

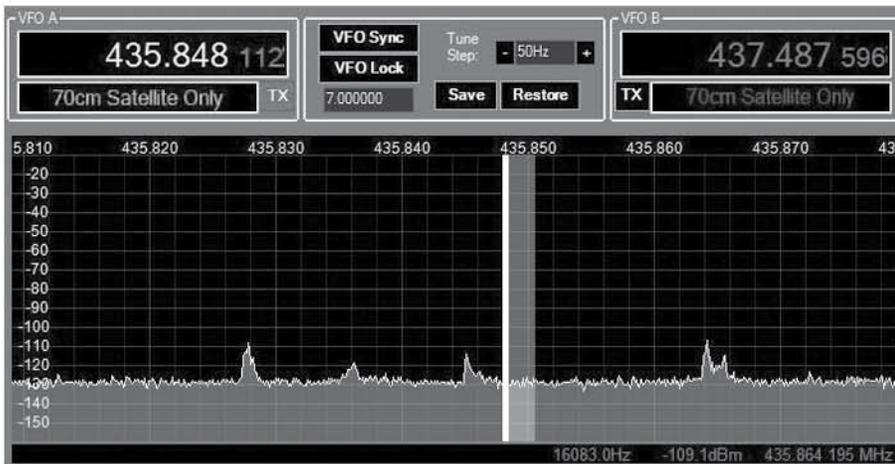
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Fox-1 Attitude Determination Experiment Simulator



A Full-Duplex VHF-UHF Satellite System Using SDR

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Introduction

One amateur radio system that is gaining popularity is the software defined radio (SDR). An SDR is a system where some of the functions traditionally performed using hardware components are done instead with software, often on a personal computer. Some functions, such as power amplification, still remain in the hardware realm. With the rapidly developing capabilities of digital signal processing, some functions can be performed better using software. Enhancing, correcting, and updating this software is often more convenient and cheaper than revising hardware.

Since many modern personal computers use powerful microprocessors and sound cards, an SDR developer can take advantage of this to provide multiple ways of displaying the RF spectrum that is being received. Some of the ways SDRs can display the frequency and time domains are:

- spectrum display, which shows a spectral view of amplitude versus frequency within the filter limits,
- panadapter display, similar to the spectrum display, but covering a wider frequency spectrum, and
- waterfall display, which shows a vertically scrolling view of signal activity in the passband.

Figure 1 shows an example of a panadapter display showing several SSB stations on a pass of FO-29.

This article describes an SDR station for working amateur radio satellites.

SDR Tuning

A major frustration I have had using amateur radio satellites was finding and tuning SSB stations on linear transponder satellites such as AO-7, FO-29 and VO-52.

When using traditional radios which are manually tuned, it is all too easy to miss a station calling CQ as one turns the VFO knob up and down the transponder sub-band. I never developed the knack of quickly tuning in an SSB station—instinctively, I almost always turned the knob the wrong direction.

Once I had the chance to try out an SDR with a panadapter on the HF bands, in my case a FLEX-3000 from FlexRadio Systems, I was hooked. The panadapter not only displayed where stations were in a given frequency band, but it also allowed me to tune a given signal by pointing to it and clicking with a mouse. With practice, I could tune almost perfectly on the first click, making any necessary adjustments with small movements of the mouse wheel. The shape of

the voice spectrum of the tuned signal allowed me to tell the difference between a YL and an OM.

System Description

When I became active again on the amateur satellites, I set out to design a system around SDRs and a panadapter. The panadapter helped solve several problems on satellites that I had not experienced on the HF bands.

First, station signals are often weak and spread out across the frequency passband of the satellite. Since time is limited on a pass, finding a signal early and quickly is an advantage.

Second, not everyone using the satellites uses Full Doppler Tuning¹⁻³. Using the panadapter makes it easier to find your QSO partner because you can see the station's signal on the display. The radio's frequency can then be quickly and easily adjusted as needed.

Another criterion for this project was to build a full-duplex amateur satellite system which allowed me to hear my own uplink on the downlink frequency. This capability is useful for tuning and making sure the system is working correctly.

I already owned a FLEX-3000 HF radio which used the Flex PowerSDR display panadapter so the satellite's transponder passband could be visually displayed. I chose to use transverters for the 2 meter and 70 cm amateur satellite bands. The FLEX-3000 is a half-duplex transceiver, but it's not ideally suited for driving a transverter in transmit mode. However, it makes an excellent receiver when the transverter is in receive mode.

FlexRadio Systems also markets a low-power transceiver, the FLEX-1500, which works with the PowerSDR software and is ideal for driving a transverter in transmit mode. A FLEX-1500 and a FLEX-3000 can co-exist on a single computer system as one radio uses a USB connection and the other uses FireWire. An ideal system for the future might use two FLEX-1500 radios (one being the transmitter and the other the receiver) if and when that configuration is supported.

To achieve full-duplex operation, I could have used a FLEX-5000A with the optional second

receiver. But, since I already owned a FLEX-3000, I decided to use it as the downlink receiver and add a FLEX-1500 as the uplink transmitter.

Although the discussion in this article is based the FLEX-1500 and FLEX-3000, a different pair of radios should be easy to use as there are a number of other receivers that have panadapter interfaces. A number of articles have been written on how to add a circuit to an existing receiver to provide a quadrature I/Q output which interfaces to SDR software and displays on a panadapter screen. One could even use a radio produced by a different manufacturer as the transmitter, provided that it covers VHF/UHF or interfaces to a transverter. Also, an inexpensive down-converter could be used with any HF radio for reception.

Transverters

For the transverters, I chose the L144-28HP and L432-28HP from Down East Microwave (DEMI). (Figures 2 and 3 show the front and rear panels of the latter.) I got the synthesized local oscillator (LO) option, split IF option, and sequenced preamplifier power insertion via the RF output connector.

The synthesized LOs of the transverters and the FLEX-1500 can be frequency-stabilized with an external 10 MHz source. I use a Trimble ThunderBolt and a DEMI 10-4 splitter.

For general information on interfacing a FLEX-1500 to transverters, see the FlexRadio Systems Knowledge Center article "Interfacing the FLEX-1500 to a Transverter" which can be downloaded from:

<http://kc.flexradio.com/KnowledgebaseArticle50496.aspx>

Interconnections

The various device interconnections are shown in Figure 4. To make it easy to switch between the four VHF/UHF modes, several switches are used.

The four modes are shown in Table 1. Mode designations V (2 m) and U (70 cm) are used in combination with the uplink listed first and the downlink listed last.

Switch		Operation	
A	B	Mode	
V	U	V/U	For example the satellites FO-29, SO-50
U	V	U/V	For example the satellites VO-52, AO-7
V	V	V/V	For example ISS, the International Space Station
U	U	U/U	

(Switch P in Figure 4 matches Switch A.)

Table 1: Switch Settings



Transverter	LO Freq	Sat Band	Rcvr Frequencies
L144-28HP	116 MHz	145.8-146.0 MHz	29.8-30.0
L432-28HP	404 MHz	435.0-438.0 MHz	31.0-34.0
Note: AO-7 is an exception to the above using 432.125-432.175 MHz			
The L432-28HP I have has the optional LO synthesizer which is programmable, so I reprogrammed the LO synthesizer to 407 MHz, putting the satellite band starting at 28 MHz:			
L432-28HP	407 MHz	435.0-438.0 MHz	28.0-31.0

Table 2: Programming the Local Oscillator Frequencies

Choice of Transverter Local Oscillator Frequencies

The default LO frequencies of the DEMI transverters used are shown in Table 2.

- For the FLEX-5000 with PowerSDR v2.4.4, the high end filter switch point is 32 MHz.
- For the FLEX-1500 with PowerSDR v2.4.4, the high end filter switch point is 37.6 MHz when using the transverter port(s).
- For the FLEX-3000 with PowerSDR v2.4.4, the high end filter switch point is 29.7 MHz as it has no transverter ports.

Since the FLEX-1500 is used only for transmission, the high end of the filter is not a problem. However, the FLEX-3000 used for reception is trying to receive frequencies above its filter point.

The L432-28HP I have has the optional LO synthesizer which is programmable, so I reprogrammed the synthesizer to 407 MHz, changing the satellite band to start at 28 MHz (**Table 2**).

I use the synthesized LO frequency of 407 MHz for all satellites except AO-7. To accommodate this difference, I use the default LO frequency of 404 MHz. The front panel power switch controls this LO change: up for default LO and down for synthesized LO.

This means that the current UHF satellites of interest are transverted to frequencies below the FLEX-3000 filter point. At some future time, I may reprogram the L144-28HP, but the VHF satellites are just slightly above the filter point and it presently seems to work just fine.

The PowerSDR XVTR Table

The PowerSDR XVTR table provides a powerful control interface to adjust the radio automatically based on the VFO A frequency. Once the local oscillator frequencies are known, the XVTR table is created using the XVTR's menu for each instance of PowerSDR.

The frequency shown on the PowerSDR VFO is the frequency that the transverter is tuning. The XVTR setup window for the receiver (in my case, the FLEX-3000) is shown in **Figure 5**.

The XVTR table also provides a link to the Universal Control Board (UCB) interface built

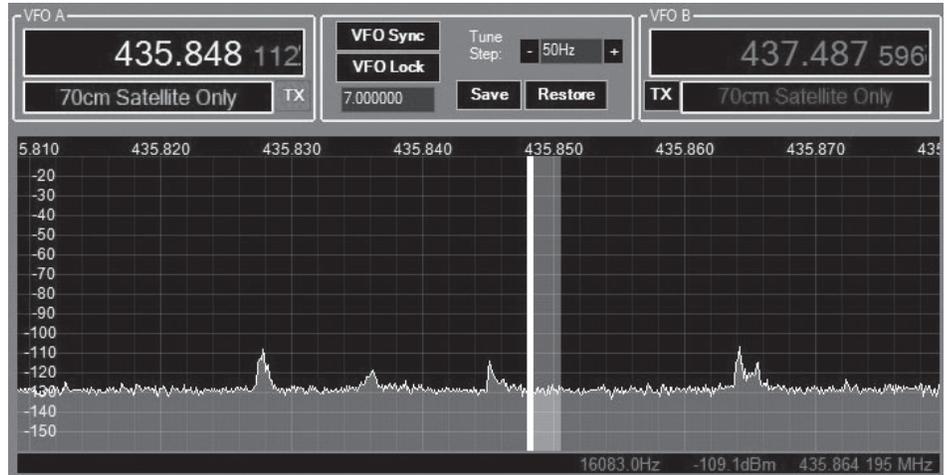


Figure 1: Panadapter example from FO-29



Figure 2: Front panel of DEMI L432-28HP transverter



Figure 3: Rear panel of DEMI L432-28HP transverter



into the Flex computers. This will be discussed in greater detail later on.

I created two UHF entries with Button Text U3000 and USYNT with the default and synthesized LO frequencies at the values discussed earlier. The appropriate UHF LO Button is selected automatically when VFO A is set to a frequency between the Begin and End frequencies in the XVTR table.

Operation and Control Using SatPC32

For operational control, Doppler shift correction, and antenna rotor control, I use the program SatPC32 by Erich Eichmann, DK1TB. This program is available from sources such as AMSAT-NA. It runs under Windows and supports Icom, Yaesu, and Kenwood radios for CAT control and also supports a variety of antenna rotors. The Doppler corrections it makes follow the rules of full Doppler tuning.

In the future, the program Ham Radio Deluxe may be a possible alternative to SatPC32 once version 6 supports two radios in this configuration.

The FLEX radios are supported by SatPC32 as a Kenwood TS-2000 via a serial port specified in PowerSDR in the Setup > CAT form. PowerSDR does not, however, support the Kenwood satellite mode for the TS-2000.

The SatPC32 Radio Setup window for this configuration is shown in Figure 6. When two radios are specified, and neither “Autom. Rx/Tx Change” or “Satellite Mode” are checked, Radio 1 will be used as the receive (downlink) radio and Radio 2 will be used as the transmit (uplink) radio.

The SatPC32 main screen showing a pass of FO-29 is shown in Figure 7. When different satellites are selected by clicking on A ... L in the bottom right-hand corner of the SatPC32 window, the correct frequencies and modes are set in both radios.

In my configuration, the FLEX-3000 is Radio 1 and the FLEX-1500 is Radio 2. The two screens of both instances of PowerSDR for the FO-29 pass are shown in Figure 8. The uplink (transmitter) window is in the upper-left and the downlink (receiver) window is in the lower-right.

Calibrating the SSB Uplink/ Downlink Frequencies Using SatPC32

The uplink and downlink frequencies used for satellites are determined by entries in a SatPC32 file named Doppler.SQF, which is accessed via the “?” menu in SatPC32. Its format is defined at the beginning of the file.

Due to inaccuracies in your radio’s frequency calibration and the satellite transponder center frequencies, the entries in Doppler.SQF must be

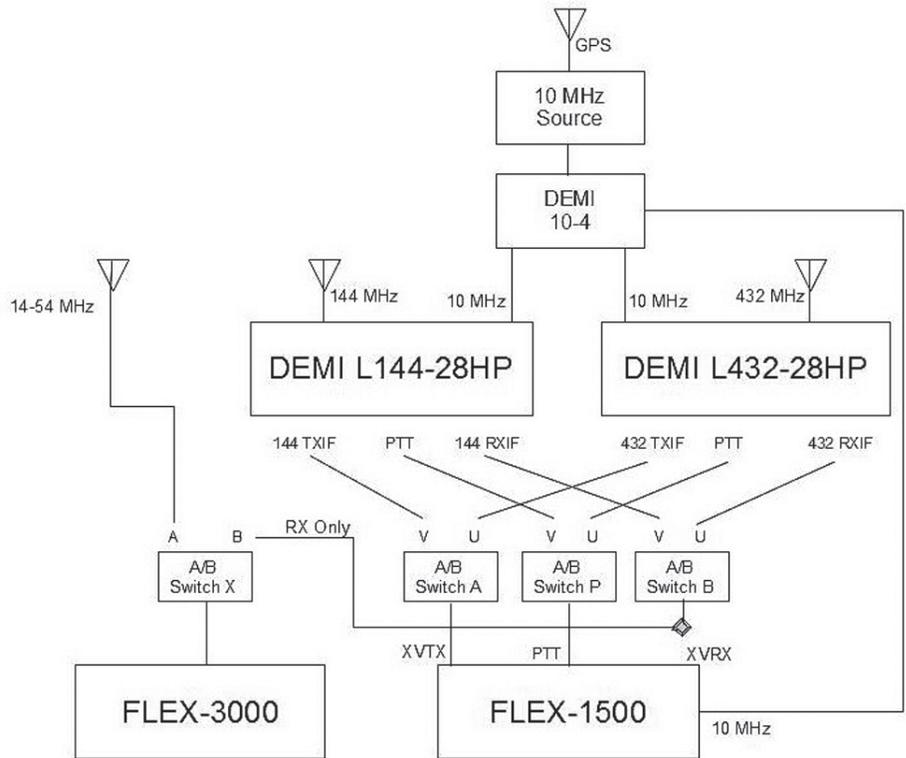


Figure 4: Full-Duplex VHF-UHF satellite system interconnections

Figure 5: XVTR Setup window for the FLEX-3000

adjusted in order for your radio’s uplink signal to be received at the calculated frequency of your radio’s downlink signal.

The entries in Doppler.SQF after SatPC32 is installed will be close to the actual values but SSB and CW signals may not sound right. The calibration for CW signals need not be precise but they should produce a tone of your liking. However, SSB signals should be calibrated as closely as possible.

To calibrate the signals, use the steps in the SatPC32 FAQ Appendix “AO-40 Operation with SatPC32” as a guide.

Start by pointing and clicking on the CAT menu

in SatPC32. This window is shown in Figure 9. However, instead of whistling or sending a CW signal to the satellite, transmit a known tone on LSB and listen for your uplink on the downlink frequency on USB. For my station, I used 600 Hz.

There are several ways to produce this tone. One can, for example, use an audio generator or a smart phone with a suitable app placed near the microphone. One can create an audio file on the computer, open it, and then insert the output sound into the transmission audio circuitry of the transmitter.

With the SatPC32 CAT menu window open, modify the transmitting frequency in 1000, 100, or 10 Hz steps up or down using the “Upl. Calibr.”

buttons. Continue adjusting the frequency until you hear the tone from your downlink at the same pitch as the tone transmitted on the uplink. This will ensure that the SSB signals are at the correct pitch. Before transmitting the tone, turn off any companding in the audio circuit as this will distort the sine wave and create harmonics.

When the tones match (i. e., close to zero-beat), click the “Change/Store Data File” button in the CAT menu. In the sub-window that then opens, click the “Uplink Calibration” button. This will change the uplink entry in the Doppler.SQF file. SatPC32 will then utilize the new calibration data.

Calibrating with FLEX Radios

A. Setup

FlexRadio’s control program for the FLEX series of radios, PowerSDR, has an expansive set of commands and features to manipulate and display the RF signal. The following procedures illustrate two methods for calibrating the uplink and downlink frequencies for satellites when each radio is a FLEX radio.

First, you need to transmit an uplink signal which will be interpreted on the downlink as a signal containing a single known tone. Use the tuning function controlled by the front panel button TUN.

In the transmitter PowerSDR Setup Transmit tab, set the Tune Drive level to a suitable value to be able to hear your own uplink signal on the downlink.

In the PowerSDR Setup DSP Keyer tab, set the CW pitch to the frequency of your choice. The default 600 Hz will work just fine, but you can change it to any value for which you can hear 10 Hz changes. By default, the tuning function transmits on the (suppressed) carrier frequency as shown on the VFO. For inverting transponders, set XIT to the negative of the value chosen for CW Pitch. For non-inverting transponders, set XIT to the value chosen for CW Pitch, and then turn XIT on. This compensates for the offset of the frequency during TUN.

Next, you need a procedure to determine when the frequency of the tone on the downlink is equal to the frequency of the tone on the uplink which is CW Pitch as set in the DSP Keyer tab. There are two ways by which this can be accomplished: an audio method and a numerical method.

B. Audio method

First, set up SatPC32 to control both the transmitter and receiver.

Click MON and TUN in the instance of PowerSDR controlling the transmitter. The FLEX transmitter will transmit an LSB signal with the CW Pitch tone.

Adjust the AF gain sliders so that you can hear both the uplink and downlink tones. Listen to

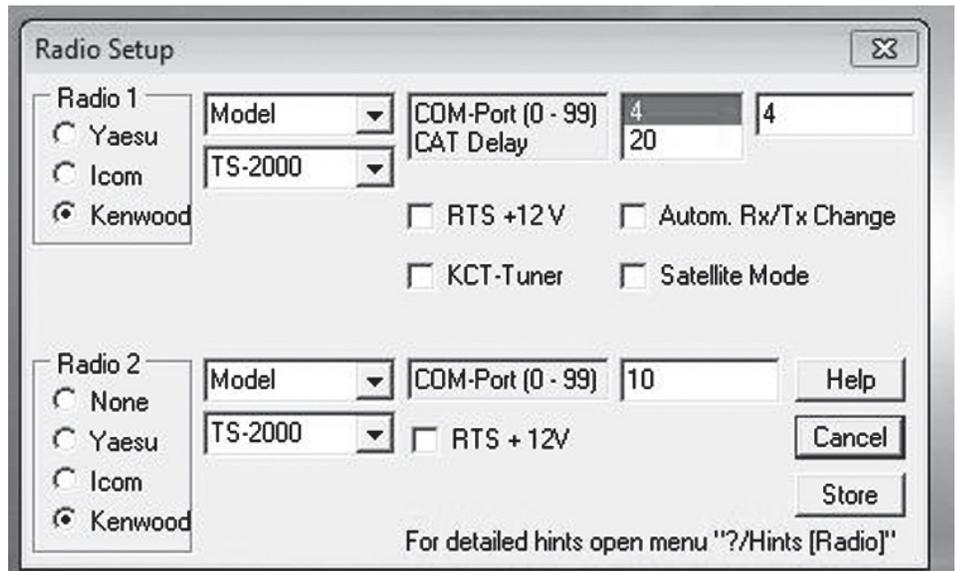


Figure 6: SatPC32 Radio Setup window

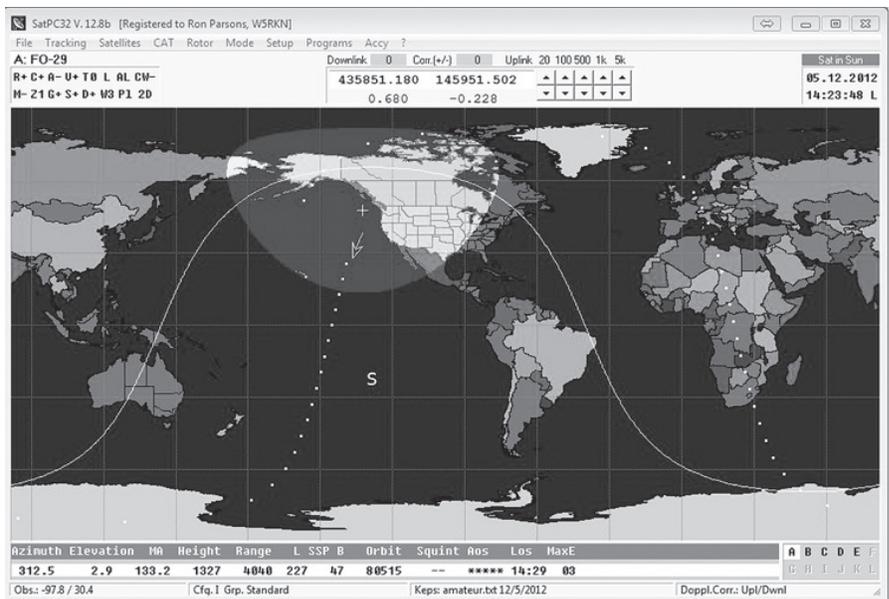


Figure 7: SatPC32 main screen showing a pass of FO-29

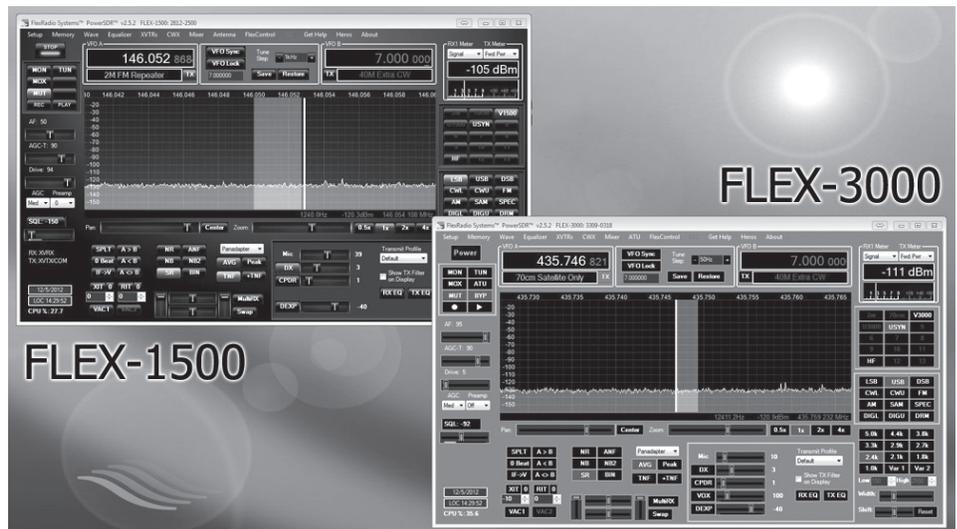


Figure 8: PowerSDR uplink and downlink radio windows



the transmitted signal on the downlink with the receiver.

Open the SatPC32 CAT menu window and modify the transmitting frequency in 1000, 100, or 10 Hz steps up or down using the “Upl. Calibr.” buttons. Continue until you hear the tone from your downlink at the same pitch as the tone transmitted on the uplink. When the tones match (i. e., close to zero-beat), click the “Change/Store Data File” button in the CAT menu.

In the sub-window that then opens, click on the “Uplink Calibration” button. This will change the TX entry in the Doppler.SQF file. SatPC32 will then utilize the new calibration data.

C. Numerical Method

First, set up SatPC32 to control both the transmitter and receiver.

Click MON and TUN in the instance of PowerSDR controlling the transmitter. The FLEX transmitter will transmit an LSB signal with the CW pitch tone.

You may click the MUT button on the front panel of both radios as this method does not require you to hear the audio tones. However, you may leave the AF gain controls up and combine this method with the audio method.

When you can see your downlink signal on the downlink panadapter display, change the frequency domain display type from Panadapter to Spectrum. You will then see a display similar to the one in Figure 10.

Note the peak in the spectrum near 600 Hz (the CW pitch in my case). The first number under the right half of the spectrum display is the frequency of the peak of the spectrum, which, in this example, is 612.4 Hz. As the frequency of the peak changes due to Doppler shift and this shift is then compensated by SatPC32, the frequency value will typically change between two values close to 600 Hz, depending on how the Doppler shift parameters are set in SatPC32.

As was done for the audio method, open the SatPC32 CAT menu window and modify the transmitting frequency in 1000, 100, or 10 Hz steps up or down using the “Upl. Calibr.” buttons. Stop when the peak frequency changes between a value just below the CW pitch and a value just above.

When this occurs, click the “Change/Store Data File” button in the CAT menu. In the sub-window that will open, click the “Uplink Calibration” button. This will change the TX entry in the Doppler.SQF file. SatPC32 will then utilize the new calibration data.

The FlexWire UCB Interface

The FlexWire™ Peripheral Interface Bus on Flex computers supports an industry standard communications bus based on the I²C protocol

and is called the Flex UCB interface.

Unfortunately, there is no complete documentation available for it. Some background information, although dated, can be found in the FlexRadio Knowledge Base article “Introduction to configuring PowerSDR and UCB for Weak Signal Microwave Applications”, which can be found at:

<http://kc.flexradio.com/KnowledgebaseArticle50258.aspx>.

This is a powerful interface with many applications. I hope it will be expanded soon and proper documentation made available.

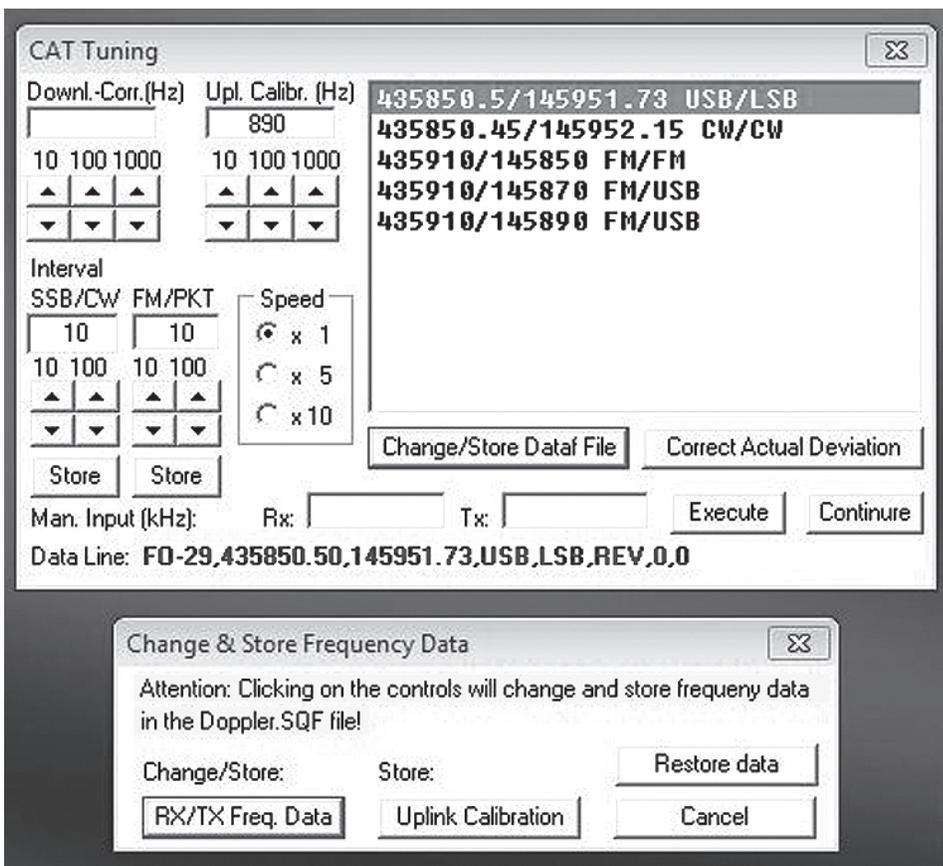


Figure 9: CAT Tuning windows in SatPC32

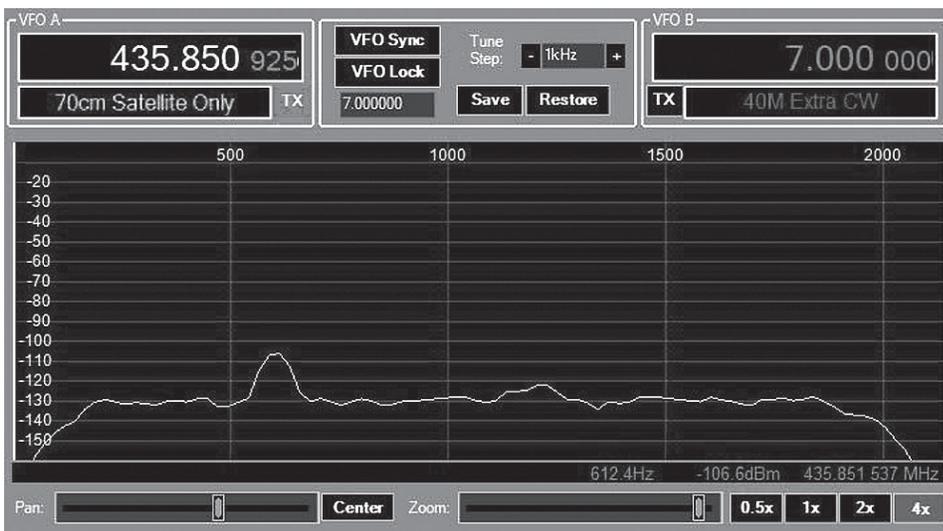


Figure 10: Downlink spectrum from the satellite during tuning

Automatic Control of Transverter and Antenna Switching using UCB

The FlexWire connector on the FLEX-1500 and other Flex radios provides an interface, using the XVTR form, to control up to sixteen devices for each of the sixteen UCB addresses.

Phil Theis, K3TUF, has made available a small interface board which plugs into the FlexWire connector. This board provides 16 open collector outputs for driving relays or other devices to change antennas, bands or transverters. The open collector outputs are capable of handling 50 volts at 500 mA. The output device is a ULN2803a Darlington device. Since there are 16 outputs, most applications can drive their loads (relays or TTL circuits) without decoding. For more information see:

<http://k3tuf.com/FW.html>

The configuration described in **Figure 4** uses three coax switches and a toggle switch to select the receiver, transmitter, and the appropriate transverter for the satellite mode in use. In addition, I had two extra coax switches to allow the UHF and VHF antennas to be used by other UHF/VHF equipment in the shack. The number of switches being used provided too many chances for making an error. Thus, the decision was made to design a more automatic method.

The PowerSDR XVTR and UCB Tables

Once the local oscillator frequencies of the transverters are known, an XVTR table entry must be created using the XVTR's menu in each instance of PowerSDR. The XVTR table for the transmitter instance of PowerSDR (in my case, the FLEX-1500) is shown in **Figure 11**.

I created two UHF entries with Button Text U1500 and USYNT with the default and synthesized LO frequencies as discussed earlier in this article. The UHF LO in use is determined by the frequency in VFO A as set by SatPC32. One additional XVTR entry, XUCB, was created to allow all the relays to be manually de-activated.

The corresponding UCB configuration is shown in **Figure 12**. A check mark in a relay box for a UCB address will cause that relay to be activated when the corresponding UCB address is selected. When a relay is not activated, the normally closed (NC) terminal is connected to the common terminal, and when the relay is activated, the normally open (NO) terminal is connected to the common terminal. Lines 2, 3 and 4 in the table specify which relays are to be activated by the Buttons V1500, U1500 and USYNT respectively. Line 9 corresponds to Button XUCB so no relays are specified for activation. Thus, when Button XUCB is selected, all relays are de-activated.

If SatPC32 is controlling the Flex radios, the

appropriate buttons are activated when the satellite is selected with that software. Thus, the chance of incorrectly setting a coax switch is eliminated.

The Configuration of the Physical Relays

The relay interconnection diagram in **Figure 13** shows the physical configuration of relays (i. e., the interconnections between the relays, antennas and radios). This mirrors the interconnection diagram in **Figure 4**, which used manual switches. Note that Relay 6, the PTT control relay, is a simple 12V SPDT relay.

A typical wiring diagram for a relay with the K3TUF interface header is shown in **Figure 14**.

When no relays are activated, the HF antenna is switched to the FLEX-3000. The VHF and UHF antennas are switched to my Icom IC-910H and Icom IC-R8500 radios.

The VHF and UHF buttons switch the appropriate transverters to the FLEX-1500 transmitter and the FLEX-3000 receiver. These buttons are controlled by SatPC32.

The U1500 button is used for the AO-7 satellite which has a 432 MHz uplink and the USYNT button is used with the more recent U/V and V/U satellites which use 435 MHz. The appropriate XVTR entry is selected automatically when SatPC32 sets either a 432 MHz frequency (i. e., for AO-7) or a 435 MHz frequency.

Cautions and Comments

Before you exit PowerSDR for the FLEX-1500, click on the XUCB button or change to an HF band so that all relays are de-activated. There is no exit configuration for the UCB interface. Unless you do this, the last configuration of the relays will remain latched.

The UCB Configuration window can be opened in PowerSDR by pressing Ctrl-Alt-U.

Additional Information

An article on using the FLEX-5000 with the V/U option and the second receiver (RX2) option in the FlexRadio Knowledge Center can be found at:

<http://kc.flexradio.com/KnowledgebaseArticle50506.aspx>

Much of the information in that article is also very useful for this configuration.

A photo of the W5RKN operating position is shown in **Figure 15**. The transverters and FLEX-1500 are on the left with the FLEX-3000 to its right. The screens also show windows for DDUtil and DXLabs programs.

Acknowledgements

I wish to thank Dave Beumer, W0DHB, for many discussions on the best methods for calibrating SatPC32 satellite frequencies. I also convey a special thanks to Rick Lawn, W2JAZ, for the many conversations we had on using panadapters with Flex and other radios for satellite operations.

References

1. Parsons, Ron, W5RKN, "A Recommendation for Doppler Tuning", *AMSAT Journal*, March/April 1996, p. 18.
2. Williamson, Paul, KB5MU, "The One True Rule for Doppler Tuning", *OSCAR Satellite Report*, No. 284, January 1994.
3. Full Doppler Tuning (also called the One True Rule) is where all participants in a QSO adjust the frequency of both their transmitter and receiver to achieve a constant frequency at the satellite. When everyone does this, there is no problem with everybody staying together on the same frequency, and there is no drift through the passband.

Enabled	Band	Button	UCB Address	Button Text	LO Offset (MHz)	LO Error (kHz)	Begin Freq (MHz)	End Freq (MHz)	RX Gain (dB)	RX Only	Power	XVTR RF TX	IF Gain	PA Enable
<input type="checkbox"/>	0	0	0	2m	1.0	2.000	3.000000	4.000000	0.0	<input type="checkbox"/>	100	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<input type="checkbox"/>	1	1	1	70cm	6.0	7.000	8.000000	9.000000	0.0	<input type="checkbox"/>	100	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<input checked="" type="checkbox"/>	2	2	2	V1500	116.0	0.000	144.000000	148.000000	0.0	<input type="checkbox"/>	5	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<input checked="" type="checkbox"/>	3	3	3	U1500	404.0	0.000	432.000000	432.999000	0.0	<input type="checkbox"/>	5	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<input checked="" type="checkbox"/>	4	4	4	USYNT	407.0	0.000	435.000000	445.000000	0.0	<input type="checkbox"/>	5	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<input type="checkbox"/>	5	5	5	AO7A	116.0	0.000	145.800000	146.000000	0.0	<input type="checkbox"/>	5	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<input type="checkbox"/>	6	6	6	6	0.0	0.000	0.000000	0.000000	0.0	<input type="checkbox"/>	100	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<input type="checkbox"/>	7	7	7	7	0.0	0.000	0.000000	0.000000	0.0	<input type="checkbox"/>	100	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<input type="checkbox"/>	8	8	8	8	0.0	0.000	0.000000	0.000000	0.0	<input type="checkbox"/>	100	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<input checked="" type="checkbox"/>	9	9	9	XUCB	0.0	0.000	28.000000	29.000000	0.0	<input checked="" type="checkbox"/>	100	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<input type="checkbox"/>	10	10	10	10	0.0	0.000	0.000000	0.000000	0.0	<input type="checkbox"/>	100	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<input type="checkbox"/>	11	11	11	11	0.0	0.000	0.000000	0.000000	0.0	<input type="checkbox"/>	100	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<input type="checkbox"/>	12	12	12	12	0.0	0.000	0.000000	0.000000	0.0	<input type="checkbox"/>	100	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<input type="checkbox"/>	13	13	13	13	0.0	0.000	0.000000	0.000000	0.0	<input type="checkbox"/>	100	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<input type="checkbox"/>	14	14	14	14	0.0	0.000	0.000000	0.000000	0.0	<input type="checkbox"/>	100	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<input type="checkbox"/>	15	15	15	15	0.0	0.000	0.000000	0.000000	0.0	<input type="checkbox"/>	100	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Figure 11: XVTR Setup window for the FLEX-1500



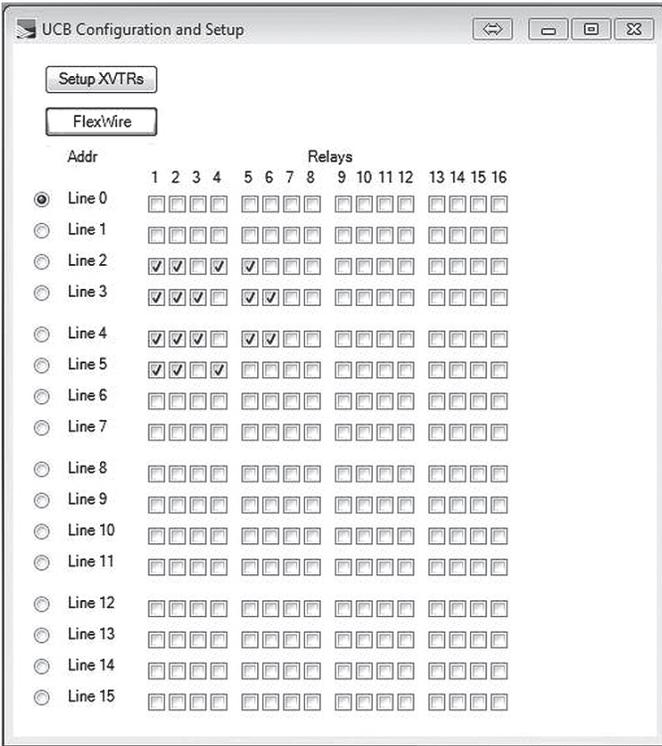


Figure 12: UCB Configuration and Setup window for the FLEX-1500

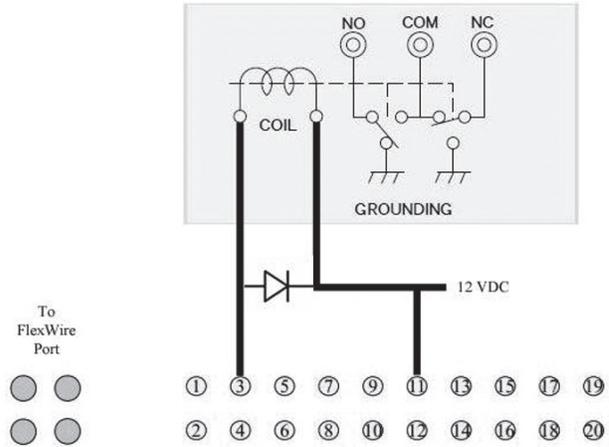


Figure 14: Typical wiring for a relay with K3TUF interface header



Figure 15: W5RKN operating position

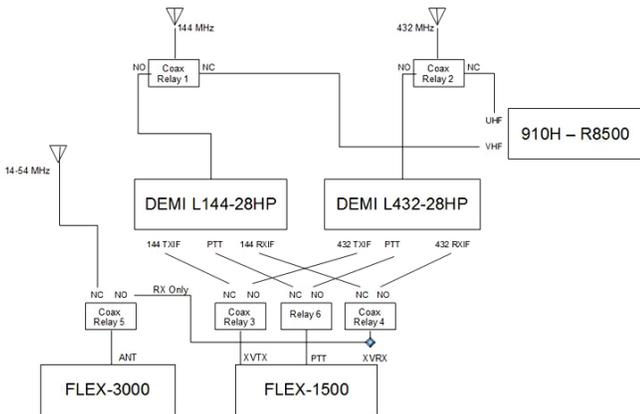


Figure 13: Relay interconnections

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