# Analyses of ELF/VLF/LF Radio Wave Variations During the Meteor Showers

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## Motivation

As a part of the atmosphere, the ionosphere is under permanent influence of different natural perturbers located in the outer space and terrestrial layers. In addition, the human activity, enabled by development of modern technology, affects its characteristics. Consequently, the ionosphere is a medium of a highly complex nature concerning numerous physical, chemical and geometrical features that govern its versatile dynamics on various spatial and temporal scales. The main motivation is to explore detectability of low ionosphere perturbations influenced by meteor showers using ELF/VLF/LF receiver.

## Introduction

Considering ionospheric response to particular event, detection of ionospheric variations can be divided in two groups:

- First, in the case of the sufficient strong changes in plasma parameters after beginning of a perturber influence, we can reliably correlate recorded ionospheric reaction and the observed event.
- Second, in the case of the weak plasma disturbances, it is very hard to demonstrate that a particular perturbation, observed close to the analysed event is related to it, because of very similar properties of perturbation induced by numerous phenomena.

Examination of various processes in weak ionospheric variations induced by different phenomena very often requires much better measurement performances, like for example time resolution, than in the first case mentioned above. Also, statistical analyses are needed for researching different phenomena property influence on the ionosphere. For these reasons, the used collected data can form big databases and investigations based on the information included require knowledge and implementation of tools for data processing. Consequently, the relevant research should be based on collaboration of scientists, engineers and experts for database management.

One of the phenomena that can be included in this group is meteor impact in the atmosphere. Namely, the previous studies indicate the possible ionospheric reaction induced by meteors (Rault, 2011), as well as the emissions of electromagnetic waves (Keay, 1992, Zgrablić et al., 2002) during their pass through the atmosphere.

In this study, we present experimental method for detections both of these appearances based on ELF/VLF/LF wave measurements and analyse possible detections of considered disturbances.

## ELF/VLF/LF Radio Receiver

In Institute of Physics in Belgrade, it is located AWESOME (Atmospheric Weather Electromagnetic System for Observation Modeling and Education) extremely low, very low and low (ELF/VLF/LF) frequency radio receiver which has been operating since 2008. It has two independent loop antennas set in NS and EW directions.

The operational regime of this device is based on two types of measurements:

- Narrowband monitoring of VLF and LF artificially generated radio signals emitted by transmitters located worldwide, and
- Broadband monitoring of electromagnetic waves in frequency range between about 1 kHz and 47 kHz.

Narrowband monitoring relate to the low ionospheric observation. Namely, although both natural waves and radio signal emitted by a transmitter at considered frequency are detected, the last one dominates, and practically recorded variations reflect changes in the low ionosphere electron density where these signals are reflected from. In these observations, global experimental setup contains numerous transmitters and receivers (they can simultaneously monitor signals from several transmitters -15 in our case) that allow a large part of the low ionosphere monitoring. Because of high time resolution (it can achieve 1 ms for our device) of recorded data (signal amplitude and phase), detection of different sudden and unexpected events could be performed. For a considered number of monitored signals and time resolution size of recorded data, the amount of collected data can be over 10 GB per day large.

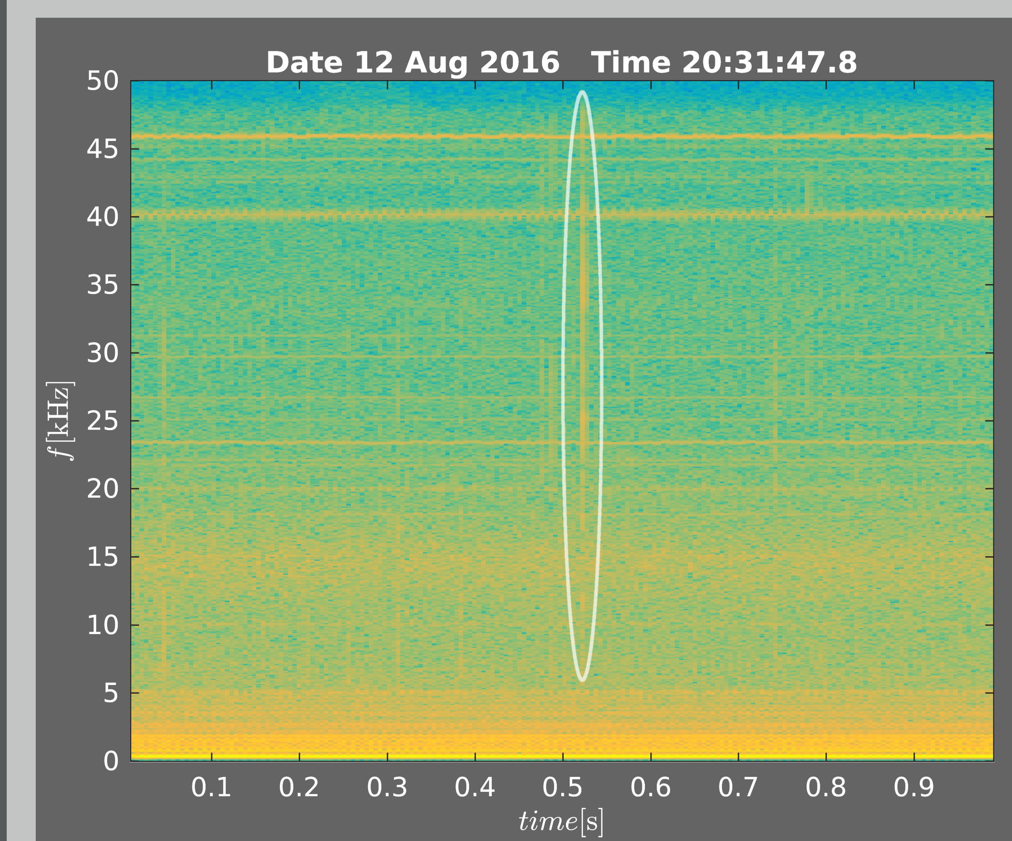
Broadband observations are based on magnetic field amplitude measurement with time resolution of 100 kHz.Using short-time Fourier transform (STFT), the recorded data can be processed and presented as spectrograms for the frequency range of electromagnetic waves below 50 kHz. The data set gathered by both receivers is 32 GB per day. Detailed explanation of this measurement and data processing is given in Cohen et al., 2010.

Belgrade ELF/VLF/LF Receiver Antenna

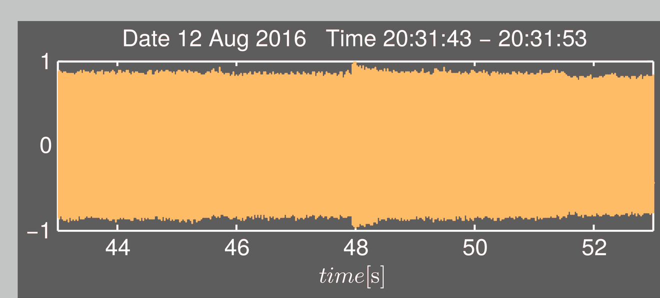
## Analyse of Wave Amplitude Variations

Although the effect of an individual meteor considering the low ionosphere reaction is weak, during meteor showers number of the reactions they produce is large, which allows statistical analyses for relatively short time period. In this study, we analysed perturbations in electromagnetic wave intensity, received by AWESOME receiver in Belgrade during the Perseid meteor shower in 2016. We extracted several shape types of sudden variations in amplitude time evolutions.

The detail study to detect variation properties requires statistical analysis, implementation and further development of the signal processing and, finally, comparison of our collected data sets with those related to the independent detection of meteor impact. In considered observation, this research is multidisciplinary – it connects geophysical and astrophysical studies based on data processing obtained by the measurements of natural and telecommunication radio signals. Considering that, it will be in focus of our upcoming research.




Detected Anomaly




Raw Signal

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