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Solar particle events contribution in the space radiation exposure on electronic equipment at the polar orbit

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We analyzed several big solar particle events in 2010-2014 and calculated its contribution in particle′s fluxes at the polar orbit. We showed that solar protons can give considerable or even main contribution in particle′s fluxes at the polar orbit comparing with radiation belts and, as consequence, the considerable contribution in electronic equipment failure due to single event effects as well as dose effects.

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1. Introduction

The space ionizing radiation is the main factor which restrict an active lifetime of electronic equipments onboard spacecrafts. The monitoring of space radiation characteristics is needed to estimate the degree of space radiation exposure on equipments. For this purpose the monitoring system of space radiation exposure on spacecraft equipment was made on demand of Roscosmos [1]. Roscosmos monitoring system includes as well flight data of charge particle′s flux from Meteor-M (presented by Fiodorov Institute of Applied Geophysics). In this paper we present processed flight data from Meteor-M and the estimation of solar particle events contribution in the space radiation exposure on spacecraft′s equipments on Meteor-M′s orbit.

2. The flight data description

Meteor-M operates on polar orbit with an altitude of 832 km and with an inclination of 99°. The spacecraft contains several detectors of charge particles as well Geiger-Muller counters and Cherenkov counter. The former measures flux of electrons with energy more than 0.7 MeV and protons with energy more than 15 MeV and flux of electrons with energy more than 1.5 MeV and protons with energy more than 25 MeV. The latter measures flux of electrons with energy more than 6 MeV and protons with energy more than 600 MeV. The flight data for 2010 - 2014 are presented in the figure 1. One can see several abrupt increasing of charge particle′s fluxes.

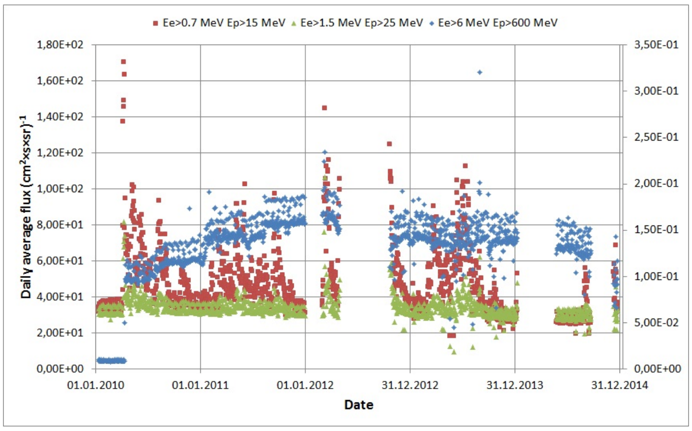

Figure 1: Charge particle′s flux on Meteor-M′s orbit in 2010 - 2014.

3. Solar proton events

Analisys of GOES [2] and Electro-L (spacecrafts on the geostationary orbit) shows that there are several events with abrupt increasing of solar energetic particles (SEP) flux: in January, 2012, in March, 2012, in May, 2013 and in January, 2014. All these events are S3 class [3]. The figure 2 show flight data in May, 2013 from GOES and Electro-L spacecrafts. Such SEP flux increasing events were observed also on the POES spacecraft [4] (figure 3) which is operating in polar orbit with altitude of 870 km with inclination of 99, and on the Meteor-M spacecraft. In this paper we are considered three solar proton events (SPE): in March, 2012, in May, 2013 and in January, 2014.

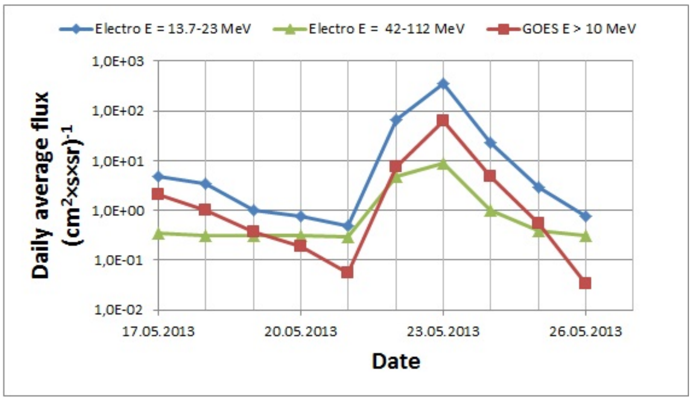

Figure 2: Proton′s flux on GOES and Electro-L (geostationary orbit) in May, 2013.

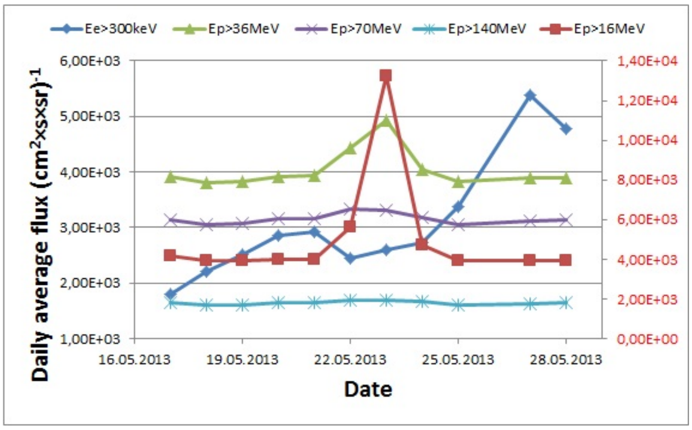

Figure 3: Proton′s and electron′s fluxes on POES (polar orbit, 870 km) in May, 2013.

4. Determination of charge particle′s spectra during SPE

To determine charge particle′s spectra during SPE we use the following approach. We determine SEP flux during SPE as a charge particle′s flux in polar regions (figure 4) and electron′s flux as an difference between total and SEP fluxes.

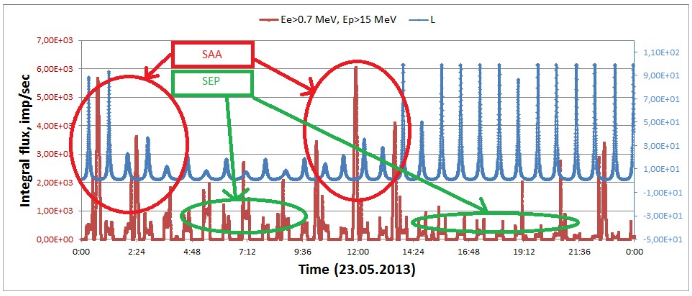

Figure 4: Charge particle′s flux on Meteor-M′s orbit during SPE event in 2013 and L values of Meteor-M′s spacecraft.

Results of SEP′s and electron′s spectra determination during SPE with its approximation are presented in figures 5, 6, 7, 8, 9, 10. Also in figure 7 proton′s spectrum during SPE in 23.05.2013 on POES orbit is presented. One can see a good quantitative agreement with Meteor-M data.

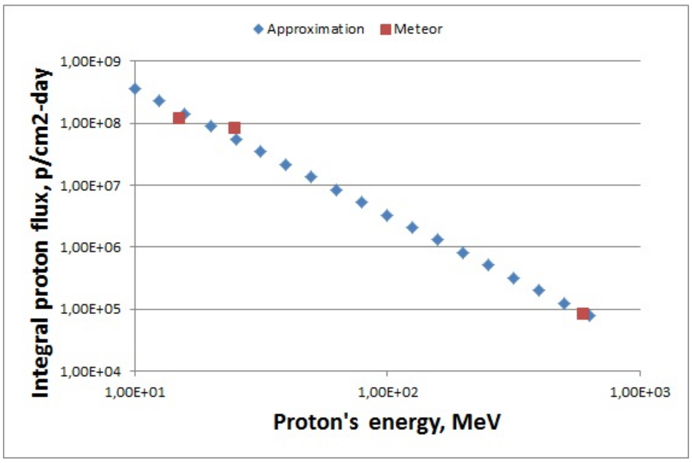

Figure 5: Integral SEP′s spectrum on Meteor-M′s orbit during SPE event in 2012.

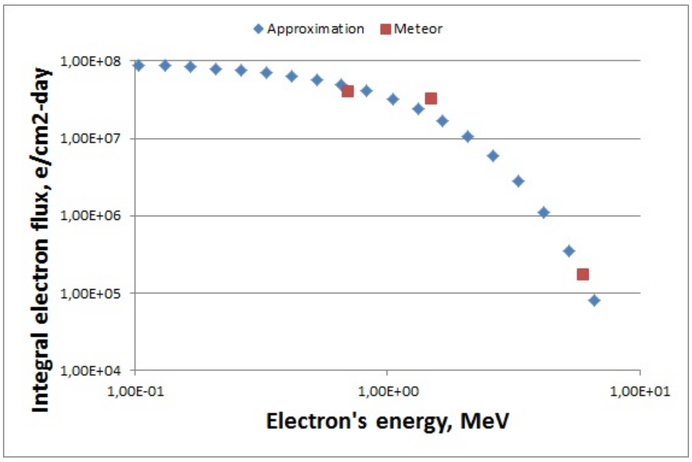

Figure 6: Integral electron′s spectrum on Meteor-M′s orbit during SPE event in 2012.

5. Determination of the SEP contribution in absorbed dose value

To determine absorbed dose from SEP and electron during SPE we use software OMERE [5] and spectra of charge particles in figures 5, 6, 7, 8, 9, 10 as an input data for software. We have got similar results for all events, which are presented in figures 11, 12 and 13. As one can see in figures 11, 12 and 13 the main contribution (98-99%) in absorbed dose value in polar orbit during SPE give SEP. It is in agreement with calculation results using charge particle′s flux models. In figure 14 calculated absorbed dose values using spectra from AE8MAX model (electron) and worst day of October, 2003 and October, 1989 models are presented. One can see that absorbed dose value from SEP in 2003 SPE is more in approximately 10 times than one in 1989 event. So absorbed dose value can differs significantly for different SPE.

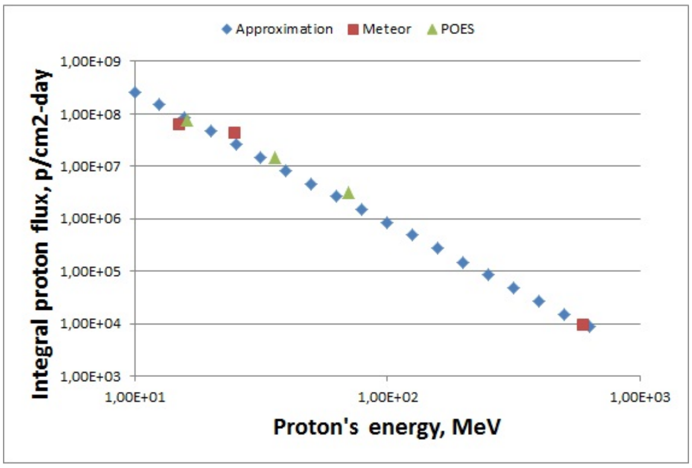

Figure 7: Integral SEP′s spectrum on Meteor-M′s and POES orbits during SPE event in 2013.

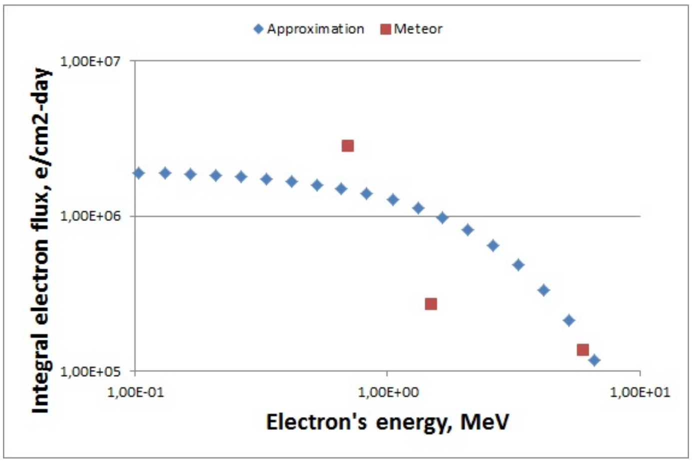

Figure 8: Integral electron′s spectrum on Meteor-M′s orbit during SPE event in 2013.

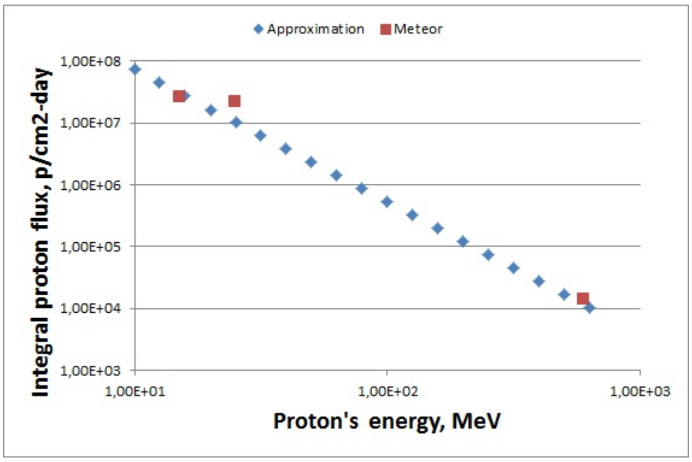

Figure 9: Integral SEP′s spectrum on Meteor-M′s orbit during SPE event in 2014.

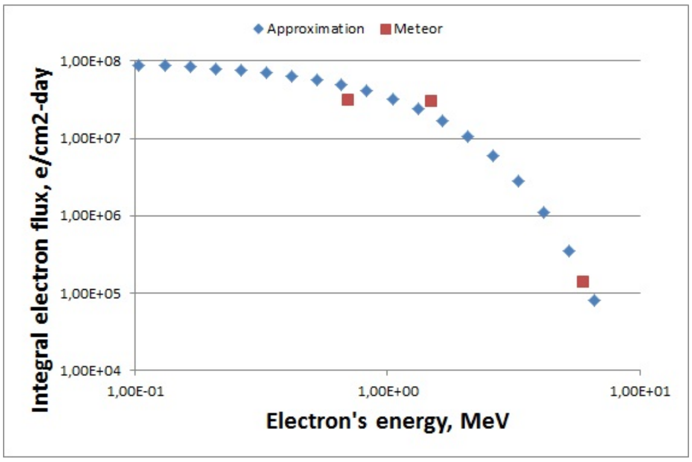

Figure 10: Integral electron′s spectrum on Meteor-M′s orbit during SPE event in 2014.

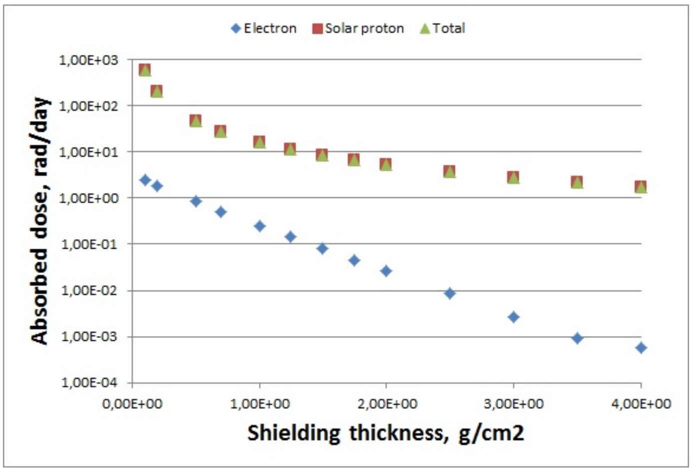

Figure 11: Calculated absorbed dose values using experimental SEP and electron fluxes on Meteor-M′s orbit during SPE event in 2012.

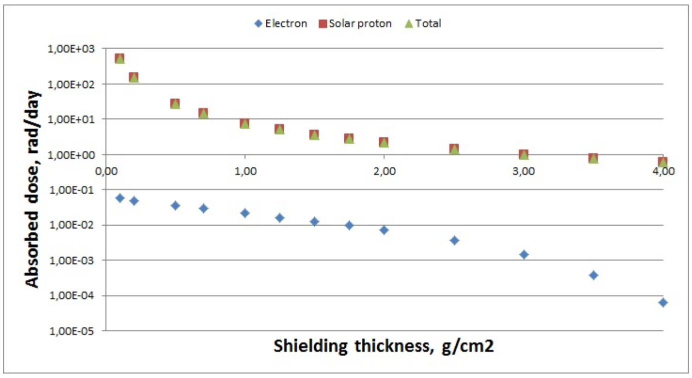

Figure 12: Calculated absorbed dose values using experimental SEP and electron fluxes on Meteor-M′s orbit during SPE event in 2013.

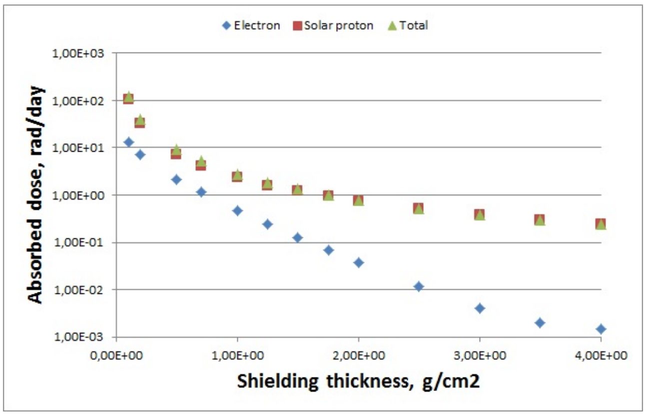

Figure 13: Calculated absorbed dose values using experimental SEP and electron fluxes on Meteor-M′s orbit during SPE event in 2014.

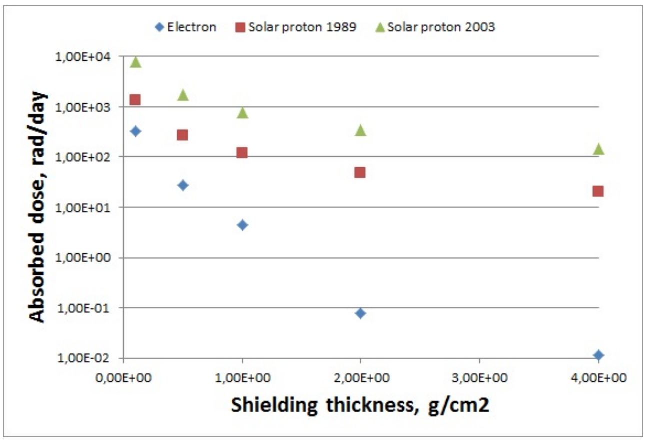

Figure 14: Calculated absorbed dose values using modeled spectra (AE8max for electron and worst day in October, 2003 and October, 1989 for SEP).

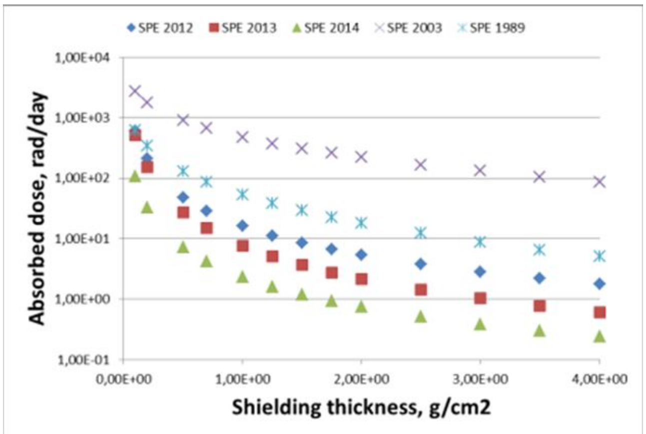

Figure 15: Calculated absorbed dose values using experimental (SPE in 2012, SPE in 2013 and SPE in 2014) and model (based on SPE in 1989 and SPE in 2003) SEP spectra.

In figure 15 absorbed dose values for fixed events (in 2012, 2013 and 2014) and earlier events (worst day in October, 2003 and October, 1989) are presented. One can see that the biggest dose value gives SPE in 2012 and the lowest - SPE in 2014 (the difference is approximatly equal factor). Also one can see that absorbed dose value from SEP in 2012 event is less in approximately 3 times than one in 1989 event and is less in approximately 30 times than one in 2003 event.

6. Conclusion

Several events of solar energetic proton fluxes large increasing are fixed on the Meteor-M orbit. It is confirmed by other flight measurements (GOES and Electro-L in geostationary orbit and POES in polar orbit). SEP fluxes during SPE, which were obtained by the processing of charge particle′s flux flight measurements on similar polar orbits of Meteor-M and POES, are coincided quantitatively. SEP flux during SPE gives the main contribution (98-99%) in total dose value. It is in agreement with calculation using charge particle′s fluxes models. Absorbed dose from the maximum fixed SPE (March, 2012) is less in ˜3 times than one from SPE in 1989 and in ˜30 times less than one from SPE in 2003. The dose rate abrupt increase can cause the abnormal operation of spacecraft′s equipment because of the TID effect (close to its failure level region). In future it is reasonable to estimate quantitatively SEP contribution in single events effects rate in different orbits using flight measurements of charge particle′s fluxes for these orbits or using calculated spectra from GOES and Electro-L data (geostationary orbit) with taking into account the real geomagnetic activity.

References

[1] V. S. Anashin, G. A. Protopopov, P. A. Shatov, and S. V. Tasenko, "Analysis of Geostationary and Polar Orbit Space Environment Data Processed by the Russian Federal Space Agency (Roscosmos) Monitoring System", 2014 IEEE Radiation Effects Data Workshop (REDW), Jul. 2014.

[2] http://www.swpc.noaa.gov

[3] http://umbra.nascom.nasa.gov/SEP/

[4] http://www.ngdc.noaa.gov/stp/satellite/poes/dataaccess.html

[5] http://www.trad.fr/OMERE-Software.html