Abstract *(Paper not available)*

External and Internal Spacecraft Charging Effects and Mitigation Techniques. Russia's Approach.

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In this talk, I will speak about a multi-step methodology developed in MIEM NRU HSE to safeguard the spacecraft successful operation in orbit as adopted in Russian space industry.

As a first step, we propose choosing dielectric materials for spacecraft application having a low Maxwell relaxation time (from 0.01 to 10 s). This time is to be evaluated after prolonged material exposure to vacuum and an elevated temperature in order to obtain conductivity data representative of the space environment. Otherwise, this data obtained by the conventional electrical techniques in ground tests is expected to underestimate the conductivity that would appear in real space conditions. These materials are considered to be good candidates for possible space application.

As a second step, we measure the radiation-induced conductivity (including its build-up and decay) of those dielectrics whose dark conductivity does not exceed about 10^-11 Ohm^-1 m^-1. After that, based on this information we estimate the maximum electric fields in a dielectric for a worst-case scenario of a magnetic substorm as these fields are controlled mainly by the above-mentioned conductivities.

An electrical method for measuring dark conductivity is well-known. Experimental as well as theoretical aspects of measuring the radiation-induced conductivity and estimating an accumulated space charge in dielectrics are successfully dealt with by the school of prof. A. Tyutnev (present at this meeting) [1]. On the final stage of a material qualification to withstand induced electric fields, we conduct laboratory tests by irradiating the material in vacuum by monoenergetic electrons with energy up to 50 keV.

The next step occurs on the design stage and consists in developing of a model describing the interaction of the spacecraft with the near-Earth space plasma. Russia has its own computer programs similar to the famous NASA NASCAP code. The above-mentioned model and the computer code (developed by L. Novikov et al.) have been successfully used to compute the potential distribution on the spacecraft outer surfaces and what is especially important they allow locating the possible sites of electrostatic discharges (ESD) [2]. As a result, we get knowledge about the anticipated potential difference producing an ESD.

Predicted ESD sites and the associated potential differences are used afterwards as input data for computations of the pulsed EMF signals in cables traced on the spacecraft outer surfaces. To carry out these computations, we employ a tailor-made "Satellite-MIEM" computer code developed in MIEM NRU HSE under leadership of professors E. Pozhidaev and V. Saenko. This computer code allows solving of the main problem: estimating pulsed interference signals in the input circuits of electronic devices which could be used on the early design stage of the space vehicle. This allows design engineers to take preventive measures in advance to make spacecraft electronics tolerable to ESD effects.

Also, we list space vehicles, rockets and upper stages (US) together with accessories (materials and electronics), which underwent in MIEM NRU HSE the multi-step methodology intended to protect a spacecraft under development against the damaging factors of the exterior spacecraft charging: International Space Station, Angara A5 Rocket, Proton Rocket , "Spektr-R" Satellite [3], Kazsat Satellite , Express MD Satellite, US Breeze, US KVTK, and some others.

Now, a few words about internal charging. In Russia, as in the West, we use the well-known circuit solutions to mitigate charging effects. As for the original variant of protection against an internal charging effects utilizing the dielectric composites with low conductivity (we call them “nanoconducting dielectrics”) which allow easy leaking of space charges and bulk potential leveling, I plan to talk specifically on this subject in my separate report at this conference.

1. A.P. Tyutnev, V.S. Saenko, E.D. Pozhidaev, R.Sh. Ikhsanov. Experimental and Theoretical Studies of Radiation-Induced Conductivity in Spacecraft Polymers // IEEE Transactions on Plasma Sciences. 2015. Vol. 43. No. 9. P. 2915 - 2924.

2. K.K. Krupnikov, A.A. Makletsov., V.N. Mileev., L.S. Novikov., V.V.Sinolits Computer simulation of spacecraft // Radiation Measurements, Pergamon Press Ltd. (United Kingdom), vol. 30, № 5, c. 653-659

3. V.S. Saenko, A.P. Tyutnev, Nikolski E. V., Bakutov A. E. Protection of the Spectr-R Spacecraft Against ESD Effects Using Satellite-MIEM Computer Code // IEEE Transactions on Plasma Science. 2015. Vol. 43. No. 9. P. 2828 -2831.

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