In contrast to the time and spectral methods of experimental data analysis, the correlation method provides high accuracy due to the determination of the correlation maximum of the external environment temperature function of time, since with a long-term measurement (more than a day), the temperature of the external environment varies rather slowly over time. The effectiveness of the method of correlation analysis has been repeatedly proved when applied in radio engineering, radar, etc. However, in the heat engineering this method is practically not used.

REFERENCES

1. Vasilyev G.P., Gornov V.F., Lichman V.A., Yurchenko I.A. A method of assessing energy consumption of buildings during commissioning // ARPN Journal of Engineering and Applied Sciences. – 2015. – T. 10, № 15. – C. 6509–6512 (in Russian).

2. Noh S.K., Kim K.S., Ji Y.K. Design of a Room Monitoring System for Wireless Sensor Networks // International Journal of Distributed Sensor Networks. – 2013. – Vol. 1–7.

3. Tabunschikov Y., Brodatch M. Optimal control of energy consumption for heating // ASHRAE Journal. – 2006. – Vol. 48. – P. 26–31 (in Russian).

4. Balajia N.C., Monto M/, Venkatarama Reddyc BV. Discerning heat transfer in building materials // Energy Procedia. – 2014. – Vol. 54. – P. 654–668.

INFLUENCE OF LOSSES ON THE AMPLITUDE AND WAVEFORM OF THE ULTRAWIDEBAND PULSE IN A TURN OF MEANDER MICROSTRIP LINE WITH BROADSIDE COUPLING

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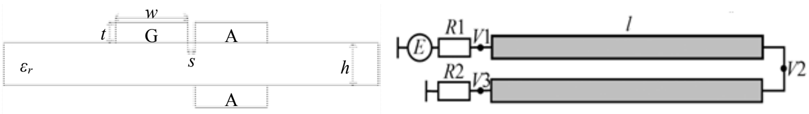
Nowadays, one of important problems is protection of radio electronic equipment (REE) against the influence of electromagnetic interference (EMI). This problem is caused by the reduction in the operating voltage of the devices and an increase of circuit density inside the equipment, which leads to an increase in the susceptibility of REE to various EMI. The most dangerous electromagnetic interference is pulses with a duration of several nanoseconds and an amplitude of several kilovolts. Such ultrawideband pulses (UWB) are able to pass into the REE and destroy its sensitive circuits. The existing protective devices are often unable to provide proper protection of REE against such EMI due to their insufficient performance, low power and parasitic parameters [1]. For protection in a wide frequency range of influence, complex and multistage devices are used, but in practice, on the contrary, there is a requirement of simplicity and cheapness for protection devices. Therefore, we have proposed a simple method of protection of the REE from UWB pulses based on the use of modal signal distortions in a turn of meander delay line [2, 3]. The possibility of protection is demonstrated in a turn of meander line with the edge [2] and broadside [3] couplings based on a microstrip.

One of the most important stages in the design of REE is preliminary modeling and analysis. In real interconnections of printed circuit boards there are losses; therefore, it is necessary to take into account these losses in the simulation. Thus, we have studied the influence of losses on the waveform and amplitude of the UWB in a turn of meander microstrip line with the edge coupling [4]. The couplings between the conductors in the meander line with a broadside coupling are of a more complex nature, so that the influence of losses may be different. Therefore, the purpose of this paper is to estimate the influence of losses in the conductor and dielectric on the ultrawideband pulse decomposition in a turn of meander microstrip line with a broadside coupling. For an estimate of the degree of the influence of losses on the waveform, it is necessary to perform a simulation with losses and without losses and compare the results.

Figure 1, *a* presents a cross section of the investigated line. It has the same parameters as in paper [3] for providing UWB pulse decomposition: the thickness of the dielectric substrate is h = 1500 μm; the width and thickness of the signal conductor are w = 6000 μm and t = 18 μm, respectively; the space between conductors is s = 200 μm. The base of the board selected is the FR4 material with a permittivity of ε_{rC} = 3.8.

Figure 2, *b* shows a schematic diagram of the line connections. It consists of two parallel conductors with the length l = 100 mm, interconnected at one end. One of the conductors is connected to a pulse source, which is presented by e.m.f. source E and internal resistance $R1$. Another conductor is connected to the receiving unit, which is shown as $R2$. In order to minimize reflections at the input and output of the line, $R1$ and $R2$ are taken to be equal to the geometric mean of the impedance of even and odd modes of a line (50 Ohm).



a *b*

Fig. 1. Cross section (*a*) and schematic diagram (*b*) of the meander line with broadside coupling

In the simulation, we used an excited pulse with the same parameters as in work [4]: the excited pulse has a shape of a trapezium with the magnitude of the e.m.f. equal to 1 V; the duration of flat top is 100 ps; the rise and fall is 50 ps.

A simulation of the investigated line is performed in the TALGAT system [5]. In the simulation, matrices of per-unit-length coefficients of electromagnetic and electrostatic induction (the **C** and **L** matrices) were calculated. In order to take into account losses in the dielectric during the simulation, the per-unit-length conductance matrix **G** was calculated. The reference value of the dielectric loss tangent, corresponding to the selected material (FR4) at frequency $f = 1$ MHz is $tg\delta = 0.017$. In order to take into account losses in the conductor, additionally the per-unit-length resistance matrix **R** was calculated. Elements of the matrix **R** are calculated taking into account the skin effect, proximity effect, and losses in the ground plane [6]. Matrices **G** and **R** are given by

$$\mathbf{G} = \begin{bmatrix} 19.32 & -14.4 \\ -12.59 & 16.7 \end{bmatrix} \mu\text{Sm/m}, \qquad \mathbf{R} = \begin{bmatrix} 0.355 & 0.144 \\ 0.146 & 0.182 \end{bmatrix} \text{Ohm/m}.$$

The obtained waveforms at the output of the investigated line with and without losses are presented in Fig. 3.

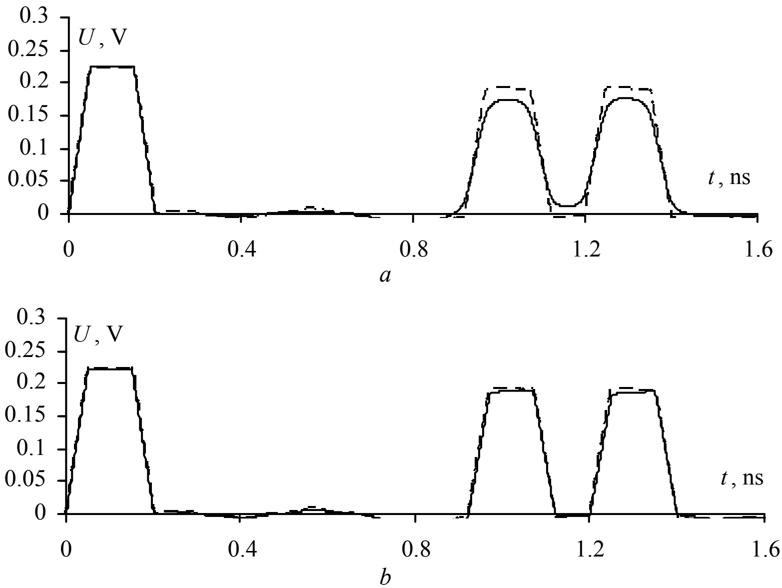


Fig. 3. Waveforms at the output of a investigated line without (– –) and with (——) losses in dealectric (*a*) and conductors (*b*)

From the waveforms in Fig. 3, *a* it is seen that dielectric losses have the biggest influence on the second and third pulses, in the form of a slight decrease in their amplitudes and a smoothing of the fronts. Thus, amplitudes of the second and the third pulses do not exceed 0.174 V (with the pulse amplitude without losses equal to 0.190 V). It is also worth to note the smoothing of a waveform (that is typical for real interconnections), which causes a positive step with amplitude of 12 mV between the second and the third pulses. In this case, the losses in the conductors have practically no influence on the form and amplitude of the signal in the investigated line (Fig. 3, *b*). Thus, the amplitude of the second pulse with the account of the losses in the conductors decreased by 1 mV, and the third – by 2 mV.

Thus, the influence of losses in conductors and dielectric on the change in the form and amplitude of the UWB pulse in the turn of meander line with a broadside connection was estimated. As a result of the studies, it was found that losses in the dielectric have a more significant influence on the amplitude and form of a UWB pulse at the end of a turn of meander line than losses in conductors. It is noteworthy that in the structure of the meander line with edge coupling, on the contrary, losses in conductors have a more significant influence.

REFERENCES

1. Gizatullin Z.M. Investigation of the Immunity of Computer Equipment to the Power-Line electromagnetic Interference / R.M. Gizatullin, Z.M. Gizatullin // Journal of Communications Technology and Electronics. – May 2016. – Vol. 61, is. 5. – P. 546–550.
2. Surovtsev R.S. Simple Method of Protection against UWB Pulses Based on a Turn of Meander Microstrip Line / R.S. Surovtsev, A.V. Nosov, A.M. Zabolotsky // 16th International Conference of Young Specialists on Micro / Nanotechnologies and Electron Devices (EDM). – Russian Federation, Altai, 29 June – 3 July, 2015. – P. 175–177.
3. Experimental confirmation of possibility of the electronic equipment protection against an ultrashort pulse by means of its decomposition in the C-section with broad-side coupling / A.V. Nosov, R.S. Surovtsev, A.M. Zabolotskiy, T.T. Gazizov // Dokladyi Tomskogo gosudarstvennogo universiteta sistem upravleniya i radioelektroniki. – 2016. – Vol. 19. – № 3. – P. 47–50.
4. Nosov A.V. Influence of losses on ultrashort pulse decomposition in a turn of meander microstrip line / A.V. Nosov, R.S. Surovtsev, T.T. Gazizov // 17th International Conference of Young Specialists on Micro/Nanotechnologies and Electron Devices. – 2016. – P. 151–154.
5. New features of electromagnetic compatibility in TALGAT simulation software / S.P. Kuksenko, A.M. Zabolotsky, A.O. Mekozerov, T.R. Gazizov // Dokladyi Tomskogo gosudarstvennogo universiteta sistem upravleniya i radioelektroniki. – 2015. – Vol. 36, № 2. – P. 45–50.

6. Matthaei G.L. Approximate calculation of the high-frequency resistance matrix for multiple coupled lines / G.L. Matthaei, G.C. Chinn // Microwave Symposium Digest. – 1992. – P. 1353–1354.

CHANNEL WAVEGUIDES OF PHOTONIC DEVICES OPTICALLY INDUCED IN LITHIUM NIOBATE WITH SURFACE-DOPED LAYER

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The rapid development of integrated optics and photonics requires intensive studies of methods to design and form the light control elements like channel waveguides and diffraction gratings based on photorefractive materials [1, 2]. One of the ways to form similar photonic elements is optical inducing in lithium niobate ($LiNbO_3$) surface– or bulk-doped by different impurities such as copper (Cu), iron (Fe) or manganese (Mn). This approach allows us to set and manage different topologies during the formation of such structures [2, 3].

The concentration rise of impurities introduced into the crystal during its growth is limited by decreasing mechanical properties of bulk sample due to the increase of defect numbers and occurrence of elastic stresses. Modern technologies of the solid-state diffusion, the ion exchange and the ion implantation allow us to significantly increase the impurity concentration within material surface layers, additionally making it possible to introduce various impurities (or their combinations) into different regions of the sample surface [4–6]. Thus, the approach of surface doping makes it possible to vary the physical properties of material surface layer within its different areas over a wide range.

The main aim of this work is experimental study of methods to form different channel waveguides including those with spatial modulation of their parameters, optically induced in lithium niobate ($LiNbO_3$) sample with Cu-doped surface layer.

Experimental setup and conditions. Channel optical waveguides are induced within surface layer of photorefractive sample at its exposure with focused laser beam using the shift of the whole sample with respect to the light spot as it is shown in Fig. 1. Laser beam with wavelengths $\lambda = 532$ nm (solid-state $YAG:Nd^{3+}$ laser with frequency doubling) or $\lambda = 450$ nm