Blackout mitigation in a plasma layer near a high-speed body in ExB fields

Sergei Poniaev[1], Yurii Kurakin[1], Alexander Schmidt[1], Sergey Bobashev[1], Lars Steffens[2], Burkradt Esser[2], Ali Gulhan[2]

[1] *Ioffe Physical-Technical Institute, Politekhnicheskaya 26, St.Petersburg, Russia*

[2] *The Institute of Aerodynamics and Flow Technology, DLR, Cologne, Germany*

When a space vehicle re-enters the atmosphere at a high velocity, a layer of ionized gas is formed around it. This layer shields the radio signal transmission to and from the vehicle. Ionization of the atmospheric gas results from aerodynamic heating. If the vehicle velocity is very high, a complete interruption of the communication can take place. This phenomenon, the so-called radio transmission "blackout", was observed during the first re-entry phase of space flights [1]. A vehicle re-entering the Earth's atmosphere from an orbital flight has a velocity of about 8 km/s at an altitude of about 120 km. At this altitude the atmospheric drag increases significantly, and the vehicle kinetic energy is converted into the gas internal energy due to deceleration. The flow around the vehicle is characterized by an extremely complex structure with a bow shock wave in front of the vehicle. For a typical re-entry trajectory of “Space Shuttle” the maximum heating corresponds to the range of altitudes 80 – 60 km.

In the shock layer between the bow shock wave and the vehicle surface the gas temperature can reach 10^4 K and the gas becomes ionized, thus forming a plasma layer in the vicinity of the vehicle surface. For a typical re-entry trajectory the plasma frequency in this layer can be significantly higher than 10^9 Hz. This gives rise to attenuation and “blackout” of radio communication with the vehicle. For the “Space Shuttle” it typically lasts approximately from 25 to 12 minutes prior to landing, which is the most critical period of time during the re-entry. If a problem in this phase of flight arises, the diagnostic telemetry cannot be received from the vehicle and necessary commands do not reach the vehicle because of the communication “blackout”. In recent years a number of papers devoted to modelling of the flow in crossed electric and magnetic fields (ExB layer) in application to the blackout mitigation problem have been published. Among them there is a series of papers concerned with the use of the MHD approach in the physical model. In this report a computational modelling of the method of mitigation of radio transmission blackout during a flight at a high velocity in crossed electric and magnetic field is presented. This computational modelling shows that a decrease in plasma frequency can be obtained by applying electric and magnetic fields to the ionized layer near the model surface, which leads to a decrease in the charged particle density in some places near the electrodes.

Some experimental results and plans for research activities using the L2K facility of DLR, Kologne [2], are also presented.

This research has been supported by the RFBR 12-01-91320-SIG_a.

[1] Hartunian, R. A. et al., “Cause and Mitigations Radio Frequency (RF) Blackout During re-entry of Reusable Launch Vehicles,” ATR 2007 (2007), ATR-2007-(5309)

[2] Gulhan, A., and Esser, B., “Arc-Heated Facilities as a Tool to Study Aerothermodynamic Problems of Reentry Vehicles,” Advanced Hypersonic Test Facilities, Progress in Astronautics and Aeronautics, Vol. 198, (2002) 375-403