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Simulation the Effect of Common-mode Excitation of Electrostatic Discharge on the Shielded Power Supply Bus Conductors

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***Abstract*—The paper presents the results of preliminary research into the propagation of common-mode excitation of electrostatic discharge along the conductors of the shielded power supply (PS) bus. To investigate signal propagation, we chose nine intervals, and detected and localized signal extreme points for the case when the exciting signals are located in the end branch conductors of the PS bus. It was revealed, that the voltage maximum was 213 V and is located in the multi-conductor transmission line (MCTL) section nearest to the source of the signal.**

Keywords—simulation, power supply bus, electrostatic discharge, shielding, voltage minimum

I. INTRODUCTION

Because of rapidly increasing demand for high-precision radioelectronic equipment, especially in the space industry, it is necessary to provide interference immunity of its components. Spacecraft crashes are widespread [1]. The influence of the geometry of a meander line on the amplitude of voltage maximum and waveform of electrostatic discharge (ESD) has been investigated in [2]. A study has been made of the anomalous behavior of satellite equipment, including the case the result of which was an ESD [3]. The methods to combat with ESD in spacecraft systems have been investigated in [4]. The relevance of investigation and the issues of ESD propagation in electronic equipment are shown in [5].

Earlier, ESD propagation has been investigated in the model of the power supply (PS) bus of a spacecraft [6]. The design of the PS bus has been changed during the development: extra conductors have been added in a central part of the branch of the PS bus, the geometry of elements used in the previous version of the PS bus has been changed, and a shielding winding has been added along the entire length of the PS bus.

The aim of this paper is to investigate the ESD propagation along the conductors of the shielded PS bus.

II. SIMULATION PARAMETERS

As a research structure, we chose the improved PS bus, which has been investigated earlier in [6]. A new design for the PS bus is being developed to increase the interference immunity of the spacecraft onboard cable network and reduce the spacecraft mass. The ESD parameters are given in [7] according to IEC 61000-4-2 [8]. To provide a high level of interference immunity to the developed PS bus it is advisable to check the influence of various types of electromagnetic interference. Electromagnetic interference may have common-mode or differential-mode components. Different simulation approaches to common-mode or differential-mode excitations are considered in [9]. However, this paper discusses the common-mode excitations of two ESD sources.

This shielding bus is being considered for the first time. An important change in the design of the PS bus is an additional shielding conductor in each of the segments of the transmission line, which in some places is grounded by connecting it to the spacecraft main body.

Fig. 1 *a* presents the circuit diagram of PS bus used with common-mode excitations when the exciting signals are located in the end branch conductors, and Fig. 1 *b* presents the one with the exciting signals located in the central branch. The sections of multiconductor transmission lines (MCTL) are numbered from 1 to 18. In the first case (Fig. 1 *b*) we selected two start nodes (A_1 and A_2), in which the waveforms will be calculated. Then, we selected the end nodes, to which the signal propagation study will be conducted (B_1–B_5).

In the second case, we selected the start and end nodes similarly (A_3, A_4, B_6–B_9). These intervals were selected to investigate possible vulnerabilities of the PS bus. The PS bus consists of 8 MCTL sections (7–12). Other MCTL sections are end branch conductors (sections 1, 2, 5, 6, 13, 14, 17 and 18) and central branch conductors (sections 3, 4, 15 and 16).

MCTL sections 1, 2, 5, 6, 13, 14, 17 and 18 are divided into 50 segments; MCTL sections 3, 4, 15 and 16 – into 25 segments; MCTL sections 9 and 10 – into 46 segments; MCTL sections 7 and 12 – into 3 segments; MCTL sections 8 and 11 – into 200 segments. This segmentation was chosen in order to provide the necessary accuracy of calculations.

The length of each segment in MCTL sections of the PS bus (sections 7–12) is 0.01 m and in the end branch conductors (sections 1–6 and 13–18) – 0.1 m. For example, the length of section 1 is 0.5 m, and section 8 – 0.204 m. In each segment, the waveform is calculated by selecting point A as a start node and point B as an end node, to which the signal propagation along the conductor was investigated.

Also, Fig. 1 indicates the localization points of voltage maximum and minimum for the interval between A_1–B_3. Fig. 2 shows cross-sections of the end (*a*) and central *(b)* branch conductors of the PS bus.

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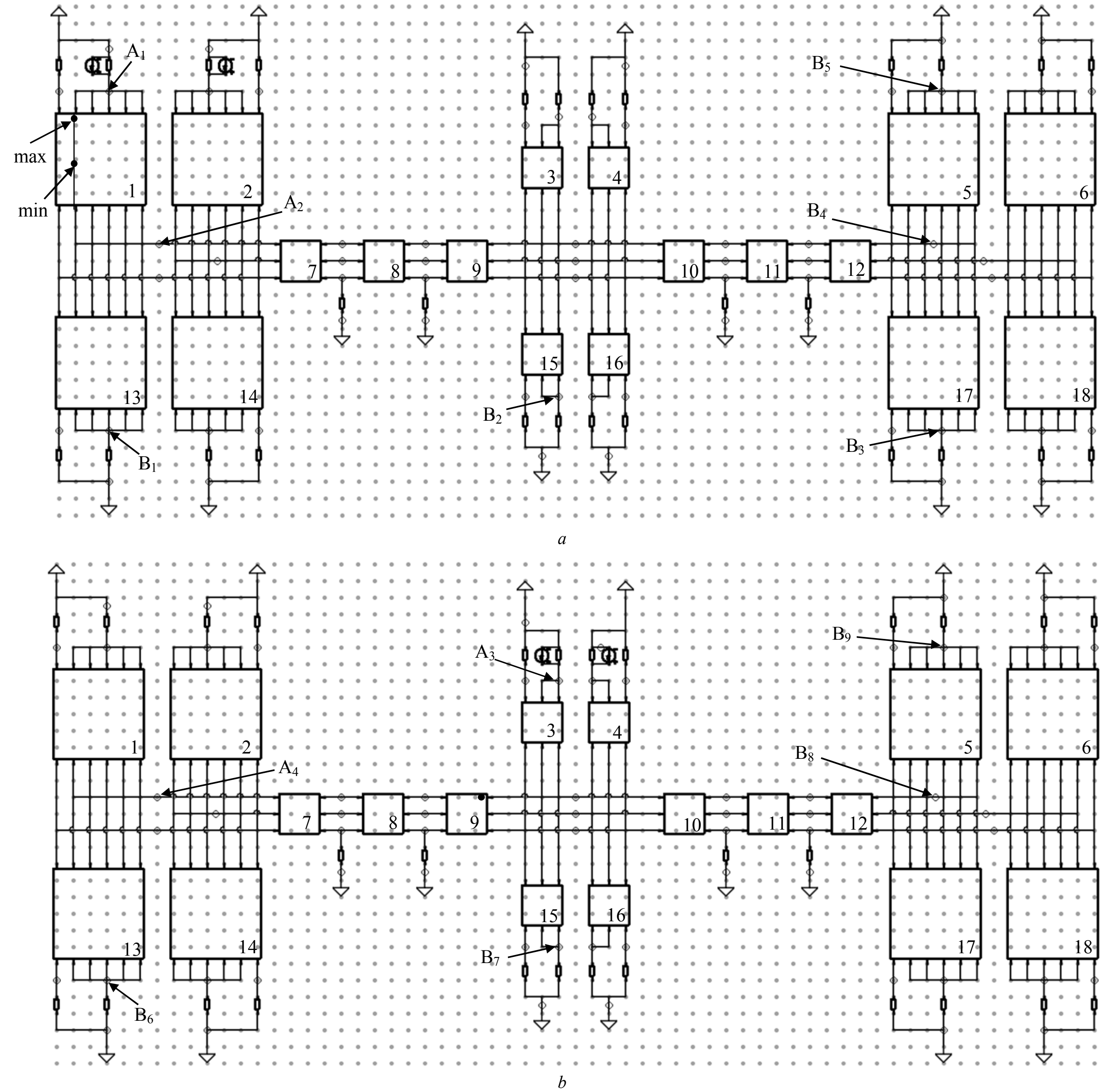

Fig. 1. Circuit diagram of the PS bus with ESD common-mode excitations in end (*a*) and central (*b*) branch conductors

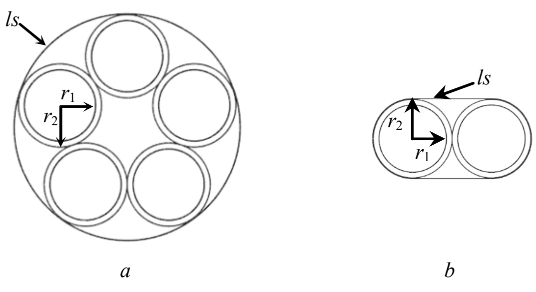

Fig. 2. Cross-sections of the central (*a*) and the end (*b*) branch conductors.

The dimensional specifications of the cross-sections (Fig. 2) are presented in Table I.

TABLE I. DIMENSIONAL SPECIFICATIONS OF THE CROSS-SECTIONS

Description	Notation	Value, mm
The radius of the branch conductor	r_1	30
The radius of the dielectric across the branch conductor	r_2	35
Lapped screen thickness	*ls*	0.06

III. Simulation Results

Below are the waveforms between nodes A_1–B_3 at the input of the conductor (Fig. 3), at the output of conductor (Fig. 4) and the voltage minimum (Fig. 5). The voltage waveform with the maximum calculated between nodes A_1 and B_3 is similar with the voltage waveform at node A_1. The time step was 10 ps.

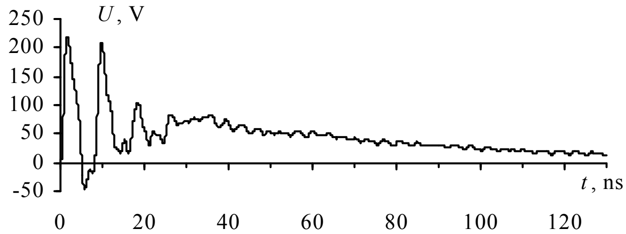

Fig. 3. Voltage waveform at the input (node A_1)

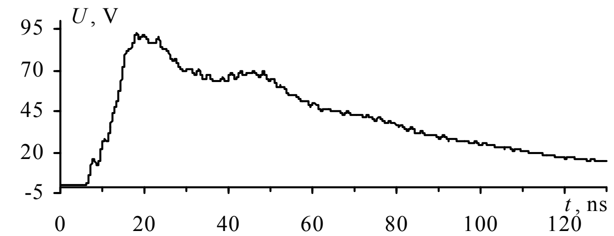

Fig. 4. Voltage waveform at the output (node B_3)

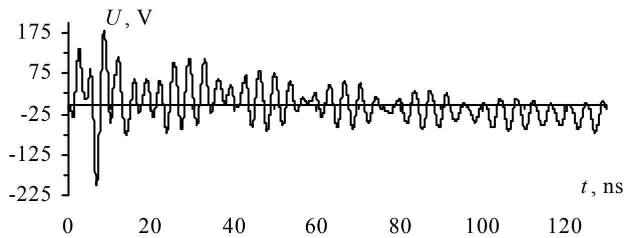

Fig. 5. Voltage waveform with the minimum between nodes A_1 to B_3

Table II shows the values of voltage maximum and minimum, the numbers of a segment and a section of the MCTL for the interval from A_1 to B_3.

TABLE II. LOCALIZATION OF VOLTAGE MAXIMUM AND MINIMUM

Signal extreme points	**MCTL Section**	**Segment**	***U*, B**
max	1	1	213.9
min	1	28	-198.7

IV. DISCUSSION OF RESULTS

Consider the voltage waveform shown in Fig. 3. This is the waveform at the input (node A_1), as well as the waveform with the voltage maximum between nodes A_1 and B_3. The main pulse of 213,9 V was observed, as well as three more, with smaller amplitudes: 220 V, 200 V and 100 V and followed by attenuation.

Consider the voltage waveform at the output shown in Fig. 4. The main pulse of 90 V was observed, as well as one more, with smaller amplitudes – 70 V, followed by attenuation to 20 V.

Consider the voltage minimum waveform shown in Fig. 5. The main pulse of minus 198.7 V was observed, as well as some more, with various amplitudes. Further, there is a fluctuation in the value of the voltage minimum from minus 50 V to 175 V.

Consider Table II of localization of voltage maximum and minimum. The voltage maximum and minimum are found to be located in the MCTL section nearest to the signal source.

V. CONCLUSION

A preliminary study of ESD common-mode excitation propagation along the conductors of the PS bus with shielding was conducted through its simulation. It is obtained that the voltage maximum (201.9 V) and the minimum (minus 198.7 V) are located in the MCTL section nearest to the source of the signal (section 1). In the future, it is advisable to conduct a more detailed investigation of the ESD propagation along conductors of the PS bus: by presenting the obtained matrices of the PS bus segments parameters and waveforms for each investigated ESD propagation path along the PS bus conductors.

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