ISSN 1068-7998, Russian Aeronautics, 2024, Vol. 67, No. 1, pp. 192–197. © Allerton Press, Inc., 2024.
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RADIO ENGINEERING
AND COMMUNICATION

Experimental Study of Electromagnetic Resistance of Technical Systems Exposed to Electromagnetic Effects from Several Sources

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Received December 6, 2023; revised December 26, 2023; accepted December 29, 2023

Abstract—A test bench was developed to study the electromagnetic resistance of technical systems and experimental studies were carried out on the electromagnetic interference induced on a microstrip communication line, when it simultaneously was exposed to several sources of external electromagnetic effects.

DOI: 10.3103/S1068799824010227

Keywords: electromagnetic resistance, ultrashort electromagnetic pulses, test bench, electromagnetic interference, technical system.

The main criterion determining the operation quality, reliability, and functional safety of technical systems is the electromagnetic resistance, as an integral part of the more general electromagnetic compatibility problem. The electromagnetic resistance of a technical system is defined as its ability to maintain a given quality of functioning under conditions of external electromagnetic effect not related to the principle of the technical system operation [1–4].

The problem of ensuring the electromagnetic resistance of technical systems is becoming most relevant due to the following reasons [4, 5].

1. Complication of the electromagnetic environment at all stages of the technical systems life cycle (from manufacture to operation), due to their filling in closed volumes of objects, for example, in aircraft.

2. A decrease in the levels of information signals and supply voltages of the elements (microprocessors, microcontrollers, and microcomputers) leads to a decrease in the electromagnetic resistance of technical systems.

3. Manufacturing process of the objects (for example, an aircraft) from composite materials (carbon fiber, fiberglass, etc.) clearly complicates the electromagnetic resistance problem solution, which is due to the low electrical conductivity of this type of material, shielding efficiency, and anisotropy.

4. The emergence of new sources (generators) of powerful pulsed electromagnetic effects with the ability to create an electromagnetic field with a strength of tens (and even hundreds) kV/m at frequencies up to tens of GHz at distances over 100 m, leads to a complication of the problem of studying and ensuring the electromagnetic resistance of technical systems.

5. The use of composite housings or blocks of technical systems complicates the use of known methods, techniques, and ways for studying its electromagnetic resistance and requires an individual solution to a number of scientific problems.

6. The problem of ensuring electromagnetic compatibility and stability of technical systems is characterized by a “cumulative effect”, i.e. meeting the requirements for electromagnetic compatibility of individual devices or subsystems does not guarantee the electromagnetic compatibility and stability of a complex technical system as a whole.

The issues of studying the functioning quality of technical systems exposed to external electromagnetic effects (lightning discharge, static electricity, electromagnetic pulse of a nuclear explosion, powerful sources of radio emission, etc.) have not found an effective solution in the works of domestic [6–9] and foreign authors [10–12]. It should be noted that there is a clear lack of research on the simultaneous effects of several sources of external electromagnetic effects. As a rule, the objects of research are simplified, so studies of electromagnetic resistance and noise immunity of technical systems are carried out without taking into account the objects of operation. Real trends in the development of complex technical systems necessitate a comprehensive study of their electromagnetic compatibility and resistance with a comprehensive account of the effects of sources and the ways of their interaction with devices of operating facilities.

Sources of external electromagnetic effects are divided by intensity, modes, and time of exposure. Sources can affect onboard equipment independently of each other and time interval, as well as complexly, with varying degrees of intensity. In turn, onboard equipment perceives external electromagnetic effects differently depending on its structure.

The purpose of this work is to develop a test bench for studying the electromagnetic resistance of technical systems when exposed simultaneously to several sources of external electromagnetic effects. The work is carried out to study electromagnetic interference induced in a circuit formed by a microstrip communication line on a printed circuit board exposed to simultaneous ultra-short electromagnetic radiation (EMR) pulse and powerful radio frequency exposure.

Carrying out measurements of electromagnetic interference in communication lines of technical systems when exposed to powerful broadband and ultra-wideband electromagnetic pulses (EMP) is associated with significant difficulties: the transience of processes when exposed to short-term EMP (the front is fractions of nanoseconds); the necessity of protecting the measuring equipment from the effects of powerful EMR. A group of different types of electromagnetic interference and their mutual transformation takes place in communication lines. Electromagnetic interference may arise from other external sources, for example, switching processes in equipment, etc. The probes of measuring instruments distort the true picture of the electromagnetic field when exposed to powerful EMR and lead to appearance of additional interference, namely, the noise on the oscilloscope screen.

In this work, a test bench has been developed (Fig. 1) that allows studying the simultaneous effects of ultrashort EMR and powerful radio frequency effects on technical systems. Here *1*—source of ultrashort EMP; *2*—antenna of a powerful radio frequency effects source; *3*—generator of powerful radio frequency effects (NSG 4070); *4*—laboratory table (wooden); *5*—tested printed circuit board; *6*—radio-absorbing material; *7*—measuring device (digital oscilloscope with a bandwidth of 1 GHz, sampling frequency 10 GHz); ASC—the anechoic screened chamber.

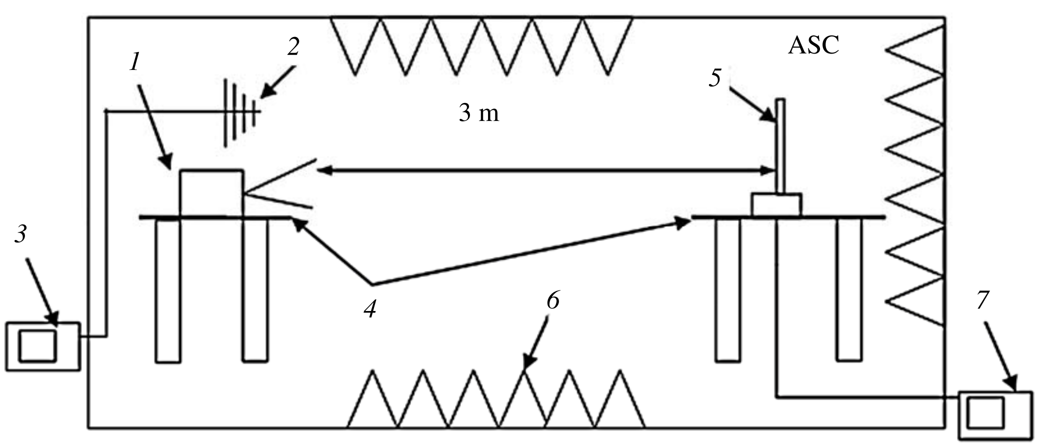

Fig. 1.

When analyzing the electromagnetic interference in communication lines, a set of at least five measurements is carried out for each case, while clearly outlying values are eliminated, and the final value is selected as the average of the measured ones.

Conducting studies of electromagnetic interference is necessary to set up a test bench and evaluate the effectiveness of exposure to two sources simultaneously. It should be noted that for experimental studies of electromagnetic interference, it is practically impossible to use real communication lines. Therefore, there is no information about experimental verification of real technical systems in the literature. It is also clear from the results of experimental works [13, 14] that the real operating conditions of technical systems are not fully taken into account nowadays.

The ultrashort EMR source consists of an EMR generator and a radiating antenna.

Let us give the main parameters of the generator: the voltage output pulse amplitude is 1 ÷ 10 kV; the pulse direction is positive; the pulse waveform is bell-shaped; the pulse duration (at 50% of the maximum amplitude) is 1.0±0.05 ns; the pulse rise time (from 10 to 90% of maximum amplitude) is 0.8±0.05 ns.

Source antenna specifications are as follows: the input voltage amplitude is no more than 10 kV; the emitted field (at a distance of 3 m) is 3 kV/m; the duration of emitted field strength pulse (at 50% of the maximum amplitude) is 0.6 ÷ 0.8 ns.

The electromagnetic interference is measured on the tested printed circuit board made of a foil-clad fiberglass (STF-2-35-0.3) of size 170×40×2.5 mm, with an interconnection size of 170×4 mm and a potential layer on the reverse side. The dielectric constant of the board is $\varepsilon = 4.9$. The load value at the ends of the interconnection is 50 Ohms. The interconnection material is copper (conductivity is 5.6×10^6 S/m, relative magnetic permeability is $\mu = 1.0$). The printed circuit board is located at a distance of 3 m from sources of external electromagnetic effects.

The results of studying the electromagnetic interference in a printed circuit board exposed to ultrashort EMR are presented in Fig. 2.

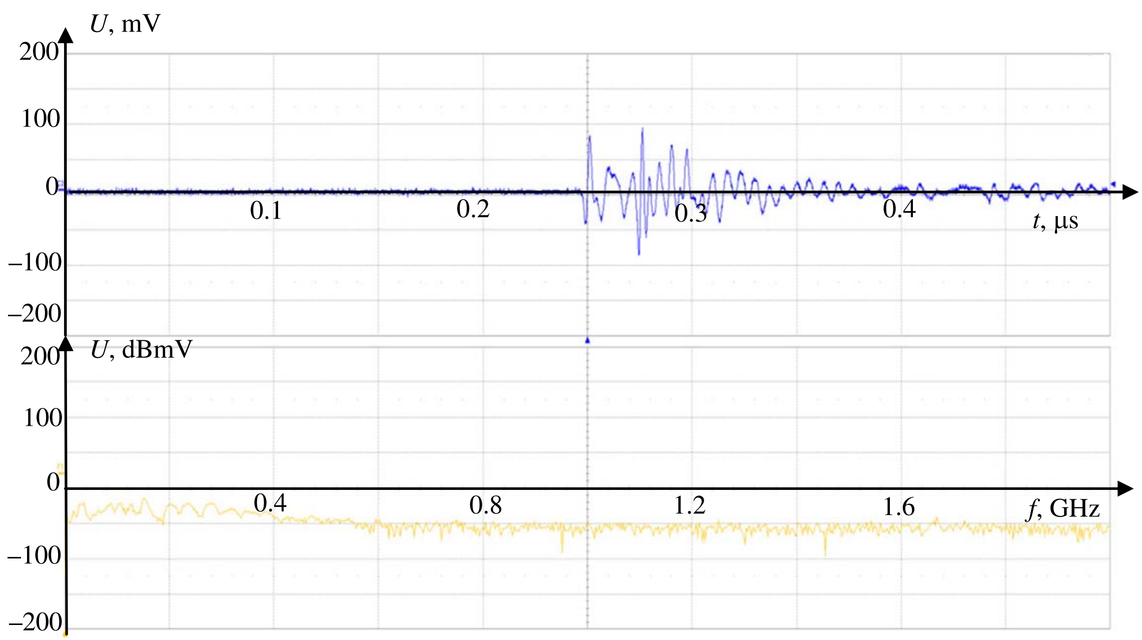

Fig. 2.

As can be seen from the results (see Fig. 2), when exposed to ultra-short EMR with a voltage of 200 kV/m in a circuit formed by the microstrip communication line and the ground bus on the printed circuit board at a load of 50 Ω, an electromagnetic interference is observed with a maximum voltage of 181 mV based on the sum of the maximum and minimum values.

The results of a study of electromagnetic interference in the printed circuit board when exposed to a powerful source of radio emission are presented in Fig. 3.

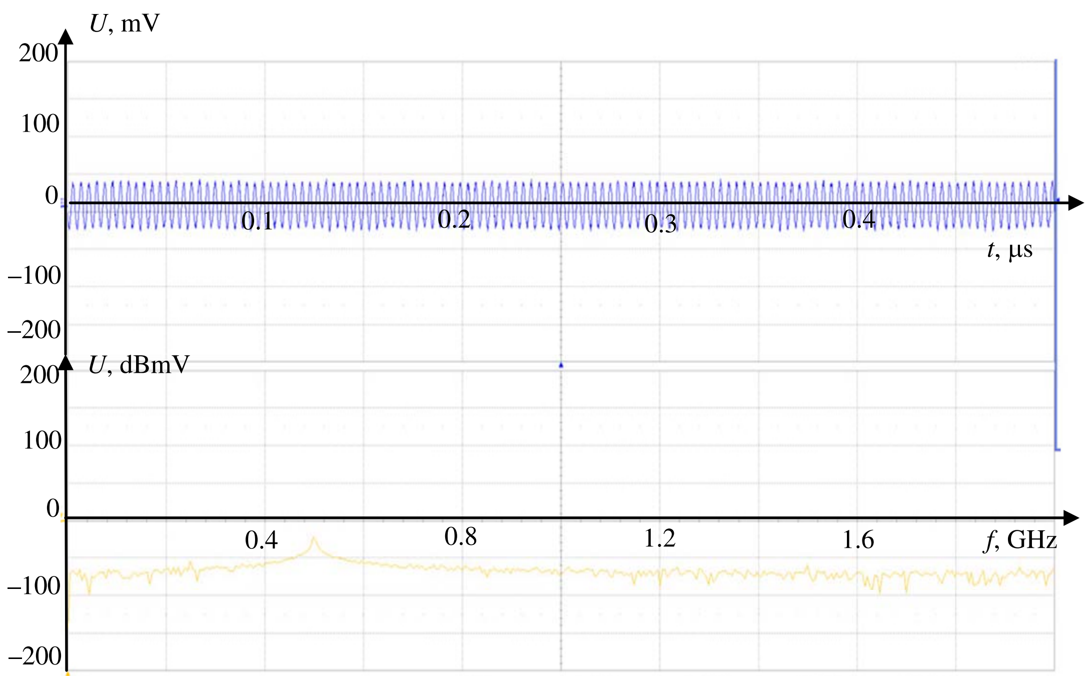

Fig. 3.

As can be seen from Fig. 3, an electromagnetic interference is observed with a maximum voltage of 69 mV based on the sum of the maximum and minimum values when exposed to powerful sources of radio emission with a voltage of 100 kV/m in a circuit formed by the microstrip communication line and the ground bus at a load of 50 Ω.

The results of studying the electromagnetic interference in a printed circuit board when exposed to two sources simultaneously are presented in Fig. 4.

As can be seen from the results (see Fig. 4), the resulting interference in the communication line of the printed circuit board is mainly determined by the maximum characteristics of the source. According to the study results, the electromagnetic interference with a maximum voltage of 230 mV is observed for the sum of the maximum and minimum meanings in a circuit formed by a microstrip communication line and the ground bus at a load of 50 Ω, when simultaneous exposed to ultra-short EMR and powerful sources of radio emission with a voltage of 200 kV/m and 100 kV/m, respectively. In this case, the resulting interference is significantly higher than the maximum values obtained as a result of sequential exposure. The spectral composition of electromagnetic interference is changed.

As a result of the research, a test bench was developed to study the electromagnetic resistance of technical systems when exposed to a source of ultrashort EMR and radio emission simultaneously. The mechanisms of simultaneous external electromagnetic effects on technical systems are substantiated taking into account the specifics of their operation.

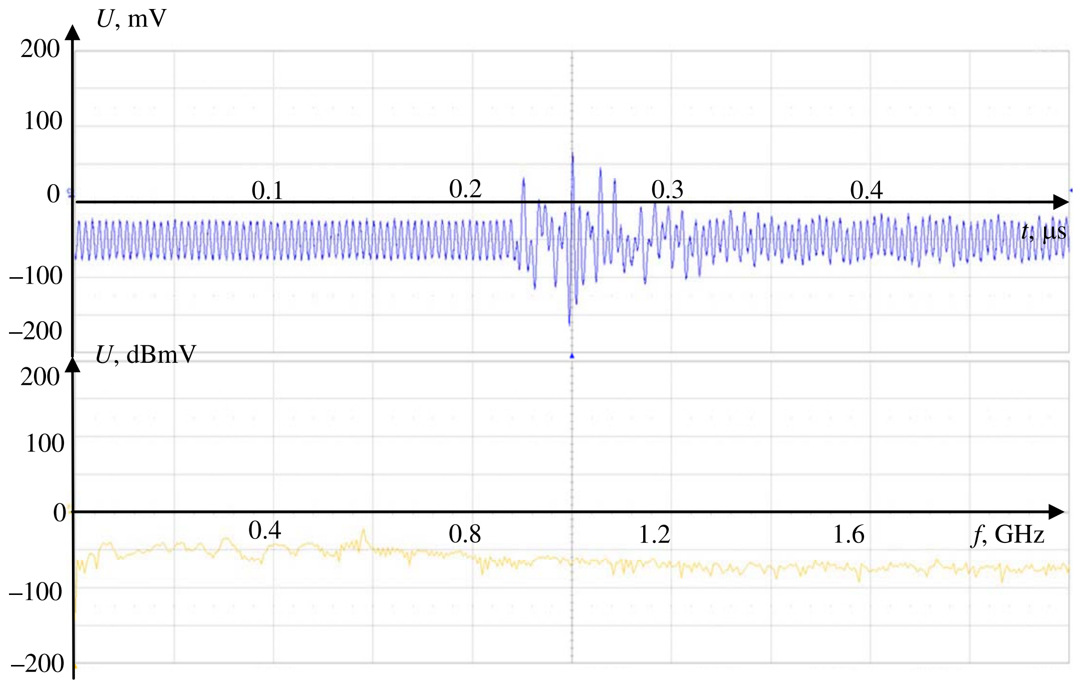

Fig. 4.

Research has been carried out on the electromagnetic interference when exposed to two sources simultaneously. Thus, the levels of the electromagnetic interference when exposed to a source of ultrashort EMR and radio emission increase significantly. The results of the study have practical utility; they allow us to evaluate the specifics of simultaneous effects of different radiation sources and can be used in comparative analysis to confirm the calculation methods of the study.

FUNDING

The work was supported by the grant of the Russian Science Foundation under Agreement no. 22-29-00890, URL: https://rscf.ru/project/22-29-00890/.

CONFLICT OF INTEREST

The authors of this work declare that they have no conflict of interest.

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