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VLF for IONospheric Studies (VLF4IONS)

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The D-layer is the lowest region of the ionosphere (60 – 90 km). Compared to the upper layers, it presents a much weaker electron density and a complex chemistry due to its high proportion in neutrals and ions. It is also a highly variable region, perturbed by a variety of external sources. Some of those variations occur on long timescales such as the solar cycle, the year or the day. However, others are much shorter: the D-layer can be perturbed by the Sun through geomagnetic storms and solar flares (tens of minutes to hours), or by electrical phenomena such as Transient Luminous Events (TLEs) or lightning strokes (seconds or less).

Being too high for atmospheric balloons and too low for satellites, the D-region is also the least known of the ionospheric layers. The most commonly used method to monitor and study its perturbations is the propagation of Very Low Frequency (VLF, 15 – 45 kHz) waves from a transmitter to a receiver. Those waves propagate in the waveguide formed by the Earth and the D-layer, over thousands of kilometers due to their relatively weak absorption (2 dB/Mm). Any perturbation of the D-layer can be assimilated to a change in the electrical properties of the upper boundary of the Earth-ionosphere waveguide, thus modifying the propagating modes. Hence, both the amplitude and phase of the resultant fields are impacted.

The project VLF4IONS (VLF for IONospheric Studies) aims to study the perturbations of the D-layer from three sources: the Sun, lightning strokes and TLEs. It also has a more societal objective in the framework of space weather. Indeed, the D-layer is responsible for the major part of HF absorption, which is a frequency band used by civil aviation. Thus, the rise of electron density in the D-layer due to solar flares can cause communication degradations. The VLF4IONS project would therefore provide real-time alerts on the state of the D-layer.

This project relies on the development of a worldwide network of VLF receivers (VNET4IONS, VLF Network for IONospheric Studies). It is based on AWESOME instruments [1], which are developed by the University of Georgia. They provide continuous measurements in two types of time series: broadband waveforms (at 1MHz and 100 kHz) with an absolute timing of 20 ns, and narrowband data (amplitude and phase) centered around several transmitter's frequencies. Measurements are performed in two orthogonal directions simultaneously.

As the solar flares impact the dayside ionosphere, and most storms cells are at low latitudes, this network would mainly be developed worldwide and around the equator, taking advantages of the various French territories there. This equatorial network would enable a continuous monitoring of the D-layer (24h/24h) and the study of many storm cells.

1. M. B. Cohen, U. S. Inan, and E. W. Paschal, 'Sensitive Broadband ELF/VLF Radio Reception With the AWESOME Instrument', *IEEE Trans. Geosci. Remote Sensing*, vol. 48, no. 1, pp. 3–17, Jan. 2010, doi: 10.1109/TGRS.2009.2028334.