Measuring the output of very low power transmitters

Wireless microphones and low power telemetry transmitters are a challenge when it comes to measuring their RF output power.

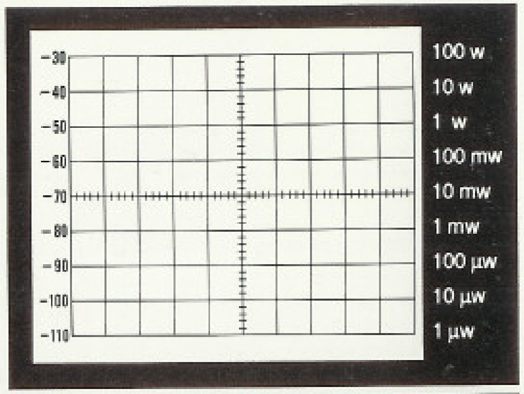
The calibrated spectrum analyzer **ANTENNA** input provides the sensitivity required to make accurate low level power measurements.

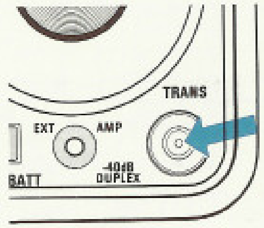
The **FREQUENCY** must be set to the transmitter output frequency so you can see the signal centered on the analyzer display.

TWEAKING NOTE:

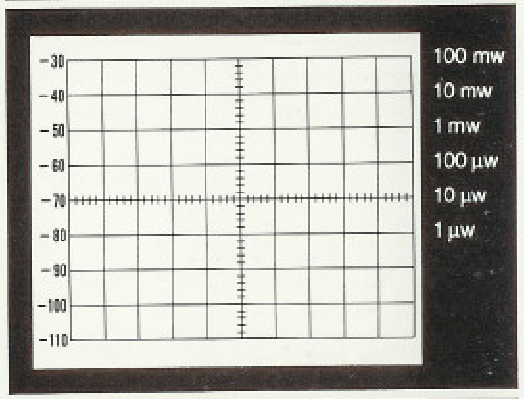
When you are trying to peak up a low power transmitter with the analyzer display, the logarithmic response *compresses* any change, making it difficult to see small changes in amplitude. Switch the **dB/DIV** switch to the **1dB** position and re-center the top of the signal with the **VERT POS** control. In this 1dB per division mode,you can see small changes much better.

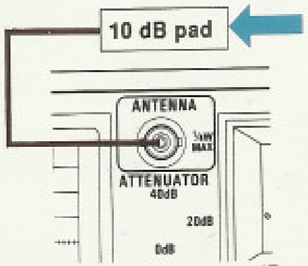
CONVERSION TABLE **dBm to WATTS**	
+50 dBm = 100 watts	-10 dBm = 100 µw
+40 dBm = 10 watts	-20 dBm = 10 µw
+30 dBm = 1 watt	-30 dBm = 1 µw
+20 dBm = 100 milliwatts	-40 dBm = 100 nw
+10 dBm = 10 mw	-50 dBm = 10 nw
0 dBm = 1 mw	-60 dBm = 1nw



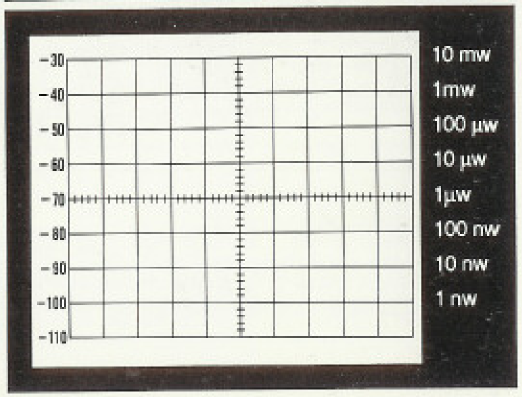


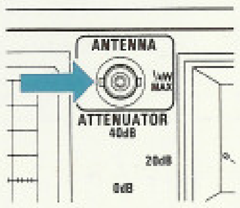
100 mw - 100 watts = Feed direct into **TRANS**mit port. (80dB path to analyzer switched in by power detector)





10 mw - 100 mw = Use 10dB external attenuator into **ANTENNA.** Switch in **40dB** internal **ATTENUATOR.**





Less than 10 mw = Feed direct into **ANTENNA** port. Switch in **40dB** internal **ATTENUATOR** .

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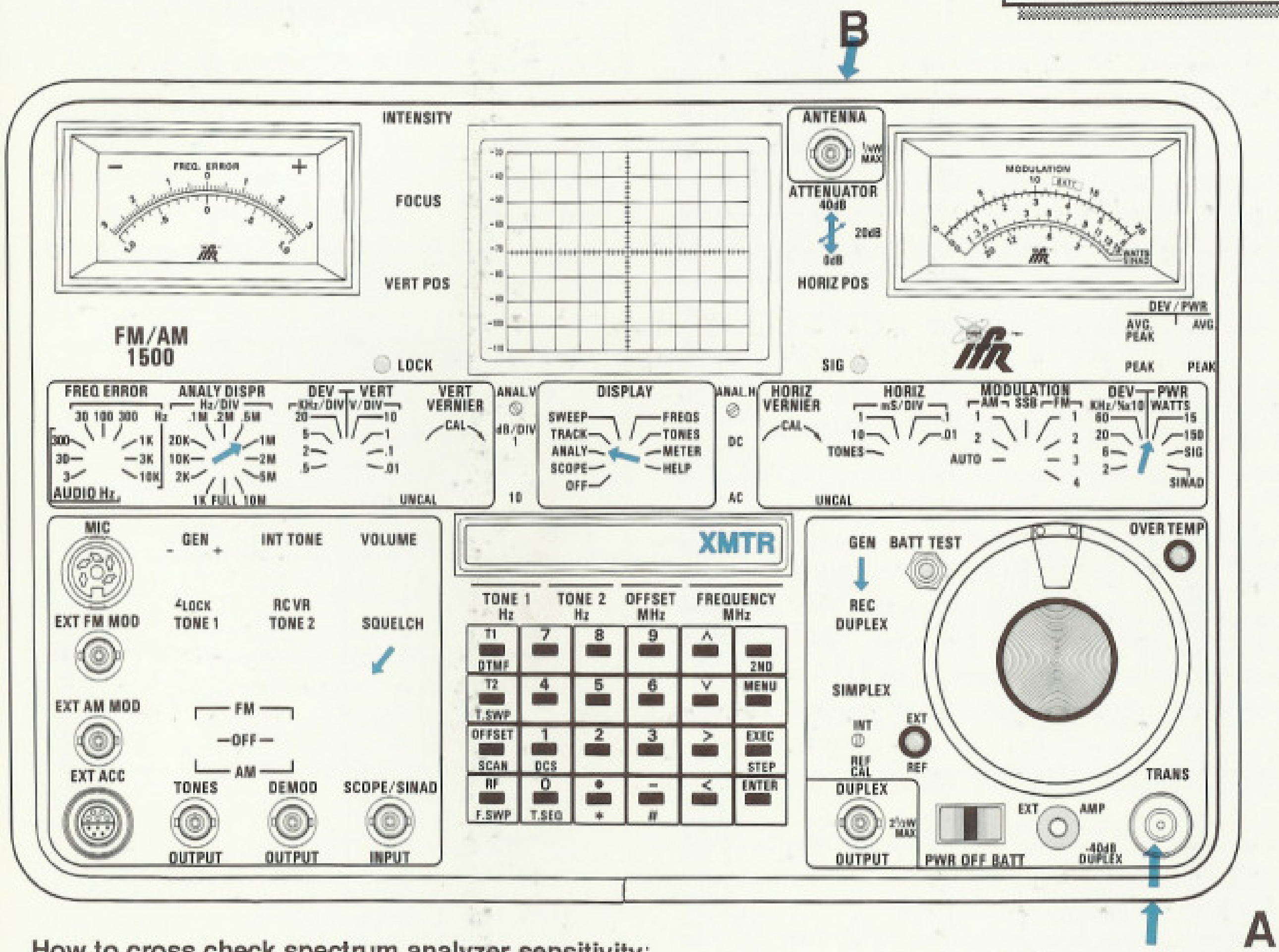


PROCEDURE:

A: Connect *ANY* transmitter to the **TRANS** jack *first.*. Set the **DEV / PWR** switch to **15** watt position. Key the transmitter and confirm that the power is ***LESS THAN 1/4 watt.*** (This step is important to guarantee that you don't smoke the front end by injecting more than a quarter watt into the **ANTENNA** jack. This quick check could save you many **$$$** in *non-warranty* repair charges.)

B: If the transmitter power is at least 100 milliwatts, the 1500 will detect it and switch in a -80dB internal path to the spectrum analyzer. The spectrum analyzer can then be used as a power indicator with the top (-30) graticule line indicating 100 watts. (See top scope photo on facing page for power correlation.)

How to cross check spectrum analyzer sensitivity:

The 1500's **DUPLEX** output may be used to check the sensitivity of the analyzer.

Connect the **DUPLEX OUTPUT** to the **ANTENNA** port.

Set **GEN / REC** to **GEN.** Set **DUPLEX / SIMPLEX** to **DUPLEX.**
(this disconnects the internal signal crossfeed from the generator)

Set **OFFSET** to **00.00.**

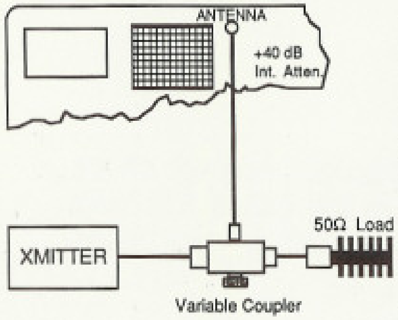
Using the RF output dial as a dBm reference, the top of the signal shown on the analyzer display should read the same.

Measuring transmitter harmonics

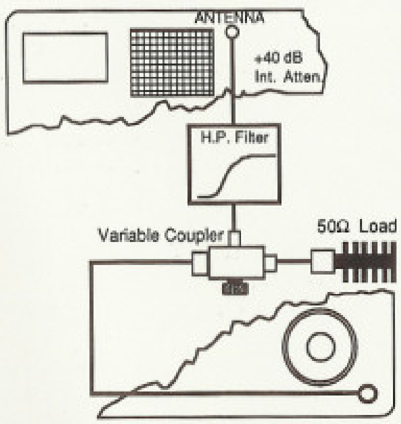
The spectrum analyzer is useful for measuring harmonic outputs. A quick check of harmonic output is easily accomplished on transmitters in the 0.2 to 100 watt range by keying them directly into the **TRANS** port as described on the facing page.

For those instances outside the 200 milliwatt - 100 watt range or where more dynamic range is required, the range expanding techniques inside this fold-out should be used.

Procedure for wider dynamic range measurements:



1. Connect as shown. With the **ATTENUATOR** switch in the **20 dB** position, key the transmitter to view the signal at the transmitter frequency. Adjust coupler to get a full scale signal on the display. If you can't get the signal down to the top line, switch to **40 dB.** Additional pads in the coupler to antenna line may be necessary depending on the loss of the coupler and the transmitter power. It is important that the transmitter fundamental level be as near the top of the screen as possible *without* exceeding it to obtain the maximum dynamic range. The internal **ATTENUATOR** needs to be in either the **20** or **40 dB** position with the fundamental signal at the top graticule line. The **ATTENUATOR** switch will be switched back to **0 dB** to extend the dynamic range once the high pass filter is installed.

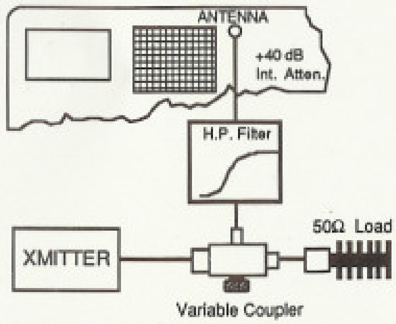


2. Measure combined loss of coupler, high pass filter, & Attenuator at F_1.

Install the high pass filter. Disconnect the coax from the transmitter and reconnect it to the 1500's **TRANS** jack. Switch the **DISPLAY** to **TRACK.** Increase the RF output level to center the fuzzy trace on the -90 dBm line at center screen. Subtract the black dial dBm reading from -90 dBm. The difference is the loss at F_1.

3. Measure coupler, HP filter, & Attenuator loss at F_2.

Change the analyzer center frequency to the second harmonic (F_2) and readjust level to center the trace at -90 dBm. Subtract dial reading from -90 to determine the loss at F_2. Now you have calibrated your measurement system at the fundamental and second harmonic.



4. Measure harmonic output of transmitter.

Reconnect the coupler coax to the transmitter. Key transmitter, reading display to determine the level of the harmonic. The attenuation of the high pass filter and the coupler *at the harmonic frequency* must be added algebraically to the result to accurately reflect the harmonic level.

Measuring transmitter harmonics

VERY LOW & HIGH POWER SITUATIONS

Transmitters with output power above 100 watts will require the use of a coupler[2] to prevent overloading the analyzer. Transmitters with outputs below 100 milliwatts will *not* switch in the 80dB path and will require a coupler or external attenuator to reduce their output to -30dBm or below so that it can be coupled directly into the **ANTENNA** port without overloading. A variable coupler is desirable so you can adjust the coupled level to the top of the analyzer screen and utilize all of the analyzer's dynamic range.

ANALYZER DYNAMIC RANGE

The 1500's spectrum analyzer has a usable dynamic range of 70dB, from -30 (top of screen) down to -100dBm. Below -100, signals become noisy enough to make measurements more difficult.

EXPANDING ANALYZER DYNAMIC RANGE

To measure signal levels beyond the 70dB dynamic range of the analyzer, a notch filter or high pass filter[1] must be used to cut the transmitter fundamental so it doesn't overload the analyzer front end. Signals above the top of the screen (-30 dBm) will overload the 1st mixer and cause spurious signals (intermodulation products) to be generated in the analyzer. These intermod "spurs" clutter the display with extra signals, often causing great confusion and heartburn.

SPURIOUS?

To quickly determine if the signal you are looking at is a spurious generated within the analyzer ...

1. Switch in the **20dB ATTENUATOR**. If the signal level drops *more than* 20dB, it is a "spur". The amount of the drop depends on the "order" of the intermodulation product.

2. Center the signal on a major vertical graticule mark by jogging the frequency up with the ^ key. After noting that frequency, jog the frequency to the *next* major vertical line. The difference in frequency should be the setting of the **DISPR** knob. If the signal moves *more* than the knob setting, it is a "spur". If you have several signals on the analyzer display, watch the *distance* each one moves as you jog the frequency. Those that move faster than others are high order "spurs".

FCC Requirements

For land mobile services at power levels below 1,000 watts, the F.C.C. harmonic specification requires that all emissions beyond 250% of the authorized bandwidth be attenuated by $43+10(\text{Log}_{10}$ output power in watts)dB.

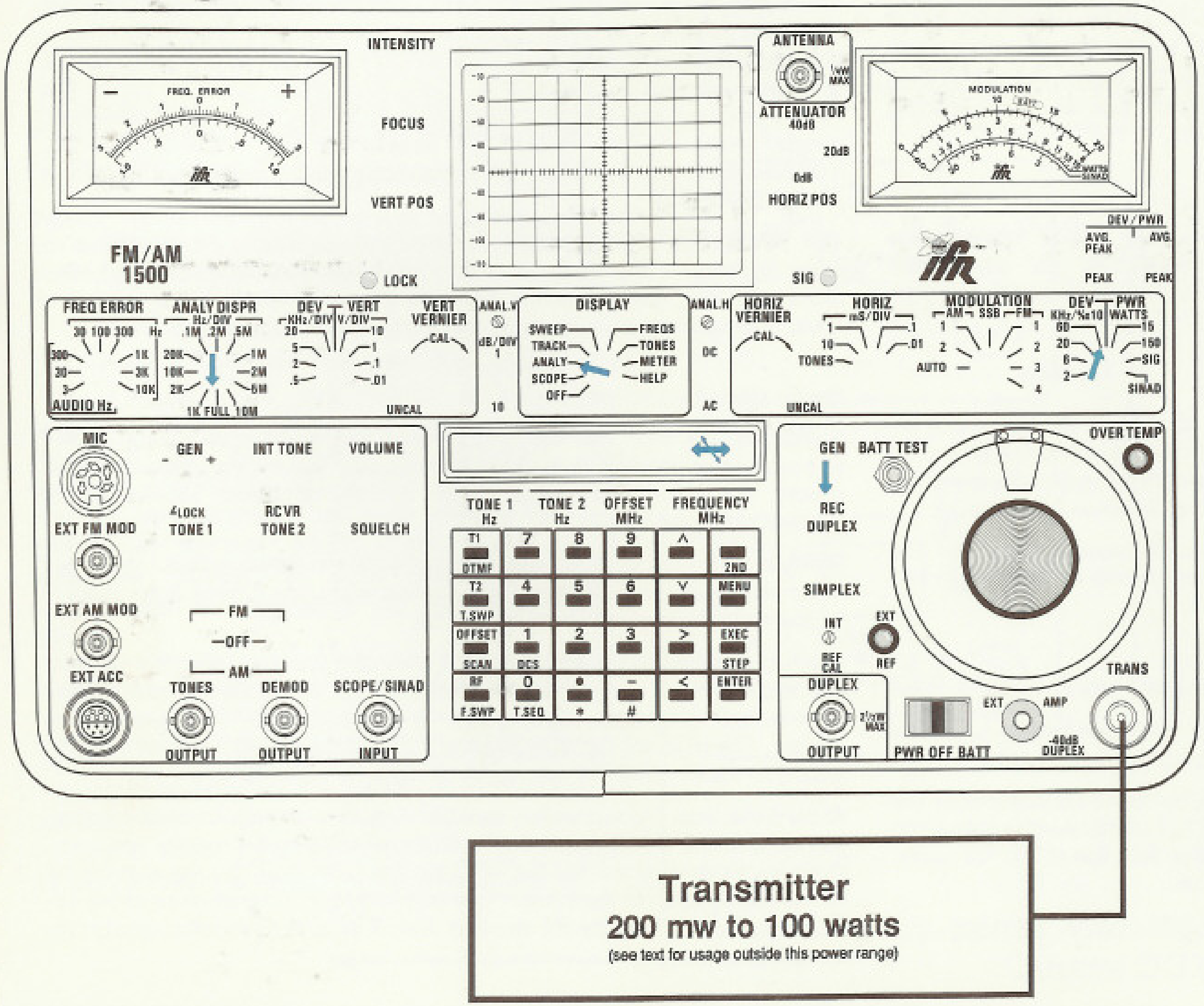
Minimum attenuation for signals ≥250% of authorized bandwidth. (harmonics & spurious)

Transmitter power in watts	Minimum attenuation, dB below carrier	Transmitter power in watts	Minimum attenuation, dB below carrier
1	43	100	63
5	50	150	65
10	53	200	66
25	57	250	67
50	60	300	68
75	62	500	70

[1] High pass filter source:
Mini-Circuits, P.O. Box 166,
Brooklyn, NY 11235, (718) 934-4500
BNC-BNC connectors, price $27.95 ea. (June '86)
30-54 MHz transmitters = BHP-100
144-174 MHz transmitters = BHP-300
450-470 MHz transmitters = BHP-700

[2] Variable coupler source:
Bird Electronic Corp.,3030 Aurora Rd.,
Cleveland, OH 44139, (216) 248-1200
Model 4275-20 Coupler, 20-1000 MHz,
"N" male & female, price $84.00 (June '86)

Measuring transmitter harmonics



QUICK HARMONIC CHECK

A quick check of harmonic output is easily accomplished on transmitters in the 0.2 to 100 watt range by keying them directly into the **TRANS** port. The top horizontal line of the analyzer is 100 watts because there is an automatic 80dB path switched in between the **TRANS** port and the analyzer when the input power threshold of 100 milliwatts is exceeded.

Look first at the fundamental (F_1) level by setting the center frequency of the analyzer at the transmitter frequency. Jot down the amplitude.
(10 watts would read about -40dBm)

Reset the **FREQUENCY** to center the second harmonic (2x F_1 = F_2). The difference in amplitude is the second harmonic level below the carrier.

Stage gain measurements using the spectrum analyzer

The spectrum analyzer is a useful tool for measuring *relative* stage gains to isolate problem areas. Defective RF devices frequently cannot be found easily by DC measurements. Probing the input and output will show when there is a major signal loss. We speak of *relative* stage gain measurements because absolute measurements are very difficult due to circuit loading and the detuning effect of any measurement device.

Analyzer input methods

Some method of coupling the signal from the individual RF and I.F. stages to the **ANTENNA** (spectrum analyzer) input is necessary to do stage gain measurements. It can frequently be done with a *sniffer loop* or an RF probe for direct probing.

RF Probes

Because the spectrum analyzer input impedance is 50 ohms, a low impedance RF probe is required to feed it. A typical 10X probe (20 dB) has an input resistance of 500 ohms at DC with an input capacity of 1 pf. A 100X probe (40 dB) looks like 5KΩ with 1 pf. (10X & 100X RF probes are available from Tektronix and others.)

The input impedance of these probes decreases as the frequency increases due to the 1 pf shunt capacity. 1 pf looks like 1600 ohms at 100 MHz but only 160 ohms at 1 GHz.

Which Probe?

Deciding which probe to buy should be influenced by the trade-offs involved.

The 10X probe provides flatter frequency response but circuit loading is greater due to the low DC resistance. Generally the 10X probe is the most useful.

The 100X probe loads high impedance circuits less but its 40 dB loss makes low level signal measurement difficult. The effect of the 1 pf shunt capacity above 300 MHz reduces the input impedance to just slightly more than that of the 10X probe. The 100X probe is best for lo freq I.F.s and H.F. RF work.

A DC block must be used with any probe to prevent analyzer damage due to DC inputs.

Sniffer loops

Pickup of RF energy is sometimes more controllable with an inductive pickup or sniffer loop, especially at VHF and UHF. It is not unusual to get considerable capacitive coupling into an RF probe before you touch a tuned circuit. You are actually building a capacitive voltage divider circuit as the pointed probe tip approaches the RF voltage source. Once you actually touch the circuit, it is usually detuned appreciably. A sniffer loop on the other hand, inductively couples energy into the analyzer and usually has less of a detuning effect. You don't have to worry about DC ratings because the sniffer loop element is fully insulated.

The construction of sniffer loops varies slightly depending on the frequency range of intended use. A 2-turn loop is good from about 100 kHz to 50 MHz. Above 50 MHz, just connecting the center connector back to the shield with a 1/4 inch diameter partial turn is sufficient. (See page 6 for *sniffer loop* details)

Stage Gain Measurements

Radios that are separated into modules with coax connectors are the easiest to troubleshoot utilizing stage gain techniques. Some manufacturers even specify the input and output levels of the modules, simplifying the troubleshooting process.

Rarely are commercial radios built with stage gain measurements in mind. Real world stage gain measurements are easiest when you have a good radio to compare with the bad one you're working on.

Injecting a signal into the stage from the generator and measuring the output of that stage with the analyzer in the **TRACK** mode is a straightforward process for receivers. Of course, injecting into the front end at the RF frequency is the easiest. The analyzer can then be used to "sniff" the RF input and output coils, looking for the amplitude increase produced by each "gain" stage.

At the same time, if you have the analyzer on a wide enough dispersion setting, you will also see the HF Local Oscillator above or below the receive frequency. Once you've determined that the RF stage has gain, "sniff" for signal at the 1st I.F. frequency around the mixer. You should see a hump of noise at the I.F. frequency coming from the RF amplifier even if there is no specific signal at the receiver frequency. →

DETAILED SETUP

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Stage gain measurements using the spectrum analyzer

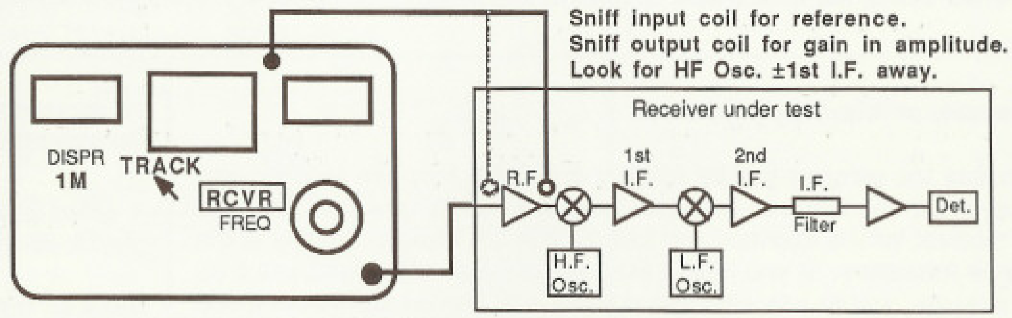
Using a xmit loop

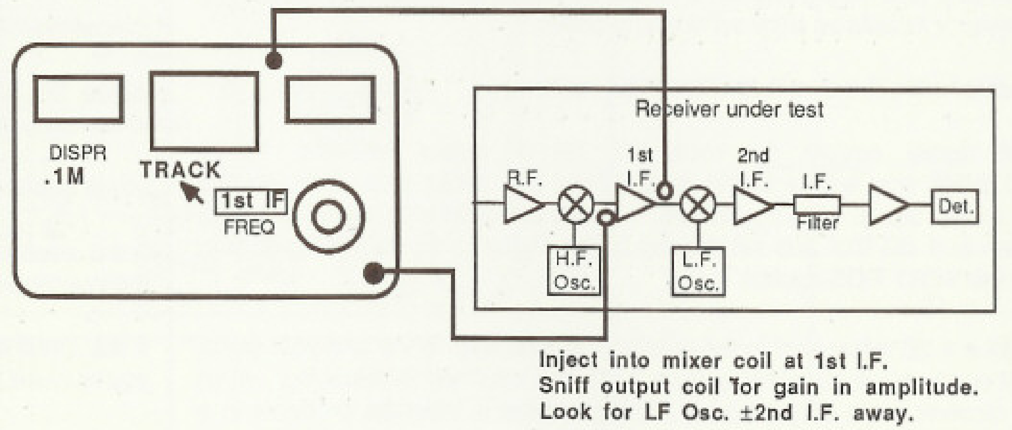
Now comes the need for the **2nd** *Sniffer Loop.* We're not going to use it to "sniff", instead we'll use it as a *source* to couple some I.F. signal into the mixer from the 1500's tracking generator. Reset the **FREQUENCY** to the 1st I.F. frequency.

Injecting the I.F. signal, you can now sniff for it down the I.F. strip to locate trouble spots quickly without trying to find test points or breaking into the circuit.

CAUTION: As you couple the output into the analyzer, you will also radiate some signal. It is possible to produce enough feedback to the input to produce oscillation, especially if you're coupling from end to end through several stages of gain. Watch for narrow, steep-sided peaks in the response curve, a sure sign of regeneration and a precursor to sustained oscillation.

Suggestion: To reduce confusion, color code each sniffer loop assembly with colored vinyl tape on both the loop and connector end. With all of those BNC's on your bench, *anything* to reduce confusion is helpful. They DO multiply and interweave in the night while you're gone.





Analyzing receiver desense caused by intermodulation distortion

When intermodulation problems occur, you must first determine whether they are generated within the receiver by mixing products or if they are produced by mixing in an external non-linear device such as corroded antenna connections or in a nearby transmitter.

Externally or internally produced?

Eliminate the receiver first by splitting the signal from the antenna and feeding both the receiver in question and the 1500's receiver. Listen to the receiver for the intermod and look for it in the analyzer display at the receive frequency. If you hear it from the receiver and do not see it on the analyzer, you've *only* determined that it is not an *on channel* intermod produced externally. It still could be a mixing product generated externally and interfering on a spurious response frequency within the receiver or it could be a mix within the receiver.

To determine if the mix is within the receiver:

Next, lightly couple the receiver's 1st IF output into the 1500's **ANTENNA** port with a sniffer loop. Tape the sniffer loop down so that the sniffed signal will be constant. When the interfering signal is heard, switch to **1 dB/DIV** and set the top of the signal to the top of the screen with the **VERT POS** control.

Install a 3 dB attenuator in the outside antenna line. If the analyzer signal level drops *appreciably* more than 3 dB, the intermod is produced within the receiver. If it only drops 3 dB, the source is external, probably in a nearby transmitter or antenna system.

To determine if the mix is within the suspected transmitter:

A tuned isolator is needed in the suspected transmitter's output line to provide different forward and reverse loss factors.

Measure the forward and reverse loss at the intermod frequency. (more on insertion loss measurements on pages 44-45)

Connect the RF Coupler's output to the 1500's **ANTENNA** input.

Adjust the coupler to establish a reference level of the intermod when it next appears.

Install isolator and note the attenuation in the intermod.

If the intermod signal drops by the forward attenuation of the isolator, the intermod is not being caused by this transmitter.

If the intermod signal drops by the reverse attenuation of the isolator, you've found the offender.

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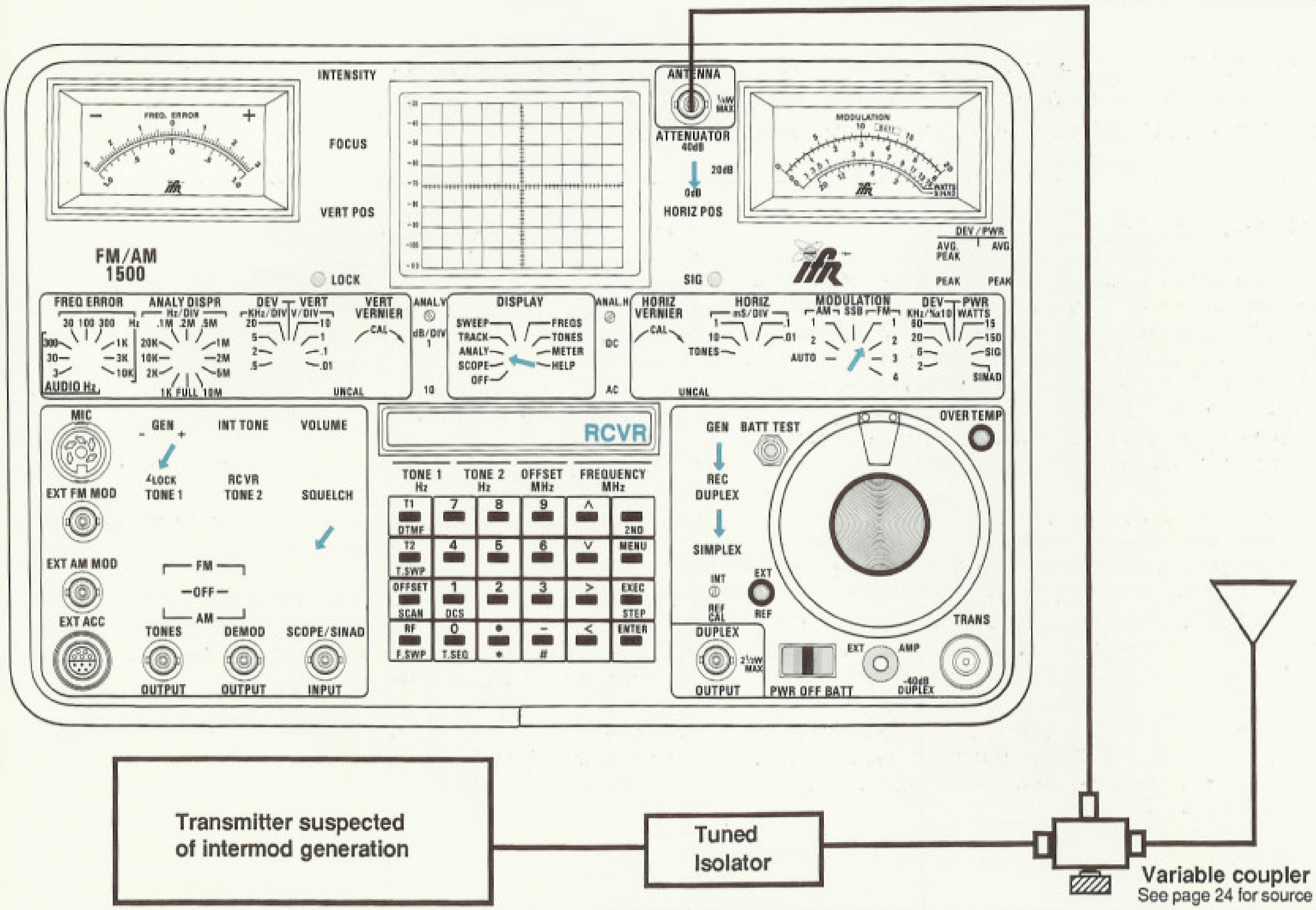
Analyzing receiver desense caused by intermodulation distortion



See page 24 for source info