ICWE 16
August 27-31, 2023
FLORENCE - ITALY
16th International Conference on Wind Engineering

Practical wind load approaches for antennas of different technical generations

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SUMMARY:
The economic and safe dimensioning of structures equipped with radio antennas (towers, masts, or radio poles) requires precise knowledge of the wind load on the attached antennas. The determination of the wind loads by the manufacturers is not harmonised and therefore does not necessarily correspond to the rules required in building codes. For this reason, all major German mobile operators have expressed interest in realistic wind load assumptions. This article presents a method with which the wind load of common antennas with supporting tubes behind it can be evaluated according to the construction safety concept. New and existing antennas and their supporting structures can thus be uniformly evaluated.

Keywords: wind load on antenna, radio tower, radio pole on roof

1. INTRODUCTION

The technical developments in communications, business and mobility (Internet of Things, autonomous driving, Agriculture 4.0, etc.) require the transmission of higher data volumes thru the mobile network. The used data protocols (e.g., 5G generation) also needs new transmission technologies as well as a higher number of transmission systems (e.g. transmitting antenna). It is predicted that the exponential increase in data volume is not finished yet (Bundesministerium für Verkehr und digitale Infrastruktur 2017).

Figure 1. Example of antenna support on a roof.

The wind load for the necessary antennas is decisive for the structural design. Usually, the aerodynamic coefficients are taken from the data sheets of the antenna manufacturers. However, it turned out that these values were not sufficiently documented. Thus, the coefficients could not be further evaluated since no transparent publication of the underlying procedures was available. Furthermore, wind load data for similar geometries but from different manufacturers were quite different. For this reason, we were asked by the working group “Antennenlasten” of the “Fachverband Mobilfunkbau e.V.” to develop uniform and practicable design rules for wind load estimation on antennas based on wind tunnel tests.

2. INVESTIGATED ANTENNA GEOMETRIES

The antennas considered here are built as elongated components with a uniform cross-section and are attached to a circular hollow section behind them via clamps. The cross-sections are usually rounded rectangles, which is why Reynolds effects could occur. Antennas are products of different manufacturers with different technical requirements - so, several hundreds of antenna types exist on the market (DFMG, Vodafone, Telefonica 2018). Therefore, a strategy was developed to reduce the number of measurements. The cross sections shown in Figure 2 (right) were selected in cooperation with the major mobile network operators and identified as representative geometrical groups. Figure 2 also illustrates a typical antenna body in isometric view and its cross section (left).

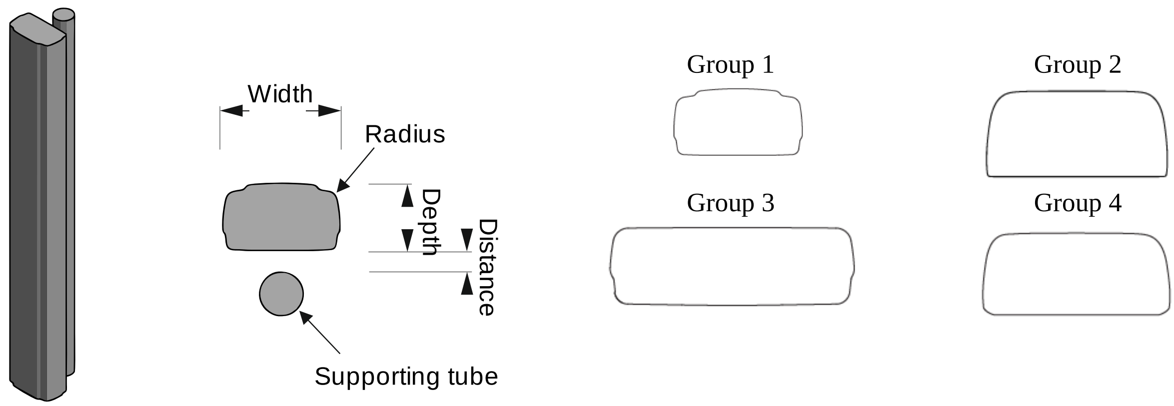

Figure 2. Example of an antenna (left) and investigated cross-sections (right).

3. WIND TUNNEL INVESTIGATIONS

3.1. Exemplary results

To investigate the influence of a holding tube, an original antenna from the company *Kathrein* was measured in the wind tunnel with and without the tube. *Kathrein* has already published wind tunnel tests for this cross-section (KATHREIN-Werke KG 2017), so that these results could be compared directly with their own tests (see Figure 3).

In the case of frontal flow direction, the force coefficients of the antenna with and without a holding tube are almost identical. Due to the normalization to the frontal surface, the force coefficients are greater from lateral directions with a holding tube than without a holding tube, since the inflow area is increased. For wind from the back, the force coefficients are lower compared to results without a holding tube.

The results of the tests without the holding tube agree well with the results from *Kathrein*. The deviations of the frontal force coefficient at 0° are due to the different test wind speeds. The "Kathrein tests" were carried out at a wind speed of approx. 42 m/s; the "RWTH-tests" at a wind speed of approx. 16 m/s. It was found that Reynolds effects occurs only for frontal flow at 0°.

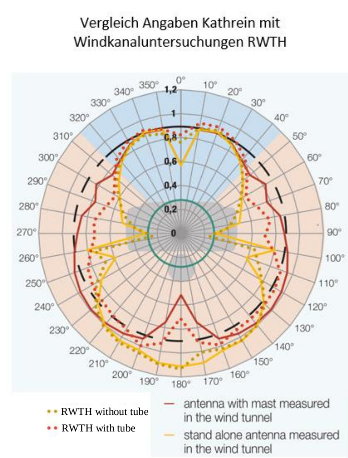

Figure 3. Mean force coeff. according to wind tunnel tests at the RWTH-Aachen and published by (KATHREIN-Werke KG 2017).

4. SIMPLIFIED WIND LOAD APPROACH

4.1. Mathematical description

One target of the experiments is to develop an easy-to-use load approach which is suitable to cover a wide range of antennas geometries. For practical implementation, a load approach according to (DIN EN 1991-1-4) is useful. Based on the assumption that the total force of the composite cross-section of the antenna and the holding tube can be determined according to the incident partial area surfaces and the associated force coefficient of the partial cross-section, a force coefficient $c_{f,R+Kr}$ weighted according to the reference areas is defined:

$$c_{f,R+Kr}(\alpha) = \frac{c_{f,R}(\alpha, A_R(\alpha)) \cdot A_R(\alpha) + c_{f,Kr}(\alpha, A_{Kr}(\alpha)) \cdot A_{Kr}(\alpha)}{A_{ref}} \quad (1)$$

where:

- $c_{f,R}$ force coeff. of rectangular sections with rounded corners acc. to (DIN EN 1991-1-4)
- α angle of attack
- A_R projected area of rectangular section
- $c_{f,Kr}$ force coefficient of circular section according to (DIN EN 1991-1-4)
- A_{Kr} projected area of circular section
- A_{ref} reference area (here: width of antenna)

For each angle of attack, the projected subareas must be determined in such way, that the shading of the respective object is considered for each flow direction. Besides the direction-dependent projected areas, knowledge of the force coefficients, which are also direction-dependent, is necessary and has been determined in wind tunnel tests for a rectangular section with rounded edges. Figure 4 shows that the determined equation (2) agrees well with experimental results.

$$c_{f,R}(\alpha) = c_{f,R,frontal/rear} \cdot |\cos(\alpha)| + c_{f,R,lateral} \cdot |\sin(\alpha)| \quad (2)$$

where:

- $c_{f,R,frontal,rear}$ force coefficient of a rectangle with frontal ($\alpha < 90$) or rear flow ($90 < \alpha < 180$) according to (DIN EN 1991-1-4)
- $c_{f,R,lateral}$ force coefficient of a rectangle with lateral flow according to (DIN EN 1991-1-4)

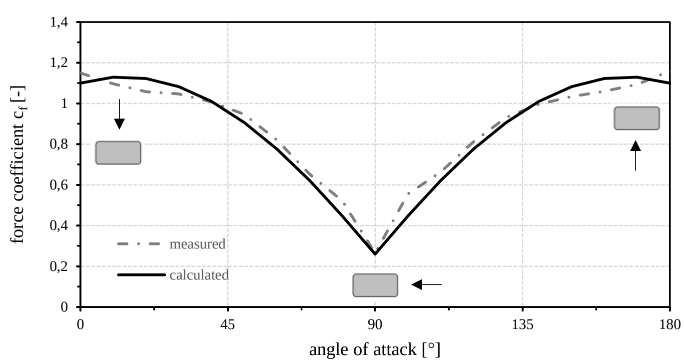

Figure 4. Force coefficients of a rectangular section with rounded corners: measured vs numerical

4.1. Comparison with wind tunnel tests

Figure 5 compares exemplarily two results of the analytic approach (Eq.1) with the wind tunnel results for different cross sections.

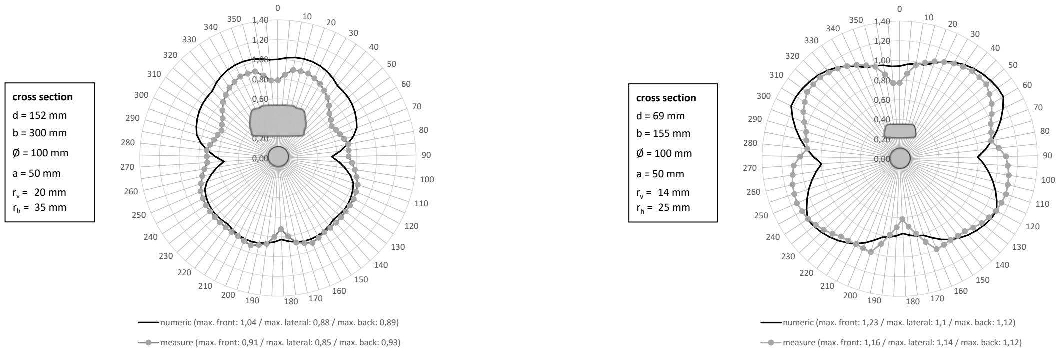

Figure 5. Force coefficients of a rectangular section with rounded corners: measured and numerical

A total of approx. 20 antennas from all four cross-sections groups (see fig. 2) were measured. The comparison of the measurement with the analytical approach shows that the curves of the force coefficients are comparable. The deviations for all angles of attack are usually smaller than 20%. The deviation is at its maximum at lateral direction. This is probably due to the row arrangement of the two bodies. For the structural analysis, it makes sense to specify the wind loads only for the three main directions. For these directions, the maximum deviation is about 15%, which is a reasonably accurate agreement for designing practice.

5. CONCLUSION

Despite similar geometries, different manufacturers of antennas have given significantly different wind load assumptions. Therefore, a series of wind tunnel experiments on many transmitting antennas were carried out. Based on the investigations a simple, transparent and standardized method for determining the wind loads on individual antennas with holding tubes was developed. Since the approach allows the wind load estimation of all investigated geometries, the safe side deviation is reasonably accurate for design practice.

ACKNOWLEDGEMENTS

The authors sincerely thank the "*Fachverband Mobilfunktechnik e.V.*" for sponsoring the investigations and for the technical exchange within the framework of the Antenna Loads Working Group.

REFERENCES

DIN EN 1991-1-4, Dezember 2012: Allgemeine Einwirkungen, Windlasten.

Bundesministerium für Verkehr und digitale Infrastruktur (2017): 5G-Strategie für Deutschland. Edited by BMVI. Available online at https://www.bmvi.de/SharedDocs/DE/Publikationen/DG/098-dobrindt-5g-strategie.pdf?__blob=publicationFile.

DFMG, Vodafone, Telefonica (2018): Interne Dokumente über die Art und Anzahl an verbauten Sendeantennen weltweit und in der Bundesrepublick Deutschland to RWTH-Aachen, 2018.

KATHREIN-Werke KG (2017): Base station antennas - reliable wind load calculation. White Paper. Edited by KATHREIN-Werke KG. Available online at https://www.kathrein.com/de/loesungen/mobilfunk/support/technische-dokumente/windlast/.