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RESEARCH OF THE IMPACT OF STRONG SOLAR FLARES ON THE LOWER IONOSPHERE BY VLF RADIO WAVES AND SATELLITE OBSERVATIONS

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The perturbations in the D-region induced by solar flares were studied using monitored amplitude and phase data from VLF/LF radio waves (3– 30 kHz and 30–300 kHz) transmitters. All data were recorded by system at Belgrade stations (44.85^{0}N, 20.38^0 E).

Statistical results show that the magnitude of the VLF perturbations is in correlation with intensity of X-ray

Fig. 1 Great Circle Paths (GCPs) of subionospherically propagating VLF radio signals recorded at Belgrade site.

VLF Station

The Belgrade station is simultaneous monitoring the properties of subionospheric propagating waves that reveal changes of the electrical properties of the ionospheric D-region during various stellar activities (Šulić & Srećković 2014). The cosmic disturbances, γ, X and UV radiation, cause numerous complicated physical, chemical and dynamical phenomena in the D-region and may directly affect human activities. We show that the VLF technique is well suited to search for stellar events, and to provide a diagnostic of high-energy astrophysical phenomena.

Solar Flares:

Strong solar flares penetrate to lower ionospheric region, cause transient changes. Study the influence of solar flares on the terrestrial ionospheric D-region by analyzing the amplitude and phase time variations of VLF radio waves emitted by transmitters (all over the world) and recorded by the receivers in Belgrade in real time (see e.g. Šulić et al. 2016). VLF and LF radio signals propagate inside the waveguide formed by the lower ionosphere and the Earth's surface. A range of dynamic phenomena occurs in D-region, and some of them are: diurnal effect (day/night), a seasonal effect (summer/winter), strong relationship with solar activity (11-year- sunspot level and solar flares), effects of lightning induced electron precipitation and red sprites.
All these phenomena are followed by changes in electron density of D-region, which affects the subionospheric VLF/LF propagation as an anomaly in amplitude and/or phase.

Results and Discussion:

Amplitude perturbations on VLF/LF radio signal induced by small and medium class solar flares.

Fig.2 shows time variation of X ray irradiance and measured amplitudes on NSC/45.90 kHz radio signal for 03 and 04 July 2012 for time interval of 24 hours. Measured data for 03 July 2012 are given as reference level for normal ionospheric condition. Results show that the magnitude of the VLF perturbations is in correlation with intensity of X-ray.

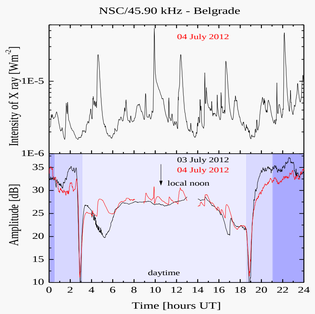


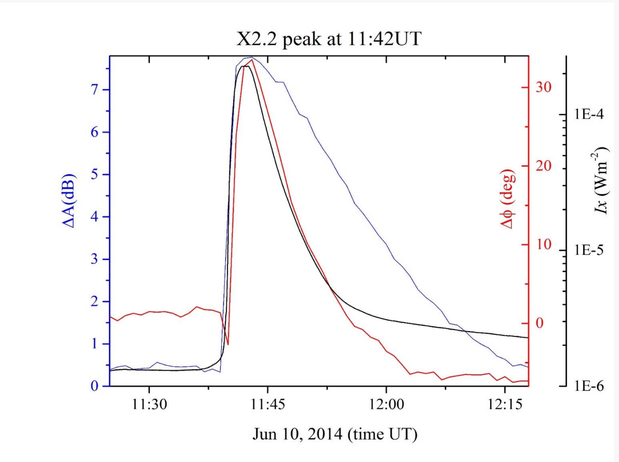
Fig 2. Variation of X-ray irradiance (panel 1), and amplitude (panel 2) on NSC/45.90 kHz radio signal recorded at Belgrade against universal
time on 03 (normal day) and 04 July 2012.

Amplitude perturbations on VLF/LF radio signal induced by strong class solar flares.

For studding SID VLF signatures we have selected solar flare events whose occurrences where in time intervals of few hours around local noon at Belgrade. Selected events (e.g. X2.2 class solar flares) were recorded under similar solar zenith angles.

Our results are presented on one example (see Fig. 3). Perturbations of the GQD/22.10 kHz radio signal are presented as temporal changes of ΔA and Δϕ during solar flare event.

Fig. 3 Variation of X-ray irradiance, phase increase and amplitude increase on GQD/22.10 kHz radio signal recorded at Belgrade against universal time on 10 Jun 2014.



Conclusions and perspectives:

-We analysed period December 2008-May 2020

- Changes of amplitude on radio signals during X class solar flares perform as well defined enhancement that follow the development of the maximum in X-ray radiation.

- During X2.2 class solar flare event electron density changes for three order of value at reference height h = 74 km in according to ambient value.

- The obtained results confirmed successful use of applied technique for detecting space weather phenomena such as solar explosive events as well for describing and modeling the ionospheric electron density which is important as the part of electric terrestrial-conductor environment

References:

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