A Radio Indication of Flare Build-up

G. Ya. Smolkov

Modes of observations by SSRT

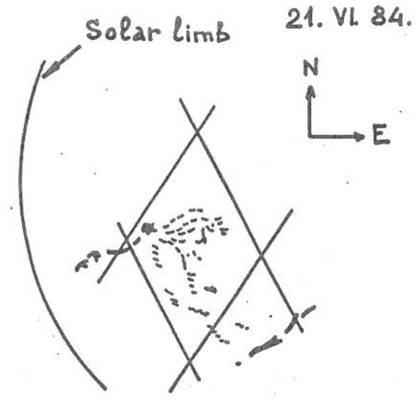
- 1-D-scans every 2.5 min by:
  - E-W array near noon
  - S-N array-near the morning
  - -near the evening

) practically full day

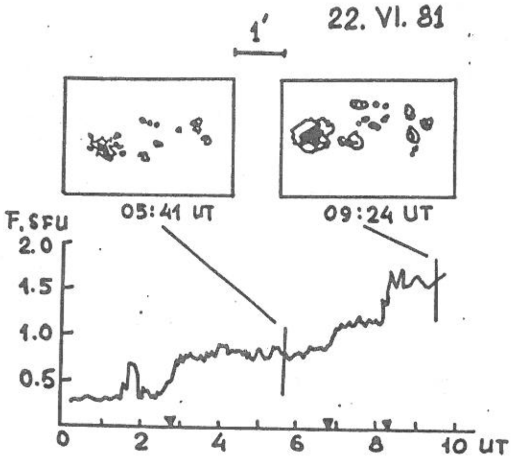
  with our high resolution (up to 17")
  - structure on all stages of evolution of AR's
  - dynamic processes
  - situation and behaviour different parts
  - preflare events

- by use of frequency scanning in observation with S-N array at local noon
  - high time resolution for investigating rapidly occuring nonstationary processes (bursts, quasi-periodic oscillations...

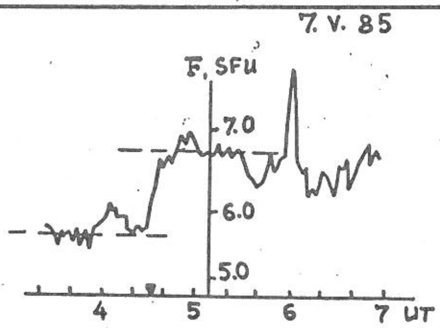
- by increasing the distance between the elements in the array in order to decrease the period of the interference beam and for a significant increase of the possibility of continuous observation of the bursts with linear array
  - bright flares

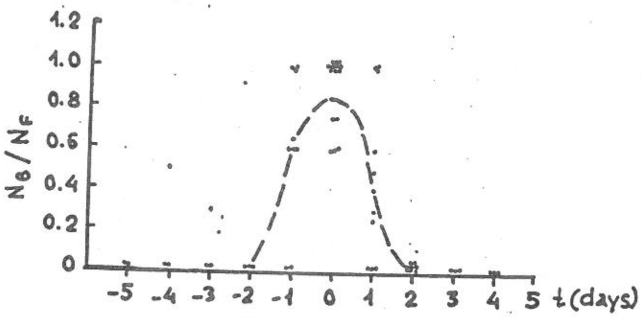

Solar limb
21. VI. 84.
N
E

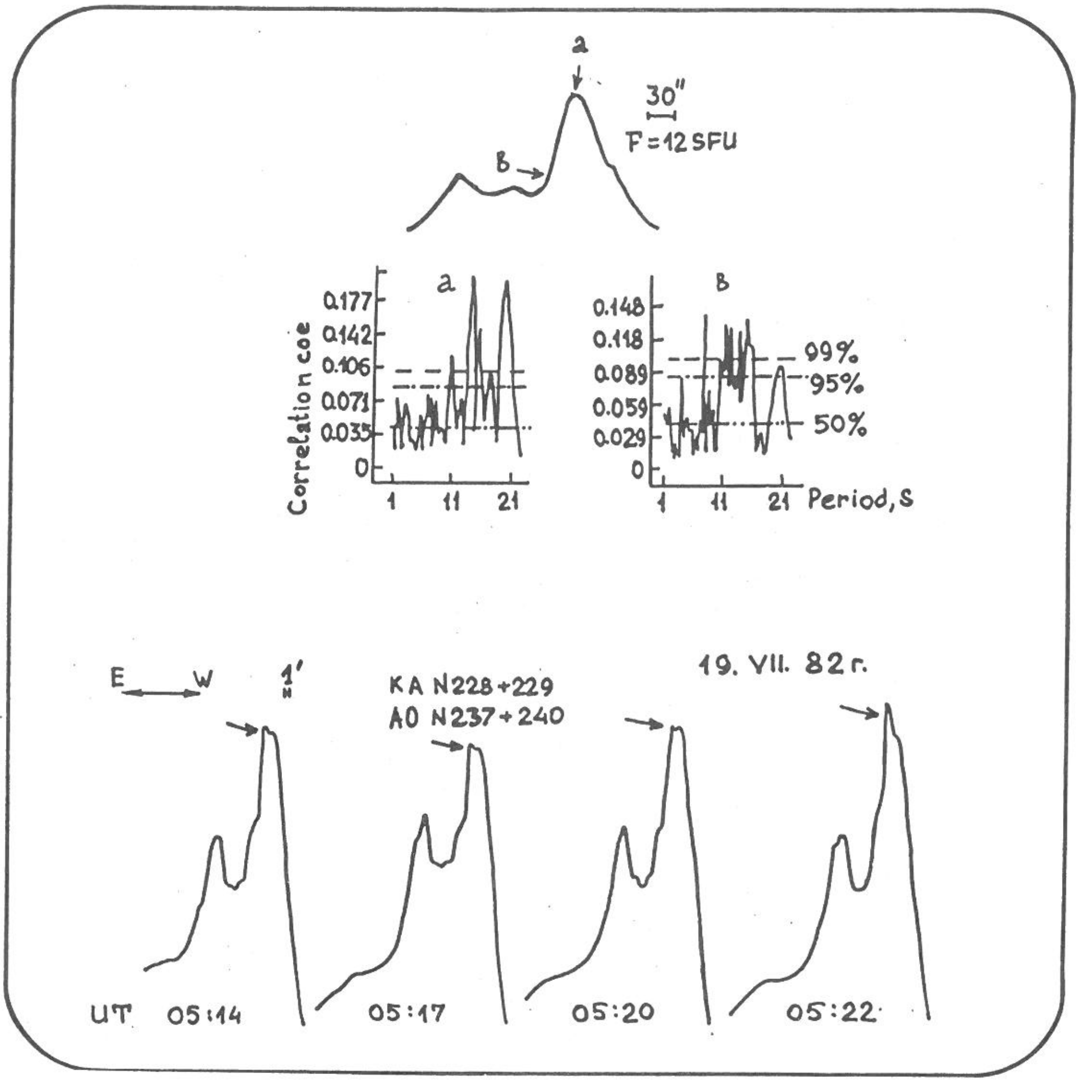
F. g 1


1'
22. VI. 81
05:41 UT
09:24 UT
F, SFU
2.0
1.5
1.0
0.5
0
2
4
6
8
10 UT

F. g 2


7. V. 85
F, SFU
7.0
6.0
5.0
4
5
6
7 UT


1.2
1.0
0.8
0.6
0.4
0.2
0
N_B / N_F
-5
-4
-3
-2
-1
0
1
2
3
4
5
t (days)

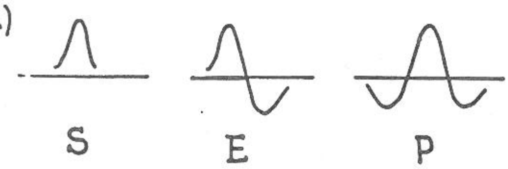


N зоны	Тип конф.	Дни	Без вспыш.	Кол-во вспышек 1N	1B	2N	2B	3N	3B	Плотность вспышек все	1N	≥ 1B
II-я (-5,-4,-3, +4,+5)	–	42	22	17	6	2	2	–	–	0,64	0,4	0,24
	S	57	32	18	18	3	6	–	1	0,8	0,3	0,5
	E	15	9	8	7	–	4	–	1	1,3	0,5	0,8
	P	7	2	8	4	–	1	–	–	1,9	1,1	0,7
III-я (-2,-1,0, +1,+2,+3)	–	18	11	5	4	1	–	–	–	0,6	0,3	0,3
	S	74	24	44	51	1	12	–	1	1,5	0,6	0,9
	E	47	25	25	11	4	2	2	–	0,9	0,5	0,4
	P	20	6	14	16	1	5	–	–	1,8	0,7	1,1

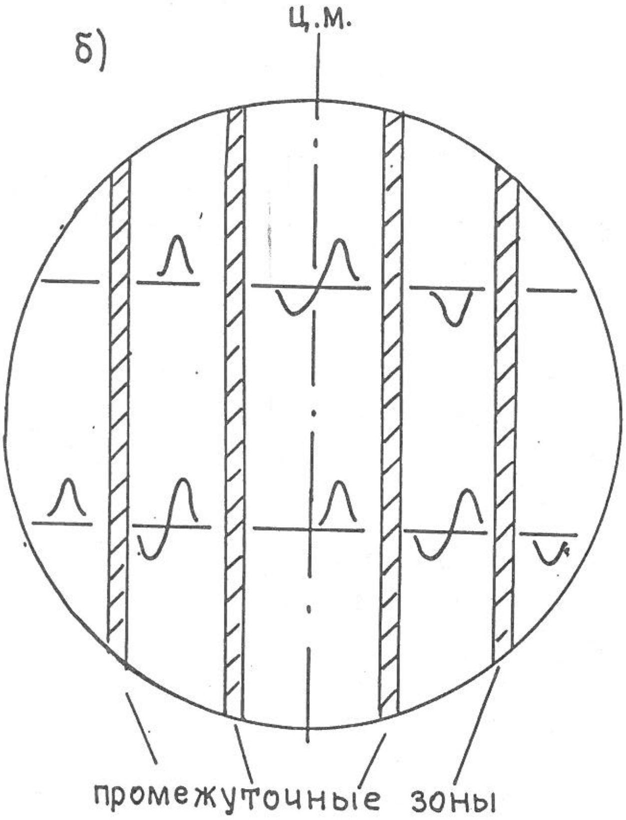
III зона

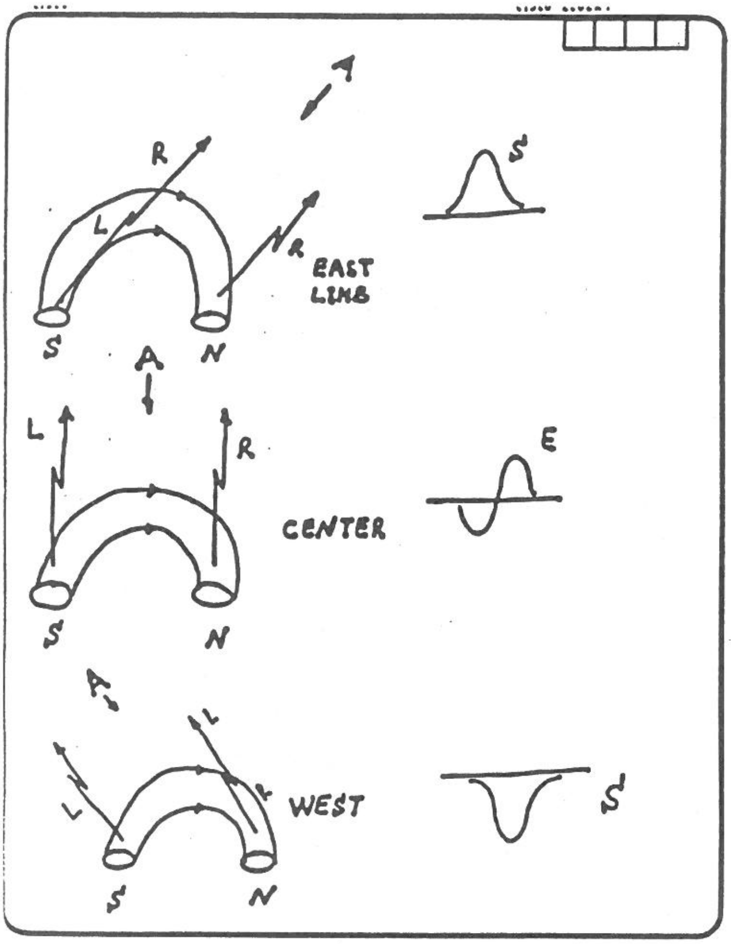
Прогнозируемый параметр	Число событий	Танака-Эноке %	Модифиц. критерий %
Спокойные дни	66	38	55
Возмущенн. дни	93	54	68
Вспышки: 1N	88	44	66
1B	82	33	82
2N	7	71	29
2B	19	37	89
3N	2	100	0
3B	1	0	100

а)



б)





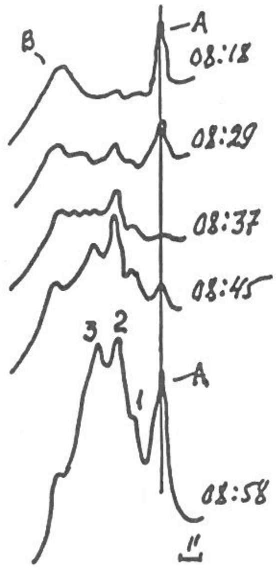


Fig.3. Development of the burst generation region 23 aug. 1988

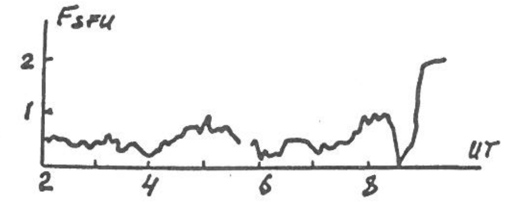


Fig.4. Flux variation of the sunspot source during several observing hours preceding the flare

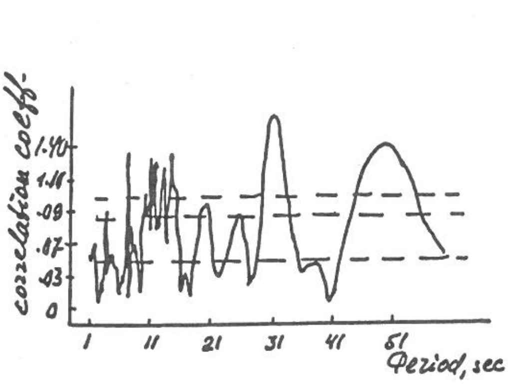


Fig.5. A fragment of second pulsations spectrum for maximum brightness of S-component source

UDC 523.98

THE DYNAMICS OF ACTIVE REGION IN MICROWAVE EMISSION

G.Ya.Smolkov

A review is given of the results of investigations of dynamical properties of the microwave emission which are attributable to evolutionary changes in the active region structure and to changes that are responsible for producing a flare situation. The investigations are based on observational data obtained on the Siberian Solar Radio Telescope during 1982-1988.

Introduction

During the past several years the Siberian Solar Radio Telescope (SSRT) /1, 2/ has been measuring, in the mode of solar activity monitoring, one-dimensional distributions of the intensity and circular polarization on the full solar disk, with a time resolution of 2.5 min and an angular resolution of up to 17" at 5.2 cm wavelength. The observations are made every day from 23 to 11 UT during the summer months and from 02 to 08 h UT during the winter months. The SSRT sensitivity permits a reliable identification of changes in radio flux density of sources of the slowly varying component of about 0.1 SFU.

Owing to such a performance, the SSRT is the most suitable instrument for investigating the evolution of active regions in the microwave emission. As is known, all its peculiarities are far from fully understood. This, in turn, sets back the understanding of the physical processes occurring in the active region in general.

The observed changes in distributions of the intensity and polarization of the microwave emission over the active region are caused by changes of physical conditions both in radio emission sources and on the path of radio wave propagation. The most important factors, having an influence upon such changes, may tentatively be divided into three groups.

1. The directivity of the microwave emission which depends on the generation mechanism and leads to changes in distributions of the emission intensity and polarization with a change in the active region location as a consequence of the solar rotation.

2. Evolutionary changes in the structure of active regions such as the appearance of new sunspots and pores in them, decay and disappearance of sunspots, and proper motions of sunspots.

3. Magnetic field changes which are responsible for producing flare situations.

It is the combination of these phenomena that leads to the formation of rather complex intensity and polarization distributions and to their changes throughout the entire active region lifetime. Determining the contribution of each of the agents to the radio brightness distribution is not a simple problem (even in the apparently simple first case there still remain many umbiguities from the observational point of view /3, 4/).

This brief review presents the main results of investigations of the active region evolution in the microwave emission as obtained with the aid of the SSRT to date.

1. Structure of the active region microwave emission and its evolutionary changes

1.1. The initial evolutionary stage of active regions. A region of increased radio emission at 5.2 cm wavelength begins to form several hours before the appearance of a facular plage in the K CaII line. Its size virtually coincides with the extent of the area, in which a disturbed structure of the chromosphere is observed. A maximum of radio emission is located where a sunspot group is produced later (Fig. 1). The radio flux fluctuates appreciably, reaching maximum values of 0.5-0.8 SFU and minimum values of 0.1-0.2 SFU. It is most likely that such a deep modulation of the radio flux indicates temperature fluctuations in the active region atmosphere because radio flux variations are not accompanied by appreciable increases in the size of the radio emission region. The brightness temperature amounts to values of the order of $8 \cdot 10^4$ K.

The appearance of the first pores is unaccompanied by an appreciable increase of radio flux, i.e., the process of penetration of strong small-scale magnetic fields into the corona is delayed from that in the photosphere by 1 or 2 h at least.

F i g. 2. The variation of the radio flux with increasing area of the following sunspot of active region 4520.

As sunspots are evolving, the radio flux increases. In this case the growth of flux proceeds abruptly: intervals, during which the radio flux remains virtually unchanged, alternate with those, when the flux increases abruptly (Fig. 2). The duration of the latter ones ranges from 10 to 30 min, which is significantly less than time intervals, during which the radio flux remains relatively stable. Thus, changes of the radio flux have the shape of "steps", whose amplitude is about 0.5 SFU /5/.

The increase in flux of the polarized emission during the evolution of a sunspot group occurs abruptly as well. However, the duration of the "steps" is somewhat longer, 40-50 min. It is interesting to note that the "steps" in the polarized emission flux sometimes do not coincide in time with those in a total intensity flux. These results confirm the picture of development of polarized emission sources in the early evolutionary stage of the active region at 3.2 cm wavelength as described in a paper /6/ which reported, for the first time, on the detection of such a step-like character in the grpwth of polarized emission.

1.2. <u>The height distribution of radio brightness in the active region corona</u>. Owing to many hours of daily observations of the S-component sources, we are able to observe the appearance of sources from behind the limb and their disappearance behind the limb.

F i g. 3. The variation of the radio flux during the appearance of a leading sunspot of the sunspot group from behind the limb.

By analyzing such observational data, it becomes possible to gain information on the height distribution of radio brightness in the active region corona.

Fig. 3 shows the variations of the radio flux during the appearance of a leading sunspot of the sunspot group from behind the limb. When the sunspot was crossing the limb, there occurred an abrupt increase of the radio flux which lasted about 30 min. Abrupt changes of opposite sign are also observed during the disappearance of large sunspots behind the limb. Such a character of the variation of the radio flux during the appearance and disappearance of sunspots behind the limb seems to be associated with the presence (in the corona over the sunspot at a small height above the photosphere) of a compact and bright source of an extent in height of the order of 1000 km. The very abrupt changes of the flux indicate that the S-component source cores appear (disappear) from behind (behind) a very thin opaque screen which is, most probably, the transition region between the chromosphere and the corona /7/.

1.3. Investigations of second oscillations of radio emission flux. Active regions are known to provide sources of solar radio emission pulsations. The SSRT high spatial resolution opens up the possibility of investigating the pulsation spectrum of the radio flux of different parts of the S-component sources.

Without going into details of the technique for making such observations /8/, we wish to note that in observations with the south beam at local noon, there emerge such conditions when the same area of the solar surface during a sufficiently long period of time (of order of several minutes) is covered by the SSRT directivity pattern, i.e., the "tracking" mode is effected. In the case of

F i g. 4. The radio brightness distribution of the S-component source (top) and the second pulsation spectra for the central (a) and peripheral (b) parts.

many-frequency reception a fan of knife-edge beams covers the entire Sun or its considerable part, which makes it possible to localize radio emission pulsation sources in the active region as well as investigating the distribution of the pulsation spectrum over the active region.

Fig. 4 gives an example of the second pulsation spectra for the central part of the S-component source and for the peripheral part. It is evident that the spectrab for the different parts of the source differ substantially.

2. Preflare changes in the active region microwave emission

2.1. The relationship of flare activity with the polarization distribution of the microwave emission. The polarization distribution of the microwave emission over the active region and, especially, the character of its variation contains important information on flare activity of the active region. As one of the three components, it is involved in the so-called Tanaka-Enome criterion /9/ which states that the occurrence probability for powerful solar flares increases with increasing intensity of the total emission flux at 3.2 cm wavelength, with increasing ratio of the 3.2 cm flux to 8 cm flux, and with the transition of the polarized emission distribution from the S- to E- and P-configurations. This criterion is used for predicting proton flares. Nevertheless, in a great variety of cases it was not possible to predict proton flares using the Tanaka-Enome method /10/.

In a paper /11/, an analysis was made of several cases of an obvious discrepancy of the Tanaka-Enome criterion with the observed polarization distribution prior to proton flares and it was pointed to the possibility of overcoming this difficulty, by taking account of the dependence of the polarization distribution on the active region location on the disk. The technique for taking it into account implies dividing the solar disk into longitudinal areas and determining a "normal" polarization distribution in each individual area /12/. A deviation of the observed polarization distribution from a "normal" one in the area where a given active region is located, rather than the correspondence of the observed polarization distribution to the particular type of configuration, is taken as the criterion for a preflare situation.

In order to verify this supposition and to extend it to flare activity, as a whole, an analysis was made of observational data on the polarization distribution over active regions as obtained on the SSRT during 1982-1986 /12, 13/. The results have shown that the predictability for quiet and disturbed days and powerful solar flares is higher with the modified criterion as compared with the Tanaka-Enome criterion.

2.2. The subflare - microwave burst correlation as a characteristic of the active region evolution. Powerful solar flares (of importance 2) approximately in 75% of cases are accompanied by radio emission bursts in the microwave range of wavelengths /14/. With decreasing flare importance, this correlation becomes substantially weaker and makes up, for subflares, not more than 50% /15, 16/. As a reflection of the higher occurrence probability for large solar flares in sunspot groups with a complex configuration of magnetic fields, the ratio of the number of bursts to the number of flares (N_B/N_F) varies during the course of the active region development and reaches a maximum value of sunspot groups of classes E, F and G /17/. Interestingly, the "subflare/burst" relationship also undergoes changes during the active region lifetime /18-20/. In some periods, especially when powerful solar flares are produced in the active region, the measure of the subflare/burst relationship can exceed 70%.

Investigations made on the basis of SSRT observations of a number of active regions with a different character of the development /21/, have shown that the degree of subflare/burst relationship does not depend or depends weakly on such characteristics of

F i g. 5. The behaviour of the subflare-burst relationship for active regions with powerful solar flares (moment of time 0 day marks the beginning or end of disturbed periods of active region development).

subflares in the H_{α}-line as the time from the flare onset to its intensity maximum and the subflare duration and area. A stronger dependence on the subflare brightness has been established. The overwhelming majority of subflares of importance SB are accompanied by microwave bursts. Subflares of importance SF predominate among subflares unaccompanied by bursts; However, there are a sufficiently large subflares SF, weak in brightness, among subflares accompanied by bursts as well.

The degree of subflare/burst correlation begins to increase approximately 24 h before the production of a large solar flare, remains high as long as large flares are observed and persists still sufficiently high the next day after cessation of large flares (Fig. 5).

Thus, the degree of subflare/burst correlation is a rather sensitive indicator of the state of the active region and, in conjunction with other flare activity criteria, can be used for purposes of making short-term predictions of powerful solar flares.

2.3. Spatial fluctuations of local radio emission sources. On the basis of an analysis of "source structure - time" diagrams, a study was made of dynamic characteristics of microwave emission distributions both during periods of quiet development of active regions and at the time of their activation. Quiet periods are characterized only by brightness fluctuations without appreciable changes in the size of the source, i.e., the source structure does not undergo any drastic deformation. In periods of increased activity, radio emission fluctuations of local sources are largely manifested in changes of its structure /22/.

F i g. 6. Successive brightenings of adifferent parts of the S-component source before a flare.

The microwave emission of active regions, in which large flares (of importance greater than unity) are observed, show alternating increases and decreases in the radio emission flux of different parts of the source (Fig. 6). This process starts in a time interval from a few tens of minutes to several hours, prior to the flare production. The time scale of such quasi-periodic oscillations is about 10 min, and the amplitude ranges from 0.1 to 1.0 SFU and increases while approaching the flare onset. Such a process takes place not only in the integral radio flux but also in its circularly polarized component /19/.

Conclusions

The observations on the SSRT have confirmed the high informativity of the microwave emission for investigating evolutionary features of active regions as well as the correctness of the design solutions when developing and constructing the telescope. Owing to this:

a) the available data on the development of active regions have been ascertained and complemented substantially;

b) new evidence has been obtained, for example, the nonmonotonous character of the corona heating over the active region or the pulsating character of the atmosphere behaviour over sunspots and the character of the atmosphere behaviour over sunspots;

c) investigations of the least-studied initial stage of development of the active region, i.e., the process of its origination and of emergence of new magnetic fields into the solar atmosphere, have been initiated; and

d) the solar flare protonicity criterion has been modified.

2) Prolonged observations on the SSRT throughout the entire daytime are very effective for the study of dynamic properties of the development of active regions and of the relationship of radio bursts with flare activity. This contributes to the study of build-up processes of flares and of their forerunners as well as of the height structure of active regions.

3) The principle of operation of the SSRT makes it possible to determine the production site of microwave emission pulsations of active regions.

R e f e r e n c e s

1. Smolkov G.Ya., Treskov T.A., Krissinel B.B., Potapov N.N. // Astrophys. Space Sci. 1986. Vol. 119. P. 3-4.
2. Smolkov G.Ya., Krissinel B.B., Treskov T.A. ~~et~~ al. // This issue. P.
3. Gelfreikh G.B., Lubyshev B.I. // Astron. zhurn. 1979. Vol. 56, N 3. P.562-573.
4. Gelfreikh G.B., Lubyshev B.I. // Solar Maximum Analysis, Additional Issue. Novosibirsk: Nauka, 1988. P.157-159.
5. Zubkova G.N., Kardapolova N.N., Lubyshev B.I. et al. // Astron. Nachr. 1990. Vol. 311, N 4. P.
6. Gelfreikh G.B., Nefedyev V.P. // Pisma v Astron. zhurn. 1975. Vol. 1, N 6. P.32-35.
7. Agalakov B.V., Lubyshev B.I., Nasonova O.V. et al. // This issue. P.
8. Treskov T.A. // Issledovaniya po geomagnetizmu, aeronomii i fizike Solntsa. Moscow: Nauka, 1983. Vol. 64.)P.188-199.
9. Tanaka H., Enome S. // Solar Phys. 1975. Vol. 40. P.123-131.
10. Korobchuk O.V., Peterova N.N. // Radio Emission of the Sun. Leningrad: LGU, 1984. Vol. 5. P.102-114.
11. Maksimov V.P., Nefedyev V.P., Smolkov G.Ya. // Issledovaniya po geomagnetizmu, aeronomii i fizike Solntsa. Moscow: Nauka, 1988. Vol. 82. P.155-160.
12. Maksimov V.P., Bakunina I.A., Nefedyev V.P., Smolkov G.Ya. // Ibid. Vol. 83. P.111-117.
13. Maksimov V.P., Nefedyev V.P., Smolkov G.Ya., Bakunina I.A. // Proceedings of the Leura STP Workshop, 1989. P.S55-S56.
14. Kundu M.R. // Ann. d'Astrophys. 1959. Vol. 26. P.3-102.
15. Davies R.D. // Mon. Not. Astron. 1954. Vol. 114. P.74-79.
16. Hachenberg O., Kruger A. // J.Atmos. and Terr.Phys. 1959. Vol.
17. Kruger A. Physics of Solar Continuum Radio Bursts, Berlin: Akademie-Verlag, 1972. 206 p.
18. Fokker A.D. // Solar Activity and Related Interplanetary and Terrestrial Phenomena. Berlin, 1973. P.117-119.
19. Zubkova G.N., Kardapolova N.N., Lubyshev B.I. et al. The evolution of local sources of microwave emission on the Sun during 9-21 July 1982 and 2-10 July 1985 as observed by the SSRT / Prepr. SibIZMIR N 14-87. Irkutsk, 1987. 25 p.
20. Zubkova G.N., Lubyshev B.I., Maksimov V.P. et al. // Solnechnye dannye, 1989, N 1. P.99-103.
21. Maksimov V.P., Zubkova G.N., Borovik A.V. // Astron. Nachr. 1990. Vol. 311, N.4. P.
22. Zandanov V.G., Sych R.A. // Solar Magnetic Fields and Corona. Novosibirsk: Nauka, 1989. Vol. 2. P.247-251.

Siberian Institute of Terrestrial Magnetism, Ionosphere and Radio Wave Propagation

Received in March 1990

"Proceedings of the Leura STP Workshop", S36.

FLARE ACTIVITY PREDICTION FROM THE POLARIZATION DISTRIBUTION OF MICROWAVE EMISSION OF SUNSPOT GROUPS

V.P.Maksimov, V.P.Nefedyev, G.Ya.Smolkov, and I.A.Bakunina
SibIZMIR, Irkutsk 33, P.O.Box 4, 664033 USSR

Abstract

In this paper using one-dimensional scans of polarization distribution of microwave emission in active regions, as obtained at the Siberian Solar Radio Telescope (SSRT, λ = 5.2 cm) during 1982-1986, an analysis is made of cases of an obvious violation of the Tanaka-Enome criterion before proton flares, and a modified criterion is suggested, which takes account of the active region position on the disk. A comparison is made of the two criteria and it is shown that the modified criterion provides a more powerful tool for predicting the active region conditions.

The polarization distribution of microwave emission over the active region and, especially, the character of its variation contains important information on flare activity of the active region. As one of the three components it is involved in the so-called Tanaka-Enome criterion (Tanaka and Enome, 1975) which states that the occurrence probability of powerful solar flares increases with increasing intensity of a total intensity flux at 3.2 cm wavelength and with increasing ratio of 3.2 cm to 8.0 cm fluxes as well as with the transition of the polarization distribution from S- to E- and F-configurations (see Figure 1a). However, in a large number of cases an obvious inconsistency of this conclusion to the observed polarization distribution was observed (Korobchuk and Peterova, 1984). Maksimov et al. (1988) analysed several cases of such an obvious discrepancy and pointed to a possibility of avoiding this difficulty by taking account of the dependence of the polarization distribution on the active region position on the disk.

As is known (Zheleznyakov, 1964), as a circularly polarized emission traverses a region of quasi-transverse magnetic field, the circular polarization changes its sign. Therefore, the polarization distribution of the emission from a bipolar active region as it passes across the disk, changes according as the emission from local sources located above the leading and following sunspots, passes through the region of quasi-transverse magnetic field between them. Thus, one can distinguish on the disk symmetric (with respect to the central meridian) zones, each of which has its own character of the polarized emission distribution in the active region ("normal" distribution): I - zone of unpolarized emission, II - zone with a largely S-configuration, and III - zone with a largely E-configuration (Figure 1b). These zones are separated by relatively narrow transition zones which may tentatively be called the zones of polarization sign inversion.

The deviation from a "normal" polarization distribution in each individual zone will largely be determined by peculiarities in the structure of coronal magnetic fields of the active region. In such a case the deviation of the observed polarization distribution from "normal" in that zone where a given active region is located, rather the belonging of the distribution to a given type of configuration, should be regarded as the criterion for a preflare situation. Following this reasoning, it might be expected that in zone II the transition from the S- to E-configuration of the polarization distribution, according to the Tanaka-Enome criterion, will indicate a high probability of powerful flare occurrence. But in zone III, conversely, the transition from the E- to S-configuration proves to be a typical signature of the preflare situation, which is opposite in sense to the Tanaka-Enome criterion. Of course, in this case we must be confident that the transition from the E- to S-configuration occurs not as a consequence of a decay or disappearance of the leading or following sunspot. In zone I and II an indication of flare activity may be, respectively, the appearance of the polarized emission from the active region and the noncorrespondence of the sign of circular polarization of the magnetic field polarity of the leading (on the east limb) or following (on the west limb) sunspot. It is natural to consider the F-configuration to be flare-dangerous in all zones.

In order to verify this supposition and to extend it to the flare activity as a whole, we have analyzed observational data on the polarization distribution in active regions as obtained at the SSHT for the period 1982–1986 (Maksimov et al., 1988). In this case for each day of active region observation, the noon scan (05:00 UT) was used to mark the type of polarization distribution, a sketch of a sunspot group was made, with the sunspot magnetic field polarity indicated, and flares of importance $\geqslant$ I N were noted. By summing data on all active regions separately for each zone and for each type of polarization distribution, we determined the number of days during which all the 28 active regions analyzed lied in given zones with a given type of polarization distribution as well as the number of flares that had occurred under these conditions. According to the same principle, we determined the number of quiet days (the day was considered quiet when the active region did not produce flares of importance $\geqslant$ 1).

A preliminary analysis has shown that, according to their characteristics, intermediate zone "day -3" is close to zone II, while intermediate zone "day +3" is close to zone III. Taking this into account we have presented the data in Table I; the density of flares for each of the zones and configurations is also given here. By the density of flares we understand the ratio of the number of flares that occurred in all active regions during their persistence in a given zone with a given polarization distribution, to the number of days during which active regions persist under these conditions. The density of flares was counted for all flares and separately for flares of importance 1N and flares of importance $\geqslant$1B. We must note, first of all, that the available data for the first and the intermediate zones are insufficient for more-or-less reliable conclusions. Therefore, we shall focus attention on analyzing the situations in zones II and III. In accordance with the Tanaka-Inoue criterion, the greatest density of flares in both zones refers to the E-configuration. In zone II the flare productivity of the E-configuration is higher as compared with the S-configuration. But in zone III, on the contrary, the flare productivity of the S-configuration is higher as compared with the E-configuration. And this effect is more pronounced for powerful flares of importance $\geqslant$ 1B. Flares of importance 1N seem to have more or less the same probability in the case of both the E- and S-configurations.

Thus, a statistical investigation confirms the conclusion drawn by Maksimov et al. (1988) that it is necessary to take account of the active region position on the disk when analyzing the polarization distribution, with the purpose of predicting powerful solar flares.

Evidence in favour of our supposition may already be found in Tanaka and Enome's (1975) paper itself. According to the data listed in Table I of their paper, six active regions with an S-configuration of the polarization distribution at 3 cm wavelength produced 7 proton flares and 2 weak proton events. In this case 5 events occurred in zone III, 2 events occurred in zone I and only 2 events (one of which was a weak one) occurred in zone II. Consequently, 7 of 9 proton events occurred in the flare-dangerous situations we are suggesting. From Table III it follows that the ratio of the number of proton flares (including weak ones) to the number of active regions with a P-, E-, and S-configuration was, respectively, 2, 0.2 and 0.5. If it is taken into consideration that the number of active regions with an S-configuration included also unipolar sunspot groups, then one should recognize that the productivity of regions with an S-configuration with respect to proton flares is high.

In order to compare the effectiveness of prediction using the Tanaka-Enome criterion and the modified criterion, an epignosis of the state of active regions using both criteria was made. Epignosis results for zones II and III and only for zone III are presented in Table 2. The number of quiet and disturbed days was predicted as well as the number of flares separately in importance. Table 2 gives the observed number of quiet and disturbed days and the number of flares for the zones indicated. The predictability for disturbed days, for example, was calculated in the following way. In each zone, the number of days was calculated, when active regions had a flare-dangerous polarization distribution (E- and P-configurations in both zones according to the Tanaka-Enome criterion, E- and P-configurations in zone II and S- and P-configurations in zone III according to the modified criterion) and, after that, the number of observed disturbed days in supposed flare-dangerous configurations was calculated. The ratio of the latter to the former in percentage was taken as the predictability for

Table I

Zone	Type of configuration	Time of persistence of all active regions in a given zone with a given configuration (days)	Number of quiet days	Number of flares of importance						Density of flares		
				IN	IB	2N	2B	3N	3B	all	1N	≥1B
First (-8, -7, +7, +8)	-	16	7	8	4		3			0.9	0.5	0.4
	S	3	2	I						0.3	0.3	0.0
Intermediate (-6, +6)	-	20	9	II	3	2	I			0.8	0.6	0.3
	S	17	8	13	2	I				0.9	0.8	0.2
	E	I	I							0.0	0.0	0.0
Second (-5, -4, -3, +4, +5)	-	42	22	17	6	2	2			0.6	0.4	0.2
	S	57	32	18	18	3	6		I	0.8	0.3	0.5
	E	15	9	8	7		4		I	1.3	0.5	0.8
	P	7	2	8	4		I			1.9	1.1	0.7
Third (-2, -1, 0, +1, +2, +3)	-	18	11	5	4	I				0.6	0.3	0.3
	S	74	24	44	51	I	12		I	1.5	0.6	0.9
	E	47	25	25	11	4	2	2		0.9	0.5	0.4
	P	20	6	14	16	I	5			1.8	0.7	1.1
		Σ 337	158	172	126	15	36	2	3			

Note. Days before (–) and after (+) central meridian passage are indicated in parentheses.

disturbed days. The day was considered disturbed if the region analyzed had produced at least one flare of importance $\geqslant 1$. The predictability for quiet days was determined in a similar way as well. The predictability for flares was determined as the ratio of the number of flares occurring at the time when active regions had a flare-dangerous polarization distribution, to the number of all flares of a given importance occurring in these active regions.

Table 2

Parameter predicted	Zones II and III			Zone III		
	Number of events	According to the Tanaka-Enome criterion	According to the modified criterion, %	Number of events	According to: Tanaka-Enome criterion	modified criterion
Quiet days	131	47	55	66	38	55
Disturbed days	149	53	65	93	54	68
Flares: 1N	139	40	53	88	44	66
1B	117	32	67	82	33	82
2N	12	42	20	7	71	29
2B	32	38	69	19	37	89
3N	2	100	0	2	100	0
3B	3	33	67	1	0	100

The Table 2 data show that the predictability for quiet and disturbed days, of flares of importance 1N, 1B and 2B according to the modified criterion is higher as compared with the Tanaka-Enome criterion, and this is most pronounced in zone III. It is obvious that because of the small number of observed cases one should not impart some special significance to the results for flares of importance 2N, 3N and 3B.

As one would expect, analysis of the polarization distribution of microwave emission only is insufficient for an effective prediction of flare activity. However, since the polarization distribution is an important component of the Tanaka-Enome criterion itself (Tanaka and Enome, 1975) and of its expanded modification

(Gelfreikh et al., 1987), a correct account of this characteristic influences substantially the effectiveness of the prediction as a whole.

References

G.B.Gelfreikh, S.V.Tsvetkov, and N.G.Peterova. - In: Abstracts of Papers Presented at the KAPG Symposium "Solar Activity Predictions and Observations of Solar Active Phenomena" (Leningrad, 18-22 May 1987), Leningrad, Nauka, 1987, p. 21.

O.V.Korobchuk and N.G.Peterova. - In: Radio Emission of the Sun, Leningrad, LGU, 1984, v. 5, p. 102.

V.P.Maksimov, V.P.Nefedyev, and G.Ya.Smolkov. - In: Issledovaniya po geomagnetizmu, aeronomii i fizike Solntsa. Moscow, Nauka, 1988, v.82, p.155.

V.P.Maksimov, I.A.Bakunina, V.P.Nefedyev, and G.Ya.Smolkov. - In: Issledovaniya po geomagnetizmu, aeronomii i fizike Solntsa. Moscow, Nauka, 1988, v.83, p.111.

H.Tanaka and S.Enome. - Solar Phys., 1975, v.40, p.123.

V.V.Zheleznyakov. - Radio Emission of the Sun and Planets. Moscow, Nauka, 1964, p. 312.

Figure Caption

Fig. 1. A classification of the polarisation distribution (a) and a schematic division of the Sun into zones with typical normal (at the top) and flare-dangerous (at the bottom) polarisation configurations in each zone (b)