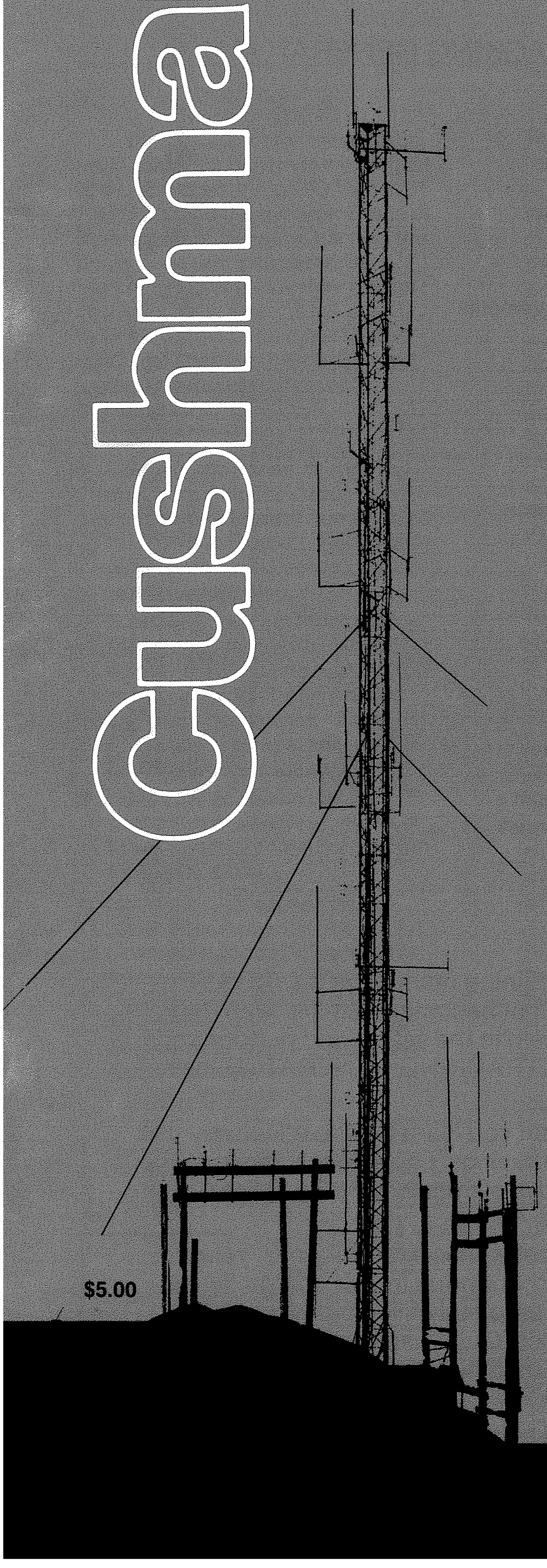
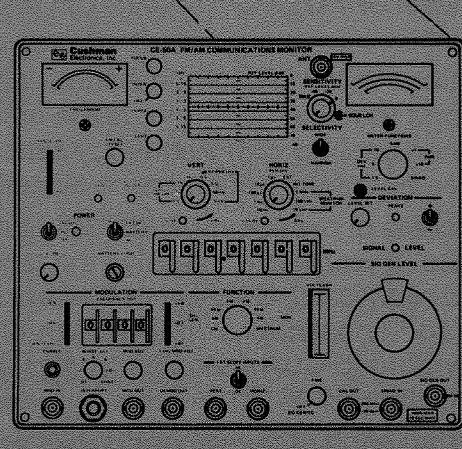
Cushman



MOBILE RADIO TESTING

Using the Cushman CE-50A Series and CE-5110 Communications Monitors

Part 3-Spectrum Monitor and Tracking Generator



$5.00

MOBILE RADIO TESTING
USING THE CUSHMAN CE-50A SERIES AND CE-5110 COMMUNICATIONS MONITORS

PART 3 – SPECTRUM MONITOR AND TRACKING GENERATOR

TABLE OF CONTENTS

To the two-way radio service technician...

This booklet is the last in a series designed for use as a training manual on the CE-50A Series Communications Monitor. It is important to note that becoming familiar with Part 1 — TRANSMITTERS and Part 2 — RECEIVERS will help in the set-up and performance of the more advanced level SPECTRUM MONITOR and TRACKING GENERATOR tests described in this booklet.

The most significant things that will become evident when you learn how to effectively use the spectrum monitor and tracking generator is the time savings, improved dynamic range, and better accuracy when dealing with frequency sensitive elements, whether it is a circuit in the radio or some element of the transmission system.

In order to control the costs of producing and mailing each series of handbooks, your cooperation is requested. If you want to receive the next handbook free of charge, fill out and return the attached reply card. Only cards that are completely filled out will be honored. If you would like additional copies, contact your local Cushman representative, or make your request in writing to Cushman Electronics, Customer Relations, 2450 North First Street, San Jose, California 95131.

It is our sincere desire that each of these handbooks will help you to fully utilize the many capabilities of Cushman's service monitors, and in so doing improve your service effectiveness.

A Few Words About Measuring Harmonics

When you want to measure the harmonics of a transmitter you must use an HP filter or high "Q" notch filter to extend the dynamic range of input attenuator. Figure 1 shows the correct test set up to measure transmitter harmonics. The reason you need the coupler is to keep from blowing out the input to the spectrum analyzer. Figure 2 shows a typical response curve for a highpass filter.

TEST PROCEDURE:

1. Connect the transmitter to the spectrum monitor through an RF coupler or a tee and dummy load, as shown in Figure 1. Temporarily remove the high pass or band reject (notch) filter.
2. Tune the Spectrum Monitor to the transmitter frequency and display the signal peak at the top of the CRT (don't worry about any distortion you see at this point; you're temporarily overloading the instrument).
3. Adjust the coupler or tee for maximum allowable signal level to the Spectrum Monitor. (0 dBm for the CE-50A-1)
4. Insert the high pass or band-reject filter in front of the Spectrum Monitor to reduce the transmitter signal. In this case, the filter must provide at least 60 dB attenuation at the carrier frequency to keep the input level below -60 dBm.
5. Tune the Spectrum Monitor through the band of interest, measuring the levels of harmonics and other spurious signals.
6. Correct the measured levels for the frequency response of the coupler or tee and the filter. For example, the correction factor for a capacitive tee is 6 dB per octave. If you're not sure about the correction factor, you can easily use the Spectrum Monitor to measure the frequency response. Insert coupler between a flat (calibrated) signal generator and the Spectrum Monitor. Then vary the frequency of the signal generator to measure the frequency response.

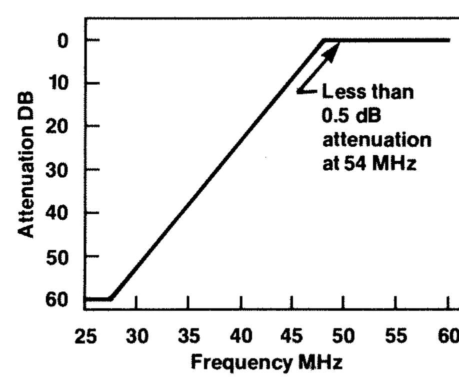
EXAMPLE:

1. You know the transmitter carrier is hitting the filter at 0 dBm because you set it up that way.
2. The measured second-harmonic level is, say, -75 dBm. That's -75 dB below the carrier.
3. In measuring the frequency response of the coupler, you find that is attenuates the fundamental by 30 dB, but offers only 25 dB attenuation to the second harmonic. Therefore, the harmonic level should be corrected to -80 dBm. That puts it 80 dB below the carrier.
4. But you also find that the filter attenuates the harmonic by 1 dB. And that's a correction in the other direction. So the harmonic is actually 79 dB below the carrier.

If in doubt about whether to add or subtract, write in the signal levels as shown in figure 1. You can easily work backward knowing the losses through the coupler and filter to determine the corrected levels at the transmitter.

Remember off the air measurements of spurious harmonics or transmitter intermodulation levels using the monitor's antenna are totally invalid because of the lack of signal control. When you are chasing interference remember to set the frequency level to the strongest signal in the band which may not be the frequency of interest. This will prevent overloading the front end of the monitor producing IM inside the monitor.

Figure 2 Typical Highpass Filter Response



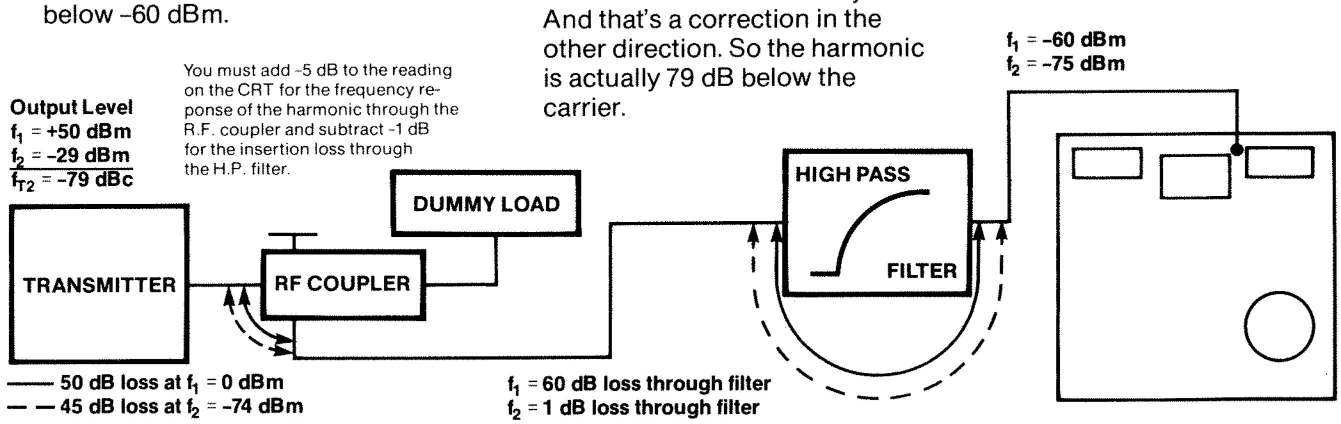
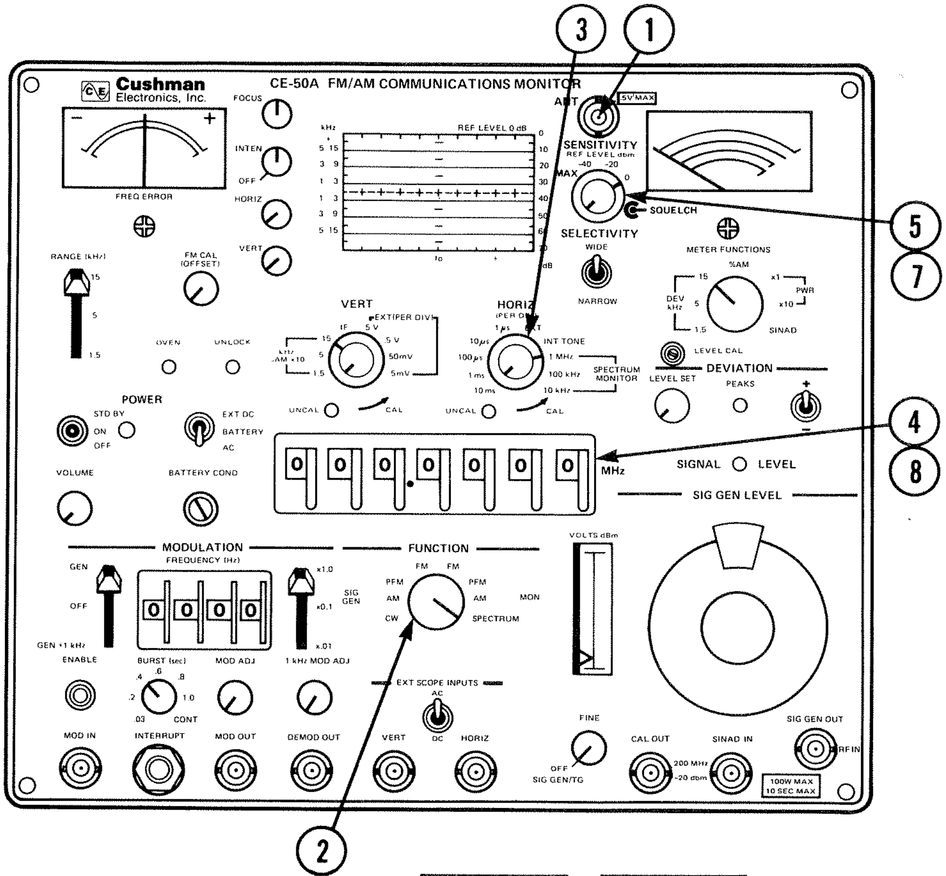


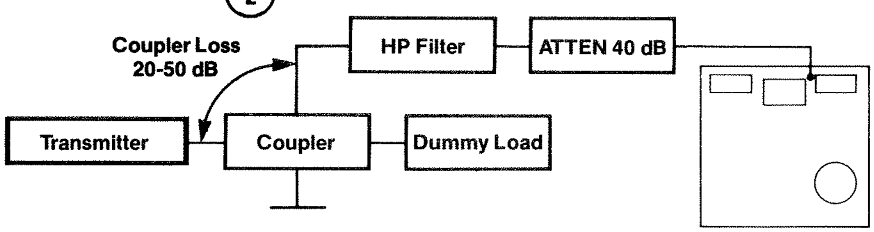
Figure 1 Test set-up to extend the dynamic range of a spectrum monitor. Level diagram helps you remember whether to add or subtract in correcting the spectrum monitor readings.

SPECTRUM MONITOR TEST SPEC-1

Recommended Test Equipment:
CE-5110, CE-50A-1
CE-50A-1/TG, CE-46A
CE-15

Measuring Transmitter Harmonics





TEST PROCEDURE:

1. Connect the transmitter to the test set up.
2. Set the FUNCTION switch to SPECTRUM.
3. Set the HORIZ switch to SPECTRUM MONITOR: 1 MHz.
4. Set the FREQUENCY select switches to the transmit frequency.
5. Set the REF LEVEL to 0 dBm.
6. Temporarily remove the highpass filter to set the carrier reference level.
7. Key transmitter and adjust the RF coupler so the signal is at the top of the CRT.
8. Reinsert the high pass filter and set the spectrum monitor to the second harmonic of the carrier.
9. Key the transmitter and measure the harmonic level relative to the carrier. Remember to algebraically add the attenuation of the high pass filter at the harmonic frequency and also the attenuation of the RF coupler at these frequencies. (See A Word About Measuring Harmonics)

CAUTION: Do not apply more than 0 dBm signal to the input of the spectrum monitor or damage may occur. Place an attenuator between the HP filter and the input if the coupler output is more than 0 dBm. (See test set-up.)

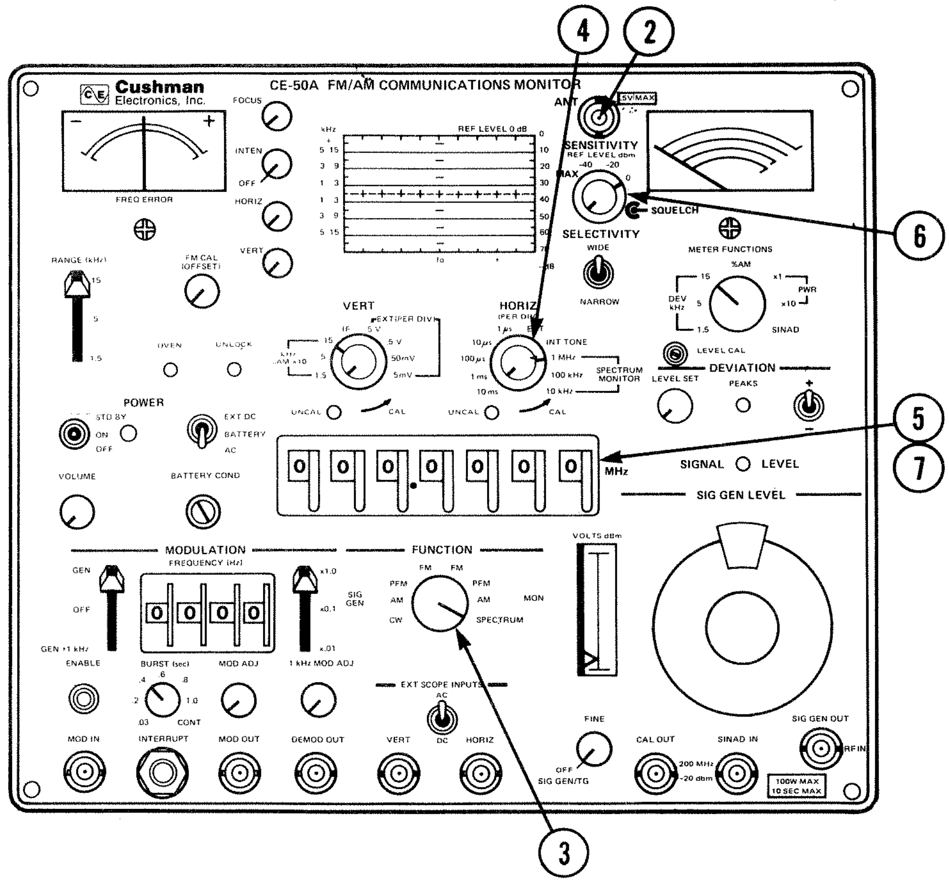
Harmonics like other spurious radiation are most often produced by defective or inexpensive transmitters. The FCC specifies harmonic suppression of 80 dB or 43 +10 Log_{10} (output power in watts), whichever is less at frequencies greater than 250% of the authorized bandwidth from the assigned frequency.

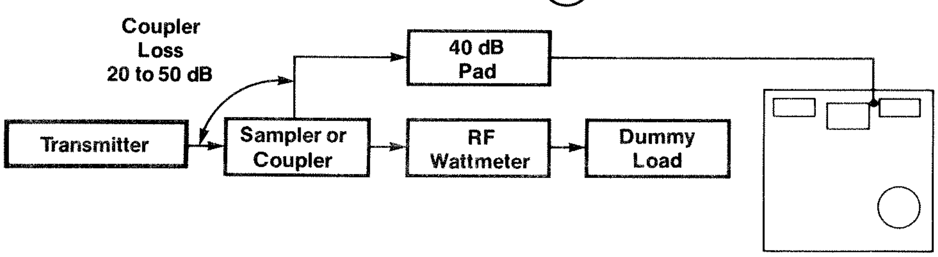
It is important that the carrier is attenuated enough so that it does not overload the front end of the analyzer creating intermodulation distortion in the first mixer. These suprious signals clutter the screen and confuse the display making it difficult to tell whether or not a real signal is being examined.

A quick check to see if internal intermod is present is to put 10 dB of attenuation between the antenna and the ANT IN connector. All real signals will drop 10 dB. All intermods will drop 20, 30 dB or more, depending upon the "order" of the intermod. If the instrument is displaying excessive intermodulation products, change the level settings to increase RF attenuation.

SPECTRUM MONITOR TEST SPEC-2

Recommended Test Equipment:
CE-5110, CE-50A-1
CE-50A-1/TG, CE-46A
CE-15





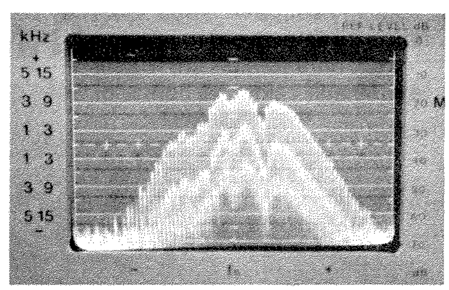
When you align a transmitter by peaking the RF wattmeter, you know you're getting maximum power out, but you don't know if all the power is concentrated in the output signal. The wattmeter is not frequency selective, it sees not only the fundamental frequency, but also any spurious RF power. With a modern, well-designed transmitter this shouldn't be a problem if the transmitter is operating properly.

But a transmitter may have a problem that isn't readily apparent. The wattmeter may be reading the main signal plus a lot of "garbage" that will eventually go on the air. When adjusting the transmitter, look for sidebands that are created by the basic crystal frequency. For example—If the basic crystal frequency is 13.2 MHz look 13 MHz or some multiple of that frequency either side of the transmitter frequency to see their levels relative to the carrier. For measuring carrier harmonics see SPEC-1 for the proper test set up.

TEST PROCEDURE:

1. Connect transmitter through an RF coupler to a directional watt meter and dummy load.
2. Connect the sampling port of the RF coupler to a 40 dB pad and connect the pad to the ANT IN connector.
3. Set FUNCTION switch to SPECTRUM.
4. Set HORIZ to SPECTRUM MONITOR 1 MHz/Div.
5. Set FREQUENCY SELECT switches to transmitter frequency.
6. Set REF LEVEL to 0 dBm and adjust RF coupler so the transmitter signal is at the top of the CRT.
7. Adjust transmitter stages for maximum power out while observing spurious output. Look 10 to 50 Mhz either side of the output frequency while adjusting the transmitter stages to ensure most of the output power is concentrated in the output frequency.

CAUTION: Never key directly into the ANT IN connector. Always use a sampler and (or) attenuator capable of handling the power between the transmitter and ANT IN connector.



CRT Photo 1 shows the output of a transmitter that has broken into oscillation. Sweep dispertion is 1 MHz/Div.

A Few Words About RF Probes

Effects of Probe Impedance

The generally accepted rule is that probe impedance should be at least 10 times the impedance of the circuit being tested to avoid loading the circuit. It should be noted, however, that internal shunt capcitance makes the probe impedance dependent of frequency. A 5k ohm probe, for example, offers its full impedance only at dc. The higher the frequency, the lower the impedance.

To calculate the probe impedance at a specific frequency, first calculate the capacitive reactance, X_C, of the probe's shunt capacitance

$$X_C \text{ (in ohms)} = \frac{1}{2\pi fC}'$$

where f is the frequency in *Hertz* and C is the capacitance in *Farads*.

Example: for 1 pF at a frequency of 200 MHz,

$$X_C = \frac{1}{(6.28)(200 \times 10^6)(10^{-12})} = 796 \text{ ohms}$$

If the nominal probe impedance (resistance) is 5 kohms, the resistance and the reactance must be combined using the parallel circuit formula:

$$Z = \frac{RX_C}{R^2 + X_C^2} = \frac{(500)(796)}{5000^2 + 796^2} = 786 \text{ ohms}$$

Thus, at 200 MHz, this probe will result in significant level-measurement errors when used on circuits with impedance of more than ~80 ohms.

The following table lists probe impedance at various frequencies for a 5k ohm probe with shunt capacitance of 1 pF:

Frequency, MHz	Impedance, Ohms
10	4770
100	1517
200	786
300	527
400	397
500	318

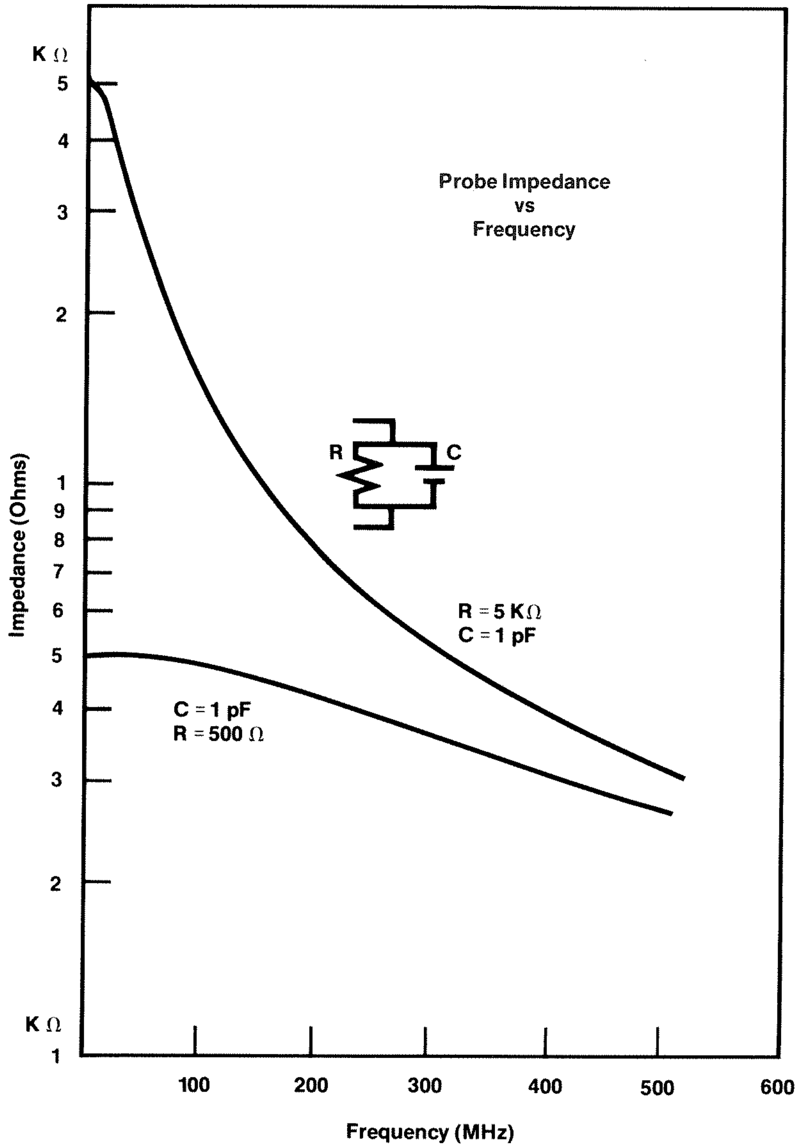
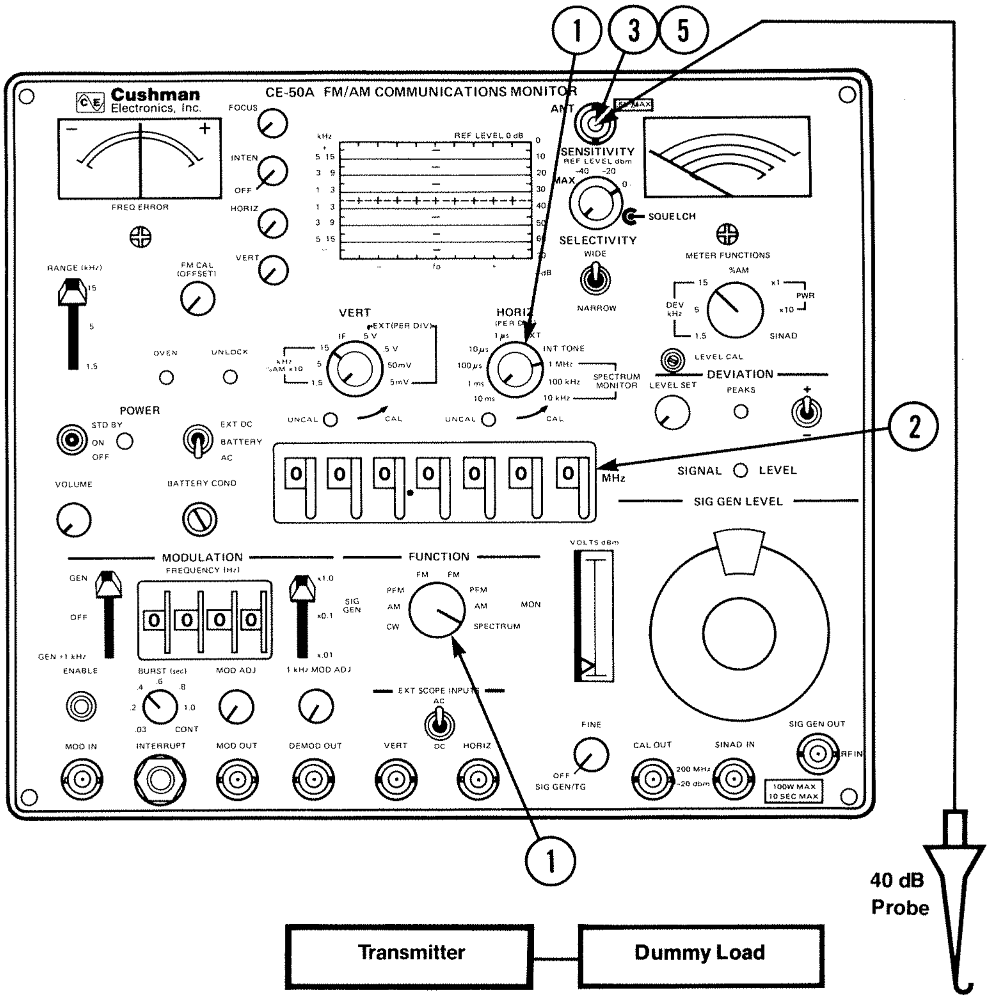


Figure 1 Effect of capacitance causes probe impedance to decrease as frequency increases

Cushman

Recommended Test Equipment:
CE-5110, CE-50A-1
CE-50A-1/TG, CE-46A
CE-15

Using The Spectrum Monitor For Stage Gain Measurements



TEST PROCEDURE:

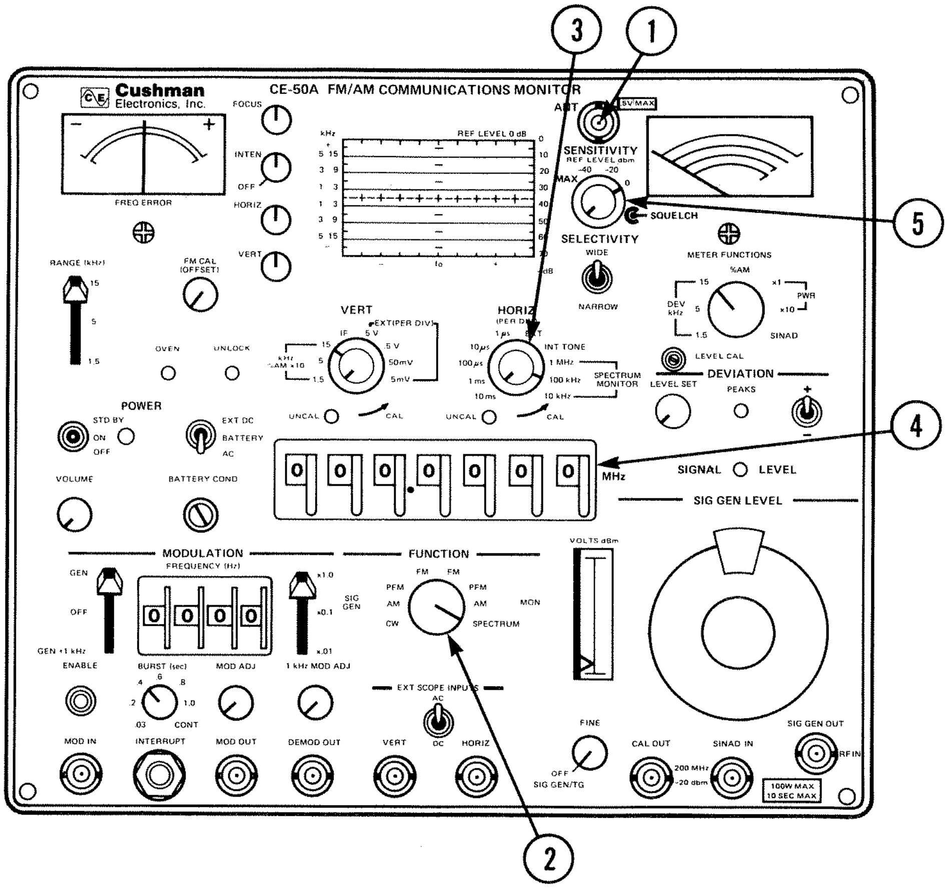
1. Set FUNCTION switch to SPECTRUM MONITOR and HORIZ. to SPECTRUM MONITOR: 1 MHz.
2. Set the FREQUENCY SELECT switches to the frequency of interest.
3. Attach 20 or 40 dB 1 pF probe to ANT IN connector (refer to probe tips for more information and considerations).
4. Check the gain of the circuit by first monitoring input noting level then check the output and noting its level. A 20 dB amplifier should deliver 20 dB of gain. The spectrum analyzer will also show any distortion that may be present.
5. Connect a sniffer to the antenna and hold or lay it close to the circuit to view the frequency of interest without loading down the circuit. You can't get an absolute level measurement but you can see that LO, for instance, is working and multiplier and injection chains are functioning.

CAUTION: Be sure to observe power levels in transmitter stages to prevent damage to the front end of the spectrum monitor input. Use an RF coupler or attenuator where necessary.

Using a spectrum monitor yields far more information than just using an RF voltmeter when signal tracing through a circuit. The spectrum analyzer gives you simultaneous level and frequency information. In addition, its sensitivity is much greater than that of an RF voltmeter. Typical sensitivities are in the order of 1-2 mV while the spectrum analyzer has a sensitivity of 1 μV or less. This difference of 60 dB or more is important when working with low level signals in the RF section of a receiver. Getting accustomed to using the spectrum monitor will in the long run save hours of troubleshooting time.

SPECTRUM MONITOR TEST SPEC-4

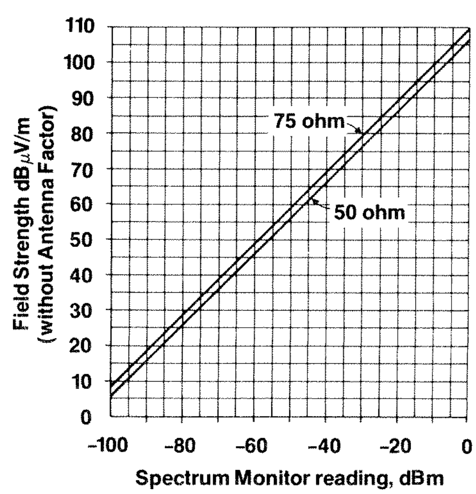
Recommended Test Equipment:
CE-5110, CE-50A-1
CE-50A-1/TG, CE-46A
CE-15



TEST PROCEDURE:

1. Connect a calibrated antenna to ANT IN connector.
2. Set the FUNCTION switch to SPECTRUM.
3. Set the HORIZ switch to SPECTRUM MONITOR 1 MHz/Div.
4. Set FREQUENCY SELECT switches to frequency of antenna or signal to be measured.
5. Set REF LEVEL to 0 dBm, -20 dBm, -40 dBm or as needed.
6. Adjust antenna for maximum reading.
7. Calculate field strength of received signal.

Field strength is normally measured in dB μV/m. dBμV means dB reference to 1 microvolt. Take the reading from the Spectrum Monitor and add 107 dB (108.75 for a 75 ohm system) to get dBμV and then add the antenna factor to dBμV/m. (see chart)



Field strength is expressed in terms of voltage per unit length. If a particular field induces a potential of one millivolt in a wire one meter long, the field strength is 1 mV/meter. This definition assumes that the wire is parallel to the electric lines of force in the received wave. To assure that the wire is parallel to the lines of force, you simply turn the antenna until you have maximum induced voltage.

It is easier to use a calibrated non-directional broad-band antenna. An antenna that is broad-band will allow simultaneous field strength measurements of a number of frequencies. To find field strength you must know the antenna factor of the antenna you select or the antenna gain. If you know the gain of the antenna find the antenna factor by using the chart or calculate the factor by using the formula:

$$K = 20 \log f - G_{dB} - 29.8 \text{ dB (for 50 } \Omega \text{ system)}$$

$$K = 20 \log f - G_{dB} - 31.5 \text{ dB (for 75 } \Omega \text{ system)}$$

where: K = antenna factor in dB/meter
f = frequency of measurement in MHz
G = antenna gain in dB (power ratio)

Example 1: If the spectrum monitor reads –75 dBm and the antenna factor is 3.8 dB/m the field strength is:

$$E = -75\ \text{dBm} + 107\ \text{dB} + 3.8\ \text{dB/m}$$
$$E = 35.8\ \text{dB}\mu\text{V/m}$$
$$E = 61.5\ \mu\text{V/m}$$

Remember: 0 dBμV = 1 μV; +20 dBμV = 10 μV; +40 dBμV = 100 μV.

To convert dBμV/m to μV/m use the formula:

$$E = 10^{\frac{(\text{dB}\mu\text{V/m})}{20}}$$

Example:

$$E = 35.8\ \text{dB}\mu\text{V/m}$$
$$E = 10^{\frac{(35.8\ \text{dB}\mu\text{V/m})}{20}}$$
$$E = 10^{(1.79)}$$
$$E = 61.5\ \mu\text{V/meter}$$

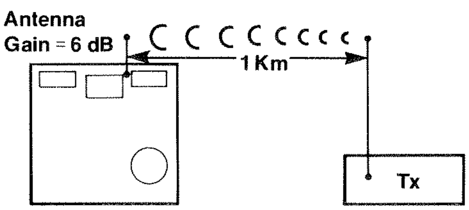
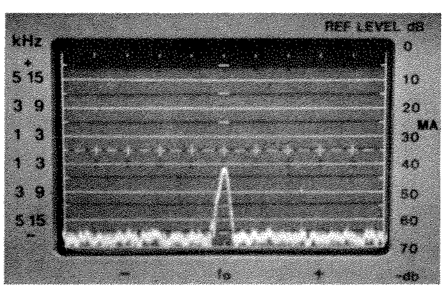


Figure 1 Field strength measurement set up.

Example 2: Suppose you want to measure the field strength of a transmitter located 1 K meter from the receiver.

The signal measured on the CE-50A-1 C.R.T. is –80 dBm.

Ref Level –40 dBm



Center Frequency 155 MHz

To convert the antenna gain to antenna factor use this formula:

$$K = 20 \log f - \text{GdB} - 29.8\ \text{dB}$$
$$K = 20 \log 155\ \text{MHz} - 6\ \text{dB} - 29.8\ \text{dB}$$
$$K = 8\ \text{dB/m}$$

To convert the spectrum analyzer reading to dBμV simply add 107 dB.

$$-80\ \text{dBm} + 107\ \text{dB} = 27\ \text{dB}\mu\text{V}$$

The field strength, E, is the sum of the adjusted spectrum analyzer reading and the antenna factor:

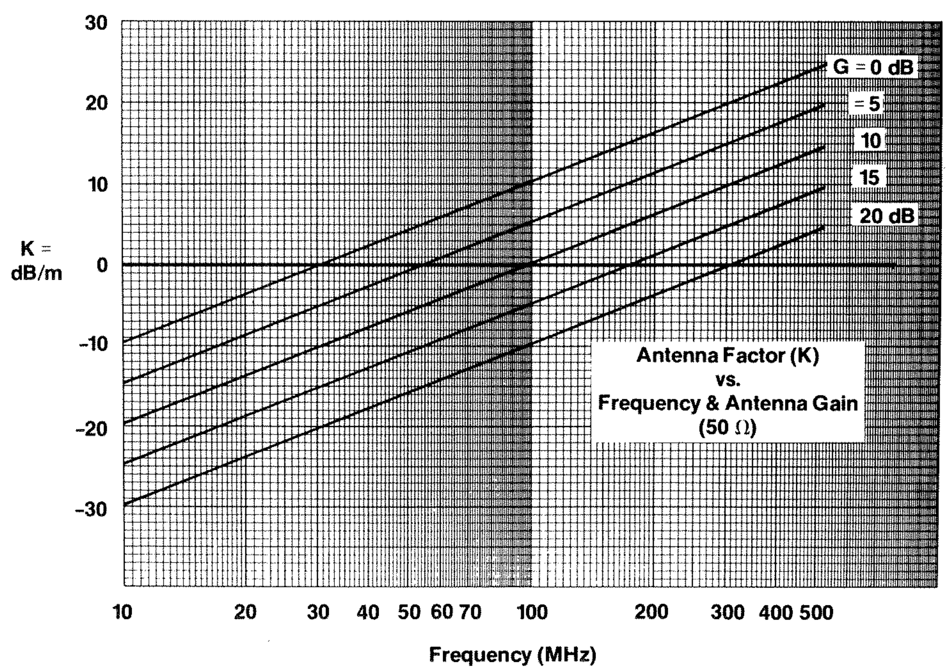
$$E = \underbrace{27\ \text{dB}\mu\text{V}}_{\text{Analyzer Reading}} + \underbrace{8\ \text{dB/m}}_{\text{Antenna Factor}} = 35\ \text{dB}\mu\text{V/m}$$

If you want to convert the field strength reading from dBμV/meter to μV/meter, use this formula:

$$E = 10^{\frac{(\text{dB}\mu\text{V/m})}{20}}$$

Example:

$$E = 10^{\frac{(35\ \text{dB}\mu\text{V/m})}{20}}$$
$$E = 10^{(1.75)}$$
$$E = 56.2\ \mu\text{V/m}$$

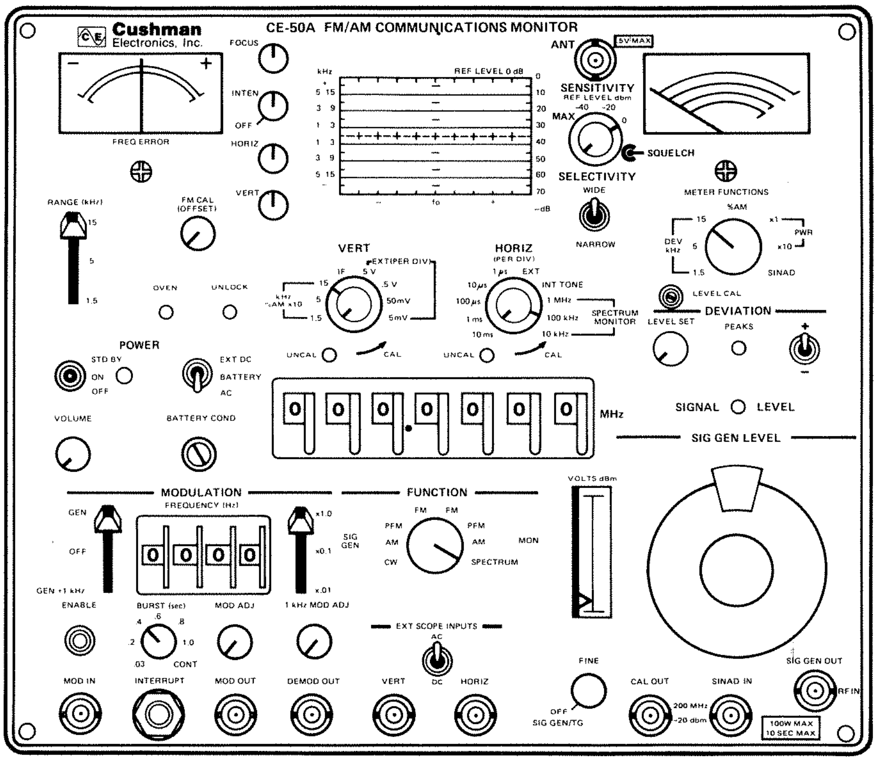


Antenna factor (K) may be obtained from the antenna gain figure and frequency.

SPECTRUM MONITOR TEST SPEC-5

Recommended Test Equipment:
CE-5110, CE-50A-1
CE-50A-1/TG, CE-46A
CE-15

Determining Antenna Patterns



TEST PROCEDURE:

1. Set the monitor up to make field strength measurements (See Spec-4 for the test set-up).
2. Make a series of measurements equi-distant from the antenna and record the levels on graph paper as in Figure 1.
3. For a mobile antenna, a practical distance would be at least 100 feet and for a base station antenna about ½ to 1 mile.

Laboratory calibrated antennas can be expensive but if chosen correctly give the advantage of determining the direction of received signals for chasing down intermod, surveillance purposes, or determining accurate signal strength over a broad band of frequencies.

In Figure 2 half inch copper tubing wired to a board is used to form the dipole. Be sure to use a 75 Ω to 50 Ω transformer or minimum loss matching pad to obtain accurate field intensity measurements. In Figure 3 the antenna is made with RG-59 coax. The braid is folded back over the outer cable jacket to form one side of the dipole. The other leg is formed by the center conductor.

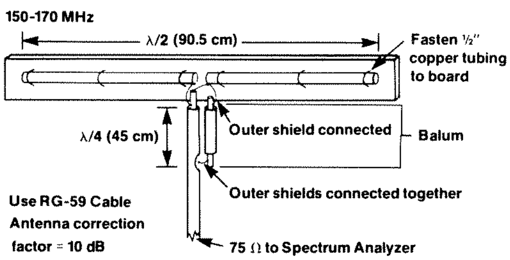
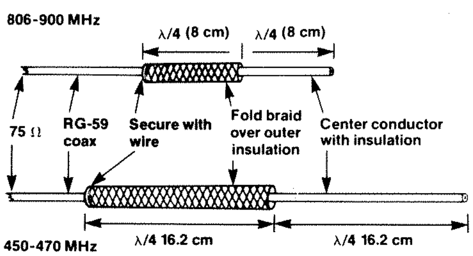


Figure 2 shows how to make a test antenna for 150-170 band.



450-470 MHz
Antenna correction factor = 19 dB
806-900 MHz
Antenna correction factor = 25 dB

Figure 3 shows how to make homemade test antennas constructed from coax cable for 450 and 900 MHz bands.

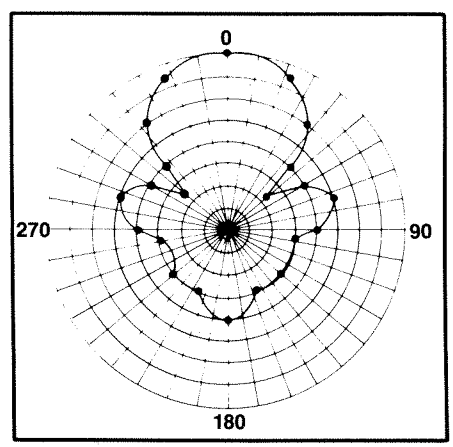


Figure 1 Plot of antenna pattern for typical roof mounted mobile antenna.

SPECTRUM MONITOR TEST SPEC-6

Recommended Test Equipment:
CE-5110, CE-50A-1
CE-50A-1/TG, CE-46A
CE-15

Analyzing External Transmitter Intermod Receiver Desense

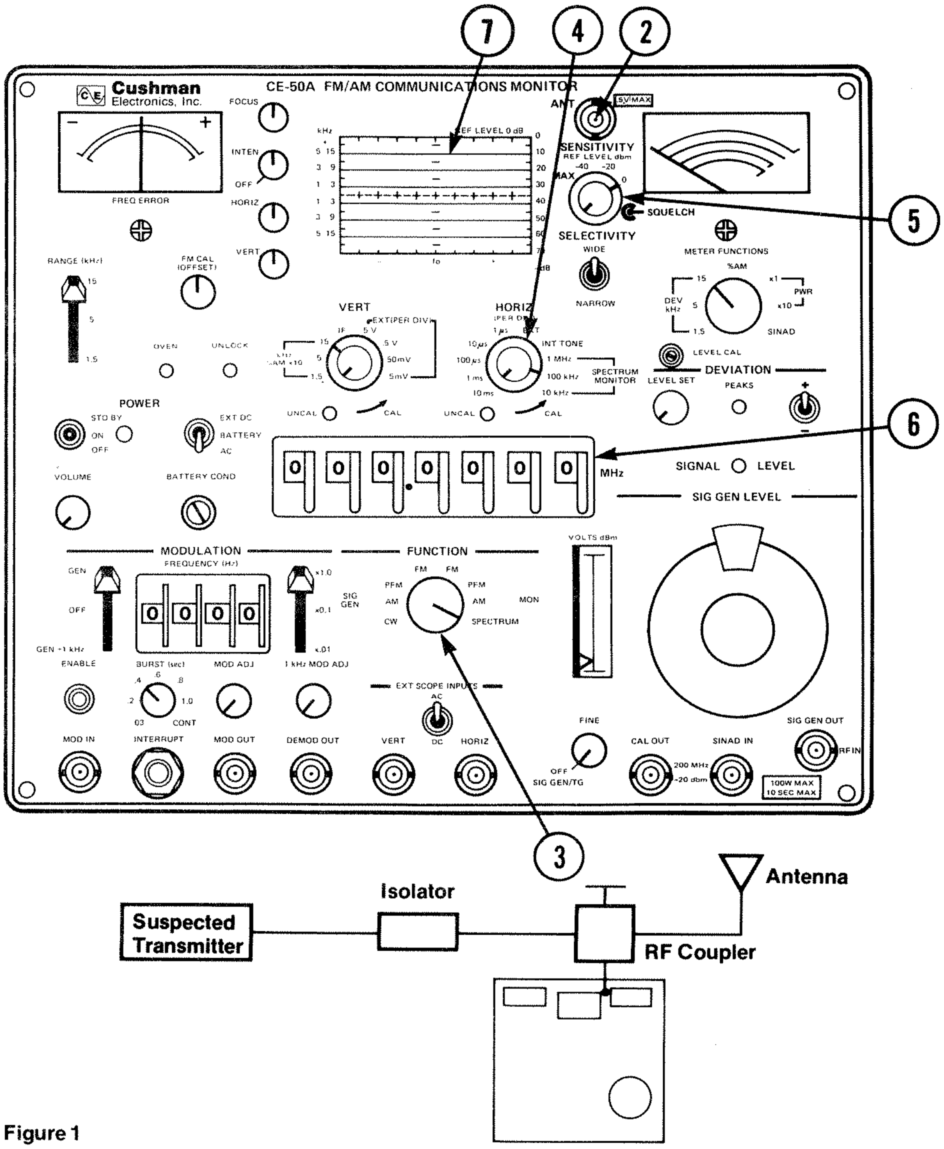


Figure 1

TEST PROCEDURE:

1 Measure the forward and reverse insertion loss of the isolator tuned to the band of interest.

2 Connect the monitor and connect the suspect transmitter to the test set-up as shown in Figure 1.

3 Set the FUNCTION switch to SPECTRUM MONITOR.

4 Set the HORIZ switch to 100 kHz/Div.

5 Set the REFERENCE LEVEL switch to 0 dBm.

6 Set the FREQUENCY SELECT switches to the frequency of the receiver being interfered with.

7 Temporarily remove the isolator and note the level of the intermod when it appears in order to set a reference level of the Intermod signal on CRT. (**CAUTION: Do not overload the front end of the spectrum analyzer.**)

8 Reinstall the isolator, and observe the level of the intermod signal when it appears again.

a) If the signal is reduced by the amount of the forward insertion loss of the isolator then the intermod is not being generated in this transmitter.

b) If the signal is reduced by the amount of the reverse insertion loss of the isolator then the intermod is in this transmitter.

If you've run the tests for receiver intermod with an antenna pad and have determined that the receiver is seeing an on-channel signal then the chances are that the intermod is being generated in a nearby transmitter. Using the spectrum monitor in combination with your knowledge of how intermods are produced, and a directional antenna, you can come up with some likely suspect.

For example, let's say that the receiver frequency is 156.3 MHz, and the spectrum monitor is showing an interfering signal right on that frequency. Checking around you find a transmitter at 156.4 and another transmitter at 156.5, a 2A-B intermod product (2 x 156.4 - 156.5 = 156.3) could be hitting the receiver. With the use of an isolator you can determine which transmitter is producing the interference.

Remember that intermodulation products are separated from the main signal by the amount of the main-signal spacing—whether it's 25 kHz or 1 MHz away.

A Few Words On Swept Frequency Measurements

There are two basic kinds of swept frequency measurements that are made using a tracking generator. The first kind is called transmission, the other is called reflection.

Figure 1 shows the basic test setup for transmission type testing. The swept tracking generator is connected to the input of the device under test (D.U.T.) and the output from the D.U.T. is connected to the input of the spectrum monitor. Since the swept frequency of the generator is tracking with the L.O. of the spectrum monitor the frequency response of the output is displayed on the CRT. The center of the CRT "fo" is the frequency dialed up on the front panel frequency select switches.

The type of tests that can be made are Frequency Response, Gain, Insertion Loss, Attenuation, Rejection, and Isolation.

Figure 2 shows the basic test set-up for reflection measurements. To do this kind of testing requires the use of a VSWR bridge. The bridge is a directional device used to measure the amount of reflected power from the D.U.T.

The swept Tracking Generator (TG) output is connected to the RF input port on the VSWR bridge. The RF output port on the bridge is connected to the input to the spectrum monitor. The antenna, preselector, cable or D.U.T. is connected to the test port, sometimes referred to as unknown.

The advantage of using a bridge to measure VSWR over a bi-directional wattmeter is the visual display of the frequency response and level of reflected power from the D.U.T. Also smaller amounts of reflected signal can be measured that a bi-directional wattmeter can not. (See chart on page 21 for return loss vs. VSWR vs. forward and reflected power conversions).

The type of test that can be made are: Reflected Power, VSWR, and Return Loss.

It is important to note that when making swept frequency measurements the test set-up should be carefully constructed. All connectors should be carefully soldered and coupled tightly to minimize VSWR and power loss. Double shielded coax like RG-223 or RG-142 should be used with shields properly fitted to the connectors to minimize stray coupling at low signal levels.

FIGURE 1. TRANSMISSION

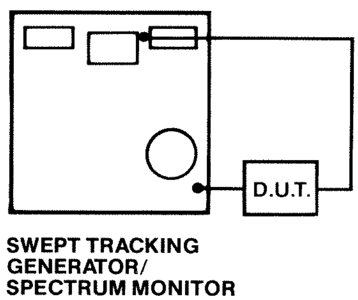
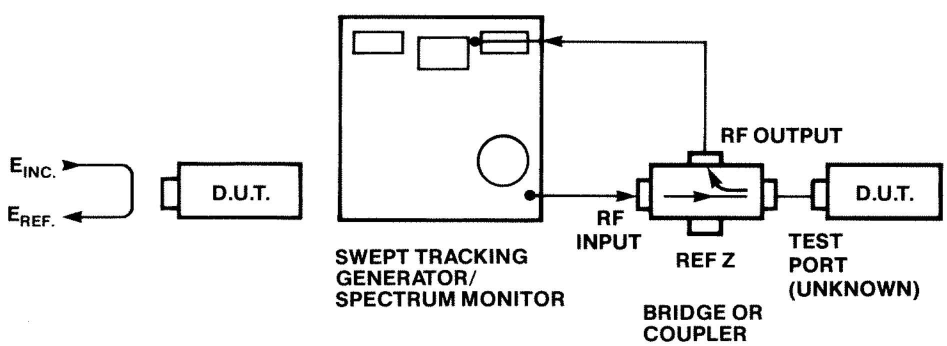


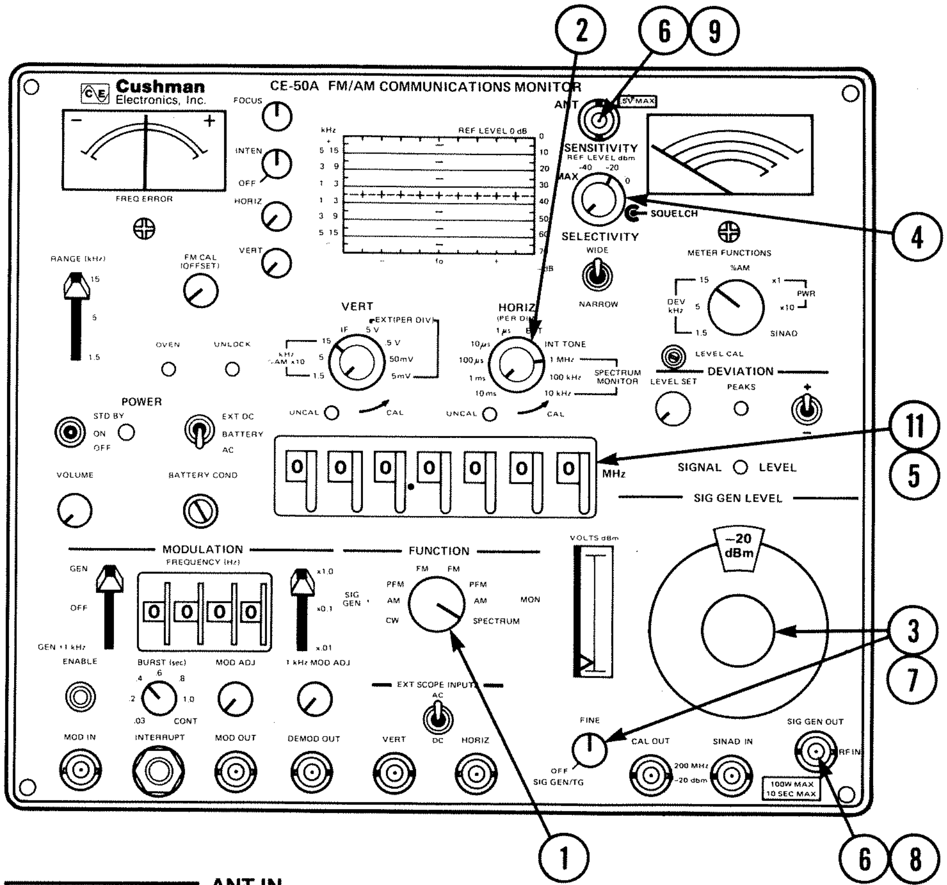
FIGURE 2. REFLECTION

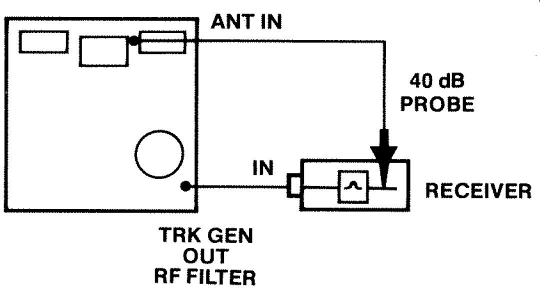


TRACKING GENERATOR TEST TG-1

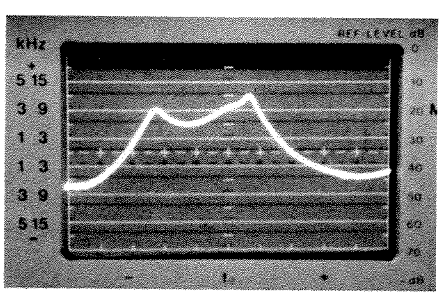
Recommended Test Equipment:
CE-5110, CE-50A-1/TG

Receiver RF Filter Alignment





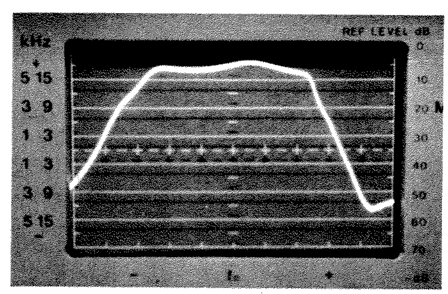
For best results when aligning Filters use Cushman's 20 dB probe for injecting the signal and use the 40 dB probe for viewing the output response. (See "A Word About Probes" in Part 3—Spectrum Analyzer for tips on using the probe). For a more complete explanation of Spectrum Monitor Applications read "Using the Spectrum Monitor" published by Cushman Electronics.



CRT Photo 1 shows a badly aligned RF filter that is located in the front end of a receiver.

TEST PROCEDURE:

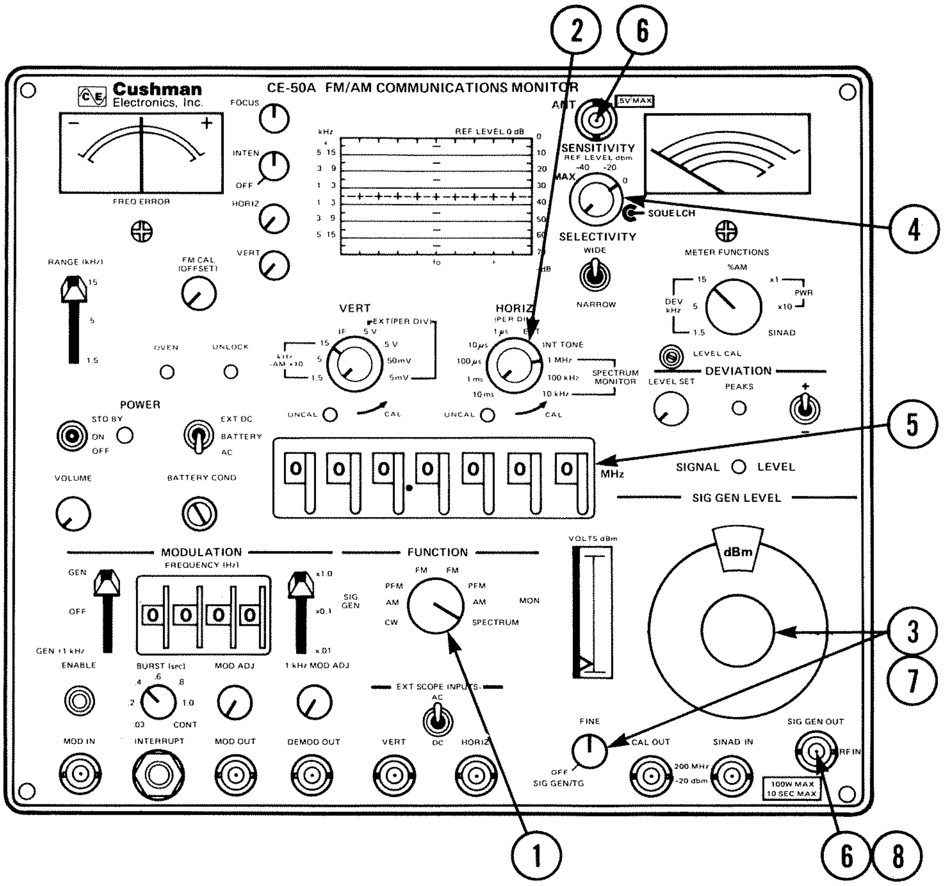
1. Set the FUNCTION switch to SPECTRUM.
2. Set the HORIZ switch to SPECTRUM MONITOR: 1 MHz/Div.
3. Set the SIG GEN LEVEL to -20 dBm; FINE -10 dBm.
4. Set the REF LEVEL (dBm) to - 20 dBm.
5. Set center frequency on monitor to filter center frequency.
6. Connect probe from SIG GEN OUT to ANT IN connector on monitor to null out cable loss.
7. Adjust SIG GEN OUT level to trace at top of CRT.
8. Connect SIG GEN OUT to receiver input.
9. Connect probe to ANT connector on monitor and place probe on filter output test point.
10. Adjust filter for flat passband response and maximum out-of-band rejection.
11. For IF alignment set monitor to IF frequency.
12. Inject signal with 20 dB probe and look at output of filter with 40 dB probe.



CRT Photo 2 shows the filter response after being properly aligned using the TG. The sweep width is 1 MHz/Div. The filter response was improved by 15 dB with an overall flatness of about 3 dB over the bandwidth of this filter, which is tuned about 5 MHz wide. Testing the filter in the circuit is a quick way to check its relative response and tune it for a precise frequency band pass.

TRACKING GENERATOR TEST TG-2

Recommended Test Equipment:
CE-5110, CE-50A-1/TG



TEST PROCEDURE:

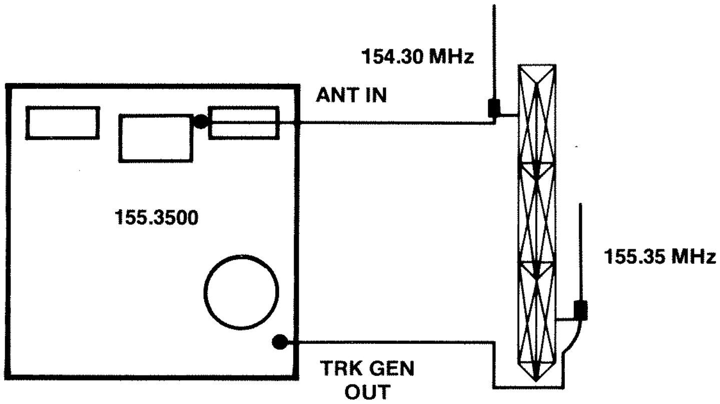
1. Set the FUNCTION switch to SPECTRUM.
2. Set the HORIZ switch to SPECTRUM MONITOR, 1 MHz/Div.
3. Set the SIG GEN LEVEL to 0 dBm FINE -10 dBm.
4. Set the REF LEVEL (dBm) to 0 dBm.
5. Set center frequency on monitor to the TX frequency.
6. Connect SIG GEN OUT to Antenna 1.
7. Connect ANT IN connector on monitor to Antenna 2.
8. Adjust antennas for maximum isolation as displayed on the CRT.
9. NOTE: This application can also be useful when installing car repeater system or two radios on different bands.

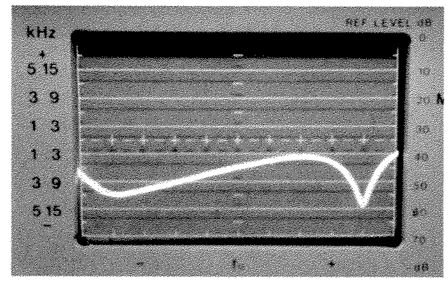
CAUTION: Disable any transmitter in close proximity to the antenna under test. Too much RF signal can overload or burn out the input to the spectrum monitor. This is especially true on building tops where there is little vertical or horizontal isolation.

This test is used when installing an antenna on a tower, building or vehicle that has more than one antenna present. By checking the isolation between 2 antenna systems, you can decrease potential interference problems before they become troublesome. Be sure to check the VSWR of the antenna connected to the SIG GEN OUT to be sure it is tuned to the frequency of the transmitter. Too much VSWR will show up as more isolation than you really have. Also, be sure that before any antenna is connected to the ANT IN connector, that the antenna transmission line has been shorted to ground to relieve any static buildup, and that any antenna that is in a close proximity to the test antenna has been disabled. The maximum input to the ANT IN is .5 V max. See Appendix D for Free-Space Loss Calculations in the booklet, "Using the Spectrum Monitor," published by Cushman Electronics. Damage to the front end of the monitor's receiver can occur if too much power is coupled to the input from any nearby radiated source.

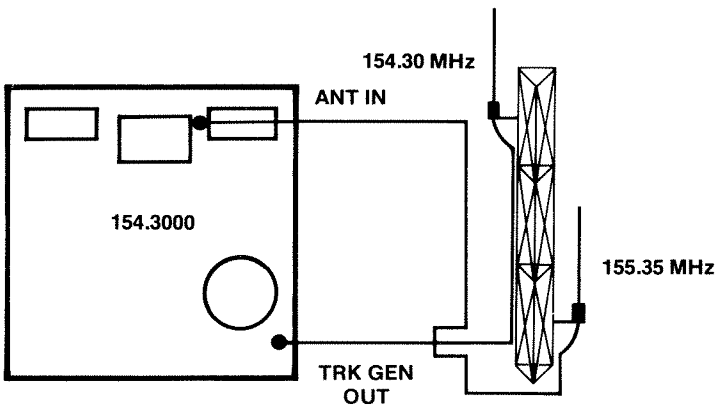
Note: This method may not work if there is a high level of ambient RF which might be desensitizing the front end of the spectrum monitor.

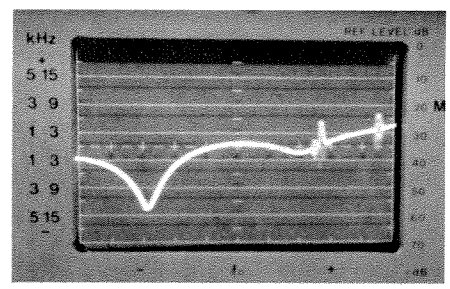
Measuring Antenna Isolation



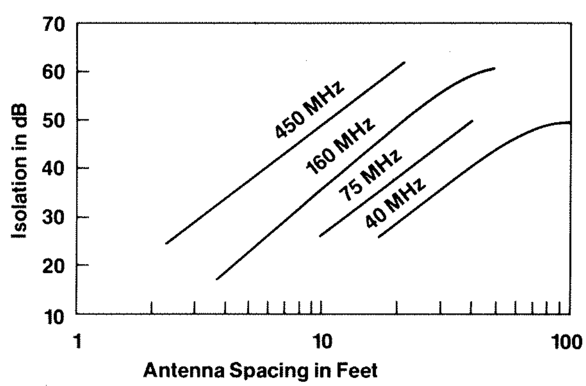


CRT Photo 1 shows a typical display for an isolation measurement. The test setup shows how to measure the isolation between a 4 element collinear array at 155.35 MHz and another 4 element collinear array at 154.30 MHz. The REF LEVEL dB was set to -20 dBm, and the dispersion is 1 MHz/Div. The total isolation at 155.35 MHz is 65 dB between the two antenna systems.

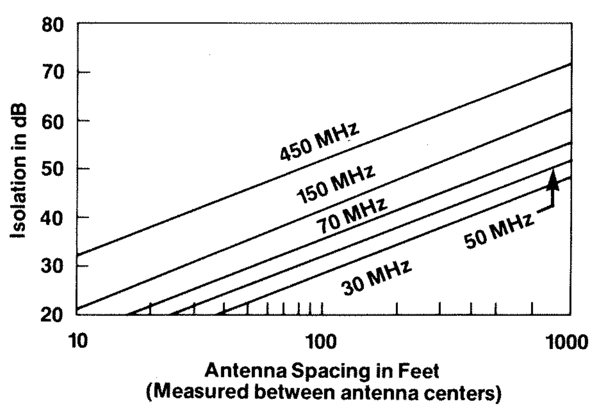




CRT Photo 2 is showing the test setup for testing the 154.30 MHz antenna. Note that the connections are reversed, and the center frequency of the tracking generator is 154.30 instead of 155.35 MHz. The REF LEVEL dB was set to 20 dB with a 1 MHz sweep width. Total isolation is 55 dB. The blips on the trace are signals that are being received by the 155.35 MHz antenna.



Vertical Isolation of Half-Wave Dipole Antennas



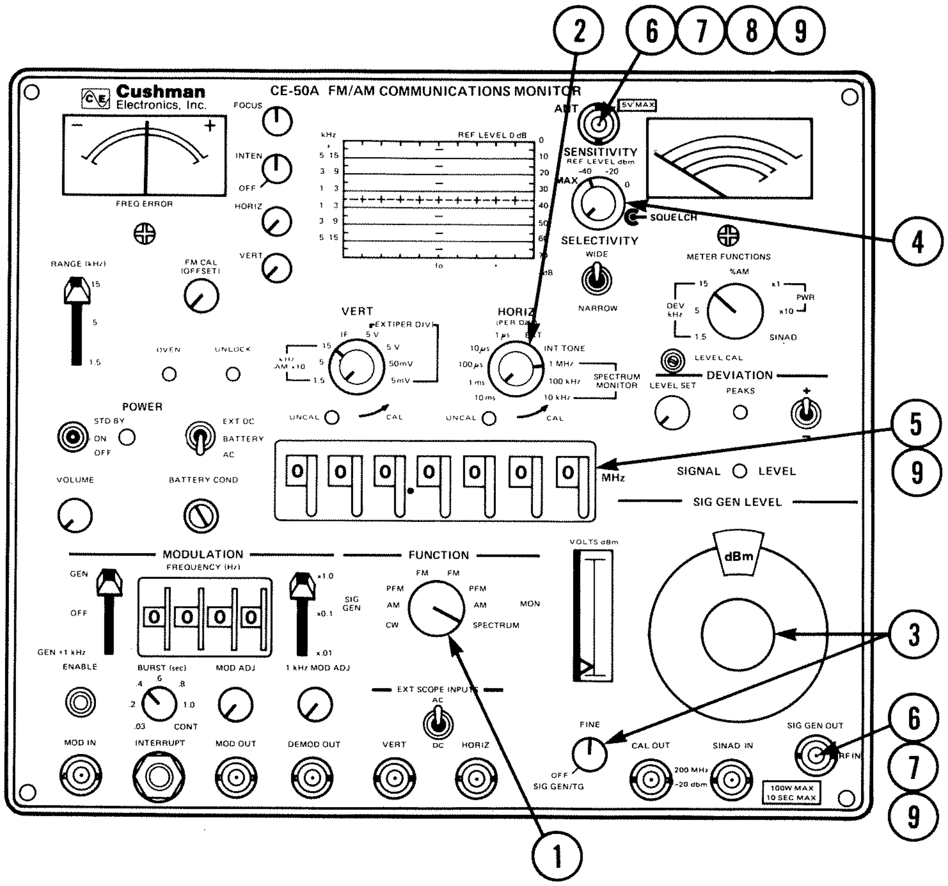
Horizontal Isolation of Half-Wave Dipole Antennas

Cushman

TRACKING GENERATOR TEST TG-3

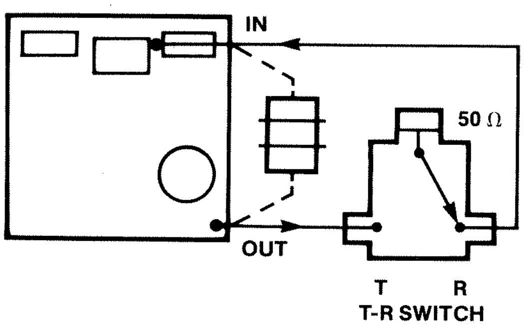
Recommended Test Equipment:
CE-5110, CE-50A-1/TG

Measuring Tx-Rx Switch RF Isolation & Insertion Loss

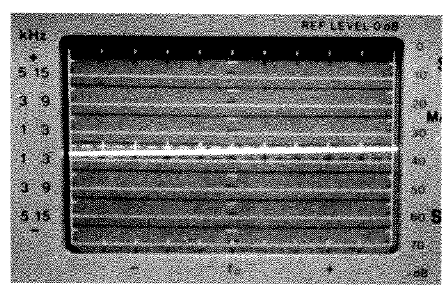


TEST PROCEDURE:

1. Set the FUNCTION switch to SPECTRUM MONITOR.
2. Set the HORIZ switch to SPECTRUM MONITOR 1 MHz/Div.
3. Set the SIG GEN LEVEL to -30 dBm: FINE -10 dBm.
4. Set the REF LEVEL to -40 dBm.
5. Set the FREQUENCY SELECT switches to the transmitter frequency.
6. Connect the SIG GEN OUT to the ANT IN through the test cables or probes and set the CRT trace to the top of the CRT display to null out any cable loss.
7. Connect the SIG GEN OUT to the transmit port; the ANT IN to the receiver port; terminate the antenna port with 50 Ω and measure the isolation between the two ports.
8. Move the coax at the receiver port to the antenna port and measure insertion loss thru the switch from TX port to antenna.
9. Connect the SIG GEN OUT to the antenna port and move the coax from the transmit port to the receiver port and again measure insertion loss thru the switch from the receiver port to the antenna port at the receiver frequency.



Calibrate out insertion loss of coax test leads first



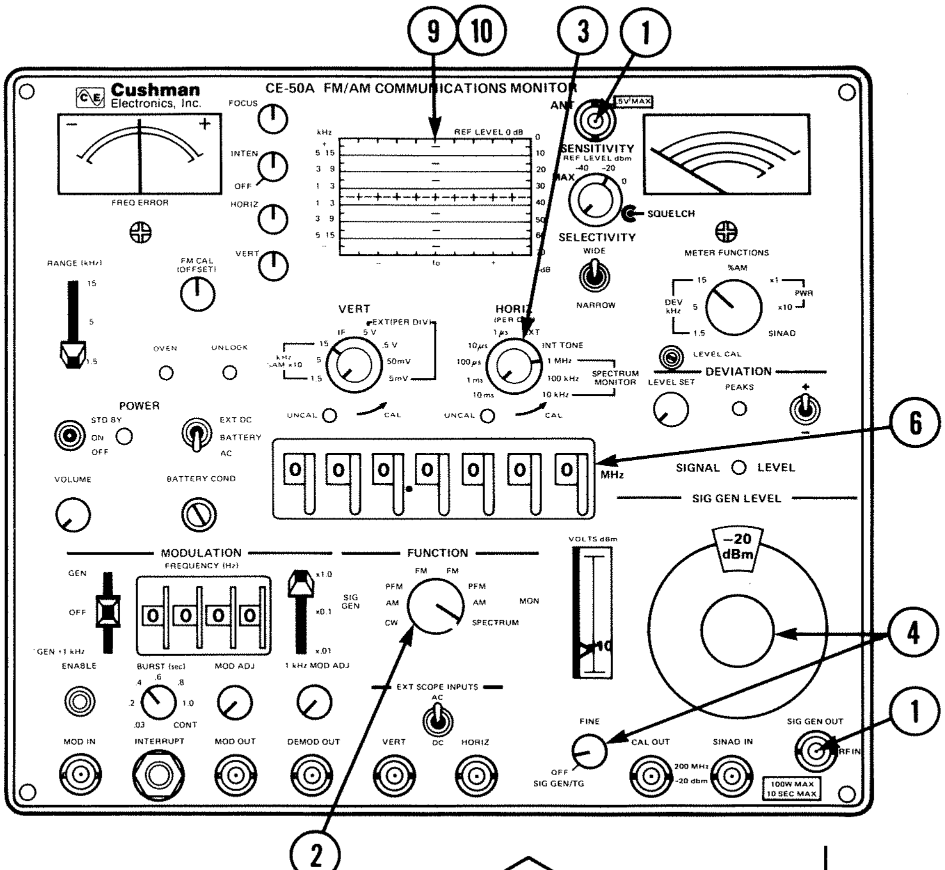
CRT Photo 1

Bad contacts on a T-R switch can cause more than just poor sensitivity of the receiver. Intermod spurious responses in the receiver can be formed by semiconductor type joints caused by corrosion on the contacts. The corroded contacts can act like a diode at radio frequencies and generate spurs when strong RF signals are picked up by the antenna. The CRT photo is displaying the isolation between the transmitter and receiver port with the antenna terminated with 50 Ω. In this case the isolation is 37 dB at 450 MHz ± 5 MHz.

TRACKING GENERATOR TEST TG-4

Recommended Test Equipment:
CE-5110, CE-50A-1/TG

Swept Tuning of λ/4 Coaxial Filters



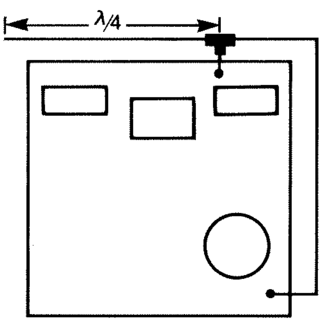


Figure 1

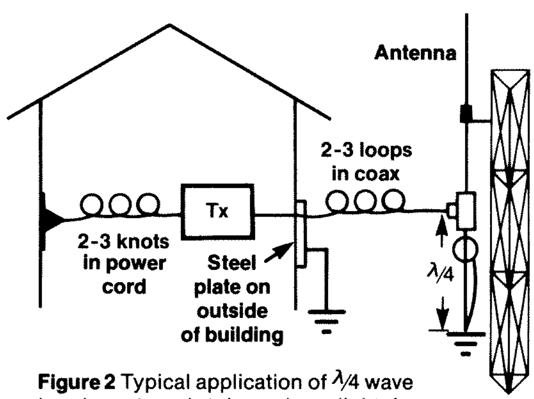


Figure 2 Typical application of λ/4 wave bandpass tuned stub used as a lightning arrestor on the antenna.

TEST PROCEDURE:

1. Connect the SIG GEN OUT to the ANT IN through a "tee." (See Figure 1).
2. Set the FUNCTION switch to SPECTRUM MONITOR.
3. Set the HORIZ switch to SPECTRUM 1 MHz/Div.
4. Set the SIG GEN LEVEL to -20 dBm, FINE to -10 dBm.
5. Set the REF LEVEL switch to -20 dBm.
6. Set the FREQUENCY SELECT switches to the center frequency of the coaxial filter.
7. Calculate the electrical λ/**4** length of the frequency of interest for the coax filter by using the formula:

$$\lambda/4 = \frac{1/F_O \text{ MHz x } 11811 \text{ x } 10^6 \text{in/sec x K}}{4}$$

Where: F_O = Frequency in MHz
1181 in/sec = Speed of light in inches
K = Propagation constant of the coax.

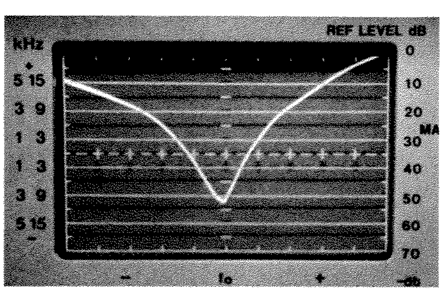
8. Install a connector on one end of the coax to be tuned and cut the coax just a little longer than the calculated λ/4 wavelength.
9. Connect the coax to the "tee" and observe the CRT display.

For a λ/4 notch filter the end of the coax is open. For a λ/4 bandpass filter the end of the coax is shorted.

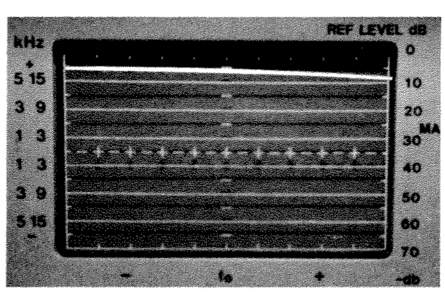
10. Cut the coax in short increments to center the notch or bandpass on the display.

Remember that the electrical length of the tuned stub will be from the center of the "tee" to the end of the coax.

NOTE: Use high quality coax with a high propagation constant for better rejection or bandpass characteristics. If two or more coax filters are connected in parallel, be sure that the coax cable between them is λ/2 long.



CRT Photo 1 shows a typical response of 2 λ/4 open end notch tuned stub coaxial filters in parallel. LOG REF LEVEL is -20 dBm and horizontal dispersion is 1 MHz. Depth of notch is -72 dB.

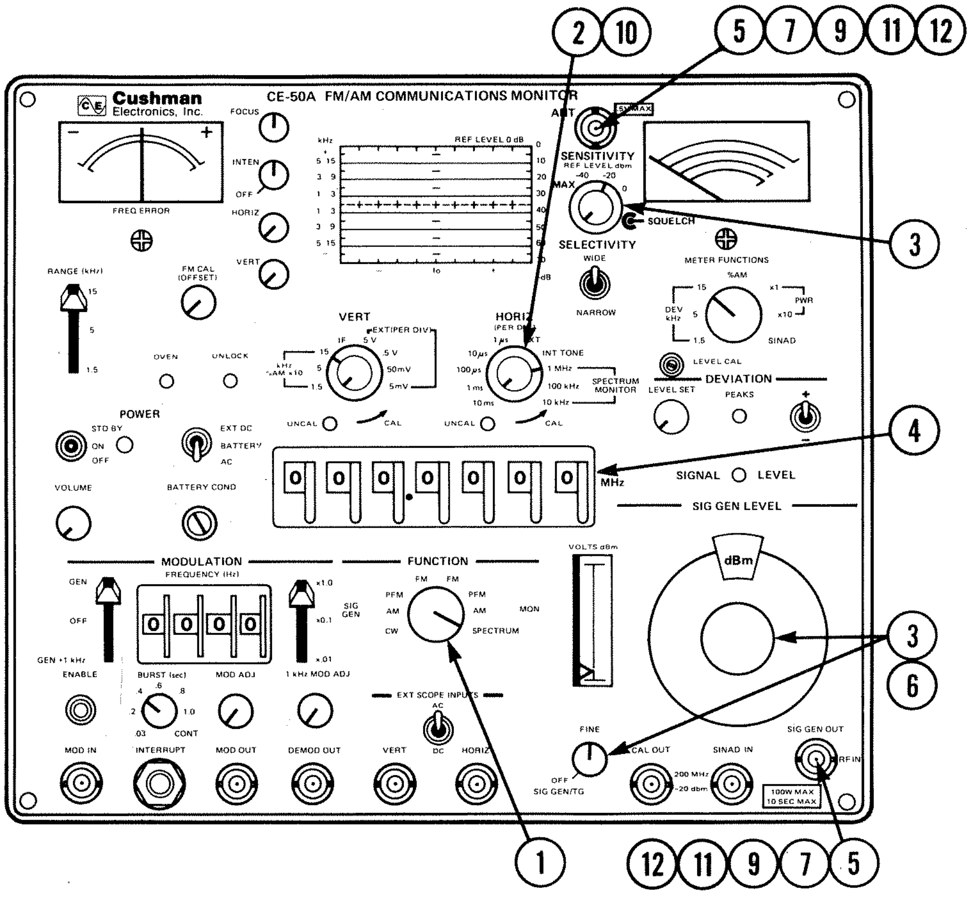


CRT Photo 2 shows the response of the same coax filter as Photo 1 except the tuned stubs have been shored to form a bandpass filter 55 MHz wide at the 3 dB points.

Cushman

TRACKING GENERATOR TEST TG-5

Recommended Test Equipment:
CE-5110, CE-50A-1/TG



Calibrate out insertion loss of coax test leads first.

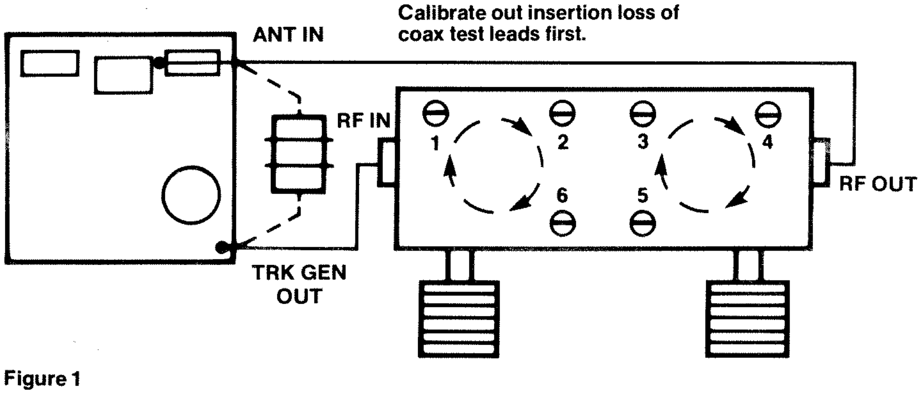


Figure 1

Be sure when you are tuning up an isolator on the bench that it is not lying on a metal surface, as this will affect the tuning of the isolator. The same holds true when installing an isolator; do not mount it directly to a steel plate or wall, use stand offs to keep the ferrite components in the isolator from interacting with a metal surface that may be too close to the case of the isolator. After installation check to see that the tuning has not been affected.

TEST PROCEDURE:

(1) Set the FUNCTION switch to SPECTRUM.

(2) Set the HORIZ switch to SPECTRUM MONITOR 1 MHz/Div.

(3) Set the SIG GEN LEVEL to -20 FINE -10 dB; SENSITIVITY to -20 dB.

(4) Set frequency on monitor to frequency of transmitter.

(5) Connect one test coax cable to ANT IN and one to SIG GEN OUT. Now connect both coax cables together.

(6) Adjust SIG GEN LEVEL to set trace at the top of the CRT display compensating for cable loss.

(7) Connect the SIG GEN LEVEL to the RF In Port on the isolator and the ANT IN to the RF OUT port. (See Figure 1).

(8) Tune the coupling adjustments for maximum output on the CRT. Start with the adjustment that is closest to the R.F. input port and tune in sequence to the adjustment that nearest the output port, i.e., 1, 2, 3, 4. Retune for interaction between coupling elements.

(9) Connect the SIG GEN OUT to the RF output port. Remove the load closest to the input port and connect the ANT IN coax. (See figure 2). Terminate RF input port with 50 Ω.

(10) Tune the coupling adjustment 5 closest to the output port for maximum dip on the CRT. Set HORIZ. to 100 kHz/Div for more resolution. (see CRT Photo 1)

(11) Connect the SIG GEN OUT to the load closest to OUTPUT port and ANT IN to the INPUT port, (see figure 3) and tune for adjustment 6 maximum dip on CRT. Terminate RF output with 50 Ω.

(12) Connect SIG GEN OUT to OUTPUT port and the ANT IN to the INPUT port (see Figure 4) and retune adjustments 5 and 6 for maximum dip on the CRT. Check forward insertion loss again.

Aligning Tunable Isolators & Circulators

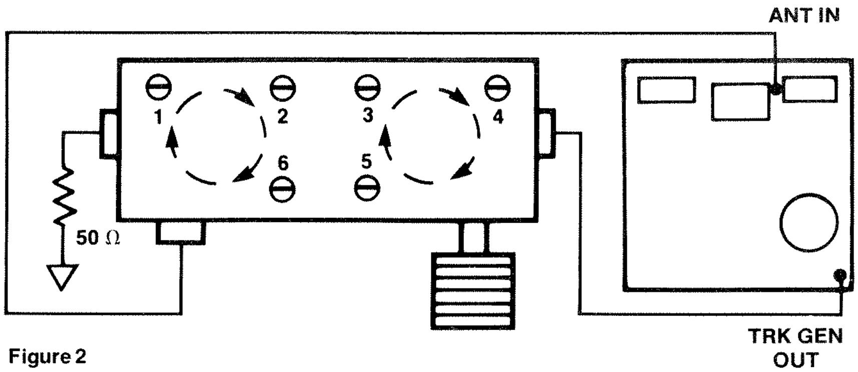
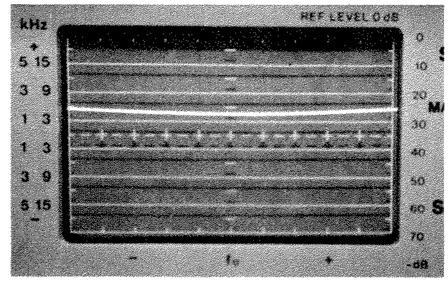


Figure 2



CRT Photo 1 shows 27 dB of rejection for reverse power in the first section of a two section isolator.

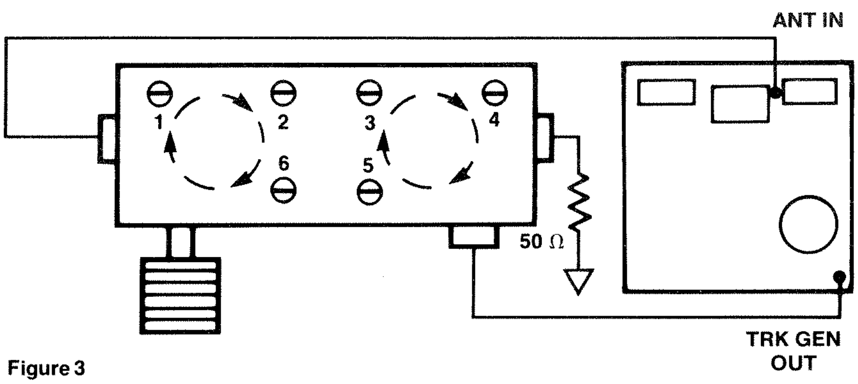
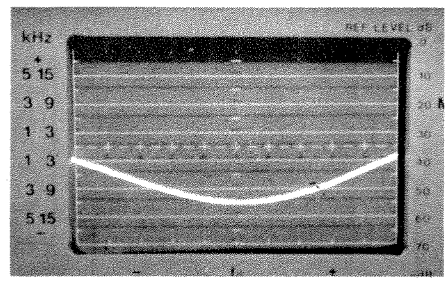


Figure 3



CRT Photo 2 shows the total isolation from output to input to be 55 dB after being properly tuned. Be sure to re-check the forward insertion loss for a slight interaction between the ferrite elements after the first tuning.

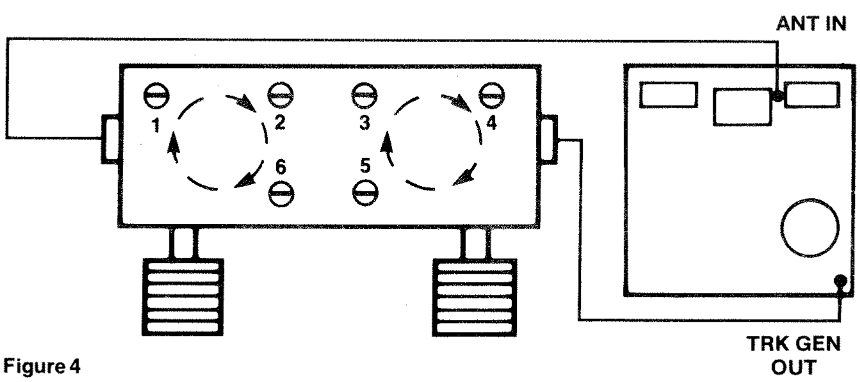
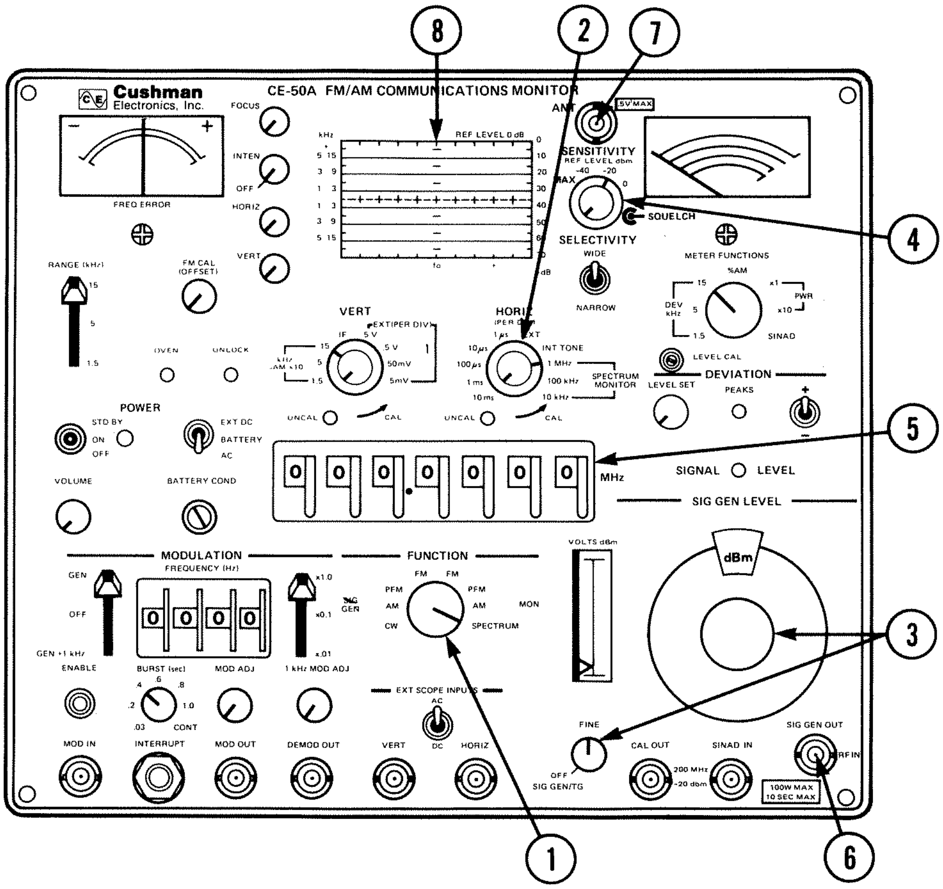
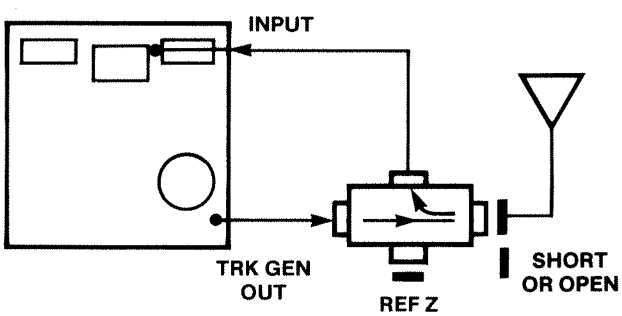


Figure 4

Recommended Test Equipment:
CE-5110, CE-50A-1/TG

Tuning Antenna For Minimum VSWR

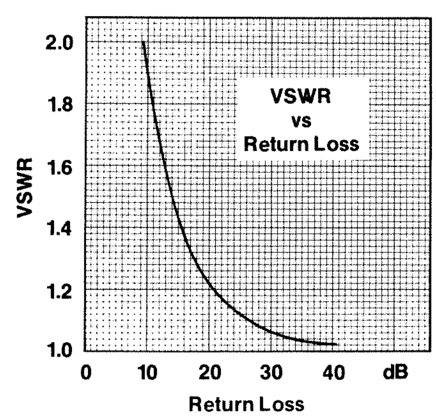


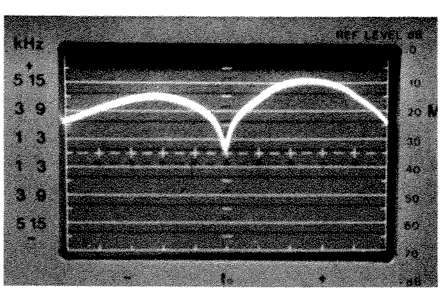


TEST PROCEDURE:

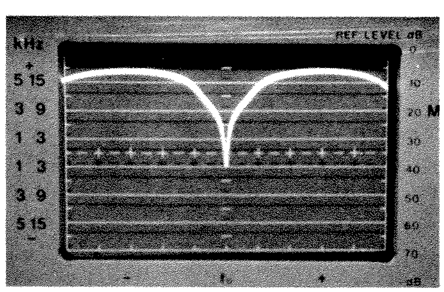
1. Set the FUNCTION switch to SPECTRUM.
2. Set the HORIZ switch to SPECTRUM MONITOR 1 MHz/Div.
3. Set thet SIG GEN LEVEL to -10 dBm: FINE -10 dBm.
4. Set the REF LEVEL to -20 dBm:
5. Set the FREQUENCY SELECT switches to the transmitter frequency.
6. Connect the SIG GEN OUT to RF IN on the VSWR bridge.
7. Connect the ANT IN to RF OUT on the bridge.
8. Set the REF LEVEL on CRT by leaving D.U.T. port on VSWR bridge open and adjusting trace to the top of the CRT display.
9. Connect antenna to D.U.T. port and tune the antenna for maximum return loss.

NOTE: All measurements are made with Wiltron VSWR bridge model 62NF50. Remember, when using a VSWR bridge maximum return loss means that most of the power is being absorbed by the D.U.T. or the VSWR is minimum. Minimum return loss means that most of the power is being reflected back from the D.U.T. and the VSWR will be high.





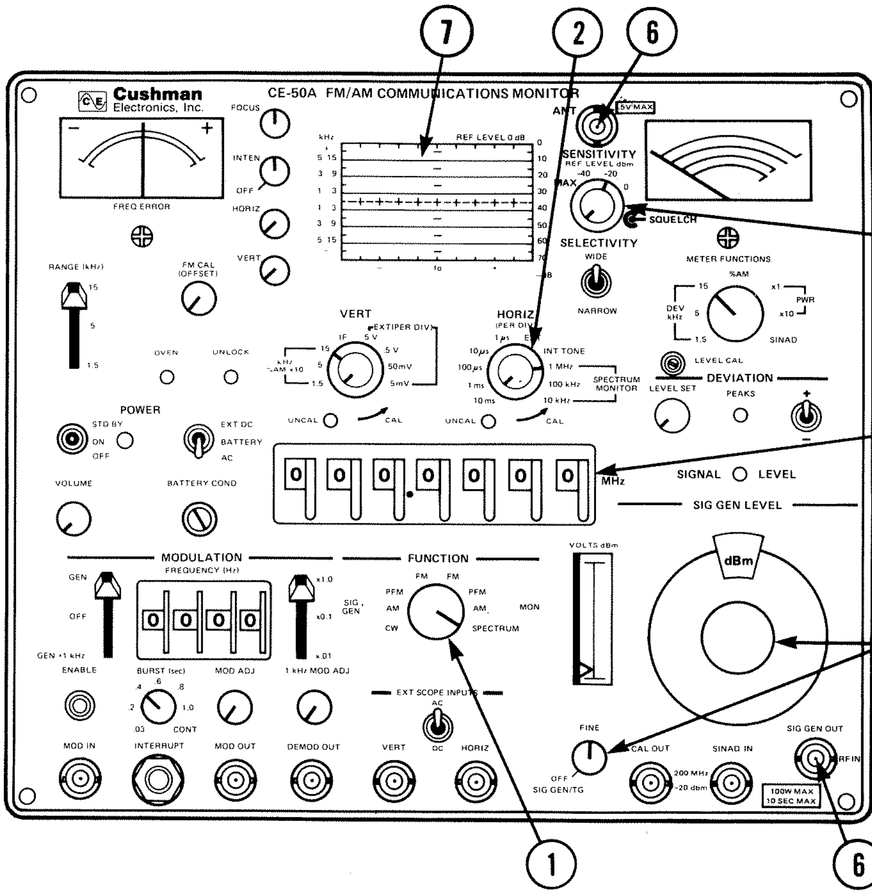
CRT Photo 1 shows the reponse for a 4 element collinear array at 152.8 MHz, while



CRT Photo 2 shows the response of 4 element collinear array at 454.3 MHz. Reference level was set to the top cradicule on the CRT.

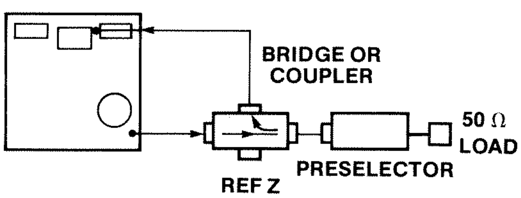
TRACKING GENERATOR TEST TG-7
Recommended Test Equipment:
CE-5110, CE-50A-1/TG

Tuning Pre-Selectors for Minimum VSWR

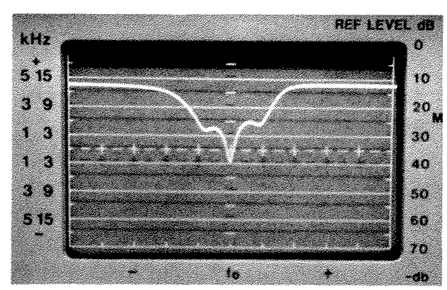


TEST PROCEDURE:

1. Set the FUNCTION switch to SPECTRUM.
2. Set the HORIZ switch to SPECTRUM MONITOR 1 MHz/Div.
3. Set the SIG GEN LEVEL to -10 dBm FINE -10 dBm.
4. Set the REF LEVEL to -20 dBm.
5. Set the FREQUENCY SELECT switches to middle of the preselector range.
6. Connect the SIG GEN OUTPUT to the RF IN on VSWR bridge and connect the RT OUT port on the bridge to the ANT IN on the monitor.
7. Calibrate out the insertion loss of the bridge by leaving the DUT port open and adjusting the trace to the top of the CRT with the coarse and fine controls of the generator.
8. Connect the preselector to the DUT port of the bridge and view the return loss on the CRT. Tune the preselector for maximum return loss over its bandwidth.



CRT Photo 1 shows the VSWR bridge response of a 3 MHz wide, 455 MHz preselector connected between the antenna and a preamplifier. Dispertion is 1 MHz/Div., and the LOG REF was set at the -10 dB graticule. Remember to terminate the output port with 50 Ω when testing passive filters.



Using the VSWR bridge when tuning up a preselector will help minimize mismatch losses and optimize preselector frequency response over the range of the filter. With the TG it is easy to adjust and observe the effect of each adjustment at different frequencies.

Conversion of Return Loss to VSWR

dB	VSWR	% FOR	% REFL	dB	VSWR	% FOR	% REFL	dB	VSWR	% FOR	% REFL	dB	VSWR	% FOR	% REFL
46.0	1.01	99.995	.005	24.0	1.13	99.65	0.35	15.5	1.40	97.2	2.8	9.5	2.00	88.9	11.1
40.0	1.02	99.99	.01	23.5	1.14	99.60	0.40	15.0	1.43	96.8	3.2	9.0	2.10	87.5	12.5
37.0	1.03	99.97	.03	23.0	1.15	99.50	0.50	14.0	1.50	96.0	4.0	8.0	2.32	84.0	16.0
34.0	1.04	99.96	.04	22.0	1.17	99.40	0.60	13.0	1.58	94.9	5.1	7.0	2.61	80.0	20.0
32.0	1.05	99.94	.06	21.5	1.18	99.30	0.70	12.6	1.60	94.5	5.5	6.0	3.00	75.0	25.0
31.0	1.06	99.91	.09	20.7	1.20	99.10	0.90	12.0	1.67	93.6	6.4	5.0	3.57	68.5	31.5
29.0	1.07	99.88	.12	20.0	1.22	99.00	1.00	11.7	1.70	93.2	6.8	4.0	4.42	60.0	40.0
28.0	1.08	99.84	.16	19.0	1.25	98.7	1.30	11.3	1.75	92.5	7.5	3.0	5.80	50.0	50.0
27.0	1.09	99.80	.20	17.7	1.30	98.3	1.70	11.0	1.78	92.1	7.9	2.0	8.72	37.0	63.0
26.4	1.10	99.77	.23	17.0	1.33	98.0	2.00	10.9	1.80	91.8	8.2	1.0	18.00	19.9	80.1
26.0	1.11	99.75	.25	16.5	1.35	97.8	2.20	10.1	1.90	90.2	9.8	0.5	34.78	11.5	88.5
25.0	1.12	99.68	.32	16.0	1.38	97.5	2.50	10.0	1.92	90.0	10.0	0.0	∞	0.0	100

A Few Words About Cavity Testing

Testing Cavity Filters

There are typically 5 tests that should be considered when installing or servicing a duplexed system. These are:

1. Center frequency alignment
2. Receiver degradation
3. Receiver isolation at transmit frequency
4. Transmitter noise suppression at receive frequency
5. Insertion loss

After alignment of the center frequency CAV/DUP tests 1-4, then the next test that should be performed is the receiver degradation test. This test will measure the receiver's sensitivity when the antenna is connected to the duplexer, and the transmitter is keyed (effective sensitivity). Tests 6 & 7 will measure the amount of isolation between the receiver and the transmitter. The insertion loss can be measured by placing a watt meter and a 50 Ω load on the output of the transmitter or isolator if one is present and measuring the power (see Figure 1). Then measure the power out of the cavities. The insertion loss can then be calculated by the formula:

insertion loss in dB = 10 log Pout/Pin

EXAMPLE: dB = 10 log 35/46

db = 10 log .76

insertion loss = 1.2 dB

Before performing any alignment procedure it is recommended that the manufacturer's data sheet and maintenance manual be consulted since each cavity manufacturer will have his own method for tuning. This will enable the service technician to more easily use the Tracking Generator and Spectrum Monitor with the particular kind of cavities under test.

Cavity and Duplexer Theory

There are 3 major categories for cavity filters. They are:

1. Band reject cavities
2. Band pass cavities
3. Band pass/band reject cavities

Band reject cavities act like a parallel resonant filter with the high attenuation at the center of the notch. These filters work well on a mobile duplexer because of their high Q and small size. They also work well filtering out one particular frequency that might be interfering with the receiver.

Band pass cavities act like a series resonant filter with a minimum attenuation at the operating frequency, and high attenuation above and below the operating frequency. These cavities are found in repeater and base station duplexers, antenna combiner systems, and on the output of transmitters to suppress spurious output as well as transmitter intermod.

Band pass/band reject cavities act like series/parallel resonant filters and produce a combination of pass and reject responses. In a leg of a duplexed system two or more of these cavities will product the best transmitter to receiver isolation and intermod suppression of the 3 major types.

A duplexer system is made by interconnecting the combination of cavities together in various ways to provide isolation between the transmitter and receiver. This will allow a repeater, base station, or mobile radio that transmits and receives on different frequencies to operate with the same antenna.

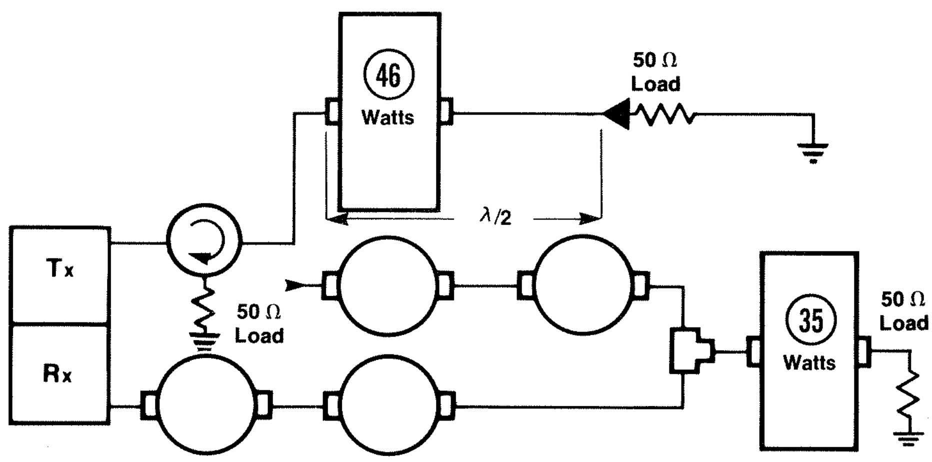
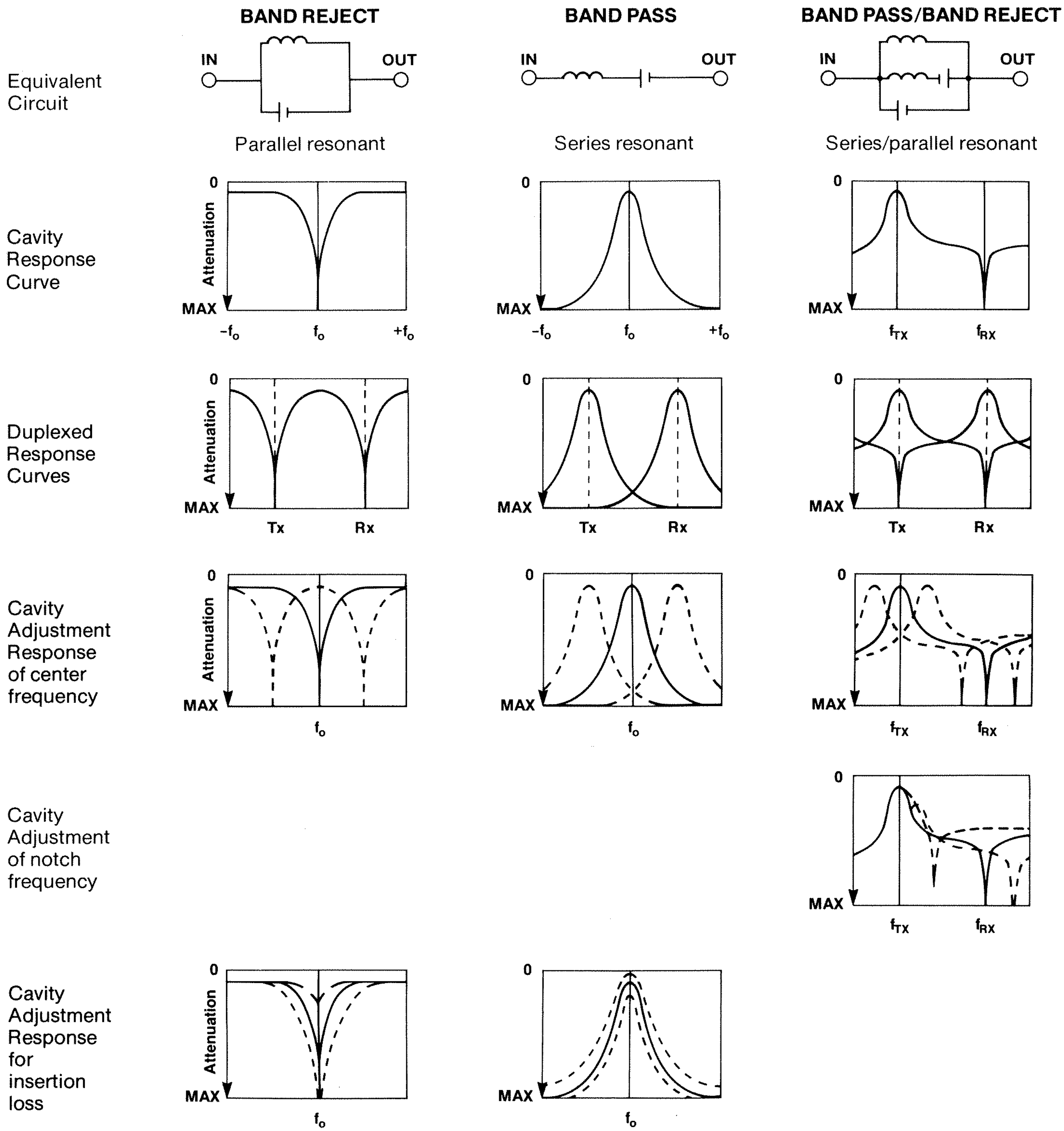


Figure 1

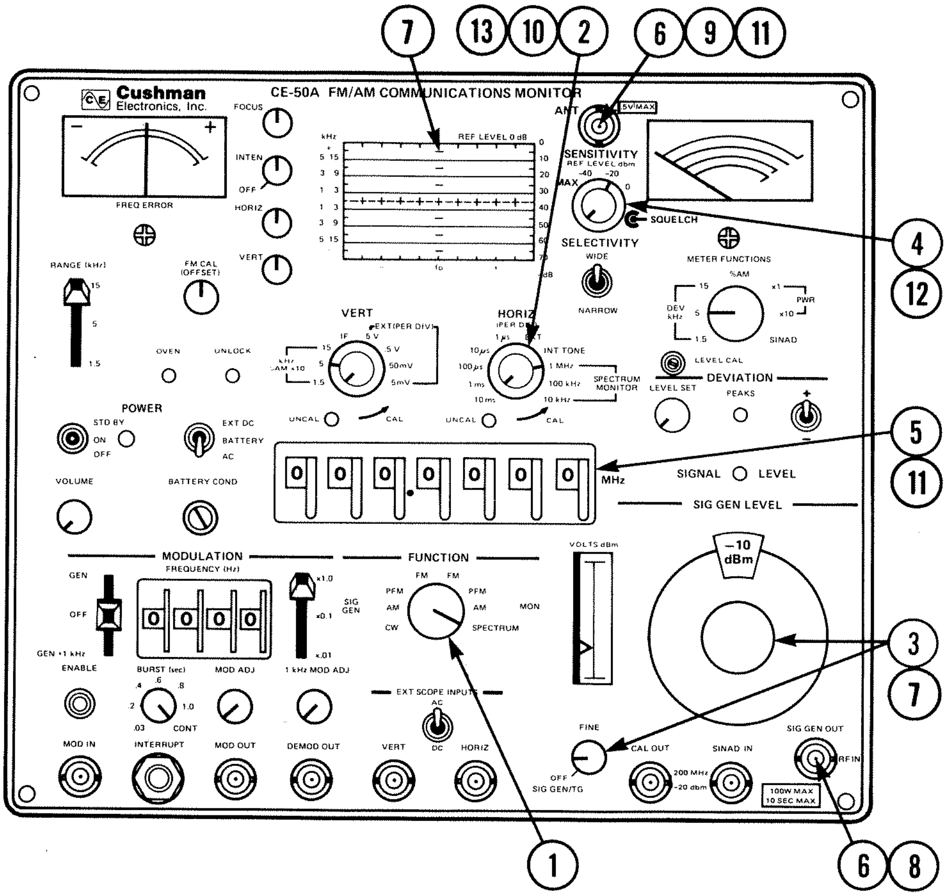
NOTE: The CE-5110 with 1 dB/Div. on the spectrum monitor will perform this test directly. (See "Total System Testing" Application booklet).

TYPICAL RESPONSE CURVES OF CAVITY FILTERS



CAVITY TEST CAV/DUPLEX-1

Recommended Test Equipment:
CE-5110, CE-50A-1/TG



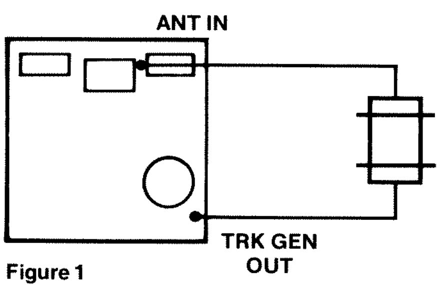


Figure 1

Always connect the coax test leads together and calibrate for the insertion loss of the cables at each frequency of interest

Note:
1. Draw a diagram of the system with frequencies indicated. Label all cables.
2. Construct and carefully inspect all connectors and cabling using double shielded coax.
3. Some types of cavities are tuned together so consult the manufacturer's tuning procedure before beginning any alignment.
4. Terminate unused ports with 50 Ω load.

TEST PROCEDURE:

1. Set the FUNCTION switch to SPECTRUM MONITOR.
2. Set the HORIZ switch to SPECTRUM MONITOR, 1 MHz/Div.
3. Set the SIG GEN LEVEL to -10 dBm; Fine control to -10 dBm.
4. Set the REF LEVEL to -20 dBm.
5. Set the FREQUENCY SELECT switches to the receiver frequency.
6. Connect two double shielded coax test leads together and connect the other ends to the SIG GEN OUT/RF IN and the ANT IN connector. (See Figure 1).
7. Adjust the SIG GEN FINE control to set the trace at the top of the CRT, nulling out the cable insertion loss.
8. Connect the SIG GEN OUT to the antenna connector on the duplexer. (See Figure 2).
9. Connect the ANT IN to the transmitter input connector on the duplexer. Terminate the receiver port with 50 Ω. (See Figure 2).
10. Tune the Tx side of the duplexer to put the notch in the center of the CRT. Set the HORIZ switch to 100 kHz/Div. for more resolution (see CRT Photo 1). Try and keep the bottom of the display above the -60 graticule on the CRT. This will keep the display out of the noise.
11. Move the coax connected to the ANT IN connector to the receive port and set the FREQUENCY SELECT switches to the transmitter frequency. Terminate the Tx port with 50 Ω. (see Figure 3).
12. Tune the Rx side of the duplexer to put the notch in the center of the CRT. Same as step 10.
13. Connect the SIG GEN OUT to the Tx port and the ANT IN to the Rx port. Terminate the Antenna port with 50 Ω. Set the HORIZ switch to 1 MHz/div. (see Figure 4).
14. View the two notches in respect to each other. (see CRT Photo 2).

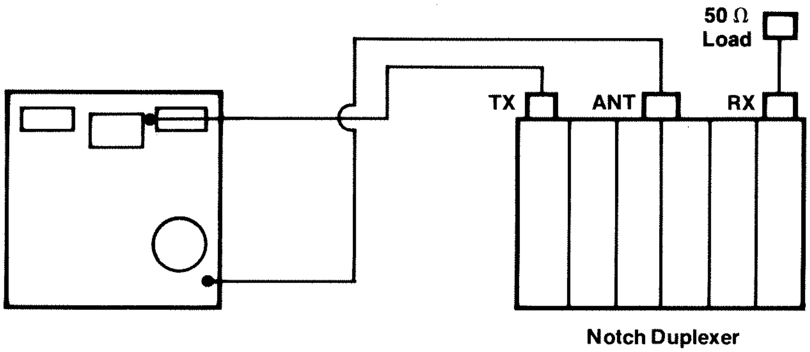
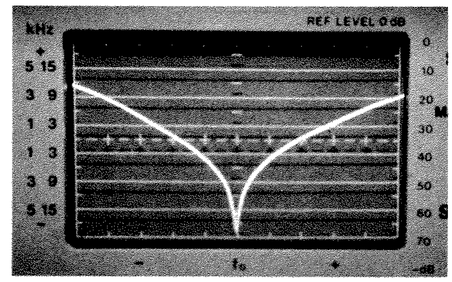


Figure 2



CRT Photo 1 shows the rejection notch of the receiver frequency looking into the transmitter port. Sweepwidth is 100 kHz/Div. REF level is -40 dBm. The total dynamic range of the notch filter when properly tuned is 110 dB.

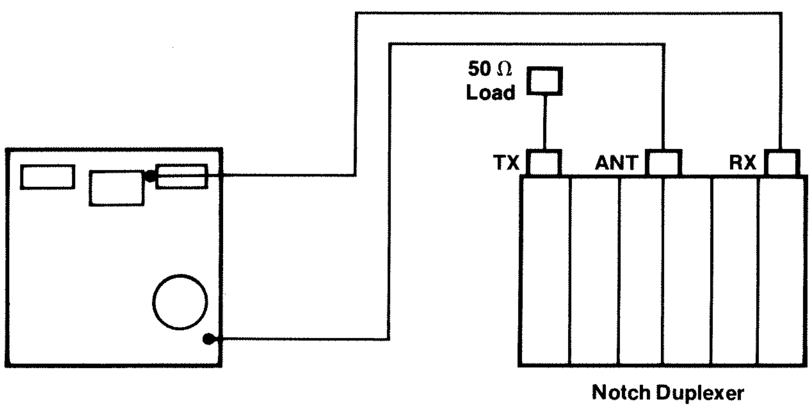
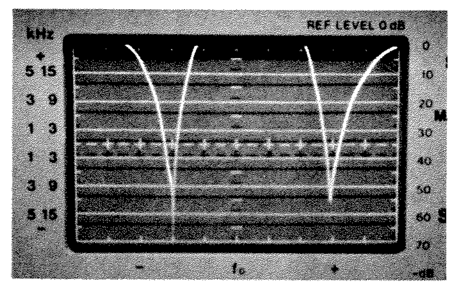


Figure 3



CRT Photo 2 shows both transmit and receive notches properly tuned for a 5 MHz split. REF LEVEL is max. (approximately -60 dBm) and sweepwidth is 1 MHz/Div.

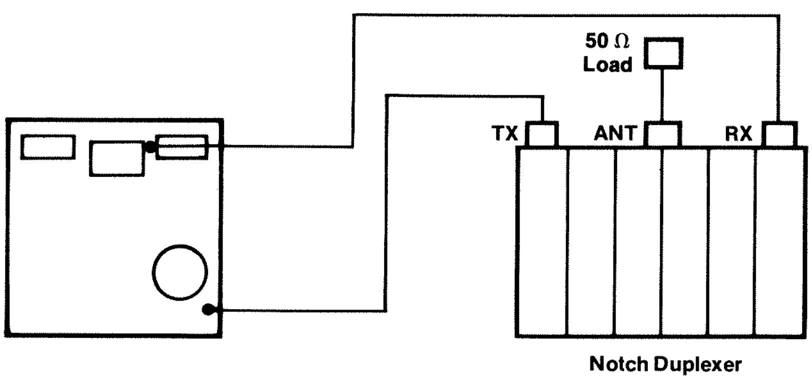
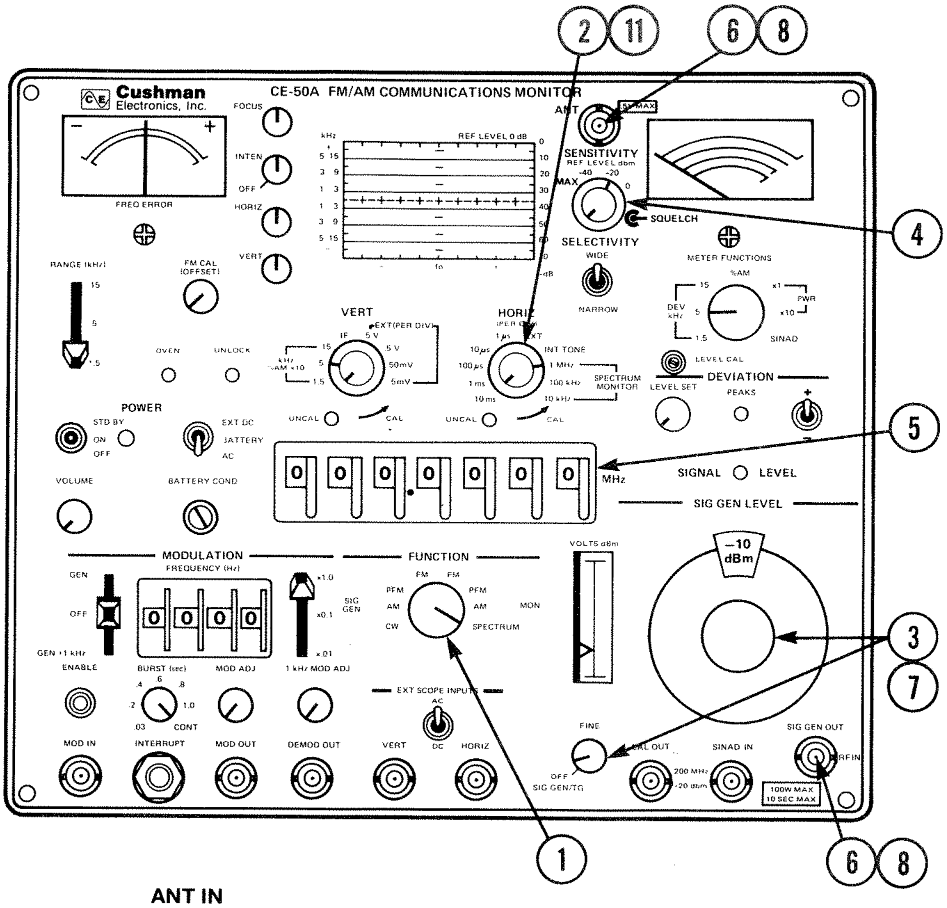


Figure 4

CAVITY TEST CAV/DUPLEX-2

Recommended Test Equipment:
CE-5110, CE-50A-1/TG



TEST PROCEDURE:

1. Set FUNCTION switch to SPECTRUM.
2. Set HORIZ switch to SPECTRUM MONITOR 1 MHz/Div.
3. Set SIG GEN LEVEL to -10 dBm; FINE control to -10 dB.
4. Set REF LEVEL switch to -20 dBm.
5. Set FREQUENCY SELECT switches to transmitter frequency.
6. Connect two double shielded coax cables together and connect the other ends to SIG GEN OUT and ANT IN (See Figure 1).
7. Adjust the SIG GEN FINE control to set the trace at the top of the CRT to compensate for the insertion loss of the coax test cables.
8. Connect SIG GEN OUT to Tx side of cavities, (do not tune cavities through an isolator.) Disconnect cable between the cavities and connect the ANT IN to the cavity that the monitor is connected to (See Figure 2).
9. Tune each cavity independently and then together. (See Figures 2, 3, 4) Reduce sweep width to 100 kHz/Div. for better resolution. (If double peaking occurs and cavities will not tune on each other, suspect wrong cable length between cavities).
10. Before measuring the return loss when the antenna is connected to cavities it's a good idea to perform the antenna VSWR test first (See Figure 5 and TG-5).
11. Connect antenna to the cavities and perform return loss measurement (VSWR) with VSWR bridge. Tune cavities for maximum return loss, then repeat step 9 (See Figure 4).

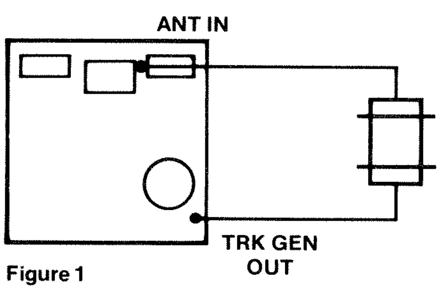


Figure 1

Always connect the coax test leads together and calibrate for the insertion loss of the cables at each frequency of interest

Note: 1. Draw a diagram of the system with frequencies indicated. Label all cables.

2. Construct and carefully inspect all connectors and cabling using double shielded coax.

The proper installation and maintenance of antenna sites is a must in today's 2-way radio world. Keeping RFI out of your neighbor's receiver or transmitter is just as important as keeping RFI out of your own equipment. Keeping your equipment, cavities, isolators, antennas, etc., well maintained will help do both. When tuning up cavities check all mechanical connections to make sure they are tight and free of corrosion. Use double shielded coax, especially with duplex systems. Make sure the antenna is flat or tuned to the transmitter frequency. Use an isolator on the output of the transmitter to keep the transmitter sidebands from being reflected back from the cavity, mixed in the output amplifier, and being retransmitted out as intermod.

Transmitter Cavity Alignment

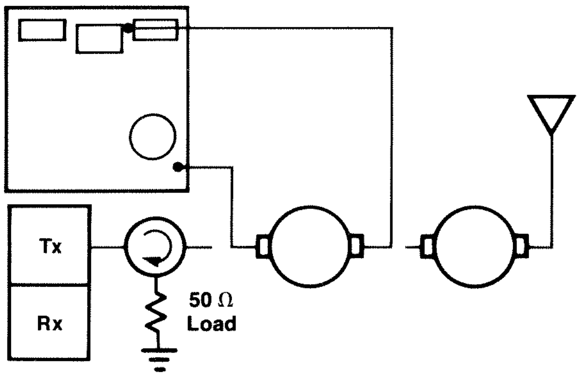


Figure 2

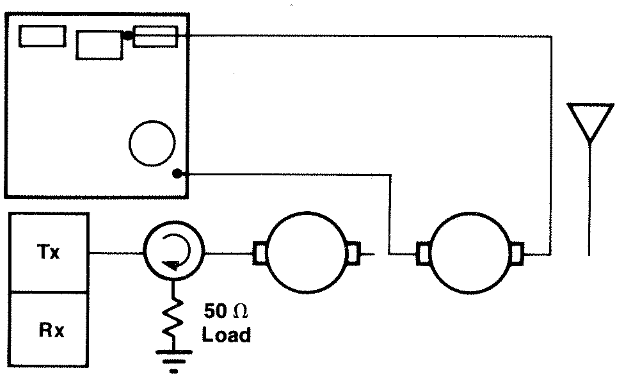


Figure 3

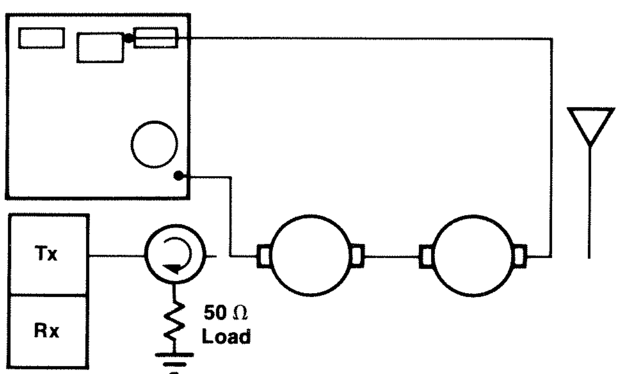


Figure 4

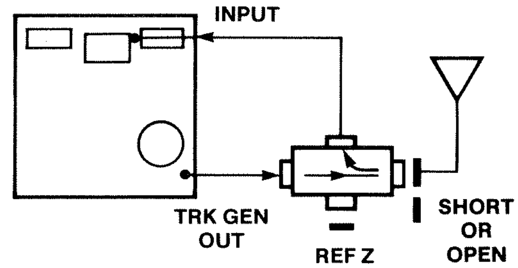


Figure 5

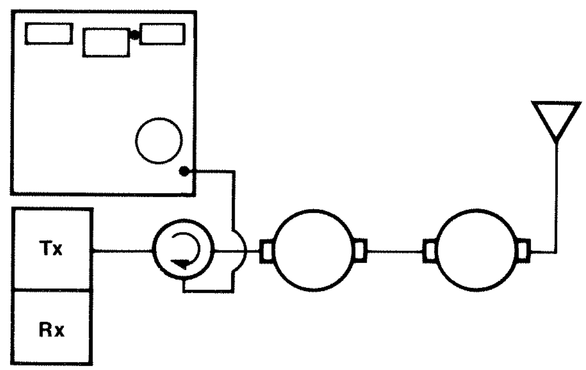


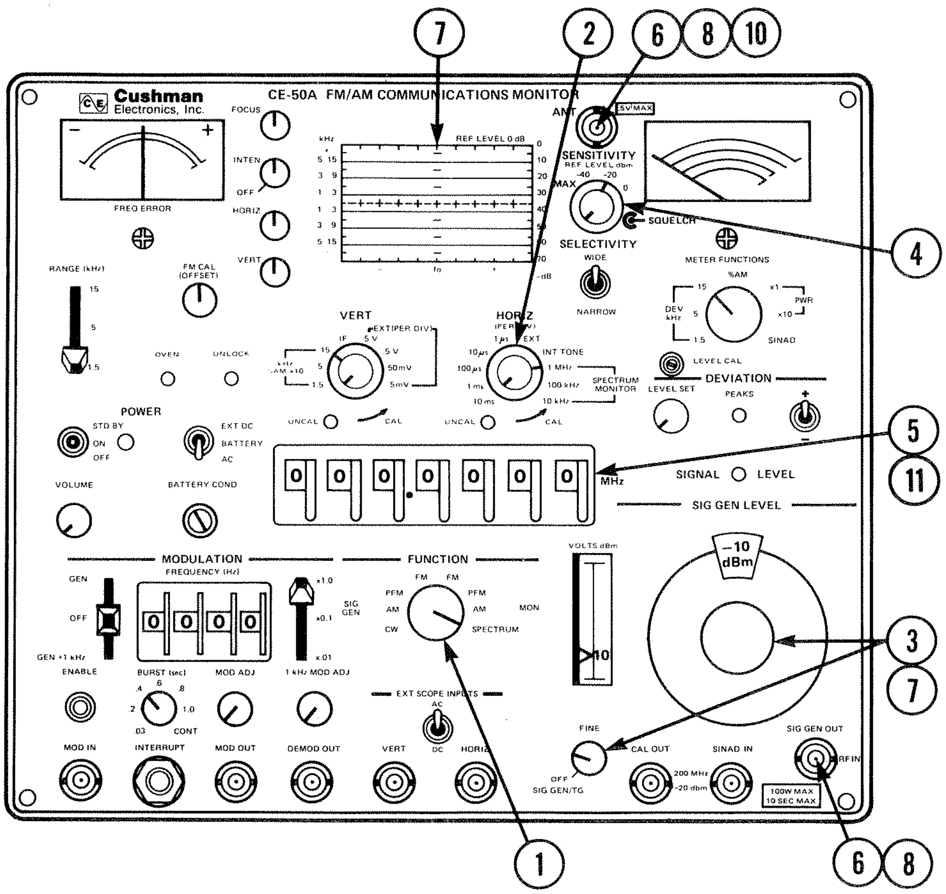
Figure 6

Figure 6 shows how to minimize the VSWR between the transmitter and the first cavity if an isolator is used in the system. This test is performed after the cavities have been aligned.

1. Remove the load on the isolator and connect the SIG GEN OUT/RF IN to the isolator in place of the load.
2. Set the METER FUNCTION switch to X1-PWR.
3. Key the transmitter and adjust the cavity closest to the isolator for minimum power on the watt meter.

CAVITY TEST CAV/DUPLEX-3

Recommended Test Equipment:
CE-5110, CE-50A-1/TG



TEST PROCEDURE:

1. Set FUNCTION switch to SPECTRUM.
2. Set HORIZ switch to SPECTRUM MONITOR 1 MHz/Div.
3. Set SIG GEN LEVEL to -10 dBm; FINE control to -10 dB.
4. Set RF LEVEL switch to -20 dBm.
5. Set FREQUENCY SELECT switches to transmitter frequency.
6. Connect two double shielded coax together and connect the other ends to SIG GEN OUT and ANT IN (See Figure 1).
7. Adjust the SIG GEN FINE control to set the trace at the top of the CRT to compensate for the insertion loss of the coax test cables.
8. Connect SIG GEN OUT to the input of the first transmitter cavity and connect ANT IN to the output of the cavity. Tune each cavity independently then together (See Figure 2). DO NOT tune through an isolator.
9. Tune the other cavities as described in step 8. (See Figure 3).
10. Connect the ANT IN to the output port on the duplexed system and tune all the cavities together. (See Figure 4).
11. Set the FREQUENCY SELECT switches to the receiver frequency.
12. Repeat step 8-9 on the receiver cavities. (See Figure 5 & 6).
13. Connect a VSWR bridge to the input of the first transmitter cavity and adjust the center frequency of that cavity only for maximum return loss on the CRT. (See Figure 7 and TG-6 for return loss measurement).
14. Perform VSWR test of antenna. (See TG-6 for return loss measurement).
15. Perform duplexer desense test CAV/DUPLEX-5.

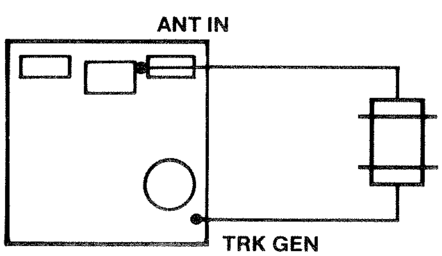


Figure 1

Always connect the coax test leads together and calibrate for the insertion loss of the cables at each frequency of interest

Note:
1. Draw a diagram of the system with frequencies indicated. Label all cables.
2. Construct and carefully inspect all connectors and cabling using double shielded coax.
3. Some types of cavities are tuned together so consult the manufacturer's tuning procedure before beginning any alignment.
4. Terminate unused ports with 50 Ω load.

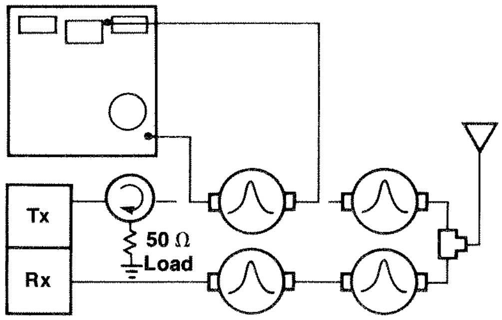


Figure 2

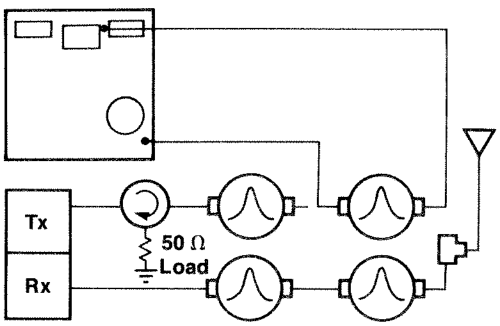


Figure 3

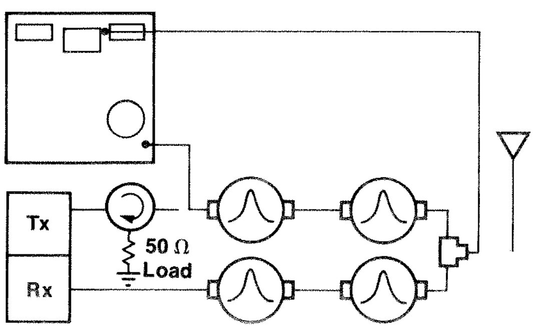


Figure 4

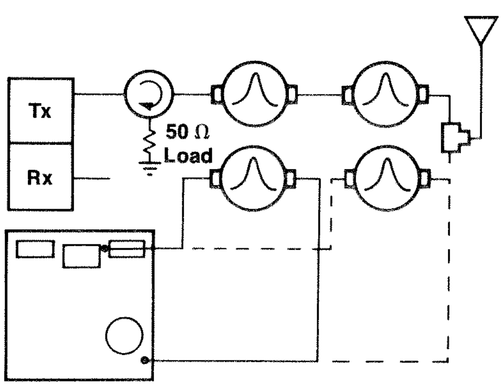


Figure 5

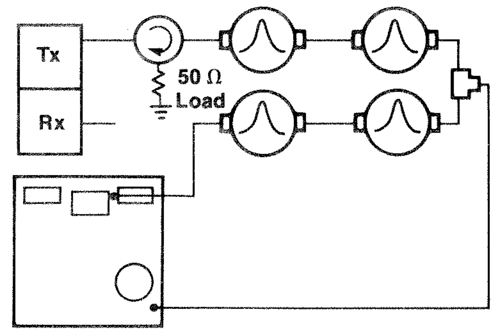


Figure 6

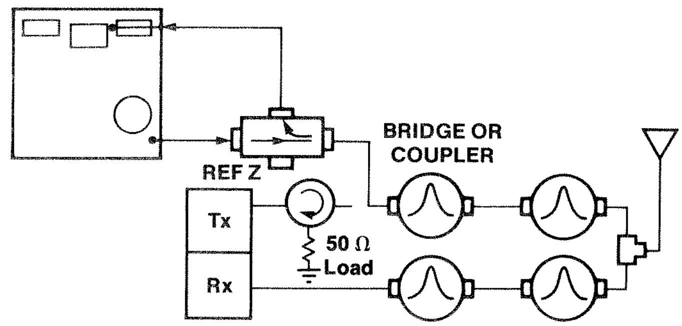
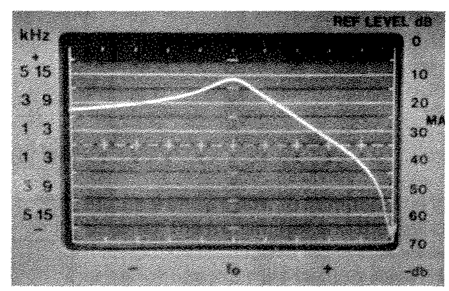
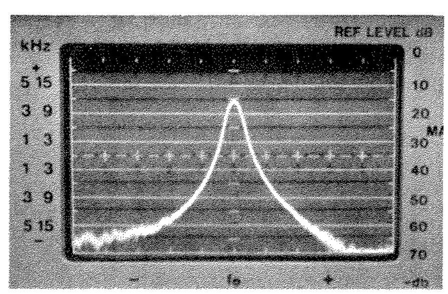


Figure 7



CRT Photo 1 shows the response for a single cavity. Insertion loss is about 2 dB. Note the broad bandpass response which reduces selectivity.



CRT Photo 2 shows the response of 3 cavities connected together. Note how the selectivity has been greatly increased. The trade off for increased selectivity is an increase insertion loss to about 5 dB.

Cushman

CAVITY TEST CAV/DUPLEX-4

Recommended Test Equipment:
CE-5110, CE-50A-1/TG

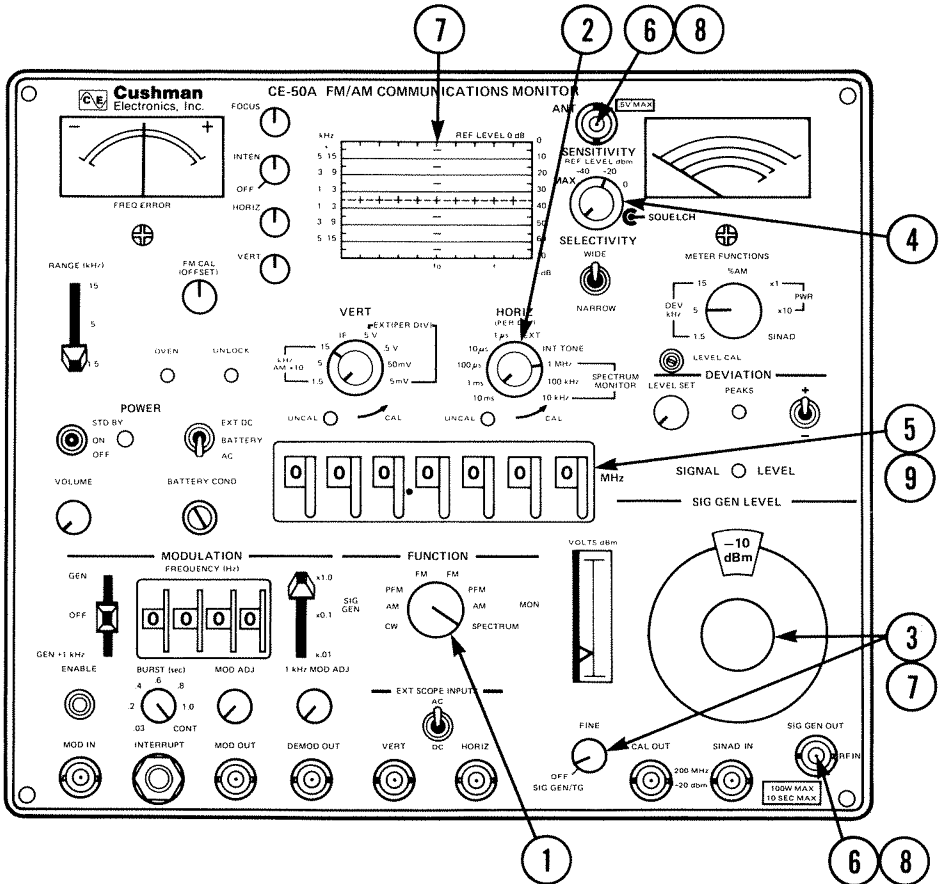
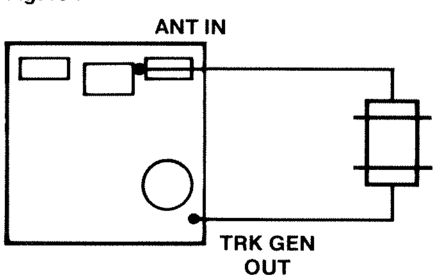


Figure 1



Always connect the coax test leads together and calibrate for the insertion loss of the cables at each frequency of interest

Note: 1. Draw a diagram of the system with frequencies indicated. Label all cables.

2. Construct and carefully inspect all connectors and cabling using double shielded coax.

3. On some types of cavities, you tune through both cavities at the same time. Consult the manufacturer's alignment procedure before starting.

4. If double peaking of the bandpass occurs suspect wrong cable lengths between cavities.

TEST PROCEDURE:

1. Set FUNCTION switch to SPECTRUM.
2. Set HORIZ switch to SPECTRUM MONITOR 1 MHz/Div.
3. Set SIG GEN LEVEL to -10 dBm; FINE control to -10 dB.
4. Set R LEVEL dBm switch to -20 dBm.
5. Set FREQUENCY SELECT switches to transmitter frequency.
6. Connect two double shielded coax together and connect the other ends to SIG GEN OUT and ANT IN (See Figure 1).
7. Adjust the SIG GEN FINE control to set the trace at the top of the CRT to compensate for the insertion loss of the coax test cables.
8. Connect the SIG GEN OUT to the cavity closest to the transmitter. (Do not tune through an isolator). Disconnect the cable between the cavities and connect the ANT IN to the other connector on the cavity. (See Figure 2).
9. Align each cavity independently tuning the bandpass first changing the FREQUENCY SELECT switches to the receiver frequency and tuning the band reject (notch) second. Retune each cavity a second time (elements in the cavities will interact slightly on the first tuning).
10. Connect the cavities to the duplexed system. (See Figure 3). Terminate the receiver side with 50 Ω and retune (first the bandpass and then the band reject).
11. Align the receiver cavities the same way as the transmitter cavities repeating steps 8-10 (See Figure 4). The bandpass is tuned to the receiver frequency.
12. Perform return loss measurement on cavity closest to transmitter (See Figure 5 and TG-6).
13. Connect the duplexed system to the repeater and perform the receiver desense test. (See CAV/DUPLEX-5).

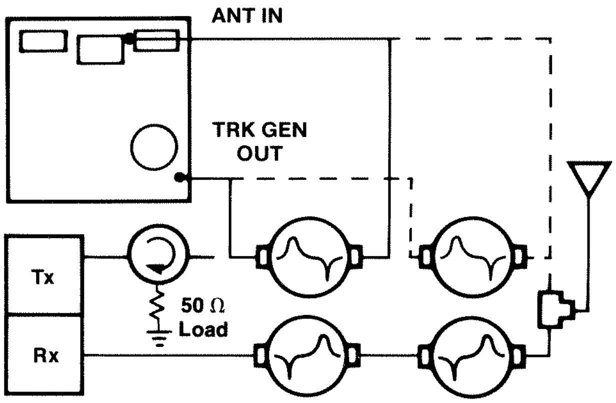


Figure 2

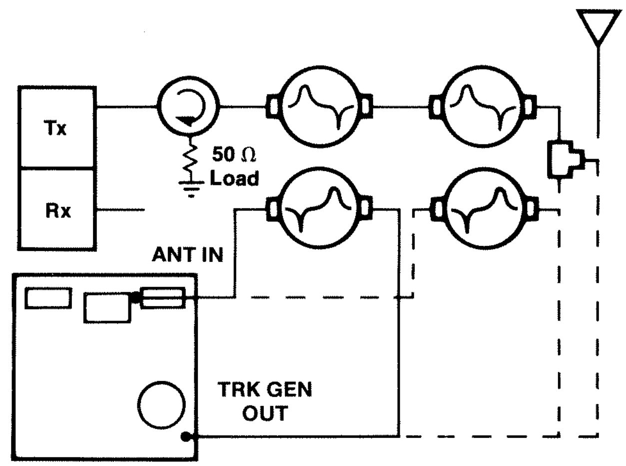


Figure 4

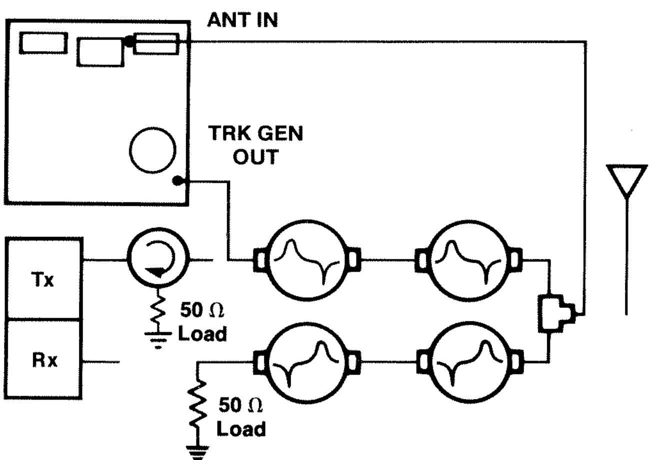


Figure 3

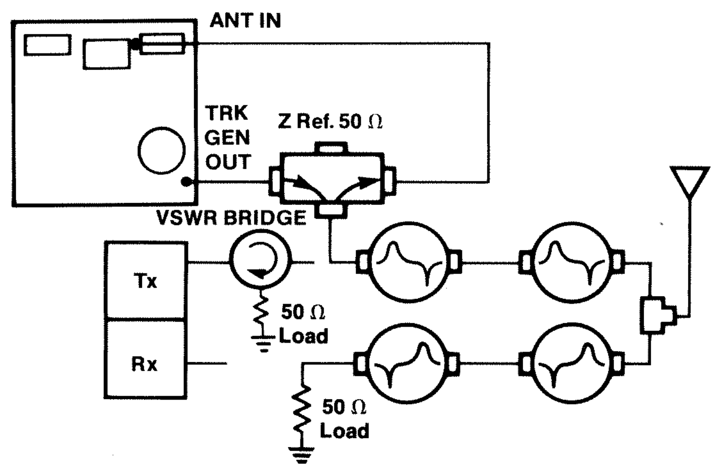
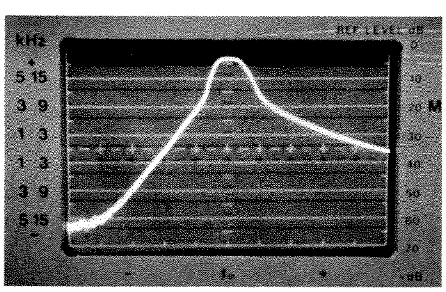
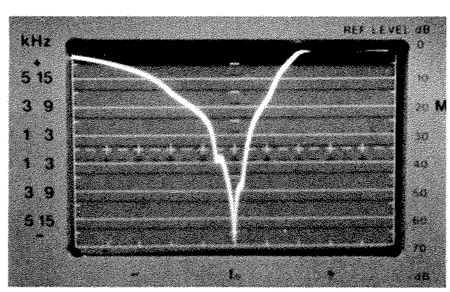


Figure 5



CRT Photo 1 shows a typical band pass display two pass/notch cavities. Center frequency is 454.3 MHz with 1 MHz/Div.



CRT Photo 2 shows the notch display for the two pass/notch cavities. The center frequency is 459.3 MHz with 1 MHz/Div. For more resolution switch to 100 kHz/Div. and recenter the notch.

CAVITY TEST CAV/DUPLEX-5
Recommended Test Equipment:
CE-5110, CE-50A Series
CE-45A, CE-46A

Measuring Receiver Degradation Of Duplexed System

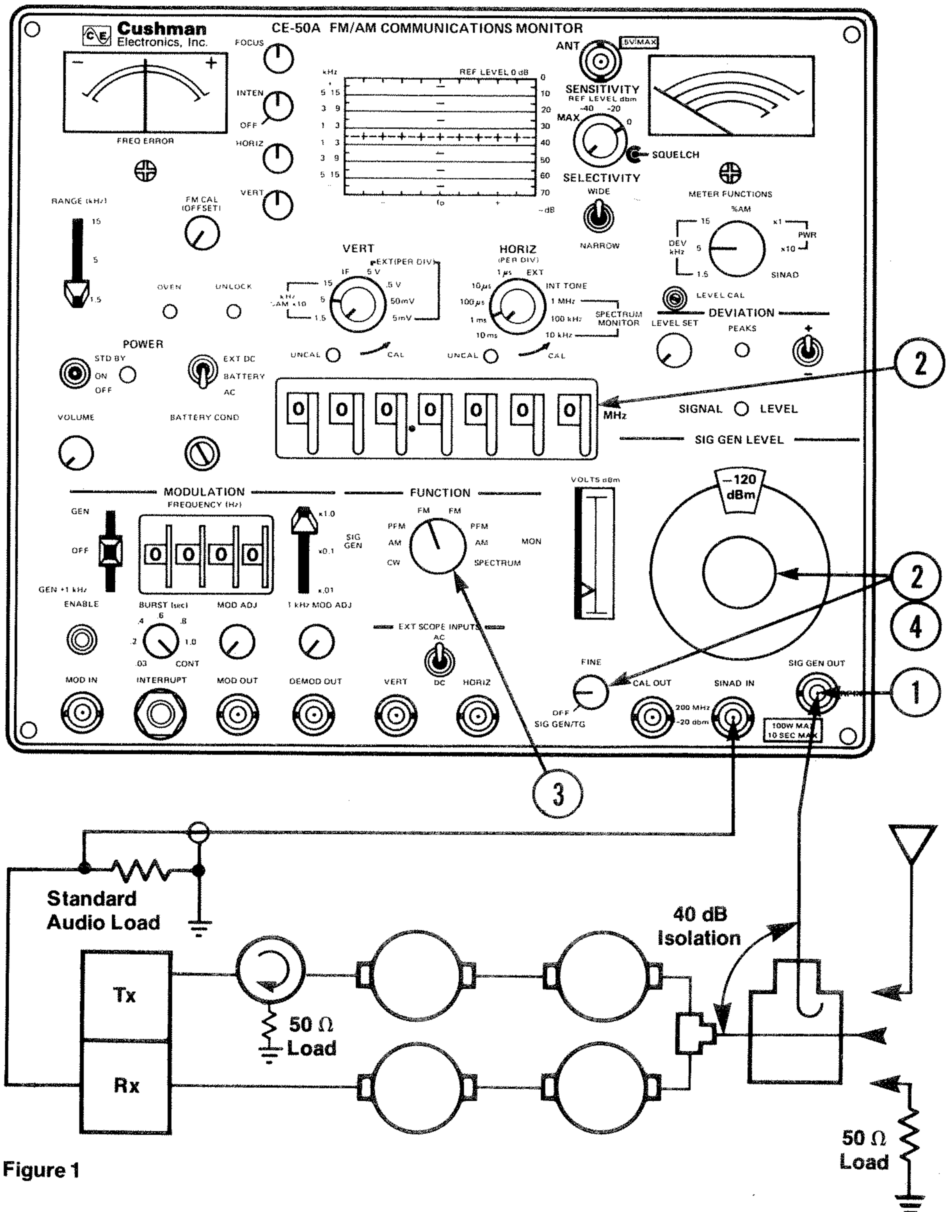


Figure 1

TEST PROCEDURE:

(1) Connect RF coupler to output of duplexer and terminate output of coupler with 50 Ω. Connect SIG GEN OUT to sampling port on coupler. (See Figure 1).

(2) Set FREQUENCY SELECT switches to the receiver frequency.

(3) Set FUNCTION switch to FM.

(4) Increase SIG GEN LEVEL until the 12 dB SINAD sensitivity of the receiver is obtained (see RX-4 Receivers Part 2, on how to measure 12 dB SINAD on a receiver). Record this level. **Note:** Disable audio bus to transmitter. (Alternate method is to use 20 dB quieting).

(5) Key the transmitter and again measure the 12 dB SINAD sensitivity.

(6) Subtract the level recorded in step 4 from the level recorded in step 5. This is the receiver degradation due to transmitter sideband noise.

EXAMPLE:

50 Ω: 12 dB SINAD Tx unkeyed	= 80 dBm
50 Ω: 12 dB SINAD Tx unkeyed	= 74 dBm
Receiver degradation due to Tx side band noise.	= 6 dB

(7) Attach the antenna to the duplexer key transmitter and again measure the 12 dB SINAD sensitivity. Record this level.

(8) Subtract the level in step 4 from the level in step 7. This is the receiver degradation due to the Tx side band noise and the antenna system.

EXAMPLE:

50 Ω: 12 dB SINAD step 4	= 80 dBm
Ant.: 12 dB SINAD step 7	= 68 dBm
Receiver degradation	= 12 dB

(9) Subtract degradation calculated in step 6 from total system degradation calculated in step 8 to get antenna system degradation.

(10) Effective sensitivity of receiver equals total system degradation calculated in step 8 minus basic receiver 12 dB SINAD sensitivity.

EXAMPLE:

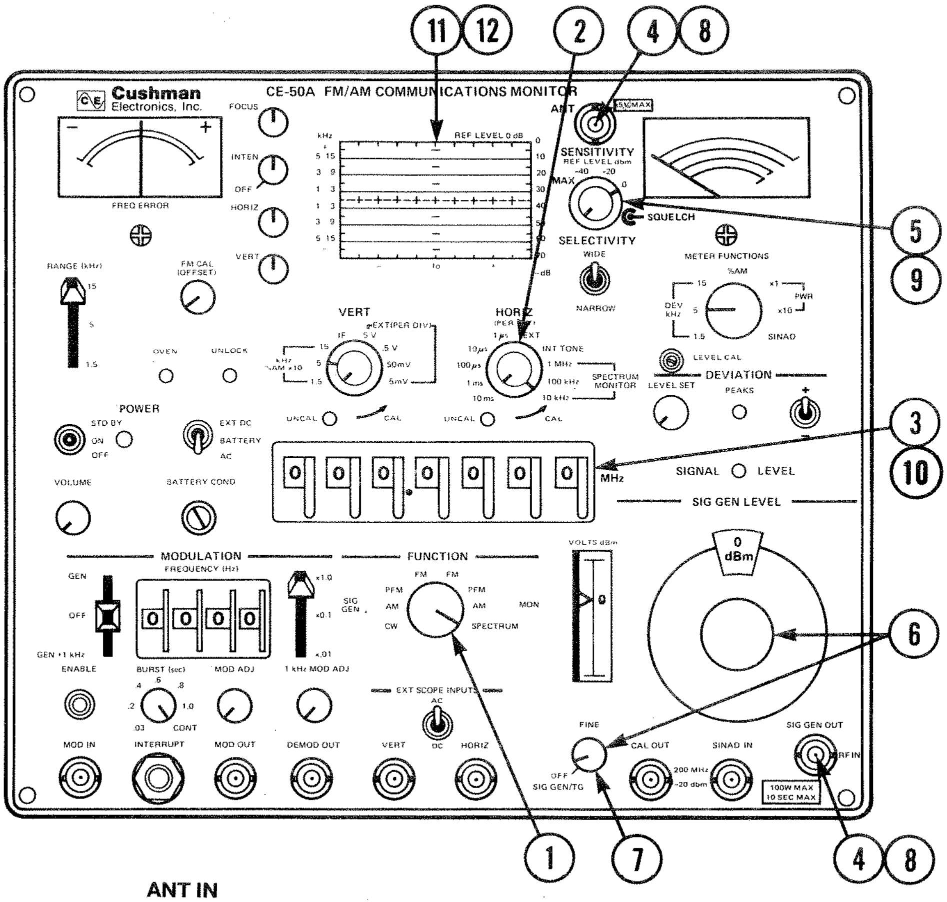
Basic 12 dB SINAD	= −113 dBm = .5 μV
Total system degradation	= 14 dB
Effective sensitivity	= −99 dBm = 2.5 μV

Tuning up a duplexer is not complete until this receiver desense measurement had been made. There are several things that can cause desense in a duplexed system when the transmitter is key. Inadequate shielding of the Tx and Rx sections in the repeater can cause desense, as well as running the Tx cable from transmitter to the duplexer too close to the duplexer antenna or receiver cable. Another cause of receiver desense is a bad joint beyond the antenna port of the duplexer. The noise generated in the bad joint comes back into the duplexer and desenses the receiver. Last there are the many sources of IM. Transmitter IM is produced by one transmitter mixing with another transmitter, generating a signal on or near the receiver frequency.

CAVITY TEST CAV/DUPLEX-6

Recommended Test Equipment:
CE-5110, CE-50A-1/TG

Measuring Receiver Isolation At Tx & Rx Frequencies



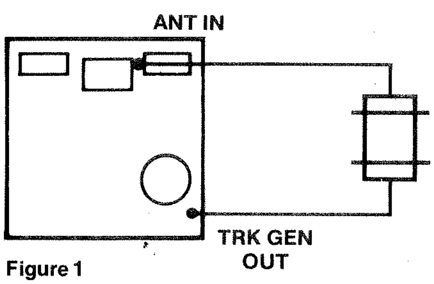


Figure 1

Calibrate out the insertion loss of coax test leads by connecting them together and setting the trace to the top of the CRT at each frequency of interest.

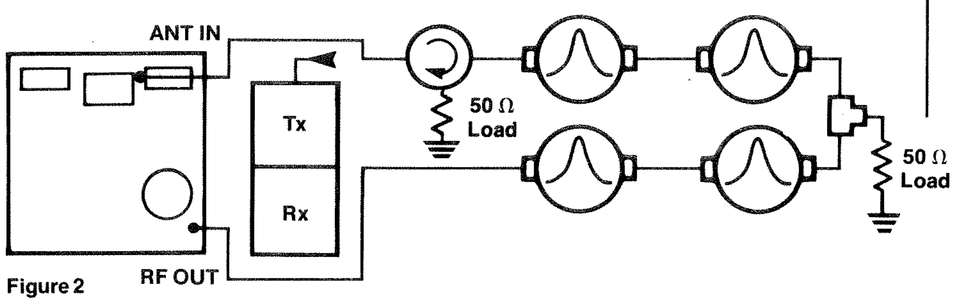


Figure 2

Isolation, expressed in dB, is one of the most important considerations in the design and maintenance of duplex systems. Sufficient isolation must be provided between the receiver and the transmitter in order to prevent the sensitivity of the receiver from being adversely affected by transmitter side band noise.

TEST PROCEDURE:

(1) Set FUNCTION switch to SPECTRUM.

(2) Set HORIZ switch to SPECTRUM MONITOR 10 kHz/Div.

(3) Set FREQUENCY SELECT switches to transmitter frequency.

(4) Connect ANT IN to SIG GEN OUT. (See Figure 1).

(5) Set REF LEVEL dBm to 0.

(6) SIG GEN LEVEL to 0 dBm out.

(7) Set trace on CRT to 0 dBm using FINE RF adjust. (This sets a calibrated reference level compensating for the loss in the test cables).

(8) Connect ANT IN to receiver side of duplexer and connect SIG GEN OUT to the transmitter side. Terminate antenna port with 50 ohms (See Figure 2).

(9) Increase REF LEVEL dBm switch to max. The top of the CRT is now ≅ 60 dBm and record level of insertion loss. Example: if level reads -50 dBm add -60 dBm + -50 dBm = 110 dBm.

(10) Repeat steps 3 through 10 only set FREQUENCY SELECT switches to receiver frequency to obtain isolation to transmitter noise at receiver input.

(11) While viewing the CRT, replace the 50 Ω load with the antenna and view the level of the noise floor on the CRT and look for on or adjacent channel desense. Key up any nearby transmitters suspected of external transmitter intermod interference.

(12) Connect the transmitter to the duplexed system and key both suspect transmitter and yours and look for on or adjacent channel desense. Internal transmitter intermod. (See SPEC-6 "Analyzing External Transmitter Intermod" to determine which transmitter is at fault.)

CAUTION: Never key the transmitter directly into the ANT IN connector.

Cushman

CAVITY TEST CAV/DUPLEX-7
Recommended Test Equipment:
CE-5110, CE-50A Series
CE-45A, CE-46

Measuring Tx Noise Suppression At Rx Frequency

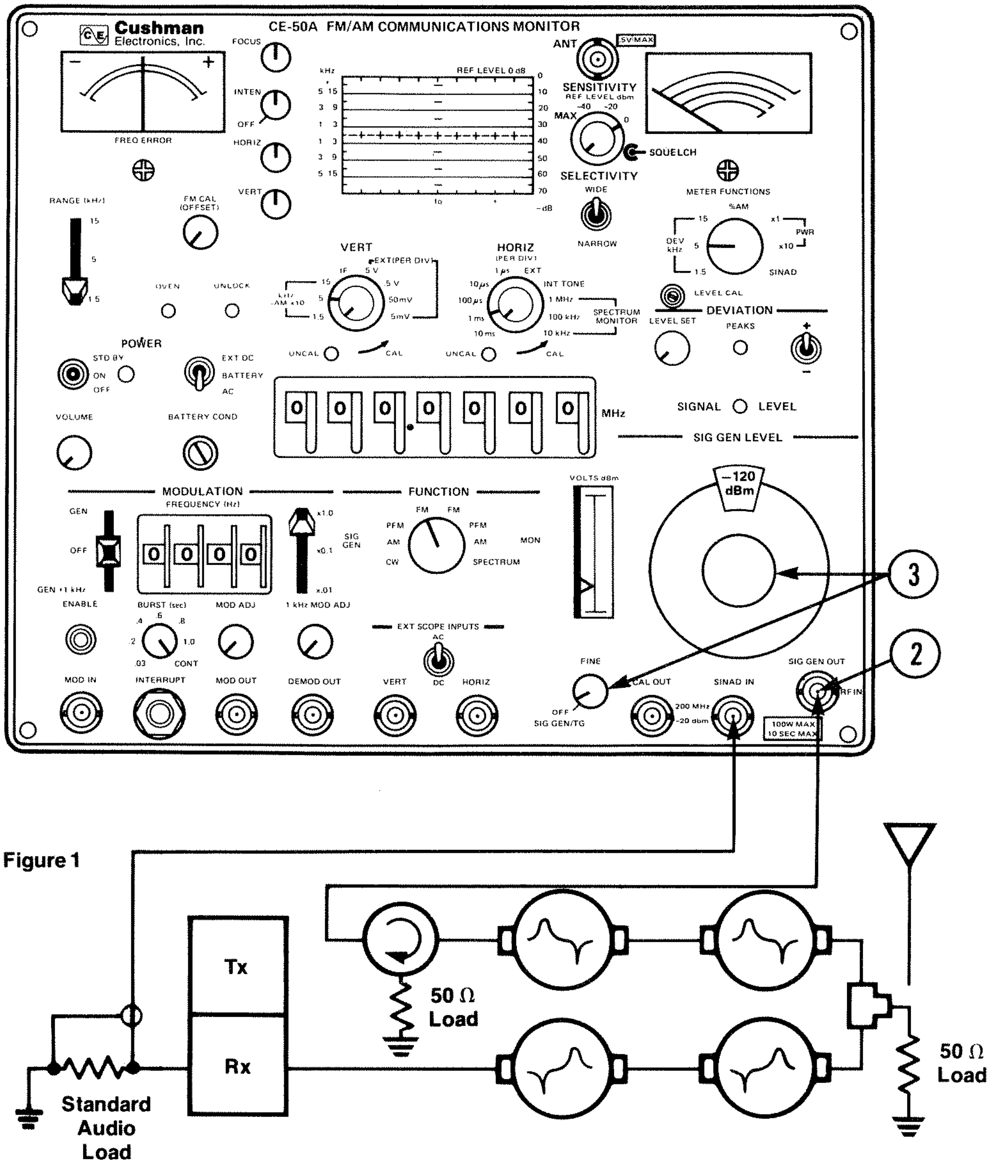


Figure 1

TEST PROCEDURE:

1. Perform 12 dB SINAD test on receiver. (See PART 2 RX-4 for test procedure.) Record sensitivity of receiver. An alternate method would be to use the 20 dB quieting sensitivity.
2. Connect SIG GEN OUT to input of cavity closest to output of Tx, or to the isolator if present. (See Figure 1).
3. Increase SIG GEN OUT until receiver is at 12 dB SINAD sensitivity. Record this level.
4. Subtract step 1 from step 3.

EXAMPLE:

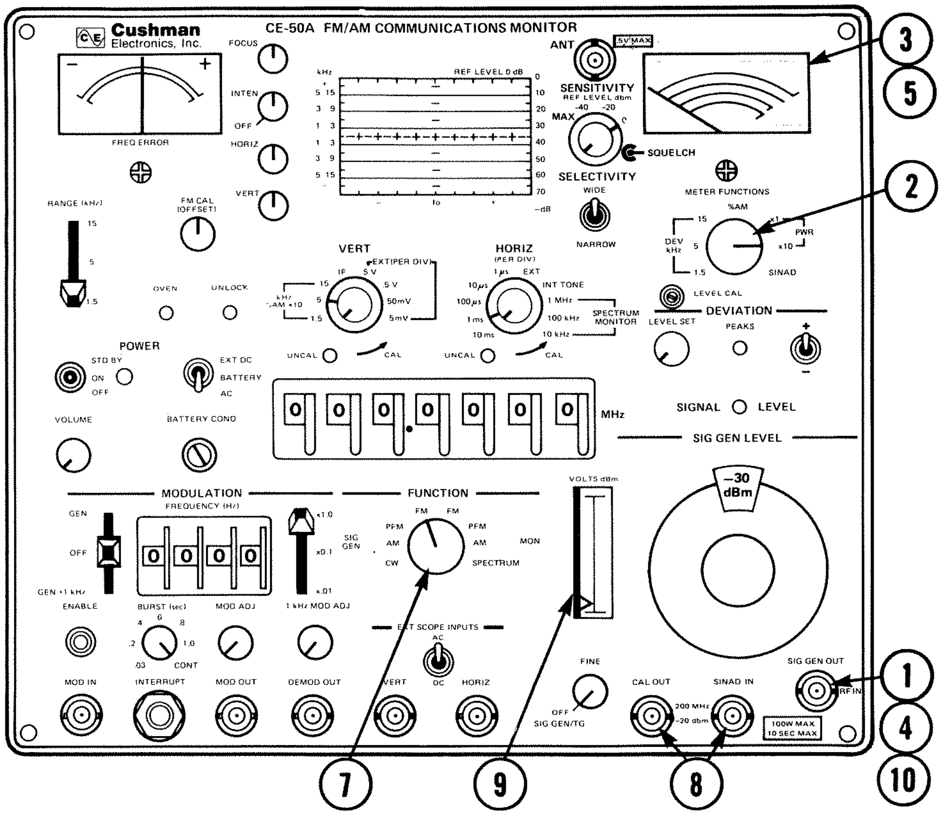
12 dB SINAD of receiver	-103 dBm
12 dB SINAD of step 3	-5 dBm
Transmitter noise suppression:	98 dB

The basic rule of thumb in two-way radio is never assume anything. Be sure to perform incoming inspection of all new equipment for proper frequency of operation insertion loss, etc. Whether it's from a well known manufacturer or small unknown company. This important step can in many ways save you time and money by not having to do a lot of unnecessary system troubleshooting of a new installation. Be sure to keep a maintenance log of all your installations including such data as power out, frequency, insertion losses in transmission line, duplexers, and VSWR measurements of antennas, etc. These, along with time and dates of repairs and modification, will be infomation appreciated by service persons working on the equipment in the future, as well as the present.

CAVITY TEST CAV/DUPLEX-8

Recommended Test Equipment:
CE-5110, CE-50A Series
CE-45A, CE-46

Measuring Cavity Insertion Loss



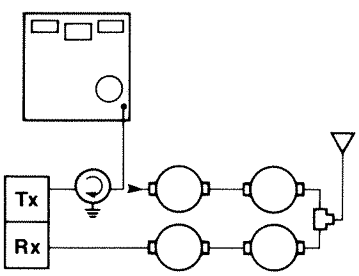


Figure 1

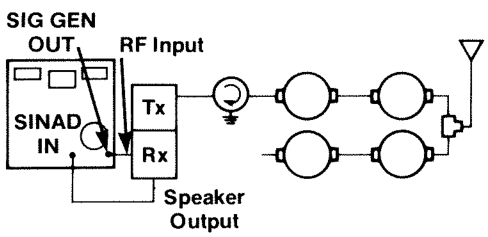


Figure 3

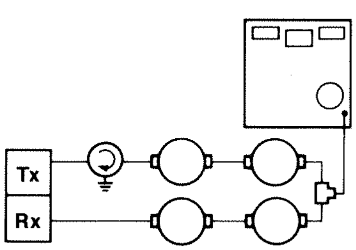


Figure 2

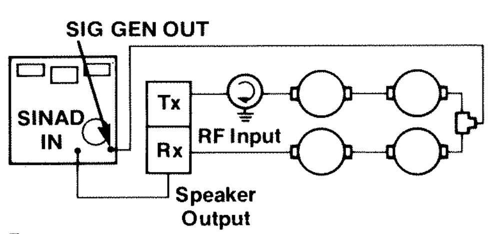


Figure 4

NOTE: The CE-5110 with 1 dB/Div. on the spectrum monitor will perform this test directly. (See "Total System Testing" Application booklet).

TEST PROCEDURE:

1. To measure transmit side of duplexer, connect the output of tranmitter to the SIG GEN OUT/RF IN connector (See Figure 1).
2. Set the METER FUNCTION switch to PWR x10.
3. Key the transmitter and read the power on the meter in watts. (record the level)
4. Connect the SIG GEN OUT/RF IN to the antenna port on the duplexer (See Figure 2).
5. Key the transmitter and read the power out of the duplexer on the meter. (record the level)
6. Calculate the insertion loss of the cavities by the formula:

   dB = 10 Log Pout/Pin.

   EXAMPLE:
   step 3 meter reads 48 watts
   step 5 meter reads 35 watts
   insertion loss in dB = 10 Log 35/48
   insertion loss = 1.37 dB.
7. Set the FUNCTION switch to SIG GEN-FM.
8. To measure the insertion loss of the receiver side of the duplexer connect the SIG GEN OUT/RF IN to the input of the receiver and connect the SINAD input across the speaker, "observe polarity" (See Figure 3).
9. Perform SINAD sensitivity measurement. (See Rx 4 Part II Receivers) Read the receiver sensitivity in dBm on the VOLTS dB meter. **Note:** Use 20 dB quieting if monitor is not equipped with SINAD meter.
10. Connect the SIG GEN OUT/RF IN to the antenna port on the duplexer and measure SINAD sensitivity in dBm on the VOLTS dBm meter.
11. Subtract the sensitivity measured in step 10 from step 8 to get the insertion loss.

    EXAMPLE:

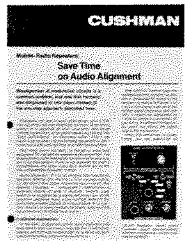
SINAD sensitivity step 8:	-113. dBm
SINAD sensitivity step 10:	-110.5 dBm
insertion loss:	2.5 dB

Product Application Notes

The following applications notes are available upon request. Use the enclosed response card to indicate which item(s) you would like to receive, along with a short form catalog of Cushman's products.

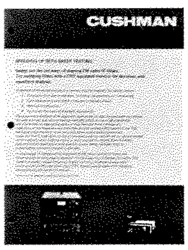
A Portable Test Set for Microwave Radio Installation and Maintenance

Shows how to utilize the combination of test instruments in the Cushman Communications Monitor to maintain and verify the proper operation of microwave radio systems to 1000 MHz.



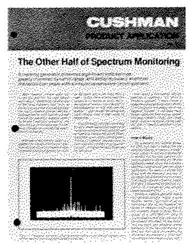
Mobile-Radio Repeaters: Save Time on Audio Alignment

Describes a method of diagnosing misalignment of modulation circuits in one step instead of the normal two-step approach, and then aligning them for a total elapsed on-site time of five minutes or less.



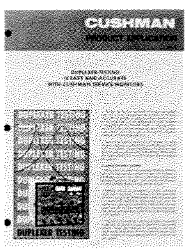
Speeding Up With Sweep Testing

Describes how to use swept frequency tuning techniques with a Communications Monitor having a CRT display to easily and quickly align receiver IFs and other tuned circuits.



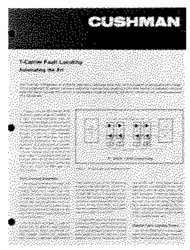
The Other Half of Spectrum Monitoring

Tells how tracking generators (TG) work, and their use with a spectrum monitor as an exceptionally useful troubleshooting aid for frequency-sensitive circuit elements such as duplexers, receiver RF and IF circuits, transmitter output filters and combiners.



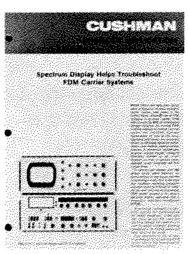
Duplexer Testing is Easy and Accurate With All Cushman Service Monitors

The test set-up and methods of testing transceiver duplexers using the Cushman Communications Monitor.



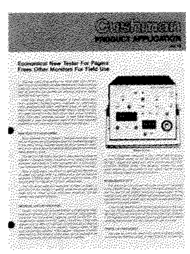
T-Carrier Fault Locating: Automating the Art

To understand why the fault-locating scheme has remained virtually unchanged through 17 years of system hardware evolution, and to find out what can be done to improve the situation.



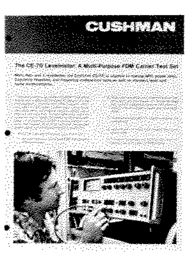
Spectrum Display Helps Troubleshoot FDM Carrier Systems

Rapidly changing conditions on a carrier system are impossible to follow using only a Frequency Select Levelmeter (FSLM). This Product Application shows how to utilize a suitable spectrum display system to swiftly, easily and accurately track these conditions in troubleshooting FDM systems.



Economical New Tester for Pagers Frees Other Monitors for Field Use

Shows a simplified test set-up for pager repair and describes how to use the CE-31A FM Radio Test Set to measure basic pager parameters.



The CE-70 Levelmeter: A Multi-Purpose FDM Carrier Test Set

Explains the procedures for using the CE-70 Frequency Select Levelmeter to make NPR, phase jitter, frequency response and frequency comparison tests as well as standard level and noise measurements.

Cushman

Cushman Electronics, Inc.
2450 North First Street
San Jose, CA 95131
(408) 263-8100
TWX 910-338-0556

Cushman Electronics, Inc.
Marketing Center—Europe
Robert Bosch Strasse 30
6072 Dreieich-Sprendingen
West Germany
Tel: (06103) 31498
Telex: 841-041-6997

Tele-Radio Systems
121 Hanlan Road
Woodbridge, Ontario
L4L 3P5, Canada
(416) 851-2231
TWX 610-492-2384

Cushman Service Centers (U.S.A.)

Western
2450 North First Street
San Jose, CA 95131
(408) 263-8100

Midwestern
4300 Lincoln Ave., Unit O
Rolling Meadows, IL 60008
(312) 934-6426

Southwestern
1335 North Beltline Road
Suite 18A, Irving, TX 75061
(214) 256-1614

Eastern
100 Route 46
Mountain Lakes, NJ 07046
(201) 696-0545

Southeastern
Suite 110/111
Northgate Office Park
3610 Interstate 85, N.E.
Atlanta, GA 30340
(404) 451-3264

Litho in U.S.A. 7/82