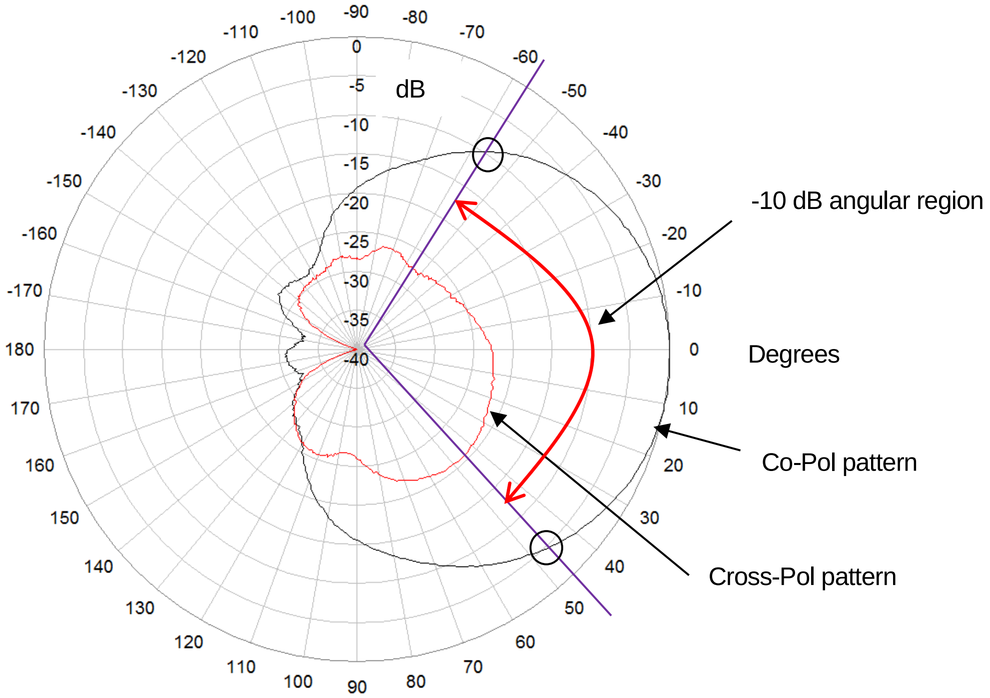


Figure 3.3-5—Cross pol discrimination over 10 dB azimuth beamwidth.

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	> 13.4	> 12.2

XML - Tag Example

<cross_polar_discrimination_over_10_db_azimuth_beamwidth value="11.8"/>

Relevance

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

3.3.6 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	> 10.7	> 9.8

XML - Tag Example

<cross_polar_discrimination_over_3_db_elevation_beamwidth value="11.3"/>

Relevance

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

3.3.7 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	> 10.2	> 9.8

XML - Tag Example

<cross_polar_discrimination_over_10_db_elevation_beamwidth value="11.0"/>

Relevance

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

3.3.8 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.

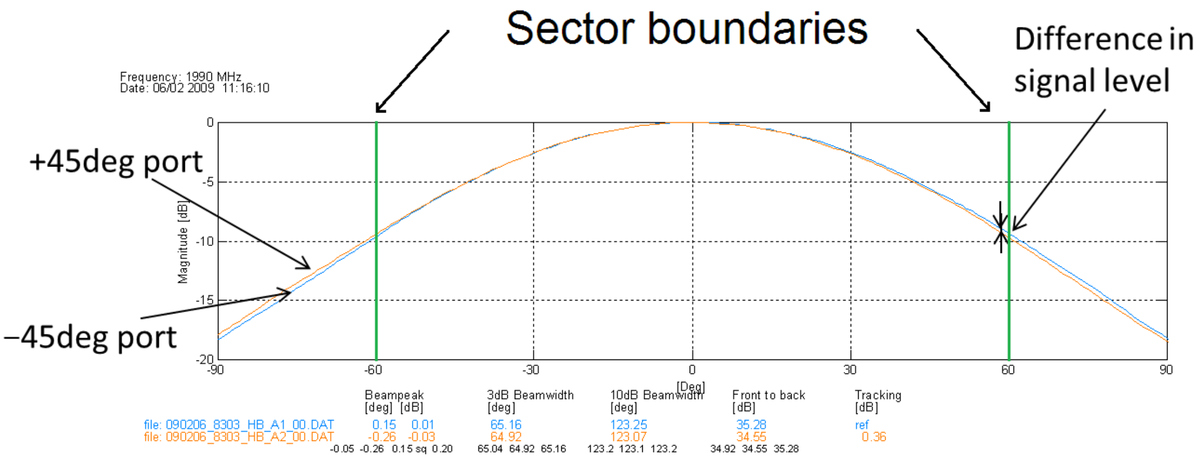


Figure 3.3-6—Azimuth beam port-to-port tracking.

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	< 1.5	< 1.6

XML - Tag Example

<azimuth_beam_port_to_port_tracking value="1.6"/>

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.

3.3.9 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.

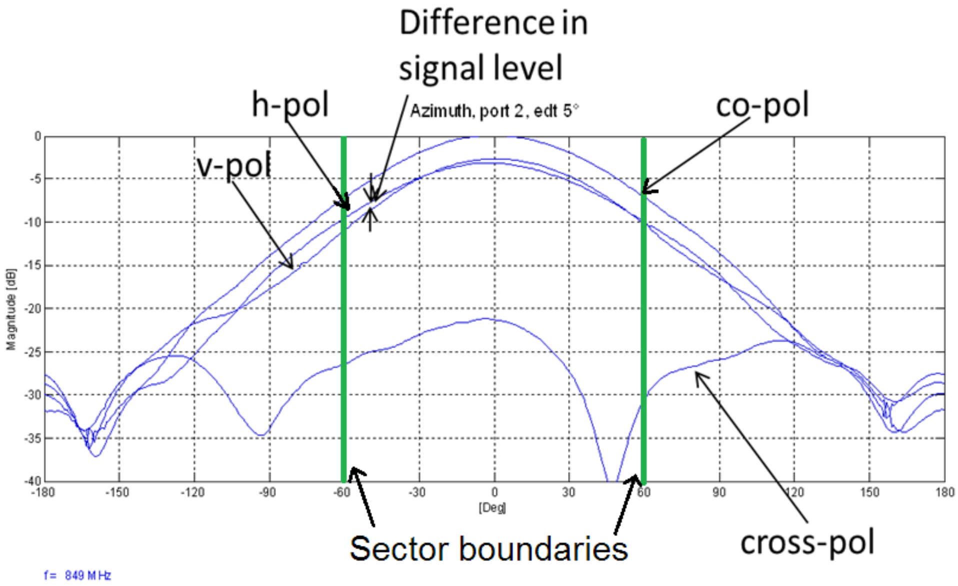


Figure 3.3-7—Azimuth beam H/V tracking.

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	< 2.2	< 1.6

XML - Tag Example

<azimuth_beam_hv_tracking value="2.2"/>

Relevance

- This parameters give an overview on the behavior 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.

3.3.10 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.

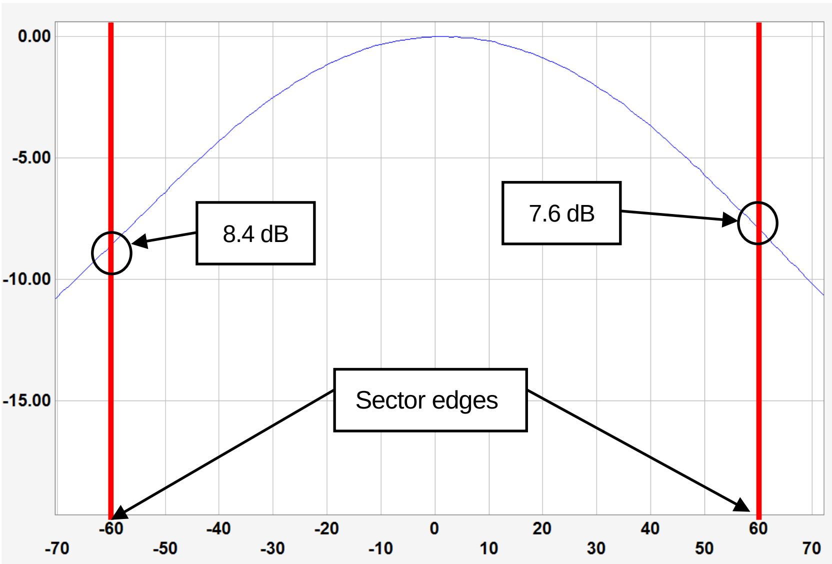


Figure 3.3-8—Azimuth beam roll-off.

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 analyzed 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 ± 1.6	9.8 ± 2.3	11.3 ± 2.1

XML - Tag Example

```
<azimuth_beam_roll_off value="11.3" tolerance="2.1"/>
```

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.

3.3.11 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 degrees above it.

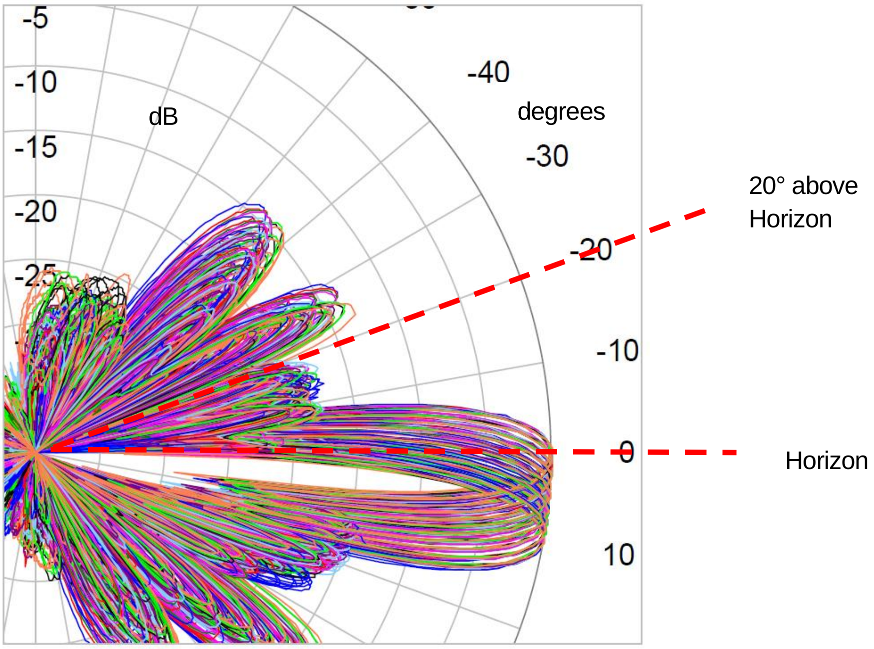


Figure 3.3-9—Upper sidelobe suppression, horizon to 20º.

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 9.5 .
- 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	> 16.6	> 18.4

XML - Tag Example

<upper_sidelobe_suppression_horizon_to_20 value="18.4"/>

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.

3.3.12 **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.

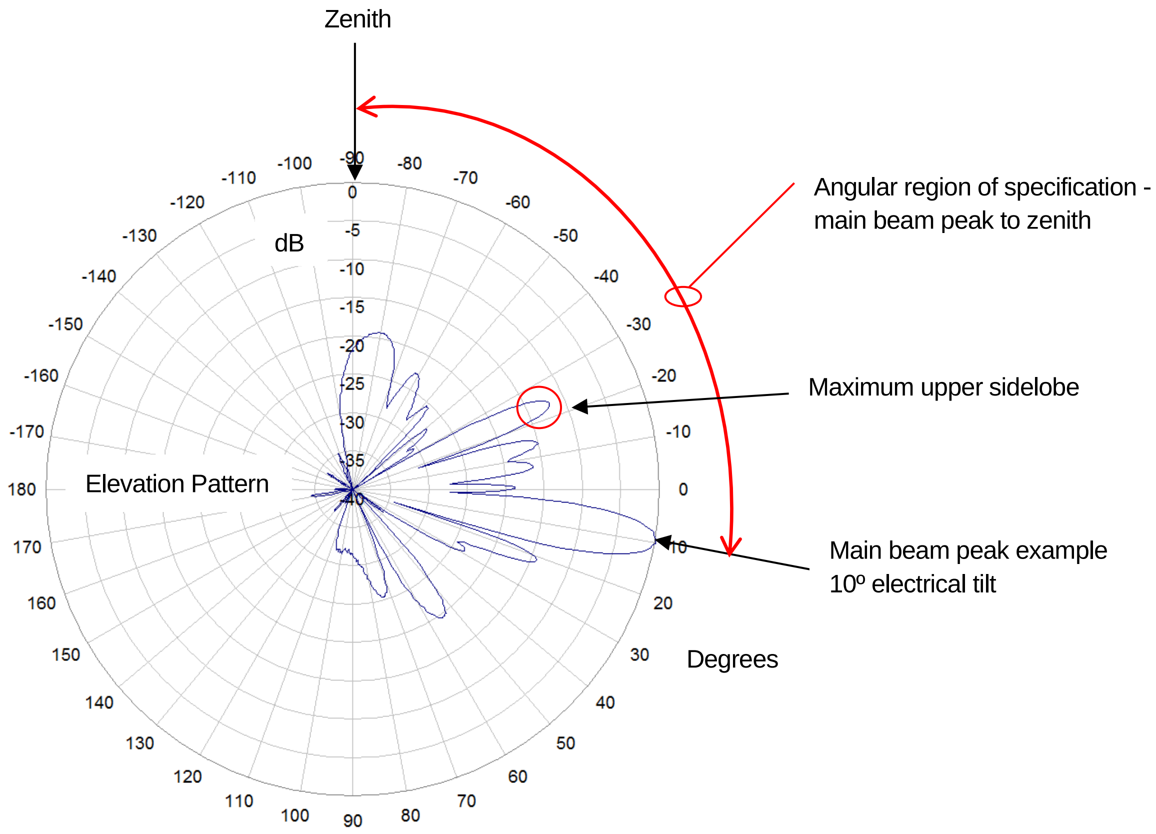


Figure 3.3-10—Maximum Upper Sidelobe Suppression.

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	> 15.1	> 15.6

XML - Tag Example

<maximum_upper_sidelobe_suppression value="14.3"/>

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.

3.3.13 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((Pd/(Pu))

Where:

- *Pd* 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.
- *Pu* 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 ± 0.5	11.5 ± 0.6	11.8 ± 0.7

XML - Tag Example

<azimuth_interference_ratio value="11.0" tolerance="0.5"/>

Relevance

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

3.3.14 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.

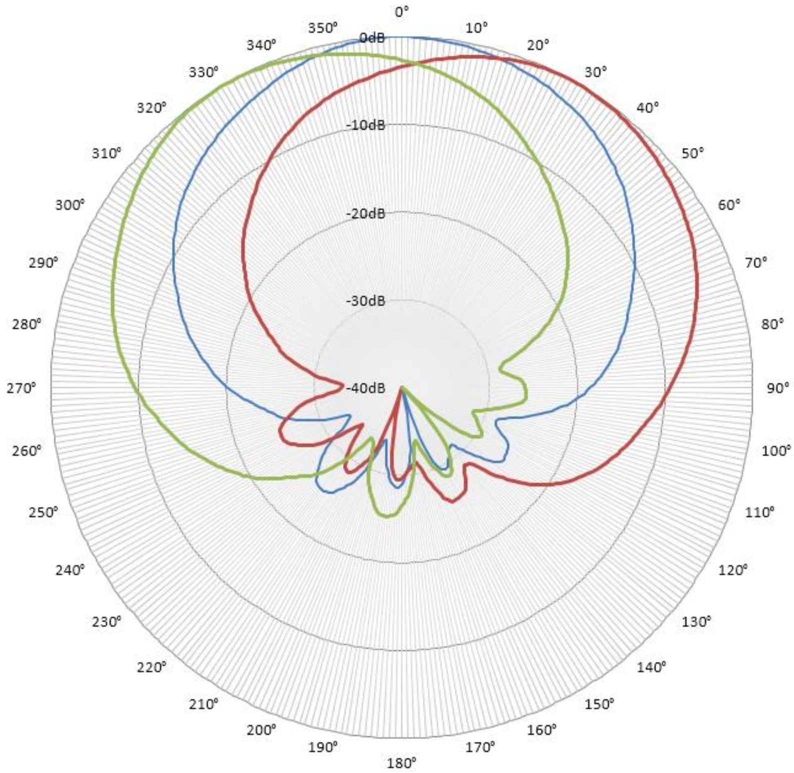


Figure 3.3-11—Some patterns of an azimuth beam steering antenna (pan angles: -30°; 0°; +30°).

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 4.2), except that the angular resolution shall in this case be at least 10 degrees. 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 file (see Section 10.1), which shall be named accordingly (see Section 10.1.1).

Specification Example

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

BASTA10-0_CELLMAX_XYZ,PANM030_1999-12-30_V00_F.xml

BASTA10-0_CELLMAX_XYZ,PANM020_1999-12-30_V00_F.xml

BASTA10-0_CELLMAX_XYZ,PANM010_1999-12-30_V00_F.xml

BASTA10-0_CELLMAX_XYZ,PANP000_1999-12-30_V00_F.xml

BASTA10-0_CELLMAX_XYZ,PANP010_1999-12-30_V00_F.xml

BASTA10-0_CELLMAX_XYZ,PANP020_1999-12-30_V00_F.xml

BASTA10-0_CELLMAX_XYZ,PANP030_1999-12-30_V00_F.xml

XML - Tag Example

- Not applicable

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 optimization.
    - RF coverage and interference optimization.
    - Sector load balancing.

3.3.15 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.

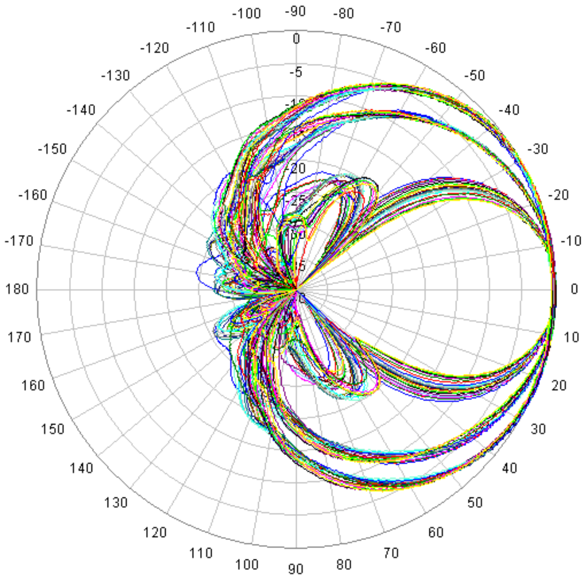


Figure 3.3-12— Patterns of a variable azimuth beamwidth BSA (35°/65°/105° pattern overlays).

Specification Definition

- For the purpose of this White Paper, a fan angle is defined as the nominal H_HPBW (see Section 2.8) 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 file (see Section 10.1), which shall be named accordingly (see Section 10.1.1).
- The parameters of antennas that are not able to vary their beam continuously shall be described by a single XML file for each fan angle possibility.
- The parameters of antennas that are able to vary their beam continuously shall be described by a single XML file for each relevant fan angle. The recommendations on the relevant fan angles are similar to those specified for the electrical downtilt (see Section 4.2), except that the angular resolution shall in this case be at least 10 degrees. The lowest fan angle shall be the reference for the all the other ones.

Specification Example

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

BASTA10-0_AMPHENOL_XYZ,FAN035_2007-05-01_V02_P.xml

BASTA10-0_AMPHENOL_XYZ,FAN065_2007-05-01_V02_P.xml

BASTA10-0_AMPHENOL_XYZ,FAN105_2007-05-01_V02_P.xml

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

BASTA10-0_AMPHENOL_XYZ,FAN065_2007-05-01_V02_P.xml

BASTA10-0_AMPHENOL_XYZ,FAN070_2007-05-01_V02_P.xml

BASTA10-0_AMPHENOL_XYZ,FAN080_2007-05-01_V02_P.xml

BASTA10-0_AMPHENOL_XYZ,FAN090_2007-05-01_V02_P.xml

XML - Tag Example

- Not applicable

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 optimization.
  - RF coverage and interference optimization.
  - Sector load balancing.

3.3.16 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 in Watts.
- 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

XML - Tag Example

<maximum_effective_power_cluster value="500"/>

Relevance

- Exceeding the specified power rating can damage the antenna.

3.3.17 Efficiency

Parameter Definition

- 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 in fact 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

$$Efficiency = 10 \cdot \log\left(\frac{G}{D}\right)$$

- 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 9.3
- According to the measured D in dB and G in dBi, the Efficiency η can be calculated by the formula

$$Efficiency = G(dBi) - D(dB)$$

- 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 9.3.2 (Gain by Directivity/Loss Method) 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±0.29	-1.12±0.31	-1.31±0.38	-1.27±0.25

XML - Tag Example

<efficiency value="-1.19" tolerance="0.29"/>

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.

3.3.18 **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.

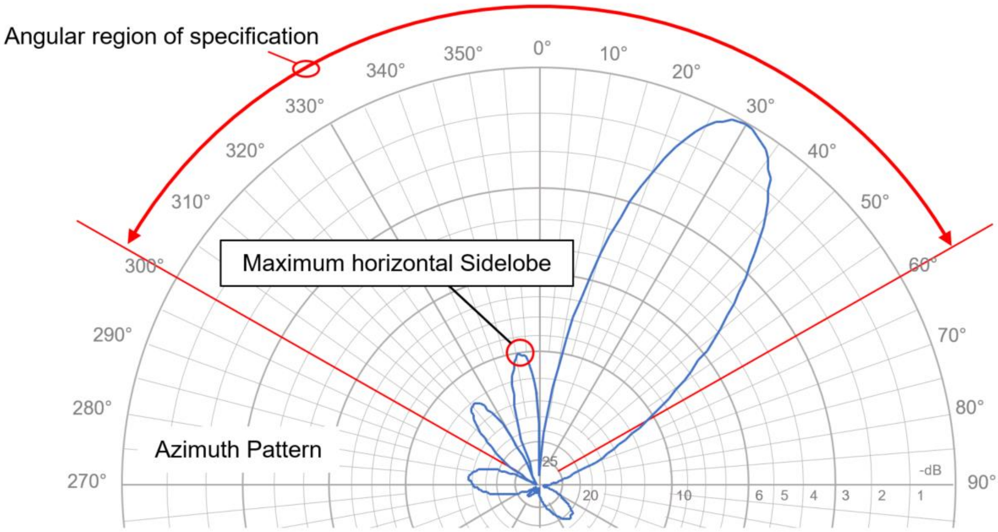


Figure 3.3-13—Maximum Horizontal Sidelobe Suppression, e.g. 8T8R antenna with four columns.

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 (dB)	> 10.5

XML - Tag Example

<maximum_horizontal_sidelobe_suppression value="10.5"/>

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.

3.4 Beamforming Antennas

First of all, it is important to clarify that this chapter 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. That is why the chapter is named 'Antennas supporting Beamforming' as these antennas can enable beamforming when connected to an external radio unit, but not by themselves.

These antennas are passive antennas and are connected to the external radio unit with cables.

The Antennas supporting beamforming usually consist of a set of dual polarized columns (e.g., four columns for 8T8R array) with typical half wave spacing and a calibration network. According to AISG single clusters (columns) are marked with letters from left to right (L-left, CL-center left, CR-center right and R-right).

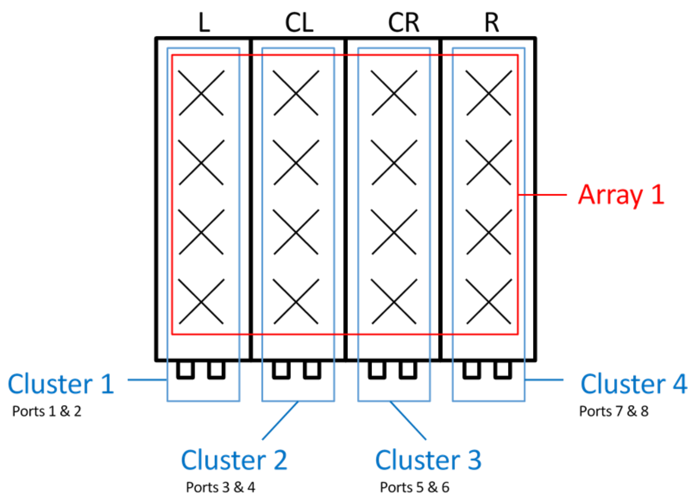


Figure 3.4-1 — 8T8R antenna array with four dual polarized columns (Front view)

The performance of antennas supporting 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 optimized by the antenna vendor to get optimal performance for each type of beam. The feeding weights are exchanged between the antenna and radio manufacturer, so the radio unit can load this information and 'know' how to feed the antenna in order 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 beams are tested through conducted measurements (without radio unit). Therefore, auxiliary devices (e.g. simple power dividers) might need to be used and calibrated out during conducted measurements. In the final deployment scenario, these auxiliary devices will not be present and the antenna will be fed directly from the external radio unit.

Typical antenna parameters like Gain, beamwidth, sidelobe suppression, etc., can be calculated for each type of beam from the conducted measurements

For all the beams defined in this section, except for the single column beams, the radiated power is highly dependent on the feeding weights. To be able to specify the beams in terms of EIRP and not only in terms of gain or if more information about different beams is needed, we refer to the document "Recommendation on Base Station Active Antenna System Standards".

The Antennas supporting beamforming typically contain a calibration network and a calibration port. 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 White Paper

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

XML - Tag Example covering a Beamforming Array

```
<beamforming_array name="P1">
    <single_beam> … </single_beam>
    <broadcast_beam> … </broadcast beam>
    <traffic_0_beam> … </traffic_0_beam>
    <traffic_30_beam> … </traffic_30_beam>
    <soft_split_beam name=”1”> … </soft_split_beam>
    <soft_split_beam name=”2”> … </soft_split_beam>
</beamforming_array>
```

3.4.1 **Required Beams**

3.4.1.1 Single Column Beam

The characteristic of a single column beam of an antenna array (e.g., 8T8R with four dual polarized 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
- Gain (see chapter 3.2.4)
- Azimuth beamwidth (see chapter 3.2.6)
- Elevation beamwidth (see chapter 3.2.7)
- Front-to-Back Ratio Total Power ± 30° (see chapter 3.2.15)

- First Upper Sidelobe Suppression (see chapter 3.2.16)

and additionally, could be described by optional parameter

- Cross-Polar Discrimination at mechanical boresight (see chapter 3.3.3)

These parameters have to be obtained by an average of the measurements of each cluster (single column) (e.g., for 8T8R 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

Parameter Set of Single Column Beam of 8T8R Array P1		
	Unit	**3300-3800 MHz**
Gain over all tilts	dBi	15.1 ± 0.5
Azimuth Beamwidth	degree	88.1 ± 1.5
Elevation Beamwidth	degree	7.0 ± 0.3
Front-to-Back Ratio, Total Power, ± 30°	dB	> 26.4
Cross-Polar Discrimination at mechanical boresight	dB	> 8.4
First Upper Sidelobe Suppression	dB	> 17.8

XML - Tag Example

```
<single_beam>
    <gain_over_all_tilts value="15.1" tolerance="0.5"/>
    <azimuth_beamwidth value="88.1" tolerance="1.5"/>
    <front_to_back_ratio_total_power_pm30 value="26.4" />
    <cross_polar_discrimination_at_mechanical_boresight value="8.4" />
  <elevation_beamwidth value="7.0" tolerance="0.3"/>
    <upper_sidelobe_suppression_first value="17.8"/>
</single_beam>
```

Relevance

- Single column beam might be useful to compare single column behavior

3.4.1.2 Broadcast Beam

In this section, Broadcast Beam refers to a Broadcast Beam Configuration as defined in "Recommendation on Base Station Active Antenna System Standards" (add to the reference list) with a single Broadcast Beam designed to cover the whole sector.

Broadcast beam must be described by parameters of

- Gain (see chapter 3.2.4)
- Azimuth beamwidth (see chapter 3.2.6)
- Elevation beamwidth (see chapter 3.2.7)
- Front-to-Back Ratio, Total Power, ± 30° (see chapter 3.2.15)
- First Upper Sidelobe Suppression (see chapter 3.2.16)

and additionally, could be described by optional parameter

- Azimuth Beam Roll-Off (see chapter 3.3.10)
- Cross-Polar Discrimination at mechanical boresight (see chapter 3.3.3)

Parameter Definition

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

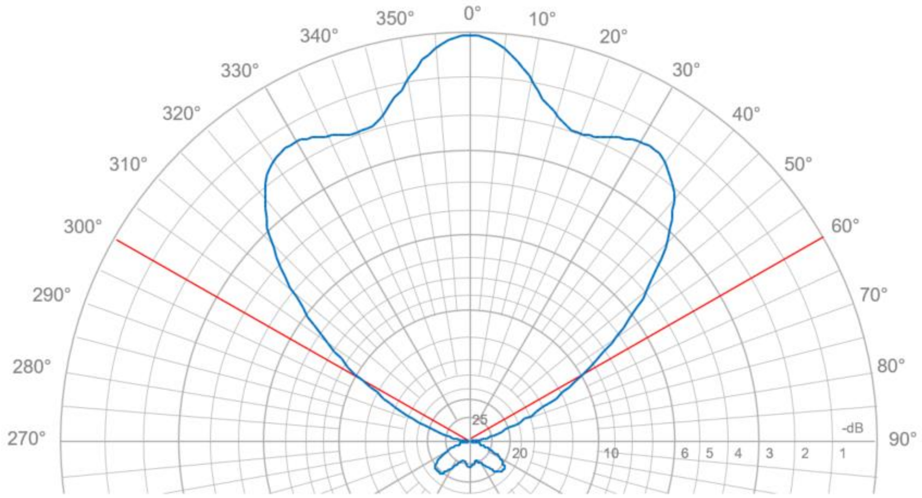


Figure 3.4-2 —Broadcast Beam, e.g. 8T8R antenna with four columns separated half wavelength and fed with amplitudes 1/2/2/1 and phase 120/0/0/120 distribution.

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

	Unit	3300-3800 MHz
Gain over all tilts	dBi	17.8 ± 0.5
Azimuth Beamwidth	degree	65.1 ± 1.5
Elevation Beamwidth	degree	7.0 ± 0.3
Front-to-Back Ratio, Total Power, ± 30°	dB	> 26.4
Cross-Polar Discrimination at mechanical boresight	dB	> 12.4
First Upper Sidelobe Suppression	dB	> 17.8

XML - Tag Example

```
<broadcast_beam>
    <gain_over_all_tilts value="17.8" tolerance="0.5"/>
    <azimuth_beamwidth value="65.1" tolerance="1.5"/>
    <front_to_back_ratio_total_power_pm30 value="26.4" />
    <cross_polar_discrimination_at_mechanical_boresight value="12.4" />
  <elevation_beamwidth value="7.0" tolerance="0.3"/>
    <upper_sidelobe_suppression_first value="17.8"/>
</broadcast_beam>
```

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 “Recommendation on Base Station Active Antenna System Standards” and therefore their definition is not considered in this document

3.4.1.3 Traffic Beam Zero

Traffic beam zero is a traffic beam in 0° direction and must be described by required parameters of

- Gain (see chapter 3.2.4)
- Azimuth beamwidth (see chapter 3.2.6)
- Front-to-Back Ratio, Total Power, ± 30° (see chapter 3.2.15)

and additionally, could be described by optional parameter

- Maximum Horizontal Sidelobe Suppression (see chapter 3.3.18)
- Cross Polar Discrimination over 3 dB Azimuth Beamwidth (see chapter 3.3.4)

__Parameter Definition__

- Traffic beam zero is a set of parameters which describes the characteristics of a traffic beam directed to azimuth direction zero degree.

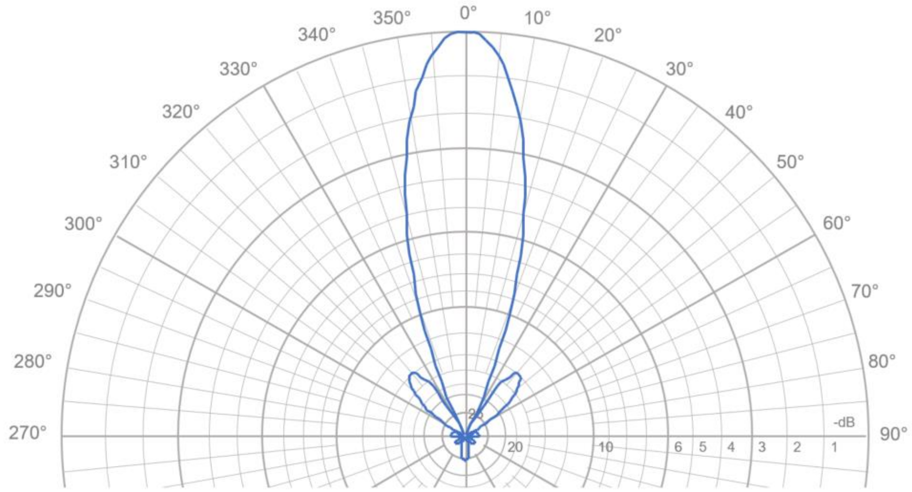


Figure 3.4-3 — Traffic Beam Zero, e.g. 8T8R antenna with four columns separated half wavelength and fed with uniform amplitude and phase distribution.

__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__

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

XML - Tag Example


```
<traffic_0_beam>
    <gain_over_all_tilts value="21.8" tolerance="0.5"/>
    <azimuth_beamwidth value="19.1" tolerance="1.5"/>
    <front_to_back_ratio_total_power_pm30 value="26.4" />
    <cross_polar_discrimination_over_3_db_azimuth value="12.4" />
    <maximum_horizontal_sidelobe_suppression value="17.8"/>
</traffic_0_beam>
```


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.

3.4.1.4 Traffic Beam 30

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

- Gain (see chapter 3.2.4)
- Azimuth beamwidth (see chapter 3.2.6)
- Front-to-Back Ratio, Total Power, ± 30° (see chapter 3.2.15)

and additionally, could be described by optional parameter

- Maximum Horizontal Sidelobe Suppression (see chapter 3.3.18)
- Cross-Polar Discrimination over 3 dB Azimuth Beamwidth (see chapter 3.3.4)

Parameter Definition

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

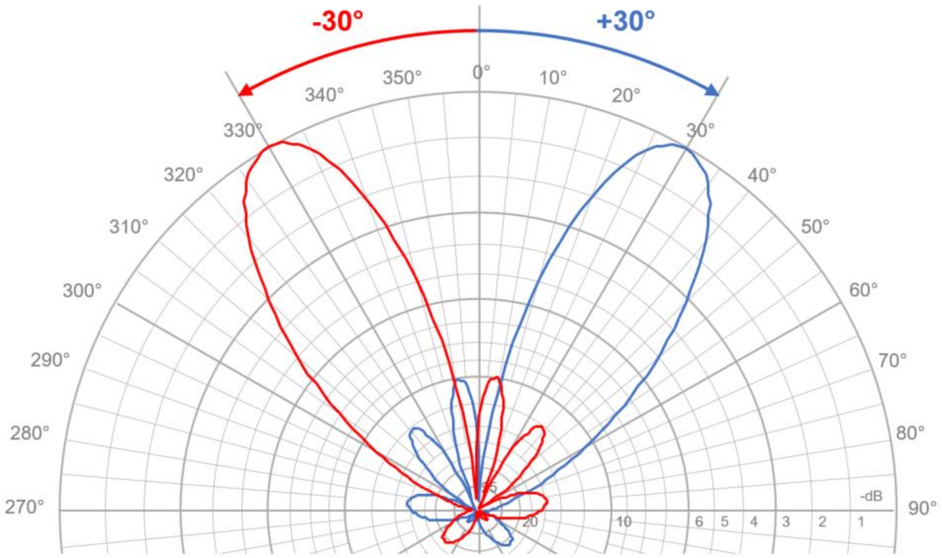


Figure 3.4-4 —Traffic Beam 30, e.g., 8T8R antenna with four columns separated half wavelength and fed with amplitudes 1/1/1/1 and phase -150/-50/50/150 (-30°) or 150/50/-50/-150 (+30°) distribution.

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 degree.
- 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

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

XML - Tag Example

<traffic_30_beam>
<gain_over_all_tilts value="21.8" tolerance="0.5"/>

<azimuth_beamwidth value="19.1" tolerance="1.5"/>
<front_to_back_ratio_total_power_pm30 value="26.4" />
<cross_polar_discrimination_over_3_db_azimuth value="12.4" />
<maximum_horizontal_sidelobe_suppression value="17.8"/>
</traffic_30_beam>

Relevance

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

3.4.2 **Optional Beams**

3.4.1.1 Soft Split Beam

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

- Azimuth Nominal Beam Directions (see chapter 3.2.22)
- Gain (see chapter 3.2.4)
- Azimuth beamwidth (see chapter 3.2.6)
- Front-to-Back Ratio, Total Power, ± 30° (see chapter 3.2.15)

and additionally, could be described by optional parameter

- Maximum Horizontal Sidelobe Suppression (see chapter 3.3.17)
- Cross-Polar Discrimination over 3 dB Azimuth Beamwidth (see chapter 3.3.4)

Parameter Definition

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

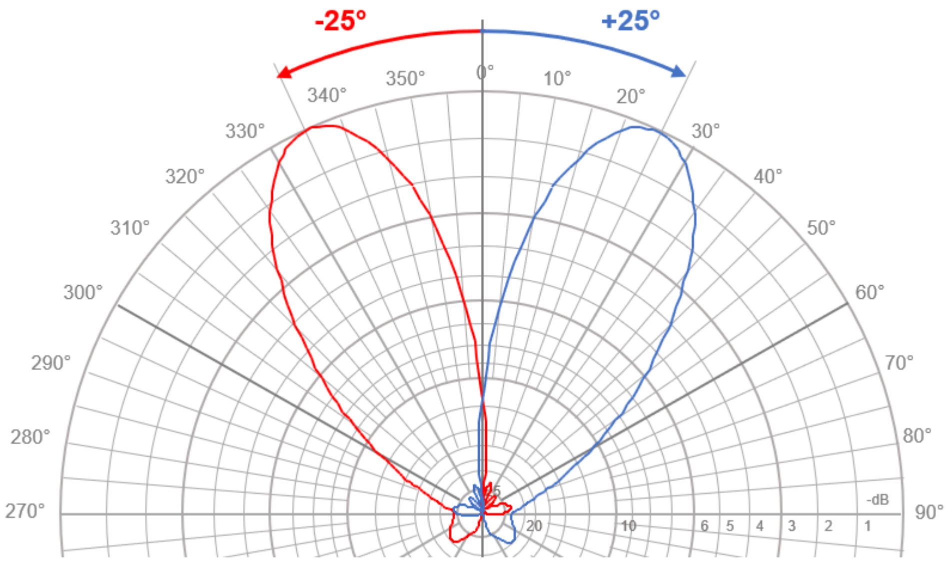


Figure 3.4-5 —Soft Split Beams, e.g., 8T8R antenna with four columns separated half wavelength and fed with amplitudes 0.25/1/1/0.25 and phase -127/-42.5/42.5/127 (Beam 1) or 127/42.5/-42.5/-127 (Beam 2) distribution.

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

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

XML - Tag Example

<soft_split_beam name="1">

<gain_over_all_tilts value="15.1" tolerance="0.5"/>
<azimuth_nominal_beam_direction value="-25"/>
<azimuth_beamwidth value="31.1" tolerance="1.5"/>
<front_to_back_ratio_total_power_pm30 value="26.4"/>
<cross_polar_discrimination_over_3_db_azimuth_beamwidth value="9.7"/>
<maximum_horizontal_sidelobe_suppression value="21.3"/>
</soft_split_beam >
<soft_split_beam name="2">
<gain_over_all_tilts value="15.2" tolerance="0.4"/>
<azimuth_nominal_beam_direction value="25"/>
<azimuth_beamwidth value="30.8" tolerance="1.4"/>
<front_to_back_ratio_total_power_pm30 value="26.7"/>
< cross_polar_discrimination_over_3_db_azimuth_beamwidth value="9.4"/>
<maximum_horizontal_sidelobe_suppression value="22.1"/>
</soft_split_beam >

Relevance

- This parameter could be used with special weight sets for virtual higher order sectorization (HOS)

3.4.3 Calibration Network

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

XML - Tag Example covering a Calibration Port

<calibration_port>
<maximum_phase_deviation_between_coupling_factors value="0.7" />
<maximum_amplitude_deviation_between_coupling_factors value="0.7" />
<coupling_factor_between_each_antenna_port_and_calibration_port value="-26"
tolerance="2" />
</calibration_port>

3.4.1.1 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.

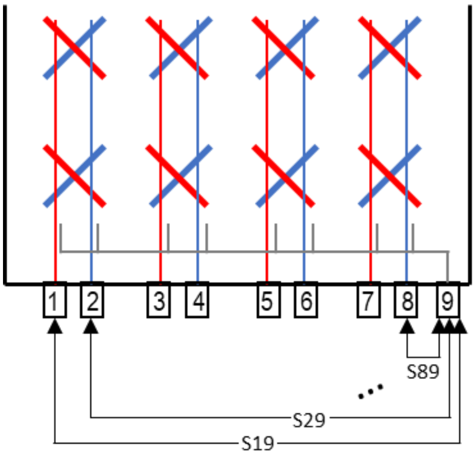


Figure 3.4-6 — Coupling factor between each antenna port and calibration port, i.e. 8T8R antenna with RF ports 1 to 8 and calibration port 9.

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 8T8R 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 (dB)	-26 ± 2

XML - Tag Example

<coupling_factor_between_each_antenna_port_and_calibration_port value="-26" tolerance="2"/>

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.

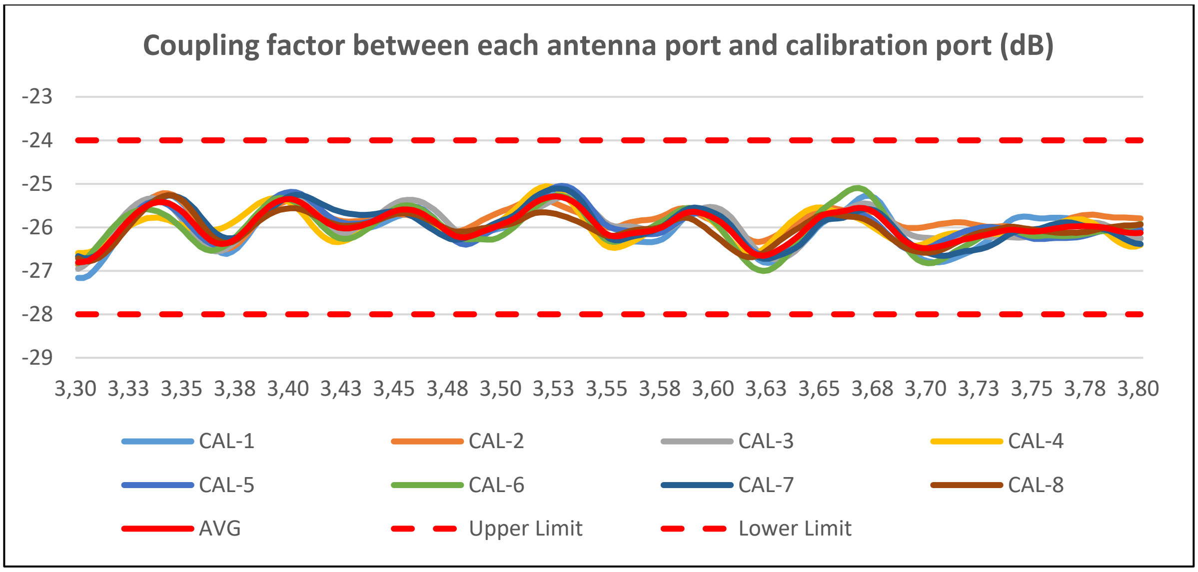


Figure 3.4-7 — Measured coupling factor between each antenna port and calibration port, i.e. 8T8R antenna with RF ports 1 to 8 and calibration port 9, including lower and upper limit as well as an average curve (AVG) at each frequency point over of all measurements

3.4.1.2 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 8T8R 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 8T8R 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

<u>Specification Example</u>

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

<u>XML - Tag Example</u>

<maximum_amplitude_deviation_between_coupling_factors value="0.7"/>

<u>Relevance</u>

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

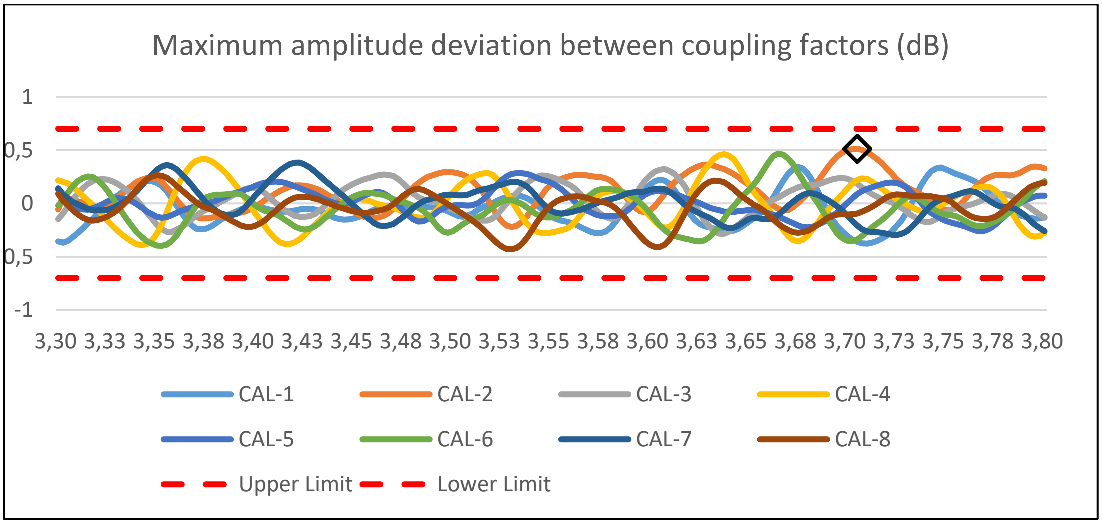


Figure 3.4-8 — Calculated difference between the amplitude of each coupling factor and the average level (AVG) shown in figure 3.2.14.

- The point marked with a diamond in the figure 3.12.15 correspond 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 fulfills the specification as the largest magnitude is within the upper and lower limits

3.4.1.3 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 degree.
- 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 8T8R 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 8T8R 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 (deg)	<0.7

XML - Tag Example

<maximum_phase_deviation_between_coupling_factors value="0.7"/>

Relevance

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

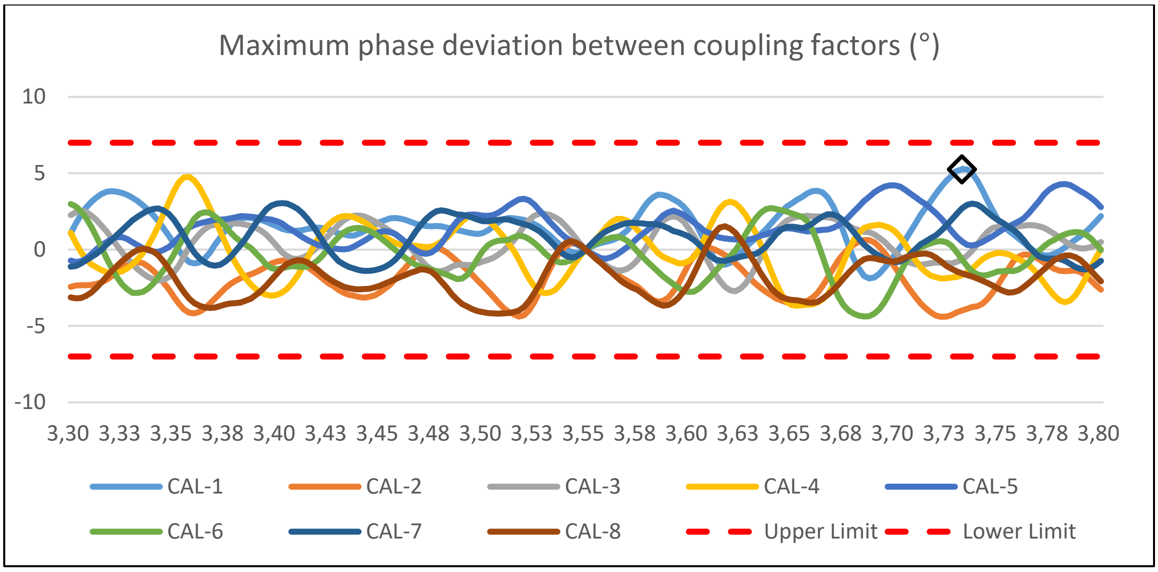


Figure 3.4-9 — Calculated difference between the phase of each coupling factor and the average phase of all coupling factors for each frequency point

- The point marked with a diamond in the figure 3.4.9 correspond to the Maximum phase deviation between coupling factors, as it represents the largest magnitude among the eight normalized phase deviation curves. In the example, the antenna fulfills the specification as the largest magnitude is within the upper and lower limits.

4 Validation and Specification of RF Parameters

4.1 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 White Paper addresses the calculation and validation of the RF specifications.

4.2 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 analyzed. 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 <u>defined by a mean value and a tolerance</u>. 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 3.2.6) and the nominal tilt degree 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 (see Figure 56). 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.

4.3 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).

4.4 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.

4.4.1 General methodology

For a given antenna model, its radiation patterns are measured at the recommended frequencies (see Section 9.1) 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 White Paper is: 1710-2170 MHz. The specified sub-bands that are used only as an example in this section of the White Paper 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 9.1.

For antennas with variable electrical downtilt, each individual pattern is measured (as specified in Section 4.2), analyzed, and finally a value is calculated according to the definition of the chosen parameter. The distribution of the resulting dataset of values is then analyzed, 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:

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					

Table 4.4-1—Parameter dataset – single sub-band, all tilts, all ports.

4.4.2 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 4.2). Their distribution-based validation is applied in the measurement units identified within their specification definition.

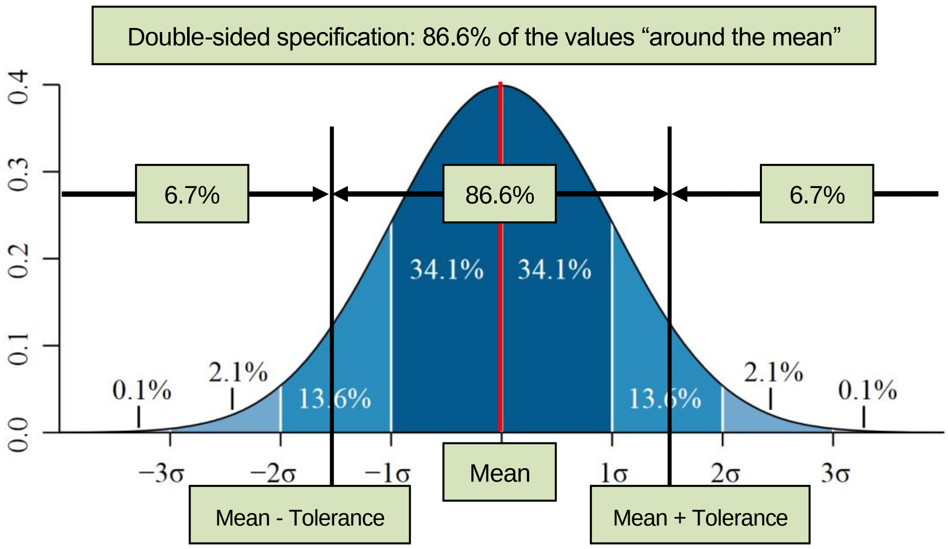


Figure 4.4-1—Double-sided specification for a normal distribution.

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 degree). 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:

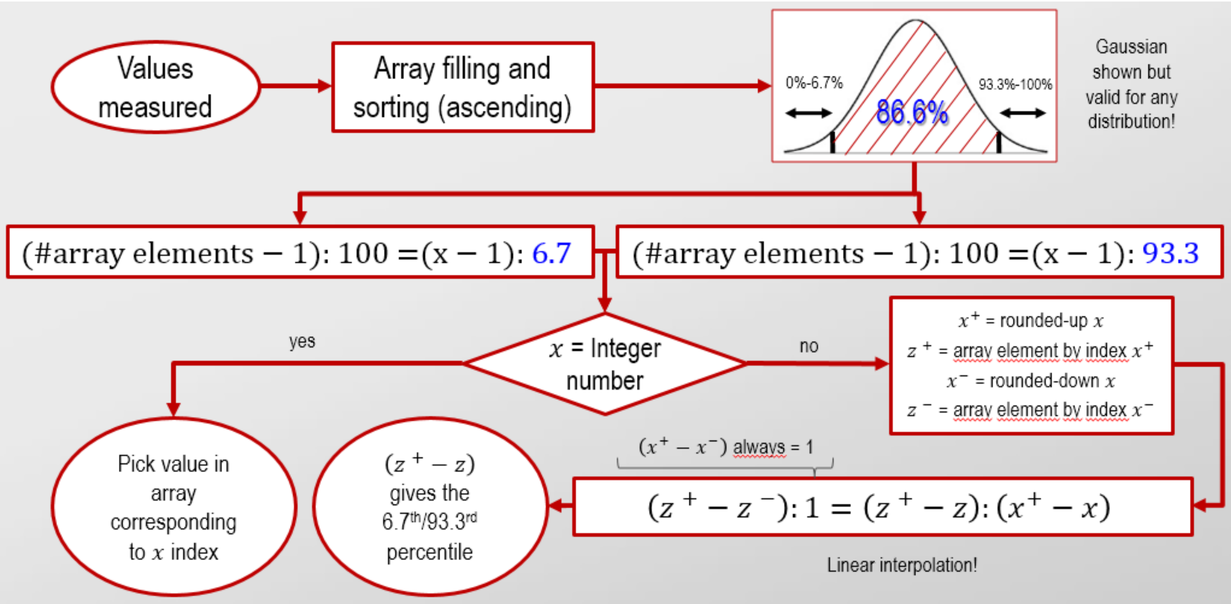


Figure 4.4-2—Algorithm to find "mean - tolerance" and "mean + tolerance"

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.

4.4.3 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 analyzed according to the parameter definition (see Section 3.2.4):

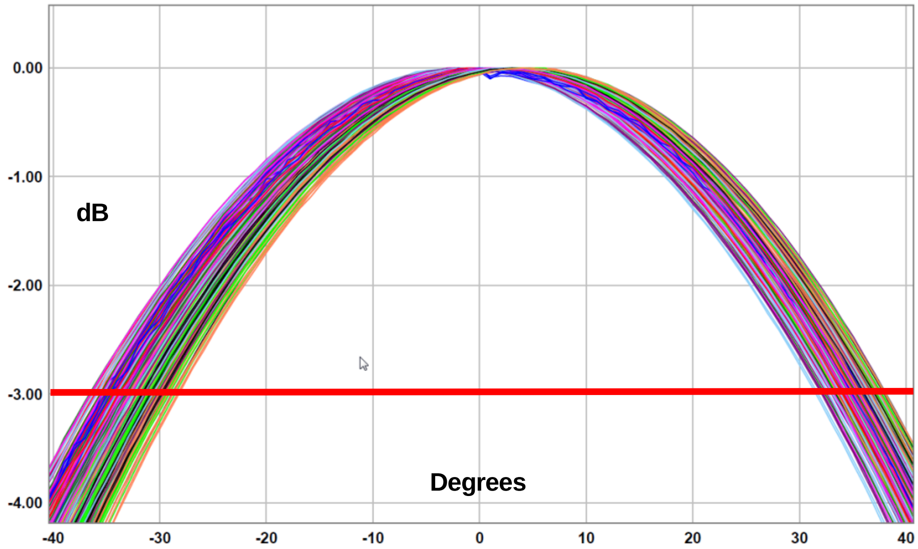


Figure 4.4-3—Azimuth beam-peak patterns plots - 1710-1880 MHz, all ports, and all tilts.

The values for azimuth beamwidth are calculated for each frequency in the sub-band, each port, and each downtilt setting:

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

Table 4.4-2—Complete dataset of azimuth HPBWs.

The distribution of the set of measured values is finally analyzed 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 (degrees 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: $(z^+\text{-}z) = 61.4°$.
- 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°.**

Azimuth beamwidth	# Array elements	Min	Max	Mean	Tolerance
1710-1880 MHz	126	58.8°	70.8°	65.1°	4.0°

Table 4.4-3—Summary of azimuth HPBW statistics.

The specification is set as:

Type: Distribution-based	**1710-1880 MHz**
Azimuth HPBW	65.1 ± 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 ± 4.0	64.8 ± 1.6	63.4 ± 2.3

For the purpose of this White Paper, 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:

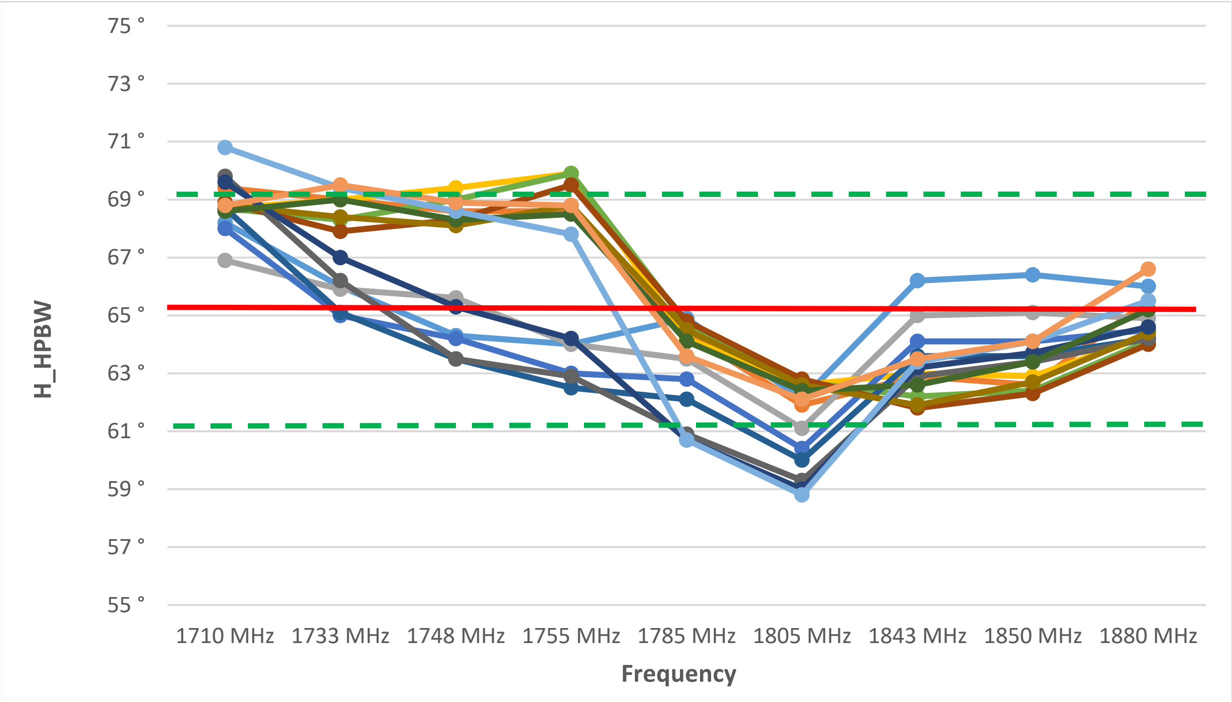


Figure 4.4-4—Azimuth HPBW for each tilt and port as a function of the frequency.

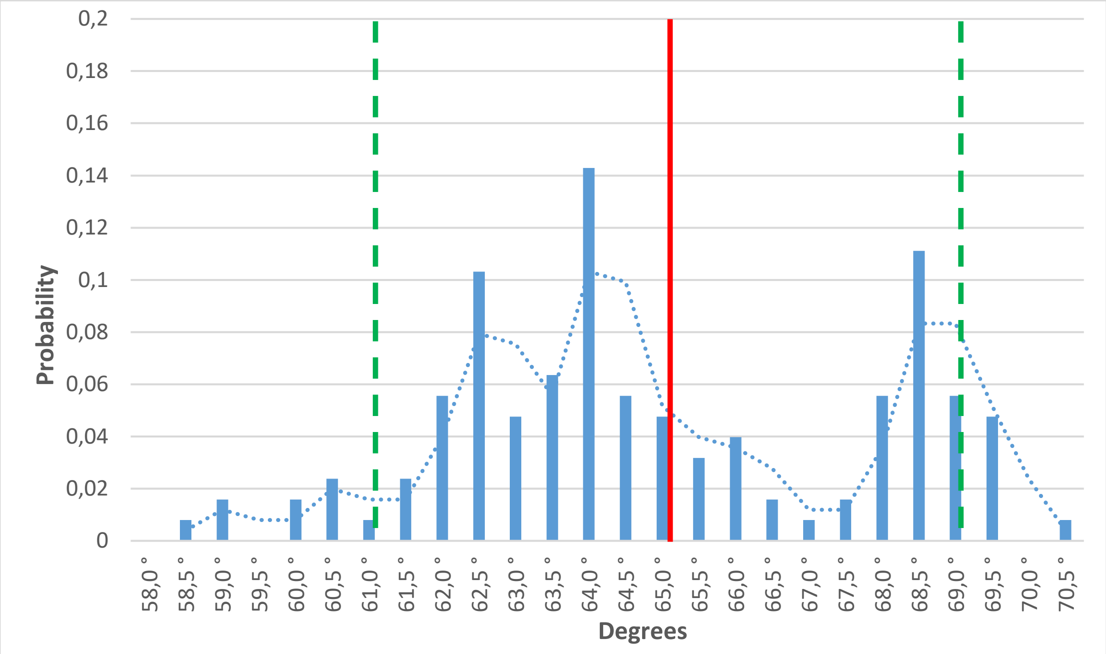


Figure 4.4-5—Histogram of azimuth HPBW values.

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°.

4.4.4 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 4.2). 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).

"Maximum (<)" Specification: 84% of the values below a threshold

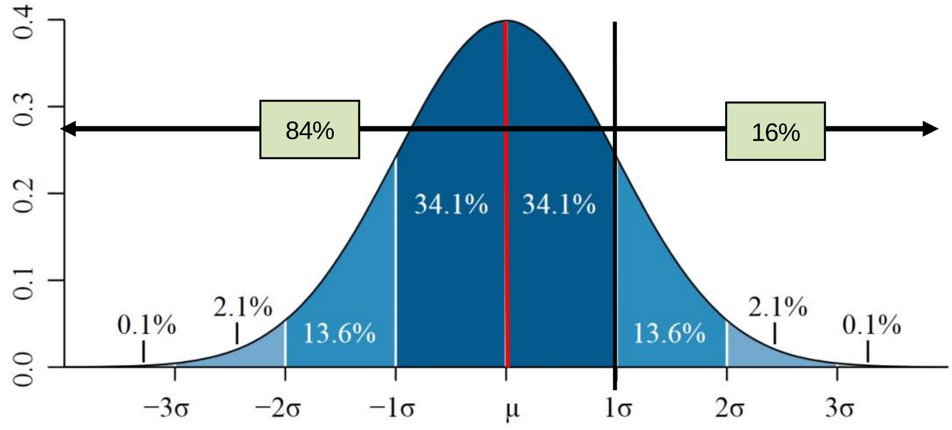


Figure 4.4-6—Single-sided specification (maximum).

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).

“Minimum (>)” Specification: 84% of the values above a threshold

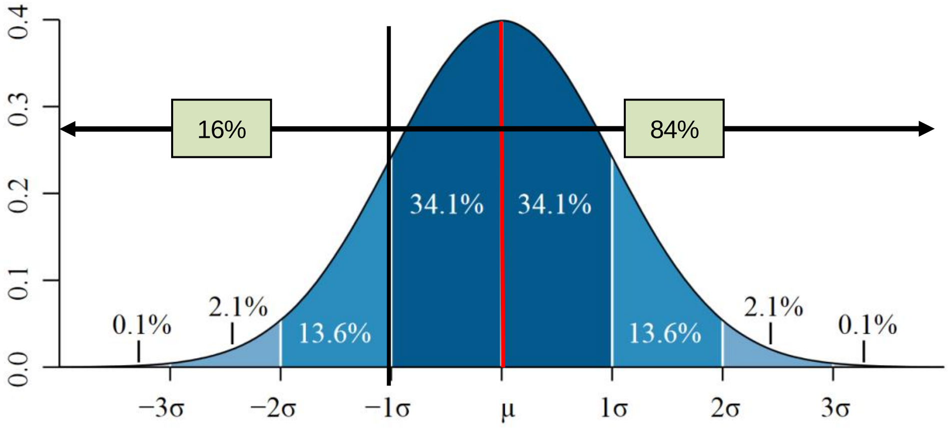


Figure 4.4-7—Single-sided specification (minimum).

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 degree). 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:

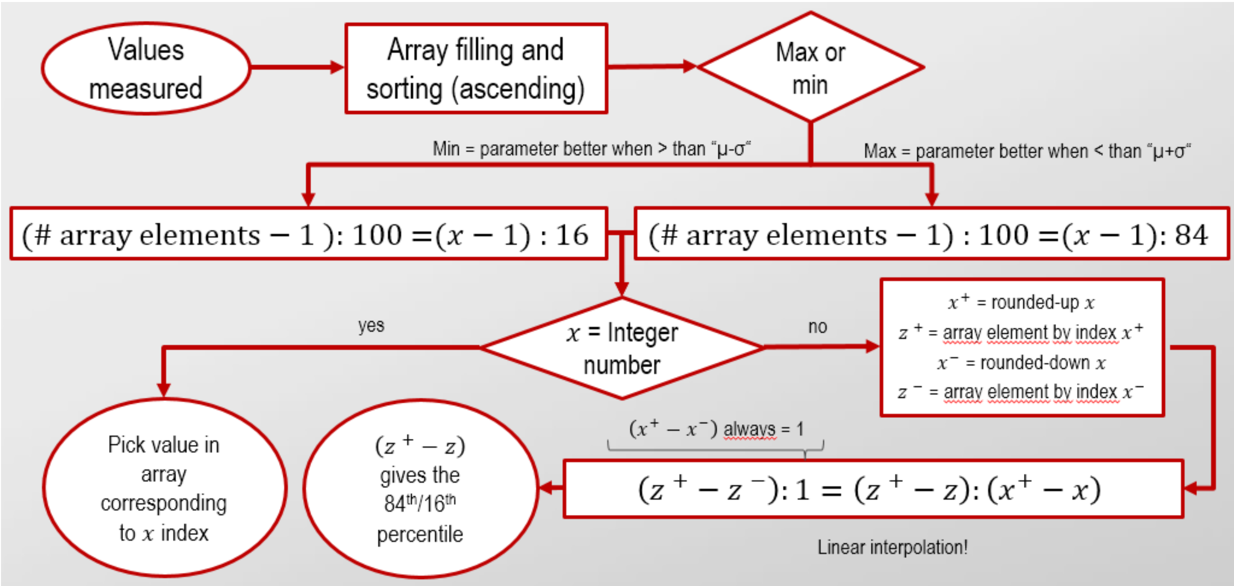


Figure 4.4-8—Algorithm to find "maximum" and "minimum".

4.4.5 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 analyzed according to the parameter definition (see Section 3.3.9):

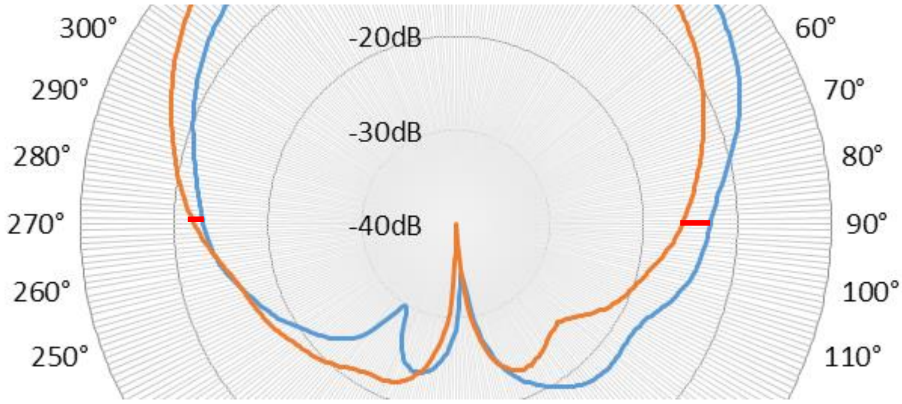


Figure 4.4-9—Polarizations pattern level difference of a 90° sector antenna for one frequency and a single downtilt degree.

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

Table 4.4-4—Complete dataset azimuth beam port-to-port tracking.

The distribution of the set of measured values is finally analyzed 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.

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

Table 4.4-5—Summary of azimuth beam port-to-port tracking statistics.

The specification is set as:

Type: Distribution-based	**1710-1880 MHz**
Azimuth Beam Port-to-Port Tracking	< 2.7

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	< 1.8	< 2.2

For the purpose of this White Paper, 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:

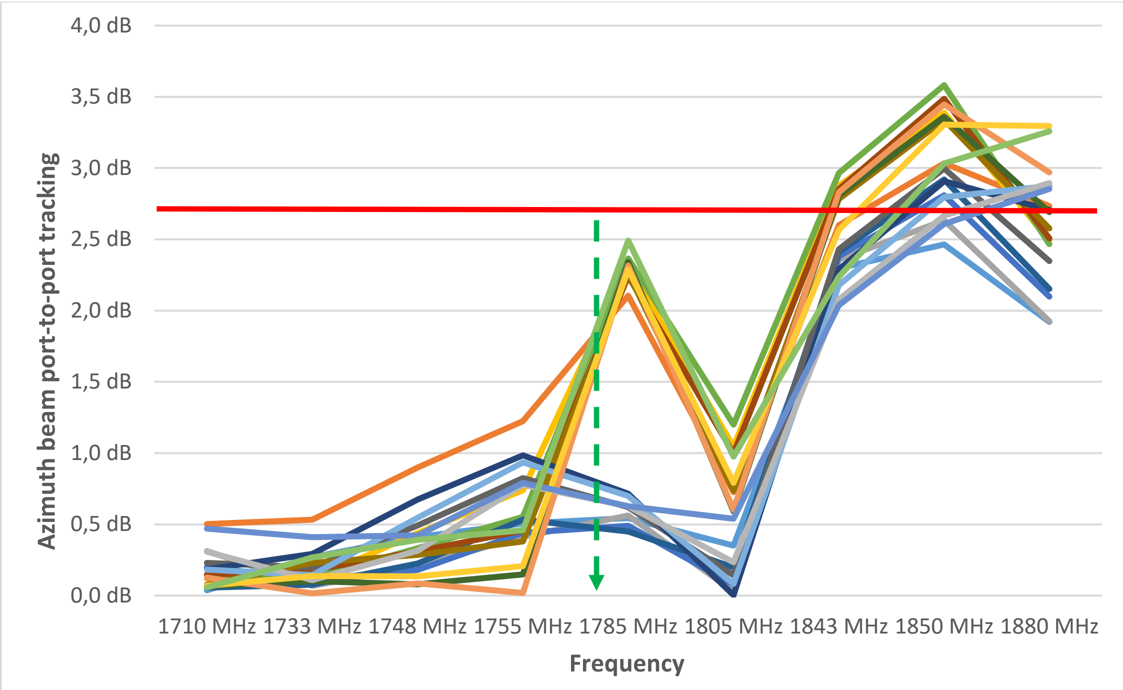


Figure 4.4-10—Azimuth beam port-to-port tracking for each tilt and port as a function of the frequency.

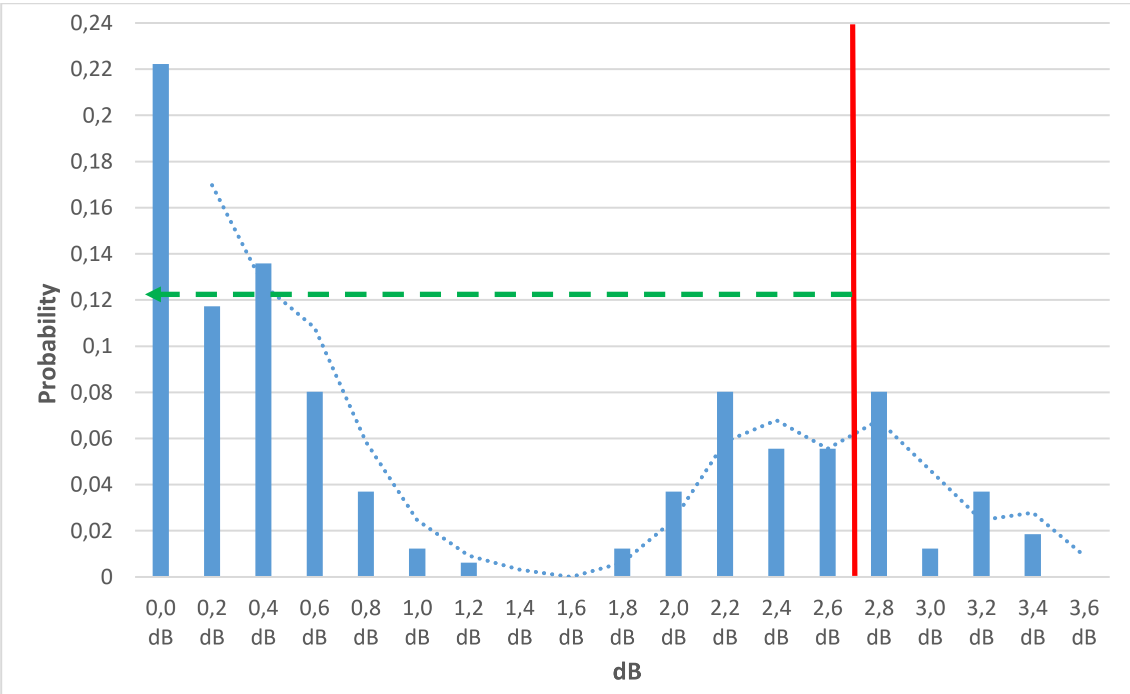


Figure 4.4-11—Histogram azimuth beam port-to-port tracking.

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.

4.4.6 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 analyzed according to the parameter definition (see Section 3.2.15):

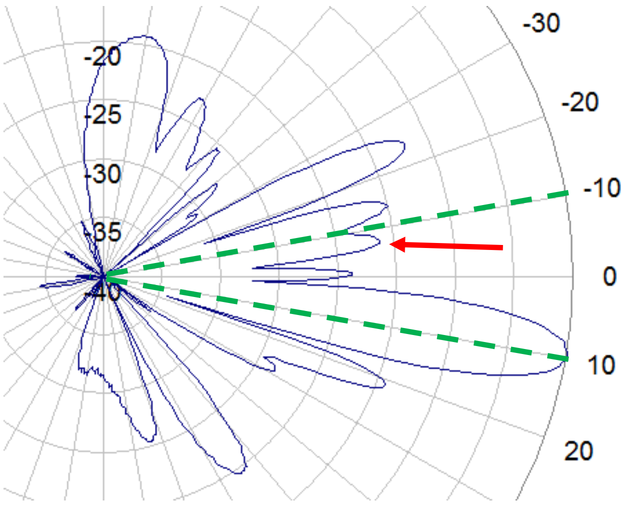


Figure 4.4-12—Worst sidelobe peak 20° above the main beam peak for one frequency, a single port and a single downtilt degree.

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

Table 4.4-6—Complete dataset upper sidelobe suppression, peak to 20°.

The distribution of the set of measured values is finally analyzed 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.

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

Table 7—Summary of upper sidelobe suppression, peak to 20° statistics.

The specification is set as:

Type: Distribution-based	**1710-1880 MHz**
Upper sidelobe suppression, peak to 20°	> 15.8

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	> 16.1	> 17.9

For the purpose of this White Paper, 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:

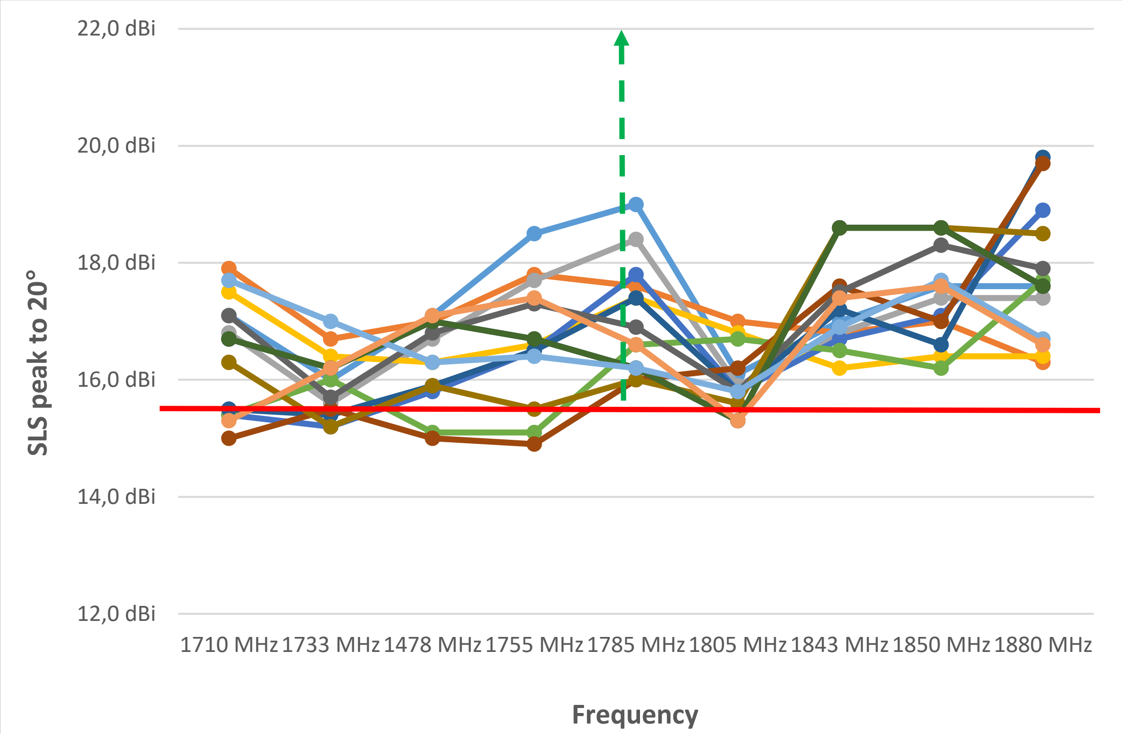


Figure 4.4-13—Upper sidelobe suppression, peak to 20° for each tilt and port as a function of the frequency.

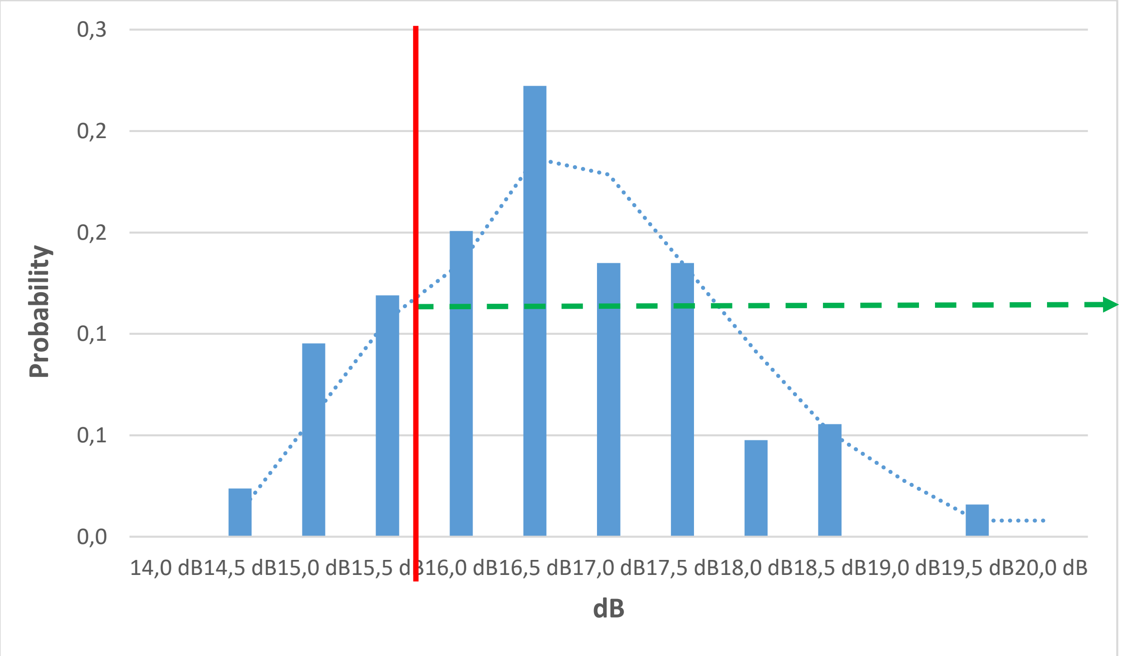


Figure 4.4-14—Histogram Upper sidelobe suppression, peak to 20°.

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.

4.5 Sidelobe Suppression Calculation and Validation

The calculation of all the parameters related to the sidelobes (in this paper: "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.

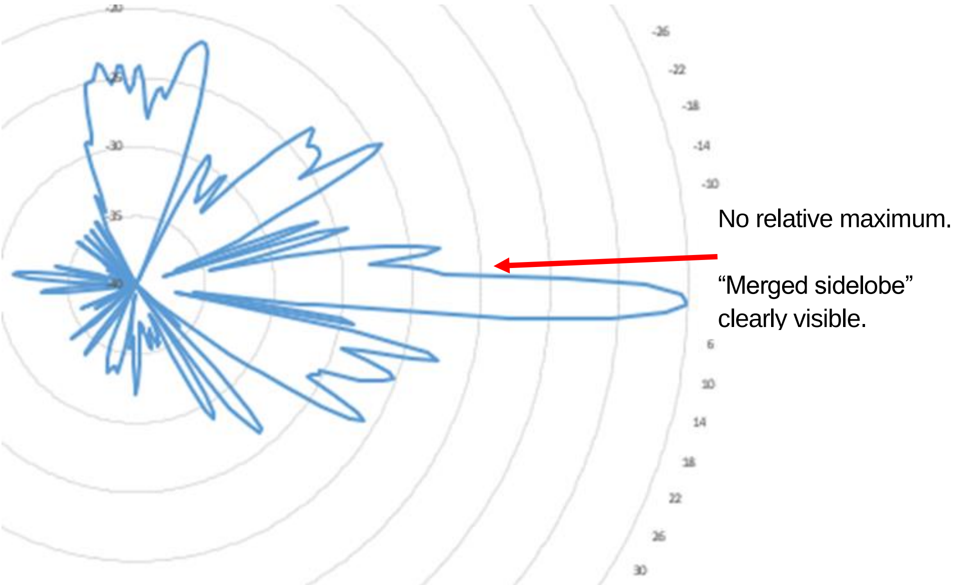


Figure 4.5-1—First upper sidelobe merged into main beam.

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.

4.5.1 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 degrees 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 4.5.1: *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 degrees.*

4.5.2 Null fill

According to the definition in Section 3.3.3, 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.

4.5.3 Upper Sidelobe Suppression, Peak to 20° / Horizon to 20°

As stated in Section 3.2.15 and Section 3.3.12, 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 degrees above (*counterclockwise in the elevation pattern*) it or by the horizon and 20 degrees above (*counterclockwise in the elevation pattern*) it.
In these cases, only one of the following three circumstances can occur:

- In the analyzed sector there is only the first merged sidelobe peak.
- In the analyzed sector there is only a portion of a sidelobe.
- In the analyzed 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 4.5.2: *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.*

4.6 Gain Validation

Gain values are typically determined by the "gain by substitution" method, or the "gain by directivity / loss" method (see Section 9.3 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 analyzed only at that tilt, not within a range of tilt degrees.
- Over all tilts of an antenna's tilt range. In this case, the validation data is analyzed over the entire tilt range as measured in specific increments of electrical downtilt (see Section 4.2).

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 9.4). 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 White Paper 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.

4.6.1 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 degrees of electrical tilt will be used.

Gain			
Type: Distribution-based	**1710-1880 MHz**	**1850-1990 MHz**	**1920-2170 MHz**
0 Tilt	**17.1**	**17.4**	**17.7**
5 Tilt	**17.3**	**17.5**	**17.7**
10 Tilt	**17.0**	**17.0**	**17.2**

First of all, the antennas radiation patterns for the sub-band are analyzed according to the parameter definition (see Section 3.2.3). The values for gain are measured for each frequency in the sub-band, each port, and 0 degrees of electrical downtilt:

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	[illegible]	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						

Table 4.6-1—Complete dataset for gain (1710-1880 MHz, 0° tilt).

The distribution of the set of measured values is finally analyzed to determine the specification (in this case the mean, which shall be calculated over the magnitude and then reconverted in dBi):

Total Gain, dBi	Min	Max	Mean
1710-1880 MHz	16.9	17.4	17.1

Table 4.6-2—Summary of gain statistics (1710 – 1880 MHz, 0° tilt).

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 degrees of electrical downtilt:

Type: Distribution-based	**All ports**	**1710-1880 MHz**	**1850-1990 MHz**	**1920-2170 MHz**
Gain	**0 Tilt**	17.1	17.4	17.7

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	17.4	17.7
	5 Tilt	17.3	17.5	17.7
	10 Tilt	17.0	17.0	17.2

Per this White Paper'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 White Paper, 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:

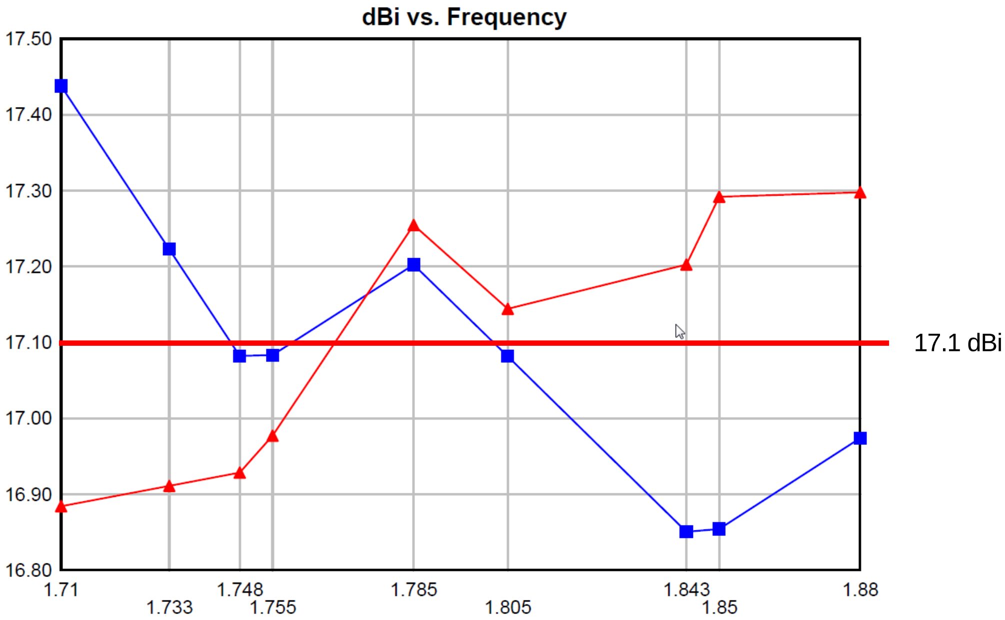


Figure 4.6-1—Gain plot for 0º tilt, both ports.

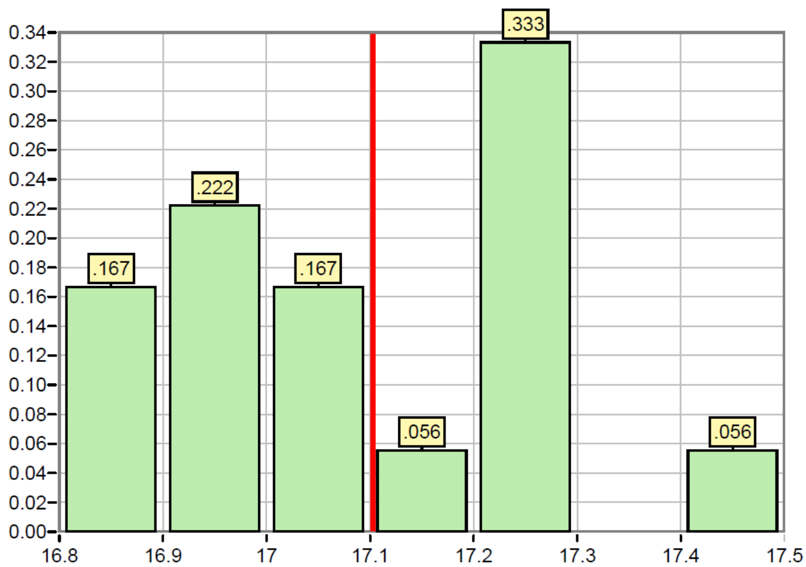


Figure 4.6-2—Gain histogram.

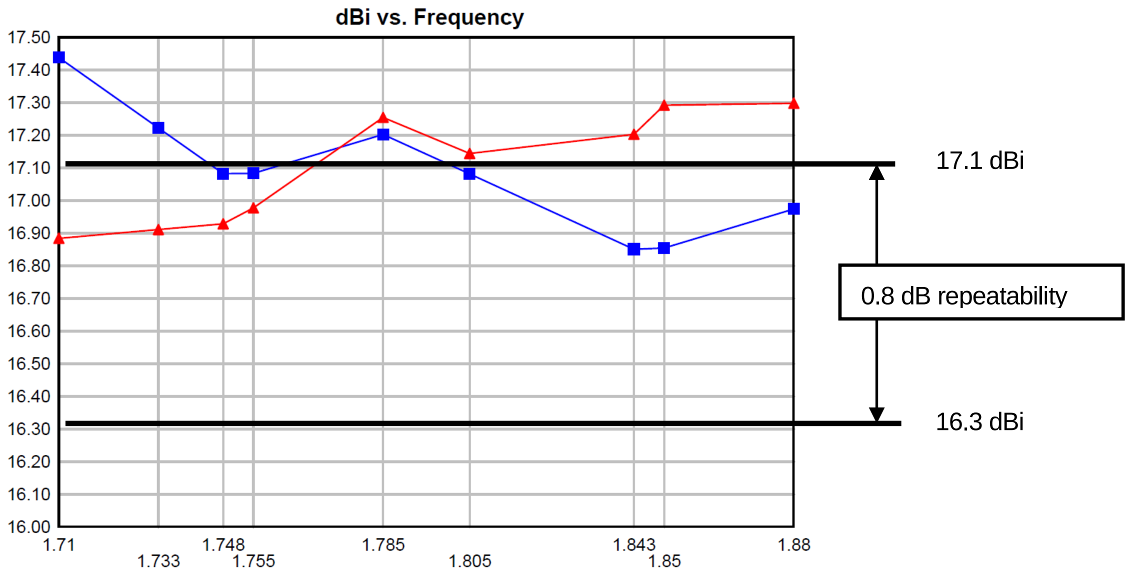


Figure 4.6-3—Gain plot with repeatability margin.

4.6.2 Gain Over All Tilts Validation

In this specification the gain is averaged for all values of the tilt range (see Section 4.2 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 analyzed according to the parameter definition (see Section 3.2.3). The values for gain are measured for each frequency in the sub-band, each port, and the whole range of electrical downtilt.

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

Table 4.6-3—Complete dataset of gain.

The distribution of the set of measured values is finally analyzed 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.**

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

Table 4.6-4—Summary of gain statistics, over all tilts, 1850-1990 MHz.

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 ± 0.3 dB

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 ± 0.2	17.5 ± 0.3	17.9 ± 0.3

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	17.4	17.7
	5 Tilt	17.3	17.5	17.7
	10 Tilt	17.0	17.0	17.2
	Over all tilts	17.4 ± 0.2	17.5 ± 0.3	17.9 ± 0.3

For the purpose of this White Paper, 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:

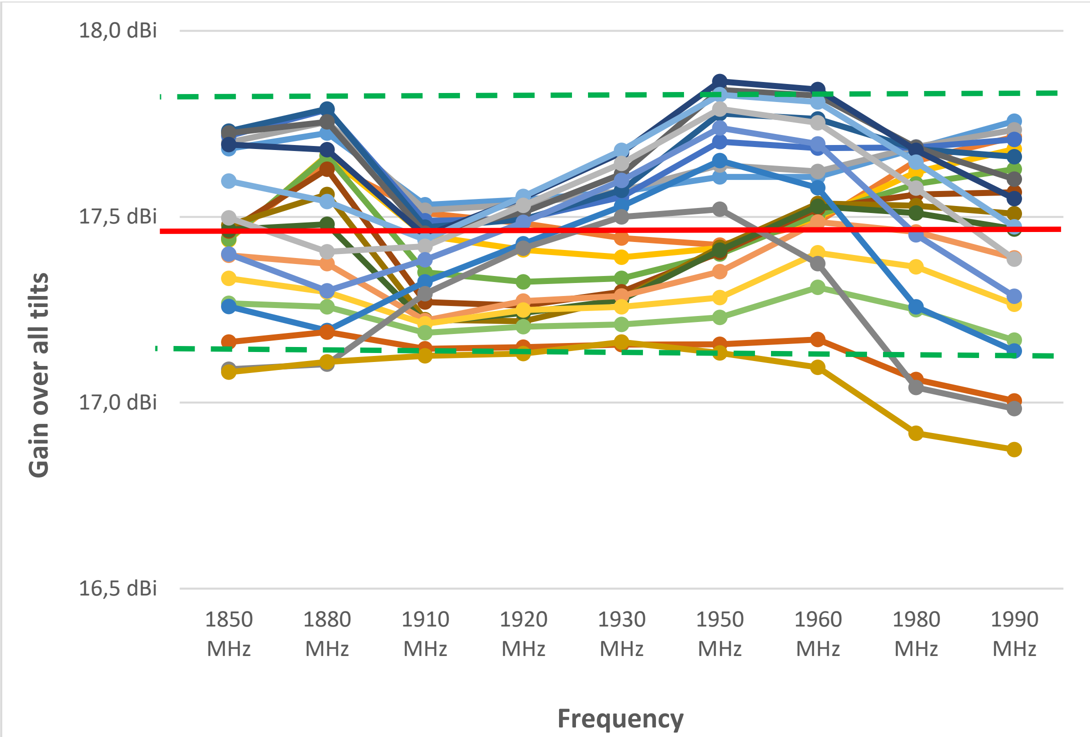


Figure 4.6-4—Gain for each tilt and port as a function of the frequency.

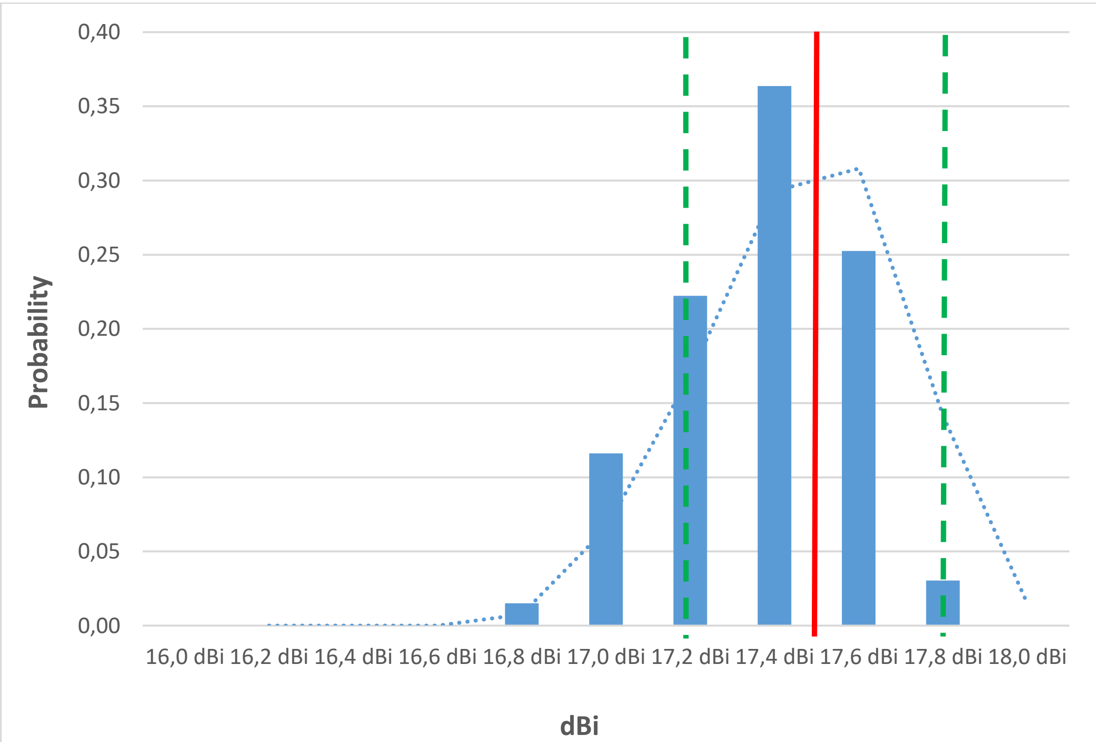


Figure 4.6-5—Gain histogram.

The repeatability margin value of 0.8 dB is graphed below:

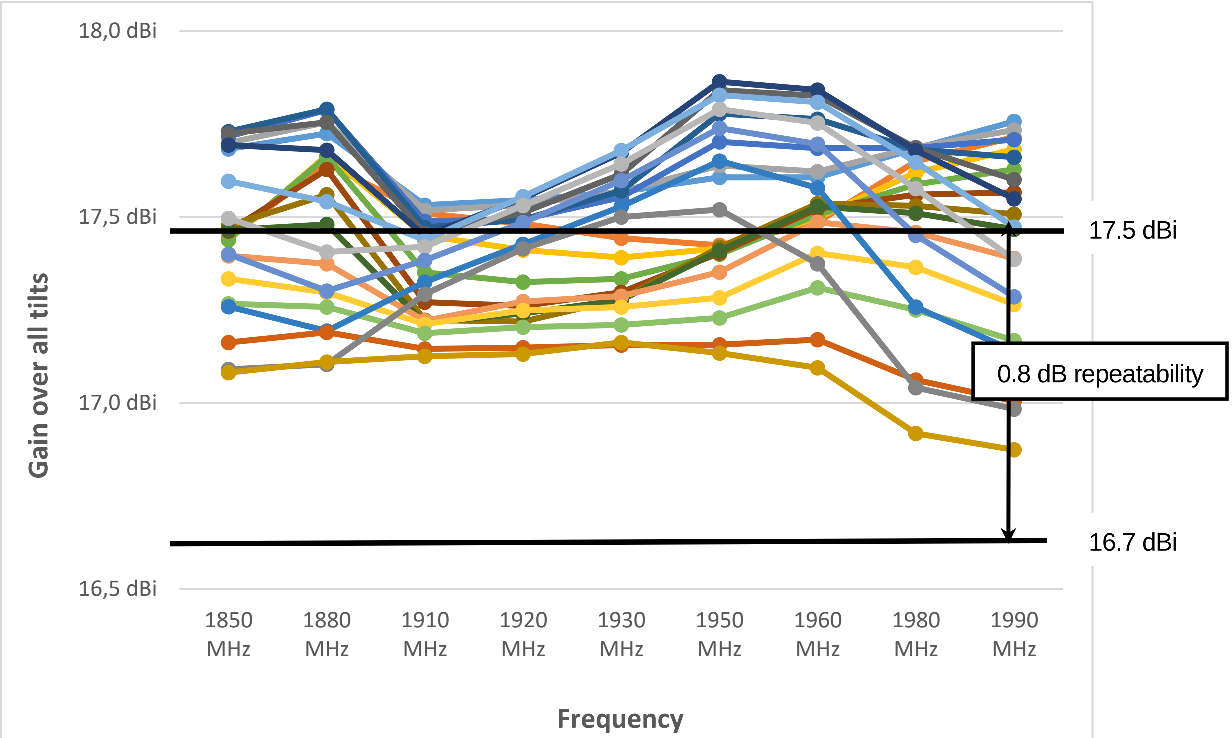


Figure 4.6-6—Gain plot with repeatability margin.

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.

4.7 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 analyzed according to the parameter definition (see Section 3.2.7). The values for the real electrical downtilt are measured (see Section 3.2.6) for each frequency in the sub-band, each port, and the whole range of electrical downtilt.

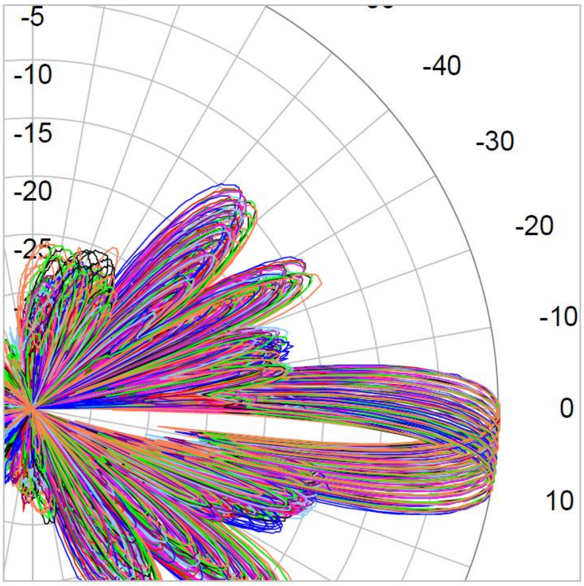


Figure 4.7-1—Elevation pattern plots – 1710-1880 MHz, all ports, and all tilts.

For each tilt degree, the real elevation electrical downtilt is compared to its nominal value, and the absolute maximum differences (deviations) between those two are calculated:

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

Table 4.7-1—Complete dataset elevation downtilt deviation.

Note that the downtilts (real ones are those not marked in gray 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 analyzed 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

4.8 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 Section 9.1.3. 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.

5 Mechanical Parameters and Specifications

In this paper 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.

5.1 Antenna Dimensions

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 5.1-1).

Specification Definition

- The antenna dimensions are its nominal values specified in millimeters.
  - 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: 1391mm x 183mm x 118mm.
  - A RET actuator cannot be attached to the antenna.
- Antenna with RET support:
  - H x W x D: 1391mm x 183mm x 118mm.
  - A RET actuator interface is present on the bottom of the antenna along the plane normal to its height.

XML - Tag Example

<antenna_dimensions height="1391" width="183" depth="118"/>

<antenna_dimensions height="1391" width="183" depth="118" reference=”H”/>

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.

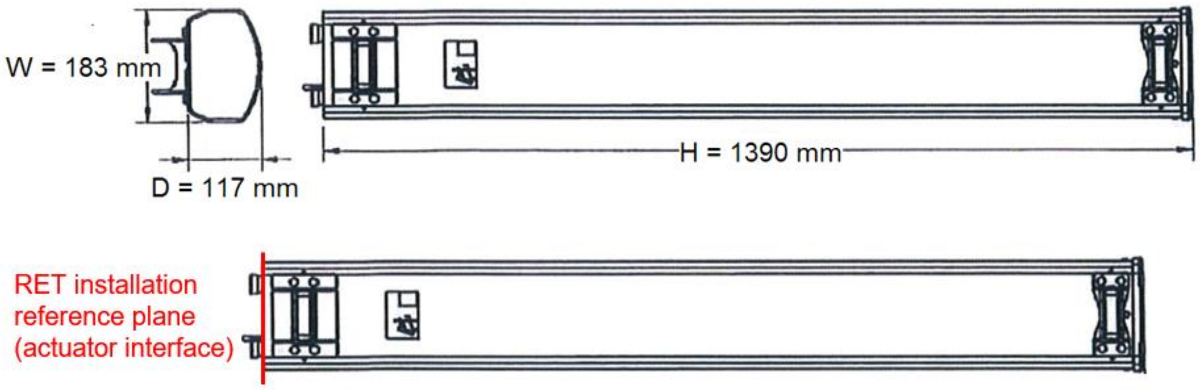


Figure 5.1-1—Antenna dimensions example.

5.2 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 millimeters.
- 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 - 1391mm x 350mm x 110 mm.

XML - Tag Example

<packing_size height="1500" width="400" depth="200"/>

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.

5.3 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.

XML - Tag Example

<net_weight wo_mtg_hardware="14.5" only_mtg_hardware="3.4"/>

Relevance

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

5.4 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.

XML - Tag Example

<shipping_weight value="22.5"/>

Relevance

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

5.5 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.

XML - Tag Example

<port name="Y2+" number="3" polarization="+45" location="bottom" connector_type="4.3-10 female long neck" />

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.

5.6 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>
```

XML - Tag Example

- Not applicable

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.

5.7 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 White Paper, 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.

XML - Tag Example

<port name="Y3-" number="6" polarization="-45" location="bottom"
connector_type="4.3-10 male"/>

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.

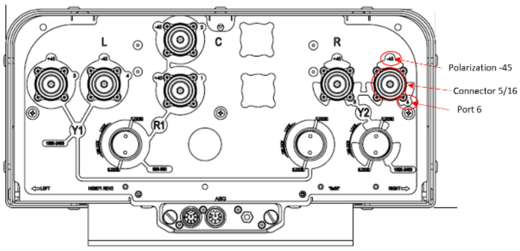


Figure 5.7-1—Antenna Bottom with connector position

5.8 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 kilometers per hour.

Specification Example

- The antenna can withstand 200 km/h without being damaged.

XML - Tag Example

<survival_wind_speed value="200"/>

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.

5.9 Definition of the Drag, Lift, and Resultant force

In the context of this White Paper, 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.

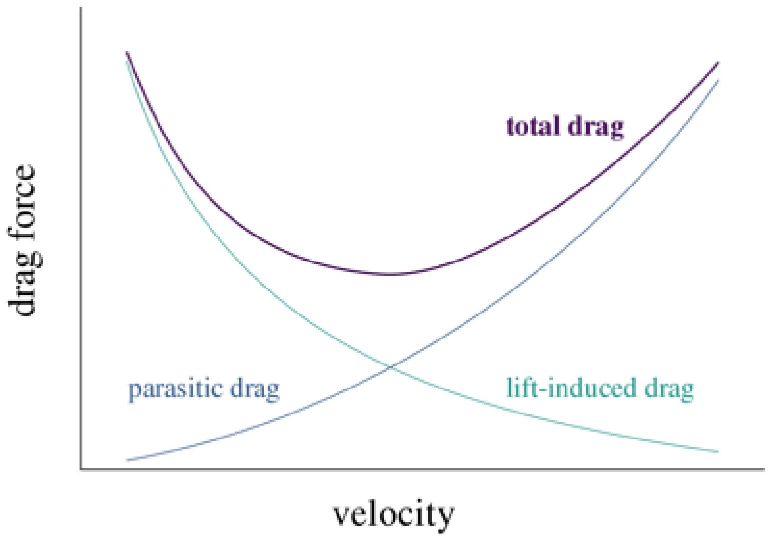


Figure 5.9-1—Drag force over velocity

- 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.

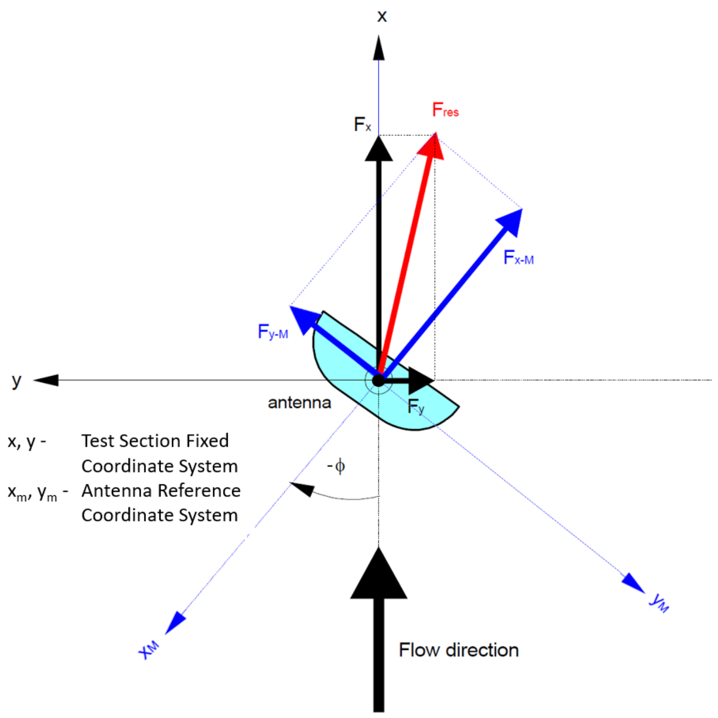


Figure 5.9-2— Illustration of an antenna in test configuration

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	$F_x = F_{Drag} = F_{x-M}.\ \cos\varphi + F_{y-M}.\sin\varphi$	(1)
Lift	$F_y = F_{Lift} = -F_{x-M}.\ sin\ \varphi + F_{y-M}.\ cos\ \varphi$	(2)
Resultant	$F_{Resultant} = F_{Total} = \sqrt{F_{x-M}^2 + F_{y-M}^2} = \sqrt{F_x^2 + F_y^2}$	(3)

The angle φ describes the angle between the flow direction of the wind and the plain that is purpendicular to the bore sight of the antenna.

5.10 Windload – Calculation Guideline

Antenna providers generally use wind tunnel testing to determine the windload of antennas. Two different standards are used for reference:

1. ANSI/TIA 222 provides guidance for windload determination in North America.
2. EN 1991-1-4 is used for windload guidance in Europe and Asia.

Based on the two standards this White Paper defines the best practice for the reliability of the results by specifying the following requirements:

- The standard used for the determination, either ANSI/TIA 222 or EN 1991-1-4, 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 zero degrees 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:

$$F_2 = F_1\left(\frac{{v_2}^2}{{v_1}^2}\right)$$

- 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 degrees in the range of 0 to 360°. (If the antenna is symmetrical, measure the antenna at an angle ranging from 0 to 180 degrees.)
- 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 5.10.1: *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.*

5.10.1 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 (see figure 2.9-1).

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).

XML - Tag Example

<windload frontal="500" lateral="370" maximum360="850" laboratory="xy,closed loop tunnel z" extrapolation ="0"/>

Relevance

- Windload values are required to calculate resulting tower loads in order to dimension the towers appropriately, and to ensure safety.

5.10.2 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 2.9-1).
- For the evaluation of this parameter the windload of the pole shall be deducted as described in section 5.10.5

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.

XML - Tag Example

<windload frontal=”500” lateral=”370” maximum360=”850” laboratory=”xy, open loop tunnel z” extrapolation =”140”/>

Relevance

- Windload values are required to calculate resulting tower loads in order to dimension the towers appropriately, and to ensure safety.

5.10.3 **Windload – Maximum360**

Parameter Definition

- The windload maximum360 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 5.10.5

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.

XML - Tag Example

<windload frontal=”500” lateral=”370” maximum360=”850” laboratory=”xy, open loop tunnel z” extrapolation =”140”/>

Relevance

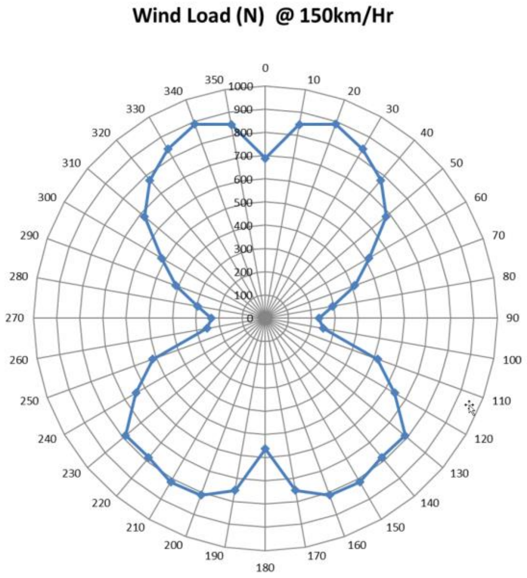
- Windload values are required to calculate resulting tower loads in order to dimension the towers appropriately, and to ensure safety.

5.10.4 **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



XML - Tag Example

```
<windload_polar unit="N">
        <azimuth direction="0" value="700"/>
        <azimuth direction ="10" value="750"/>
        <azimuth direction ="20" value="900"/>
        <azimuth direction ="30" value="850"/>
        ...
        <azimuth direction ="330" value="850"/>
        <azimuth direction ="340" value="900"/>
        <azimuth direction ="350" value="750"/>
</windload_polar>
```

Relevance

- Windload values are required to calculate resulting tower loads in order to dimension the towers appropriately, and to ensure safety.

5.10.5 **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 (Fig. 5.10.5.1, Fig. 5.10.5.2)
In direction where the antenna is shielding the mast fully or partly only the mast sections above and below the antenna shall be deducted (Fig. 5.10.5.2)

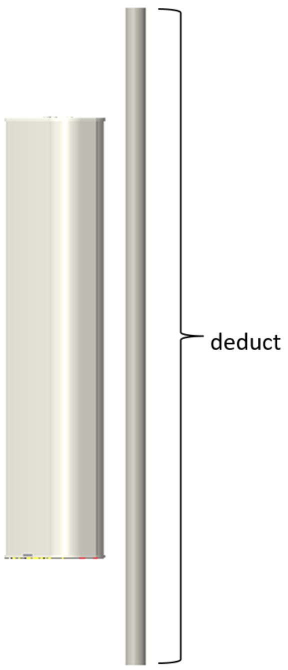


Figure 5.10-1—Full pole deduction

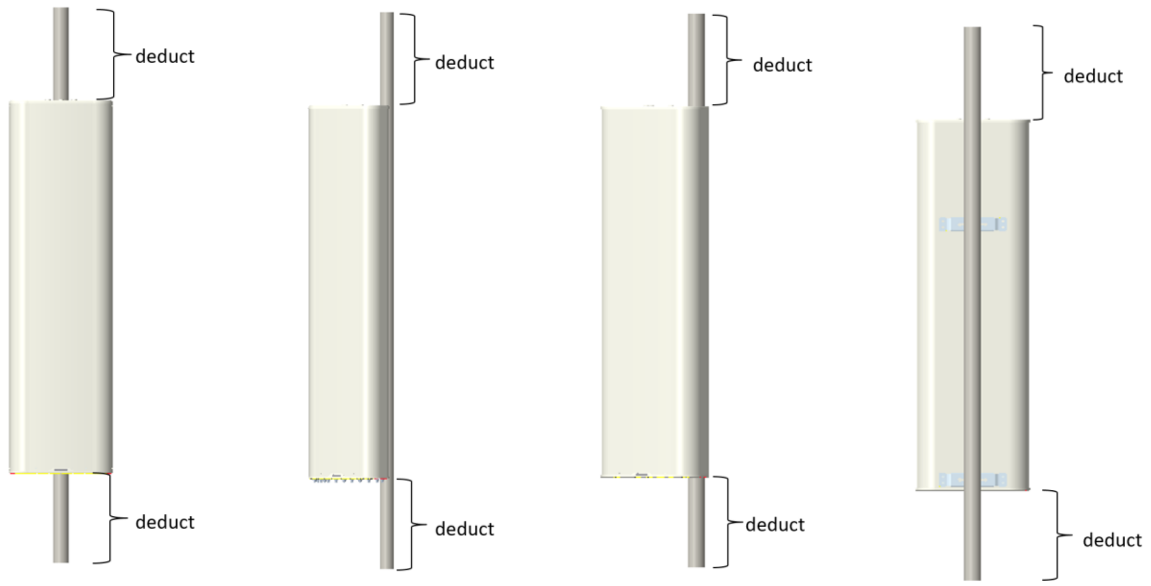
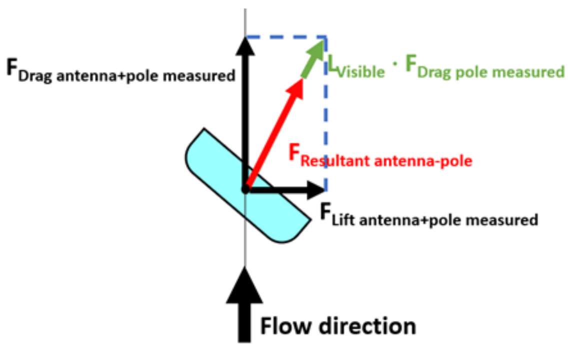


Figure 5.10-2— Partly pole deduction

Following formula shall be applied:

$$F_{Resultant\ antenna-pole} = \sqrt{\left(F_{Drag\ antenna+pole\ measured}\right)^2 + \left(F_{Lift\ antenna+pole\ measured}\right)^2} - L_{Visible} \cdot F_{Drag\ pole\ measured} \quad (5)$$

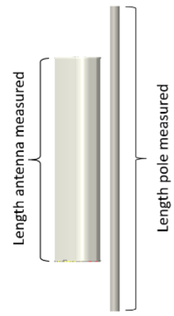


F$_{\text{Resultant antenna-pole}}$	N or LB	Resultant force of the antenna with pole deduction
F$_{\text{Drag antenna+pole measured}}$	N or LB	Drag component of the measured antenna force
F$_{\text{Lift antenna+pole measured}}$	N or LB	Lift component of the measured antenna force
L$_{\text{visible}}$	-	Factor dependent on the visible length of the pole - Definition see formula (5)
F$_{\text{Drag pole measured}}$	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-$L_{antenna}$/L_{pole} shown in figure 5.10.5.2.

$$L_{visible} = \begin{cases} 1 \quad ; \textit{if the pole is fully visible} \\ 1 - \dfrac{L_{antenna\ measured}}{L_{pole\ measured}} ; \textit{if antenna or pole are shielding each other} \end{cases} \quad (5)$$

L$_{\text{visible}}$	-	Factor dependent on the visible length of the pole
L$_{\text{antenna measured}}$	m or ft	Length of the measured antenna
L$_{\text{pole measured}}$	m or ft	Overall length of the used pole



5.10.6 **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:

$$F_{Resultant\ with\ length\ x} = F_{Resultant\ with\ lenght\ measured} \cdot \frac{L_{antenna\ x}}{L_{antenna\ measured}} \quad (6)$$

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:

$$F_{Resultant\ antenna-pole} = \left(\sqrt{\left(F_{Drag\ antenna+pole\ measured}\right)^2 + \left(F_{Lift\ antenna+pole\ measured}\right)^2} - L_{Visible} \cdot F_{Drag\ pole\ measured}\right) \cdot \frac{L_{antenna\ x}}{L_{antenna\ measured}} \tag{7}$$

With $L_{visible}$ see formula (5).

5.11 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

- Example: antenna radome is made from a PVC material.

XML - Tag Example

<radome_material value="PVC"/>

Relevance

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

5.12 Radome Color

Parameter Definition

- The radome color is a simple statement about the color of the radome. This is commonly related to the material used to build it.
- Color options for BSA radomes are uncommon.

Specification Definition

- RAL color code.

Specification Example

- The radome's color is RAL7005.

XML - Tag Example

<radome_color value="RAL7005"/>

Relevance

- The radome color might be of interest to minimize obtrusiveness of an antenna installation.

5.13 Product Environmental Compliance

Parameter Definition

- Overall, the environmental compliance is the combination of all individual environmental compliance statements declared for the product (see Chapter 6).
- 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 fulfill 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.

Specification Definition

- The environmental standard name and optionally a compliance to a particular class.

Specification Example

- RoHS, Reach, WEEE, ETSI EN 300019-1-2 class 4.1 E, etc.

XML - Tag Example

<product_environmental_compliance_general standard="RoHS" compliance="full_compliant"/>

<product_environmental_compliance_transportation standard="ETSI EN 300019-1-2" compliance="Class 2.3"/>

<product_environmental_compliance_environmental_conditions standard="ETSI EN 300019-1-4" compliance="Class 4.1 E "/>

<product_environmental_compliance_storage standard="ETSI EN300019-1-1" compliance="Class 1.2"/>

<product_environmental_compliance_packed_storage standard="ETS EN300019-1-1" compliance="Class 1.1"/>

Note 5.13.1: *it is possible to insert more product environmental compliances by adding more XML tags. Should this be necessary, the following tag format shall be used:*

<product_environmental_compliance_xxx standard="yyy" compliance="zzz"/>

Where "xxx", "yyy" and "zzz" can be customized by the antenna producer.

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.

5.14 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 millimeters.

Specification Example

- Example: S1 = 1274 mm (see figure 5.14.1)

XML - Tag Example

<mechanical_distance_between_mounting_points_antenna value="1274"/>

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.

5.15 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 millimeters.

Specification Example

- Example: S2 = 1019 mm (see figure 5.14-1)

XML - Tag Example

- Antennas may have different options for their mounting kits, therefore the value associated to this parameter may change consequently. Vendors should therefore consider as a good practice to state all the possibilities under the vendor_comments tag (see Section 10.1.8).

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	

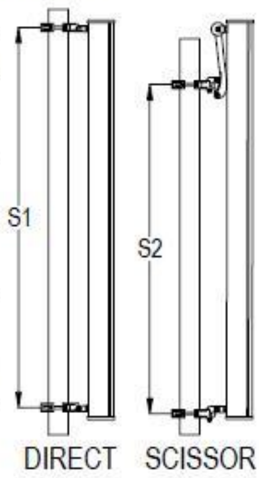


Figure 5.15-1—Potential differences between "distance between antenna mounting points" and "distance between pole mounting points".

5.16 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.

XML - Tag Example

<lightning_protection value="yes"/>

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.

6 Remote Electrical Tilt System

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 degree of electrical downtilt. 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 categorized 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 (AISG) 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.

In this paper the RET parameters will always be, when not specifically otherwise written, intended as required.

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

XML - Tag Example covering RET topics

<RET vendor_name="XY" vendor_ret_type="XY">

<!— Here all XML Tags of RET parameters are placed -->

</RET>

6.1 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 6.1-1 below).
- 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 6.2-1 below).

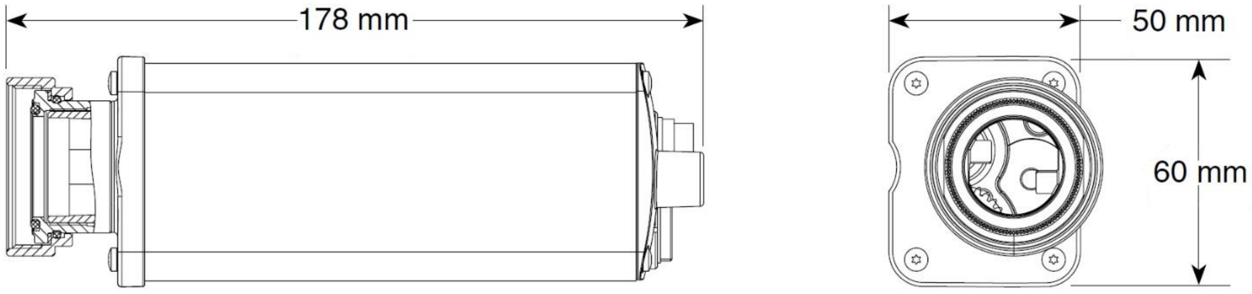


Figure 6.1-1—Example of an external RET.

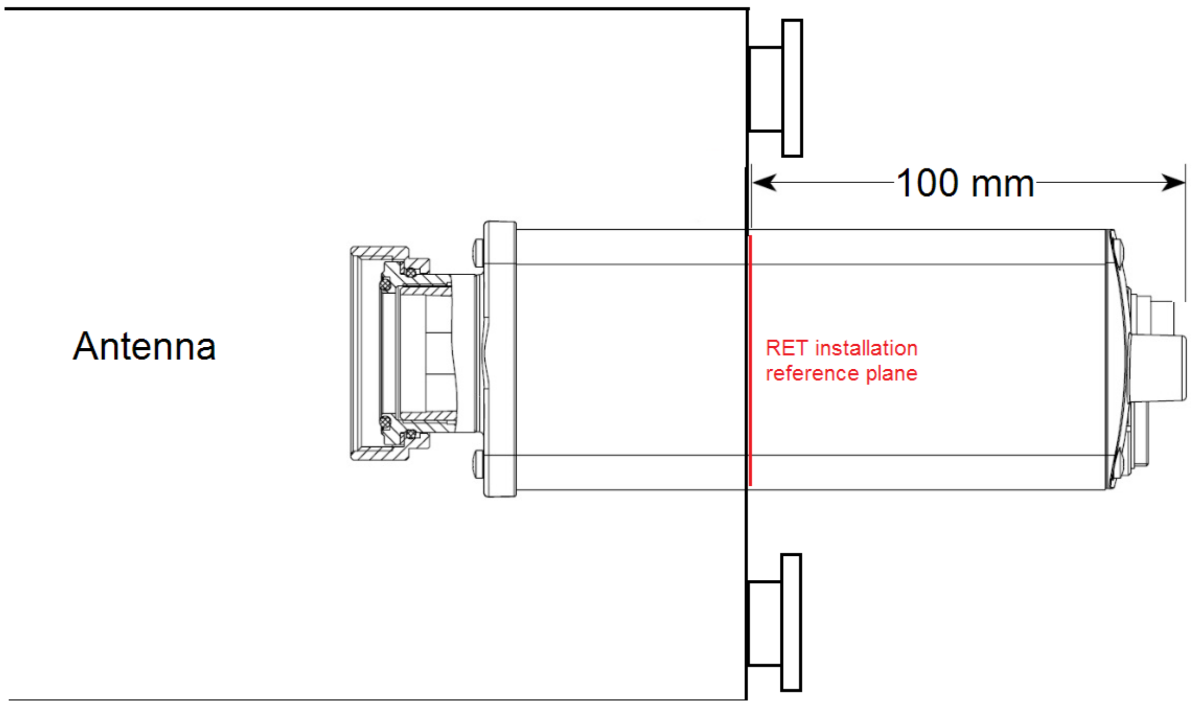


Figure 6.1-2—Example of the height dimension of an installed partially external RET. Its protrusion out of the antenna lies along the antenna height plane (H).

Specification Definition

- The RET stand-alone dimensions are its nominal values specified in millimeters.
- 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: 178mm x 60mm x 50mm (see figure 6.1-1).
    - Partially external RET - H x W x D: 178mm x 60mm x 50mm (see figure 6.1-2.

- Installed dimensions:
    - External RET - H x W x D: 178mm x 60mm x 50mm (see figure 6.1-1).
    - Partially external RET - H x W x D: 100mm x 60mm x 50mm (see figure 6.1-2).
    - Integrated RET - H x W x D: 0mm x 0mm x 0mm.

XML - Tag Example

<dimensions height="178" width="60" depth="50"/>

<protrusion height="100" width="60" depth="50"/>

<unit_installation_reference_plane value= "H"/>

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.

6.2 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.

XML - Tag Example

<working_temperature_range max="60" min="-20"/>

Relevance

- The RET working temperature range is relevant to evaluate the overall operational working temperature of the RET system and ensure its correct operation.

6.3 Power Consumption

Parameter Definition

- The RET's consumption of energy.

Specification Definition

- Nominal values in Watts.
- 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 = 0.5W; High power consumption = 5W.

XML - Tag Example

<power_consumption high_power="5.0" low_power="0.5"/>

Relevance

- The RET power consumption is relevant to estimate a correct overall energy economy.

6.4 Loss of Position on Power Failure

Parameter Definition

- This parameter defines, in accordance to 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

- True / False.

Specification Example

- True

XML - Tag Example

<lose_position_on_power_failure value="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.

6.5 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.

XML - Tag Example

```
<compatible_standards>
    <standard value="AISG 1.1" />
    <standard value="AISG 2.x" />
    <standard value="3GPP Release 17" />
    <standard value="AISG 3.1.4" />
</compatible_standards>
```

Relevance

- Compliance to standards is relevant for RET installation and controlling.

6.6 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.

XML - Tag Example

```
<compatible_protocols>
    <protocol value="A proprietary"/>
    <protocol value="B proprietary"/>
</compatible_protocols>
```

Relevance

- Important to handle the refarming of the sites where the old RET systems are maintained with proprietary protocols.

6.7 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.

XML - Tag Example

<configuration_management value="Integrated RET, 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.

6.8 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

- True / False.

Specification Example

- Configuration file is not available.

XML - Tag Example

<antenna_configuration_file_available value="false"/>

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.

6.9 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.

XML - Tag Example

<antenna_configuration_file_upgradable value="true" info="Yes, by base station and proprietary portable controller"/>

<antenna_configuration_file_upgradable value="false" info="No"/>

Relevance

- RETs that can be installed and/or configured for an antenna in the field might require configuration per one of these methods.

6.10 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.

XML - Tag Example

< software_upgradable value="true" info="Yes, by base station and proprietary portable controller"/>

<software_upgradable value="false" info="no"/>

Relevance

- For a RET that allows the software to be upgraded in the field, this defines the available methods for upgrading the software.

6.11 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.

XML - Tag Example

```
<field_replacement_allowed value="true" info="Yes, only removing antenna"/>

<field_replacement_allowed value="false" info="No"/>
```

Relevance

- This parameter is relevant to the operators involved in maintenance and installation of RETs.

6.12 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

- True / False.

Specification Example

- A visible indicator of tilt change is not implemented.

XML - Tag Example

<visual_indicator_available_on_tilt_change value="false"/>

Relevance

- This parameter is relevant to the operators involved in maintenance and testing of RETs.

6.13 Daisy Chain Available

Parameter Definition

- This parameter defines whether it is possible to connect the RET to another one via daisy chain.

Specification Definition

- True / False.

Specification Example

- Daisy chain is possible

XML - Tag Example

<daisy_chain_available value="true"/>

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.

6.14 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.

XML - Tag Examples

<smart_bias_t_available value="false"/>

<smart_bias_t_available value="true"/>

<smart_bias_t_assigned_port value="1"/>

<smart_bias_t_assigned_port value="3"/>

<smart_bias_t_assigned_port value="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.

7 Environmental Standards

7.1 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.

Environmental Parameter	**Classes**				**Unit**
	4.1	**4.1E**	**4.2L**	**4.3H**	
Minimum air temperature	-33	-45	-65	-20	*ºC*
Maximum air temperature	40	45	35	55	*ºC*
Minimum relative humidity	15	8	20	4	*%RH*
Maximum relative humidity	100	100	100	100	*%RH*
Minimum absolute humidity	0.26	0.03	0.003	0.09	*g/m3*
Maximum absolute humidity	25	30	22	36	*g/m3*
Rain intensity	6	15	15	15	*mm/min*
Maximum temperature change rate	0.5	0.5	0.5	0.5	*ºC/min*
Minimum air pressure	70	70	70	70	*kPa*
Maximum air pressure	106	106	106	106	*kPa*
Solar radiation	1120	1120	1120	1120	*W/m2*
Maximum wind speed	50	50	50	50	*m/s*

Table 7.1-1—ETSI 300 019-1-4 stationary, non-weather protected environmental classes.

The standard BSA product complies to the ETSI EN 300019-1-4 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 White Paper.
Standard BSAs comply also with:

- ETSI EN 300019-1-1 for storage: Class 1.2 (see Section 6.3.1).
- ETSI EN 300019-1-2 for transportation: Class 2.3.

Note 7.1.1: *Should the standards be updated, or should better standards be available, the recommendation is to use those instead.*

7.2 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 IEC 60068) 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 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, 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 behavior, 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.

7.3 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 with the IEC60068 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 White Paper recommends test limits that may deviate from corresponding ETS and IEC recommendations.

7.3.1 Packaged Storage

While packaged, transported and stored, antennas shall tolerate non-temperature-controlled-weather-protected-environments without degradation (Baseline: ETS 300 019-1-1 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 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.

7.3.2 Cold Temperature Survival

Antennas shall operate within their specifications after exposure to cold air temperature following IEC 60068-2-1 test methods (Baseline: ETS 300 019-1-4 Class 4.1; 16 hours at -33°C / Extended: ETS 300 019-1-4 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 behavior of all antenna parameters during the cold temperature survival test. The operation of the device is verified prior and following to the test.

7.3.3 Hot Temperature Survival

Antennas shall operate within their specifications after exposure to hot air temperature following IEC 60068-2-2 test methods (Baseline: ETS 300 019-1-4 Class 4.1; 16 hours at +40/55°C / Extended: ETS 300 019-1-4 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 behavior of all antenna parameters during the cold temperature survival test. The operation of the device is verified prior and following to the test.

7.3.4 Temperature Cycling

Antennas shall operate within their specifications after exposure to temperature cycling following IEC 60068-2-14 test methods (Baseline: ETS 300 019-2-4 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 strongly differs from the one defined in the cycle testing of IEC 60068-2-14, but considered that technically the risk for failures increases in the lower end of the temperature range, and having acknowledged the testing capabilities, this White Paper 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.

7.3.5 Vibration – Sinusoidal

Antennas shall operate within their specifications after (non-operating) exposure to sinusoidal vibration following IEC 60068-2-6 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 1.0g). This White Paper recommends 5 Hz as minimum frequency due to test equipment limitations.

7.3.6 **Humidity Exposure**

Antennas shall operate within their specifications after (non-operating) exposure to humidity exposure following the IEC 60068-2-30 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 expert teams shall instead apply the more rigid 6 cycles/24 hours testing.

7.3.7 **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 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 White Paper considered an acceptable compromise between the ETS and IEC characteristic severities.

7.3.8 **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 "degrees of protection provided by enclosures (IP Code)".

This White Paper 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).

7.3.9 **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 "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 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 White Paper recommends the value not to be stated in the technical customer documentation and datasheets.

7.3.10 **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) and/or EIA/TIA 222. The detailed reference to be used might vary by country and has to be checked accordingly.

The maximum wind velocities cited in ETS 3000019 are 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 modeling & simulation.
- Similarity to existing verified products.
- Analytics applying best structural engineering practices.

This White Paper 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.

7.3.11 **Solar/Weather Exposure**

Antenna materials shall not degrade significantly after simulated solar exposure following the IEC 60068-2-5 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 White Paper. As an example, these material specific limits could be defined considering following behavior 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 color 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.

7.3.12 **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, 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 White Paper recommends the test duration defined in IEC 60068-2-11 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.

7.3.13 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 charateristics. The test method is indicated by IEC 60068-2-27 "Test Eb: Bump" (Baseline: antenna without packaging, half-sine bumps from 6 directions, 100 bumps in each direction).

This White Paper recommends applying, irrespective of the product weight, the test specifications below:

Antenna Weight	Input Acceleration	Duration
<50kg	100 m/s²	6 ms
>50kg	50 m/s²	11 ms

7.3.14 **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 charateristics. The test method is indicated by IEC 60068-2-31 (Baseline: packaged antenna, 1 fall per face or 2 falls, altitude specified in the table below).

Mass [kg]	Free fall test height [m] Class T 2.2	Free fall test height [m] Class T 2.3
< 10	0.8	1.0
< 20	0.6	0.8
< 30	0.5	0.6
< 40	0.4	0.5
< 50	0.3	0.4
< 100	0.2	0.3
> 100	0.1	0.1

Table 7.3-1—Free fall test heights.

This White Paper 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).

7.3.15 **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 charateristics. The test method is indicated by IEC 60068-2-64 "Test Fh: Vibration broadband".

This White Paper recommends the tested frequency spectrum for broadband random vibration to be aligned with the one applied for the sinusoidal testing (see Section 7.3.5).

7.3.16 **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 "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 IEC 60068-56 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 White Paper too.

8 Reliability Standards

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.

9 Additional Topics

9.1 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 standardized by organizations such as ETSI and 3GPP, hence here it will not be necessary to define them anew. This White Paper 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).

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 9.1-1— 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	UTRA Band number	Uplink (UL) BS receive			Downlink (DL) BS transmit			Duplex Mode
			UE transmit			UE receive			
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

Table 9.1-2— Unpaired bands in NR, E-UTRA, UTRA (3GPP TS 37.104 V17.2.0, 2021-06)

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 degrees and the polarizations, the "coordinates", where the electrical parameters' specifications shall be measured.

As an example, let an antenna's electrical downtilt range from zero to two degrees, two polarizations (+45° and -45°), and let the E-UTRA operating band 31 of previous table be the sub-band to be analyzed. 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 neighborhood (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).

9.1.1 **Frequency Ranges Choice Method**

The first steps of this algorithm consist in:

- Finding the most recent frequency table (see previous section).
- Copying the UL range in the DL column when the DL is marked by "N/A" (see Table 13) 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 13, the following should be obtained as results here:

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

Table 9.1-3—Sorted frequency table.

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 White Paper contemplates a **unification of the sub-bands** in accordance to 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 analyzed 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 too 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 analyzed 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 should look as follows:

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

Table 9.1-4—Frequency table after sub-bands unifications.

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: <u>selecting samples that are frequency-wise distant one from another means dealing with a dataset containing very different values</u> (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 split** 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 15), if 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.

<u>*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.*</u>

<u>*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.*</u>

Cases in which these divisions take place are highlighted in orange in Table 15. After this process, the frequency table shall be sorted again (see beginning of this section) and should look as in the table below:

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

Table 9.1-5—Frequency table after sub-bands divisions.

The listed sub-bands shall eventually be merged, split, 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 follows:

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

Table 9.1-6—Frequency table at the end of the merging/splitting/sorting processes.

None of the sub-bands listed above can be merged or split. At this time another issue should be considered: the algorithm described until now works with respect to a frequency table that is already standardized, 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

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 standardized 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.

9.1.2 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.

Width [MHz]	Number of frequency samples	Samples
$W < 10$	1	$f_{start} + W/2$
$10 \le W < 30$	2	f_{start} f_{stop}

$30 \leq W < 60$	3	f_{start} $f_{start} + W/2$ f_{stop}
$W \geq 60$	4	f_{start} $f_{start} + W/3$ $f_{stop} - W/3$ f_{stop}

Table 9.1-7—Frequency sampling.

All the samples calculated this way shall be approximated to the nearest unit of megahertz. Below the list of frequency samples associated to each sub-band:

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

Table 9.1-8—Samples associated to sub-bands' portions.

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 analyzed. 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 degree of redundancy that can be reduced through optimization. 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:

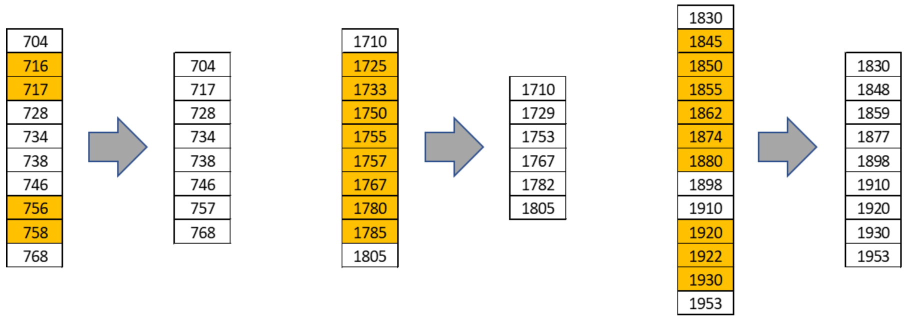


Figure 9.1-1—Examples of frequency samples redundancy optimization.

On the left there are two cases where the highlighted frequency-samples are simply averaged. In the center 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 18 with the optimized 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.

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)b+(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				

Table 9.1-9—Final frequency table. Samples undergoing optimization (orange) as well as new samples compared to WP11.1 (blue) are highlighted.

9.1.3 Compatibility with old White Paper 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 White Paper. 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 White Paper guarantees (antenna's patterns are different in this neighborhood, 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 not be included in antennas' BASTA-compliant datasets.

9.2 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.

9.2.1 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 degrees 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.

9.2.2 Phase Center Check

The antenna shall be rotated around its own phase center. 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 center of the system, until it is aligned with the antenna phase center.

9.2.3 Antenna Pattern Testing

The system shall be set up to measure the antenna's patterns by the frequencies identified through the rules described in Section 9.1. 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 degree 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".

9.2.4 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 degrees) 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.

9.3 Gain Measurement

In the following sections two methods to calculate the gain of an antenna will be described.

9.3.1 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 center 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 center 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.

9.3.2 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:

$$G = k \cdot D$$

with *k* representing the antenna efficiency factor (0 £ k £ 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:

$$G[dB] = D[dB] - a_{antenna}[dB]$$

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 (theta θ and phi ϕ).

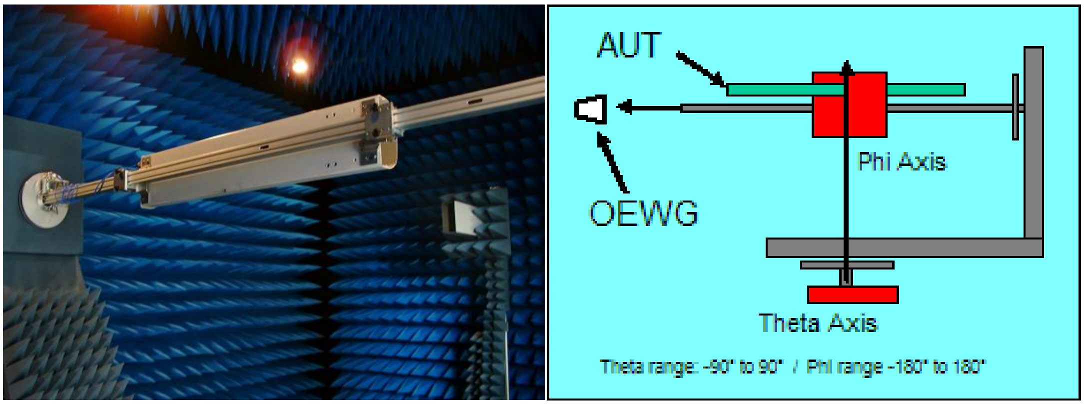


Figure 9.3-1—Spherical near-field system.

The directivity cannot be measured directly, but shall be computed from the far-field power pattern normalized to its maximum value:

$$D = \frac{4\pi\, P_n(\varphi_m, \theta_m)}{\oiint P_n\,(\varphi, \theta)\sin\theta\; d\varphi d\theta}$$

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:

$$D[dB] = MaxFF[dB] - Powersum[dB] + 10 \cdot log(4\pi)$$

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.

Measuring the Internal Losses of an Antenna

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:

$$a_{antenna} = a_{network} + a_{antennamismatch} + a_{radome}$$

The feeding loss $\alpha_{network}$ can be measured with a network analyzer as shown in the following picture:

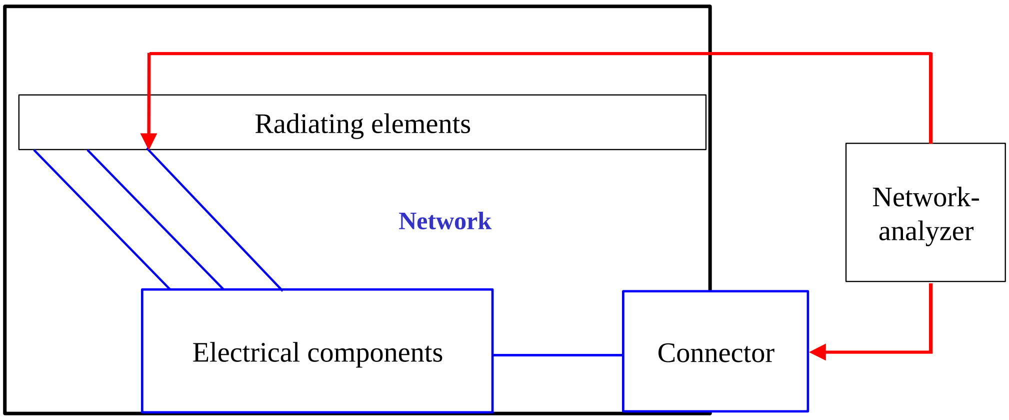


Figure 9.3-2—Block diagram of loss measurement.

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:

$$a_{mismatch} = -10 \cdot \log_{10}\left(1 - e^{-\frac{RL}{10}}\right)[dB]$$

where *RL* is the return loss.

In the end, the overall network loss is:

$$a_{network} = a_{cables} + a_{components} + a_{network\_mismatch}$$

The dielectric losses of the radome depend on its loss factor *tanδ*, 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.

9.4 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.

9.4.1 Antenna Mismatch between Reference Antenna and AUT

The measurement system is typically calibrated by the interface of the receiver (network analyzer) 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 analyzer is < -20 dB.

9.4.2 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.

9.4.3 Temperature and Humidity Drift in Instruments

The signal level measured at the receiver (network analyzer) 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 7).

9.4.4 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.

9.4.5 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.

9.4.6 **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.

9.5 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

$$Efficiency = 10 \cdot \log\left(\frac{P_{rad}}{P_{in}}\right) = 10 \cdot \log\left(\frac{\oiint G_{calibrated}(\theta,\varphi)\ sin\theta\ d\theta d\varphi}{4\pi}\right)$$

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.

9.5.23 **Near-Field Efficiency Measurement**

- Using the calibration reference antenna for gain calibration.
- It is recommended that for the Antenna installation: The phase center 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

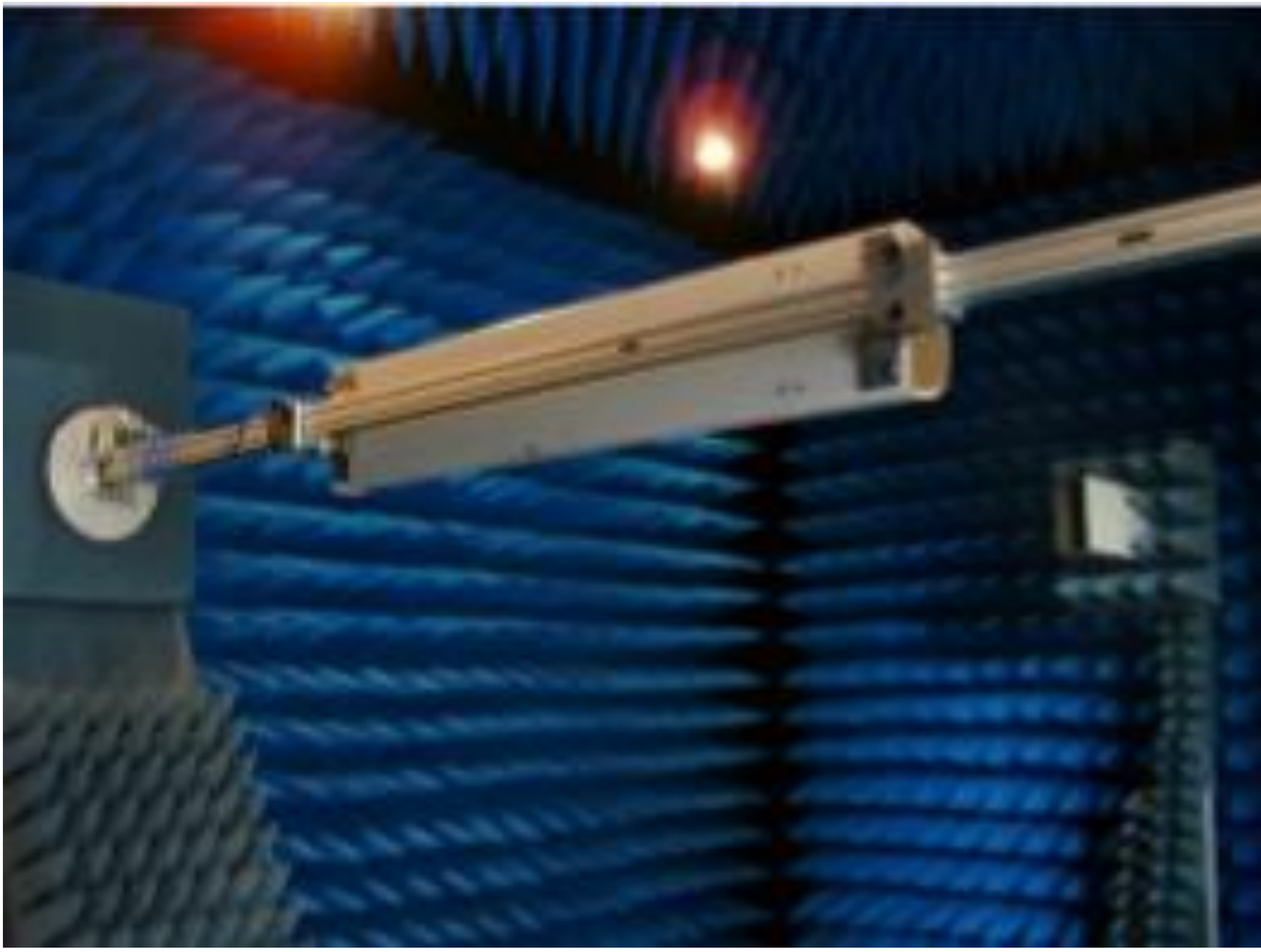


Figure 9.5-1— Example of a spherical near-field system

9.5.24 **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-polarized 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.

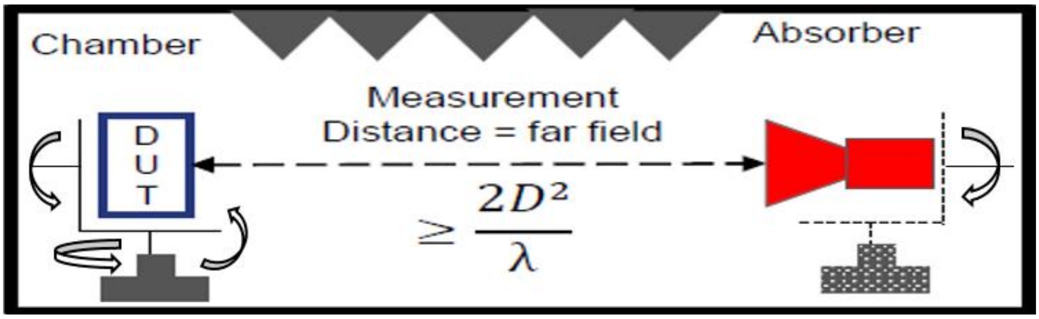


Figure 9.5-2— Calculated difference between the phase of each coupling factor and the average phase of all coupling factors for each frequency point

9.5.25 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 section 9.3.2 (Measuring the internal losses of an antenna).

In this case, the efficiency would be calculated by the formula

$$Efficiency = -\,a_{antenna}$$

where $a_{antenna}$ represents the antenna losses.

9.5.26 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.

$$Efficiency\ [\%] = 10^{\ Efficiency\ [dB]/10} * 100\%$$

The following table shows the results in 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%

Table 9.5-1— Efficiency in dB and percentage.

9.6 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.

9.7 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 labeling 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 labeling 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 labeled 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 labeling on the rear side of an antenna:

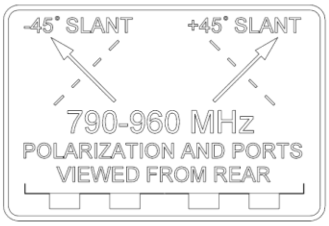


Figure 9.7-1—Example of polarization conventional label.

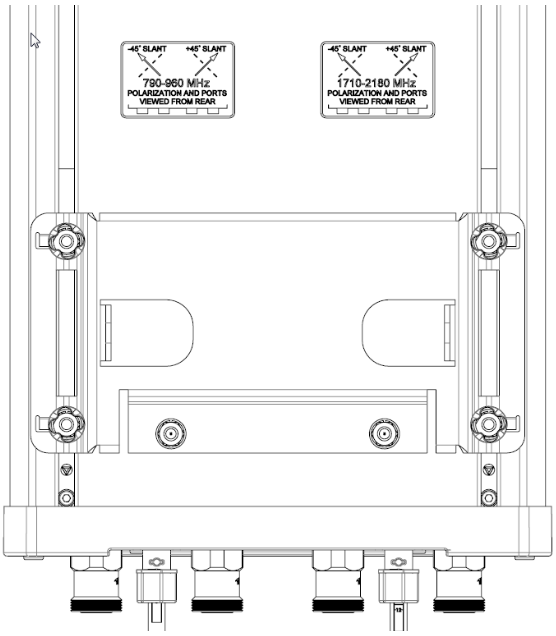


Figure 9.7-2—Polarization conventional label affixed on the antenna back.

Finally, an example of the ports labeling per the convention described on the antenna:

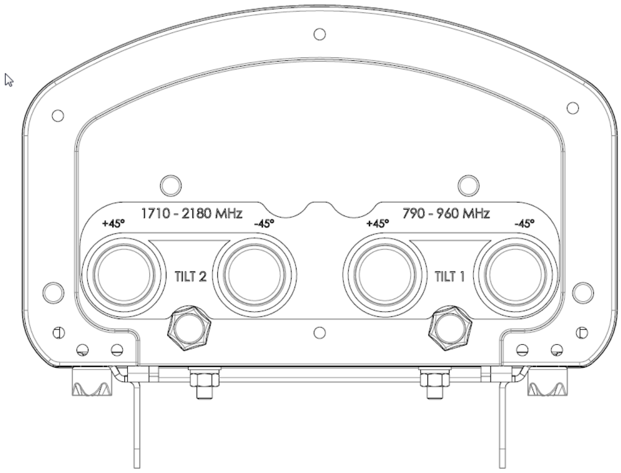


Figure 9.7-3—Ports identified by polarization.

10 Format for the Electronic Transfer of Specification Data

Antenna vendors are expected to disclose antennas' specifications through datasheets. In the past this was done by providing the final user with paper documents, but since it has become common practice that operators request data in electronic format in addition, it is useful to have an agreed upon format for electronic data interchange. Requirements for the above mentioned format were identified in:

- Very limited flexibility for providing information outside the agreed content.
- Easiness of exchange (export / import of data).
- No dependency on any proprietary software.
- Low to no risk of file structure or format (extension etc.) change.

XML was elected as the only format for electronic data interchange to be recommended in this White Paper. It consists in an open-standard system that defines rules to encode information in a file, and due to its readability and simplicity, at the time the edit of this White Paper it was largely widespread. XML files can populate databases by being loaded through specific XML-reader software but can also be loaded from the most common web-browsers and word-processors for a fast consultation.

XML key terminology will be extensively used in the next sections, so for a quick reference it is helpful to list the most important definitions:

- A **tag** is a line of text contained inside the two markup symbols "<" and ">". Tags are defined as:
  - Start tag (e.g.: <tag>).
  - End tag (e.g.: </tag>).
    Some tags can also have a structure that allows them to start and end in the same string, such as:
  - <tag element/>
- Between start and end of a tag there is an **element** that is a logical "block", which can contain only a number of attributes as in the following example:

  <tag name1="value1" name2="value2"/>

  or one or more tags as shown below:

  <tag>

  <child_tag>

  <grandchild_tag name1="value1" name2="value2"/>

  </child_tag>

  </tag>

  where the element of tag is everything enclosed between its start and end tags.

- An **attribute** is a set of two entities: **name** and **value** (see examples above), which are linked together by an equality.

More information on XML specifications can be easily found on the web.

10.1 XML use for BSA specifications

As already written, XML defines a set of general rules to encode documents, but it is also necessary, for the scope of this White Paper, to have agreements on the structure and content of the very NGMN P-BASTA XML-code, so that it can be easily read both by machines and humans, yet fulfilling the requirement to be a satisfying datasheet for an antenna.

In this release a XSD schema file for antennas with the defined XML tags was created and stored on the NGMN web server (Link: https://www.ngmn.org/schema/basta/).

Additionally, an example of an XML antenna datasheet was uploaded to the same folder.

- An XML file shall have an unambiguous name, structured in accordance to the antenna's datasheet name and version (see Section 10.1.1).
- An XML file shall never contain any information on how to obtain (measure or calculate) the values of an antenna's parameters, their definition or specification, their measurement units or, more in general, anything that is already covered by this White Paper.
- An XML file shall not contain information unrelated to this White Paper (e.g.: new parameters, alternative calculations, etc.).
- Every user interested in the use of XML files for BSA specifications shall be redirected to this document upon request of information.
- The order of the tags in an element and the order of the attributes in a tag shall not be arbitrary, so that the general structure of the code remains the always the same for everyone (in the appendices there are complete XML structure samples of a fictitious antenna and of a fictitious RET).
- All the tags are treated as not case sensitive, but in this White Paper it is recommended that tags and attributes are written with lower case characters only, and with the underscore symbol ("_") for separating words. The values of attributes are an exception to this rule and may contain uppercase letters and/or spacing.
- Comments can be used everywhere (see XML comment syntax on the web).
- Decimal numbers shall always be written with the full stop symbol (".") and not with comma (",").
- Each tag in the XML code shall have the optional Boolean attribute applicable, that can be set to applicable="false" if, for some reason, the tag refers to parameter that cannot be measured or calculated by its definition. In that case all the elements belonging to the tag shall not be taken in account (attributes values can be random).

The XML code structure shall reflect the logical structure of antennas, which can be schematized as shown in the following picture:

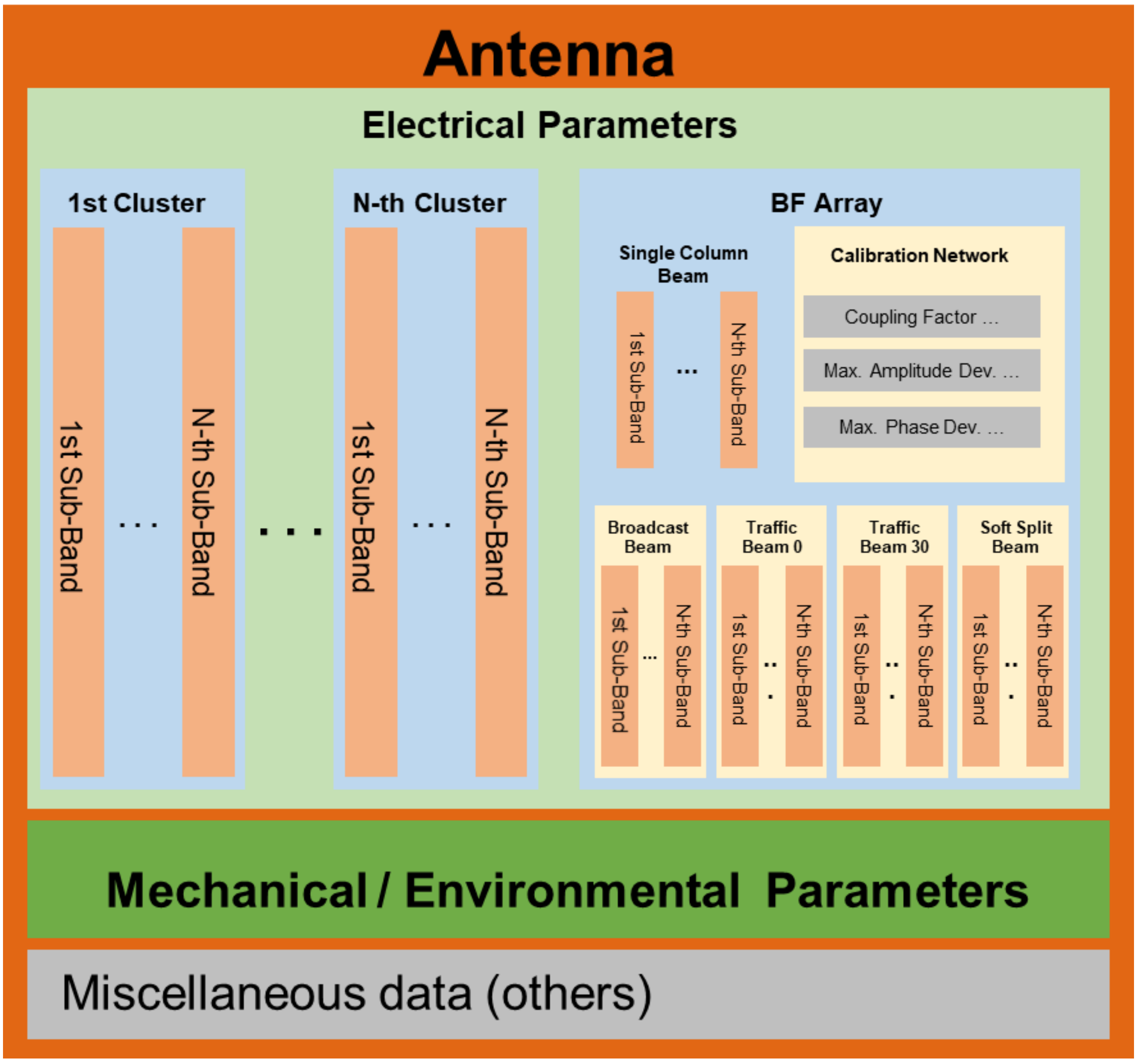


Figure 10.1-1—Block-scheme of an antenna.

Corresponding to the block scheme illustrated above, the XML code shall be structured as follows:

```
<antenna description="Antenna XY " model="AntennaModelNo" vendor="NAME">
        <!-- parameters tags to be inserted here -->
 <electrical_specifications>
  <!-- parameters tags to be inserted here -->
  <cluster name="1st" beam_forming="false" nominal_direction="0" nominal_sector="120"
      nominal_horizontal_half_power_beamwidth="65">
               <!-- parameters tags to be inserted here -->
   <frequency_sub_range start="XX" stop="YY">
    <!-- parameters tags to be inserted here -->
   </frequency_sub_range>
               <!-- parameters tags to be inserted here -->
   <frequency_sub_range start="WW" stop="ZZ">
    <!-- parameters tags to be inserted here -->
   </frequency_sub_range>
  </cluster>
               <!-- more clusters -->
  <cluster name="n-th" beam_forming="false" nominal_direction="0" nominal_sector="120"
      nominal_horizontal_half_power_beamwidth="65">
               <!-- parameters tags to be inserted here -->
   <frequency_sub_range start="XX" stop="YY">
    <!-- parameters tags to be inserted here -->
   </frequency_sub_range>
               <!-- other frequency_sub_ranges -->
   <frequency_sub_range start="WW" stop="ZZ">
    <!-- parameters tags to be inserted here -->
   </frequency_sub_range>
  </cluster>
               <!-- clusters with beamforming capabilities -->
  <cluster name="1st"  beam_forming="true" nominal_direction="-45" nominal_sector="30"
      nominal_horizontal_half_power_beamwidth="90">
               <!-- parameters tags to be inserted here -->
   <frequency_sub_range start="UU" stop="VV">
    <!-- parameters tags to be inserted here -->
   </frequency_sub_range>

               <beamforming_array name="BF1st">
                    <single_beam>
                         <!-- BF parameters tags to be inserted here -->
                    </single_beam>
                    <broadcast_beam>
                         <!-- BF parameters tags to be inserted here -->
                    </broadcast_beam>
                    <traffic_0_beam >
                         <!-- BF parameters tags to be inserted here -->
                    </traffic_0_beam>
                         <!-- BF parameters tags to be inserted here -->
                    </traffic_30_beam>
                    <soft_split_beam name="1">
                         <!-- BF parameters tags to be inserted here -->
                    </soft_split_beam>
                    <soft_split_beam name="2">
                         <!-- BF parameters tags to be inserted here -->
                    </soft_split_beam>
                    <calibration_port>
```

```
                                    <!-- CAL parameters tags to be inserted here -->
                              </calibration_port>
                        </beamforming_array>
                  </cluster>
  </electrical_specifications>

  <mechanical_specifications>
            <!-- mechanical & environmental parameters tags to be inserted here -->
  </mechanical_specifications>
  <miscellaneous_data>
            <!-- other parameters tags to be inserted here -->
  </miscellaneous_data>
</antenna>
```

This architecture allows the larger blocks/elements to include specifications that are valid for all the blocks/elements that they contain, while the smallest one describes a very specific part of the antenna.

A number of tags and attributes, which were not discussed in the appropriate parameter sections, shall be used to complete the antenna's logic structure. Those will be discussed in the following sections.

10.1.1 Filename

Each XML file shall be labeled in a way that readily indicates the content version, thus providing version tracking when multiple files occupy the same folder. The filename should also allow a user (human or machine) to easily identify basic information about the datasheet contained and perform basic queries between files to find a specific version of an antenna's datasheet. A filename shall always be written with uppercase letters, and its archetype shall be:

BASTAVERSION_VENDORNAME_ANTENNANAME,PAN,FAN_DATE_VERSION_STATUS

where:

- BASTAVERSION is the version of the NGMN-P-BASTA White Paper that has been used to create the XML file. The symbol of full stop (".") in the version string shall be replaced with the symbol of minus ("-").
- VENDORNAME is the name of the antenna's vendor.
- ANTENNANAME is the name of the antenna model.
- PAN is the combination of the string "PAN" and the value in degrees of a specific antenna pan angle (see Section 3.3.16). This value shall be identified by a letter indicating the sign ("P" for "plus" and "M" for "minus") and three figures, which shall vary between "000" and "359". "000" shall always be preceded by "P". Moreover, if an antenna has no pan capability, PAN shall be an empty string, and the comma before it shall be deleted.
- FAN is the combination of the string "FAN" and the value in degrees of a specific antenna fan angle (see Section 3.3.17). This value shall be identified by three figures, which shall vary between "001" and "360". Moreover, if an antenna has no fan capability, FAN shall be an empty string, and the comma before it shall be deleted.
- DATE is the date in which the datasheet inside the file was created. The format to use shall be YYYY-MM-DD (four numbers for the year, two for the month and two for the day).
- VERSION is written with a "V" letter and followed by two numbers. It represents the version of the datasheet contained in the file. The first version shall always be the "00". Along with DATE,

ensures that there can be a maximum of 100 datasheets of the same antenna created in one day.
- STATUS shall describe the datasheet status. Only two values of it shall be possible: F (for "final") and P (for "preliminary").
- The extension of the file shall be ".xml"

An example of filename of an antenna capable of panning and fanning:

BASTA10-0_RFS_APXV99LL20BI-U,PANM150,FAN010_1999-12-30_V00_F.xml

An example of filename of an antenna not capable of panning and fanning:

BASTA10-0_RFS_APXV88LL25BI-U_2000-08-12_V10_F.xml

10.1.2 Preamble

The preamble is a part of code that was not mentioned before. It is nevertheless worth to dedicate a section to it due to the fact that it completes the code with useful information. It contains only two tags:

XML version and encoding:

```
<?xml version="1.0" encoding="UTF-8"?>
```

This is defined by the XML format. For information concerning this tag, it is recommended to refer to the appropriate documentation on the web.

BASTA and its version:

```
<basta version="12.0"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" xmlns="http://
https://www.ngmn.org/schema/basta/"
xsi:schemaLocation= " https://www.ngmn.org/schema/basta/
NGMN_BASTA_Passive_XML_datasheet_antennas_schema_V12_0.xsd">
```

The basta tag opens the datasheet, and its first attribute version points to the version of the NGMN-P-BASTA White Paper that has been used to create the XML file. The value associated to it shall be a string containing the version number, which shall be the same one used to generate the filename (see Section 10.1.1).

A tag dedicated to annotations belongs to the basta tag too:

```
<annotation>here you can write what you want</annotation>
```

10.1.3 Antenna

The antenna element is the largest block and contains information that characterize/are valid for the whole antenna:

Antenna name, brand and description:

```
<antenna vendor ="huawei" model="atr4517r1" description="dxxx-790-960/1710-2690/1710-2690-
65/65/65-15i/17.5i/17.5i-m/m/m-r">
```

All the three attributes contain a string that describes respectively the antenna's vendor, the antenna model and a brief description of the antenna itself. vendor and model shall coincide respectively with VENDORNAME and ANTENNANAME in the filename (see Section 10.1.1). This redundancy has been added to avoid mistakes during XML files renaming. Files whose name and antenna tag don't coincide should not be used.

Datasheet replacement:

<replacement_datasheet datasheet="BASTA9-6_COMMSCOPE_SBNHH-1D65B,FAN065_2001-01-01_V10_P"/>

replacement_datasheet is an optional tag that shall appear as an element inside antenna when the datasheet contained in the file replaces a previous version of itself. An antenna replacing an older model typically changes instead its name, therefore its datasheet shall not be taken as a substitute to an older one, but as a brand-new datasheet. The value of datasheet shall be a string equal to the name of the replaced datasheet without the ".xml" extension. Notice that the value of datasheet is written with uppercase letters.

10.1.4 Electrical Specifications

The electrical specifications block is the only element containing antennas' parameters concerning its radiation pattern and electrical features. It contains every cluster block and two other elements that have no child tags:

Maximum power for the whole antenna:

<maximum_effective_power_antenna value="1200"/>

This tag is basically self-explanatory. Its value attribute shall be a positive integer number.

10.1.5 Cluster and Ports

Inside a cluster block there are all the parameters that belong to the specific section of the antenna connected to a number of ports (typically two in case of directional single beam antennas or eight in case of 8T8R antennas with beamforming capabilities). A cluster is, in fact, defined by more tags, which contain its core informations: name, ports and supported frequencies.

Cluster name:

<cluster name="R1" beam_forming="false" nominal_direction="0"
nominal_sector="120" nominal_horizontal_half_power_beamwidth="65">

Or

<cluster name="P1" beam_forming="true" nominal_direction="0"
nominal_sector="120" nominal_horizontal_half_power_beamwidth="65">

In the name attribute it is useful to have a basic information on the set of frequencies supported by the cluster directly. Therefore the name that shall be used is the same string that would be found on the interface graphics on the end caps which is defined in the latest "AISG specification for antenna ports color coding".

Each cluster shall refer to the nominal_direction, which is from type integer in the range of -180 to +180, and refer to the nominal_sector and the nominal_horizontal_half_power_beamwidth, which are from type integer in the range of 0 to 359. In former releases these parameters were defined as single required parameters. Additional, the boolean attribute beam_forming characterizes if a cluster has beamforming capabilities.

Ports:

<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"/>

<port name="P1_L+" number="17" polarization="+45" location="bottom" connector_type="4.3-10 female"/>

<port name="P1_L-" number="18" polarization="-45" location="bottom" connector_type="4.3-10 female"/>

<port name="P1_L+" number="17" polarization="+45" location="bottom" connector_type="MQ5 female Pin4"/>

<port name="P1_L-" number="18" polarization="-45" location="bottom" connector_type="MQ4 female Pin4"/>

As already stated, the port tags complete, along with its name and supported frequencies, the definition of a cluster. Port name, location and polarization shall be strings whose values shall follow the recommendations given in the latest "AISG specification for antenna ports color coding" document. Additional port number shall is necessary to identify the port and might also reference to special ports with integrated Bias-Ts mentioned in section 6.14. Port number shall be positive integer. For a single cluster there are typically two ports.

Port names of antennas with capability of beamforming e.g., 8T8R beamforming arrays with four columns, shall be named with the array code e.g., Y1, P1 and additional the name of the connected antenna system according to the latest "AISG specification for antenna ports color coding" (L+,L-,CL+,CL-,CR+,CR-,R+,R-).

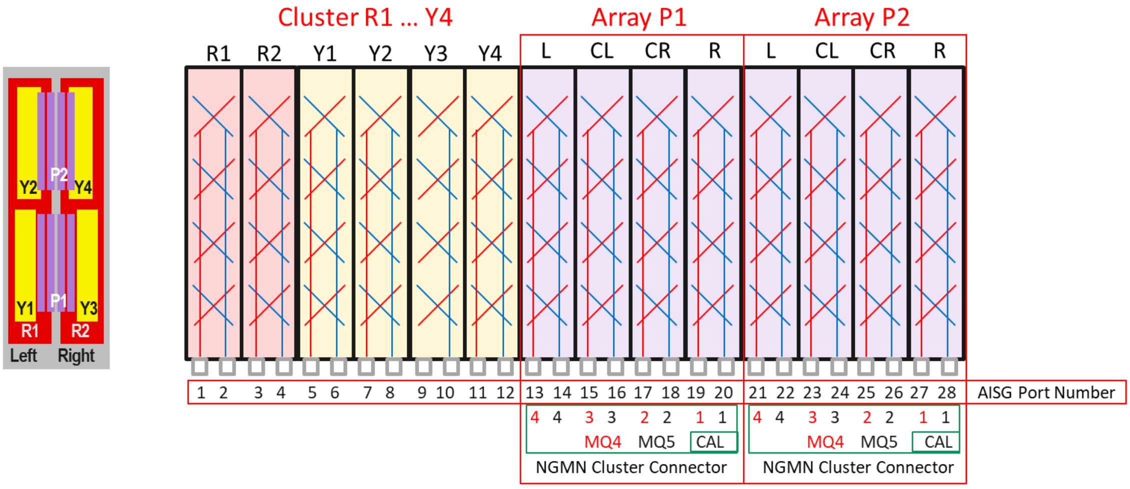


Figure 10.1-2—Example of Clusters and Ports.

Supported frequencies:

<frequency_range start="698" stop="960"/>

The frequency_range tag gives the user insight into the cluster's supported frequencies. All the ports associated to the cluster shall support all the frequencies between start and stop (included). These two attributes shall be equal to a positive integer value (rounded to the nearest unit, if necessary) with stop > start.

A cluster can support a broader band than the broadest combination of all the sub-bands specified by the vendor in the sub-frequencies block (see Section 10.1.6).

Other tags contained in cluster:

TAG	Attribute variable format
<mechanical_boresight value="XXX"/>	Integer number between -180 and 180
<electrical_downtilt start="XXX" stop="XXX"/>	Both float with one digit. stop > start
<isolation_inter_cluster value="XXX"/>	Positive integer
<impedance value="XXX"/>	Positive integer
<vswr value="XXX"/>	Positive float with one digit
<return_loss value="XXX"/>	Positive float with one digit
<passive_intermodulation value="XXX"/>	Negative integer
<maximum_effective_power_per_port value="XXX"/>	Positive integer
<maximum_effective_power_cluster value="XXX"/>	Positive integer

10.1.6 Sub-Band

A frequency sub-band block is a section of a cluster that characterizes only a part of its whole supported spectrum. It is the smallest logical block but also the most specific, also because it contains the highest number of parameters. A sub-band block has no name and is uniquely defined by its frequency range.

Sub-Band:

<frequency_sub_range start="698" stop="806"/>

All the parameters included in frequency_sub_range shall only be associated to the specified frequency range between start and stop (included). These two attributes shall be equal to a positive integer value (rounded to the nearest unit, if necessary) with stop > start. start cannot be lower than the cluster's frequency_range start; similarly, stop cannot be higher than the cluster's frequency_range stop.

All tags contained in sub-band:

TAG	Attribute variable format
<gain_at_tilt min="XXX" mid="XXX" max="XXX"/>	Positive float with one digit
<gain_over_all_tilts value="XXX" tolerance="XXX"/>	Both positive float with one digit
<azimuth_interference_ratio value="XXX" tolerance="XXX"/>	Both positive float with one digit
<azimuth_beamwidth value="XXX" tolerance="XXX"/>	Both positive float with one digit
<azimuth_beam_squint value="XXX" tolerance="XXX"/>	Both positive float with one digit
<azimuth_beam_port_to_port_tracking value="XXX"/>	Positive float with one digit
<azimuth_beam_hv_tracking value="XXX"/>	Positive float with one digit
<azimuth_beam_roll_off value="XXX" tolerance="XXX"/>	Both positive float with one digit
<elevation_beamwidth value="XXX" tolerance="XXX"/>	Both positive float with one digit
<elevation_downtilt_deviation value="XXX"/>	Positive float with one digit
<front_to_back_ratio_total_power_pm30 value="XXX"/>	Positive float with one digit
<null_fill value="XXX"/>	Positive float with one digit
<upper_sidelobe_suppression_first value="XXX"/>	Positive float with one digit
<upper_sidelobe_suppression_peak_to_20 value="XXX"/>	Positive float with one digit
<upper_sidelobe_suppression_horizon_to_20 value="XXX"/>	Positive float with one digit
<upper_sidelobe_suppression_maximum_level value="XXX"/>	Positive float with one digit
<cross_polar_discrimination_over_sector value="XXX"/>	Positive float with one digit
<cross_polar_discrimination_at_mechanical_boresight value="XXX"/>	Positive float with one digit
<cross_polar_discrimination_over_3_db_azimuth_beamwidth value="XXX"/>	Positive float with one digit
<cross_polar_discrimination_over_10_db_azimuth_beamwidth value="XXX"/>	Positive float with one digit
<cross_polar_discrimination_over_3_db_elevation_beamwidth value="XXX"/>	Positive float with one digit

<cross_polar_discrimination_over_10_db_elevation_beamwidth value="XXX"/>	Positive float with one digit
<isolation_intra_cluster value="XXX"/>	Positive float with one digit

10.1.7 Beamforming

The characteristic of a single column of antennas with beamforming capabilities shall be described similar to a cluster whereby the attribute beam_forming shall be set on 'true' mentioned in the XML tag example in section 10.1.5.

The parameters of the beamforming capabilities shall be described for the whole frequency band.

All tags contained in the frequency band:

TAG	Attribute variable format
<azimuth_nominal_beam_direction value="XXX"/>	Integer in the range of [-180…180]
<azimuth_beamwidth value="XXX" tolerance="XXX"/>	Both positive float with one digit
<cross_polar_discrimination_at_mechanical_boresight value="XXX"/>	Positive float with one digit
<cross_polar_discrimination_over_3_db_azimuth_beamwidth value="XXX"/>	Positive float with one digit
<gain_over_all_tilts value="XXX" tolerance="XXX"/>	Both positive float with one digit
<front_to_back_ratio_total_power_pm30 value="XXX"/>	Positive float with one digit
<maximum_horizontal_sidelobe_suppression value="XXX"/>	Positive float with one digit
<coupling_factor_between_each_antenna_port_and_calibration_port value="XXX" tolerance="XXX"/>/>	value negative integer tolerance positive integer
<maximum_amplitude_deviation_between_coupling_factors value="XXX"/>	Positive float with one digit
<maximum_phase_deviation_between_coupling_factors value="XXX"/>	Positive float with one digit

10.1.8 Mechanical and Environmental Specifications

The mechanical and environmental block encompasses, under the mechanical_specifications tag, the following elements:

TAG	Attribute variable format
<antenna_dimensions height="XXX" width="XXX" depth="XXX" reference="XXX"/>	All positive integer except reference that is an optional string.
<packing_size height="XXX" width="XXX" depth="XXX"/>	All positive integer
<net_weight wo_mtg_hardware="XXX" only_mtg_hardware ="XXX"/>	Both positive float with one digit
<shipping_weight value="XXX"/>	Positive float with one digit
<survival_wind_speed value="XXX"/>	Positive integer
<windload lateral="XXX" frontal="XXX" maximum360="XXX" laboratory="XXX" extrapolation="XXX"/>	All positive integer except laboratory which is a string
<windload_polar unit="XXX"> <azimuth direction="XXX" value="XXX"/> </windload_polar>	All positive integer except unit which is a string
<radome_material value="XXX"/>	String
<radome_color value="XXX"/>	String
<lightning_protection value="XXX"/>	Boolean
<mechanical_distance_between_mounting_points_antenna value="XXX"/>	Positive integer

There is also a variable number of environmental specifications included in the same element (see Section 5.11). Below an example:

TAG	Attribute variable format
<product_environmental_compliance_general standard="XXX" compliance="XXX"/>	Both strings
<product_environmental_compliance_transportation standard="XXX" compliance="XXX"/>	Both strings
<product_environmental_compliance_environmental_conditions standard="XXX" compliance="XXX"/>	Both strings
<product_environmental_compliance_storage standard="XXX" compliance="XXX"/>	Both strings

<product_environmental_compliance_packed_storage standard="XXX" compliance="XXX"/>	Both strings

10.1.9 **Miscellaneous data**

Finally, there is an element of antenna that cannot be considered as a part of the antenna's block architecture: miscellaneous_data. It contains only two tags:

Compatible RETs:

<compatible_ret value=" 1st RET_UNIT_TypeNo "/>

<compatible_ret value=" 2nd RET_UNIT_TypeNo "/>

This tag's attribute value is actually a string with the product name of a RET model that is compatible to the antenna. Additional tags shall be used if more than one RET model is available to this antenna. It will be assumed that the vendor of these RET models is the same of the antenna's.

Comments:

<vendor_comments value="antenna clamps included"/>

<vendor_comments value=" ret included"/>

Since traditionally the vendors include in their paper datasheets more information about the antenna (such as: optionals, pieces included in the package, etc.) rather than specifying only parameters values, vendor_comments is an optional tag merely thought for vendors to provide additional information regarding the antenna. Its only attribute shall be a string.

10.2 XML use for RET specifications

In this release an XSD schema file for RET with the defined XML tags was created and stored on the NGMN web server (Link: https://www.ngmn.org/schema/basta/).

Additionally, an example of an XML RET datasheet was uploaded to the same folder.

Block-scheme-wise a RET is, as a matter of fact, an appendix to an antenna (even if the RET is integrated), hence it can be described by a stand-alone file, whose structure follows all the rules defined in the previous section and all its relevant comprehended sections (Sections 10.1 to Section 10.1.3).

The ret tag contains only the following elements:

TAG	Attribute variable format
<replacement_datasheet datasheet="XXX"/>	String (filename)
<dimensions height="XXX" width="XXX" depth="XXX"/>	All positive integer
<unit_installation_reference_plane value="XXX" />	string
<working_temperature_range min="XXX" max="XXX"/>	Both integer > -273 with max > min
<power_consumption low_power="XXX" high_power="XXX"/>	Both positive float with one digit and high_power > low_power
<lose_position_on_power_failure value="XXX"/>	Boolean
<compatible_standards> <standards value="XXX"/> <standards value="YYY"/> <standards value="ZZZ"/> </compatible_standards>	String
<compatible_protocols> <protocol value="XXX"/> <protocol value="YYY"/> </compatible_protocols>	String
<configuration_management value="XXX"/>	String Enumeration
<antenna_configuration_file_available value="XXX"/>	Boolean
<antenna_configuration_file_upgradable value="XXX" info="XXX" />	value is Boolean, info is a string
<software_upgradable value="XXX" info="XXX"/>	value is Boolean, info is a string
<field_replacement_allowed value="XXX" info="XXX"/>	value is Boolean, info is a string Enumeration
<visual_indicator_available_on_tilt_change value="XXX"/>	Boolean
<daisy_chain_available value="XXX"/>	Boolean
<smart_bias_t_available value="XXX"/>	Boolean
<smart_bias_t_assigned_port value="XXX"/>	Positive integer starting at 1

APPENDIX – LOGICAL BLOCK STRUCTURE (ANTENNA+RET)