Chapter 3
Observations of Sweep Frequency, Fixed Frequency and Flare Related Radio Bursts

3.1 Introduction
Solar activity has its effect on telegraphic lines, and radio communications. However, earlier there was no scientific proof for this link. Astronomers and physicists knew there was a sun–earth connection, but without direct observational data, it remained unproven. The scientific proof came when we got our first look at the sun from outside our protective atmosphere [1, 2]. In the 1970s, the Voyager spacecrafts were the first to confirm the existence of the solar wind. Later it was found that there is a link between increases in radiation from the sun, solar wind, solar flares, and coronal mass ejections (CME) were first detected. Finally, the sun-earth interconnect became a scientific fact. Before going in details about solar activity, let us at first learn some fact about our Sun [3-5]. The Sun is a normal star of spectral type G2V, which means that it is burning hydrogen in its core, which it has been doing for the last 5 billion years, and will continue to do for more 5 billion years. The core temperature is about 14 million K, and the temperature falls off with distance from the core. It’s surface temperature about 5800 K [6]. The photons generated in the core take about 1 million years to reach the surface, as they propagate outward in a randomly with a very short mean free path. They finally get scattered in the photosphere, after which they are free to stream out into space. Because they are in thermal equilibrium with the photosphere, they have a pure blackbody spectrum corresponding to the 5800 K temperature, but ejected out to space they encounter the more tenuous gas of other regions of the solar atmosphere. These regions are the chromospheres and the corona [7, 8].

3.2 Importance of Solar Radio Observations
Solar radio observations are important, as radio observations allow us to study the parameters of magnetic field and plasma in the solar corona, where observations at other wavelengths usually fail due to low plasma density. Radio emission of solar flares is produced by the high-energy electrons that are the key factor in development of the flares. There, radio observations allow us to study the parameters of these electrons [9].

3.3 Solar Cycle and Sunspot Produced in Active Regions
The solar cycle was first realized by observing the change in sunspots number over a period of 11 years. The solar cycle, at the present time is the Solar Cycle 24, which is the 24th solar cycle since 1755, when recording of solar sunspot activity began. The solar cycle was discovered in 1843 by Samuel Heinrich Schwabe, who after 17 years of observations
noticed a periodic variation in the average number of sunspots seen from year to year on the solar disk. Sunspots are cooler areas on the solar surface [10-13]. Now sunspots have been identified as regions with strong magnetic fields and are divided into three groups called Alpha, Beta and Delta groups. These active regions are carefully observed, as they could be possible indication flare activity [14]. The solar cycle (or solar magnetic activity cycle) is the periodic change in the sun's activity which includes changes in the levels of solar radiation, ejection of solar material, changes number of sunspots, flares, etc. Solar cycles have an average duration of about 11 years [15]. When bipolar magnetic fields develop between sunspots then the group is called a Beta group. When a Beta group becomes intense, with strong, bipolar magnetic fields between sunspots, then the group is called a Delta group. Alpha group are sunspots with no bipolar magnetic fields, and are with little threat for the occurrence of a flare. Beta groups have potential of causing C and M class flare, and Delta groups have high potential for causing large M and X class flare [16]. Figure 3.1 illustrates the different groups of sunspots.

![Image](Magnetic fields above a sunspot)

**Figure 3.1** Sunspot group’s illustration [17]

### 3.4 Solar Flare

A flare is defined as a sudden, rapid, and intense variation in brightness. A solar flare occurs when magnetic energy that has built up in the solar atmosphere is suddenly released. Radiation is emitted across the entire electromagnetic spectrum, from radio waves, through optical mission to x-rays and gamma rays. The amount of energy released is the equivalent of millions of 100-megaton hydrogen bombs exploding at the same time [18-20].

The first solar flare was recorded on September 1, 1859. Two scientists, Richard C. Carrington and Richard Hodgson, were independently observing sunspots at the time, when they viewed a large flare in white light. There are three stages of a solar flare. First is the precursor stage, where the release of magnetic energy is triggered [21, 22]. Soft x-ray
(SXR) emission is detected in this stage. In the second or impulsive stage, protons and electrons are accelerated to energies exceeding 1MeV. During the impulsive stage, radio waves, hard x-rays (HXR), and gamma rays are emitted. The gradual build up and decay of soft x-rays can be detected in the third stage called the decay stage [23, 24]. A schematic view of a solar flare is shown in Figure 3.2. It clearly shows a reconnection-plasmoid ejection model for compact loop flares. Note that plasmas confined by a closed field (in two-dimensions) or by a helically twisted flux tube (in three-dimension) are called plasmoids, as often used in magnetospheric community. In the classical picture of the two ribbon flares, the cool (nearly $10^4$ K) plasmas associated with the twisted flux tube is the filament or prominence. Hot (> $10^6$ K) plasma ejections are expected to be associated with the twisted tube or expanding loop high above the reconnected (SXR) loop. The crosshatched region at the footpoints of the SXR loop shows the bright HXR/SXR double sources. The hatched region at the footpoints of the expanding (helical) loop penetrating the plasmoid shows predicted HXR/SXR distant sources.

![Figure 3.2 A schematic view of a solar flare](image)

The solar flare starts with a period of energy storage, called flare build-up, that can occur over a period of days, but often results from the eruption of new magnetic flux from below the photosphere, which can take only hours. The stored energy takes the form of a non-potential magnetic field distribution. During this time, the changes take place in conditions of ideal MHD (Magnetohydrodynamics), meaning that there is a balance of magnetic and gas pressures, and the field lines are "frozen in"[26]. Once conditions in the corona are right, the magnetic field can release its energy, sometimes in seconds, through a mysterious process called magnetic reconnection. In this process, the field lines are cut (something normally impossible in ideal MHD) and reconnected to a lower-energy configuration that is closer to potential [27]. The difference in energy between the original non-potential configuration and the resulting, more potential configuration is available for mass motions, acceleration of charged particles, and generation of waves [28-30].
The flare can represent the immediate release of energy, the initial heating and acceleration of the charged particles, and all phenomena associated with the resulting mass motions and subsequent thermal ionization of the particles. One associated phenomenon is the Coronal Mass Ejection (CME), which is a magnetic bubble that becomes unstable and buoyant, leaving the Sun and propagating out into interplanetary space [31, 32].

### 3.5 Solar Flare and Solar Radio Bursts

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 [33]. Solar radio bursts were amongst the first phenomena identified as targets for radio astronomy. Characteristic studies of solar radio bursts are a great importance for determining the solar flare and Coronal Mass Ejections (CME) phenomenon. Solar radio bursts at frequencies below a few hundred MHz were classified into 5 types. They are type I, II (slow drift), type III (fast drift), type IV (broadband continuum) and type V radio bursts [34, 35]. The dominant features of different type of radio bursts are shown in Table 3.1.

#### Table 3.1
Dominant features of different type of solar radio burst [9]

<table>
<thead>
<tr>
<th>Type</th>
<th>Features</th>
<th>Duration</th>
<th>Frequency Range</th>
<th>Associated Phenomena</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Short, narrow-bandwidth bursts</td>
<td>Single burst ~ 1 second</td>
<td>80-200MHz</td>
<td>Flares, eruptive prominences, active regions</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Storm: hours to days</td>
<td></td>
<td></td>
</tr>
<tr>
<td>II</td>
<td>Slow frequency drift bursts</td>
<td>3-30mins</td>
<td>20-150MHz</td>
<td>Flares, proton emission, etc</td>
</tr>
<tr>
<td>III</td>
<td>Fast frequency drift bursts</td>
<td>Single burst ~ 1-3 seconds</td>
<td>10 kHz- 1 GHz</td>
<td>Flares, active regions.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Group: 1 to 5 minutes Storm:</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>minutes-hours</td>
<td></td>
<td></td>
</tr>
<tr>
<td>IV</td>
<td>Broadband continuum</td>
<td>Hours to Days</td>
<td>20 MHz- 2 GHz</td>
<td>Flares, eruptive prominences, proton emission, etc.</td>
</tr>
<tr>
<td>V</td>
<td>Smooth, short-lived continuum, follow some III type burst</td>
<td>1-3 minutes</td>
<td>10-200 MHz</td>
<td>Flares, active regions</td>
</tr>
</tbody>
</table>
3.6 Classification of Solar Radio Bursts

There are different classes of solar radio bursts, the recorded bursts are classified into the following categories:

3.6.1 Sweep Frequency Radio Bursts

Sweep Frequency Events (Type II, III, IV and V events) - Energetic solar events often produce characteristic radio "bursts". These bursts are generated by solar material plunging through the solar corona. Type III and type V events are caused by particles being ejected from the solar environment at near relativistic speeds. Type II and IV events are caused by slower-moving solar material propagating outward at speeds varying between approximately 800 and 1600 kilometers per second. Type II and IV radio bursts are of
particular importance. These sweep frequency radio events are signatures of potentially dense solar material which has been ejected from the solar surface [37].

3.6.2 Fixed Frequency Radio Bursts

Fixed frequency radio bursts are the bursts observed at 8 discrete fixed frequencies. These frequencies are 245, 410, 610, 1415, 2695, 4995, 8800 and 15400 MHz. The US Air Force operates four solar radio observatories at various locations around the world. These are collectively known as the Radio Solar Telescope Network or RSTN. Each observatory monitors solar radio emissions on these 8 discrete fixed frequencies. We are interested with the observation of solar radio emissions at the frequency 245 MHz, as the antenna we used for our observation can receive solar signals in the frequency range from 50 MHz to 300 MHz [38-40].

3.6.3 Optical flare in H alpha classification

Solar flare is classified based on H-alpha spectral observations. The scheme uses both the intensity and emitting surface. The classification in intensity is qualitative, referring to the flares as: f for faint, n for normal or b for brilliant. The emitting surface is measured in terms of millionths of the hemisphere and is described below (The total hemisphere area \( A_H = 6.2 \times 10^{12} \text{ km}^2 \)) [41-43].

<table>
<thead>
<tr>
<th>Classification</th>
<th>Corrected Area [millionths of hemisphere]</th>
</tr>
</thead>
<tbody>
<tr>
<td>S</td>
<td>&lt; 100</td>
</tr>
<tr>
<td>1</td>
<td>100 - 250</td>
</tr>
<tr>
<td>2</td>
<td>250 - 600</td>
</tr>
<tr>
<td>3</td>
<td>600 - 1200</td>
</tr>
<tr>
<td>4</td>
<td>&gt; 1200</td>
</tr>
</tbody>
</table>

A flare then is classified taking S or a number that represents its size and a letter that represents its peak intensity, e.g. Sn represents normal sub-flare [44].
3.6.4 X-ray events

The optical evidence of the flare is very difficult to detect due to the normally bright surface of the sun. For this reason, flares are now determined by the x-ray radiation, detected onboard the GOES, LASCO and SOHO satellites, not optically [45]. Solar flares are classified as A, B, C, M or X according to the peak flux (in watts per square metre, W/m$^2$) of 100 to 800 picometre X-rays near Earth, as measured on the GOES spacecraft [46, 47].

3.6.5 Disappearing Solar filament

A solar filament that suddenly disappears on a timescale of minutes to hour is called disappearing solar filament (DSF). The prominence material is often seen to ascend but can fall into the Sun or just fade. DSF is a probable indicator of coronal mass ejections [48].

3.7 Instruments Used for Observing Radio Bursts

The instruments, we used for observing solar radio bursts, are log periodic dipole array (LPDA), and digital storage oscilloscope (DSO). The log periodic dipole array basically consists of a number of dipole elements. These diminish in size from the back towards the front. The main beam of this RF antenna is coming from the smaller front. The element at the back of the array where the elements are the largest is a half wavelength at the lowest frequency of operation. The element spacing also decreases towards the front of the array where the smallest elements are located. In operation, as the frequency changes, there is a smooth transition along the array of the elements that form the active region. To ensure that the phasing of the different elements is correct, the feed phase is reversed from one element to the next.

The wind-proof time-shared LPDA we have designed and 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. Recorded data simulation is important and depends upon the particulars and some physical properties of the Log Periodic Dipole Array.

Digital Storage Oscilloscope of GDS-1000 Series we used for recording purposes. In the Digital Storage Oscilloscope (DSO), vertical input is digitized by the DSO’s own signal analysis software and the created data set is stored in the computer. This data set is used to detect and analyze the solar radio bursts, by comparing the amplitude of the signal voltage obtained at different time [49].
3.8 Methodology

Our receiving systems linked to two log periodic dipole array can receive solar signals in the frequency range from 50 MHz to 300 MHz. Two low noise amplifiers (LNA) are used to reduce the local noises and thereafter the signal is fed to high frequency amplifier to amplify the received signal. A schematic diagram of the whole arrangement is shown in Figure 3.4. The received signal through the amplifier is fed to the digital storage oscilloscope (DSO) connected to the master computer. We observe constantly varying signal voltages along the vertical axis ('Y’ axis), against the horizontal time axis ('X’ axis).

![Schematic diagram of the experimental set up](image)

**Figure 3.4** Schematic diagram of the experimental set up

Our time of measurement was mostly from 8 AM (IST) in the morning to 5 PM (IST) in the evening. For the purpose we have divided the total time domain into three parts. Part-1 which is from 08:00 hrs to 11:00 hrs (IST), during which we have not received direct solar signals (IST – 5 hr 30 min = UT), Part-2 which is from 11:00 hrs to 14:00 hrs (IST), during which we receive direct solar signals and Part-3 which is from 14:00 hrs to 17:00 hrs (IST), during which we again have not received direct solar signals. Figure 3.5 shows how the two log periodic dipole array antennas are used for recording data.
When recorded, the variation of solar radio signal with time was digitalized 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 to 1 second, we obtained the variation of solar radio signal for an
interval of ten seconds in each CSV file. Each file contains its time of recording. Scatter
plot of one such file is shown in Figure 3.6.

### Table 3.3

<table>
<thead>
<tr>
<th>Times (IST)</th>
<th>Positions of the Sun with respect to the vertical line</th>
</tr>
</thead>
<tbody>
<tr>
<td>06:00 hrs</td>
<td>90 degree</td>
</tr>
<tr>
<td>08:00 hrs</td>
<td>60 degree</td>
</tr>
<tr>
<td>11:00 hrs</td>
<td>15 degree</td>
</tr>
<tr>
<td>12:00 hrs</td>
<td>0 degree</td>
</tr>
<tr>
<td>14:00 hrs</td>
<td>30 degree</td>
</tr>
<tr>
<td>17:00 hrs</td>
<td>75 degree</td>
</tr>
<tr>
<td>18:00 hrs</td>
<td>90 degree</td>
</tr>
</tbody>
</table>
Thus, we obtained hundreds of CSV files for showing variation of solar signal per hour. Then using these CSV file we analyze these solar signal variations and manually recorded it for different points of time. We recorded the mean amplitude of the solar signal at different points of time and also the marked the peak values. We also make a note of solar bursts recorded on a particular date, its starting time, peak time and also the end time. When a burst was obtained (solar signal amplitude goes beyond 0.1 volt), we isolate the peak values of the bursts while recording the time of the corresponding values. We did the same for non burst components. Using these data’s, we calibrated and plot a one hour plot of solar radio signal variations as shown in Figure 3.7.

As 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 shown by us have their time in UT (UT= IST–5 hr 30 min). Here is another 10 seconds plot obtained from a different CSV file, showing a different peak value (Figure 3.8).
3.10 Analysis of the Recorded Data

We start collecting solar data, using DSO, from 7\textsuperscript{th} February, 2013. As we had lectures to attend, we were unable to collect data on a regular basis. Instead we collected data for 11 days in the month of February, 12 days in the month of March, and 7 days in the month of April. We collected data till 7\textsuperscript{th} April, 2013, a total of 30 days. Out of these 30 days, we obtain bursts for 7 days in February, 11 days in March, and 1 day in April, a total of 19 days. We obtain our first two bursts on 12\textsuperscript{th} February, 2013, and a maximum number of 6 burst on 28\textsuperscript{th} February, and 18\textsuperscript{th} March, 2013. The numbers of bursts recorded on specific dates are shown in the Table 3.4:

Table 3.4

<table>
<thead>
<tr>
<th>Observing dates</th>
<th>Number of bursts</th>
</tr>
</thead>
<tbody>
<tr>
<td>12/02/2013</td>
<td>2</td>
</tr>
<tr>
<td>20/02/2013</td>
<td>2</td>
</tr>
<tr>
<td>21/02/2013</td>
<td>3</td>
</tr>
<tr>
<td>22/02/2013</td>
<td>1</td>
</tr>
<tr>
<td>25/02/2013</td>
<td>1</td>
</tr>
<tr>
<td>26/02/2013</td>
<td>3</td>
</tr>
<tr>
<td>28/02/2013</td>
<td>6</td>
</tr>
<tr>
<td>04/03/2013</td>
<td>3</td>
</tr>
<tr>
<td>05/03/2013</td>
<td>4</td>
</tr>
<tr>
<td>06/03/2013</td>
<td>4</td>
</tr>
<tr>
<td>12/03/2013</td>
<td>2</td>
</tr>
<tr>
<td>16/03/2013</td>
<td>2</td>
</tr>
<tr>
<td>18/03/2013</td>
<td>6</td>
</tr>
<tr>
<td>19/03/2013</td>
<td>2</td>
</tr>
<tr>
<td>20/03/2013</td>
<td>1</td>
</tr>
<tr>
<td>23/03/2013</td>
<td>1</td>
</tr>
<tr>
<td>24/03/2013</td>
<td>2</td>
</tr>
<tr>
<td>06/04/2013</td>
<td>1</td>
</tr>
</tbody>
</table>
We obtained 18 bursts on the month of February, 27 bursts on the month of March, and 1 burst on the month of April, a total number of 46 bursts. Our time of measurement was mostly from 8 AM (IST) in the morning to 5 PM (IST) in the evening. The percentage of occurrence of bursts within this time are divided into 5 intervals as shown in Table 3.8 and also plotted in the histograms of Figure 3.9.

Table 3.5
Number of bursts received at different hours of the day

<table>
<thead>
<tr>
<th>Time interval (IST)</th>
<th>Percentage of occurrences of bursts</th>
</tr>
</thead>
<tbody>
<tr>
<td>8-10 AM</td>
<td>6.52</td>
</tr>
<tr>
<td>10AM-12PM</td>
<td>28.26</td>
</tr>
<tr>
<td>12-14AM</td>
<td>19.56</td>
</tr>
<tr>
<td>14-16PM</td>
<td>39.13</td>
</tr>
<tr>
<td>16-18 PM</td>
<td>6.52</td>
</tr>
</tbody>
</table>

Figure 3.9 Histogram showing the occurrences of bursts at different parts of the day

3.10.1 Day-to-day Study of the Recorded Data

With our instruments we were unable to record any data corresponding to the frequency of the bursts. Therefore, we cannot classify the solar radio bursts that we observed. However, we correlate these bursts with different solar events, X-ray events, and other solar observations which were recorded by various observatories around the globe. For this we used the website of SWPC (Space Weather Prediction Centre) [50, 51]. Upon comparing our recorded data with that reported by SWPC (Space Weather Prediction Centre), we find that, out of the 46 bursts recorded by us, 33 bursts can be nearly correlated with SWPC’s reported bursts and other events. We have shown these 33 bursts in the table 3.6:
Table 3.6
Recorded bursts at Kalyani, compared to others reported data

<table>
<thead>
<tr>
<th>Solar Data Recorded at Department of Physics, University of Kalyani</th>
<th>Data Reported from SWPC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date</td>
<td>Event No.</td>
</tr>
<tr>
<td>21/02/2013</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>4</td>
</tr>
<tr>
<td>22/02/2013</td>
<td>6</td>
</tr>
<tr>
<td>25/02/2013</td>
<td>7</td>
</tr>
<tr>
<td>28/02/2013</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>12</td>
</tr>
<tr>
<td>04/03/2013</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>14</td>
</tr>
<tr>
<td>05/03/2013</td>
<td>15</td>
</tr>
<tr>
<td>06/03/2013</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>17</td>
</tr>
<tr>
<td></td>
<td>18</td>
</tr>
<tr>
<td>12/03/2013</td>
<td>19</td>
</tr>
<tr>
<td>16/03/2013</td>
<td>20</td>
</tr>
<tr>
<td>18/03/2013</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td>23</td>
</tr>
<tr>
<td></td>
<td>24</td>
</tr>
<tr>
<td></td>
<td>25</td>
</tr>
<tr>
<td>19/03/2013</td>
<td>27</td>
</tr>
<tr>
<td>24/03/2013</td>
<td>31</td>
</tr>
<tr>
<td></td>
<td>32</td>
</tr>
<tr>
<td>06/04/2013</td>
<td>33</td>
</tr>
</tbody>
</table>

Here, **: Missing data, FLA: Optical flare observed in H-alpha, RSP: Sweep-frequency radio burst, RBR: Fixed-frequency radio burst (245 MHz), XRA: X-ray event (flare), DSF: Disappearing solar filament
We have assign numbers (Event No.1-33) to the solar bursts recorded by us. In some cases, as for Event No. 31 and 32, we can see that there is only one event reported by SWPC which starts from 5:05 UT and ends at 8:44 UT. Within this time interval we recorded two separated bursts, one starting from 5:41 UT and ending at 5:43 UT, and the other starting from 6:19 UT and ending at 6:27 UT. This is shown in the Figure 3.10.

![Burst recorded on March 24, 2013](image)

**Figure 3.10** Burst recorded on March 24, 2013

It is clear from the above fact that, though we obtain bursts on the same date, the starting, peak, and end time difference between our recorded data and the data reported by SWPC may significantly vary. The time differences between the recorded and reported starting, peak and end time are shown in the following tables (Table 3.7, 3.8 and 3.9). When calculated time difference exhibits negative, shade marks are given in the tables.
Table 3.7
Difference between recorded and reported starting time

<table>
<thead>
<tr>
<th>Event No.</th>
<th>Recorded Starting Time (UT)</th>
<th>Reported Starting Time (UT)</th>
<th>Time Difference (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>9:46</td>
<td>10:29</td>
<td>-2580</td>
</tr>
<tr>
<td>2</td>
<td>10:44</td>
<td>10:41</td>
<td>180</td>
</tr>
<tr>
<td>3</td>
<td>5:33</td>
<td>5:16</td>
<td>1020</td>
</tr>
<tr>
<td>4</td>
<td>5:53</td>
<td>5:16</td>
<td>2220</td>
</tr>
<tr>
<td>5</td>
<td>6:23</td>
<td>5:16</td>
<td>4020</td>
</tr>
<tr>
<td>6</td>
<td>6:26</td>
<td>9:32</td>
<td>-11160</td>
</tr>
<tr>
<td>7</td>
<td>7:07</td>
<td>5:15</td>
<td>6720</td>
</tr>
<tr>
<td>8</td>
<td>5:30</td>
<td>6:28</td>
<td>-3480</td>
</tr>
<tr>
<td>9</td>
<td>7:18</td>
<td>7:02</td>
<td>960</td>
</tr>
<tr>
<td>10</td>
<td>8:43</td>
<td>8:28</td>
<td>900</td>
</tr>
<tr>
<td>11</td>
<td>9:32</td>
<td>9:20</td>
<td>720</td>
</tr>
<tr>
<td>12</td>
<td>10:40</td>
<td>11:05</td>
<td>-1500</td>
</tr>
<tr>
<td>13</td>
<td>7:10</td>
<td>6:57</td>
<td>780</td>
</tr>
<tr>
<td>14</td>
<td>9:47</td>
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<td>16</td>
<td>4:58</td>
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<td>17</td>
<td>6:05</td>
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<td>480</td>
</tr>
<tr>
<td>18</td>
<td>6:20</td>
<td>5:57</td>
<td>1380</td>
</tr>
<tr>
<td>19</td>
<td>7:43</td>
<td>8:25</td>
<td>-2520</td>
</tr>
<tr>
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Difference between recorded and reported peak time

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Figure 3.11 Plot showing the variation of time difference (starting, peak and end) with event number

It appears from the Figure 3.11, there are some few cases that a time differences between our recorded data and data reported by SWPC. But starting time and end time show opposite type of time-phase, i.e. when starting time is recorded before that for SWPC then end time of reported burst lead in phase over our data or vice-versa. We observe the peak times for burst are almost the same for both the cases as compared to the peak or end time.

3.11 Discussion

The solar spectrum shows many spectral lines. These lines 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 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 [52, 53].
With our observations, we observed and verified 33 out of 46 solar radio bursts most of which were correlated with solar flares, X-ray events and other low frequency solar observations. The log periodic dipole array (LPDA) antenna at Department of Physics, University of Kalyani, can receive direct solar signals from 11:00 hrs to 14:00 hrs (IST). From Figure 3.10 we can see that, we received a number of 13 bursts from 10:00 hrs (IST) to 12:00 hrs (IST), and a number of 9 bursts from 12:00 hrs (IST) to 14:00 hrs (IST). Here we can also observe that a small number of 3 bursts occurred respectively between 8:00 hrs (IST) to 10:00 hrs (IST) and between 16:00 hrs (IST) to 18:00 hrs (IST). This was well expected as we do not receive direct solar signals during this interval of time. However we recorded a maximum number of 18 solar radio bursts in the time interval from 14:00 hrs (IST) to 16:00 hrs (IST). From this we can conclude that, the LPDA we used for capturing solar signals, is sensitive enough to receive radio signals even when it is not receiving solar signals directly [54].

References


[51] SWPC.Webmaster@noaa.gov/glossary
