Automated PC-Based Control and Monitoring of Radio Observations Using LPDA

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Abstract

Automated PC-based control Log Periodic Dipole Antenna (LPDA) performance of solar burst monitoring in the range of 50-300 MHz is presented. The paper describes signal detection by LPDA designed for solar monitoring with very high-performance. Low-frequency solar radio emission arises in the solar atmosphere at the levels where events like solar bursts have been identified. The different type of radio burst are described and illustrated using data received at Kalyani and their potential use as diagnostics of Space Weather is discussed.

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Introduction

Discovery of solar bursts from the Sun opened a new vista in the field of solar radio astronomy. Solar radio bursts are basically a radio demission of solar flares which emphasizes its brief energetic and explosive characteristic. The classification of bursts is based on frequency drift rate, bandwidth, and duration of the emission. There are five fundamental types of solar burst (I, II, III, IV and V) which are generated by beams of fast electrons at levels of the local plasma frequency. One of the main reasons of detecting solar burst is as it can be used as an important tool for specifying magnetic, thermal and density structures at the time. Solar radio bursts at low-frequency originate in the same layers of the solar atmosphere in which geo-effective disturbance is assumed to originate. This is where the solar flares and Coronal Mass Ejections (CMEs) are to launch. Solar flares, a sudden large energy release in the magnetic active region, are an important active manifestation of solar activity. It might be defined as a rapid
brightening in H-alpha, but simultaneously can have manifestations right across the electromagnetic spectrum. Further, most solar emission contains the plasma emission which is also related to Langmuir waves. Plasma emission is prevalent in the solar atmosphere, appearing in some form quite a large fraction of flares [1]. High sensitivity and resolution studies of so-called decametric continuum showed that the continuum is composed of several kinds of bursts. Generally, type III burst occurs in groups of overlapping burst are due to upward and downward directed beams of non-thermal electrons, considered as one of the best indicators of release of electron beams near the Sun along open magnetic field lines. At low frequencies, where the radiation lasts for some ten of minutes, single burst are not common except during the quiet times. Automated PC-based control and monitoring was employed for the present investigation of radio observations. With a brief description of the technique employed, some interesting results are presented in this paper.

2. Log Periodic Dipole Antenna

The Log Periodic Dipole Antenna (LPDA) is essentially a coplanar linear array of parallel linear dipoles fed by a twisted balanced transmission line that suit for wide band applications. It also plays an important role in the modern communication and radar system [2]. This straightforward design is capable of operating over a frequency range of about 2:1. It is designed on the concept of gradually expanding periodic structure array which radiates most effectively when the array elements (dipoles) are resonances. We constructed Log Periodic Dipole Antenna to cover the range of frequency from 50 MHz till 300 MHz with a view to monitoring solar activities. They consist of two crossed logarithmic periodic dipole antennas, one aligned in north-south direction while the other in east-west direction. Log Periodic Dipole Antenna (LPDA) is a type of antenna that requires an N number of elements with different size for driving the voltage loaded by arbitrary reactors at each center. One advantage of LPDA is the boom length of the antenna that enhances a greater performance particularly in gain compared to Yagi antenna [3]. However, it might be too long depending on the range of the frequency. Radiation from the quiet Sun is produced by the thermal mechanism of bremsstrahlung, and radio bursts of several kinds are produced by the non-thermal mechanisms of plasma radiation and also rarely, gyro synchrotron radiation can be detected by using LPDA [4]. A diagram of the log-periodic dipole array antenna is shown in Fig 1. A standard crisscross connection was assumed and implemented with two parallel layer structures by the black and white colors.

In order to demonstrate the frequency dispersion observed in the output pulses generated by an LPDA antenna, we adopt the differentiated Gaussian pulse as the waveform that is used for exciting the current sources to drive the LPDA elements. It has a highly capacitive nature and the far zone electric field generated by this infinitesimal dipole antenna is proportional to the time derivative of the current pulse that excites it. An infinitesimal dipole can thus radiate theoretically all of the frequencies in the bipolar pulse driving it. LPDA can be matched to a realistic source over a wide range of frequencies [5, 6].

The basic positioning of two static antennas to form a uniform wide angle beam is presented in Fig 2. Both the
antennas form a uniform beam within the angle subtended by them based on the uniform gain power spectrum antenna pattern theorem. Combining the power of more antenna pairs it behalves like an array with increased sensitivity and uniform gain [7].

Fig. 2. Basic positioning of two static antennas to form a uniform wide angle beam.

The design dimensions of the log periodic antennas have shown in Fig 3. The central transmission line of the design is not exhibited in the figure. The system consists of a pair of square aluminum tubes connecting all the dipoles in zigzag fashion and hence acts like a transmission line.

In the actual pattern, a metallic skeleton structure built with aluminum tubes in a manner so that a metallic mesh spread out. The size of the mesh is less than 10 cm, which is one tenth of wavelength corresponding to 300 MHz. This type of construction is preferred for reducing the manufacturing cost of the system.


Magnetic reconnection topologies that may apply in the formation of flares are shown in Fig 4. Three models have shown in the figure before (upper row) and after (lower row) reconnection. The left column reveals reconnection
of two open field lines in a “helmet–streamer” configuration for producing one closed field line and one open field line no longer connected to the solar surface at either end; the middle column exhibits the “quadrupolar” configuration in which two closed field lines reconnect for producing two new closed field lines; and the right column shows the case where one open and one closed field line swap topology [8, 9].

Solar radio bursts were amongst the first phenomena identified at frequencies below a few hundred MHz and classified into five types. Solar flares and CMEs can excite plasma oscillations and emitting radiation at metric and decametric wavelengths. Type I bursts are short-duration narrowband features that are associated with an active regions [10–12]. Type II bursts are thought to be excited by magneto-
hydrodynamic shockwaves associated with CMEs [13], while Type IIIs are due to energetic particles escaping along open magnetic field lines. Type IV bursts show broad continuum emission with rapidly varying fine structures [14]. The smooth short-lived continuum following a Type III burst is called a Type V. For Space Weather studies, three of the burst types are most relevant viz. Types II, III, and IV.

Fig. 4. Magnetic reconnection topologies that may apply in the formation of solar flares [3]

Fig. 5. Some plots obtained from different CSV files showing different peak values
Here we have shown in Fig 5 some typical bursts recorded in our laboratory using automated PC-based control of observations as recorded in spectrum analyzed and simultaneously stored in storage oscilloscope. We correlated the recorded data with the data reported by SWPC (Space Weather Prediction Center), we converted the time of recording, which is in IST (Indian Standard Time), to UT (Universal Time). All the plots given below have their time in UT (UT = IST – 5 hr 30 min).

Fig. 6. Some other typical bursts recorded on (a) February 28, 2013 and (b) March 5, 2013 in our laboratory, showing characteristic differences with time on the same date.
In Fig 6 we have shown some other 10 seconds plot obtained from different CSV files, each showing different peak values. The solar spectrum shows many spectral lines which are mostly absorption lines that tell us that the temperature falls to lower values above the photosphere, to about 4500 K in the temperature minimum region. But what is surprising is that above this height the temperature rises again, and in fact rises very steeply at about 2000 km above the photosphere to form a very hot (several million K), very tenuous plasma that we call the corona. In the core of the sun there is a massive thermo-nuclear reaction is taking place which generates very short wavelength energy (gamma and x-rays). This energy works its way to the surface of the sun and the wavelength gets elongated into the radio wavelengths which become the background radiation from the sun called the solar flux (SF).

If the sun is radiated as a thermal source only, then the brightness received would vary directly with frequency, from ultraviolet and visible light to the radio spectrum. This is called Plank’s black body radiation law. Optical observations at different wavelengths do follow the black body radiation which proves that optical wavelengths from our sun are thermally generated. However, radio energy does not follow black body radiation, proving the radio energy from our sun is not generated thermally.

4. Conclusions

The Sun is considered as very active star that produces large-scale energetic events like solar flares and coronal mass ejections (CMEs) which are observable across the electromagnetic spectrum, from gamma rays at hundreds of MeV to radio waves with wavelengths of tens of metres. Understanding the signal patterns assist to recognize any kind of unwanted signal toward a more accurate data eliminating noise by subtracting the background. It further helps to avoid the range of frequency which has permanent interference. Thus it can provide a quality data and best results of analysis process. The nature of low–frequency solar radio bursts and their potential for the study of Space Weather is enormous. Solar radio observations will continue to play an important role in Space Weather studies as they are sensitive to the regions of the solar atmosphere where many Space Weather phenomena originate. They can also find features that are not visible at other wavelengths and so complement other facilities such as satellite–borne coronagraph instrumentation. In addition, Space Weather is the study of the conditions in the solar wind that can affect life on the surface of the Earth, particularly the increasingly technologically sophisticated devices that are part of modern life. Solar radio observations are relevant to such phenomena as they generally originate as events in the solar atmosphere, including flares, coronal mass ejections and shocks which produce electromagnetic and particle radiations that impact the Earth [15, 16].

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