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A STUDY OF THE LOCAL AND GLOBAL PROPERTIES OF THE SPECTRAL RESONANCE STRUCTURE OF THE ULF MAGNETIC NOISE ON THE BASIS OF MEASUREMENTS IN TWO POINTS SEPARATED MORE THAN 1000 KM

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Abstract. This study is devoted to the analysis of simultaneous measurements of tangential components of the magnetic field on two stations New Life and Lovozero for the period of 2006-2007. Strong distinction of the SRS character in the above-mentioned observatories is revealed. The high degree of the equidistance of the SRS basic frequencies at station Lovozero is observed practically during all seasons; at the same time the SRS in the middle-latitude station New Life has more complex character shown in the occurrence of secondary maxima and simultaneous existence of different frequency scales. The numerical simulations on the basis of the IRI-2001 model and two interpolation models of F2 topside profile were performed. The observation results and the more detailed results of the theoretical research allowed us to investigate the influence of inclined magnetic field and of source location on SRS properties.

1. Introduction

For the first time the resonance structure of the background low frequency noise spectrum was discovered at mid latitude point New Life [*Belyaev,* 1990]. The resonance structure is connected with influence of the ionospheric Alfven resonator on propagation of the low frequency waves (frequency band 0.1-10 Hz) in cavity Earth-ionosphere and reveals itself in deep oscillations of the ground magnetic noise spectra. Later, the spectral resonant structures (SRS) were discovered and carefully explored at high (Sodankyla, Finland, 67.4°N, 26.5°E.) [*Belyaev,* 1999] and low (Crete, Greece, 35.15°N, 25.20°E) [*Bosinger,* 2002] latitudes. The behavior of the spectrums of the background noise is more complex and more multiform at low latitude due to the SRS fine structure, which appears in a frequency scale of 0.1-0.15 Hz [*Bosinger,* 2004]. Theoretical modelling of the resonance structure for the plane layered ionosphere model with the vertical magnetic field was fulfilled in [*Polyakov*, 2003]. At mid latitude point New Life the SRS peculiarities were investigated, and the detailed analysis of dependencies of SRS parameters on direction to the source was performed taking in the account the inclined magnetic field [*Ermakova,* 2008]. In the abovementioned paper the modeling of the ionospheric parameters was based on the international reference ionosphere model (IRI-2001), and the method of SRS modeling was designed, which allows to take into account the daily and seasonal changes of the ionosphere.

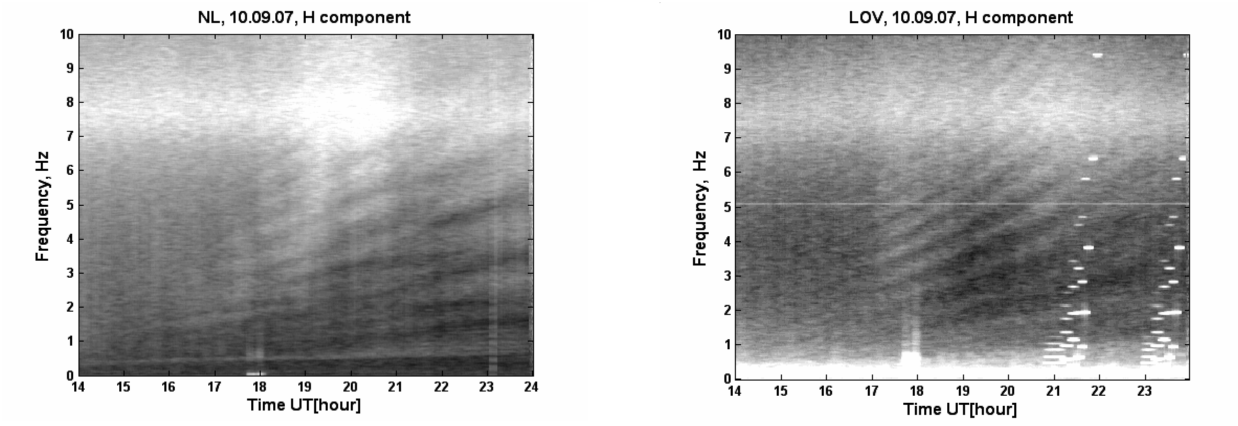
The present paper is devoted to the analysis of simultaneous measurements of tangential components of the magnetic field at New Life (55.97 N, 45.74 E) and Lovozero (68N, 35E) stations for the period of 2006-2007. Properties of SRS at frequencies up to 16 Hz are considered, namely: the occurrence of SRS during different seasons; frequency scales; the occurrence of additional maxima; the distinction of the frequency scales in H and D components; the presence of the mirror symmetric resonant oscillations in different components.

Also, the method of SRS modeling designed in [*Ermakova,* 2008] has got the further development. Modeling was performed for three ionospheric models with different topside electron density profiles above maximum F-layer. This allows to interpret the appearance of the several frequency scales of SRS as well as a distinction of the main SRS frequencies in different magnetic components.

2. Results of observations

The magnetic data (H_{N-S}, H_{E-W} components) from two stations New Life and Lovozero were analyzed for the period of 2006-2007. The data processing consisted of obtaining the set of the 10 - seconds spectra and subsequent averaging over 80 – 100 spectra that corresponds to the 15 – 20 min time interval. The time of the averaging was chosen so that SRS frequency scale did not change greatly. The statistical analysis of the occurrence rate of SRS was performed for both stations. It was found that the SRS occurrence rate in New Life reaches 80-90% and does not depend on season that is typical for the mid latitude station during period of the solar activity minimum. As for Lovozero the occurrence rate reaches 20-30% and strongly depends on season: maximum of the SRS occurrence is observed in spring-autumn. The sharp distinction in the character of resonance spectrum is also found: in Lovozero SRS has, as a rule, oscillation with the only frequency scale, and oscillations in both components are in phase; the

New Life spectrum demonstrates more complicated structures. The dynamic spectra of the *H* components are presented in Fig. 1 for 10.09.2007, which demonstrate highly equidistant spectrum in Lovozero and non equidistant one in New Life.



Frequency [Hz] **Frequency [Hz]**

Fig. 1. An example of SRS at New Life and Lovozero.

Besides, the appearance of the additional maximum in spectrum is registered in New Life that leads to the appearance of the frequency scale ΔF/2. Also, the great difference of the SRS frequency scales in different magnetic components is observed (Fig.2).

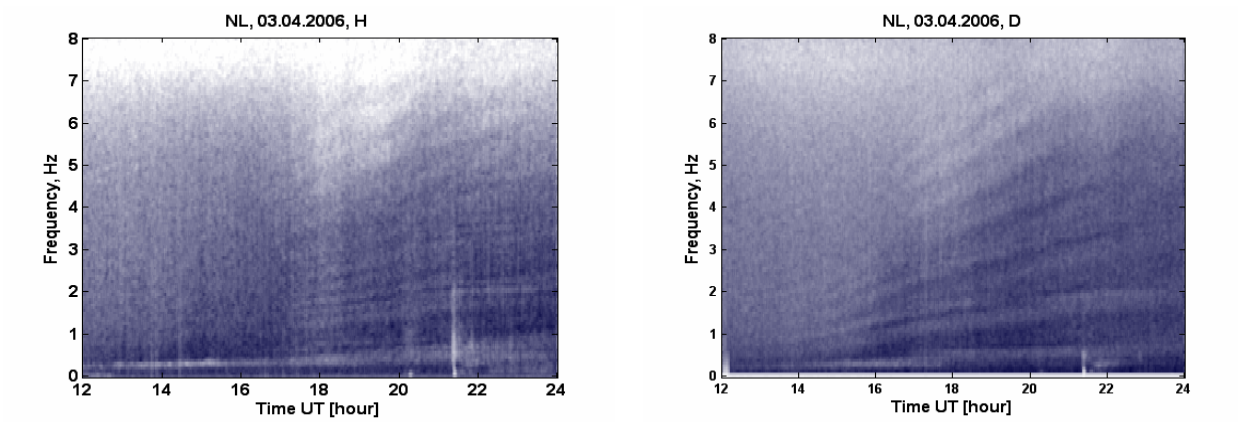


Fig. 2. The example of SRS with different frequency scales in H and D components.

The analysis of the spectral peculiarities shows that such complicated SRS nature is observed in New Life, as a rule, in spring and autumn; at the same time SRS is often observed in a broad range of the frequencies (up to 16 Hz). SRS in frequency interval up to the second Schumann resonance is observed in Lovozero too (Fig 3). One more SRS particularity observed in New Life is the mirror symmetry in H and D component oscillations. Such peculiarity is observed more often in winter during maximum of activity of the African source of thunderstorms (Fig 4).

3. Simulation procedure, ionosheric models and results

The solution of the problem of excitation of the Earth-ionosphere waveguide with inclined magnetic field obtained in the work [*Sobchakov*, 2003] was used for modeling of the low frequency spectrum. It was accepted that source of the noise in the frequency range of interest is a vertical lightning discharge (dipole $\vec{P} = \vec{I} \times \vec{l}$), located on distance *r* from reception point in the Earth-ionosphere waveguide with thickness *h.* The ionosphere is considered not uniform in vertical direction and anisotropic. The Earth's magnetic field lies in *ZY* plane and forms the angle θ with the vertical line. In the case of the inclined magnetic field, expressions for the magnetic field component depend on the angle between direction to the source and plane of the magnetic meridian (φ). The magnetic component amplitudes H_r and H_φ are described by different expressions that could lead to difference of SRS parameters in different components of the field [*Ermakova, 2008*].

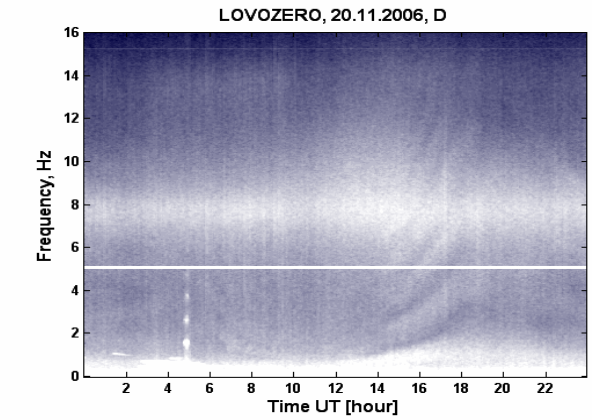


Fig. 3 Example of SRS observed up to the second Schumann resonance

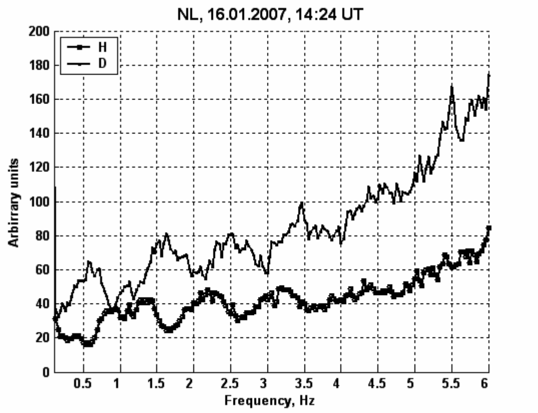


Fig. 4 Example of the mirror symmetric resonant oscillations in different components.

For the numerical calculation it is necessary to provide the height ionospheric profiles. To obtain the set of ionospheric parameters (electron and ions distributions, neutral temperature and composition, geomagnetic field parameters) the international models for the ionosphere (IRI-2001), atmosphere (MSIS-E-90) and geomagnetic field (DGRF/IGRF) were used (http://modelweb.gsfc.nasa.gov/). Two analytical functions (α-Chapman and Vary-Chapman functions) were used for modeling of the F-layer topside electron density profile [*Reinisch 2007]:*

$$N(h) = N_m \left(\frac{H_m}{H(h)}\right)^{1/2} \exp\frac{1}{2}\{1 - y(h) - \exp[-y(h)]\}\,;\; y(h) = \int_{h_m}^{h} \frac{dh}{H(h)}$$

$$H(h) = H + \frac{H_m - H_T}{\tanh(\beta)} \tanh\left(\beta \frac{h - h_T}{h_m - h_T}\right)$$

N_m, h_m, and H_m are the density, altitude and scale height at the F2 layer peak. For α-Chapman function H(h)=Hm=const. The transition height $h = h_T$ is the height, where the dominant ion species change from O^+ to H^+.

Three models of the topside electron density profile greatly differ from each other: the most smooth decrease of the electron density above maximum F-layer is given by the IRI-2001 model, the strongest variations of the electron density and low frequency refractive index in ionosphere is obtained using α-Chapman function.

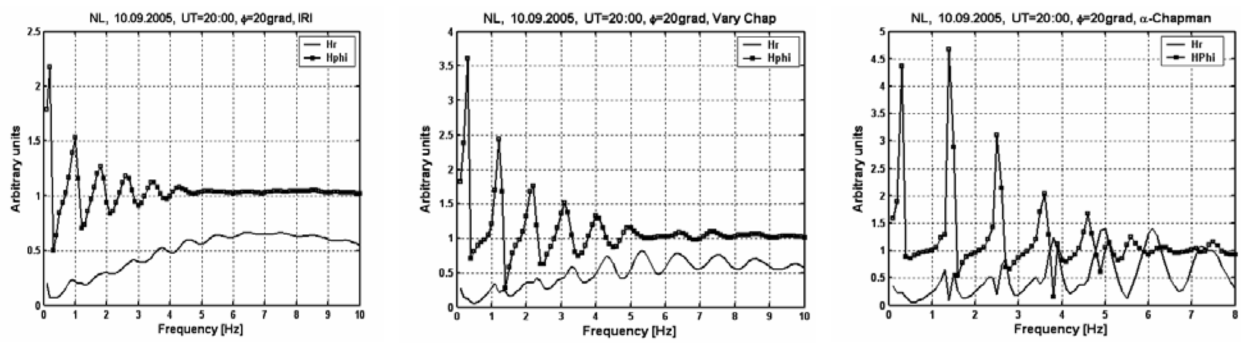


Fig. 5 Results of numerical simulation for New Life for different F2 topside models

Fig. 5 presents the results of SRS modeling for New Life using the three above-mentioned topside profiles. As one can see the different character of the electron density changing brings not only to increasing of the depth of the SRS oscillations, but also to changes of the character of the spectrum and to appearance of the additional maxima (for α-Chapman function). Moreover, the amplitude of these maxima depends greatly on the direction to the source.

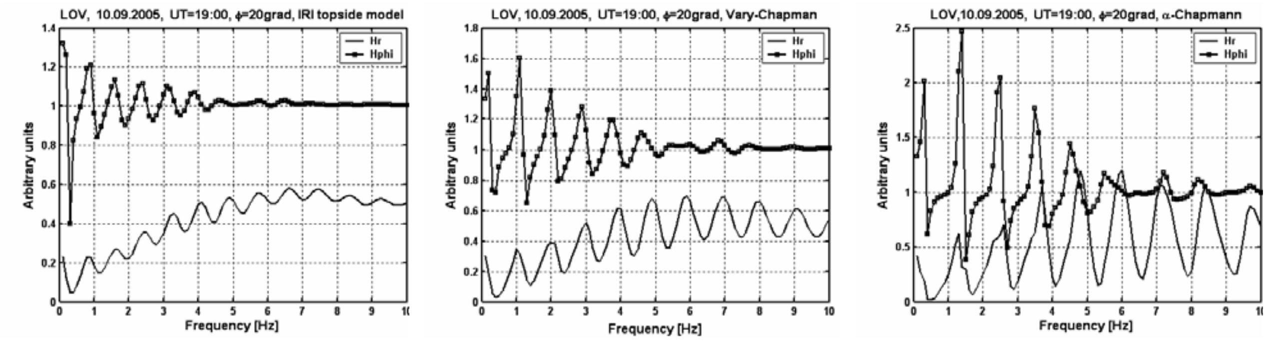


Fig. 6 Results of numerical simulation for Lovozero for different F2 topside models

Fig 6 presents the results of the SRS calculation for Lovozero. The oscillation's character does not change greatly and the spectra remain equidistant for all three models. The influence of the Earth magnetic field inclination could be formulated as: the smaller anglesθ (for New Life θ ≈20°, for Lovozero θ ≈12.2°) the more is the regularity of the SRS oscillations. This is confirmed by observations. The analysis of the numerical modeling results for the sources located at different directions from a plane of the magnetic meridian shows the possibility of appearance of the mirror symmetry in resonance oscillations in different components. However, the value of the shift of the basic frequencies in *H* and *D* components depends also on the topside ionosphere profile.

Conclusions

Strong distinction of the SRS character for stations New Life and Lovozero is revealed. The high degree of the equidistance of the SRS basic frequencies at station Lovozero is observed for all seasons; at the same time in the middle-latitude station New Life, SRS has more complex character seen in the occurrence of secondary maxima and simultaneous existence of different frequency scales. The complex character of SRS at New Life usually correlates with the SRS observation in broad frequency band (up to the second Schumann resonance). The numerical simulations on the basis of the IRI-2001 and interpolation models show that the stronger decay of the electron density above the F-region peak can result in the more complicated character of SRS (for instance, in the occurrence of frequency scales ΔF/2) even under small inclination of the Earth magnetic field (about ≈ 20° for the station New Life). The numerical simulations of SRS for the models with sharp density decay and inclination of 12.2° (as for the station Lovozero) shows, however, the "correct" SRS character with the only frequency scale. The influence of the direction towards a source on the SRS features in H and D components also depends on the shape of the F2 layer topside profile.

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