THE CURRENT DISTRIBUTION AND CHARACTERISTIC IMPEDANCE OF MULTIWIRE HEXAEDRIC ANTENNA

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Abstract

Both the current distribution and characteristic impedance variations along a hexaedric antenna are analysed in this paper. The presented arrangement by auxiliary wires may ensure equal currents in all antenna wires. The results are required for calculations of the field in the operating volume and may be used for antenna design.

Keywords:
Electromagnetic simulator, hexaedric antenna, parallel-plate antenna, current distribution

1. Introduction

Electromagnetic simulators are used for an immunity testing of electronic devices in high level electromagnetic field. The simulator consists of a power generator of test signal and a radiating system (antenna), which forms an electromagnetic field in its operating volume.

Many types of radiating systems were designed for EM simulators. A hexaedric antenna have been used often for wide band simulators. It consist of shaped line sections formed by conducting plates or planar wire systems and a matched load. This radiating system is known as parallel-plate antenna as well.

The TEM wave excitation is assumed often for this wire system. It can be considered as a line with a characteristic impedance Zo and described by potential and charge distribution. This approach will be used for an analysis of a multiwire hexaedric antenna. The results will complete published data for antennas formed by conducting plates or wire pairs [1].

The characteristic impedance depends on transverse dimensions of the line section. It can vary along the conical section if both the vertical and horizontal wire separations are chosen arbitrarilly. In such case, the characteristic impedance variations cause a current distortion [2].

The distribution of currents among parallel connected wires influences essentially the electromagnetic field in working volume of antenna. Relative values of current in each wire must be known to compute the field distribution and for antenna optimization.

2. Method of solution

The analysed hexaedric antenna is shown in Fig.1. The front, middle and rear parts of antenna are formed by planar system of n parallel connected wires. The sections O-A and D-L connect the antenna with a generator and a load respectively.

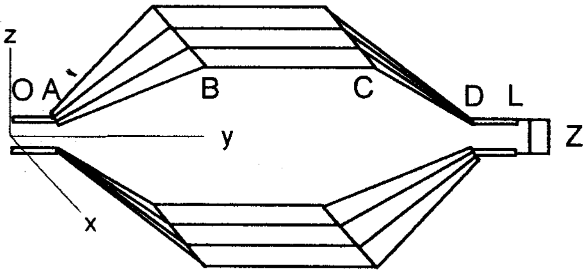

Fig.1 Hexaedric antenna

Provided that only TEM wave exist on the analysed antenna, the wire system of antenna can be consider as two-wire line. Both the current distribution and the characteristic impedance Zo may be calculated as the ratio of potential and the longitudinal charge density.

Let the system of wires is charged up by ± Q. The longitudinal charge density q is not constant and it is given by condition of constant potential at all points of wires. If values q and φ are known for each point, both the capacitance $C_1 = q_i/\varphi_i$ and the characteristic impedance Z_o can be calculated for an arbitrary point of antenna. The relative value of current in any wire is proportional to charge density in this wire.

For numerical solution, the antenna wires are divided into small elements of length Δl and both asked quantities -the potential and the charge density- may be obtained by iteration. The zero-order iteration assumes equal values of charge density q_i in all elements. The potential of each element is

$$\varphi_i = \frac{1}{4\pi\varepsilon}\sum_j \frac{q_j \Delta l_j}{r_{ij}} \qquad (1)$$

where r_{ij} denotes the distance of center points of the i-th and j-th elements. In the next (m+1)th iteration, the charge densities are corrected according to average value of potential $\overline{\varphi}$

$$q_j^{(m+1)} = q_j^{(m)} \frac{\overline{\varphi^{(m)}}}{\varphi_j^{(m)}} \qquad (2)$$

In order to keep constant the total charge Q , all the values $q_j^{(m+1)}$ are multiplied by ratio $Q/\Sigma(q_j\,\Delta l_j)$. The cycle of iteration is repeated until practically constant values of potential are achieved on all elements.

The contribution to the potential due to its own charge (i=j) was calculated in the following way. The value of potential varies on the element surface and its average value φ_{ia} is

$$\varphi_{ia} = \frac{q_i}{4\pi\varepsilon} f(w) \qquad (3)$$

The function $f(w)$

$$f(w) = \ln\left[\sqrt{w^2+1}+w\right] - \ln\left[\sqrt{w^2+1}-w\right] \qquad (4)$$

depends on the ratio $w=\Delta l/2a$, where a denotes the wire radius . If the charge $q_i\,\Delta l_i$ is concentrated to one point, it forms the same potential in the certain distance a_e

$$a_e = \Delta l / f(w) \qquad (5)$$

This is substituted instead of r_{ij} in (1).

3. Results of analysis

The hexaedric antenna shown in Fig.1 was analysed in the described way. The antenna was symmetrical and its main points are determined by co-ordinates (in meters) O [0,05;0;0,05], A [0.05;0,5;0,05], B [1,0;1,5;1,0], C [1,0;3,5;1,0], D [0,05;4,5;0,05], L [0,05;5;0,05] . The antenna has n equidistant wires with a diameter $2a$ = 4 mm. The results calculated for some values of n demonstrate variations of charge density in transverse direction and along the antenna wire. The currents in parallel connected wires are proportional to charge density on each wire. The values I_i in Table 1. are given by the ratio of current in i-th wire to the average value of current in all wires. The outer wire has the largest index.

The largest current may be expected in outer wires of system. If the number of wires n ≥ 6 , the currents of outside wires is significantly larger then in the others. This transverse current distribution is practically constant along the antenna.

Table 1 Current distribution among antenna wires

n	I_1	I_2	I_3	I_4	I_5
4	0,89	1,11			
6	0,81	0,91	1,28		
8	0,77	0,82	0,97	1,44	
10	0,75	0,78	0,86	1,04	1,57

The longitudinal charge density varies along antenna wires too. This changes are significant especially on front and rear parts of antenna, where both vertical distance of wires and the width of line vary. In a similar way, local values of characteristic impedance Z_o varies on all wires. This is shown in Fig. 2 for the front part of antenna with n = 4. The charge densities are related to their values in the centre of antenna wire.

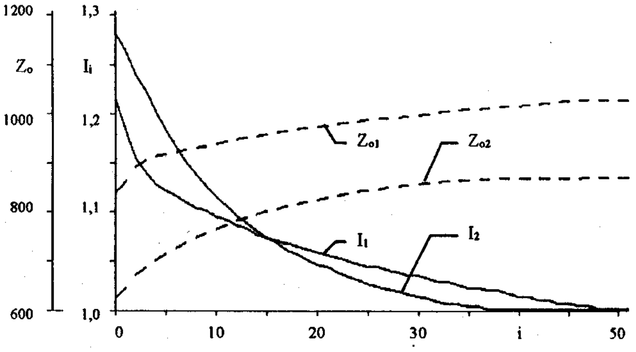

Fig.2 Variations of charge density and characteristic impedance along the front part of antenna.

Both of mentioned quantities varies significant at points near feed lines, where both the transverse dimensions of antenna part are small. The variations of relative value of charge density are similar on all the wires and they are nearly indepent on number of wires n . The numerical values of characteristic impedance differ in consequence of current distribution in parallel connected wires. It may be remind, the characteristic impedance of complete antenna may be obtained as parallel connection of characteristic impedances of individual wires.

4. Correction of characteristic impedance variations

A significant variation of characteristic impedance on conical parts is concentrated in limited section near the terminals of antenna. This part of conical line is significantly inhomogenous and causes the mentioned distortion of current shape. The effect may be supressed by auxiliary wires [2], which are fixed in parallel to each antenna wire. The separation d between the pair of wires is not constant along the antenna and this pair realises an equivalent radius a_e according to (3). To keep the constant value of potential in all antenna points with constant length density of charge q_i, the value of a_{ei} must be corrected by

$$a'_{ei} = a_{ei} \frac{q_i}{\bar{q}} \tag{6}$$

where $\bar{q}$ is the charge density corresponding the even charge distribution on all antenna wires. After correction of a_{ei} according to (6), the new charge distribution q_i is obtained by the known iteration procedure. By this double iteration, both conditions (the constant value of Z_o along the wire and the same values of current in all antenna wires) are fulfilled. The comparison of origin results with that after correction shows Table 2 for the half of antenna length. There, i denotes the order of antenna element (the front part has 48 elements) and f_i is the potential of element. The values d were calculated from the formula

$$d_i = \frac{a'^2_{ei}}{a} = \frac{\Delta l_i^2}{a} \cdot \frac{m}{(m+1)^2} \tag{7}$$

where $m = \exp(\Delta l / a'_{ei})$. Both dimensions d and a are given in milimeters in Table 2.

Table 2 Changes of characteristic impedance Z_o along antenna without correction Z_o (left) and after it (right)

i	q_i	f_i	Z_o		q_i	f_i	Z_o	a'	d
		wire 1					wire 1		
1	4,28	0,65	912		4,15	0,67	972	1,0	0,5
10	3,69	0,65	1060		4,14	0,67	976	2,6	3,4
20	3,57	0,65	1094		4,11	0,67	982	3,5	6,2
30	3,49	0,65	1120		4,08	0,67	988	4,2	8,9
40	3,43	0,65	1138		4,06	0,67	994	4,7	11,3
50	3,40	0,65	1148		4,05	0,67	996	5,0	12,7
60	3,44	0,65	1156		4,05	0,67	996	4,9	11,9
		wire 2					wire 2		
1	5,24	0,65	742		4,14	0,67	976	0,5	0,1
10	4,51	0,65	864		4,13	0,67	978	1,1	0,6
20	4,26	0,65	916		4,12	0,67	980	1,5	1,2
30	4,13	0,65	944		4,11	0,67	982	1,8	1,6
40	4,09	0,65	954		4,11	0,67	982	1,9	1,9
50	4,08	0,65	956		4,11	0,67	982	1,9	1,9
60	4,03	0,65	958		4,11	0,67	982	2,0	2,0

The results on the right show practically constant values of characteristic impedance Z_o and equal currents (they are proportional to q_i) in all parallel wires. If the charge densities get equal, their values decrease on outer wires. To keep the constant value of potential on this antenna parts, the equivalent radius a'_{ei} must be decreased there. Then, the values of a'_{ei} less than the considered value $a = 2$ mm exist in Table 2 together with values $d < a$.

5. Conclusion

The numerical analysis of multiwire hexaedric antenna is presented under assumption of TEM wave on the antenna. The relative value of current may be obtained for each antenna wire by an easy way. The results allow a more exact analysis of the antenna properties and its optimization as well.

The correction of characteristic impedance variations by auxiliary wires gives a possibility to rich prescribed currents in individual wires of antenna system. The described procedure can be apply to system with nonequal distances among wires too. It offers the next possibility to form the field distribution in the working volume of antenna.

References

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About author...

Zdeněk Nováček was born in Kamenná, Czechoslovakia, in1945. He received the M.E. degree in electrical engineering from TU Brno, in 1969 and Ph.D. degree in radioelectronics from TU Brno, in 1980. He is currently the senior lecturer at the Department of radioelectronics of the TU Brno. Research and pedagogical interests: Antennas and propagation of radio waves (signal processing, antennas, antenna measurements).