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Long period oscillations of microwave emission of solar active regions: observations with NoRH and SSRT

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Abstract. In this work we present the first results of study and comparison of the parameters of quasi-periodic long-term oscillations of microwave emission of large (>0.7 arcmin) sunspots as a result of simultaneous observations with two radioheliographs – NoRH (17 GHz) and Siberian Solar Radio Telescope (SSRT) (5.7 GHz) with 1 minute cadence. Radioheliographs have been working with quite large time overlap (about 5 hours) and have the high spatial resolution: 10 arcsec (NoRH) and 20 arcsec (SSRT). We have found that quasi-periodic long-term oscillations are surely observed at both frequencies with the periods in the range of 20–150 min. We detected common periods for common time of observations with two radioheliographs and interpret this as the consequence of the vertical-radial quasi-periodic displacements of sunspot as a whole structure.

Keywords. high angular resolution, oscillations, magnetic fields, sunspots

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Quasi-periodic long-term oscillations of the solar flux radio emission with periods about 1 hour have being studied since 1970-th (Kobrin, Pahomov & Prokof'eva 1976, Durasova, Kobrin & Yudin 1986). New radio telescopes, such as Nobeyama Radioheliograph (NoRH), opened new possibilities for studying oscillations of solar radio emission from sources above sunspots with high spatial resolution (Gelfreikh, Nagovitsyn & Nagovitsyna 2006). Quasi-periodic long-term oscillations of sunspots registered with the optical methods (Zeeman and Doppler effects) have periods from 40 to 200 minutes and have global character and physical origin sharply different from the well-known 3-5 minute oscillations in sunspots (Efremov, Parfinenko & Solov'ev 2007, Efremov, Parfinenko & Solov'ev 2008, Solov'ev & Kirichek 2006, Solov'ev & Kirichek 2008, Kshevetskii & Solov'ev 2008). Whereas the latter are MHD-waves trapped inside the magnetic flux tubes of the sunspots, the low-frequency oscillations are concerned with quasi-periodic displacements of the whole sunspot as a well localized and stable formation. These are the oscillations of sunspot itself, but not the oscillations of some elements into the sunspot's magnetic tubes (Solov'ev & Kirichek 2008, Kshevetskii & Solov'ev 2008): sunspot oscillates as a whole, keeping its own structure (umbra - penumbra) but changing geometrical sizes, strength and vertical gradient of the magnetic field. These oscillations are possible because sunspots are turned to be relatively "shallow" formations. The depth of their so called lower magnetic boundary is only 3-5 thousands of kilometers. This theoretically predicted general property of sunspots (Solov'ev & Kirichek 2008, Solov'ev 1984a,

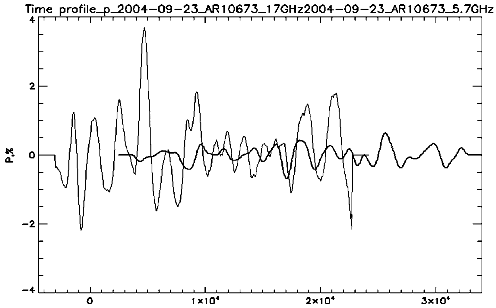

Figure 1. Time profile of the degree of circular polarization P at 17 GHz (NoRH) (thin line, time of observation from - 0.3×10^4 sec till 2.3×10^4 sec) and 5,7 GHz (SSRT) (thick line, time of observation from 0.3×10^4 sec till 3.3×10^4 sec). Vertical axis - P, %, the circular polarization degree, smoothed (9 minutes) and trend component is subtracted; horizontal axis - time of observation, sec

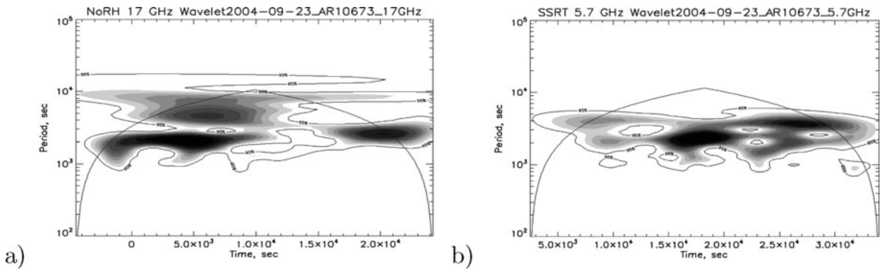

Figure 2. Wavelet spectra ("filter" with moving average 50 min) for the degree of circular polarization P: a) at 17 GHz (time of observation from -0.3×10^4 sec till 2.3×10^4 sec), b) at 5,7 GHz (time of observation: from 0.3×10^4 sec till 3.3×10^4 sec). Vertical axes - period of oscillations, sec; horizontal axes - time of observation, sec

Solov'ev 1984b, Nagovitsyn 1997) is surely confirmed by the data of local helioseismology (Zhao 2001, Kosovichev 2006).

We present the first results of study and comparison of the parameters of quasi-periodic long-term oscillations of microwave emission of large (>0.7 arcmin) sunspots in the non-flare bipolar and unipolar active regions (AR) as a result of simultaneous observations with two radioheliographs – NoRH (17 GHz) and Siberian Solar Radio Telescope (SSRT) (5.7 GHz) with 1 minute cadence for revealing common periods at both frequencies during of two radio-heliographs work time overlap (about 5 hours). These common periods in the microwave range may be considered as a consequence of eigen oscillations of a sunspot (assuming hyrocyclotron emission at both frequencies): as the Alfven times are considerably less than a period of these oscillations, magnetosphere above a sunspot re-forms fastly, and we observe the system's passing through continuous series of the equilibrium states in the microwave range.

On the radio maps sunspot-associated sources were identified and time profiles of their maximum brightness temperatures and circular polarization degree for each radio source were calculated. We studied 11 sunspots-associated radio-sources (20 days of observations) (2001-2006 y.y.) using smoothing procedure (moving average) for both SSRT and NoRH temporal data raws and calculating deviation of original signal from average signal because of nonstationary data and day's changing of the antenna beam and also we used the interpolation method for nonequidistant temporal data raws of SSRT. We calculated the degree of the circular polarization $p = TVmax/TI$ (where $TVmax$ – maximum of the brightness temperature of Stock's parameter V above sunspot, TI – brightness temperature of Stock's parameter I) because it is the most reliable parameter due to nonstability of SSRT data. Wavelet spectra (wavelet Morle–6) (Torrence & Compo 1998) and FFT spectra and cross-correlation function as a function of temporal delays were calculated for parameter P.

One should notice that microwave emission at two different frequencies comes from two different heights of sunspot's magnitosphere, so we can't expect inphase oscillations of P but moreover – antiphase oscillations are more probable because of different sign of the temperature gradient at the heights in the upper chromosphere and lower corona where third hyrolevel at 17 GHz and second and third hyrolevels at 5.7 GHz are located. One example of temporal data raws of P on both frequencies, and wavelet spectra of the microwave emission above the leading sunspot of AR 10673 NOAA, 23 of September 2004, is demonstrated on figures 1 and 2.

We can see from fig. 2 a) and b) that during common time of observations (from 0.3×10^4 sec till 2.3×10^4 sec) there are three common periods: about 33, 40 and 66 minutes. Period of about 40 minutes is most pronounced. Coefficient of cross-correlation function of two spectra is -0.7 under time delay about 0-10 minutes.

Conclusions:

Using wavelet, FFT and cross-correlation analyses we found out that:

1) long period oscillations are surely observed at both frequencies and have wave trains character;

2) periods of the long-term oscillations at both 17 and 5.7 GHz are surely observed in the range of 20 – 150 min, but we should point out at the existence of more long oscillations;

3) we detected common periods (for example – fig. 2 a) and b)) and quite similar spectra for common time of observations with two radioheliographs that may be considered as a consequence of eigen oscillations of a sunspot.

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