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Coverage of Solar Radio Spectrum in Malaysia and Spectral Overview of Radio Frequency Interference (RFI) by Using CALLISTO Spectrometer from 1MHz to 900 MHz

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Abstract: Solar radio emission has become increasingly interested in attempts to understand the Sun activities during maximum and minimum cycle. Present work deals with Radio Frequency Interference (RFI) testing measurement for the solar monitoring purpose. The progress of CALLISTO network is also being discussed. Implications of the results for large scale of CALLISTO coverage are reviewed. Observational tests of Radio Frequency Interference (RFI) are also explained. In short, we conclude that National Space Centre, Sg. Lang, Selangor Malaysia is one of the strategic countries to monitor the Sun due to consistent 12hours per day throughout the year. When a module of subtraction of RFI automatically implemented for each data, one can study the evolution of solar bursts and further predict the behavior of solar flare other solar activity phenomena.

Key words: Solar radio emission · Solar burst · Radio Frequency Interference (RFI) · RFI sources · e-Callisto

INTRODUCTION

Solar radio emission has become increasingly interested in attempts to understand the Sun activities during maximum and minimum cycle. It arises from several different phenomena and can be divided into three (3) main components (i) the quiet sun component, which is always present, (ii) the slowly varying component and (iii) the active sun component which is caused by sunspots and flare activity. However, the dynamics of the solar corona is still not understood and new phenomena are unveiled every year [1]. There are many review has been described on this issue including [2] and [3] for observational reviews, [1, 4, 5] for the theory of radio emission in these bursts and [6, 7] for the relationship with space weather. It is well understood that different region of the Sun is observed at different wavelength. The study of radio emission, specifically solar burst is the great area of interest because it is related to space weather environment. Solar radio emission correlates well with solar EUV flux [8], a fact which makes it important. Untill now, one still unresolved puzzle about the chromosphere is why at some frequencies (at least 10-100 GHz) the polar coronal holes appear brighter than the rest of the quiet Sun. The radio emission is thought to be produced by the plasma emission mechanism [9], involving the generation of Langmuir waves by nonthermal electrons accelerated during the eruption and the conversion of Langmuir waves to electromagnetic radiation. Meanwhile, radio spectrum is very important in order to detect weak emission from celestial sources in radio astronomy compare with other electromagnetic spectrum. At decimeter wavelength, the burst is highly variable and complex.

In general, solar bursts consist of five (5) main types; (i) short, narrow band events with a broader band continuum (ii) slow drift from high to low frequencies associated with fundamental and second harmonic frequency structure (iii) Rapidly drift from high to low frequencies and often accompany the flash phase of large flares (iv) burst related broadband continuum and (v) broadband continua which may appear with III bursts that

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last 1 to 2 minutes, with duration increasing as frequency decreases. All of these bursts originate by bremsstrahlung, gyrosynchrotron and plasma radiations. Between these bursts, type III is the most associated with solar flares. Solar radio bursts (types I, II, III were then known) are due to ‘plasma emission’ in which Langmuir waves are excited and secondary processes produce escaping radiation near the plasma frequency and its second harmonic. Type II is the most recent interest focuses because it be possible to predict the potential of radio emission regarding CMEs heading toward Earth [10]. Meanwhile, type IV bursts are associated with very energetic CMEs (average speed ® 1200 km/s), confirming the earlier fnding by [11] for the continuum events at metric wavelengths. Melnik *et al*. [12] reported on the properties of type IV bursts observed by ground based radio telescopes operating in Ukraine in the frequency range 10-40 MHz. Associated with Type III bursts are the last of the original classes of meter-wavelength radio bursts, type V. It can be characterized by long-duration low-frequency component that looks to be attached together with the decay phase of the type III burst.

Study of radio emission specifically in radio bursts at low frequency become extensively serious for a CALLISTO network research developed by Monstein in 2002. Our study is focused on low frequency from 45 MHz till 870 MHz with 19 sites all over the world to obtain 24 hours solar monitoring. Up to date, coverage of solar activities has been reached more than 90 percent. In Malaysia, solar radio research has just started since 2011 and joining the e-CALLISTO network is one of our strategy. Construction Log Log Periodic Dipole Antenna (LPDA) and installation of CALLISTO system has successfully done by 22nd February 2012. Our data consist 12 hours monitoring per day.

However, as more and more diverse uses for the radio spectrum emerge, the number of signals that may potentially cause interference inexorably increases. The increasing of technological applications exponentially affected range that's suitable for solar observations. Moreover, the sensitivity of equipment and other ground based noise also produce some minor impact of the noise level. In addition, population density and site of observations also need to be considered. The growing demand on electromagnetic spectrum especially in the radio wavelength could not neglect. This scenario has also happened all over the world. Radio frequency interference (RFI), a cyclostationary signal that statistically a periodic signal could come from different sources and frequencies. As a result, spectrum manangement of Radio Frequency Interference (RFI) now becoming an issue that need to be focused and protected.

This paper contains two (2) analyses that address (i) coverage of Solar Radio Spectrum in Malaysia and (ii) spectral overview of Radio Frequency Interference (RFI) by using CALLISTO spectrometer in 1MHz to 900 MHz. System configuration and coverage of solar spectrum will be discussed in section 2, while the Radio Frequency Interference (RFI) testing will be explained in the following section. Discussion and conclusions are presented in section 4.

Callisto System Configuration and Malaysia Solar Spectrum Coverage: In recent years, Compact Astronomical Low-cost Low-frequency Instrument for Spectroscopy in Transportable Observatories (CALLISTO) spectrometer is been used extensively as a heterodyne receiver designing and leading by Christian Monstein and Radio and Plasma Physics Group from ETH Zurich, Switzerland in order to study the magnetic activity of a wide range of the Sun [13]. Radio spectrometers of the CALLISTO type to observe solar flares have been distributed to nine locations around the globe [14]. This detector also operates since 2002. The e-CALLISTO system has had its first success already in December 2006, when the last large flares of the present cycle occurred [14]. In principle, data that obtained from CALLISTO can be transferred to a computer and saved locally via a R232 cable in FIT files. Current solar observatories, it provides a wealth of data at high spectral, temporal and spatial resolutions with specification of 0.25 sec time resolution and 1 millisecond integration time. Besides concentrating on determination of solar burst at range 45-870 MHz, we can investigate the correlation between total duration, peak, flux and total energy of the extended decimeter of radio emission. This study also revealed the prediction of a solar trend by comparing solar flare in X-ray region. It is lead us to understand factors in global climate change which is believed to be closely related with Sun activities. The Compact Astronomical Low-cost Low-frequency Instrument for Spectroscopy and Transportable Observatory (CALLISTO) has been described in detail by [15].

We have successfully installed the CALLISTO system at National Space Centre, Banting, Selangor located (3°5'00N 101°32'00E). This is one of candidate sites for radio astronomical purpose in Malaysia. Figure 1. showed the current status CALLISTO coverage in Malaysia compared with worldwide coverage in universal time (UT) and month of the year parameters.

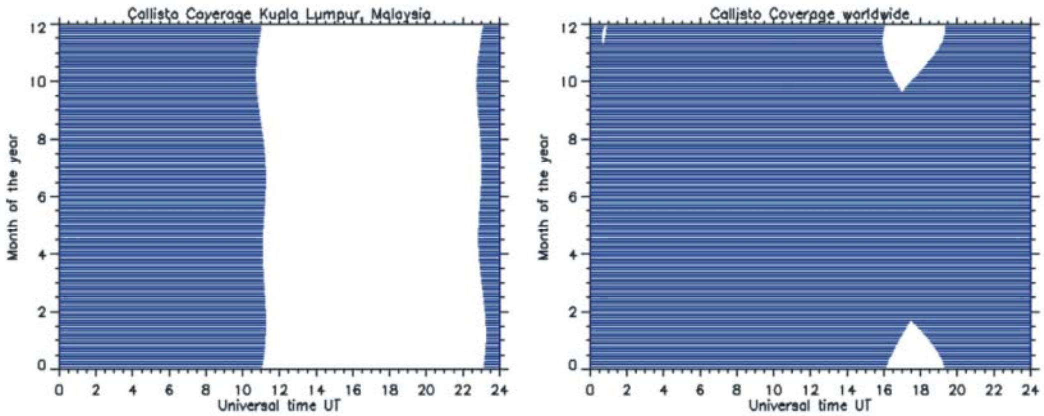

Fig. 1: Current status CALLISTO coverage of Kuala Lumpur Malayisa (on left) and worldwide (on right)

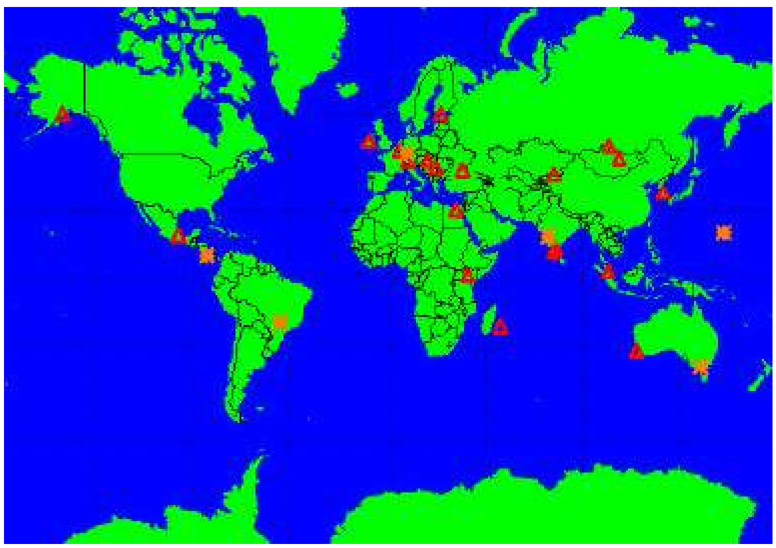

Fig. 2: IDL map e-CALLISTO distribution

Radio Frequency Interference (RFI) Testing: Due to 12 hours monitoring, Malaysia almost covered fifty percent of the CALLISTO data. This makes our data should be reliable and consistent. It also an advantage for us to observe solar activities especially solar flare and Coronal Mass Ejection (CMEs) phenomena in a long term period. So far, there are 19 sites that confirmed obtained a daily data from CALLISTO network. There is a gap between 16 to 18 hours for that make us could not observe the Sun in October to February. 24 hour solar monitoring throughout the year could be fulfill if there is a site that interested to join this research group. The candidate sites are Ethiopia, Scotland, Ecuador, Peru, Turkey, Spain and Nigeria countries. Distribution of CALLISTO data using IDL map is shown in Figure 2.

Recent work has shown the spectral overview at ANGKASA, measured with a 20dB preamplifier is presented in Figure 2. It must be emphasized that there is an interference level which are rather high with up to 50 dB external interference. Apparently, It is shown that in the UHF-band we can recognize (besides a lot of analog-TV) two (2) DVB-T channels between 650 MHz and 700 MHz. Meanwhile, it also observed that there is a high level interference is received from FM-band (80 MHz-108 MHz), from VHF-band and from UHF-band. It is interesting to note that from the analysis, we also can detect mobile phone transmission while around 390 MHz a strong signal from TETRA (international police communication) at a frequency above 850 MHz. An interesting feature we can observe between 240 MHz and 280 MHz. It shows downlinks from US military satellites with about 10 dB above the noise level.

In our case, the purpose of doing so was to find out if there was only influenced from other means that have been included in the measurements of those orientation distributions of the samples. This will helps us

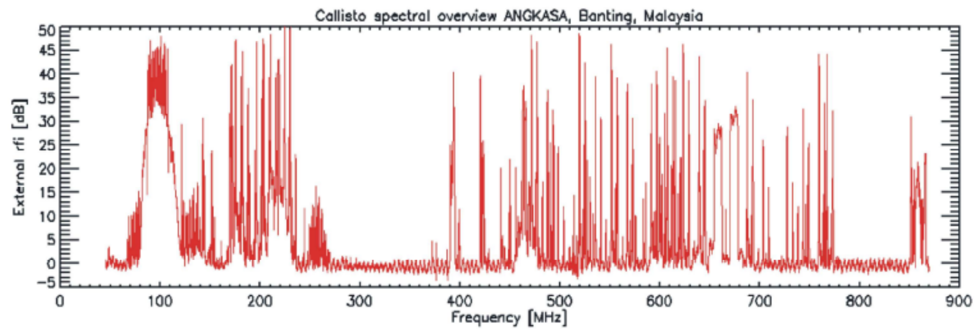

Fig. 3: Spectral overview measured in National Space

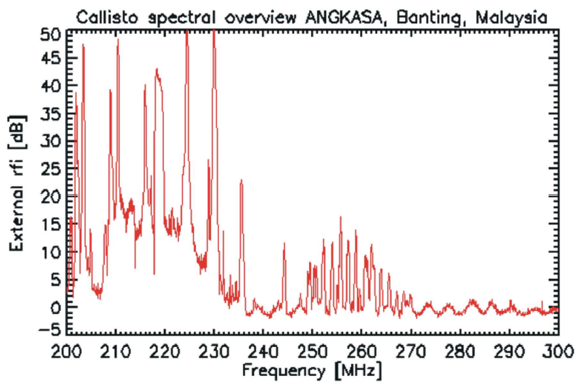

Fig. 4: External RFI from local interference in dB unit

to appreciate what questions we might hope to answer by analyzing the frequencies. If the impression effect can be filtered out, the actual orientation of solar bursts could be predicted. The testing was carried out by conducting RFI measurement for a day period. Measurements were done with a log periodic dipole antenna pointing to the zenith connected to the CALLISTO spectrometer with detector sensitivity of 25mV/dB and channel resolution is 62.5KHz designed and built by ETH Zurich (Benz, 2004). A preamplifier was mounted between the Log Periodic Dipole Antenna (LPDA) with long cable directly to CALLISTO spectrometer.

RFI survey has been done in a day starting from 9.00am till 17.00 pm on 21st of February 2011. Measurement direct to the Sun is called ON-source while the measurement away from the sun is called the OFF-source. We then identify the continuous signal of frequency responses from the CALLISTO spectrometer. Data then will be transferred to a computer for further analysis. This measurement involve technical basis to decide how to continue concerning spectroscopic measurements below 870 MHz. Occasionally, the Sun was very quiet a few days after installation and configuration. Detailed analysis also revealed the interference sources that caused an interruption of solar signal. In order to achieve a good signal of the Sun, it is necessary to recognize the range of minimum interference. Figure 4 shown the spectral overview measured in National Space Agency from 1-900 MHz. Spectral overviews from 1-900 MHz in dB unit is illustrated in Figure 3.

Centre, Banting Selangor from 1-900 MHz in dB unit It must be emphasized that there are different types of interference unpredictable, well-known interference, permanently and non-permanently RFI. From the present data one may derive several predictions. Based on the spectral overview, a lot of military satellites between 190 MHz and 270 MHz and a local oscillator at 296 MHz. Several bands of spectral ranges are almost free from interferences. We can clearly observed that in the range of 300 MHz till 400 MHz, this part of the spectrum is very clean and undisturbed. In additon, we can also used the range from 250 till 270 MHz although there is a moderate interference. All reserved frequencies are still free from interference. Unfortunately, most of the strong and fluctuate interferences are home made by local electronic devices and local oscillators and clearly been seen from 85 MHz till 150 MHz. However, it would be difficult or impossible to eliminate it completely. Due to the results, three (3) frequency ranges can be identified for useful astronomical observations (i) between 45 MHz and 80 MHz (ii) between 240 MHz and 380 MHz and (iii) between 780 MHz and 850 MHz.

To further illustrate the influence of RFI, we made a narrow range of frequency beginning from 200 MHz till 300 MHz as in Figure 4. From the instrumentation aspect, this ‘comb’ of signals proves that the whole system is working correctly with good sensitivity. This feature can be used to check the system as part of periodic maintenance. However, there is a noise floor at all frequencies below 3 dB is in fact not noise, but represent standing waves due to the fact that the LPD antenna is not matched to the 50Ω coaxial cable (boom distance is too small). Total sensitivity can be improved by impedance matching of the antenna and RG8 coaxial cable.

DISCUSSIONS AND CONCLUSION

In order to solve such problem, we strongly suggested that this monitoring should be consistently being doing in order to avoid irrelevant data while doing observations. There are many different methods for both determining the presence of RFI in an observation and also for removing it. These include online techniques, where the correction is applied in real time as the signal is received, detected and integrated and offline techniques; with the correction occurring after the signal has been recorded. However, the growing number of radio applications is deteriorating the radio frequency spectrum every year, consequently continuous RFI monitoring is obligatory. We could not prevent the increasing of RFI sources but we can eliminate it by subtracting the background data in the analysis process. One of the best ways to ensure the safety of radio astronomical measurements is by choosing the protected frequency bands for the measurements. It is suggested that the antenna that will be constructed for the e-CALLISTO system should have a higher gain and sensitivity in order to get a good data and eliminate unwanted signal of RFI. It should be noted that the cable that connected from the antenna to the spectrometer should be less than 5 meters. It is hoped that the survey will continue from time to time in a consistent mode so that any polluted signal for radio astronomy purpose can be protected.

In short, we conclude that more work is required before we will be in a position to analyze the nature of solar radio bursts, although preliminary indications are promising. The growing number of radio applications is deteriorating the radio frequency spectrum every year, consequently continuous RFI monitoring is obligatory. We could not prevent the increasing of RFI sources but we can eliminate it by subtracting the background data in the analysis process. One of the best ways to ensure the safety of radio astronomical measurements is by choosing the protected frequency bands for the measurements. Finally, we want to mention that the observation of RFI would give a clear picture for us to select a good data. In short, we conclude that National Space Centre, Sg. Lang, Selangor Malaysia is one of the strategic countries to monitor the Sun due to consistent 12hours per day throughout the year. When a module of subtraction of RFI automatically implemented for each data, one can study the evolution of solar bursts and further predict the behavior of solar flare other solar activity phenomena.

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