SPECM: Monitoring the Solar Spectrum in Centimeter Band

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Abstract

This work presents the development and the first results of the SPECM solar instrument, whose objetive is to monitor the solar activity from 1 to 18 GHz. It is installed in the INPE unit at Cachoeira Paulista, SP. The instrument consists of one 1.9 m antenna, in an alt-azimutal mount that tracks the Sun continuously. This low cost mount was previously used on the 26 antennas of the BDA interferometer. The signal from the feeder is amplified and digitized in a spectrum analyser and transmited to the computer. A software was developed for control and data acquisition, consisting of several processes comunicating via shared memory. The storage format is FITS, following the standard format of the CALLISTO international network. Data is transmitted at the end of the day to be stored in the database of the INPE Spatial Climate Program. Some representative solar events are presented.

Overview

The goal of the SPECM instrument is to monitor the Solar spectra from 1 GHz to 18 GHz for Space Weather applications, looking for deep and intense burst events that could originate Coronal Mass Ejections (CME) affecting communications on Earth. It consists of a 1.9 m parabolic dish on a steerable mount, a receiver system and a computer for data acquisition, instrument control and mount control.

Receiver System

- Low cost mount holds the parabolic dish.
- Parabolic dish focus the incoming radiation on the feeder.
- Feeder converts this radiation to a radio-frequency (RF) electrical signal.
- Low-noise amplifier (LNA) amplifies the RF signal, increasing its Signal-to-noise ratio (SNR).
- Pre-amplifier drives the signal to the control room.

Electronics at the base

- Small embedded computer (Moxa) monitors the temperature of the pre-amplifier; can shut it down if it gets too hot.
- The Moxa can also shut down the mount, by remote command.
- Also present: power supply, mount controller and motor drivers.

Control Room

- Spectrum analyzer (R&S model) sends Sun spectra to the PC by Ethernet each 0.4 s.
- PC records the spectra to disk files.
- PC sends files to the Space Climate Program Archive by Internet.
- PC clock is syncronized to a Rubidium GPS time server.

Tracking the Sun

- PC calculates the position of the Sun in real-time (JPL code).
- Reads current position from the mount, sends new position.
- Monitors any deviation from the Sun.
- Turns off the mount in case of anomaly.
- Presents information to operator: current calculated Sun position, current mount deviation, amplifier temperature and current data file being written.
- Operator can send commands to initialize the mount, to start acquisition and to put the antenna in parking position. Everything else is fully automated.

Current situation

- Data available in archive since 2012 (reduced bandwidth).
- Full bandwidth observations since Sept. 2014.
- Shutdown for repairs since March 2017.

Future directions

- Make data archive available from Web interface.
- Investigate if it is possible to improve the data rate from the analyzer.
- Determine the exact time when each channel is scanned by the analyzer.
- Measure and compensate for the cable attenuation.
- Evaluate pointing accuracy by tracking the solar limb.

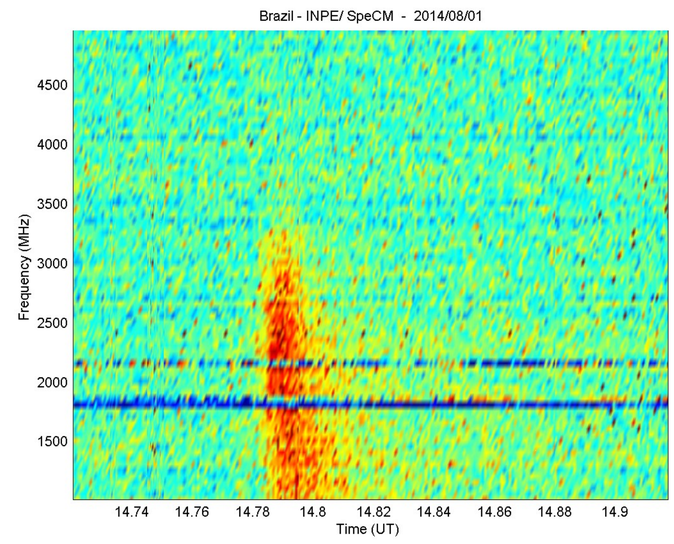
References

[1] Chernov, G. P.,2011. Fine structure of solar radio bursts (Vol. 375). Springer Science & Business Media.

[2] E. Ebenezer, 2014. Conclusion of hardware and software with broadband dynamic spectrum generation for solar observations with SPECM to complement BDA. CNPq report.

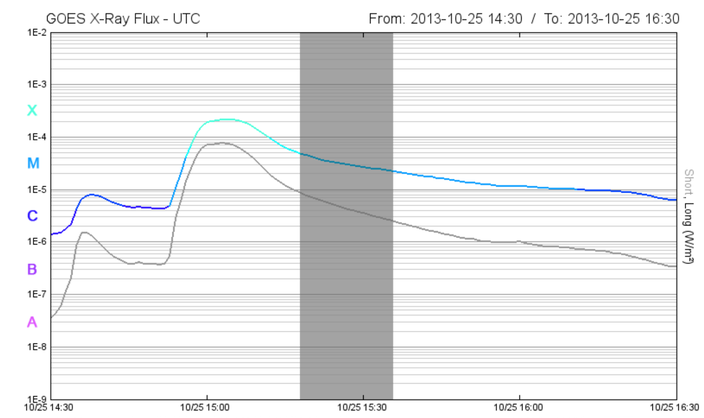
[3] McLean, D.J., Labrum, N.R., 1985. Solar Radiophysics. Division of Radiophysics. CSIRO, Sydney, Australia, p. 291.

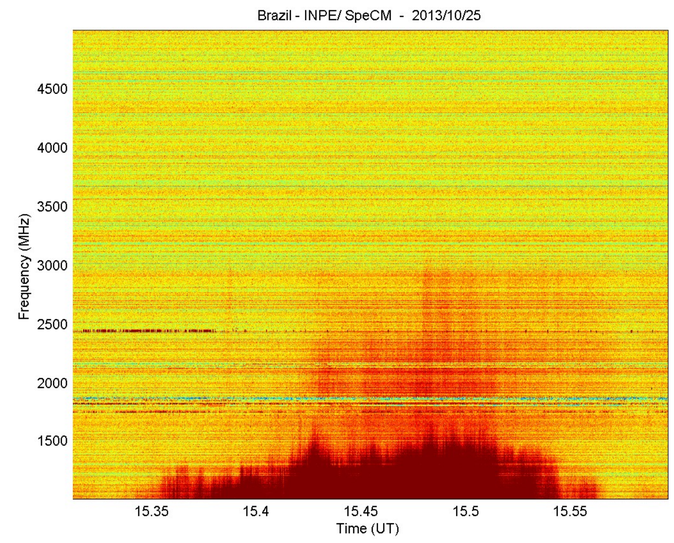
Observation: Type III burst



Type III bursts are the fast frequency drifting signatures in the dynamic spectrum. They have been observed from kHz to GHz and interpreted as the radio signatures of energetic electron beams propagating along the magnetic field lines in the solar corona or interplanetary space with a speed of 0.2 – 0.6c [3]. Type III bursts are the possible radio precursors of the flare and CME. One such burst was observed at SPECM on August 1, 2014 [2].

Observation: Fine Structures





Fine structure (bottom figure) seen in October 25, 2013 recorded from 15:18 UT to 15:36 UT [2], around 20 min after the peak of a X2.1 class event (shaded region in the GOES plot above). Structures above 2000 MHz may not be visible due to the limited bandwidth of the amplifier used at that time. There are various fine structures e.g. zebras, fiber bursts, spikes, pulsations, and so on. They are produced by different mechanisms during the different phases of flare. The study of the fine structure of the solar radio emission is a key to understanding the plasma processes in the solar corona. Plasma mechanism is predominant in the metric and decimetric bands. Therefore, the data of high temporal and spectral resolution can improve our studies about the fine structures from the flare and CME [1].