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Analysis of type II and type III solar radio bursts

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Abstract. Solar radio burst is an arrangement of a frequency space that variation with time. Most of radio burst can be identified in low frequency range such as below 200 MHz and depending on frequencies. Solar radio bursts were the first phenomenon identified in the field of radio astronomy field. Solar radio frequency range is from 70 MHz to 2.2 GHz. Most of the radio burst can be identified in a low frequency range such as below 200 MHz. Properties of low-frequency radio were analyzed this research. There are two types of solar radio bursts were analyzed, named as type II and type III radio bursts. Exponential decay type could be seen in type II, and a linear could be indicated in type III solar radio bursts. The results of the drift rate graphs show the values of each chosen solar radio burst. High drift rate values can be seen in type III solar flares whereas low to medium drift rate values can be seen in type II solar flares.

In the second part of the research the Newkirk model electron density model was used to estimate the drift velocities of the solar radio bursts. Although the special origin of the solar radio burst is not known clearly we assumed. The chosen solar radio bursts were originated within the solar radius of 0.9 - 1.3 range from the photosphere. We used power law in the form of $(x) = A \times 10^{-bx}$ were that the electron density related to the height of the solar atmosphere. The calculation of the plasma velocity of each solar radio burst was done using the electron density model and drift rates. Therefore velocity of chosen type II solar radio bursts indicates low velocities. The values are $233.2499 \text{ Km s}^{-1}$, $815.9522 \text{ Km s}^{-1}$ and $369.5425 \text{ Km s}^{-1}$. Velocity of chosen type III solar radio bursts were $1443.058 \text{ Km s}^{-1}$ and $1205.05 \text{ Km s}^{-1}$.

1 INTRODUCTION

Solar activity is one of the most significant events take place in the climate of the solar system which is unpredictable. Solar activities include solar flares, coronal mass ejections, high-speed solar wind, and solar energetic particles[1][2]. All solar activities are driven by the changes occur in the solar magnetic field. Solar flare is an intense burst of electromagnetic wave coming from the sun due to release of magnetic energy associated with sunspots.

Solar radio burst is an arrangement of a frequency space that variation with time [3]. Most of radio burst can be identified in low frequency range such as below 200 MHz and depending on frequencies. Solar radio bursts (SRB) were the first phenomenon identified in the field of radio astronomy field.



Solar radio frequency range is from 70 MHz to 2.2 GHz[3][4]. Most of the radio burst can be identified in low frequency range below 200 MHz. Depending on the frequencies radio burst are classified into five categories as mentioned below[1][2][5].

- Type I burst (noise storm)
- Type II burst (slow drift rate)
- Type III burst (fast drift rate)
- Type IV burst
- Type V burst

Type II and type III solar radio bursts were detected by e-CALLISTO network system, a system operates in 67 locations around the world. In this study using the data gathered by CALLISTO network system, type II and type III solar radio bursts were analyzed to obtain useful information.

2 METHODOLOGY

In this research, few SRB events were selected covering type II and III radio bursts using e-Callisto system which is used to calculate drift rates, electron density and plasma velocity of solar radio bursts to make a comparison between type II and type III.

2.1 Analysis of drift rates of solar radio bursts

Type II is a slow drift from high to low frequency in dynamic radio spectra burst, but type III has a fast drift rate. For us to distinguish them, the frequency drift rate of a solar burst is a power law in the frequency of emission. Drift rate (df/dt) is a displacement of the peak in frequency per unit time. It can be determined by taking start time to end time and start frequency to end frequency of the solar burst type II and type III[6]. The equation of drift rate of solar radio burst of type II and III was defined in equation 01[7][8][9]

$$\text{drift rate; } \frac{df}{dt} = \frac{(f_e - f_s)}{(t_e - t_s)} \left(\frac{\text{MHz}}{\text{s}} \right) \text{----- (01)}$$

f_s is a frequency of starting time, f_e is a frequency of ending time, t_e is an end time and t_s is a start time. MATLAB software could be used for analysis of drift rate graphs and selecting few solar radio stations which belong to e-callisto network system were selected.

Few SRB flares from each type were taken for getting better comparison between type II and type III. Drift rate graphs of solar flares can be plotted by using frequency (which corresponding to highest intensity) with time. This method is used to get the best drift rate graph of solar radio burst flares. Each type of solar radio flares was extracted by using MATLAB software.

Several noises could be realized in these images. These noises can be reduced by isolating the solar radio burst part, using the crop tool. This method was successful to reduce noise in certain levels, but not for all. Using cropped image, maximum intensity frequency corresponding to time can be calculated. Each maximum frequency point and related time were obtained. Subsequently feat those points, maximum frequency vs time graph was plotted to obtain the drift rate graph. The above method could be used for each solar flares which were selected. However a certain amount of noise was still present in the graph. That noise frequency needs to be eliminated to get the best distribution graph. The drift rate could not be retrieved from the shape of distribution under the noise frequency. That might possibly affect our final comparison. Noise frequency was eliminated by deleting the repeating same patterns of frequencies in this research. This method was repeated to all other selected images. After recognizing the noise area of the images help to eliminate the noise frequency. The frequency time graph from each image could be obtained by plotting those points. Comparing these graphs it is possible to identify, what is type II and what is type III. Model equations for each solar radio burst type could be initiated by using frequency vs time graph. The drift rate vs frequency graph was plotted after the frequency vs

time graph. Thus to find a drift rate of each solar radio bursts, should differentiate each model equation separately. After obtaining those derivatives we could see a variation of drift rates for each solar radio burst. There by finding the mean value of these drift rates, one could obtain an average value for the particular solar radio burst.

2.2 Analysis of electron density and height of solar radio bursts

The major issue of this research was to find the electron density on chromosphere in the sun. The several solar chromosphere models can be used to find electron density. Newkirk model is one of the best models that can be used. Newkirk model could be used reversely to verdict each electron density and height of solar radio bursts. The frequency corresponds to electron densities should be found for calculating a height of each solar radio burst. The electron densities of each radio burst could be initiated by using equation 02. The main frequency of plasma radiation F is proportional to electron density $\sqrt{N(r)}$ [3][10][11][12].

$$F_{elec} = 8.973 \times 10^{-3} \sqrt{Ne(r)} \text{ MHz} \text{ --- (02)}$$

Where F_{elec} is a plasma frequency in MHz and $\sqrt{Ne(r)}$ is the electron density in cm^{-3} .

A wide range of frequency was selected to get better distributions and it reduced error factor. The electron density vs plasma frequency graphs could be plotted by collaring the electron densities related to the plasma frequency. This research only got the highest intensity frequencies as mentioned earlier and by using same frequency value could use to find related electron densities and heights as well. The height distribution of electron density could be found by using Newkirk model as well. Newkirk model equation is shown in equation 03[3][12][13].

$$Ne = N \times 10^{4.32Ro/R} \text{ --- (03)}$$

Where $N_0 = 4.2 \times 10^4 \text{ cm}^{-3}$. - Concentration, R_0 - solar radius, R - distance from solar center to source of type burst.

The distribution graph of electron density vs height could be plotted after getting height values corresponding to electron densities. The above step was repeated for other chosen solar radio bursts.

2.3 Analysis of plasma velocity of solar radio bursts

Calculation of electron densities and ejection heights were used to calculate its plasma velocities. For this calculation following parameters need to be used as well.

- I. Plasma frequencies of each solar radio bursts
- II. Change of Electron density with respect to height
- III. Drift rate value for each solar radio bursts.

Frequency vs time graphs as mentioned in above paragraphs was used to calculate the plasma frequency of each solar radio burst. Calculation of the change of electron density with respect to height was the next step and the electron density vs height graphs was used for it. The each value of the change of electron density with respect to height should be calculated by differentiating above mentioned graph.

By using the above mentioned parameters (plasma frequency, electron density, drift rate, change of electron density with respect to height) in the equation 04, could successfully give the plasma velocities of the solar radio bursts[2][14].

$$v = \frac{(2 \frac{df}{dt} N)}{f \frac{dN}{dr}} \text{----- (04)}$$

Where

v – plasma velocity (km s^{-1}), $\frac{df}{dt}$ – drift rate (MHz s^{-1}),

N – electron density (cm^{-3}), f – plasma frequency (MHz)

$\frac{dN}{dr}$ – change of electron density with respect to height ($\text{cm}^{-3} R_o^{-1}$)

3 RESULTS AND DISCUSSION

There were five major solar radio bursts images selected to in this research and they are shown in figure1, 2, 3 and 4.

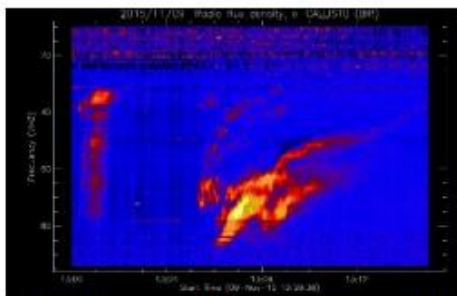


Figure 1- Type II solar radio burst extracted from BIR station 09-11-2015 time period between 13.04UT- 13.12U

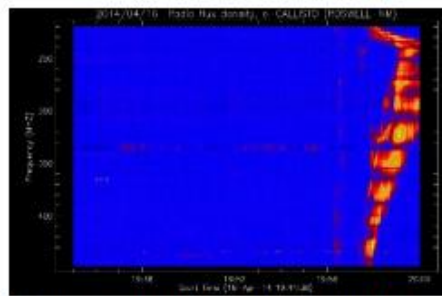


Figure 2- Type II solar radio burst extracted from ROSWELL station 16-04-2014 time period between 19.56UT- 20.00UT

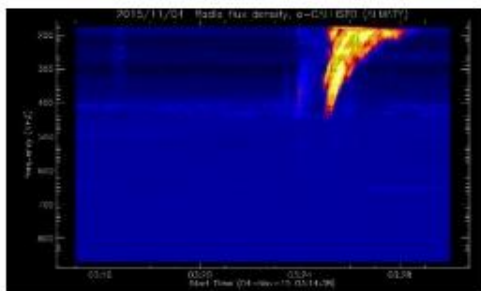


Figure 3- Type II solar radio burst extracted from ALMATY station 04-11-2015 time period between 03.24UT- 03.28UT

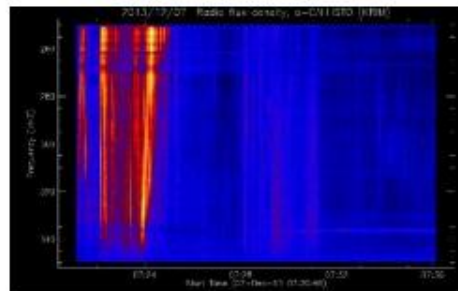


Figure 4- Type III solar radio burst extracted from KRIM station 07-12-2013 time period between 07.24UT- 07.25UT

Drift rates and frequency vs time graphs were obtained in the first part of the research. Variations of drift rates between type II and type III solar radio bursts can be observed from these plots. A difference between type II and type III was also observed by the distribution of solar radio bursts which were shown in the frequency vs time graphs of figure 5 and 6. The research thoroughly and successfully analyzed the five images of solar radio bursts. Using those analyzed images variations of type II and type III could be retrieved. Details of frequency vs time graphs are shown in Table 1. According to Table 1,

we could see that the type II solar radio burst indicates some exponential curve fitting model and type III solar radio bursts indicates straight line curve fitting model. Following these data we could find the drift rates of each solar radio burst types. Drift rate graphs tables are shown in Table 2. Table 2 shows the drift rate values obtained from graphs of each chosen solar radio burst. High drift rate values can be seen in type III solar flares whereas low to medium drift rate values can be seen in type II solar flares. Fast drift rate values indicate the fast distribution type and this may range from few seconds to minutes. Slow drift rate values indicate the slow distribution type and this may take quite a few minutes. Table 2 shows the main difference between type II and type III solar radio bursts.

In the second part of this research, the electron density of solar radio bursts, ejection height and plasma frequency were calculated. Using Newkirk model, we could get the above mentioned parameters. According to the results of plasma frequencies and electron densities some distributions look like their original image forms. However, their height values depict different values. That meaning to say that each solar radio burst ejects different heights [3][12]. Hence we could see that the chosen solar radio bursts split into sub types. According to Hanslmeier and A., & Messerotti, chosen solar radio burst types belong to type II Bb, type II FS and type III B [3]. These sub types do not provide a perfect difference between type II and type III because chosen solar radio burst does not show high variations. All the chosen solar radio bursts were located in solar radius of 0.9 - 1.3 range, but main point was that they always obey the Newkirk model. The research results demonstrated that the electron density vs height graph always follows power equations in the form of $f(x) = A \times 10^{-bx}$, as shown in figure 7.

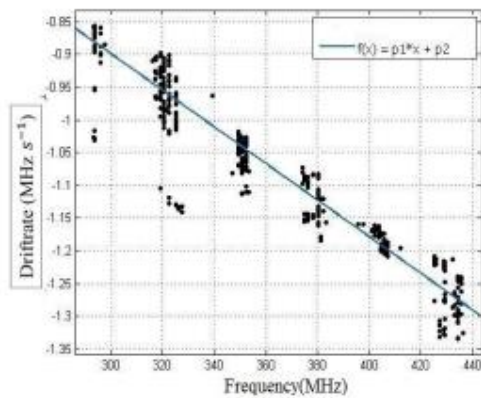


Figure 5- Type II solar drift rate vs frequency graph extracted from flare ROSWELL-NM 16-04-2014

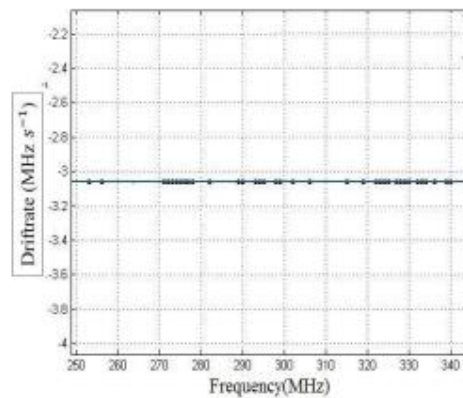


Figure 6- Type III solar drift rate vs frequency graph extracted from flare KRIM 07-12-2013

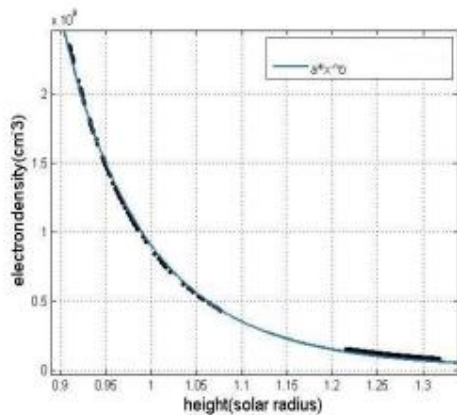


Figure 7- Type III and II solar radio burst electron density vs height graph

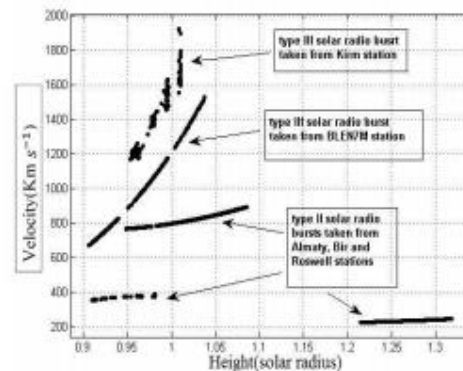


Figure 8- Type II and type III solar radio bursts velocity vs height graphs taken from chosen station

Final part of this research is the calculation of plasma velocity of each solar radio burst. Accordingly we could see low and medium velocities for type II solar radio bursts and a high velocity for the type III solar radio burst. This conclusion is in agreement with the figure 8. When Coronal Mass Ejection (CME) was associated with type II solar radio bursts it helps to improve the velocity. In this research mean velocities of 233.24 Km s^{-1} , 815.95 Km s^{-1} and 369.54 Km s^{-1} for type II solar radio bursts and $1443.05 \text{ Km s}^{-1}$, $1205.058 \text{ Km s}^{-1}$ for type III solar radio burst were obtained. According to G. A. Newkirk, type II solar radio bursts could get the mean velocities less than 500 Km s^{-1} and if the CME was associated, they might get fast mean velocity values.

Table 1

| Solar radio burst type | Curve fitting model |
|------------------------|--|
| TYPE II | Exponential curve fitting $f(x) = A \times e^{-bx}$ |
| TYPE III | Straight line curve fitting $f(x) = -mx + c$ |

Table 2

| Solar radio burst type | Drift rate value($MHz s^{-1}$) |
|-------------------------------|----------------------------------|
| ALMATY TYPE II 2015-11-04 | -1.458 |
| BIR TYPE II 09-11-2015 | -0.098 |
| ROSWELL-NM TYPE II 16-04-2014 | -1.079 |
| BLEN7M TYPE III 10-06-2014 | -2.375 |
| KRIM TYPE III 07-12-2013 | -3.062 |

4 CONCLUSION.

The properties between Type II and type III of solar radio burst was accrued. Drift rate values of type II, solar radio bursts were less than type III. However, the drift rate value of type III solar radio burst could be seen in type II roughly and rarely. Type II and type III solar radio bursts always obey the Newkirk model and different between of electron density vs height graphs could not be indicated. Additionally, subtypes of type II and type III was identified, thus the variation of height was only indicated. Plasma velocity of type III was higher than type II. However, one of a type III solar radio bursts was originated from type region. Properties of type II and type III could be seen in that type III solar radio burst.

In this research, we have calculated the drift rate of type II and type III solar radio bursts more accurately. The drift rate was obtained by differentiating each point on the model fitted line of frequency vs time graph. Applying the parameters of the chosen solar flares to the Equation 1, drift rates were calculated. The calculated drift rates are approximately equal to the values previously obtained. This was done to verify the validity of and accuracy of results by this method.

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