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Statistical analysis of Associated and non-Associated type II solar radio bursts during the increasing phase of solar cycle 23

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Abstract: Type II and Type III bursts are probably the most intensively studied form of radio emission in all of astrophysics. Immense effort has gone into the elucidation of both the observational and theoretical aspects. The bursts have captured the attention of plasma theorists because a considerable body of information exists on the plasma parameters and because there is adequate space and time in the solar corona for the evolution of various particle and wave processes. In our work, we have studied the type II bursts and their association with type III bursts during the increasing phase approaching the peak phase of solar cycle 23. For the period 2000-2001, type III bursts data of Culgoora observatory is referred. The parameters such as duration drift rate, shock speed, band width of these associated/non associated bursts are compared .Results indicate that the above parameters almost remain uniform for associated and non-associated type II bursts.

Keywords: Shock Speed, Drift Rate, Plasma Frequency, Dynamic Spectrum

1. Introduction

Solar radio bursts were amongst the first phenomena identified as targets for radio astronomy. Solar radio bursts at frequencies below a few hundred MHZ have been extensively studied. Among the 5 types of solar radio bursts, the type ii and type III bursts are most important from the perspective of space weather prediction.

Type III bursts are the fast drift bursts which are an attractive tool to investigate fast acceleration processes, which must be considered to be the cause of the high exciter velocities. They can be used as natural plasma probes traversing the corona and yielding information about different plasma parameters. Fast drift phenomenon provides an opportunity to study processes of different wave–particle and wave-wave interactions which has stimulated a considerable progress in developing in developing physical methods for a quantitative investigation. Therefore the type III bursts can be used as tracers of the magnetic field configuration and also other parameters in the coronal and solar wind. The investigation of the interplanetary medium through the analysis of the type III solar radio bursts at long wavelengths can in principle provide information about the structure and properties of active region streamers, Fainberg and Stone (1971).The type III phenomenon contains message about the interaction of beam with plasma and so it induced plasma physicists to study the possible mechanisms of such interactions and to treat the problem of how plasma processes can give rise to the emission of electromagnetic radiation.

The main defining characteristic of type III bursts was recognized by Wild (1950b) and Wild & Mcready (1950); it is that their emission drifts rapidly from high to low frequencies. The drift rate is roughly 100MHz/s in the meter wave range, some 100 times faster than drifting bursts, such as type I chains and type II bursts. Of the various forms of radio burst emissions from the Sun, the type III bursts are most likely to be indicative of the escape of energetic particles from the Sun. These radio bursts exhibit a rapid frequency drift (~80 MHz/s at 100MHz) from high to low frequencies and have been shown to be due to disturbance propagating outward in the solar corona at speeds of ~c/3 (c is velocity of light) (Wild et al., 1954:1959).Alvarez & Haddock (1973) made the suggestion that bursts are caused by streams of electrons. These streams move out through the corona along the open field lines at a speed of about c/3 and their passage sets up plasma oscillations – Langmuir waves then radiate at their characteristic frequency. Because the electron density and consequently the plasma frequency decrease outward from the Sun, the emission frequency of the bursts does likewise. According to plasma hypothesis (Wild, 1950) type III emission at the plasma frequency is given by

$$f_p = 9 \times 10^{-3} N^{\frac{1}{2}}$$

where N is in cm^{-3} is the electron density.

It is clear that for the type III bursts extending to low frequencies the exciting agent escapes from the Sun. The nature of the exciting agent has been hypothesized to be both proton(Wild et al.,1954;Friedman and Hamberger,1969) and electron streams(Wild et al.,1959).There are theoretical grounds for the choice of proton streams as the excitation agent (Smith,1970).However, protons of the requisite energy(~50MeV) are rarely observed to be emitted by the Sun, and when they are emitted, they are not necessarily accompanied by type III radio emission but rather by type IV and type II (Lin,1970).Smith(1970) raises the possibility that proton flux from a type III burst is too small to be observed above galactic cosmic ray background. Solar electros of ~c/3 velocity (~32keV) energy are frequently observed in the interplanetary medium. Almost every solar electron event of ~40keV is accompanied by such type III burst emission (Lin, 1970).The plasma hypothesis was confirmed by interferometer measurements of the type III source height at different frequencies which showed successively lower frequencies being emitted from successively greater heights (Wild et al., 1959).Interferometer observations show that the average radial velocity varies from 0.2c to 0.8c between the 60 and 45 MHz plasma levels. Individual type III bursts observed over a frequency range from 200 to 12MHz, i.e., from $0.15R_o$ to $2R_o$ above the photosphere, have rift rates which correspond to radial source velocities ~c/3. Wang et al. (2001) studied type III groups and concluded that type III bursts may be caused by energetic electrons accelerated during a non linear reconnection process in the larger magnetic loop of solar corona. During the reconnection, the magnetic field will become more complex in local smaller area, there will be some explosive and fast instability, such as Tokamak instability, in the smaller area which might case the relevant change in induced electric field and cause acceleration of electrons.

The distinguishing characteristic of type III bursts is their harmonic structure; because this has been a subject of controversy and their circular polarization. Harmonic structures are exhibited by a significant proportion of type III bursts at meter and decameter wavelengths. The frequency ratio of harmonic to fundamental averages to 1.8:1 with a range from 1.6:1 to 2.0:1 (Wild et al.,1954, Stewart,1947b).Type III bursts do not always drift down to very low frequencies. On many occasions bursts observed at metric wavelengths are not observed at decametric wavelengths, and similarly many bursts are not observed at hectometric and kilometric wavelengths which are seen by ground based observations which extend to decametric wavelengths (Hartz, 1969).the reasons for these cutoffs are not well understood. To study the possibility whether the exciting agent is impeded or dispersed in its progress outward through corona. Alvarez, et al. (1972) studied type III bursts which extend to kilometric wavelengths (frequencies $\leq$ 0.350MHz at height $\geq 50R_o$) and compare them with > 45KeV electron events observed at 1AU. They found that one to one correspondence exists between kilometric wavelengths type III burst above a threshold of approximately 10^{-13} $W/m^2/Hz$ and >45Kev observed at 1AU.They concluded that streams of ~10-100keV electrons are the exciting agents for the type III bursts and that ~ 5 x 10^{32} electrons with energy > 100keV are emitted in a strong type-III burst. A problem which remains is to explain the cutoff of many type-III bursts before they reach kilometric wavelengths. They observed that such correlation may be due to stopping of the electron beam before it reaches 1AU.The time profiles of the radio emission contain important information about the particle streams and their interaction with the interplanetary medium. A study of the characteristic range of these parameters with distance from Sun can lead to a better understanding of the propagation and interaction of energetic particles in the interplanetary medium, Evans et al (1973).The time profile of type III solar bursts can be used for the determination of the coronal temperature if we assume that the decay of the emission is due to the damping of plasma oscillations by electron-ion collisions (Kundu, 1965). The temperature T is related to the damping constant through the formula

$$T = 0.65 \times 10^{-4} f^{\frac{4}{3}} \tau^{\frac{2}{3}}$$

Here f is the frequency in hertz, τ is the damping constant in seconds. The frequency drift rate at meter wavelengths according to Alvarez and Haddock (1973) is given by

$$\frac{df}{dt} = -0.01 f^{1.84}$$

The drift rates were converted to velocity by assuming that the bursts propagated along a coronal streamer possessing the density distribution of Newkirk streamer model (Newkirk, 1961).

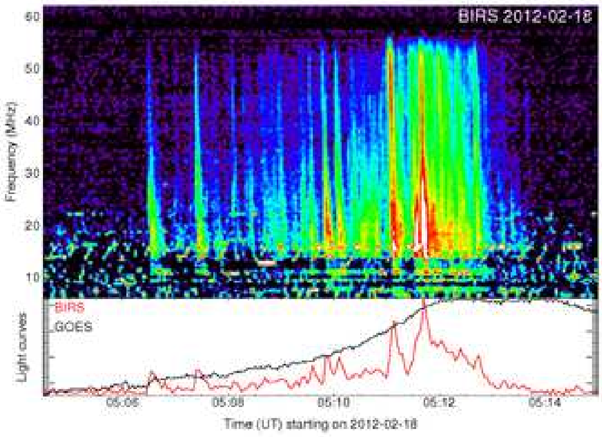


Fig 1: *Typical example of Type III radio burst observed with BIRS observatory on 18/02/2012.The bursts begin at 05:50UT and are observed at till 06:14UT.*

The problem of exciter origin is not yet solved satisfactorily. The short duration of Type III bursts should provide valuable hints for the investigation of the related acceleration processes. Their special significance in relation to solar flares is their occurrence in compact groups of intense bursts lasting a minute or two; at the flash phase which marks the time of the basic flare explosion (J P Wild et al., 1970).The drift rate and duration of type III bursts are known to be determined by the expressions given below

Duration = 60 / $f^{0.7}$ seconds

f is the drift rate MHz/s

Deceleration of exciter speeds is obtained from Fainberg (1971) as

D lob V_e / d log R = -0.38

V_e is the exciter speed in terms of velocity of light (Km/s)

R is the distance from the Sun in solar Radii and

D is the Deceleration in Km/s^2

The position of type III burst radiation source is determined by the path of the exciting particles in space. Due to the smaller gyro radii, the electrons are forced to follow the magnetic field direction. The starting heights of the type III bursts may not be regarded as the actual heights where the acceleration is initiated; the location of the exciter origin is obscured. Zaitsev (1985) concluded that in a spatially bound stream inspite of quasi linear relaxation plasma waves can be generated for a long time owing to faster particles escaping out of the front of the stream.

2. Type II Solar Radio Bursts

Payne-Scott observed large outburst of March 08, 1947 from Sun at three frequencies 10, 20 and 60MHz and found that the lower frequency emission was delayed with respect to higher frequencies. The Magneto Hydro Dynamic (MHD) Shock was found to be moving with speed 500-750km/s from higher to lower frequency plasma levels in the corona. Wild and Mcready(1950) classified these outbursts as type II radio bursts in contrast to type I storms and the fast drifting type III. All these bursts are due to non- thermal electrons and represent energy release in the corona. Type II bursts are the violent eruptions from the Sun that result in shock waves propagating through the corona and interplanetary medium. The origin of the shock waves in the solar corona that manifest themselves as solar type II radio bursts is one of the most important subjects of solar and terrestrial physics. A general picture of emission from type II shocks suggests that the emission mechanism is plasma emission near the fundamental and second harmonic (Smith, 1970; Melrose, 1980).Langmuir waves are produced by beams produced in the shock. The excited Langmuir waves may be converted into escaping radio waves by non linear wave-wave processes (Goldman & Smith, 1986: Cairns et al., 2003; Aschwanden, 2004).The study of type II is thus important for the understanding of the large scale structure and dynamics of the inner heliosphere. Since type II are good indicators of shocks that eventually cause sudden commencement of geomagnetic storms, their study is necessary for space weather predictions.

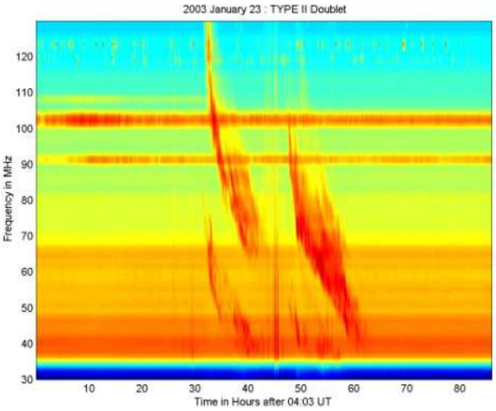


Fig 2: *Typical example of type II radio doublets observed with the Gauribidanoor digital solar radio spectrograph. Two type II bursts are seen in sequence with the first one starting at 04:32 UT and the second one at 04:49UT.Both these bursts show the fundamental and harmonic structures.*

Type II bursts are observed in the meter wave regime at frequencies <150MHz.Ground based instruments observe type II down to ionospheric cutoff (~15MHz). Space borne radio instruments observe type II bursts at frequencies below ionospheric cutoff in interplanetary medium. WIND/WAVES experiment(Bougeret,1995) has detected type II bursts in the previously unexplored regime of 1-14MHz.Ulyssis spacecraft has detected type II bursts at a distance of several AU from the Sun. Dynamic spectrum is a plot of the observed radio intensity as a function of frequency and time. Radio interferometric observations give positional information of the bursts. Two dimensional interferometric arrays known as radio heliographs provide detailed information on the spatial structure and position of the radio bursts. The emission is observed in fundamental and harmonic modes. The rate at which the emission frequency changes is known as the drift rate and corresponds to the motion of exciting agency (an MHD shock) through the corona (Wild, 1959).the typical drift rate is 0.1MHz/s. Using statistical analysis of type II bursts at frequencies >40MHz, Mann (1996) found that the type II bursts have a drift rate of -0.16 +/- 0.11 MHz/s. The drift is negative because the bursts drift from higher frequency to lower frequencies. For the harmonic component the drift rate is 0.2MHz/s but when normalized to the central frequency of emission, the rates are same. Bursts starting at very high frequencies seem to have high drift rates. Mann (1996) found a linear relationship

$$\frac{df}{dt} = 0.046-[0.002 /(s/f)]$$

s is the duration in seconds and
f is the bandwidth in MHz.

Statistical studies have shown that duration of type II bursts is about 5-15 minutes. The radio emission is considered to be due to a plasma emission process which involves the following steps.

1. An instability condition is set up due to propagation of an exciting agency through the corona resulting in the generation of high frequency plasma waves at the local plasma frequency f_p.

2. These plasma waves (Langmuir waves) scatter on the background ions resulting in electromagnetic waves of roughly the same frequency which propagate towards the observer and are detected as fundamental emission. Two plasma waves can coalesce resulting in an electromagnetic wave at a frequency 2fp which is observed as harmonic component. The condition for instability is maintained for the duration the agency passes through a given plasma layer. Once the agency leaves the layer, there is no more free energy available so the plasma waves decay to the thermal level and the generation of electromagnetic waves ends. The agency is a shock wave.

3. Fine Structure in Type II: (Band Splitting)

In the dynamic structure of type II, the F and H components are composed of two parallel lanes of emission. The frequency separation is about 10% of the central frequency .In the two dimensional images, the lower split bands originate higher in the corona than the upper side band. The band splitting seems to be related to the inhomogeneity in the medium. Several studies are being made to find answers to questions on origin height of type II and type III bursts. Dulk et al., (1971) pointed out that this finding is supported by the observation that type II sources often appear in the same regions as the type III sources that precede them in the flash phase and the inference that the type II bursts occasionally observed at frequencies as low as10MHz.The type II emission is generated behind the shock front,-i.e., in the region of enhanced electron density. This means that the electron density of the source as derived from the fundamental frequency of emission does not refer to the undisturbed corona but to temporarily compressed regions. One may therefore expect that at a given frequency type II and type III bursts would be generated at different heights. There is no statistical evidence to support this prediction. This matter requires careful observational investigation since, if established, an equal height for type II and type III bursts may force one to seek type II models in which the radiation is generated ahead of shock front.

4. Association between Type II and Type III Radio Bursts

The association between type II and type III radio bursts are necessary in several aspects. I n most of the cases, groups of type III radio bursts occur at the start of a flare. These type -III radio bursts in most cases are followed by a type II radio bursts. Type III bursts are fast drifting bursts with duration of few seconds. Type II solar bursts can sometimes occur without preceded by type III radio bursts also. It is interesting to study whether the characteristics of type II bursts associated with type III bursts are different from those not associated with type III bursts. This will lead to the understanding of drivers of type II radio bursts. In our work, we have studied the type III bursts and their association with type II bursts. For the period 2000-2001, radio bursts data of Culgoora observatory is referred.

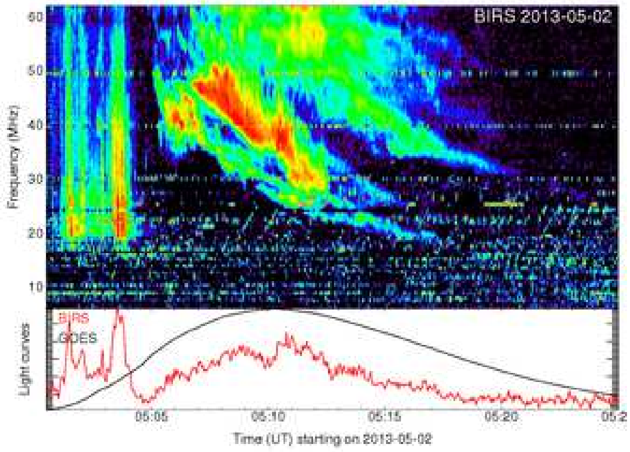


Fig 3: *Typical type II and type III radio burst associated event observed with BIRS on 02/05/2013. The type III burst begins at 06:05UT and the associated type II begins at 06:15UT.Harmonic features of type II bursts are observed.*

5. Data Selection

In this study, we have used the data of type II radio bursts published by Culgoora radio observatory in the Solar Geophysical Data for the period January 2000 to December 2004. In our work, we have studied the type III bursts and their association with type II bursts. We have considered events in which type III and type II bursts are occurring with the time separation less than 30 minutes. A very large number of unclassified types of bursts exist in the decameter range. For our purpose, the bursts have been selected using the following criteria- they have to be observed on at least two adjacent frequencies- the delay between the bursts observed on the two frequencies must correspond to the normal frequency drift of type III bursts- the bursts must be well isolated so that its time profile cannot be the superposition of different emissions. The observing period 2000-2001 being the increasing phase of Solar cycle 23, the activity was moderate. Table 1 summarizes the data set for the period 2000 - 2001.

Table 1

Observatory	**Year**	**Number of type II associated with type III events**	**Number of type II not associated with type III events**
Culgoora	2000	30	12
	2001	31	10

Typical examples of the non associated and associated type II radio bursts are shown in figure 2 and 3 respectively.

We have analyzed the following parameters from the data.

1. Total Duration
2. Start Frequency
3. End Frequency
4. Bandwidth
5. Drift rate
6. Estimated Shock Speeds (ESS)

The radio parameters data measured in our study is given below.

2000 Not associated Fundamental

date	**duration (min)**	**starting frequency(MHz)**	**ending frequency(MHz)**	**ESS(Km/s)**	**Bw(MHZ)**	**df/dt(MHz/s)**
12-Feb	8	35	90	-	55	0.114583333
17-Feb	15	25	90	-	65	0.072222222
	7	30	85	-	55	0.130952381
5-Mar	5	30	90	-	60	0.2
24-Mar	3	55	80	-	25	0.138888889
12-May	13	23	50	-	27	0.034615385
5-Jun	7	18	100	-	82	0.195238095
7-Jul	3	40	70	-	30	0.166666667
18-Jul	6	30	90	-	60	0.166666667
7-Sep	3	25	35	-	10	0.055555556
3-Oct	5	28	40	-	12	0.04
16-Nov	11	25	70	-	45	0.068181818

2000 Not Associated Harmonic

date	**duration (min)**	**starting frequency(MHz)**	**ending frequency(MHz)**	**ESS(Km/s)**	**Bw(MHZ)**	**df/dt(MHz/s)**
12-Feb	9	60	180	800	120	0.222222222
17-Feb	15	26	180	800	154	0.171111111
	11	40	150		110	0.166666667
5-Mar	6	60	140	900	80	0.222222222
	15	40	110	450	70	0.077777778
24-Mar	9	40	180	700	140	0.259259259
12-May	11	70	170	550	100	0.151515152
5-Jun	26	28	100	600	72	0.046153846
7-Jul	7	75	200	700	125	0.297619048
18-Jul	7	70	140		70	0.166666667
7-Sep	19	30	180	500	150	0.131578947
3-Oct	6	50	80		30	0.083333333
16-Nov	7	50	90	550	40	0.095238095

2000 Associated Fundamental

date	duration (min)	starting frequency(MHz)	ending frequency(MHz)	ESS(Km/s)	Bw(MHZ)	df/dt(MHz/s)
2-Jan	6	55	110	450	55	0.152777778
12-Jan	12	18	65	650	47	0.065277778
12-Feb	7	30	70	800	40	0.095238095
20-Feb	9	50	90	450	40	0.074074074
18-Mar	10	28	70		42	0.07
	4	35	45		10	0.041666667
	6	50	110	600	60	0.166666667
25-Mar	16	23	130		107	0.111458333
27-Mar	7	28	90		62	0.147619048
3-Mar	16	28	65		37	0.038541667
3-Mar	18	18	90		72	0.066666667
6-Apr	9	30	80		50	0.092592593
9-Apr	6	30	65		35	0.097222222
12-Apr	8	35	90	500	55	0.114583333
20-Apr	8	35	65		30	0.0625
1-May	9	25	60		35	0.064814815
18-Jun	14	30	650	750	620	0.738095238
23-Jun	9	30	60		30	0.055555556
26-Jun	7	20	60		40	0.095238095
10-Jul	12	28	80		52	0.072222222
15-Jul	4	30	55		25	0.104166667
25-Jul	7	50	270	700	220	0.523809524
27-Jul	2	110	160		50	0.416666667
28-Jul	4	30	50		20	0.083333333
22-Aug	6	50	90		40	0.111111111
16-Sep	10	20	70		50	0.083333333
25-Sep	10	30	180		150	0.25
9-Oct	6	18	35		17	0.047222222
9-Oct	15	18	35		17	0.018888889
9-Nov	9	18	55	1000	37	0.068518519

2000 Associated Harmonic

date	duration (min)	starting frequency(MHz)	ending frequency(MHz)	ESS(Km/s)	Bw(MHZ)	df/dt(MHz/s)
2-Jan	6	110	220	450	110	0.305555556
12-Jan	22	23	130	650	107	0.081060606
12-Feb	7	60	140	800	80	0.19047619
20-Feb	8	100	180	450	80	0.166666667
13-Mar	23	40	180		140	0.101449275
18-Mar	11	45	140		95	0.143939394
	6	45	80		35	0.097222222
	6	90	180		90	0.25
25-Mar	13	40	240	600	200	0.256410256
27-Mar	8	40	180	1400	140	0.291666667
	17	45	130	400	85	0.083333333
6-Apr	9	60	160	800	100	0.185185185
9-Apr	9	60	130	700	70	0.12962963
12-Apr	9	60	160		100	0.185185185
19-May	15	25	120	650	95	0.105555556
15-Jun	11	60	130	300	70	0.106060606
18-Jan	17	35	260		225	0.220588235

date	duration (min)	starting frequency(MHz)	ending frequency(MHz)	ESS(Km/s)	Bw(MHZ)	df/dt(MHz/s)
23-Jan	15	40	120	500	80	0.088888889
26-Jan	11	35	120	800	85	0.128787879
10-Jul	17	28	180	850	152	0.149019608
15-Jul	7	60	150	600	90	0.214285714
21-Jul	9	40	80	450	40	0.074074074
25-Jul	7	100	550		450	1.071428571
27-Jul	4	55	140	850	85	0.354166667
28-Jul	5	35	100	1300	65	0.216666667
1-Aug	6	45	90	750	45	0.125
15-Sep	3	60	100		40	0.222222222
16-Sep	12	30	150	1100	120	0.166666667
9-Oct	8	25	70	1000	45	0.09375
9-Oct	12	25	70	700	45	0.0625
9-Nov	9	25	90		65	0.12037037

2000 Start time difference and End Time Differences of Type II & Type III

date	Start time difference(min)	End Time Difference(Min)	Duration(Min)	BW(MHz)	df/dt(MHz/s)
2-Jan	4	-1	5	970	3.2333333
12	8	5	3	162	0.9
12-Feb	6	2	4	232	0.9666667
20-Feb	1	0	1	480	8
18-Mar	5	3	2	155	1.2916667
	3	-15	18	152	0.1407407
	2	0	2	447	3.725
27-Mar	4	1	3	143	0.7944444
	7	4	3		0
25-Mar	2	1	1	97	1.6166667
3-Mar	1	-4	5	1080	3.6
6-Apr	6	3	3	105	0.5833333
9-Apr	48	46	2	122	1.0166667
12-Apr	10	-14	24	112	0.0777778
20-Apr	20	2h47min	3h7min	135	Insufficient Data
19-May	21	2h21m	0	147	Insufficient Data
18-Jun	0	-7	7	162	0.3857143
23-Jun	9	5	4	300	1.25
26-Jun	5	1	4	140	0.5833333
10-Jul	6	4	2	230	1.9166667
15-Jul	9	-4	13	150	0.1923077
25-Jul	1	0	1	1782	29.7
27-Jul	5	4	1	300	5
28-Jul	6	5	9	150	0.2777778
22-Aug	13	-3	16	55	0.0572917
16-Sep	6	2	4	1382	5.7583333
26-Sep	1	3h17m	3h18m	157	Insufficient Data
9-Oct	3	-12	15	675	0.75
16-Oct	9	5	4	50	0.2083333
9-Nov	7	0	7	160	0.3809524

2001 Fundamental Associated

date	duration (min)	starting frequency(MHz)	ending frequency(MHz)	ESS(Km/s)	Bw(MHZ)	df/dt(MHz/s)
20-Jan	3	18	30		12	0.066666667
10-Mar	8	30	70	800	40	0.083333333
20	2	60	90		30	0.25
24	2	40	80		40	0.333333333
2-Apr	5	28	55	800	27	0.09
14-Apr	2	75	20	750	-55	-0.458333333
10-Apr	4	23	70	2000	47	0.195833333
18-Apr	16	18	130		112	0.116666667
22-Apr	6	60	140		80	0.222222222
12-May	5	23	90		67	0.223333333
11-Jun	3	35	45		10	0.055555556
	4	30	50	800	20	0.083333333
10-Jun	2	57	100		43	0.358333333
30-Jun	3	57	90		33	0.183333333
	17	57	300		243	0.238235294
31june	5	57	150		93	0.31
17-Sep	6	60	150	600	90	0.25
20-Sep	3	57	70		13	0.072222222
25-Sep	2	57	70		13	0.108333333
3-Sep	11	57	140		83	0.125757576
9-Oct	5	57	90		33	0.11
11-Oct	5	57	90		33	0.11
19-Oct	6	57	90		33	0.091666667
	1	57	110		53	0.883333333
21-Oct	4	57	130	750	73	0.304166667
5-Oct	6	57	90		33	0.091666667
8-Nov	4	57	150		93	0.3875
22-Nov	5	57	80		23	0.076666667
29-Nov	8	57	150		93	0.19375
9-Dec	1	57	75		18	0.3
19-Dec	2	57	70		13	0.108333333

2001 Harmonic Associated

date	duration (min)	starting frequency(MHz)	ending frequency(MHz)	ESS(Km/s)	Bw(MHZ)	df/dt(MHz/s)
9-Jan	4	60	180	1200	120	0.5
10	13	20	160	1200	140	0.179
17	9	70	130	300	60	0.111
10-Mar	7	60	130		70	0.167
20-Mar	2	120	170	750	50	0.417
24-Mar	12	50	230	700	180	0.25
2-Mar	5	55	110		55	0.183
10-Mar	4	40	140		100	0.417
14-Mar	2	140	190		50	0.417
18-Mar	16	40	260	550	220	0.229
22-Mar	21	55	290	550	235	0.187
12-May	8	40	180	950	140	0.292
21-May	8	50	150	550	100	0.208
8-Jun	13	30	90	600	60	0.077
11-Jun	3	70	90		20	0.111
	9	30	100		70	0.13

date	duration (min)	starting frequency(MHz)	ending frequency(MHz)	ESS(Km/s)	Bw(MHZ)	df/dt(MHz/s)
7-Jul	17	57	150	500	93	0.091
10-Aug	2	100	180		80	0.667
30-Aug	2	57	70		13	0.108
	11	57	150	750	93	0.141
31-Aug	11	57	300	750	243	0.368
17-Sep	5	120	200		80	0.267
20-Sep	6	57	140	750	83	0.231
25-Sep	15	57	120	550	63	0.07
9-Oct	11	57	180	550	123	0.186
11-Oct	14	57	170	400	113	0.135
19-Oct	12	57	180	500	123	0.171
	2	70	220	1800	150	1.25
21-Oct	4	120	260		140	0.583
8-Nov	6	65	300	1000	235	0.653
22-Nov	6	57	170	900	113	0.314
29-Nov	8	110	280	600	170	0.354
9-Dec	5	70	150	650	80	0.267
19-Dec	2	110	130	500	20	0.167
26-Dec	4	57	80	800	23	0.096
28-Dec	8	57	150	800	93	0.194

2001 Fundamental Not Associated

date	duration (min)	starting frequency(MHz)	ending frequency(MHz)	ESS(Km/s)	Bw(MHZ)	df/dt(MHz/s)
3-Jan	6	57	75		18	0.05
25-Jan	7	57	85		28	0.0666
19-Sep	1	57	70		13	0.2166
	4	57	130		73	0.3041

2001 Harmonic Not Associated

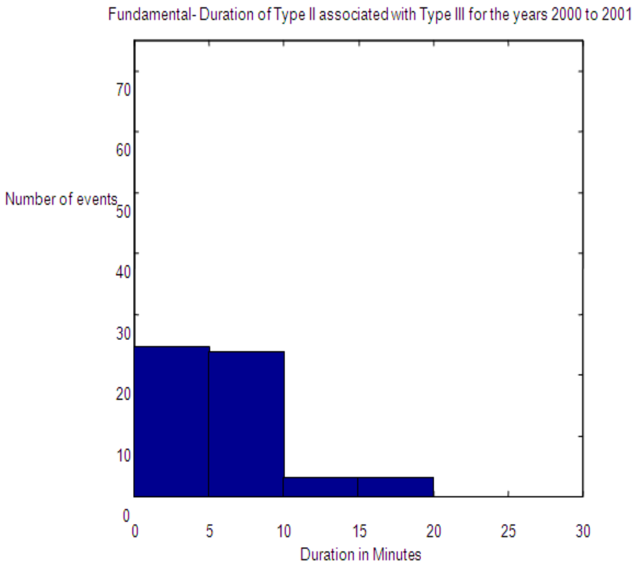
date	duration (min)	starting frequency(MHz)	ending frequency(MHz)	ESS(Km/s)	Bw(MHZ)	df/dt(MHz/s)
3-Jan	11	57	150	520	93	0.1409
31-May	11	57	85	400	28	0.0424
19-Sep	3	70	140	1000	70	0.3888
21-Sep	9	57	260	900	203	0.3759

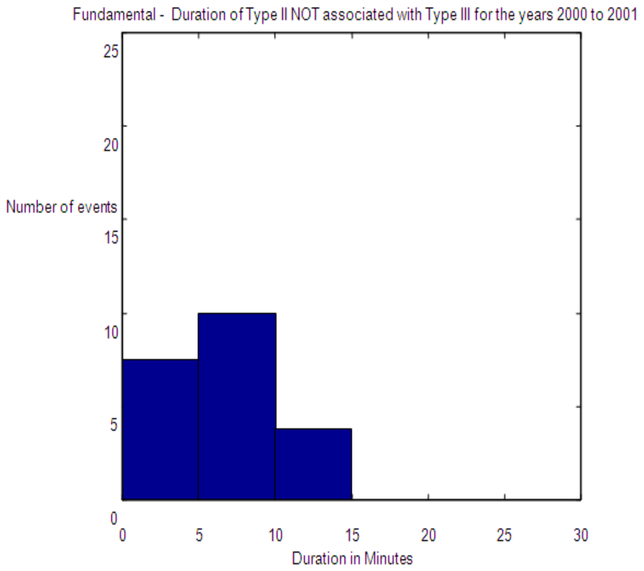
2001 Start time difference and End Time Differences of Type III & Type II

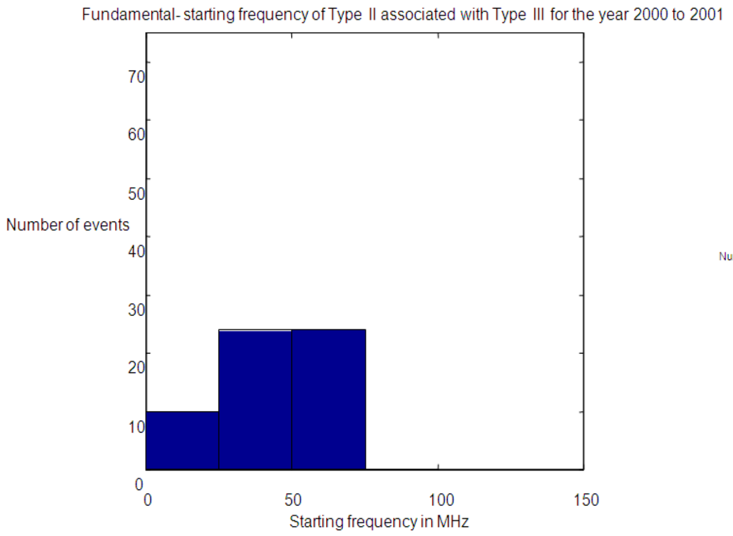
date	Start time difference(min)	End Time Difference(Min)	Duration(Min)	BW(MHz)	df/dt(MHz/s)
6-Feb	6	2	4	193	0.8041667
16	6	6	6	203	0.5638889
20	7	5	2	343	2.8583333
27	4	3	11	123	0.1863636
1-Mar	12	9	3	343	1.9055556
12	13	13	0	250	Insufficient Data
4-Apr	14	14	0	123	Insufficient Data
	5	-22	27	123	0.0759259

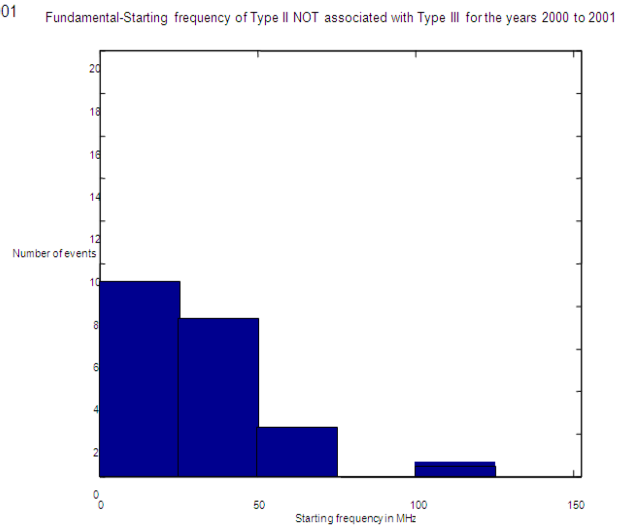
date	Start time difference(min)	End Time Difference(Min)	Duration(Min)	BW(MHz)	df/dt(MHz/s)
9-Apr	2	0	2	83	0.6916667
12	10	1	9	540	1
	3	2	1	123	2.05
21-Apr	6	1	5	323	1.0766667
21-May	6	0	6	1243	3.4527778
12-Jun	12	9	3	123	0.6833333
1-Jun	2	1	1	1743	29.05
20-Jul	2	-2	4	273	1.1375
23-Jul	1	-3	4	1243	5.1791667
29-Jul	0	-1	1	300	5
14-Aug	1	-1	2	103	0.8583333
16-Aug	46	-88	2h14m	33	0
18-Aug	13	3	10	1543	2.5716667
21-Aug	2	0	2	643	5.3583333
	5	1	4	1243	5.1791667
23-Aug	6	4	2	83	0.6916667
24-Aug	6	3	3	123	0.6833333
	6	4	2	1540	12.833333
2-Sep	4	3	1	1243	20.716667
30-Sep	6	1	5	832	2.7733333
4-Oct	3	-1	4	502	2.0916667
5-Oct	4	2	2	90	0.75
14-Oct	4	1	3	150	0.8333333
27-Oct	7	-12	19	92	0.0807018
6-Nov	20	-12	33	162	0.0818182
10-Nov	4	-2	6	457	1.2694444
	10	4	6	457	1.2694444
4-Dec	5	-4	9	482	0.8925926
19-Dec	1	0	1	233	3.8833333
	3	-12	15	342	0.38
	2	2	0	180	0

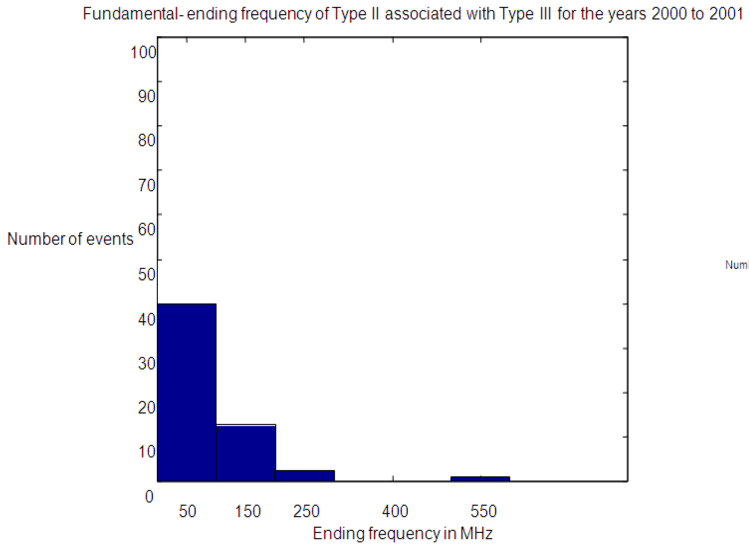
From the statistical analysis, the following graphs were obtained.

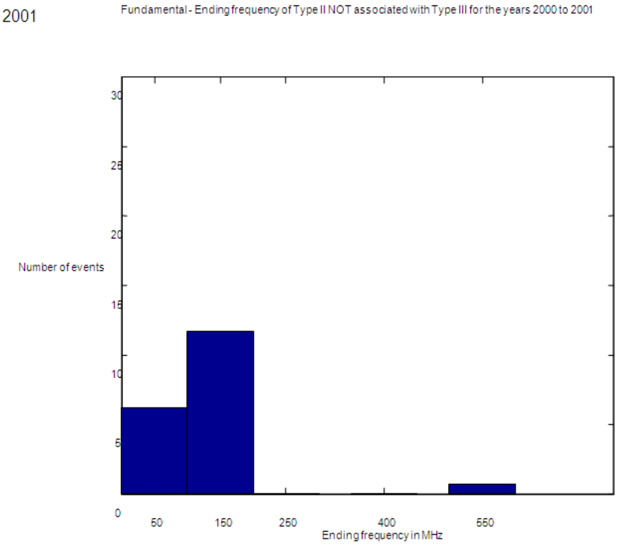

Fundamental- Duration of Type II associated with Type III for the years 2000 to 2001

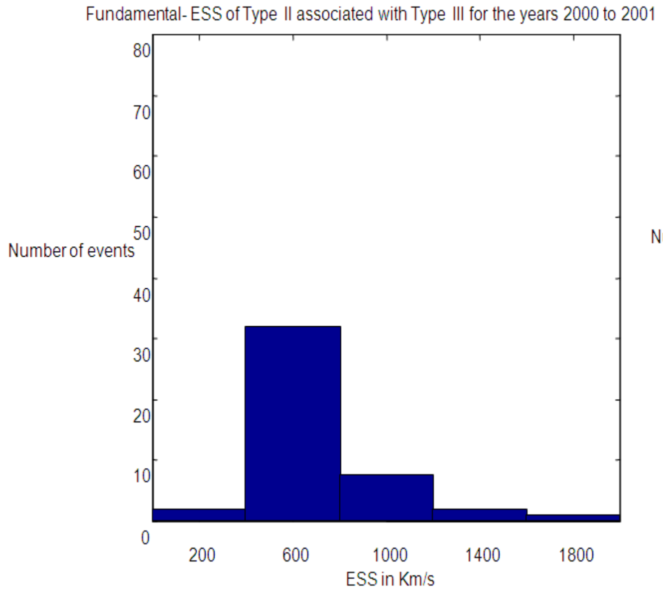

Fundamental - Duration of Type II NOT associated with Type III for the years 2000 to 2001

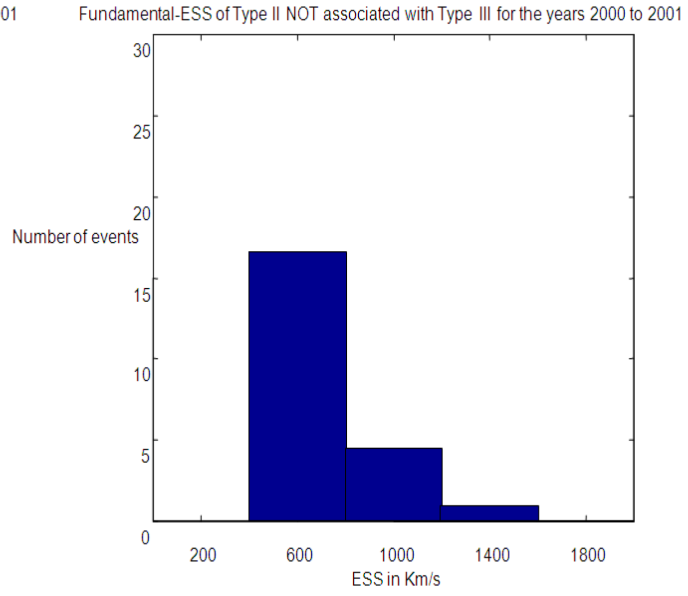

Fundamental- starting frequency of Type II associated with Type III for the year 2000 to 2001
Number of events
70
60
50
40
30
20
10
0
0
50
100
150
Starting frequency in MHz


Fundamental-Starting frequency of Type II NOT associated with Type III for the years 2000 to 2001
Number of events
20
18
16
14
12
10
8
6
4
2
0
0
50
100
150
Starting frequency in MHz

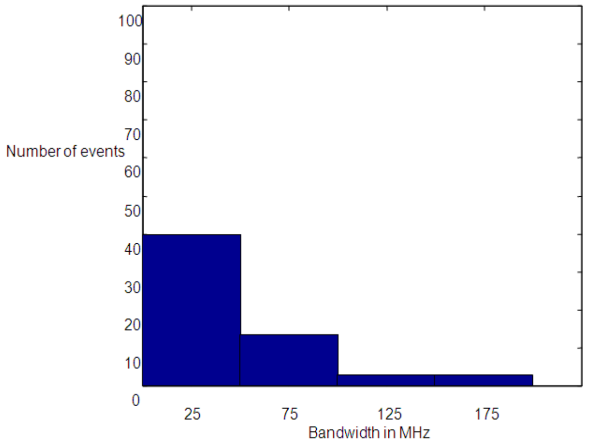

Fundamental- ending frequency of Type II associated with Type III for the years 2000 to 2001
Number of events
100
90
80
70
60
50
40
30
20
10
0
50
150
250
400
550
Ending frequency in MHz


Fundamental - Ending frequency of Type II NOT associated with Type III for the years 2000 to 2001
Number of events
30
25
20
15
10
5
0
50
150
250
400
550
Ending frequency in MHz

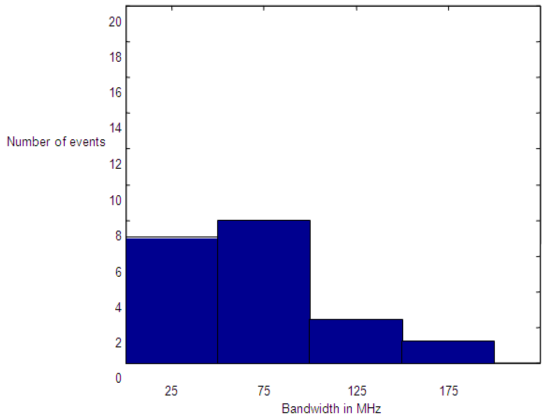

Fundamental- ESS of Type II associated with Type III for the years 2000 to 2001
Number of events
80
70
60
50
40
30
20
10
0
200
600
1000
1400
1800
ESS in Km/s


Fundamental-ESS of Type II NOT associated with Type III for the years 2000 to 2001
Number of events
30
25
20
15
10
5
0
200
600
1000
1400
1800
ESS in Km/s

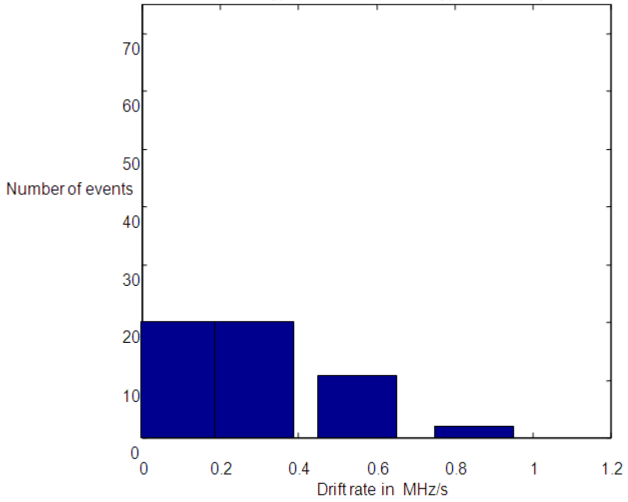
Fundamental- Bandwidth of Type II associated with Type III for the years 2000 to 2001



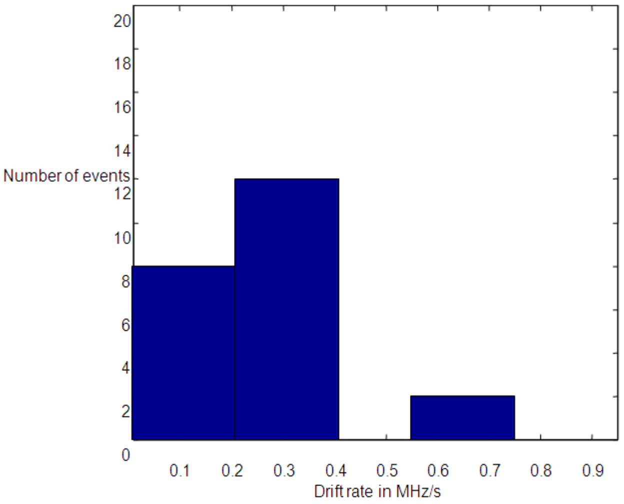
Fundamental-Bandwidth of Type II NOT associated with Type III for the years 2000 to 2001



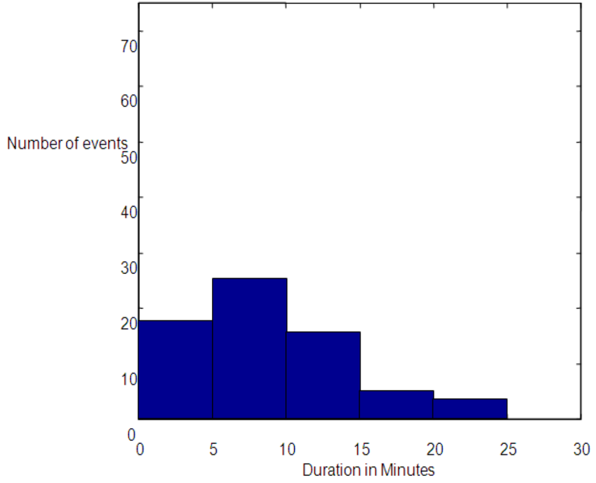
Fundamental- Drift rate of Type II associated with Type III for the years 2000 to 2001



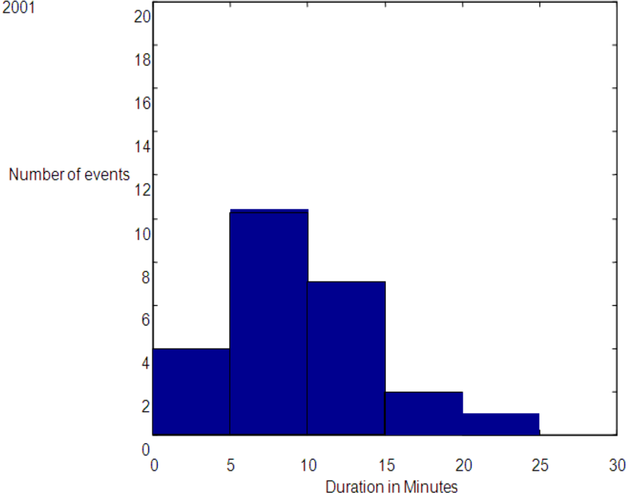
Fundamental-Drift Rate of Type II NOT associated with Type III for the years 2000 to 2001

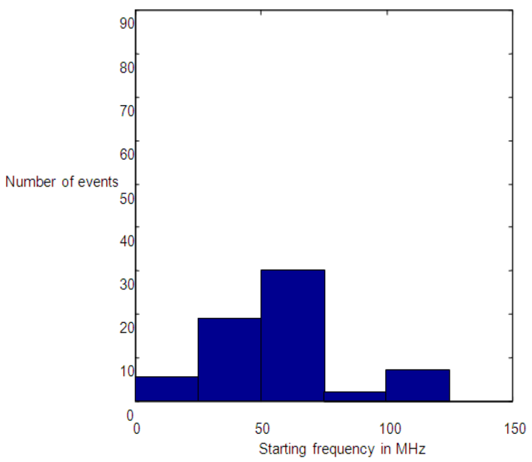


HARMONIC - Duration of Type II associated with Type III for the year 2000 to 2001

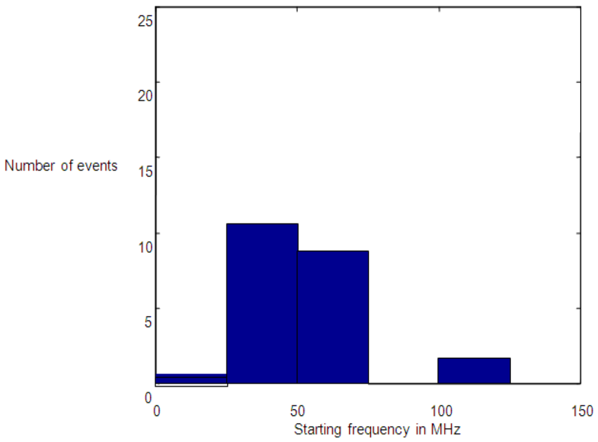


HARMONIC-Duration of Type II NOT associated with Type III for the years 2000 to 2001

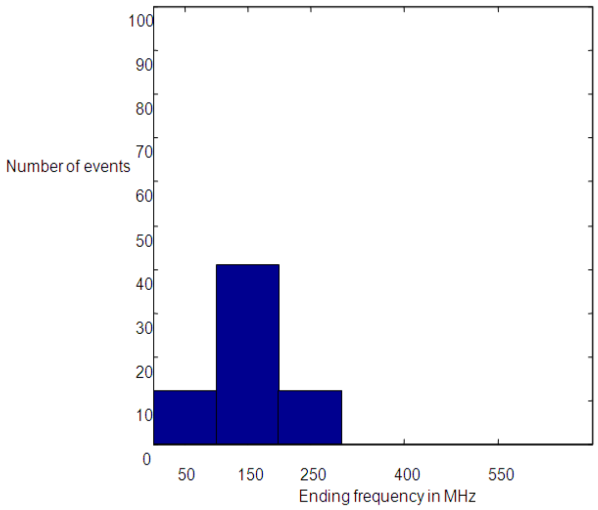




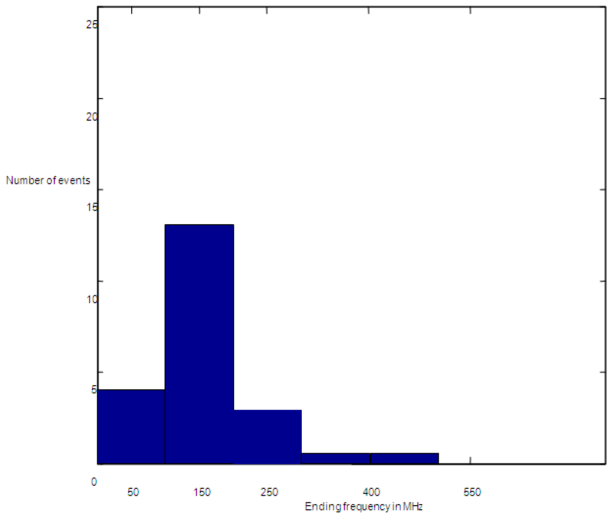
HARMONIC - Starting Frequency of Type II associated with Type III for the years 2000 to 2001



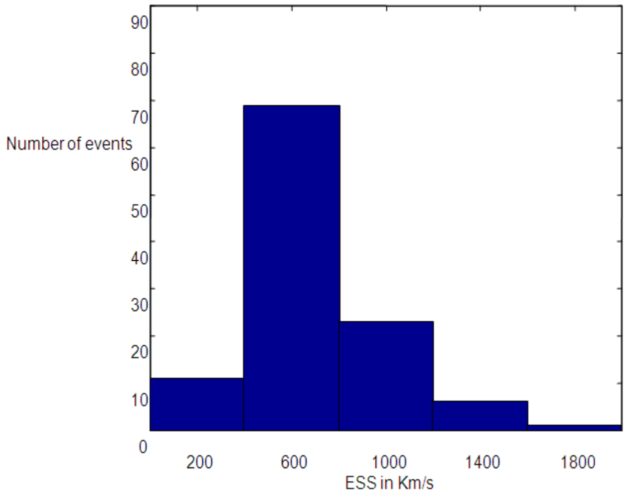
HARMONIC-Starting frequency of Type II NOT associated with Type III for the years 2000 to 2001



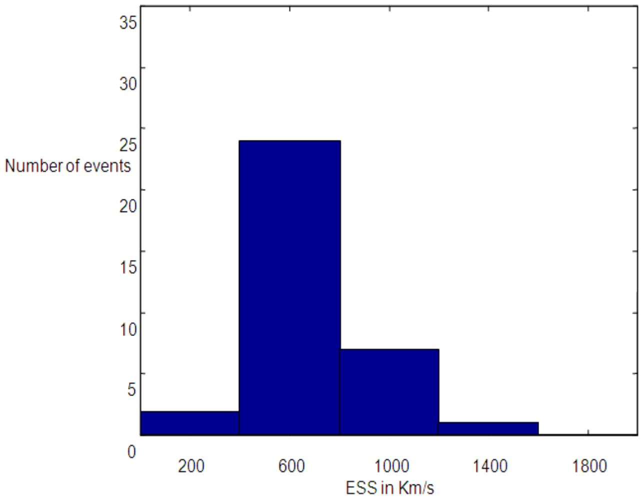
HARMONIC - Ending Frequency of Type II associated with Type III for the years 2000 to 2001



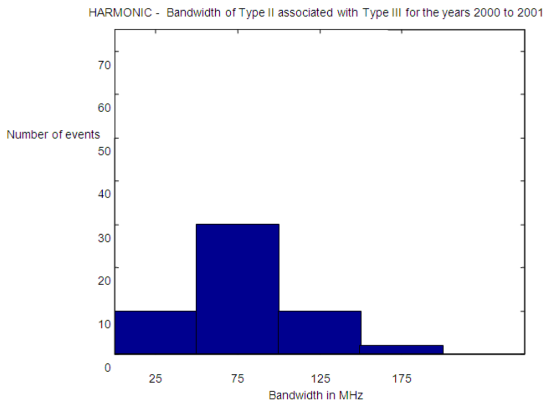
HARMONIC-Ending frequency of Type II NOT associated with Type III for the years 2000 to 2001

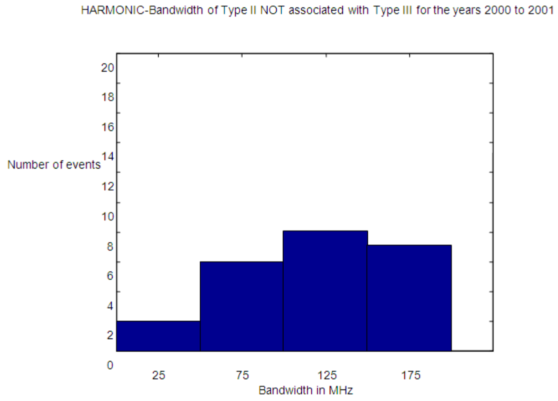


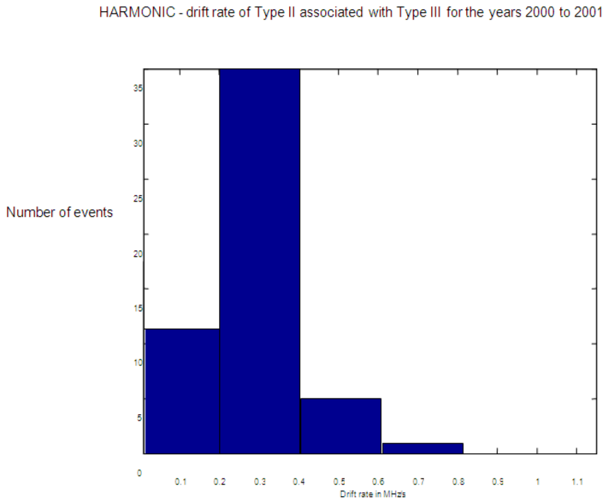
HARMONIC - ESS of Type II associated with Type III for the years 2000 to 2001

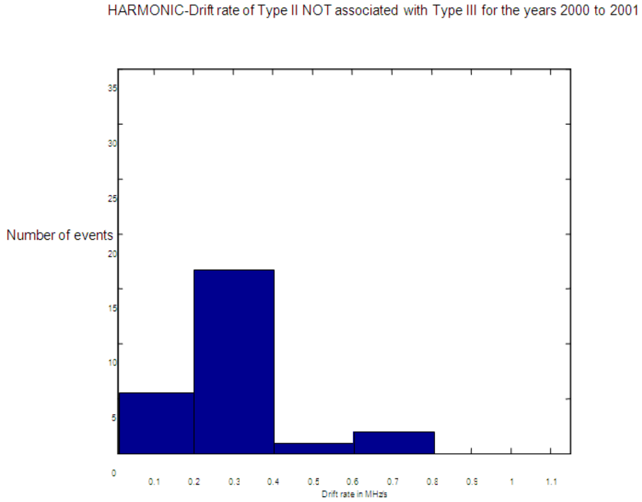


HARMONIC-ESS of Type II NOT associated with Type III for the years 2000 to 2001


HARMONIC - Bandwidth of Type II associated with Type III for the years 2000 to 2001


HARMONIC-Bandwidth of Type II NOT associated with Type III for the years 2000 to 2001


HARMONIC - drift rate of Type II associated with Type III for the years 2000 to 2001


HARMONIC-Drift rate of Type II NOT associated with Type III for the years 2000 to 2001

6. Results and Discussion

1.The time profile of a burst at a given frequency is believed to represent the passage an electron stream through the plasma frequency level and the temperature of the corona at different heights (Aubier et al., 1972).The burst duration at each level is believed to be related to the duration of excitation(i.e. the time required for the exciter to cross the level) rather than the response of the medium; it increases with time , which indicates an increase of the exciter length with the distance traversed by the beam due to dispersion(Poquerusse et al.,1984).

In the case of fundamental emission, the number of associated type II radio bursts with a duration of 1-5 minutes is almost same as (26 events) the bursts with duration between 5-10 minutes (25 events) whereas harmonic emissions have more bursts with duration 5-10 minutes (25 events) than those with 1-5 minutes(19). The same pattern can be seen in the case of type II radio bursts non-associated type III radio bursts .In the case of fundamental emissions 8 events had the duration of 1-5minutes and 10 harmonic emissions had the duration of 5-10minutes.

2. The starting frequencies of majority of associated type II radio bursts lie in the range of 25 to 75 MHz (58 out of 59 events in case of associated fundamental emissions and 53 out of 62 events in case of harmonic events).With non-associated events, a similar pattern was observed (21 out of 24 fundamental bursts and 23 out of 25 harmonic bursts). The ending frequencies are in the range 50-200MHz (58 events out of 60 in associated fundamental events and 54 out of 66 in harmonic events).With non-associated bursts, most of the bursts possessed ending frequencies in the range 50-200MHz (20 out of 21 fundamental events and 21 out of 23 harmonic events).

3. The Estimated shock speeds (ESS) of associated type II radio bursts are in the range of 400 to 800 km/s in majority of the cases (38 out 43 events). In the case of non-associated type II radio bursts also, the ESS is in the range of 400 to 800 km/s in most of the cases (21 out of 22 events). In very few cases, a higher ESS of 2000km/s (2 out of 68 cases including associated and non- associated events) is noticed.

4. Bandwidth of associated bursts is less than 50 MHz for fundamental emission (in 40 cases out of 61) whereas for harmonic emission; it increases up to 100 MHz (30 out of 63 cases). In the case of non associated bursts, 18 out of 20 fundamental bursts had bandwidth in the range of 1-100MHz.Interestingly 9 out of 24 non-associated harmonic bursts possessed a bandwidth of 1-100MHz and 15 out of 24 events were in the range 100-200MHz.

5. Around half of the associated bursts (23/61) had a drift

rate in the range of 0.01-0.099MHz/s where as in 49 out 61 events, the drift rate was in the range 0.1 to 0.4 MHz/s. Only in two cases, it was above 0.8MHz/s. Drift rate of majority of harmonic emissions is in the range 0.1 -0.4 MHz/s (45 out 64 events) and hence is higher than the fundamental emission. In the case of non-associated type II bursts, 20 out of 22 fundamental events, the drift rate was in the range of 0.01-0.4MHz/s and 23 out of 26 harmonic events had the drift rate in the range of 0.1 -0.4MHz/s.

7. Conclusions

Based on association of type II radio bursts and type III radio bursts, the variation in the parameters such as duration , bandwidth, ESS, drift rate of type II radio bursts associated/non associated with type III radio bursts during the increasing phase (2000 & 2001) of solar cycle 23 are explained. The time structure characteristics of type III radio bursts associated with type II radio burst is carried out.

The results of this study have been obtained by an extensive analysis of several data sets. The figures in this paper do not necessarily do justice to the complicated phenomena that are under study. Neither do conventional written reports. Using the available data we have concluded that:

1. Although the sources and origin processes of type II bursts and the type III bursts are different, the plasma parameters remain almost uniform and variation in the plasma parameters of associated and non-associated events is very marginal except in the case of bandwidth. Since the duration of our study and the number of events is not fairly large, this observation needs further examination.
2. The dynamic spectra of events associated with interplanetary solar energetic particles are very complex and rarely show well defined type II bursts i.e. slowly drifting, harmonically-related pairs of narrow bands. The type II features that are observed appear to be composed of limited frequency type III bursts. The dominant feature is overlying wideband type III emission.

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