FlexRadio Systems
Software Defined Radios

FLEX-5000 Built In Test Equipment (BITE) Diagnostics and Alignment Procedures

The FLEX-5000™ family of products incorporates extensive Built In Test Equipment (BITE) capabilities. Other than power/SWR bridge calibration, the only external equipment normally required for basic diagnostics and calibration is a reasonable quality, 50 Ohm 100W dummy load. For power/SWR bridge calibration, an Array Solutions PowerMaster meter and two additional 50 Ohm dummy loads connected in parallel (to create a 25 Ohm load) are required.

If desired, loop back cable assemblies can also be assembled to test all front and rear panel IO connections. Those functions are normally used for automated production testing and would not be required to test individual input or output functions.

The FLEX-5000 consists of three major RF subassemblies:

1. HTRX Board – this is the main transceiver board located on the underside of the internal heat sink assembly called the H-Plate. The H-Plate is a 1/4 inch thick aluminum plate that separates the top and bottom cavity inside the radio. The HTRX board contains the main receiver (RX1), the exciter (TX1), the FireWire interface, and assorted input/output connections. Connections are provided on the HTRX board for a second receiver (RX2), the main power amplifier board (HPA100), and the rear panel RF I/O board (HRFIO).
2. HPA100 Board – this is the 100W, 160-6m linear power amplifier assembly located on the top side of the H-Plate. It amplifies the exciter output from approximately 100 mW to 100W and includes the RF power/SWR bridge. Connections are provided on the board for RF input from the HTRX board, control of the optional automatic tuning unit (5000-ATU), RF output to the rear panel HRFIO board, DC power for an internal transverter option, and power on control for the PC power supply on the FLEX-5000C version.
3. HRFIO board – this board provides all of the receiver and transmitter RF connections for the radio. It is located on the rear panel and includes six BNC and three UHF type connectors. It includes internal connections to the HTRX, HPA100, 5000-ATU option, RX2 option, and the internal transverter option.

PowerSDR™ includes special forms that can be activated through three key sequences to calibrate and diagnose the FLEX-5000. The same forms that are used in production can be used for field diagnosis and alignment. There are two main test forms that are used in this process:

1. FLEX-5000 Production HTRX Test Form – CTRL>SHFT>P – tests and calibrates the HTRX board.
2. FLEX-5000 Production PA / IO Test Form – CTRL>SHFT>F – tests both the HPA100 and HTRX boards and calibrates the HPA100 board.

HTRX Test Form

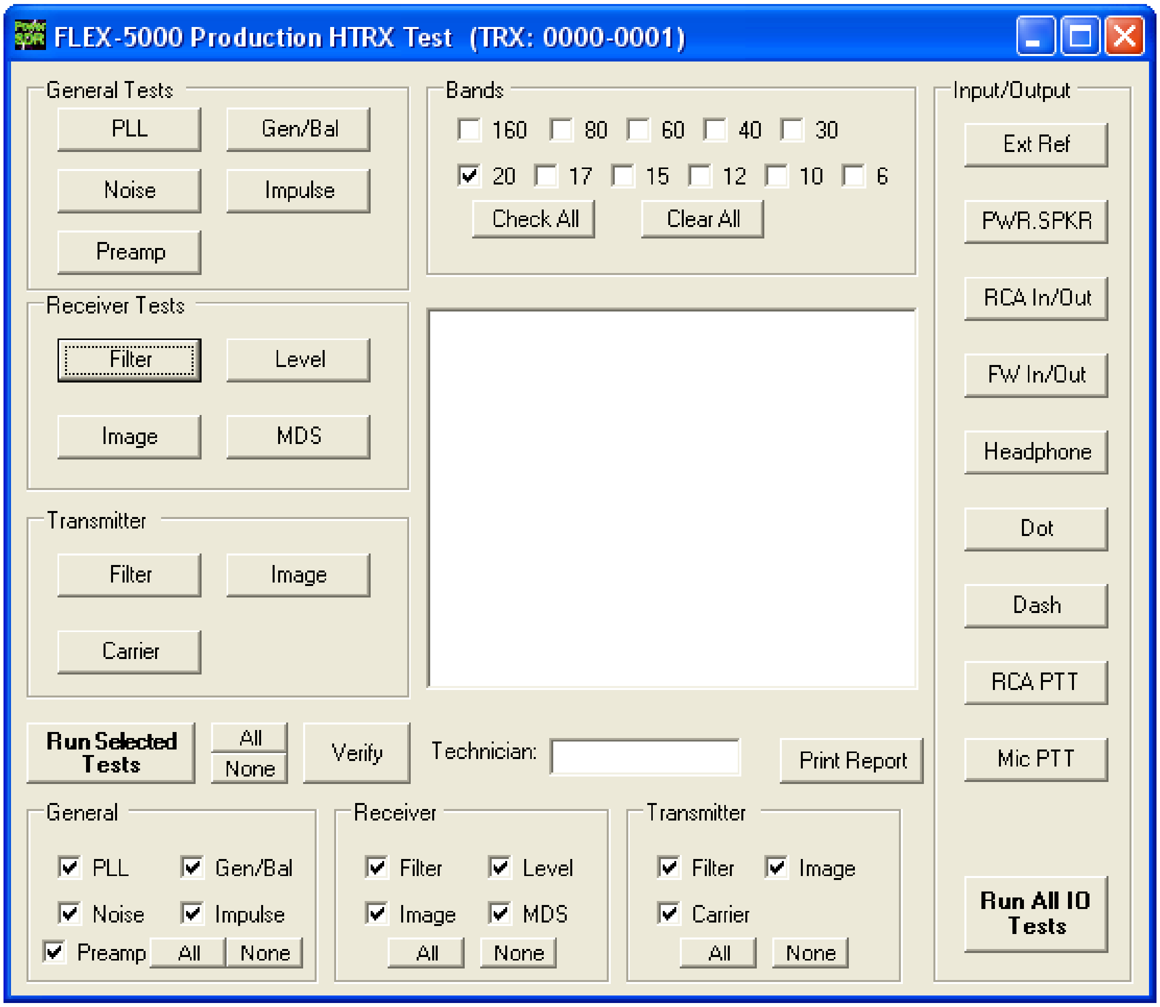

Figure 1 HTRX Test Form

The HTRX Test Form is intended to test and calibrate the functionality of the FLEX-5000 related to only the HTRX board (as opposed to the HPA100 or HRFIO boards). To open the form with PowerSDR running hold Control and Shift and then press the 'P' key. Specifically, this will test the receiver and the exciter, but not the PA or antenna I/O which are covered in the Final Test Form section. See below for a full description of each of the tests/calibrations.

There are a few general things to note about this form. The buttons will turn various colors while running the tests to indicate different things to the operator. A **yellow** button generally indicates that the particular test is underway, but has not yet completed. A **green** button indicates that the test has passed. A **red** button indicates that the test has failed. The white box in the lower right will display debug information in order to help understand why a particular test failed. See the descriptions below for explanations on the debug output. In the upper middle, you can select which band(s) will be tested and calibrated for those tests which run on individual bands. This includes all of the Receiver and Transmitter tests (but not the General Tests or I/O).

To start a test, simply press the associated button or press the Run Selected Tests button to successively run the tests selected via the checkboxes along the bottom row. If a test has failed, you can hover over the button to bring up a tooltip for more information on what bands failed. Note that focus must be on the form for this to work.

General Tests:

PLL: The PLL test checks that the phase locked loop in the AD9511 is in a locked state. We do this by reading the status line with the AD9511 Register 0x08 set to 0x47. The test **passes** if a **lock is detected**, but **fails** otherwise. A PLL failure can indicate any of the following: AD9511 (IC22) or associate voltage regulator failure (IC16), loss of 10 MHz reference oscillator (QG2), or a loss of the 500 MHz oscillator (QG3). If there is no 500 MHz output from IC22, all receiver and transmitter tests will fail.

Gen/Bal: The generator/balance (shortened to Gen/Bal) test checks the signal to noise ratio of the internal signal generator as well as the correct gain and I/Q balance of the receiver signal chain. The internal signal generator is actually one of the transmitter's DDS lines routed back into the receiver through a unity gain buffer and 20 dB attenuator pad.

The test turns on the internal generator at 14.2MHz in DSB mode with the Preamp off, a 2kHz filter (-1000, 1000) selected, and takes readings on the RX Meter for ADC_L (left) and ADC_R (right). It then takes another reading with the generator off and tests the values. If both the ADC_L and ADC_R signals are at least **55dB larger** than the no signal value AND the **difference between the ADC_L and ADC_R** values is **no more than 1dB**, the test is **passes**. The value of the difference between the two will be displayed in the debug window. Also, the value of ADC_L must be –XX dBFS +/- 1 dB and ADC_R must be –XX dBFS +/- 1dB. Otherwise, the test **fails**. **Note that Gen/Bal is a fundamental test that must pass in order for all other transmitter and receiver tests to pass and be valid.**

Noise: The noise test verifies that the receive signal is coming in at a reasonable level. Because level calibration has not yet been performed, we use a signal at 14.2MHz with the Preamp on and simply average 5 measurements of the ADC_L channel of the RX Meter. We compare this average with **-75dBFS**. If the value is higher than this (meaning more noise), there is likely an issue with the receive chain, so the test **fails**. Otherwise, the test **passes**.

Note: This test is very susceptible to local noise issues and may need to be run more than once over a period of time to prevent false negatives.

Impulse: The impulse test verifies that the impulse generator affects the noise floor of the receiver. This is a very difficult thing to quantify. First, we take an average of 5 readings of the noise floor using ADC_L in dBFS. Then, we start a separate thread that toggles the impulse so it fires as rapidly as possible and take another set of 5 readings. The test passes if the noise floor **increases by 6dB** or more. Otherwise, the test **fails** as the impulses did not seem to affect the noise floor.

Note: This test is very susceptible to local noise issues and may need to be run more than once over a period of time to prevent false negatives.

Preamp: The preamp test verifies that the receiver preamplifier is working properly. Again, because we have not performed a level calibration at this point, we use the RX Meter and compare the difference between 2 readings (one with the preamp on and one with it off) to the expected gain of the preamp which is ~14dB. If the difference between the readings is **14 +/- 1dB**, the test passes. Otherwise, it **fails**.

Receiver Tests:

Filter: The RX Filter test checks that the 11th-order receiver filter insertion loss is at a reasonable level. We check this by injecting a strong signal from our internal test generator and then by taking averaged peak display measurements with the filter inline and then bypassed. This test is run on all 11 bands on the following frequencies:

Table 1 Multiple Band Calibration Frequencies

Band	160m	80m	60m	40m	30m	20m	17m	15m	12m	10m	6m
Freq (MHz)	1.85	3.75	5.3665	7.15	10.125	14.175	18.1	21.3	24.9	28.4	50.11
Avg Loss (dB)	1.4	1.3	0.9	1.2	0.6	0.7	0.7	0.6	0.5	0.7	0.5

The difference between the filter inline and when bypassed (which is equivalent to the insertion loss) is compared to a tolerance of 0.5dB. If the insertion loss is more than that on any band, the test **fails**. If all of the bands pass, the test passes. The values shown in the debug window are ([filter bypassed], [filter inline], [insertion loss]).

Level: The RX Level button calibrates and tests the relative value of the received A/D samples given the stability of the internal signal generator. This calibration affects the display, the RX Meter and includes testing the difference with the Preamp on and off. The value of the internal generator has been determined to be -25dBm +/- 0.75dBm using multiple HP 8640Bs, so that is our calibration point. The internal signal generator is turned on and a measurement is made on both the display and the meter with the preamp on and then off. The difference between the known signal (-25dBm) and the read signal becomes the offset. The frequencies used to calibrate are the same as those listed in the Filter test. Once the calibration has completed, we compare the offsets to an average based on previous test runs. Those averages are as follows:

Band	160m	80m	60m	40m	30m	20m	17m	15m	12m	10m	6m
Offset (dB)	-60.5	-61.1	-61.4	-60.8	-60.5	-60.0	-59.5	-59.5	-59.5	-59.6	-59.3
Preamp (dB)	-7.0	-13.3	-13.6	-14.0	-14.0	-14.0	-13.8	-13.8	-13.8	-13.7	-13.4

ERIC NEEDS TO ADD METER OFFSET TO THE TABLE

The calibration offsets are compared to the tables above. If the **offset is +/- 2.5dB from the table and the preamp is +/- 1.5dB from the table** on all bands, the test passes. Otherwise, the test **fails**. Note that even with a fairly severe failure, the display can still look correct as the software is compensating for the extra loss/gain. Do NOT assume that since the display/meter looks correct that this is a false negative. The values shown in the debug window are ([display offset], [preamp offset], [meter offset]).

Image: The RX Image button calibrates and tests the image rejection for the receiver. Using the internal generator with the receiver up twice the IF (typically 9kHz) to put the image in the passband, we toggle between manipulating the Image Gain and Phase up and down to achieve maximum rejection. The calibrations frequencies are the same as those in the Filter test. In order for this test to **pass**, **all bands must have rejection more than or equal to 80dB -OR- the rejection must be within 10dB of the noise floor**. Otherwise, the test **fails**. The values displayed in the debug window are ([image rejection], [distance from floor]).

MDS: The RX MDS button tests the minimum discernible signal of the receiver on all bands. Using the fact that our meter will read out the MDS directly using a 500Hz filter, we simply use the frequencies as described in the Filter test and take meter readings on each band. Once the readings have been taken, we compare them to an average based on previous test runs. These averages are as follows:

Band	160m	80m	60m	40m	30m	20m	17m	15m	12m	10m	6m
MDS (dBm)	-128.8	-133.7	-134.4	-135.7	-134.3	-131.6	-132.4	-132.0	-131.4	-131.7	-129.2

The readings are compared to the averages and if **all bands are within 20dB of the average**, the test passes. Otherwise it **fails**. Note that this test not very stringent due to the noisy test environment in which it is performed. We are simply trying to catch gross MDS issues here. The values in the debug window are ([mds in dBm]).

Transmitter Tests:

Filter: The TX Filter test checks that the transmit filter insertion loss is at a reasonable level. We check this by injecting a strong signal from our internal test generator through the transmitter and then by taking averaged peak display measurements with the transmit filter inline and then bypassed from our Pre-Driver Tap which monitors the exciter. This test is run on all 11 bands as described in the RX Filter test. As long as the filter loss is less than 1.0dB (and is not negative) on all bands, this test **passes**. Otherwise it **fails**. The values in the debug window are ([filter bypassed], [filter inline], [insertion loss]).

Image: The TX Image button calibrates and tests the image rejection for the transmitter. Using the internal generator with the receiver tuned to the transmit frequency and using the Pre-Driver tap to put the image in the passband, we toggle between manipulating the TX Image Gain and Phase up and down to achieve maximum rejection. The calibrations frequencies are the same as those in the Filter test. In order for this test to **pass**, **all bands must have rejection more than or equal to 55dB**. Otherwise, the test **fails**. The values displayed in the debug window are ([image rejection]).

Carrier: The TX Carrier button calibrates and test the transmit carrier. We use the Pre-Driver tap to observe the transmit carrier (MOX with no drive) and manipulate the 4 resistive controls to minimize the carrier (by balancing the voltage on the 4 legs of the QSE). In order for this test to **pass, all bands must have carrier levels less than -105dBm**. Otherwise, the test **fails**. The values shown in the debug window are ([carrier level]). Note that in several tests, the Pre-Driver tap will read ~-45dBm @ 100w drive levels.

Input / Output:

ADD A CABLE DIAGRAM/SCHEMATIC FOR THE IO CONNECTIONS

Ext Ref: The external reference test verifies that the PLL is locked with an external 10MHz clock attached at 0dBm. The test activates the external reference relay and then checks the PLL. If it is locked, the test passes.

Pwr Spkr: This test actually tests both the powered speaker output as well as the balance microphone input and these should be connected on the back panel with an 1/8" to ¼" TRS cable. A sine wave is put on the output and measured on the TX Meter (not visible). Using the meter, measurements are taken with no signal, an out of phase signal (sine wave), and an in-phase signal (sawtooth) in order to test both the stereo output as well as the balanced input. The test passes if the out of phase – no signal is at least 50dB and the out of phase – in phase is at least 20dB. The values shown in the debug window are ([No signal], [Out of phase], [In phase]).

RCA In/Out: This test verifies the RCA In and Out work as they should. The two should be connected directly via an RCA cable. The test puts out a sine wave and measurements are taken with the signal on and off. If the difference between these is at least 50dB, then the test passes. The values in the debug window are ([Signal On], [Signal Off]).

FW In/Out: This test verifies the FlexWire audio In/Out work as intended. The two lines (on pins 2 and 9) should be shorted with a DB9 connector. The test puts out a sine wave and measurements are taken with the signal on and off. If the difference between these is at least 50dB, then the test passes. The values in the debug window are ([Signal On], [Signal Off]).

Headphone: This test actually tests both the headphone output and the front panel microphone input. The stereo headphone outputs should be connected in parallel through resistors to the microphone audio input (pin 8). It puts out a signal first on the left channel only and then the right channel only and compares the measured signal on the TX input to no signal. If each is more than 40dB, the test passes. The values written to the debug window are ([Off], [Left], [Right]).

Dot: This test actually tests both the Dot input and the TX1 output. Dot and Dash should be connected via a ¼" to dual RCA to TX1 and TX2. TX1 is toggled and Dot is read to verify that it changed state in both directions. If Dot does not change state, the test fails.

Dash: This test actually tests both the Dash input and the TX2 output. Dot and Dash should be connected via a ¼" to dual RCA to TX1 and TX2. TX2 is toggled and Dash is read to verify that it changed state in both directions. If Dash does not change state, the test fails.

RCA PTT: This test actually tests both the RCA PTT input and TX3. These should be connected directly via an RCA Y-cable between TX3 on one end and RCA PTT and Mic PTT on the other. TX3 is toggled and RCA PTT is read to verify that it changes state in both directions. If RCA PTT does not change state, the test fails.

Mic PTT: This test actually tests both the Mic PTT input and TX3. These should be connected directly via an RCA Y-cable between TX3 on one end and RCA PTT and Mic PTT on the other. TX3 is toggled and Mic PTT is read to verify that it changes state in both directions. If Mic PTT does not change state, the test fails.

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PA / IO Form

HAVE ERIC UPDATE THE FORM SCREENSHOT AND THE DESCRIPTION OF THE CURRENT FORM

ADD CONNECTION DIAGRAM FOR PA AND RFIO TEST HERE

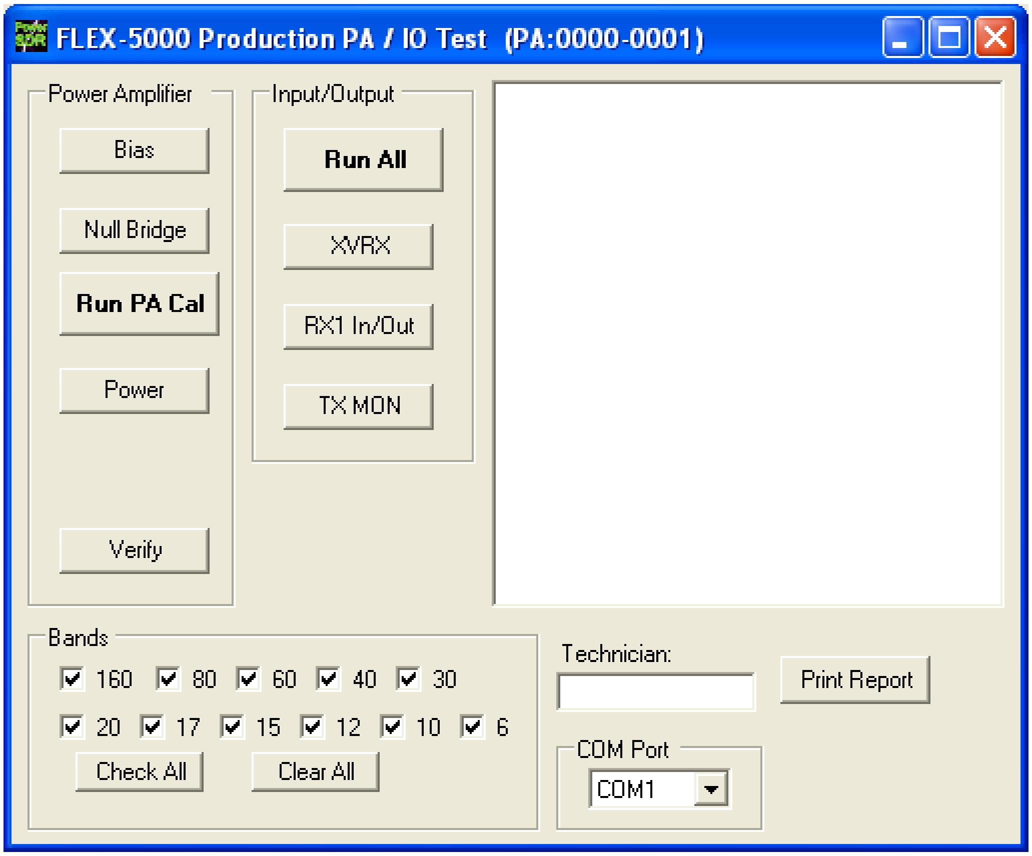

Figure 2 PA / IO Test Form

This form is used to test and calibrate the 100W PA as well as the I/O ports not on the HTRX board. To open this form, hold Control and Shift and press the 'F' key. The amplifier calibrations need to be run in order from top to bottom while the I/O tests can be run in any order provided that the external connections are made (see the individual test descriptions for details.

Power Amplifier:

Bias: The bias calibration calibrates the driver and final bias to the calibration points (200mA driver, 1.4A final). The controls used to calibrate the bias are on the FLEX-5000 Debug form (accessible via Control + Shift + D shortcut). The driver is done first by adjusting the coarse controls followed by the fine controls. Then the finals are done the same way. The final values can be verified by polling the bias values in the lower left of the debug form with the bias on (check the Bias checkbox in the lower left of the group of checkboxes). If the calibration is unable to adjust the Bias to the calibration points, the test fails.

Null Bridge: The bridge null calibration is the only manual calibration in the entire FLEX-5000. The test will put out ~50w, so make sure a dummy load is connected to ANT 1 before starting and ensure airflow is present (use an external fan if performing this test on a T-frame). Using a non-conducting tool, adjust the pot after clicking this button to minimize the reverse voltage on the power bridge. Ideally the minimum will be below 10mV, but some radios may be more than that. Above 50mV would be considered a problem. When finished, click the Abort button on the status dialog to stop the test. Note that this test will abort if it does not see at least 20w coming out as read by the PowerMaster wattmeter.

Run PA Cal: This calibration actually calibrates 3 parameters: Bridge, Power, and SWR.

Bridge: The bridge cal uses the Array Solutions PowerMaster wattmeter connected to a COM port to calibrate the bridge voltage to 6 power points (1, 2, 5, 10, 20, and 90 watts). This calibration ensures that the internal wattmeter is accurate. Make sure the wattmeter has power, is inline, and the correct COM port is selected before starting this calibration. The test will put out high power, so make sure a dummy load is connected to ANT 1 before starting and ensure airflow is present (use an external fan if performing this test on a T-frame). The bridge calibration uses a check to verify that the 2 value is more than 1, 5 > 2, etc. If any of those are not true on any band, the test fails.

Power**:** Once the bridge has been calibrated, we use the internal wattmeter to calibrate the drive control at the following points on each band: 1, 2, 5, 10, 20, 30, 40, 50, 60, 70, 80, 90, and 100 watts. The test will put out high power, so make sure a dummy load is connected to ANT 1 before starting and ensure airflow is present (use an external fan if performing this test on a T-frame). The test for passing ensures that each value on every band has been set.

SWR**:** Now that the forward power has been calibrated, we need to calibrate the reflected power so the SWR meter will be accurate. Running the SWR calibration will put out a reasonable amount of power into a 25Ohm load on ANT 2 and then make an adjustment based on the read power with the knowledge that the SWR should be exactly 2.0:1. This test passes after the adjustment has been made on all bands.

Power: This button runs just the power cal mentioned above in order to save time when doing debug work with failing PA units.

Verify: The verification test verifies that both the bridge and power calibrations are within reason compared to the PowerMaster wattmeter at 10 and 100w settings. The readings on both the internal wattmeter and the PowerMaster are compared as well as comparing the selected drive to the external PowerMaster to a tolerance of 5w. The 3 numbers shown in the debug window are ([Drive], [Internal Meter Reading], [Power Master Reading]).

Run PA Cal: This test will run the Bridge/Power test followed by the SWR and then finally the Verify routine. This test is available in order to eliminate having to wait for the earlier tests to finish before starting the later ones, thus saving time in production test.

Input / Output:

The I/O tests verify the functionality of all of the audio and RF ports for the FLEX-5000. Below are descriptions of the hookups and criteria for passing for each individual test. Note that many of the tests are verifying an input and an output at the same time, so a failure could mean either of those are a problem.

XVRX: This test actually tests both the XVTX and XVRX lines and these should be connected on the back panel. A sine wave is injected into the transmitter with the following signals active: QSE, XVTR, XVTXEN, XVEN. The signal is measured with the meter and compared to a no-signal case. If the difference between the signals is at least 20dB, the test **passes**. The values shown in the debug window are ([Signal On], Signal Off]).

RX1 In/Out: This test actually tests both the ANT 3 input as well as the RX1 In and RX1 Out connections. This test assumes that an XG-1 is connected to ANT 3 and that RX1 In and RX1 Out are bridged with a BNC loop. A reading is taken with the RX1 Loop enabled and one with it bypassed. The two values should be fairly equivalent. If the values are no more than 1dB apart and they are both within 2dB of –73dB (S9), the test **passes**. Otherwise it **fails**. The values shown in the debug windows are ([Loop On], [Not used], [Loop Off]).

TX Mon: The Transmit Monitor test verifies that the resistive tap from the antenna is functional and the level is within reason. We transmit a 10w signal and expect to see greater than -55dBm. If the measured value is below that value, the test fails.