Drift frequency of kilometric radio burst type III with solar wind speed and density

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Abstract. Solar radio burst is a signature of solar flare generated by plasma emission mechanism. Radio burst is a diagnostic tool to study electron beam evolution and plasma background properties in corona and interplanetary medium. Sudden release magnetic energy up to 1032 ergs due to magnetic connection accelerates electron located at accelerated site to propagate near relativistic. This fast group of electron propagating through plasma background induced high level of Langmuir wave due to bump in tail instability. Non linear wave-wave causing radio burst near the local plasma frequency. In this paper, frequency drift of burst is calculated only from 1 MHz to 400 kHz and the data is obtained from Coordinated Data Analysis Web (CDAweb). The data is analysed by identifying time during maximum intensity of burst at the particular frequency range. Only 45 burst observed in September 2017 is considered in this paper. Meanwhile the data of solar wind speed and density is collected from Advanced Composition Explorer (ACE) satellite. Drift frequency of burst then compared to average of solar wind and density. From the analysis, drift frequency of burst decreasing against solar wind speed and solar wind density. But both relationship shows very weak correlation between drift frequency and solar wind properties.

1. Introduction
Solar radio bursts have been studied more than 60 years and many properties of the radio burst is explored. Solar radio burst type III (SRBT III) is the most frequent radio burst occurred due to solar activity and it always associated with solar flare [1], [2]. Radio burst generated from the corona to interplanetary medium is due to propagation of near relativistic electron beam outward the Sun along open magnetic line through plasma emission [2]–[4]. This shows radio burst type III is a signature of non-thermal energetic electron beam travelling from acceleration site via plasma environment outward to the Earth, so the generated SRBT III is also depend on the solar wind and local plasma frequency [5].

One of the properties which are often observed is drift frequency of radio burst [6]. The sign of drift frequency indicated the motion of electron either moving away or moving toward the Sun[6], [7].
Most of the drifts are started from high to low frequency. The drift frequency is important tool in understanding the origin of burst source[8]. The drift frequency also can be used to estimate the speed of energetic electron beam along the open magnetic field [9].

In this paper, 45 SRBT III events occurred at kilometric wavelength by considering maximum intensity of the burst. Each drift frequency is calculated by tracing maximum intensity of radio burst that change the frequency against time. The average solar wind speed, solar wind density and average intensity of burst also calculated and compared to the drift frequency to determine their correlation.

2. Observations

Kilometric SRBT III consider in this paper only occurred in September 2017. Only 45 SRBT III events are considered started from 2 September 2017 to 19 September 2017. All the data is obtained from CDAWeb hosted by National Aeronautics and Space Administration (NASA). In this paper, data observed by radio receiver band 1 (RAD1) on the WIND spacecraft only considered. RAD1 sensor measured radio emission from 20 to 1040 kHz consist of 256 channels [10]. Time resolution of RAD1 data provided by CDAweb is 1 minute.

SRBT III can have starting frequency from MHz down to kHz. In this paper, the drift frequency is calculated started from 1 MHz to 400 kHz even the starting frequency started at higher frequency. The duration of burst is obtained by determine the start and end time of burst type III at 1 MHz and 400 kHz as shown by red arrow in Figure 1. The obtained duration is used to calculate the average solar wind speed and density during the burst.

The maximum intensity of the selected burst is traced then for each time, $t_i$ we find the frequency $f_i$ of maximum intensity. This work done by using MATLAB software. Then drift frequency is defined as

$$\frac{df}{dt} = \frac{f_f - f_i}{t_f - t_i}$$

where $f_f$ is final frequency, $f_i$ is initial frequency, $t_f$ is final time and $t_i$ is initial time. The frequency $f_i$ is usually does not lie on smooth line and concentrate on particular time as shown in Figure 2. In this
paper, the graph of frequency against time of particular burst is plotted and linear fitting is applied to obtain the drift frequency.

The solar wind speed and density is obtained from the Solar Wind Electron, Proton, and Alpha Monitor (SWEPAM) on board the Advanced Composition Explorer (ACE) satellite. Solar wind level 2 data obtained from CDAWeb has 64 second resolution detect the ion with energy between 0.26 and 36 keV. The average of solar wind speed and density during SRBT III occurred from 1 MHz to 400 kHz is calculated. This data then compared to drift frequency to obtain the correlation.

3. Data and Analysis
During September 2017 2–19, 45 single SRBT III is obtained which all have negative drift. All the burst have different duration start and end frequencies, frequency bandwidth, intensity and drift rates. The drift rate is analysed base on solar wind speed and density. The present study only considered 45 bursts where the shortest duration of burst is 480 s while the longest duration of burst is 3540 s. All of the bursts discuss in this paper has negative drift frequency.

Figure 2. Frequency against time of maximum intensity of radio burst is plotted. The frequency $f_i$ is concentrated at particular time. The linear regression fitting is applied to obtain frequency drift.

Figure 3. Example of speed and density of solar wind data. The inset shows numerical data for specific time. (a) Solar wind speed measured by ACE satellite on 7 September 2017. (b) Solar wind proton density measured by ACE satellite on 7 September 2017.
3.1. Drift frequency and solar wind speed

There are 45 bursts detected in September 2017 occurred at different solar wind speed and density. From 45 bursts, 21 bursts occurred below 500 km/s solar wind speed, 8 bursts between 500 km/s and 599 km/s, 12 bursts between 600 km/s and 699 km/s and 4 bursts for above 700 km/s. The distribution of drift frequency in the solar wind speed scale shows no strong correlation. But it still shows the tendency of decreasing drift frequency as increasing the solar wind speed (Figure 4).

![Figure 4](image)

**Figure 4.** Scatter plot of drift frequency against average solar wind speed for all data shows weak correlation.

![Figure 5](image)

**Figure 5.** Scatter plot of drift frequency against solar wind speed for different range of solar wind. (a) For the range of wind speed between 400 km/s to 499 km/s. (b) For the range of wind speed between 500 km/s to 599 km/s. (c) For the range of wind speed between 600 km/s to 699 km/s. (d) For the range of wind speed between 400 km/s to 499 km/s.
3.2. Drift frequency and solar wind density

Figure 6 represent scatter plot of drift frequency against average solar wind density. To be considered in the average density, the density during of the bursts event is from 1 MHz to 400 kHz. Most of the burst concentrated in the range of 2 to 4 number of proton per cm$^3$. The linear fit is applied to find out the correlation between drift frequency and solar wind density. The gradient shows that the drift frequency of radio burst decreasing while solar wind density increasing. From the scatter plot, the drift frequency shows quite large distribution against solar wind density meaning that the obtained correlation is very weak.

Figure 6 Scatter plot drift frequency against average solar wind density for all 45 bursts. Linear regression fitting is applied and the results shows higher solar wind density causes lower drift frequency.

4. Discussion

In this paper, we have selected 45 kilometric radio burst and performed regression fit analysis to ascertain whether drift frequency of burst depend on solar wind properties or not. For all cases, we found that all drift frequencies is negative. This shows that energetic electron beam travelling outward from the Sun. We also found the drift frequency decreasing as speed and density of solar wind increasing but the correlation is very poor. After further investigation, for speed of solar wind between 400 km/s to 499 km/s and 600 km/s to 699 km/s, drift frequency increasing as the speed increase but not for the range of solar wind speed between 500 km/s to 599 km/s and 700 km/s to 799 km/s. The source of the radio can be originate directly from the solar corona that travelling along open magnetic field or originate from other sources faces many possibilities while travelling through interplanetary space. This suggests that drift frequency radio burst doesn’t depend solely to the speed solar wind and more data is needed to confirm their relationship.

The data of frequency $f_i$ concentrate on certain time also affect the accuracy of getting the drift frequency. The low time resolution of RAD1 contributes to this inefficiency. The data also shows that the drift frequency in the range between 0.5 kHz/s to 5.5 kHz/s. This means the drift frequency of burst at kilometric range is slower compared at the corona. The energetic electron beam which is responsible in emitting radio burst due to plasma emission mechanism also depend on open magnetic field line and velocity dispersion. The location of radio source also plays important in generating radio burst. Plasma density also plays important role in emitting radio emission through plasma emission mechanism. Low plasma density causes low local plasma frequency and radio emission easily emitted [11]. This is one of the factor leads to the lower drift frequency at kilometric range.

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