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Decimetric and metric digital solar radio spectrometers of the Yunnan Astronomical Observatories and the first-light results

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HIGHLIGHTS

- Two new fully digital radio spectrometers of YNAO have put into observation.
- Both of them have the spectral resolution of 200 kHz (highest).
- The first-light results have been shown in the paper.

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ABSTRACT

Based on an old decimetric solar radio spectrometer working in the frequency range of 625–1500 MHz of the Yunnan Astronomical Observatories (YNAO) during the last solar cycle, we designed a fully digital Fast Fourier Transform (FFT) spectrometer to upgrade the old one. The new digital spectrometer has the spectral resolution of 200 kHz, much higher than the old one (about 1.3 MHz). In addition, we also established a new metric solar radio telescope working in the frequency range of 70–700 MHz located at the Fuxian Solar Observatory of YNAO, deploying the same type of the digital FFT spectrometer. The two instruments have begun to operate in a daily survey mode since September 2009 and March 2012, respectively, and many solar radio bursts have been observed. In these events, various types of decimetric and metric fine structures with fairly meticulous spectral features were recognized. These features were never resolved in previous observation and studies. We have introduced these two instruments with their detailed technological components, as well as a set of observational data obtained during the first-light of the instruments. The information revealed by these data can improve our knowledge and understanding of the physics of the energy conversion, particle acceleration and transportation during the solar eruption.

1. Introduction

It is now generally accepted that solar flares, eruptive prominences, and coronal mass ejections (CMEs) are three different but related phenomena (e.g., Forbes and Lin, 2000; Klimchuk, 2001; Priest and Forbes, 2002; Lin et al., 2003). In the eruptive process, energy release, plasma heating, particle acceleration, and particle transport in the magnetized plasma are long-standing questions (Bastian et al., 1998). Solar radio bursts in decimetric and metric wavelengths are dominated by plasma emission, which correspond to the electron density between 10^8–10^{10} cm^{-3}, where the primary energy release and particle acceleration processes of the flare and CME take place (Bastian et al., 1998; Jiřička et al., 2001; Rosa et al., 2008; Veronese et al., 2011; Sawant et al., 2011). In these wavelengths, various radio signatures have been observed. Types III and II bursts indicate the transport of energetic electrons and the propagation of shock waves in the corona, respectively. Other radio fine structures give the important information about the small scale magnetic structures, different emission mechanisms, and magnetic reconnection.

Solar spectral observations with high temporal and spectral resolutions began in 1980s. Isliker and Benz (1994) summarized the observations of Phoenix Spectrometers and classified solar radio fine structures in the frequency range of 1–3 GHz into five types.

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Furthermore, on the basis of the observations from 1992 to 2000 by the Ondřejov Radio Spectrometer in 0.8–2.0 GHz, Jiřička et al. (2001) classified radio bursts and fine structures into 10 different types, including continua, pulsations, isolated broadband pulses, fast drift bursts, narrow band type III bursts, slowly drifting bursts, narrowband spikes, fiber structures, zebra patterns, and lace bursts. In addition, during the last solar cycle, the Solar Broadband Radio Dynamic Spectrometer (SBRS) of China, which consisted of five spectrometers working in five different wave bands (0.7–1.5, 1.0–2.0, 2.6–3.8, 4.5–7.5, and 5.2–7.6 GHz), observed abundant microwave fine structures (Fu et al., 2004a,b; Huang et al., 2007; Ning et al., 2009; Yan et al., 2010; Gao et al., submitted for publication). These five spectrometers adopted the analog multi-channel, scanning frequency, and auto-correlation techniques. Their temporal and spectral resolution were in the ranges of 1–10 ms and 1.3–10 MHz, respectively, a relative high level at that time.

Development of digital electronic technology after the year of 2000 allows the fully digital spectral analysis covering much broader waveband than before to be realized. In the 24th solar cycle, a newly digital spectrometer is designed with the highest spectral and temporal resolutions of 200 kHz and 2 ms, respectively. This instrument (decimetric spectrometer hereafter) in the frequency range from 625 to 1500 MHz, upgrades the old one which have operated since the 23rd solar cycle at YNAO (Fu et al., 2004a,b). In addition, in order to cover the metric band, which is very important for solar radio physics and space weather, a new radio telescope working in the frequency range from 70 to 700 MHz was constructed. This telescope (metric spectrometer hereafter) is located at the Fuxian Solar Observatory (FSO) of YNAO and equips with the same type of the digital spectrometer. Observations of the daily survey mode by the decimetric and metric spectrometers began in September 2009 and March 2012, respectively. Since then, a lot of solar radio bursts with various fine structures have been detected, and they have not been observed or recognized to our knowledge.

In this paper, we introduce the technological details of the both spectrometers of YNAO in Section 2; we present and discuss observational results obtained during the first light in Section 3. Finally, we summarized this work in Section 4.

2. Instruments

2.1. Front-end

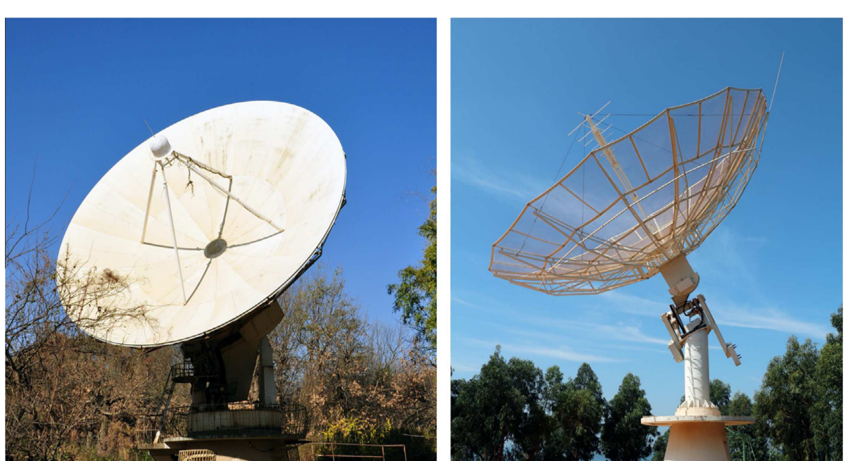
The decimetric solar radio telescope is located in the headquarter of YNAO at the east of Kunming city (102°.79 E, 25°.02 N). A 10-m parabolic antenna is used for collecting the signals from the Sun (see Fig. 1(a)). It covers the frequency range of 625–800 MHz and 975–1500 MHz. The frequency band of 800–975 MHz is abandoned because of serious cellphone frequency interference. The linear polarization signals are converted to the circular polarization components via a phase-shifter with the precision better than 10%, and then transport to the low noise amplifier (LNA), the filters, the amplifiers, and the receiver. The total bandwidth is divided into four sub-bands with the bandwidth of 175 MHz. With a local oscillator, the radio frequency (RF) signals of the four sub-bands are converted into intermediate frequency (IF) signals, and then each IF signal is divided into 2 channels with the bandwidth of 87.5 MHz. A microwave-switch is used for sending the signals of 16 channels (8 channels $\times$ 2 polarizations) to the analog-to-digital converters (ADCs) of FFT spectrometer for spectral analysis (see the upper panel in Fig. 2).

The metric solar radio telescope is located at FSO of YNAO (102°.57 E, 24°.34 N). A 11-meter meshed parabolic antenna (see Fig. 1)(b) and broad band log-period dipole feed are used. It covers the frequency range of 70–700 MHz. Also via a phase-shifter, the linear polarization signals of the two circular polarizations go through the LNA, the filters, the amplifiers, and the receiver. The total bandwidth is divided into 8 channels (70–100, 100–175, 175–262.5, 262.5–350, 350–437.5, 437.5–525, 525–612.5, and 612.5–700 MHz). A microwave-switch is used for sending the signals of 16 channels (8 channels $\times$ 2 polarizations) to ADCs of the digital spectrometer (see the lower panel in Fig. 2).

In addition, we have to use notch filters to suppress serious interferences, such as frequency modulation (FM) mainly in 70–110 MHz, open radio bands in ranges from 145 to 175 MHz and from 420 to 490 MHz, respectively. Hence, three notch filters are used in the three metric bands.

2.2. Spectrometers

There are several kinds of spectrometers based on different technologies, such as acousto-optic spectrographs (AOS), autocorrelation spectrometers, and FFT spectrometers. The FFT spectrometers mainly based on advanced digital processors, such as Field Programmable Gate Array (FPGA), Digital Signal Processor (DSP), and so on, are developed very quickly. Taking advantage of ADC with higher speed sampling rate (up to several Gigabit sampling per second [Gsps]) and processor with advanced computing capability, we can observe the wider bandwidth with higher spectral and temporal resolution (Sawant et al., 2001; Benz et al., 2005;



(a) (b)

Fig. 1. Decimetric (a) and metric (b) solar radio telescopes located in the headquarter and in FSO of YNAO, respectively.