International Journal of Electronics Communication and Computer Engineering
Volume 5, Issue 4, ISSN (Online): 2249–071X, ISSN (Print): 2278–4209

Formation and Behavior of the Solar Events Originated in Solar Bursts during the Solar Cycle Maximum Activity

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***Abstract* – The paper examines the formation and behavior of various solar events originated in solar bursts during the maximum activity of the solar cycle with special emphasis on their peak activity hours and the variation of their time differences. The analysis reveals that out of the fifteen recognized solar events for various time zones the probability of occurrences of each of the type is different. It has been noted that the XRA type is more probable than other types in the morning between 8.00 hr IST and 9 hr IST while at midday FLA and RBR events are more probable supporting that not all kinds of wavelengths are being emitted simultaneously during a solar burst.**

***Keywords* – Solar Events, Bursts, Magnetosphere, Solar Cycle.**

I. INTRODUCTION

Solar storms become more severe and more frequent during peak activity of 11-year cycles. The peak of the current cycle was expected in 2013. Since the last peak in activity, the world's reliance on electronic technology and therefore vulnerability to space weather has increased substantially. The Earth's magnetic shield, called the magnetosphere, can usually take the worst of the Sun's radiation, preventing it reaching the delicate molecules of life on the Earth's surface [1]. Normally, all we see of this high-energy radiation are the beautiful Northern Lights, the aurora borealis and its southern equivalent, the aurora australis. In 1921, space weather wiped out communications and generated fires in the northeastern United States. A study by the Metatech Corporation in 2008 showed that a repeat of the 1921 solar storm today would affect more than 130 million people. In March 1989, a geomagnetic storm caused Canada's Hydro-Quebec power grid to collapse within 90 seconds, leaving millions of people in darkness for up to nine hours. In 2003, two intense storms travelled from the Sun to Earth in just 19 hours, causing a blackout in Sweden and affecting satellites, broadcast communications, airlines and navigation. The purpose of the paper is to examine the activity of the solar events caused by bursts, with special emphasis on their peak activity hours and the variation of their time differences [1].

II. BACKGROUND

It became apparent in the early 1960s that certain space weather events might interfere with the manned mission to the moon. In particular, the Sun emits continuous electromagnetic energy and electrically charged particles which can cause disturbances in the near-Earth environment and disrupt satellite communications. Among these concerns there was the possibility of a geomagnetic storm of solar origin. Metric Type II radio bursts, signatures of coronal shock waves or coronal mass ejections, were known to be commonly associated with solar flares. The United States Air Force Research Laboratory (AFRL) was thus assigned the task of developing and validating a network of ground-based solar observatories. AFRL established a world-wide network of sweep frequency recorders from which one can estimate the shock speed in the corona. This network, called the Radio Solar Telescope Network (RSTN), uses a bandwidth from 25 MHz to 85 MHz. The prototype was assembled and operated at the Sagamore Hill Solar Radio Observatory. This observatory began operating solar patrols in 1966. The Air Force Geophysics Laboratory (AFGL, currently Phillips Lab) transferred operation of the observatory to Detachment 2 of the 2nd Weather Group of the Air Force Weather Agency in October 1978. However, Phillips Lab continues to work in an advisory capacity to the observatory.

III. TYPES OF SOLAR RADIO BURSTS

Solar radio bursts were amongst the first phenomena identified as targets for radio astronomy. Solar radio bursts originate in the same layers of the solar atmosphere where energy is released in solar flares, energetic particles are accelerated and coronal mass ejections (CME) are launched [1], [2].

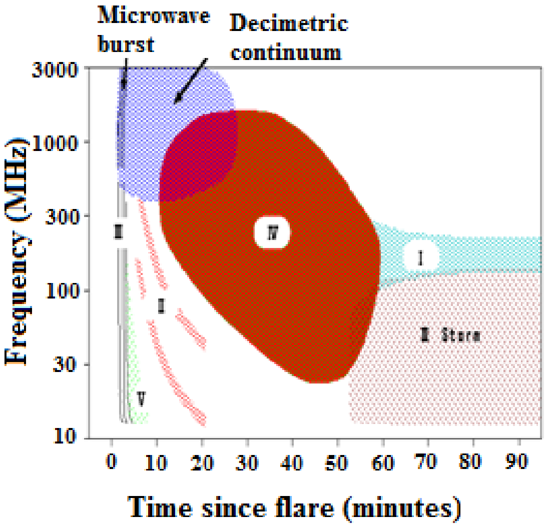


Fig.1. Schematic diagram of different bursts

Characteristic studies of solar radio bursts have great importance for determining the solar flare and CME phenomenon. Solar radio bursts at frequencies below a few hundred MHz were classified into five types. The essential features of different types of solar radio bursts are shown in the schematic diagram (Figure 1). The figure shows clearly the time since flare in minutes and the corresponding frequencies in MHz.

IV. INSTRUMENTS EMPLOYED FOR OBSERVING RADIO BURSTS

We have used Log-periodic Dipole Array (LPDA), Spectrum Analyzer and Digital Storage Oscilloscope (DSO) for capturing solar radio bursts. The digital storage oscilloscope stores and analyses the signal digitally rather than using analogue techniques. It is now the most common type of oscilloscope in use because of the advanced trigger, storage, display and measurement features which it typically provides for capturing solar radio bursts. The LPDA mainly consists of a number of dipole elements. This diminishes in size from the back towards the front. The main beam of this RF antenna is coming from smaller front. The element spacing also decreases towards the front of the array [2]. The element at the back of the array where the elements are the largest is a half wavelength at the lowest frequency of operation. In operation, with the frequency change a smooth transition occurs along array of the elements which form the active region. To ensure that the phasing of the various elements is correct, the feed phase is reversed from previous to the next element. Wind-proof LPDA antennas were developed in the department of Physics, Kalyani University. Being a simple lobe, the broadband antenna has a wide range of applications. However, design and construction of LPDA for ultra-wide band applications is highly difficult for many reasons. It is practically unviable to build LPDA antenna that covers VHF & UHF frequencies owing to the size of the antenna and the enormous amount of dipoles it would have. Further, the antenna would have low portability and its installation would be complicated and expensive, particularly to prevent the arrays with its structure as a whole during prevalent atmospheric condition accompanied by circulation of high speed wind.

The wind-proof time-shared LPDA [1] constructed at Kalyani (22.98°N, 88.46°E) in the Department of Physics, Kalyani University in West Bengal, for the purpose of capturing radio signals emitted during disturbed sun and thereby to investigate its plasma behaviour under such situation. In fact, the log-periodic antenna built is to reduce problems of frequency dispersion and non-linear phase responses over ultra wide bands besides its low cost and prevention from possible damages owing to high speed air movements even during the days of Nor'westers. Particulars of the Log Periodic Dipole Array are shown in Table I and some physical properties of the LPDA are shown in Table II.

Table I: Particulars of the LPDA

Specifications	Particulars
Frequency Range	50-300 MHz
Input Impedance	50 ohms
Symmetry	+/- 0.5 dB
Connector	Type N Female
System Gain	9-12 dB
Individual Antenna	6 dBi
Effective Gain	170-180 dBi

Table II: Physical properties of the LPDA

Physical Properties	Particulars in meters
Height	13.3
Width	3.65
Slanting Height	18.0

We used DSO of GDS-1000 series for recording purposes. In DSO vertical input is digitized by its own signal analysis software and the recorded data set is stored in the computer. The DSO's own signal analysis software can extract many useful time-domain features (e.g. rise time, pulse width, amplitude). This data set is used to detect and analyze the solar radio bursts, by comparing the amplitude of the signal voltage obtained at various time.

V. DATA RECORDING TECHNIQUES

Our receiving systems linked to two LPDAs to receive solar signals in the frequency range from 50 MHz to 300 MHz. Use of two low noise amplifiers (LNA) reduces the local noise significantly and thereafter the signal is fed to high frequency amplifier (VHF) to amplify the received signal [2]. The received signal through the amplifier is fed to the digital storage oscilloscope (DSO) connected to the master computer as well as to the spectrum analyzer.

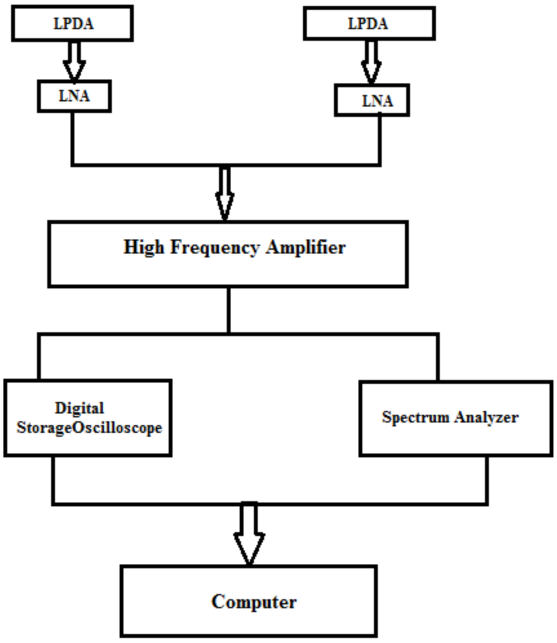


Fig.2. Our Experimental Setup

As the storage oscilloscope is used simultaneously for recording we observed constantly varying signal voltages along the vertical axis ('Y' axis), against the horizontal time axis ('X' axis). The experimental set up is shown in Figure 2. The receiving systems work in the frequency range from 50 MHz to 300 MHz. Two low noise amplifiers are used to reduce the local noises and thereafter the signal is fed to high frequency amplifier to amplify the received signal. The received signal through the amplifier is fed to connect to the master computer.

In our observing technique we have recorded the continuous solar signals from 09.00 hrs IST to 17:00 hrs (IST) with a view to detect the solar burst and other features. For this purpose, we divided the total time domain into three parts: (i) Part-1 is from 09:00 hrs to 10:30 hrs (IST), [IST– 5 hr 30 min = UT]. (ii) Part-2 is from 10:30 hrs to 14:00 hrs (IST), during which we receive direct solar signal. (iii) Part-3 is from 14:00 hrs to 17:00 hrs (IST).

VI. ANALYSES AND RESULTS

During the observations, depending on frequency differences one can detect about fifteen types of solar flare events. They are listed as: BSL = Bright surge on the limb, DSF = Filament disappearance, EPL = Eruptive prominence on the limb, FIL = Filament, FLA = Optical flare observed in H-alpha, FOR = Forbush decrease (cosmic ray decrease), GLE = Ground-level event (cosmic ray increase), LPS = Loop prominence system, PCA = Polar cap absorption, RBR = Fixed-frequency radio burst, RNS = Radio Noise Storm, RSP = Sweep-frequency radio burst, SPY = Spray, XFL = SXI X-ray flare from GOES Solar X-ray Imager (SXI), XRA = X-ray event from SWPC's Primary or Secondary GOES spacecraft. Figure 3 shows the plot for the number of occurrences against the time of occurrences of thirteen types of solar events as recorded in our observatory. It reveals that for various time zones, probability of occurrences of each of the thirteen types is different.

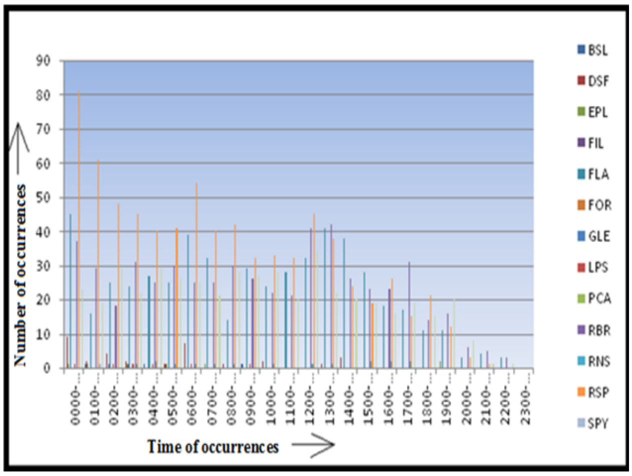
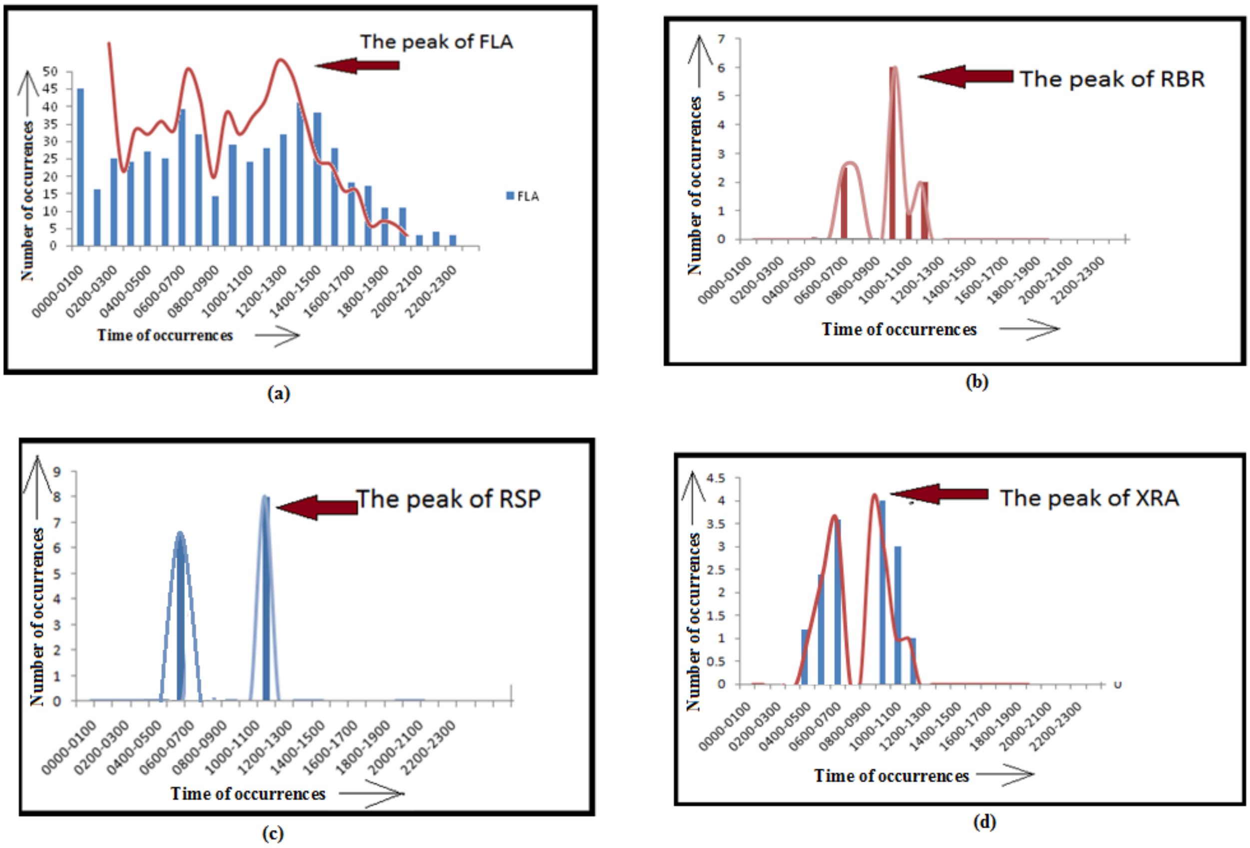


Fig.3. Difference in the number of occurrences among different types of flares for the same time zone



(a)

(b)

(c)

(d)

Fig.4. Probability of occurrences of FLA, RBR, RSP and XRA types

Other two types of solar flares, viz., PCA and XFL, could not be observed during our observational period. Also we have failed to detect some of the SPY, FIL and BSL type of flares during our observational period. According to the above Figure 4, probability of occurrences of FLA, RBR, RSP and

XRA types are found to be greater. It is interesting to note from the observed data that XRA type is more probable than other types in the morning between 8.00 hr IST and 9 hr IST. On the other hand, at midday FLA and RBR are marked to be more probable. Therefore, it appears that not all kinds of wavelengths are being emitted simultaneously during the solar activity.

6.1 Typical Record of Bursts

When we recorded the data, the variation of solar radio signal with time was digitalised and stored in the computer in the form of CSV (commas separated value) file. As we had set the time per division knob of the DSO as 10 second, we got the variation of solar radio signal for an interval of 100 seconds in each CSV file. Each file contains its time of recording. The plot of one such file is shown in the Figure 5.

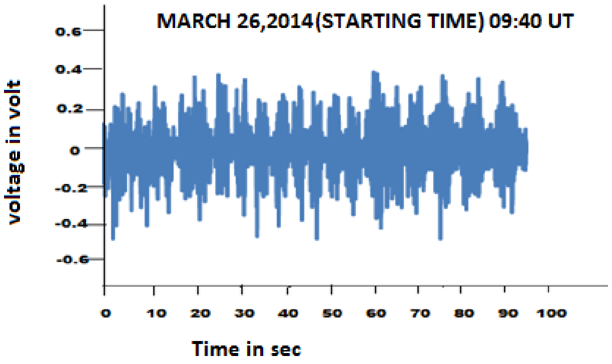


Fig.5. Variation of amplitude of solar radio signal with time as obtained from one CSV file

Using these CSV files, we analyzed these solar signal variations. We made a note of the onset time, peak time and ending time of the solar bursts recorded on a particular date. When we obtained a burst (solar signal amplitude going beyond 0.1 volt), we isolated the peak values of the bursts while recording the time of the corresponding values and take out the mean of the non-burst components. Using these data, we calibrated and made one-hour plot of solar radio signal variations. As we correlated these data with the data reported by SWPC (Space Weather Prediction Centre), we converted the time of recording, which is in IST (Indian Standard Time), to UT (Universal Time).

6.2 Comparison with SWPC Data

We correlated these bursts with different solar events, X-ray events and other solar observations as reported by several observatories around the world. We used the website of SWPC (Space Weather Prediction Centre) for this purpose. After comparing our recorded data with that reported by SWPC, we observed that out of 57 bursts recorded by us, 40 bursts can be supported by SWPC. From the plot we can say that the time differences between recorded and reported data in case of ending time and peak time are considerably larger than the starting time. From this we can also say that the duration of the bursts observed by us is small compared to that reported, though the bursts seem to start approximately at the same time. Figure 6 shows a plot of the variation of time difference (onset, peak and end) with event number.

[Series1-starting time, Series2-peak time, Series3-end time]

Fig.6. Plot showing the variation of time difference (starting, peak, ending) with event number

VII. DISCUSSION

A large part of the energy flux released in the solar atmosphere travels into interplanetary space and impacts on the Earth's bow shock, energizing the magnetosphere and changing the composition, energy balance and dynamics of the ionosphere, plasma sphere and plasma pause [3]-[5]. The activities of the plasma process of the solar atmosphere have a direct impact over the ionosphere down to troposphere, thus affecting the radio communication in the different frequency bands [6]. Depending upon the energy release from the different activity centers of the Sun and the transfer processes the different layers of the earth atmosphere are distributed. More precisely, the D-region of the ionosphere reflects very low frequency radio waves and absorbs high frequency radio waves in presence of the sun. Regarding the propagation of the signal, the long distance very low and low frequency radio wave propagation is only possible by successive reflections between the earth’s surface and lower ionosphere [7]. The radiation flux, originating in the core is transported outward, driven by the temperature gradient. The inner parts of the Sun, till 500,000 km from the centre, are in radiative equilibrium, while the uppermost 200,000 km is convective, i.e. characterized by up and downward moving gas. The granulation cells, visible in the photosphere, are manifestations of these convective motions. They are short lived and moving; upward with velocities of about 1 km/s and downward with higher velocities because of the lower temperature of the downward streaming gas [8], [9]. Clouds of particles that are emitted from the Sun, e.g. those resulting from a Coronal Mass Ejection and those related to the Ephemeral Polar Regions and the Polar Facular Regions will move along these interplanetary field lines. A consequence is that at Earth’s distance we normally receive gas emitted from sources at about 50° western solar longitude. The Sun moves through interstellar space with a velocity (with respect to the near stellar and gaseous environment) of 20 km/s towards the apex, a point in the constellation of Hercules (right ascension 18 h, declination 30°). In the collision with the interstellar gas a shock forms in front and around the moving Sun, at the distance where the dynamic pressure of the carried along solar wind equals the interstellar gas pressure. Thus the heliosphere originates; it is the drop-shaped volume inside the bow shock where the motion of the gas is dominated by the solar magnetic fields and the solar wind. Its largest diameter, measured at right angles to the direction of motion varies between about 80 and 100 AU. In the direction of motion it is much larger because of its long tail [10], [11].

Though the basic causes of the solar variability and solar cycles are still under debate, researchers suggest that there may be a relation with solar inertial motion. Duration of existence of sunspots has been observed from a few days to a few months, but they eventually decay and this releases magnetic flux in the solar photosphere. This magnetic field is dispersed and churned by turbulent convection and solar large-scale flows [12]. In our observation solar disturbances in different frequencies are observed and analyzed to find out the probability of each kind in different time zone. We have noted that XRA type is more probable than other types in the morning between 8.00 hr IST and 9 hr IST while at midday FLA and RBR are more probable. It thus appears that not all kinds of wavelengths are being emitted at the same time during solar activity. With our observations, we correlated 40 out of 57 solar radio bursts with solar flares and other low frequency solar observations.

ACKNOWLEDGEMENTS

We are thankful to the University PURSE program for financial support. Thanks are also due to the Space Weather Prediction Centre for their supported data.

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