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Using modal reservation in the three-conductor structure for ultrashort pulse attenuation after failure

The paper considers the relevance of research into the efficient use of cold standby by means of modal reservation (MR) methods in order to increase resistance to ultrashort pulses. A quasistatic analysis of the ultrashort pulse propagation was performed in a three-conductor structure with MR in a 50 Ohm path. The faults of two types were considered: a short circuit and an open circuit. It is shown that in operation, the difference in mode delays at the far end of the active conductor located in average is approximately twice as big as that located at the edge, and the maximum amplitude is more than 16%. In the case of a short circuit at one end of the extreme or both conductors, the maximum amplitude at the far end of the active conductor in average increases by 8.8 or 16.89%, respectively. In all other cases, the maximum amplitude either stays unchanged or decreases.

Keywords: electromagnetic compatibility, reliability, cold standby, modal reservation, printed circuit board, failure, ultrashort pulse.

When creating maintenance-free or partially serviced radio electronic equipment (REE), for example, for space or aviation applications, much attention is paid to reliability and electromagnetic compatibility (EMC). Conducted and radiated emissions can lead to disruption of the onboard REE. Therefore, it is necessary to consider EMC in the early stages of design [1]. Particularly dangerous is the impact of powerful ultrashort pulses, as existing surge protectors do not protect against them [2]. There are a number of industrial devices that protect against ultrashort pulses but they have large dimensions and high cost, so there is no low-cost or effective protection alternative against ultrashort pulses. However, the increasing role of electronics makes this protection more urgent.

One of the methods to increase the reliability of onboard REE is cold standby [3]. It allows creating highly reliable systems from typified widespread products using the inactive part of electronic equipment in the case of a malfunction in a functioning part. The need for proper protection against ultrashort pulses, as well as from the redundancy caused by cold standby, will greatly complicate all parts and, as a result, the final design of the equipment. Meanwhile, the presence of redundancy can be efficiently used.

So, there has been proposed the idea of modal reservation (MR), which allows improving the noise immunity of REE on the basis of modal filtering [4]. The proposed technique employs inactive electrical interconnects to protect electronic systems from electromagnetic interference. MR is based on the use of electromagnetic couplings between the reserved and reserving conductors of the reserved and reserving circuits.

The implementation of MR in two-wire microstrip structures of printed circuit boards (PCBs) with an additional dielectric between conductors is described in [5]. Multiwire microstrip structures for the protection against ultrashort pulses have been studied in [6]. However, a three-conductor microstrip structure with an additional dielectric between the conductors has not been studied. Meanwhile, it can affect the attenuation of the noise and the difference in the mode delays during MR, being different for different types of failure.

The purpose of this work is to investigate a three-conductor structure with MR in the event of failure of electronic components. For this, a quasistatic simulation of ultrashort pulse propagation was performed in a three-conductor structure with MP in a 50 Ω path. Faults of two types were considered: a short circuit (SC) and an open circuit (OC).

Structures under Research

The cross section of the simulated structure is shown in Fig. 1. Parameters for simulation were: the width of the conductor $w = 185$ μm, the conductor thickness $t = 36$ μm, the distance from the end of the conductor to the end of the dielectric $d = 555$ μm, the distance between the conductors for the three-conductor structure with MR $s = 85$ μm, the distance from the conductors to the reference layer $h = 200$ μm, the permittivity $\varepsilon_{r1} = 30$, $\varepsilon_{r2} = 4$. The simulation was performed in the TALGAT computer simulation system [7].

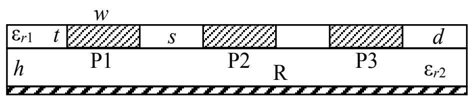

Fig. 1. Cross section of a three-conductor microstrip structure with additional dielectrics

Schematic diagrams for simulating a three-conductor structure with a length of 1 m and with MR are presented in Fig. 2. In case of the reserved circuit failure, it is assumed that the reserving circuit takes over the functions of the reserved circuit. In the simulation, for Fig. 2, *a* and *b*, the values of the active conductor resistors R1 and R2, as well as R3 and R4, respectively, were chosen equal to 50 Ohms. The resistors for the passive conductors were set to 50 ohms, 1 MOhm (OC), 1 μOhm (SC) for different failure modes.

Simulation Results

For the circuit in working condition (resistors at the ends of the passive conductor are 50 Ohms), Fig. 3, *a* shows the voltage waveforms at the near end of the three-conductor structure with the extreme (node 2 in Fig. 2, *a*) and middle (node 3 in Fig. 2, *b*) active conductors. Fig. 3, *b* shows the voltage waveforms at the far end of the active conductor, when it is extreme (node 5 in Fig. 2, *a*) and middle (node 6 in Fig. 2, *b*), as well as the maximum pulse amplitudes (0.45 and 0.58 V in the case of extreme and middle active conductors, respectively). The mode delays in response are 6.85, 7.7, 8.8 ns at the extreme and 6.85, 8.8 ns at the middle active conductors. Thus, with the middle active conductor, the amplitude of the pulses is 16% larger than with the extreme one, but the middle pulse, due to the symmetry of the effect, is lacking, which doubles the maximum duration of the decomposed pulse.

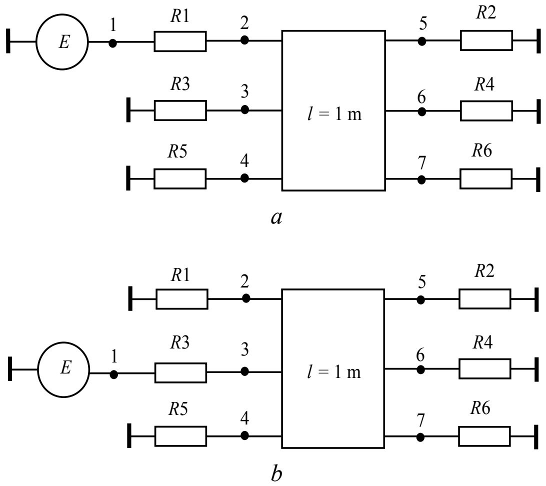

Fig. 2. Schematic diagram of a three-conductor structure with MR with active conductors P1 (*a*) and P2 (*b*) made in the TALGAT system

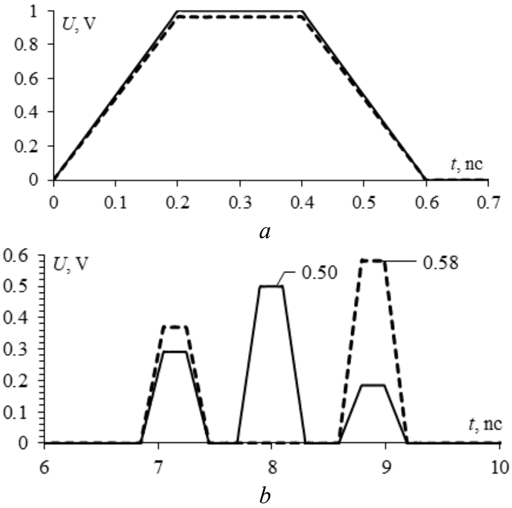

Fig. 3. Waveforms at the near (*a*) and far (*b*) ends of a three-conductor structure with extreme (–) and middle (- -) active conductors

Figs. 4 and 5 show the voltage waveforms at the far end of the three-conductor structure with the extreme (node 5 in Fig. 2, *a*) and middle (node 6 in Fig. 2, *b*) active conductors in the structure with MR under various boundary conditions at one end of the passive conductor, which can occur in the case of the component failure. For the open circuit (Fig. 4) at the far ends of the passive conductors, the maximum voltage amplitudes of the pulses at the far end of the active conductor are less than in the working state. For a short circuit (Fig. 5) at the far end of passive conductors, the maximum pulse voltage amplitudes at the far end of the active conductor are either equal to or greater than in the operating state.

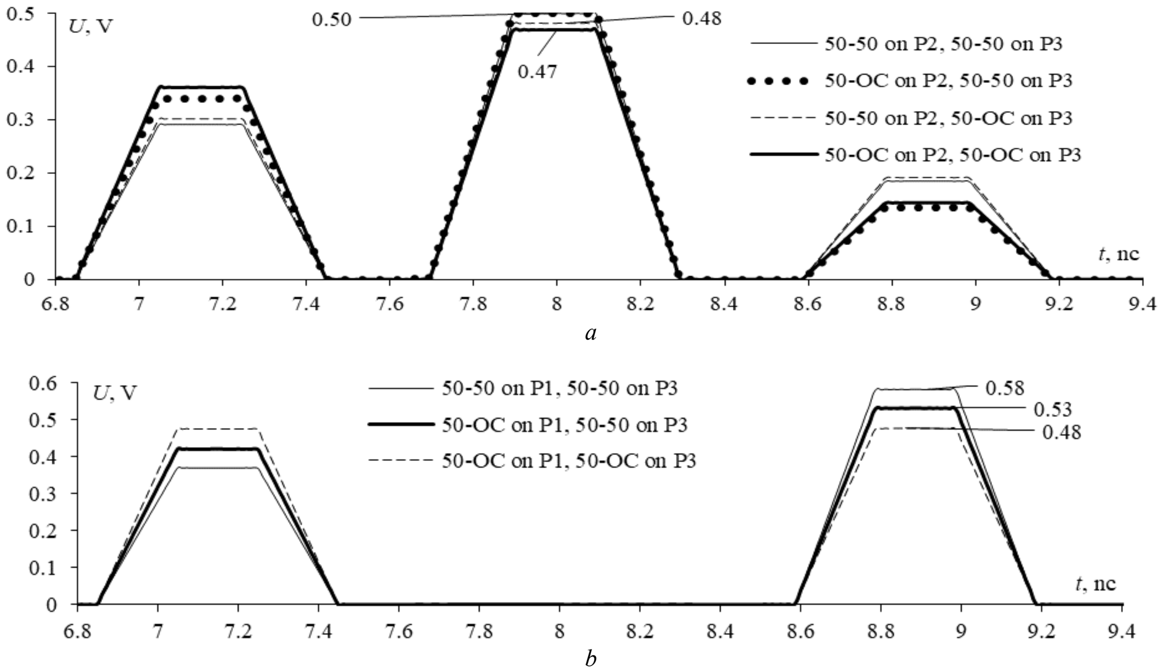

Fig. 4. Waveforms at the far end of the active conductor in the structure with MR at OC at one end of the passive conductor with active conductors P1 (*a*), P2 (*b*)

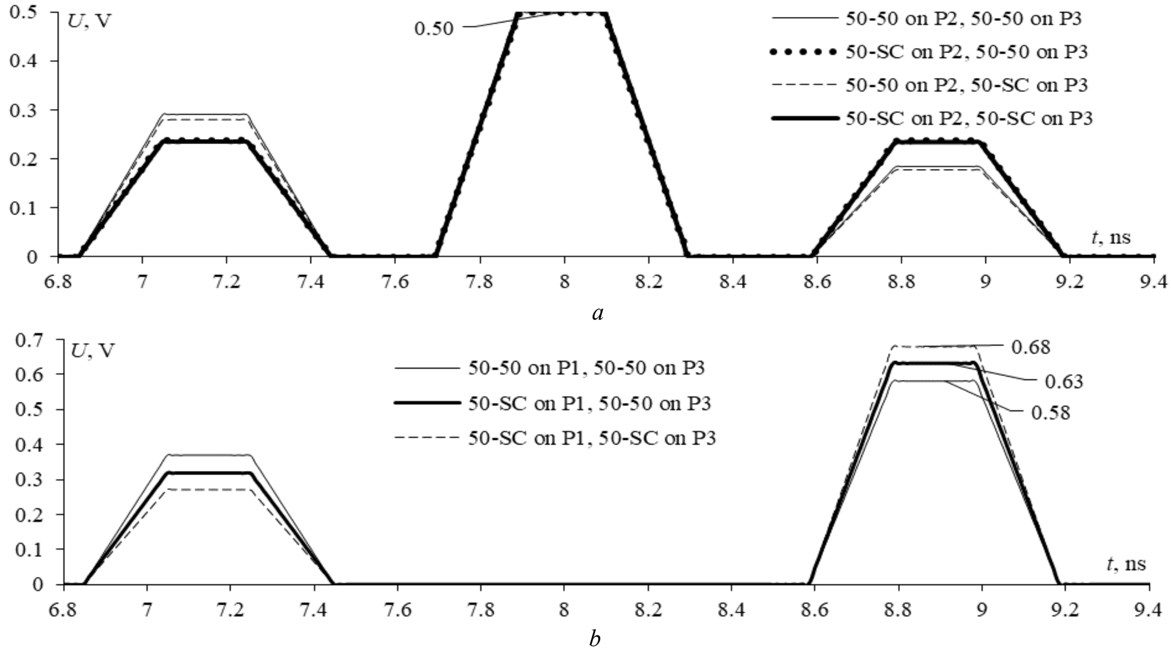

Fig. 5. Waveforms at the far end of the active conductor in the structure with MR at SC at one end of the passive conductor with active conductors P1 (*a*), P2 (*b*)

Conclusion

The paper considered the failure of the system components with MR placed on the 50 Ohm path. It was assumed that the circuit is in operation, if the boundary conditions at the ends of the conductors are approximately 50 Ohm, and if one component of the system fails, a SC or OC is formed at one end of the circuit. It is shown that in the working state, the difference in the mode delays at the far end of the active conductor in the middle is approximately twice as large as that at the edge, but the maximum amplitude is 16% larger. In the case of a SC at one end of the extreme or both conductors, the maximum amplitude at the far end of the active conductor P2 increases by 8.8 and 16.9%, respectively. In other cases, the maximum amplitude either stays unchanged or decreases. Thus, in case of failures, the change in signal amplitude is small. Meanwhile, a detailed analysis of the results allows us to formulate the most preferable choice and order of circuit switching for MR.

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References

1. Paul C.R. Introduction to Electromagnetic Compatibility. – Wiley Interscience. – 2006, 1013 p.

2. Gizatullin Z.M., Gizatullin R.M. Investigation of the immunity of computer equipment to the power-line electromagnetic interference // Journal of Communications Technology and Electronics. – 2016. – No. 5. – P. 546–550.

3. Patel M.R. Spacecraft Power Systems. – CRC Press, 2005. – 691 p.

4. Gazizov T.R., Orlov P.E., Zabolotsky A.M., Kuksenko S.P. New concept of critical infrastructure strengthening // Proc. of the 13th Int. Conf. of Numerical Analysis and Applied Mathematics. – 2015. – P. 1–3.

5. Buichkin E.N., Orlov P.E. Soverhenstvovanie modalnoy filtracii v nowih konstrukciah pethatnih plat s rezervirovaniem // Ilektronnii sredstva i sistemi ypravlenia. – 2015. – P. 18–21. (in Rus.). перевод на англ.???

6. Belousov A.O., Gazizov T.R., Zabolotsky A.M. Multiconductor microstrip line as a modal filter for protection against ultrashort pulses // Doklady TUSUR. – 2015. – P. 124–128 (in Rus.).

7. Kuksenko S.P., Gazizov T.R., Zabolotsky A.M. et al. New developments for improved simulation of interconnects based on method of moments // Advances in Intelligent Systems Research (ISSN 1951-6851), proc. of the 2015 Int. Conf. on Modelling, Simulation and Applied Mathematics (MSAM2015). – 2015. – P. 293–301.

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