Measuring isolation and insertion loss in Tx-Rx switches

T-R relays can be a source of several problems. Low transmitter power, poor receiver sensitivity and even intermod interference problems.

**TRANSMITTER POWER LOSS**
Transmit power loss caused by the relay is easily isolated by measuring output power with and without the relay.

**RECEIVER SENSITIVITY LOSS**
Receiver sensitivity loss is isolated by measuring the transmission loss at the receiver frequency. Sensitivity loss is more apt to be an intermittent problem due to the lack of power to punch through the thin corrosion layer on the receive contacts.

**T-R RELAY MAY BE AN INTERMOD SOURCE**
Corrosion on contacts may act as a diode, creating an unwanted mixer when excited by strong RF signals from the antenna.
Measuring isolation and insertion loss in Tx-Rx switches

See facing page for actual connections.

Use 10dB/DIV for loss measurements of 10dB or more.

Use 1dB/DIV for higher resolution measurements (<10dB)

Use VERT POS to re-center reference.

Always "calibrate out" cable and connector loss at each frequency of interest.
Monitoring SSB & ACSB testing

SSB

Single Sideband signals are easily monitored with the 1500's MODULATION switch in the SSB position. An accurate phase locked beat frequency signal [BFO] is automatically injected on the 1500's last IF frequency.

SSB Frequency error

Setting the frequency of a SSB transmitter is easiest when the transmitter can be switched or jumped into a CW mode. Sometimes the carrier balance control can be misadjusted slightly to produce a small CW signal. The frequency can then be read conventionally on either the digital or analog Error Meter. (See pages 34-35 for 0.1 Hz resolution method.)

If CW operation is not practical, the precision frequency audio generator capability of TONE 1 is used to modulate the SSB transmitter with a 1,000.0 Hz tone.

The 1500's FREQUENCY is then set 1 kilohertz above or below the suppressed carrier frequency depending upon whether the upper or lower sideband is used.

The frequency error can then be read directly on the digital DISPLAY in the METER position or on the analog FREQ ERROR meter.

Marine radio note: To achieve the ±20 Hz accuracy required by FCC for marine HF radios, the oven option must be installed in the 1500.

ACSB TRANSMITTER TESTS

To confirm compressor performance:

Monitor through the ANTENNA port as shown on facing page.

Set FREQUENCY to suppressed carrier of ACSB signal.

With modulation turned off, key transmitter and note that FREQ ERROR meter reads the frequency of the pilot tone.

Modulate transmitter with TONE 1 at 1000.0 Hz. When modulation is at maximum, the FREQ ERROR meter should read 1 kHz.

ACSB Frequency error

Use either digital or analog FREQ ERROR meter to measure the frequency error of the unmodulated ACSB signal. The unmodulated signal will be 3.1 kHz above the suppressed carrier.

Viewing transmitter modulation envelope

Reset DISPLAY to SCOPE.

Modulate the transmitter with TONE 1 set at 1800 Hz.

Adjust TONE 1 level to display a modulation envelope. Adjust HORIZ VERNIER for a stable display.

Overdriving the transmitter output causes flattening of peaks. Watch for parasitic oscillations which appear as a fuzzy halo on the envelope.

ACSB RECEIVER TESTS

SRTM (Standard Receiver Test Modulation) [test signal with pilot and 1 kHz test tone.]

Set FREQUENCY MHz to the suppressed carrier +1 kHz.

Set MODULATION switch to AM1.

Set TONE 1 to 2100.0 Hz. Set the modulation level to 63%.

To measure SINAD:

Connect audio output to SINAD input.

Increase RF level to achieve 12 dB SINAD.

Checking pilot capture & AFC tracking

After achieving 12 dB SINAD, vary TONE 1 frequency in hundred hertz steps from 1400 Hz to 3000 Hz to make sure that receiver tracks the pilot tone. SINAD indication should remain constant.

Receiver capture of pilot: Set radio squelch to threshold with no RF. Increase RF level until squelch opens.

Vary FREQUENCY MHz ±500 Hz.

SINAD should remain constant.

Checking receiver expander

Set FREQUENCY MHz to suppressed carrier frequency.

Set TONE 2 to 1000 Hz. Set modulation to 20% with TONE 2 level control.

Set TONE 1 to 3100.0 Hz. Increase TONE 1 to obtain 40% total modulation.

View radio's 1 kHz speaker audio on SCOPE.

Increase / decrease 1 kHz (TONE 2) level. Audio level should change correspondingly.
Monitoring SSB & ACSB testing

RECEIVER TEST SETUP

Sensitivity is measured using the same connections as any other radio. (see page 10-11 for SINAD setup)

TRANSMITTER TEST SETUP

A coupler and an external load are necessary on SSB & ACSB if the RF output with no modulation is less than 100 milliwatts.

The 1500's TRANS port has a 100 mw power detector that switches in an 80 dB path between the TRANS and ANTENNA ports for viewing transmitter signals on the analyzer.

With average power levels varying through this 100 milliwatt threshold during modulation, the 1500 will toggle back and forth.
Synchronizing Simulcast Transmitters

Simulcasting requires that the RF frequency of all of the transmitters be set very close to each other. The 1500 is capable of measuring the frequency direct or off the air with a resolution of ± .1 Hz. The needle trend of the analog FREQ ERROR meter makes coarse frequency setting easy. The digital FREQ ERROR shown on the DISPLAY in the METER position provides ±1 count resolution.

Off-the-air checking would of course require that you have control of each individual transmitter from the measurement site or be able to discriminate between received signals so you know which transmitter you’re receiving.

Note: The standard 1500 will resolve RF signals to 0.1 Hz, but the frequency stability required for simulcast testing requires the oven oscillator option be installed.

Allow the 1500 at least 15 minutes warm-up from a cold start before attempting accurate frequency setting. The oven can be kept hot between transmitter sites by using the cigarette lighter plug to run the 1500 on the service vehicle battery.

CAUTION: It is wise to unplug the cord during the vehicle starting process to protect the 1500 from those brutal transients!

For 1 Hz resolution

The 30 Hz FREQ. ERROR position on the analog FREQ. ERROR meter provides 1 Hz resolution so it’s as easy as setting the 1500’s FREQUENCY to the desired and tweaking first one transmitter to zero and then the other to zero on the error meter.

The digital error display shown when the DISPLAY switch is in the METER position will also reflect the frequency error ±1 Hz.

For 0.1 Hz resolution.

Tenth Hertz resolution is available by switching the MODULATION to SSB. In the SSB position a phase locked beat frequency oscillator is injected into the 1500’s last IF. This BFO produces an audio beat note which may then be compared to TONE 1 with the difference displayed on the FREQ. ERROR meter and read out on the CRT digital DISPLAY in the METER position.

EXAMPLE

Suppose that you wanted to set a transmitter to a frequency that was not on an even hundred hertz step, say 155.500145. 145 Hz above 155.5.

Setting the 1500’s FREQUENCY MHz will get you to 155.5001. With the FREQ. ERROR switch in the 100 Hz position you can see the +45 Hz error on the meter.

Key in 45.0 Hz in TONE 1 and switch the FREQ. ERROR switch to 300 Hz AUDIO. Tweak the transmitter frequency to center the needle on the FREQ. ERROR meter. Switch down to 3 Hz position to center it within a tenth hertz.
Synchronizing Simulcast Transmitters

Transmitter "A"

Transmitter "B"
Measuring Antenna Isolation

With antenna site space a valuable commodity, multiple antennas in close proximity are a fact of life. Isolation between antennas becomes important to reduce the possibility of intermod interference.

To measure the isolation between antennas, one antenna is fed with the tracking generator (TRANS port) and the 1500's receiver / spectrum analyzer (ANTENNA) is connected to the other antenna.

The transmission loss versus frequency curve is then displayed directly on the analyzer.

For most UHF and low gain VHF antennas, one measurement is usually sufficient because the antenna selectivity doesn't affect the measurement appreciably. In the adjacent example, there was essentially no difference in the measurement curves because both antennas were cut the same.

When high gain/narrow band antennas are used, the measurement procedure should be done twice. Swap coax lines and re-measure the loss. The curves will be different due to the selectivity of each antenna.

Check for possible front end overload levels before making this measurement by setting the FREQUENCY to 500 MHz and the ANALY DISPR to FULL. Look for any signals that exceed the top of the display. If there are any, switch in the 20dB ATTENUATOR.

Re-couple the connecting coax test cables to each other and increase the RF output to re-establish a "top of the screen" reference.

EXAMPLE

A single four stack collinear array was split into two 2 stack collinear UHF arrays, separated by about 10 feet vertically.

The 35-40 dB isolation between these two antennas proved to be marginal and created some intermod problems.

Control settings for the above measurements:

- DISPLAY: TRACK
- FREQUENCY: 462.0 MHz
- ANALY DISPR: 2 MHz/DIV
- DB/DIV: 10
- GEN/REC: GEN
- ATTENUATOR: 0dB
- RF OUTPUT: -30 dBm
CAUTION: Be sure to discharge any outside antenna coax before connecting to the 1500's ANTENNA port to reduce the possibility of static damage to the front end.

Antenna Isolation: 1
5/31/86
50%

Measuring Antenna Isolation

APPROXIMATE ISOLATION PROVIDED BY ANTENNA SEPARATION

ATTENUATION PROVIDED BY VERTICAL SEPARATION OF DIPOLE ANTENNAS

ATTENUATION PROVIDED BY HORIZONTAL SEPARATION OF DIPOLE ANTENNAS

Antenna Spacing in Feet

20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200 210 220 230 240 250 260 270 280 290 300 310 320 330 340 350 360 370 380 390 400 410 420 430 440 450 460 470 480 490 500 510 520 530 540 550 560 570 580 590 600 610 620 630 640 650 660 670 680 690 700 710 720 730 740 750 760 770 780 790 800 810 820 830 840 850 860 870 880 890 900 910 920 930 940 950 960 970 980 990 1000

Isolation in dB

20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200 210 220 230 240 250 260 270 280 290 300 310 320 330 340 350 360 370 380 390 400 410 420 430 440 450 460 470 480 490 500 510 520 530 540 550 560 570 580 590 600 610 620 630 640 650 660 670 680 690 700 710 720 730 740 750 760 770 780 790 800 810 820 830 840 850 860 870 880 890 900 910 920 930 940 950 960 970 980 990 1000

Antenna Spacing in Feet

(average separation)
Tuning Antennas for Minimum VSWR

Using a VSWR BRIDGE

A VSWR bridge\(^1\) used with the tracking generator/spectrum analyzer can provide more useful antenna information than a directional wattmeter. The VSWR bridge method will tell you the frequency where resonance occurs. By knowing the resonant frequency, you’ll know which way to tune it. You won’t have to tell the boss, “I cut it off and cut it off and it’s still too short.”

NORMAL procedure

The bridge method is simple, just connect the bridge as shown leaving the DUT (“DEVICE UNDER TEST”) port open. Raise the RF output to set the trace to the top line at the center of the screen for your REFERENCE. Connect the antenna to the DUT port and read the return loss at center screen. The deeper the dip, the more power is being absorbed. The width of the dip is determined by the bandwidth of the antenna. A “broadbanded” antenna will have more than one tuned element and will display more than one dip.

HIGH RESOLUTION procedure

The 10 dB/DIV scale will show major antenna deficiencies. Definitive measurement of VSWR of less than 2 to 1 is best accomplished by using the 1 dB/DIV setting to increase the display resolution. The return loss is then read using the dB scale of the RF output dial.

Connect the bridge as shown leaving the DUT port open. Set the RF output to -40 dBm. Bring the trace back to mid-screen with the VERT POS control, this becomes your REFERENCE POSITION. Connect the device being tested to the DUT port. Bring the trace back to the REFERENCE POSITION by increasing the RF level to compensate for the RETURN LOSS. Subtracting the new RF dial reading from the -40 dBm reference gives you the RETURN LOSS. Use the CONVERSION CHART to determine VSWR.

| RETURN LOSS - VSWR - REFLECTED POWER |
| --- | --- | --- | --- | --- |
| Return Loss | VSWR | %REFL | Return Loss | VSWR | %REFL |
| dB | | | dB | | |
| 1.0 | 17.4 | 79.4 | 16.0 | 1.38 | 2.5 |
| 2.0 | 8.72 | 63.1 | 17.0 | 1.33 | 2.0 |
| 3.0 | 3.88 | 50.1 | 18.0 | 1.29 | 1.8 |
| 4.0 | 4.42 | 56.6 | 19.0 | 1.25 | 1.5 |
| 5.0 | 3.57 | 31.6 | 20.0 | 1.22 | 1.0 |
| 6.0 | 3.01 | 25.1 | 22.0 | 1.17 | 0.6 |
| 7.0 | 2.61 | 20.0 | 24.0 | 1.13 | 0.4 |
| 8.0 | 2.32 | 15.6 | 26.0 | 1.11 | 0.3 |
| 9.0 | 2.10 | 12.6 | 28.0 | 1.08 | 0.16 |
| 10.0 | 1.93 | 10.0 | 30.0 | 1.07 | 0.10 |
| 11.0 | 1.78 | 7.9 | 32.0 | 1.06 | 0.06 |
| 12.0 | 1.67 | 6.3 | 34.0 | 1.04 | 0.04 |
| 13.0 | 1.58 | 5.0 | 36.0 | 1.03 | 0.03 |
| 14.0 | 1.45 | 4.0 | 38.0 | 1.03 | 0.02 |
| 15.0 | 1.43 | 3.2 | 40.0 | 1.02 | 0.01 |
Reference = Bridge with open N to BNC adaptor.

Scope photos are double exposures to show both reference and unknown VSWR.

50 Ω BNC termination connected directly through N to BNC adaptor.

FREQUENCY = 500 MHz
ANALY DISP = FULL

Reference = 17 ft. RG-58 with open BNC barrel.
Reference drop due to coax loss.

Same 50 Ω termination as above except it's on the end of 17 ft. of RG-58 coax.

Reflected power ripples, caused by summing of reflection vectors, must be averaged to approach accurate VSWR.

MORAL: Connect bridge DIRECT to antenna if possible.

Reference = 17 ft. RG-58 with open BNC barrel.
Reference drop due to coax loss.

Same 50 Ω termination at the end of 17 ft. of RG-58 coax.

ANALYZer DISPersion set at 10 MHz / DIV.

Dotted line indicates average of ripple.