Description of the University of Iowa Portable RFI Monitor and Preliminary Results from the LWDA and TP Sites

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LWA Memo

1 - Introduction

The University of Iowa Portable RFI Monitor (IPRM) is a mobile system capable of monitoring and recording a local site's RF signals in a user-specified frequency and time range. The IPRM consists of a (user-supplied) broadband antenna, low-noise pre-amplifier, remotely controlled spectrum analyzer with LAN port, GPS receiver, and a laptop PC running Labview. The frequency coverage is limited by the pre-amplifier to a range 1-500 MHz, although in practice the antenna will likely have a more limited effective bandwidth. The equipment has a power load ~250W and can easily be operated in remote locations using a small portable power generator supplying 115VAC. The system can also be operated remotely (with limited functionality) using a web browser if a suitable Internet connection is available.

The IPRM was designed primarily to monitor radio frequency interference (RFI) in the 10-90 MHz band in support of site selection for the Long Wavelength Array. RFI surveys were performed by Pat Crane and John Dickel on the LWDA (12/06/06) and the TP (Twin Peaks, see LWA Memo #63) candidate site (12/15/06) using the IPRM along with the LWA "Big Blade" antenna. Each survey consists of two consecutive 30 min samples saves as FITS images. The preliminary analysis of each sample is discussed later in this document.

2 - Hardware

The IPRM hardware consists of five elements:

- Antenna (discone or user-supplied)
- Low noise amplifier (LNA) - *Minicircuits ZFL-500LN and Low-pass filter (5-pole Butterworth, ~150 MHZ 3dB roll-off frequency)*
- Spectrum Analyzer - *Agilent N1996A*
- GPS receiver - *Garmin eTrex® Handheld GPS*
- Laptop PC - *IBM Thinkpad T40 w/ Windows XP Professional and National Instruments (NI) Labview 8.0 Software*

The IPRM has a small power requirement and can be run by use of a battery pack for time intervals shorter than 2 hours. For longer collection periods, a small gas powered generator (along with line filter) can be utilized. The LNA (27 dB gain and 2.8 dB noise figure) is used to ensure that the sensitivity of the IPRM is dominated by the noise temperature of the LNA (T_N ~250K) instead of the poor noise fig-
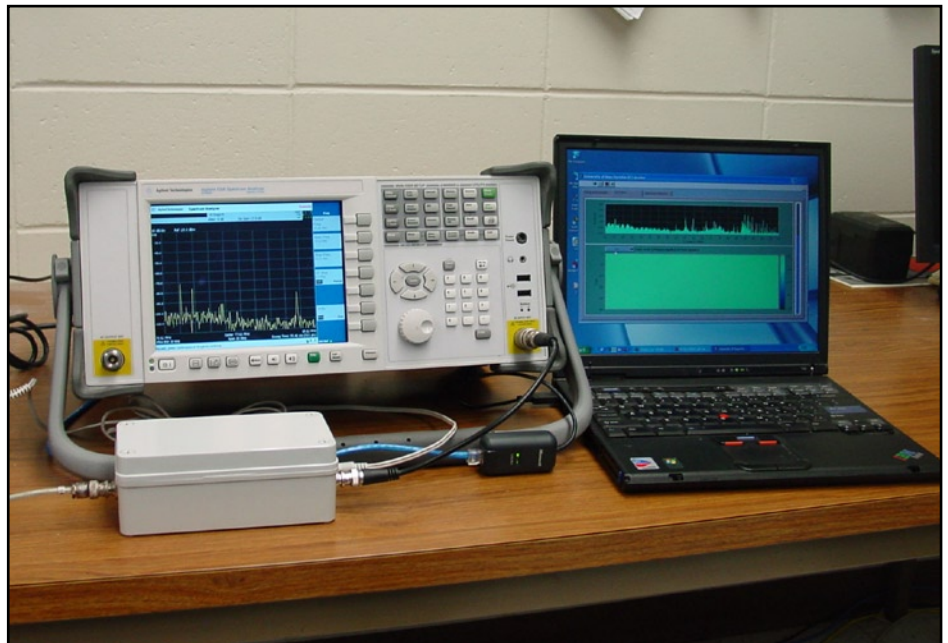
IPRM Setup

ure of the spectrum analyzer (perhaps 15 dB). The LNA module also contains a 5th order Butterworth low-pass filter with a 155 MHz 3 dB cutoff frequency to minimize aliasing of strong signals over 200 MHz. This filter can be supplemented by adding an optional second Low-pass filter (5-pole Butterworth, ~78 MHZ 3dB roll-off frequency) to suppress strong FM sources. For locations with internet access, the IPRM setup may also be configured to enable remote control through the use of a Labview web applet. This applet runs as an internet browser plug-in which is downloadable on the Nation Instruments site.

A block diagram of the IPRM hardware is shown below.


IPRM Hardware Diagram
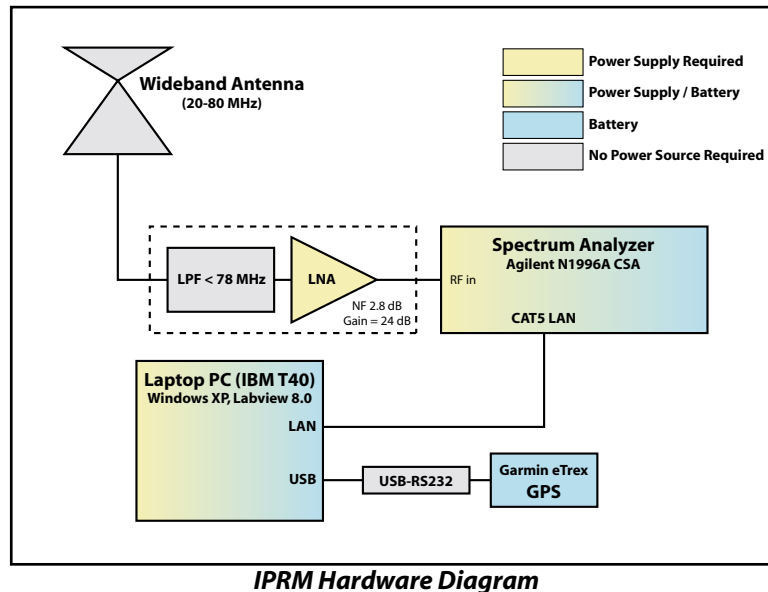
3 - Software

The IPRM Labview VI's along with front-end perform three main tasks; setup, collection, and data storage. During the Setup phase, IPRM users set the data capture parameters for the system. Pop-out windows (many of which contain helpful calculations based on the current setup values) are used to set the frequency range and resolution, collection period, file format, as well as location information including time and position coordinates.

While in the collection phase, the IPRM software formats the setup information and repeatedly requests and receives intensity vs. frequency information from the spectrum analyzer. Individual spectrum are accumulated over the desired collection period and arranged as a time vs. frequency dynamic spectrum. This process typically takes ~ 1 second per resolution window length (resolution x 501 spectral channels). The IPRM displays the progress of each scan, along with a 2D frequency vs. intensity plot and a 3D waterfall plot of the dynamic spectrum. During this stage, the IPRM can also be programmed to perform statistical calculations on the returning data (at the cost of time resolution) and produce five dynamic spectrum representing the max, min, median, mean and standard deviation of the individual frequency bins over a desired interval of single sweeps. This calculation is optional and the specific parameters can be set during the Setup phase.

Once the requested collection time has surpassed, the IPRM saves the dynamic spectra as FITS binary table images. These images are either saved as 2D dynamic spectra or 3D data cubes (when statistic calculations are requested). In the 3D data cube case, the cube levels represent dynamic spectra tabulated for each statistical quantity. The FITS header keys are set to properly scale and display the time, frequency and intensity values when viewed offline in FITS viewers such as AIPS or DS9. The details of the system setup are also stored in the FITS header along with any field notes recorded by the user during the initial setup phase.
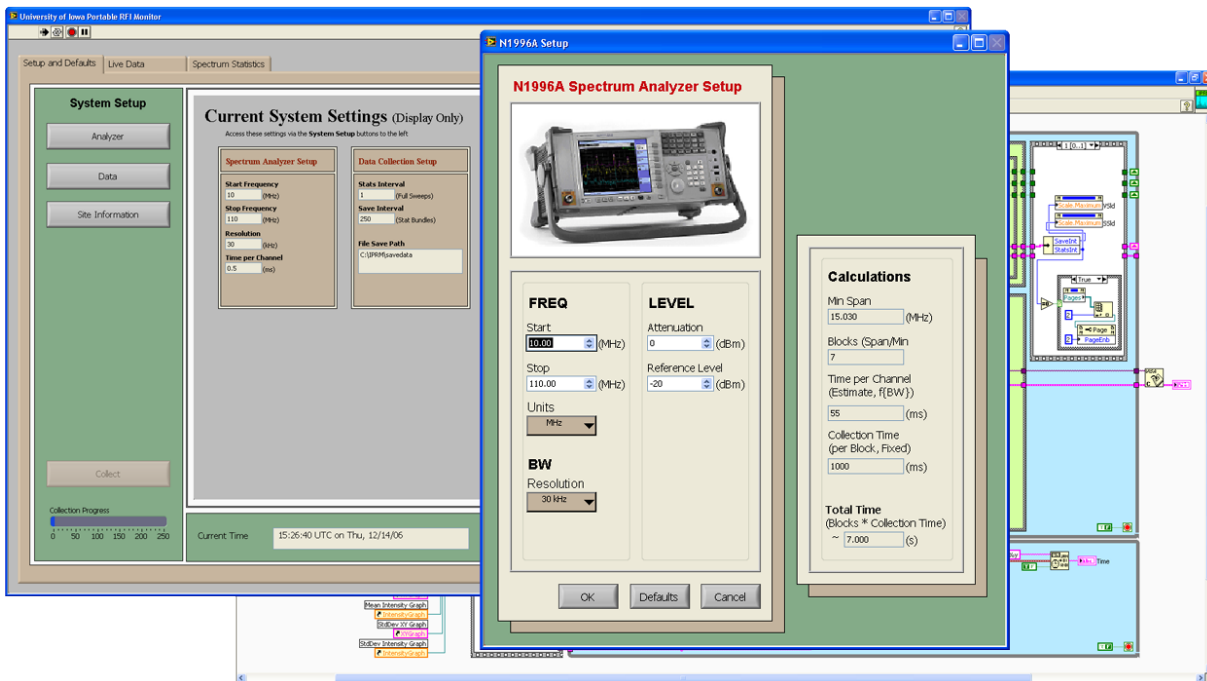
IPRM Sample Labview Interface

4 - Data Collection and Analysis

For further analysis and discussion, the dynamic spectra collected from the LWDA and TP sites (along with some simple offline analysis) is displayed in the pages that follow this section. The following datasets were obtained from the IPRM using the LWA "Big Blade" antenna.

(LWDA, 12/06/06, 21:48 UT to 22:46 UT)
data-120606-2217.fts
data-120606-2246.fts

(TP, 12/15/06, 20:50 UT to 21:49 UT)
data-121506-2119.fts
data-121506-2149.fts

The LWDA and TP surveys consist of two consecutive 30 minute samples which cover a frequency range of 5 MHz to ~110 MHz with a frequency resolution of 30 kHz and a time resolution of ~ 7.1 seconds. For each data set, the complete dynamic spectrum and three highlighted subsets have been displayed. The mean signal strength of the entire 30 minute sample was also calculated and displayed. A second page containing information extracted from the FITS image header, a calculation and plot of the standard deviation in a given frequency channel, and a time history plot for channel displaying the largest standard deviation was also added.

**IPRM and "Big Blade" at the TP site**

5 - Preliminary Results and Comments

(LWDA Sample)
The RFI survey performed at the LWDA site shows a high density of RF sources both above 88 MHz (FM Band, 87.5 MHz to 108.0 MHz) and below 18 MHz, along with the presence of VHF signals in the region above 54 MHz. The dynamic spectrum and mean signal strength plots show a ~5 dBm ripple which indicates a possible mis-match in the antenna. To further understand this issue, a return loss measurement of the antenna while located at the test site is needed. A standard deviation calculation on the 30 min of frequency data from each data set reviled a high degree of amplitude fluctuation (~40 dBm) for some RF sources. Shorter collection times may miss these fluctuations. Longer collection times may prove useful for follow-up surveys.

(TP Sample)
The RFI survey performed at the TP site displayed similar RF signals to the LWDA survey. The ~ 5 dBm ripple apparent in the LWDA frequency data does not appear in the TP data, though a return loss measurement of the antenna could still be helpful. There is also a smaller density of RF signals below 18 MHz compared to the LWDA site. A standard deviation calculation on the frequency data again revealed a high degree of amplitude fluctuation, although in the data-121506-2149.fts analysis, the 30 min sample length did not observe the fluctuation in the 17.87 MHz signal observed in the preceding 30 min sample. Further RFI testing should continue on an interval at least equal to the 60 minute sample times for the LWDA and TP surveys.
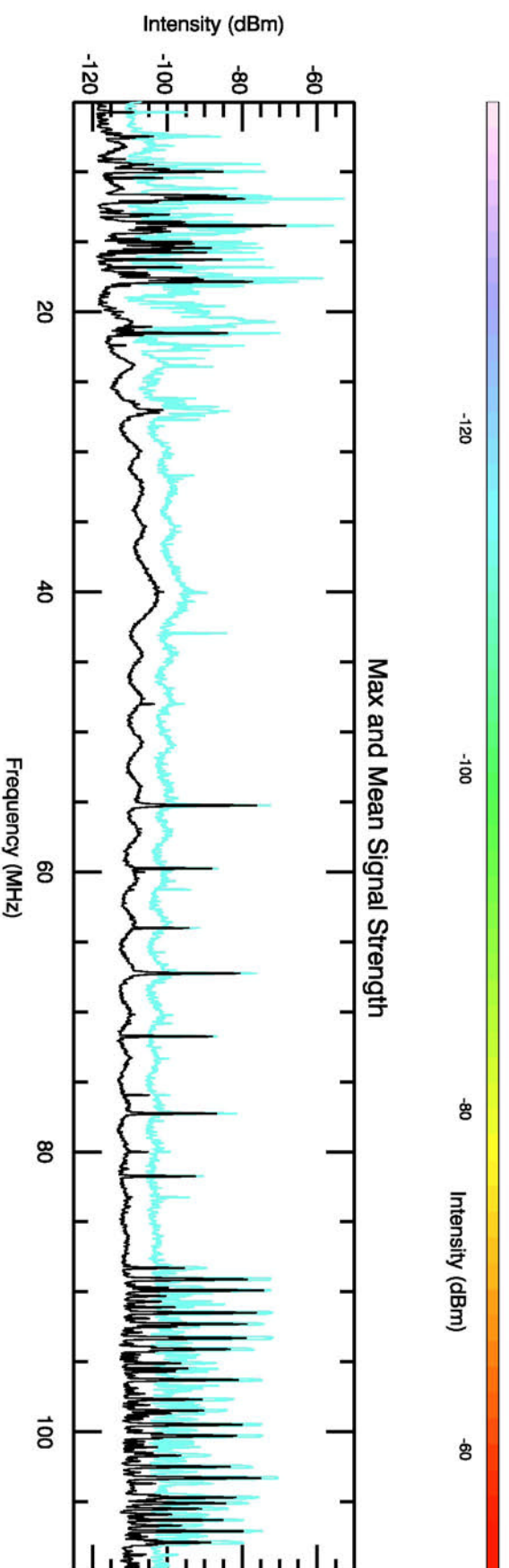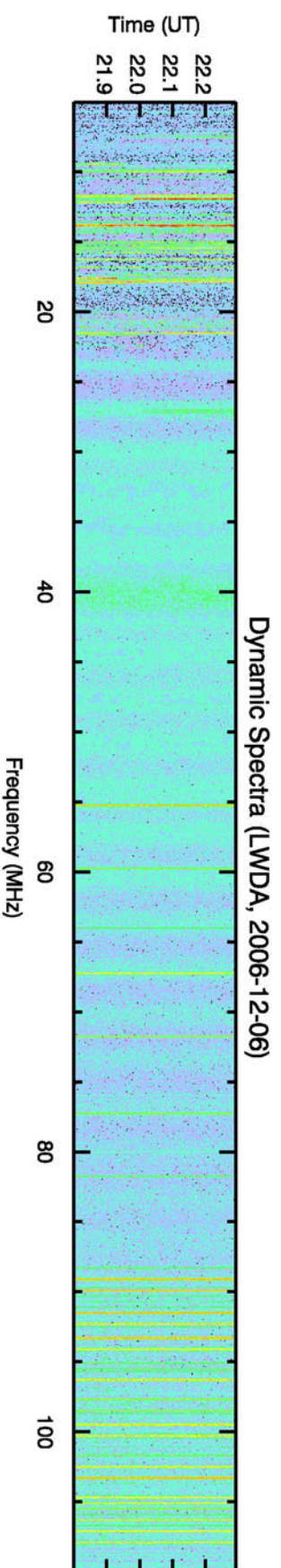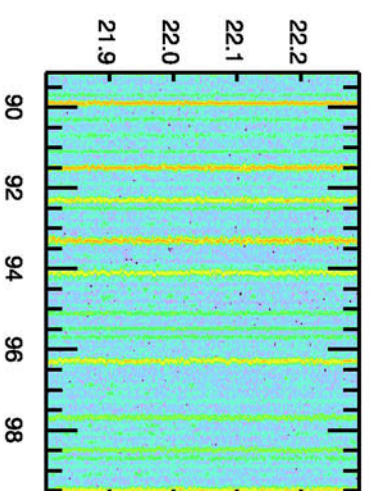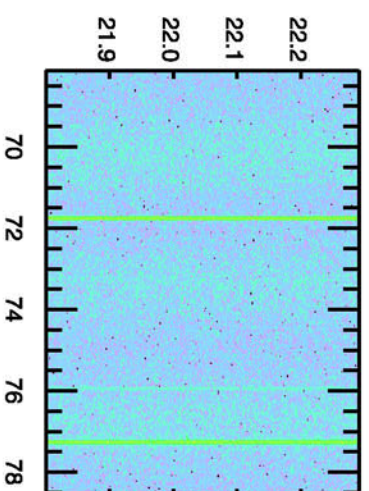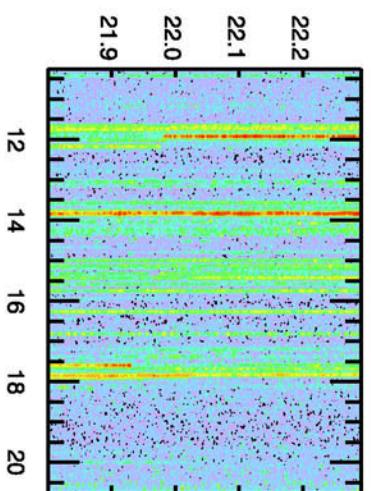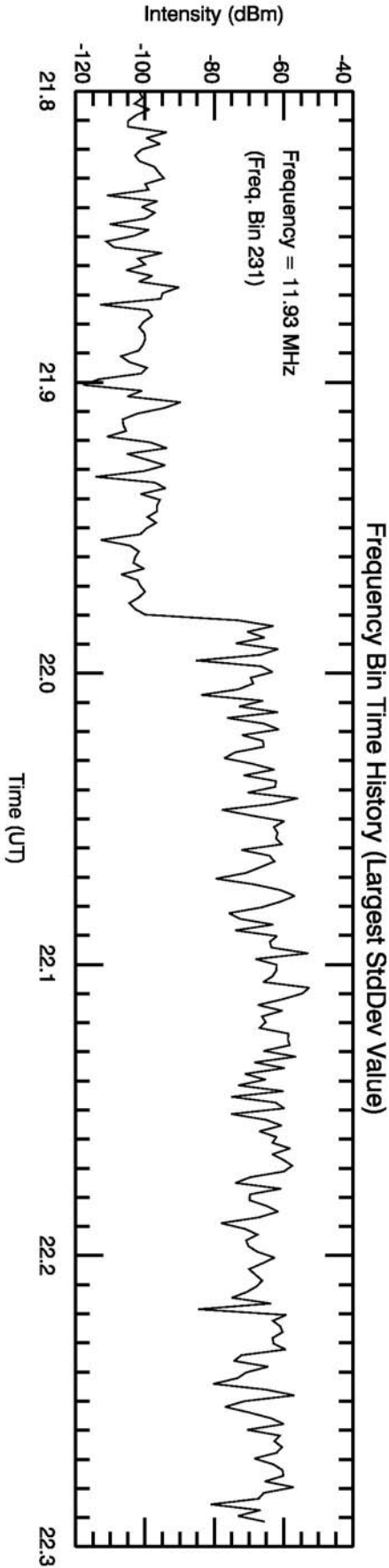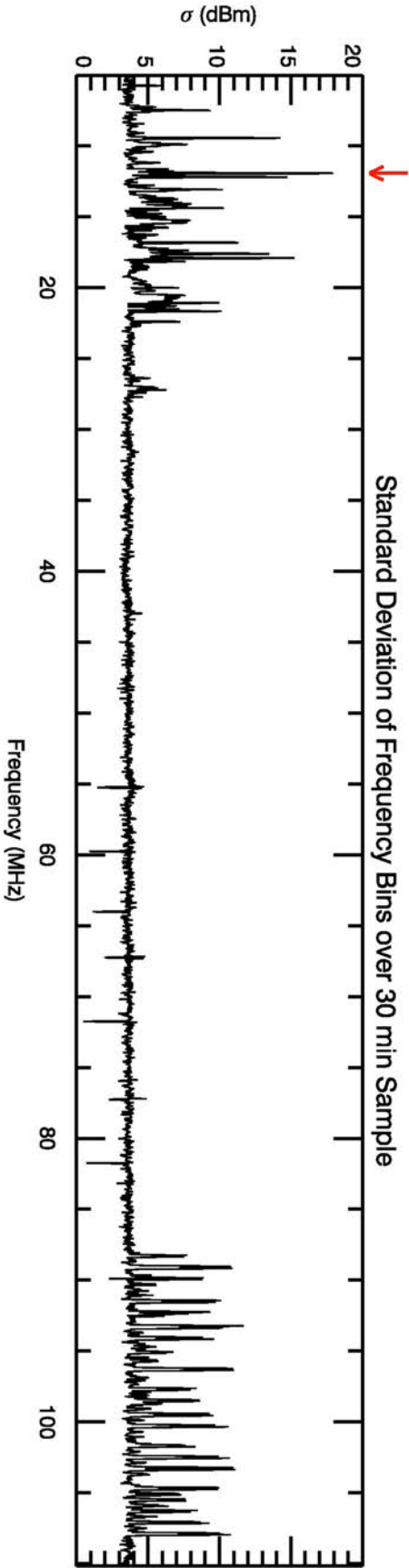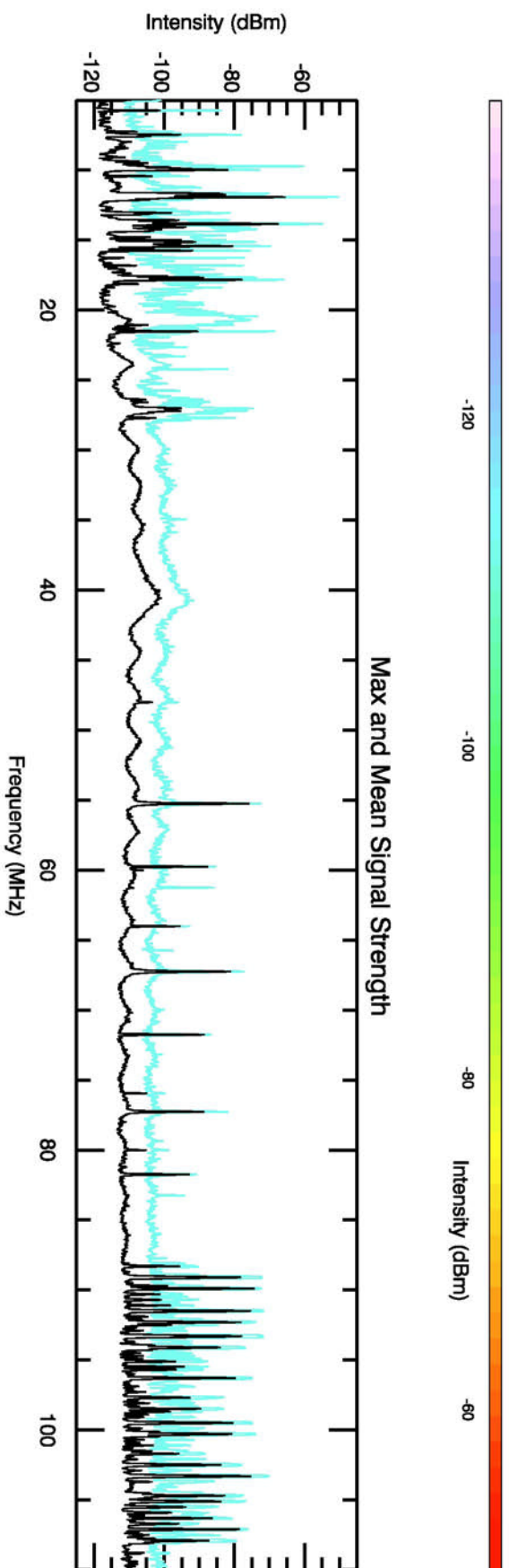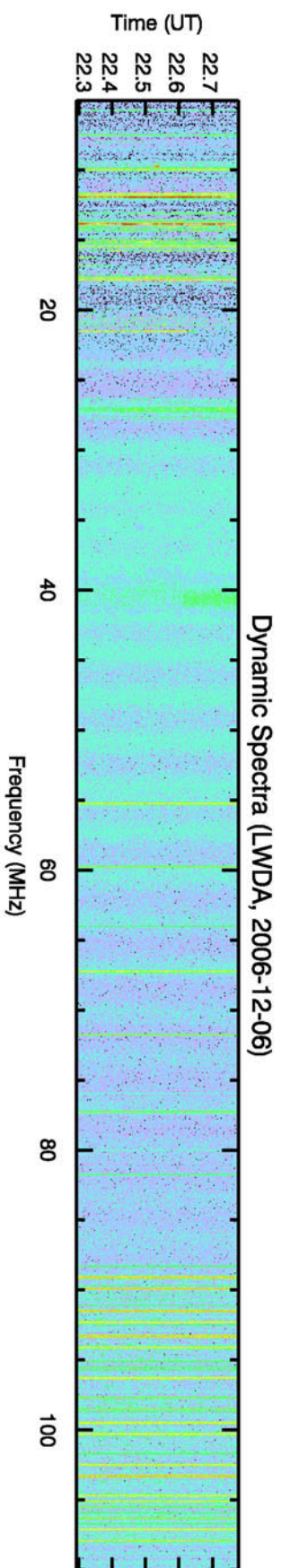
Dynamic Spectra (LWDA, 2006-12-06)

Max and Mean Signal Strength

data-120606-2217

Information from FITS Header

ORIGIN = "LWDA '

NLAT ='34:04:10'   / North Latitude of ORIGIN dd:mm:ss

WLON ='107:37:40'   / West Longitude of ORIGIN dd:mm:ss

TELESCOP= 'Big Blade'

OBSERVER= 'Crane and Dickel"

DATE-OBS= '2006-12-06T21:48:01' / UTC

JD   =   2454076.41867936 / [days] Julian Date at center of collection

Further Information

File Name = data-120606-2217

Image Dimentions = (3507x250) ~ 105 MHz by 30 min

Freq Resolution = 30.0000 kHz

Time Resolution = 7.09996 sec
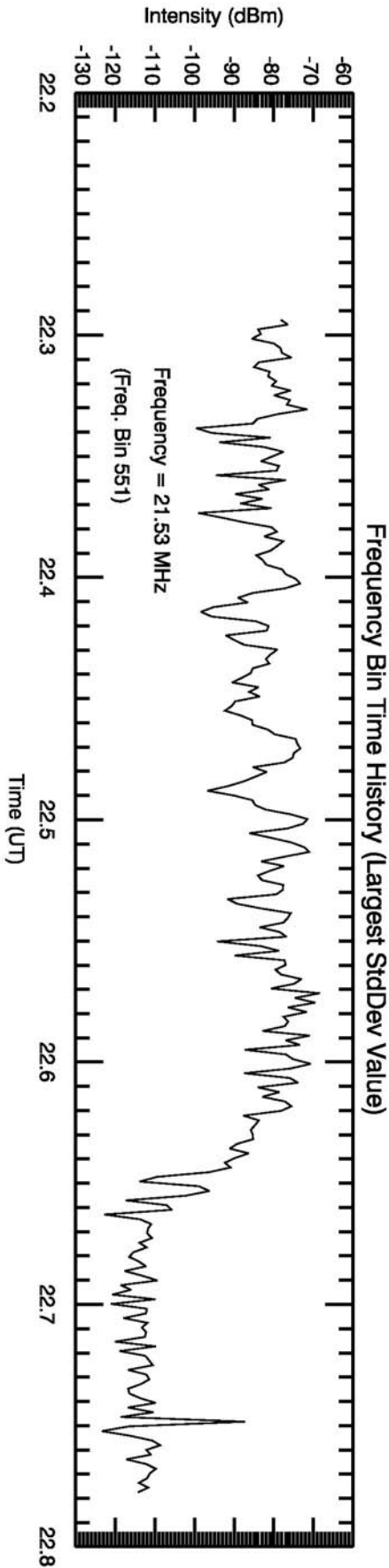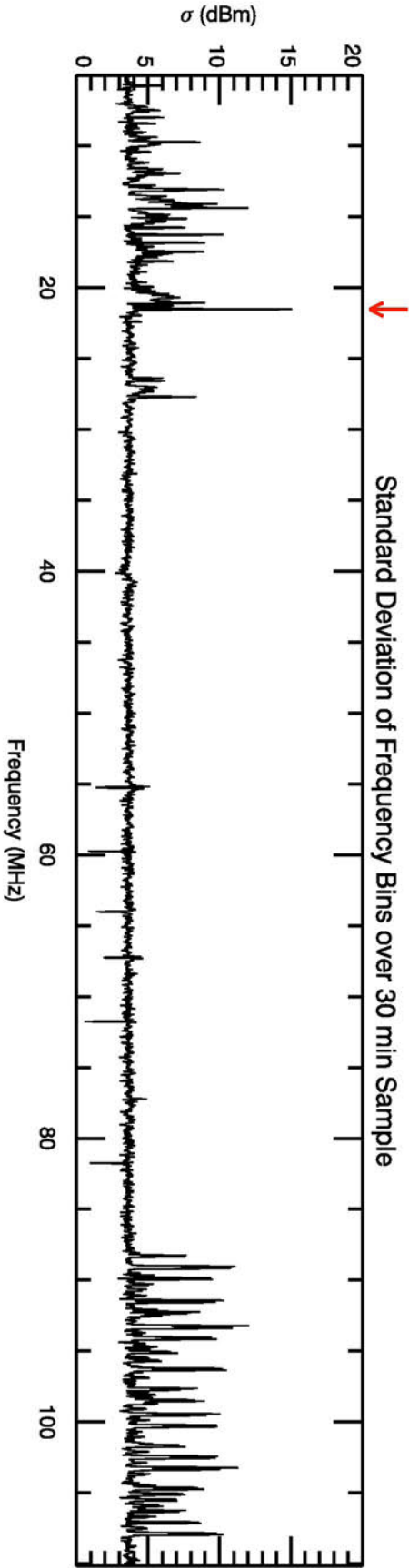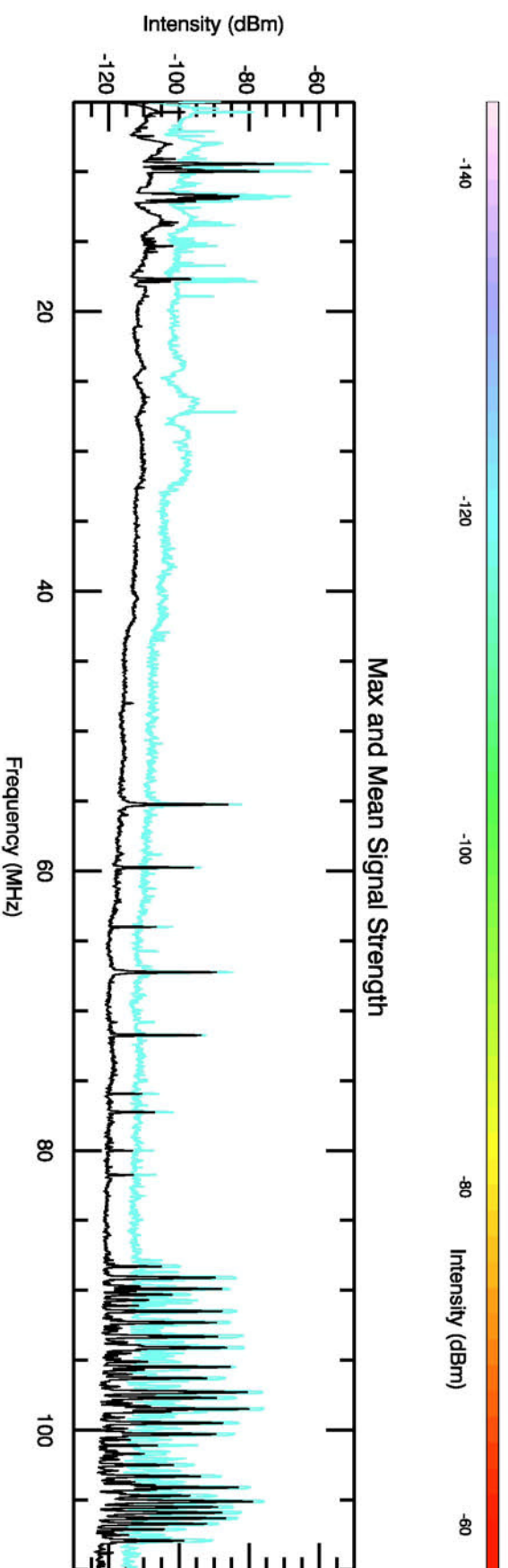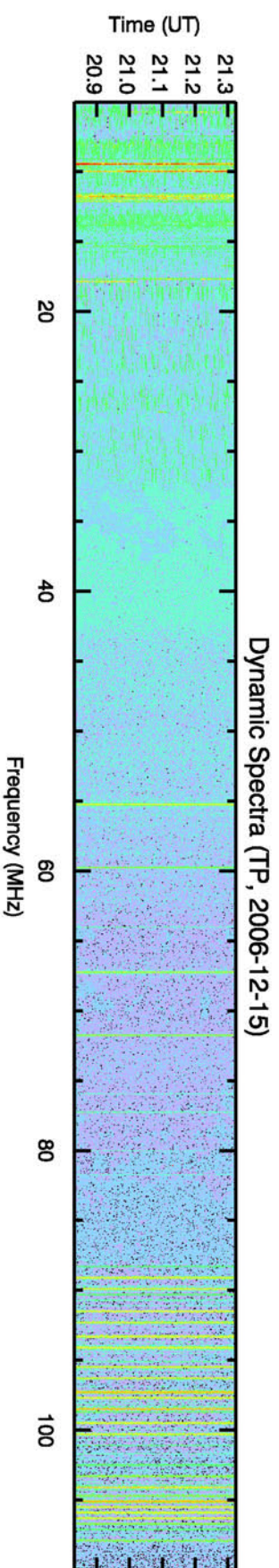
Time per Frequency Channel ~ 2 ms
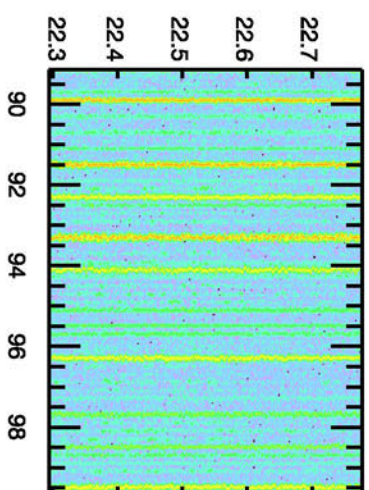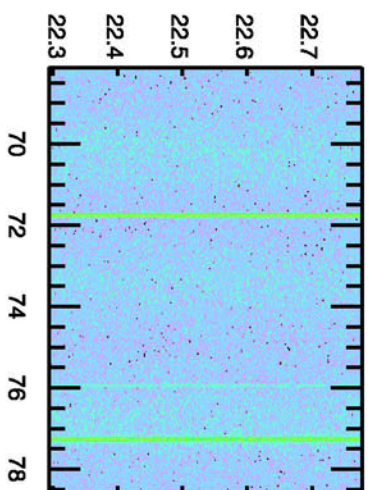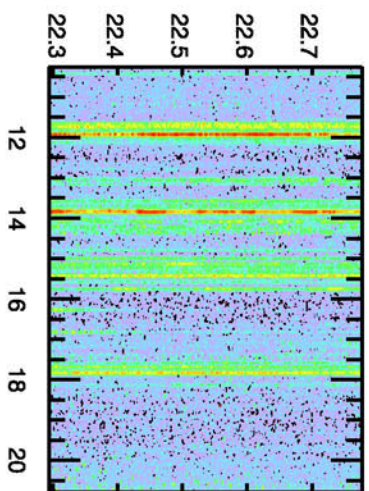
Standard Deviation of Frequency Bins over 30 min Sample

Frequency Bin Time History (Largest StdDev Value)

Frequency = 11.93 MHz
(Freq. Bin 231)

Dynamic Spectra (LWDA, 2006-12-06)

Max and Mean Signal Strength

data-120606-2246

Information from FITS Header

ORIGIN = "LWDA "

NLAT = '34:04:10' / North Latitude of ORIGIN dd:mm:ss

WLON = '107:37:40' / West Longitude of ORIGIN dd:mm:ss

TELESCOP= 'Big Blade'

OBSERVER= "Crane and Dickel"

DATE-OBS= '2006-12-06T22:17:37' / UTC

JD = 2454076.4389978† / [days] Julian Date at center of collection

Further Information

File Name = data-120606-2246

Image Dimentions = (3507x250) ~ 105 MHz by 29 min

Freq Resolution = 30.0000 kHz

Time Resolution = 6.99459 sec

Time per Frequency Channel ~ 2 ms
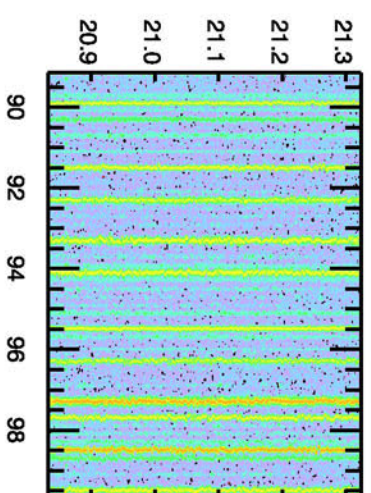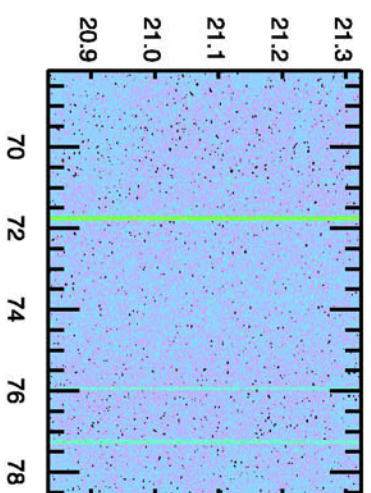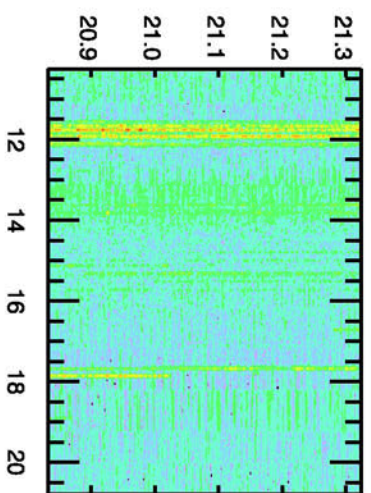
Standard Deviation of Frequency Bins over 30 min Sample

σ (dBm)

Frequency (MHz)

Frequency Bin Time History (Largest StdDev Value)

Frequency = 21.53 MHz
(Freq. Bin 551)
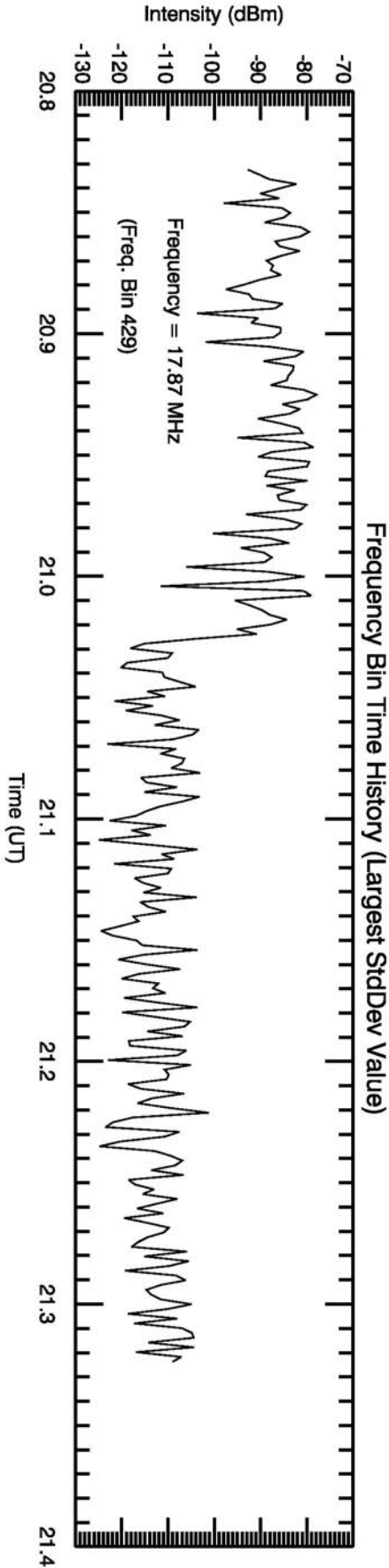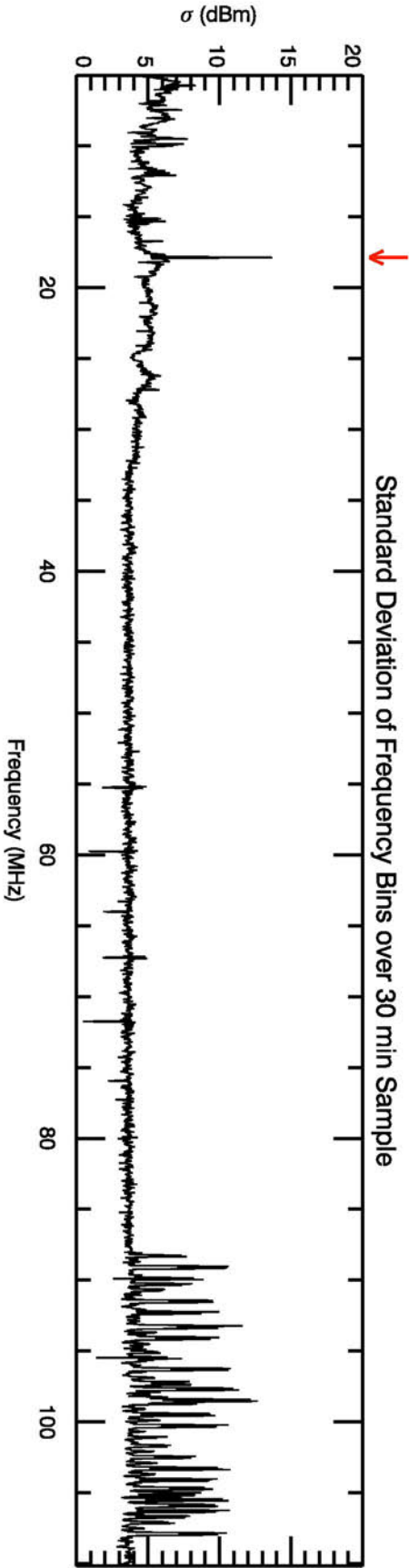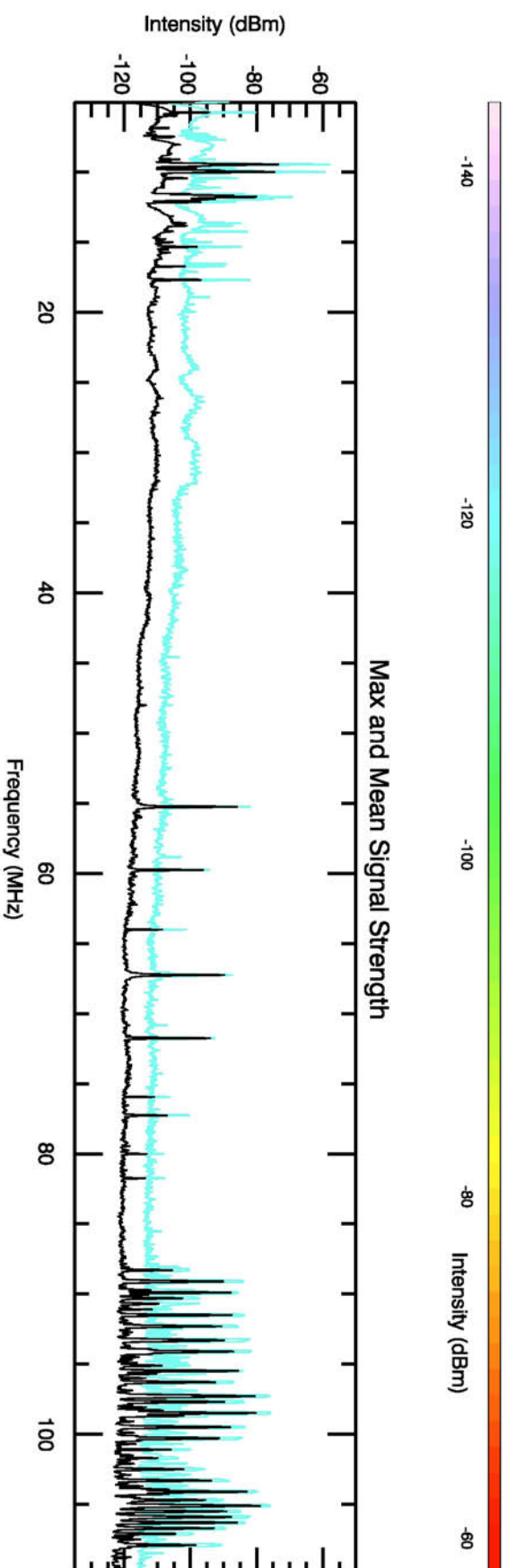
Intensity (dBm)

Time (UT)

data-120606-2246

Dynamic Spectra (TP, 2006-12-15)

data-121506-2119

Information from FITS Header
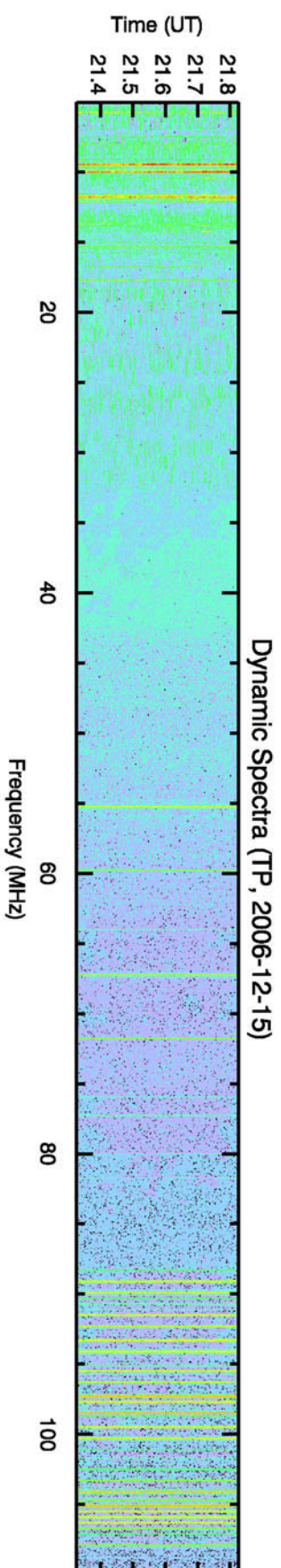
ORIGIN = 'TP   '

NLAT   = '34:07:37'   / North Latitude of ORIGIN dd:mm:ss

WLON   = '107:40:16'   / West Longitude of ORIGIN dd:mm:ss

TELESCOP= 'Big Blade'

OBSERVER= 'Pat Crane and John Dickel'

DATE-OBS= '2006-12-15T20:-49:56' / UTC

JD   =   2454085.37826424 / [days] Julian Date at center of collection

Further Information

File Name = data-121506-2119

Image Dimentions = (3507x250) ~ 105 MHz by 30 min

Freq Resolution = 30.0000 kHz

Time Resolution = 7.10359 sec

Time per Frequency Channel ~ 2 ms

Note : Adjusted data post collection to correct for a bug in the
IPRM code which failed to add the pre-amp offset value of -21 dBm

Standard Deviation of Frequency Bins over 30 min Sample

σ (dBm)

Frequency (MHz)

Frequency Bin Time History (Largest StdDev Value)

Intensity (dBm)

Frequency = 17.87 MHz

(Freq. Bin 429)

Time (UT)

data-121506-2119

Dynamic Spectra (TP, 2006-12-15)

Max and Mean Signal Strength

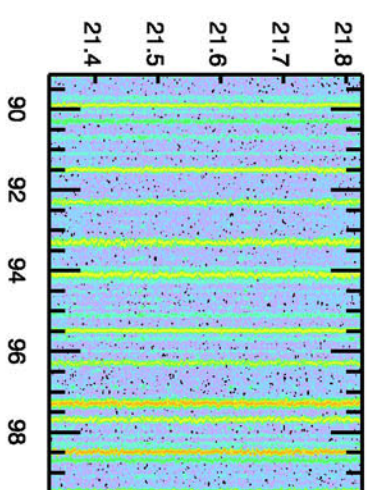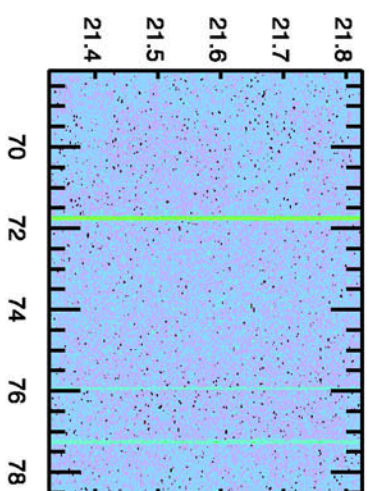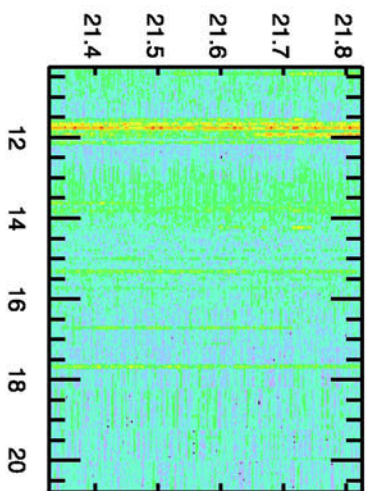data-121506-2149

Information from FITS Header

ORIGIN = 'TP '

NLAT = '34:07:37' / North Latitude of ORIGIN dd:mm:ss

WLON = '107:40:16' / West Longitude of ORIGIN dd:mm:ss

TELESCOP= 'Big Blade'

OBSERVER= 'Pat Crane and John Dickel'

DATE-OBS= '2006-12-15T21:19:34' / UTC

JD = 2454085.39900146 / [days] Julian Date at center of collection

Further Information

File Name = data-121506-2149

Image Dimentions = (3507x250) ~ 105 MHz by 30 min

Freq Resolution = 30.0000 kHz

Time Resolution = 7.21725 sec

Time per Frequency Channel ~ 2 ms

Note : Adjusted data post collection to correct for a bug in the
IPRM code which failed to add the pre-amp offset value of -21 dBm

Standard Deviation of Frequency Bins over 30 min Sample

σ (dBm)

Frequency (MHz)

Intensity (dBm)

Frequency Bin Time History (Largest StdDev Value)

Frequency = 98.53 MHz
(Freq. Bin 3118)

Time (UT)

data-121506-2149