Evolution of the compact microwave inter-sunspot source before strong flare

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Abstract. Under this study we considered active region 09415 of the 23-rd cycle of solar activity which was observed with the 2D spatial resolution at three frequencies: 17 and 34 GHz with the Nobeyama Radioheliograph (NoRH) and 17 GHz with the Solar Siberian Radiotelescope (SSRT). We detected rapid development of a compact microwave source above the neutral line of the magnetic field of leading sunspot (NLS-source) few hours before the X-class flare. The position of this source is associated with the place of the maximum of magnetic field gradient at the photosphere.

1. Introduction

Daily solar two-dimensional observations using Nobeyama radioheliograph (NoRH) at a wavelength of 1.76 cm have shown that microwave inter-sunspot sources (Neutral Line Associated Sources - NLSs) are typical and often dominant sources in the ARs, where strong flares of class X-LDE and CMEs occurred [4, 5, 6, 2, 7]. It was found the relationship between conditions of the development of active region (AR), the appearance of NLS and the beginning of the flare. It was concluded that NLS observed at 1.76 cm can be used as a prognostic factor of strong flares. According [3] NLS is a typical (sometimes dominant) component of the microwave emission of developing (and in the most cases flaring) active regions.

In this study we consider magnetic neutral line associated microwave source in the AR 09415. Such kind of sources are long lasting (few days) and sometimes are associated with sudden flare energy releases. The purpose of the work is to show the behaviour of the microwave emission of the source before the powerful solar flare. Three types of inter-spots radio sources (ISS) have been detected under 2D observations ([1]): 1) an extended sources in intensity, covering the whole group of sunspots, having low degree of circular polarization (~ 1%), and observed simultaneously at three frequencies 17, 34 and 5.7 GHz; 2) a compact source - Neutral Line Associated Source (NLS) - with a highly variable degree of circular polarization: from a few to 100% at 17 GHz and 5.7 GHz. It is characterized by a shift of the centers of brightness in the polarization and intensity; 3) A diffuse source of thermal bremsstrahlung with low degree of circular polarization, observed only at high frequencies 17 and 34 GHz, and existing during a transition of an AR through the solar disk.

We have found that the first two types of ISS are connected with powerful solar flares. Some
emission properties indicating a long preflare injection and accumulation of nonthermal electrons in magnetic loops are discussed in [1].

2. Analysis of the pre-flare behavior of the compact ISS in AR 09415

AR 09415 (passed Central Meridian (CM): April 9, 2001) had a complex magnetic configuration that has gone through the following stages according to the Observatory, Big Bear (http://www.solarmonitor.org): beta (3.04-4.04), beta-gamma (5.04 -7.04), beta-gamma-delta (8.04-13.04), beta-gamma (14.04), and then again beta (15.04). Altogether 69 flares, including 6 flares in X-rays of class X were registered during the period of its passing through the solar disk from 03 to 15 April 2001. We consider behavior of the compact NLS source before powerful flare X2.3 (05:06) at April 10, 2001, which had the following coordinates: X (arcsec): 88 ,Y (arcsec): -309, i.e. it occurred near or above the neutral line separating the magnetic polarity of the tail (the north) and the head (the southern) parts of AR 09 415 (Figure 1 and http://solar.nro.nao.ac.jp/norh/html/event/20010410_0532/ norh20010410_0532.html).

![Figure 1](image-url)

**Figure 1.** Compact ISS in AR 09415 on the day of flare X2.3 (05:06), 10.04.2001. NLS observed at frequencies 17 GHz and 5.7GHz in the head part of the AR, above leading sunspot of dual magnetic polarity. a)NoRH,34 GHz, b)NoRH,17 GHz, c) SSRT, 5.7 GHz partial images. Color map (background) shows SOHO/MDI magnetograms (black - S-, white - N-polarity of the magnetic field). Countours of white color- negative circular polarization, black - positive (TV, brightness temperature in a circular polarization); yellow countours - TI ( brightness temperature in intensity ).

From figure 1 it is clear that above leading sunspot of AR 09415 the compact ISS (NLS) was formed.

To analyze the pre-flare dynamics of the ISS we used NoRH data at 17 GHz - maps in intensity and circular polarization synthesized with a cadence of 1 minute.

Solar flare X2.3 (05:06) occurs on the boundary of the leading and following parts of AR 09415, wherein in the NLS of radio emission at 17 GHz, which is located above leading sunspot, a decline in the flux of intensity of the part of the NLS, which is located above magnetic flux of south polarity (Figure 2, left panel), and an increase in the flux of intensity above magnetic flux of north polarity (Figure 2, right panel) are observed during about 6 hours before the flare. Noticeable oscillations of the peak strength of the magnetic field of south polarity with a period of ∼3 h are observed (Figure 3), and similar oscillations are observed in the degree of circular polarization especially distinct above the south magnetic polarity (figure 2, c, left panel).
Figure 2. Left: Dynamics of the flux of intensity a), the flux of circular polarization b), the
degree of circular polarization $P = FV/FI$ c) from the left part of NLS-source (above the magnetic
field of south polarity, box 5 (arc) x15 (arc)) at 17 GHz during the full time of NoRH observations
with cadence 10 min. Right: Dynamics of the flux of intensity d), the flux of circular polarization
e), the degree of circular polarization $P = FV/FI$ e) from the right part of NLS-source (above the
magnetic field of north polarity, box 5 (arc) x15 (arc)) at 17 GHz during the full time of NoRH
observations with cadence 10 min.

Figure 3. Dynamics of the peak’s strength of the magnetic field of south polarity (in Gs) at
the head of AR 09415, April 10, 2001, according to the data of SOI MDI / SOHO with 1 minute
cadence.

From figure 2 one can see a significant changes of fluxes I and V and degree of circular
polarization of the NLS within 6 hours before powerful flare. And behavior of radio parameters,
from the left and from the right parts of the source, located above the magnetic fluxes of
different polarities are different: in the left part above the south magnetic polarity the flux of
radio intensity drops, and the flux of circular polarization of the negative sign drops, too; the
degree of circular polarization noticeably oscillates with a period of $\sim 3$ h (figure 2, c, left panel).
This may be caused by the growth of a neighboring magnetic flux of opposite polarity.

In the right part of the same source over magnetic field of north polarity, on the contrary,
the flux of intensity increases and flux of negative circular polarization increases, too, which can
indicate on the emersion of a new magnetic flux (figure 2, right panel).

Thus, compact ISS, or NLS, demonstrates variations like trends in I and V-parameters and
oscillations in P-parameter of radio emission for a few hours before a powerful flare, obviously,
being an indicator of a restructuring of the magnetic field in the active region.

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