DELMEC

Comparison of EPA values based on TIA-222-G, TIA-222-H and wind tunnel test. Their impact on the structure capacity.

WHITE PAPER

NATALIA KONONOVA – MARCH 2023

Executive Summary

To cope with the incessant growth of data demand, wireless service providers need to continuously add capacity. This is subsequently achieved acquiring new spectrum bandwidth or optimizing the use of the one already allocated.

In both cases, MNO's will sooner than later have to upgrade their existing RF Antenna Systems, swapping old legacy RF panels (single and multiband) with new wideband models able to deliver MIMO capabilities, or deploying additional passive panels and or active antennas.

5G networks are now deployed in relatively small scale, in a number of countries worldwide but their implementation has already highlighted the limitations of legacy cell sites, pushing the utilization of existing structures to their upper limits, if not exceeding them, and consequently resulting in overloaded towers and monopoles.

Due to the huge cost and logistical challenges of structural reinforcement or worse, structure replacement, Base Station Antenna (BSA) manufacturers soon realized that there was a concrete opportunity to exploit the challenges and shortcomings of structures designed and installed decades earlier for a far smaller number of appurtenances and started putting more emphasis in the aerodynamic performance of their products.

Advancement in the BSA products didn't immediately translate in actionable steps to reduce the wind loading on MNO's towers, having to rely on the guidance provided by the applicable building codes in force to determine the force transferred by the antennas to the structures, but highlighted the difference between such calculated values and the ones measured from wind tunnel testing.

We will be looking and comparing several approaches: ANSI/TIA-222-G, ANSI/TIA-222-H and wind tunnel test.

The ANSI/TIA-222-G version introduced us to the EPA and its new way of calculating the antenna surface taking into account the drag coefficient.

The new version of ANSI/TIA-222 (Rev. H 2018) has introduced a major change in the definition of force coefficients for supports, adding a new family of forms, the HSS (Rounded Edge Prisms). Such geometry better fits the actual shape of the majority of the latest RF panels as confirmed by extensive wind tunnel measurements.

We will be looking into wind tunnel testing which is becoming an essential part of the deliverables that manufacturers need to provide in accordance with the latest recommendations on passive base stations antenna system (BASTA).

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Introduction

1.1 Purpose

This document reviews the changes introduced by the most recent version of ANSI/TIA-222 (Rev.H) in the definition of the design wind on appurtenances and with some worked examples, compares the results obtained with the laboratory measured values provided by manufacturers performed using the latest BASTA guidelines.

We will also look at the TIA-222-G approach to calculate wind load and the introduction of EPA (Effective Projection Area).

Since 2010, under the auspices of the NGMN Alliance (Next Generation Mobile Networks Alliance), base station antenna manufacturers and mobile operators came together to discuss the development of a set of recommended standards to help guide the industry. The project became known as the base station antenna standards working group or BASTA, and since 2017 BASTA has introduced the wind load as one of the mechanical specifications and parameters to be included for each antenna. Lastly in 2022 release, (V12.0), a detailed standardized methodology for wind tunnel testing and data submission format

While comparing the calculated wind force on antennas using TIA-222 (G,H) formulas with wind tunnel tests, we will discuss how both the cross section and overall external dimensions of an antenna utilization affect its aerodynamic performance, and, as a consequence, why it is necessary for both MNO and TowerCo to become well-aware of the notion of EPA, how it is calculated for an antenna and why it is far more important than the simple area in the definition of both antenna loading, structure capacity and spare utilization

In many cases, the cost of renting tower space depends to a large extent on the loading of a base station antenna that adds to the tower's structure. MNO’s frequently use wind load data from base station antenna manufacturers to decide which antennas to deploy. As a result, it is important that MNO’s and TowerCo’s have a clear understanding of how wind load data is calculated so that accurate comparisons can be made between different antenna designs. This white paper presents the methods determines frontal and lateral wind load values, as well as the effective drag area.

The guideline is useful for understanding the rationale behind the support load calculation tool, thus ensuring its proper application.

1.2 History

The introduction of new technologies like 5G and frequency bands in mobile telecommunications systems translates into additional equipment to be installed on existing sites. The total capacity of a structure is measured by the Effective Projected Area (EPA) in square meters of the antennas for a given base wind speed that can be installed at the top. In most cases, MNO use FPA (Flat

Project Area) for antenna load calculation in the simple FPA (Length x Width) way. This leaves room for discussion since any invention of aerodynamics for antennas is ignored. This may contribute to the full use of antenna support structures, by ensuring that the design antenna loads are within authorized limits.

2. 0 Step-by-Step explanations

2.1 What is EPA?

The Telecommunications Industry Association (TIA), under its Engineering Committee TR-14 is responsible for the release revision of its "*Structural Standard for Antenna Supporting Structures and Antennas*" commonly refer as "*TIA-222*".

In the revision G of such standard, published in 2005, TIA introduced the concept of EPA, Effective Projected Area in the calculation of the wind forces on an a discrete appurtenance (example, an RF antennas)

As the adjective "effective" implies, wind forces were not simply the product of the Wind Pressure by the Antenna Area, but drag coefficients need to be accounted for.

In 2018 TIA published the most recent TIA-222-H standard, and rectangular HSS members were added to the member basic shapes.

To date, few studies describe the structural impacts of EPA use.

The procedure for the evaluation of the Design Wind on Appurtenances is defined in Paragraph 2.6.11.2 of the TIA-222-H.

2.6.11.2 Design Wind Force on Appurtenances

The design wind force on appurtenances (either discrete or linear but excluding microwave antennas), F_A, shall be determined from the equation:

$$F_A = q_z G_h (EPA)_A$$

where:

q_z = velocity pressure at the centerline height of the appurtenance from 2.6.11.6

G_h = gust effect factor from 2.6.9

(Note: See 2.6.11 for G_h for the strength design of appurtenances.)

$(EPA)_A$ = effective projected area of the appurtenance including ice for loading combinations that include ice

In the absence of more accurate data specifying effective projected area values for each critical wind direction, the effective projected area, $(EPA)_A$, of an appurtenance shall be determined from the equation:

$$(EPA)_A = K_a[(EPA)_N \cos^2(\theta) + (EPA)_T \sin^2(\theta)]$$

where:

θ = relative angle between the azimuth associated with the normal face of the appurtenance and the wind direction (refer to Figure 2-6)

$(EPA)_N$ = effective projected area associated with the windward face normal to the azimuth of the appurtenance

$(EPA)_T$ = effective projected area associated with the windward side face of the appurtenance

In the absence of more accurate data, an appurtenance shall be considered as consisting of flat and round components in accordance with the following:

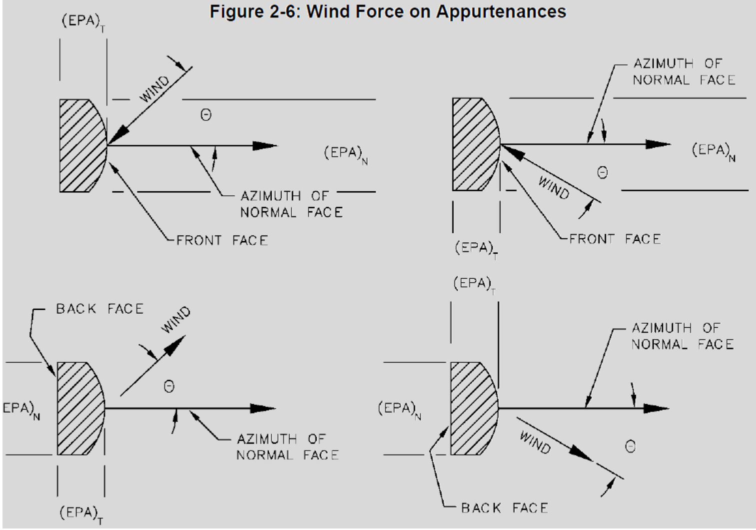
$$(EPA)_N = \Sigma(C_a A_a)_N$$

$$(EPA)_T = \Sigma(C_a A_a)_T$$

C_a = force coefficient from Table 2-9

A_a = projected area of a component of the appurtenance. The additional projected area of ice shall be considered as a round component for loading combinations that include ice

Figure 2-6: Wind Force on Appurtenances



As mentioned in the paragraph, in absence of more accurate data, the EPA for antennas can be estimated from their geometry introducing a force coefficient Ca, that is function of the antenna overall dimensions (Aspect Ratio = Height/Width) and cross section.

2.2 What is Ca and correlation with significant changes in EPA under TIA-222-G(H)?

As per previous releases, the force coefficients (***C_a***) for generic appurtenances are estimated based on their aspect ratio (height/width and height/depth), using linear interpolation from tabulated values in Table 2-8

In Rev. H of the TIA-222, such values has been replaced by the ones in Table 2-9

The fundamental difference, that redefines the generic Appurtenences force coefficients, is the introduction of a new family of shapes, the Square & Rectangular HSS (rounded edges rectangular prism)

ANSI/TIA-222-G

Table 2-8
Force Coefficients (C_a) For Appurtenances

Member Type		Aspect Ratio ≤ 2.5	Aspect Ratio = 7	Aspect Ratio ≥ 25
		C_a	C_a	C_a
Flat		1.2	1.4	2.0
Round	C < 32 [4.4] (Subcritical)	0.70	0.80	1.2
	32 ≤ C ≤ 64 [4.4 ≤ C ≤ 8.7] (Transitional)	$3.76/(C)^{0.485}$ [$1.43/(C)^{0.485}$]	$3.37/(C)^{0.415}$ [$1.47/(C)^{0.415}$]	$38.4/(C)^{1.0}$ [$5.23/(C)^{1.0}$]
	C > 64 [8.7] (Supercritical)	0.50	0.60	0.60

Where:

C = (I Kzt Kz)0.5 (V)(D) for D in ft [m], V in mph [m/s]
V is the basic wind speed for the loading condition under investigation.
D is the outside diameter of the appurtenance.
Aspect ratio is the overall length/width ratio in the plane normal to the wind direction. (Aspect ratio is independent of the spacing between support points of a linear appurtenance, and the section length considered to have uniform wind load).

Notes:

1. For cylindrical appurtenances, when irregularities such as flanges, hangers, etc., are present, effective projected areas shall be calculated as follows:
   a. When Ra ≤ 0.1, the projected areas of the irregularities may be ignored.
   b. When 0.1 < Ra ≤ 0.2, the value for Ca shall be multiplied by 1.0 + 3(Ra – 0.1), and the projected areas of the irregularities may be ignored.
   c. When Ra > 0.2, or alternatively for any value of Ra, the value of Ca for subcritical flow shall be used. The projected areas of irregularities shall be considered separately in addition to the appurtenance using the appropriate force coefficients.

   Where Ra is the ratio of the projected area of the irregularities (perpendicular to the wind direction) to the projected area of the appurtenance without the irregularities for the portion being considered. For iced conditions, the ice thickness need not be considered in the determination of Ra
2. For flat appurtenances, when irregularities such as flanges, hangers, etc., are present, the projected areas of the irregularities shall be considered separately in addition to the appurtenance using appropriate force coefficients except when Ra is less than or equal to 0.1, the projected areas of the irregularities may be ignored.
3. For iced conditions, Ca shall be based on subcritical flow for all values of C.
4. Linear interpolation may be used for aspect ratios other than those shown.
5. Subcritical force coefficients may conservatively be used for any value of C.

Section 2 **ANSI/TIA-222-H**

Table 2-9: Force Coefficients, C_a, For Appurtenances

Member Type		Aspect Ratio ≤ 2.5	Aspect Ratio = 7	Aspect Ratio ≥ 25
		C_a	C_a	C_a
Flat		1.2	1.4	2.0
Square & Rectangular HSS		$1.2 - 2.8(r_s) \geq 0.85$	$1.4 - 4.0(r_s) \geq 0.90$	$2.0 - 6.0(r_s) \geq 1.25$
Round	C < 39 [5.3] (Subcritical)	0.70	0.80	1.2
	39 ≤ C ≤ 78 [5.3 ≤ C ≤ 10.6] (Transitional)	$4.14/(C)^{0.485}$ [$1.57/(C)^{0.485}$]	$3.66/(C)^{0.415}$ [$1.60/(C)^{0.415}$]	$46.8/(C)^{1.0}$ [$6.36/(C)^{1.0}$]
	C > 78 [10.6] (Supercritical)	0.50	0.60	0.60

where:

r_s = ratio of outside corner radius to outside width normal to the wind direction

$C = (K_{zt} K_z K_e)^{0.5} (V)(D)$ for D in ft. [m], V in mph [m/s]

V is the basic wind speed for the loading condition under investigation.

D is the pole outside diameter for rounds or the outside corner-to-corner width for polygons.

When the outside corner radius is not known, r_s shall be determined based on an outside corner radius equal to 2.25 times the nominal wall thickness of the HSS member.

Aspect ratio is the overall length/width ratio in the plane normal to the wind direction. (Aspect ratio is independent of the spacing between support points of a linear appurtenance, and the section length considered to have uniform wind load.)

Notes:

1. For cylindrical appurtenances, when irregularities such as flanges, hangers, etc., are present, effective projected areas shall be calculated as follows:
   a) When $R_a \leq 0.1$, it shall be permissible to ignore the projected areas of the irregularities.
   b) When $0.1 < R_a \leq 0.2$, the value for C_a shall be multiplied by $[1.0 + 3(R_a – 0.1)]$, and it shall be permissible to ignore the projected areas of the irregularities.
   c) When $R_a > 0.2$, or alternatively for any value of R_a, the value of C_a for subcritical flow shall be used. The projected areas of irregularities shall be considered separately in addition to the appurtenance using the appropriate force coefficients.

   Where R_a is the ratio of the sum of the projected areas of the irregularities on both sides of the appurtenance (perpendicular to the wind direction) to the projected area of the appurtenance without the irregularities for the portion being considered. For iced conditions, the ice thickness need not be considered in the determination of R_a.
2. For flat appurtenances, when irregularities such as flanges, hangers, etc., are present, the projected areas of the irregularities shall be considered separately in addition to the appurtenance using appropriate force coefficients except when R_a is less than or equal to 0.1, the projected areas of the irregularities may be ignored.
3. For iced conditions, C_a shall be based on subcritical flow for all values of C.
4. Linear interpolation may be used for aspect ratios other than those shown.
5. Subcritical force coefficients may conservatively be used for any value of C.

Now we can account for the smooth edges of the antennas (function of the ratio Corner Radius/Width - rs) that can reduce substantially the drag coefficient ***C_a***. Below are three different shapes of the base station antennas and the impact they have on EPAs.

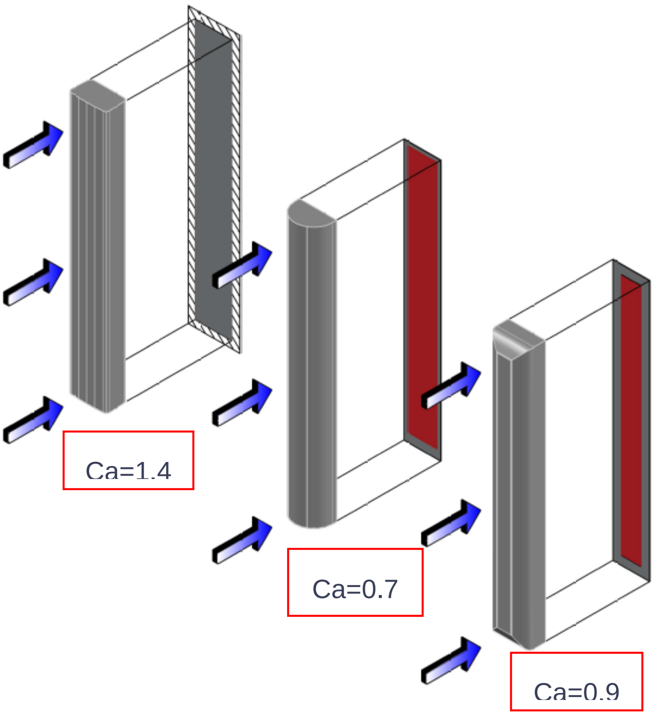


Figure 1 - Ca coefficients for different geometries

All three antennas have the same front area (in 222 is referred as Flat Plate Area or FPA) as 2.0 m^2. Nevertheless, their coefficient of force, Ca (or drag factor) is very different as a result of their shape with reference to Fig.1 above , ANT1 has a flat area exposed to the wind with sharp edges. Its Ca value can be approximately 1.4. In case of ANT2, the antenna has a round shape exposed to the wind that results in a significantly lower Ca value, approximately 0.7. In the ANT3 there is a panel antenna with heavily rounded edges. It yields can be approximately Ca=0.9.

The corresponding EPA for each antenna is then obtained by multiplying the FPA by their respective Ca values. From there, we can see how the shape of the antenna is a major factor in determining the wind loads on them.

In fact, BSA radomes have rounded edges and as demonstrated by wind tunnel modelling, their coefficient of force can be determined more realistically using the formula specified for the rectangular HSS.

Below is the simplicity used to model the antenna radome in an equivalent rectangular HSS form in the Excel tool.

- Draw the rectangle which covers the cross-section of the radome.
- Utilize the minimum angle radius for all edges.

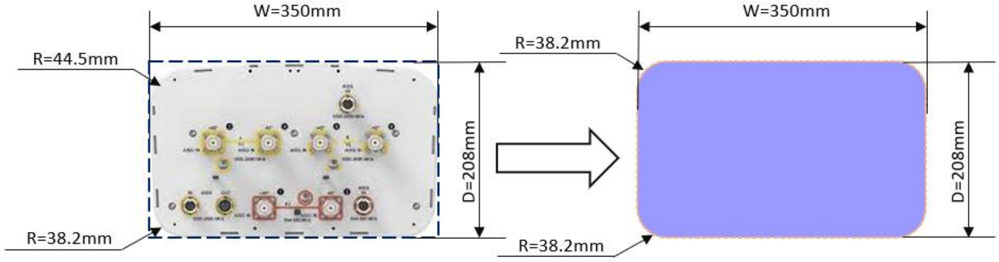


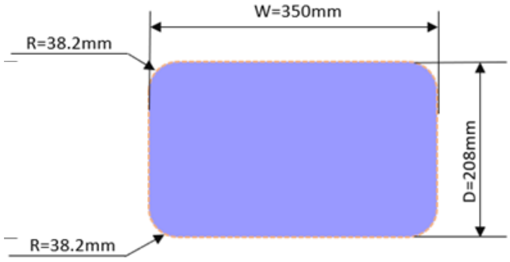
Figure 2 - Calculations of the force Coeff for RF antennas

The force coefficient is then calculated based on the corresponding ratio:

- r_{sFRONT} = R/W
- r_{sSIDE} = R/D.

As an example, let's calculate the Force coefficients for the same RF panel, (Commscope VVPX310.11B) considering the 2 scenarios:

1. Flat panel approach
2. Equivalent HSS shape



Panel dimensions

H =	2533mm	(Max Antenna Height)
W =	350mm	(Max Antenna Width)
D =	208mm	(Max Antenna Depth)
R =	38.2mm	(Minimum Edge Radius)

- Flat panel scenario

A_{FRONT} = H x W = 0.887 m^2

A_{SIDE} = H x D = 0.527 m^2

Panel aspect ratio (Front) = W/H = 2533/350 =7.24 → C_{aF} = 1.41

Panel aspect ratio (Side) = W/H = 2533/350 = 12.18 → C_{aS} = 1.57

EPA_{FRONT} = A_{FRONT} x C_{aF} = 1.248 m^2

EPA_{SIDE} = A_{SIDE} x C_{aS} = 0.829 m^2

- Equivalent HSS shape

A_{FRONT} = H x W = 0.887 m2

A_{SIDE} = H x D = 0.527 m2

R = 38.2mm (Minimum edge Radius)

Front Ratio of outside corner radius r_{SFRONT} = R/W = 0.11

Side Ratio of outside corner radius r_{SSIDE} = R/D = 0.18

Panel aspect ratio (Front) = W/H = 2533/350 =7.24 → C_{aF} = 0.97

Panel aspect ratio (Side) = W/H = 2533/350 = 12.18 → C_{aS} = 1.00

EPA_{FRONT} = A_{FRONT} x C_{aF} = 0.861 m2

EPA_{SIDE} = A_{SIDE} x C_{aS} = 0.527 m2

As evident from the comparison of calculated values, the second approach allows considerable reduction in the EPA for the RF panel.

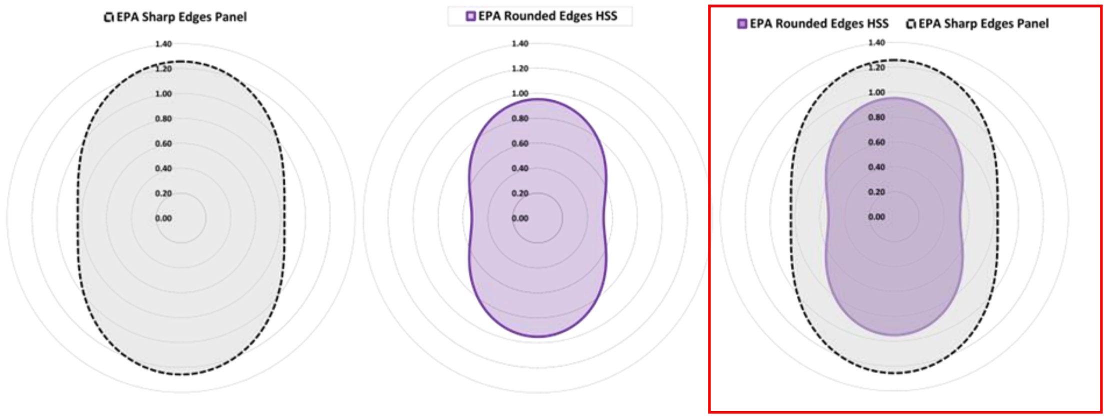
Below the 360-degree analysis for a single panel using the TIA-222 formula for the 2 configurations: Flat Panel (Sharp Edges) and Rounded Edges

$$(EPA)_\theta = [(EPA)_N \cos^2(\theta) + (EPA)_T \sin^2(\theta)]$$

Section 2 ANSI/TIA-222-H

Table 2-9: Force Coefficients, C_a, For Appurtenances

Member Type	Aspect Ratio ≤ 2.5	Aspect Ratio = 7	Aspect Ratio ≥ 25
	C_a	C_a	C_a
Flat	1.2	1.4	2.0
Square & Rectangular HSS	$1.2 - 2.8(r_s) \geq 0.85$	$1.4 - 4.0(r_s) \geq 0.90$	$2.0 - 6.0(r_s) \geq 1.25$



The 360 analysis shows EPA reduction from a minimum of 24% to 36%.

2.3 What is Aspect ratio and correlation with EPA?

In the example we have just presented, a fundamental role is played by the antenna Aspect Ratio, meaning the ratio between the height of the panel and its width,

It is important to highlight that, with the exception of cylindrical antennas, for each RF panels we need to calculate 2 Aspect Ratios, Frontal and Side.

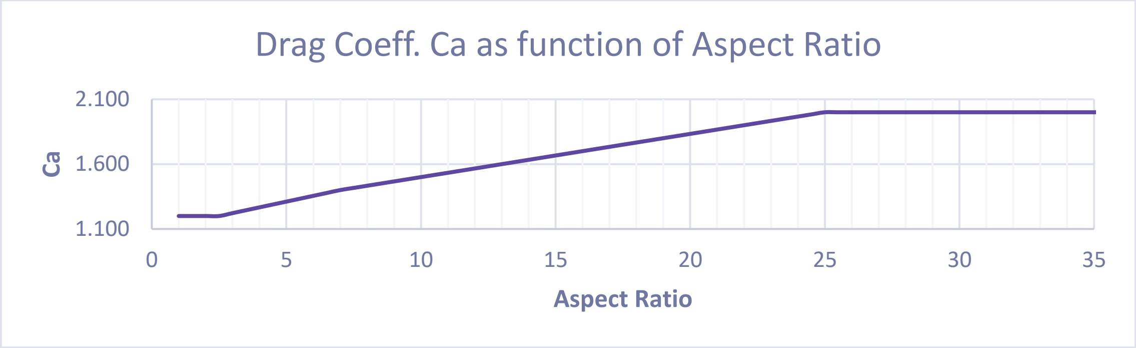


Figure 2 - Ca/Aspect Ratio

The figure above is plotting the calculated drag force Ca as function of Aspect Ratio.

It is immediate to see then the variation is more important when moving from relatively low AR, and it plateaus at AR =25

The reason behind such behavior is quite immediate if we think about how the build-up pressure of the airflow against the object dissipates.

An infinitely long object has the same airflow around each cross-section, the pressure cannot be released from Top or Bottom.

When an object is more compact, the pressure dissipated in both directions, meaning, air flow moves around it, on its sides, as well as on top and bottom

When the shape is as tall as wide, meaning Square (AR =1) than the drag coefficient is at its minimum

Normally multiple antenna models from the same manufacturer share have identical cross section, also referred to as platform, but they have variable lengths.

if in the past the Aspect Ratio of a single or multiband RF Panels was falling between 6.5 and 10, today’s Active and Ultrawideband passive Antennas have lower AR values, lowering the bar down to 2.5 To 5 respectively

2.4 What is wind tunnel testing and the impact on the EPA values?

Before 2018, the P-BASTA V9.6 guidelines presented antenna manufacturers with three possible methodologies to calculate and report antenna's wind performances. Different methodologies, however, inevitably provide different results, and manufacturers product datasheets often didn't mention what approach was used to obtain such figures

As a result, a unified method of calculating the wind load on antenna became the goal of the subsequent BASTA document releases. Between 2017 and 2018, P-BASTA organized a working group dedicated to antenna wind load and made great efforts to resolve this issue. At present, the method of obtaining antenna wind load by wind tunnel testing has been adopted by the majority of BSA manufacturers and it is by far the most reliable option for carriers and TowerCo.

In comparison to the standardized calculations presented by multiple building codes, the wind tunnel tests provide actual measurements taken in an environment as close as possible to the real scenario

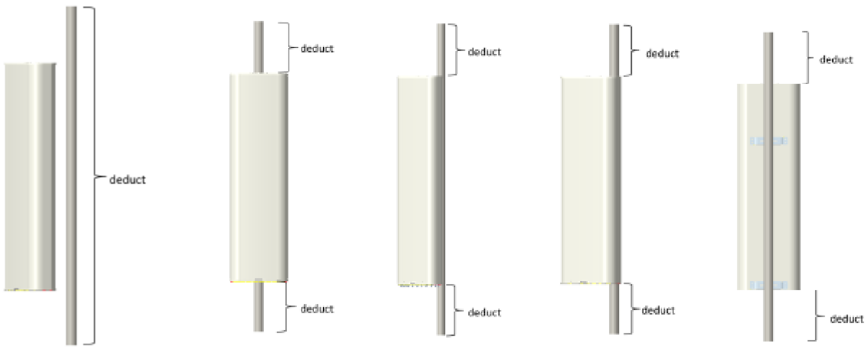


Figure 3 – Wind load reduction

As a general rule, antenna manufacturers will perform wind tunnel tests on a 10 degrees increment, from 0 (frontal) to 180 degrees (back) and in their reports the following is commonly listed:

- *Frontal Wind*
- *Lateral Wind*
- *Back Wind*
- *Maximum Wind*

Tests are conducted for a wind speed equal to 150 km/h wind speed.

Exact procedures are defined in APPENDIX F of the NGMN P BASTA Recommendation on Base Station Antenna Standards V12. Below a quick summary:

Frontal side wind load $F_{frontal}$

$F_{frontal}=F_{w\_frontal} - F_{mast(p1+p2)}$

From the front, the pole part with the same length as the antenna against the rear of the antenna are completely shielded by the antenna, which has little impact on the wind load. As a result, the front wind load is equal to the total wind load minus the wind load of the part of the pole beyond the antenna.

Lateral side wind load $F_{lateral}$

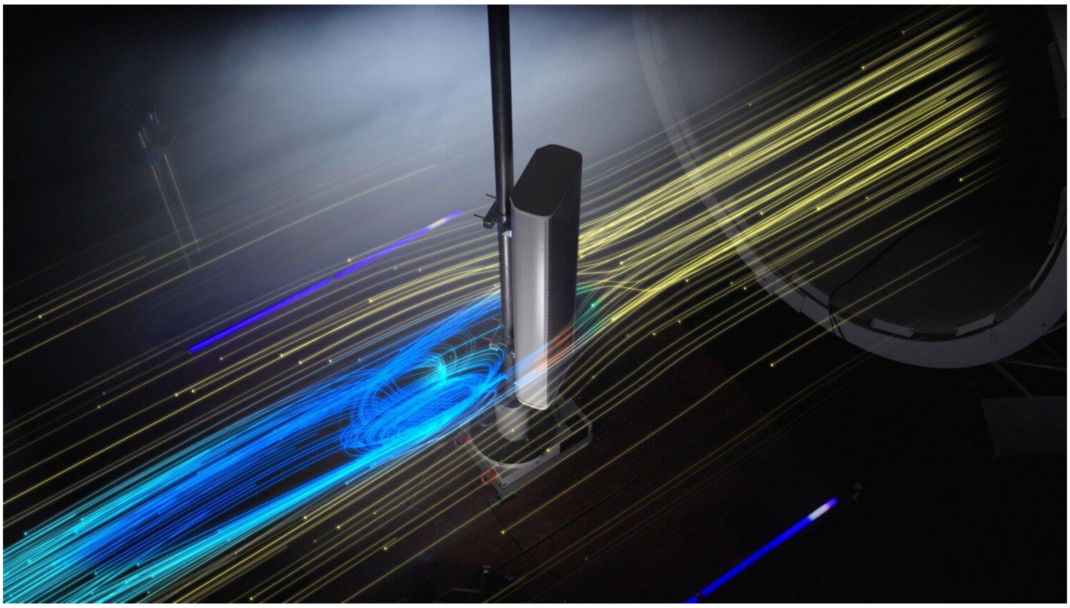
$F_{lateral}=F_{w\_lateral} - F_{mast(p)}$

On the side, since the post is not protected by the antenna, the proportion of the wind load of the post is large. Therefore, you have to subtract the wind load from the whole pole to get the wind load from the antenna on the side.

Maximum wind load $F_{maximal}$

$F_{maximal}=F_{w\_maximal} - F_{mast(p1+p2)}$

When the antenna shape is not the same, the maximum value can be at any angle. In that case, the antenna is heavily connected to the pole. The wind load of the pole at the rear of the antenna is modified and cannot be precisely calculated and removed.



3.0 Comparison between EPA values calculated using TIA-222-G, TIA-222-H prescriptions and Wind tunnel test

In the standard site configuration, an antenna system is implemented deploying 3 sectors configuration, each of them carrying one supporting pole, 1 or 2 RF panels, and a number of RRU, function of the band and technologies on site.

When specifying the technical requirements for antenna supporting structures (towers and monopoles) it is common to consider such 3 sectors uniformly distributed along the 3 main directions, 0, 120 and 240 degrees.

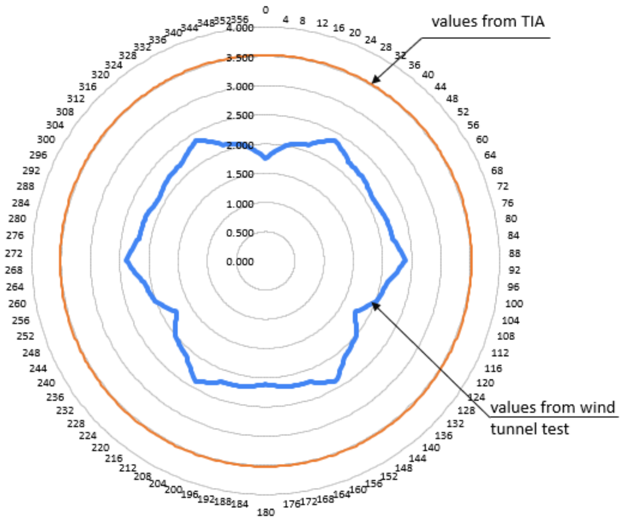
We have conducted calculations based on the values received from TIA-222 (G) and wind tunnel tests from the antenna manufacture. Below presented results of the multiplies BSA and position of the antennas were taken into consideration.

3.1 TIA-222-G versus wind tunnel test

For instance, we took several antennas for comparison of EPA values:

RFS P2-BBUU26-I0 (2749x369x206mm)	
$EPA_{(TIA)}$, m^2	$EPA_{(Wind)}$, m^2
3.5219	2.383

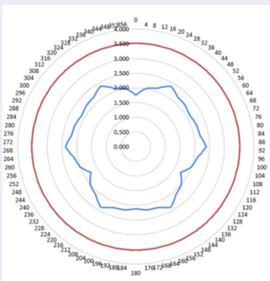
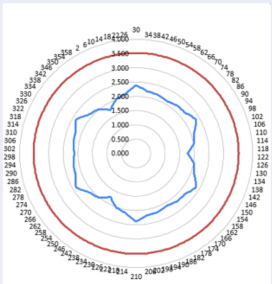
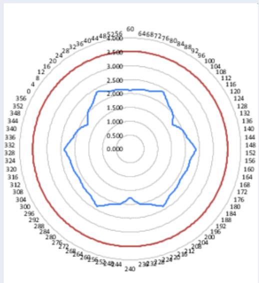
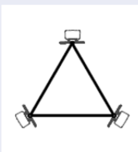
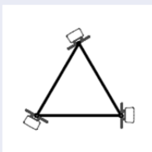
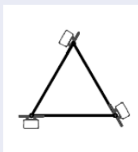
The comparison of the EPA calculated by TIA-222-G with the EPA from the wind tunnel tests is illustrated below:



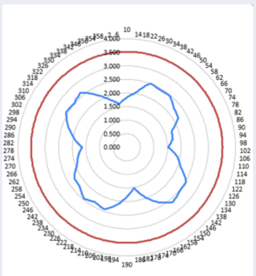
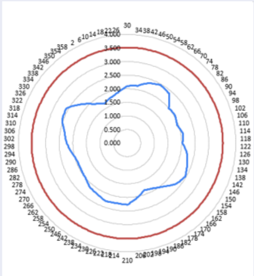
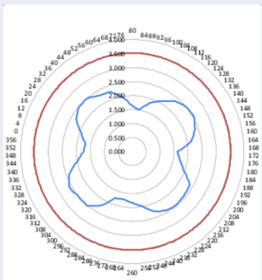
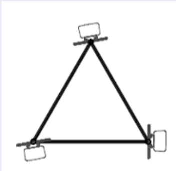
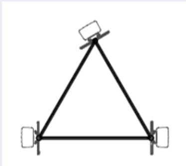
There is a 32% difference in EPA. Wind tunnel tests have a significant reduction in the EPA values.

In reality the sector distribution on an ON-AIR site can be quite different, due to customized antenna azimuth, coupled remote radio heads, as well as additional sectors (it is not uncommon to have a 4th sector on high capacity sites).

To properly analyse and assess a structure it is therefore not only necessary to have the RF details but detailed As Built plans as well. We will examine other combinations of three sectors and their impact on EPA values.

RFS P2-BBUU26-I0 2.6m (2749x369x206)		
EPA(WindT) =2.383 m2	EPA(WindT) =2.383 m2	EPA(WindT) =2.383 m2
0°, 120° , 240°	30°, 150° , 270°	60°, 180° , 300°
		
		

We examined other BSA configurations that were not typical. Below are the results of the exercise showing how the position of the antennas plays an important role in EPA consolidation.

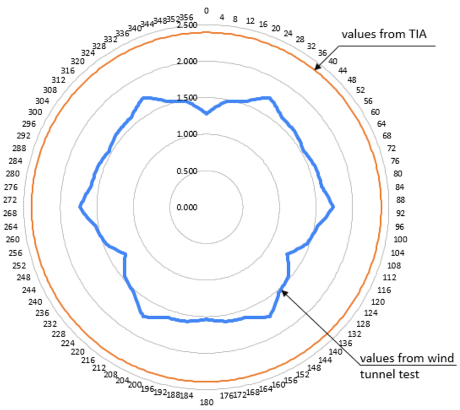
RFS P2-BBUU26-I0 2.6m (2749x369x206)		
EPA(WindT) =2.637 m2	EPA(WindT) =2.581 m2	EPA(WindT) =2.592 m2
10°, 190° , 270°	30°, 120° , 270°	60°, 270° , 350°
		
		

There is a variation of approx. 25% difference in EPA. Wind tunnel tests have a significant reduction in the EPA values.

We examined an antenna of the same width and thickness, but varying in length. The results below indicate a co-relationship between the EPA and the aspec ratio.

RFS P2-BBUU20-I0 (2000x369x206)	
$EPA_{(TIA)}$, m^2	$EPA_{(Wind)}$, m^2
2.3931	1.733

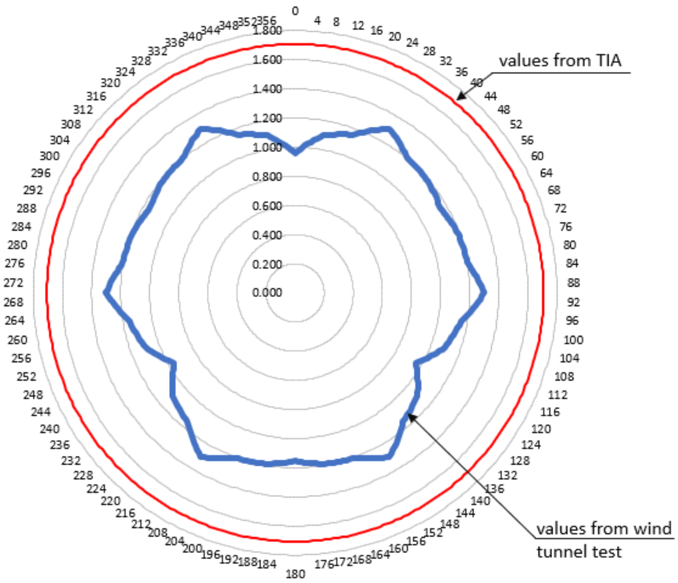
The comparison of the EPA calculated by TIA-222-G with the EPA from the wind tunnel tests is illustrated below:



There is a 27% difference in EPA. Wind tunnel tests have a significant reduction in the EPA values.

RFS P2-BBUU15-I0 (1500x369x206)	
EPA$_{(TIA),}$ m^2	EPA$_{(Wind),}$ m^2
1.7073	1.301

The comparison of the EPA calculated by TIA-222-G with the EPA from the wind tunnel tests is illustrated below:

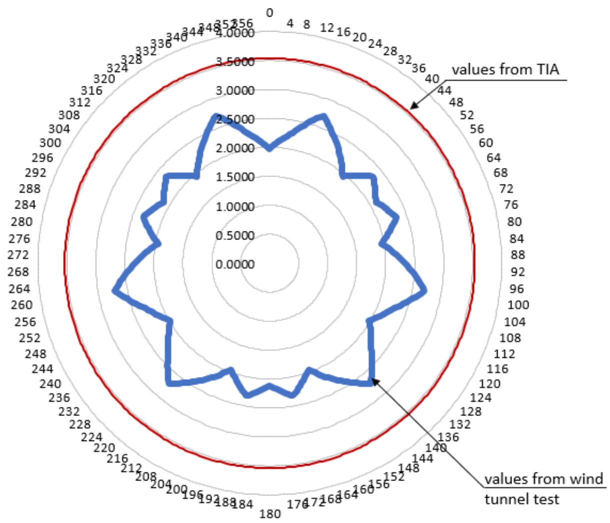


There is a 23% difference in EPA. Wind tunnel tests having a significant reduction in the EPA values

Delmec examined other types of antennas to understand if the EPA trend continues to change because of the shape of the antennas.

RFS APXVBB26H2_43-C-I20 (2498x469x205)	
EPA$_{(TIA),}$ m^2	EPA$_{(Wind),}$ m^2
3.5377	2.711

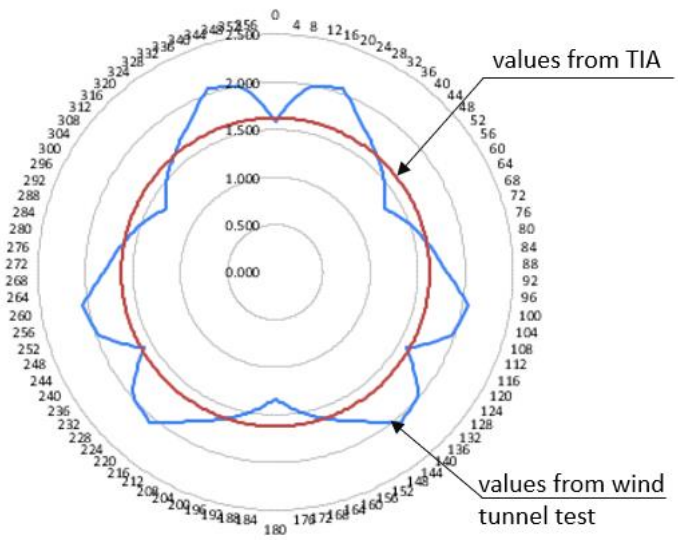
The comparison of the EPA calculated by TIA-222-G with the EPA from the wind tunnel tests is illustrated below:



There is a 23% difference in EPA. Wind tunnel tests having a significant reduction in the EPA values

RFS APXVAA4L18N_43-U-I20 (1219x499x215)	
EPA$_{(TIA)}$, m^2	EPA$_{(Wind)}$, m^2
1.622	2.059

The comparison of the EPA calculated by TIA-222-G with the EPA from the wind tunnel tests is illustrated below:

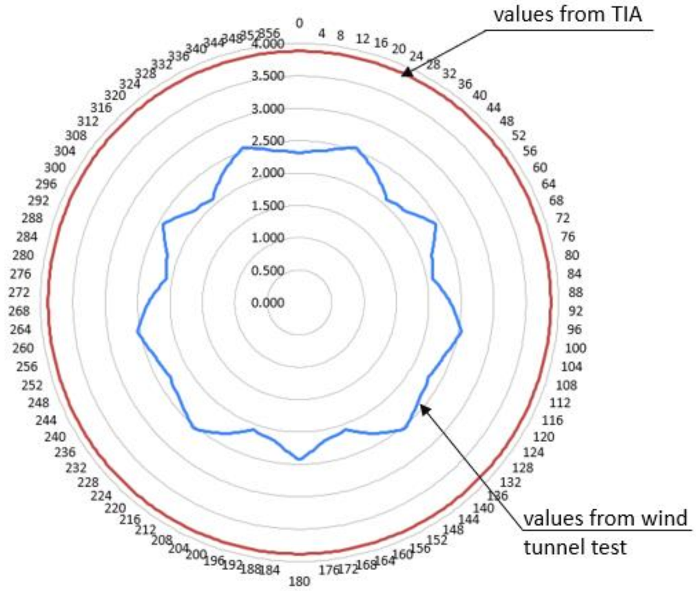


There is a 26% difference in EPA. Wind tunnel tests have a significant increase in the EPA values.

Other manufacture antennas were looked at:

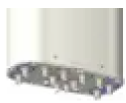
Others (2695x469x206)	
EPA$_{(TIA)}$, m^2	EPA$_{(Wind)}$, m^2
3.8834	2.541

The comparison of the EPA calculated by TIA-222-G with the EPA from the wind tunnel tests is illustrated below:

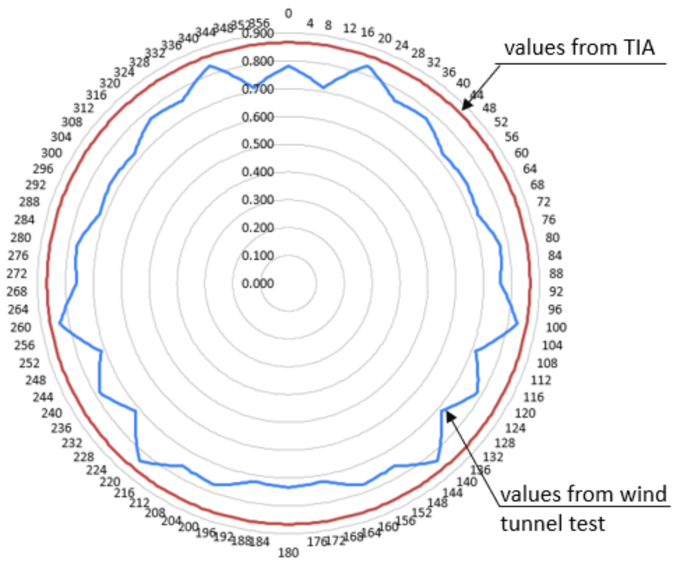


There is a 34% difference in EPA. Wind tunnel tests have a significant increase in the EPA values.

Others (1100x259x135)	
EPA$_{(TIA)}$, m^2	EPA$_{(Wind)}$, m^2
0.8664	0.8333



The comparison of the EPA calculated by TIA-222-G with the EPA from the wind tunnel tests is illustrated below:



There is a 4% difference in EPA. Wind tunnel tests have a significant increase in the EPA values.

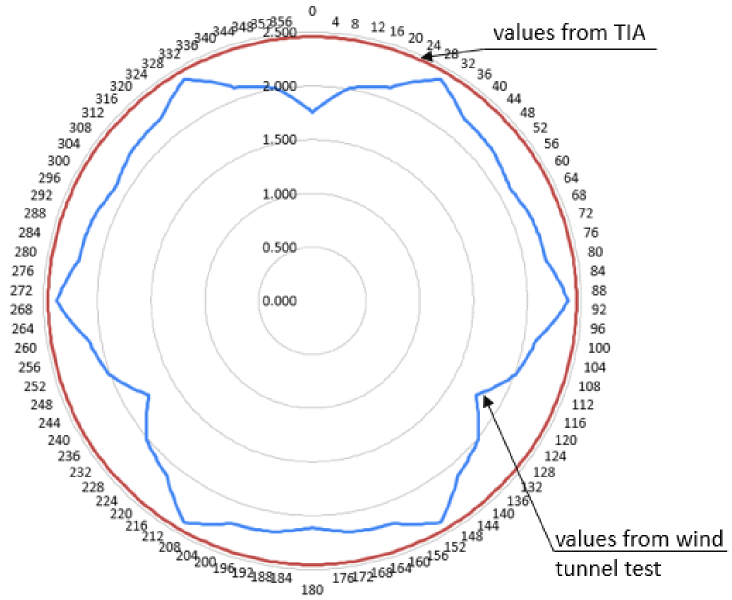
3.2 TIA-222-H versus wind tunnel test

Let us now examine the comparison between the TIA-222-H and wind tunnel test values. It is important to mention that the TIA-222-H is highly dependent upon antenna shapes. In order to conduct analyses, data on antenna manufacturing dimensions must be provided: length, width, thickness, top and bottom radius. Due to limited data from manufacture we were able to compare only one antenna type.

For instance, we took several antennas for comparison of EPA values:

RFS P2-BBUU26-I0 (2749x369x206mm)	
$EPA_{(TIA),}$ m^2	$EPA_{(Wind),}$ m^2
2.4584	2.383

The comparison of the EPA calculated by TIA-222-H with the EPA from the wind tunnel tests is illustrated below:

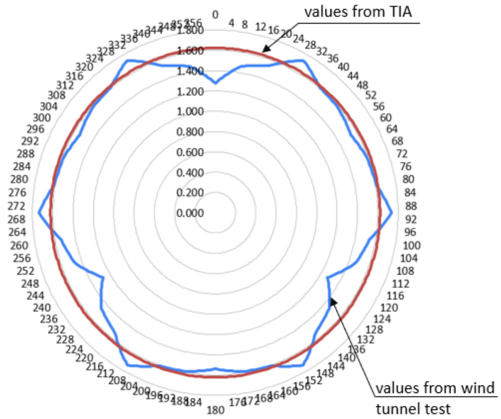


There is a 3% difference in EPA. Wind tunnel test with slight reduced compared to EPA values.

We examined an antenna of the same width and thickness, but varying in length. The results below indicate a co-relationship between the EPA and the aspec ratio.

RFS P2-BBUU20-I0 (2000x369x206)	
EPA$_{(TIA)}$, m^2	EPA$_{(Wind)}$, m^2
1.6218	1.733

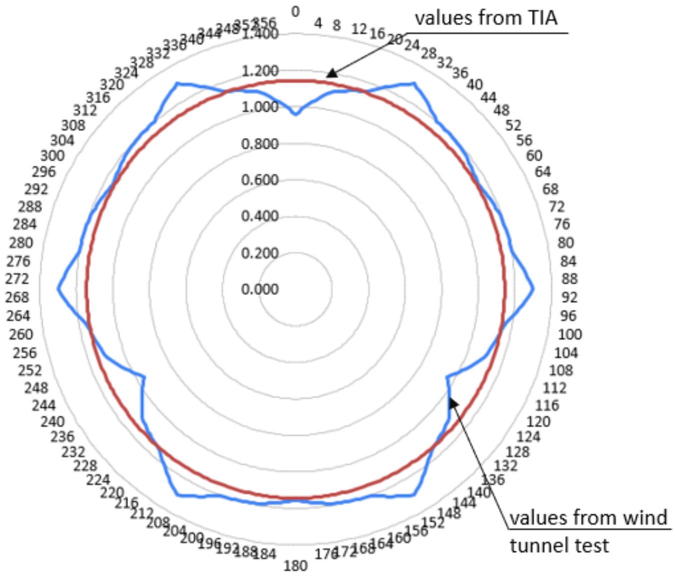
The comparison of the EPA calculated by TIA-222-H with the EPA from the wind tunnel tests is illustrated below:



There is a 6% difference in EPA. Wind tunnel tests slightly increase the EPA values.

RFS P2-BBUU15-I0 (1500x369x206)	
EPA$_{(TIA)}$, m^2	EPA$_{(Wind)}$, m^2
1.1442	1.301

The comparison of the EPA calculated by TIA-222-H with the EPA from the wind tunnel tests is illustrated below:

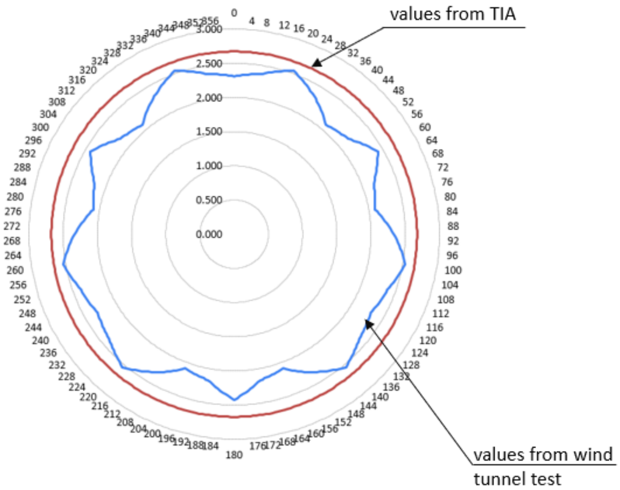


There is a 12% difference in EPA. Wind tunnel tests have increase in the EPA values.

Other manufacture antennas were looked at:

Others (2695x469x206)	
EPA$_{(TIA)}$, m^2	EPA$_{(Wind)}$, m^2
2.6734	2.541

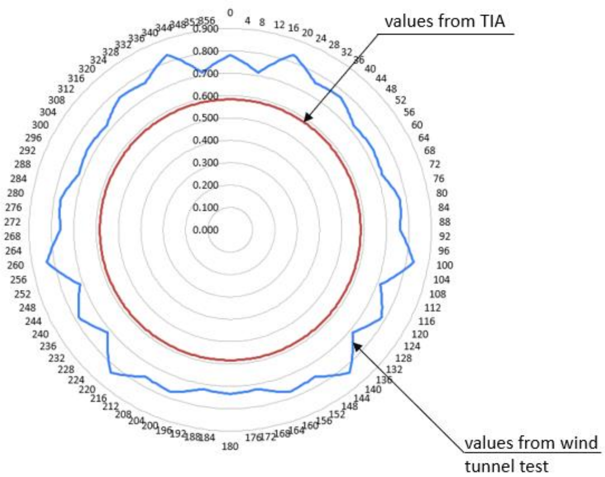
The comparison of the EPA calculated by TIA-222-H with the EPA from the wind tunnel tests is illustrated below:



There is a 5% difference in EPA. Wind tunnel test with slight reduced compared to EPA values.

Others (1100x259x135)	
EPA$_{(TIA),}$ m^2	EPA$_{(Wind),}$ m^2
0.5835	0.8333

The comparison of the EPA calculated by TIA-222-H with the EPA from the wind tunnel tests is illustrated below:



There is a 30% difference in EPA. Wind tunnel tests have increase in the EPA values.

4.0 Conclusions

The ability to minimize and manage wind load is a key factor in helping wireless operators reduce rental costs while maintaining quality of service. I have shown the requirements of the relevant design standard (TIA-222-G, TIA-222-H and actual wind tunnel test) and I have also presented a real-world impact on the EPA values based on them.

As indicated in the comparison of results between TIA-222-G and RFS wind tunnel test data. It can be assumed that there is a clear advantage in the EPA reduction from wind tunnel test compared to building code. Also other antenna manufacturers have similar model in the result.

Based on TIA-222-G, we can observe significant differences in the results in the favorable for the wind tunnel trial. According to the analyses, the difference between the results of the building code and those of the wind tunnel is between 20 and 30%, which plays an important role in the structure's capabilities.

Based on the TIA-222-H standards versus the wind tunnel test, we can observe that the H standard slightly underestimated the values of the EPAs compared to the wind tunnel test. It was noted that longer antenna having higher EPA from TIA-222-H than wind tunnel test values. As the analyses indicated, the gap between the TIA-222-H and the wind tunnel test widens because of the reduced aspect ratio (short antennas). It is recommended that the wind test result be used for analytical purposes whenever available from the manufacturer. These results are consistent across different antenna manufacturers.

These are just samples made with a limited number of antennas. Before it is recommended that you obtain data from the manufacturer, compare the results, and generate a correction coefficient accordingly.

As a result of the analysis performed, it is evident that IN THE EVENT THAT THE CONTRACT clause REGULATING THE ANTENNA LOAD ALLOWANCE AND/OR its ECCESS between MNO and TOWERCO is expressed in flat plate area, this is a lose-lose scenario:

the surface area is not directly proportional to the forces applied to the structure (since dependent on 2 additional factors, cross section and aspect ratio), and this leaves a level of uncertainty that inevitably translates in unutilized capacity and/or excess fees.

On the other hand, if such contracts already adopt EPA as unit of measure for the antenna systems, the advantages offered can be equally split between parties.

The exact fixed proportionality between EPA and wind forces (wind force = wind pressure x EPA) allows to optimize structure utilization leaving no room to assumptions.

As seen, the last revision of the ANSI/TIA standard, 222-H, introduced the force coefficients for rounded edges prism geometry appurtenances.

It is important to understand that the ANSI/TIA-222-H Revision changes the way the EPA of a single antenna is calculated, but not the formula to evaluate the "EPA envelope", meaning the EPA referred to an Antenna System (commonly 3 antenna sectors).

Par. 2.6.9.2 TIA-222-G and Par. 2.6.11.2 TIA-222-H are identical, word by word.

In the absence of more accurate data specifying effective projected area values for each critical wind direction, the effective projected area, (EPA)A, of an appurtenance shall be determined from the equation:

$$(EPA)_A = K_a[(EPA)_N \cos^2(\theta) + (EPA)_T \sin^2(\theta)]$$

In the absence of more accurate data, an appurtenance shall be considered as consisting of flat and round components in accordance with the following:

(EPA)N = L(Ca AA)N

(EPA)r = L(Ca AA)r

Ca = force coefficient from Table 2-8 (TIA-222-G), Table 2-9 (TIA-222-H)

$$(EPA)_N = \Sigma(C_a A_a)_N$$

$$(EPA)_T = \Sigma(C_a A_a)_T$$

C_a = force coefficient from Table 2-9

What are the implications?

Reading the above sentence, it is clear that there is no mutual dependence between the standard used to calculate the tower and the one used to evaluate the appurtenance EPA

Applying the TIA-EIA-222-H revision to calculate respectively (EPA)T, *effective projected area associated with the windward face normal to the azimuth of the appurtenance and (EPA)T = effective projected area associated with the windward side face of the appurtenance* is simply providing more precise figures to input in the EPA envelope formula, and a corresponding sensible reduction of the total EPA associated to antenna systems.

The last point is related to the use of the wind tunnel test.

Again, both G and H revision of the TIA-222 Standard allow the use of the formula in *Par. 2.6.9.2 TIA-222-G and Par. 2.6.11.2 TIA-222-H respectively* to calculate the force coefficients to be applied to the front and side flat plate area unless more accurate data is available.

What is more reliable than a full-size wind tunnel simulation, where data are actually measured, and not estimated.

Once again, the Standard used to analyze the antenna supporting structures is totally independent on the methodology used to calculate the **single appurtenance EPA.**

The **single appurtenance EPA** can be calculated in **3 different ways**, according to G, H or wind tunnel results.

What is important is that even if the contract clauses are not mentioning the latest standard revision, calculations of a tower can be performed with G and H standards, and for the **same EPA envelope** they will provide the **same tower member utilization** (with exception of tubular leg member towers, having lower Ca Coeff, refer to table 2.9 round elements).

References

1. TIA-222-H, Telecommunications Industry Association, Structural Standard for Antenna Supporting Structures and Antennas and Small Wind Turbine Supporting Structures, Effective January 01, 2018.
2. TIA-222-G Structural Standard for Antenna Supporting Structures and Antennas, August 2005
3. NGMN BASTA PASSIVE ANTENNAS WHITE PAPER V12 – April, 2022
4. Base Station Antennas: Pushing the Limits of Wind Loading on Macro Sites 20july22

https://www.rfsworld.com/pictures/white%20papers/rfs_white_paper_windloading_20july22.pdf