

On Multiple Type II Bursts and Coronal Mass Ejections

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Abstract We have investigated 42 multiple type II events observed during the period 1997-2007 for the complete solar cycle 23 recorded by WAVES/WIND instrument and point out that the average speed of associated CMEs is 1311 km/s and 57% of CMEs have their widths larger than 200 degree or they are halo CMEs. The mean of starting and ending frequencies is 9.09 MHz and 1.82 MHz, respectively. The linear correlation factor is 0.052 which implies that starting and ending frequencies have no correlation.

Keywords Sun, Coronal Mass Ejections, Radio Burst, Solar Cycle

1. Introduction

First of the observations of type II bursts occurring in non thermal solar radiation were reported by [1]. Type II burst appears as an emission band slowly drifting from high to low frequencies in dynamic radio spectra, in contrast to the type I storms and the fast drifting type III bursts. Type IV bursts from moving and stationary coronal structures and type V bursts, a variant of type III bursts, were subsequently added to the types of radio bursts. These bursts are interpreted as the radio signature of shock waves in the solar corona. Such shock waves can be generated by flares and/or coronal mass ejections [2, 3, 4]. The type II bursts are signatures of violent eruptions from the Sun that result in shock waves propagating through the corona and the interplanetary (IP) medium. The study of type II bursts is thus important for the understanding of the large scale structures and dynamics of the inner heliosphere.

More often than not, the appearance of type II radio bursts is preceded by groups of bursts of the type III family. The dynamic spectra of the onset of the type III activity seems to be in the same spectral range as the backward extrapolated type II lanes. [5] named this type of event compound and concluded that both the type III and type II originated from a common source. [6] reported two more spectral features physically related to the type II exciter; the type II precursor which consists of fast drift bursts or pulsations with a restricted bandwidth near the spectral range of the backward extrapolated type II lanes; the arc consists of a series of

narrow band bursts immediately preceding the type II onset. It has an inverted U-shaped envelope, hence its name. The relationship of type II bursts with CMEs has been explored by [7, 8, 9, 10, and 11]; using the uniform and extended high quality data on radio bursts from WIND/WAVES and CMEs from SOHO/LASCO, have studied the properties of the radio rich CMEs which produce type II i.e. decametric - hectometric or DH radio bursts. These DH CMEs are relatively faster and wider than the normal CMEs. These special characteristics of radio-rich CMEs could be used to identify the population of geoeffective CMEs, which are quite relevant to space weather. Like type III radio bursts which sometimes occur in groups, type II radio bursts can also occur in multiples. [12] were the first to report multiple type II bursts and to suggest that they were due to a single shock intersecting different coronal structures.

Most of the type II bursts have fundamental and harmonic signatures in the dynamic spectrum. As reported by [12 and 13], a multiple type II burst consists of multiple bands in the dynamic spectrum. These bands often have different frequency drift rates or are significantly displaced in frequency in a manner different from the normal fundamental harmonic or split band relationships [14]. The presence of these multiple bands may indicate the interaction of a single shock front with different coronal structures. Alternatively, the various bands may indicate successive shocks. Thus the study of multiple type II shocks and their physical origin is of great interest.

The study of multiple types II bursts is rare. [12] Reported that nearly 20% of all the type II is multiple types II. [15 and 16] made a detailed analysis of multiple type II radio bursts observed by culgoora radio spectrograph from January 1997 to July 2003, and concluded that the probability of observing the multiple types II is higher when the strength of the flare is high, and the width of the CMEs is large. The results are also

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discussed with a focus on the various possibilities on the origin of multiple type II bursts. Prakash et al have [17] investigated the properties of type II burst pairs (m-and DH type IIs) associated with flares and CMEs during the period 2000 to 2005. They concluded that the difference between class I and II events in durations and starting frequencies of type IIs is insignificant. However, most of the class I DH-type IIs start below 14 MHz, whereas class II events are already present at 14 MHz which is the WAVES upper starting frequency.

The different components in a multiple type II event might be assumed to be generated by a single shock traveling through different coronal structures. It may be said that the flares and CMEs (front or flank) both might be the source of multiple type II bursts.

Here we extend the aforesaid studies from 1997 to 2007 that is for the complete solar cycle 23, in view of its importance to space weather related problems.

2. Data Selection, Analysis and Results

A list of all solar type II and IV radio bursts recorded by WAVES/WIND instrument has been obtained from the online catalog available at <http://www-lep.gsfc.nasa.gov/waves/waves.html>. A total of 510 events were recorded by WAVES/WIND instrument in the period 1997-2007 for the complete solar cycle 23, of which 468 events were type II bursts. Out of which 42 events have multiple tones and are said to be multiple type II bursts. CME data has been taken from the website <http://cdaw.gsfc.nasa.gov/nasa.gov/cmelist>. Different observatories use different density models, for the calculation of the estimated shock speeds and different methods to determine the characteristics of the bursts. As already pointed out our study considers the bursts observed by WAVES/WIND instrument. In the following Table 1 we exhibit starting, ending frequencies, CMEs speeds and band width. For convenience, on line data is exhibited in table 2, as appendix.

Table 1. Properties of 42 multiple type II radio bursts

S. No.	Property	Mean	Median	Standard deviation
1	Starting frequency (MHz)	9.09	14	5.62
2	Ending frequency (MHz)	1.82	0.73	2.52
3	CMEs Speed (Km/s)	1311	1388	540
4	Bandwidth (MHz)	7.27	6.75	5.34

2.1. Life Time

Figure 1 shows distribution of life times of multiple type II radio bursts. The life time of bursts varies from 1 to 1437 minutes, and the mean value is 272 min.

2.2. Start Frequency

The histogram of the starting frequency is shown in figure 2. The start frequency for most of the multiple type II lies in the range of 1- 14 MHz. The mean of starting frequency is 9.09 MHz with a standard deviation of 5.62 MHz.

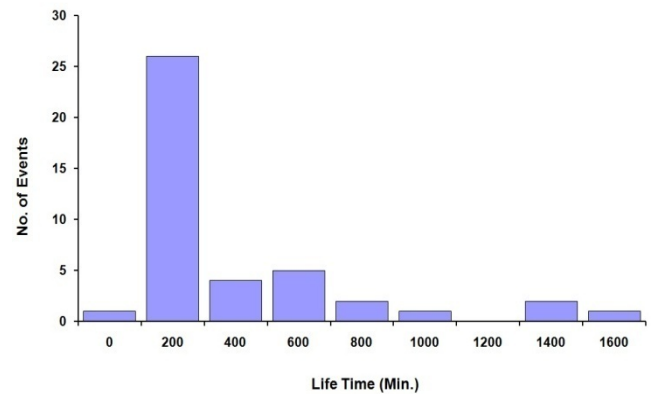


Figure 1. Distribution of life times of multiple type II radio bursts

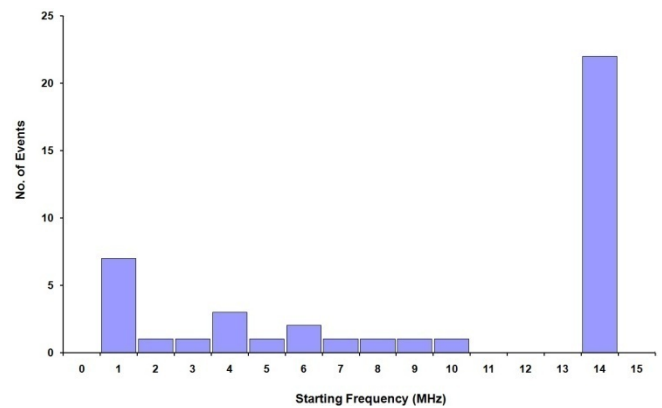


Figure 2. Shows the starting frequency of 42 multiple type II bursts

2.3. End Frequency

The distribution of the end frequencies of type II bursts is shown in figure 3. The end frequency varies from 1 to 10 MHz with most of its value lying around 1 MHz. The average end frequency is 1.82 MHz.

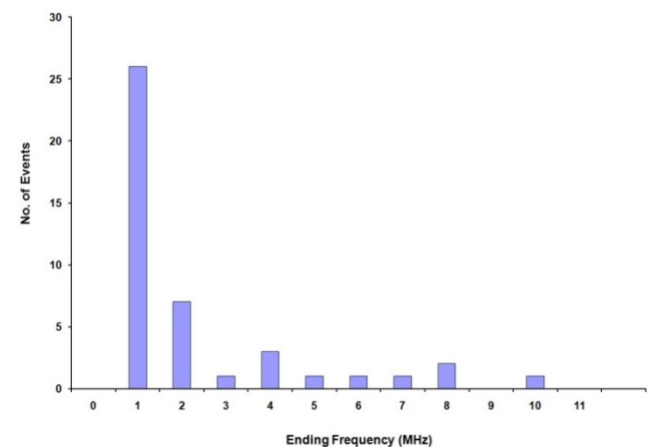


Figure 3. Shows the ending frequency of 42 multiple types II bursts

2.4. Band Width

Figure 4 shows the histogram of bandwidths (difference of start and end frequencies). The band width varies from 0.08 to 13.96 MHz, and the average band width is 7.27 MHz.

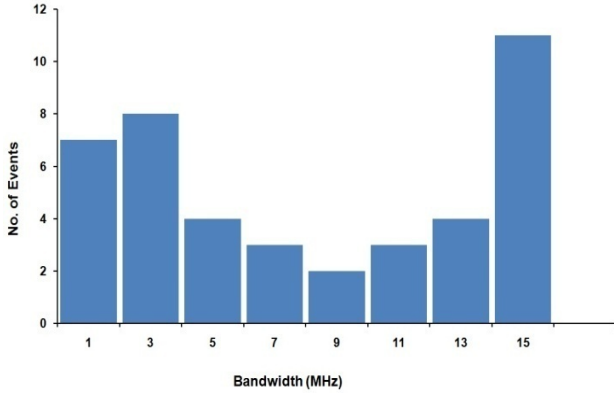


Figure 4. histogram showing the distribution of bandwidth of 42 multiple types II bursts

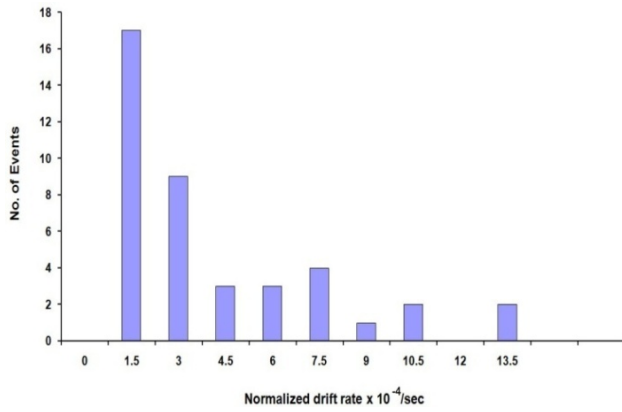


Figure 5. Distribution of normalized drift rates of type II radio bursts

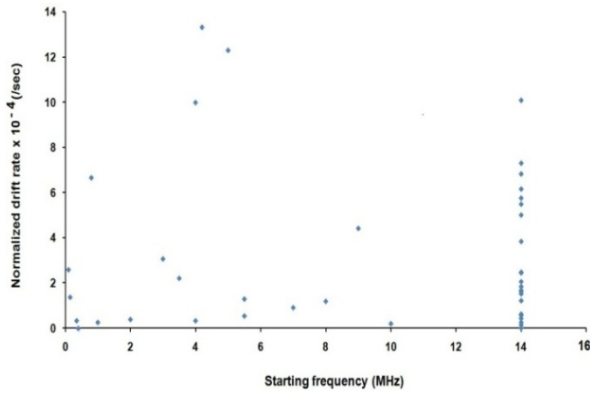


Figure 6. The scatter plot of the start frequency of type II bursts and their normalized drift rates

2.5. Drift Rate

The drift rate is determined from the starting and ending frequencies, and the time duration of type II bursts[18] given by the following relation;

$$\frac{df}{dt} = \frac{(f_s - f_e)}{T_d}$$

where T_d is the time duration between the start and end. f_s and f_e are starting and ending frequencies, respectively.

The normalized drift rate is denoted by $\frac{1}{f} * \frac{df}{dt}$ [16]. These rates have been determined and shown in figure 5. The mean normalized drift rate is $3.23 * 10^{-4} \text{ sec}^{-1}$.

Figure 6 shows scatter plot between the start frequency of type II bursts and their normalized drift rate. Here the linear correlation coefficient $r = 0.034$ which implies very poor correlation.

2.6. Drift velocity

The type II shock velocities V_{drift} are determined from the normalized drift rate by using the relation[19].

$$V_{\text{drift}} = -19.9 * \frac{\frac{1}{f} * \frac{df}{dt}}{[\ln(0.037 f^2)]^2}$$

where f is the frequency in MHz and V_{drift} is in solar radii per second. Here radial propagation of the MHD shocks and emission at the first harmonic of the local Langmuir frequency is assumed.

The velocities of CMEs in km/s (V_{CME}) versus drift velocities of associated type II bursts (V_{drift}) in km/s are exhibited in figure 7. Here we compare velocities of CMEs with associated type II drift velocities. In order to account for all errors in the estimation of speeds, following[20], we assume that a velocity ratio in the range 0.5-2 gives type II MHD shock which originates in the CME front. Only 9 of the CMEs associated with type II bursts come in this category.

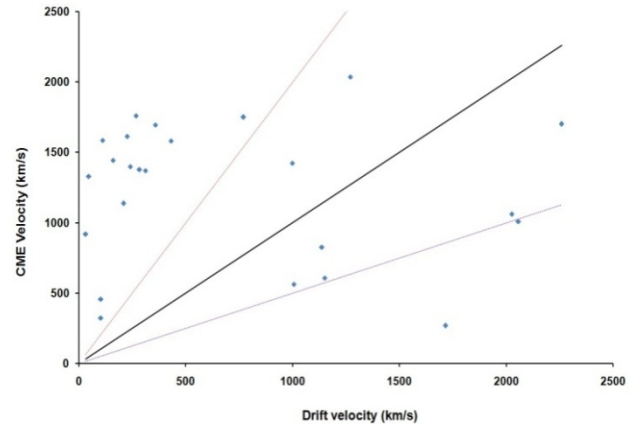


Figure 7. Shows the distribution of CMEs velocities and drift velocities of multiple type II radio bursts

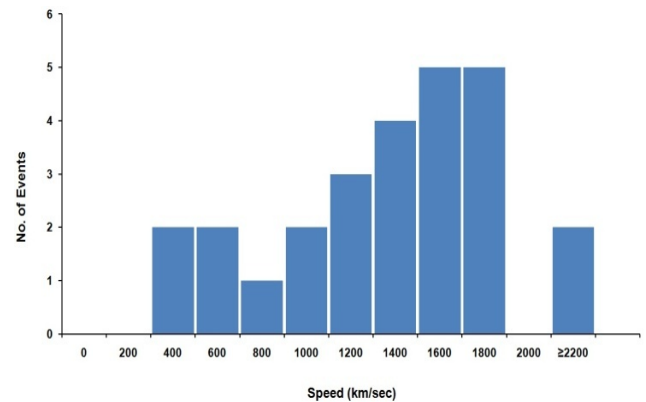


Figure 8. Shows the speeds of CMEs associated with multiple types II bursts

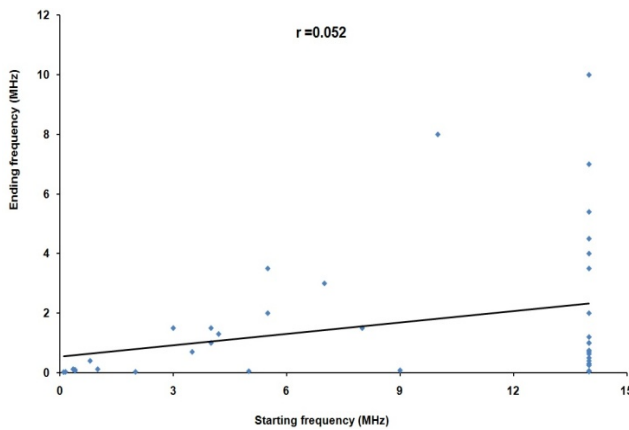


Figure 9. Scatter plot of ending and starting frequencies of 42 multiple type II bursts

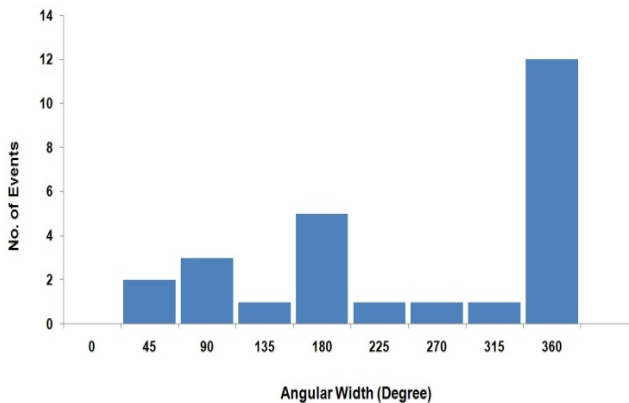


Figure 10. Distribution of angular width of CMEs associated with multiple type II bursts

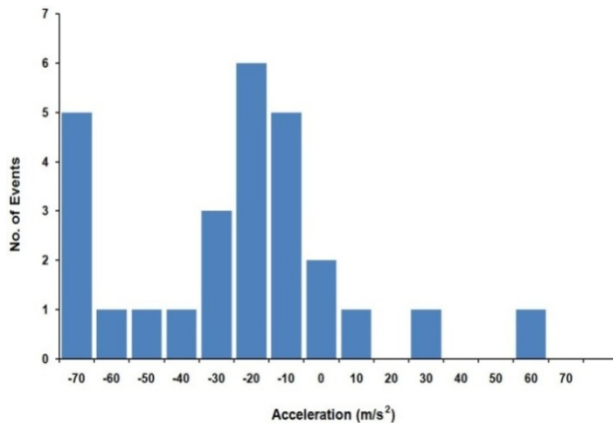


Figure 11. Distribution of acceleration of CMEs associated with type II bursts

The upper dotted line corresponds to $V_{CME} = 2V_{drift}$, the lower dotted line corresponds to $V_{CME} = 0.5 V_{drift}$ and the solid line corresponds to $V_{CME} = V_{drift}$.

Figure 8 gives distribution of speed of CMEs associated with multiple type II radio bursts. Mittal et al have investigated [21 and 22] speeds of all the types of CMEs in detail.

In figure 9 ending frequencies are plotted against starting frequencies, of type II bursts. Figure 10 and 11 give the

distribution of angular width and acceleration of CMEs associated with multiple types II bursts.

3. Discussion and Conclusions

We have analysed the characteristics of type II bursts and associated CMEs. Our analysis shows that most of the multiple type II bursts have life time around 200 min, the start frequencies around 14 MHz (see, e.g. Fig. 2) and ending frequencies around 1MHz (Fig 3).

The starting frequencies peak at about 14 MHz, whereas the ending frequency peaks at about 1MHz, the number of events decreases when the frequency increases. The relatively high values of starting frequencies may be due to flare blast wave.

The normalized drift rates of many of type II bursts are around $1.5 \times 10^{-4}/\text{sec}$. (cf. Fig. 5). These drift rates and starting frequencies seem to be uncorrelated, the correlation coefficient $r = 0.034$ (cf. Fig. 6). The starting and ending frequencies also seem to have no correlation, the correlation coefficient $r = 0.052$ (cf. Fig 9). This is in contradiction to [16].

Most of the CMEs associated with type II bursts are halo CMEs (Fig 10) with negative acceleration around -20 m/s^2 (Fig. 11) which is two times that reported by [16].

Figure 7 shows that only 7 of the type II MHD shocks originate in the CME front, the remaining may correspond to CME flank.

The association of type II bursts with flares will be the subject matter of our next article.

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Appendix

WIND/WAVES, SOHO/LASCO observations

Table-2 provides a brief summary of multiple type II bursts and corresponding CMEs during the study period. Column 1 give the date of events, start time, end time and frequency range are given by column 2,3, and 4 respectively. Column 5,6 and 7 gives the CMEs time, speed and width respectively from the SOHO/LASCO lists.

Table 2. List of multiple type II burst and corresponding CMEs events

Multiple Type II burst

26 events of CMEs

Date	start time	end time	Freq. (KHz)	time	speed (km/s)	Width	Acc. (m/s ²)
97/12/12	2245	2320	14000-8000	-	-	-	-
98/03/29	340	352	14000-7000	348	1397	360	-4.9
98/09/23	720	2320	2000-30	SOHO Data gap	-	-	-
99/05/10	2000	2000	150-30	-	-	-	-
99/09/10	730	735	5500-2000	754	1469	125	-30.2
99/11/30	2330	2400	400-100	-	-	-	-
00/03/09	2030	1200	400-60	-	-	-	-
00/03/17	100	1200	1000-120	128	323	46	7.7
00/04/18	2215	2320	4000-1000	-	-	-	-
00/06/06	1900	2000	7000-3000	-	-	-	-
00/07/21	525	550	14000-2000	506	268	47	1.1
001/05/04	600	1400	350-120	630	456	12	-27
001/06/15	1605	1620	14000-3500	1556	1701	360	56.9
001/09/17	835	847	14000-5400	854	1009	166	-14.5
001/10/9	1310	2300	5000-50	-	-	-	-
001/04/03	340	725	14000-700	326	1613	292	-16.7
001/11/22	2050	230	14000-40	2030	1443	360	-43.3
002/01/27	1235	1700	14000-300	1230	1136	360	-19.2
002/3/22	1130	1240	14000-500	1106	1750	360	-22.5
002/07/8	430	1320	800-400	-	-	-	-
002/07/29	1210	1245	4200-1300	1207	562	154	-4.3
002/8/16	615	930	14000-300	606	1378	162	-3.7
002/8/16	1220	2100	14000-60	1230	1585	360	-67.1
002/10/13	1810	1840	14000-4000	-	-	-	-
002/10/14	1435	1650	14000-1200	1454	1694	360	-55.4
002/12/22	420	450	5500-3500	-	-	-	-
003/04/22	725	722	3500-700	736	918	171	-8.9
003/08/19	1115	1200	14000-1000	-	-	-	-
003/10/26	700	915	8000-1500	654	1371	>207	-62.1
003/11/02	923	1120	14000-630	930	2036	360	-64.3
003/11/3	115	125	3000-1500	159	827	65	-28.3
003/11/17	905	920	4000-1500	926	1061	>242	-2.7
004/01/7	415	615	14000-750	406	1581	171	-60.4
004/09/12	45	2100	4000-40	36	1328	360	22.5
004/10/30	735	755	10000-8000	-	-	-	-
004/11/07	1625	2000	14000-60	1625	1759	360	-19.7
004/11/10	225	340	14000-1000	226	3387	360	-108
004/12/29	1635	1700	14000-4500	1645	607	12	-15.2
005/07/13	1415	1505	14000-1000	1430	1423	360	-14.1
005/07/30	740	2000	9000-80	-	-	-	-
005/09/15	1130	930	100-20	-	-	-	-
006/12/05	1050	2000	14000-250	no CME event	-	-	-

(-) Means that there is no CME data for the particular start time of the multiple type II burst

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