PRIMARY AND SECONDARY PARAMETERS OF THE COAXIAL MICROWIRE

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Abstract. The coaxial microwire is a perspective element for application in microelec-tronic devices of a radio-frequency wave band. Theoretical definition of primary (linear) parameters of a coaxial microwire is carried out. The received expressions allow to carry out more exact calculation of primary parameters in comparison with the traditional approach.

Key words: coaxial, microware, parameters, mathematical model.

INTRODUCTION

The modern software of the electronic engineer is based on the complex specified mathematical descriptions of electronic elements - mathematical models. Than more exact will be model of an electronic element, that computer model of the electronic circuit will be adequate to describe behavior of a real electronic device or its blocs, so, the result will be in decrease of time and material costs on development of new products.

On the basis of a coaxial microwire can be executed various types of filters, matching elements and transformers, delay lines and other devices for using in microelectronic devices of a centimetric and millimetric wave band. For correct calculation of elements on the basis of a coaxial microwire, right choice of its constructive characteristics, more careful definition of its key parameters, such as wave resistance, linear resistance, capacity, inductance and conductivity, distribution factors is necessary.

There is an extensive number of works [1, 2, 3] in which the process of distribution of electromagnetic waves in a coaxial cable are described and on the basis of it its key parameters are determined. In [4] it is mentioned about influence of the proximity effect on the current distribution in the cable sheath, thus the maximal concentration of a current occurs on an internal surface of the sheath, that have an influence on the value of coaxial impedance. For a coaxial microwire the factor of comparability of the linear sizes with thickness of a skin-layer it is necessary to take into account.

Mathematical model. The examination of the coaxial microwire parameters we shall carry out according to the following model. The contour of cross section of a coaxial microwire will consist of two circles which it is accepted located in the center of cylindrical system of coordinates r, α, the axis of a wire is directed along an axis z, as shown in fig. 1.

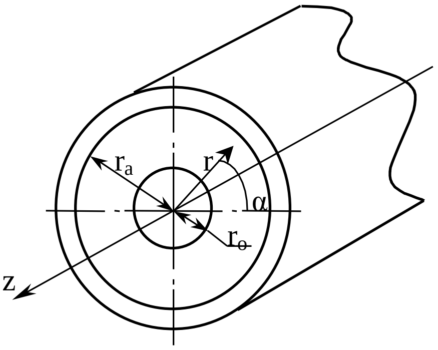

Fig.1. Cross section and sizes designation of a coaxial microwire

Accepting a condition, that electric and magnetic fields do not depend on coordinate z, i.e. $\partial/\partial z = 0$, and also in cylindrical system of coordinates components of vectors $\vec{E}$ and $\vec{H}$ do not depend on a corner α, i.e. $\partial/\partial\alpha = 0$, for electric and a magnetic field strength field in the thread, isolation and cable sheath the following expressions [1,2,3,5] were received:

$$\dot{E}_z = \frac{1}{\sigma}\left[\dot{A}J_0(kr) + \dot{B}Y_0(kr)\right] \tag{1}$$

$$\dot{H}_\alpha = \frac{1}{k}\left[\dot{A}J_1(kr) + \dot{B}Y_1(kr)\right] \tag{2}$$

where $k^2 = -j\omega\mu\sigma$ - a medium distribution constant,

$\dot{A}$ и $\dot{B}$ - integration constants,

$J_0(kr), J_1(kr)$ - Bessel functions of the zero and the first order of a first type,

$Y_0(kr), Y_1(kr)$ - Bessel functions of the zero and the first order of the second type or Neumann functions,

σ - conductivity, ω - circular frequency, ε - electric permittivity,

μ - magnetic permeability of the corresponding examined medium.

Let's enter for indexing the following designations: for the internal conductor (thread) at $0 < r < r_0$ we shall designate i; for the external conductor (cable sheath) at $r_a < r < r_b$ we shall designate a; for dielectric, which is filling space between an internal and external conductor at $r_0 < r < r_a$ we shall designate g.

The decisions of the equations (1), (2) for the internal conductor [1-7], sheath [1], and for the dielectric medium filling space between them:

$$\dot{E}_{zi} = \frac{k_i \dot{I}_z}{2\pi\sigma_i r_0}\frac{J_0(k_i r)}{J_1(k_i r_0)} \tag{3}$$

$$\dot{H}_{\alpha i} = \frac{\dot{I}_z}{2\pi r_0}\frac{J_1(k_i r)}{J_1(k_i r_0)} \tag{4}$$

$$\dot{H}_{\alpha a} = -\frac{\dot{I}_z}{2\pi r_a}\frac{Y_1(k_a r_b)\cdot J_1(k_a r) - Y_1(k_a r)\cdot J_1(k_a r_b)}{Y_1(k_a r_a)\cdot J_1(k_a r_b) - Y_1(k_a r_b)\cdot J_1(k_a r_a)} \tag{5}$$

$$\dot{E}_{za} = -\frac{k_a \dot{I}_z}{2\pi\sigma_a r_a} \frac{Y_1(k_a r_b)\cdot J_0(k_a r) - Y_0(k_a r)\cdot J_1(k_a r_b)}{Y_1(k_a r_a)\cdot J_1(k_a r_b) - Y_1(k_a r_b)\cdot J_1(k_a r_a)} \tag{6}$$

$$\dot{H}_{\alpha g} = \frac{\dot{I}_z}{2\pi r_0 r_a} \frac{(Y_1(k_g r_0)r_0 - Y_1(k_g r_a)r_a)J_1(k_g r) + (J_1(k_g r_a)r_a - J_1(k_g r_0)r_0)Y_1(k_g r)}{Y_1(k_g r_0)\cdot J_1(k_g r_a) - Y_1(k_g r_a)\cdot J_1(k_g r_0)} \tag{7}$$

$$\dot{E}_{\alpha g} = \frac{\dot{I}_z \cdot k_g}{2\pi r_0 r_a \sigma_g} \frac{(Y_1(k_g r_0)r_0 - Y_1(k_g r_a)r_a)J_0(k_g r) + (J_1(k_g r_a)r_a - J_1(k_g r_0)r_0)Y_0(k_g r)}{Y_1(k_g r_0)\cdot J_1(k_g r_a) - Y_1(k_g r_a)\cdot J_1(k_g r_0)} \tag{8}$$

The received expressions for the magnetic and electric strength components of an electromagnetic field are a basis for definition of parameters of a coaxial microwire in an alternating current of high frequency.

The complex resistance of the internal conductor (9) and cable sheath (10):

$$Z_i = R_i + j\omega L_i = \frac{\dot{E}_{zi}(r = r_0)}{\dot{I}_z} = \frac{k_i}{2\pi\sigma_i r_0} \frac{J_0(k_i r_0)}{J_1(k_i r_0)} \tag{9}$$

$$Z_a = R_a + j\omega L_a = \frac{\dot{E}_{za}(r = r_a)}{\dot{I}_z} = -\frac{k_a}{2\pi\sigma_a r_a} \frac{Y_1(k_a r_b)\cdot J_0(k_a r_a) - Y_0(k_a r_a)\cdot J_1(k_a r_b)}{Y_1(k_a r_a)\cdot J_1(k_a r_b) - Y_1(k_a r_b)\cdot J_1(k_a r_a)} \tag{10}$$

where R_i, R_a - active resistance, $j\omega L_i$, $j\omega L_a$ - reactance, L_i, L_a - inductance of the internal and external conductor respectively, ω - circular frequency of a signal.

Except for inductance of the internal conductor and of the sheath, there is so-called external inductance caused by the magnetic field in an interval between conductors [1]:

$$L_g = \frac{\mu_g}{2\pi} \ln \frac{r_a}{r_b} \tag{11}$$

Thus, the common longitudinal linear resistance of a coaxial microwire:

$$Z = Z_i + Z_a + j\omega L_g \tag{12}$$

The expressions for cross components of an electromagnetic field [1, 6] and for value of cross conductivity are in a similar way received:

$$Y = G + j\omega C = \frac{2\pi\sigma_g + \omega\varepsilon_g'' tg\delta}{\ln \frac{r_a}{r_i}} + j\omega \frac{2\pi\varepsilon_g'}{\ln \frac{r_a}{r_i}} \tag{13}$$

where C - linear capacity of the coaxial microwire, ε' and ε'' - real and imaginary parts of dielectric permittivity.

The attenuation and phase factor can be found as real and imaginary parts of complex distribution factor γ:

$$\gamma = \sqrt{Z \cdot Y} = \sqrt{(Z_i + Z_a + j\omega L_g)\cdot(G + j\omega C)} \tag{14}$$

And, at last, wave resistance of a coaxial microwire:

$$\rho = \sqrt{Z / Y} = \sqrt{(Z_i + Z_a + j\omega L_g)/(G + j\omega C)} \tag{15}$$

On fig.2-7 the frequency dependences of primary parameters R, G, L, C, wave resistance, attenuation and a phase factor of coaxial copper microwires with thickness of the covering of the sheath 0,5 μm are shown.

On the basis of the submitted expressions (9,10,13-15) and references [4,7] the comparative calculations were carried out. The big divergence of results is present and is especial on low frequencies. First of all, it is connected by that fact, that in the majority of expressions [4,7], thickness of the sheath and its influence on parameters of coaxial cables is not taken into account.

Conclusions. The received expressions allow to determine the parameters of coaxial microwires and to take into account properties of materials of a microwire.

Expressions for calculation of frequency dependent values of linear parameters of a coaxial microwire, attenuation and a phase factors, wave resistance can form a basis for calculation of more exact and reliable mathematical models of elements on the basis of a coaxial microwire, such as radio-frequency filters and delay lines.

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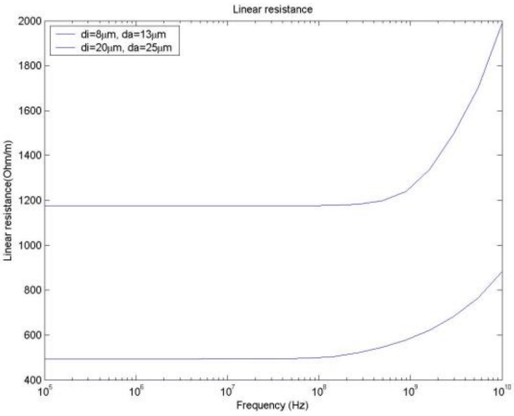

Fig.2

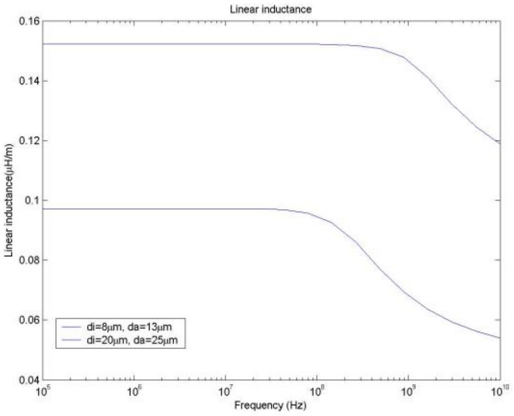

Fig.3

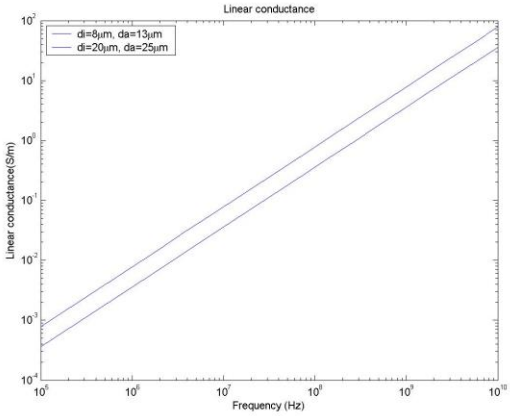

Fig.4

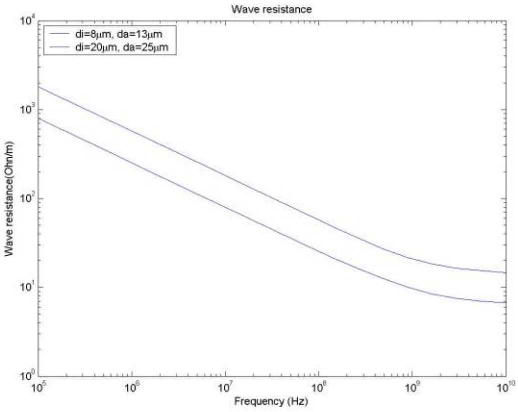

Fig.5

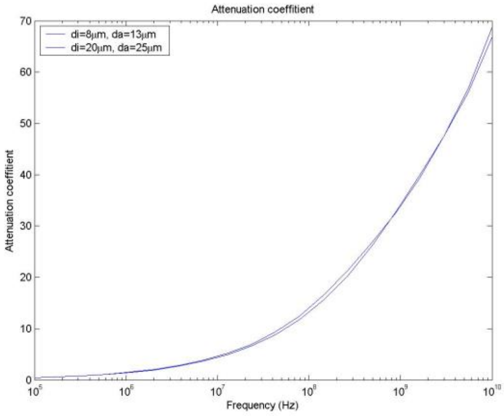

Fig.6

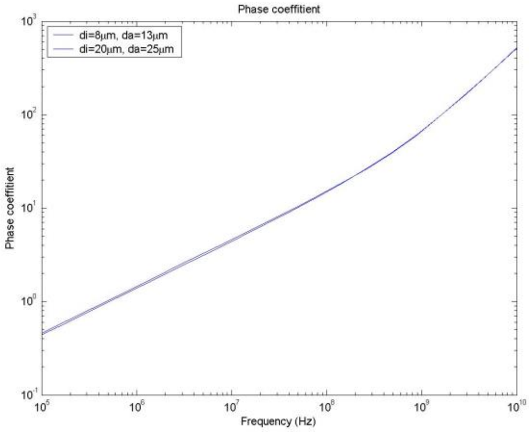

Fig.7

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