Satellite launch vehicle effect on the Earth's lower ionosphere

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Abstract:

The effect of the rocket exhaust products on the D-region of the ionosphere is investigated with the help of Very low frequency (VLF) electromagnetic wave propagation characteristics within the Earth-ionosphere waveguide. The changes in the electron density profile are computed from the observed VLF signal amplitude perturbations during the rocket launch. We find a localized electron depletion in the lower ionosphere at an altitude of around 58 km, that is thought to be originated by the water molecule in the exhaust product of first stage burn of Geosynchronous Launch Vehicle (GSLV) rocket at the time of GSLV launched from Sriharikota, India, on 27 August 2015 at 11:22 UT (16:52 IST). The ionospheric depletion perturbed the navigational VLF signal (VTX=17 kHz) signal after the 137.8 seconds after the launch of the GSLV rocket. A Long Wave Propagation Capability (LWPC) model study supports the findings. Our results are first of its kind from the Indian subcontinent.

Key words: Lower ionosphere; GSLV rocket fuel; VLF electromagnetic wave

1. Introduction: In earlier days of ionospheric research, in-situ experiments were conducted to observe the effects of rocket exhaust product in the upper ionosphere [2]. In recent times, satellite-based observations [6], has been performed by several workers to understand the effects of rocket exhausts products on the ionosphere in greater details [3]. The localized ions were reduced due to the presence of the water and hydrogen molecule in the exhaust plume of the Van-guard-II rocket [1]. In the last few decades, VLF/LF method has become a powerful tool to perform quantitative studies to infer the changes in electron density in the D-region of the ionosphere [5]. We present a case study on the exhaust plume effect on the lower ionosphere for the 9^{th} Geosynchronous Satellite Launch Vehicle (GSLV-D6) that was launched on August 27, 2015, from the Satish Dhawan Space Centre, Sriharikota Island, India.

2. Results and discussion: After 137.8 seconds of the liftoff (during 1^{st} stage burn) we note a perturbation in VLF signal amplitude with respect to its normal day variation at an altitude about 58 km as shown in figure 1. In GSLV Rocket, 1^{st} stage engine fuel contains Hydroxyl-terminated polybutadiene (HTPB) and unsymmetrical dimethyl hydrazine (UDMH). After burning of UDMH with nitrogen tetroxide (N_2O_4), the exhaust products are N_2, H_2O and CO_2, in which H_2O is dominant. The water molecules enhance chemical recombination between O^+ and ionospheric

electrons [4] and it rapidly diffuses into the atmosphere. For further verification of the results whether the perturbation in the VLF signal could be due to any space weather events or geophysical events, we scrutinized the solar activity like solar flares, geomagnetic storms, coronal mass ejection etc. and geophysical phenomenon like an earthquake over the great circle path of the signal and found absolute quiet period of space and geophysical activity.

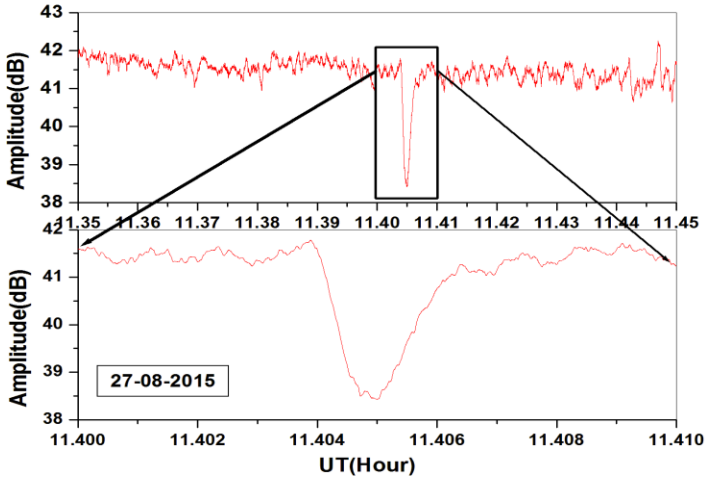

Figure 1: Time series plot of the VLF signal amplitude during the GSLV launch. The black square box at the upper panel represents the perturbation time and zoomed plot of that region is shown at the lower panel of the figure

3. Conclusion: VLF signal of the VTX/17 kHz transmitter from Vijayanarayanam, India recorded at Tripura University, India shows perturbation in terms of amplitude depletion during the period of GSLV launch. This perturbation could be due to the variation of ion density in the lower ionosphere during the period of 1st stage of rocket fuel burn.

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