CALLISTO spectrometer for solar radio bursts monitoring in Chiangmai

N Prasert¹, A Phakam¹, K Asanok¹, P Jaroenjittichai¹, A Chumthong¹ and T Thongmeearkom¹
¹National Astronomical Research Institute of Thailand, Chiangmai, 50180, Thailand
*E-mail: nkom@narit.or.th and nphyiii@gmail.com

Abstract. Solar radio bursts are important phenomena for studying solar activities such as flares and coronal mass ejections (CMEs). A worldwide network is ≃ 90 stations, known as, e-CALLISTO, has been developed such purpose. This CALLISTO spectrometer was installed at Princess Sirindhorn AstroPark, National Astronomical Research Institute of Thailand, Chiangmai, in January 2019. The instrument has been designed for monitoring and collecting the data of solar radio activities at the frequency range between 45 and 870 MHz. In this paper, we report the installation and preliminary measurements of the CALLISTO spectrometer. The data collected will be stored in Radio Astronomy Center of NARIT and transferred to the ETHZ data archive.

1. Introduction

A Compound Astronomical Low-cost Low-frequency Instrument for Spectroscopy and Transportable Observatory (CALLISTO) is a programmable heterodyne receiver designed by Swiss Federal Institute of Technology in Zurich (ETHZ), Switzerland. The frequency coverage of this spectrometer is between 45 and 870 MHz with a frequency resolution of 62.5 kHz. The detector sensitivity is about 25 mV/dB, which covers the dynamic range of 50 dB. The maximum sampling rate with an internal clock of 800 S/s over 200 channels, while the integration time is about 1 ms. This frequency range allows for solar activities observation such as solar flares and coronal mass ejections (CMEs). Since solar flares and CMEs can be excited the plasma oscillation which results in term of radio emission in the order of metric and decametric wavelengths, i.e. called solar radio bursts. They can be classified into five main types [1]. The characteristics of these bursts are summarized in table 1 [2]. Besides, the numbers of CALLISTO spectrometer around the world ≃ 90 stations have been formed the extended CALLISTO (e-CALLISTO) network dedicated for 24 hours a day solar radio bursts observation throughout the year [3].

Here we report on the implementation of CALLISTO spectrometer for solar radio bursts monitoring in Chiangmai station at Princess Sirindhorn AstroPark, National Astronomical Research Institute of Thailand (NARIT). It includes instrument setup in this station, some preliminary results of measurement and the summary.

2. Instrument setup

CALLISTO spectrometer in Chiangmai station was installed since January 2019, this station there is geographical coordinates of 18:51:00 N, 98:57:36 E and 332 meters above mean sea-level.
Table 1. The summarize of solar radio bursts classifications [4]

| Type | Characteristic | Duration | Frequency bandwidth | Associated phenomenon |
|------|----------------|----------|---------------------|-----------------------|
| I    | Short-duration and narrow band bursts superimpose with continuum emission | Single burst \( \simeq 1 \) second, Noise storm for hours or days | 50-500 MHz | Active regions, flares, eruptive prominences |
| II   | Irregular slow drifting bursts towards lower frequencies accompany with second harmonic | 3-30 minutes | 20-150 MHz | Flares, CMEs |
| III  | Fast drifting bursts occur in singular, groups or storms | Single burst 1-3 seconds, Group 1-5 minutes, Storm minutes-hours | 10 kHz-1 GHz | Active regions, flares |
| IV<sub>s</sub> | Smooth varying of broadband continuum emission | Hours -days | 20 MHz-2 GHz | Flares, proton emission |
| IV<sub>m</sub> | Slow drifting and smooth varying of broadband continuum emission | 30-120 minutes | 20-400 MHz | Eruptive prominence, CMEs |
| V    | Smooth and short lived continuum emission with follow by Type III | 1-3 minutes | 10-200 MHz | Active regions, flares |

The main system of this station is shown in figure 1, which consists of an antenna, a low noise amplifier (LNA), a receiver, and a PC.

![Figure 1. Schematic diagram of CALLISTO spectrometer system at Chiangmai station, these consist of antenna, LNA, receiver, and PC.](image)

The antenna used in the system is a log-periodic dipole antenna, which there is the frequency range between 50 MHz and 1300 MHz. The half power point is about 60-70 degrees with forwarding gain in free space of 6-7 dBi. The impedance is 50 ohms which matches to its receiver (CALLISTO spectrometer). This antenna is fixed installation, pointed toward the West direction.
with an elevation of 60 degrees and a height of 4.5 meters above the ground (figure 2). It is connected to 20 dB gain LNA via 4 meters LMR-400 cable and then connected to CALLISTO spectrometer over the same type of cable with 4 meters long. The LNA, spectrometer, and PC are installed inside the container.

![CALLISTO spectrometer system at Chiangmai station. A log-periodic dipole antenna is installed outside, and other components are installed inside the container.](image)

3. Preliminary results
We have determined the optimum direction to point antenna and frequency range for solar radio bursts observation at Chiangmai station by conducting radio frequency interference (RFI) measurement. Preliminary results showed that the strong RFI suffer to LNA and produce cross-modulation due to saturation in the semiconductor, we then removed the LNA from this system and measured the signal again. The result showed that cross-modulation was canceled out. We continued to measure RFI again and found the lowest RFI in the West direction. However, both the upper and lower edges of this frequency range still wasted by presenting very strong RFI when compared to the referenced signals (the blue line in panel (a) of figure 3). Therefore, the available frequency range for solar radio bursts observation at this station is between 300 MHz and 580 MHz (figure 3 (a)). From this measurement, we can also determine external RFI at this station by using equation (1) [5]:

\[ Y_{dB} = \frac{V_{RFI} - V_{ref}}{25.4mV} \]

where \( Y_{dB} \) is the external RFI in dB, \( V_{RFI} \) is the measured RFI in mV, and \( V_{ref} \) is the measured 50 ohms terminator in mV. Figure 3 (b) shows calculated external RFI; this implies that how
strong RFI over spectrometer frequency range regardless of the internal noises and internal RFI. It confirms that both upper and lower edges of this frequency range are not suitable for solar radio burst observation as external RFI is significant high.

![Graph showing RFI and reference signals](image_url)

**Figure 3.** A plot of the CALLISTO spectrometer’s receiving signals in the West direction at Chiangmai station. In panel (a) measured RFI (red) and reference signals (blue), and in (b) external RFI (cyan) were determined from the measured RFI and reference signals.

We have determined the flux density of incoming RFI by using equation (2) [5]:

\[ S_{RFI} = \frac{2kT_{RFI}}{A_{eff}} \]  

where \( S_{RFI} \) is the flux density of incoming RFI (in dB), \( k \) is the Boltzman constant \((1.3806485 \times 10^{-23} \text{J/K})\), \( T_{RFI} \) is the antenna temperature of RFI (in Kelvin), and \( A_{eff} \) is the effective aperture of the antenna (in m²). We can determine the minimum system sensitivity by using equation (3) [5] as follow:

\[ S_{min} = \frac{2k\Delta T}{A_{m eff}} \]  

where \( S_{min} \) is the minimum system sensitivity (in dB), \( \Delta T \) is the temperature resolution (in Kelvin), and \( A_{m eff} \) is the effective aperture of the main beam (in m²). The flux density of incoming RFI and minimum system sensitivity are shown in figure 4. The cyan line represents the flux density of incoming RFI, and the green line represents minimum system sensitivity. The mean value of flux density of incoming RFI at the frequency range of 300 MHz to 580 MHz is about -196 ± 6 dB. This result indicated that incoming RFI limit the sensitivity of the system. Similarly, the solar flux density measurement of solar radio bursts are limited by this value of incoming RFI.

After installation, the results showed that there was no solar radio burst found. One possibility could be explained this happening because there was no solar radio burst that strong enough when compare to the flux density of incoming RFI and system background has been reported. Therefore, the LNA is necessary for the CALLISTO spectrometer system to amplify these weak solar radio burst detectably. However, we have to add FM notch filter in front of the LNA to suppress the strong RFI at the lower frequencies of CALLISTO spectrometer.
Figure 4. Flux density of incoming RFI (cyan) and system sensitivity (green) of CALLISTO spectrometer.

4. Summary
CALLISTO spectrometer at Chiangmai station was successfully installed since January 2019. After installation, we have measured the RFI environment at this station and found that the optimum position is in the West direction and the frequency range for solar radio bursts observation is between 300 MHz to 580 MHz. Therefore, when compared to the list types of solar radio bursts, some of them are limited to observe due to the high level of noises, e.g. type II and V.

We have also determined the flux density of incoming RFI of this station and the mean value of flux density of incoming RFI at the frequency range of 300 MHz to 580 MHz is about -196 ± 6 dB. This value indicated that incoming RFI limit the sensitivity of the system, which means that it also limits the solar flux density measurement of solar radio bursts.

In addition, there was no solar radio burst found since the installation has been finished. Because their reported flux density of solar radio bursts are not strong enough when compared with the flux density of incoming RFI and the noises of the system background. Therefore, the LNA is necessary for the system, but we have to add FM notch filter in front of LNA to suppress the stong RFI signals.

References
[1] Zucca P, Carley E P, McCauley J, Gallagher P T, Monstein C and McAteer R T J 2012 Sol. Phys. 280 591
[2] Monstein C 2016 Catalog of Dynamic Electromagnetic Spectra (Zurich: Institute for Astronomy)
[3] Benz A O, Monstein C, Meyer H, Manoharan P K, Ramesh R, Altyntsev A, Lara A, Paez J and Cho K S 2009 Earth Moon Planets 104 277
[4] Sasikumar Raja K, Subramanian P, Ananthakrishnan S and Monstein C 2018 arXiv e-prints arXiv:1801.03547
[5] Monstein C 2012 Radio Interference versus Receiver Sensitivity (Zurich: Institute for Astronomy)