RASDRviewer

RASDR2 Control and Analysis Software

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ABSTRACT

The Radio Astronomy Software Defined Receiver (RASDR) is a system that provides a versatile Software-Defined Receiver (SDR) that is optimized for Radio Astronomy. RASDR2 is the current hardware that is in testing with a planned general release at this conference. See multiple other presentations at this conference as well as previous SARA Journals and Proceedings publications for the history of this SARA project.

RASDRviewer is the software that controls RASDR2 and presents captured data to the user. It uses a Windows based GUI that is designed for portability to both the Linux and MAC platforms. This portability is mainly based on the use of the wxWidgets development tool that is available as open source freeware. wxWidgets abstracts most of the common graphical window objects to a common language that is applicable across all of the platforms. Thus the look and feel of the user experience is the same regardless of the platform being used. Loading and using RASDRviewer on a Windows operating system is straightforward.

This paper describes the RASDRviewer software and documents some of the experiences in its implementation. A brief discussion of the Windows Driver and FX3 firmware is also included.

RASDRviewer is an extension of the Lime Microsystems FFTviewer to optimize radio astronomy functionality. The original FFTviewer presented three charts, I & Q samples vs time, I vs Q for system verification and an output display showing results of a large Fast Fourier Transform (FFT) that operates in near real time. The FFT is capable of delivering up to 16,384 frequency bins multiple times per second. The control of the system required knowledge of the Lime chip architecture and RF engineering theory.

For RASDRviewer, modifications have been made to customize the software for Radio Astronomy use. This includes optimization of control functions for radio astronomy use, addition of a Power vs Time plot, file outputs and inclusion of a simplified selection of the user options. In addition, RASDRviewer makes full use of the receive capabilities of the Lime Chip including sample rates up to 32 M Samples/Second and 28 MHz of bandwidth. RASDRviewer is being demonstrated at this conference. The demonstration will include real-time control of RASDR2 to produce three dimensional FFT plots. A copy of the software executable is included in the CD for this meeting. The source code will be made available to anyone who requests a copy and is willing to be coached through the setup of the compiling environment.

SOFTWARE LANGUAGE

The system uses a combination of C, C++,wxWidgets, FFT-W and Open GL with the Code::Blocks Interactive Development Environment. The system uses a driver provided by Cypress the maker of the USB3 chip on the RASDR2–Digi-Red board. These development tools have created a powerful GUI and data processing capability. The GUI provides the user interface in a format that is familiar to the user of the chosen platform. However, the complexity of the compilation chain can prove difficult to establish. This complexity has limited the porting of the system to platforms beyond Windows at this time.

USER PLATFORMS

RASDRviewer currently operates on most Windows platforms that are in current use. This includes Windows 2000, Vista, XP, 7 and 8. It has been tested on Windows 7 and XP. Plans include the porting of the system to Linux and MAC platforms.

SOFTWARE ARCHITECTURE

The software is organized in classes, modules and files to allow maximum flexibility in the reuse of code. Threading, Call back and event timers are used to maximize the high speed processing of the data. To allow the slower machines or those with only a USB2 interface to operate, the user can set performance parameters to optimize the system for their platform. The high speed multiple core platforms will provide the maximum performance which includes data collection at 32 M Samples/Second and the full 28 MHz bandwidth of the RASDR2 board.

FIRMWARE

The system uses custom firmware that is loaded onto the FX3 chip in the Digi-Red board. This includes a unique SARA Vendor and Product ID (VID/PID) pair. This allows the user to connect to RASDR2 without concern of not finding the correct USB3 channel. The software uses this unique VID/PID together with a version register on the Lime Chip to verify that system connections are correct.

The firmware provides not only the high speed data interface, but also a capability of establishing a Serial Peripheral Interface (SPI) bus to perform the control of the chips on RASDR2. In addition, the firmware provides the use of the General Purpose Input Output (GPIO) pins on RASDR2. Thus there is no need for a separate micro-controller or FPGA on RASDR2. This has significantly reduced the cost of RASDR2.

GRAPHICAL USER INTERFACE (GUI)

When the user executes RASDRviewer, they are presented with a screen that provides charts of the collected data. Figure 1 shows this screen. Starting in the upper left side, the In Phase (I) and

Quadrature (Q) samples are displayed against time. The range on the chart was set to display the quadrature relationship of the I & Q signals where I is leading Q by 90 degrees.
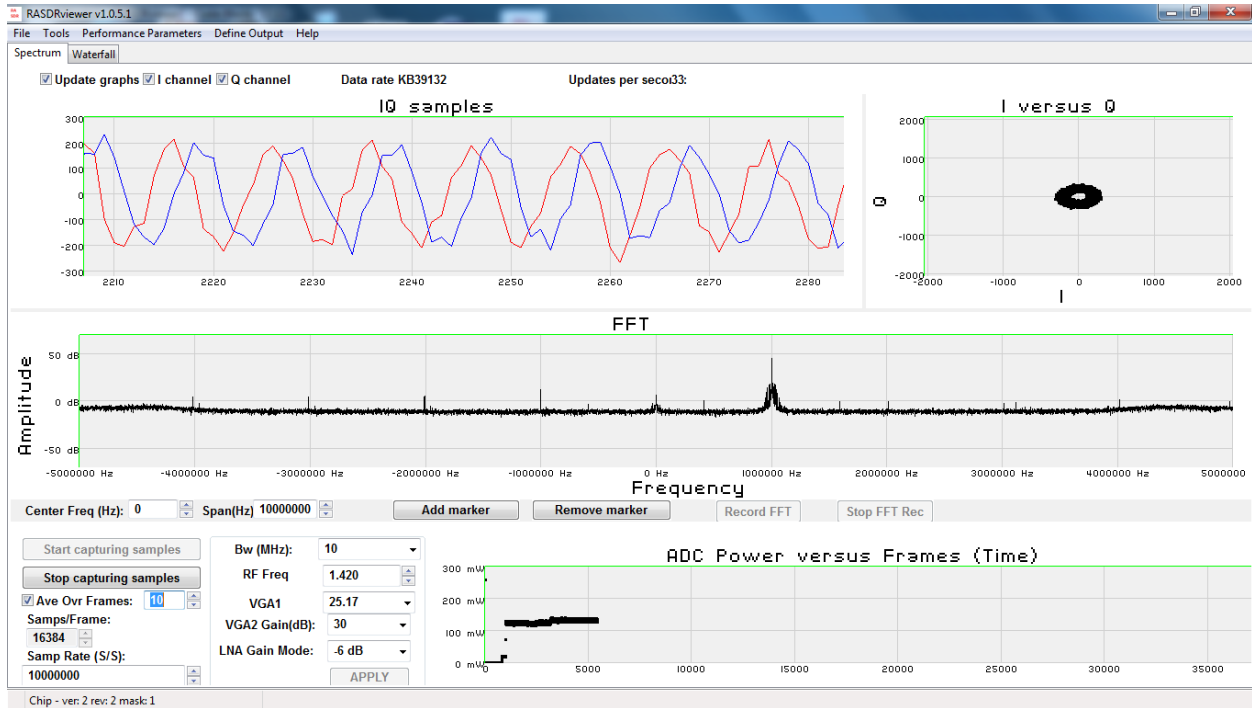

Figure 1 the main RASDRviewer Screen with an inserted CW signal

To the right, there is a chart that displays the phase relationship between the I and Q samples. Since a significant spectral line is present, the circle is present. The circle is created by the 90 degree relationship between the samples. This chart is used mainly to verify the system. However, it is a useful educational tool for students that are learning the phase relationship between I & Q signals and flags the existence of any possible imbalance between I and Q channels.

In the middle of the screen there is a display of the FFT output. The vertical axis is in dB. The horizontal axis is the frequency of the FFT bin at baseband. Zero frequency corresponds with the center RF frequency. The frequency bin bandwidth can be changed by using different sample rates and samples per frame that is set on the bottom left of the screen. Appendix A contains a spreadsheet that displays a few of the possible bin bandwidths. Figure 2 shows an enlarged portion of the screen where chip parameters can be set.
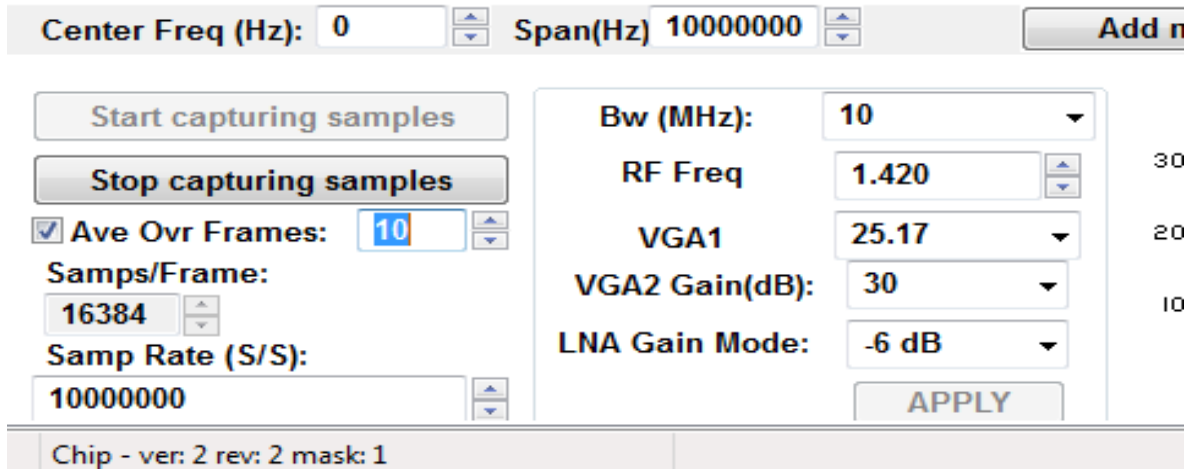
Figure 2 Enlargement of the bottom left portion of RASDRviewer Screen

In the bottom right corner is a display of power at the ADC input. Figure 3 shows this portion enlarged. The power is calculated over a frame of complex samples creating a display of the RMS power in the frame. Although the values are in milliwatts, to obtain the corresponding total power at the antenna would require calibration. The main purpose of the power chart is for use during drift scan experiments. The power will peak when the desired object is centered in the antenna beam width.
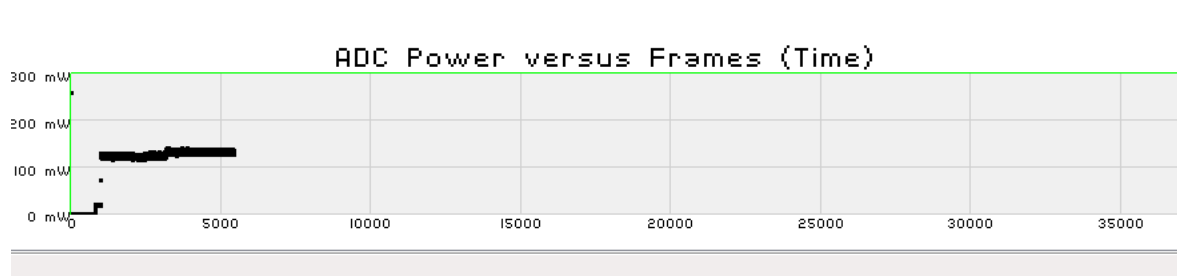

Figure 3 The ADC Power chart enlarged

All of the charts have the feature where the user can change the range of the chart by dragging a box around the section of the chart to enlarge. Clicking on the left side of the chart restores the default ranges.

The FFT chart has the ability to set markers to help identify the specific frequency and peak value of a spectral line. The marker controls are below the FFT chart enlarged in Figure 4. To add a marker, click the "Add Marker" button. Then move the cursor to the screen and click where the marker should be placed. The marker can be moved left or right by dragging it with the mouse. With a little bit of practice, the user can find the peak value.

The user can also set the span and center frequency of the display.

Figure 4 Enlarged showing the FFT display controls and record buttons

The charts are updated multiple times per second. The time between updates varies with different setup parameters. The frequency (updates / Second) is shown on the top of the screen.

The user can change the experiment parameters by using the controls in the bottom left section of the screen. See Figure 2 for enlargement. This is where one would set the frequency, bandwidth, sample rate, frame size and gain. The changes are not placed in effect until the user pushes the apply button. When the apply button is clicked, the system forwards the necessary commands via the SPI bus described above to the Lime chip on RASDR2.

The top left portion of the controls section on Figure 2 contains buttons which start and stop the capturing of the data. When the start button is clicked, the charts will show the results of the samples. The start button will also activate the "Apply" button which ensures that changes in parameters are included in the results.

Just below the "Start" and "Stop" buttons is where the user can establish averaging of the FFT output. This is done by clicking the check box and setting the number of FFTs to average. Averaging is useful to enhance spectral lines by reducing the baseline noise. Since the baseline noise is random, its average value is reduced to the mean of the noise. Since the Spectral line is not (or partially) random, it is enhanced.

Setup FFT Output to Disk

Recording data to a disk file or files can be accomplished by using the Define Output menu item on the second line of the screen. Clicking the button will bring up a sub-menu of the types of outputs available (only FFT output at present). Clicking the FFT output menu item will bring up an overlaid screen for the setup of the parameters of the recording. Figure 2 is a screen shot of this window.

On the left of the top line the user can select the File type. Two options are available. The first is for use in MS-Excel where the number of frequency bins is reduced to a maximum of 128 to allow Excel to be able to process a 3D chart in a reasonable period of time.

The user can select the General Purpose output for use in other post processing programs. The output in this case uses whatever sample rate, samples per FFT and bandwidth is present in the controls on the bottom left of the main screen. The general purpose output produces a comma delimited data file with a .csv file extension.

The top center of the setup window is used to determine the behavior in the event multiple record sessions are desired. There are two options one to append the data to the previous file and one to create a new file with a suffix number in the file name.
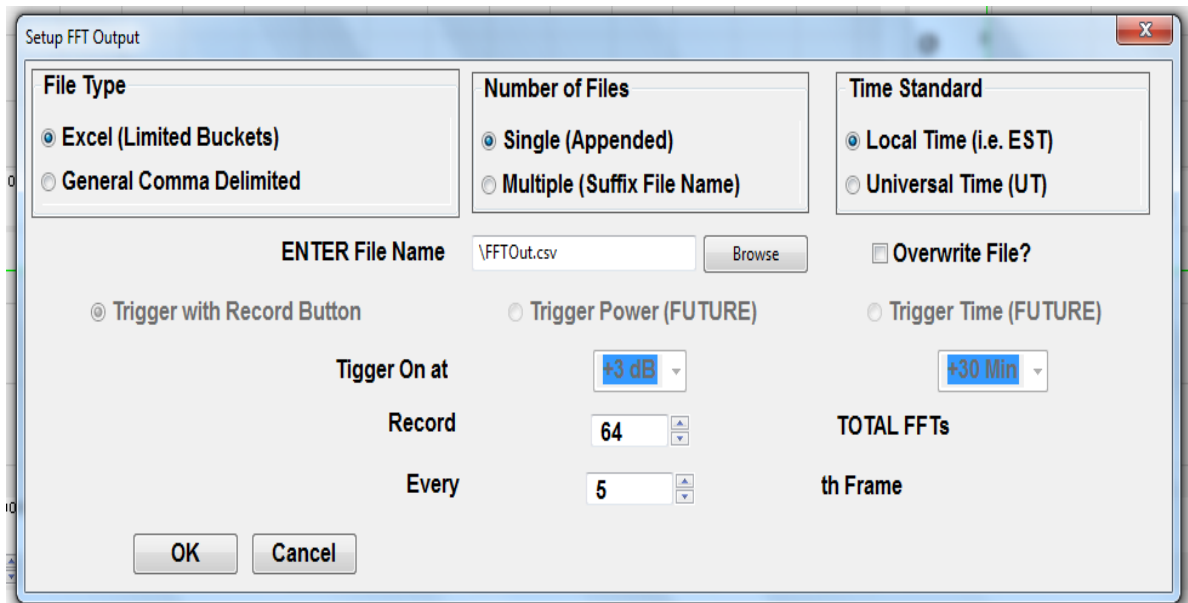

Figure 2 the FFT Output Setup Screen

The top right section of the setup screen is used to define the type of time stamp to be used. There are two options Universal Time and Local Time.

The second section of the Setup Window is used to define the file name. A browse button is included to allow the user to find the directory and file name for the data. If the file already exists, it is necessary to either select a different file name, or check the "Overwrite" box.

On the next line, in the future, the user will be able to define the condition which will trigger the recording to the disk. At present, only the manual trigger is operational.

Near the bottom of the screen is where the user can establish how many FFTs to record and how frequently.

The bottom section contains the "OK" and "Cancel" buttons. To abandon the setup, click the cancel button. To establish the selected parameters, click ok.

Recording FFT Output to Disk

The user clicks the "Record FFT" button which is located on the line below the FFT chart. See Figure 1 and 4. This button is only active when data is being captured by use of the "Start Capturing Samples" button on the left of the screen and an output is defined. The defined

number of FFTs will be recorded on the disk. The "Stop FFT Rec" button can be used to stop recording data before the defined number of FFTs is recorded.

Once the recording is stopped, the "Record FFT" button can be clicked for additional data as defined (either appended or new file suffix).

<div align="center">**RESULTS OUTPUT**</div>

The following chart shows an example of the capability to produce 3D charts using the Excel output option.
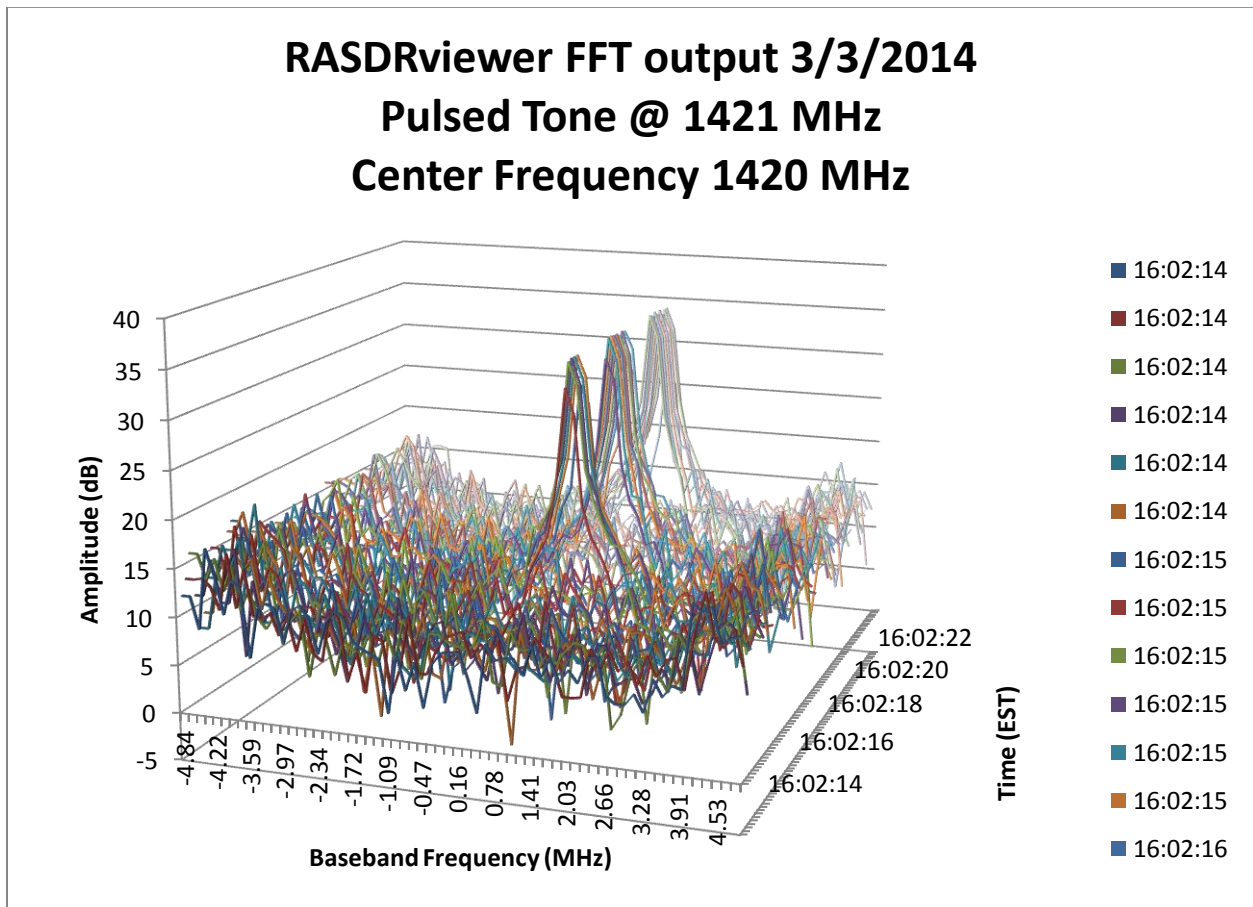
The chart was created by inserting a 1421 MHz CW signal on the input to RASDR2. The signal was manually pulsed. All data processing was done with RASDRviewer. Excel was used to produce the chart without any data processing.

The following chart was created using a Python Post processing program.

Collected between 2014-05-07T15:50:57 and 2014-05-07T15:54:32
Averaged over 998 frames
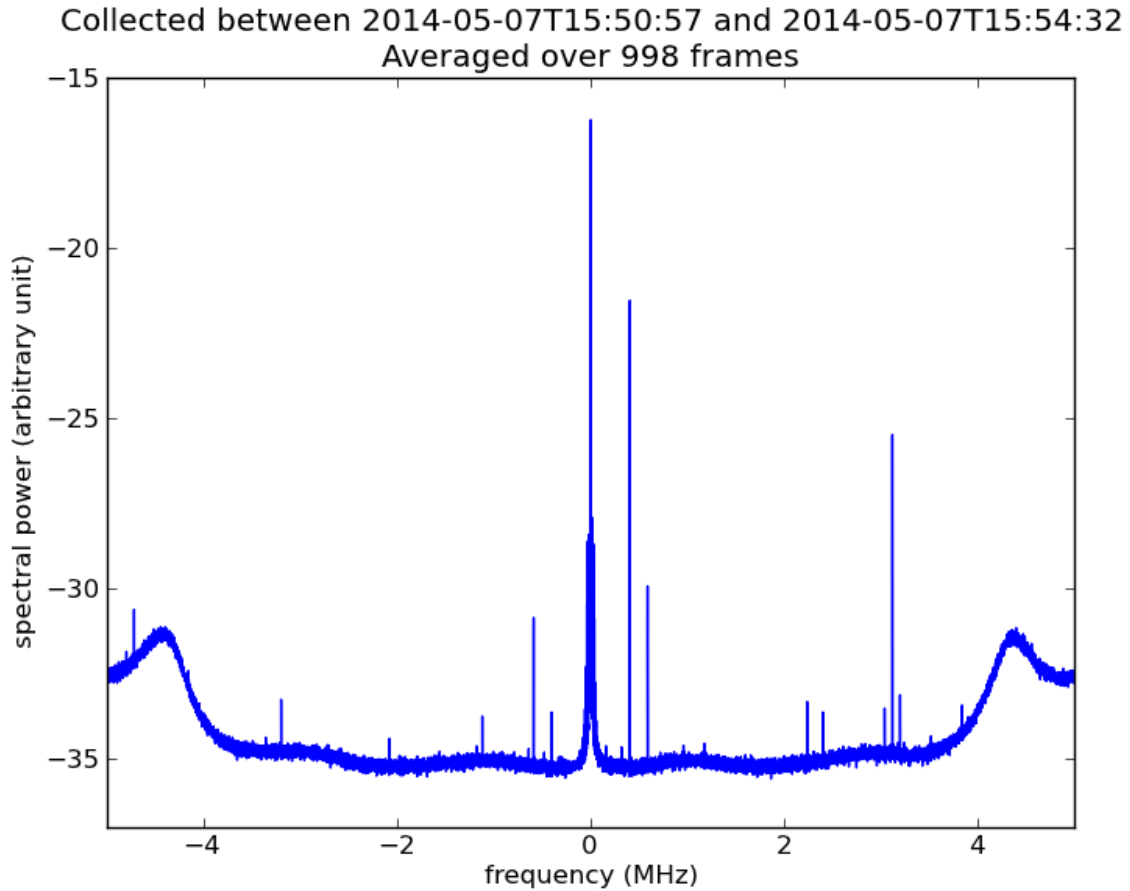
The data was collected using a center frequency of 1420 MHz, 10 MHz bandwidth, 10 M Samples/Second and default gain. A Pulsed CW signal was inserted at -100 dBM at 1420.4 MHz. This produced the spectral line that is closest to zero frequency at baseband. The peak at zero and the other peaks are system produced spurs.

The chart shows how one can enhance spectral lines using a large amount (998 frames) of averaging. The pulsed nature of the input signal was averaged out of the data leaving only the single input spectral line at 0.4 MHz. It also shows that the system spurs can also be enhanced. Thus the user must be careful when interpreting the data to ignore the enhanced spurs.

The following chart was created by subtracting the background from 10 FFTs where the pulse wasn't present. This leaves just the spectral line from the pulsed CW signal and a residual noise floor.

Collected between 2014-05-06T15:50:57 and 2014-05-06T15:54:32
Averaged over 998 frames, with background subtraction
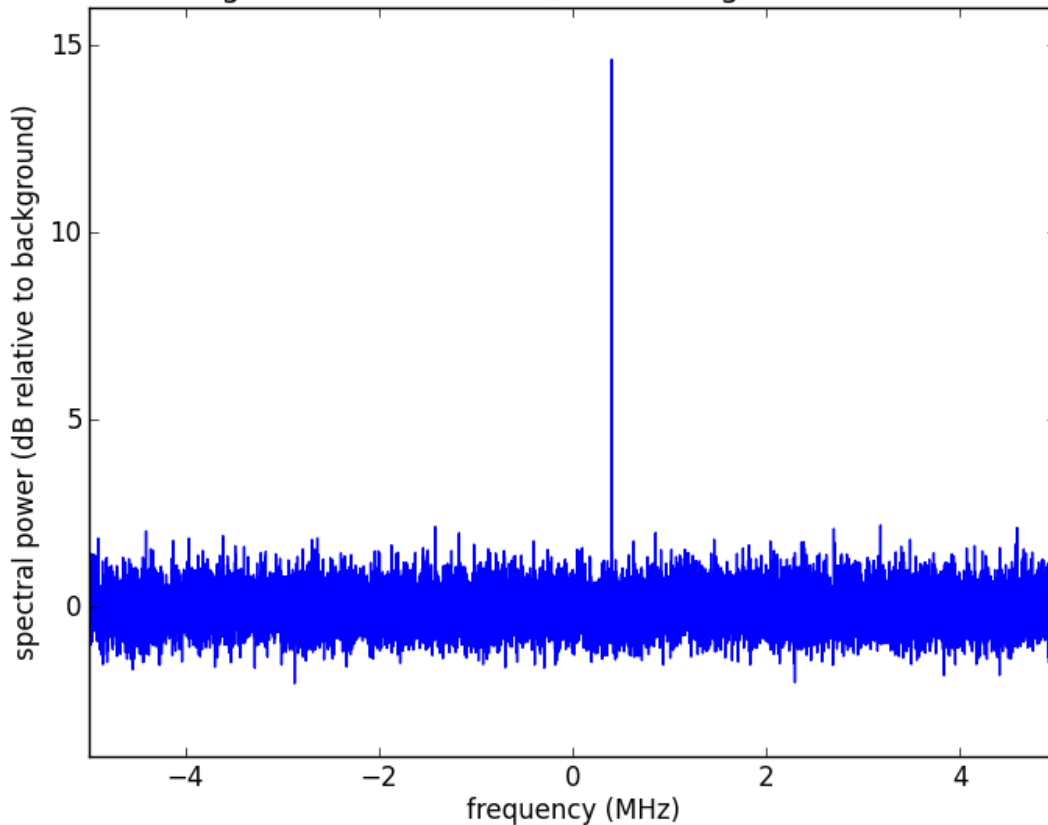
CONCLUSION

RASDRviewer has been proven to provide the necessary software support for RASDR2. The high degree of flexibility in setting parameters will allow the user to customize RASDR2's performance to meet their needs. The user has a choice for output post processing. The 3D Excel charting capability is useful. For other types of processing such as large amounts of FFT averaging or removing the background, the system supports external programs.

FUTURE ENHANCEMENTS

Work is in progress to add a configuration storage file. This will allow the user to pick up where they left off without reentering the configuration parameters. A binary source data file will be added for post processing the raw I & Q samples. If it proves possible, either a real time waterfall or 3D chart will be added on separate screen within the main notebook. Help is needed with the waterfall feature.

ACKNOWLEGEMENTS

APPENDIX A

The following spreadsheet shows some examples of the ability to obtain multiple FFT bin widths with different RF bandwidths, samples/FFT and sample rates.

A.

Sample Rate	Samples / FFT (Bins)	Bin BW (Hz)
2.048E+07	16384	1250.00
	8192	2500.00
	4096	5000.00
	2048	10000.00
	1024	20000.00
	512	40000.00
	256	80000.00
	128	160000.00
	64	320000.00

B.

Sample Rate	Samples / FFT (Bins)	Bin BW (Hz)
2.800E+07	16384	1708.98
	8192	3417.97
	4096	6835.94
	2048	13671.88
	1024	27343.75
	512	54687.50
	256	109375.00
	128	218750.00
	64	437500.00

C.

Sample Rate	Samples / FFT (Bins)	Bin BW (Hz)
1.00E+07	16384	610.35
	8192	1220.70
	4096	2441.41
	2048	4882.81
	1024	9765.63
	512	19531.25
	256	39062.50
	128	78125.00
	64	156250.00

D.

Sample Rate	Samples / FFT (Bins)	Bin BW (Hz)
6.40E+05	16384	39.06
	8192	78.13
	4096	156.25
	2048	312.50
	1024	625.00
	512	1250.00
	256	2500.00
	128	5000.00
	64	10000.00

Section A shows a high sample rate that would produce similar results to SpecrtraCyber with the 5Kz bin bandwidth using 4096 samples per bin. Section B shows the bin widths with the maximum available RF bandwidth (28 MHz). Section C shows the bin bandwidths using the default sample rate of 10 MHz. Section D shows the bin bandwidth with the sample rate set low enough to provide a 5 KHz bin bandwidth when used with 128 Samples/FFT. This setup may be useful to produce Excel 3D charts where the number of bins must be limited to 128 or less.

The user can design their experiment to make use of any sample rate that is a power of 2 samples/FFT that best meets their needs. The Bin Bandwidth can be calculated by dividing the sample rate by the number of samples / FFT. Nyquist Criteria must be met when setting the RF bandwidth.