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A New Solar Radio Spectrometer at 1.10–2.06 GHz and First Observational Results *

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Abstract An improved Solar Radio Spectrometer working at 1.10–2.06 GHz with much improved spectral and temporal resolution, has been accomplished by the National Astronomical Observatories and Hebei Semiconductor Research Institute, based on an old spectrometer at 1–2 GHz. The new spectrometer has a spectral resolution of 4 MHz and a temporal resolution of 5 ms, with an instantaneous detectable range from 0.02 to 10 times of the quiet Sun flux. It can measure both left and right circular polarization with an accuracy of 10% in degree of polarization. Some results of preliminary observations that could not be recorded by the old spectrometer at 1–2 GHz are presented.

Key words: instrumentation: spectrometer — sun: radio radiation

1 INTRODUCTION

The solar radio spectrometer working at 1–2 GHz (temporal resolution=100 ms and spectral resolution=20 MHz) as one component of the Broadband Solar Radio Spectrometer developed in 1991 cannot meet the specifications in temporal and spectral resolution (Ji et al. 1997; Fu et al. 1995, 2004). However, information rich in fine structure comes in this waveband from the most active transition region of the solar atmosphere. So the old spectrometer had to be improved, and it was upgraded in 2001. According to the EM environment at Huairou Station (RF interferences are much stronger and denser below 1000 MHz than above 1000 MHz) the working frequency range of the new instrument was selected to be 1.10–2.06 GHz, the frequencies of the first local oscillator were selected to be 1.80, 2.04, 2.28 and 2.52 GHz, and a high-pass filter with high quality was installed in the front of the LNA, so the RF lower than 1000 MHz and the mirror interferences were easily suppressed (if the first local oscillator frequencies were selected at 640, 880, 1120 and 1360 MHz then the strong mirror signals over the ranges of 320−560 and 560–90 MHz would be difficult to suppress), and the inter-modulation products could be

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decreased. Because the amplifiers of every stage, mixers and especially the detectors of the new instrument are all provided with enough high dynamic range, the FR interferences of 1800 and 1900 MHz falling in the working frequency band could not cause any saturation or blocking of the system, even when there are strong solar radio bursts (to date we have not inserted band-stop filters to suppress the RF interferences of 1800 and 1900 MHz to avoid losing useful signals around them). In order to prevent IF interferences and overcome the imbalance of the signals in amplitude caused by the transmission though a long cable, a range of 100–220 MHz was selected for the second IF.

2 INSTRUMENTATION AND OBSERVATIONS

The new spectrometer is a multi-channel (60 Surface Acoustic Wave (SAW) filters) frequency switch instrument (the output frequency of the first local oscillator switches among 1.80, 2.04, 2.28 and 2.52 GHz every 5 ms). This type of construction makes the instrument the best compromise among temporal resolution, sensitivity and costs. The specifications of the new instrument are summarized in Table 1. A block diagram of the new system is shown in Fig. 1 (for details see Li et al. 2001).

Table 1 Specifications of The New Spectrometer

Frequency range	1.10–2.06 GHz
Spectral resolution	4 MHz
Temporal resolution	5 ms (960 MHz bandwidth); 1.25 ms (240 MHz bandwidth)
Sensitivity	better than 0.02 of the quiet Sun flux
Dynamic range	10 times the quiet sun background
Polarization measurement accuracy	better than 10%

The spectrometer uses a 7.3 m parabolic reflector and a crossed log-periodic dipole with a linear-circular converter as the primary feed. The antenna system is of an equatorial structure and driven by a computer-controlled step motor.

A microwave switch is used to select alternately the LHCP and RHCP component from the feed and the intensity calibration signal from a solid noise source. A high-quality band-pass filter is used to suppress the RF interference from outside working band. The signal is first amplified by a Low Noise Amplifier (LNA) and then passed through a low-pass filter to enter the first mixer. The first local oscillator is a voltage-controlled oscillator (VCO) which outputs the signals of 1.8, 2.04, 2.28 and 2.52 GHz in turn. The 1.10–2.06 GHz signals are divided into four sections (1.10–1.34, 1.34–1.58, 1.58–1.82 and 1.82–2.06 GHz) and down converted to 460–700 MHz in sequence. The signal passes through a band-pass filter and an Intermediate Frequency (IF) amplifier and then is divided into two parts (460–580 MHz and 580–700 MHz) by a power divider. After passing through the band-pass filters and the second mixers, the two parts are both down converted to 100–220 MHz. The second local oscillators are all phase locked. The 100–220 MHz signals passed through the band-pass filters and IF amplifiers and go into the indoor receiver through the long low- loss RF cables. The signals then passed through the IF amplifiers and the voltage-controlled attenuators to enter the corresponding SAW filter bank. Each SAW filter bank has 30 channels with 4 MHz bandwidth. After passing through 60 IF amplifiers, detectors and integrators/holders, the outputs the of SAW filter banks go into a multiplexer and are converted into digital signals by an analog to digital converter (A/D), to be collected by a Pentium computer.

We used the physical mode to save the data observed on a hard disk (for details see Wang et al. 2001). After a daily observation only data of bursts are formed directly into files with 5 ms time resolution (if there are any bursts recorded), while the whole day's data and calibration

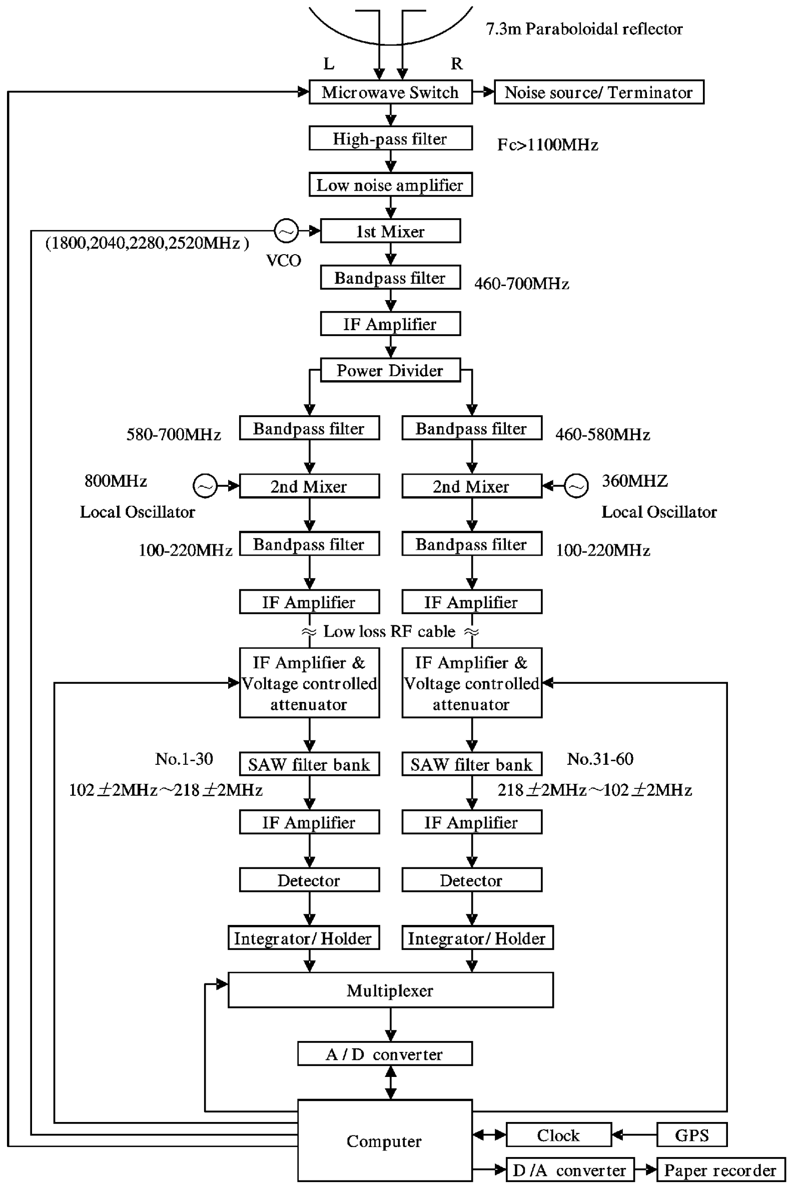


Fig. 1 Block diagram of the new spectrometer at 1.10–2.06 GHz.

data are formed into files with 0.2 s time resolution which are all transmitted to a server through the local network and saved on the hard disk and eventually stored on CD-ROM. This way, the problem of high rate data acquisition (200 kbit s^{-1}) and the storage of vast amount data (6–10 Gbit d^{-1} during different seasons) is solved with minimum costs.

There are two types of real-time monitoring: real-time display of the dynamic spectrum on the computer screen, updated every 25 s, and real-time display of the intensity of any one of the channels on a paper recorder to operate calibration and monitor bursts, as well as adjust the IF attenuator in time to keep the linearity of the system when the strongest bursts occurred.

Frequency Calibration: the frequency accuracy of the first local oscillator is better than 1 MHz as tested by the instantaneous frequency testing technique. The second local oscillators are phase locked, so the signal frequency received by channel N can be calculated according to the formula: $f_N = 1102 + 4 \times N$, here N is from 0 to 239.

The intensity calibration, timing and software of instrument testing and data processing are available and similar to the other two components (for details see Ji et al. 2003).

3 RESULTS OF PRELIMINARY OBSERVATIONS

Quite a few of solar radio bursts with various fine structures such as spikes, type III with high frequency drift rate, Zebra pattern structure, fiber structure, pulsation drift structure and so on, have been detected since the instrument was put into operation in August 2001. Here, we give some examples to show its capabilities.

Figures 2 and 3 present a strong solar radio burst event and its fine structures on 2003 October 26.

A distinct ZPS dynamic spectrum recorded by the 1.10–2.06 GHz spectrometer is shown in the middle and bottom panel of Fig. 2. This fine structure was also simultaneously detected by over the range of 750–1500 MHz at Yunnan Observatory.

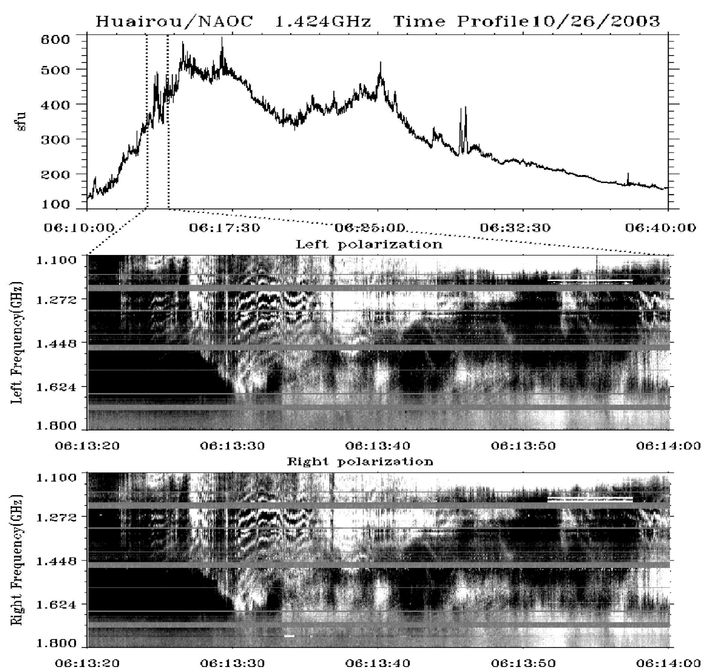


Fig. 2 Top panel: a single frequency (1.424 GHz) time profile of a strong radio burst recorded by the new spectrometer on 2003 October 23. Middle and bottom: dynamic spectra of ZPS (occurring in rise phase of the burst) in left- and right-hand circular polarization.

Figure 3 shows a group of type III bursts with average drifting rate about 2 GHz s^{-1}. The flare on 2003 October 23 is classified as X1.2/3B, and was accompanied by type II, type IV bursts and CME observed at 05:57–07:33 UT (Max 06:54 UT) in the NOAA 10486 active region at position S15 E44. A group of narrow band spikes burst on 2003 October 27 is shown in Fig. 4. The flare on 2003 October 27 is classified as M1.2/2F observed at 07:51–09:24 UT (Max 08:33 UT) in the NOAA 10484 active region at position N00 W45.

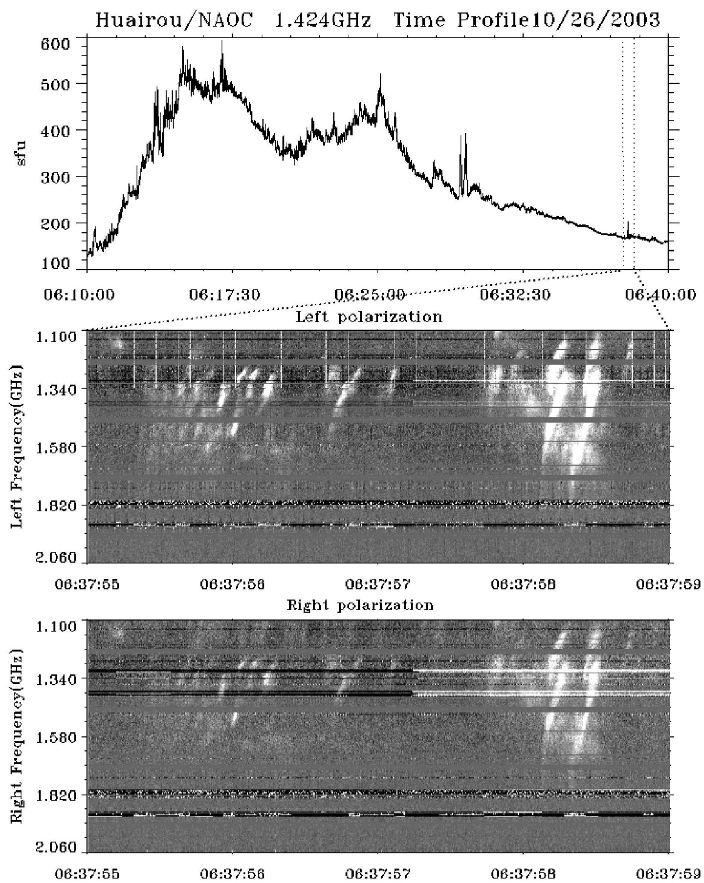


Fig. 3 Top panel: a single frequency (1.424 GHz) time profile of a strong radio burst recorded by the new spectrometer on 2003 October 23. Middle and bottom: dynamic spectra of type III burst during 06:37:55–06:37:59 UT (occurring in the decay phase of the burst) in left- and right-hand circular polarization.

A group of fiber bursts with strong right hand circular polarization on 2004 January 5 is shown in Fig. 5a, while the Fig. 5b shows what this event would be like if we used the old instrument.

The flare on 2004 January 5 is classified as M6.9/2N, accompanied by type II bursts and CME observed at 02:50–05:20 UT (Max 03:45 UT) in the NOAA 10536 active region.

Figure 6 shows a strong solar radio burst event and its fine structures on 2004 September 14. This event was also simultaneously recorded by the spectrometer (temporal resolution =100 ms) over the range of 800–2000 MHz at the Ondrejov Astronomical Observatory, Czech.

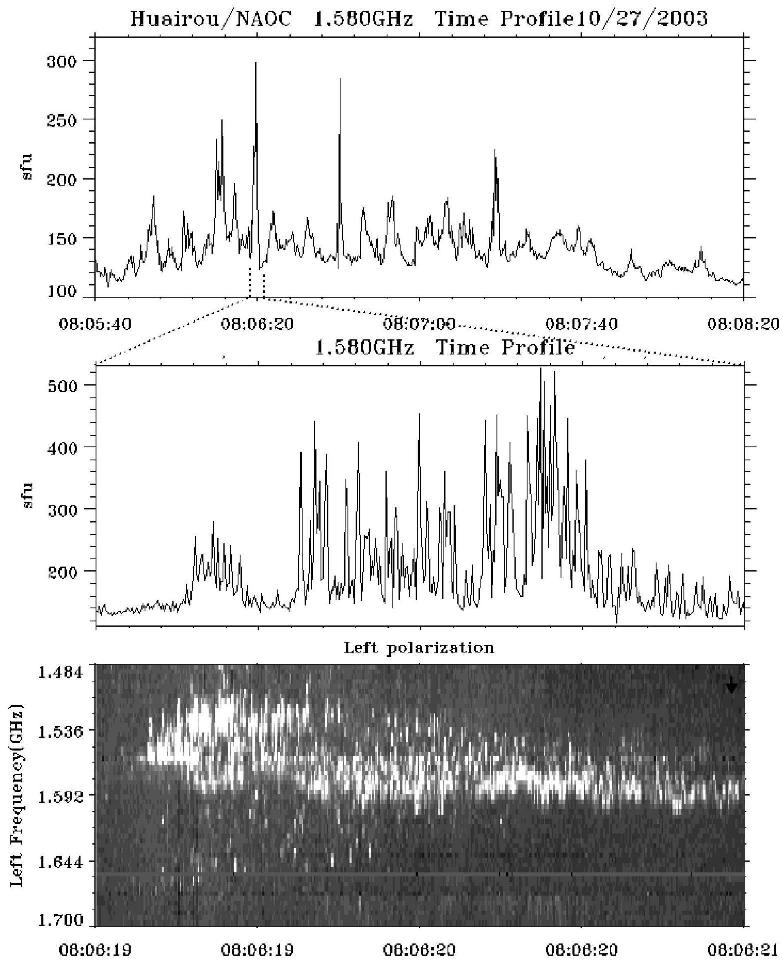


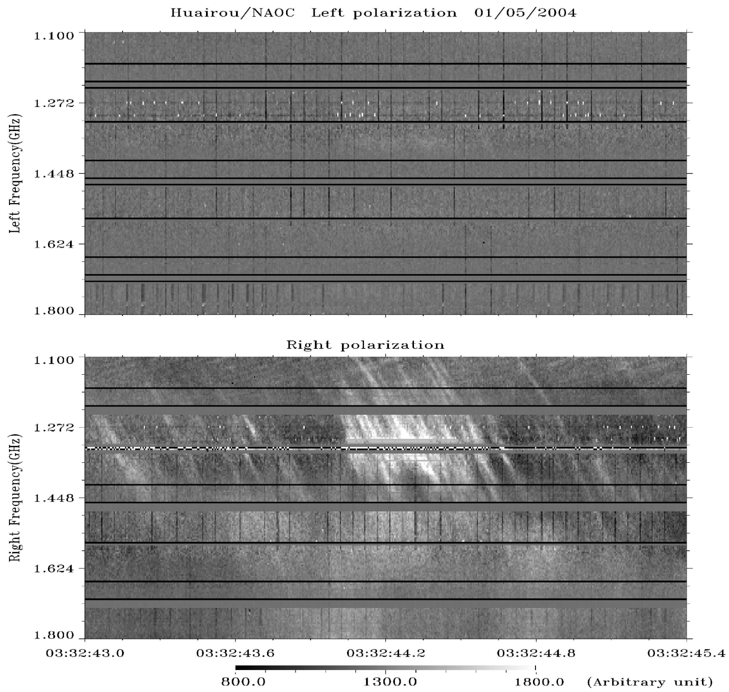
Fig. 4 Top panel: a single frequency (1.58 GHz) time profile of the strong radio burst recorded by the new spectrometer on 2003 October 27. Middle and bottom: a single frequency (1.58 GHz) time profile and a dynamic spectrum of narrow band spike burst during 08:06:19–08:06:21 UT are shown.

The flare on 2004 September 14 is classified as M1.5/1F, it was accompanied by type II, type IV bursts and CME, observed at 08:48:39–09:54:36 UT (Max 09:22:10 UT) in the NOAA 10672 active region at position N04E17.

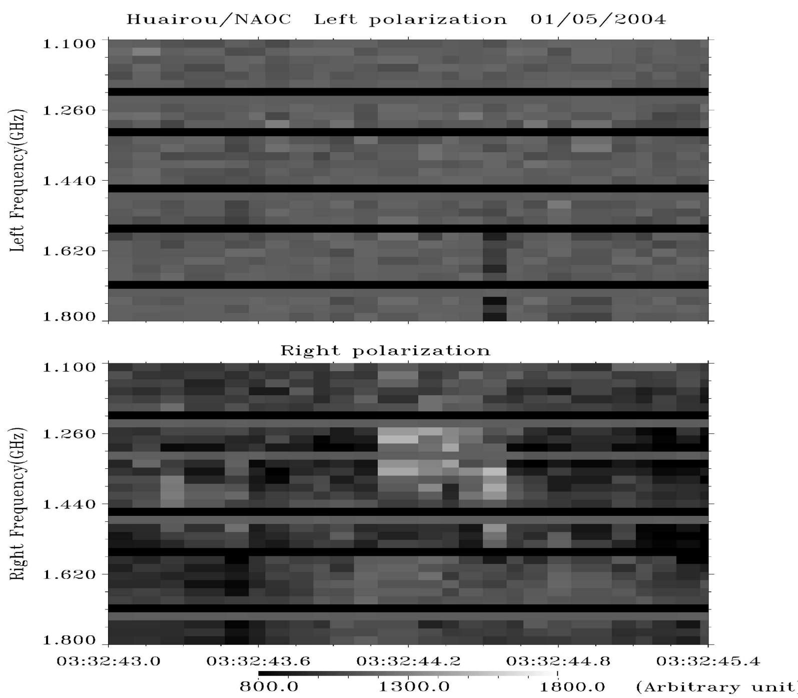
Figure 7 shows a group of intermittent fine structure with a drifting rate of about – 150 MHz s^{-1} and a 100 ms duration, recorded by the new spectrometer with 1.25 ms resolution on 2004 November 3.

We note that this kind of fine structure has never been recorded by any other spectrometers in this range up to now.

The flare on 2004 November 3 is classified as M1.6/1N, accompanied by type II, type IV bursts and CME, observed at 03:23–03:57 UT (Max 03:36 UT) in the NOAA 10696 active region at position N09 E45.



(a)



(b)

Fig. 5 (a) Top and bottom panel: dynamic spectra of fiber bursts in left- and right- hand circular polarization on 2004 January 5. (b) The same if observed by the old spectrometer.

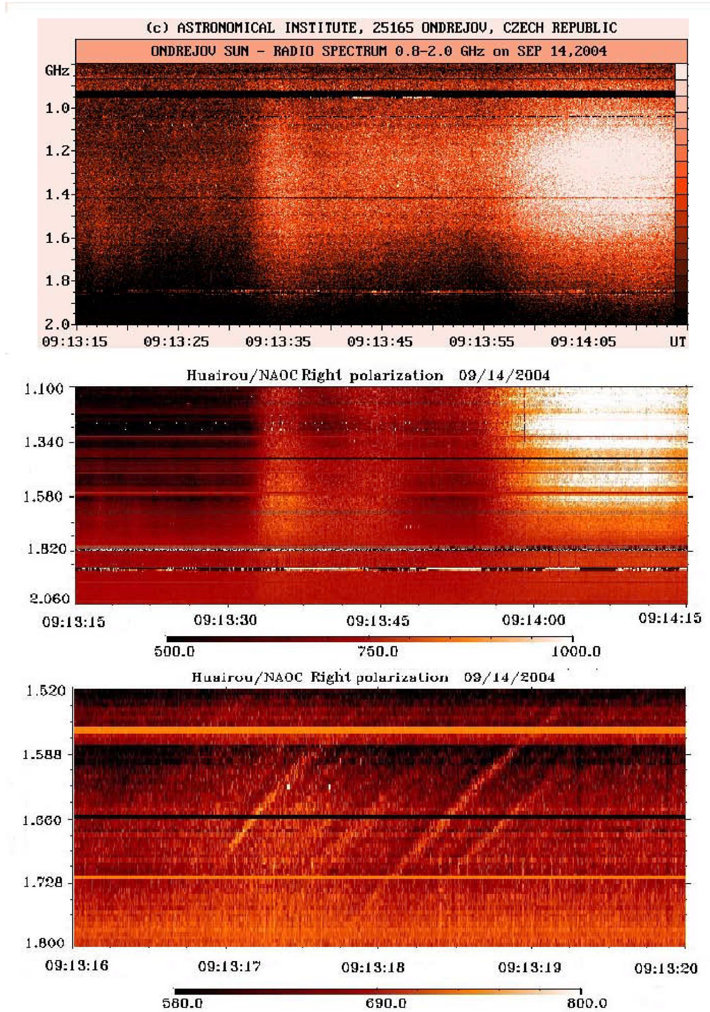


Fig. 6 Top panel: dynamic spectrum of the strong burst recorded by the spectrometer of Ondrejov Astronomical Observatory, Czech Republic. Middle and bottom: dynamic spectrum of the strong bursts and its fine structure (fiber structure occurring during 09:13:16-09:13:20 UT), respectively, recorded by the new spectrometer.

Analyses of these fine structures are helpful for us to diagnose the plasma parameters during flare processes so as to understand flare dynamics. This is not, however, the main thrust of the present paper, rather, it can be found in Tan et al. (2004).

4 CONCLUSIONS

The new spectrometer at 1.10–2.06 GHz, as one component of the "Solar Radio Broadband Dynamic Spectrometer", has been upgraded successfully and its performance shows to be enhanced significantly. A vast amount of interesting data with fine structure has been recorded (some of which have never been detected before, see Fig. 7) at decimeter wavelengths.

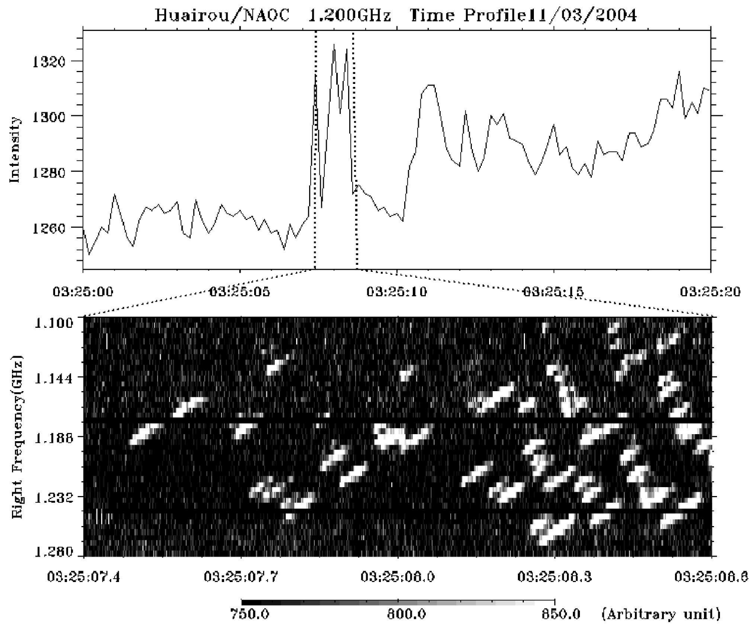


Fig. 7 Top panel: a single frequency (1.424 GHz) time profile of the burst. Bottom: dynamic spectrum of the intermittent fine structure in left hand circular polarization (occurring in the rise phase of the burst, no polarization).

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References

Fu Q. J., Qin Z. H., Ji H. R., Pei L., 1995, Solar Physics, 160, 97

Fu Q. J., et al., 2004, Solar Physics, 222, 167

Ji H. R., et al., 1997, Acta Astrophysica Sinica, 17, 219

Ji H. R., et al., 2000, Chin Astron. Astrophysics, 24, 394

Ji H. R., et al., 2003, Solar Physics, 213, 359

Li S. K., et al., The Manual of the Solar Radio Spectrometer at 1.10–2.06 GHz, NAOC Technical Report, 2001

Tan C. M., Fu Q. J., Yan Y. H., Liu Y. Y., 2004, Chin. J. Astron. Astrophysics, 4, 176

Wang Z., et al., The data acquisition system of the Solar Radio Spectrometer at 1.10–2.06 GHz, NAOC Technical Report, 2001