Date: May 15, 2016
Version: 1.04 (Fox-1A, Fox-1Cliff, Fox-1D)

AMSAT Fox-1
Telemetry Decoder Manual

1 Introduction

Thank you for downloading the Fox Telemetry Decoder. You can use this program to demodulate, store and analyze telemetry data from AMSAT's Fox series of Cube Sats. We hope that you will also upload the telemetry you receive to the AMSAT server so that it can be used by other scientists, students and our research partners, whose experiments fly with the Fox satellites.

FoxTelem is experimental. We are sure it can be improved. Please provide feedback and suggestions. Email contact details can be found on the Help->About screen.

Fox-1 satellites include two telemetry formats:
- Slow Speed, also called Data Under Voice (DUV) is 200 bps FSK data sent at the same time as the transponder audio. Whenever the transmitter is on, data is being sent. This happens during beacons and during live QSOs.
- High Speed is 9600 bps FSK sent instead of the transponder. This is used for data intensive experiments such as the Virginia Tech Camera (on Fox-1Cliff, Fox-1D) and University of Iowa HERCI experiment (on Fox-1D). On Fox-1A we will test high speed and use it to download additional radiation data from Vanderbilt University's experiments. This mode is only active when commanded from the ground. You can recognize High Speed because it sounds like an old school computer modem.

FoxTelem will receive and store both formats assuming you can feed it clean audio or IQ signals from an SDR.

1.1 License

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FoxTelem is Copyright (C) 2015,2016 amsat.org

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3   Getting Started

3.1   Installing

FoxTelem is supplied as an archive file (.zip on windows and MacOS, .tar.gzip on Linux). You can unzip the contents and put it in the directory of your choice. Right on the desktop works well, as does somewhere in your home directory or documents directory. If you install it into MacOs Applications or into the Windows "Program Files" folder, then you will need to choose a different directory to write the decoded data into. You can do this the first time you run the program.

3.2   Running

Run FoxTelem by double clicking FoxTelem.exe on Windows or the Application file on MacOS. On Linux, you should be able to double click FoxTelem.jar, or run it from the command line with the FoxTelem start script. On all platforms you can run it from the command line with "java –jar FoxTelem.jar". That can be helpful if your desktop is locked down and you are unable to add programs.

When FoxTelem starts you should have the Welcome screen shown below. The "Simple" install will use the installation directory to store the decoded data. This keeps everything in one place, but mixes the program with its data. If you want to write the data to another directory, choose "Custom", click "Continue" and specify the directory on the next screen.
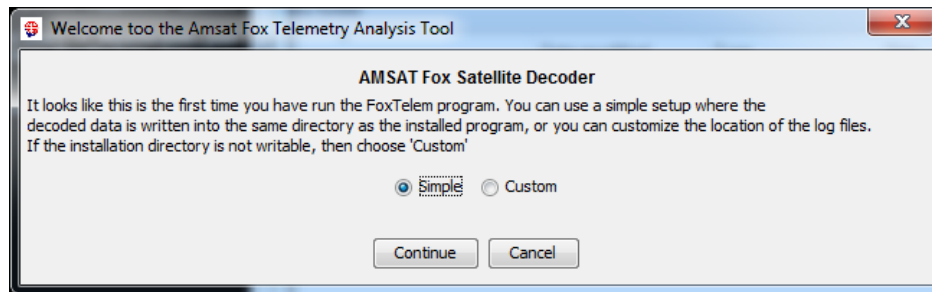
FoxTelem will not start if you do not have java installed, or have a version before Java 6. You will get a message from the launcher telling you to download and install the latest version from java.com.

If you get an error message from Windows Smartscreen like the below, then click "More Info" and then "Run Anyway". Windows gives this message for new or little know applications that have not established a reputation.
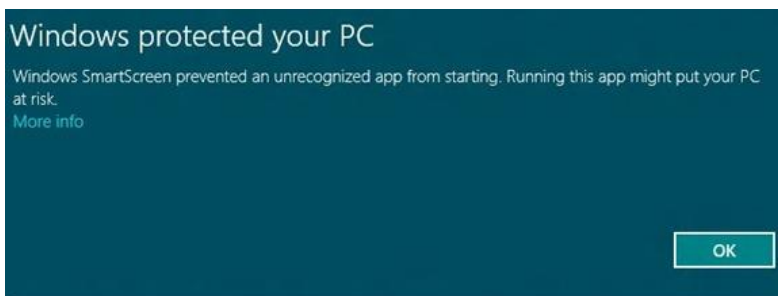
MacOS has similar security precautions and will give you a message like the below. It may also say that FoxTelem is corrupt.
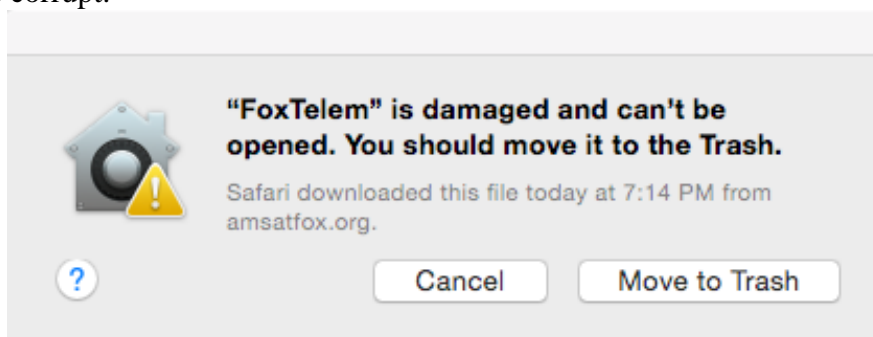
FoxTelem is not really damaged and it can in fact be opened. You can hold the "Command" key while you double click the application and it will run. After that it will run without the Command key. This message is displayed because your "Security and Privacy" settings do not allow applications that are not installed from the Mac App Store. If the "Command Click" option does not work then you will need to temporarily change your Security and Privacy settings. Change them back after you have run FoxTelem. It should run the next time without changing the settings.

If you are on Windows and the program complains that it is missing MSVCR100.dll or something similar to that, then you need to install the Microsoft Visual C++ redistributable:
For 32 bit windows: http://www.microsoft.com/download/en/details.aspx?id=5555
For 64 bit windows: http://www.microsoft.com/download/en/details.aspx?id=14632

If you do not know if you have 32 or 64 bit windows then Open System by clicking the *Start* button, right-clicking *Computer*, and then clicking *Properties*. Under *System*, you can view the system type.

If you are using MacOS 10.7 or later and you get the message below, then follow the instructions and install Apple's "legacy" version of Java.

FoxTelem is written and compiled with the latest version of Java (Version 8 in Sept 2015) but it is compliant with Java 6 so that it works on older Mac operating systems. On other platforms you can run FoxTelem with any versions of Java from Java 6, but Apple and Oracle have not made this simple on the Mac.

If FoxTelem still won't start, then see the troubleshooting section at the end of the manual or ask for help on the amsat-bb mailing list.

3.3   Testing with a wav file

To confirm everything is working you can download a test wav file from amsat.us/FoxTelem/recordings. A recording ending in AF is audio as received from a radio. A recording ending in RF is an IQ file.

Select "Load Wav File" from the FoxTelem "File" menu and navigate to the directory where you saved the file. Then press the "Start" button.

The file will play through the decoder and the audio waveform will be shown together with an eye diagram. You should get a number of frames decoded.
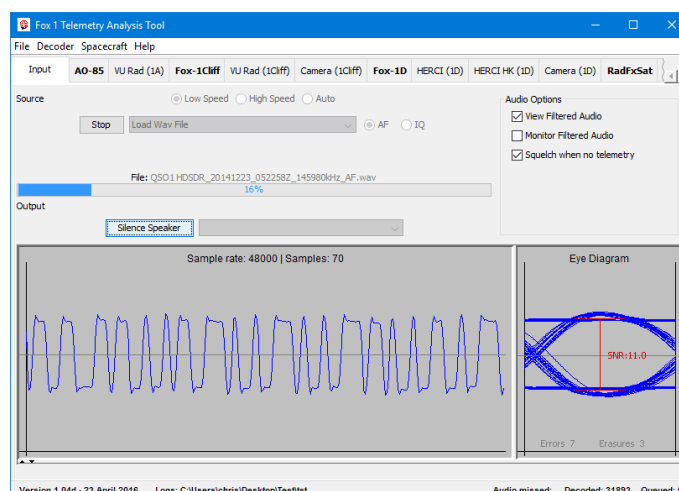
There should be data visible on the Satellite's tab. If the data is difficult to read because the font is too large or too small then open the settings screen from the File menu and change the font size for the Health Modules.

4   Decoding

The telemetry for Fox-1 is sent in two different ways. While the transponder is on, low speed telemetry is sent on the same frequency, even while the transponder is in use. This is sent as Data Under Voice (DUV) in the audio band from 0 to 200Hz in the same FM channel as the transponder audio. So while a QSO is in progress, we can receive telemetry from the spacecraft.

This makes certain demands on the ground station. There should be no high pass filtering of the FM audio. Ideally the band from 0 to 200Hz is untouched when it is received from the telemetry decoder. Unfortunately, this is not the case for almost all radios.

What we want to receive is something like below. You can see all of the bits, although there is some "ringing" from filtering in the decoder itself. The eye diagram shows the last set of bits received, drawn one on top of another. We can see a nice shape and it fits into the sample window. The bits are sampled vertically at the midpoint, with the signal to noise shown by the red line. We want a signal to noise ratio of at least 3. Higher is better. 2 is marginal. We also see the Error rate in the Eye Diagram window. This is updated each time we receive a frame from the satellite and shows the number of bytes that were corrected by the Reed Solomon Decoder (Errors and Erasures).
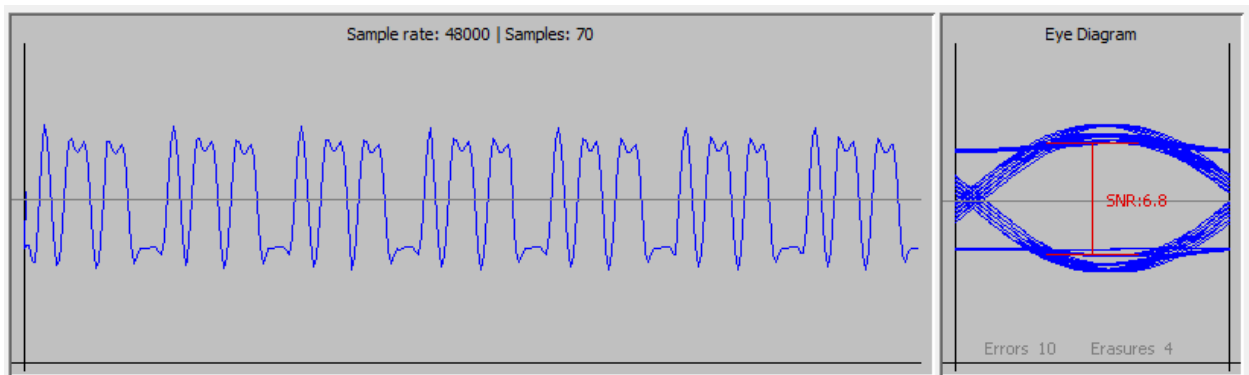
4.1 Selecting a source

FoxTelem decodes audio, but there are many ways for it to source it. On the Input tab you select the source in the pull down box near the top, just to the right of the "start" button. Typically you would pick one of your sound cards and then feed audio into that sound card from a radio. In the example below FoxTelem is reading from the "Microphone" source, it will process Low Speed (Data Under Voice) with a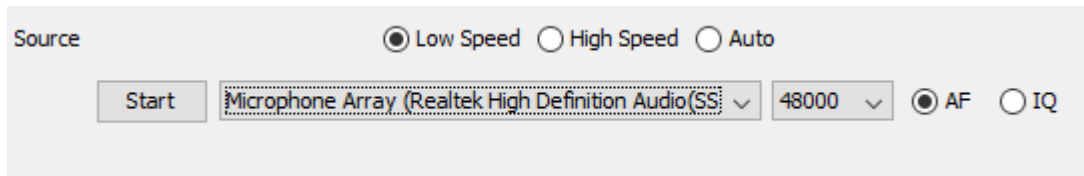 48000 bits per second sample rate. (This is the sample rate that the sound card has and FoxTelem needs to match it. You can't change the sample rate that FoxTelem runs at without changing the sample rate of the audio that it receives.) Finally it is expecting normal audio (AF) from a radio.

FoxTelem can also read IQ audio and act as a Software Defined Radio (SDR). You do this by selecting a source that supplies In Phase audio on one stereo channel and Quadrature audio on the other. You set the correct sample rate and you choose IQ, rather than AF (to the right of the sample rate pull down). If the device is the FunCube Dongle then you should also be able to set the frequency directly. If it is another device then you will need an external program to control it. FoxTelem will just read the IQ audio.

On some Mac Computers, FoxTelem may only read from the default device (this is likely a bug that I need to fix). You can select the default device from System Preferences>Sound then select Input and set the device you want as the sound input.

If you are not seeing any sound card devices on the Mac, then you may have the sample rate set to a level where no sound cards are supported. Try setting it to 48000. If you no longer have a sample rate pull down, then you need to delete the foxtelem.properties file as a work around. This is a known issue.

4.2   Setting up the levels

You may need to adjust the sound levels in your operating system. I had to adjust the levels in Windows. From the control panel I selected: Hardware and Sound> Manage Audio Devices> and then adjusted the properties for the sound card on the Custom and Levels tabs.
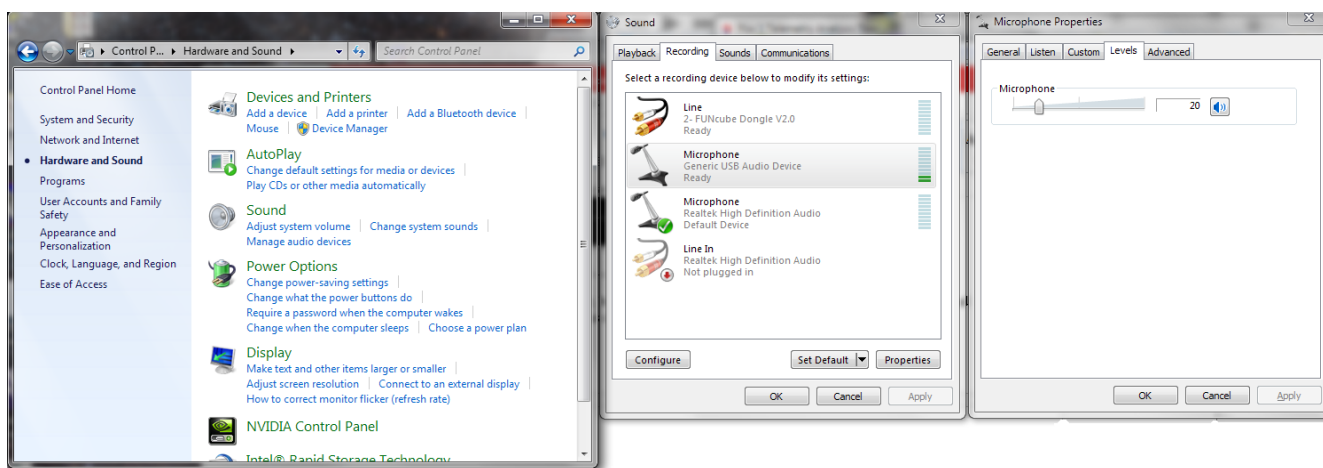
On the Custom tab I unchecked AGC and on the Levels tab I set it to 50. You may have other settings for your sound card.

To set the levels correctly uncheck the "View Filtered Audio", shown below on the right, and make sure that the signal is visible but does not take up more than half of the display. If its too low, you won't decode frames, if it is too high you will see it square off on the display. The exact setting is not critial because FoxTelem has some AGC built in. Also note that the white noise when there is no signal is usually much louder, which is to be expected. This may well drive the decoder into distortion. A quiet transponder, which has been keyed, but which has no audio signals in it, should not distort. The spacecraft will still be tranmitting telemetry and you can decode it.
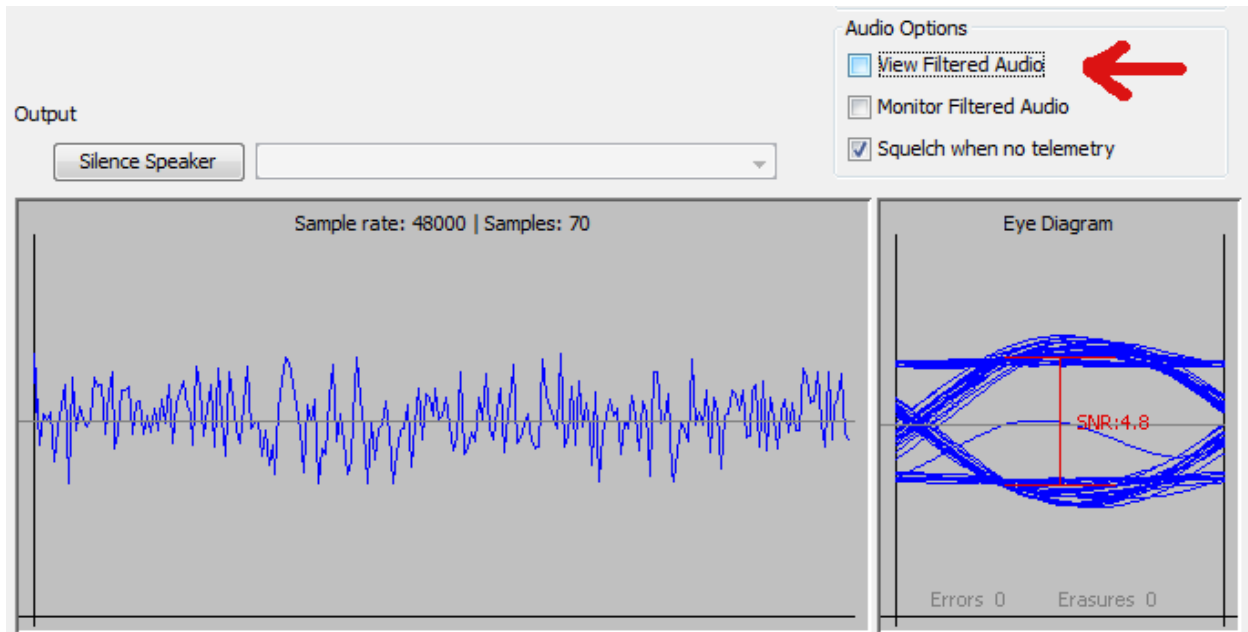
Also note that the sample rate is shown on the Advanced tab (in the Windows example screens). Windows typically defaults it to 44100 and the decoder defaults to 48000. Your Operating System may default to something else. The sample rate in the sound card setup needs to be the same as the sound card sample rate in the decoder or you will get a poor decode rate. The image above shows the sound card rate near the top.

Why do we default FoxTelem to 48000 if Windows defaults to 44100? Because 44100 does not work as well. 9600 bits per second and 200 bits per second both divide equally into 48000. This means fewer corrections to keep the clock in sync and a better decode rate.

4.3   Feeding the Audio

You can wire a cable from the data out port of your radio to both stereo channels of a 3.5mm plug and connected it to the sound card. Select the widest audio bandwith that you can, because we want a response down to nearly DC. Usually this is a 9600 baud packet setting or a direct feed from the FM discriminator. I got the best results by modifying my FT-736R to feed audio from the discriminator, but my FT-817 was also able to decode Fox without modification.

The results from a radio are workable but not ideal. The audio below is from the FT-817. Note the shape of the bits. This is characteristic of high pass filtering. The bits start at their full value then steeply slope.
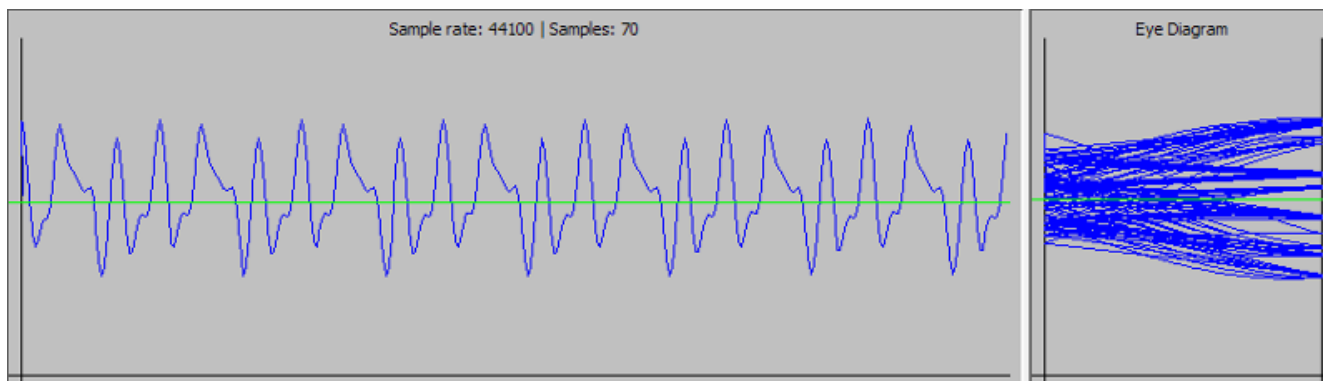
The frequency spectrum shows a null below 20Hz and the FT-817 seems to decode about 10% fewer rames than the modified FT-736R.
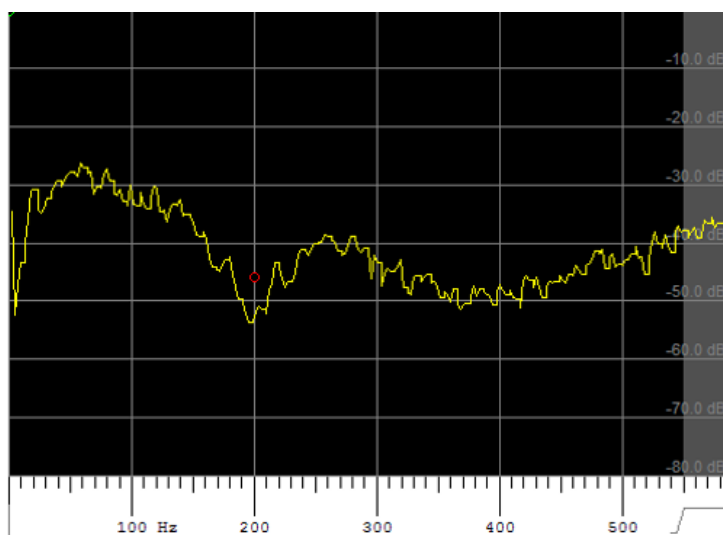
4.4   Decoding from an IQ source such as the FUNCube Dongle

A software defined radio is a better choice because we get no filtering of the low frequency audio. The Funcube Dongle, for example, can receive the telemetry and pass the IQ baseband audio untouched to FoxTelem.

You have two choices to set this up. Either receive the audio in your favorite SDR software and feed the demodulated FM audio to the telemetry decoder or use the IQ demodulation in the telemetry decoder itself. Both should work. Here are the advantages and disadvantages of using FoxTelem's IQ demodulator:

Advantages
- FoxTelem will find the satellites signal when it appears and will follow the Doppler. You do not need a separate application to set the frequency assuming it is in the pass band of the SDR.

- FoxTelem will measure several parameters about the received signal such as Signal to noise ratio and Time of Closest Approach (TCA), which AMSAT would like to collect and analyze.
- You don't need to use another piece of software, such as Virtual Audio Cable, to connect the two programs. Or feed the audio out of the computer and back in again with a physical cable.

Disadvantages
- A separate SDR program may have better capabilities than the SDR in the Telemetry Decoder.
- Your existing SDR may already be configured to work with Doppler correction software and the rest of your ground station
- FoxTelem can be more compute-intensive than some other SDR programs and may not work as well on slower computers

In either case, you should receive bits that are something like image below in "Starting the Decoder" (which is using the IQ demodulation in the decoder and shows the Frequency spectrum).

4.5   Starting the decoder

The start button kicks off the decoder and FoxTelem reads audio from the audio source that you selected. If this is audio from a separate SDR program such as SDR# or HDSDR then make sure the AF radio button is selected and the sample rate is the same as your sound card or SDR/Virtual Cable. If it is IQ audio from the Funcube Dongle or another SDR, then make sure that the IQ radio button is selected.
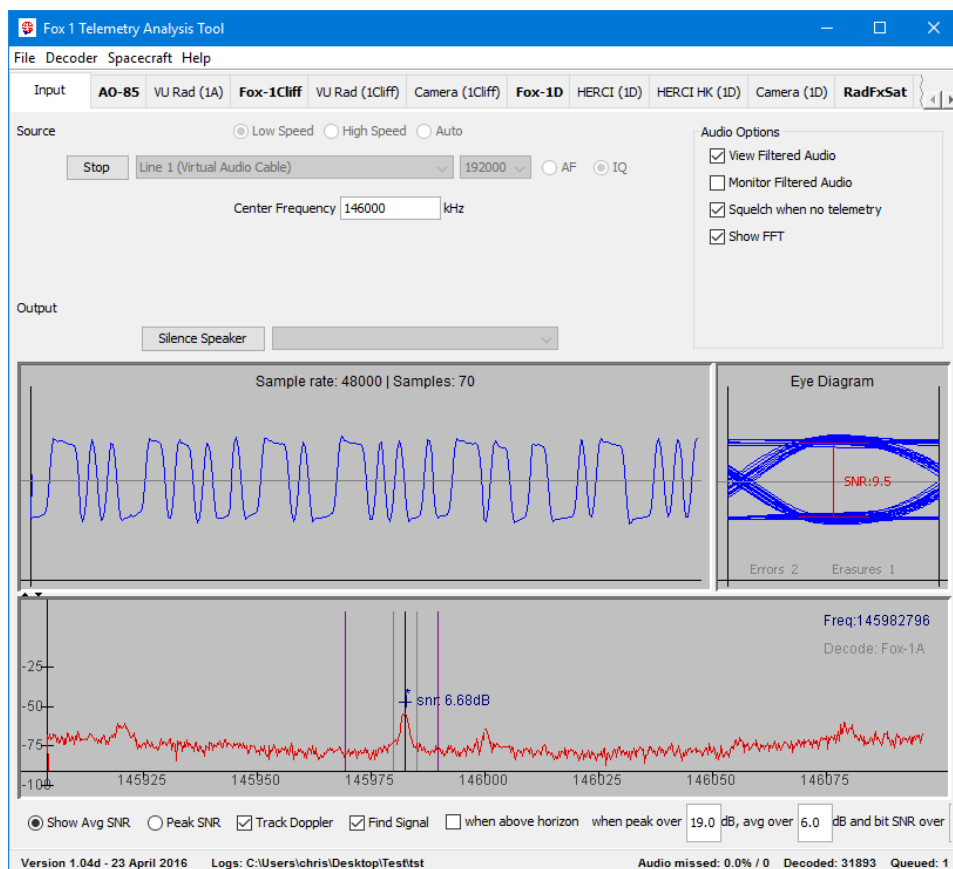
If you are receiving from the Funcube Dongle then setting the frequency will change the frequency that the dongle is tuned to and set the correct filters. For any other SDR, you will need to use a separate control program to set the frequency and any filters. In both cases, the frequency will be shown as the center frequency on the RF spectrum. This is not the frequency that you are receiving, which is shown by the vertical line. FoxTelem will measure the receiver frequency by calculating the offset from the center. You should avoid decoding the satellite in the center of the spectrum because it will be distorted by a noise spike that sits in the middle.

4.6 Finding the Satellites Signal

FoxTelem can monitor several satellites if they fit into the pass band. For example, with the center frequency set to 145930, Fox-1A, Fox-1Cliff and Fox-1D can all be monitored if 192kHz of spectrum is available.

If "Find Signal" is selected (just below the frequency spectrum) then FoxTelem will monitor the frequencies close to the expected downlink. The scan range is set by the `minFreqBoundkHz` and `maxFreqBoundkHz` parameters in the spacecraft files. These are described in the Spacecraft Configuration File section later in this manual.
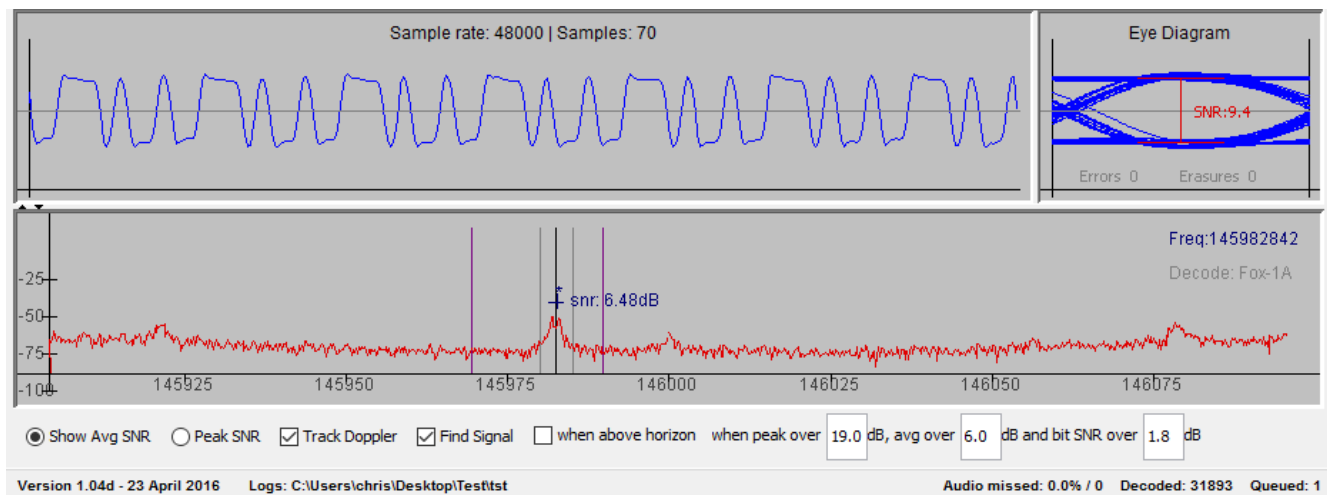
When FoxTelem finds a signal in the expected frequency range, it checks to see if it contains valid satellite telemetry. If it does, then it pauses the scan and decodes the data in the normal way. You should leave Track Doppler checked so that FoxTelem will follow the doppler on the satellite.

If the signal is lost then FoxTelem waits 2 minutes before resuming the scan. This is the period between beacons and will allow FoxTelem to track a pass when the satellite is in Safe Mode or when the transponder is not in use.

After 2 minutes, if no signal is received, then FoxTelem assumes the pass is over and scanning is resumed. Paramaters such as Time of Closest Approach (TCA) are calculated at the end of a pass.

Find Signal can be further refined as follows:

1. Checking "when above horizon" will wait until SatPC32 indicates that this satellite has risen before FoxTelem tries to decode it. For this to work the name of the satellite needs to be the same as the name in SatPC32. You can change the name in FoxTelem on the Spacecraft screen from the spacecraft menu.   In SatPC32 you can temporarily test the connection using ?>Auxilary Files>DivOptions.SQF. In that file you set Line #2 to +. This will cause SatPC32 to constantly output DDE data and FoxTelem will believe that the spacecraft is above the horizon

2. Setting "when peak over X dB" to a value will fine tune when FoxTelem jumps to a signal to test it. If you have interference in the pass band then you may want to set this higher to avoid scanning them. If you have a clear passband but the spacecraft is often weak, you may want to set it lower. This value is the same as the "snr" value displayed beside a signal when "Peak SNR" is checked

3. When FoxTelem has switched to a signal it then confirms that the "Average is over Y dB". This is the average signal to noise and is the same as the value shown beside a signal when "Show Avg SNR" is checked.

4. If the Average Signal to Noise ratio is high enough then FoxTelem checks the Signal to Noise Ratio of the bit stream. If it is above the third threshold then it decides that this is a signal from a Fox satellite and locks onto it

4.7   Auto Mode

While you can manually select Low Speed or High Speed decoding, this is not ideal for an unattended decoder. There is a third option labeled auto. In this mode FoxTelem runs two decoders in parallel. Both decoders are executing the Find Signal algorithm, if it is enabled, and both decoders are attempting to decode frames.

It may sometimes seem to take FoxTelem a while to switch from one decoder to another, but no data is missed. The decoders are not really switched. The decoder being displayed on the screen is swapped from one to the other, but it has been decoding in the background all the time.

Auto mode is not the default because it is CPU intensive. If your computer is able to run both decoders at the same time, then this is a good setting to choose.

4.8   Running multiple copies of FoxTelem

Some users may want to run more than one copy of FoxTelem. This may be to test configurations, receiver from multiple receivers or to have different decoders focused on different satellites. If you run two copies of FoxTelem on the same machine then they will share the same settings and write their received data into the same location. This is probably not what you want.

Instead, prepare a startup script for each decoder. This would be a batch script under windows or a shell script on Linux or MacOS. The script is simple and needs to contain only the following:

cd <directory where FoxTelem is installed>
java -Duser.home=<directory where the settings will be stored> -jar FoxTelem.jar

The "directory where FoxTelem is installed" is where the executable program is and where the spacecraft directory can be found. The "directory where the settings will be stored" is where FoxTelem will save the properties file. This will keep them separate from another running copy of FoxTelem. It can be in the same directory as your data.

When you run the script you should get the initial prompt asking where you want to save the data, as though you are running FoxTelem for the first time. Chose "Custom" and select where you want the data to be saved.

An example of this script on my PC is shown below:
cd C:\Program Files (x86)\foxtelem_1.04d_windows\
java -Duser.home="C:\Users\chris\Desktop\FoxTelem\parallelTest" -jar FoxTelem.jar

4.9 Automatically starting the decoder
If the decoder is running when you stop FoxTelem, then it will be running when you start FoxTelem again. This allows you to start FoxTelem from another program or have FoxTelem automatically start when the Operating System boots. You can find instructions online to add FoxTelem to the boot sequence and to configure the BIOS so that your computer automatically restarts after a power failure.

5 Fox Telemetry Format

5.1 Data Under Voice
During Safe Mode beacons, when the voice announcement says "Fox X, Safe Mode", during Transponder beacons, when the announcement says "Hi, this is Amateur Radio satellite Fox X" and when the transponder is on, data is being sent to the ground. This is 200 bps data sent in the sub audible band.

DUV data is transmitted in a Frame with a Header, Payload and a set of Forward Error Correction (FEC) bytes. The header contains 6 bytes of data and holds the Fox id for the spacecraft, the reset (number of times the computer has rebooted), the uptime in seconds since the last reboot and the type of payload.

There are 4 types of DUV payload, each 58 bytes in length. Type 1 payloads contain real time telemetry values from the spacecraft. Type 2/3 contain the maximum and minimum values of the real time telemetry. Type 4 payloads contain 58 bytes of experiment data and vary depending on the experiments that the spacecraft is carrying. On Fox-1A this contains data from the Vanderbilt University Low Energy Proton experiment which is measuring the effect of radiation on non space rated (COTS) memory chips.

The FEC trailer contains 32 checkbytes and allows us to correct significant errors due to fading or noise.

It takes the spacecraft 4.85 seconds to send a DUV frame (10 bits for the sync word, 960 bits of data, at 200 bps). We receive 2 frames in each beacon and 12 frames per minute in transponder mode. The beacon frames alternate between Real Time Telemetry and Max/Min Payloads. The transponder sends telemetry and experiment payloads in an alternating pattern of frames.
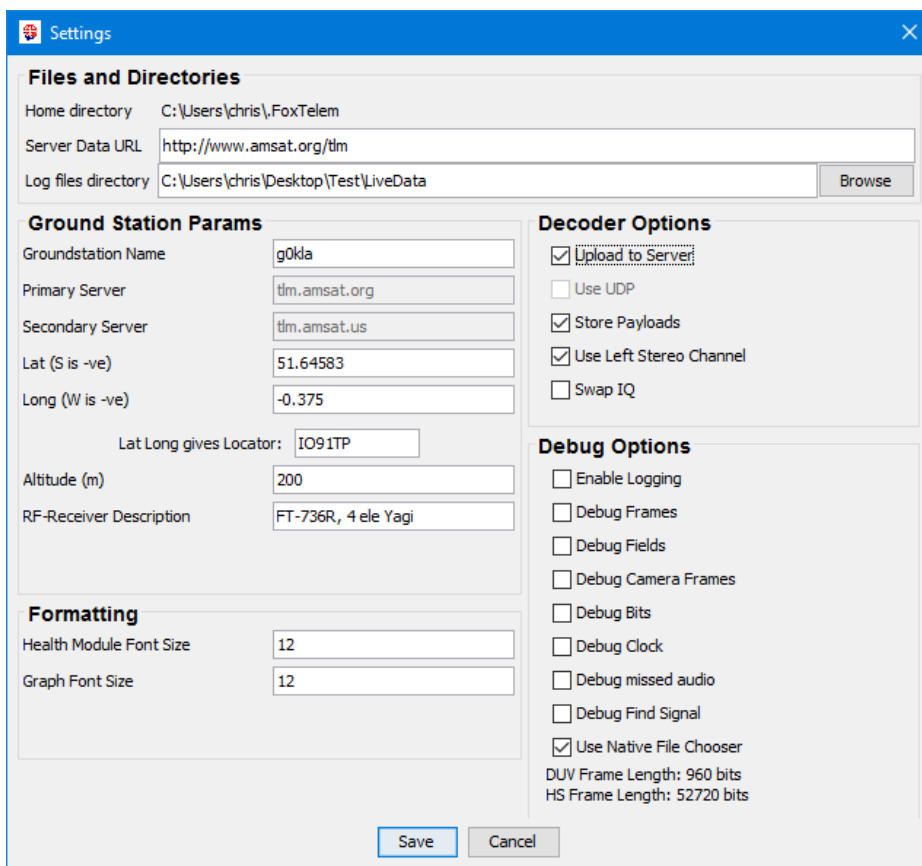
5.2   High Speed Telemetry

High speed telemetry is sent at 9600 bps. Each high speed frame also takes about 5 seconds to send, but they contain a lot more data. The High Speed frame contains a header with the Fox id for the spacecraft, the reset (number of times the computer has rebooted) and the uptime in seconds since the last reboot. The header is followed by Type 1, Type 2 and Type 3 telemetry payloads.

The rest of the high speed frame contains experiment data. In Fox-1A this is data from the Vanderbilt Radiation experiment. It is especially useful for downloading data from the experiment's buffer, which contains stored readings over many orbits. The number of type 4 payloads included in the high speed frame is variable, but is typically 16 – 30. When a high speed frame is decoded you will see a big jump in the number of payloads on the radiation tab and in the footer (beside the word Decoded). The number of frames queued for upload or the number of frames you see on the Telemetry Leaderboard will only increment by one, so for high speed they will not equal the number of payloads decoded.

6   Sending Data to the Server

You can help the research of students at participating Universities and contribute to the design and build of future AMSAT satellites by sending your received telemetry frames to the AMSAT server.

To send data first open the Setting screen from the File menu. Select the checkbox labeled "Upload to Server".   You then need to supply your Amateur Radio callsign or some other unique identifier (e.g., "Kilowatt County Elementary School"). The identifier can also have an optional additional identifier so KA2UPW is valid, but so is KA2UPW-9 (indicating a second station this callsign is using to also collect telemetry) or something like KA2UPW-FM13 (this is indicating a grid square where the station is collecting telemetry).

You also need to supply latitude and longitude of your ground station. This calculates the grid square that you are in as a check. Or you can enter the 6 digit maidenhead grid square and lat-long is calculated for you.

There are two AMSAT servers. It does not matter which one you send to. By default one is the primary and the other is the secondary. If either server is down, the program will automatically send data to the other sever.

7   Understanding the Data

7.1   Fox Health Screen

The health screen shows the latest real time values received from the spacecraft at your ground station. It also shows the latest Maximum and Minimum values. You can access previous values by clicking on the telemetry row and a graph will open up. Data can then be analyzed and extracted. See the Graphing section below.
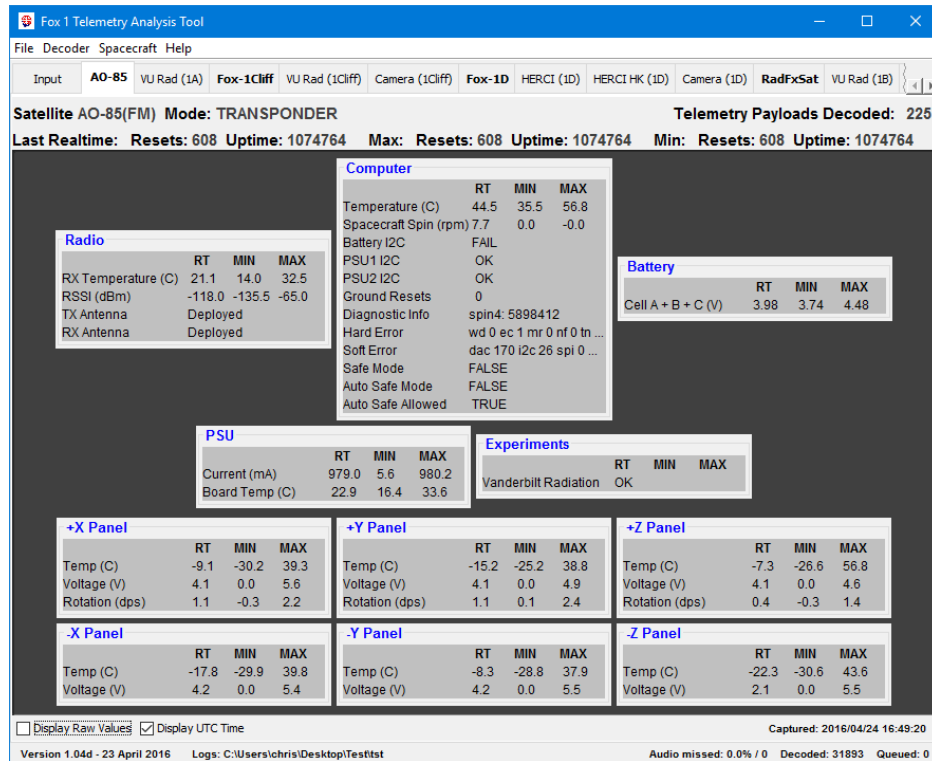
7.2 Graphing Telemetry Values

A graph opens when a telemetry row in the health tab is clicked with the mouse. By default the graph shows the last 180 readings. A real time value is downloaded once every 10 seconds or so in slow speed telemetry mode. So 180 readings is about 1800 seconds of data, or 30 minutes. This will therefore show a complete pass of the satellite without changing the settings.

The graph below shows the Internal Temperature of the onboard computer or Internal Housekeeping Unit (IHU). The time axis is recorded on the spacecraft and shows Uptime in seconds since the last reset, with the reset number underneath the first Uptime label.
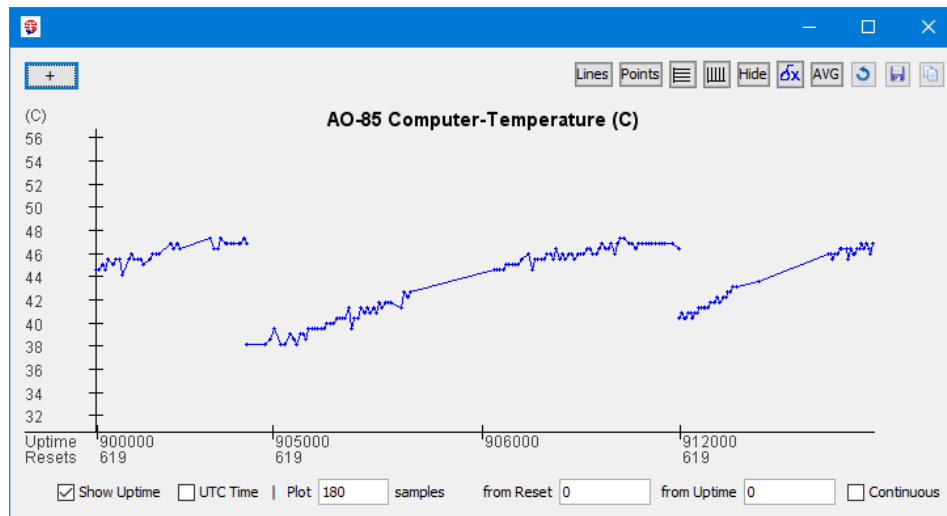
You can plot more or fewer samples by changing the number from 180 and hitting enter.

By default the "from Reset" and "from Uptime" are set to zero. These are ignored and the graph automatically selects the latest samples and plots them. This shows a continuously updating graph for real time monitoring of the spacecraft. This is probably what you want if you are listening live to a satellite pass.

If you change the "from Reset" and "from Uptime" you can plot a subset of the data. This will no longer automatically grab the latest samples from the spacecraft, but rather will plot samples forward from that reset/uptime. If that includes the latest samples, then you will still see them appear live. If it does not, then the data will remain static. If you are completely confused and the graph is not doing what you want, then hit the reset button in the top right to reset the graph to its default values.

If no data is received from the spacecraft for some time, then you probablly do not want to plot it. In that case, the graph automatically cuts out blank sections of the data. This allows you to see several passes one after the other, without large gaps in between them. If you want to show the data in the right positions on the graphs timeline then tick "Continuous".

There are three ways to copy data from the graph.

Firstly, your Operating System probably has a print screen function. In Windows Alt-PrntScrn will copy just the active window and will allow you to past the result into another document.

If you want to have just the graph itself, then use the Copy button in the top right. The previous graph is show below, copied in this way.
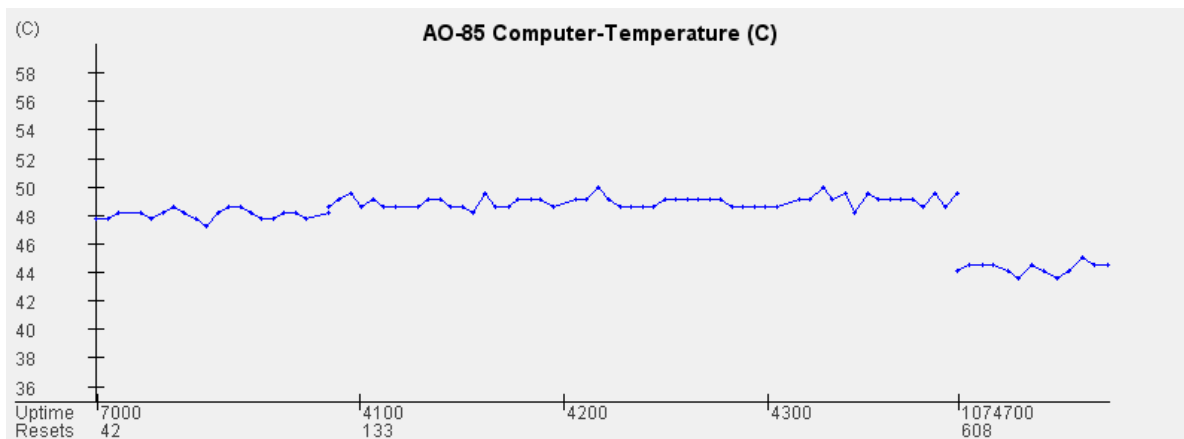
Finally, you can save the data values to a csv file using the save button. This will save the subset of data that you have selected for display.

In addition to the reset, copy and save buttons, there are two buttons in the top right that draw and additional graph trace. AVG draws a running average by summing the samples around a given point. The default is 12 samples, but you can change the amount in a new field that appears on the bottom of the graph. The dx (or delta x) button plots the first difference of the samples (which is equivalent to

the first derivative for a continuous graph). Try that with a frequency plot of the last pass and see if you can tell how TCA is calculated.

7.3 Multiple Variables on one graph

The "+" sign on the top left of a graph can be used to add additional traces. If we add BATT_C_V, the Battery Voltage, to the IHU Temperature graph then we get the following graph. Note that the Voltage is now shown with a new axis on the right. You can keep adding additional traces as long as the units are the same as one of the two vertical axis. All other graph functions work as expected, including exporting data to a file, which exports all variables chosen.
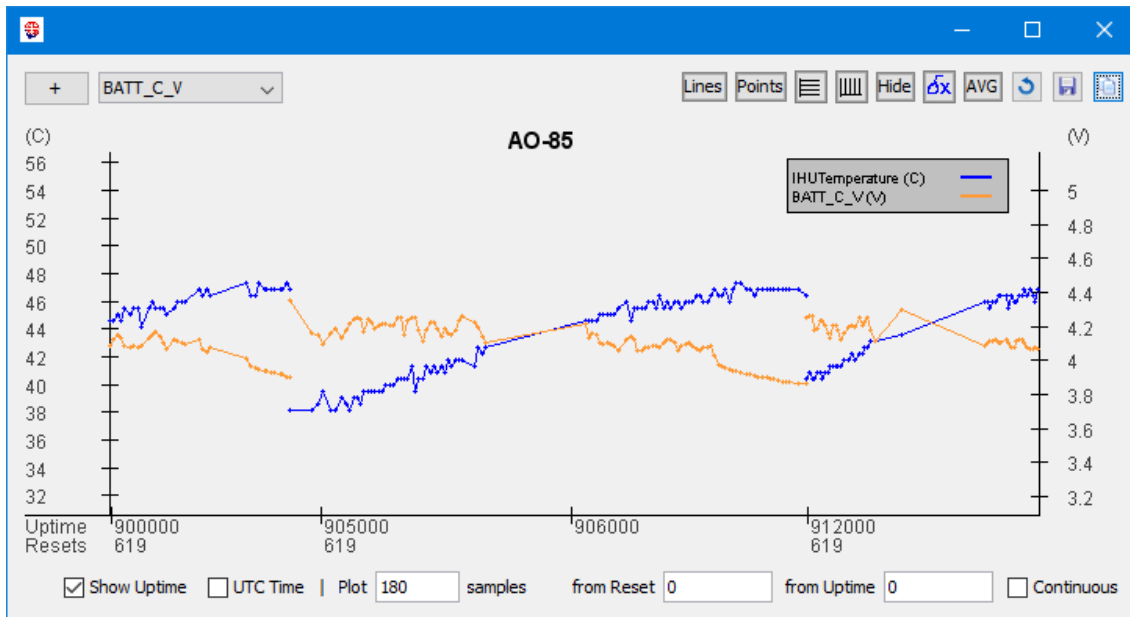
7.4 Radiation Experiment

The Vanderbilt University Radiation Experiment is testing Commercial Off the Shelf (COTS) memory chips in space to see how they are affected by radiation.

7.5 Camera Images

Camera Images are downloaded in High Speed telemetry mode if the Virginia Tech Camera is present on the spacecraft. Fox-1A does not have a Camera, but Fox-1Cliff and other spacecraft will.

8 Making Measurements

8.1 Overview

In addition to the telemetry and science data received from the satellite, you can make measurements at your ground station and store them for analysis. Out of the box, FoxTelem can measure:
- Signal To Noise level of the received bits
- Signal To Noise level of the RF (in IQ mode)
- RF signal strength (in IQ mode)

- Azimuth and Elevation (from SatPC32, using the DDE interface on Windows)
- Frequency (in IQ mode or using the SatPC32 DDE interface on Windows)
- Time of Closest Approach (TCA) through Doppler analysis (in IQ mode)

Each of these measurements are stored at the time a frame is detected and they are timestamped with both the current UTC time and with the reset/uptime that was on the received frame. This gives a sample about every 5 seconds.

8.2 Signal to Noise Measurements

Signal to noise measurements can be used to optimize your station and to help understand how radio signals are propagated from the spacecraft. Store the results and compare them when you have made changes. What difference does a pre-amp make? A higher gain antenna? A different receiver? What is the difference in signal to noise vs elevation at your QTH (ground station location)? Does the RF signal to noise ratio correlate with the bit signal to noise ratio? Which should be optimized?

8.3 Azimuth and Elevation

FoxTelem can not read your rotator directly, but it can grab the information from another program such as SatPC32 using its DDE interface. This will currently only work on Windows. See the DDE Interface section of SatPC32's manual for details on setting this up.

This is useful information and I am open to suggestions on how best to store it when using other prediction software or on Linux and MacOS. Please email me.

8.4 Time of Closest Approach

The Doppler on the frequency of the satellite tells us something about how the spacecraft is moving relative to our current position on the earth. We can use this to work out when the spacecraft is closest to our ground station. This is the Time of Closest Approach (TCA) and it is a very helpful measurement to confirm or refine orbital elements. We can also use it to see how stable the downlink frequency is. TCA is especially useful when a spacecraft has recently been launched.

You can measure TCA by logging the frequency of the downlink signal. If the frequency at the satellite was unconditionally stable and we knew exactly what frequency it was on, then you could measure when the received frequency at your ground station equals the nominal frequency and call it TCA. However, a small 10cm CubeSat has a challenging thermal environment and we can not rely on the frequency of the downlink for this measurement. Instead, this measurement will tell us what the nominal frequency is.

If you are running FoxTelem in IQ mode then it will store the downlink frequency throughout a pass. At the end of a pass it calculates when the frequency changes as the fastest rate. This should be at or very near to the nominal downlink frequency. It then stores the time when this happened (TCA) and the frequency at that time. You can see the measurements for the last pass on the measurements tab.

We can not measure TCA by reading the frequency from SatPC32 or another prediction program. We need to know the actual frequency of the satellite, not the calculated frequency.

8.5   Sky Plots of Measurements

There are two options for graphing measurements. You can click on the measurement value and open a graph, just as you can for spacecraft telemetry. In addition there is a button to the right of each value that opens a sky plot, which plots the data against elevation and azimuth, as seen from your ground station. Below you can see the received signal strength in dBm plotted against the satellites position in the sky. A darker color is a stronger signal.
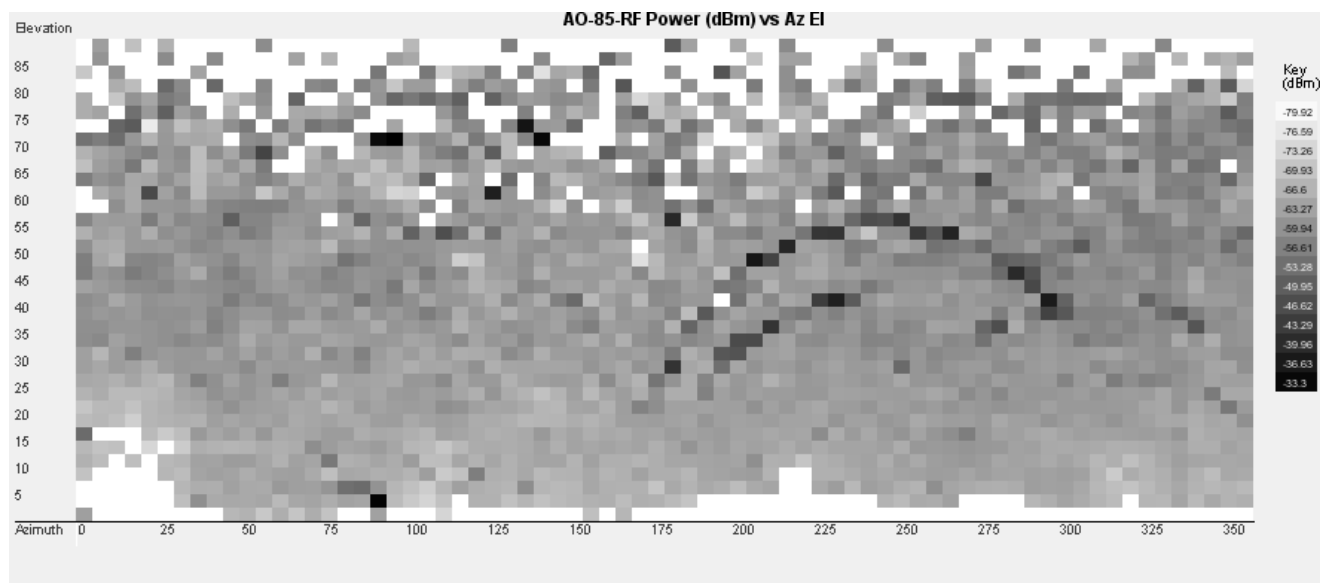
9   Getting Better Decodes

9.1   Eye Diagram

A subtle distortion in the eye diagram like the plot on the left perhaps shows a mismatch between the sample rates at some point in the chain. A much better eye diagram is shown on the right.
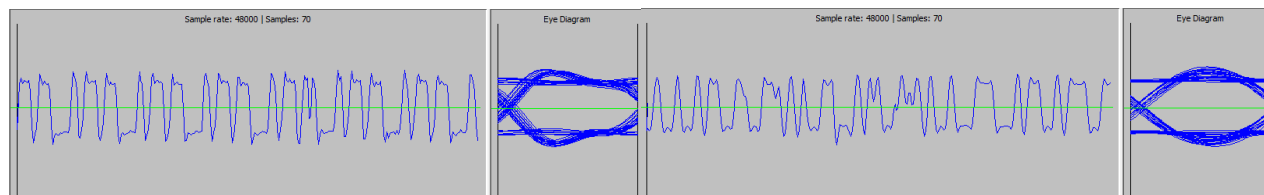
First of all, set the sample rate to 48000 samples per second if possible. The divides evenly into 200 bps and 9600 bps and gives slighly better decodes. With a strong signal it makes no difference , but if the signal is distorted or weak then it can help.

Secondly, make sure that the sound card or audio source is also set to 48000. Windows likes to set everything to 44100 by default, so you need to go into the Control Panel to change it. If you are using a virtual cable to connect an SDR to FoxTelem, then be aware that when initially started cables will be defaulted to 44100 by Windows. FoxTelem or the SDR can not then reset them to 48000. Virtual Audio Cable is a good example of this and it mentions the issue in its manual. When you configure a

new cable you give it a range of sample rates. Windows will then pick 44100 if it is available. Even if that is not what you wanted. So I setup two cables, and narrowed the range of samples rates to one value. One cable is then for 48000 and the other is for 192000. Then there is no question about the rate that Windows will give them.

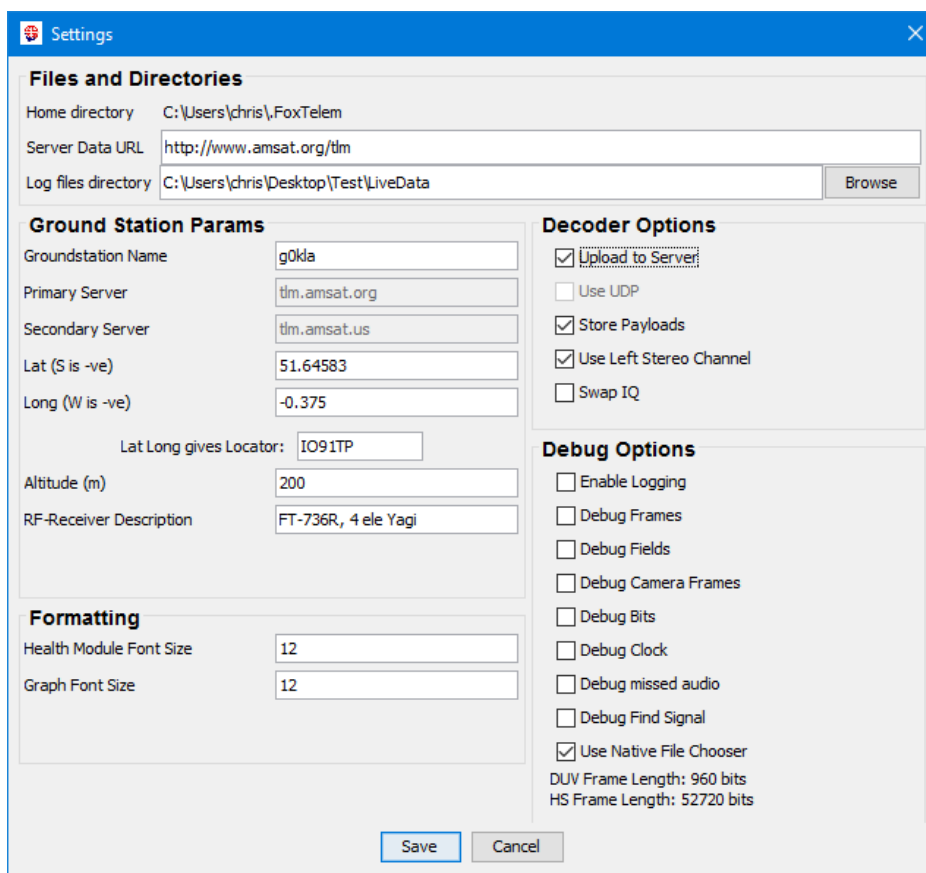## 9.2   High Speed Bandwidth

High speed data from Fox is 9600 bits per second FSK. The FM signal is 20kHz wide. Make sure that the radio you are using is on a wide enough setting to accommodate.

10 Settings

The settings screen is accessed from the File menu. This contains 5 types of options:
- Files and Directories
- Decoder Options
- Server Upload Parameters
- Formatting
- Debug Options

10.1 Files and Directories

The Home Directory is noted because this is the location of the properties file. It is unlikely that you will need to directly edit the properties, but it is good to know where they are stored.

The Server Data URL is the location of the server data. If you go to this URL you will be able to see the data that has been uploaded by ground stations around the world. This is also the URL used by FoxTelem to download data from the server.

The Log files directory sets the directory that the downloaded telemetry data is stored in. FoxTelem has a number of files that it stores on disk. It's worth describing them first. They are as follows:

- `spacecraft` – directory that stores the spacecraft configuration files
- `images` – directory that stores images downloaded from the Virginia Tech Camera (if present)
- `seq.dat` – file that stores the next sequence number to be sent to the server
- `rawHSframes.log` – queue of the high speed frames to upload to the server
- `rawDUVframes.log` – queue of the low speed frames to upload to the server
- `FoxTelemDecoder.log` – the log file from FoxTelem. Updated if the Setting "Enable Logging" is checked.
- `FoxTelem.jar` – The FoxTelem core program classes
- `FoxTelem.properties` – The FoxTelem settings that are stored between program executions. Editable from the File>Settings screen and elsewhere in the program. Not designed to be user editable. This is stored in the Home Directory, shown at the top of the settings screen
- `Fox3jpg_index.dat` – An index file the stores the images that have been downloaded from the VT Camera. Present on Fox-1C
- `FOXDB` – Your logs of the payloads downloaded from Fox. Additional log files will be created for other satellites. You do not need to send this data to AMSAT. This is your own personal archive for experimentation and analysis. You can send it to other people, who can open it with FoxTelem by pointing FoxTelem at a different directory where they save the files.

10.2 Decoder Options

Upload to Server – select this if you want to send your collected data to the AMSAT telemetry server. You will need to supply some of the Ground Station parameters if you check this option, specifically a Ground Station Name and your location.

Store Payloads – uncheck this if you do not want to store the payloads on disk

Use Left Stereo Channel – The default is for FoxTelem to read audio from the left stereo channel of your soundcard. If you uncheck this it will read from the right. There is no issue if you supply audio to both channels. This setting is ignored in IQ mode, when both channels are read.

Swap IQ – This swaps the I and Q channels in the IQ decoder

10.3 Ground Station Parameters

Ground station name is the unique identifier that you will use to store data on the AMSAT telemetry server. If you are a licensed Amateur Radio Operator, we recommend you use your callsign. Otherwise use the name of your organization or something else that will be unique. This is limited to 32 characters.

To be clear, we do not enforce uniqueness. We only use the name to keep track of how many frames each station supplied.

Primary and Secondary server are not user editable

Latitude / Longitude or Locator need to be specified if you supply decoded data to AMSAT. You can either enter a Maidenhead locator or your lat/long. One will calculate the other

Altitude will be supplied to AMSAT along with your data if you specify it.

RF-Receiver can be specified to give us an idea of the types of stations that are in operation. This is limited to 50 characters.

10.4 Formatting

Health Module Font Size – change the size of the font on the Satellite tabs so that it is more readable or so that it fits in the space available
Graph Font Size – change the size of the font on the graph axis

10.5 Debug Options

Enable Logging: Write additional debug and errors to the log file. This creates a significant volume of data and should only be used temporarily.

Debug Frames: Print out information about the decoded frames, such as the start and end bit positions, the payload type, the number of erasures and corrections.

Debug Fields: Print out the decoded payloads field by field, so that you can see all of the raw values in the log file.

Debug Camera Frames: Print out details of the camera frames. Very verbose. Prints one line for each byte in the camera payload. This will not work when listening live and needs to be run against a recording

Debug Bits: Very verbose. Prints out the bit level showing the 10b words and their 8b decode.

Debug Clock: Prints out details of the clock recovery, showing how much the clock was adjusted each time it was updated.

Debug Missed Audio: Displays some debug information on the audio graph to help understand the performance of the audio sampling sub-system.

Debug Find Signal: Prints out details of the find signal state machine to the log file.

Use Native File Chooser: When files are opened from the GUI, the default is to use the File choosing window that is supplied by the Operating System. If you have problems with opening files then try unchecking this. A cross platform Java File Chooser will then be used.

11 Spacecraft Configuration

The spacecraft directory contains a number of files that are used to setup FoxTelem for each Fox Satellite. As more Fox Satellite are launched, we will supply more configuration files. The directory contains a set of files such as the following, with additional files if more Satellites are configured or more experiments are onboard.

- `FOX1x_fm.dat` – The spacecraft configuration file for the Fox 1x Flight Model. This is the one that is flying in space.
- `FOX1x_rttelemetry.csv` – the layout file for the Real Time Telemetry Payloads and the configuration needed to display them in FoxTelem
- `FOX1x_mintelemetry.csv` – the layout file for minimum values payloads
- `FOX1x_maxtelemetry.csv` – the layout file for maximum values payloads
- `FOX1x_rssiFM.tab` – a lookup table for the Received Signal Strength telemetry raw value. There are several look up tables for each satellite.
- `jpeg_header.out` – Virgina Tech's header file for the JPEG images that will be part of FOX-1C
- `jpeg_header_low_res.jog` – Virginia Tech's header file for the Fox-1D images
- `measurements.csv` – the layout file for the ground station measurements
- `passmeasurements.csv` – the layout file for the ground stations pass measurements
- `stpHeader.csv` – the layout of the STP_HEADER table. Used by the server.

11.1.1 Spacecraft Configuration File

A spacecraft configuration file exists for each Fox satellite that you wish to receive data from. We will supply new files as new Fox satellites are launched. If you edit this file, make a backup of the existing file. You can view these paramaters from the Spacecraft menu. Here is the Fox-1A screen:

The data is stored in a java "properties" file which consists of key-value pairs. A line either starts with a #, meaning it is a comment, or it has a key followed by an = then the value.

The valid keys are:

foxId – this is the id of the satellite, where 1 = 1A, 2 = 1B etc. You can not load two satellite configuration files with the same foxid

catalogNumber – this is the NORAD catalog number for the satellite and is unused currently

name – this is the name that is displayed in FoxTelem for this satellite. E.g. Fox-1A or AO-85. If SatPC32 is used to indicate when the spacecraft is above the horizon, then this name needs to be the same as the name in SatPC32.

description – this is a helpful description so we know which satellite we are talking about

model – this is the model number where 0 = Engineering Model, 1 = Flight Model and 2 = Flight Spare

IHU_SN – this is the serial number of the IHU board

EXPx – this indicates what is in experiment x slot, where x is 1 – 4. The value is then a number, which indicates the following:
0 – Experiment slot is empty
1 – Vanderbilt Vulcan Radiation Experiment
2 – Virginia Tech Camera
3 – IOWA State HERCI Experiment
4+ are currently reserved for future use

telemetryDownlinkFreqkHz – the nominal transmit frequency for the downlink telemetry, e.g. 145980 for Fox-1A

minFreqBoundkHz – the lower frequency bound when the "Find Signal" algorithm is searching for this satellite

maxFreqBoundkHz – the upper frequency bound when the "Find Signal" algorithm is searching for this satellite

BATTERY_CURRENT_ZERO – the calibration point for zero battery current, e.g. -1.839 for Fox-1A

rssiLookUpTableFileName – the lookup table to use for RSSI values

ihuTempLookUpTableFileName – the lookup table to use for the IHU temperature. Specific to each IHU Serial Number

ihuVBattLookUpTableFileName – the lookup table to use for Battery Voltage

rtLayoutFileName – the layout file for the RT Telemetry

maxLayoutFileName – the layout file for the MAX Telemetry

minLayoutFileName – the layout file for the MIN Telemetry

radLayoutFileName – the layout file for the Raw Radiation Bytes. This is the format that is saved to disk

rad2LayoutFileName – the layout file for the Radiation Telemetry. This is the format displayed in the Vanderbilt Radiation Tab if "Telemetry" is selected.

measurementsFileName – the layout file for the measurements made locally at your ground station

passMeasurementsFileName – the layout file for the measurements made for each satellite pass

useIHUVBatt – set to true if the IHU is used to measure Battery Voltage, rather than the Battery Board.

11.1.2 Telemetry Layout Files

The telemetry layout files contain a row for each value in the telemetry. These are read by FoxTelem when it starts and are used to parse the received telemetry once it has been demodulated. The first row of the file contains the number of rows, followed by the column names. The number of rows specified then follows, with a value REQUIRED in each column. The file is comma delimited and is easiest to edit in a spreadsheet program such as Microsoft Excel. Make sure you save it as a csv file again.

The columns are as follows:

TYPE - For information only. RT, MAX, MIN or RAD. Ignored by the program

FIELD - The name of the field. Must be unique. Used by FoxTelem to keep track of the value internally.

BITS - The number of bits in the field. (As a side note Fox sends bits with the most significant bit first, but it is little endian, so we get the least significant byte first. This made the decoder more entertaining to write.)

UNIT - The units that the telemetry value will have after we convert the raw value. This is displayed on screens and graphs.

CONVERSION – The conversion routine to run on the raw value. This is an integer value. See Conversions below to understand what the integers mean.

MODULE – The name of the module on the "Health" tab that this value should be displayed in. If RT, MAX and MIN are displayed on the same line, then this only needs to be set in the RT layout file.

MODULE_NUM – The number specified determines the order of the modules on the Health tab. The first module should be "1". Modules then follow numerically. Modules starting with "10+" are displayed in the lower half of the screen.

MODULE_LINE – This is the line in the module that the value is displayed on, starting with line 1.

LINE_TYPE - A numeric value, with the following meanings:
    0 – Display value in the Real Time columnonly on this line. E.g., Antenna Status has no Max or Min value. Confusingly, we use this to display things like "Soft Error" which is only in the MIN Values Payload. So we specify the module and module line for it, but give it LINE_TYPE 0
    1 – Display value in the MAX column – never used
    2 – Display value in the MIN column – never used
    3 – Display values in ALL columns – used for most values

SHORT_NAME – The name that is displayed on the Health Tab for this telemetry value .

DESCRIPTION – The description that appears when the mouse is hovered over this value.

11.1.3 Conversions
It turns out that taking raw values measured by Analog to Digital Converters (ADCs) on the spacecraft and converting them into real, accurate measurements across multiple satellite, is non trivial. We have therefore specified 23 conversion routines and will add more in the future as they are needed. The numbers refer to the following conversions

Integer	Name	Description	Conversion
0	*CONVERT_NONE*	Use the raw value as is	None
1	*CONVERT_INTEGER*	Use the raw value as an integer	Round to zero decimal placed
2	*CONVERT_V25_SENSOR*	Treat the raw value as a reading by the 2.5V ADC	Raw * 2.5/4096
3	*CONVERT_V3_SENSOR*	Treat the raw value as a reading by the 3V ADC	Raw * 3/4096
4	*CONVERT_BATTERY*	Convert the raw value into a battery voltage depending on the	Battery A uses the 2.5V ADC, Battery B uses the

Integer	Name	Description	Conversion
		resistor network used to apply the value to the ADC	2.5V sensor / 0.76, Battery C uses the 2.5V sensor / 0.5
5	*CONVERT_SOLAR_PANEL*	Convert the raw value from the solar panels	Raw * 3V ADC / 0.428
6	*CONVERT_SOLAR_PANEL_TEMP*	Converts the raw value to a temperature in Celsius	Lookup the value in the Solar Panel Temperature Table, held inside FoxTelem
7	*CONVERT_TEMP*	Converts the raw value to a temperature in Celsius	Lookup the value in the Temperature Table, held inside FoxTelem
8	*CONVERT_BATTERY_TEMP*	Converts the raw value to a temperature in Celsius	Lookup the value in the Battery Temperature Table, held inside FoxTelem
9	*CONVERT_BATTERY_CURRENT*	Calculate the positive or negative battery current in mA given the voltage across a sense resistor	((rawValue * 2.5V ADC - 0.05) * Battery Zero Value (in the spacecraft file) + 2) * 1000
10	*CONVERT_PA_CURRENT*	Calculate the PA current in mA given the voltage across a sense resistor	((rawValue * 3V ADC) / 50 / 0.2) * 1000
11	*CONVERT_PSU_CURRENT*	Calculate the PSU current in mA given the voltage across a sense resistor	((rawValue * 3V ADC) / 0.003)
12	*CONVERT_SPIN*	SPIN is 3.8 fraction fixed point.	If raw value > 2^11 (2048) - 1 then value = value - 2^12 (4096). This gives a signed value which we then divide by 256 to get a signed double
14	*CONVERT_RSSI*	Converts the raw value to the Received Signal Strength in dBm	Lookup the value in the RSSI table, which is specified in the Spacecraft configuration file
15	*CONVERT_IHU_TEMP*	Convert the raw value to the IHU internal temperature in Celsius	Lookup the value in the IHU Temperature table, which is specified in the Spacecraft configuration file
16	*CONVERT_ANTENNA*	Convert the 2 bits into values for the antenna deployment status	0 = Stowed, 1 = Deployed
17	*CONVERT_STATUS_BIT*	Convert the bit into a status value	0 = OK, 1 = FAIL
18	*CONVERT_IHU_DIAGNOSTIC*	A set of diagnostic bits that are converted into values for debugging the IHU	
19	*CONVERT_HARD_ERROR*	Watchdog status and the type of error that last reset the spacecraft	
20	*CONVERT_SOFT_ERROR*	Other non fatal errors	
21	*CONVERT_BOOLEAN*	Convert the bit into a boolean value	0 = FALSE, 1 = TRUE
22	*CONVERT_MPPT_CURRENT*	Calculate the current from the Maximum Power Point Tracker	(rawValue * 2.5V ADC) / 2.5

Integer	Name	Description	Conversion
		(if installed) based on the voltage across a sense resistor	
23	*CONVERT_MPPT_SOLAR_PANEL*	Calculate the voltage for each solar panel, as measured by the Maximum Power Point Tracker	rawValue * 2.5V ADC * (6.54/2.42)
24	*CONVERT_MPPT_SOLAR_PANEL_TEMP*	Calculate the temperature of each solar panel, as measured by the Maximum Power Point Tracker	Lookup the value in the MPPT Solar Panel Temperature table
25	*CONVERT_16_SEC_UPTIME*	Convert Vulcan uptime to seconds	rawValue * 16

12 Troubleshooting

Symptom	Solution
Poor decodes or no decodes	1. Are you trying to decode directly from the radios headphone jack or speaker output? That won't work. See the earlier sections of the manual on decoding from a radio. 2. Is the sample rate different to the sound card? Has Windows (or another OS) set the sound card up with 44100, even though you told it not to? 3. Is Virtual Audio Cable (VAC) or another similar audio transport running at a different rate? 4. Do you have the free version of Virtual Audio Cable (VAC)? It contains a voice announcement that impacts decoding and increases the error rate. 5. Is your SDR outputting audio at a different rate? 6. Is your SDR audio filtering set to cutoff important frequencies? 7. Is the volume set to high and the wave form is distorted? 8. What is the Signal to Noise ratio of the eye diagram – assuming you have one? It should be 2+, preferably 6+
Decoder stalls when a frame is received	1. Is the bit level debugging on, or some other verbose debugging? Check on the File>Settings screen 2. Has the FoxTelemDecoder.log file grown to a huge size? 3. Are you nearly out of disk space?
I am using HDSDR and I have missing lines in the images I am receiving from the Virginia Tech	We have seen a bug in HDSDR where it skips a few bits and the decode is corrupted. Set the

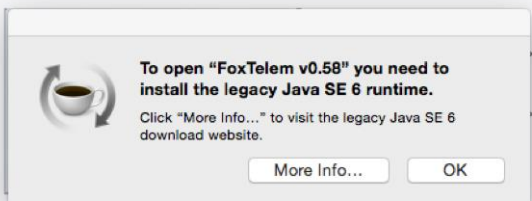|	
Camera onboard Fox-1C (or another Fox sat)	Bandwidth to 96000 in HDSDR and the Sample Rate to 96000 in VAC (if you use it) and in FoxTelem. This should work around the issue.
FoxTelem does not start when I launch it	1. Maybe you have a FunCube dongle connected to your computer and it has crashed. Try unplugging the dongle and restarting FoxTelem. 2. If you edited the spacecraft files, perhaps something is causing FoxTelem to crash. Try putting the default spacecraft files back in place. 3. See if the file FoxTelemDecoder.log has been created in the installation directory. See if this contains and error messages. 4. Try running FoxTelem from the command line to see if any errors are reported to the console. 5. If a file called foxtelem.properties has been created in the installation directory, you could manually edit it and set logging=true. Then try again and see if error messages are written to the console or to the FoxTelemDecoder.log file. 3. If FoxTelem ran previously, try renaming foxtelem.properties temporarily. FoxTelem will create a new properties file when it starts up.
I try to run the FoxTelem.exe file on Windows and it tells me that it is missing MSVCR100.DLL or a similar error	This is the Microsoft Visual C library and should already be installed with Windows. An aggressive Uninstall application may have removed it from your system. See this help article from Microsoft: http://answers.microsoft.com/en-us/windows/forum/windows_other-performance/msvcp100dll-missing/9a687c31-0619-4ee9-b511-020985e29b5f
I'm confused about Java on the Mac. Apple do not seem to support it anymore, what is going on?	Before MacOS 10.7 (Lion) you used the Apple supplied version of Java (version 6). You should be able to do this through Software Update in the System Preference. Apple no longer maintains the Java runtime environment, so post 10.7.3 you are advised to install the latest runtime environment, which you can download from java.com. However, this is not compatible with FoxTelem on the Mac (even though it is on all other platforms). So you will need to install the old version of Java. See the issue below.

I try to run FoxTelem on the Mac and it tells me that it is a "legacy" app and I need an old version of Java	To maintain compatibility with older Macs (see the question above) we have made FoxTelem available with Java 6. Follow the instructions and install the legacy version.
To open "FoxTelem v0.58" you need to install the legacy Java SE 6 runtime. Click "More Info…" to visit the legacy Java SE 6 download website. More Info… OK	
The Frequency Spectrum is truncated in IQ mode and only seems to show the middle part. See Figure 1.	Even though you may have set FoxTelem to the right sample rate (e.g. 192000 or 96000) the audio source you are reading from is supplying audio at a lower rate. Figure 1 shows FoxTelem expecting samples at 192000 and receiving samples at 48000.

Figure 1: Too narrow a bandwidth on audio device used for IQ source