UPDATE: A Full-Duplex VHF-UHF Satellite System Using Flex SDR

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The article, "A Full-Duplex VHF-UHF Satellite System Using SDR," that appeared in the July/August 2013 issue of *The AMSAT Journal* – **www. flexradio.com/downloads/w5rkn_julyaugust2013withcover-pdf/** – described a fixed ground station for working satellites using two FlexRadio Systems® radios. This update describes a number of modifications and improvements to the original station configuration. The two transmit and receive radios were replaced with a single Flex-6500, a tuning knob was added, and a software program, FlexSATPC, written by David Beumer, W0DHB, was incorporated to tie all the functions together. [See "Using SatPC32 with FlexRadio Systems Radios," p. 13.]

Implementation

Three major changes were made to the system. The first was the addition of a software program, FlexSATPC, which acts as the system central control point. FlexSATPC provides an interface between SatPC32, the tracking and Doppler control software, and SmartSDR, the FlexRadio control and display software because SatPC32 does not support SmartSDR. FlexSATPC also includes a logging interface that enables all required logging by just entering the callsign. All other fields required for logging are automatically entered. FlexSATPC also facilitates uplink frequency calibration to match the satellite's transponder.

The second change was to improve the full-duplex operation, made possible with version 1.5.0 of FlexRadio's SmartSDR control program. The third was adding a FlexControl tuning and control knob. The knob controls the frequency of the active slice and other programmable functions. If the operator is using the FlexControl to tune the radio and a separate logging operator is entering data in other programs, the FlexControl only controls SmartSDR, leaving other programs under mouse control. I made good use of this feature when operating as W1AW/5 and W7O.

The original design used a FLEX-1500 for transmit and a FLEX-3000 for receive, but the required switching between various bands and antennas was very complex. The single antenna port on the FLEX-3000 made it difficult to operate HF or satellites which use HF such as AO-7 Mode A.

When FlexRadio introduced its newest Signature Series model in May 2014, the FLEX-6300, the SmartSDR software that controls the new radio did not support use of transverters. In August 2014, FlexRadio added transverter support, so I replaced the two radios in the original system with one FLEX-6300. Effecting the change was simple, requiring adjusting the CAT COM port and moving the coax from the receive transverter coax switch for the FLEX-3000 to the FLEX-6300 ANT2 port and moving the coax from the transmit transverter coax switch on the FLEX-1500 to the FLEX-6300 XVTR port. That left the FLEX-6300 ANT1 output free for 6-meter use.

FLEX-6300 users must be very careful with implementing and operating a system that allows the physical hardware to transmit into the RX IF port of the transverters. I tried to minimize this risk by automating the signal routing and other software settings. FlexSATPC also contains checks to help avoid this potential problem. Still, the operator must be aware of this risk and operate accordingly.

To completely eliminate this risk, I traded in my FLEX-6300 for a FLEX-6500, which has a separate receive-only port RX A that is connected to the RX IF ports of the transverters. The XVTR port is connected to the TX IF ports of the transverters for transmitting.

Major Features

Full Duplex

The addition of full-duplex capability in FlexRadio's Signature Series radios – FLEX-6300, 6500, and 6700 – enables the audio from the radio's receive slice to pass through to the speakers/headphones even when another slice is transmitting.

"Slice" is the term used by FlexRadio for a segment of the entire spectrum sampled by

the wide-band Spectral Capture Unit. Each slice is tuned to a specific frequency much like a VFO in a traditional radio. A receiver slice takes in 10-20 kHz of spectrum and performs operations to output the desired signals.

The full-duplex capability appears in the radio's spectrum power display and its waterfall historical representation. This provides an easy interface to calibrate the uplink/downlink frequencies of the satellite transponder both graphically and audibly. To use the Uplink Calibration function in FlexSATPC, press the Tune button and use the up/down buttons to adjust the uplink signal so it is displayed at the suppressed carrier frequency of the downlink signal.

Operating full duplex has some disadvantages and many advantages. If your downlink sound volume is too loud, the latency can turn you into a stuttering nincompoop, but with reasonable volume you have a very good check on your audio quality and frequency response. You get immediate feedback if you are off frequency or if someone is trying to break in or is drifting into your signal because of inaccurate Doppler tracking. If you want to tune your uplink very accurately, place a tone generator next to your microphone and adjust your uplink frequency for zero-beat with your downlink signal.

Transverters' IF on the Same Band

Both the VHF and UHF transverters in my current system (Down East Microwave Inc. (DEMI) L144-28HP and L432-28HP) have their IF on the 28 MHz band. While this has not caused a problem, it could be problematic if a satellite should have both uplink and downlink frequencies IF-transverted to almost the same frequency. The only restriction is that the operator can't listen to the TX slice audio unless the RX frequency of the TX slice is more than 12 kHz away (this stops echoes).

The transverters have programmable local oscillator (LO) frequencies, so one of the transverters could be changed to another LO for more uplink/downlink IF frequency separation.

10 MHz Reference Clock Input

The FLEX-6500 and both of the DEMI transverters have the capability to use a GPS-disciplined 10 MHz Reference Clock input

to maintain precise frequency control of the radio's master oscillator and the transverter's synthesized LO. The FLEX-6500 also has an optional built-in GPS disciplined oscillator if a 10 MHz reference is not available.

Automated Switching

The former implementation with the FLEX-3000/1500 used the I2C interface to switch coax relays automatically when the satellite choice was changed in SatPC32. This protocol has not been implemented in the FLEX 6000-series radios. The solution was to acquire a USB-8 relay control board and control it using FlexSATPC or DDUtil. With DDUtil, this solution is restricted to using the transmit frequency as the sole criterion to select the relay configuration. A more flexible solution is available within FlexSATPC using both TX and RX frequencies for controlling the USB-8. The revised schematic diagram of the satellite system interconnections is shown in Figure 1.

Operator Displays

SmartSDR with the FLEX-6000 radios has more flexibility to configure its window than PowerSDR used by the older Flex radios. Taking advantage of this, I use the lower three-fourths of one of my computer display screens to show a portion or the entire passband of the satellite's transponder downlink with both current spectrum and historical waterfall displayed. The upper one-forth shows my uplink spectrum. See Figure 2 for an example of this for a pass of FO-29.

Several SSB QSOs appear in the receive passband. The slightly darker bands in the downlink waterfall depict transmit periods. A brief glimpse of my transmitted spectrum can be seen in the uplink waterfall. Also note the effect of the Doppler shift on the received signals. The frequency grid of the spectrum and waterfall display stays stationary and the frequency of the slice receiver changes to compensate for Full Doppler Tuning, keeping the frequency at the satellite a constant under control of SatPC32.

Figure 3 shows the windows for the SatPC32, FlexSATPC, the logging program Log4OM, and the logging window of FlexSATPC below it. A callsign is the minimum user input required to log a contact. QRZ.com looks up the callsign and retrieves the contact's name and grid square. Other information, such as a signal report and comment, can be added

and a grid square or name can be modified. The contact is entered when the button "Log It" is clicked. FlexSATPC automatically populates all other required log information (Date, Time, Satellite Name, Up/Downlink Band and frequency, etc.).

Operational Improvements

Additional Use of Antennas

The system was enhanced by adding a coax relay between each satellite antenna and the two transverters. The normally closed connection of the two relays provides easy access to additional receivers/transmitters for testing purposes or other uses. When the satellite system is active, the normally open connection of the relays connects the antenna signals to/from the transverters. FlexSATPC or DDUtil and a USB-8 relay board control the switching of all the coax relays.

Automated Startup

Several programs must be started before using the satellite system. These include SmartSDR, SatPC32, and FlexSATPC. In addition, the logging program supported by FlexSATPC, Log4OM, should be started if required. Log4OM (and many other programs) provides a feature to start additional programs either before or after Log4OM starts. This provides a convenient method to start all the necessary programs.

Satellite and HF Switching

The FLEX-6500 is a 100 W HF-72 MHz transceiver. It provides a transverter port (XVTR) and a receive-only port (RX A) in addition to two selectable general purpose antenna connections, ANT1 and ANT2. I use XVTR and RX A for the satellite operation and ANT1 and ANT2 for HF and 50 MHz bands.

SmartSDR has a feature called Profiles that stores the configuration of the radio in a named file. This data file includes the number of slice receivers, where they are tuned and how they are set up. Each of these "global profiles" can be recalled quickly when changing between satellites.

To switch from satellite operation to HF, click on the Disconnect button in FlexSATPC and then choose an HF Profile. Similarly, to switch from HF to satellite operation, click on the Connect button in FlexSATPC and the
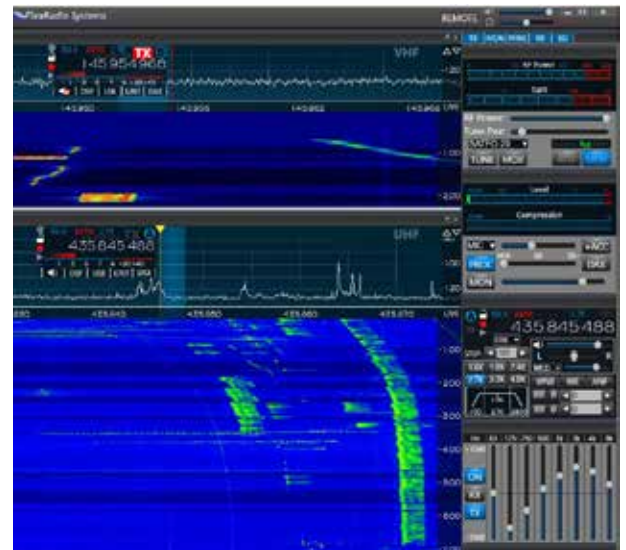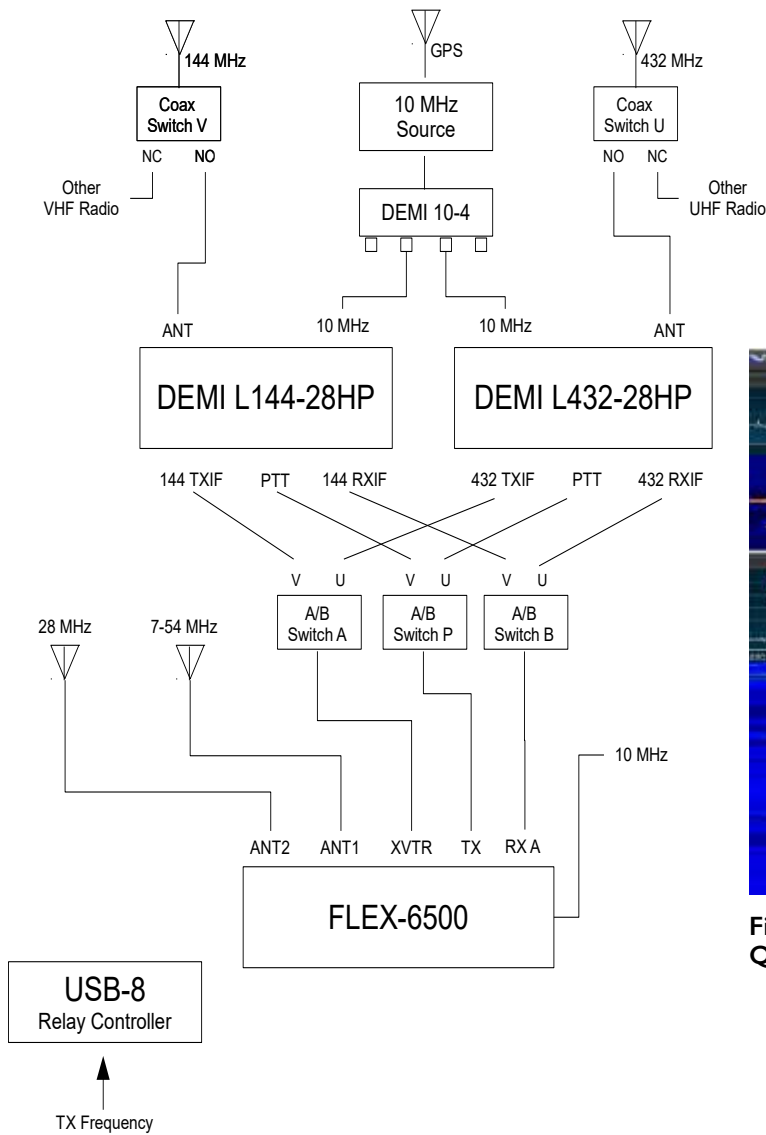
Figure 1 - Schematic diagram of the satellite system interconnections

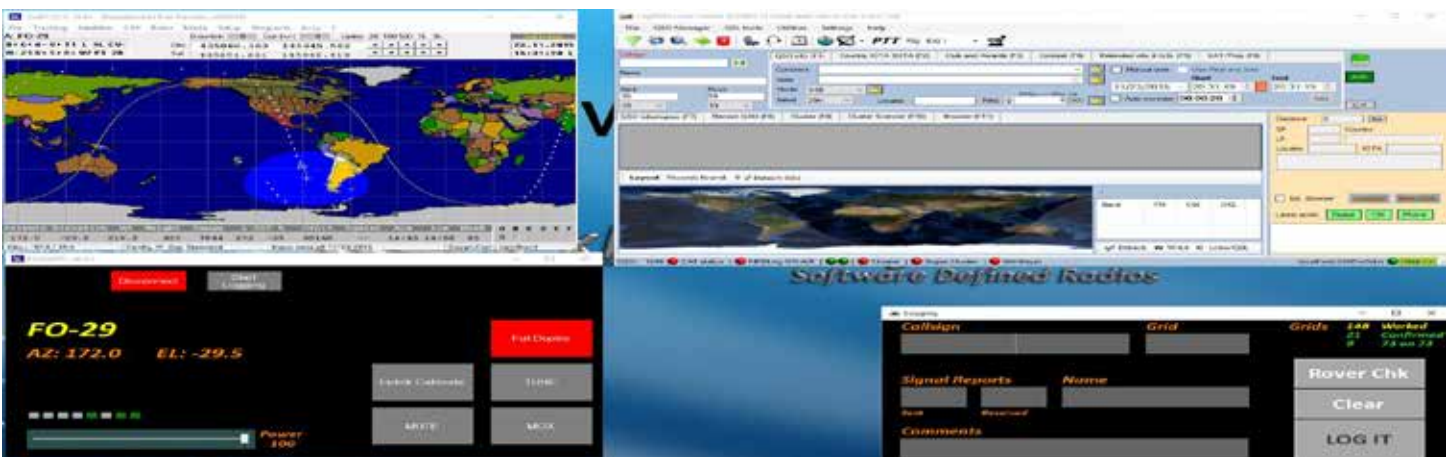**Figure 2 - SmartSDR interface showing several QSOs on FO-29**

Figure 3 - Second screen showing SatPC32, FlexSATPC and Log4OM

appropriate satellite profile will load.

Transverter Support

Figure 4 and Figure 5 show my two transverter setup panels in SmartSDR for VHF and UHF satellites. The user enters the low end RF frequency and the low end IF frequency and the program calculates the required LO frequency of the transverter. When a frequency above the RF frequency is entered into a slice, the LO frequency will be subtracted from the displayed RF frequency and the slice will operate at the difference frequency but display the VHF/UHF frequencies.

The UHF transverter uses a LO frequency of 407 MHz which is stabilized in the UHF transverter to a 10 MHz Reference Clock Input. This converts the AO-7 uplink frequency of 432.150 MHz to 25.150 MHz. The FLEX-6500 handles this by automatically opening up the Bandpass Filters to the wideband mode. Other current UHF satellites use the 435-437 MHz band that converts to an IF frequency of 28-31 MHz and does not require the wideband mode.

The maximum power output from the XVTR port is also set in these panels. Figure 6 shows a slice using the VHF transverter setup at the top (Slice B) and a slice using the UHF transverter setup at the bottom (Slice A). Slice B is enabled for transmitting. The green value in the upper left, RX A, specifies the antenna port used when the slice is receiving. The red value to the right of that specifies the antenna port used when the slice is transmitting. Note that when transmitting with Slice B, the output goes through the XVTR port that is limited in power to the value specified in the transverter setup, in my case 0 dBm.

FM Support

FlexRadio has added support for a Digital FM data mode to the FLEX-6500 software, making seamless transitions possible among FO-29, AO-7 (Modes A and B), SO-50, AO-73, and AO-85.

Conclusion

Much additional information on operation and implementation of transverters can be found in my article from the July/August 2013 issue of *The AMSAT Journal*. That article also contains more information on using SatPC32 for tracking and Doppler frequency control.

I have found that the availability of a spectrum panadapter covering much if not all of a satellite's passband is the single most valuable operating aid for an enjoyable satellite experience. It avoids tuning up and down the passband looking for stations. One can usually notice a station calling CQ on the waterfall as a series of short transmissions with silence between. It is also easy to notice when one or more parties in a QSO are off frequency. Accurate calibration of the uplink/downlink tuning is facilitated by FlexSATPC. It is a real pleasure having a lengthy QSO when all parties are on frequency and are using Full Doppler Tuning with computer control by programs such as SatPC32 or MacDoppler. Just sit back, take your hand off the tuning knob, and ENJOY!

Addendum

With the release of FlexRadio's SmartSDR software version 1.6.17 on January 11, 2016, it is now possible to define two UHF XVTR tabs to allow both the old satellite band at 432 MHz, still used by AO-7, and the current satellite band at 435 MHz to use the same IF frequency. For example, an LO frequency of 404 MHz for AO-7 and an LO frequency of 407 MHz for other UHF satellites will produce an IF of 28 MHz for each. The appropriate XVTR tab will be selected for each band.

Acknowledgments

Figure 4 - VHF XVTR panel

Figure 5 - UHF XVTR panel

Figure 6 - Two slice panels used with satellites