

VLF REMOTE SENSING OF THE LOWER IONOSPHERE AND REAL TIME SIGNAL PROCESSING

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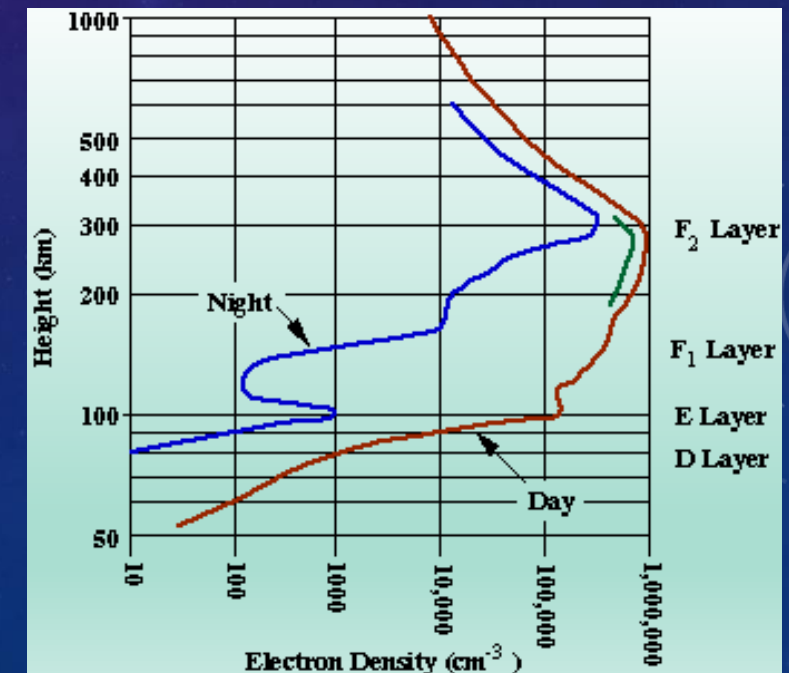
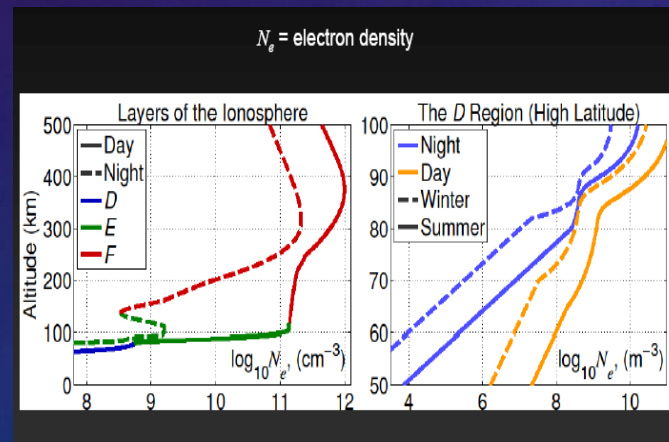
²ASTRONOMICAL OBSERVATORY BELGRADE

V.A. Srećković, from Belgrade University, member of VLF group. I work on investigation and influence of the ...atomic and molecular processes in stellar atm. Ionospheric plasma investigation.

- (Belgrade VLF group started working by installing the first station (AbsPAI) in 2003 at the Institute of physics. We have many members from different institutions.)
 - A. Nina *Institute of Physics, Belgrade, Serbia*
 - D. Šulić, *Faculty of Ecology and Environmental Protection*
 - D. Jevremović, and other colleagues from AOB, Vujčić, etc., implement and at the same time to test solutions from LSST (alert sim. and etc.) .
 - and many collaborators and colleagues all over world:, colleagues from Stanford, India, Brazil, Tunis, V. Žigman, *University of Nova Gorica, Nova Gorica, Slovenia* .
 - We are members of the few Bilateral projects.
 - also members of the projects III 44002, 176002.

THE IONOSPHERE AND VLF WAVES

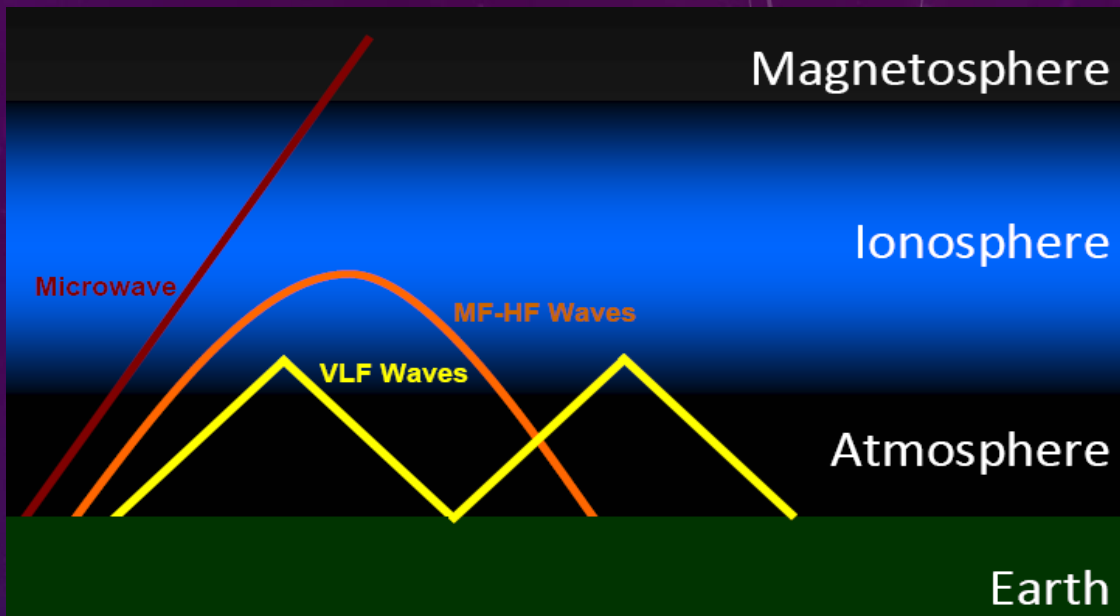
- Characteristics of the ionosphere and their changes are very important for life and human activity on the Earth. There are numerous studies about influences of ionospheric disturbances (from outer spac.) on operation of powerful energetic systems, navigation and remote radio communication systems, the atmospheric weather, the human health and the state of the entire biosphere.
- Methods of investigation of the ionospheric vertical structure are diverse and depend on the applied measuring techniques.



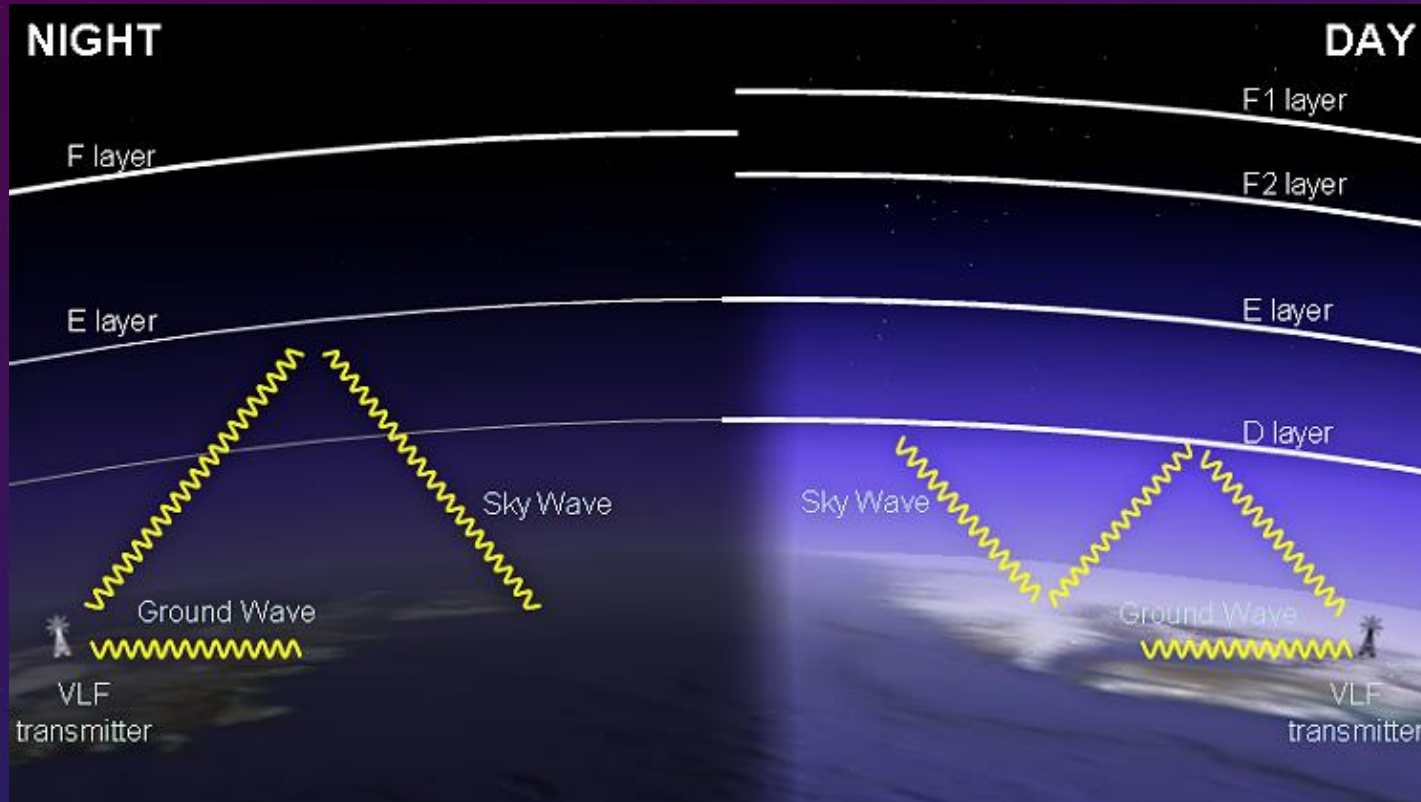
STUDYING THE IONOSPHERE, TECHNIQUES, D REGION

- There are few traditional techniques for studying the Ionosphere

- Unmanned balloon record altitude: 51.8 km
- Lowest reasonable satellite altitude: ~200 km
- How to make measurements in between
 - Rocket passes (brief)
 - GPS (sensitive mostly to F region)
 - Radar (cannot scatter off D region)
 - VLF (aha!)

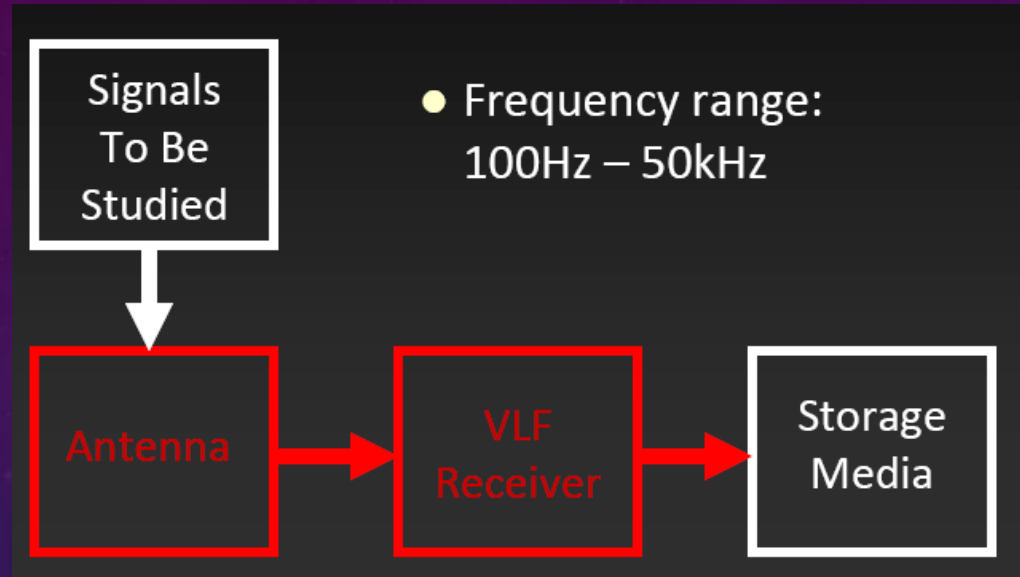


- - on this slide you can see how the different waves behave as they pass through the ionosphere.
- - VLF 3 kHz to 30 kHz , wavelengths from 10 to 100 kilometers (reflect off D)
- - MF 300 kHz to 3 MHz
- HF 3 MHz to 30 MHz (passes and reflect like this)
- Microwave 300 MHz (0.3 GHz) and 300 GHz (passes)
- Good thing about it is that VLF waves reflect on the D region and give us information about that ionosphere layer.
- By analyzing the amplitude and phase time variations of very low frequency (VLF) radio waves emitted by many transmitters and recorded by the receivers in real time we can map that layer.



- On this slide you can see how the VLF waves behave at night and day. D region almost disappears at night (due to the deficiency of ionization). Later I will discuss about signal i.e. amplitude and phase behavior .

What is a VLF Receiver?



- Monitor (or VLF receiver) consists of a VLF antenna (small, medium or large: from few meters to several tens of meters) , preamplifier box, and a line receiver box. This equipment is connected to PC and Storage media. VLF data can be recorded locally and transmit to a central database.

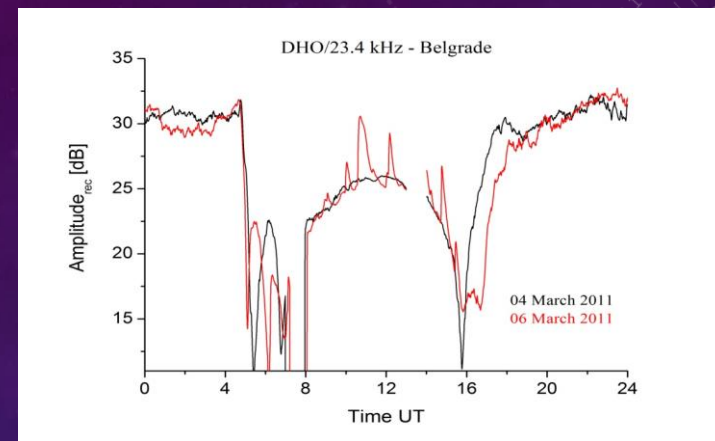
AWESOME Receiver – Pictures



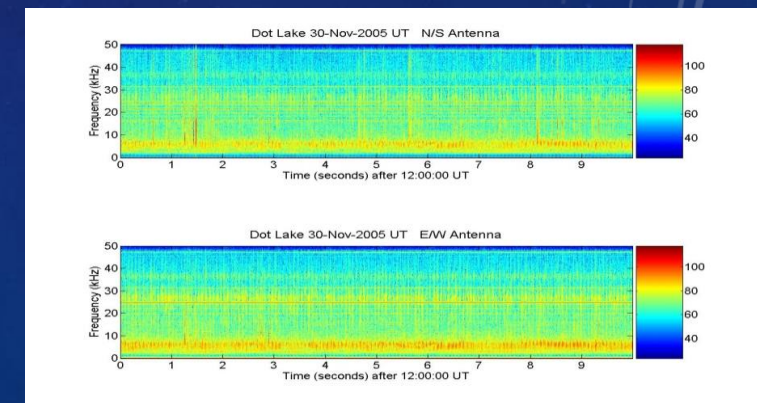
- Medium large. This receiver is install 2008 at the Institute of physics. We have Abspal antenna receiver too.
- Daytime: monitor solar activity
- Nighttime: GRB, monitor atmospheric phenomena (e.g. lightning)

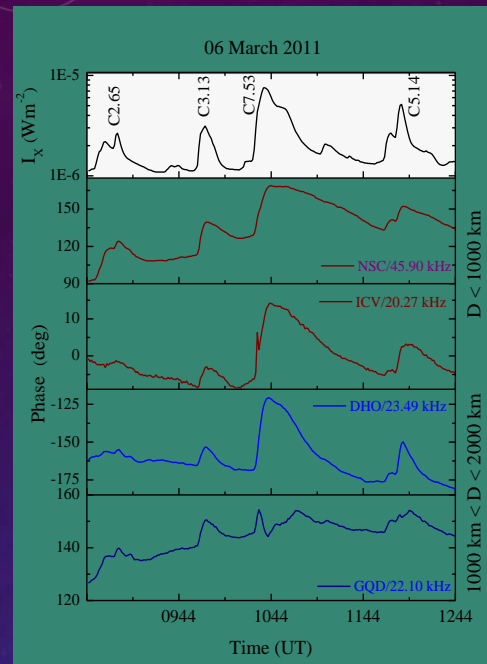
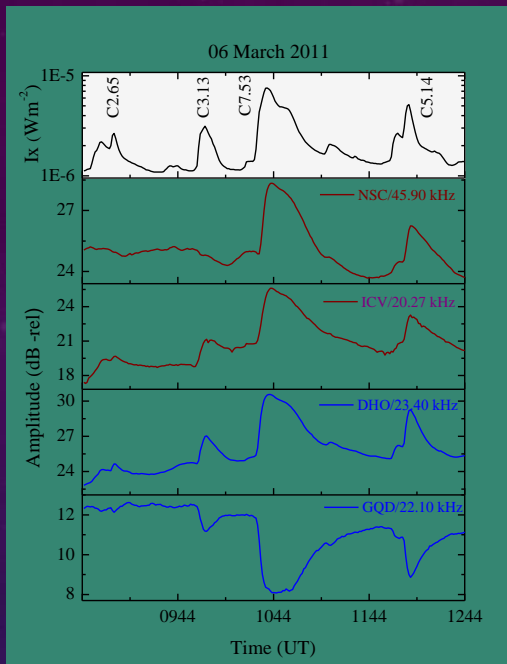
Data

- There are two types of recordings made by AWESOME
- Narrowband: Several Gbyte of data in one day (1 GB 1 h) (depends low-res or hi-res). This type of data is called narrowband. This simply involves taking the amplitude and phase, separately, of a single narrow frequency range, specified in the software, and usually corresponding to the frequency of a VLF transmitter. Such data is generally saved in two different resolutions, hi-res (50 Hz), and low-res (1 Hz). Narrowband data takes up a much smaller amount of room, ~1GB per hour, per transmitter. Low-res can be use for some kind of observations (for phenomena that take longer)and high res are better for other.
- Broadband: Broadband saves the waveform received from antenna exactly as it was digitized, at the full 100 kHz sampling rate. It thus includes information at all frequencies between the systems cutoffs (300 Hz – 47 kHz). Broadband data is very large, taking up few GB per hour.



spectrogram





- A lot of data: With Ser. LSST team we are doing some thinks to solve this issue.
- **First:** Current stage now, is development database, as well as to develop online service.
- **Second:** We are testing some LSST solutions and implementing solutions from LSST alert sim (in real time analyze data before it is stored). When event like solar flare starts software is triggering equipment and from low res. data we start to record in high res.

THANK YOU FOR YOUR ATTENTION