URSI AP-RASC, Sydney, Australia, 17-22 August 2025

Doppler HF monitoring of the ionosphere during the solar eclipse of 8 April 2024

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During the solar eclipses the observed variations in the solar flux of the ionizing radiation are usually faster than those observed under normal conditions. Therefore, observations of the ionosphere's response to eclipses can provide valuable experimental data about the features of photoionization, recombination, and plasma transport processes at different altitudes. During the total solar eclipse of April 8, 2024 we conducted HF Doppler measurements using signals of opportunities from precise time service stations (CHU and RWM), as well as dedicated transmission from the *Akademik Vernadsky* Ukrainian Antarctic station. These transmissions were monitored at several receive sites around the world: in Boston area (USA), near Fredericton (Canada), at the LOFAR PL610 observatory (Borowiec, Poland), in Tromsø (Norway), at the *Akademik Vernadsky* station, and onboard of the Ukrainian research vessel *Noosfera*, which was near the Antarctic Peninsula during the eclipse. So that the HF signal trajectories were close to or crossing the path of the eclipse totality. Measurements were carried out over five days: two days before the eclipse, on the day of the eclipse, and on two following days.

The response to the eclipse was recorded in the variations of the Doppler frequency shifts (DFS) on the CHU-Fredericton, CHU-Boston, and CHU-PL610 radio paths. On the day of the eclipse, some changes in the signal characteristics were also observed on the CHU-*Noosfera* path at 14670 kHz.

To interpret the effects of the eclipse, we calculated the variations in the integrated solar luminance of the HF radio paths. This approach had been tested earlier to explain the effects observed during the solar eclipse of 2008. It was then demonstrated that on medium- and long-distance radio paths, the characteristics of HF signals were mainly affected by photochemical processes in the lower ionosphere [1]. The DFS variations were shown to be proportional to the derivative of the integrated luminance at all frequencies. However, the stronger DFS variations were observed for the lower sounding frequencies, thus indicating that the changes in electron density along the path produced by the eclipse were the dominant factor causing DFS variations rather than the changes in the HF signal reflection height.

Comparison of the modeling to the observations made during the eclipse of April 8, 2024, confirmed earlier results obtained for medium and short radio paths. Thus, the amplitude of the DFS variations on the CHU-Boston path at the sounding frequency of 3330 kHz was greater than that at 7850 kHz, which supports the conclusion on the primary role of the changes in electron density along the path below the reflection point. The ionospheric response to the eclipse was also observed at 14670 kHz using the CHU transmissions which was above the maximum usable frequencies (MUF) for the receive sites in Boston and Fredericton. An interesting effect observed at this frequency was a significant time shift between the DFS variations and the derivative of the integrated illumination on the straight paths. Hypotheses are put forward regarding the possible propagation trajectories of the signals along which they could have acquired the DFS observed in the experiment. Raytracing modeling results for the HF signal propagation through the region of totality on single hop radio links are also presented.

1. S. B. Kascheev, A. V. Zalizovski, A. V. Koloskov, V. G. Galushko, I. I. Pikulik, Y. M. Yampolski, V. I. Kurkin, G. I. Litovkin and A. I. Orlov, “Frequency Variations of HF Signals at Long-Range Radio Paths during a Solar Eclipse” *Radio Physics and Radio Astronomy*. Vol.14 (4), 2009, pp. 353-366