Solar Radio Bursts Observed at Anchorage, Alaska in the High Frequency Band

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1. Introduction

Solar radio emissions have three distinct components: 1) Quiet Sun; 2) Bright regions; and 3) Transient disturbances generally associated with flares. The transient disturbances are called *radio bursts*. Radio bursts are associated with solar flares and originate from all levels of the solar atmosphere between the lower chromosphere and outer corona to heights of several solar radii. Descriptions of the chromosphere and corona can be found at {Chromo} and {Corona}.

This paper discusses radio bursts received in 2012 at Anchorage, Alaska during the first peak of solar sunspot cycle 24 (figure 1) with frequencies between 10 and 34 MHz (wavelengths between about 9 and 30 meters). Bursts at these frequencies originate in the outer corona. It should be noted that Earth's ionosphere generally blocks extraterrestrial emissions below about 15 MHz, although the blocking frequency varies with solar activity and sunspot cycle. However, some bursts are so powerful that they can be received on Earth at frequencies below this approximate cutoff at locations where the ionosphere's density is relatively low.

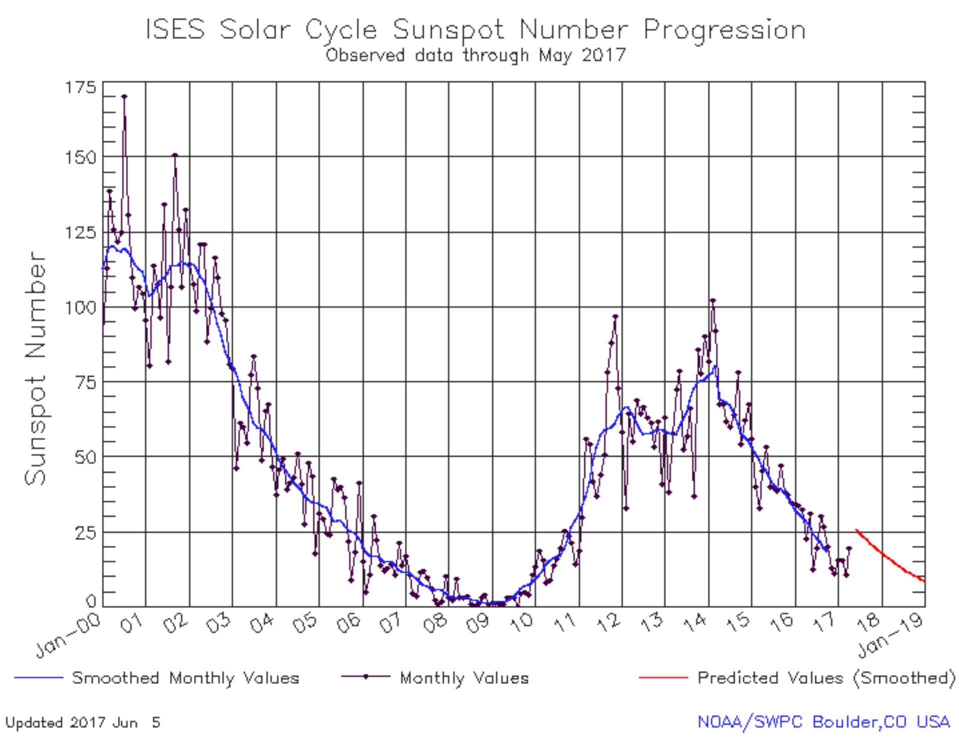


Figure 1 ~ Solar cycle sunspot number progression through May 2017. All radio bursts discussed in this paper occurred in 2012 near the first peak of cycle 24. Cycle 24 began in early 2008 and showed two peaks, one in late 2011 and another in early 2014. Image courtesy NOAA/SWPC.

2. Radio Burst classifications

Solar radio bursts are classified on the basis of their frequency and time (spectral and temporal) characteristics into seven types, Type I through Type VII with Types I through Type V being basic types and Types VI and VII being extensions of Type III and Type V. See Table 1 for a summary of spectral classifications; for additional descriptive information see {IPSCat}. This article does not include any Type I or Type IV bursts. Type I bursts normally are received at frequencies above those discussed in this paper, and my instrumentation recorded no Type IV bursts during the time period covered.

Identification of the burst spectral classifications in this article were aided by Space Weather Prediction Center (SWPC) Events reports at {SWPCEvent }. I also received assistance from Nigel P. Prestage at Culgoora Solar Observatory (see acknowledgements in section 5). The SWPC reports provide many details including emissions types, frequencies, start, end and peak times and burst classifications (table 2). In section 4 I show radio spectrograms of several burst types from my archives and compare them to the associated data in SWPC reports.

3. Instrumentation

The solar radio bursts described here were received on an RFSpace NetSDR software defined radio receiver connected to a Sun-tracking HF log periodic antenna (figure 2). Additional details on this system may be found at {Reeve}.

The spectrogram images are screenshots of Moetronix SpectraVue software and were cropped to eliminate details not necessary to the presentation. The frequency range is shown along the left vertical axis. For most spectrograms the range is 10 MHz to 34 MHz but exceptions are noted. The low end of most spectrograms is 10 MHz; that frequency was chosen to minimize visual interference with time-stamps; it was not expected that bursts would be received below about 15 MHz.

Time-stamps are embedded in the spectrogram image as black vertical boxes along the top. Most spectrograms show a 5 minute time span but some show longer time spans and actually are two or more 5 minute spectrograms that have been cropped and spliced together using Microsoft Digital Image Suite 2006 software.

The color of each pixel indicates the relative power level at that pixel's particular frequency and time. The color progression is black-blue-green-yellow-red-magenta, lowest to highest power. The power levels indicated are based on a logarithmic scale in decibels. A dB range of 32 or 42 dB was used for these spectrograms and was chosen based on ambient radio frequency interference (RFI) background at the time of observation. The bright horizontal and vertical bands in the spectrograms are RFI.

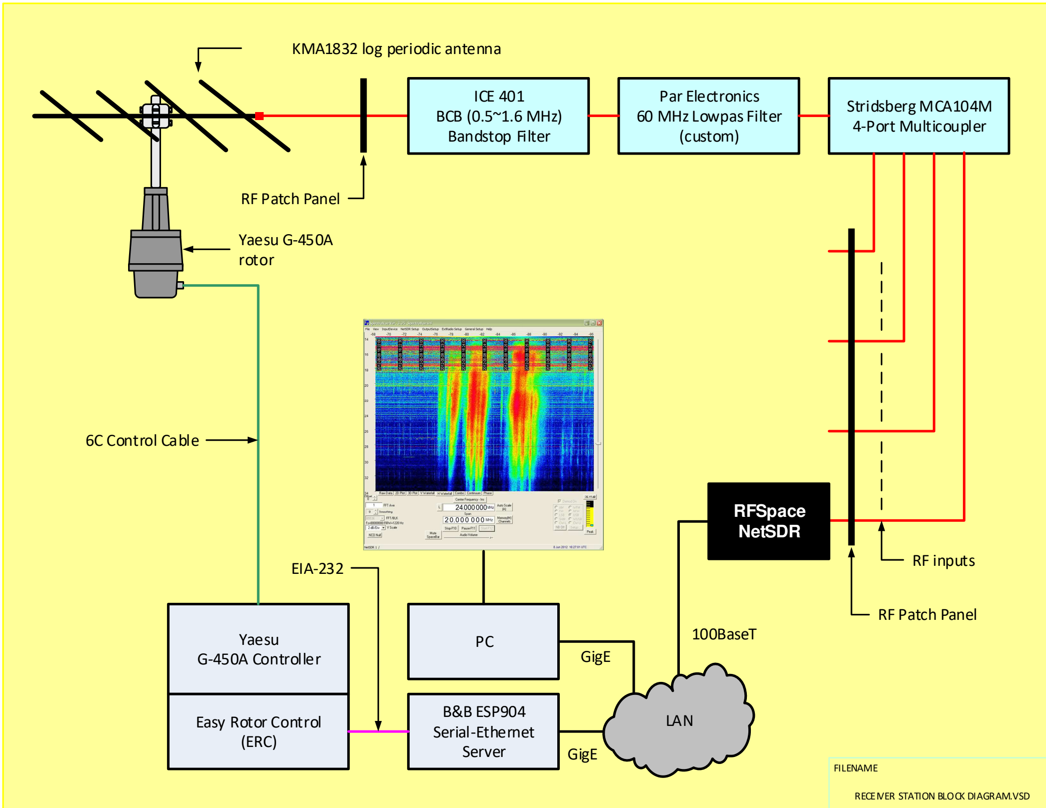


Figure 2 ~ System block diagram. The NetSDR is a software defined radio receiver running with SpectraVue software to receive solar radio bursts.

Table 1
Solar Radio Burst Spectral Classifications. Table references: {IPSCat}; {SWPCRead}

Type	Characteristics	Duration	Frequency Range (MHz)	Associated Phenomena
I	Short, narrow-bandwidth bursts. Usually occur in large numbers with underlying continuum	Single: ~1 second Storm: hours – days	80 – 200	Active regions, flares, eruptive prominences
II	Slow frequency drift bursts. Usually accompanied by a second harmonic	3 – 30 minutes	Fundamental: 20 – 150	Flares, proton emission, magneto-hydrodynamic shockwaves
III	Fast frequency drift bursts. Can occur singularly, in groups, or storms often with underlying continuum. Can be accompanied by a second harmonic	Single: 1 – 3 seconds Group: 1 – 5 minutes Storm: minutes – hours	0.01 – 1000	Active regions, flares
IV	Stationary Type IV: Broadband continuum with fine structure	Hours – days	20 – 2000	Flares, proton emission
	Moving Type IV: Broadband, slow frequency drift, smooth continuum	0.5 – 2 hours	20 – 400	Eruptive prominences, magneto-hydrodynamic shockwaves
	Flare Continua: Broadband, smooth continuum	3 – 45 minutes	10 – 200	Flares, proton emission
V	Smooth, short-lived continuum. Follows some type III bursts. Never occurs in isolation	1 – 3 minutes	10 – 200	Same as type III bursts
VI	Series of Type III bursts over a period of 10 minutes or more, with no period longer than 30 minutes without activity	> 10 minutes	See Type III	See Type III
VII	Series of Type III and Type V bursts over a period of 10 minutes or more, with no period longer than 30 minutes without activity	> 10 minutes	See Type III and Type V	See Type III and Type V

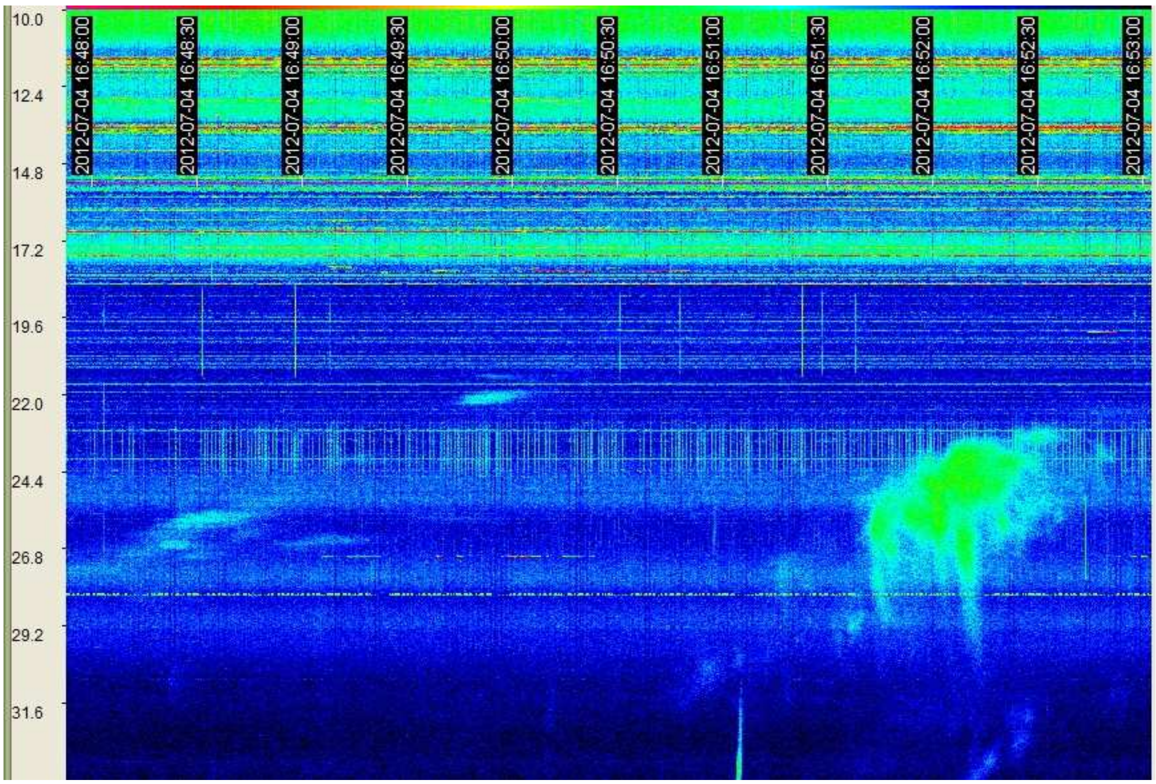
Table notes:
1. Drifting bursts almost always drift from high to low frequencies
2. Frequency range is the typical range in which the bursts appear and not their bandwidth
3. Sub-types of Type IV are not universally agreed upon

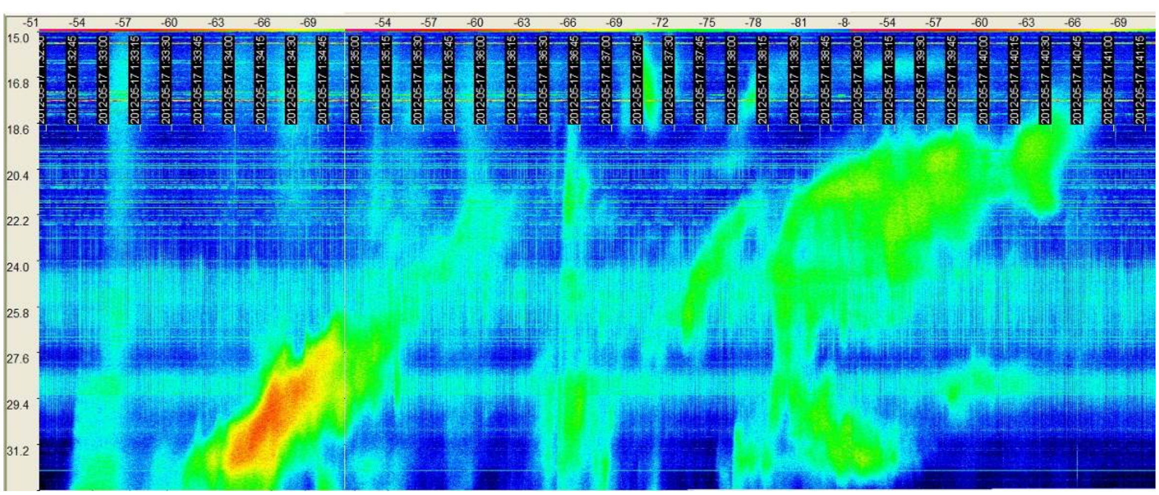
Table 2 ~ Excerpt from a typical report of a solar radio event. Each event is numbered in the first column. The next three columns show the Beginning, Maximum and Ending times. The Obs column shows the observatory followed by the quality of the observation. For bursts of RSP Type, the frequency is shown next followed by additional details. In this example from 17 May 2012, observed at Learmonth in Australia (LEA), one of the sweep-frequency radio burst (RSP) bursts was Type II slow drift burst observed in the frequency range 25 to 180 MHz with major relative intensity of (3). The radio data quality was a corrected report (C). The shock speed was 645 km/s. The last column is the NOAA solar region number assigned by SWPC.

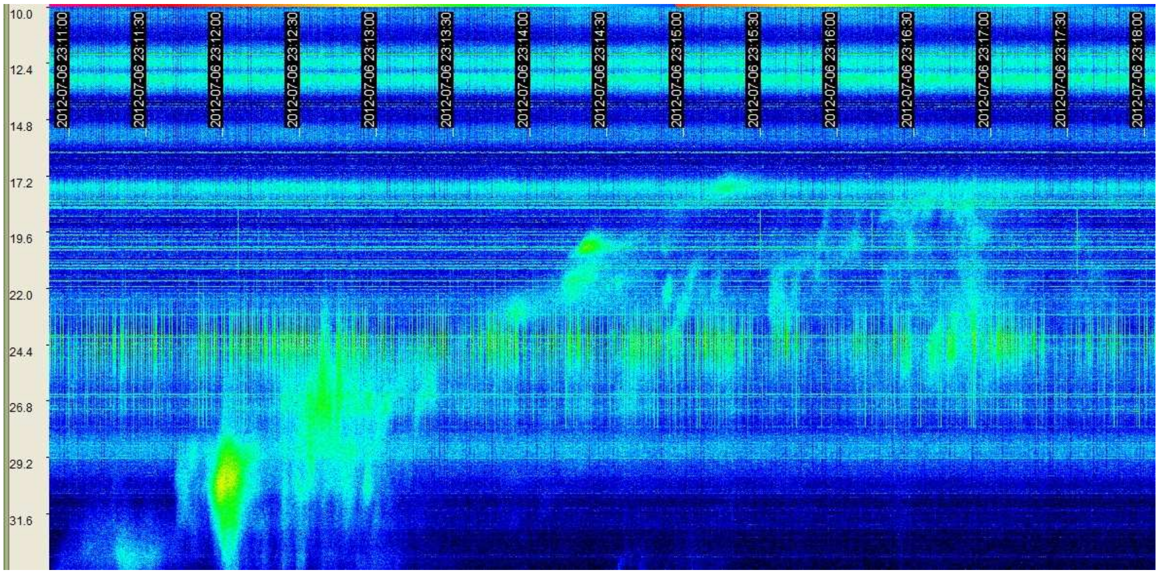
```
#Event     Begin     Max        End   Obs   Q   Type   Loc/Frq    Particulars       Reg#
#--------------------------------------------------------------------------------------
4620 +      0131    ////       0141   LEA   C    RSP   025-180    II/3     645       1476
4620 +      0132    ////       0252   LEA   C    RSP   025-180    IV/2               1476
4620 +      0133    ////       0137   CUL   C    RSP   018-200    III/3              1476
```

4. Burst examples

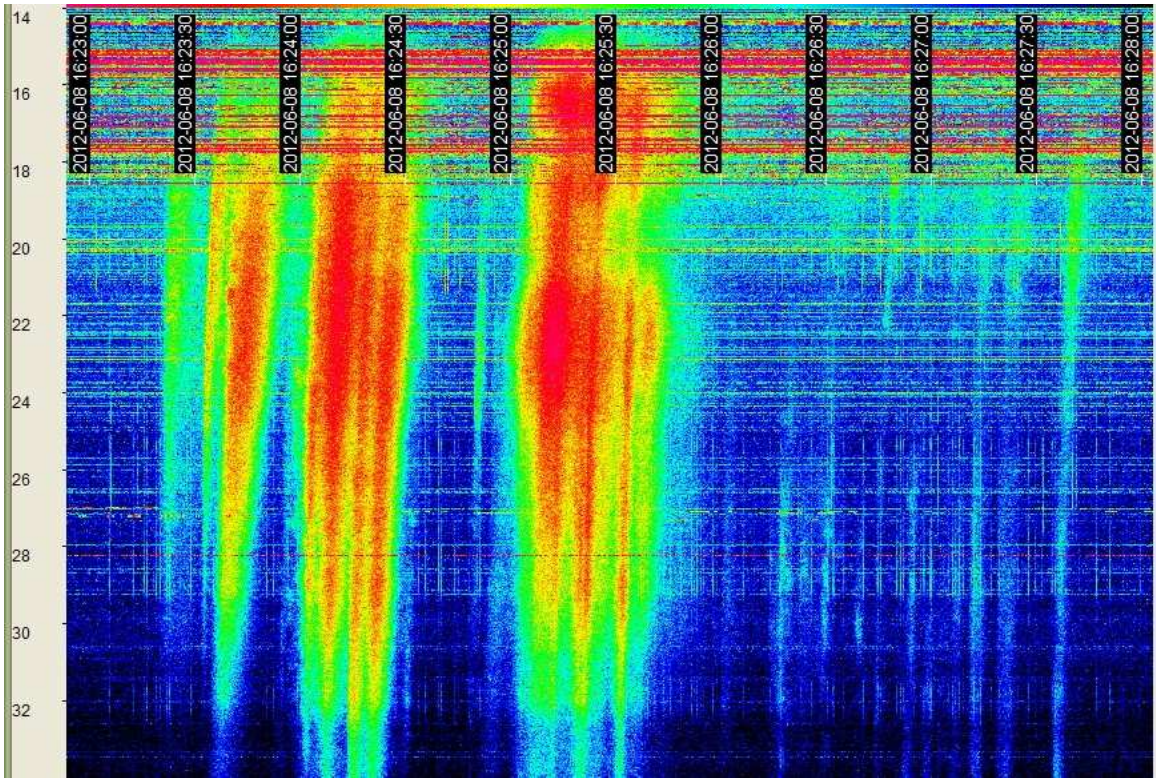
Type II ~ Slow drift burst. Type II bursts have drift rates of about 250 kHz/s. In the first spectrogram below, weak Type II bursts can be seen on the left and a solitary Type II burst with some fast reverse drift complexity can be seen on the right. This spectrogram was obtained on 4 July 2012. The second spectrogram is a composite for a 9 minute time span on 17 May 2012. It shows several Type II bursts as well as some Type III bursts. The third spectrogram was obtained on 6 July 2012 and shows Type II bursts over a 7 minute time span.

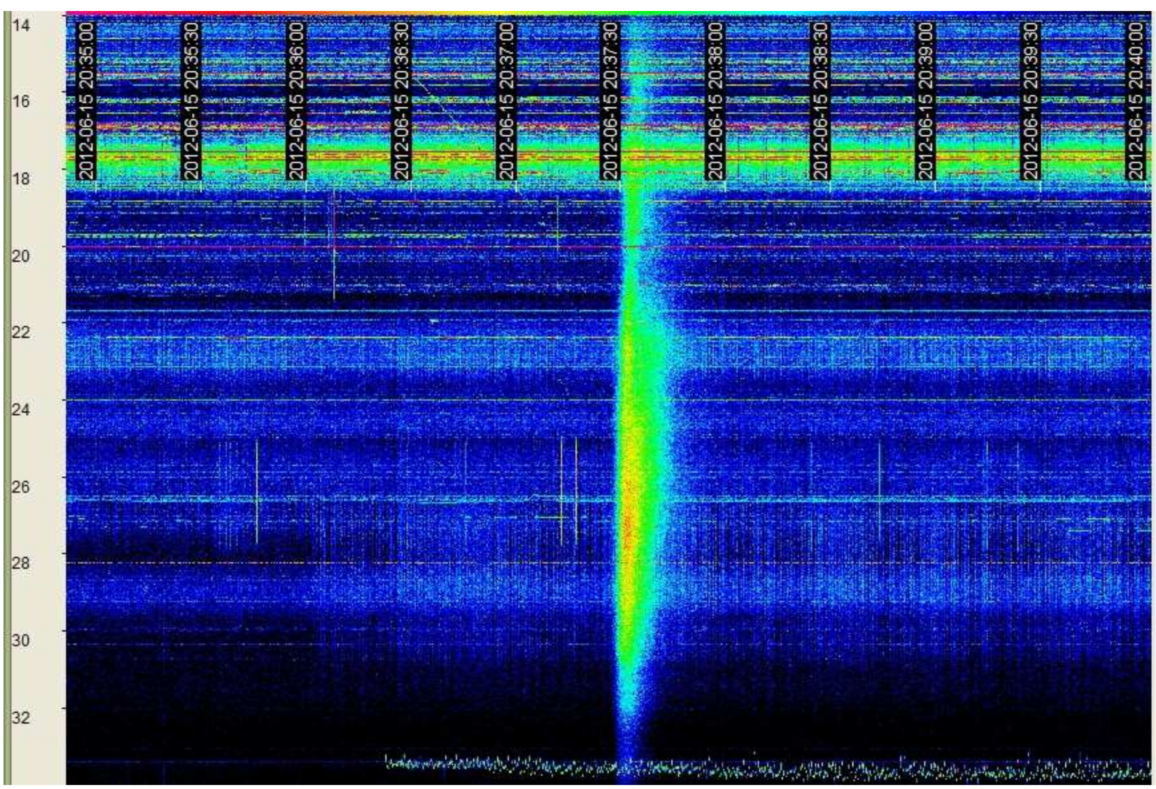


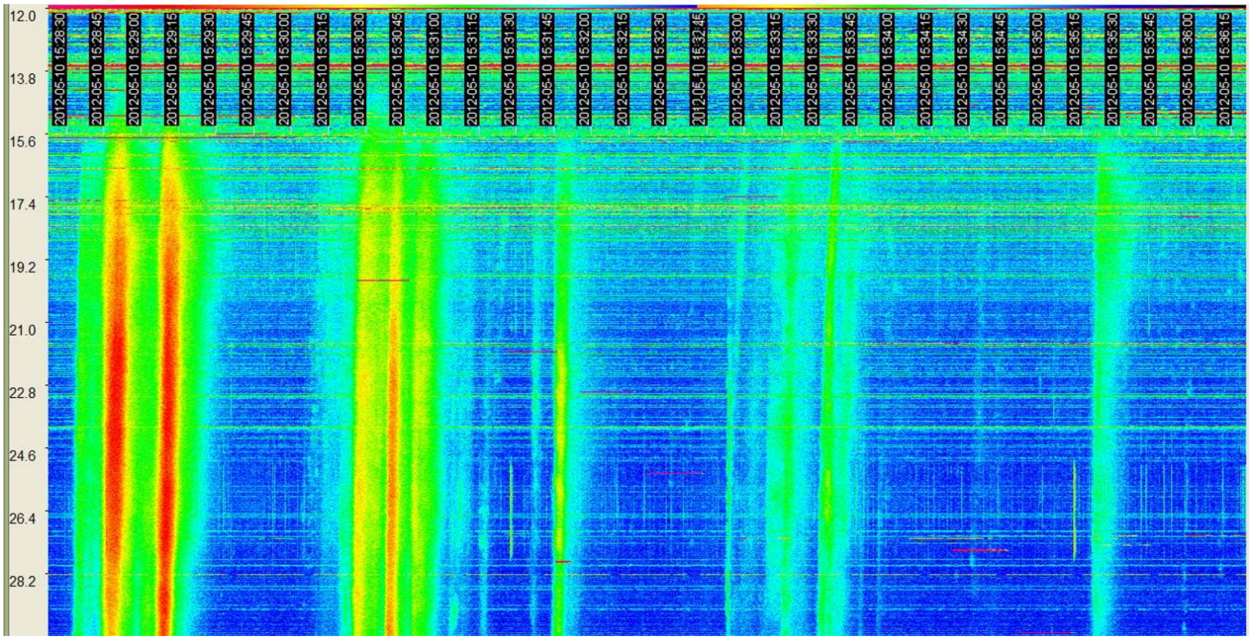



10.0
12.4
14.8
17.2
19.6
22.0
24.4
26.8
29.2
31.6
2012-07-06 23:11:00
2012-07-06 23:11:30
2012-07-06 23:12:00
2012-07-06 23:12:30
2012-07-06 23:13:00
2012-07-06 23:13:30
2012-07-06 23:14:00
2012-07-06 23:14:30
2012-07-06 23:15:00
2012-07-06 23:15:30
2012-07-06 23:16:00
2012-07-06 23:16:30
2012-07-06 23:17:00
2012-07-06 23:17:30
2012-07-06 23:18:00

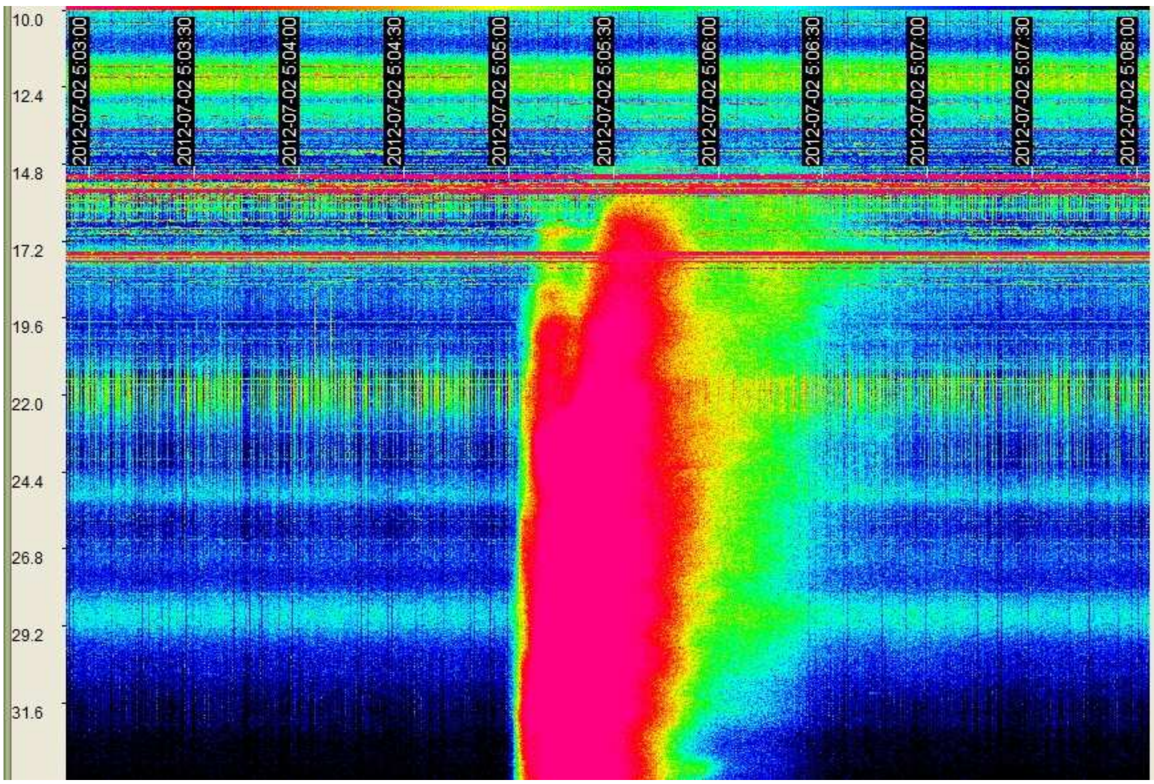
Type III ~ Fast drift burst. Type III bursts have been received most often and are characterized by fast frequency sweep or drift in the HF range of 1 to 10 MHz per second. Type III bursts can occur singularly or in groups. The first spectrogram shows a group obtained on 8 June and the second shows a singular Type III burst on 15 June 2012. Both spectrograms have a frequency range of 14 to 34 MHz. The third spectrogram shows an 8 minute time span with many Type III bursts on 10 May 2012. The frequency range is 12 to 30 MHz.

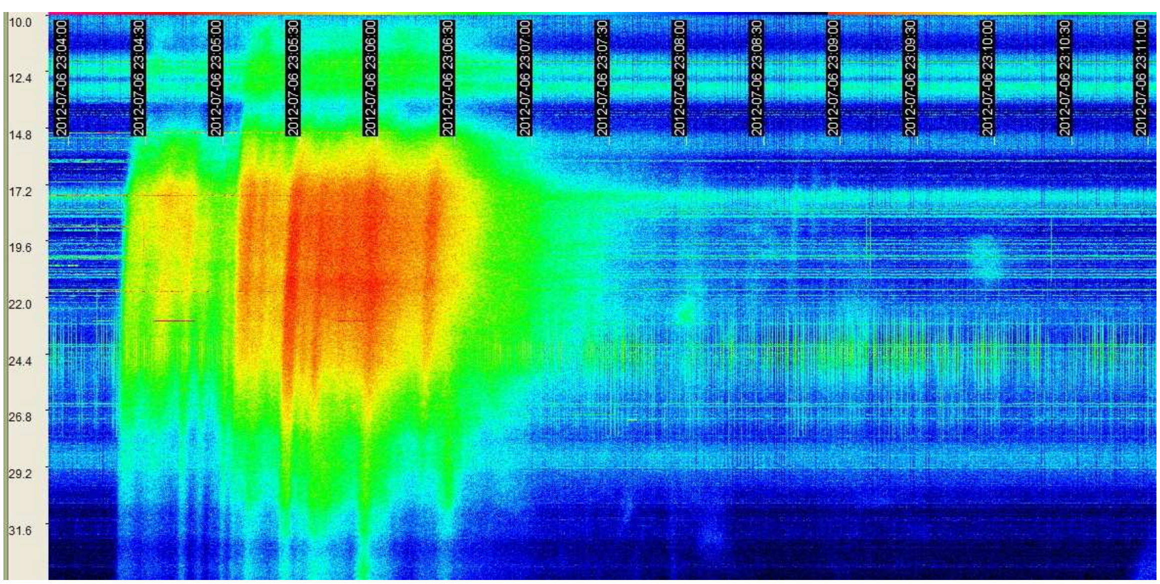


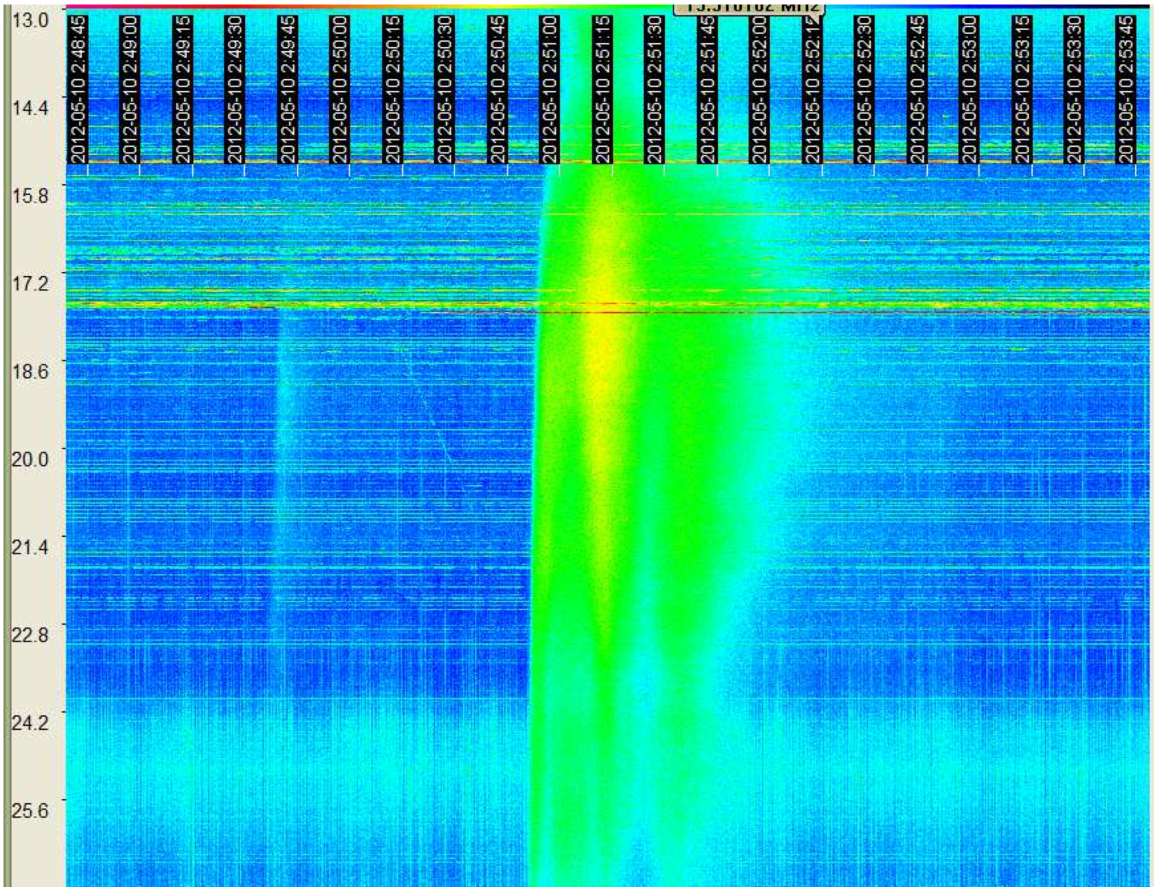



12.0
13.8
15.6
17.4
19.2
21.0
22.8
24.6
26.4
28.2
2012-05-10 15:28:30
2012-05-10 15:28:45
2012-05-10 15:29:00
2012-05-10 15:29:15
2012-05-10 15:29:30
2012-05-10 15:29:45
2012-05-10 15:30:00
2012-05-10 15:30:15
2012-05-10 15:30:30
2012-05-10 15:30:45
2012-05-10 15:31:00
2012-05-10 15:31:15
2012-05-10 15:31:30
2012-05-10 15:31:45
2012-05-10 15:32:00
2012-05-10 15:32:15
2012-05-10 15:32:30
2012-05-10 15:32:45
2012-05-10 15:33:00
2012-05-10 15:33:15
2012-05-10 15:33:30
2012-05-10 15:33:45
2012-05-10 15:34:00
2012-05-10 15:34:15
2012-05-10 15:34:30
2012-05-10 15:34:45
2012-05-10 15:35:00
2012-05-10 15:35:15
2012-05-10 15:35:30
2012-05-10 15:35:45
2012-05-10 15:36:00
2012-05-10 15:36:15

Type V ~ Brief continuum burst, generally associated with Type III bursts. The first spectrogram below, obtained on 2 July 2012, shows a Type V burst that occurred at the same time as a Type III burst. It has slightly longer persistence at lower and middle frequencies. The second spectrogram shows a very strong Type V burst included with numerous Type III bursts associated with an X1.1 flare on 6 July 2012. Similarly, the third spectrogram, obtained 10 May 2012 and covering a frequency range of 13 to 27 MHz, shows several closely spaced Type III bursts with Type V brief continuum following them. The fourth spectrogram is from 18 May and shows a Type V burst occurring at the same time as a Type III. Finally, the fifth spectrogram shows a rare "detached" Type V burst following Type III bursts on 3 July.






13.0
14.4
15.8
17.2
18.6
20.0
21.4
22.8
24.2
25.6
2012-05-10 2:48:45
2012-05-10 2:49:00
2012-05-10 2:49:15
2012-05-10 2:49:30
2012-05-10 2:49:45
2012-05-10 2:50:00
2012-05-10 2:50:15
2012-05-10 2:50:30
2012-05-10 2:50:45
2012-05-10 2:51:00
2012-05-10 2:51:15
2012-05-10 2:51:30
2012-05-10 2:51:45
2012-05-10 2:52:00
2012-05-10 2:52:30
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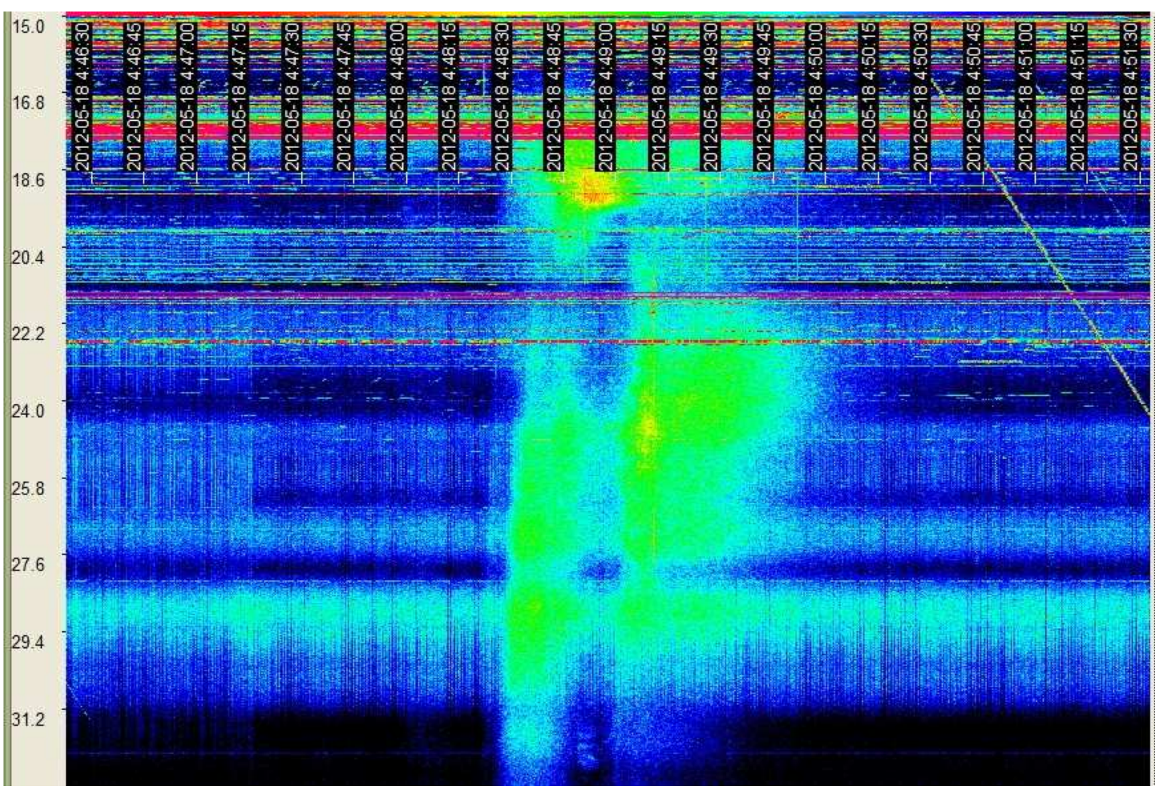
2012-05-10 2:53:45


15.0
16.8
18.6
20.4
22.2
24.0
25.8
27.6
29.4
31.2
2012-05-18 4:46:30
2012-05-18 4:46:45
2012-05-18 4:47:00
2012-05-18 4:47:15
2012-05-18 4:47:30
2012-05-18 4:47:45
2012-05-18 4:48:00
2012-05-18 4:48:15
2012-05-18 4:48:30
2012-05-18 4:48:45
2012-05-18 4:49:00
2012-05-18 4:49:15
2012-05-18 4:49:30
2012-05-18 4:49:45
2012-05-18 4:50:00
2012-05-18 4:50:15
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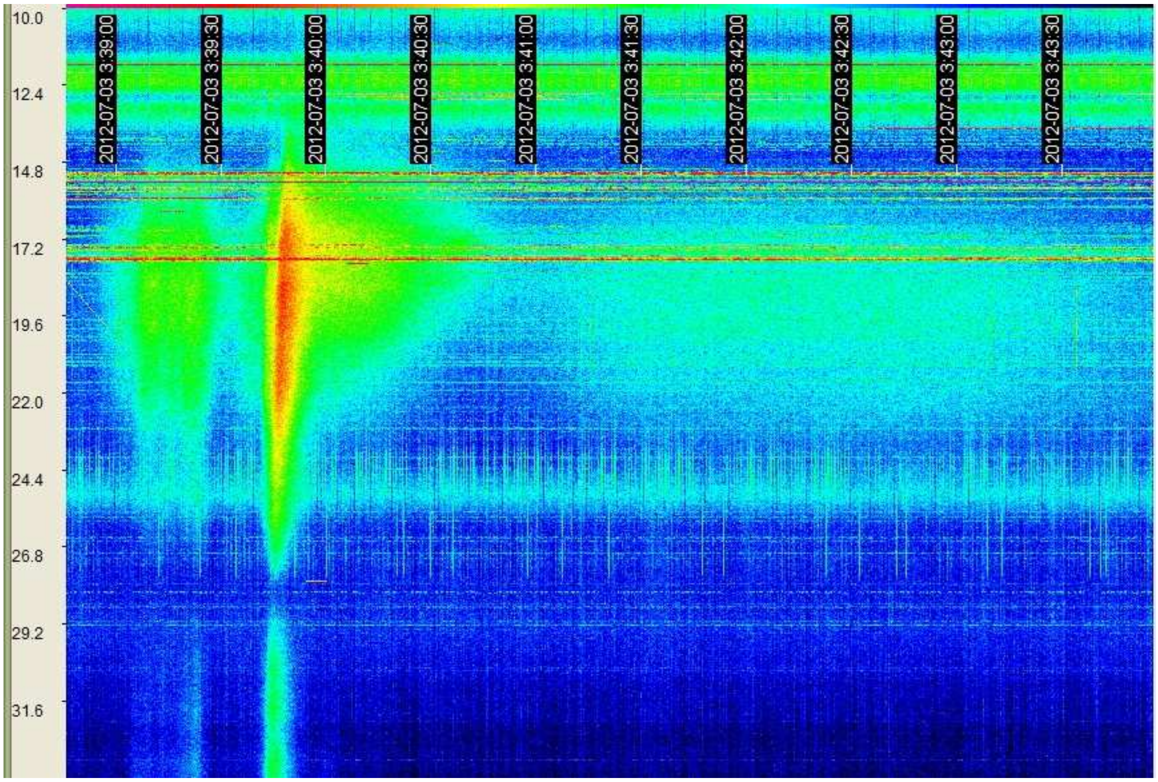
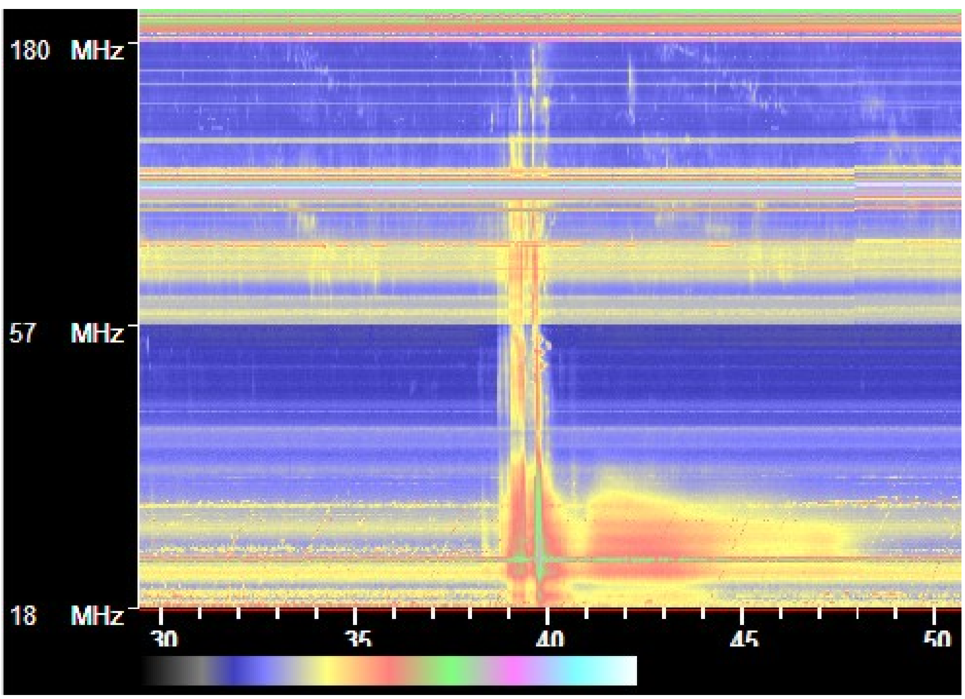
2012-05-18 4:51:30





The spectrogram left was provided by N.P. Prestage from the Culgoora Solar Observatory in Australia (see acknowledgements in section 5) showing the same event as above but over a much wider frequency range. The Culgoora spectrogram has frequencies sweeping from bottom to top, so it is opposite the spectrogram shown above. The preceding Type III bursts extended all the way to 1.6 GHz (above the range of the spectrogram seen here).

5. Acknowledgements

Nigel P. Prestage at Culgoora Solar Observatory, IPS Radio and Space Services, Bureau of Meteorology, Australian Government helped verify the burst types shown in this article. He also provided the example "detached" Type V spectrogram from Culgoora Observatory.

6. References and Web Links

{WikiChrom} http://en.wikipedia.org/wiki/Chromosphere
{WikiCoron} http://en.wikipedia.org/wiki/Corona
{IPSCat} http://www.ips.gov.au/Category/World%20Data%20Centre/Data%20Display%20and%20Download/Spectrograph/A%20Brief%20Introduction%20of%20Radiospectrogram%20Analysis.pdf
{Reeve} http://www.reeve.com/Solar/HighFrequency/high_frequency.htm
{SWPCEvent } ftp://ftp.swpc.noaa.gov/pub/warehouse/
{SWPCRead} ftp://ftp.swpc.noaa.gov/pub/indices/events/README

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0.2 (Added SWPC event report and SSN chart, 6 Feb 2016)

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