UKRAINIAN PROGRAMME OF OBSERVING SPACE WEATHER EFFECTS AT ULF- ELF

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Among the structural formations that can readily respond to variations of space weather the large-scale resonators stand out which exist about the Earth owing to the spatial nonuniformity of the geomagnetic field and the plasma environment. These are the magnetospheric resonator (MR) in the area of closed magnetic lines of force [1]; the ionospheric Alfven resonator (IAR) which is formed along a magnetic tube between the lower ionosphere and the topside level where the Alfven velocity undergoes a sharp increase [2,3], and the Schumann resonator (SR) represented by the spherical cavity between the Earth's surface and the lower ionosphere [4,5]. These structures are physically adjacent to one another (and even overlapping), occupying quite a range of radial distances above the surface. The Schumann cavity lies between 0 and ~100 km; the IAR extends from 100 km to 10^3 km, and finally the resonances characteristic of the MR are formed over a few Earth radii, R_E, or tens of R_E. The resonance frequencies in the three structures are

$$f_n^{MR} = (10^{-3} \text{ to } 10^0) \text{ Hz (ULF pulsations)} \quad f_n^{IAR} = (0.1 \text{ to } 10) \text{ Hz (ELF)}$$

$$f_n^{SCH} = (c/2\pi\ R_E)\ n^{1/2}(n+1)^{1/2} \quad (\sim 8 \text{ Hz; } 14 \text{ Hz; } 21 \text{ Hz, etc., ELF}).$$

The basic parameters of these resonators, i.e. eigenfrequencies and Q-factors are determined by characteristic geometries of the three structures and spatial distributions of *Ne* (electron density) and V_e (collision frequency), all of which may vary under the impact of geophysical factors. Among the factors to disturb the average state of the geospace plasma and affect wave field parameters outstanding are powerful variations of the geomagnetic field (magnetic storms and the like), energetic particle precipitations from radiation belts, solar eclipses and aftereffects of solar events like flares, coronal mass ejections or disturbances in the solar wind. For example, the effect of particle precipitation in the night-time auroral ionosphere may be a two- or threefold increase in the height-integrated conductivity [6].

The central idea of the programme currently pursued by a few research teams in Ukraine is to develop methods for space weather monitoring through measurements of correlated variations in the three resonators. One of the ways for achieving the goal is to perform simultaneous ground-based observations from a single site, using magnetometers calibrated in a like way to cover the entire ULF/ELF range.

Observation site. Measurements of the ULF and ELF wave fields are carried out at the Ukrainian Antarctic station *Akademik Vernadsky* (formerly *Michael Faraday* of the UK) close to the Southern polar circle, at 65° 15' S; 64°16' W. This choice of the observation site is not accidental, being dictated by the requirement of minimal local interference. Thunderstorms practically do not occur in Antarctica, while industrial activities accompanied by intense production/consumption of electricity (hence, electromagnetic emissions of noticeable levels) are forbidden by international agreements. Meanwhile, the presence of useful ULF and ELF signals is conditioned exactly by the existence of the resonators which act either as resonant cavities proper, or as wave guiding structures to deliver an electromagnetic disturbance from some remote site to the point of observation.

Equipment.

A) Low frequency detectors

The magnetometers at Station *Vernadsky* include

- a three-axis LEMI-008 (Lviv Centre design): frequency range 0 to 0.5 Hz; resolution 0.1 nT; sampling rate 1 Hz;
- a dual-axis, GPS-timed LEMI-112A (LC ISR): frequency range 0.3 to 250 Hz;
- a 2 +1-axis LEMI – 112A3 0.01 to 10 Hz; noise level 0.03 to 5 $pT/Hz^{1/2}$.

B) Ionosphere diagnostics:

Digital ionosonde

VLF radio receivers

Parameters of the field-line resonances in the MR are critically dependent on MHD reflection coefficients from the "end mirrors", i.e. conjugate ionospheres. The coefficients are controlled by integrated transverse conductivities of the lower ionosphere, while the resonance frequencies vary with variations in the Alfven velocity profile. The natural factors influencing the transparency/reflectivity of the MR mirrors include regular effects, like diurnal and seasonal variations of the radiation fluxes incident on the ionosphere, and sporadic phenomena (e.g. precipitation of energetic particles, which can modify the balance of ionization in the E- and D-layer).

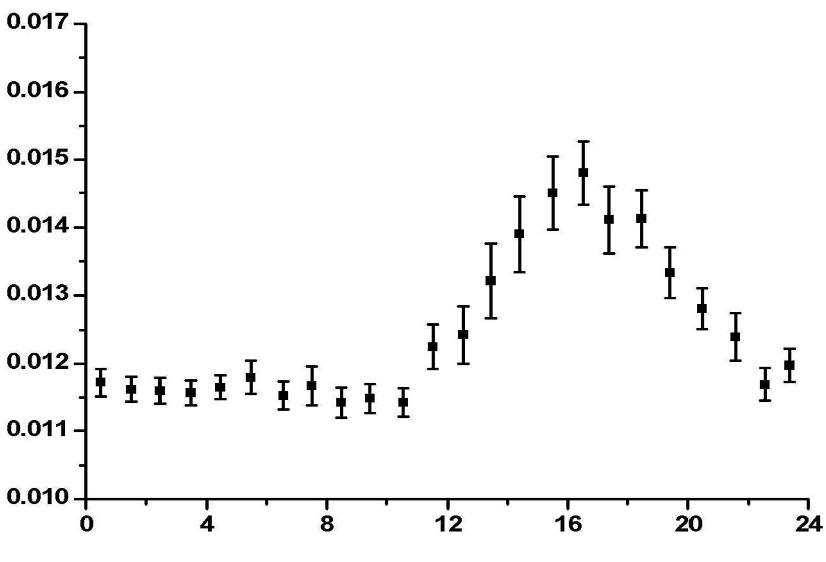


Fig.1. Diurnal variations in the frequency (Hz) of geomagnetic pulsations at Station *Vernadsky* in January, 2004 (Southern summer)

A local reflection coefficient is controlled by the ratio of integrated transverse conductivities of the ionospheric plasma to the ‘wave conductivity’ $\Sigma_w = c^2 / 4\pi V_A$ of the line of force (V_A is the Alfven velocity). Typical values of Σ_w under quiet conditions are a few Siemens (10^0 Sm), while characteristic magnitudes of the transverse conductivities are about 10^{-1} Sm at night and 10^1 Sm in the daytime [7,8].

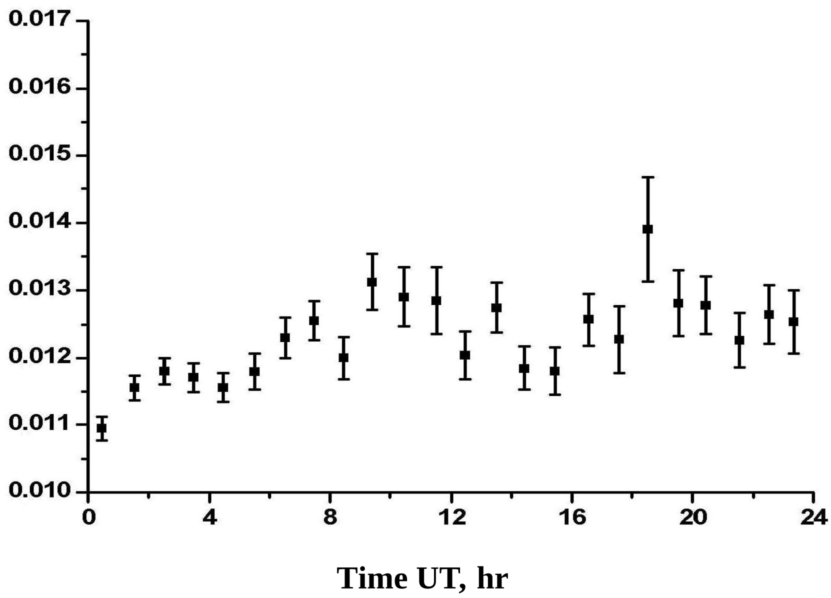


Fig.2. Diurnal variations in the frequency (Hz) of Pc4 pulsations at *Vernadsky* (winter, July 2004)

The properties of the IAR are fully determined by ionospheric plasma parameters in a single relevant hemisphere. The lower wall of the IAR is represented by the E- layer, i.e. again the area of localization of the transverse conductivities. Accordingly, it would be natural to expect correlated responses of the MR and IAR to a plasma disturbance (however, with the effect dependent on location of the observation site).

First IAR observations in Antarctica.

The lower-frequency portions of spectrograms from LEMI 112A and LEMI 112 A3 obtained at *Vernadsky* in April – June, 2005 show a characteristic set of narrow traces at 0 to 5 Hz representing the IAR (Fig.3). The resonances are observable about 40 % of the total measurement period, with the number of traces varying between 3 and 9. The intensity changes essentially with time over 6 to 10 hour intervals, up to a complete loss of detectability. At each moment the traces are separated in frequency in an almost equidistant way, the interval being 0.5 to 1.5 Hz. The detection probability demonstrates a pronounced diurnal variation, reaching maximum values at night. Normally, the resonances were observed between 20:00 UT and 10:00 UT (i.e. 4 to 5 p.m. and 4 a.m. local time at Station *Vernadsky*). Also, the probability appears to be higher on magnetically quiet days. The intensity of the resonant peaks seems to have a diurnal run as well.

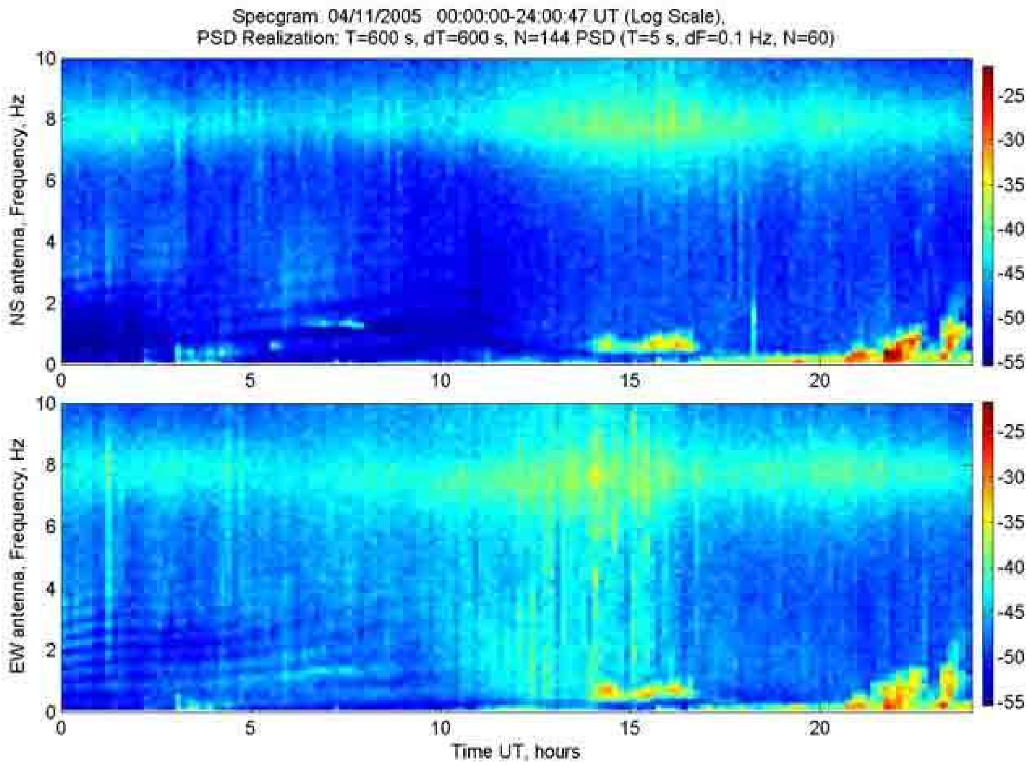


Fig.3. Dynamic spectrum of the magnetic ground signature from the resonant wave field in the ionospheric Alfven resonator (Station *Vernadsky*, April 2005)

Shown in Figs. 4 and 5 are diurnal variations of the relative frequency (probability) of IAR observation, averaged over the April-through-June period, and of critical frequencies in the E_S, E and F layers of the ionosphere.

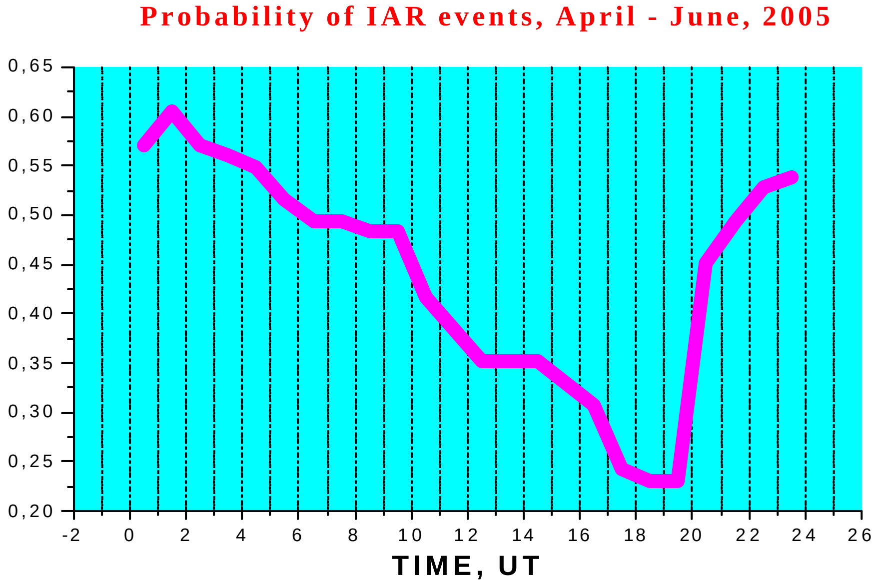
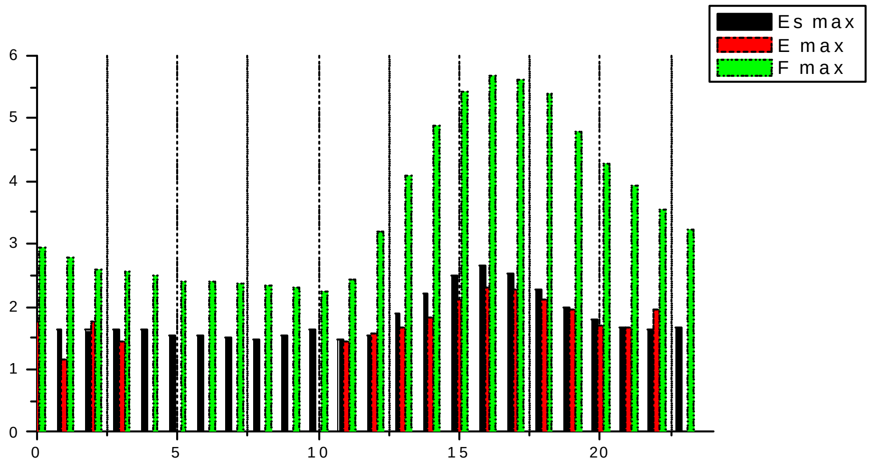


Fig.4. Relative frequency of IAR ground signature detection at *Vernadsky* (daily data averaged over the winter period, April to June)



Time, UT

Fig.5 Critical frequencies of ionospheric layers over *Vernadsky*, April – June, 2005

As can be seen, the curves in Figs.4 and 5 demonstrate a noticeable negative correlation, which is evidence for a weaker resonance field at the ground level at times of enhanced reflection of the hydromagnetic waves incident upon the ionosphere 'from above'.

Schumann resonances are observed at *Vernadsky* mostly with the LEMI-112A detector. (The programme of ELF observations involves detection and analysis of the Schumann resonances and identification of emissions from extra-powerful lightning discharges, including sprites [9]).Because of the low level of local interference in the band, it proves possible to detect record numbers of resonance modes in Antarctica (up to 6 or 7 as is the case in Fig.6, apparently in contrast to the standard mid-latitude observations). The continuous monitoring permits following frequency variations in the lower-order modes.

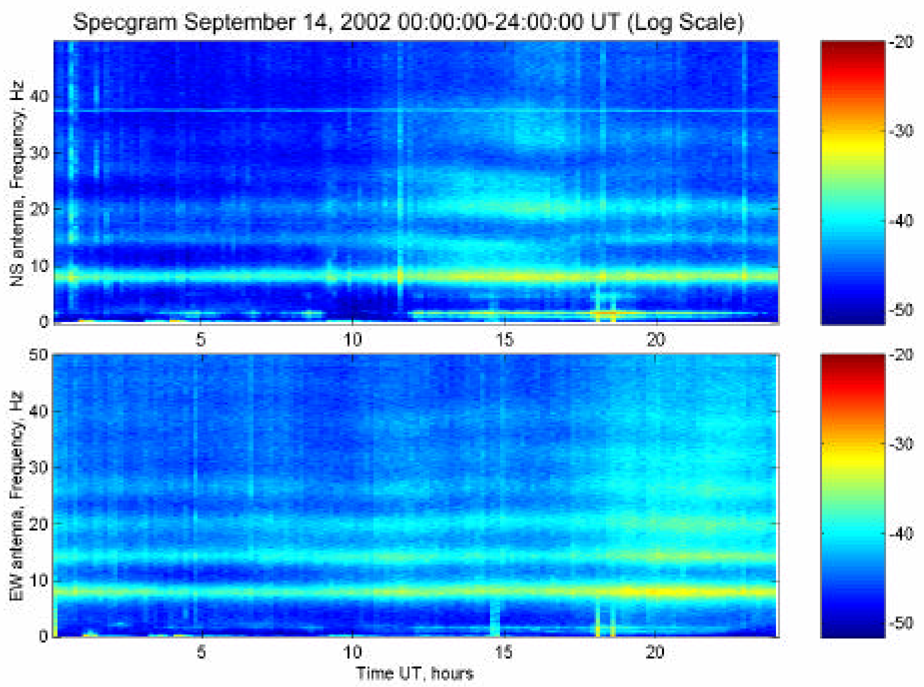


Fig.6 Schumann resonance signatures at *Akademik Vernadsky*

What is being done

The programme is oriented toward studying the MR, IAR and SR as parametrically coupled structures that may offer correlated responses to disturbances of space weather. The appearance of concerted variations of wave field parameters in the characteristic frequency bands as widely separated as they are in the three resonators should be evidence for a common source of excitation of such variations – apparently, as a result of space weather disturbances. In order to identify this genetic coupling between wave field variations and external impacts, it has been suggested to look for noticeable deviations of field parameters from their quiet values that may have occurred about time moments of abrupt significant changes in the geospace conditions, like magnetic storms/substorms; variations of the solar wind speed; changes in the amount and energy spectrum of particles in the plasmasphere; particle precipitations, etc. This is being done both retrospectively and for the current observational material.

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