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**Environmental Engineering (EE);
Analysis of test method and test severity for
mechanical test of equipment installed on poles/towers**

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Foreword

This Technical Report (TR) has been produced by ETSI Technical Committee Environmental Engineering (EE).

The present document applies to all telecommunications equipment installed on communication tower.

Modal verbs terminology

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1 Scope

The present document is intended to provide suggestions on how to set vibration specification for telecommunication equipment installed on towers.

2 References

2.1 Normative references

Normative references are not applicable in the present document.

2.2 Informative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

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The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

[i.1] ETSI EN 300 019-1-4: "Environmental Engineering (EE); Environmental conditions and environmental tests for telecommunications equipment; Part 1-4: Classification of environmental conditions; Stationary use at non-weather protected locations".

[i.2] IEC 60068-2-6: "Environmental testing - Part 2-6: Tests-Test Fc: Vibration (sinusoidal)".

[i.3] IEC 60721-3-4: "Classification of environmental conditions-Part 3: Classification of groups of environmental parameters and their severities-Section4:Stationary use at non-weather protected locations".

[i.4] High-Rise Buildings under Multi-Hazard Environment: "Assessment and Design for Optimal Performance", Authors: Huang, Mingfeng.

[i.5] ETSI EN 300 019-2-4: "Environmental Engineering (EE); Environmental conditions and environmental tests for telecommunications equipment; Part 2-4: Specification of environmental tests; Stationary use at non-weather protected locations".

3 Definition of terms, symbols and abbreviations

3.1 Terms

Void.

3.2 Symbols

For the purposes of the present document, the following symbols apply:

g gravity acceleration (m/s^2)
grms root mean square of g

3.3 Abbreviations

For the purposes of the present document, the following abbreviations apply:

FFT	Fast Fourier Transform Algorithm method
PSD	Power Spectral Density

4 Historical vibration specification review

The original mechanical test specifications are given in table 5 contained in ETSI EN 300 019-2-4 V2.4.1 [i.5].

The test severity is chosen based on IEC 60721-3-4 [i.3]. 4M3 and 4M5 is defined as follows in IEC 60721-3-4 [i.3]:

- 4M1, 4M2: 4M1 and 4M2 apply to locations which are protected from significant vibration and shock.
- 4M3: In addition to the conditions covered by 4M1 and 4M2, 4M3 applies to locations which are protected from significant vibrations, but may receive some transmitted shock, for instance from local blasting or pile-driving activities.
- 4M4: In addition to the condition covered by 4M3, 44M4 applies to locations where transmitted vibration from machines or passing vehicles is experienced.
- 4M5: In addition to the conditions covered by 4M4; 4M5 applies to locations where higher level shock may be experienced, for instance from adjacent machines or conveyor belts.

It is clearly stated that different levels are based on whether there is a certain amount of vibration or shock event around installation location.

The classification is relatively rough since it does not include the special case during which base station antenna is mounted on the tower.

In the case when the antenna (either passive or active antenna) is mounted on tower, if an adjacent machine or equipment make significant vibration/shock response, very small portion of vibration or shock event would be transmitted to the antenna as the tower is relatively big and would absorb most of the vibration or shock event on it.

On the other hand, when wind forces are acting on the tower, the wind would drive the tower into vibration. The vibration response of the antenna is mainly decided by the stiffness of the base station tower and wind speed. Also the higher the wind speed, the higher vibration level the antenna would go through.

As indicated in ETSI EN 300 019-1-4 [i.1], the severities specified are those which will have a low probability of being exceeded; generally less than 1 %. Also the vibration test specification listed in ETSI EN 300 019-2-4 [i.5] should cover the vibration requirement when the tower mounted antenna is subjected to a wind speed of 50 m/s.

Clause 5 provides an example of how to get the response on the base station antenna under wind force. The vibration standard of base station antenna can be deduced based on the acquired data.

5 Vibration response investigation for antennas mounted on tower

5.1 Strategy for vibration response investigation

It would be quite straight that the vibration response under 50 m/s should be derivated in following two ways:

- Data acquisition: Mount a multi-axis accelerometer on the mounting location of the antenna. Record the vibration response continuously. In case the wind speed exceeds 50 m/s on the tower, analyse the vibration response and thus the response can be the test specification of base station antenna.

- Derivation: 50 m/s is a very high wind speed that it is unlikely to occur under most circumstances. Thus, the derivation of the vibration response from low wind speed to high wind speed would be very important. The derivation process follows a certain rule which is decided by different wind speed spectrum. The wind speed spectrum include Davenport [i.4] or Harris spectrum which can be decided by normal usage.

5.2 Data acquisition

5.2.1 Introduction

This clause describes the test setup of data acquisition and the final vibration response.

5.2.2 Acquisition location

In order to get the response of the antenna under high wind speed, a location with high wind speed should be chosen. According to the wind distribution in China, Hami City in XinJiang province has the highest average wind speed annually. The average wind speed in August is 10,5 m/s from the year 2003 to ~2011 and it is a very good location for relatively high wind speed observation. Thus, Hami city is chosen for data acquisition this time.

It is also suggested that the location which did not have the highest average wind speed but have a big chance of hurricane such as YangJiang City in Guangdong Province can be chosen for long time data acquisition.

5.2.3 Acquisition setup

Data acquisition is realized using a data recorder device able to register the acceleration data. The recorder has a three-axis accelerometer inside. It records the data in a single event. The triggered gravity level is 0,2 g, and the sampling frequency is 2 560 Hz. Thus, in a case where the vibration level is higher than 0,2 g, the recorder would record the event for 1 second. The FFT can transform the data from time domain to frequency domain with 1 000 Hz upper frequency.

It is also suggested that continuous vibration data acquisition is used. In this case cables used for power and vibration data should be placed on the tower and a computer should be put in the central room under the tower.

5.2.4 Choice of Tower and mounting location

There are basically three types of towers in the world including single-pole tower, self-supporting tower and guyed steel mast. Self-supporting tower can be divided between triangular lattice tower and rectangle lattice tower. The tower height may range from 20 m to 100 m. The choice of the tower is basically based on the historical maximum wind speed and total amount of equipment mounted on the tower. In this case, a triangular lattice tower of 60 m high is chosen as representative to conduct vibration response acquisition.

As stated in IEC 60068-2-6 [i.2], during vibration test, the deviation of vibration response between fix point and test specification is clearly specified. Thus, in order to define a test specification, the recorder should be close to the fix point of the equipment. In this case, the recorder should be mounted close to the mounting bracket of the antenna (see figure 1).

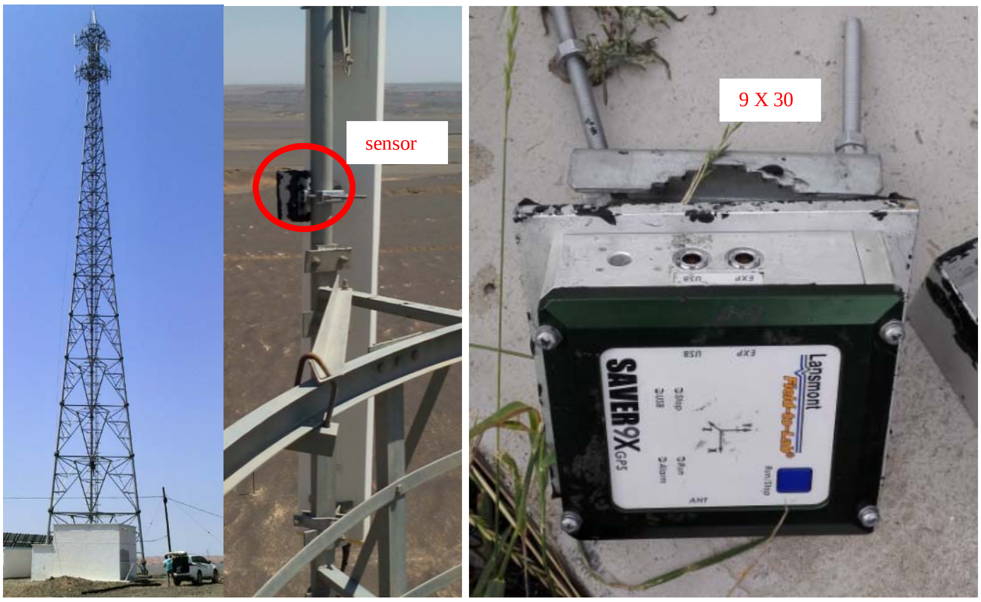

Figure 1: 60 m triangular lattice tower and mounting location

5.2.5 Vibration data

The acquisition was conducted from August to September in Hami city. The highest wind speed is 30 m/s and the vibration response of three axis is listed in figure 2.

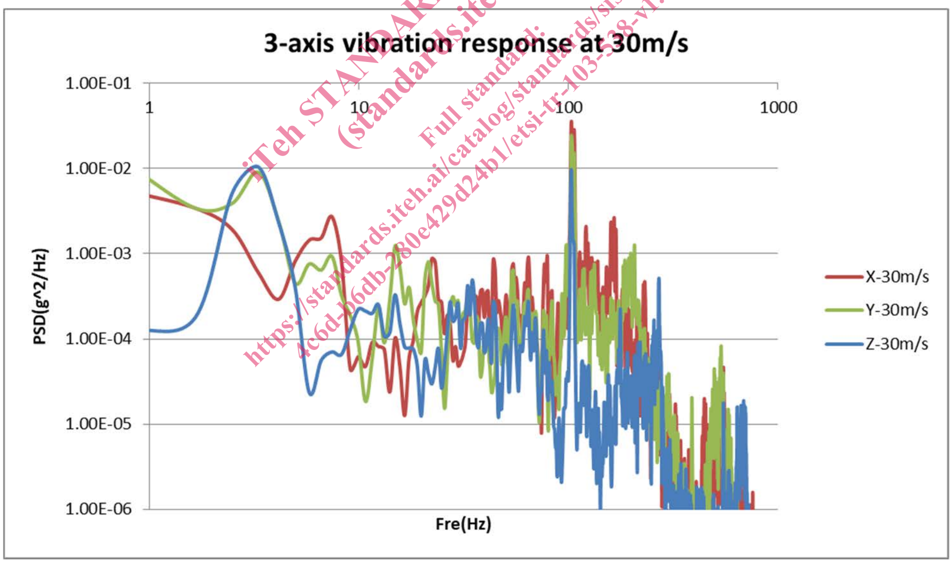

Figure 2: Vibration response of mounting location on a 60 m triangular lattice tower

The grms values in the three directions are:

- 0,45 grms in X;
- 0,39 grms in Y; and
- 0,22 grms in Z.

5.3 Derivation of vibration response

The vibration response of the tower is decided by the frequency response function of the tower and the excitation spectrum caused by wind. Regarding the wind spectrum, Davenport spectrum [i.4] is used for the derivation of vibration response from low wind speed to 50 m/s.

The formula of the Davenport spectrum is as follows:

$$S_v(n) = 4k\overline{v_{10}}^2 \frac{x^2}{n(1+x^2)^{4/3}}$$

where:

$S_v(n)$ is pulsing wind speed power spectrum,n is pulsing wind frequency;

x = 1 200 n/ v_{10};

v_{10} is the average wind speed at a height of 10 m;

k is the surface roughness factor.

Considering the relation between wind force and wind speed, the ratio of two pulsing wind force spectrum is roughly the power of 8/3 of the ratio of the wind speed.

In this case, the vibration response of 50 m/s can be derivated in following ways as described in figure 3.

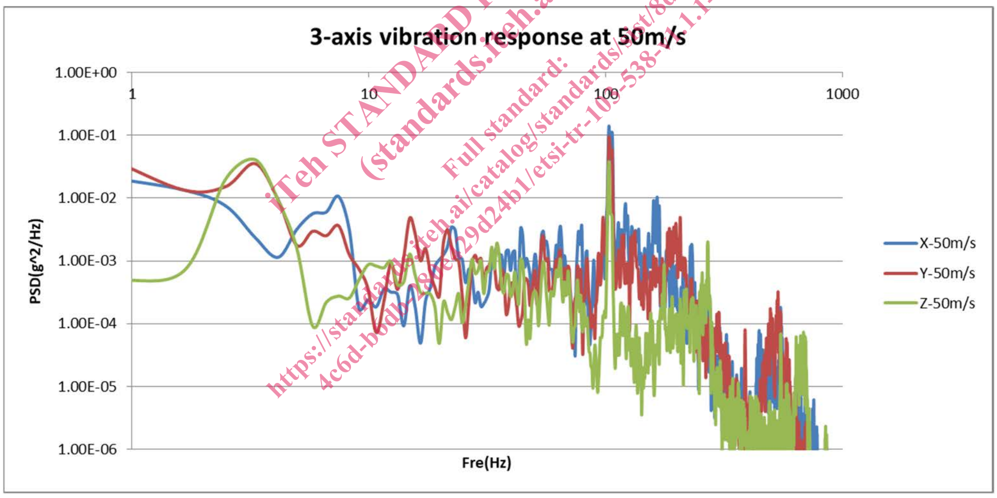

Figure 3: Deduced vibration response of 50 m/s

The grms values in the three directions are:

- 0,88 grms in X;
- 0,77 grms in Y; and
- 0,43 grms in Z.