White Paper

Wind Load Test and Calculation of the Base Station Antenna

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Contents

Abstract

Wind load is an important parameter for designing base station antenna structure, including the tower and supporting structures. It directly affects the reliability of the antenna application and the safety of the tower.

In recent years, with the rapid development of MIMO, antennas are becoming increasingly integrated and the antenna size is constantly increasing, leading to more concerns for the impact of antenna wind load on the tower. The evaluation on tower safety and economic efficiency requires greater antenna wind load calculation accuracy.

Since 2017, the standardization organization NGMN-P-BASTA has established a base station antenna wind load working group. This working group has organized several workshops with multiple antenna manufacturers and carriers to normalize wind load standards and wind load calculation methods in the antenna industry. The standardized method of calculating the base station antenna wind load has been released in the P-BASTA V11.1 standard. Huawei develops the antenna wind load specifications according to the latest P-BASTA standard. This document describes the wind load test and calculation methods of Huawei base station antennas.

Figure 1 Communication tower

Wind Load Calculation Methods

According to Section 5.10 in *NGMN-P-BASTA Recommendation on Base Station Antenna Standards V9.6*, the wind load can be obtained in the following ways:

1. Based on the released standards
2. Through computational fluid dynamics (CFD) simulation
3. Through wind tunnel testing

1. Standardized Calculation

In this mode, the wind load is calculated using the formula provided by the released wind load standards.

The wind load is calculated using the following formula:

$$F_w = C_d * q_v * A$$

Where,

F_w: wind load (N)

C_d: drag coefficient

q_v: wind pressure (Pa)

A: windward projection area (m^2)

The wind pressure is subject to the air density and wind speed. Its calculation formula is as follows:

$$q_v = \frac{1}{2} * \rho * v^2$$

Where,

ρ: Air density (kg/m^3)

v: Wind speed (m/s)

The drag coefficient Cd is calculated using different methods in various wind load standards. The calculation of antenna wind load usually complies with the European standard EN1991-1-4 and North American standard TIA-222-G. Table 1 lists the value of the antenna drag coefficient Cd in the TIA-222-G standard. For details, see Table 2-8 in *TIA-222-G Structural*

Member Type	Aspect Ratio ≤ 2.5	Aspect Ratio = 7	Aspect Ratio ≥ 25
Flat	1.2	1.4	2.0
Round (Supercritical)	0.5	0.6	0.6

Table 1 Definition of the drag coefficient in the TIA-222-G standard

Standard for Antenna Supporting Structures and Antennas.

In the TIA standard, the antenna is regarded as an auxiliary part, and only the drag coefficients of panel and circular antennas are defined. However, the shape of an antenna section is generally between a panel and a circle. Therefore, it is difficult to accurately calculate the antenna wind load using this standard.

In the EN1991-1-4 standard, the drag coefficient Cd is calculated using the following formula:

$$C_d = C_{f0} * \Psi_r * \Psi_\lambda$$

Where,

C_{f0}: force coefficient for rectangular sections without rounded corners, as shown in Figure 2

Ψ_r: reduction factor for a rectangular section with rounded corners, as shown in Figure 3

Ψ_λ: end-effect factor, as shown in Figure 4

Compared with the TIA-222 standard, the EN1991-1-4 standard also provides the impact of the ratio of thickness to width, ratio of round to width on the drag coefficient. Therefore, the EN1991-1-4 standard can be used to more accurately calculate the wind load of antennas of different shapes. Huawei used the EN1991-1-4 standard before 2018 to calculate the antenna wind load.

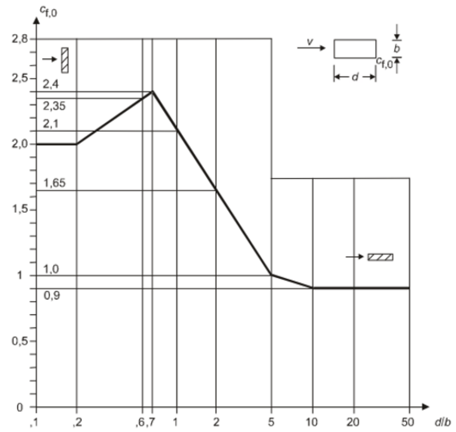


Figure 2 Force coefficient for rectangular sections without rounded corners

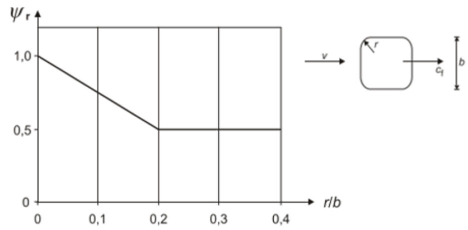


Figure 3 Reduction factor for a rectangular section with rounded corners

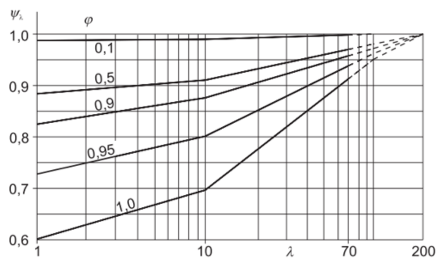


Figure 4 End-effect factor

2. CFD Simulation

With the rapid development of computer technology, CFD has developed rapidly, and has become an important means of product development with experimental fluid mechanics. It provides a faster and more economical method for product design. However, due to the complexity of the fluid, simulation is not enough to calculate the wind load, and a large number of wind tunnel tests are also required. Figure 5 shows the antenna wind load simulation.

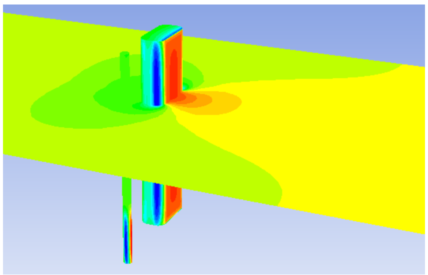


Figure 5 Simulation of antenna wind load

3. Wind Tunnel Testing

Among wind load measurement tests, the wind tunnel test simulates the environment most similar to the actual natural environment of the product and therefore is the most accurate test method.

The wind tunnel test is widely used to measure the wind load and perform various aerodynamics studies in airplane, automobile, building, and other fields (see Figure 6). The test provides strong support for reducing wind load and improving wind load prevention performance. In the antenna industry, wind tunnel tests are also used to obtain antenna wind load.

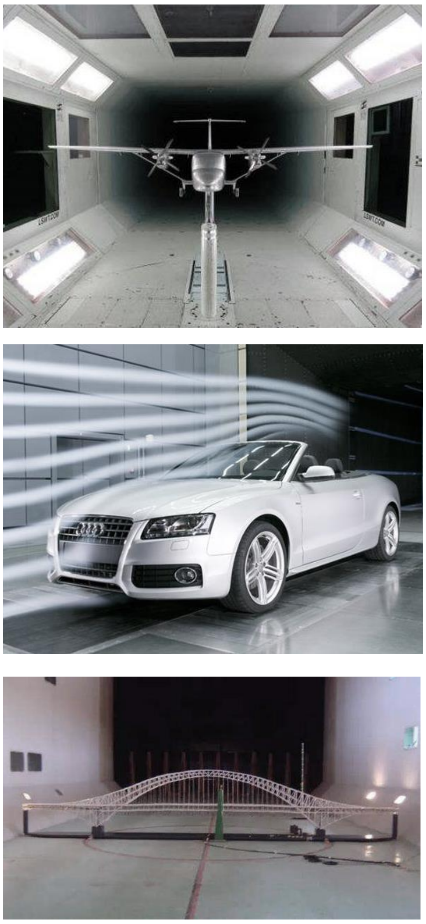


Figure 6 Wind tunnel test in industrial applications

P-BASTA Standard and Antenna Wind Tunnel Test

Before 2018, the P-BASTA V9.6 standard allows antenna manufacturers to use the preceding three methods to calculate and claim antenna wind load. However, different antenna manufacturers may adopt different methods, and the obtained wind load results are different even for the same antenna. Therefore, a unified antenna wind load calculation method becomes very necessary.

From 2017 to 2018, the P-BASTA organized a dedicated antenna wind load working group and made great efforts to solve this problem. Currently, the method of obtaining antenna wind load through wind tunnel testing has been recognized by most manufacturers and carriers. Compared with the standardized calculation and CFD simulation, the wind tunnel test provides an environment that is closer to the actual scenario to obtain the wind load.

Figure7 Installation spacing requirements of the antenna wind tunnel test

Section 5.9 in *NGMN-P-BASTA Recommendation on Base Station Antenna Standards V11.1* defines the antenna wind tunnel test method and test conditions, as shown in Figure 7.

- The test is conducted in the wind tunnel lab.
- The antenna is vertically installed on the pole with a mechanical downtilt of 0°. The diameter of the pole is 60 mm to 100 mm.
- The distance between the bottom of the antenna and the ground of the wind tunnel must be greater than the maximum value between the antenna width and thickness. If both the width and thickness of the antenna are less than 300 mm, the distance between the bottom of the antenna and the ground of the wind tunnel

must be greater than or equal to 300 mm.

- The test wind speed is 150 km/h. If resonance occurs, the wind speed can be reduced. The wind load corresponding to the wind speed of 150 km/h can be obtained through interpolation calculation.

Wind load calculation:
Test the wind load of the antenna mounted on a pole in the wind tunnel environment, including the front-side and lateral-side wind load. When calculating the wind load on the front side of the antenna, subtract the wind load of the part of the pole protruding from the antenna. When calculating the wind load on the lateral side of the antenna, subtract the wind load of the entire pole from the total wind load.

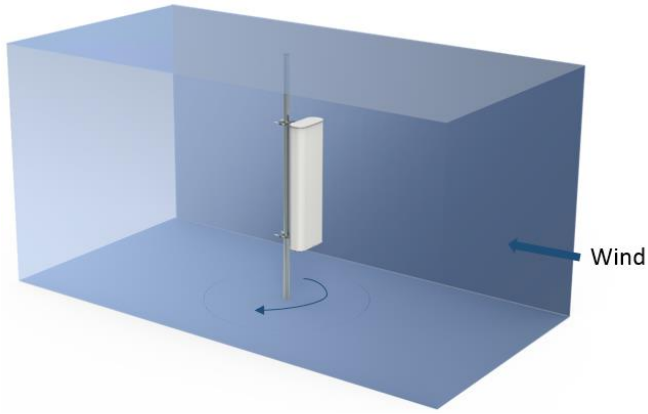
The drag coefficient of the antenna with the corresponding length can be calculated based on the wind load measured through the wind tunnel test. The drag coefficient and wind load of antennas with different lengths can be calculated by multiplying the drag coefficient by the end-effect factor. The end-effect factor can be obtained from the EN1991-1-4/TIA-222 standard.

Definition of Huawei Antenna Wind load

Huawei antenna wind load complies with the P-BASTA V11.1 standard. The wind tunnel test data is used as the basis for wind load calculation.

Wind Tunnel Test

The wind tunnel test of Huawei antennas is completed in the wind tunnel lab of Central South University (see Figure 8). The antenna is installed on a pole. The distance between the antenna bottom and the wind tunnel ground is greater than 300 mm. The test wind speed is 150 km/h. The pole can rotate freely with the wind tunnel rotating tray in the 0–360° range. Because the antenna adopts a symmetric structure, the test angle is 0–180°. Perform a test and record data every 5°/10°, as shown in the following figure.



Measure the wind load of the antenna and pole through the wind tunnel test.

$$F_w = F_{antenna} + F_{mast}$$

In any angle of the antenna rotation, the pole that exceeds the antenna length is not shielded and the wind load can be subtracted. Therefore, the wind load and drag coefficient of the wind tunnel test cover only the pole with the same length as the antenna against the rear of the antenna.

The drag coefficient of the wind tunnel test is calculated using the following formula:

$$C_d = \frac{F_w}{\frac{1}{2} * \rho * V^2 * A_{Antenna}}$$

In the wind tunnel test, antennas with different profiles are selected. The test results show that the drag coefficient of the antenna varies sharply with the profiles.

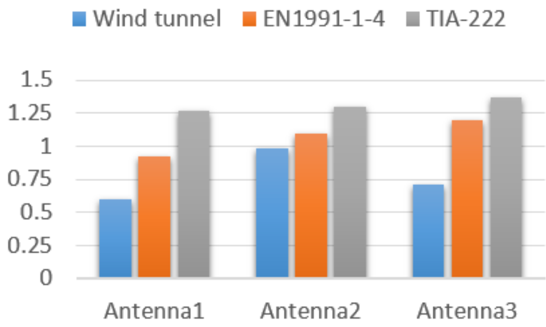
Figure 8 Antenna wind tunnel test in Central South University

The drag coefficient of the antennas with similar profile shapes is similar.

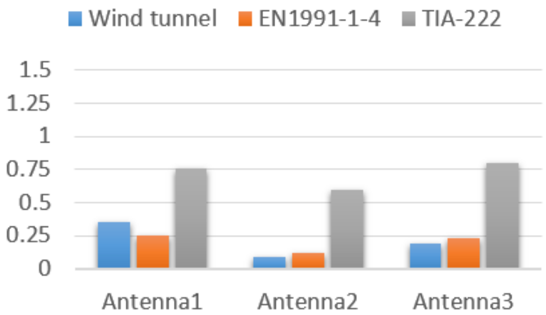
Figure 9 and Figure 10 show the drag coefficients of the antennas with the ratios of thickness to width equal of 0.44 and 0.26, respectively in the wind tunnel test.

The wind tunnel test result is different from the standardized calculation result. The following figure compares the test results of three antennas when wind tunnel tests, EN1991-1-4, and TIA-222 are used.

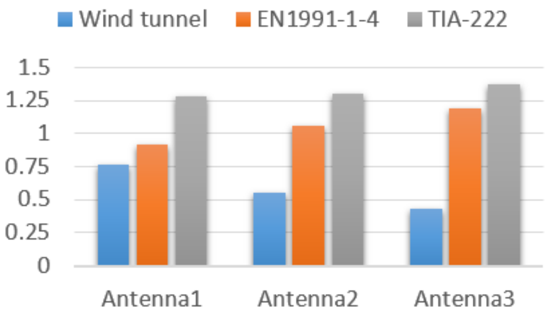
Comparison of the drag coefficients on the front side of the antennas:



Comparison of the drag coefficients on the lateral side of the antennas:



Comparison of the drag coefficients on the rear of the antennas:



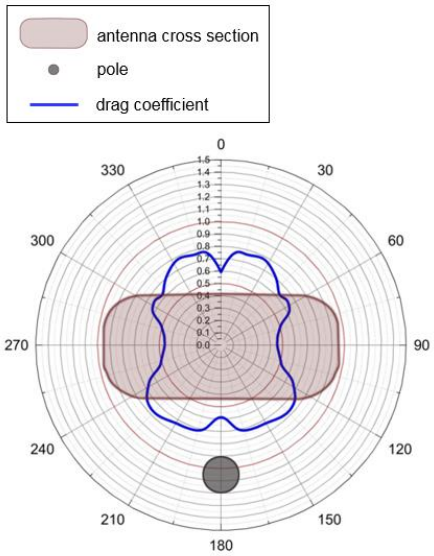


Figure 9 Drag coefficient of the antenna with the ratio of thickness to width of 0.44

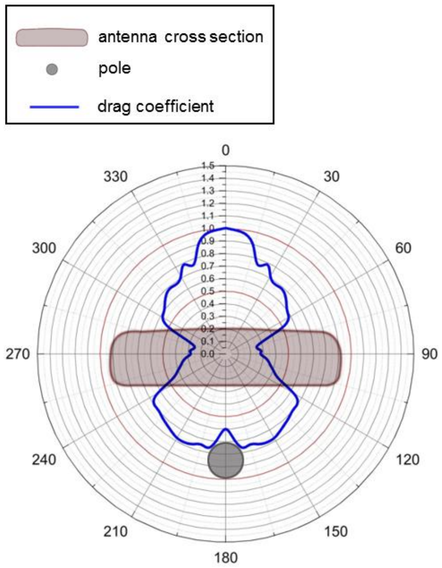


Figure 10 Drag coefficient of the antenna with the ratio of thickness to width of 0.26

Note: The data in the figure covers poles with the same length as the antenna in all angles. The projection area used to calculate the drag coefficient is selected based on the front projection area of the antenna (antenna length x antenna width).

Wind load Calculation and Datasheet Claimed Value

The Huawei antenna product datasheet provides the front-side, lateral-side, and maximum wind load values at the wind speed of 150 km/h.
The front and lateral are defined and calculated based on APPENDIX F in *NGMN-P-BASTA Recommendation on Base Station Antenna Standards V11.1.* The maximum value is closely related to the installation scenario. Huawei defines the maximum value based on the specific environment of the wind tunnel test.

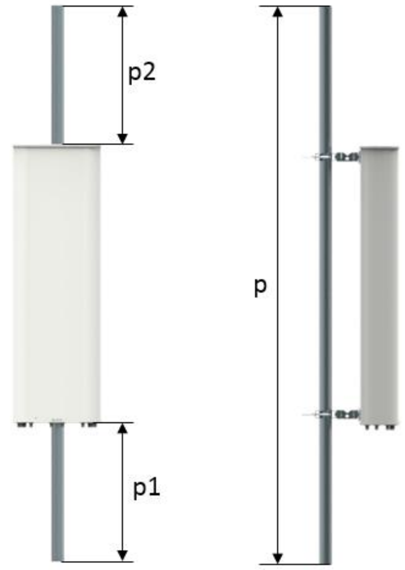


Figure 11 Subtracting the wind load of the pole

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. Therefore, the front-side wind load equals the total wind load minus the wind load of the pole part beyond the antenna.

Lateral-side wind load $F_{lateral}$

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

On the lateral side, because the pole is not shielded by the antenna, the proportion of wind load of the pole is large. Therefore, the wind load of the entire pole needs to be subtracted to obtain the wind load of the antenna on the lateral side.

Maximum wind load $F_{maximal}$

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

When the antenna shape is different, the maximum value may be at any angle. In this case, the antenna is strongly coupled with the pole. The wind load of the pole on the rear of the antenna is changed and cannot be accurately calculated and removed.
Therefore, the maximum value is equal to the

maximum value of the wind tunnel test minus the wind load of the pole part beyond the antenna.

Wind load of antennas with the same profile but different lengths

If the wind load F_{w_L1} of an antenna (length: L1) is obtained through the wind tunnel test, the drag coefficient $C_{d\_profile}$ of the antenna can be calculated based on the end-effect factor Ψ_λ according to the EN1991-1-4 standard.

$$C_{d\_L1} = \frac{F_{w\_L1}}{\frac{1}{2}\rho v^2 * A_{L1}}$$

$$C_{d\_profile} = \frac{C_{d\_L1}}{\Psi_{\lambda\_L1}}$$

For antennas with the same profile and different lengths (indicated by L2), the wind load F_{w_L2} is calculated using the following formula:

$$F_{w\_L2} = C_{d\_profile} * \Psi_{\lambda\_L2} * \frac{1}{2}\rho v^2 * A_{L2}$$

The method as shown in Figure 12 is used for Ψ_λ calculation.

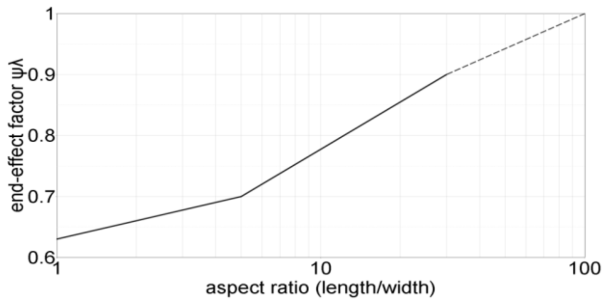


Figure 12 End-effect factor

Remarks on the Wind load in the Datasheet

1. Wind load and its changes

Complies with P-BASTA V11.1. The wind load in Huawei antenna datasheet refers to the drag force at the wind speed of 150 km/h. Drag force refers to the force along the wind direction.
The wind load measured through the wind tunnel tests is less than that calculated according to the EN1991-1-4 or TIA-222 standard.

2. The wind load of the antenna rear is no longer considered.

Due to the influence of the pole, the wind load at the rear of Huawei's antennas with various profiles is lower than that on the front side. Therefore, the wind load on the rear-side is not reflected. If necessary, the load can be evaluated based on the load of the front side. The P-BASTA V11.1 standard also cancels the rear-side value.

3. Treatment of wind load on the lateral side of the antenna

On the lateral side, the pole is completely exposed. The proportion of the projection area of the pole to the entire projection area is large. That is, the proportion of the wind load of the pole is large (see Figure 13). Therefore, the lateral-side wind load in the datasheet is calculated by subtracting the wind load of the entire pole.

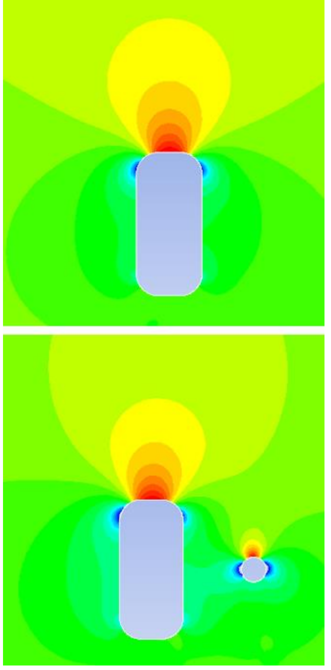


Figure 13 Impact of the pole on the lateral-side wind load

4. Maximum Value

The maximum wind load of antennas is not necessarily at front-side or rear-side. Instead, it may be at a scope of 0° to 90° or 90° to 180°. The maximum wind load in the wind tunnel test is greatly affected by the pole. In the angle of the maximum value, the coupling of the flow with the antenna and pole is too strong.as shown in Figure 14. This coupling brings the load enhancement effect. The coupling effect varies according to wind tunnel environments and poles, and the test results may be different. The maximum value of Huawei antenna datasheet is based on the wind load in a specific wind tunnel test environment.

In actual applications, antennas are installed on poles with various lengths and diameters. In most cases, multiple antennas are installed on the same pole, which also bears cables, RRUs, and other devices. As a result, the wind flow field of the antenna is totally different, and the maximum wind load of the antenna is different. Therefore, the maximum value under a specific condition in datasheet is used as a reference only in actual applications.

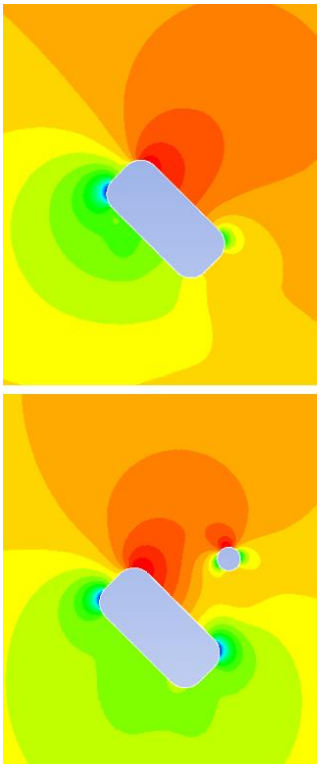


Figure 14 Impact of the pole on the maximum wind load

Design and Research of Reduced Wind load of Huawei Antennas

Huawei has made great efforts in reducing antenna wind load design, made in-depth research on antenna size and modeling design, and applied these achievements to the radome structure design. Due to these achievements, Huawei antennas are characterized in low wind load. However, research on wind load changes in different installation and testing environments is not enough.

In the coming 5G era, antenna applications and installation scenarios will be more complex. Huawei will continue to study the coupling effect of antennas, installation scenarios, and poles, and participate in the P-BASTA organization to improve and formulate more comprehensive and practical engineering standards.

Antenna Wind Load Engineering Application

The wind load in the antenna datasheet is measured per antenna at the specified wind speed of 150 km/h. In actual conditions, antennas are installed in various environments. For example, multiple antennas are installed on a pole, or an RRU or a combiner is installed, which affects the wind load of the antennas.

In addition, the wind load in the datasheet is measured and calculated at the stable wind speed. In the actual natural environment, the wind is random and pulsating, and its behavior is complex. In different geographical locations, heights, and surrounding environments, the performance of the wind is also different. The vibration of the tower or pole also generates a dynamic coupling effect. Therefore, site engineers need to further calculate the wind load according to the local tower engineering specifications. Therefore, in engineering application, the wind load in the antenna datasheet can be used only as the initial guidance data. Site engineers should perform systematic analysis and calculation according to specific application scenarios to determine and evaluate the wind load of the entire system.

Conclusion

1. The wind load measured in the wind tunnel test is less than that calculated according to the EN/TIA standard.
2. The maximum wind load is related to different poles and installation environments and its value varies with different conditions. Huawei provides the maximum drag force in a specific wind tunnel environment for reference.
3. The wind tunnel test is used to obtain the wind load performance of a single antenna. However, in actual applications, the wind behavior and installation environment are more complex than those in the wind tunnel. Therefore, further analysis is required by site engineers.
4. With the antenna shape design, Huawei antennas have excellent wind load performance. Huawei will continue to invest in research in reducing the antenna wind load on poles and towers in various installation scenarios.

Appendix

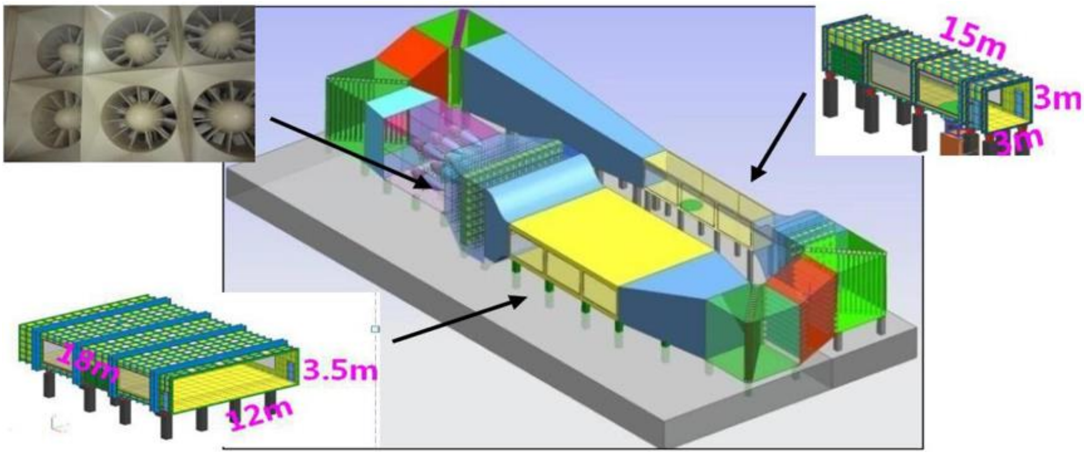
Introduction to the Wind Tunnel Laboratory of Central South University

CSU-1 wind tunnel lab belongs to the National Engineering Laboratory for High-speed Railway Construction. Its flow field calibration and acceptance were completed in June 2012. CSU-1 wind tunnel is a close-circuit atmospheric boundary layer wind tunnel with two test sections.

The first test section (high-speed section) is 3.0 m wide, 3.0 m high and 15.0 m long, with the wind speed ranging from 0 m/s to 94 m/s, turbulence intensity less than 0.3%, non-uniformity of the velocity field less than 0.5%, yaw angle/inclined angle less than 0.5°, coefficient of dynamic pressure stability less than 0.6%, and axial static pressure gradient less than 0.0005/m. The second test section (low-speed section) is 12.0 m wide, 3.5 m high, and 18.0 m long, with the wind speed ranging from 0 ms to 20 m/s, turbulence intensity less than 0.8%, non-uniformity of the velocity field less than 2%, yaw angle/inclined angle less than 1°, coefficient of dynamic pressure stability less than 0.1%, and axial static pressure gradient less than 0.007/m. The wind tunnel has a full-steel structure. CSU-1 wind tunnel is characterized by its large-scale test sections, high design wind speed, and high flow quality and is suitable for the experiments for bridge wind engineering, train aerodynamic, structure wind engineering and wind environment.

Address: 22 Shao-shan south road, Changsha, Hunan, China

Website: http://www.windcsu.org



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