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Relationship of decametric-hectometric type II radio burst, coronal mass ejections and solar flare observed during 1997–2014

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HIGHLIGHTS

- The starting frequency of 85% DH type-II bursts lies in the range of 1–14 MHz.
- DH type II radio bursts (1–16 MHz) originate between 2.2–4.5 R_S.
- 48% DH Type II associated CMEs are located between ± 40° of solar central disc.
- Mean linear/initial speed of DH Type II associated CMEs are 1157/ 1200 km/s.
- Most of type II bursts are associated with strong SXR (X, M) class of solar flares.

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ABSTRACT

In the present study we have investigated 426 DH Type II radio burst and associated CMEs events observed during the time period of 1997–2014. The starting frequency of most of associated DH type-II bursts (85%) lies in the range of 1–14 MHz (364 out of 426) with mean value of starting frequency is ~11 MHz. The study of starting frequency (1–16 MHz) of DH type II bursts and heliocentric distance in solar radii indicate that DH type II radio bursts originate from 2.2–4.5 (R_S) heliocentric distance in solar radii. We also found that the ~ 48% DH Type II radio bursts associated CMEs are located between ± 40° of solar central disc and we also found that duration of DH type II radio bursts located at solar disc center are more than the duration of DH type II radio bursts located at solar limb. It is found that mean value for linear and initial speed of DH Type II associated CMEs are 1157 km/s and 1200 km/s, respectively. The CMEs speed are not correlated with duration of DH Type II radio bursts indicate that the durations of DH Type II radio bursts does not depend on speed of CMEs. The study also show that 426 DH type II radio bursts associated CMEs/flares occurred when there is coronal holes(CH) in nearby area and the mean distance between DH type II burst associated CMEs/ flares and boundary of coronal hole (CH) is 26°. The study also shows that there is no relation between drift velocity of DH type II radio bursts and speed of CMEs. The study also indicate that about 45% flares those associated DH Type II radio bursts have duration about 60 minutes and long duration DH Type II radio bursts are associated with X-class flares. We have also discussed that the results obtained in the present investigation in view of latest heliophysics interpretations.

1. Introduction

Solar radio bursts were amongst the first phenomena identified as targets for radio astronomy. Study on type-II radio bursts have been carried out by solar astronomers more than half century (Kundu, 1965; Reiner, 2000). The properties of type-II burst wavelength (1–16 MHz) associated with Coronal mass ejections (CMEs) were studied by several authors (Gopalswamy et al., 2001, Sharma et al, 2008, 2015, Suresh and Sangramanju, 2015, Mittal et al., 2016). The CMEs associated with DH-type-II radio bursts are called DH-CMEs. The shocks driven by CMEs accelerated electrons; produce type-II bursts. CMEs associated with Type radio II bursts are more energetic on the average and there is a hierarchical relationship between CME kinetic energy and the wavelength range of Type II radio bursts (Gopalswamy et al., 2005; Lara et al., 2003; Gopalswamy, 2006a). The average speeds of CMEs associated with Type II bursts confined to metric wavelengths is 610 km/s, only about 30% higher than the average speed (~470 km/s) of all CMEs. On the other hand Type II bursts with emission in the

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metric to kilometric wavelengths (the so-called m-km Type II bursts) are associated with CMEs of higher average speed: 1490 km/s, which is ∼3 times the average speed of all CMEs. CMEs associated with decameter-hectometric (DH) Type II bursts have intermediate speed 1115 km/s. Interestingly, the average speed (1524 km/s) of CMEs associated with large solar energetic particle (SEP) events is very similar to that of CMEs with m-km Type II bursts. This is consistent with the idea that CME-driven shocks accelerate both ions and electrons. Statistical studies have confirmed this close association (see e.g. Gopalswamy, 2003; Cliver et al., 2004). Thus, Type II bursts, especially those occurring at longer wavelengths, have become good indicators of SEP events. There are some observations that contradict the above picture. It was recognized long ago that some fast CMEs observed during 1979–1982 were not associated with metric Type II bursts (Sheeley et al., 1984). These CMEs had speeds up to 1600 km/s with a median value of ∼455 km/s. When CMEs move faster than the characteristic speed of the ambient medium (say, the Alfvén speed), they drive fast-mode MHD shocks, which in turn accelerate electrons to produce the Type II bursts. In this scheme, the radio-quietness (i.e. the lack of Type II bursts in the metric and DH wavelengths) can be explained as being due to either the fast CMEs not attaining super-Alfvénic speeds, or the CME-driven shocks are unable to excite Type II emission (Sheeley et al., 1984).

Gopalswamy (1998) study a set of m-type-II radio bursts without interplanetary (IP) counterparts and IP shocks without m-type-II radio bursts and conclude that the shocks inferred from m-type-II radio bursts and the IP shocks are of different origin. It is now well-known that space weather is significantly controlled by coronal mass ejections (CMEs) which can affect our Earth environment in many ways (Gopalswamy, 2006a; Iyer et al., 2006; Mittal and Narain, 2010). The starting frequency of a type II burst is of particular interest because it is indicative of the height of shock formation ahead of the CME. By studying a large number of type II bursts associated with EUV waves or white-light CMEs, Gopalswamy et al., (2013) were able to determine the heights of shock formation. They found that the starting frequency (f) of a type II is smaller when the shock forms at a greater heliocentric distance according to the empirical relation, $f = 308.17r^{-3.78} - 0.14$, where f is in MHz and r is the heliocentric distance in solar radii. Gopalswamy et al., (2015) found that for the 2000 September 12 event, $f = 24$ MHz, so the shock formation height was $r = 1.97$ Rs, corresponding to the outer corona which is consistent with the estimate of ∼1.92 Rs made from the flare acceleration method (Mäkelä et al. 2015). According to Gopalswamy et al., (2015) the frequency range 2–14 MHz corresponds to plasma frequencies in the 3–10 R_S heliocentric range and hence provides radio observations filling the gap between metric and kilometric observations.

Shelke and Pande (1985) suggested that in many cases type II radio bursts are produced after shock waves gets connected with open magnetic fields of coronal holes. Earlier, Verma and Pande (1989) and Verma (1992, 1998, 2002) suggested that the CME events are perhaps have been produced by some mechanism, in which the mass ejected by some solar flares or active prominences, gets connected with the open magnetic lines of CHs (coronal holes: source of high speed solar winds) and moves along them to appear as CMEs. The papers of Liu, et al. (2006), Liu (2007), Jiang, et al. (2007) and Asai et al. (2008, 2009) carried out studied CMEs and found that CHs close to the active region involved in the coronal mass ejections.

In the present paper we propose to investigate relationship between DH Type II radio burst and associated CMEs including other solar phenomena observed during the interval period of 1997 to 2014. No studies have ever dealt with such a large sample of 426 DH Type II radio burst associated CME events, to understand the properties of Type II radio burst associated CMEs. In Section 1 of the paper we try give an introduction about various facts of Type II radio burst associated CMEs related research work. In Section 2 of paper we mentioned about observational data and analysis. In Section 3 we have discussed the results obtained in the present investigation. A brief summary and conclusions are delivered in last Section 4.

2. Observational data, analysis and results

In present study we have considered 426 DH Type II bursts associated CMEs those are available online at the CDAW Data Center (http://cdaw.gsfc.nasa.gov/CME_list/radio/waves type2.html). The detailed information for CMEs and solar flares observed LASCO (Brueckner et al., 1995) and other instruments are taken from CDAW catalogue (http://cdaw.gsfc.nasa.gov/CME_list). The DH-type-II bursts are recorded in the frequency range between 16 MHz to 20 kHz using RAD-2 (16–1 MHz) and RAD-1 (1MHz–20 kHz) instruments by the Radio and Plasma Wave (WAVES) experiment on board the Wind spacecraft (Bougeret et al., 1995). The Type II burst starting frequency indicates the height at which shocks are being formed from the eruption (Gopalswamy et al., 2005). Total 482 events are observed during period 1997–2014, but 56 events does not have clear frequency and time duration, therefore after excluding 56 events we are left with 426 DH Type II radio bursts.

2.1. DH type II radio bursts associated CMEs and solar flares

The probability density distributions and cumulative distribution function of starting and ending frequency of DH Type II radio burst events are presented in Figs. 1 and 2. Fig. 1 shows the starting frequency of DH type-II bursts varies from 16 to 1 MHz, where 16 MHz is the upper cutoff frequency of the WAVES instrument. The starting frequency of events at 16 MHz implies that they cover the whole range of the WAVES instrument and some of them may be a continuation of metric type-II bursts. We calculated the mean value of DH type II radio bursts starting frequency of 426 events is 11 MHz as shown in Fig. 1. From distribution we can conclude that 34% DH type-II bursts have starting frequencies below or equal to 10 MHz and remaining 66% events has frequency greater than 10 MHz. The type-II burst ending frequency indicates the energy of CMEs (Gopalswamy et al., 2005, 2006b); that is, when the kinetic energy of the associated CMEs are more than the shock can travel to larger distance in the interplanetary medium. Fig. 2 shows that 84% events have ending frequency within the range of 20KHz to 5 MHz and the remaining 16% DH type-II bursts have frequency greater than 5 MHz. The mean value of DH type II bursts ending frequency is 2.23 MHz as shown in Fig. 2.

According to Gopalswamy et al., (2015) the frequency range 2–14 MHz corresponds to plasma frequencies in the 3–10 R_S heliocentric range and hence provides radio observations filling the gap between metric and kilometric observations. Gopalswamy et al., (2013) were able to determine the heights of shock formation. They found that the starting frequency (f) of a type II is smaller when the shock forms at a greater heliocentric distance according to the empirical relation, $f = 308.17r^{-3.78} - 0.14$, where f is in MHz and r is the heliocentric distance in solar radii. We have used above relation to calculated the heliocentric distance in solar radii for all 426 events. The starting frequency of DH type II radio bursts versus heliocentric distance in solar radii is shown in Fig. 3.

Out of 426 DH Type II radio burst associated SXR flares considered for study, the locations of 77 DH Type II radio burst associated SXR flares are not known. The spatial location of 349 DH Type II radio burst associated SXR flares on solar disc are shown in Fig. 4.

In Fig. 4 we have plotted solar disk locations of Type II radio burst associated CMEs related solar flares on x axis as an east