MUTUAL INTERACTION BETWEEN VEE-DIPOLES PLACED OVER THE INTERFACE BETWEEN TWO MEDIA

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Abstract

A system of two Vee-dipoles with sinusoidal current distribution placed over a flat interface between two isotropic media which one of them is dissipative is considered. Each dipole arm as an independent radiator is considered. The method of induced EMF to find the mutual impedances between the dipoles arms is used. The voltages at the inputs of the dipoles arms are presented in a system of Kirchhoff's equations which allows obtaining the mutual impedances between the dipoles. The computation results for the mutual impedances between two Vee-dipoles are given.

Keywords: Vee-dipoles; Imperfect Ground; Method of induced EMF; Mutual impedances

1. INTRODUCTION

As radiating elements of modern radio engineering systems the Vee-dipoles frequently are used. They are applied in long-wave radio astronomy [1], in systems of reception-transmission UWB signals [2] and a number of other applications.

In spite of the fact that investigations of the Vee-dipoles are carried on for a long time, some aspects of their work are deals up insufficiently full. In particular, there is an open question on how presence of the real earth influences interaction between the Vee-dipoles. This paper is devoted determination of mutual resistances of the Vee-dipoles placed over interface of two media.

2. THEORY

2.1. PROBLEM FORMULATION

Draw a boundary plane that dividing considered area of space on two parts. We will consider that the top part of space, is filled by an perfect dielectric ($\sigma_1 = 0$), and the bottom halfspace is filled a media with arbitrary parameters $\varepsilon_2, \mu_2, \sigma_2$.

Over interface, the radiating system consisting of two Vee-dipoles *p*-th and *q*-th that arms (*k*, *i* and *m*, *n* accordingly) located in a horizontal plane, and their direction can be arbitrary (fig. 1). Inputs of dipoles located in points with co-ordinates (x_p, y_p, z_p) and (x_q, y_q, z_q) . Let's define mutual resistances of the Vee-dipoles.

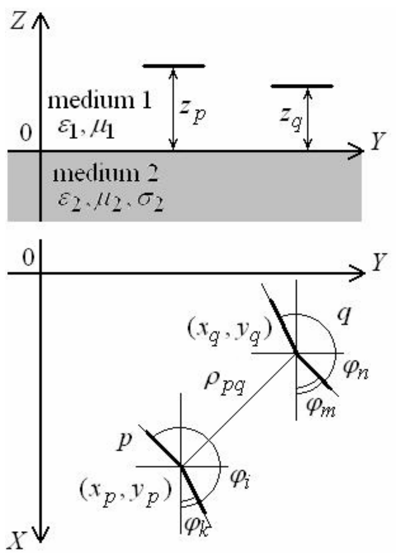
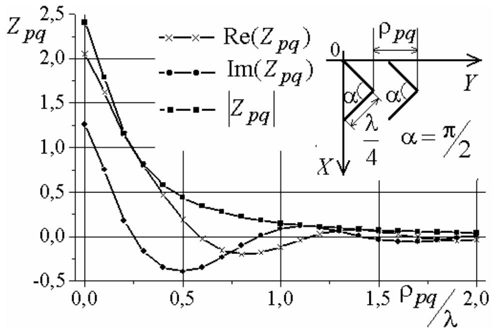


Fig. 1. Two elements over the ground .

2.2. MODELLING TECHNIQUE

Consider each dipole, as the system consisting of two independent radiating units which role is played by arms of dipoles. Current distribution to each arm follows the sinusoidal law. Calculation of mutual resistances between dipoles we will performs by means of a method of induced EMF. Mutual impedance Z_{mn} between arbitrary *n*-th and *m*-th arm of dipoles is convenient to present in the form of the sum:

$$Z_{mn} = Z_{mn}^{\infty} + \Delta Z_{mn} . \qquad (1)$$



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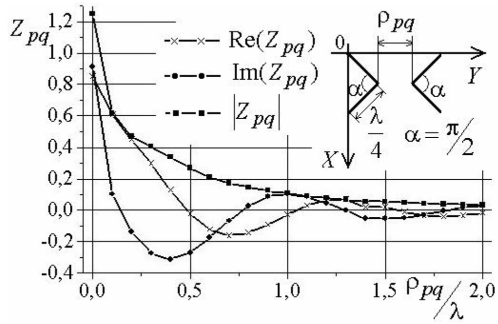

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Fig. 2. Mutual impedances of two Vee-dipoles.

Here the first item Z_{mn}^{∞} is mutual impedance between arms of dipoles over perfectly conductivity ground, and the second item ΔZ_{mn} is represents the additive term which takes in account distinctions between the second medium and a perfect conductor. For its determination we will use of the results presented in work [3], obtained with use of decomposition of fields in a spectrum of planar waves:

$$\Delta Z_{mn} = -\mathrm{j}\frac{l_{em} l_{en}\sqrt{\mu_1/\varepsilon_1}}{4\pi}\int_0^{\infty}\Big(\gamma_1 T_\varepsilon \cdot I_\varepsilon(\kappa) - \frac{1}{\gamma_1}\tilde{T}_\mu \cdot I_\mu(\kappa)\Big) \mathrm{e}^{-\gamma_1(z_n+z_m)}\,\kappa\, d\kappa, \qquad (2)$$

Where

$$\left.\begin{matrix} I_\varepsilon(\kappa) \\ I_\mu(\kappa) \end{matrix}\right\} = \frac{1}{2\pi}\int_0^{2\pi} \overset{*}{s}_m(\kappa,\alpha)\, s_n(\kappa,\alpha) \left\{\begin{matrix} \cos(\alpha-\varphi_m)\cos(\alpha-\varphi_n) \\ \sin(\alpha-\varphi_m)\sin(\alpha-\varphi_n) \end{matrix}\right\} \mathrm{e}^{\mathrm{j}\kappa\rho_{mn}\cos(\alpha-\varphi_{mn})}\, d\alpha\,;$$

l_{em} – length of m-th radiating unit length; $s_m(\kappa,\alpha)$ – spectral density of m-th radiating unit; $\gamma_{1,2} = \sqrt{\kappa^2 - k_{1,2}^2}$; $\tilde{\varepsilon}_{1,2} = \varepsilon_{1,2}(1 - \mathrm{j}\sigma_{1,2}/\omega\varepsilon_{1,2})$; $T_\varepsilon = 2\gamma_2\tilde{\varepsilon}_1/(\gamma_1\tilde{\varepsilon}_2 + \gamma_2\tilde{\varepsilon}_1)$; $\tilde{T}_\mu = 2\gamma_1\mu_2/(\gamma_1\mu_2 + \gamma_2\mu_1)$; $\varphi_{mn} = \mathrm{arctg}\big[(y_m - y_n)/(x_m - x_n)\big]$; $k_{1,2} = \omega\sqrt{\tilde{\varepsilon}_{1,2}\,\mu_{1,2}}$.

The obtained expressions allow determining voltages on inputs of dipoles arms:

$$\begin{matrix} U_k = Z_{kk}I_k + Z_{ki}I_i + Z_{km}I_m + Z_{kn}I_n \\ U_i = Z_{ik}I_k + Z_{ii}I_i + Z_{im}I_m + Z_{in}I_n \\ U_m = Z_{mk}I_k + Z_{mi}I_i + Z_{mm}I_m + Z_{mn}I_n \\ U_n = Z_{nk}I_k + Z_{ni}I_i + Z_{nm}I_m + Z_{nn}I_n \end{matrix} . \qquad (3)$$

Considering that currents and voltages on inputs of dipoles and their arms are in following relationships: $U_k + U_i = U_p$, $U_m + U_n = U_q$, $I_k = I_i = I_p$, $I_m = I_n = I_q$ between the Vee-dipoles (fig. 1) it is possible to present mutual resistances in a following kind:

$$Z_{pq} = Z_{ni} + Z_{mi} + Z_{mk} + Z_{nk}\,. \qquad (4)$$

The relation (4) allows finding mutual resistance of the Vee-dipoles located near to interface between two media.

3. Numerical results

As an illustration we will consider two examples (fig. 2) when the Vee-dipoles are identical, but in the first case are oriented unidirectionally (fig. 2, a), and in the second – they are opposite directed (fig. 2, b). As argument the distance between vibrators in this case is. Dependences, normalized to the real part of self impedance of the Vee-dipole in free space are presented on fig. 2. Calculations were spent on frequency f = 6 MHz. Earth parameters were accepted equal $\varepsilon_r = 10$, $\mu_r = 1$, $\sigma = 0{,}01\,[1/\mathrm{Ohm}\cdot\mathrm{m}]$. The dipoles are arranged in one plane at height 0,25 λ .

From the dependences presented on fig. 2 it will be obvious that mutual resistance between the Vee-dipoles quickly decreases, and makes on the module approximately 2-3 % from own resistance already on distance 2 λ .

4. Conclusion

The approach which allow correctly accounts influence brought by interface between air/earth on interaction between elements is treated on the presented system of the Vee-dipoles. It can be useful at the design of high-frequency antenna systems.

References

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