

Application Note

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Installed Radio Testing with the 3500



Aeroflex has uniquely designed the Aeroflex 3500 portable radio test set for complete testing of installed radio communication systems. The 3500 is ideal for testing installed radios in ground vehicles and in rotary and fixed wing aircraft. This is because the Aeroflex 3500 is a lightweight portable radio test set and is able to test both the transmitter and receiver of HF/VHF/UHF AM and FM radio communication systems, without having to remove them.

In addition, the 3500 can take the testing further by direct testing of the radios, cables, and antennas. This application note will focus on the method for performing testing of installed radios used for voice communications.

Testing Installed Radio Communication Systems

Before we begin testing any radio communication system, we need to assess the parts that make up that system and the environment in which we are required to test the system. The parts of an installed system include the radio, the cables and connectors, and the antenna. The voice communication system in many vehicles and aircrafts includes HF, VHF and UHF radios. These radios may transmit using AM, FM, or SSB modulation. Often the HF radios use SSB or AM modulation, and the VHF and UHF radios use AM or FM modulation. The affect of the environment that we test the radio in depends on the type of testing that we are performing. If it is an over-the-air test, the environment can have a tremendous impact on the accuracy of the test results. A direct connect test will mostly be immune from the environment that the test is performed.

The 3500 is capable of performing the tests require on an installed radio system. This application note will describe the procedures for using the 3500 to do the various tests on an installed radio.

TESTING PROCEDURE

We will divide the testing of the installed radio into three different sections. The first section will focus on over-the-air testing of the installed radio. The second section will describe the procedure of direct connect testing of the radio. The last section will cover the testing of the cables and antennas.

PART I - OVER-THE-AIR TESTING

Regardless of the type of radios we are testing, over-the-air testing of an installed radio requires that we follow a consistent testing procedure. This is because the affects of multipath can greatly change the results, especially for over-the-air signal strength and sensitivity checks.

Multipath is the result of the transmitted or received signal following two or more paths. The cause of the multiple paths is the signal reflecting off the ground, vehicles, walls, ceilings, etc... The affects of multipath depends on the relative phase of the multipath signals. If the different signals are in phase, they add together and the signal strength increases. If the signals are out of phase, they partially cancel each other out, decreasing the signal strength. The signals arriving on different paths have different distances that they travel. The delay in arrival of the reflected signals is what causes the phase differences.

If we always follow the same procedure, our results for signal strength and sensitivity should be very consistent and the relative measurement results very useful in determining a pass/fail for the radio under test. Probably one of the most important variables under our control in the over-the-air testing of the installed radios is the position of the test equipment with respect to antenna of the radio under test. We need to determine the location that provides us with a line of sight view of the antennas for the radios that we are testing. This is relatively simple if the vehicle only has

one antenna, but for multiple antennas, we may have to move around some before we find just the right location. Ideally, we will be able to find one position that is suitable for all of the antennas on the vehicle. This would reduce errors and testing time. Once we find that ideal position, it is important that we record the location so that we can refer back each time we do the testing. The drawing shown in Figure 1 is an example of recording the position for testing the radios on an airplane.

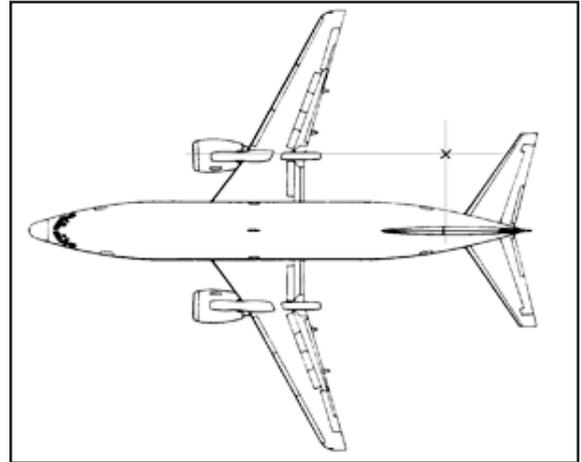


Figure 1 -Example of marking position of a 3500

The height that we hold the test set is also important. We should hold the test set at about 4 to 5 feet above the ground. The location and height of the 3500 will have an affect on the signal strength measurement and squelch point/sensitivity measurements.

We can then make the following measurements:

1. Receive Signal Strength
2. FM Deviation
3. AM Percent Modulation
4. RF Frequency Error
5. Relative Squelch Open Level
6. Relative Squelch Close Level
7. Relative Sensitivity Level

The following sections will describe each of these tests in detail.

Transmitter Test Procedure

There are three measurements to make on the transmitter of the radio under test. These three measurements are received signal strength, RF frequency error, and modulation.

Received Signal Strength

The receive signal strength measurement is an indication of the level of the transmitted signal of the radio under test. This measurement is related to the output power of the radio, but is much lower due mostly to the distance that the signal travels from the antenna on the aircraft or vehicle to the 3500 antenna. The purpose of this test is to make a determination that the radio is transmitting all the way through the cabling to the antenna. In order for us to make this determination we will need to have

something of which to compare the measurement . We can make this comparison with previous measurements made on this radio or a better way is to create a baseline measurement with a known good radio. If the transmit power is substantially lower than the normal measurement (or lower than the baseline measurement), then we will need to do further testing, which will require us to directly connect to the radio or cable and antenna.

RF Frequency Error

RF frequency error is a measurement of the difference between the transmit frequency of the radio and the frequency on which it should be transmitting. Multipath does not adversely impact this measurement and is therefore an easier measurement to make.

Modulation

The final measurement of the transmitter is modulation. This measurement is dependent on the type of modulation in the radio that we are testing. We will measure AM modulation in units of percent modulation and FM modulation in units of kHz of frequency deviation. The SSB modulation measurement is a little different. We will measure SSB modulation with the frequency error meter. The amount of frequency error for SSB should be the same as the frequency of the modulating signal with USB causing a positive error and LSB causing a negative error. If a 1 kHz test tone is available in the radio that we are testing, then we will use this built in tone for the modulation signal. Otherwise, we will use a microphone, with the operator whistling to produce the modulating signal. Whistling may sound like an unscientific way of testing the modulation, but it is an effective way of generating the maximum amount of modulation. The multipath that is present on over-the-air measurements, does not significantly affect this measurement.

Step by Step Procedure

We will do this testing using the 3500 Transmitter Test screen. From the system level menu in the 3500, select "4 - BENCHTOP" and then "2 - TRANSMITTER TEST". This screen will look something like the screen in figure 2 (depending on the last setup).

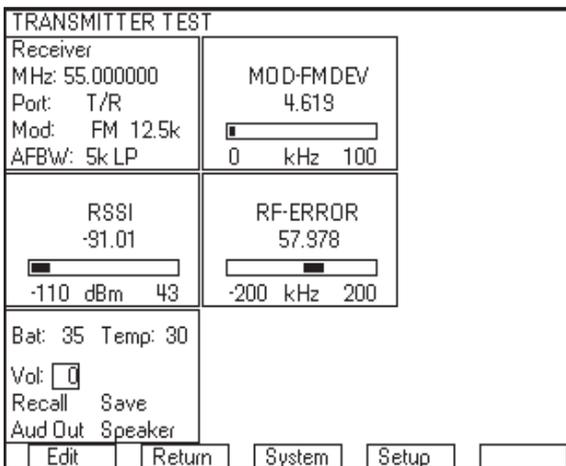


Figure 2 - TRANSMITTER TEST screen

The following is detailed step by step instructions for performing

these transmitter tests.

1. Move the cursor, using the arrow keys, to the Receiver MHz field.
2. Enter the same frequency as the radio under test and then press the done softkey.
3. Move the cursor to the Port field. Press the Edit softkey and then with the up/down arrow keys toggle the Port field to ANT. Press the Done softkey.
4. Move the cursor to the Mod field. Press the Edit softkey and with the up/down arrow keys toggle the Mod field to match the modulation (AM or FM) of the radio under test. Press the Done softkey.
5. Move the cursor to the next field to the right. Press the Edit softkey and then using the up/down arrow keys select a bandwidth of 25 k. Press the Done softkey.
6. Move the cursor to the AFBW field. Press the Edit softkey and then using the up/down arrow keys select 15 kHz LP. Press the Done softkey.
7. Press the Setup softkey and the screen in Figure 3 should appear.

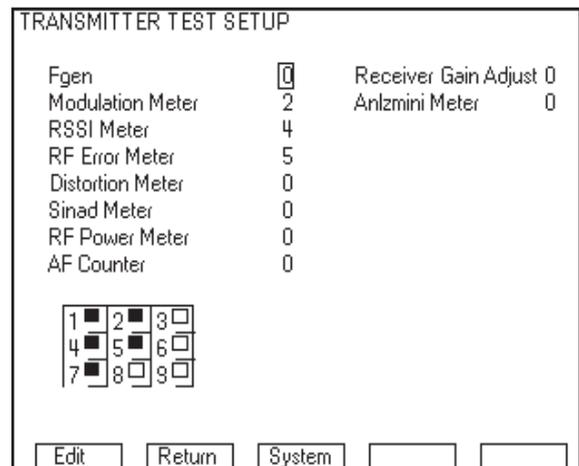


Figure 3 -TRANSMITTER TEST SETUP

8. This screen selects the meters that are on the transmitter screen. Move the cursor to the Modulation Meter field and set to number 3. Press the Done softkey.
9. Following the same procedure set RSSI Meter to 6 and RF Error Meter to number 9.
10. Set the other Meters to 0.
11. Press the Return softkey. Now the TRANSMITTER TEST screen should look like Figure 4.

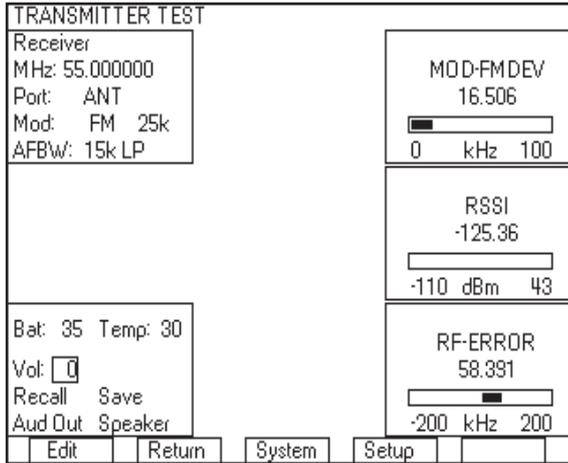


Figure 4 - TRANSMITTER TEST screen

Radio	BAND-MOD	RSSI (RF Power)	RFError	Modulation
UHF	UHF-AM			
VHF/UHF #1	VHF-AM			
	VHF-FM			
	UHF-AM			
	UHF-FM			
VHF/UHF #2	VHF-AM			
	VHF-FM			
	UHF-AM			
	VHF-FM			
HF	HF-AM			
	HF-LSB			
	HF-USB			

Table 1 - Transmitter Test Matrix

Evaluating the Results

Once we have made these measurements and recorded them, the next step is to evaluate them. These three measurements that we have made on the transmitter are enough to verify that the radio is transmitting correctly. The key is to evaluate them while understanding the impact that the method of test and the environment had on the test.

Even though an over-the-air measurement impacts the RSSI reading, it should be consistent from our know good baseline radio to measurements made on the radio under test. Therefore, we should compare the results of this measurement with the results from the measurement of a known good radio. Any variance of more than 5 or 6 dB is an indication that there could be a problem with the transmitter.

The frequency error reading is an accurate measurement, since over-the-air measurement conditions do not impact the reading. This measurement should be less than the manufacturer's specification of the radio under test plus or minus the accuracy specification of the 3500.

Over-the-air measurement conditions also do not impact the modulation measurement, but the reading will vary with the level of the test signal. If we have made the measurement using the built in test signal, the modulation should be consistent from one vehicle to the next. When a test signal is not available and the operator whistles into the MIC, the level of modulation may vary. In this case, the amount of modulation will usually be the maximum that the radio can produce. We will only be concerned with the results of this test when the radio does not produce any modulation at all. Or to quantify a pass/fail criteria, the modulation from the radio under test should be at least 2 kHz of FM deviation or 30% of AM modulation. The modulation reading for SSB is a special case. The number that we recorded was a reading that we measured from the RF-error meter. The frequency error should be a positive number for USB and a negative number for LSB. The frequency of the RF-error should be the same as the frequency of the modulating signal. A 1 kHz tone should cause a frequency error of 1 kHz (\pm frequency error of the radio under test).

12. Connect your test antenna to the ANT port of the 3500. Always use the same antenna for this test.

13. The location and positioning of the 3500 is critical to these tests. See the introduction to over-the-air testing for instructions on positioning the 3500 (also see Figure 1).

14. Turn on the transmitter of the radio under test.

15. Wait a few seconds for the RSSI meter on the 3500 to settle.

16. Record the RSSI reading.

17. Record the RF Frequency error reading.

The next three instructions are for AM and FM modulation only.

18. Enable the 1 kHz test tone in the radio under test or you can whistle into the MIC if there isn't a test tone in the radio.

19. Wait a few seconds for the Modulation meter to settle.

20. Record the Modulation reading. This value will be in kHz for FM modulation and represents the FM deviation. For AM, the value will be in % modulation and represents the depth of modulation.

The next five instructions are for SSB modulation only.

21. Select USB, also sometimes called UIV, on the radio under test.

22. Enable a test tone if available in the radio, or connect the headset and microphone and whistle into the MIC.

23. Record the RF Frequency error reading as the Modulation.

24. Select LSB, also sometimes called LV, on the radio under test.

25. Repeat steps 22 and 23.

You should repeat this procedure for each modulation type and frequency band of the radios that you are testing. An example transmitter test matrix is shown in Table 1.

In summary:

RSSI	< +/- 5-6 dB with respect to known good radio
Frequency error	Within specification of radio under test
FM Modulation	> 2 kHz Deviation
AM Modulation	> 30 % AM Modulation
USB Modulation	Positive RF-error
LSB Modulation	Negative RF-error

Table 2 - Transmitter Test Pass/Fail Criteria

Receiver Test Procedure

We will be performing three tests on the receiver portion of the radios under test. With these three tests, we will find the squelch open point, squelch close point and subjective sensitivity of the radios. The squelch open point is the receive level at which the radio just breaks squelch as the RF level of the 3500 is slowly increased. The squelch close point is the level at which the audio is squelched off when the RF level is slowly decreased. The subjective sensitivity of the radio is the lowest receive level, at which we can clearly hear the audio. We will find the squelch open point first, the squelch closed point second and then we will switch off the squelch and change the 3500 output level until we find the lowest output level at which we can still clearly hear the audio.

We will perform these tests at one selected frequency for each band and modulation type present in the radios that we are testing. Even though the 3500 does not have a SSB modulation type, we can produce this modulation by offsetting the generator frequency by the modulation frequency. For example, to produce an upper side band (USB) with a modulation frequency of 1000 Hz, we simply need to offset the generator frequency by +1000 Hz.

Step by Step Procedure

To perform these tests, we will use the 3500 Receiver Test screen (Figure 5). To get to this screen from the Transmitter Test screen, press the Return softkey and then select "1 - RECEIVER TEST". Your screen may look slightly different than Figure 5 since some of the optional meters may be different from yours. We do not need any meters for this test, so you could remove the meters by going to the Setup screen and entering zeros in all of the meter selection fields.

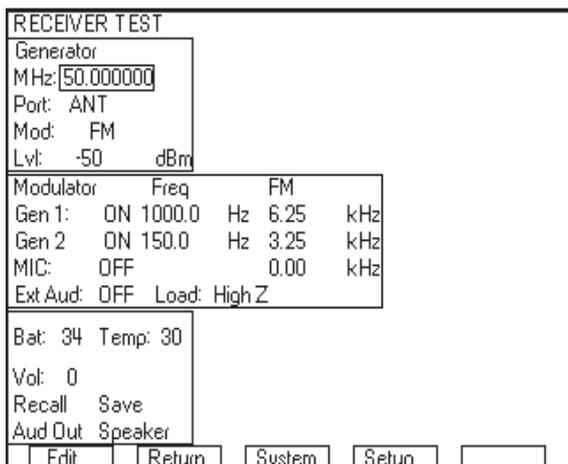


Figure 5 - Receiver Test Screen

Here are the step by step instructions for the Squelch open and close test.

1. Move the 3500 cursor using the arrow keys to the Generator MHz field. Set the MHz field to the frequency of the radio under test and press the Done softkey.
2. If the modulation type of the radio under test is SSB (USB, LSB, LIV, or LV), we will create this modulation by offsetting the value of the MHz field by 1000 Hz. For USB (also called LIV) increase the field by .001000 MHz (1000 Hz). For LSB (also called LV) decrease the field by 0.001000 MHz (1000 Hz). This will add 1000 Hz SSB modulation to the carrier. Press the Done softkey.
3. Move the cursor to the Port field. Press the Edit softkey and then toggle the setting to SWR using the up/down arrow keys. Press the Done softkey.
4. Move the cursor to the Mod field. If the modulation type is AM or FM then press the Edit softkey and set the Mod field to the modulation type of the radio under test. If the modulation type is SSB (USB, LSB, LIV or LV), then you should select none for modulation type. Press the Done softkey.
5. Move the cursor to the Lvl unit's field (dBm or uV). Press the Edit softkey and using the up/down arrow keys select dBm. Press the Done softkey.
6. Move the cursor to the Lvl field. Press the Edit softkey and set the Lvl field to -5.0 dBm. Press the Done softkey.

The next several steps are for AM and FM modulation only. You should skip to step 15 for SSB modulation.

7. Move the cursor to the Modulator Gen1 ON/OFF control field. Press the Edit softkey and using the up/down arrow keys, set the Gen1 ON/OFF field to ON. Press the Done softkey.
8. Move the cursor to the right to the Modulator Freq field and set the Modulator Freq to 1000.0 Hz. Press the Done softkey.
9. Move the cursor to the next field to the right (the AM modulation index or FM deviation field). If the modulation is AM then this field should be set to 80 %. If the modulation is FM then this field should be set to 3.00 kHz.
10. Move the Cursor to the Gen 2 / DCS field. Press Edit and toggle to DCS.
11. Move cursor to the right to the ON/OFF field. Press Edit and toggle to OFF.
12. Move the cursor back to the DCS field. Press edit and toggle to Gen 2.
13. Move the cursor back to the ON/OFF field. Press Edit and toggle to OFF
14. In the same way, make sure that Ext Aud and MIC are OFF.
15. The Receiver test should now look like Figure 6 (slightly different for AM or SSB modulation).

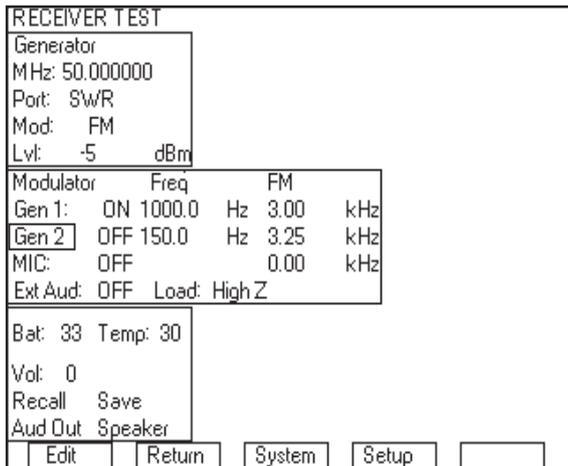


Figure 6 - RECEIVER TEST after initial setup

Radio	BAND-MOD	Squelch Open	Squelch Close	Sensitivity
UHF Radio	UHF-AM			
VHF/UHF #1	VHF-AM			
	VHF-FM			
	UHF-AM			
	UHF-FM			
VHF/UHF #2	VHF-AM			
	VHF-FM			
	UHF-AM			
	VHF-FM			
HF Radio	HF-AM			
	HF-LSB			
	HF-USB			

Table 3 - Receiver Test Matrix

Evaluating the Results

The squelch open point is the level at which the radio just breaks squelch. This level should be consistent with the baseline radio (known good radio) that you measured. The squelch open point should not vary by more than 5-6 dB or there could be a problem with the receiver of the radio, antenna, cabling or the setup of the level of the squelch open point. Likewise, the squelch close point should not vary from a known good radio by more than 5-6 dB.

The sensitivity should also be consistent with the measurement made with the baseline radio. If the sensitivity varies by more than 5-6 dB then you probably have a problem with the radio, antenna, or cabling.

Over-the-air Testing Conclusion

Since so many of the measurements that we have taken have a subjective element to them, it is important that the test results include notes on how you made the measurement. In order to reduce the amount of user error, you should record the height of the 3500, the angle of the 3500 antenna, and the location that you did the testing. The more notes you take, the easier it will be to reproduce the same results, the next time you make these measurements.

PART II - DIRECT CONNECT TESTING

When the over-the-air tests indicate that there may be a problem with the radio, the next step is a direct connect test. For these tests we will need to connect a coax from the T/R port of the 3500 to the transmit/receive port of the radio under test. Then, we will perform a test of the transmitter and receiver of the radio under test. As you will see, these tests are similar to the transmitter and receiver tests that we made over-the-air. The major difference now though is that we no longer have the uncertainties of path loss and multipath.

Transmitter Test Procedure for Direct Connect

This procedure is very similar to the over the air transmitter test procedure. One difference is that now we can provide the audio signal that modulates the transmitter of the radio under test. We can do this by using the AF generator that is part of the 3500. With the correct cables and connectors, we can route the audio from the 3500 handset, Ext Aud Out connector to the audio input of the radio under test. The level that we set our audio frequency generator at will control the amount of modulation on the radio

16. If the radio under test has a squelch On/Off switch, make sure that it is on.
17. Move the cursor to the Lvl field. Press the Edit softkey and using the left arrow key, select the "10s" digit of the Lvl field.
18. Using the down arrow key, step the Lvl field down in 10 dB steps until you can no longer hear the 1000 Hz tone.

Note: If you have lowered the level of the 3500 RF as far down as it can go (-65 dBm) when the SWR port is selected, you will need to switch the port to ANT. Move the cursor up to the Port field, press Edit, then toggle the selection to ANT and press Done. Don't forget to move the antenna from the SWR port to the ANT port of the 3500.

19. Using the right arrow, select the "1s" digit of Lvl.
20. With the up arrow, increase the level in 1 dB steps until you can hear the 1000 Hz tone.
21. Record the value in the Lvl field as the squelch open point.
22. Using the down arrow, decrease the level in 1 dB steps until you can no longer hear the 1000 Hz tone.
23. Record this value in the Lvl field as the squelch close point.

Continue from this point to do the second part of the test, the relative sensitivity test.

24. Turn off the squelch on the radio under test.
25. Increase or decrease the level in 1 dB steps, using the up/down arrow keys, until the audio has static or noise, but a listener could still hear it "comfortably".

"Comfortably" means that you can easily hear the 1000 Hz tone, but there is some static present.

26. Record the value in the Lvl field as the Receiver Sensitivity.

You should repeat this procedure for each band and modulation type of the radios in the radio communication system. A sample table for recording the results is shown in Table 3.

under test. It will help us if we know what the relationship is between the level of the audio in signal and the amount of modulation produced by the radio. We can look for this information in the specification of the radio under test. If we don't know this relationship, then we may need to determine it from a known good radio.

Step by Step Procedure

Just as in the over-the-air test, we will do this testing using the 3500 Transmitter Test screen. From the system level menu in the 3500, select "4 - BENCHTOP" and then "2 - TRANSMITTER TEST". Your 3500 screen should now look something like Figure 7, depending on the last setup.

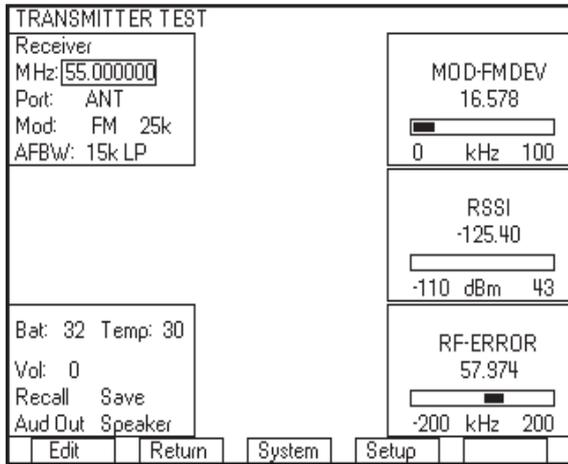


Figure 7 - TRANSMITTER TEST screen

The following is detailed step by step instructions for performing the direct connect transmitter tests.

1. Move the cursor to the Receiver MHz field and then enter the same frequency as the radio under test. Press the Done softkey.
2. Move the cursor to the Port field. Press the Edit softkey and then with the up/down arrow keys toggle the Port field to T/R. Press the Done softkey.
3. Move the cursor to the Mod field. Press the Edit softkey and with the up/down arrow keys toggle the Mod field to match the modulation (AM or FM) of the radio under test. Press the Done softkey.
4. Move the cursor to the next field to the right. Press the Edit softkey and then using the up/down arrow keys select a bandwidth that is appropriate for the radio under test. Press the Done softkey.

Note: The bandwidth selected should be at least as wide as the bandwidth of the radio under test. If you are not sure, use a bandwidth of 25 kHz.

5. Move the cursor to the AFBW (Audio Frequency Band Width) field. Press the Edit softkey and then using the up/down arrow keys select 15 kHz LP. Press the Done softkey.
6. Press the Setup softkey and the Transmitter Test setup screen should appear.

7. Next, set FGEN to number 4, Modulation Meter to 2, RF Error Meter to 3, Distortion Meter to 6, RF Power Meter to 8, and AF Counter to 9.

8. Set the other Meters to 0.

9. Now your screen should not look like Figure 8.

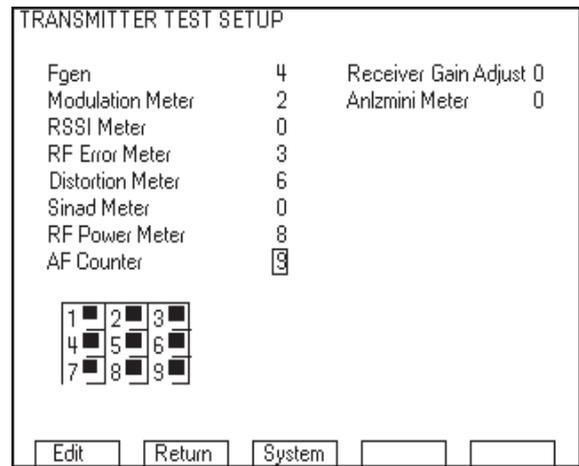


Figure 8 - TRANSMITTER TEST SETUP after changes

10. Press the Return softkey.

11. Move the cursor to the distortion meter. This meter name will reflect the audio signal that you are measuring, either DIST-AUDIN or DIST-DEMODO.

12. Press the Zoom softkey and the screen in Figure 9 should appear.

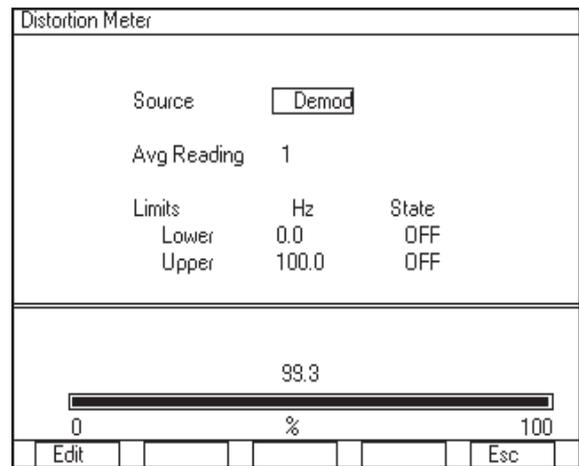


Figure 9 - Distortion Meter

13. Press Edit and toggle the Source to Demod.

14. Move the cursor to the Avg Reading and set this value to 1.

15. Press Esc and the 3500 should return to the TRANSMITTER TEST screen.

16. Move the 3500 cursor to the AF-COUNTER and press the Zoom softkey.

17. You should now see the screen shown in Figure 10.

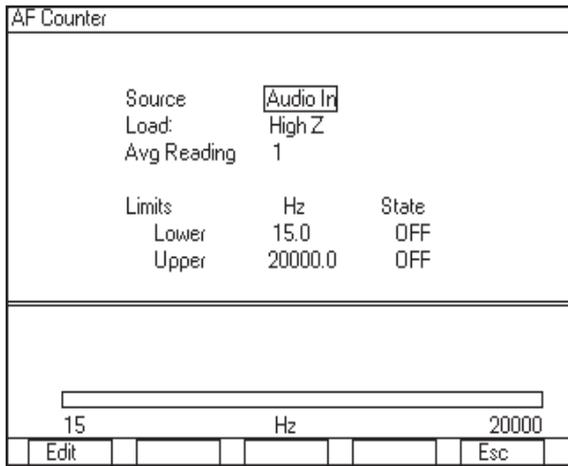


Figure 10 - AF Counter screen

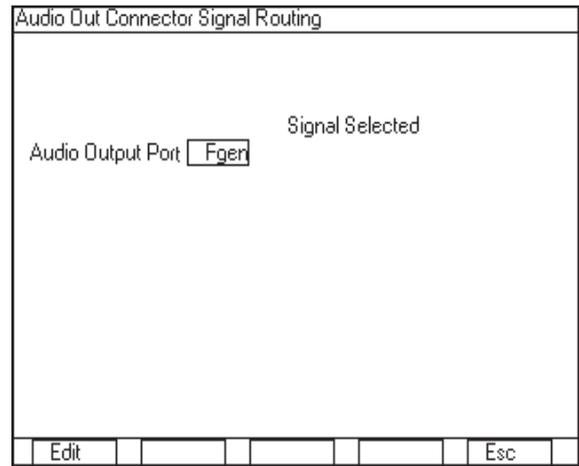


Figure 12 - Audio out connector signal routing

18. Press the Edit softkey and toggle the Source field to be Demod.
19. Make sure that Avg Reading is set to 1.
20. Press the Esc key to return to the TRANSMITTER TEST screen
21. Now the TRANSMITTER TEST screen should look like Figure 11.

25. Press the Edit key and then toggle the Audio Output Port to be Fgen. Press the Done softkey and then press the Esc softkey.
26. Connect a cable from the 3500 T/R port to the transmit port of the radio under test.
27. Connect the 3500 handset and then connect a cable from the 3500 handset "AUDIO OUT" BNC connector to the audio in port of the radio under test.

Note The audio in port of the radio under test will vary from radio to radio. The type of connector is dependent on the manufacture of the radio.

28. Turn on the transmitter of the radio under test and wait a few seconds for the RF Power meter on the 3500 to settle. See Figure 13.

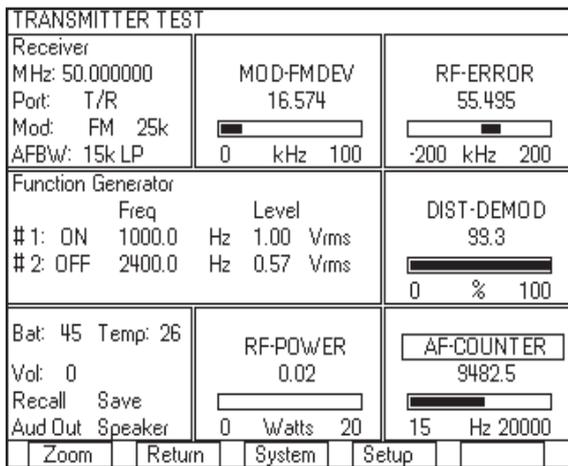


Figure 11 - TRANSMITTER TEST screen

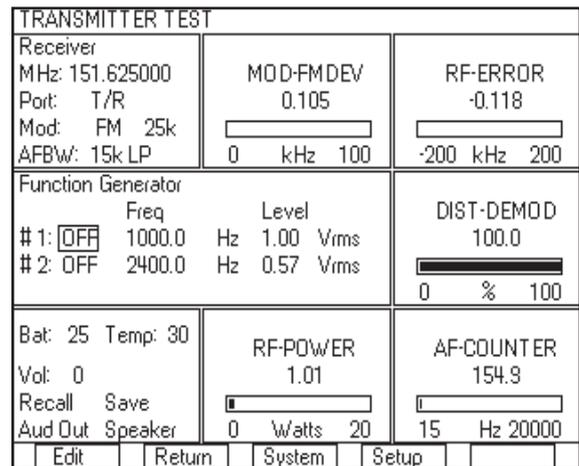


Figure 13 - Measuring power of an FM transmitter

22. Move the cursor to the Function Generator #1 field. Press the Edit key and then toggle the field to OFF. Press the Done softkey.
23. In the same manner, turn Function Generator #2 off.
24. Move the cursor to the Aud Out field and press the zoom softkey. The Aud Out setup screen should appear (See Figure 12)

29. Record the RF Power reading from the RF-POWER meter.
30. Record the RF Frequency error reading from the RF-ERROR meter.
31. Move the cursor to the Function Generator #1 field. Press the Edit key and then toggle the field to ON. Press the Done softkey.

32. Move the cursor to the Function Generator Freq field. Set the field to 1000.0 Hz and press the Done key.
33. Move the cursor to the Function Generator Level field. Set this field to a level that will produce approximately 3 kHz of FM deviation or 60% of AM modulation in the radio under test. This level will vary depending on the radio, but should be consistent each time this radio is tested. Press the Done softkey.

Note: The level that you set the FGEN to is in volts, but the resulting measurement that you take is in kHz of deviation for FM or % modulation for AM. The specification of the radio under test may include a specification for audio sensitivity. The audio sensitivity is the input rms voltage level that you must apply to the input terminals of the dummy microphone circuit to produce the standard test modulation .

34. Wait a few seconds for the Modulation meter to settle.
35. Record the Modulation reading. This value will be in kHz for FM modulation and represents the FM deviation. For AM, the value will be in % modulation. If the modulation is SSB then record the RF Frequency error reading as the Modulation. The 1000.0 Hz AF Gen tone should produced an RF freq error of 1.000 kHz (\pm frequency error of radio under test).
36. For AM and FM signals record the distortion (DIST-DEM0D) and audio frequency (AF-COUNTER). The audio frequency should be 1000 Hz, since it should match Function Generator #1.

You should repeat this procedure for each modulation type and frequency band of the radios that you are testing.

Evaluating the Results

Each one of the parameters that we measured should be less than the specification of the radio under test. If you have a specification, you should have a relatively easy time of determining whether the transmitter has a problem or not. If you do not have the specification for any of these parameters, then you should compare the results with a known good radio.

Receiver Test Procedure for Direct Connect

The direct connect receiver test is very similar to the over-the-air test. The major difference, as you will see, is that with a direct connect we will be able to perform an accurate measurement of the squelch and sensitivity of the radio. In addition, we can measure the amount of distortion in the received audio. Here is a list of the tests:

- Squelch Open Test
- Squelch Close Test
- Sensitivity Test
- Distortion Test

The testing that we perform with a direct connect is not a subjective test as it was over the air. Therefore, each one of these tests should meet or exceed the specification of the radio.

Step by Step Procedure

For this testing, we are going to use the 3500 Receiver Test screen (Figure 14). To get to this screen from the Transmitter Test screen, press the Return softkey and then select "1 - RECEIVER TEST". If you are in the System menu, you should press "4-BENCHTOP", and then "1 - RECEIVER TEST".

We are going to start by adding some meters to the RECEIVER TEST screen.

1. Press the Setup softkey and the screen shown in Figure 14 appears.

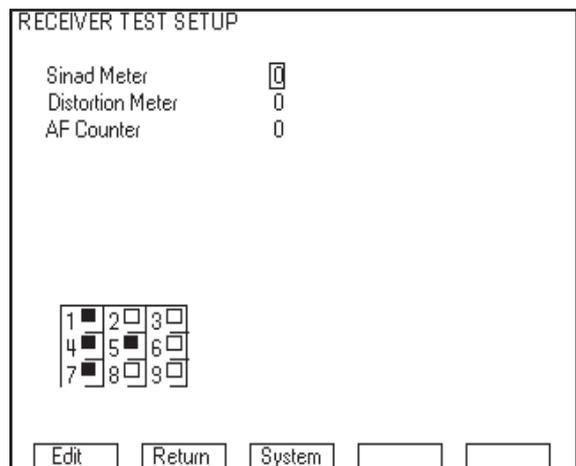


Figure 14 - RECEIVER TEST SETUP screen

2. Move the cursor to Sinad Meter and set to 3. Press the Done softkey.
3. In the same manner, set Distortion Meter to 6 and AF Counter to 9 and then press the Return softkey.

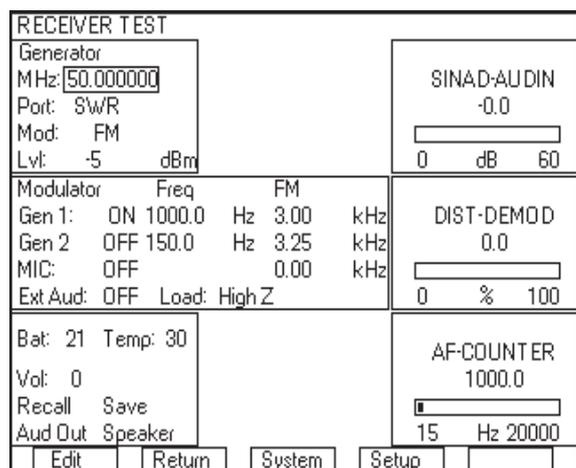


Figure 15 - RECEIVER TEST screen after setup

These next steps are the setup for the RECEIVER TEST screen.

4. Move the cursor to the SINAD meter. Press the Zoom softkey and the screen shown in Figure 16 should appear. Make sure that the Source is Audio In and the Avg Reading is 1. Press the Esc softkey to return.

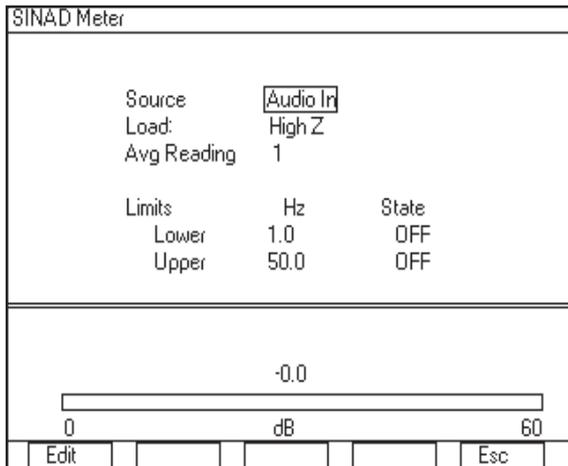


Figure 16 - SINAD Meter screen

5. Move the cursor to the DIST meter. Press the Zoom softkey and the screen shown in Figure 17 should appear. Make sure that the Source is Audio In and the Avg Reading is 1. Press the Esc softkey to return.

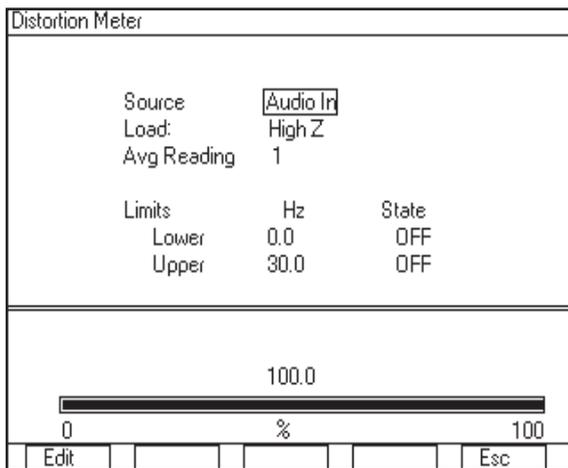


Figure 17 - Distortion Meter screen

6. Move the cursor to the AF-COUNTER meter. Press the Zoom softkey and make sure that the Source is Audio In and the Avg Reading is 1. Press the Esc softkey to return.
7. Move the 3500 cursor using the arrow keys to the Generator MHz field and set the MHz field to the frequency of the radio under test. Press the Done softkey.
8. If the modulation type of the radio under test is Single Side Band (also called SSB, USB, LSB, UV, or LV), we will create this modulation by offsetting the value of the MHz field by 1000 Hz. For Upper Side Band (also called USB or UV) increase the field by .001000 MHz (1000 Hz). For Lower Side Band (also called LSB or LV) decrease the field by 0.001000 MHz (1000 Hz). This will create a 1000 Hz SSB modulation on the carrier. Press the Done softkey.

Example for SSB: If the frequency of the radio is 8.000000 Mhz, then to add an LSB set the frequency to 7.999000.

9. Move the cursor to the Port field. Press the Edit softkey and then toggle the setting to T/R using the up/down arrow keys. Press the Done softkey.

10. Move the cursor to the Mod field. If the modulation type is AM or FM then press the Edit softkey and set the Mod field to the modulation type of the radio under test. If the modulation type is SSB (USB, LSB, UV or LV), then you should select OFF for modulation type. Press the Done softkey.

11. Move the cursor to the Lvl unit's field (dBm or uV). Press the Edit softkey and using the up/down arrow keys select dBm. Press the Done softkey.

12. Move the cursor to the Lvl field and set the Lvl field to -80.0 dBm. Press the Done softkey.

The next several steps are for AM and FM modulation only. You should skip these for SSB modulation.

13. Move the cursor to the Modulator Gen1 ON/OFF control field. Press the Edit softkey and using the up/down arrow keys, set the Gen1 ON/OFF field to ON. Press the Done softkey.

14. Move the cursor to the right to the Modulator Freq field and set the frequency to 1000.0 Hz. Press the Done softkey.

15. Move the cursor to the next field to the right (the AM modulation index or FM deviation field). If the modulation is AM then this field should be set to 80 %. If the modulation is FM then this field should be set to 3.00 kHz.

16. Move the Cursor to the Gen 2 / DCS field. Press Edit and toggle to DCS.

17. Move the cursor to the right to the ON/OFF field. Press Edit and toggle to OFF.

18. Move the cursor back to the DCS field. Press Edit and toggle to Gen 2.

19. Move the cursor back to the ON/OFF field. Press Edit and toggle to OFF.

20. In the same way, make sure than Ext Aud, and MIC are OFF.

These next steps are for finding the squelch points of the radio under test.

21. Connect a cable from the 3500 T/R port to the receive or antenna port of the radio under test.

22. Connect the 3500 handset and then connect a cable from the 3500 handset "Aud In" BNC connector to the audio out port of the radio under test.

Note: The audio out port of the radio under test will vary from radio to radio.

23. If the radio under test has a squelch On/Off switch, make sure that it is on.

24. Move the cursor to the Lvl field. Press the Edit softkey and using the left arrow key, select the "10s" digit of the Lvl field.

25. Using the down arrow key, step the Lvl field down in 10 dB steps until you can no longer hear the 1000 Hz tone.

Note: The minimum level that the 3500 can generate is -120 dBm, so if you reach -120, but can still hear the test tone, then you will know that the squelch level is less than -120 dBm. Record <-120 dBm as the squelch open and close point and then move to step 28.

26. Using the right arrow, select the "1s" digit of Lvl.
 27. With the up arrow, increase the level in 1 dB steps until you can hear the 1000 Hz tone.
 28. Record the value in the Lvl field as the squelch open point.
 29. Using the down arrow, decrease the level in 1 dB steps until you can no longer hear the 1000 Hz tone.
 30. Record this value in the Lvl field as the squelch close point.
- Continue from this point to do the second part of the test, the relative sensitivity test.
31. If the radio has as squelch On/Off switch, then switch the squelch off.
 32. Increase or decrease the level in 1 dB steps, using the up/down arrow keys, until the SINAD-AUDIN meter reads about 12 dB.

33. Record the value in the Lvl field as the Receiver Sensitivity.

These next few steps are for the distortion measurement.

34. Move the cursor to the Lvl field. Press the Edit softkey and set the Lvl field to -50. Press the Done softkey.
35. Wait for the DIST-AUDIN meter to settle.
36. Record the DIST-AUDIN as the distortion of the radio under test. You should also record the AF Counter value. If the AF-Counter is measuring something other than 1000 Hz, then the Distortion measurement is not valid, as the 3500 only measures distortion on a 1000 Hz tone.

You should repeat this procedure for each band and modulation type of the radios in the radio communication system. I have included a sample table for recording the results in table 3.

Radio	BAND-MOD	Squelch		Sensitivity	Distortion	AF Counter
		Open	Close			
UHF Radio	UHF-AM					
	VHF/UHF #1	VHF-AM				
		VHF-FM				
	UHF-AM	UHF-AM				
UHF-FM						
VHF/UHF #2	VHF-AM					
	VHF-FM					
	UHF-AM					
	VHF-FM					
HF Radio	HF-AM					
	HF-LSB					
	HF-USB					

Table 3 - Receiver Test Matrix

Evaluating the Results

Compare the results of this test to the specification of the radio. If you do not have a specification, then compare the results with a known good "baseline" radio.

PART III - ANTENNA AND CABLE TESTING

This next group of tests that we will perform will tell us if the cabling and antenna of the installed radio system is working correctly. With the 3500 we will be able measure the VSWR and return loss of the antenna, and the loss and the distance to fault of the cable. Each one of these measurements will be useful to us

in determining where any potential problem in the installed radio system may be. We will make these measurement from the SWR TEST screen. To get to this screen from the system level menu in the 3500, select "2 - SWR TEST".

Calibrating the SWR TEST screen

Before we make any of the measurements on the SWR TEST screen, we will need to perform calibration. The purpose of this calibration is to normalize out the affects of temperature, connectors, or any cables that you may use as a connection to the cable and/or antenna under test. We will perform this procedure from the SWR TEST screen.

1. You start the calibration procedure by pressing the Cal softkey. The screen shown in Figure 18 should appear.

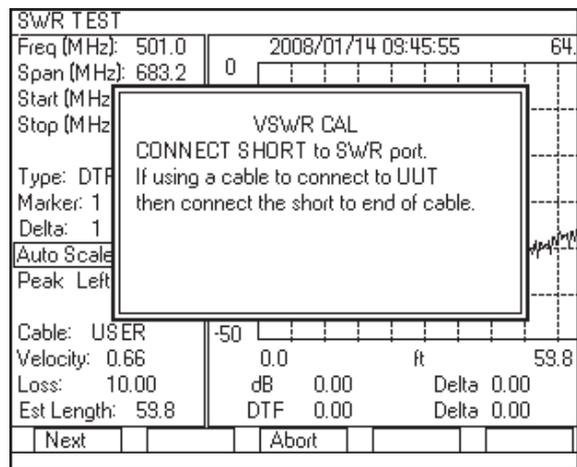


Figure 18 - SWR Test screen with Cal procedure started

2. Included with your 3500 should be a Short-Open-Load that looks like Figure 19.



Figure 19 - Short-Open-Load Calibrator Device

3. As instructed on the screen, connect the SHORT to the SWR port. If you are using a test cable to connect the 3500 to the cable under test, then you should connect the SHORT to the end of the test cable. Press the Next softkey.

Note: You may need to locate an appropriate adapter to connect the calibrator device to the 3500.

4. After this first step completes, another message box will appear with the next instructions. As instructed on the screen, connect the OPEN to the SWR port. Press the Next softkey.
5. After this second step completes, another message box will appear with more instructions. As instructed on the screen, connect the LOAD (or the 50 ohm load) to SWR port. Press the Next softkey.

6. After this third step completes, another message box will appear, telling you that the calibration is complete. Press the Done softkey.

Measuring Distance to Fault

The distance to fault is the first measurement that we will make, since if there is a break in the cable, there is not much point in measuring the VSWR or return loss of the antenna. If you know the length of the cable that connects the radio to the antenna then you will be able to tell from this measurement if there is a break in the cable. If you don't know the length of the cable then this measurement will provide you either with the length of the cable or the distance to fault, since a break in the cable will look the same as the end of the cable. If the fault in the cable is not a hard break, but simply a problem with a connector or some kind of flaw, then the distance to fault measurement will show both the fault and the end of the cable. Figure 14 shows a graph of distance to fault which shows both a fault and the end of the cable. This graph is a plot of the return loss of the cable versus distance. Since a fault in the cable creates a higher return loss, any spike in the graph indicates that a fault is located at that distance. In Figure 20, marker 1 is located at a fault in the cable and marker 2 is the end of the cable. The DTF field below the graph indicates the location of the active marker, marker 1, with a location of 7.05 ft.

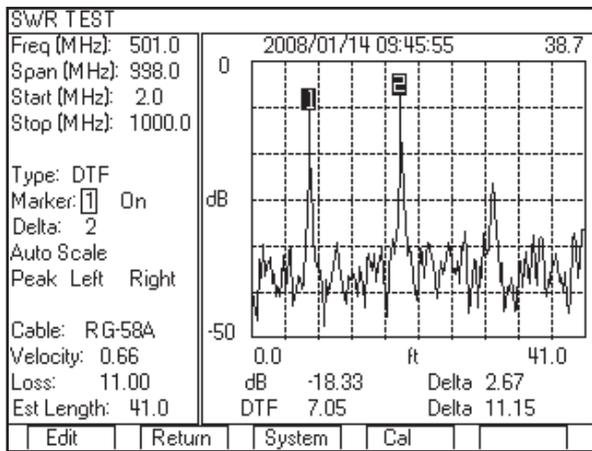


Figure 20 - DTF showing cable fault and end of cable

The following is a step by step procedure is for making a distance to fault measurement of a cable.

Step by Step Procedure

1. Move the cursor to the type field. Press the Edit softkey, and then using the arrow keys toggle the value to be DTF. Press the Done softkey.
2. Move the cursor to the cable field. Press the Edit softkey, and then using the arrow keys toggle the value to the cable type you are testing. Press the Done softkey.
3. Move the cursor to the Ext Cable field. Enter what you estimate the length of the cable to be plus about 30%. Press the Done softkey.
4. Connect the cable that you are testing to the 3500 SWR port. If you are using a test cable to connect to the cable under test, you should connect the cable under test to the end of the test cable.

5. Each analysis of the cable takes about 7 seconds. Wait for a couple of updates of the graph to occur.

6. The graph should now indicate with a spike any faults in the cable and the end of the cable. The graph may look something like figure 15 or if there is no fault in the cable, there should only be one spike in the graph. One spike in the graph with a location equal to the actual length of your cable is indicative of a good cable.

7. To find the location of the fault we will use a marker. Move the cursor to the Marker field and select 1.

8. Move the cursor to the right to the On/Off field. Press the Edit softkey; toggle the value to On, and then press Done.

9. Move the cursor to the Peak/Move field. Press the Edit softkey; toggle the value to Peak, and then press Done.

10. Move the cursor to the right to the Right field. Press the Enter key until the marker has moved to the peak. The field below the graph labeled DTF should now indicate the distance to fault.

Measuring VSWR and Return Loss

VSWR and Return Loss are really the same measurements, but with different units. Both of these measurements are an indication of how much of the generated power is reflected back by the antenna. Ideally, all of the power that the radio generates would be transmitted out the antenna. In reality, though, some of the power will always be reflected back. Return loss is a measurement of the ratio of the amount of power reflected (in watts) to the amount generated (in watts) by the radio. Stated in dB, return loss is the difference between the reflected power and the transmitted power. The 3500 displays return loss in dB versus frequency.

Similarly, VSWR is also a ratio. It is a ratio of the maximum peak to peak voltage to the minimum peak to peak voltage present at any point on the cable. Since it is difficult to measure voltages at different points along the cable, this measurement is made by calculating it from the reflection coefficient.

$$\text{Reflection coefficient} = V_{\text{reflected}} / V_{\text{generated}}$$

and

$$\text{VSWR} = (1 + \text{Reflection coefficient}) / (1 - \text{Reflection coefficient})$$

The VSWR is always going to be greater than 1. A perfect antenna with no reflection has a VSWR of 1. Most antennas have a specification stating what the VSWR or the return loss should be at a certain frequency.

The following is a step by step procedure for measuring the VSWR or return loss. We will make this measurement from the same screen that we measured the distance to fault.

Step by Step Procedure

1. Move the cursor to the Type: field. Press the Edit softkey, and then using the arrow keys toggle the value to be SWR. Press the Done softkey.
2. Move the cursor to the Start (MHz) field and enter the start frequency. The 3500 will start the VSWR sweep on this

frequency. Press the Done softkey.

3. Move the cursor to the Stop (MHz) field and enter the stop frequency. The 3500 will stop the VSWR sweep at this frequency. Press the Done softkey.
4. Connect the antenna or the cable that you have connected to the antenna to the SWR port.
5. Wait for a couple of sweeps to complete.
6. The SWR TEST screen should look something like Figure 21. The display is showing the VSWR of the antenna versus frequency.

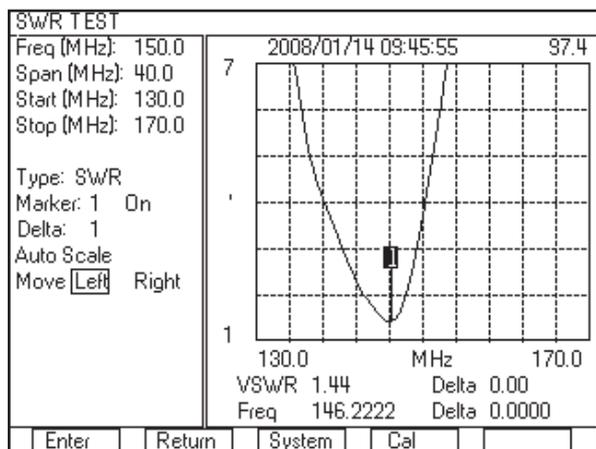


Figure 21 - SWR TEST screen showing VSWR

You can use this same procedure to find the return loss of the antenna versus frequency. The only difference to the procedure is that in step 1 you should toggle the Type: field to RL. After a couple of sweeps, move the cursor to the Auto Scale field. Press the Enter softkey. The result is a display that looks something like Figure 22.

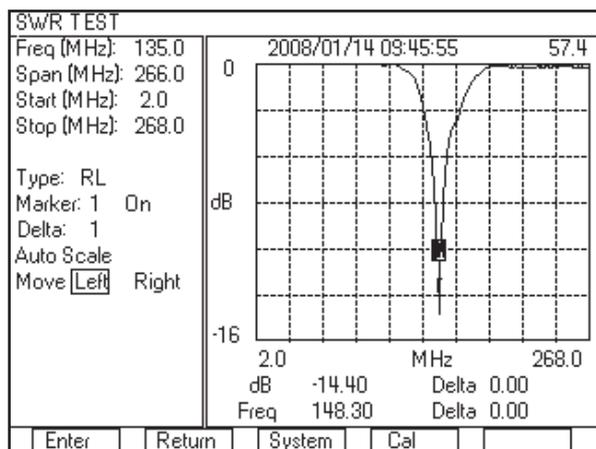


Figure 22 - SWR TEST screen showing RL (return loss)

Measuring Cable Loss

The final measurement that we can perform is the Cable Loss measurement. This measurement will be able to tell us what the loss of the cable is over the frequencies that we want to use the cable. We can perform this test by connecting just one end of the

cable that we are testing to the SWR port. The other end of the cable must not be connected to anything. It must be left open or the measurement will be incorrect.

Step by Step Procedure

1. Move the cursor to the Type: field. Press the Edit softkey, and then using the arrow keys toggle the value to be LOSS. Press the Done softkey.
2. Move the cursor to the Start (MHz): field and then enter the start frequency for the cable sweep. Press the done softkey.
3. Move the cursor to the Stop (MHz) field and then enter the stop frequency for the cable sweep. Press the done softkey.
4. Connect one end of the cable to the SWR port. You must leave the other end of the cable unconnected. If it is connected to an antenna, then the antenna must be disconnected.
5. Wait for a couple of sweeps to complete. Each sweep will take about 7 seconds.
6. The display should now look something like Figure 23.

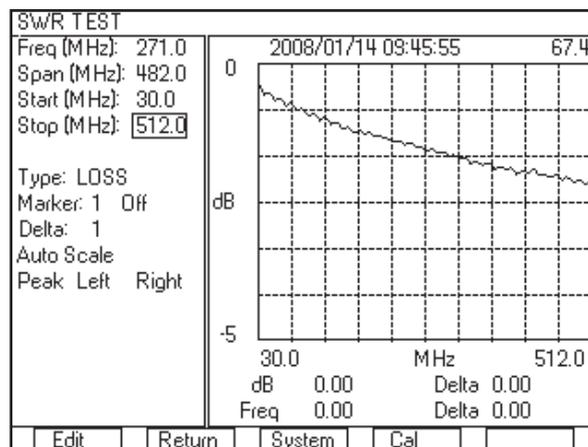


Figure 23 - SWR TEST screen showing cable loss

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