PAPER • OPEN ACCESS

Studying the switching order for a three-wire structure with modal reservation after failures

To cite this article: A V Medvedev 2020 *IOP Conf. Ser.: Mater. Sci. Eng.* **919** 052022

IOP Conf. Series: Materials Science and Engineering **919** (2020) 052022 doi:10.1088/1757-899X/919/5/052022

Studying the switching order for a three-wire structure with modal reservation after failures

A V Medvedev

Department of Television and Control, Tomsk State University of Control Systems and Radioelectronics, 40 Lenin Avenue, Tomsk 634050, Russian Federation

E-mail: medart20@rambler.ru

Abstract. The paper considers a quasistatic analysis of the ultrashort pulse propagation was performed in a three-conductor structure with MR in a 50 Ohm path. The sequential faults of two types were considered: a short circuit (SC) and an open circuit (OC). It is shown that if the probability of which type of failure is greater is not known, then it is preferable to choose the middle active conductor before failures, since of all the options for failures, its maximum amplitude is less than that of the edge active conductor, and is 58 % to half of the EMF. If a failure of only one type (either OC or SC) is possible, then the preferred switching option after failures of the SC type is with the middle active conductor before failures, and after failures of type OC, it is option 2 with the edge active conductor before failures, since after failures the maximum amplitudes are less and are 58 and 50 %, respectively.

1. Introduction

To improve the reliability of unattended or semi-attended radio-electronic equipment (REE), especially for space or aircraft systems, the developers use reservations [1]. The probability of system failure increases over time because reliability is a decreasing function of time. The total duplication of the operating part of the REE provides the required operability under conditions of complete or partial failure. In terms of the load level, there are hot, warm, and cold reservations, with the last type being the most common due to the simplicity of implementation.

Conducted and radiated emissions from the power and switching circuits can cause malfunction of the on-board REE. Therefore, it is especially important to consider electromagnetic compatibility at an early stage of the design of an on-board electrical power system [2]. Modal reservation (MR) is a long-term solution of a cold reservation [3, 4]. Its main idea is to trace reserved and reserving conductors on a printed circuit board (PCB) with strong electromagnetic coupling between them. This makes it possible to use modal distortions to suppress conducted interferences of short duration.

The papers [5, 6] describe the MR implementation in multilayer PCBs. In [7] the authors considered the reduction of the ultrashort pulse amplitude before and after the failure of the electronic components; the failure was simulated by short or open circuits at one end of the structures with single and triple MR. In a structure with double MR, a change in the signal amplitude is observed after failures [8]. Thus, a detailed analysis of the results allows us to formulate the most preferable choice and order of switching the circuits in MR. The purpose of this work is to study the order of switching for a three-wire structure with MR in case of failure of electronic components. In this work, a quasi-static simulation of the propagation of an USP in a three-wire structure with MR with a wave path of 50 Ohm was performed. Failures of two types were considered: a short circuit (SC) and an open circuit (OC).

2. Preparation to simulation

The structure with double MR was studied using the example of modeling a three-wire structure with an additional dielectric. The cross section of the simulated structure is shown in figure 1. The simulation parameters were: the width of the conductor $w = 185$ μm, the conductor thickness $t = 36$ μm, the distance from the edge of the conductor to the edge 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 $\varepsilon_{r1} = 4$, $\varepsilon_{r2} = 30$. For simulation, the TALGAT software was used [9]. Schematic diagrams for simulating a three-conductor structure with a length of 1 m and with MR before and after failure are presented in figure 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 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 Ohm, 1 MOhm (OC), 1 μOhm (SC) for different failure modes. Also shows the choices after failures. With a middle active conductor before failures, there is only one choice after failures, and with an edge – two. The paper [8] describe the waveforms at the far end of an active conductor when a component of the same type failure at one end of the passive conductor.

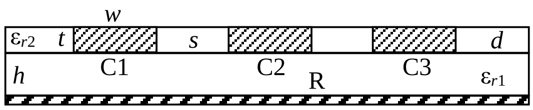

Figure 1. Cross section of a three-conductor structure.

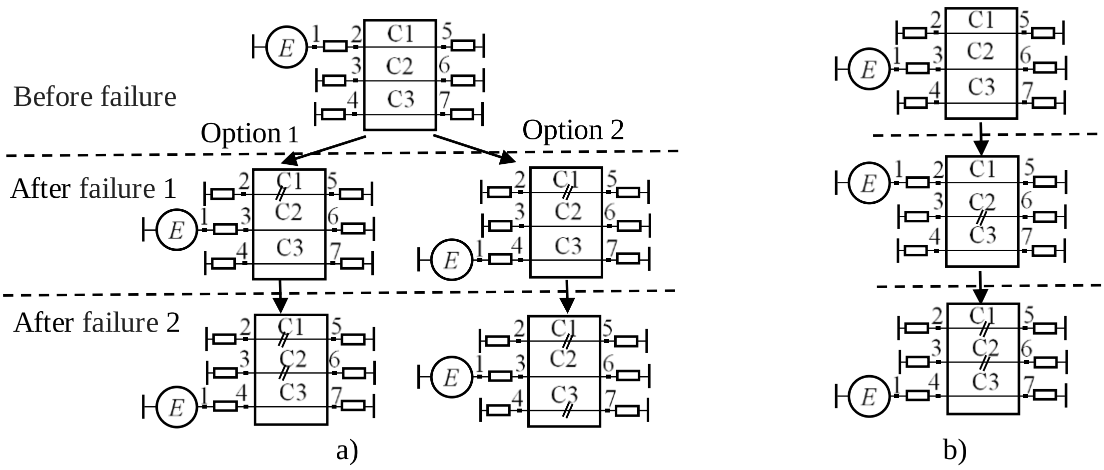

Figure 2. Variants of choosing an active conductor before and after failure at one of the ends of the structure with MR with the edge (a) and middle (b) active conductors before failure.

3. Simulating the time response

Figures 3 and 4 show results for different types of component failure that were not considered in [8]. For the case with the edge active conductor (figure 3), the voltage amplitudes are greater than before failure, and in the middle (figure 4) – either equal or greater.

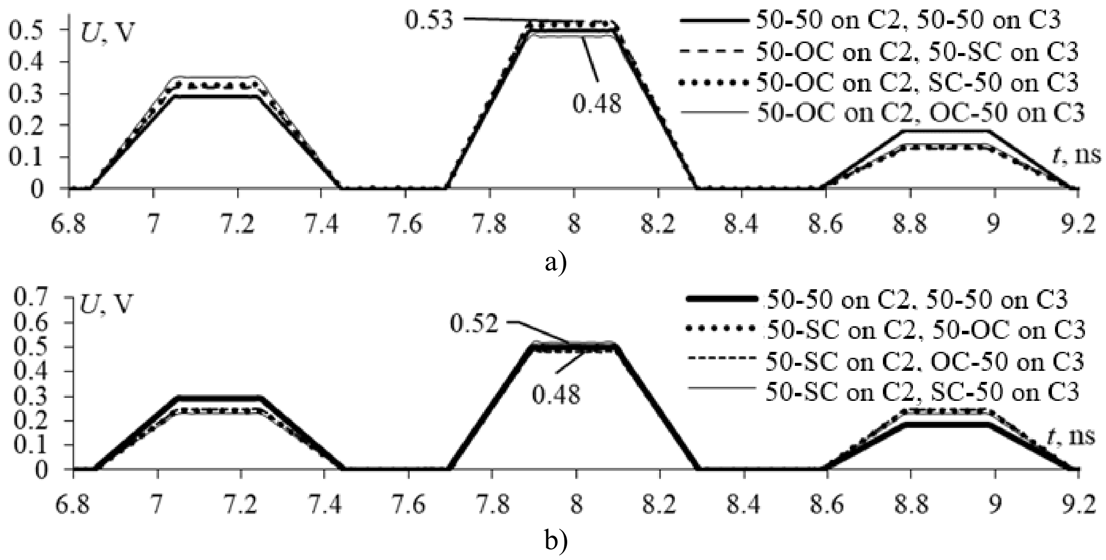

Figure 3. Waveforms at the far end of the active conductor C1 at OC (a) or SC (b) at the end of the passive conductor C2 under various boundary conditions at C3.

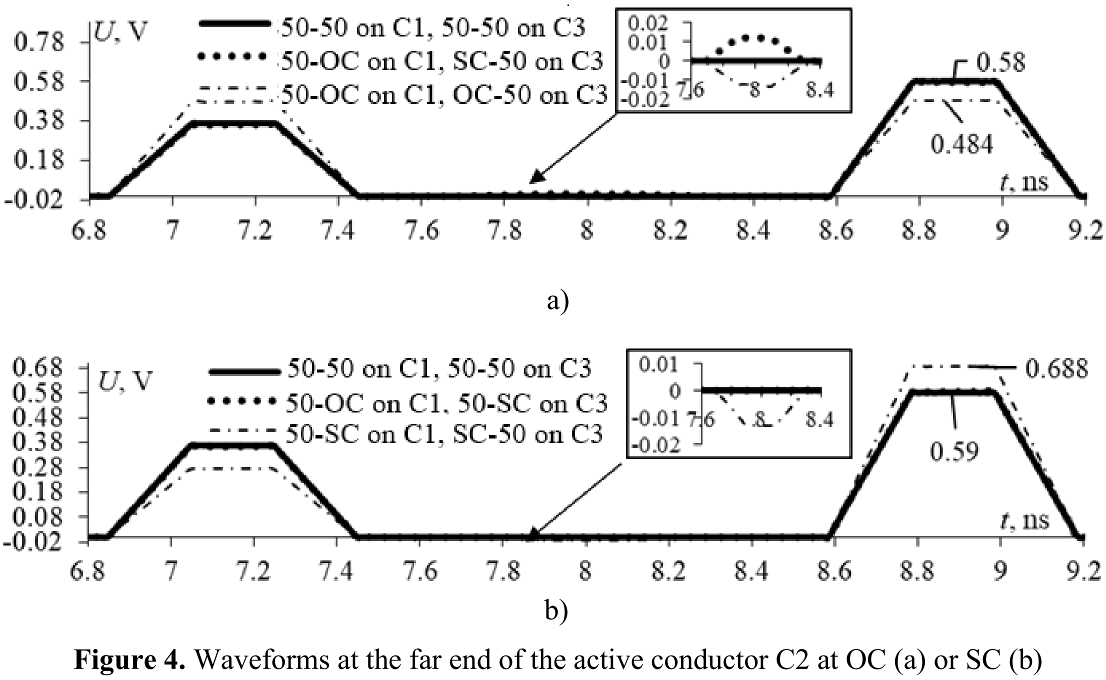

Figure 4. Waveforms at the far end of the active conductor C2 at OC (a) or SC (b) at the end of the passive conductor C1 under various boundary conditions at C3.

The voltage amplitudes at the far end of the active conductor before and after various switching options after failures are summarized in table 1. Only those voltage waveforms are considered that are not identical for different failure modes. For example, the waveforms with an active conductor C1 and C3 are identical. Moreover, the waveforms are identical if the boundary conditions on the passive conductors are symmetrical for different failure modes. For example, the waveforms of the option 50-50 at C2, 50–SC at C3 is identical to 50–50 at C2, SC–50 at C3, etc.

With the edge active conductor before failures, for option 1 after failures, there is a decrease to 0.469 V and an increase in the maximum amplitude to 0.63 V relative to half the EMF. For option 2, after failures, there is a decrease by 0.47 V and an increase in the maximum amplitude by 0.688 V relative to half of the EMF. For the switching option with an middle active conductor before failures, we observe after failures a decrease to 0.469 V and an increase in the maximum amplitude to 0.58 V relative to half of the EMF. Thus, if we do not know the probability of which type of failure is greater, then the preferred switching option is with an middle active conductor before failures, since for all failure options the maximum amplitude is less.

Table 1. Voltage amplitudes after different variants of failures at one end of the structure with MR.

Active conductor in a structure before faults	U_{max}, V	Option	After failure 1	U_{max}, V	After failure 1	U_{max}, V
edge	0.499	1	50–OC on C1, 50–50 on C3	0.53	50–OC on C1, 50–OC on C2	0.469
					50–OC on C1, OC–50 on C2	0.48
					50–OC on C1, 50–SC on C2	0.49
					50–OC on C1, SC–50 on C2	0.48
			50–SC on C1, 50–50 on C3	0.63	50–SC on C1, 50–SC on C2	0.49
					50–SC on C1, SC–50 on C2	0.52
					50–SC on C1, 50–OC on C2	0.53
					50–SC on C1, OC–50 on C2	0.517
		2	50–OC on C1, 50–50 on C2	0.48	50–OC on C1, 50–OC on C3	0.47
					50–OC on C1, OC–50 on C3	0.484
					50–OC on C1, 50–SC on C3	0.585
					50–OC on C1, SC–50 on C3	0.58
			50–SC on C1, 50–50 on C2	0.499	50–SC on C1, SC–50 on C3	0.679
					50–SC on C1, 50–SC on C3	0.688
					50–SC on C1, 50–OC on C3	0.585
					50–SC on C1, OC–50 on C3	0.58
middle	0.58	-	50–OC on C2, 50–50 on C3	0.499	50–OC on C1, 50–OC on C2	0.469
					50–OC on C1, OC–50 on C2	0.48
					50–OC on C1, 50–SC on C2	0.49
					50–OC on C1, SC–50 on C2	0.48
			50–SC on C2, 50–50 on C3	0.499	50–SC on C1, 50–SC on C2	0.49
					50–SC on C1, SC–50 on C2	0.52
					50–SC on C1, 50–OC on C2	0.53
					50–SC on C1, OC–50 on C2	0.517

However, if it is known that under certain operating conditions only failure of type OC or SC is possible, then the optimal switching option may be different. With the edge active conductor before failures, for option 1 after OC or SC failures, there is a decrease to 0.469 V and an increase in the maximum amplitude to 0.53 V, or a decrease to 0.49 V and an increase in the maximum amplitude to 0.63 V relative to half of the EMF, respectively. For option 2, after OC or SC failures, there is a decrease to 0.47 V and an increase in the maximum amplitude to 0.499 V, or a decrease to 0.499 V and an increase in the maximum amplitude to 0.688 V relative to half of the EMF, respectively. For the switching option with an middle active conductor before failures, after OC or SC failures, there is a decrease to 0.469 V and an increase in the maximum amplitude to 0.58 V, or a decrease to 0.49 V and an increase in the maximum amplitude to 0.58 V relative to half of the EMF, respectively. Thus, if either OC or SC failure is possible, then the preferred switching option after SC failures is with an middle active conductor before failures, and after failures of OC type, it is option 2 with an active conductor before failures, since after failures the maximum amplitude is less.

4. Conclusion

The failure of the system components with MR based on the 50 Ohm path was considered. 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, an SC or OC is formed at one end of the circuit. It is shown that if the probability of which type of failure is greater is not known, then the preferred switching option is with an middle active conductor before failures, since for all failure options the maximum amplitude is less and equal to 0.58 V. If only OC or SC failure is possible, then the preferred switching option after failures of type SC is with an middle active conductor before failures, and after failures of type OC, it is option 2 with an edge active conductor before failures, since after failures the maximum amplitudes are less and equal to 0.58 and 0.499 V, respectively. However, it is necessary to study in more detail the question of the switching order in structures with multiple MR.

Acknowledgment

The reported study was funded by Russian Science Foundation (project №20-19-00446) in TUSUR.

References

[1] Patel M R 2004 *Spacecraft Power Systems* (CRC press)
[2] Paul C R 2006 *Introduction to Electromagnetic Compatibility* vol 184 (John Wiley & Sons)
[3] Sharafutdinov V R and Gazizov T R 2019 *Systems of Control, Communication and Security*
[4] Gazizov T R, Orlov P E, Zabolotsky A M and Kuksenko S P 2016 *AIP Conference Proceedings* **1738** (AIP Publishing LLC) 440007
[5] Orlov P E, Buichkin E, Belousov A and Gazizov T R 2017 *Control and Communications* 1-4
[6] Orlov P, Buichkin E, Belousov A and Gazizov T 2017 *Proc. of the XIII Int. Siberian Conf. on Control and Communications* pp 1-4
[7] Sharafutdinov V and Medvedev A 2019 2019 *International Multi-Conference on Engineering, Computer and Information Sciences (SIBIRCON)* (IEEE) pp 0293-6
[8] Belousov A O, Chernikova E B, Samoylichenko M A, Medvedev A V, Nosov A V, Gazizov T R and Zabolotsky A M 2020 *Symmetry* **1117** 1-39
[9] Kuksenko S P 2019 IOP *Conf. Series: Materials Science and Engineering* **560** 1-7