RECOMMENDATION ON BASE STATION ACTIVE ANTENNA SYSTEM STANDARDS

V1.0

Recommendation on Base Station Active Antenna System Standards

by NGMN Alliance

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Abstract

The current release of the whitepaper provides recommendations on standards for parameters describing an Active Antenna Systems (AAS). Specifically, electrical, mechanical and ElectroMagnetic Field (EMF) exposure related parameters and a format for electronic data exchange are introduced.

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1 INTRODUCTION AND PURPOSE OF DOCUMENT

1.1 Preface

The main scope of the present document is to describe and capture the electrical and mechanical key performance parameters of AAS and how to exchange this data electronically.

In addition, for the aim of RF-EMF exposure, a description of mechanisms to monitor and limit the power radiated by AAS is provided.

The current release of this White Paper (WP) does not address the topics of uplink related parameters and testing. However, since these are key topics, they will be addressed in the next release of the WP.

The topic related to “mixed passive-active” antenna systems is foreseen to be dealt with in a specific document focused on site solutions for AAS in-field introduction. Nevertheless, an informative appendix (see APPENDIX BAPPENDIX AAPPENDIX A) is temporarily provided in the current release of the WP to anticipate the matter of a typical deployment scenario for AAS, where a passive antenna system includes an enclosure called “Mechanical Installation Kit” (MIK) that is intended to host an AAS inside.

The reader must be familiar with the NGMN BASTA document titled: “Recommendations on Base Station Antenna Standards” [2].

1.2 Introduction

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

In particular, the following topics will be covered:

- Definitions of relevant AAS electrical and mechanical parameters
- EMF monitoring parameters
- A format definition for the electronic transfer of AAS specifications described in Section 3

AAS Datasheet shall be written also in XML format according to the P-BASTA datasheet XML Schema Definition (XSD) file. The latest and previous versions of this XSD file are accessible in real time at (http://www.ngmn.org/schema/basta) and the filename of the XSD file is “P-BASTA_datasheet_schema_vX.Y” where X.Y represents the version of the file.

Furthermore, an antenna’s far-field radiation pattern file(s) are provided which:

- Represents numerically the far-field radiation pattern
- Shall contain at least the co-polar azimuth cut and elevation cut radiation patterns
- Shall specify the field level with appropriately sampled data and guidelines for correct reading
- Shall contain additional cuts or 3D patterns – as indicated in this document, when requested

The scope of this paper is limited to base station active antennas systems. Even though antennas will not be categorized in performance-classes, this paper addresses antennas built for different purposes and frequency ranges.

1.3 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 whitepaper, 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 whitepaper
- ***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.

1.4 Abbreviations

The abbreviations used in this WP are written out in the following table.

Abbreviation	Definition
3GPP	3rd Generation Partnership Project
AAS	Active Antenna System
AR	Angular Region
BB	Broadcast Beam
BS	Base Station
CPD	Cross-Polar Discrimination
DL	DownLink
EBB	Eigen Based Beamforming
EIRP	Equivalent Isotropic Radiated Power
EL	Elevation
EMF	ElectroMagnetic Field
ETSI	European Telecommunication Standards Institute
FF	Far-Field
FDD	Frequency Division Duplex
GoB	Grid of Beams
HPBW	Half-Power Beamwidth
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical & Electronic Engineers
LHCP	Left-Handed Circular Polarization OR Circularly Polarized
MIK	Mechanical Installation Kit
M-MIMO	Massive MIMO
MIMO	Multiple Input/Multiple Output
MU-MIMO	Multi User MIMO
MTBF	Mean Time Between Failures
N/A	Not Available or Not Applicable
NF	Near Field

NGMN	Next Generation Mobile Network Alliance
NR	New Radio
PAS	Passive antenna system
P-BASTA	Project Base Station Antennas
PCF	Polarization correlation factor
PDF	Probability Distribution Function
QoS	Quality of Service
RAT	Radio Access technology
RDN	Radio Distribution Network
RET	Remote Electronic Tilt
RF	Radio Frequency
RHCP	Right-Handed Circular Polarization OR Circularly Polarized
RL	Return Loss
RXU	Receiver Unit
SDMA	Space Division Multiplexing Access
SU-MIMO	Single user MIMO
TDD	Time Division Duplex
TEM	Transverse Electric and Magnetic
TR	Techical recommendation
TRX	Transceiver
TXU	Transmitter Unit
TS	Technical specification
UE	User Equipment
UL	Up Link
UMTS	Universal Mobile Telecommunications System
USLS	Upper SideLobe Suppression
VNA	Vector Network Analyzer
VSWR	Voltage Standing Wave Ratio
WP	White Paper
XML	eXtensible Markup Language
XPD	see CPD

Table 1-1—Acronyms and abbreviations table.

1.5 References

1. IEEE Std. 145-2013 Standard definitions of Terms for Antennas
2. NGMN "Recommendations on Base Station Antenna Standards v11.1"
3. 3GPP TS 37.104 Base Station (BS) radio transmission and reception
4. 3GPP TS 38.104 Base Station (BS) radio transmission and reception
5. 3GPP TS 38.141-2 Base Station (BS) conformance testing. Part 2: Radiated conformance testing
6. 3GPP TS 37.105 Active Antenna System (AAS) Base Station (BS) transmission and reception
7. IEC TR 62232: 2019, Edition 3.0 - Determination of RF field strength, power density and SAR in the vicinity of radiocommunication base stations for the purpose of evaluating human exposure (106/511/CD of 2019-12-20)
8. IEC TR 62669: 2019 - Case studies supporting IEC 62232 - Determination of RF field strength, power density and SAR in the vicinity of radiocommunication base stations for the purpose of evaluating human exposure

9. B. Thors, A. Furuskär, D. Colombi, and C. Törnevik, "Time-averaged Realistic Maximum Power Levels for the Assessment of Radio Frequency Exposure for 5G Radio Base Stations Using Massive MIMO," IEEE Access, Vol. 5, pp. 19711-19719, September 18th, 2017
10. P. Baracca, A. Weber, T. Wild, and C. Grangeat, "A Statistical Approach for RF Exposure Compliance Boundary Assessment in Massive MIMO Systems," International Workshop on Smart Antennas (WSA), Bochum (Germany), Mar. 2018, arxiv.org/abs/1801.08351
11. IEC 60529 Degrees of Protection Provided by Enclosures (IP CODE)
12. 3GPP TS 38.211 Physical channels and modulation
13. 3GPP TS 37.145-2 Active Antenna System (AAS) Base Station (BS) conformance testing, Part 2: radiated conformance testing

2 DEFINITIONS

This section contains the definitions used throughout this WP.

2.1 Antenna terms

Unless otherwise stated, definitions from [1] and [2] by IEEE and NGMN, respectively, applies.

2.2 AAS definition

An AAS is an antenna that also contains active electronic components in addition to passive components such as metal rods, capacitors and inductors that can be found in passive antennas.

In a Base Station (BS), the AAS architecture is represented by three main functional blocks:

- a set of Transceivers (TRXs), interfacing the base band processing equipment with the composite antenna,
- a Radio Distribution Network (RDN),
- an Antenna Array (AA).

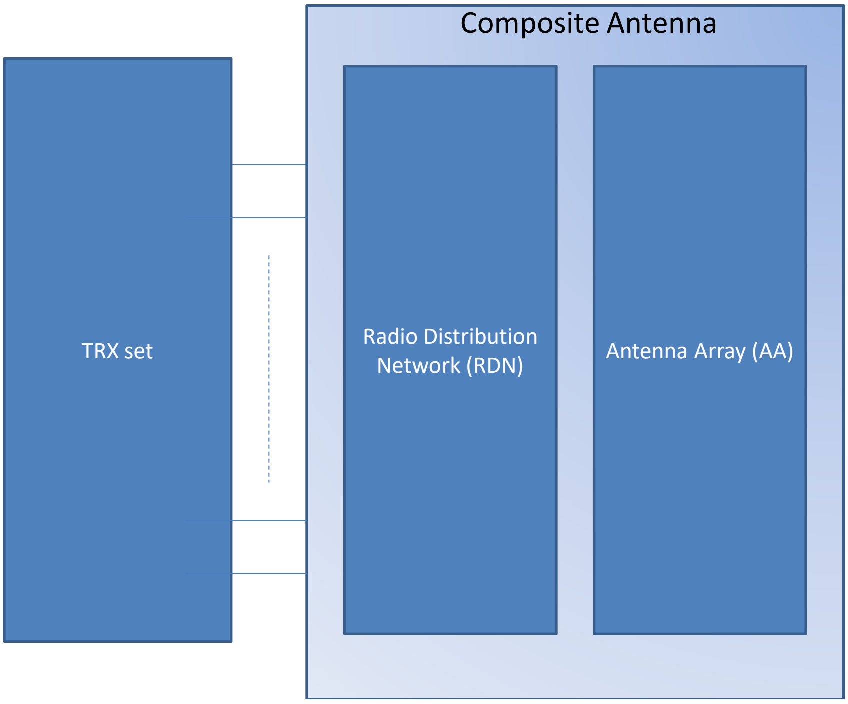

Figure 2.2-1— General Architecture of an Active Antenna System

The TRX consists of transmitter units (TXUs) and receiver units (RXUs). The TXUs take the baseband signals on input and provide RF signals on output. Such RF signals are distributed to the elements of the antenna array via an RDN. An RXU performs the reverse of the TXU operations.
In 3GPP documents, for example in [4], 3 different BS types are considered:

- Type 1-C is already addressed in [2] and will not be dealt with in the current document.
- The 1-H type has connectors between the TRX set and the composite antenna.
- The 1-O and 2-O are integrated antennas and hence have no such connectors available.

2.3 Antenna Reference Coordinate System

In this whitepaper the antenna reference coordinate system is identified by a right-handed set of three orthogonal axes $(\bar{x}, \bar{y}, \bar{z})$ whose origin coincides with the center of an antenna's FF radiation sphere, whose spherical angles (Θ, φ) are defined as in the figure below:

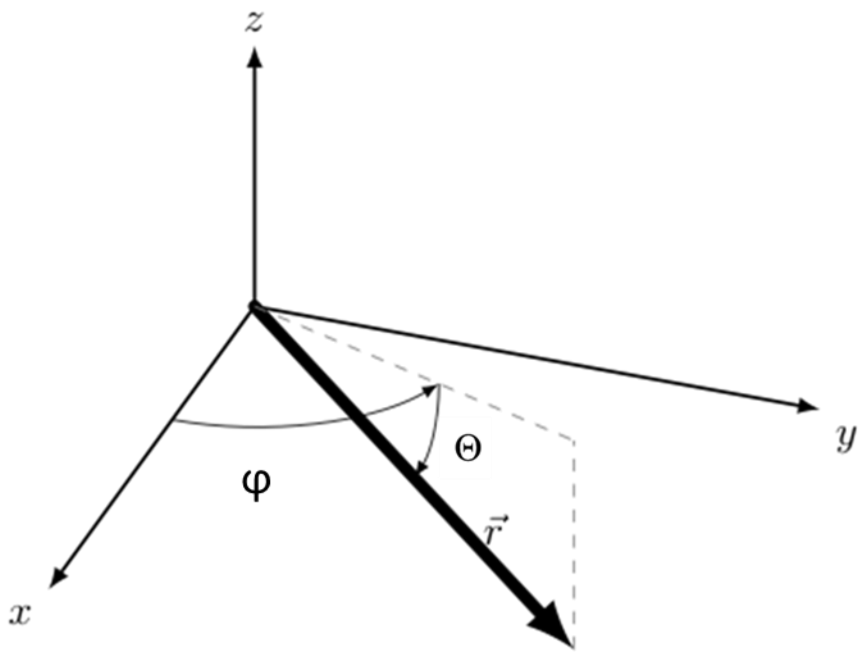

Figure 2.3-1—Antenna Reference Coordinate System.

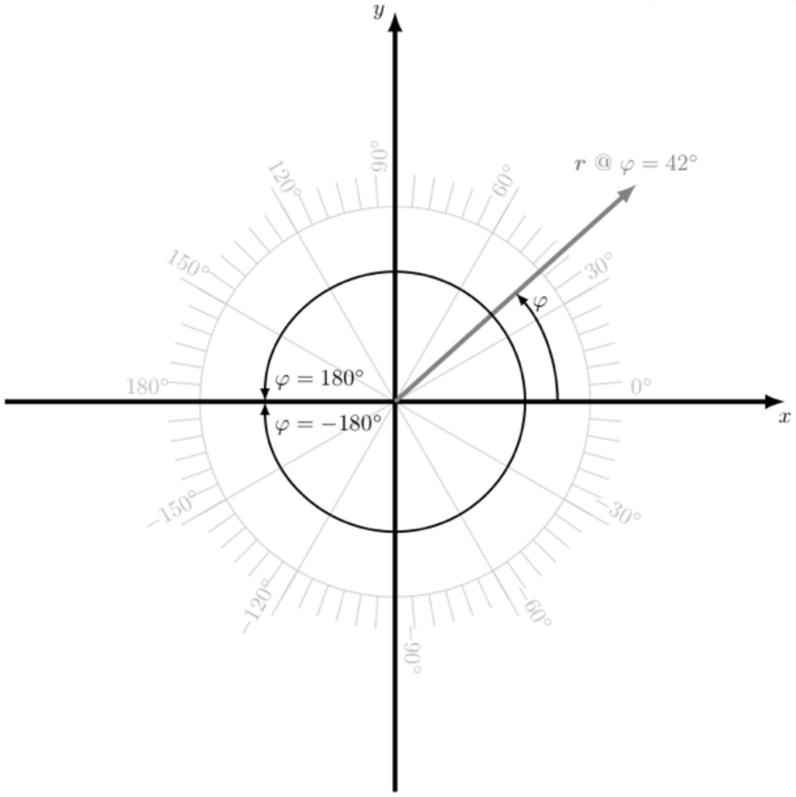

Figure 2.3-2— Definition of the azimuth angle φ

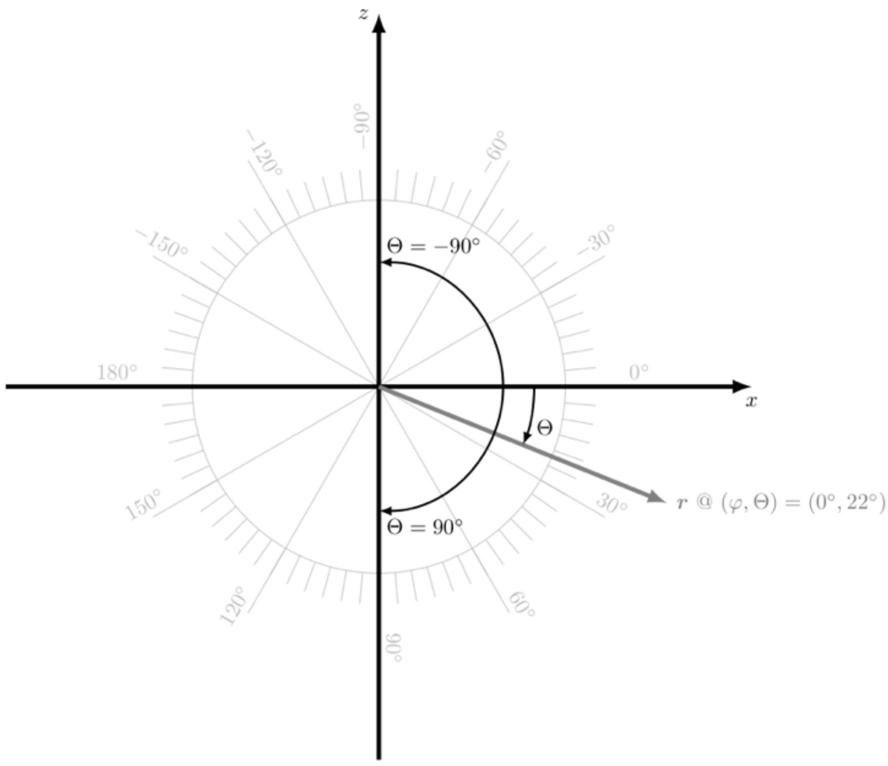

Figure 2.3-3— Definition of elevation angle Θ.

The azimuth angle φ is the angle in the x/y plane, between the x-axis and the projection of the radiating vector onto the x/y plane and is defined from -180° to +180°.

The elevation angle Θ is the angle between the projection of the vector in the x/y plane and the radiating vector. Note that Θ is defined as positive along the down-tilt direction and in some contexts can be also referred to Ias downtilt angle.

For completeness, the equations that relate the spherical coordinate system with the cartesian coordinates is given:

$$x = r \cos\Theta \cos\varphi$$

$$y = \mathrm{r} \cos\Theta \sin\varphi$$

$$z = -\mathrm{r} \sin\Theta$$

NOTE: It is strongly recommended that the AAS is placed such that its front side is facing towards the x-axis and its top towards the z-axis. If another AAS orientation is used this shall be described in the radiation pattern file.

2.4 Angular Region

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

$$\Theta_{start} \leq \Theta \leq \Theta_{end}$$
$$\varphi_{start} \leq \varphi \leq \varphi_{end}$$

NOTE: in other contexts outside current document the AR concept can be also denoted as “Segment or Angular Segment” [7].

An example on how to divide the served sector into ARs is shown in Figure 2.4-1 and Figure 2.4-2, and in Table 2-1, for an AAS covering a sector of ±60º in azimuth range and from -5º to +20º in elevation range.

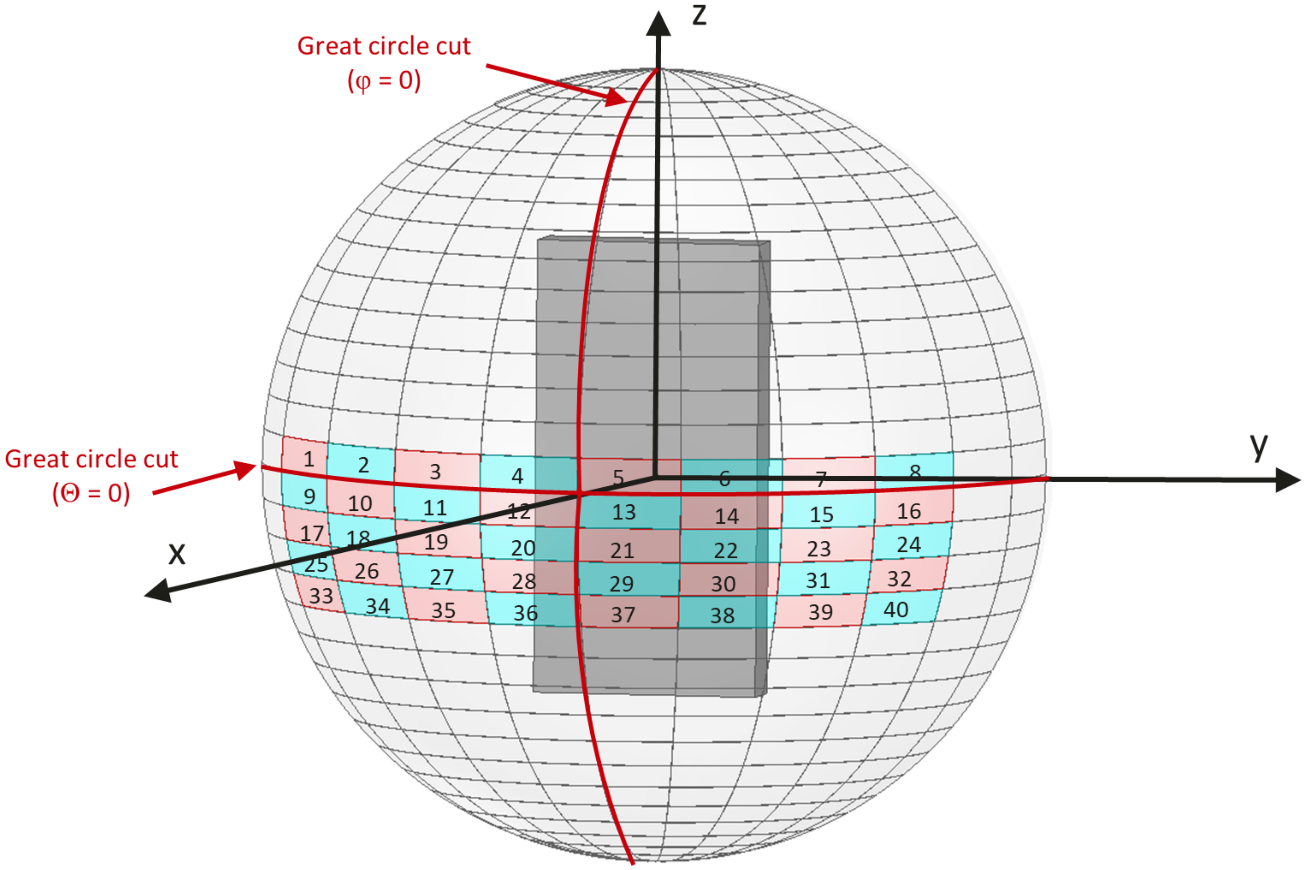

Figure 2.4-1— Example of sector divided into ARs

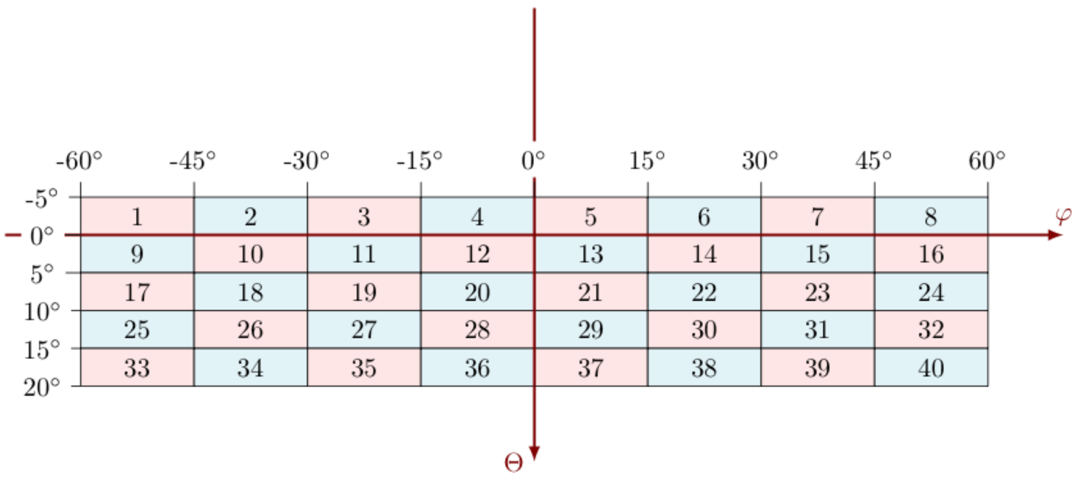

Figure 2.4-2— Planar representation of the ARs

Angular Region ID	Azimuth Range	Elevation Range		Angular Region ID	Azimuth Range	Elevation Range
1	-60º to -45º	-5º to +0º		21	0º to +15º	5º to 10º
2	-45º to -30º			22	+15º to +30º	
3	-30º to -15º			23	+30º to +45º	
4	-15º to 0º			24	+45º to +60º	
5	0º to +15º			25	-60º to -45º	10º to 15º
6	+15º to +30º			26	-45º to -30º	
7	+30º to +45º			27	-30º to -15º	
8	+45º to +60º			28	-15º to 0º	
9	-60º to -45º	0º to 5º		29	0º to +15º	
10	-45º to -30º			30	+15º to +30º	
11	-30º to -15º			31	+30º to +45º	
12	-15º to 0º			32	+45º to +60º	
13	0º to +15º			33	-60º to -45º	15º to 20º
14	+15º to +30º			34	-45º to -30º	
15	+30º to +45º			35	-30º to -15º	
16	+45º to +60º			36	-15º to 0º	
17	-60º to -45º	5º to 10º		37	0º to +15º	
18	-45º to -30º			38	+15º to +30º	
19	-30º to -15º			39	+30º to +45º	
20	-15º to 0º			40	+45º to +60º	

Table 2-1— AR tabular description of the example given in Figure 2.4-1

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

2.5 EIRP

Equivalent (or Effective) Isotropically Radiated Power (EIRP) in a direction, is the Total radiated power radiated if the radiation intensity the device produces in that direction would be radiated isotropically. Hence, EIRP is a farfield parameter like the radiation intensity. The SI unit of EIRP is W.

Radiation intensity [1] is the power radiated per unit solid angle and the SI unit is Watt per steradian (W/sr).

In formula,

$$EIRP(\Theta, \varphi) = 4\pi I(\Theta, \varphi)$$

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

Traditionally, EIRP is defined as the directive antenna gain (G) times the net power accepted by the antenna ($P_{accepted}$), see e.g. [1]. Moreover, gain is radiation intensity divided by the radiation intensity of an isotropic radiator radiating the accepted power [1], i.e.,

$$G(\Theta,\varphi) = \frac{I(\Theta,\varphi)}{P_{accepted}/4\pi}$$

Note that the traditional definition also implies $EIRP(\Theta,\varphi) = 4\pi I(\Theta,\varphi)$. In this form the definition of EIRP has the advantage of being independent of accepted power and gain which are not measureable for tightly integrated AASs.

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

$$I(\Theta,\phi) = \lim_{r\to\infty} \frac{\left|\vec{E}(r,\Theta,\varphi)\right|^2}{Z_0} r^2$$

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

Relations to other parameters

- EIRP = $S(\mathrm{r},\theta,\phi)4\pi r^2$ where r is the distance from the antenna and $S(r,\theta,\phi)$ is the radial power flux per unit area.
- $\mathrm{EIRP}(\theta,\phi) = D(\theta,\phi)\mathrm{TRP}$ where TRP is the Total radiated Power and D is directivity.

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

NOTE: The meaning of "configured output power" is to be defined and provided by the manufacturer.

Attributes applied to EIRP, radiation intensity and related parameters follow [1] and are summarized here for completeness:

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

Example: The statement "EIRP = 50 dBm", means that the Peak Total EIRP is 50 dBm. An EIRP pattern is a Total EIRP pattern if not otherwise stated. If only one polarization component is measured e.g. +45 degs slanted polarization, then "Partial EIRP +45" should be used.

2.6 Beam

A beam is the radiation pattern of the antenna.

Beam might also be used as the main lobe of the radiation pattern of an antenna e.g. as stated in [2].

A beam can be characterised by:

- The half-power beamwidth (HPBW) along two orthogonal directions, see definition of HPBW section **Fehler! Verweisquelle konnte nicht gefunden werden.**
- The beam peak direction: the direction of the maximum of the radiation pattern,
- The beam peak centre: the direction corresponding to the center of the angular region where the HPBW is calculated.
- The radiation pattern ripple

In general, for symmetrical beams, the beam peak and the beam center are the same but in case of asymetrical beams, or beams with strong ripple the beam peak and the beam centre directions might be different, see example on **Fehler! Verweisquelle konnte nicht gefunden werden.**

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

Even if it is not necessarily used in operational configurations, an AAS can generate, in any direction, for each frequency, a particular beam, that is the most directive one among other possible beams sharing the same direction. This beam is simply called the most directive beam.

2.7 AAS Beam-types definition

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

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

2.7.1 Broadcast Beams

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

It is useful to introduce the following definitions:

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

Broadcast beams in a given broadcast beam configuration could be selected sequentially in a loop over time (selecting across beams), [12].

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

2.7.2 Traffic Beams

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

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

2.7.2.1 Grid of Beams

In GoB configuration, traffic beams are selected among a finite number of pre-configured beams. An AAS may have more than one GoB configuration in order to adapt to the cell scenario. An example of GoB configuration is shown in Figure 2.7-1.

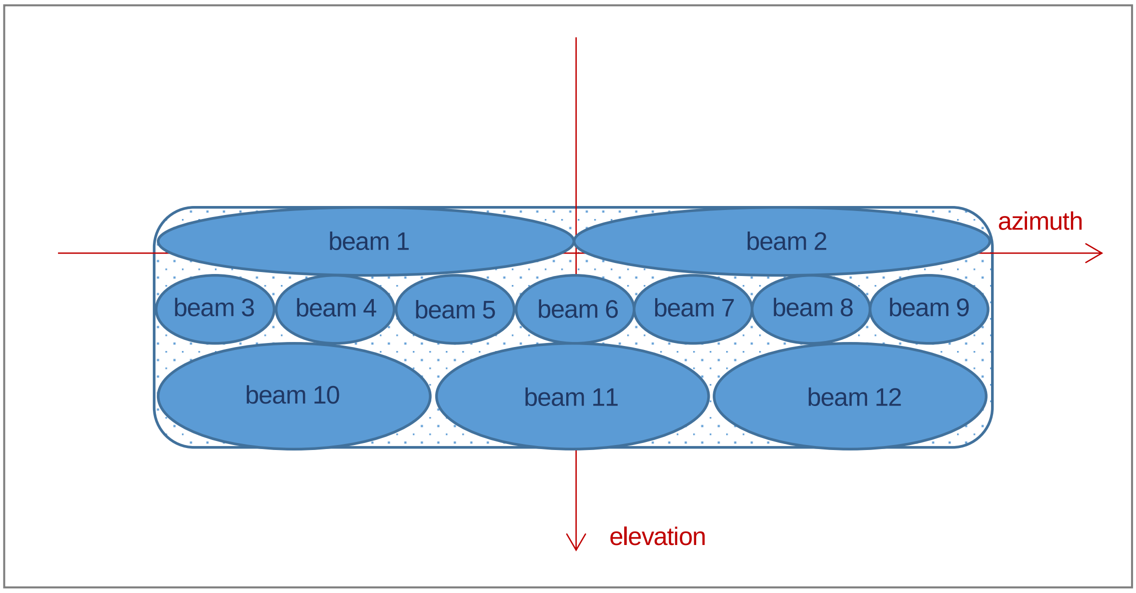

Figure 2.7-1: GoB example

2.7.2.2 Eigen-Based Beamforming

In Eigen-Based Beamforming (EBB), the calculation of the traffic beam (i.e. the array weights/precoders applied to each Array Element) is done adaptively in real-time to cope with the variations of the propagation channel. EBB relies on the reciprocity of the propagation channel.

2.8 Beamwidth

The X dB beamwidth is, in a radiation pattern cut containing the direction of the maximum of a lobe, the angle between the two directions in which the radiation intensity is X dB below the maximum value.

When the beamwidth is not calculated over the Total radiated power radiation pattern (see section 2.8 in [2]), the term co-polar beamwidth shall be used.

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

In the **Fehler! Verweisquelle konnte nicht gefunden werden.** a peak normalized radiation pattern cut is d epicted as a reference for azimuth and elevation half-power beamwidth calculation example. The distance between the HPBW points (red) are used for HPBW calculations, and the mid-point (green) defines the beam peak centre.

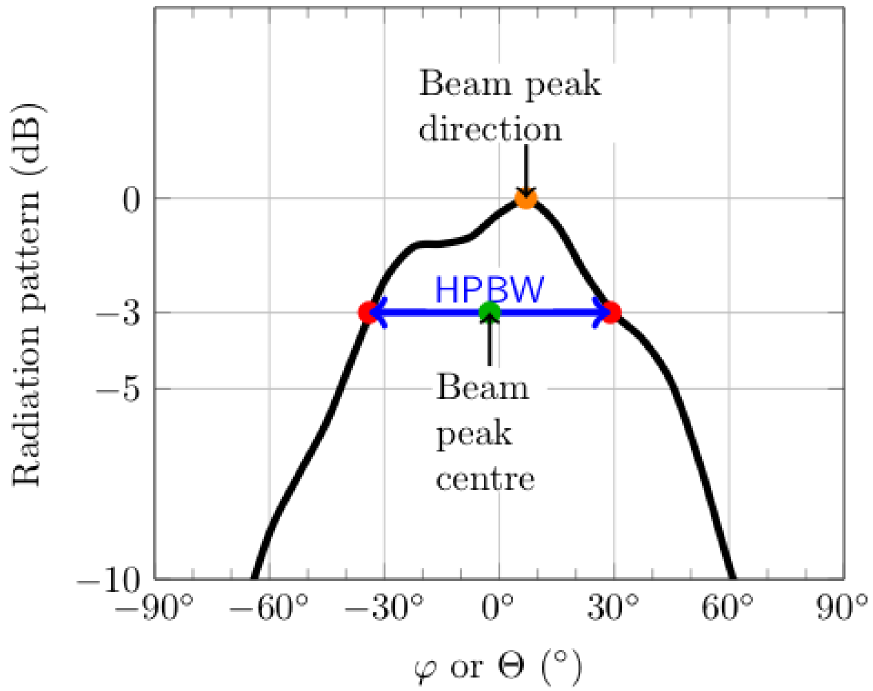

Figure 2.8-1— Illustration of HPBW beam peak centre, and beam peak direction.

2.8.1 Azimuth Beamwidth

The azimuth beamwidth is determined on the azimuth radiation pattern conical cut containing the main beam peak, see Figure 2.8-2

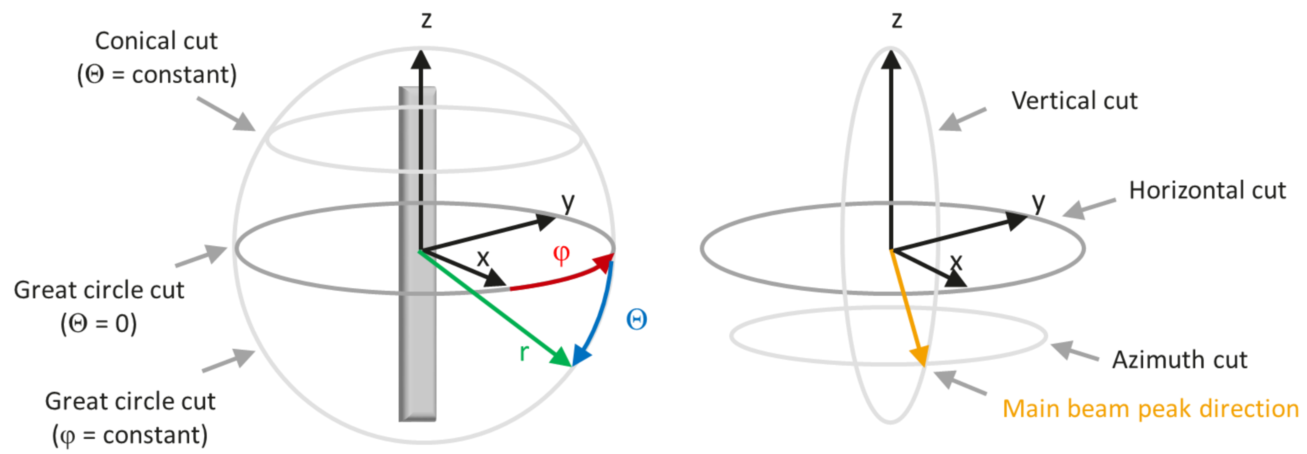

Figure 2.8-2—Cuts over the radiation sphere.

2.8.2 Elevation Beamwidth

The elevation beamwidth is determined on the elevation radiation pattern great circle cut containing the main beam peak, see Figure 2.8-2.

The elevation beamwidth is the beamwidth in the elevation radiation pattern cut which is the great circle cut containing the main beam peak. Such a cut is obtained over a path in which φ is constant and Θ is a variable, see Figure 2.8-2.

2.9 Envelope Radiation Pattern

The Envelope Radiation Pattern is a non-physical radiation pattern obtained by taking, for each direction in azimuth and elevation, the maximum of the absolute, not peak normalized, radiation pattern among the radiation patterns that the AAS can generate.

Radiation pattern parameters defined in [2] also apply to envelope radiation patterns, with the exception of the changes described in the following sub-sections.

2.9.1 Envelope azimuthal beamwidth and pan direction

The azimuthal beamwidth of the Envelope Radiation Pattern is defined as the angular region between two reference angles A and B, on the azimuthal cut containing the peak, where the pattern decays by X dB with respect to the maximum, as shown in
Figure 2.9-1— Envelope Azimuthal Radiation Pattern and related parameters example

. For the calculation of Envelope azimuthal beamwidth, the procedure described in section 2.8.1 shall be used

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

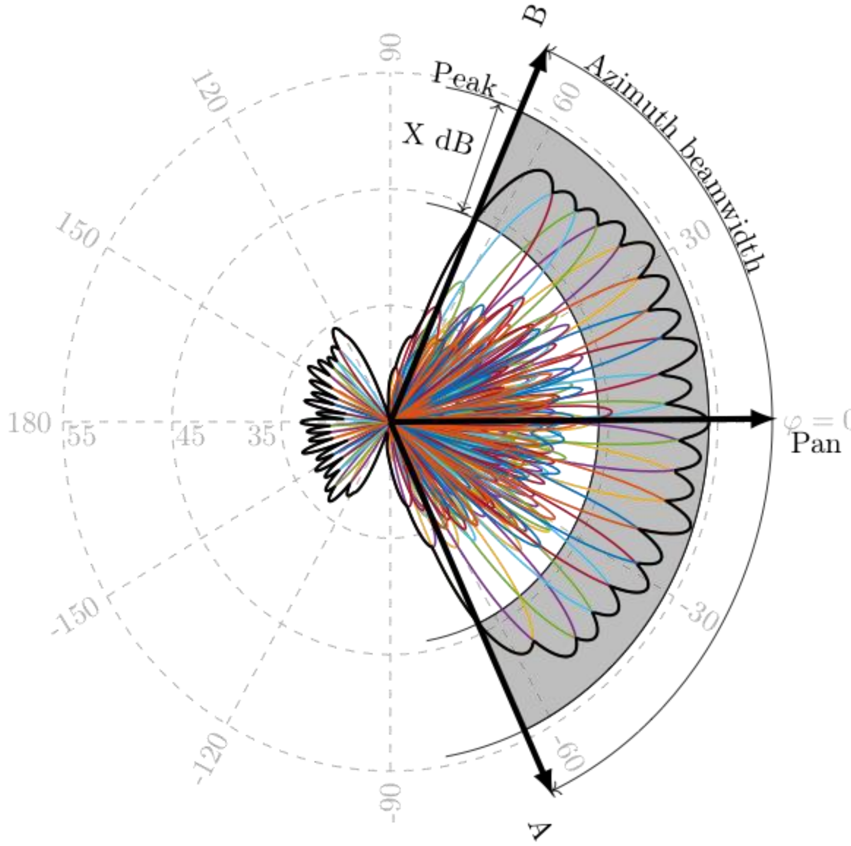

Figure 2.9-1— Envelope Azimuthal Radiation Pattern and related parameters example

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

2.9.2 Envelope elevation beamwidth and tilt direction

The elevation beamwidth of the Envelope Radiation Pattern is defined as the angular region between two reference angles C and D, on the great circle cut containing the peak, where the pattern decays by X dB with respect to the maximum, as shown in
Figure 2.9-2— Envelope elevation beamwidth and Tilt direction and related parameters example

.For the calculation of envelope elevation beamwidth, the procedure described in section 2.8.2 shall be used

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

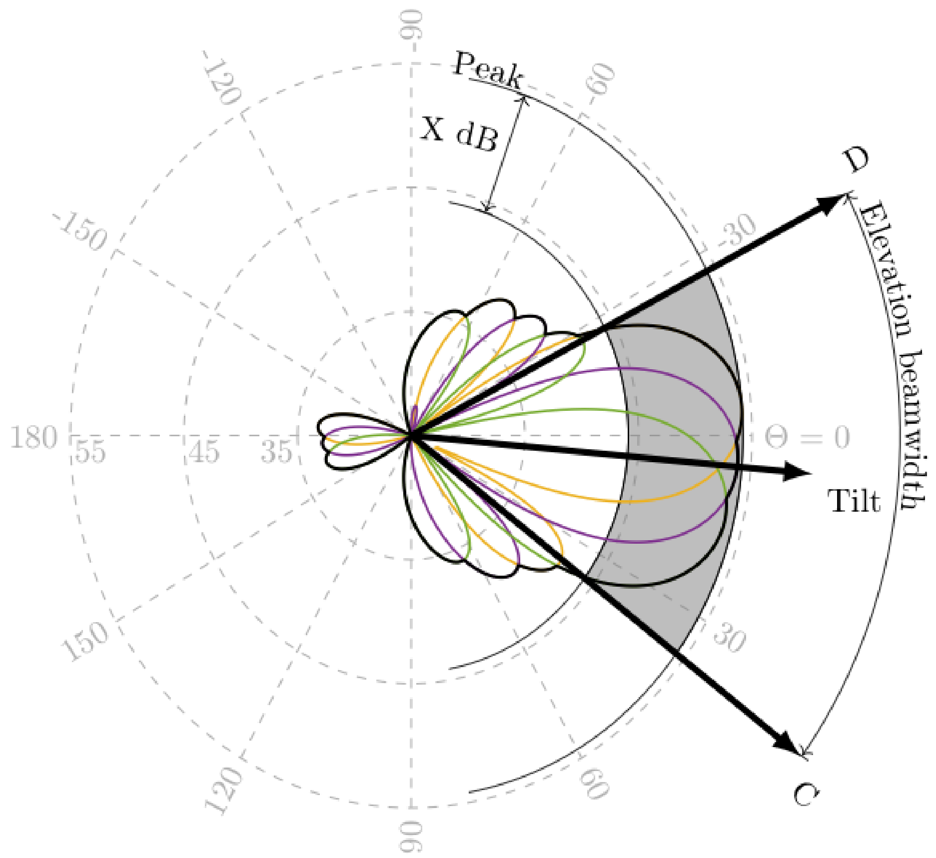

Figure 2.9-2— Envelope elevation beamwidth and Tilt direction and related parameters example

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

2.9.3 Radiation pattern ripple

The radiation pattern ripple is defined as the difference between the highest and the lowest radiation pattern levels per AR (see section 2.4) and it is expressed in dB. If no AR is defined, then it is intented as the azimuthal and elevation scanning ranges, see Sections 3.2.10 and 3.2.11.

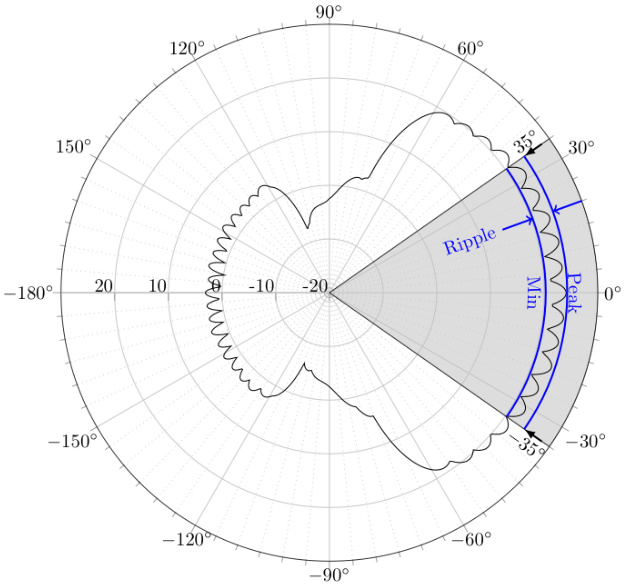

Figure 2.9-3— Ripple example of normalized envelope radiation pattern. The grey area illustrates the AR.

2.10 Electrical Downtilt Angle

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

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

2.11 Radiation Pattern Format

Main elevation and azimuth cuts of the radiation pattern shall be given in MSI format.

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

An example of the information required to exchange 3D patterns is listed below. In future releases of the WP, a more formal format to exchange 3D patterns will be proposed.

- The BASTA-AA reference coordinates are used
- All units shall be declared (preferred choices are degrees for angles, dBm for EIRP and dBm for peak values)
- The file should contain:
    - A file header with the necessary meta data: Peak EIRP, Configured output power, Power range, Frequency (MHz) if single
    - A data section with first two lines

- %DATA
- %POLARIZATION xxx

- And then column data with headers (frequency only if many): Theta (deg), Phi (deg), Frequency (MHz), EIRP (dBm)

2.12 Frequency range and bandwidth

The following definitions are mainly taken from 3GPP terminology. See [3],[6],[4] for more details and additional parameters.

2.12.1 Operating band and supported frequency range

- The operating band defined here follows [4] for New Radio (NR) and [6] for Multi Standard Radio (MSR) definition.
- The supported frequency range is a specific band within the operating band and defined by a continuous range between two frequencies.

2.12.2 Occupied bandwidth

The definition of Occupied Bandwidth (OBW) used e.g. in [4] and [6] applies. This refers to 99% symmetric power utilization, i.e., 0.5% relative power leakage outside each band edge.

2.12.3 Aggregated Occupied Bandwidth

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

2.12.4 Instantaneous Bandwidth

The Instantaneous Bandwidth (IBW) is the span between the highest frequency and the lowest frequency of the signals that can be output at the same time. The IBW is always greater or equal to the Aggregated OBW. IBW is identical to "Maximum radiated Base Station RF Bandwidth for non-contiguous operation." (D9.19) Sec. 4 in [5].

Figure 2.12-1 shows an example of calculation of IBW and Aggregated OBW.

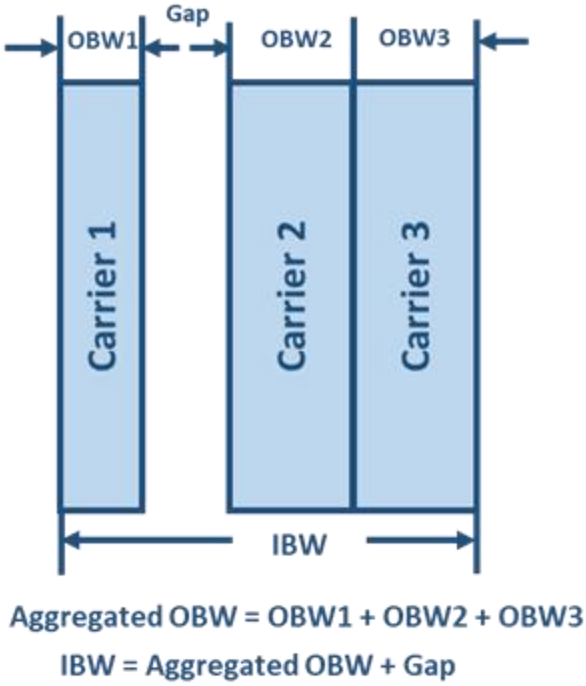

Figure 2.12-1— IBW and Aggregated OBW calculation example

3 RF PARAMETERS AND SPECIFICATIONS

An AAS can be indicated as "BASTA-AAS compliant" only if:

- Parameters used in its BASTA-AAS XML file or its BASTA-AAS datasheet coincide with the ones listed in this section.
- Values associated to each parameter used in its BASTA-AAS XML file or its BASTA-AAS datasheet are calculated according to the methods defined here.
- Its far-field radiation pattern files are made available.

3.1 Format, parameter definitions, validation and XML tags

Parameter description and format used in this WP follow what is provided in [2] section 3.1

For validation and specification of RF parameters, [2] will be used as a reference as well, and more specifically the section 4 of it.

XML tags and examples are provided in a separate document that will be published together with the WP.

3.2 Required RF Parameters

3.2.1 Frequency range and bandwidth

Parameter Definition

- Supported frequency band configuration(s), expressed in the terms defined in Section 2.12

Specification Definition

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

Specification Example

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

3.2.2 Number of carriers

Parameter Definition

- Number of carriers supported by the AAS.

Specification Definition

- For defining the number of carriers it is recommended to follow 3GPP documents [4] for New Radio (NR) and [6] for Multi Standard Radio (MSR)
- If the AAS supports more than one Operating Band, the supported number of carriers shall be specified for each Operating Band

Specification Example

  - Number of Carriers: 2

3.2.3 Polarization

Parameter Definition

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

Specification Definition

- Linear polarizations are declared as: H and V, +45 and -45, etc
- Circular polarizations are typically declared as RHCP and LHCP.

Specification Example

- Type: Polarization:
  - +45º and -45º

3.2.4 Maximum Total Output RF power

Parameter Definition

The Maximum Total Output RF power is the maximum power achievable by the AAS during the transmitter ON period, typically when all power amplifiers have the (same) maximum power at their outputs. Maximum Total Output RF power is identical to "OTA BS Output Power" Sec 9.5 in [4], this is a TRP value declared by the vendor.
Power values are intended to be RMS with respect to time.

Specification Definition

- Maximum Total Output RF power is specified in W or dBm.

Specification Example

- Type: Absolute
  - Maximum RF power: 200 W

3.2.5 Broadcast Beam Set

Parameter Definition

A broadcast beam set is defined as the collection of all the preconfigured broadcast beams (see section 2.7.1). Each beam is declared according to the table below. The configured output power associated to the given EIRP shall be reported.

Specification Definition

Beam ID	Frequency Band	EIRP	Azimuth		Elevation	
			HPBW	Pan	HPBW	Tilt
		[dBm]	[deg]	[deg]	[deg]	[deg]

Specification Example

Beam ID	Frequency Band	EIRP	Azimuth		Elevation	
			HPBW	Pan	HPBW	Tilt
		[dBm]	[deg]	[deg]	[deg]	[deg]
1	n78	75.5	15	-52.5	6	6
2		76		-37.5		
3		76.5		-22.5		
4		77		-7.5		
5		77		+7.5		
6		76.5		+22.5		
7		76		+37.5		
8		75.5		+52.5		

3.2.6 Broadcast Beam Configuration

Parameter Definition

A broadcast beam configuration is defined as the overall radiating behavior for a given deployment/coverage scenario (see section 2.7.1) obtained by radiating one or more beams selected from the ones belonging to the broadcast beam set.

The broadcast beam configuration can be:

- Composed by just one of the beams of the broadcast beam set;
- Composed by a number of broadcast beams of the broadcast beam set selected in a way for solving specific coverage needs. There can be a different number of available broadcast beam configuration implemented by the AAS, each one composed by beams belonging to the broadcast beam set.
- Sweeping across beams type, see section 2.7.1.

. The broadcast beam configuration can:

- Have an associated envelope radiation pattern as described in section 2.9

- Refer to a single beam ID. In the case this section is not relevant

Example of configuration:

A possible configuration may comprise 8 beams, with the same elevation pointing direction ($\theta = 0$ degs for example) and equally distributed in azimuth from – 50 to + 50 degs. The following picture illustrates this example. Each single beam is depicted in green, the red curves (H65) correspond to a traditional coverage beam of a passive antenna.

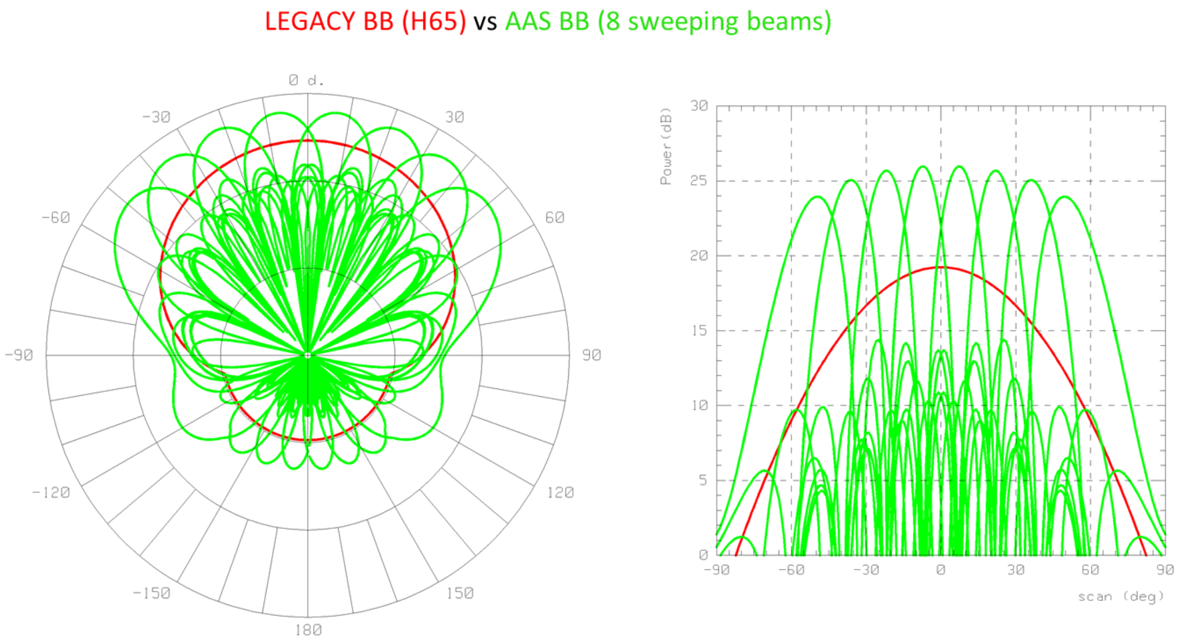

Figure 3.2-1— Broadcast beams configuration example (8 beams)

Other possible examples are depicted in the following pictures.

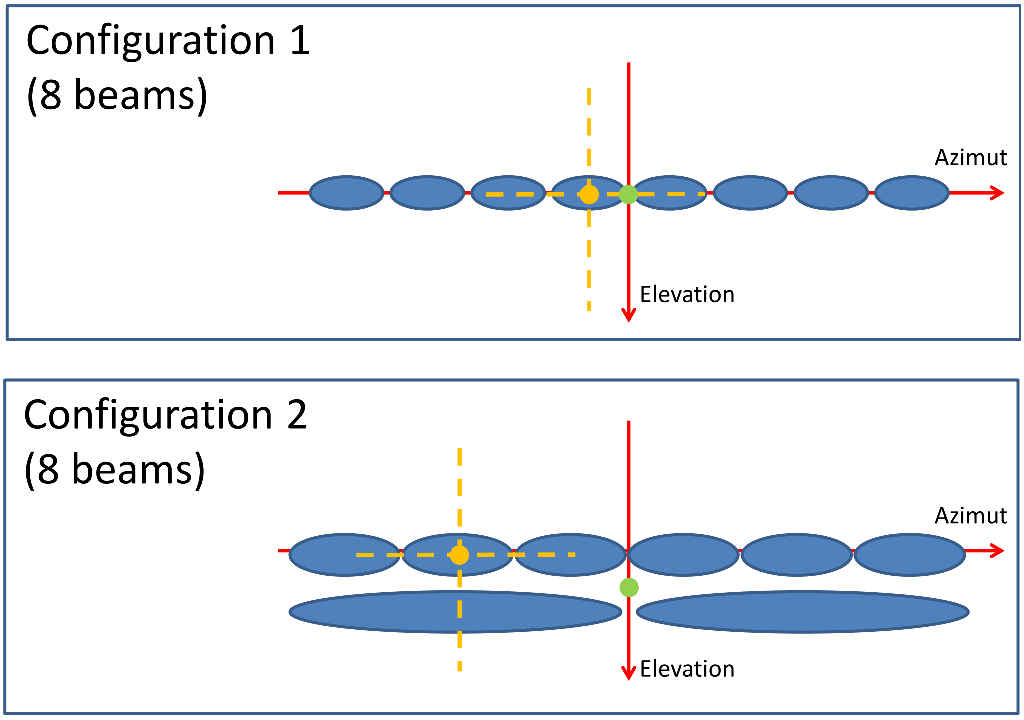

Figure 3.2-2—Broadcast beams configuration examples, using 8 beams where the green and orange dots indicate the envelope centre and peak direction, respectively (see also Figure 2.8-1).

Specification Definition

- For each configuration ID the main characteristics of the corresponding envelope radiation pattern are to be provided according to the following table format. For the values of Pan, Tilt and Beamwidth, either a single value or a set of values can be stated. If there is more than one beam, by default we can assume that sweeping across beams is applied, see section 2.7.1.

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

Specification Example

Config. ID	Frequency Band	EIRP	Envelope Azimuth			Envelope Elevation		
			HPBW	Pan	Conical Cut Direction	HPBW	Tilt	Great Circle Cut Direction
		[dBm]	[deg]	[deg]	[deg]	[deg]	[deg]	[deg]
1	n78	77	60	0	0,5,10	6	0,5,10	7.5
2		74	60	0	0,3,6	12	0,3,6	7.5

3.2.7 Traffic Beams

The following two mutually exclusive parameter definitions apply according to the traffic beam types defined in section 2.7.2.1 and section 2.7.2.2

3.2.7.1 GoB approach

Parameter Definition

The characteristics of each beam in a traffic GoB set (see section 2.7.2.1) have to be specified according to the table given below. Beams having different Pan and Tilt are considered different, so a specific Beam_Id is associated to each beam.

When the number of beams in a traffic GoB is so large that it can be difficult, time consuming or inefficient to describe the characteristics of each beam in the set, the manufacturer can describe the traffic performances of the GoB AAS with one or more envelope patterns, as defined in section 2.9.

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

Specification Definition

Beam ID	Frequency Band	EIRP	Azimuth		Elevation	
			HPBW	Pan	HPBW	Tilt
		[dBm]	[deg]	[deg]	[deg]	[deg]

Specification Example

<table>
<tr><th rowspan="3">Beam ID</th><th rowspan="3">Frequency Band</th><th rowspan="2">EIRP</th><th colspan="2">Azimuth</th><th colspan="2">Elevation</th></tr>
<tr><th>HPBW</th><th>Pan</th><th>HPBW</th><th>Tilt</th></tr>
<tr><th>[dBm]</th><th>[deg]</th><th>[deg]</th><th>[deg]</th><th>[deg]</th></tr>
<tr><td>1</td><td rowspan="8">n78</td><td>73</td><td rowspan="8">30</td><td>-45</td><td rowspan="8">6</td><td rowspan="4">3</td></tr>
<tr><td>2</td><td>74</td><td>-15</td></tr>
<tr><td>3</td><td>74</td><td>+15</td></tr>
<tr><td>4</td><td>73</td><td>+45</td></tr>
<tr><td>5</td><td>73</td><td>-45</td><td rowspan="4">9</td></tr>
<tr><td>6</td><td>74</td><td>-15</td></tr>
<tr><td>7</td><td>74</td><td>+15</td></tr>
<tr><td>8</td><td>73</td><td>+45</td></tr>
</table>

3.2.7.2 EBB approach

Parameter Definition

An AAS implementing traffic beams by using the EBB approach generates, in real time, radiation patterns whose shape depends on traffic conditions. For such systems, the radiating performance is summarized by the envelope radiation pattern as defined in section 2.9.

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

Specification Definition

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

Envelope ID	**Frequency Band**	**EIRP**	**Ripple**	**Azimuth**		**Elevation**	
				HPBW	**Pan**	**HPBW**	**Tilt**
		[dBm]	**[dB]**	**[deg]**	**[deg]**	**[deg]**	**[deg]**

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

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

Specification Example

Envelope ID	**Frequency Band**	**EIRP**	**Ripple**	**Azimuth**		**Elevation**	
				HPBW	**Pan**	**HPBW**	**Tilt**
		[dBm]	**[dB]**	**[deg]**	**[deg]**	**[deg]**	**[deg]**
1	n78	77	3	60	0	12	6

3.2.8 Minimum Azimuth HPBW

Parameter Definition

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

Specification Definition

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

Specification Example

Minimum Azimuth HPBW = 12° to 16°

3.2.9 Minimum Elevation HPBW

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

Specification Definition

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

Specification Example

Minimum Elevation HPBW = 5.5° to 7.5°

3.2.10 Azimuth scanning range

Parameter Definition

Range of angles in azimuth in which the AAS is optimized and intended to be operated. It is a subset of the OTA peak direction set defined in 3GPP, see [4] and [6]

Specification Definition

The nominal range of values in degrees.

Specification Example

Azimuth Scanning Range = –60° to +60°

3.2.11 Elevation scanning range

Parameter Definition

Angular range in elevation in which the AAS is optimized and intended to be operated. It is a subset of the OTA peak direction set defined in 3GPP, see [5] and [13].

Specification Definition

The nominal range of values in degrees.

Specification Example

Elevation Scanning Range = –15° to +15°

3.2.12 Number of Tx/Rx channels

<u>Parameter Definition</u>

Number of independent TX and RX channels in the AAS. For each TX/RX branch there can be one or more radiating elements connected to it.

<u>Specification Definition</u>

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

<u>Specification Example</u>

Number of Tx/Rx channels = 64T64R

3.2.13 Maximum number of layers

<u>Parameter Definition</u>

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

<u>Specification Definition</u>

Integer value describing the maximum number of layers

<u>Specification Example</u>

Maximum number of layers = 8

4 MONITORING COUNTERS

In the context of RF-EMF exposure assessment [7] and [8], it is required that antenna manufacturers make available to operators a certain number of counters (see Section B.6.5.3 in [7] and Section 13.3.3.3 in [8]). In line with those requirements, the following power monitoring counters are defined:

- Total radiated power counter
- Directional power counters

The following characteristics mandatorily apply to such counters:

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

The availability of monitoring counters is required.

Specification Example

- Total Radiated Power Counter: Available
- Per AR Radiated Power Counter: Available
- Per Beam Radiated Power Counter: NotAvailable

If radiation control mechanisms are implemented, see Section 5, the corresponding counters are required.

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

4.1 Total radiated power counter

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

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

4.2 Directional power counters

Directional power counters are introduced to monitor the time-averaged power delivered to specific directions where exposure issues can happen.

Directional power counters can be associated to either an AR (per-AR radiated power counter) or a specific beam (per-beam radiated power counter).

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

4.2.1 Per-angular region radiated power counter

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

$$AR\ TRP = \frac{1}{4\pi}\int_{\Theta_{min}}^{\Theta_{max}}\int_{\varphi_{min}}^{\varphi_{max}} \mathrm{EIRP}(\Theta,\varphi)cos\Theta \mathrm{d}\Theta \mathrm{d}\varphi$$

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

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

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

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

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

Similar counter reporting EIRP can also be provided.

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

4.2.2 Per-beam radiated power counter

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

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

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

Similar counter reporting EIRP can also be provided.

5 RADIATED POWER CONTROL MECHANISMS

In this chapter the capability of controlling the AAS radiated power [1], either statically or dynamically depending on the scenario where it is operated, is addressed.

The purpose of such mechanisms is to limit the power radiated by an AAS, either in general or towards specific directions (e.g. to comply with RF-EMF exposure limits).

Power limiting mechanisms are always associated to the corresponding power monitoring counters described in chapter **Fehler! Verweisquelle konnte nicht gefunden werden.**, which allow the operator to monitor the evolution of the power radiated by the AAS over time.

The availability of radiated power control mechanisms is required.

Specification Example

- Total Radiated Power Control: Available
- Per AR Radiated Power Control: Available
- Per Beam Radiated Power Control: NotAvailable

5.1 Total radiated power limiting mechanism

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

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

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

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

5.2 Directional radiated power limiting mechanism

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

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

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

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

A direction can be defined either by the AR it refers to or by the beam associated to it in case of GoB approach. Whatever choice is made, two different directional power limiting mechanisms can be defined (associated to the corresponding directional power monitoring counters of sections 4.2.1 and 4.2.2), which are described in the two following two sections.

5.2.1 Per-AR radiated power limiting mechanism

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

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

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

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

5.2.2 Per-beam radiated power limiting mechanism

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

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

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

- Beam ID (Section 3.2.7.1) where the power limiting mechanism is operated;
- a description of the mechanism, by explicitly indicating whether the implemented mechanism is either static or dynamic;
- the range and the steps used to limit the power per beam.

6 MECHANICAL PARAMETERS AND SPECIFICATIONS

Unless otherwise stated, mechanical definitions and specifications in [2] are applicable. The required parameters in [2] are:

- Weight
- Dimensions
- Wind load
- Max. operational wind speed (km/h)
- Survival wind speed (km/h)

Required parameters that are not considered in [2] are listed below.

6.1 Heat dissipation

Parameter Definition

- Maximum Heat Dissipation

Specification Definition

- Nominal values in kilowatt

Specification Example

- Maximum Heat Dissipation = 0.47kW

NOTE: The manufacturers may specify the cooling type e.g. natural cooling

6.2 Operational temperature

Parameter Definition

The operational temperature is the temperature range in which the AAS is designed to operate.

Specification Definition

Nominal values in Celsius degrees.
Minimum and Maximum operating temperatures.

Specification Example

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

6.3 Relative humidity

Parameter Definition

The relative humidity is the relative humidity range in which the AAS is designed to operate.

Specification Definition

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

Specification Example

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

6.4 Ingress protection index

Parameter Definition

The ingress protection index is classification according to [11] in which the AAS is designed to operate.

Specification Definition

IP index

Specification Example

IP 65

6.5 Maximum power consumption

Parameter Definition

The maximum power consumption is the maximum power to be supported for operating the AAS

Specification Definition

Maximum Nominal values in Watt.

Specification Example

Maximum power consumption = 800W.

NOTE: The manufacturers may specify the maximum power consumptions conditions e.g. traffic load and operating temperature (100% load 55℃).

APPENDIX A – EXAMPLE OF ACTIVE ANTENNA DATASHEET

NOTE: Below is an example of an active antenna datasheet. All the data in the table below is only given for exemplary purposes and it is not intended to reflect the specifications of any existing product.

RF parameters	
Operating Band	n78
Supported Frequency Range (MHz)	3400 - 3600
Aggregated OBW (MHz)	160
IBW (MHz)	200
Number of carriers	Carriers:2, BW:100 MHz
Polarization	+45° and –45°
Maximum total output RF power (W)	200, Absolute
Broadcast beam set	See XML datasheet
Broadcast beam configuration	See XML datasheet
Traffic beams – GoB approach	See XML datasheet
Traffic beams – EBB approach	See XML datasheet
Minimum azimuth HPBW (°)	Min. 12, Max. 16
Minimum elevation HPBW (°)	Min. 5.5, Max. 7.5
Azimuth scanning range (°)	–60 to +60
Elevation scanning range (°)	–15 to +15
TR/RX Channels	TX: 64, RX: 64
Maximum number of layers	8
Monitoring counters	
Total Radiated Power Counter	Available
Per AR Radiated Power Counter	Available
Per Beam Radiated Power Counter	NotAvailable
Radiated power control mechanisms	
Total Radiated Power Control	Available
Per AR Radiated Power Control	Available
Per Beam Radiated Power Control	NotAvailable
Mechanical specifications	
Dimensions (H x W x D) (mm)	1391 x 183 x 118
Weight Without Accessories (kg)	14.5
Weight of accessories only (kg)	3.4
Survival wind speed (km/h)	200
Windload – frontal at 150km/h (N)	500, at 150km/h
Windload – lateral at 150km/h (N)	360, at 150km/h
Heat Dissipation (kW)	0.47, Natural cooling
Operational Temperature (ºC)	–20 to +60
Relative humidity	5% RH～100% RH
Ingress protection index	IP65
Maximum power consumption (W)	800

Table A-1— AAS datasheet example

APPENDIX B – MIXED PASSIVE-ACTIVE ANTENNA SYSTEMS

Informative appendix on Mechanical Installation Kit (MIK) for mixed passive-active antenna systems. This information is temporally maintained in the BASTA AA white paper, and the plan is to move it to a specific white paper focusing on site solutions.

Generally, 5G antennas are deployed in the same sites as the legacy (2G/3G/4G) systems. To install this new equipment, 3 possible options are shown in the figure below:

1. Add the new AAS antenna beside the existing antenna(s)
2. Create a modular "concept" to hide a M-MIMO antenna, thanks to a "Mechanical Installation Kit" (MIK)
3. Replacing the existing passive high band with an embedded MMIMO (interleaved solution)

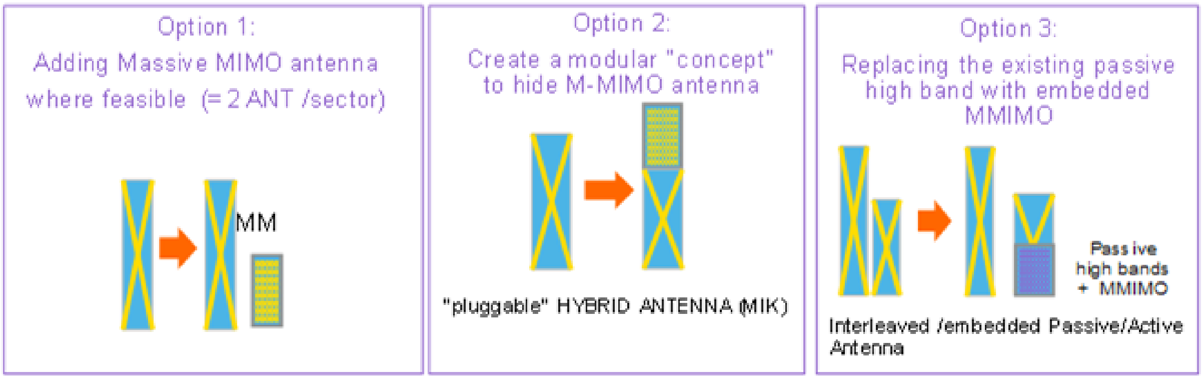

Figure B-1— Deployment scenarios

Option 2 and 3 are mixed passive-active antenna systems. The scope of the present section is option 2 only. Option 3 will be presented in a later version.

In many cases, option 1 is not possible or desirable (site negotiation, aesthetic reasons). In those cases, only option 2 and 3 are possible. Option 2 is a "mixed passive-active" system, which is based on at least two independent and field-replaceable units:

a) a Multi-Band passive antenna module called Passive Antenna System (PAS);
b) an enclosure called Mechanical Installation Kit (MIK) to host a M-MIMO AAS inside.

General description and parameters of the MIK solution

The MIK is developed to fit the dimensions of the PAS.

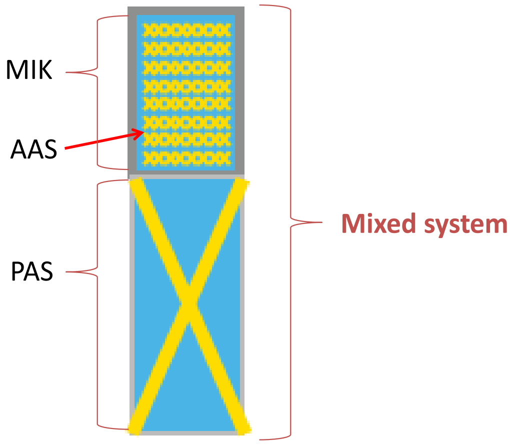

Figure B-2— Mixed passive-active antenna system

MIK mechanical parameters

The AAS should be capable of being installed afterwards inside the MIK by putting the MIK onto the ground (without removing the pole brackets), installing the AAS inside and lifting the AAS+MIK back onto the pole/mast into its original position.

As an example of implementation, the MIK (to host AAS) could be based of 3 main sub-units:

a) A rear mounting structure which allows to be installed on a pole/mast and to fix a Vendors's AAS on it
b) A radome covering the AAS and fixed on the mounting structure. This radome must have the same shape and color as the radome of the PAS.
c) A disposable wind shield covering the back of the "empty" MIK. To be used with empty MIK and removed when AAS is installed afterwards.

Note : the AAS is a field-installable unit and the MIK should allow easy AAS installation in the field at ground level (installation on the pole/mast is not required).

An example of datasheet with the main MIK parameters is provided below. All environment parameter are defined in passive antenna white paper [2]:

MIK parameters	Example value	Comment
The minimum dimensions (H x W x D) (mm) inside clearance (to host the AAS)	1000*450*250	MIK shall be aligned with the radome profile, width and depth of the PAS.
Weight of the "empty" MIK unit (kg)	10	Weight including brackets that are attached to the MAA??

Wind load (N)	Frontal:500 Lateral:210 Rear side:515 at 150km/H	
Max. operational wind speed (km/h)	150	
Survival wind speed (km/h)	200	
Temperature range (ºC)	–40 to +55	
Heat Dissipation	Natural Cooling	
Ingress protection index	IP65	
Relative humidity	5% RH～100% RH	
Mounting/installation	On a mast or pole of 55mm up to 110mm diameter.	
Mechanical tilt (degrees)	0-10	Should be available with 0 degrees mechanical tilt and 5 degrees mechanical tilt variants and should be interchangeable without the need of additional interfaces or tooling.

Table B-1— MIK datasheet example

Example of MIK performance validation

Even though the topic of AAS testing is not covered in this first release of the whitepaper, as a reference relevant tests, for evaluation of the impact of the MIK on AAS, are described below.

The goal of the test is to evaluate the influence of the MIK on the AAS performance. For this purpose one UE is emulated in different spatial directions. Pre-calculated pre-coders are then applied to the BBU to emulate the UE different spatial directions. The AAS traffic beam patterns in the three steering directions specified in Table B-2 below are generated and tested

Beams	Validation Scenario	
	Standalone AAS	AAS with MIK
Azimuth :0° Elevation : 0°		
Azimuth : 0° Elevation : Max		
Azimuth : Max Elevation : 0°		

Table B-2— List of traffic beams to be validated

For each of the tested beams, the parameters listed in Table B-3— List of the parameters to be calculated and compared for each beam are calculated and compared. In addition, the azimuth and elevation radiation pattern cuts shall be provided (see Figure 2.8-2 for the definition of the cuts) in order to allow the comparison the patterns in terms of HPBW, SLS, etc.

The angles where the radiation pattern cuts are to be obtained shall correspond to the directions defined in the Table B-2 above

Validation Scenario	EIRP (dBm)	Azimuth Beam Peak (°)	Elevation Beam Peak (°)
Standalone AAS			
AAS with MIK			

Table B-3— List of the parameters to be calculated and compared for each beam

APPENDIX C – EMF SCENARIOS, ASSUMPTIONS AND EXAMPLES – INFORMATIVE

In order to better understand the behavior of EMF in several relevant scenarios simulations have been performed. By monitoring EIRP in all directions of the antenna and defining a power grid, statistics have been collected. The model is based on a cluster of 21 cells using 3D-Uma 3GPP model. Three different scenarios have been evaluated; evenly distributed users, fully centralized users and **single user**.

Scenarios (S#i)	Description
S#1: Normal MU	21 cells，50UE evenly distributed per cell
S#2: Extreme MU	21 cells，50UE fully centralized per cell
S#3: Single UE	21 cells，single UE distributed per cell

Table C-1— Simulation scenarios

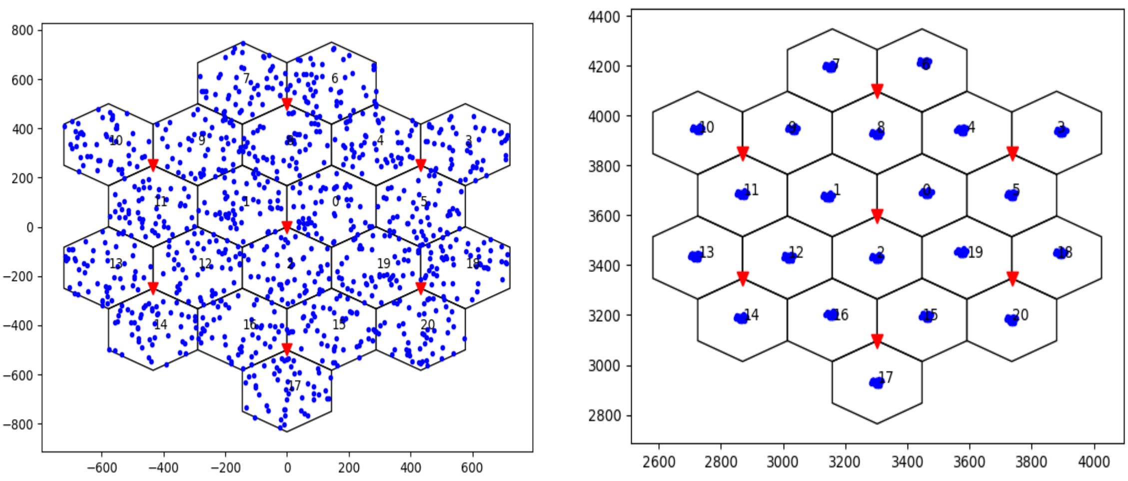

Figure C-1— Example of UEs distribution for S#1 and S#2 – see left and right figure

General Parameters	Description	Values
Scenarios		3D-UMa
Layout		Hexagonal grid, 7macro sites, 3 sectors per site，ISD 500m
UE Rx configuration		4T4R
UE mobility		3km/h
BS antenna height		29m
Total BS Tx Power		43 dBm for 10MHz(50 PRBs)

Carrier frequency		3.5 GHz
Min. UE-eNB 2D distance		35m
UE height (h_{UT}) in meters	General equation	$h_{UT}=3(n_{fl} – 1) + 1.5$
	n_{fl} for outdoor UEs	1
	n_{fl} for indoor UEs	n_{fl} ~ uniform(1,N_{fl}) where N_{fl} ~ uniform(4,8)
Indoor UE fraction		80%
UE distribution (in x-y plane)	Outdoor UEs	Uniform in cell
	Indoor UEs	Uniform in cell
Traffic Model		Fullbuffer (2/4/8 layer)

Table C-2— Simulation assumptions

Each grid point represents an AR. Then the EIRP value is recorded in each point.

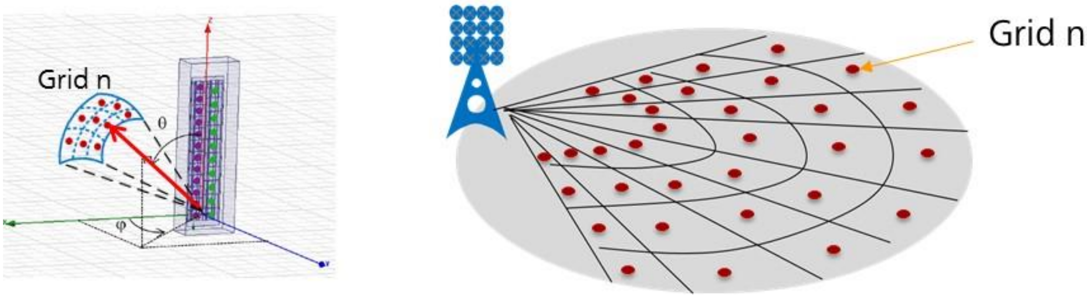

Figure C-2— Grid points of the antenna

<u>Scenario 1: Evenly Distributed Users</u>

When looking at the instantaneous probability of exceeding a threshold of -6 dB backoff, one can notice that for 2 layers, the probability is close to 10% in some grid points. For 4 layers, the probability is almost zero. The CDF for all grid points, shows a 95% probability, that the output power of the antenna is 9-11dB less than peak power.

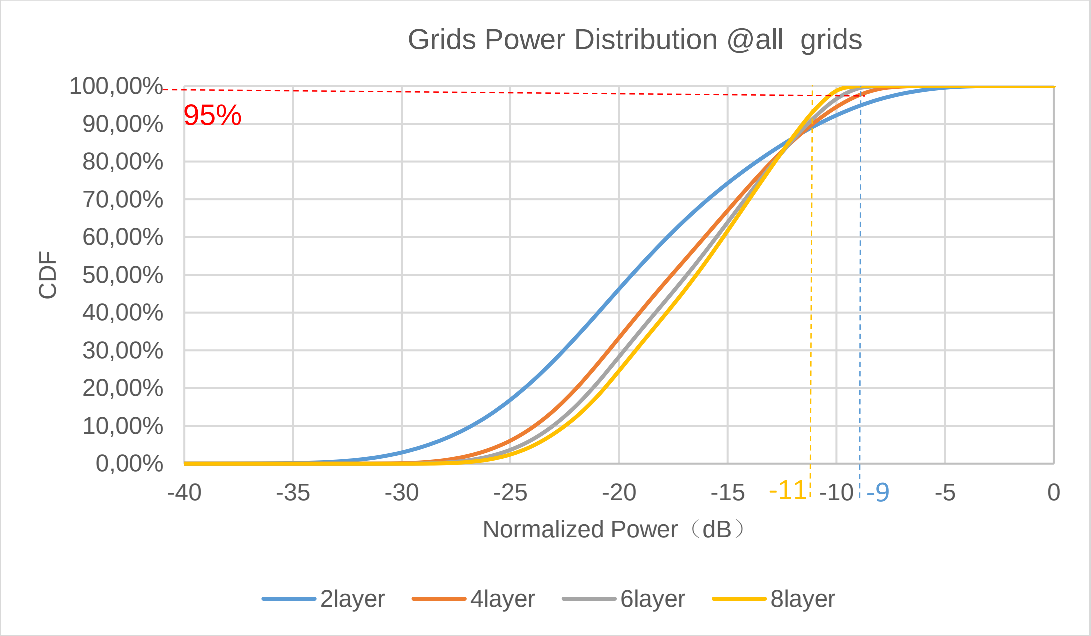

Figure C-3— Grids Power distribution (Scenario 1)

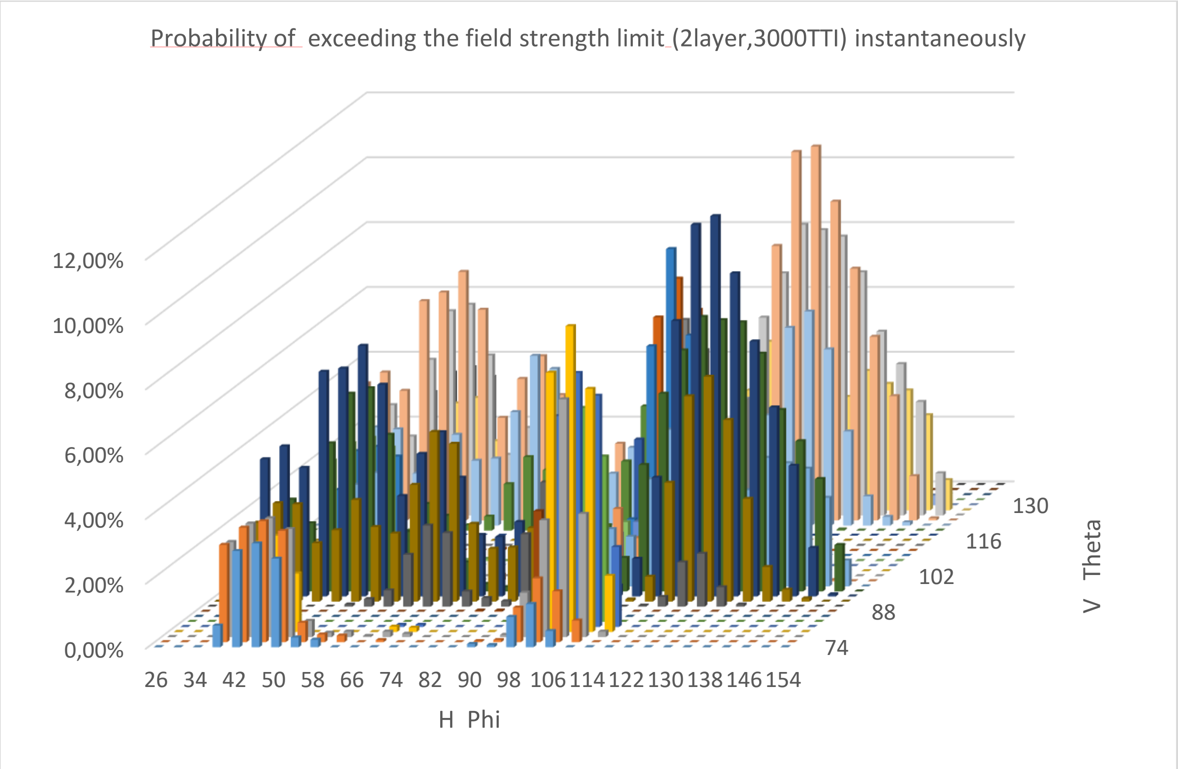

Figure C-4— Probability of exceeding the field strengt limit (2 layers, scenario 1)

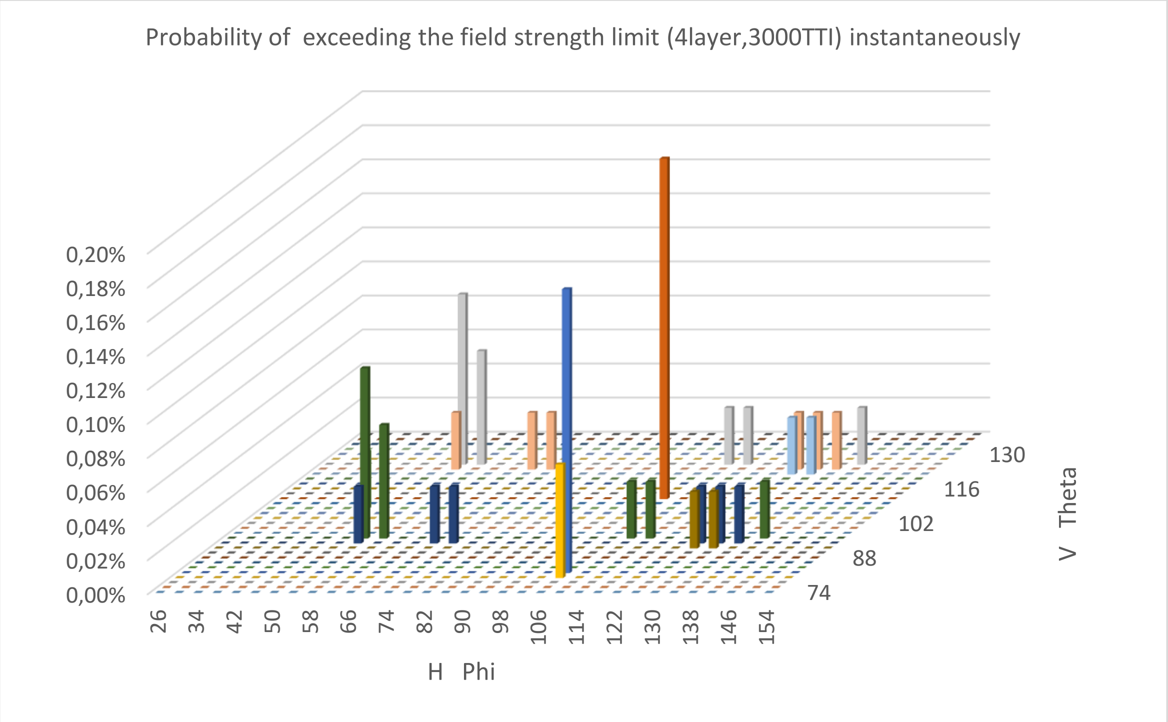

Figure C-5— Probability of exceeding the field strength limit (4 layers, scenario 1)

If we now study the averaged power in each grid point, we find that the level is always less than the -6 dB threshold (Pn=0.25). The averaging is here done over three seconds but similar result is expected using a longer filtering time such as 6 minutes as defined by ICNIRP.

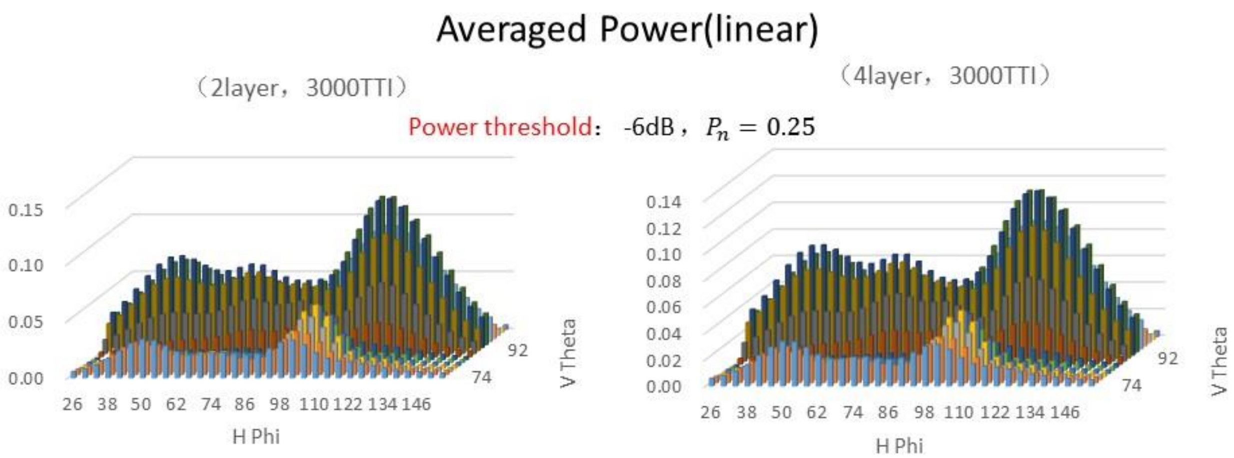

Figure C-6— Grid points for averaged power (scenario 1)

The conclusion is that thanks to multi paths, multi user and user distribution, it is clear that the average power levels of a massive MIMO antenna system will be much lower than the peak levels.

Scenario 2: Centralized Users

inthis scenario, all users are close to the antenna, we can see that the instantaneous probability that the power level exceed the -6 dB threshold will be significantly higher.The CDF for all grid points, shows a 95% probability, that the output power of the antenna is 8-10 dB less than peak power i.e. 1 dB more compared to scenario 1.

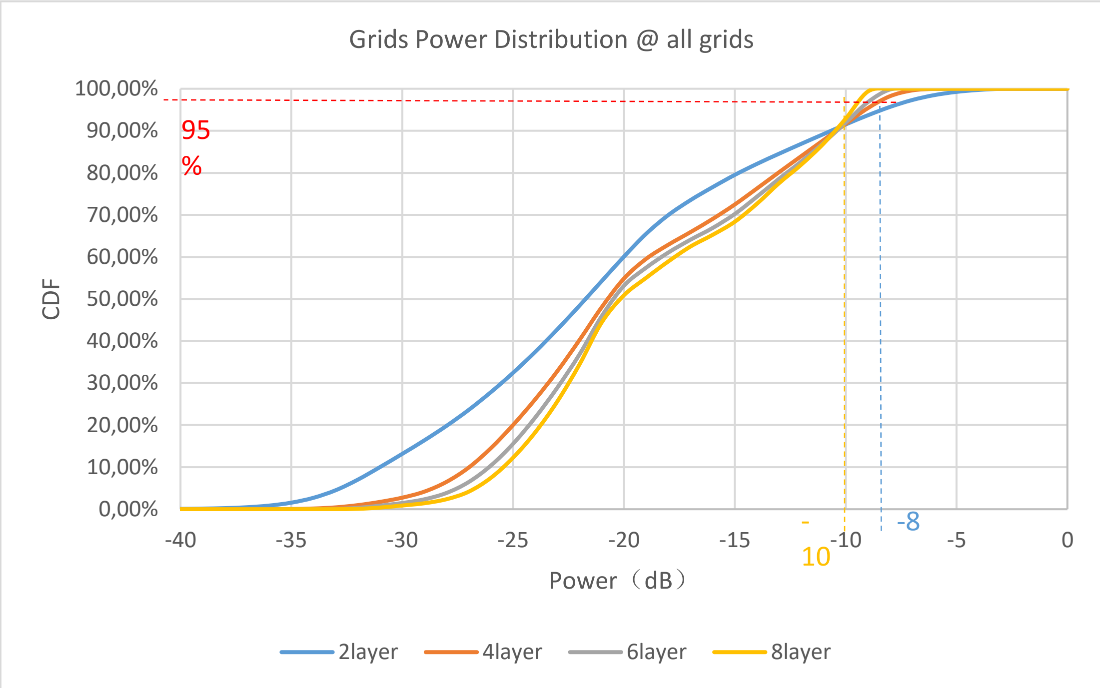

Figure C-7— Grids Power distribution (Scenario 2)

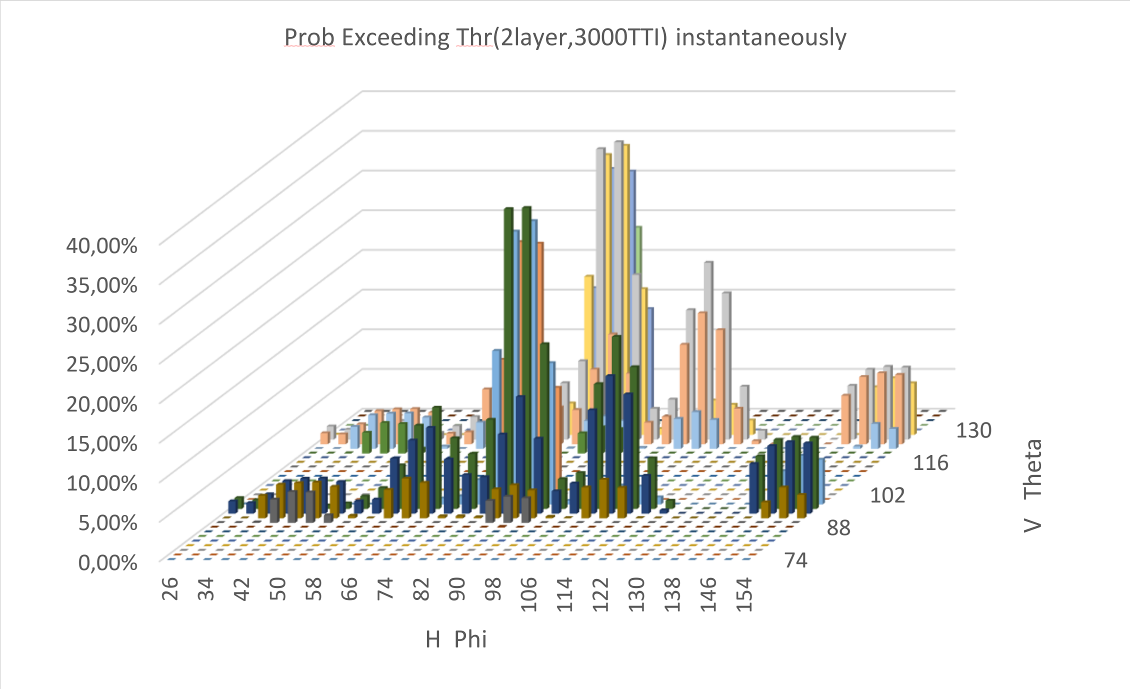

Figure C-8— Probability of exceeding the field strength limit (2 layers, scenario 2)

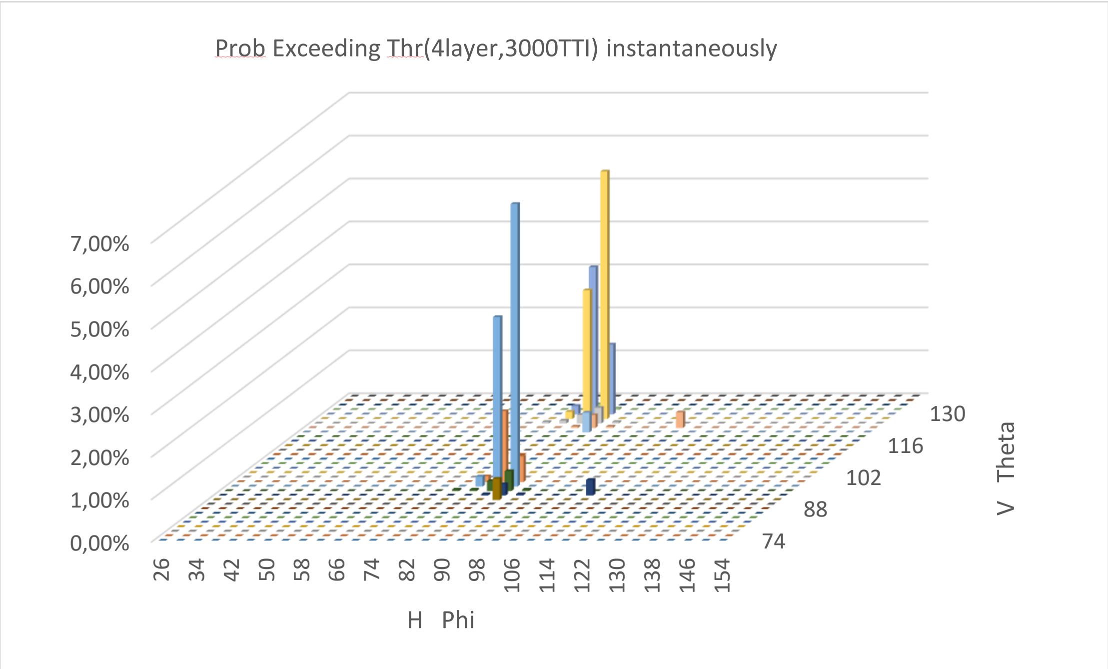

Figure C-9— Probability of exceeding the field strength limit (4 layers, scenario 2)

If we now study the averaged power in each grid point, we find that the levels are very similar to those in scenario 1, i.e. always less than the -6 dB threshold (Pn=0.25), see also [ref]. It is clear that beamforming can create spatial separation between different users even though the users are close to each other.

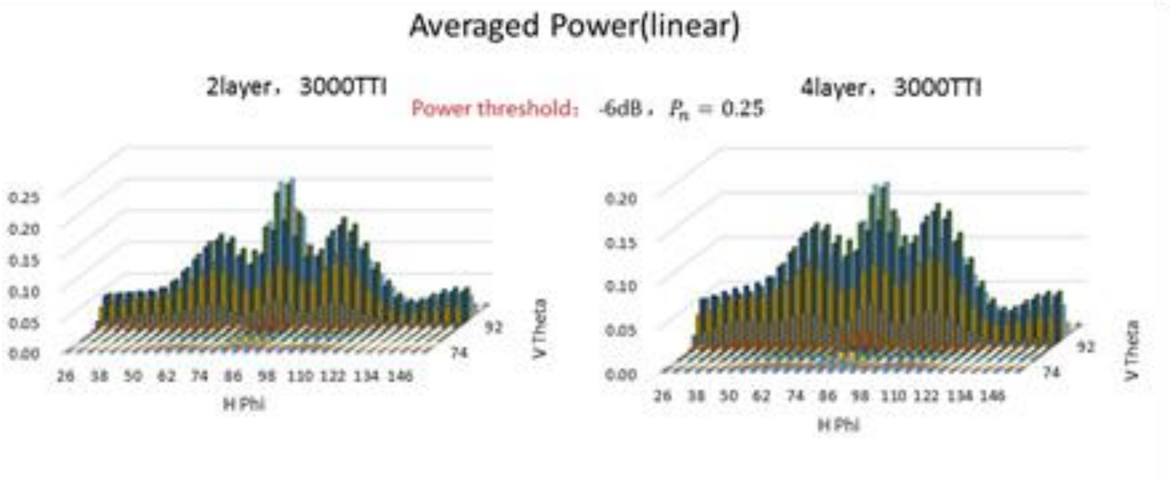

Figure C-10— Averaged power per grid point (scenario 2)

Scenario 3: Single User

In case of a single user, the CDF for all grid points will be similar to scenario 1 and 2 and the probability to exceed the -6 dB level will be low. However, since we are transmitting all the power to a single user there will be no backoff when averaging the power. This is a case that needs to be mitigated.

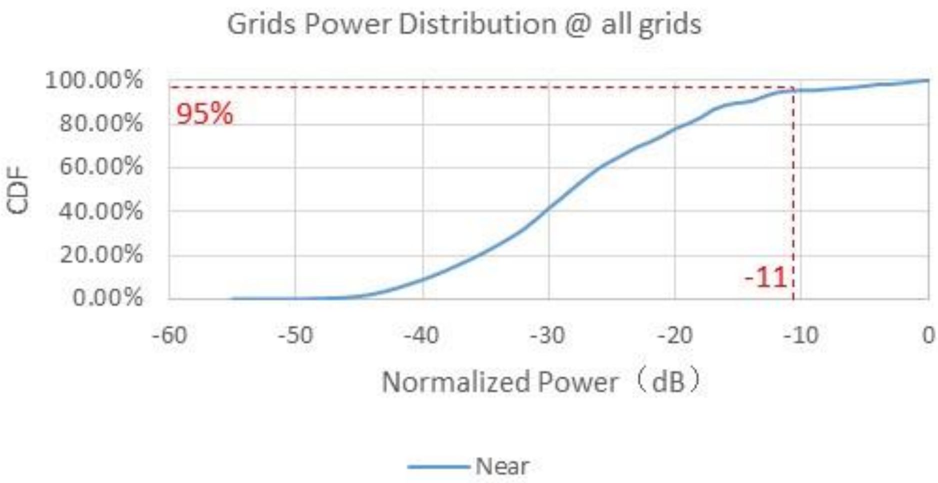

Figure C-11— Grids Power distribution (Scenario 3)

Additional Examples

Additional examples of implementation of EMF compliance based on actual maximum transmitted power or EIRP can be found in [8] as well as in [9] and [10].

APPENDIX D – BASICS FOR COUNTERS

This appendix outlines some relations between power flux density, radiation intensity and EIRP relevant for EMF counters. The basic quantity is the radiated power per area, i.e., the power flux density

$$S(r,\Theta,\varphi) = \frac{\left|\vec{E}\right|^2}{Z_0}$$

Here, $\left|\vec{E}\right|$ is the RMS value over time and $Z_0 \approx 377\ \Omega$ is the free space impedance. In the farfield region, the power density can be expressed in terms of radiation intensity (radiated power per solid angle) or EIRP. The relations to power flux density are [1]

$$S(\Theta,\varphi) = \frac{I(\Theta,\varphi)}{r^2} = \frac{EIRP(\Theta,\varphi)}{4\pi\, r^2}$$

If the coordinates of Fig. 2.3-1 are used, and $\Theta \in [-90°, 90°]$, then the area suspended by small angles $\mathrm{d}\Theta$ and $\mathrm{d}\varphi$ becomes $dA = r^2 cos\theta \mathrm{d}\Theta\mathrm{d}\varphi$. Hence,

$$\mathrm{d}P_{rad}(\theta,\phi) = I(\Theta,\varphi)\cos\Theta\mathrm{d}\Theta\mathrm{d}\varphi = \frac{EIRP(\Theta,\varphi)}{4\pi} cos\Theta\mathrm{d}\Theta\mathrm{d}\varphi$$

The power radiated in an angular sector, given by the intervals $\theta \in [\theta_{START}, \theta_{STOP}]$ and $\phi \in [\phi_{START}, \phi_{STOP}]$, is then

$$P_{sector} = \int_{\Theta_{START}}^{\Theta_{STOP}} \int_{\varphi_{START}}^{\varphi_{STOP}} I(\Theta,\varphi) cos\Theta d\Theta d\varphi = \frac{1}{4\pi} \int_{\Theta_{START}}^{\Theta_{STOP}} \int_{\varphi_{START}}^{\varphi_{STOP}} EIRP(\Theta,\varphi) cos\Theta d\varphi$$

NOTE: If EIRP is integrated over an angular region, a scaling factor of $\frac{1}{4\pi}$ is required to get the power radiated in the angular region.

The reverse action is to estimate the field strength at a distance and in a given angular region from a given power level P_{sector}. Since P_{sector} is retrieved from an integrated value, only the average EIRP or Radiation Intensity is possible to estimate. The angular average of the radiation intensity is

$$I_{av} = \frac{1}{\Omega_{sector}} \int_{\Theta_{START}}^{\Theta_{STOP}} \int_{\varphi_{START}}^{\varphi_{STOP}} I(\Theta,\varphi) cos\Theta d\Theta d\varphi = \frac{P_{sector}}{\Omega_{sector}}$$

Here,

$$\Omega_{sector} = \int_{\Theta_{START}}^{\Theta_{STOP}} \int_{\varphi_{START}}^{\varphi_{STOP}} cos\Theta d\Theta d\varphi = (\sin\Theta_{STOP} - \sin\Theta_{START})(\varphi_{STOP} - \varphi_{START})$$

is the solid angle of the angular sector. At a fixed distance r, the angular average of the power flux density is

$$S_{av} = \frac{1}{r^2}\frac{P_{sector}}{\Omega_{sector}}$$

Finally, the angular average RMS E-field strength is calculated as

$$|\vec{E}| = \frac{1}{r}\sqrt{\frac{Z_0 P_{sector}}{\Omega_{sector}}}$$

APPENDIX E - POLARIZATION CORRELATION FACTOR

For a dual polarized system Polarization Correlation Factor (PCF) is defined as:

$$\mathrm{PCF}(\theta,\phi) = \frac{\left|\overrightarrow{E_1}(\theta,\phi)\cdot\overrightarrow{E_2^*}(\theta,\phi)\right|^2}{\left|\overrightarrow{E_1}(\theta,\phi)\right|^2\left|\overrightarrow{E_2}(\theta,\phi)\right|^2}$$

This is a directional metric and the farfields $\overrightarrow{E_1}(\theta,\phi)$ and $\overrightarrow{E_2}(\theta,\phi)$ are

- Generated by two beams serving the same direction for GoB systems
- Not yet defined, in the EEB case

PCF generalizes the concept of Cross Polar Discrimination (CPD) wherein one of the fields has a constant polarization. NOTE: In the case of orthogonal polarizations PCF = 0 and for equal polarizations PCF = 1 or equivalently 100%. This definition is related to the IEEE definition of Polarization Mismatch Factor [1].

Synonym to PCF is “Polarization Parallelity”

The following table illustrates PCF and may be used for reference calculations

Polarization 1	$\vec{E}_1$	$\lvert\vec{E}_1\rvert^2$	**Polarization 2**	$\vec{E}_2$	$\lvert\vec{E}_2\rvert^2$	$\lvert\vec{E}_1\cdot\vec{E}_2^*\rvert$	**PCF** (%)
V	$\widehat{\Theta}$	1	H	$\hat{\varphi}$	1	0	0%
V	$\widehat{\Theta}$	1	V	$\widehat{\Theta}$	1	1	100%
V	$\widehat{\Theta}$	1	+45/-45	$\widehat{\Theta} \pm \hat{\varphi}$	2	1	50%
V	$\widehat{\Theta}$	1	LHCP/RHCP	$\widehat{\Theta} \pm j\hat{\varphi}$	2	1	50%
Elliptical	$\widehat{\Theta} + 2\hat{\varphi}$	5	Elliptical	$\widehat{\Theta} - \hat{\varphi}$	2	1	10%
Elliptical	$\widehat{\Theta} + 2j\hat{\varphi}$	5	Elliptical	$2j\widehat{\Theta} - \hat{\varphi}$	5	0	0%
Elliptical	$\widehat{\Theta} + 2j\hat{\varphi}$	5	Elliptical	$\widehat{\Theta} - 2j\hat{\varphi}$	5	3	12%

Table 0.12-1— Examples of Polarization Correlation Factors (PCFs)