Research of output characteristics of the heterodyne executed on the printed circuit board with the increased resistance to electrostatic discharges

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***Abstract*— In operation results of computer simulation of characteristics of the standard analog device – the heterodyne executed on the printed circuit board from the composite dielectric having feeble conductivity are explained. Results of simulation showed that increase in specific bulk conductivity of material of the printed circuit board to $2 \cdot 10^{-7}$ $Ohm^{-1} \cdot m^{-1}$ practically does not change operating characteristics of a heterodyne. The possibility of effective use of the composite poorly carrying out dielectrics in standard radio engineering devices allowing to prevent origin of electrostatic discharges is set.**

Index Terms — Heterodyne, Printed Circuit Board, Composite dielectric, Computer simulation, Conductivity, Radio engineering devices, electrization and electrostatic discharge.

I INTRODUCTION

Mathematical and computer simulation, radiation electrization of dielectrics of spacecrafts [1] showed that use of the composite poorly carrying out dielectrics with the specific bulk conductivity lying in the range of 10^{-10}-10^{-9} $Ohms^{-1} \cdot$ the m^{-1}, provides a sink and alignment of the charge accumulated by dielectric in case of contact with the space plasma surrounding the device and prevents origin of electrostatic discharges (ESD) leading to failures and failures of an onboard radio-electronic equipment.

The potential difference between elements of the spacecraft (SCr) gradually increasing in case of charge accumulation and reaching critical value of an electric field in case of which there is a discharge is an origin of ESD. Thus, in essence the fact that dielectrics of space application have big relaxation time of Maxwell therefore the collecting charge does not manage to reflux or be aligned is a basic reason of originating ESD.

One of criteria of origin of ESD is the fluence of 2.1010 electrons/cm2 acquired by SCr dielectric in 10 hours. This criterion is offered by Frederikson [2] on the basis of the experimental data obtained in full-scale conditions of a geosynchronous orbit (GSO) in case of a research of processes of internal electrization on the special technological CRRES Spacecraft. This criterion is representing quite reasonable. When using on SCr of dielectrics with specific bulk

conductivity of an order 10-15 Om-1m-1 there is less a situation in case of which stationary surface potentials on SCr KA are set for the tenth fractions of a second, and relaxation times of Maxwell of these dielectrics make units and tens of hours. It is equivalent to installation on SCr of "a mine of delayed action".

Direct method of elimination of conditions of origin of ESD on the SCr working at geostationary and high-elliptic earth orbits is use of the composite poorly carrying out dielectrics.

In case of design of analog radio engineering devices such materials, now, are practically not applied as it is considered that their use will lead to violation of normal operation of devices.

We will consider the possibility of use of the composite poorly carrying out dielectrics on the example of a heterodyne - as standard functional assembly of the analog radio-engineering device.

II PURPOSE AND TASKS

The purpose of the real operation are reasons for a possibility of application composite the composite dielectric with controlled conductivity of dielectrics during creation of analog radio engineering devices of different function.

For achievement of the goal in operation, the following tasks are solved:

- as the researched analog radio engineering device the heterodyne is selected,
- its mathematical model considering material of the printed circuit board is constructed
- computer simulation of the heterodyne executed on the printed circuit board from composite composite dielectric with controlled conductivity dielectric is carried out and the values of specific conductivity of material of the printed circuit board leading to signal distortions by operation at different frequencies are defined.

III THEORETICAL PART

Changeover of traditional dielectric of the printed circuit board by poorly carrying out composite dielectrics is equivalent to appearance of the current leaks between nodes of the electric schematic diagram of the functional assembly [3].

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Their account in case of computer simulation is made by adding in computer model of the corresponding resistance. The adequacy of such model is shown in [3] by conducting the pilot studies on a real sample.

In the same work, it is shows that a defining factor in case of assessment of a possibility of use of the printed circuit boards executed using the composite poorly carrying out dielectrics is correlation of nominals of resistance imitating leaks with nominals of resistance of the functional assembly.

In case of simulation of characteristics of the heterodyne executed on the printed circuit board from the composite dielectric having feeble conductivity it is important to find the level of resistance of leak in case of which changes in operating characteristics of a heterodyne appear and to connect it to value of specific bulk conductivity of a dielectric material of the printed circuit board. This operation by us was executed as follows.

Capacity of dielectric was calculated from expression:

$$C = \varepsilon_0 \cdot \varepsilon \cdot \frac{S}{d}, \quad (1)$$

Where ε_0 = 8,85·10-12 F ·m^{-1} – an electrical constant;

ε – the relative dielectric constant of dielectric (for glass fiber laminate ε = 3,5 is accepted);

d – thickness of dielectric, m;

S – the irradiated surface (area) of dielectric accepted in our calculations by equal 1 m^2.

Resistance of dielectric corresponding to leak resistance was calculated from expression:

$$R = \frac{d}{\gamma \cdot S}, \quad (2)$$

where γ - specific bulk conductivity of dielectric.

Combining them expression (1) and (2), we receive:

$$\gamma = \frac{\varepsilon_0 \cdot \varepsilon}{R \cdot C} \quad (3)$$

Expression (3) allows carrying out assessment of unit volume resistance of the printed circuit board. In case of standard width of the printing conductor of 0.5 mm, both distance between the conductor and the screen of 1.5 mm for printed circuit boards with the screening surface according to [4] we receive value of stray capacitance 8 pF.

IV THE EXPERIMENTAL PART

For carrying out computer simulation of output characteristics of a heterodyne (fig. 1), executed on the printed circuit board using the composite poorly carrying out dielectrics, we will apply freely extended subsystem of *LTSpice*.

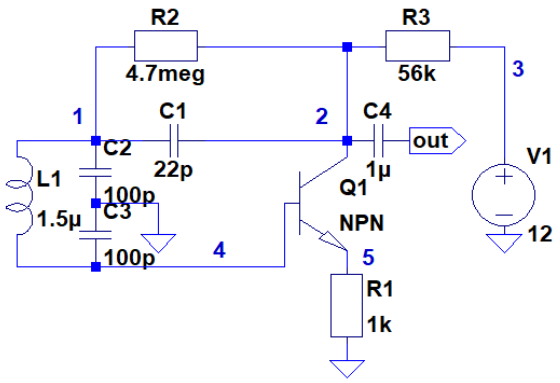

Fig. 1. Electric circuit of a heterodyne

The computer model of a heterodyne is given in fig. 2.

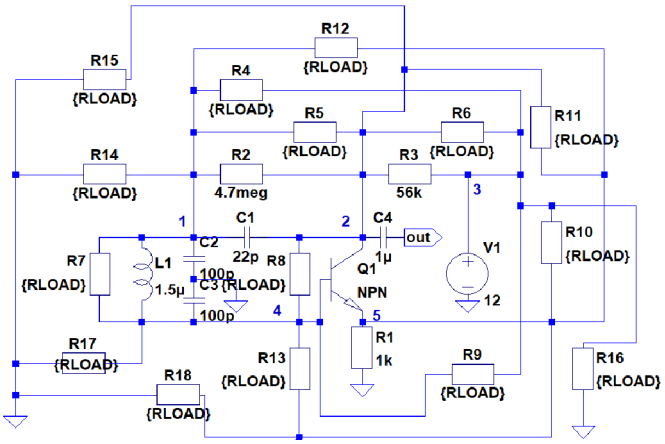

Fig. 2. Computer model of the heterodyne executed using the composite poorly carrying out dielectrics

In it R4 resistors – R15 model the leakage currents arising when using of the composite poorly carrying out dielectrics.

Computer simulation of a heterodyne is carried out for three carrier frequencies 9 MHz, 18 MHz and 37 MHz.

As an example in fig. 3 diagrams of voltage output of a heterodyne at a frequency of 18 MHz for different values of resistance of leak are shown.

Results of simulation are provided to tab. 1.

The analysis of results of computer simulation of an output characteristic of a heterodyne allows to drawing the following conclusions:

• **for the frequency of 37 MHz.** The period of output voltage begins to decrease in case of resistance of leakage of 3 megohms. Value of amplitude of output voltage begins to decrease in case of resistance of leakage of 20 megohms, and phase displacement of output voltage begins to be watched in case of resistance of leakage of 20 megohm;

• **for the frequency of 18 MHz.** The period of voltage output does not change in case of leak resistance in the range of 3 - 200 megohms. Value of amplitude of voltage output begins to decrease in case of resistance of leakage of 10 megohms, and phase displacement of voltage output begins to be watched in case of resistance of leakage of 10 megohm;

• for the frequency of 9 MHz. The period of voltage output does not change in case of leak resistance in the range of 3 - 200 megohms. Value of amplitude of voltage output begins to

decrease in case of resistance of leakage of 10 megohms, and phase displacement of voltage output begins to be watched in case of resistance of leakage of 10 me ohm.

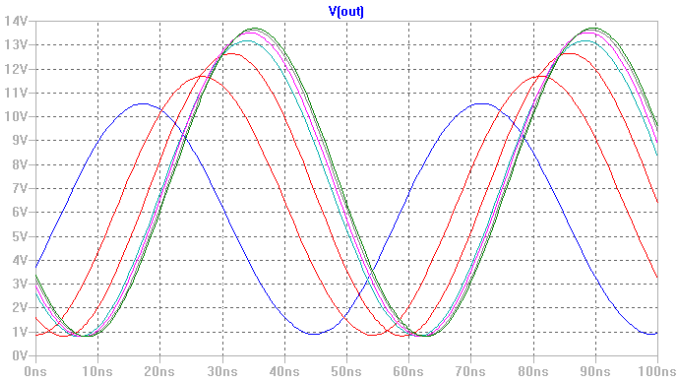

Fig. 3. Diagrams of voltage output of a heterodyne

TABLE I.
Results of simulation of characteristics of a heterodyne

		∞	200 MOhm	50 MOhm	20 MOhm	10 MOhm	3 MOhm
37 MHz	T, ns	27,3	27,2	27,1	27,3	27.2	26.8
	F, MHz	36,9	36.8	36,9	36,6	36.7	37.3
	V_{amp}, V	6.74	6.73	6.63	6.42	6.13	5.01
18 MHz	T, ns	54,4	54,1	54,2	54,4	54.1	54.7
	F, MHz	18,4	18,5	18,4	18,4	18.5	18.3
	V_{amp}, V	6.83	6.85	6.75	6.17	5.9	4.81
9 MHz	T, ns	108,3	108,3	108,3	108,3	108, 3	108. 7
	F, MHz	9,23	9.24	9,24	9,23	9,23	9.2
	V_{amp}, V	6.75	6.8	6.75	6.75	6.55	5.14

We see that at all researched frequencies the period of output voltage begins to change when the leak resistance caused by use of poorly carrying out dielectrics in case of manufacture of the printed circuit board is 3 megohms. In case of leak resistance less than 3 megohms begin to be watched frequency change of output voltage.

As show results of simulation, value of amplitude of output voltage at frequencies of 37 and 18 MHz begins to decrease in case of resistance of leakage of 20 megohms, and at a frequency of 9 MHz in case of leak resistance 10 megohms. Last has a talk commensurability of value of resistance of leak with parameters of circuit elements of a heterodyne.

Phase displacement of output voltage begins to be watched in case of resistance of leakage of 10 megohms and less.

From the analysis of results of simulation it is possible to draw a conclusion, in case of leak resistance 20 MHz and above change of output characteristics do not occur. We will estimate value of the appropriate specific bulk conductivity of material of the printed circuit board, using expression (3).

With a standard width of the printing conductor of 0.5 mm and distance between the conductor and the screen of 1.5 mm for printed circuit boards with the screening surface according to [4] we receive value of stray capacitance 8 pF. Adding this value together with value of resistance of leak, equal 20 MHz, in expression (3), we receive value of specific bulk conductivity:

$$\gamma = \frac{\varepsilon_0 \cdot \varepsilon}{R \cdot C} = \frac{8.85 \cdot 10^{-12} \cdot 3.5}{20 \cdot 10^{6} \cdot 8 \cdot 10^{-12}} = 1.95 \cdot 10^{=7} \quad \text{ohm}^{-1} \cdot \text{m}^{-1}$$

Thus, results of simulation showed that use of poorly carrying out dielectrics as a part of printed circuit boards has no significant effect on operation of a heterodyne in the range of the frequencies of 9 - 37 MHz when specific volume the conductivity of a dielectric material of the printed circuit board does not exceed 2·10-7 Ohms-1 · m-1. This value is two orders more than usually used values of specific bulk conductivity of poorly carrying out dielectrics providing a sink and alignment of an embeddable charge and excluding probability of origin of ESD.

V CONCLUSION

Results of simulation of characteristics of the standard analog device – the heterodyne executed on the printed circuit board from the composite dielectric having feeble conductivity showed that increase in conductivity of material of the printed circuit board up to 2·10-7 Ohms-1·m-1 practically does not change operating characteristics of a heterodyne in the range of the frequencies of 9 - 37 MHz. The possibility of effective use of the composite poorly carrying out dielectrics in standard radio engineering devices allowing to prevent origin of electrostatic discharges is set.

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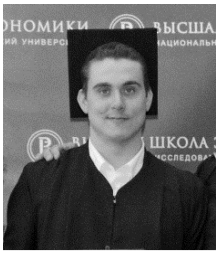

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