A Broadband Solar Radio Spectrometer and Fine Structures in Microwave Bursts

Qijun Fu, Yuying Liu, Huirong Ji, Congling Cheng, Zhijun Chen, and Debang Lao
Beijing Astronomical Observatory, Chinese Academy of Sciences, Beijing 100012
Zhihai Qin, Guo Yang
Department of Astronomy, Univ. of Nanjing, Nanjing 210093 China
Liben Pei, Guangli Huang, Hongao Wu, Qijun Yao
Purple Mountain Observatory, Chinese Academy of Sciences, Nanjing 210008, China
Zhiguo Xia and Ruixiang Xie
Yunnan Astronomical Observatory, Chinese Academy of Sciences, Kunming 650011, China
E-mail (QF): fuqj@cenpok.net

Abstract

Since 1994, a project for setting up a solar radio broadband spectrograph with high resolution in time and frequency has been carried out. Some new and interesting results obtained with 2.6–3.8 GHz and 1.0–2.0 GHz radio spectrometers are briefly introduced. This equipment will be the key observation facility in coming solar maximum years in China.

Key words: solar radio emission – microwave burst – solar radio – spectrograph

1. Research on FS in Microwave Bursts and the Broadband Solar Radio Spectrometer

One of the most challenging problems in solar physics is related to the sudden release of energy stored in very hot magneto-active plasma confined above sunspots in the solar atmosphere. During the flare processes, the time profiles of electromagnetic fluxes in hard X-ray and microwave are signatures of the energy conversion mechanism at the origin of solar flare. The distinction between continuum and discrete (FS) energy production brings drastic conceptual consequences for the interpretation of the energy conversion processes. As more sensitive detectors were used on measurements with higher time resolution, the notion of continuum energy release in the flare processes is being replaced by the concept of repetitive energy production or Elementary Flare Bursts manifested at HXR and by rapid time FS in microwave emissions (reference to Kaufmann 1996; Benz 1994).

Microwave fine structures superimposed on microwave bursts are spectral phenomena, consequently, a radiospectrometer with broad frequency coverage in decimeter and centimeter wave bands to be able to make detailed observations of intensity and polarization with high resolution in time and in frequency and high sensitivity for recording the dynamic spectrum of microwave FS, is essential. Under the support of the Chinese Academy of Sciences, a project for setting up "A Broadband Spectrometer for Decimeter and Centimeter Wave Bursts" has been in progress since 1994. It is a key project for the investigation of solar activity in the 23rd solar activity cycle in China. This project has been carried out by Beijing Astronomical Observatory (BAO), Purple Mountain Observatory (PMO), Yunnan Astronomical Observatory (YAO), and Nanjing University (NJU) (Fu et al. 1995).

A suite of microwave spectrometers will span a frequency range of 0.7–7.6 GHz (or 12 GHz) using a 10 m dish at YAO (0.7–1.4 GHz), a 7.3 m dish at BAO (1.0-2.0 GHz), and a 3.3 m dish at BAO (2.6– 3.8 GHz and 5.2–7.6 GHz). The 4–5.2 GHz range will be obtained at PMO. With the exception of the 4–5.2 GHz range, dual-circular polarization measurements are made. The frequency resolution of the spectrometers is 1–10 MHz, or 20 MHz, and the time resolution is 1–10 msec. The flux sensitivity is $\Delta S/S \leq 2\%$ (where S is the solar background flux). The accuracy of the measurement of the degree of circular polarization is 5–10%.

The current status of this project is as follows: The 2.6–3.8 GHz radiospectrometer has been operating since the end of September, 1996. The main parameters of the spectrometer are as follows: It can be operated over a bandwidth of 1.2 GHz with a time resolution of 8 msec, or a bandwidth of 300 MHz with a time resolution of 2 msec. A frequency resolution of 10 MHz is used in both cases. The 1.0–2.0 GHz radiospectrometer came into operation in January, 1994. The time resolution of this instrument is 50 ms, the frequency resolution is 20 MHz for the bandwidth of 1 GHz, 2 ms, and 1 MHz for the bandwidth of 20 MHz. The performance of this spectrometer will

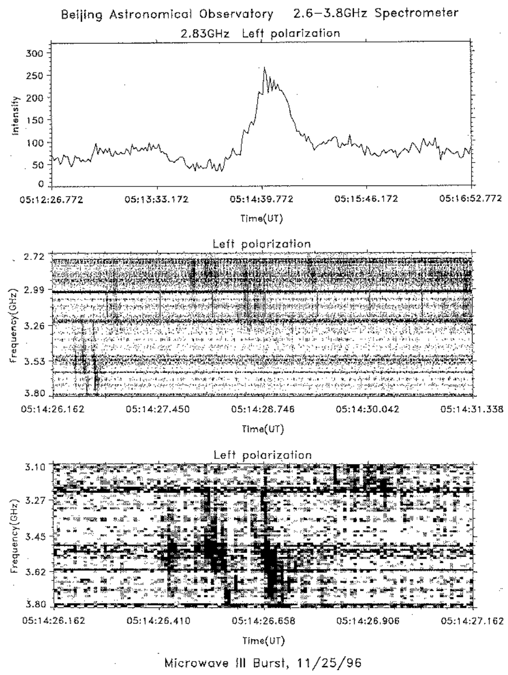

Fig. 1.. The event of November 25, 1996. Top: the time profile of the event at 2.83 GHz. Middle: the grey scale spectrogram of a 5 sec section in rising phase, some microwave type III burst groups appear. Bottom: the extended spectrogram of the strongest one (the left one in the middle panel)

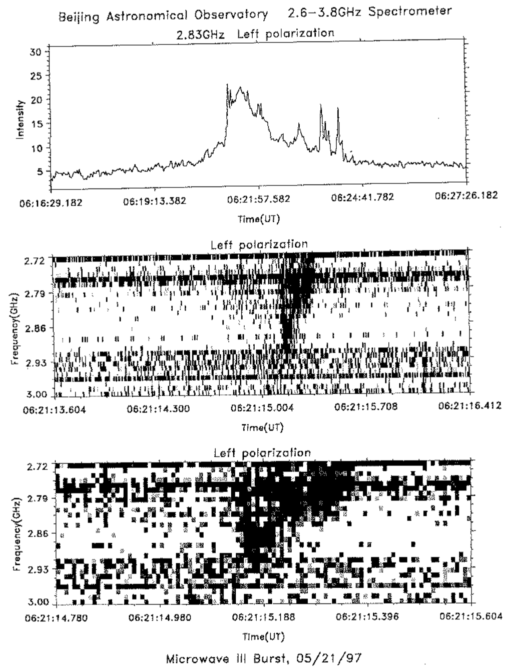

Fig. 2.. The event of May 21, 1997. Top: the time profile of the event at 2.83 GHz Middle: the grey scale spectrogram of a 3 sec section in rising phase Bottom: the extended spectrogram of the microwave type III burst, at least four small components can be found in the type III burst.

be improved. The 0.7–1.4 and 5.2–7.6 GHz radiospectrometers will be completed in the first half of 1999, as will be the 4–5.2 system.

2. Some Preliminary Results and Discussion

2.1. The November 25, 1996 event

This is a very small event. Fig. 1 shows this event, where at least six groups of microwave type III bursts can be seen in the spectrogram, and the bottom panel is the extended spectrogram. The group in the bottom of Fig. 1 consists of three components, the first one with the frequency drift rate (FDR) of more than 56 GHz/s may be a spike emission, and the second and third ones with the FDR of about 9 GHz/s are microwave type III bursts.

2.2. The May 21, 1998 event

Fig. 2 shows the May 21, 1998 event. In the middle panel of Fig.2 between 0621:14.7–0621:14.84 UT a normal type III burst in frequency range of 2.72–2.92 GHz with the FDR of 2.84 GHz/s can be found. From the bottom panel of Fig. 2, it seems likely that the type III burst consists of at least four small components, each one with frequency bandwidth of less than 100 MHz and a duration of about 50 ms. It also can be seen in the bottom panel of Fig. 1 that each of the two type III bursts in the event of November 25, 1997 consist of at least 9–10 components. This phenomenon is consistent with the theory developed by Vlahos (1994), showing that the fine structures (type III) are composed of a number of elementary components, super-FS.

2.3. The January 5, 1994 event–a particle acceleration region found in microwave range in corona

A microwave type III burst pair characterized by two branches with FDR of −0.23 GHz/s and +0.22 GHz/s respectively, and separatrix frequency between 1660 MHz and 1760 MHz, superimposed on the microwave burst of January 5, 1994, was found for first time (Fu et al. 1997). From the middle and bottom panels of Fig. 3, it can

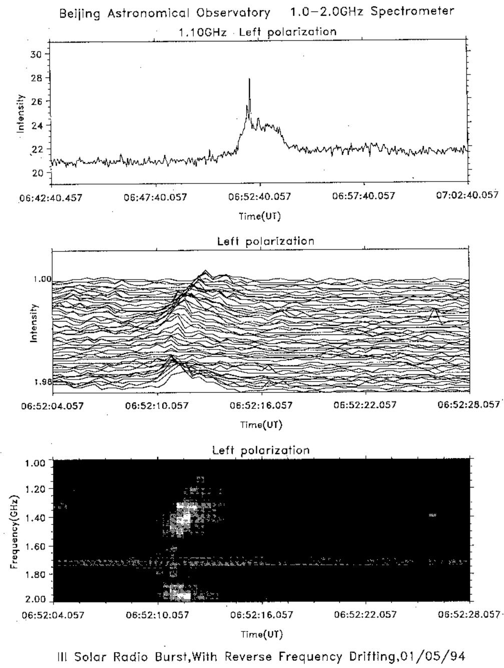

Fig. 3.. The event of January 5, 1994. Top: the time profile of the event at 1.10 GHz Middle: the spectrogram of the type III burst pair in multi- channel plot Bottom: the spectrogram of the type III burst pair in grey scale.

be seen that a "frequency gate" without type III burst emission appears between the start frequencies of the two branches of the type III burst pair. These are deduced that the height of the electron acceleration region of this event is at 3×10^4 km above photosphere and the height range of the electron acceleration region, as well as the forming region of type III bursts is about 650 km, and the electron beam's speeds are 0.106c and 0.102c, respectively.

The most crucial problem in the understanding of the solar flare process is the localization of the energy release and acceleration region (Aschwanden & Treumann 1997). To find the separatrix frequency of type III burst pair, in particular in microwave band, and bi-directional (upward/downward direction) electron beams is significant aspect for resolving the problem mentioned above. Most of type III bursts are only one branches appearing, although most of known acceleration mechanisms are able to accelerate particles in upward and downward directions. The important problems are: Why most of type III bursts only occur one branch? are upward/downward directed electron beams accelerated together or independently? Is the upward/downward acceleration asymmetric?

2.4. A pair of spike emissions

This phenomenon was found in the event of Nov. 2, 1997. Fig. 4 shows the time evolving radio spectrum of the spike emission pair superimposed on the Nov. 2, 1997 event in grey-scale. Fig. 5 is the same as Fig. 4 in contour plot. From the separatrix frequency (2.90 GHz) there are two branches, one is upward with FDR of -21 GHz/s, the other is downward with FDR of 56 GHz/s. It is the first time that the FDR of microwave spike emission were measured. Note the obvious difference between the spike emission pair and the type III burst pair, there is a frequency gate around the separatrix frequency without radio emission in the type III burst pair, but not in the spike pair.

2.5. Mini-U bursts

U-type burst is generally interpreted as being produced by electron beams traveling along closed magnetic field lines, either within a bipolar active region, from one active region to another, or from an active region to part of the quiet sun. The most of total duration of type U-burst ranges from 10-20s, the size of large loops of inter-active-region is about $1 - 5 \times 10^5 km$.

Some mini-U bursts have been found in our 2.6-3.8GHz data. One of them is shown in Fig.6, which was found in

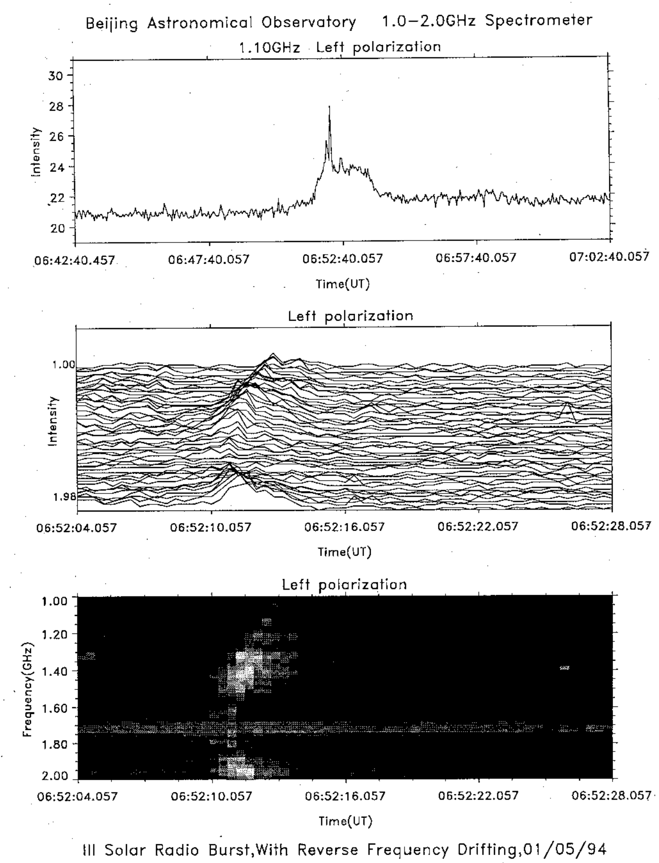

Fig. 4.. The time-evolving radio spectrum of the spike emission pair superimposed on the Nov.2, 1997 event in grey scale.

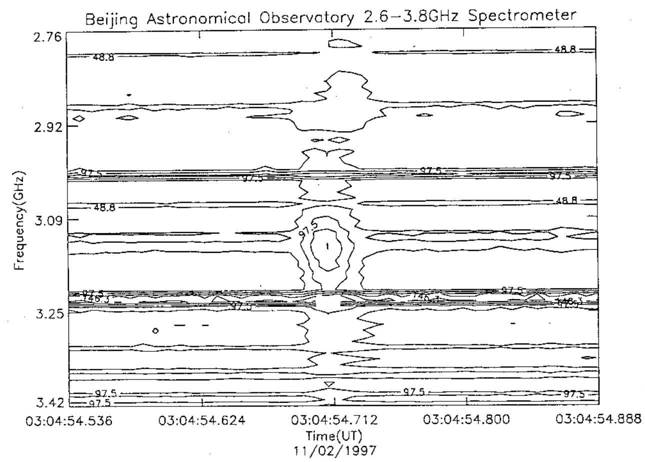

Fig. 5.. Same to Fig. 4 in contour plot

the event of 0759:54UT, April 15, 1998. The total duration is only 32ms, then, the size of the mini-loop to be able to deduce is about 400-800km.

3. Conclusion

Under the untiring efforts of the solar radio astronomy community of China, remarkable successes have been achieved, not only in the instrumental and observational aspects, but also in the data analyzing and theoretical work aspects. Since 1994, a new project for getting up a solar radio broadband fast sampling spectrograph has been approved by the Chinese Academy of Sciences and has being carried out by the BAO, PMO, YAO and NJU. Now, the component spectrometers in 2.6–3.8 GHz and 1.0–2.0 GHz have come into operation. The new results recorded with 2.6–3.8 GHz radiospectrometer demonstrate that the new instruments with excellent properties are capable of achieving the scientific aims of the project. This equipment will be the key observation facility in coming solar active maximum years in China.

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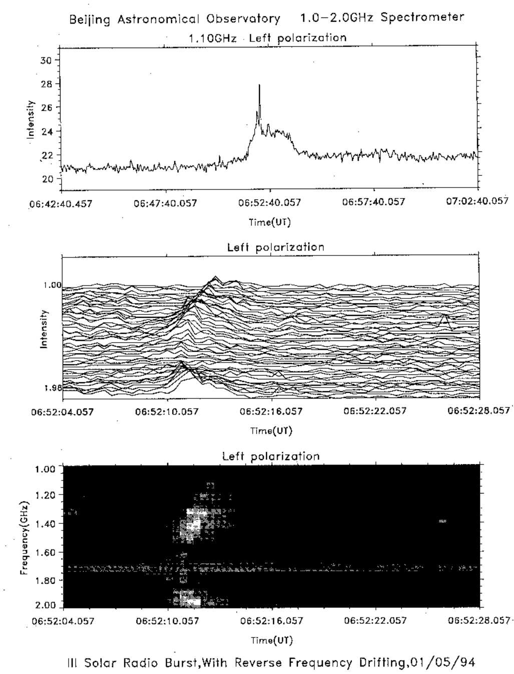

Fig. 6.. The dynamic spectrum of the mini-U burst in the April 15, 1998 event in grey scale. Top: the time profile at 3.38 GHz, Middle: the multi-channel time profiles, bottom: same to the middle panel in grey scale.

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