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Modeling Broadband Wire Antennas with Complex Geometry

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Abstract

This paper is focused on the choice of an optimal model of broadband wire antenna with complex geometry for electromagnetic numerical simulators. Different models of antenna may be chosen and therefore different results may be obtained in different times. In case of the Bilog antenna, as a typical broadband antenna used mainly in electromagnetic interference measurement, we observed the influence of model choice on the antenna parameters results. Four different models were chosen: the model consisting of just wire elements, just surface triangle patches, their combination and CAD model. The verification of results is performed using feature selective validation method. Then the appropriate model is chosen as a compromise between the shortest simulation time and the best accuracy of simulation results.

Keywords: Broadband wire antenna; Bilog; antenna model; feature selective validation

1. Introduction

It is very difficult to analyze the problems analytically in the area of an electromagnetic field, as antenna theory or propagation of electromagnetic waves, due to unsymmetrical and inhomogeneous structures or objects [1,2]. In such case numerical simulations have become more popular. The simulation still creates an integral part of constructing and testing the devices during the process of development. Nowadays there is no general approach to the numerical modeling of antennas in rf electromagnetic field area. The computing power of current personal computers is often sufficient to simulate most problems. However simulation of complex antennas with amount of data requires specific

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demands on computer properties. Therefore it is very important to choose a rational process of creating the antenna's simulation model. Thus, the model has to copy the real problem at full, but simultaneously it cannot be demanding on computational power and the time of simulation [2].

While older numerical simulators allowed to analyze only the wire models (simple wire antennas) [3,4,5], newer ones [6,7] already allow analyzing various systems consisting of wire, surface or space elements (mostly based on various CAD systems). In this paper we will focus on the choice of the optimal model of wire antenna with complex geometry (antenna consisting not only of straight wire elements), which can be represented by the Bilog antenna. All simulations are executed by the numerical simulator FEKO [8]. The characteristic parameters of antennas are obtained and compared with each other to evaluate the properties of given models using the method of feature selective validation [9], which has been proposed as a technique allowing the objective comparison of two data sets.

Nomenclature

ADM amplitude difference measure
FDM feature difference measure
GDM global difference measure

2. Problem analysis

The analysis of the effect of model accuracy on simulation results was realized on the broadband Bilog antenna. The Bilog antenna represents a combination of a biconical antenna and a log-periodic dipole array, both used in electromagnetic interference measurements. Such an antenna consists not only of straight wire elements but also curved wires and mechanical connection of dipole elements. The log-periodic part is 785 mm long, 1660 mm wide and consists of 15 pairs of dipole elements. The scale factor and the spacing factor of the log-periodic dipole array elements are 0.855 and 0.13 (where the longest dipole element is 640 mm long). Biconical part of the antenna, a bow-tie element, has a flare angle of 37°, the triangle height is 775 mm and the feed point height is 55 mm. The Bilog antenna is intended for the frequency range from 30 MHz to 1GHz.

Numerical methods can be divided into three categories: frequency domain, time domain and eigenmode or modal solvers. The most suitable methods for antenna analysis are solvers in frequency domain. They generally solve Maxwell's equations in their integral form described formally [10]:

$$\iiint_V \nabla X \, dx\, dy\, dz = Y \tag{1}$$

where Y is the source and X — the unknown function, V — the analyzed area and ∇ is the Hamiltonian operator.

Frequency domain solvers discretize the solution domain, build a matrix, invert matrix and use iteration to find the solution X [10]:

$$X = [f_n]\left[l_{mn}^{-1}\right][g_m] \tag{2}$$

where f_n are the basis functions, g_m — exciting functions and l_{mn} are the linear operators. The matrix building and its solution must be repeated for each frequency. The typical numerical method based on mentioned principle is Method of Moments (MoM). The simulator FEKO also makes use of MoM in combination with other auxiliary methods [8]. The FEKO allows defining the structure of analyzed antennas as text as well as a 3D model and it is suitable not only for antenna analysis, but also for other problems in electromagnetics [11,12].

Four different models of the Bilog antenna, shown in Fig. 1, were created to analyze their result:

- Wire model – the simplest model of the antenna; the model consists only of the wire elements; dipole elements are connected with each other by non-radiating transmission lines (Fig. 1a);
- Surface model – all elements are created from triangle patches; it means that dipole elements of the antenna are hollow (Fig. 1b);
- Combined model – similar as in the previous case, but the cylindrical parts are made up of wire elements, while angular parts of triangle patches (Fig. 1c);
- CAD model - the truest copy of the antenna; this model is created by importing the antenna from CAD environment (Fig. 1d).

The exciting element of the models is situated in the tip of a log-periodic part, which is situated in the center of the coordinate system. The properties of these antenna models are simulated and compared with known measured values of the Bilog antenna.

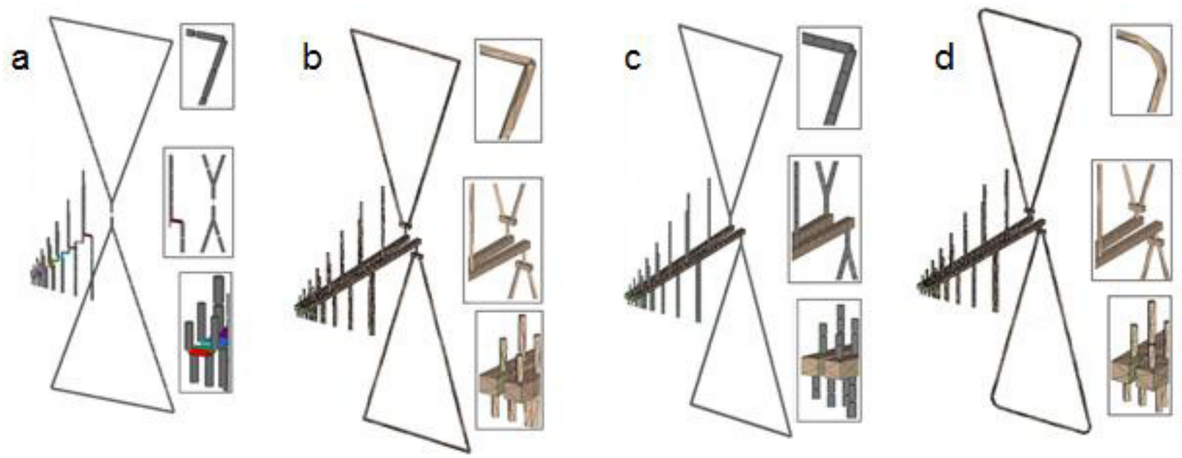

Fig. 1. Types of Bilog antenna models (a) wire; (b) surface; (c) combined; (d) CAD.

The feature selective validation (FSV) method has been presented in [9] as a validation for computational electromagnetics modeling and simulations. Validation procedure is given by standard [13], it serves for validation of particular solution of data set by comparing it with another data set obtained by measurement or some other methods. The basis of the FSV technique is the decomposition of the results to be compared into two component measures and then the recombination of the results to provide a global goodness of fit measure [11]. The components used are the amplitude difference measure *ADM*, which compares the amplitudes and 'trends' of the two data sets, and the feature difference measure *FDM*, which compares the rapidly changing features (as a function of the independent variable). The *ADM* and *FDM* are then combined to form a global difference measure *GDM* [13]:

$$GDM = \sqrt{ADM^2 + FDM^2} \tag{3}$$

All of the *ADM*, *FDM* and *GDM* are usable as point-by-point analysis tools or as a single, overall measurement. The range of these values can be divided into six categories form excellent to very poor, each with a description of comparison quality.

3. Results

Three antenna parameters are obtained and compared with known measured values – the antenna factor, the gain and the direction patterns. They are obtained for some discrete frequencies in frequency range of the antenna (from 30 to 1000 MHz) and compared with the measured values. Also the parameters of numerical simulations are compared with each other.

The most important parameter of the antennas if they are used in a measuring chain is the antenna factor which represents the transfer properties of the antenna. It specifies what the received voltage is in the presence of an electric field. The antenna factor measurement was performed using three-antenna method according to international standards [14]. The comparison of obtained antenna factor values is shown in Fig. 2a. As it may be seen also in Table 1 all the models, except of wire model, show a good agreement with measured values of antenna factor of Bilog - *GDM* = 0.23 (in case for the wire model *GDM* = 0.33).

The simulator calculates also the gain at any angle during a far-field calculation, but we compare only the gain in the direction of maximal radiation. The antenna gain is achieved by pattern alteration (directivity) but antenna losses are subtracted. Measured values of gain are typically obtained by measurement of three-antenna method for measuring distance 3 m. Comparison of Bilog gain expressed in dBi is in Fig. 2b. The more precise copy of antenna -CAD model means a better agreement between measured values and results of simulation - *GDM* = 0.31 (see also Table 1).

Table 1. Comparison of *ADM*, *FDM* and *GDM* values of antenna factor and gain for different models of Bilog antenna

	Antenna factor			Gain		
Type of model	*ADM*	*FDM*	*GDM*	*ADM*	*FDM*	*GDM*
Wire model	0.161	0.288	0.33	0.541	0.653	0.872
Surface model	0.110	0.176	0.231	0.223	0.253	0.347
Combined model	0.109	0.173	0.227	0.225	0.220	0.326
CAD model	0.116	0.175	0.232	0.215	0.208	0.310

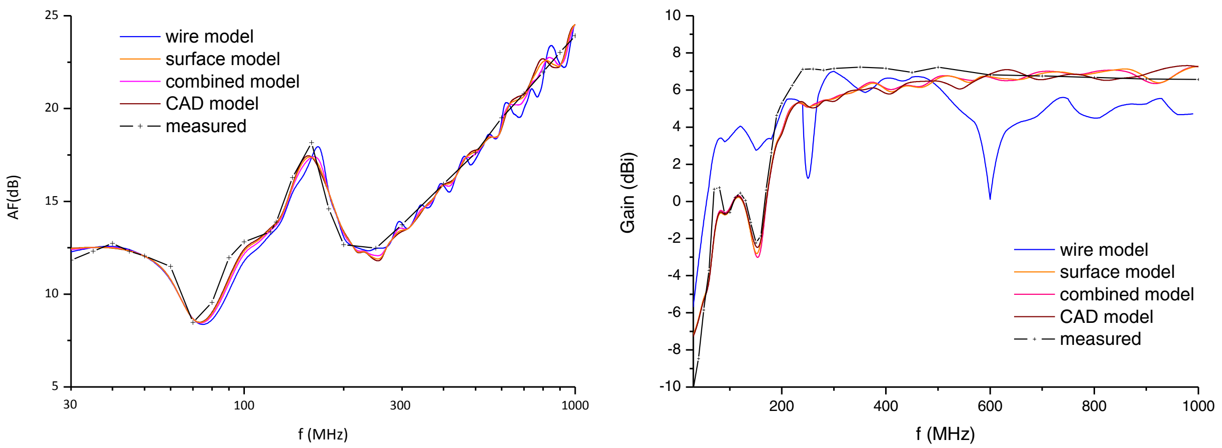

Fig. 2. Comparison of (a) antenna factor and (b) gain values for different models of Bilog antenna.

During the far-field calculation the radiation patterns (or normalized one so called direction pattern) can be obtained. The measured patterns are obtained from the measurement in an anechoic chamber. Because the chamber is not fully anechoic, these patterns can be influenced by its surrounding. Also the presence of antenna feeder affects the measured direction patterns primarily in the back lobe. In Fig. 3a and 3b there are comparisons of directional patterns in E-plane and H-plane for frequency 500 MHz. At this frequency wire model fails, while results of other models copies the measured pattern quite well, as it is also in previous cases.

Not only the results of numerical simulations, but also their parameters are very important as well. These parameters are expressed in Table 2 (the time of simulation was obtained in case of the common personal computer - Intel ® Core CPU 2.8 GHz, 4 GB RAM). The wire segment in surface and CAD models represents the exciting element. The least computing power and the shortest time of simulation may be achieved in case of the wire model. This is proportional to the number of segments – more segments means bigger matrices and longer simulation time. When other models are being compared, it is convenient to use the combined model of the antenna.

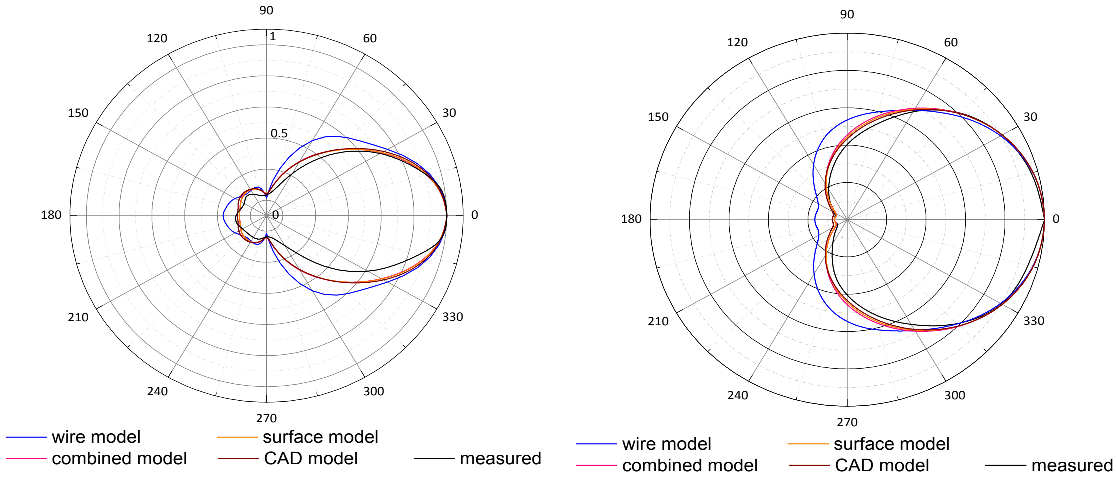

Fig. 3. Comparison of directional pattern for different models of Bilog antenna(a) in E-plane; (b) in H-plane.

Table 2. Numerical simulation parameters for different models of Bilog antenna

Type of model	Time of simulation	Number of triangular segments	Number of wire segments	Required memory RAM	Evaluation matrix size
Wire model	160 s	0	188	487.6 kB	176 × 174
Surface model	14256 s	3046	1	166.5 MB	4656 × 4643
Combined model	4887 s	774	379	18.9 MB	1552 × 1543
CAD model	16475 s	3308	1	190 MB	4976 × 4964

4. Conclusion

There has been no guide on how to model wire antennas for electromagnetic numerical simulators, different models are used in practice. Four different models, which represent used types of models, of complex wire antenna - Bilog are compared in this paper. There is no doubt that we can get results in the shortest time if the wire model is used due to the least number of model segments. However, results obtained using such a model do not correspond to known measured values in general. Then other models should be used, which give us more accurate results (closer to the measured values). The obtained results for surface, combined and CAD models are very similar and similar to the known values. However, the simulation takes too long for surface and CAD models. Then, the combined model gives us the "correct" results with the least computational requirements. All this research has been conducted to recommend an optimal antenna model if there is a necessity of computational power (and also time) saving for numerical simulation of a large and complex system containing such antennas.

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References

[1] R. Cicchetti, O. Testa, D. Caratelli, A numerical procedure for the analysis of EMC/EMI problems in radio communication systems operating in complex environment, IEEE trans. on EMC. 54(2012) 1269-1280.
[2] I. Ndip, et al., Modelling the shape, length and radiation characteristics of bond wire antennas, IET on Microw., Ant & Prop. 6(2012) 1187-1194.
[3] N. Van Dijk, Uncertainties in 3-m radiated emission measurement due to the use of different types of receive antennas, IEEE Trans. on EMC. 47 (2005) 77-85.
[4] Z. Chen, M.D. Foegelle, T. Harrington, Analysis of the log periodic dipole array antennas for site validation and radiated emission testing, in: Proc. of IEEE Int. Symp. on EMC, Seattle, 1999, pp. 618-623.
[5] J.S. Belrose, S. White, Modelling real practical antennas - guidelines and tips from code users' notebooks, in: Proc. of 12th Int. Conf. On Ant. & Prop., Exeter, 2003, pp. 712-715.
[6] M. Bittera, M. Stih, Modelling of wire antennas, in: Proc. of 12th Int. Conf. On Mechatronics, Trencianske Teplice, 2009, pp. 73-76.
[7] P. Jothilakshmi, S. Raju, Development of multiband antenna for high frequency applications, Procedia Engineering, 30 (2012) 1013-1019.
[8] EMSS - FEKO Website, http://www.feko.info
[9] R.F. Harrington, Field computation by moment method, first ed., Wiley, New York, 1993.
[10] A. Duffy, et al., The feature selective validation (FSV) method, in: Proc. of IEEE Int. Symp. on EMC, Chicago, 2005, pp. 272-277.
[11] R. Hartansky, V. Smiesko, L. Marsalka, Isotropic electromagnetic sensor measurement error, in: Proc. of 9th Int. Conf. On Meas., Smolenice, 2013, pp. 283-286.
[12] J. Hallon, K. Kovac, Improvement of electromagnetic field homogeneity within EMC immunity testing area, in: Proc. of 9th Int. Conf. On Meas., Smolenice, 2013, pp. 343-346.
[13] IEEE 1597.1, Standard for validation of computational electromagnetics computer modeling and simulation, IEEE Standard, 2009.
[14] ANSI C63.5, American national standard for calibration of antennas used for radiated emission measurements in electro magnetic interference, American National Standard, 2006.