Polarization characteristics of the Schumann resonance modes in Tomsk

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ABSTRACT

The article describes the experimentally determined distribution of ellipticity coefficient for the first three modes of the Schumann resonances (SR) for different seasons in 2014. Established the presence of seasonal variation of the frequency of occurrence for different types of polarization of the first three modes SR. It is shown that the frequency of occurrence of elliptical polarization for different modes of SR is about 70–80%. Circular polarization - a very rare event, the frequency of its occurrence is less than 1% for every season of the year.

Keywords: Schumann resonances, polarization of electromagnetic waves, monitoring.

1. INTRODUCTION

The main physical mechanisms defining global distribution of the electromagnetic (EM) energy to the environment in the range of extremely low frequency (3-30 Hz) are the Schumann resonances (SR) [1, 2]. This mechanism was first theoretically predicted by W.O. Schumann in 1952 [3], which is why its name. Subsequently M. Balser and C. Wagner have discovered this phenomenon experimentally [4]. Currently, much attention is given to the experimental study of polarization characteristics of the SR, which is the first study carried out D.D. Sentman in 1987 [5]. The purpose of this work is to determine the statistical regularities of any kind of polarization SR Tomsk, depending on the season.

2. EXPERIMENTAL

Measurements of extremely low frequency EM background are conducted in during continuous monitoring since January 2013 at the site of Tomsk State University "Kolarovo" (SS 56.34, 84.95 VD), located 17 km from the city of Tomsk. Measurements are taken by using the three-induction magnetometer LEMI-30. It allows defining the energy, frequency and polarization characteristics of SR. Methods of determining the polarization characteristics consist of several stages. On the first stage happening decomposition daily time realizations of the horizontal magnetic component by 480 three-minute intervals, each of which are calculated average power S_{xx}, S_{yy} and the mutual spectra S_{xy}:

$$S_{ij}(f_n) = H_i(f_n)H_j^*(f_n), \quad (1)$$

$$H_x(f_n) = \sum_{k=0}^{N-1} H_x(t_k)e^{-i\frac{2\pi}{N}kn} \equiv \sum_{k=0}^{N-1}\left(H_x^k \cos(\frac{2\pi}{N}kn) + iH_x^k \sin(\frac{2\pi}{N}kn)\right) \equiv \mathrm{Re}\,H_x(f_n) + i\,\mathrm{Im}\,H_x(f_n), \quad (2)$$

where i and j correspond to the channels «north-south» (X) and «East-West» (Y), $H_x(f_n)$ – complex amplitude component X at the frequency f_n, n – number of spectral harmonics ($n = 0..N/2$), k - number of the time frame [0 ... N-1] (corresponds to the range – 10 sec.), $N = 128$ Hz × 10 = 1280, for the component $H_y(f_n)$ – analogously.

Detailed method of calculation of the spectral characteristics electromagnetic background and the selection modes Schumann resonances (resonance frequencies and amplitudes SR modes) is presented in [6].

In a second step under the received spectral realizations horizontal component of the magnetic induction module going calculation of the Stokes parameters [7] for each frequency (further, frequency dependence is omitted):

$$I = S_{xx} + S_{yy} = (\mathrm{Re}\,H_x)^2 + (\mathrm{Im}\,H_x)^2 + (\mathrm{Re}\,H_y)^2 + (\mathrm{Im}\,H_y)^2, \quad (3)$$

$$Q \equiv S_{xx} - S_{yy} = (\mathrm{Re}\,H_x)^2 + (\mathrm{Im}\,H_x)^2 - (\mathrm{Re}\,H_y)^2 - (\mathrm{Im}\,H_y)^2, \quad (4)$$

$$U \equiv 2\,\mathrm{Re}\,S_{xy} = 2(\mathrm{Re}\,H_x\,\mathrm{Re}\,H_y + \mathrm{Im}\,H_x\,\mathrm{Im}\,H_y), \quad (5)$$

21st International Symposium on Atmospheric and Ocean Optics: Atmospheric Physics,
edited by G. G. Matvienko, O. A. Romanovskii, Proc. of SPIE Vol. 9680, 96806H

doi: 10.1117/12.2205708

$$V \equiv 2\,\mathrm{Im}\,S_{xy} = 2(\mathrm{Im}\,H_x\,\mathrm{Re}\,H_y - \mathrm{Re}\,H_x\,\mathrm{Im}\,H_y)\,. \tag{6}$$

Next, using the expression (4–6) is computed ellipticity coefficient ε and the position angle of the polarization ellipse Ψ:

$$\varepsilon = \frac{V}{\sqrt{Q^2 + U^2} + \sqrt{Q^2 + U^2 + V^2}}, \tag{7}$$

$$\Psi = \frac{1}{2}\mathrm{arctg}\left(\frac{U}{Q}\right), \tag{8}$$

ellipticity coefficient ε has a value from -1 to +1. For linear polarization ε = 0; ± 1, when there is a circular polarization, the positive sign corresponds ε rotation of the magnetic induction vector in the horizontal plane in a clockwise direction, negative - in the opposite direction. The second parameter Ψ allows you to define orientation the polarization ellipse relative to the north geographic pole.

3. RESULTS

For the calculation of polarization parameters (7, 8) was written specialized software [10], by which for each month in 2014 were computed the ellipticity coefficient and the position angle Ψ for the first three modes of the Schumann resonances (Figure 1).

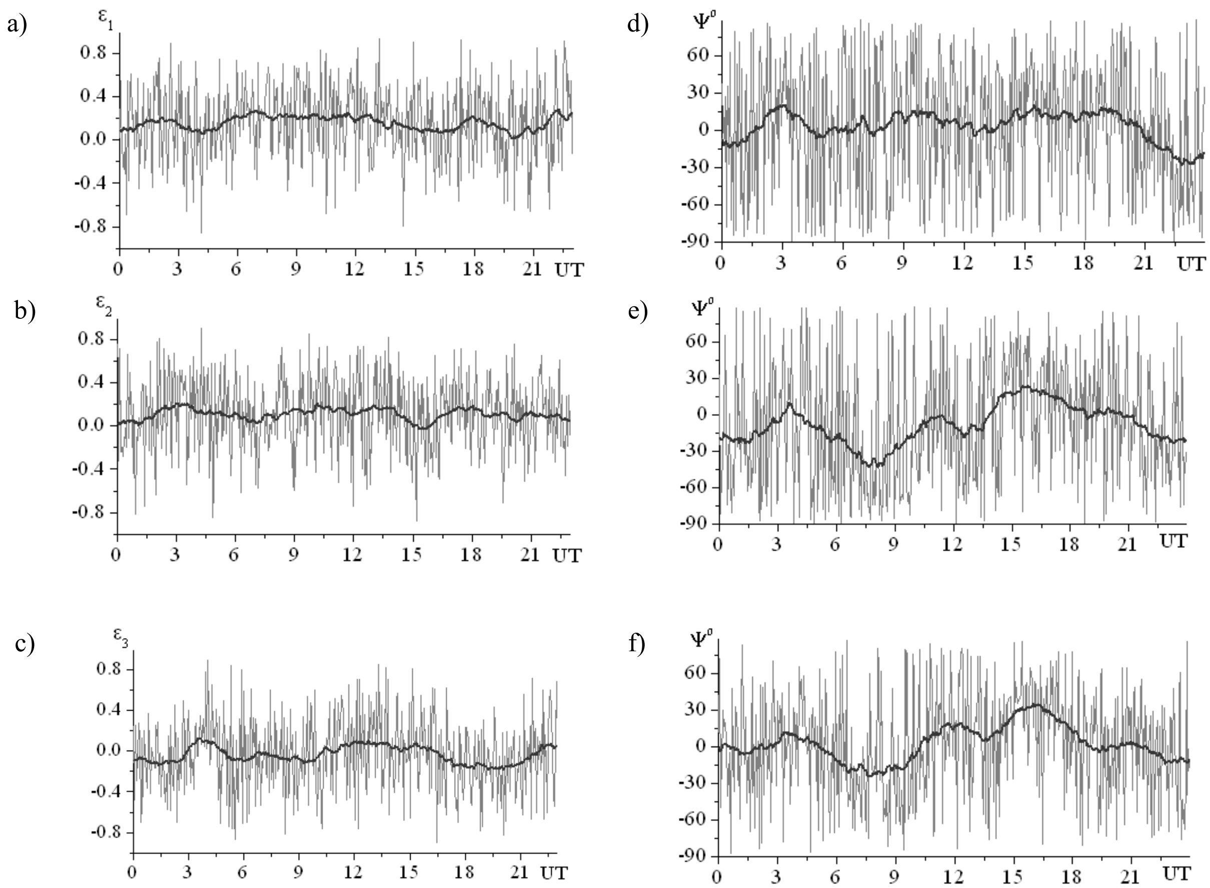
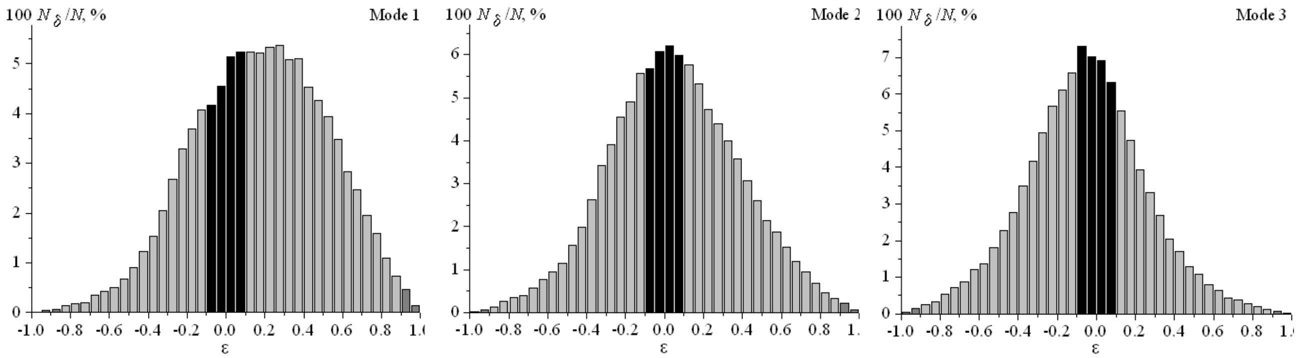


Figure 1 – an example of the daily behavior of the ellipticity coefficient (a–c) and the position angle of the polarization ellipse (d–f) of the first three modes of SR (15 May 2014)

The black line (Figure 1) is derived from the moving averaging time window 2 hours calculations were performed in a standard packet data (Origin 7.0). For the first mode SR mainly observed right rotation of the magnetic induction in the horizontal plane. The second mode SR almost equally has both left and right-handed polarization, with a slight predominance of the latter in May. The position angle is changed within ± 90 ° (0 ° corresponds to the direction of the north geographic pole).

Polarization parameters have been processed using statistical methods. Namely, the frequency of appearance was determined by the type of polarization for the first three modes of the SR 2014 (Figure 2). Separation into types of polarization was carried out as follows. Simply match the value of linear polarization ε = 0. But to obtain reliable quantitative estimating the frequency appearance of linear polarization of the value range has been expanded to ± 0,1. Similarly, the frequency of appearance was determined by circular polarization. All remaining values refer to the elliptical polarization.



a) b) c)

Figure 2 – Distribution of the ellipticity coefficient for the first three modes of the SR 2014. Light gray denotes elliptical polarization, black – linear, and dark gray (edge distributions) – Circular

The results obtained for 2014 show that for all three considered modes SR dominant average is elliptical polarization (Figure 1). Circular polarization is extremely rare (less than 1%). With increasing numbers modes SR frequency of appearance elliptical polarization decreases (first mode SR ~80%, the second ~76%, third ~72%), and the linear polarization – on the contrary increased (~19%, ~24% and ~28%). There is also a trend with increasing mode number SR transition from the dominance of the right polarization to the left. For example, for the first and second mode SR prevails right polarization (Table 1).

Table 1 – Frequency of different types of polarization for 2014

Month	1st mode				2nd mode				3rd mode			
	P_{line}	P_{left}	P_{right}	P_{circle}	P_{line}	P_{left}	P_{right}	P_{circle}	P_{line}	P_{left}	P_{right}	P_{circle}
1	17,70	22,56	59,22	0,52	21,83	34,30	43,33	0,54	25,77	38,72	35,25	0,26
2	18,15	21,69	59,61	0,55	22,11	31,45	45,96	0,48	25,43	36,25	37,94	0,38
3	17,57	23,21	58,57	0,65	21,65	33,50	44,46	0,39	23,26	38,76	37,53	0,45
4	17,30	24,71	57,35	0,64	20,79	31,68	47,05	0,48	23,23	38,10	38,27	0,40
5	18,83	26,97	53,54	0,66	21,20	31,28	47,07	0,45	21,94	39,70	37,91	0,45
6	18,54	29,41	51,40	0,65	20,58	32,69	46,26	0,47	22,39	39,55	37,70	0,36
7	20,04	29,85	49,66	0,45	20,97	33,63	44,93	0,47	23,01	40,44	36,00	0,55
8	18,90	30,34	50,22	0,54	21,21	35,30	42,94	0,55	21,93	43,49	34,10	0,48
9	22,00	26,95	50,56	0,49	21,64	32,43	45,36	0,57	21,75	44,73	32,92	0,6
10	18,22	25,31	55,84	0,63	21,22	33,56	44,71	0,51	22,69	42,16	34,72	0,43
11	18,07	23,04	58,29	0,60	20,84	34,96	43,68	0,52	23,73	39,53	36,38	0,36
12	19,95	24,98	54,50	0,57	22,89	36,68	40,02	0,41	24,92	39,88	34,80	0,4

The behavior of the position angles of the polarization ellipse is marked diurnal and seasonal variations throughout the year (Figure 3). For the third modes winter months observed three peaks: at 01 UT (Ψ ~ 19° -21°); 14 UT (Ψ ~ 23° -24°) and 22 UT (Ψ ~ 11° -15°). In the summer months the main peak (14 UT) to become less pronounced. The appearance of additional peaks at 10 UT (Ψ ~ 5°); 14 (Ψ ~ 11° -13°); 18 UT (Ψ ~ 17° -19°). For spring and autumn seasons of the year on all modes of SR 8 UT traced maximum of Ψ ~ -17° -20°.

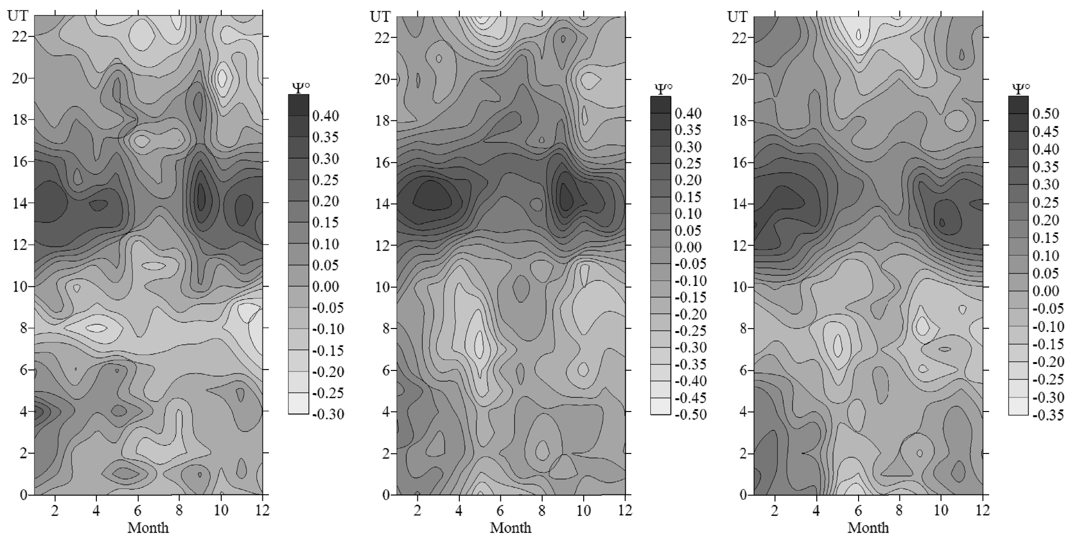


Figure 3 – diurnal and seasonal distribution the positional angles of the polarization ellipse for 2014 year

4. CONCLUSION

The experimentally determined distribution of the ellipticity coefficient for the first three modes of the Schumann resonances for different seasons in 2014. Established the presence of seasonal variation of the frequency of occurrence for different types of polarization of the first three modes SR.

It is shown that frequency of appearance of elliptical polarization for different modes Schumann resonance is ~ 75-80%. Circular polarization - a very rare event, the frequency of its occurrence is less than 1% for every season of the year.

For the first mode of the Schumann resonance is dominated by right-polarization, which agrees well with the known results. With increasing numbers modes SR frequency of appearance elliptical polarization is reduced and the linear polarization - on the contrary increases.

The most probable value of the position angles of the polarization ellipse as follows: for the first mode SR ~ 20 °; for the second ~ -20°; third to ~ 10°.

ACKNOWLEDGMENTS

This study was performed at the Department of Cosmic Physics and Ecology RFF under the program to improve the competitiveness of the TSU.

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