Evolution of active regions in microwave emission at the stage of their initiation

Daniel Yu. Myachin, Vladilen P. Nefedyev *, Arkadii M. Uralov,
Sergey V. Lesovoi and Genadii Ya. Smolkov
Institute of Solar-Terrestrial Physics, Lermontov St. 126, Irkutsk, Russia 664033
E-mail(FI): myachin@iszf.irk.ru

Abstract

A detailed study is made of the birth and development of more than 20 active regions based on radio maps obtained by the Siberian Solar Radio Telescope at 5.7 GHz. We found 23 events with fast increasing of total flux from one average level to the other. In some cases such a stepwise increase in the active region flux preceded or was accompanied by the appearance of an intermediate burst source between two main sunspot associated sources. The phenomenon of a stepwise increase in the radio flux signals the evolutionary transition of the active region from one quasi–stationary state to an other.

Key words: Sun: microwave emission — Sun: solar active regions evolution

1. Introduction

An active region (AR) comes into existence after the emergence of a new magnetic flux into the photosphere within or in the immediate vicinity of the old field (Bappu, Grigorijev and Stepanov 1968). It is known that the evolution of active regions is accompanied by various structural changes whose duration can be as long as several minutes. They include such phenomena as the appearance and development of pores, their merging together to form sunspots, a change in magnetic field strength at the photospheric level, as well as a stepwise increase in the flux of microwave emission of AR (Nefedyev, Agalakov, Kalman et al. 1993). Here, "stepwise increase" means the relatively fast transition of AR microwave flux from one average level to the next (this level difference is denoted by "step" in Figure 4a.).

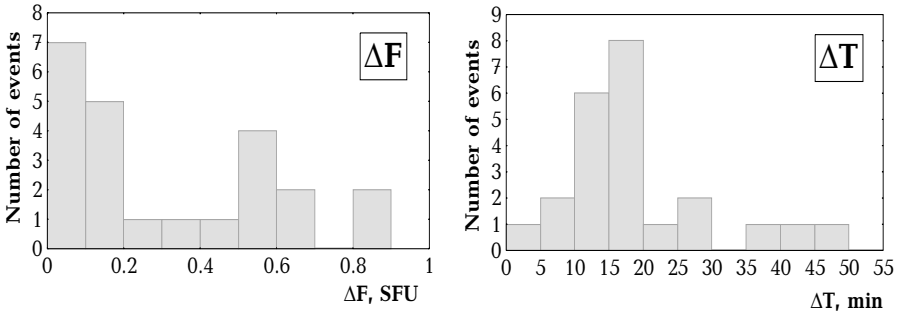

Fig. 1.. Histograms of the distribution of duration and magnitudes of a stepwise increase in microwave flux.

The non-monotonic character of an increase in the circularly polarized radio emission flux at the stage of sunspot development was pointed out for the first time by Gelfreikh and Nefedyev (1975). But the nature of a stepwise increase in microwave flux of young AR's is so far unclear.

∗ Vladilen Petrovich Nefedyev passed away on May 20th, 1998.

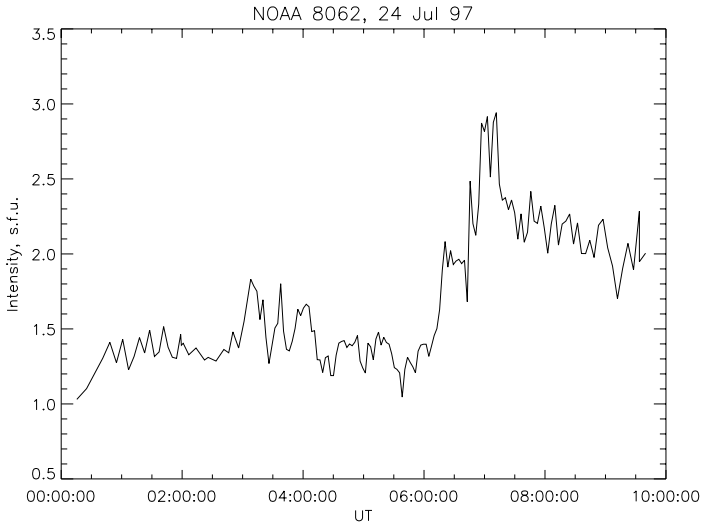

Fig. 2.. Behavior of the total flux of the active region NOAA 8062.

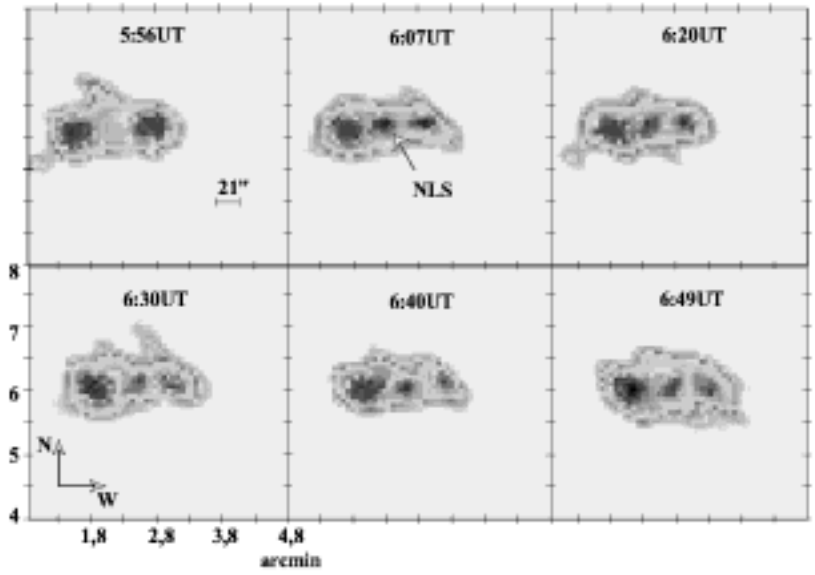

Fig. 3.. A sequence radio images of the AR NOAA 8062 (No. 350 SSRT) during stepwise increase in microwave flux.

2. Observations and Conclusion

We have studied the birth and development of more than 20 active regions, which traversed the solar disk in 1997, based on radio maps obtained by the Siberian Solar Radio Telescope (SSRT, 5.7 GHz). The SSRT sensitivity in the two–dimensional mapping mode makes it possible to observe with a fair degree of confidence relatively weak features on the solar disk with 0.1 sfu flux. The spatial resolution was as high as $21''$, with time intervals of 2–3 min. The active regions under investigation include 23 events of a stepwise increase in the total flux with a mean transition time between two levels of 19 min and with a mean increase in the flux by 0.32 sfu (Fig. 1). About 60 % all of the AR evolutions are stepwise.

It was found that in some cases a stepwise increase in the active region flux preceded or was accompanied by the

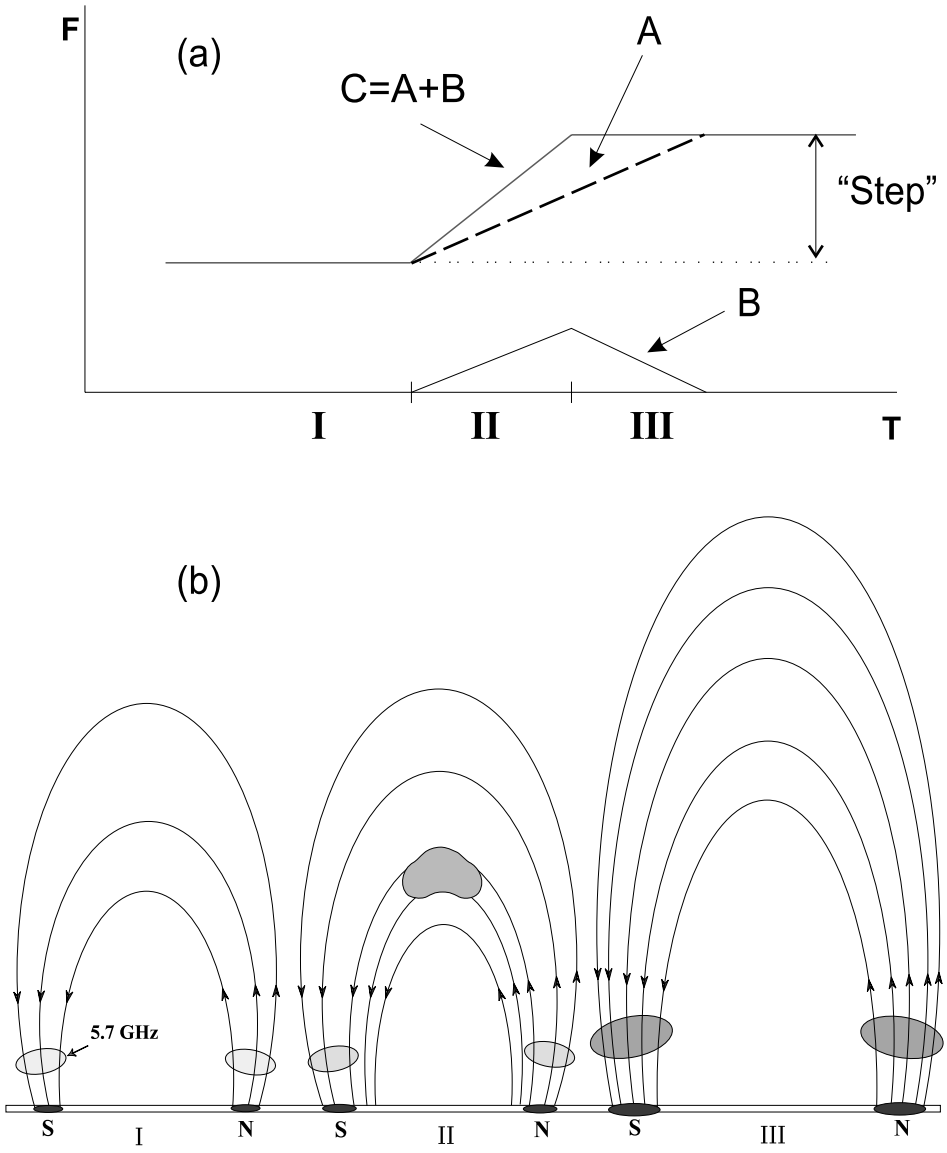

Fig. 4.. A qualitative scheme of the bipolar active region at the stage of initiation at 5.7 GHz accompanied by a stepwise increase in microwave flux (SIMF). I – before SIMF, II – stage of a fast increase in AR microwave emission, accompanied by shear motions on the photosphere. III – after SIMF. A – flux of sourses above small sunspots (denoted by the thin dashed line), B – flux behavior of the loop top source (NLS), C – total flux behavior.

appearance of the neutral line associated burst source (NLS) between two main sunspot associated sources (Figs. 2 and 3). H_α filtergrams and photoheliograms taken at the photospheric and lower-chromospheric level at the Baikal astrophysical observatory were used in the analysis of the active region evolution to estimate the proper motion of sunspots. As an example, we presente the result of detailed study of AR8062. In Figure 2, the light curve of the total flux variation is shown. Sharp increases of flux value can be identified around 06:15 and 06:50 which coincide with the radio burst and with the timing of an H_α flare in AR8062 reported in the Solar Geophysical Data. And the relation of flares and stepwise active region flux evolution is quite regular for all events. On 1997 July 24 a stepwise increase in AR microwave flux in the bipolar group AR 8062 was accompanied by the moving apart of the leading and following sunspots, which is an indication of the emergence of the magnetic field to the corona.

An increase in radio brightness in the region between sunspots may be caused by the appearance of short-living

(non-neutral) current sheet between slightly sheared fluxes of "new" and "old" magnetic fields. Fig. 4 presents a qualitative behavior of AR microwave flux (Fig. 4a) and bipolar active region evolution (Fig. 4b). The appearance of the source at the magnetic loop tops corresponds to the stage of a fast increase in microwave emission. Meanings of radio flux increases are different for different emission mechanisms. Most likely the emission mechanism of the loop top source is the superposition of the thermal free-free and non-thermal gyrosynchrotron processes. The decay of this burst source (plot B in Fig. 4a) is accompanied by a gradual increase (plot A in Fig. 4a) of the flux, as well as the size and brightness temperature of the gyroresonance sources located in the immediate vicinity of sunspots. The total AR flux behavior is represented by plot C=A+B in Fig. 4a. On the whole, the phenomenon of a stepwise increase in the flux of microwave emission signals the evolutionary transition of the active region from one quasi-stationary state to an other.

We highly appreciate Mr. B. Agalakov for making the software programs available to us and we are much grateful to Dr. V. Grechnev for his assistance in preparation of the manuscript. We would like to thank the referee for helpful suggestions and critical comments.

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