Observations of Low Frequency Solar Radio Bursts from the Rosse Solar-Terrestrial Observatory

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The Rosse Solar-Terrestrial Observatory (RSTO) was established at Birr Castle, Co. Offaly, Ireland in 2010 to study solar radio bursts and the response of the Earth’s ionosphere and geomagnetic field. To date, three Compound Astronomical Low-cost Low-frequency Instrument for Spectroscopy and Transportable Observatory (CALLISTO) spectrometers have been installed, with the capability of observing in the frequency range 10-870 MHz. The receivers are fed simultaneously by biconical and log-periodic antennas. RSTO is optimized to record dynamic spectra of Type II, III and IV radio bursts. In particular, fine-scale structure such as herringbones and Type II band splitting can be detected by RSTO. Here we describe RSTO instrumentation and present some example-spectra.

1. INTRODUCTION

The Sun is an active star that produces large-scale energetic events, such as solar flares and coronal mass ejections (CMEs). These phenomena are observable across the electromagnetic spectrum, from gamma rays to radio waves. Solar flares and CMEs can excite plasma oscillations which can emit radio-bursts at metric and decametric wavelengths. These bursts are classified in five main types. Type I bursts are short-duration narrowband features associated with active regions (Melrose, 1975). Type II bursts are excited by magnetohydrodynamic (MHD) shockwaves associated with CMEs (Nelson and Melrose, 1985), while Type III bursts result from energetic particles escaping along open magnetic field lines. Type IV bursts show broad continuum emission with rapidly-varying fine structures (Mikael and Lahmann, 1985). The smooth short-lived continuum following a Type III burst is called a Type IVa.

In order to monitor solar activity and its effects on the Earth, we set up an autonomous solar radio observing station, the Rosse Solar-Terrestrial Observatory (RSTO), which has been operating since September 2010 (Zucca et al. 2012). RSTO employees a suite of low-cost CALLISTO radio spectrometers used to monitor metric and decametric radio bursts (Benoit et al. 2005), and an Atmospheric Weather Electromagnetic System of Observation, Modeling, and Education (AWESOME; Cohen, Inan, and Paschal, 2010) which is used to monitor Earth’s ionospheric response to solar radio-bursts. RSTO is located in the grounds of Birr Castle, Co. Offaly, Ireland. One of the important features of RSTO is the particularly low radio frequency interference (RFI) of the site (Figure 1).

2. RADIO SPECTROMETER INSTRUMENTATION

RSTO operates three CALLISTO receivers fed by a broadband log-periodic antenna and a biconical antenna (Figure 2). Nominally, the RSTO set-up operates at 600 channels with a sampling time of 250 ms per second. CALLISTO 1 observes at 10-100 MHz, CALLISTO 2 at 100-200 MHz, and CALLISTO 3 at 200-400 MHz. The system has been optimised to measure the dynamic spectra of Type II radio bursts produced by coronal shock waves, and Type III radio bursts produced by near-relativistic electrons streaming along open magnetic field lines.

3. OBSERVATIONS

Observations started in September 2010, and first light was achieved on 17 November 2010. Since then, a large number of radio bursts have been recorded. We present a number of observations and give a brief description of each. All RSTO data is provided to the community at www.rosseobservatory.ie.

TYPE II BURSTS

The appearance of Type II radio bursts can vary significantly in dynamic spectra. The 22 September 2011 Type II radio burst shown in Figure 4 was associated with an X-class flare which started at 10:29:00 UT. The flare was identified to have originated in NOAA active region 11302 and was associated with a CME. The burst started at 10:39:06 UT, and shows both fundamental (F) and harmonic (H) bands of emission. The fundamental emission is visible between 20 and 60 MHz, while the harmonic backbone lies between 60 and 80 MHz.

4. FUTURE WORK AND CONCLUSIONS

We are now in the process of testing a flux-gate magnetometer to measure fluctuations in the Earth’s magnetic field in Ireland. Using CALLISTO, we will measure the on-set time of solar radio bursts near the Sun, measure their effects on the Earth’s ionosphere with AWESOME, and ultimately determine their effects to the geomagnetic field in Ireland. As part of a worldwide network of observatories, RSTO will provide an extensive capability to monitor solar activity and its effects on Earth in a real-time, continuous manner. This is made possible by the low RFI of the Birr Castle Demesne site. RSTO has been earmarked as an ideal location for a LOFAR station (www.lofar.nl). When combined with data from space-borne observations, such as NASA’S STEREO and Solar Dynamic Observatory (SDO) spacecraft, this will contribute towards a capability to track and understand the propagation of storms from the surface of the Sun to their local effects on Earth.

REFERENCES

A. Cohen, C. Monstein, H. Mayr, Callisto A New Concept for Solar Radio Spectrometers, Solar Physics 226, 145-151, 2005
M. B. Cohen, U. S. Iran, E.W. Paschal, Sensitive Broadband EU/FAST Radio Reception With the AWESOME Instrument. 2010
S. O. Mokken, N.R. Labrum, Solar radioastronomy: Studies of emission from the sun at metre wavelengths, 1992
D. H. McNaught, Plasma emission due to isotropic fast electrons, and types I, II, and III solar radio bursts, Solar Physics 43, 211–236,1975
P. Zucca, E. P. Carley, J. McCauley, P. T. Gallagher, C. Monstein, R. T. McAteer, Observations of Low-Frequency Solar Radio Bursts from the Rosse Solar-Terrestrial Observatory, Solar Physics, 2012, http://physi/stopaper

Figure 1. Radio frequency survey of the RSTO (blue), Bleanan Radio Observatory in Switzerland (red: cso by 10 dB) and from Posiden Borsum (green: cso by 20 dB). The RSTO spectrum is extremely quiet at frequencies between 20 and 870 MHz.

Figure 2. The RSTO set-up consists of three CALLISTO receivers, one connected to a bicone antenna using a frequency up-converter and measuring from 10 to 100 MHz. The other two receivers are connected to a log-periodic antenna measuring from 100 to 200 MHz and 200 to 400 MHz. The system can potentially observe between 10 and 870 MHz.

Figure 3. Several Type III radio bursts observed on 21 October 2011. Broadband emission is superimposed on the bursts. Also shown is Type II burst between 140 and 330 MHz.

Figure 4. Dynamic spectrum of the 22 September 2011 Type II radio burst (top) and related GOES-15 light curve showing an X1.4 flare. This burst shows fundamental (F) and harmonic (H) emission. Band splitting of the order of 10 MHz can also be seen in the harmonic backbone at times around 10:42 UT. Detail of the herringbone features is shown in the bottom panel.

Figure 5. Dynamic spectrum of the 07 June 2011 Type II radio burst. In the inset of panel (a) a short-lived fundamental and harmonic backlight are visible. Multiple herringbone structure are visible at 40-80 MHz in panel (b).