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QUASISTATIC ANALYSIS OF AN MR-BASED STRUCTURE WITH CONDUCTORS ON THE OUTER LAYER OF THE PCB

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This paper presents the analysis of the characteristics of the structure with conductors on the outer layer of the printed circuit board (PCB) with modal reservation (MR). The authors consider the dependences of the difference of per-unit-length delays and the geometric mean impedances of the modes on the structure parameters. Recommendations for changing the geometric parameters to maximize the difference of per-unit-length delays are proposed.

Keywords: electromagnetic compatibility, modal reservation, printed circuit board.

When printed circuit boards (PCB) are created for critical electronic equipment, much attention is paid to electromagnetic compatibility and functional safety of electronic circuits [1]. Redundancy is a cardinal method for improving functional safety. Cold redundancy differs from hot redundancy in that if the reserved system fails, it switches over to the reserving system that was switched off. However, redundancy does not protect against the effects of systematic electromagnetic interference (EMI), since if the reserved system fails due to EMI, the reserving system will also fail.

Ultrashort pulses (USPs), which have high energy, are of short duration. To prevent the influence of USPs, technologies based on modal filter-

ing (MF) are used [2]. Modal reservation (MR) is an approach to layout and to route reserved conductors in a cold reserved system that implements MF [3]. There exist several ways to layout and route conductors of PCBs with MR. Their disadvantage is the difficulty in tracing conductors with a large number of electronic circuits. A tracing method was developed [5], which is distinguished by the presence of conductors on the outer and inner layers of the PCB. This method allows tracing conductors of the electronic circuits with a large number of components. A preliminary study of this method with non-optimized parameters was performed [6]. In further studies, it is necessary to consider the influence of the cross-sectional parameters of structures with conductors on the outer and inner layers of the PCB with MR in order to develop recommendations for optimizing the cross-sectional parameters.

The purpose of this work is to analyze the characteristics of the structure with conductors on the outer layer of the PCB with MR.

Figure 1, *a* shows the cross-sectional model. Simulating is performed in the TALGAT system [7] without taking into account losses in conductors and dielectrics. The cross-sectional parameters are: signal conductor width w = 200 μm, distance between conductors s = 200 μm, conductor thickness t = 18 μm, lower dielectric layer thickness h_1 = 200 μm, upper dielectric layer thickness h_2 = 200 μm, permittivities ε_{r1} = 10,2 and ε_{r2} = 4.

Figure 1, *b* shows the circuit diagram, which is a two-conductor structure (length l=1 m) with loads at the near and far ends, with a source of action in the active line. The load resistance $R1$–$R4$ is taken equal to the geometric mean of the even and odd mode impedances (67 Ω), while the impact has the following characteristics: the pulse shape is trapezoidal, EMF is 2 V, the duration of the rise, fall and flat top is $t_r = t_{fr} = t_d$ = 10 ps.

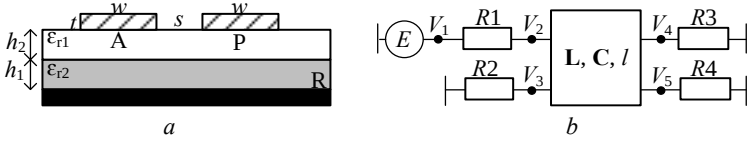
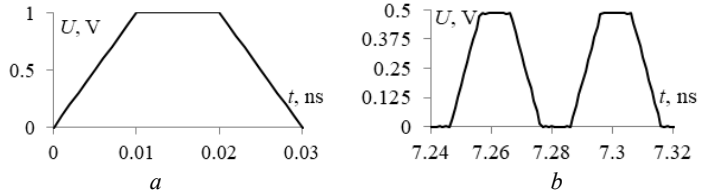


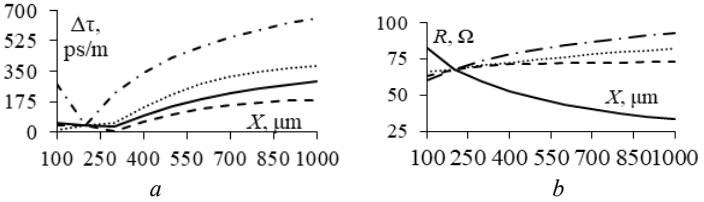
Fig. 1. Structure with conductors on the outer layer (*a*), where A is an active conductor, P is a passive conductor, R is reference; circuit diagram (*b*)

Figure 2 shows the waveforms at the near (Fig. 2, *a*) and far (Fig. 2, *b*) ends for the initial set of parameters. In what follows, all dependences of the parameters are considered with respect to this set. At the far end of the structure, two decomposition pulses of a smaller amplitude than at the near end are observed. The mode delay difference is Δt = 0.04 ns.



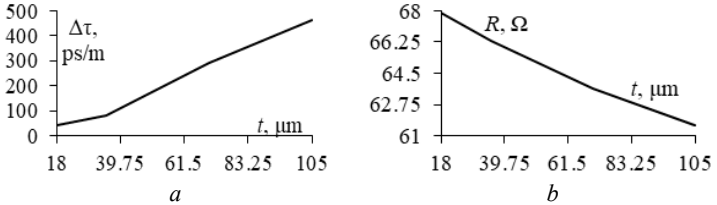
a *b*

Fig. 2. Waveforms at the near (*a*) and far (*b*) ends with the initial set of parameters



a *b*

Fig. 3. Dependences of Δτ (*a*) and *R* (*b*) on *X*, where *X* is equal to: *w* (–), *s* (---), h_1(-·-·-), h_2(…)



a *b*

Fig. 4. Dependences of Δτ (*a*) and *R* (*b*) on *t*

The presented results show that of all the considered parameters, the parameters h_1 and *t* most strongly affect Δτ. Thus, to increase Δτ, it is necessary to take each of the parameters the maximum possible, since the value of Δτ increases with an increase in each of the parameters. However, if the geometric parameters are changed as recommended, *R* will also change a lot. In cases where impedance control is required, it is necessary to monitor changes in *R*.

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REPRESENTING COMBINATORIAL SETS DEFINED BY THE FUBINI NUMBERS IN THE FORM OF AND/OR TREE STRUCTURES

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This article discusses the process of developing combinatorial generation algorithms based on the use of AND/OR trees. Specifically, we study the dependence of the combinatorial generation algorithms on the cardinality functions for the same combinatorial set. As an example, we consider a combinatorial set defined by the Fubini numbers that have three different formulas satisfying the requirements of the research method.

Keywords: bijection, combinatorial set, combinatorial generation algorithms, ranking, unranking, Fubini numbers, ordered Bell numbers, AND/OR tree.

Combinatorial generation is a scientific field that combines computer science, programming, and combinatorics, and studies algorithms aimed at numbering and generating elements of a combinatorial set [1]. A combinatorial set is a finite set of elements having a certain structure, as well as