Mechanical-electrical Coupling Analysis of Vertical Cage Antenna Electrical Performance under Multi-wind Direction Wind Loads

LONGJUN ZHOU, ZHENJI LIU, XIAOBO SHOU, LIANG YANG, LING WANG, ZELIN XIONG

Wuhan Maritime Communication Research Institute

Abstract

The complex weather environment has an important influence on the structural deformation and electrical performance of the vertical cage antenna. In this paper, a mechanical-electrical coupling analysis method is proposed to analyze the nonlinear response of the vertical cage antenna under multi-wind direction wind loads. The nonlinear finite element method is used to analyze the structure of the vertical cage antenna under the multi-wind direction wind loads. Based on the geometric model of the deformed vertical cage antenna, the electrical performance of the antenna is analyzed by the method of moments. The import impedance and the VSWR of the vertical cage antenna under multi-wind direction wind loads are calculated.

Keywords

Multi-wind direction, Wind load, Mechanical-electrical coupling analysis

Introduction

Vertical cage antennas are blind-free antennas with excellent radiation characteristics such as wide frequency band, omnidirectional in the horizontal plane, and low elevation angle in the vertical plane, which are widely used in the field of shortwave transmission or reception [1]. Vertical cage antennas often use flexible cable structure materials to make the element and the stay wire, this lightweight flexible cable structure will produce large displacement under the effect of wind load and other complex weather environments, and then affect its electrical performance. Therefore, it is necessary to study the electrical performance of vertical cage antennas under multi-wind direction wind loads.

This paper proposes a mechanical-electrical coupling analysis method for the nonlinear response of the vertical cage antenna under multi-wind direction wind loads.

Introduction Of Vertical Cage Antenna

The vertical cage antenna is mainly composed of elements, upper ring, lower ring, crossbars, diagonal bars, mast, stay wires, base insulator, and lightning rod, as shown in Fig. 1.

The main dimensions of the vertical cage antenna are shown in Fig. 2.

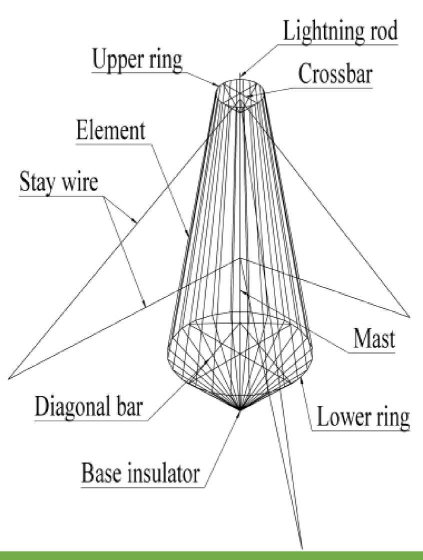

Fig.1

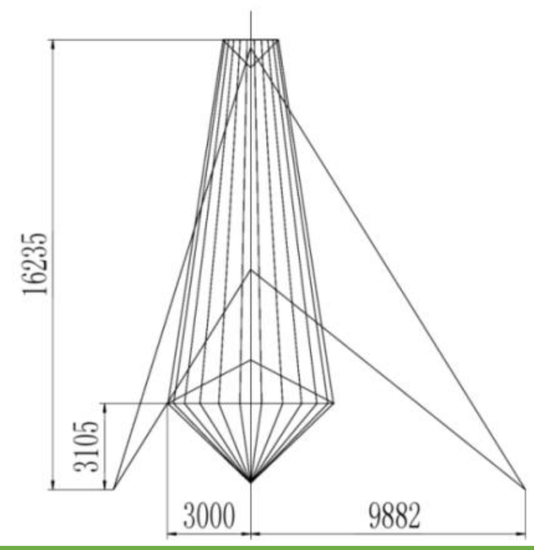

Fig.2

Mechanical-electrical Coupling Analysis Method

Firstly, the vertical cage antenna is discretized into several structural elements, and the geometric nonlinearity theory is applied, and a nonlinear system of equations with nodal displacement as the unknown quantity is established, which is solved by using the Newton-Raphson algorithm method combined with boundary conditions [2]. The ANSYS uses the Updated Lagrange column method to obtain the element nonlinear stiffness matrix [3].

The nodal displacements can be obtained after the solution is completed in ANSYS, and the deformed finite element model can be obtained after updating with the UPGEOM command.

The electrical performance is analyzed using the method of moments. The method of moments is a method of discretizing a continuous equation into an algebraic system of equations. The integral equation to be solved is written as an operator equation with the integral operator, the function to be solved is expressed as a linear combination of basis functions and brought into the operator equation, and the resulting equation is taken as the momenta with the weight function to obtain the algebraic system of equations, and the results are obtained by numerical calculation [4]

Structural Analysis

When dividing the mesh, the Link180 element is selected to simulate the elements and the stay wires, and the Link180 element is set to be subjected to tension only; the Beam189 element is selected to simulate the mast and other parts [5].

The angle between the wind direction and the vertical cage antenna is shown in Fig. 3.

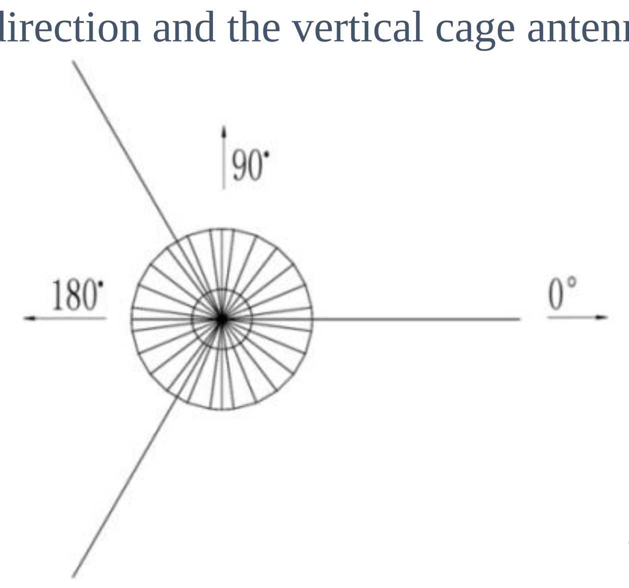

Fig.3

This paper is calculated with the effect of wind force scale 14 (43.8m/s). After calculation, under the action of 0-degree wind angle, the displacement of the antenna element is the largest. The maximum displacement of the antenna element under different wind angles is shown in Table I and Fig. 4.

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Wind angle（degree）	0	15	30	45
Maximum displacement of the antenna element（m）	0.6115	0.5862	0.582	0.5823
Wind angle（degree）	60	75	90	105
Maximum displacement of the antenna element（m）	0.5862	0.5958	0.6013	0.5576
Wind angle（degree）	120	135	150	165
Maximum displacement of the antenna element（m）	0.5819	0.5868	0.5891	0.5891
Wind angle（degree）	180	-	-	-
Maximum displacement of the antenna element（m）	0.5904	-	-	-

Table I

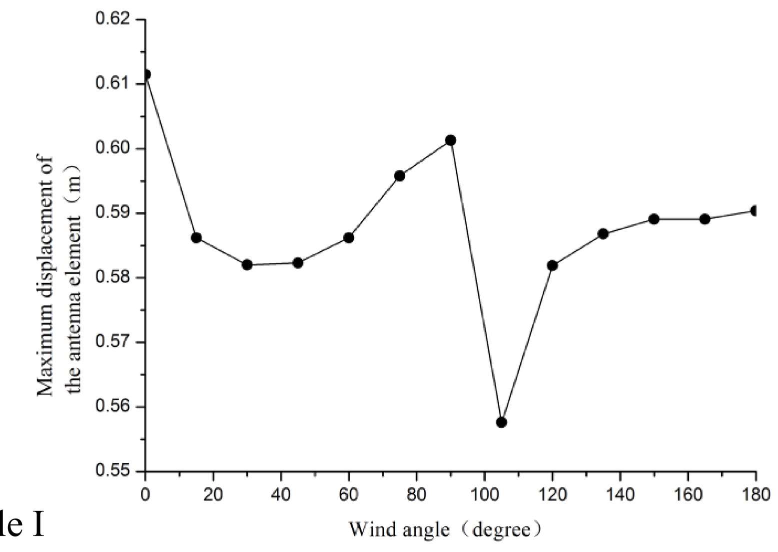

Fig.4

The maximum displacement of the vertical cage antenna is 0.6257m, which is located in the middle section of the stay wire, as shown in Figure 5.

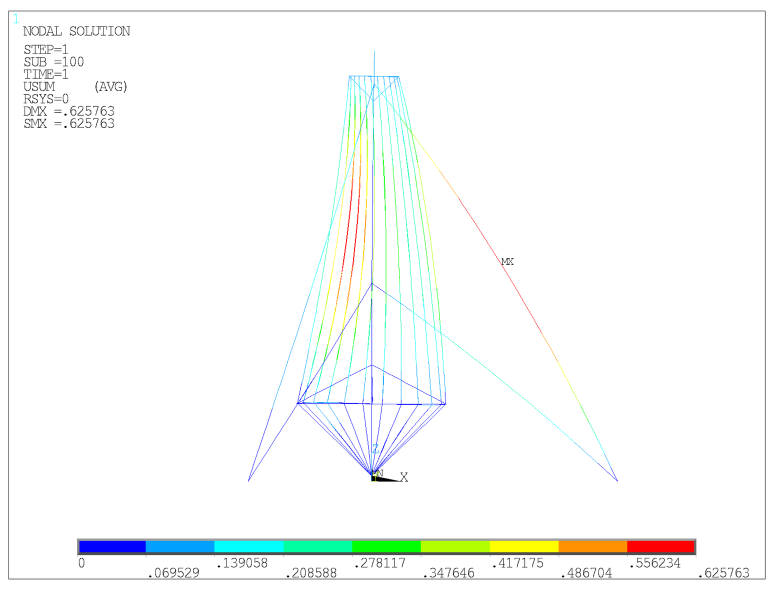

Fig.5

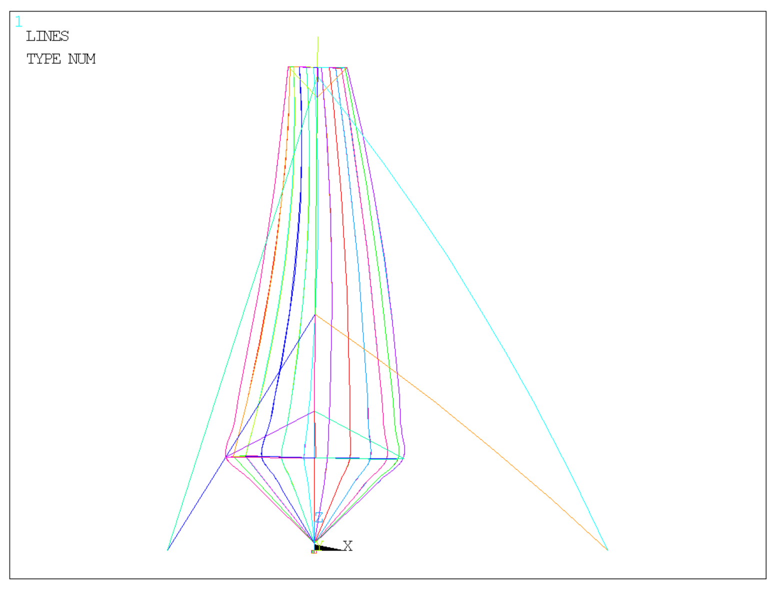

Fig.6

Reconstructing The Geometric Models

The geometric model of the vertical cage antenna exported from ANSYS software after deformation under the action of wind load is shown in Fig. 6. Since the geometric model file is used to transfer data without node and mesh information, the method of reconstructing the geometric model proposed in this paper can directly import the antenna geometric model into FEKO software without format conversion, which solves the problem of inconsistency between the antenna structural model mesh and the electrical model mesh [6].

Electrical Analysis

Based on the geometric model of the vertical cage antenna after deformation, the electrical characteristics of the antenna are analyzed. The calculation is based on the method of moments (MOM). The parameters of the electromagnetic simulation model are: the antenna elements and masts are PEC wires, the diameters of which are 4mm and 100mm. The masts and all the stay wires are insulated to the ground. The lossy ground is calculated as half-space Sommerfeld integrals, the relative permittivity of the lossy ground is 4, and the conductivity is 0.02s/m.

The import impedance of the antenna under multi-wind direction wind loads is calculated, results are shown in Fig. 7. The VSWR of the antenna is shown in Fig. 8.

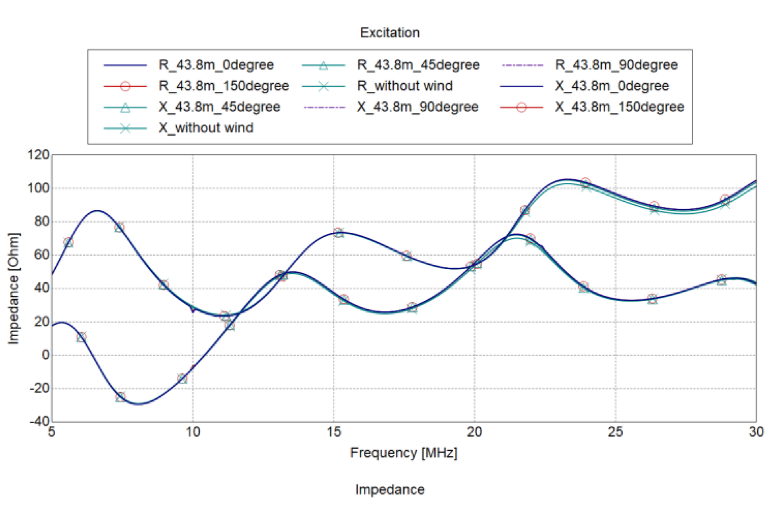

Fig.7

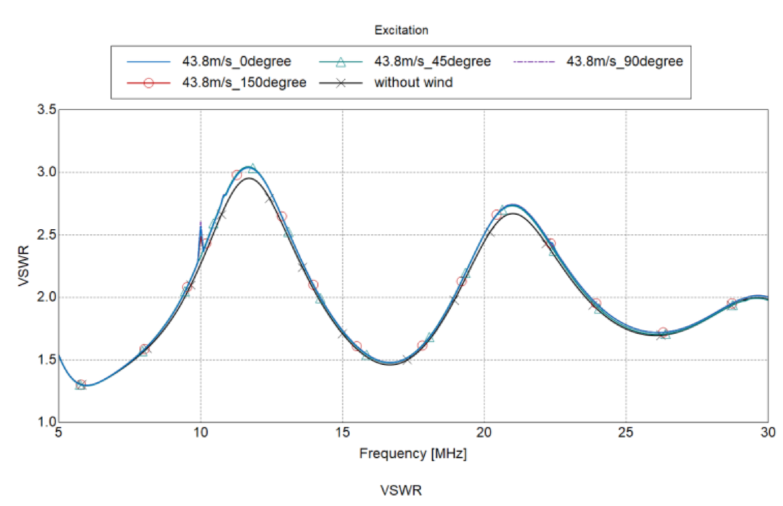

Fig.8

The calculation results show that the import impedance of the antenna with multi-wind direction wind loads changes a little. The VSWR of the antenna with multi-wind direction wind loads is 0.3 larger than the condition without wind loads.

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