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Midrange periodicity of basal component of solar radio flux during the extended solar minimum of cycle 23–24

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Abstract. Radio observations serve as a powerful tool to study the physical conditions of the radio emitting sources for understanding the characteristics of solar atmosphere. It is also a useful method for understanding the physical properties and the dynamics of the solar corona. It is evident from various experimental observations that the recent 23–24 solar cycle minimum was elongated for much longer time compared to previous minima. In this paper, the mid-range periodicity (in the range of 50–250 days) for non-magnetic components of solar radio flux at eight discrete frequencies viz. 245, 410, 610, 1415, 2695, 4995, 8800 and 15400 MHz during the extended solar minimum period (2007–2009) have been explored using Lomb-Scargle periodogram technique. The periodicities obtained in the mid range (50–250 days) for different frequencies during this minimum have been identified with the periodicities within the range of standard deviation obtained from different analysis for different time span with different phase of previous solar cycles by different workers. The observations of basal component (non magnetic component of solar radio flux) are interpreted in terms of the internal dynamics of the Sun. The obtained periodicities also provide physical information about the source region of the solar atmosphere.

Keywords : Sun: radio radiation – Sun: activity – sunspots – Sun: corona

1. Introduction

The study of solar radio emission provides precise information about source region of the radio emission. It also provides detailed information about the temperature profile, constituents, density, ionization, magnetic fields and the physical nature of the various sources inside the solar

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Table 1. Different radio frequencies and their origin in the solar atmosphere.

Frequency (MHz)	Wavelength	Level of origin
245	1.2m	Lower corona
410	73.2 cm	Upper chromosphere
610	49.2 cm	Upper chromosphere
1415	21.2 cm	Upper chromosphere
2695	11.1 cm	Middle chromosphere
4995	6.0 cm	Middle chromosphere
8800	3.4 cm	Lower chromosphere
15400	1.9 cm	Lower chromosphere

Taken from http://www.swpc.noaa.gov/ftpdir/lists/radio/README

structure (Kundu 1965). Thus, to diagnose the solar atmosphere and the magnetic energy released from the Sun, radio observations serve as a powerful tool. The radio flux has its origin from solar atmospheric layers high in the chromosphere and low inside the coronal region, though the precise level of origin is not yet fully understood (Kane 2004). Observations at different radio frequencies give information about the various depths and the physical structure of the solar atmosphere. It is already shown in the literature that various frequency bands in the range starting from 245 MHz to 15400 MHz originate from different layers of the solar atmosphere starting from lower chromosphere to upper corona. The observations are tabulated in Table 1. The quiet Sun emission at different frequencies contains information about densities and temperatures in different layers of the solar atmosphere (Watari 1996). It is one of the prime reasons for studying solar radio emission at different frequencies during the solar minimum period which provides an opportunity to study the physical behaviour of the solar atmosphere.

During the solar cycle minima, it is observed that the solar corona becomes asymmetrical in shape (Das & Nag 1998). The radio sources are situated far away from the centre and are also randomly distributed. Many workers have performed spectral analysis of the solar radio flux variations (Gupta & Sarkar 1971; Mohamed & Scherrer 1973) which provide valuable information regarding the nature and shape of the corona (Das & Nag 1999). Solar radio flux also provides information regarding the dominating solar magnetic fields associated with particular frequencies of the solar radio flux spectrum. Watari (1996) analyzed the solar radio emission at several frequencies to investigate their irregularities, time variation and the coronal activity at different heights. Kane, Vats & Sawant (2001); Vats et al. (1998); Mouradian, Bocchia& Botton (2002) used the solar radio fluxes at different frequencies to study the coronal rotation period at different heights and its differential as a function of the altitude (Vats et al. 2001). Meheta (2005) has studied the relationship of rotation period with different phases of the solar cycle. Zieba et al. (2001) has shown that the daily measured radio fluxes at various frequencies are very useful for the systematic study of solar periodicities observed in the different layers of the solar atmosphere. Das & Nag (1998, 1999) has also studied the periodicity of radio flux at frequency range 245-

15400 MHz for 1975, 1986 and 1996 solar minimum. Das & Nag (1998) have explored the harmonic dependence of periodicity on frequency of observation during the minimum period. In this paper we have searched the mid-term periodicities for the last solar minimum.

Statistical significance of mid-range radio periodicities of different solar activity parameters is very important because it provides the information on properties of the Sun (Bai 2003). Many researchers have shown that mid term periodicity is an important feature in solar activities e.g., flare occurrence rate, X-ray peak flux, Hα flare index, production of solar energetic photon, production of energetic electrons in interplanetary space, sunspot number, sunspot areas (Lean & Brueckner 1989; Lean 1990; Oliver & Ballester 1995; Oliver, Ballester & Baudin 1998; Krivova & Solanki 2002; Richardson & Cane 2005; Joshi, Pant & Manoharan 2006). The changes in the magnetic flux generated deep inside the Sun are being manifested by mid-term fluctuation in the solar fields (Bisoi et al. 2014). So studies of midterm periodicities are very important to get the idea of the changes in the interior dynamics of the Sun. Forgács & Borkovits (2007) indicated that the mid-term periodicities are manifested in almost all solar data like sunspot numbers, solar flare index, solar radio flux, IMF, proton speed etc. Reiger et al. 1984 have shown 154-day periodicity in occurrence of hard X-ray flares during the declining phase of cycle 21. Ichimoto et al. (1985) have shown 155-day periodicity in solar activity using H alpha flare data. Bai & Sturrok (1991) reveals 152-day periodicity in solar flare occurrence rate and considers it as a global phenomenon. Ballester, Oliver & Carbonell (2002) have shown 160-day periodicity in photospheric magnetic flux. All these pieces of work are on the periodicity of magnetic components and magnetic related activity. Periodicity dependent on magnetic structures which are independent of sunspot activity has not been widely studied in the literature. Zieba et al. (2001) investigated solar periodicities generated in solar atmosphere by various phenomena related to the periodic emergence of diverse magnetic structures. It has been shown that this periodicity is strongly dependent on the phase of the solar cycle. The solar cycle 23-24 minimum is characterized by an extremely low level of solar activity and extending for longer duration (Gopalswamy et al. 2012). Therefore the analysis of the midterm periodicity of the solar radio flux parameters during the minimum phase of cycle 23/24 is highly required for exploration of solar radio characteristics for this cycle. As the current minimum has a longer duration, it is also likely to have more data during the period which is important to study the mid-range periodicities to get a statistically significant result.

2. Datasets

Solar radio flux data have been collected covering frequencies 245, 410, 610, 1415, 2695, 4495, 8800 and 15400 MHz of Sagamore Hill station from Solar Geophysical Data bulletin published by the U.S. Department of Commerce. The international sunspot number data have been obtained from National Geophysical Data Center. The radio flux data are in Solar Flux Unit (SFU) [1 SFU = 10^{-22} W m^{-2} Hz^{-1}]. For compensation of intensity variations caused by the change in distance between the Sun and the Earth, the solar radio fluxes are adjusted to 1 A.U. The solar minimum for the cycle 23-24 started from 2006. But the quietest Sun was observed from 2008 (http://science.nasa.gov/science-news/science-at-NASA/2009/01apr_deepsolarminimum).

Table 2. List of 'B_0' and 'a' values obtained for different frequencies.

Frequency (MHz)	'B_0' value	'a' value
245	11.49718	0.0517
410	21.88383	0.06885
610	27.52522	0.07435
1415	39.33328	0.31972
2695	66.27326	0.5287
4995	122.22077	0.53172
8800	200.42067	0.59371
15400	438.10539	0.36972

During 2007, 2008 and 2009 there were 163, 266 and 262 spotless (http://www.ngdc.noaa.gov/stp/space-weather/solar-data /solar-indices/sunspot-numbers/international) days respectively. For the present analysis, the solar radio flux data of 1096 days have been taken for the period of 2007 to 2009.

3. Basal component of radio flux

Theoretically, the solar radio flux can be described as the sum of the thermal component, a constant component namely basic component (B) and a slowly varying component (SVC). The SVC component is proportional to the sunspot number (SSN). The daily value of solar radio flux F_i can be written as

$$F_i = B + (SVC)_i = B + a(SSN)_i \tag{1}$$

where, i is the day number. The theoretical radio flux (F_i) for each day depends only on the term $[a(SSN_i)]$ of that day but independent of basic component (B) for a stipulated period. But from observations it is evident that due to various reasons the basic component (B) is modulated, so the observed radio flux of a day depends not only on the term $[a(SSN_i)]$ but also on the basic component. Therefore basic component (B) have two parts and out of that one part is steady denoted by B_0 which is constant for the total interval of the observations and another is the variable part B_b which changes from day to day. The B_b component is the variable component but independent of the daily SSN. So now the modified equation for the observed solar radio flux F_{Obs} is

$$((F_{Obs})_i) = B_0 + (B_b)_i + a(SSN)_i \tag{2}$$

where B_0 = steady part of basic component and B_b is the variable part of basic component and is called Basal component. For the calculation of the basic component the linear model rather that the Boltzman formula model for the mentioned period has been taken as the period of interest is the minimum period which has been considered here for analysis (Zieba et al. 2001). The selection of linear model is also supported by earlier workers (Das, Nag & Chatterjee 1996a;

Das & Chatterjee 1996b; Das & Nag 1998, 1999) for calculation of basic component. From the regression analysis we have obtained the value of B_0 (the value of radio flux at zero sunspot number from a linear fit) and 'a' (the value of the slope from the linear fit) for the whole data span. Table 2 lists the calculated values of B_0 and 'a'. It can be noted that the B_0 component increases as the frequency increases and the correlation coefficients between the sunspot number and the radio flux of different frequencies obtained are not very good as we are considering the solar minima period. SVC is proportional to a certain daily index of activity like sunspot number (SSN) as indicated in Eqn 1. Now the basal component can be calculated from the daily difference between the observed daily radio flux and the sum of B_0 and the product of 'a' and SSN of that particular day. It can be describe as

$$((B_b)_i) = ((F_{Obs})_i) - [a(SSN)_i + B_0] \tag{3}$$

4. Periodogram analysis

To calculate the power spectra of all data sets at different frequencies, the Lomb-Scargle periodogram method (Scargle 1982) has been used. This algorithm is very significant for studying the astronomical time series. Periodogram analysis using this method is exactly equivalent to the least-square fitting of sine curves to the data. For a time series X (t_i), i = 1,2,....N, the probability distribution function of power called periodogram as a function of frequency ω is defined as (Scargle 1982).

$$P_N(\omega) = \frac{1}{2\sigma^2}\left[\frac{[\sum_{i=1}^{N}(x_i - \bar{x}\cos\omega(t_i-\tau))]^2}{\sum_{i=1}^{N}\cos^2\omega(t_i-\tau)} + \frac{[\sum_{i=1}^{N}(x_i - \bar{x}\sin\omega(t_i-\tau))]^2}{\sum_{i=1}^{N}\sin^2\omega(t_i-\tau)}\right] \tag{4}$$

Where, $\bar{x}=\frac{1}{N}\sum_{i=1}^{N}(x_i)$, $\sigma^2=\frac{1}{N-1}\sum_{i=1}^{N}(x_i-\bar{x})$ is the total variance of the data set and τ is defined by the relation $\tan(2\omega\tau)=\frac{(\sum_{i=1}^{N}\sin 2\omega t_i)}{(\sum_{i=1}^{N}\cos 2\omega t_i)}$

P_N (ω) is defined in such a mode that if X (t_j)is pure noise then the power in P_N (ω) follows an exponential probability distribution (Horne & Baliunas 1986). The inclusion of (ω) terms makes the periodogram invariant to a shift of the origin of time. This exponential probability distribution function of power P_N (ω) helps us in evaluating False Alarm Peaks (FAP) for estimating the probability whether a given peak is a true signal or erratically distributed noise.

The probability that P_N (ω) is greater than a pre-assigned value z is given by Pr[P_N (ω) >z]=e(-z/k), k is the normalization factor and can be determined empirically (Delache, Laclare & Sadsoud 1985; Bai 1992). Here we have assumed the value of k =1, that is the time series data, is statistically independent Gaussian noise. The False Alarm Peak has been defined in the following way Horne & Baliunas (1986). If z is the highest peak in a periodogram that sampled over N independent frequencies then the probability that each peak of the independent frequencies smaller than z is (1 - e^z), and this gives us the probability that every peak of independent frequencies lower than z as (1 - e^z)N. Thus, the probability that at least one of the peaks is of height z or higher is defined as the FAP and FAP equals to (1 - e^z)N. The physical significance of FAP is upper limit to

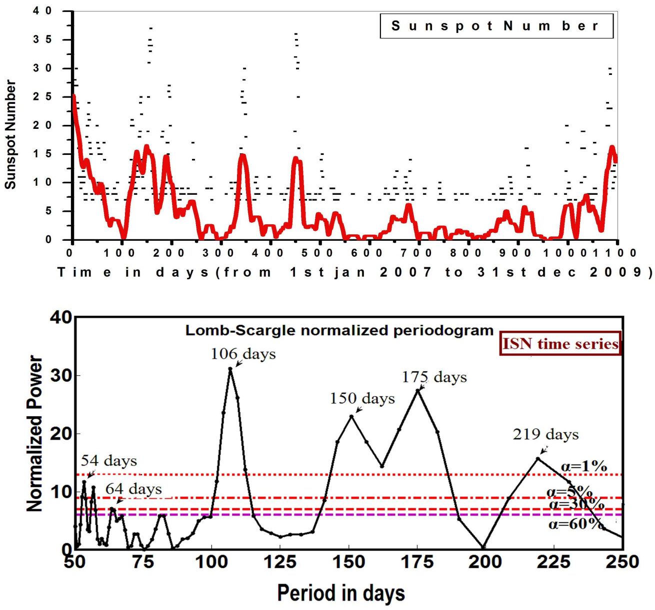

Figure 1. (a) Original variation of sunspot numbers (scattered points represent the daily sunspot number and the red line represents a 10-day smoothed plot) (b) Periodogram for sunspot number during the minimum period.

the false alarm probability means a lower limit to the significance Baluev (2008). Lomb Scargle Periodogram technique has many advantages over conventional Fast Fourier Transform method as it is suitable for analysis of unevenly spaced data, that is, it can take the edge off missing data problem Horne & Baliunas (1986). In this paper, this technique has been employed for investigating in the midrange periodicities and scanning the power spectra of radio flux for the periods in the range 50-250 days and for periodicity calculation for 23/24 minimum solar cycle period.

5. Observations

For exploring the midrange periodicity, we have used the periodogram technique for sunspot time series and non-magnetic component of solar radio flux for eight discrete solar radio frequencies. The sunspot number time series for the minima period has been shown in Fig. 1(a). The original and the basal component for all the frequencies have been shown in panels (a) and (b) of Figs. 2 to 9. The periodogram for sunspot number time series (Fig. 1(b)) shows peaks at ~106, 150, 175, 219 days with false alarm probability (FAP) of 1%. It also shows peak at 54 days (with FAP 5%) and 64 days (with FAP 30%). For 245 MHz (Fig. 2(c)) solar radio frequency, peaks have been found at 205 days (with FAP 1%) and at ~57, 84, 106, 120, 164 days with FAP 5%. Peaks have been found at ~ 65, 137, 190, 243 days with FAP 1% and at ~ 52, 76, 112 days with FAP

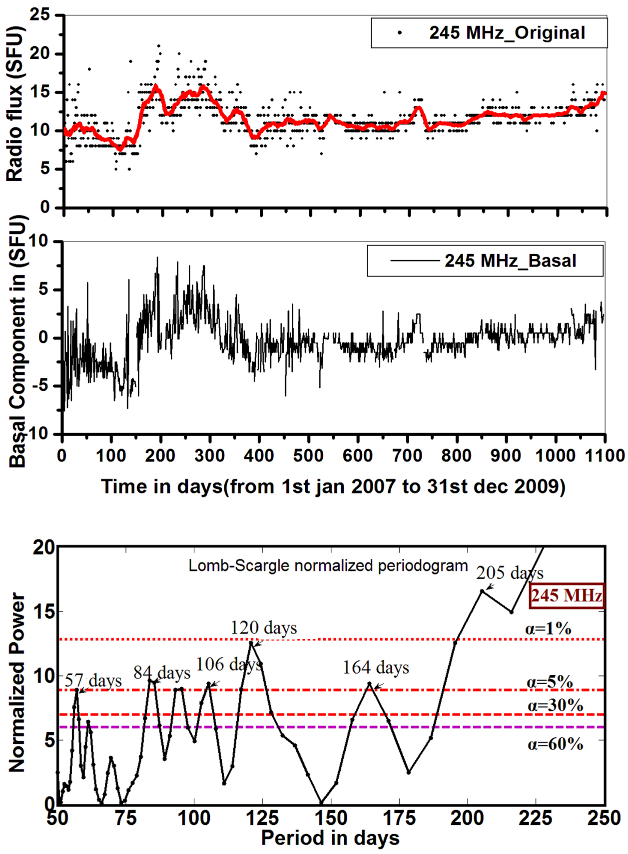

Figure 2. (a) Variation of 245 MHz radio flux (scattered points represent the daily 245 MHz flux values and the red line represents a 10-day smoothed plot); (b) Basal component of radio flux time series for 245 MHz; (c) Periodogram for basal component of 245 MHz radio flux during the minimum period.

5% for 410 MHz (Fig. 3(c)). In case of 610 MHz (Fig. 4(c)) peak has been found at ~ 102, 137, 200 days with FAP 1% and ~54, 65 and 243 days with FAP 5%. For 1415 MHz (Fig. 5(c)) observed peak is at ~ 146, 182 days with FAP 1%, at ~96 day and 72 day with FAP 5% and 60% respectively. For 2695 MHz (Fig. 6(c)) peaks are at ~183 day and 118 day with FAP 1% and 5% respectively. In case of 4995 MHz (Fig. 7(c)) peaks have been found at ~112 days and ~91 days with FAP 30% and 60% respectively. For 8800 MHz (Fig. 8(c)) peaks have been found at ~156 and 243 days with FAP 1% and ~65 days with FAP 60%. In case of 15400 MHz (Fig. 9(c)) peak is at ~198 days with FAP 5%. All the obtained periodicities for different solar radio frequencies are listed in Table 3.

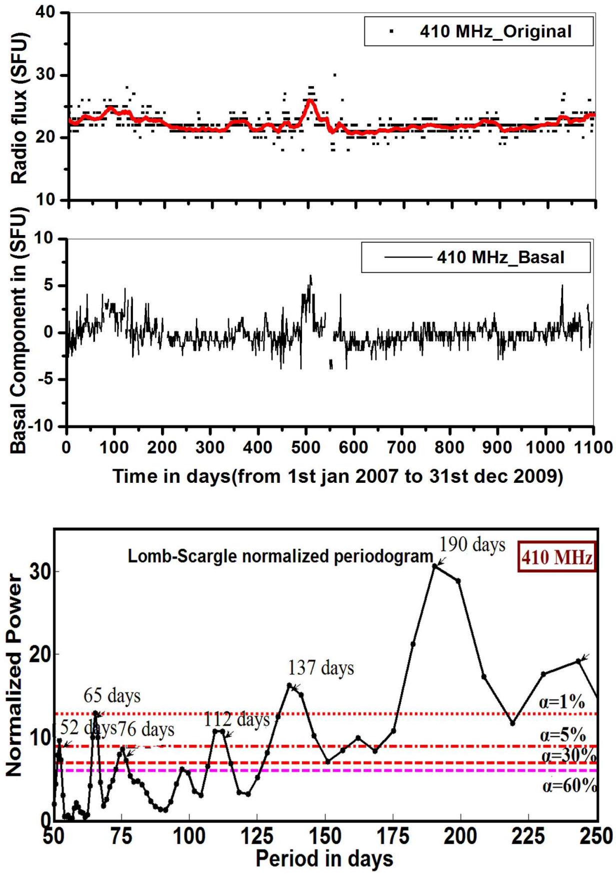

Figure 3. (a) Variation of 410 MHz radio flux (scattered points represent the daily 410 MHz flux value and the red line represents a 10-day smoothed plot); (b) Basal component of radio flux time series for 410 MHz; (c) Periodogram for basal component of 410 MHz radio flux during the minimum period.

6. Discussion

The Lomb Scargel periodogram analysis for solar minima of solar cycle 23/24 reveals the existence of different significant periodicities. All the observed periodicities have been identified with the periodicities obtained from different analysis for different time span with different phase of solar activity by different workers. Peaks at ~54(27X2) day and ~243(27 X 9) days have been discarded as they are an integral multiple of solar synodic rotation of 27 days (Das & Nag 1998). Now in this Section, all the other obtained periodicities (except 54 and 243 day) in terms of the available literature have been discussed. From Table 1 it is clear that for 245, 410 and 610 MHz, the obtained periodicities are nearly the same. Among these the 57, 52, 54-day periodicities can

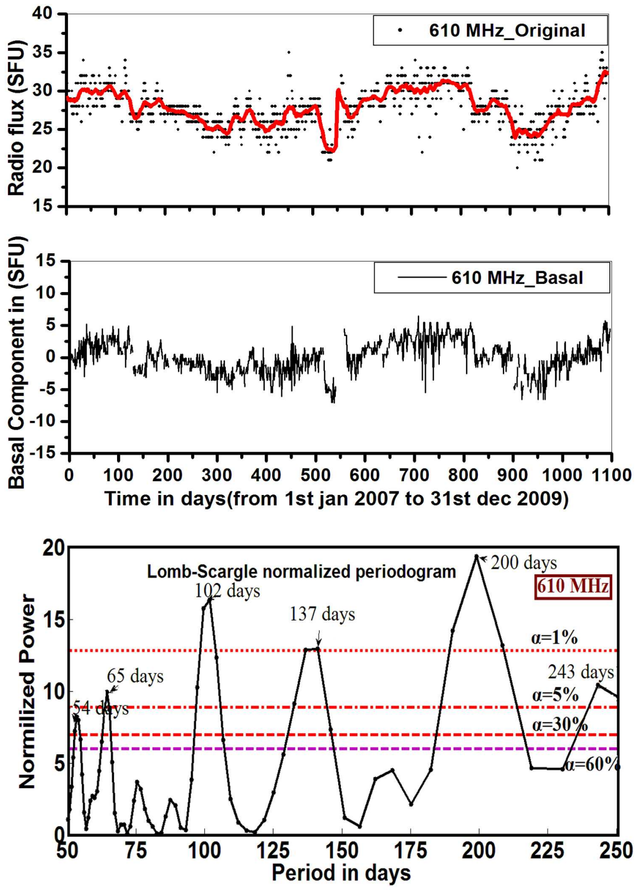

Figure 4. (a) Variation of 610 MHz radio flux (scattered points represent the daily 610 MHz flux value and the red line represents a 10-day smoothed plot); (b) Basal component of radio flux time series for 610 MHz (c); Periodogram for basal component of 610 MHz radio flux during the minimum period.

be omitted as these are also very close to integral multiple the of solar synodic rotation. Other peaks obtained at 65 days which may be correlated with a 63-day periodicity that has been found by Chowdhury, Khan & Ray (2009a) for solar electron flares. A 65 day periodicity has also been found for 8800 MHz. But we have obtained a peak around 64 days in sunspot activity and that's why we are not considering this 65-day periodicity as a contribution from basal component.

During the last minimum 1996, Zieba et al. (2001) found that the 75-day periodicity was the strongest periodicity of solar radio flux for that period. Here in our observations also 76-day (for 410 MHz) periodicity is present. Another periodicity at 72 days (for 1415 MHz) is also present here, which can be correlated with periods 73-78 days observed by several workers (Bai

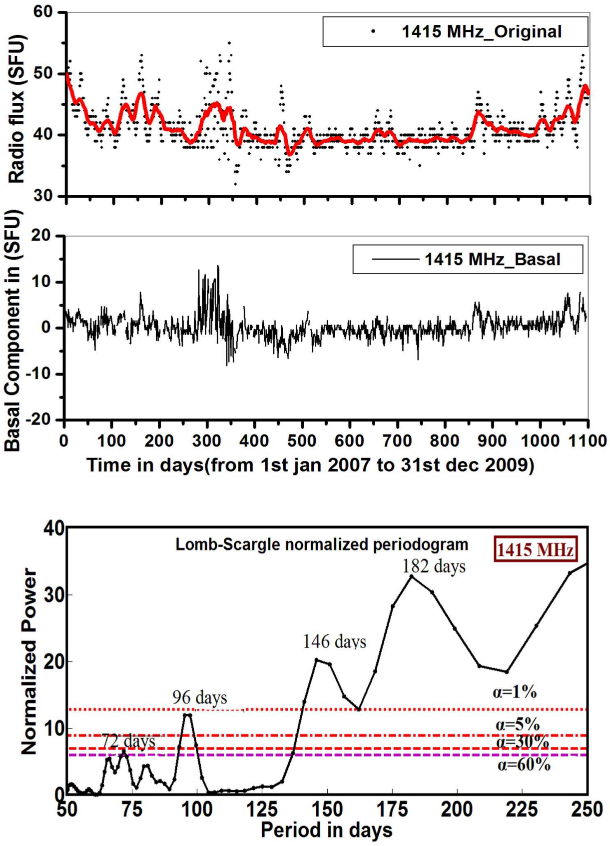

Figure 5. (a) Variation of 1415 MHz radio flux (scattered points represent the daily 1415 MHz flux value and the red line represents a 10-day smoothed plot); (b) Basal component of radio flux time series for 1415 MHz; (c) Periodogram for basal component of 1415 MHz radio flux during the minimum period.

& Sturrok 1991; Bai 1992) mainly in flare activity during solar maximum period. In case of 245 MHz, the 84-day periodicity may be related to the 86 day periodicity that has been found by Oliver & Ballester (1995) analyzing the sunspot area data and Chowdhury et al. (2009a) for solar electron flares.

Other peaks have been found at 95 days at 245 MHz, nearly 96-day periodicity at 1415 MHz and 91-day periodicity at 4995 MHz. These periodicities may be related to 92-day periodicity obtained for solar radio flux during 1996 minimum by Zieba et al. (2001). For 245 MHz, 105-day periodicity has been found and nearer to this, 109-day (for 410 MHz), and 102-day (for 610 MHz) periodicites are also reported here. These are in the range of quasi-periodicities of 87-106 days as detected by Chowdhury, Khan,& Ray, (2009b) and also close to the 106-day

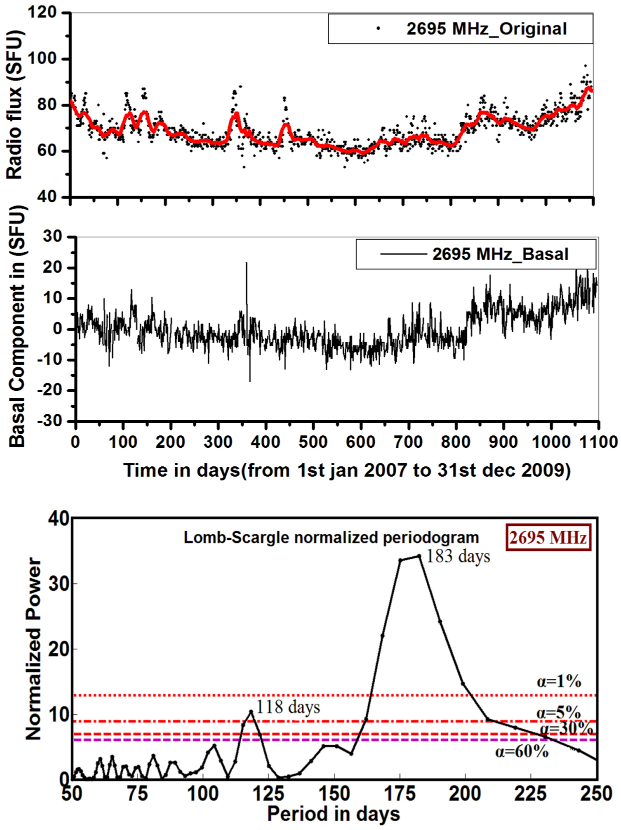

Figure 6. (a) Variation of 2695 MHz radio flux (scattered points represent the daily 1415 MHz flux value and the red line represents a 10-day smoothed plot); (b) Basal component of radio flux time series for 2695 MHz; (c) Periodogram for basal component of 2695 MHz radio flux during the minimum period.

periodicity obtained for sunspot series. So we will not also consider this as a periodicity of basal component. Chowdhury & Dwivedi, (2011) have found 110 - 130 day periodicities in coronal index data sets in different time intervals. Özgüç , Atac & Rybak (2002) studied the harmonic behavior of solar flare index for the ascending part of Cycle 23 and reported a periodicity of 116 days. Recently, Kilic (2008) have investigated the periodicities of solar flare index data and they reported significant periodicities of 115 days during Cycle 23. Here also we have obtained 112-day (for 4995 MHz) periodicity in this range. With slight delay from this range 118-day (for 2695 MHz) and 120-day (for 245 MHz) periodicities are also present in our analysis. According to Joshi et al. (2006) 133±2 day period is present in sunspot number data in the interval 1998-2003. Here in our study 137-day periodicity is observed for 410 and 610 MHz. Chowdhury & Ray, (2006), after studying low and medium energy electron flares, found that during the

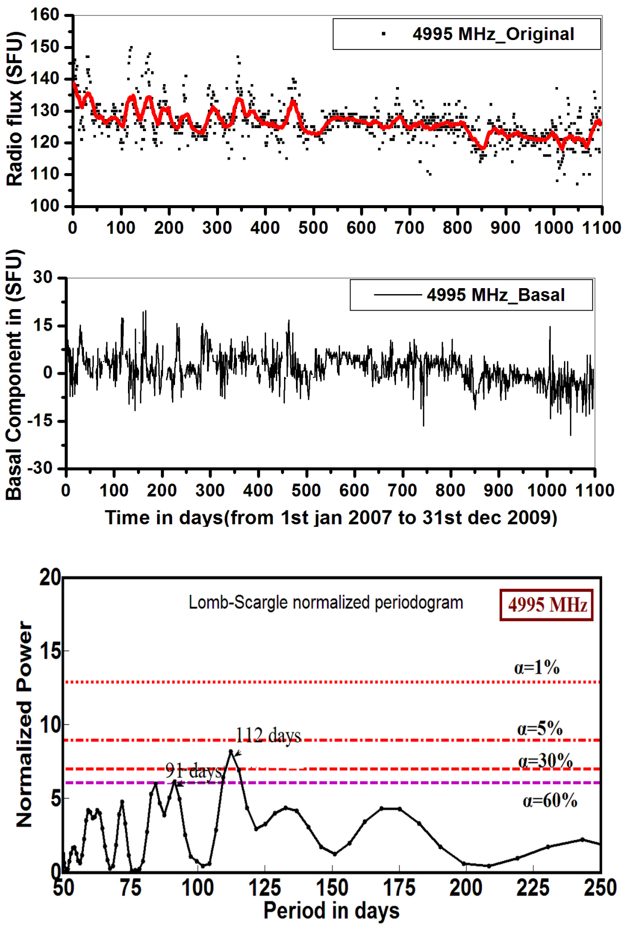

Figure 7. (a) Variation of 4995 MHz radio flux (scattered points represent the daily 1415 MHz flux value and the red line represents a 10-day smoothed plot); (b) Basal component of radio flux time series for 4995 MHz; (c) Periodogram for basal component of 4995 MHz radio flux during the minimum period.

ascending phase of Cycle 23, ∼ 175-day periods were prominent. Knaack, Stenflo & Berdyugina (2005) also detected 175 - 180 days periodicity in the time series of the photospheric magnetic field of the Sun. Here we have found 182-day (for 1415 MHz) and 183-day (for 2695 MHz) periodicity. Chowdhury et al. (2009a) has detected a range of periodicity of 194 -219 days for sunspot area in different phase of cycle 23. Here also we have detected 205-day (for 245 MHz), 190-day (for 410 MHz), 200-day (for 610 MHz) and 198-day (for 15400 MHz) periodicities. The mid range periodicities are mainly known as activity lines (Zieba et al. 2001), because of the presence of strongest period of 154 days, namely Rieger periodicity (Rieger et al. 1984) in this range. According to Bai & Cliver (1990) the mid term periodicity is a feature of events

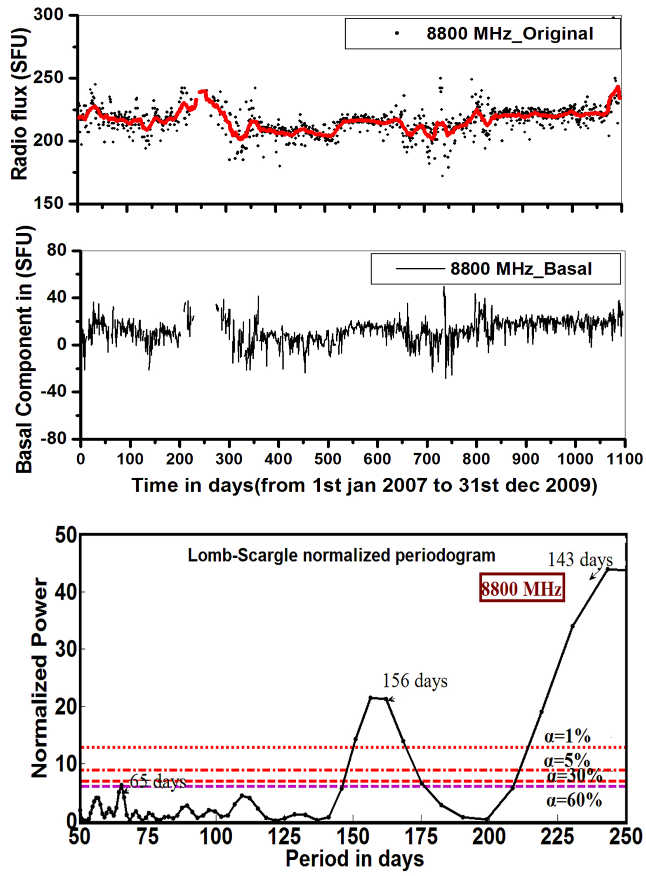

Figure 8. (a) Variation of 8800 MHz radio flux (scattered points represent the daily 1415 MHz flux value and the red line represents a 10-day smoothed plot); (b) Basal component of radio flux time series for 8800 MHz; (c) Periodogram for basal component of 8800 MHz radio flux during the minimum period.

dependent on magnetic activity. But interestingly, here we have found 164-day (for 245 MHz) and 156-day (8800 MHz) periodicities in basal component which is dependent on magnetic structures that are not related to sunspot activity, for this extended minimum period. This periodicity was also present in radio flux data during last minimum period (Zieba et al. 2001). The all obtained periodicities by several workers were for solar maximum or rising phase of the solar cycle. During minimum time the corona becomes more asymmetrical in shape and the radio sources are situated far away from the centre and also randomly distributed. As the periodicity is directly proportional to the cube of the radius of the position of the radio-emitting zone (Das & Nag 1999), so the period should become greater during times of solar cycle minima, when the radio sources are far from the centre of the Sun. here also our analysis reveals a slightly longer periodicity, which may be due to

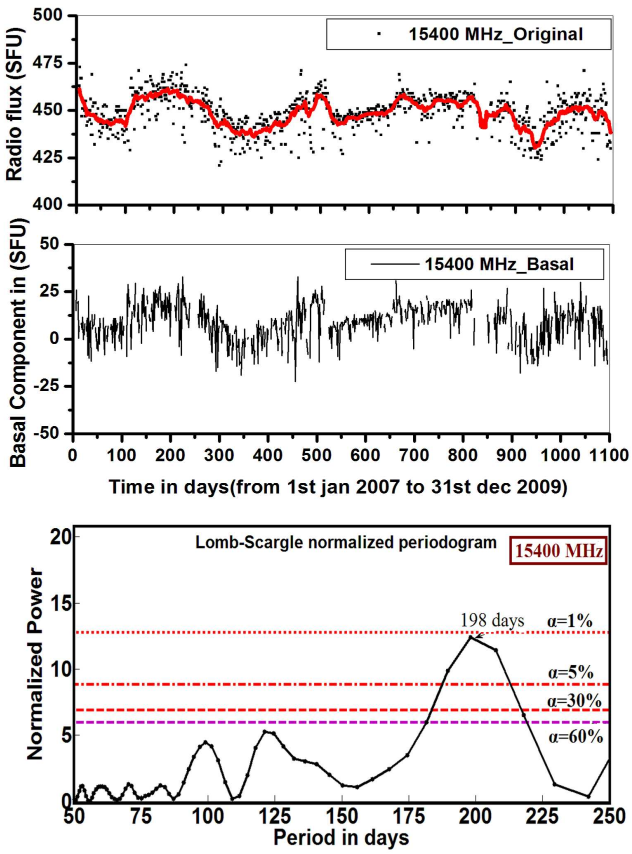

Figure 9. (a) Variation of 15400 MHz radio flux (scattered points represent the daily 1415 MHz flux value and the red line represents a 10-day smoothed plot); (b) Basal component of radio flux time series for 15400 MHz; (c) Periodogram for basal component of 15400 MHz radio flux during the minimum period.

the observation during solar minimum period. Several theories have been proposed for analyzing periodicities for different solar activity parameters but till now not a single one is fully satisfactory and needs further more investigation. According to Ichimoto et al. (1985) periodicity is related to the time-scale for storage or escape of magnetic fields in the solar convection zone. Bai & Sturrok (1987) proposed that physical process of periodicity must be a mechanism involving all layers of Sun. Sturrock et al. (1999), Lou (2000) and Sturrock (2004) suggested a possible mechanism of periodic emergences of magnetic flux, that the Rieger and similar Rieger-type periodicities are related to physical properties of Rossby-type waves or r modes (Wolff & Blizard 1986; Dzhalilov & Staude 2004). Chowdhury & Ray (2006) , Chowdhury et al. (2009b) have given the explanation of physical reasons of periodicity in the light of the r mode oscillation of the Sun. Our results also consistent with the periods detected theoretically with r-mode oscillations

Table 3. List of periodicities obtained for different frequencies.

Frequency (MHz)	p1	p2	p3	p4	p5	p6	p7	p8	p9
245	57	-	84	95	105	120	164	205	-
410	54	65	76	-	109	137	-	190	243
610	-	65	-	-	102	137	-	200	243
1415	-	-	72	96	-	-	146	182	-
2695	-	-	-	-	-	118	-	183	-
4995	-	-	-	91	112	-	-	-	-
8800	-	65	-	-	-	-	156	-	243
15400	-	-	-	-	-	-	-	198	-

p1,p2,p3,p4,p5,p6,p7,p8,p9 are periodicities in days in increasing order

or Rossby type of waves as calculated by Chowdhury et al. (2009b). The results obtained here give an indication that there may be connectivity between sunspot independent magnetic field and some other solar activity parameters as the periodicities of both types of magnetic structures are nearly matching. It also confirms that the basal components are also related to the internal dynamics of Sun, that's why the periodicity of other solar activity parameters is reflecting in the periodicity of this parameter. This may be an indication to the underlying global mechanism that modulates different solar parameters.

7. Conclusions

Here we have studied the basal component of radio time series ranging from 245 to 15400 MHz which is known to originate from the region between the lower corona and lower chromospheres (Table 1). Radio emission can be by several mechanism e.g., bremsstrahlung, gyrosynchrotron and Cerenkov. The radio emission considered here are mainly due to bremsstrahlung (Kane 2004), and the frequency that is emitted depends upon the plasma density of the region of emission. The periodicity obtained for basal component of these frequencies reveal the physical nature of the source regions. Basal component is associated with large magnetic structures like coronal holes, coronal neutral sheet etc. (Zieba et al. 2001) which are independent of sunspot activity. From the above discussion it is clear that the basal component at frequencies of 245, 410 and 610 MHz have nearly the same periodicity. These frequencies originate from the lower corona to upper chromosphere region. So it may be considered that this region emitting at 245, 410 and 610 MHz have fairly homogeneous large magnetic structures, independent of sunspot activity and same rotation.

As frequency increases the altitude decreases so emission at these frequencies originate from the depth of the solar atmosphere. From Table 3 it is clear that as the frequency increases the obtained periodicities of basal component shows a random nature and is also different from the coronal region which may reveal that the homogeneity disappears towards the interior of the solar atmosphere. Due to solar surface dynamics the complexity increases as the depth decreases, so the periodicities at higher frequencies show a different nature from those obtained at lower frequencies. Our study also shows similar variation in periodicity at higher frequencies. So the periodicities obtained for basal component at different frequencies here reveal the variation of rotation of large magnetic structures (independent of sunspot activity) in different layers of solar atmosphere during the solar minimum period. It may be concluded that the large magnetic structures (independent of sunspot activity) of coronal region might have a similar rotation with fairly homogeneous structure during this minimum period and towards the chromospheric layers the homogeneity disappears and the rotation rate also differs for different portions of the chromospheres.

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