INSTRUCTIONS

Price: $3.00

BATTERY INSTALLATION

Obtain a standard 9 volt batterry. Use an **alkaline** battery for best life. (About 12 hours of intermittent use.) Using your thumb, slide back the battery compartment on the back. This may take some pressure. Don't pull it up -- it slides.Install the battery without pulling the battery leads excessively and replace the cover.

INITIAL FAMILIARIZATION

Tap the on/off switch. The first number which flashes is the **program code** version, e.g. PC2.0. A higher number indicates later software, which may reflect even a minor, unnoticeable, change, or could even reflect a hardware change. This is the "model number" of your unit.

When you turn the unit on it enters the **FREQ** mode. The "tune" knob changes the frequency. The "fine" knob also changes the frequency, but much slower, for bandspread when zeroing in on a frequency.

Now tap the **BAND** button.The unit switches to the next of 5 bands. Now, hold down the band button. Notice that the unit continuously cycles between bands.

Now, tap the **SWR** button. An upper box appears in the left digit showing you're in the SWR mode, but the SWR reading is "H," meaning too HIGH to register,since nothing is connected to the coax connector.The "H" appears for any SWR above about 15:1.

Now, tap the Z button. The meter is now reading the impedance of the meters stray output capacitance at the frequency in use. If you're at a low frequency, a lower box appears in the left digit, showing you're in the Z (IMPEDANCE) mode, and an "H" appears in the right digit, meaning too HIGH. The "H" appears for any impedance above 2000 ohms.

Now, change bands by tapping or holding the band button. Note that the new frequency appears first (briefly) and then the meter reverts back to the previous mode selected, in this case impedance. Note that at the higher frequencies, the impedance of the meters stray output capacitance...about 7 pf..is displayed. More about this below.

Now, tap the **C** button. A small c appears at the lower left, indicating the C mode. The meter will probably show a large "L" in the right digit, meaning that the capacitance is too low to measure.
Now, tap the **L** button. Instead of a small c, a small L appears in the first digit. The right digit show "H", meaning the inductance is too high to measure. Remember, the left digit shows you which mode you're in, and the right digit shows any overrange--"H=HIGH" or "L=LOW".

Now, hold down the FREQ and SWR buttons, and release them at the same time. Notice that the meter now cycles between the FREQ and SWR modes.Try the same with the FREQ and C buttons to cycle between these two modes. In fact, if you hold down 3 buttons, you can usually cycle between 3 modes, but more may "lock up" the computer, and you'll have to turn the unit off/on to reset it.

BATTERY

The unit has an "automatic off" feature to save the battery. It will automatically turn itself off after about 20 minutes of no use--no button pushed. To disable this feature: First turn the unit off. Then hold down the frequency button. Then tap the on/off button. You will not see the PCx.x indication, confirming that auto-off is disabled.

The unit is totally voltage regulated as the 9 volt battery drops to 6.5V. Between 5.5 and 6.5V the accuracy is degraded a few percent. At 5.5V the display dims very noiceably as a reminder to replace the battery. The unit draws 35-60 ma.--the most at the highest frequencies. It can be run from any DC source 6.5 to 15 V.

IMPEDANCE MEASUREMENT

RF impedance is measured by rectifying RF voltages using diodes. These diodes introduce errors in the measurement which are compensated by the microprocessor software , but not quite perfectly. In addition, even an inch of lead wire to a resistor can produce a noticeable change in Z at the higher frequencies !

Because of the above, a DC digital voltmeter will be more accurate than your RF ANALYST for measuring DC values of resistors, but is, of course, useless for measuring RF impedance.

The figure below shows impedance accuracy. Note that accuracy is best near 150 ohms, and degrades below 20 and above 900 ohms. Your unit may fall outside the "typical" curve at a few points, but it is likely to be more accurate overall. Most antennas, except short verticals and small loops, fall within the high-accuracy range.

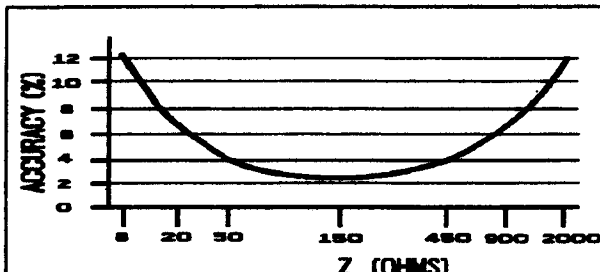

Fig. 1. Typical Impedance Accuracy

For the purists, the meter itself has a parallel output capacitance of 6 to 7 pF, and a series inductance of .02 uH. Neither of these are compensated by the microprocessor in the Z mode since this wouldn't make sense. So bear in mind that you are measuring not only the load, but the above values in series and parallel.

Normally, this is no problem. But you can see it, for example, when the meter is at a high frequency with nothing connected. The Z is not infininity! Why? You are measuring the Z of the output capacitance of the meter. Note that this has a negligible affect on antenna resonant impedance measurements, because it is reactive, so it only shifts the apparent resonant frequency an insignificant amount.

Also note that most of the meters internal L and C is in the coax connector. When coax is connected to the meter, these become part of the "transmission line" and virually disappear.

SWR

SWR is measured relative to 50 ohms. SWR is generally accurate to 10% below 3:1, and 20% up to 6:1. The accuracy tends to be better for large Z's than for Z < 10 ohms.

Please note that there is a "suckout" effect below SWR's of 1.2 caused by diode drops. This is typical of most SWR bridges, although most manufacturers don't mention it. So we're all happy with our "perfect" 1:1 SWR's. And, as a practical matter, a **1.2:1 SWR means less than 1% reflected power !**

We are mentioning it because the RF analyst is meant to be serious instrument which does not mislead you. Fortunately, the Z function can give you more accurate SWR below 1.2 as shown by an example:

We measured a commercial dummy load, and found its Z to vary from 47 ohms at 1.2 MHz to 56 ohms at 35 MHz. However, the SWR read 1.0 over this range due to "suckout." But, we know that the SWR is at least as high as given by the formula :

(1) $SWR >= Z / 50$ or $50 / Z$, whichever is larger.

In this case, we know the SWR is at least 56/50= 1.12 at 35 MHz. It could be higher if reactance is significant, however. But we've learned that it's at least 1.12:1, but less than about 1.2, where the SWR reading would kick up. And, of course, we know the impedance extremely accurately.

L & C MEASUREMENT

The RF-1 calculates L and C by combining the measured Z and frequency to yield L or C. It is important to note that the meter will not tell you whether a coil or capacitor is connected to it! If you connect a coil, or a resistor, it will also show a capacitance on the C range! This is handy, as discussed below.

The basic L and C accuracy is the same as the impedance accuracy. That is, to estimate accuracy, switch to the Z mode briefly, and see that the Z is somewhere in the 20 to 900 ohm range for best accuracy. This will usually be true. For example, a 5 uH coil is typical for an antenna tuner at 7 MHz. This coil has a Z of about 220 ohms at 7 MHz. (For C greater than 2000 pF or so, C accuracy is degraded because the possible steps in displayed C become very large.)

The meter will over-range...show "H" or "L" in the right digit.. when the impedance is greater than 2000 ohms, or less than 8 ohms. A large capacitor or coil will read "H." If you reduce the frequency you may be able to bring it within range. Similarly, if you get a "L" reading in the right digit, try increasing the frequency. **This is important.**

The meters internal 7 pF capacitance is subtracted from any C readings, so you don't notice it. But, when measuring capacitors with test leads you must subtract any lead capacitance. Simply lay the leads down (open circuit) and measure any residual C before connecting to the part to be measured. Then subtract this residual from the measured value.

When measuring coils, **short** the test leads and measure the residual L of the leads, then subtract this from the measured L. **The meters internal L of .02 uH. is not subtracted from the reading** as the 8 pF stray capacitance is, but you take care of that when you short the test leads.

There is another factor when measuring L. The 7 pf internal meter capacitance tends to make the L look larger near frequencies where the coil "parallel resonates" with 7 pF. The microprocessor does some complicated calculations to compensate for this. As you increase frequency toward resonance you may see a slight change in apparent L, then an abrupt "H" even though the impedance is still well below 2000 ohms. The microprocessor overranges since it knows its L measurement will not be very accurate.

Combining the 8 ohm, 2000 ohm, and resonance limits, the measurement range of the meter is shown below for reference. Remember, the meter warns you by overranging when it's about to become inaccurate, so you don't need to carry these curves around with you.

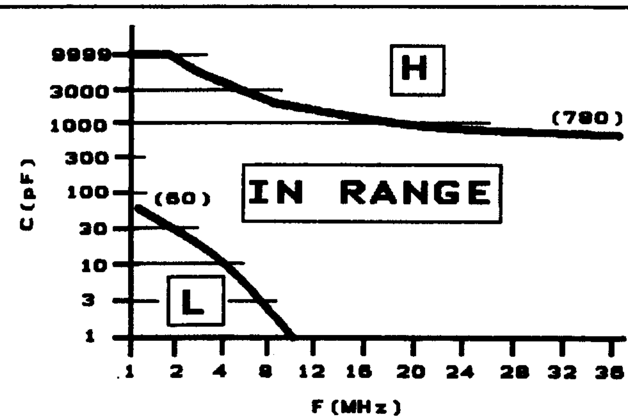

Fig. 2. Capacitance Measurement Range

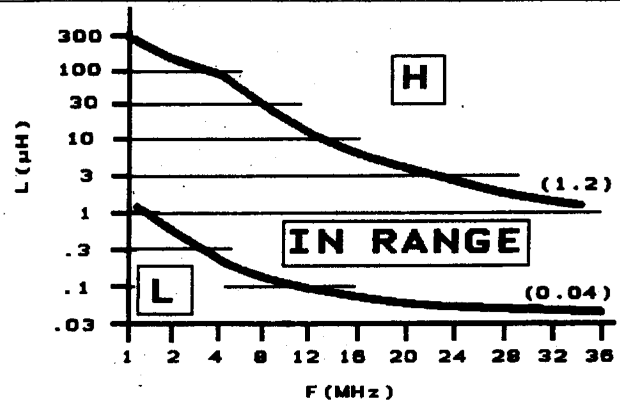

Fig. 3 Inductance measurement range

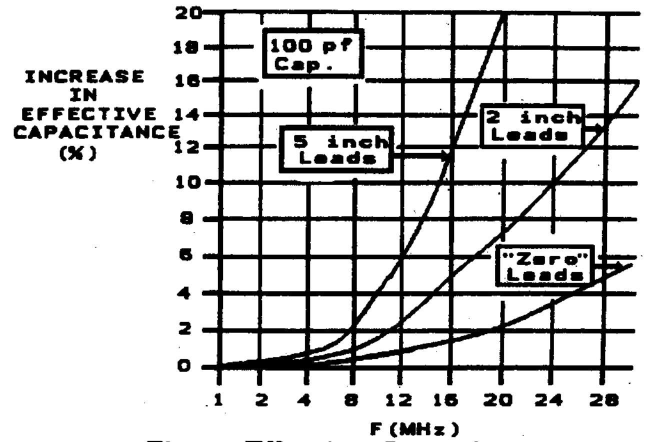

Fig. 4 Effective Capacitance Can Vary With Lead Length. Keep Leads Short

CAPACITOR SERIES INDUCTANCE

Lead inductance can make a capacitor appear to have a larger value as frequency is increased. This is because the lead inductance ""cancels-out" some of the capacitors reactance, and makes its capacitance appear larger. To check for this, measure the capacitor at a low frequency, and watch for any dramatic increase as frequency increases. Fig. 4 shows the effect of leads on a 100 pf capacitor. Fig. 5 shows that larger capacitors must be measured at a lower frequency. Again, you should always check Z to be sure its in the high-accuracy range of Fig. 1 for best accuracy. (For rough checks of C the "H" and "L" indications are sufficient to show when the C is in range.)

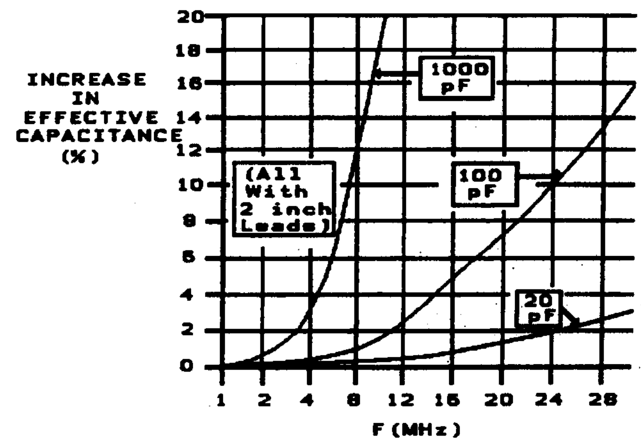

Fig. 5. Measure Large capacitors At Low Frequencies

CONVERTING BETWEEN L AND C AND Z

As mentioned, the meter shows L even when measuring C and vice-versa. These readings give you a rough idea of the component value needed to resonate with the part being tested at the frequency you're using.These readings would be "exact" except for the stray capacitance/inductance of the meter and test leads. But, you can get a quick idea as follows:

If you're measuring a coil, simply switch over to the C range, and add 14 pf to the C reading.This is near the value of C needed to resonate with the coil! After measuring a capacitor, you can also switch to L to get a rough idea of the inductance needed to resonate with the C at the frequency in use. However, this L will always be too high, and the amount of L to subtract depends on the C reading. Small (less than 50 pf) C's give the most error in this estimate.

When measuring an L or C, switching to Z will give the impedance of the coil or capacitor at the frquency in use.(However, remember that this is the Z of the part in test in parallel with the 7 pF meter output capacitance and in series with the .02 uH internal meter inductance. These are often negligible.)

Similarly, when measuring an R, switching to L shows the L value which has that Z at the frequency in use. Switching to C shows the equivalent C value, except you must add 7 pf to the meters C value because it has compensated for its own stray capacitance. (The L conversion has the least accuracy when C measures below 30 pf or so because of the resonant-frquency compensation discussed above.)

Formulas are more accurate, but the above procedures can be handy when estimating values.

ADJUSTING ANTENNA LENGTH

The formulas for common antennas are (e.g.from Ref.1):

(2) 1/4 Wave Vertical(ft) = 225/F(MHz)

(3) Dipole length (ft) = 468/F(MHz)

(4) Full Wave Loop (Quad)= 1005 / F(MHz)

The formula for a 1/2 wavelength of trasmission line is:

(5) 1/2 wave (ft.) =492 * VF / F(MHz)

Where VF=velocity factor of the line, generally 0.66 for ordinary coax (RG58,RG8, etc.) and .79-.80 for equivalent foam coax, and higher for open-wire line. Table 1 shows values for some common frequencies.

The recommended procedure when erecting an antenna is to make it 2 to 5 % longer than the value above...it's easier to delete wire than splice it on. The values shown above are seldom exact in practice due to nearby objects, ground effects, etc. After erecting the antenna, use your meter to find the frequency where the lowest swr occurs. If this frequency is too low, you need to shorten the antenna; if too high, you need to lengthen it. You can make this measurement at the antenna, or at the other end of the feedline. A final measurement at the other end of the feedline (transmitter end) is recommended when the feedline might affect the antenna (sloping diplole?)

It's recommended that you look for the extreme Z reading, which is more accurate than minimum SWR. Also, if you don't have a 50 ohm line, the extreme Z still shows resonance.

The procedure for changing the antenna length can be illustrated with an example. Say you erect a 40 meter (7.1 MHz) dipole and cut it a little long at 70 feet (35 feet per side.) You raise the antenna and go to your shack and measure its lowest SWR or Z at 6.521 MHz. So, your antenna is too long. The correct length should be:

(6) Desired Length = Actual Length * Actual Freq./Desired Freq.

For the example:

Desired Length = 70 feet * 6.521 / 7.1 = 64.29 feet

(This is shorter than the formula, which is not unusual.) So you must remove 70-64.29 = 5.71 feet, or 2 ft. 10 inches from each side. This is a big adjustment, so you might want to only remove 2 feet and repeat the above procedure to zero-in on the correct length.

MAKING 1/4 and 1/2 WAVELENGTH TRANSMISSION LINES

These lengths are often used for phased arrays, stubs, and have other uses. Using a loose length of cable (not connected to your antenna), connect the meter to the cable (Fig. 6). You can either short the other end of the cable or leave it open, whichever is convenient. Now, measure the Z of your cable vs frequency.You'll get a curve like Fig. 7.

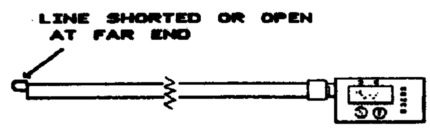

Fig. 6. Measuring Transmission Lines

To simplify, we recommend SHORTING the other end of the cable and looking for the first minimum Z. As an example, lets say we have 50 feet of cable. We short the loose end and measure Z starting at 1.2 MHz. We see the Z rising as we increase frequency then it peaks and falls again to a broad minimum around 6.48 MHz, probably as low as a few ohms, or even zero ohms. This is the FIRST NULL FREQUENCY. The coax is exactly 1/2 wave at this frequency. By manipulating eqn. 5, the velocity factor of the cable is:

(7) VF = First Null Frequency * Cable Length (ft) / 492

Frequency (Mhz)	1/4 Wave Vertical (ft.)	Dipole (ft)	QUAD (ft)	1/2 Wave Coax (VF= 0.66)
1.83	123	256	549!	177.4
3.75	60	125	268	86.6
7.1	31.7	65.9	142	45.7
10.15	22.2	46.1	99	32
14.1	16	33.1	71.3	23
18.1	12.4	25.9	55.5	18
21.1	10.7	22.2	47.6	15.4
24.9	9	18.8	40.4	13
28.5	7.9	16.4	35.2	11.4

Table 1. Some Common Lengths

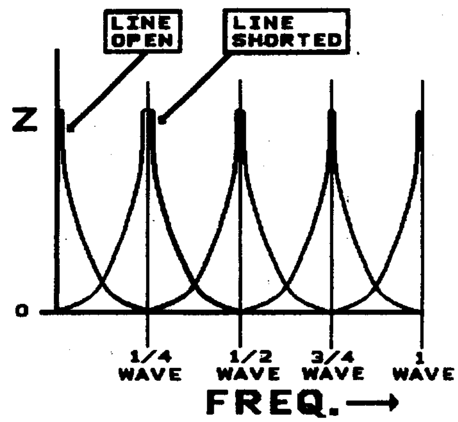

Fig. 7. Transmission Line Impedance vs. Frequency

Or, in the example

(8) VF = 6.48 MHz * 50 ft/ 492 = 0.658

Now that we know VF we can calculate the appropriate length using equation 5. For example, say we wanted 1/2 wave of this coax at 14.2 MHz. Using equation 5, the length would be

(9) 492 * 0.658 / 14.2 = 22.8 feet.

If we cut the cable to 22.8 feet, and short the end, we should see the minimum Z at 14.2 MHz now, confirming that we have 1/2 wave of line.Other lengths are obvious from the 1/2 wave calculation.For example, the line would be half as long (11.4 feet) for a 1/4 wave. As Fig 7 shows, we could leave the end of the line OPEN and check for the minimum Z to confirm that we have 1/4 wave at the desired frequency.

These measurements are usually remarkably accurate with only a slight discrepency between the maximum and minimum impedance frequencies due to second-order affects.

By the way, once you've made this measurement you already know the loss of your cable, as we'll see next!

MEASURING CABLE LOSS

How lossy is your transmission line? Has weathering ruined it? Now you can tell with a very simple measurement using your RF Analyst. In fact there are two ways to do it. **In both cases, connect the meter to either an open or shorted transmission line as in Figure 6.**Cable loss increases with frequency , so don't be surprised to see unmeasurable loss at 1.2 MHz, and higher loss at 28 MHz. Do these tests with a reasonable length of cable, say over 30 feet,since loss is proportional to cable length .The longer the better.

1.SWR METHOD

Simply measure the SWR of the cable versus frequency. A low-loss cable will show an "H" SWR reading. Anything less than 15:1 SWR will show on the meter. Simply read the loss at the frequency of use from Fig. 8.
One problem with this method is that the meters indicated SWR is not as accurate when Z is low (less than 10 ohms). So, if you see inconsistent readings, check the Z at the frequency of measurement.Also, this method is only valid for 50 ohm lines.As seen from the curve, a loss as low as 0.6 dB can be measured !

2. IMPEDANCE (Z) METHOD

Either open or short the line and find the minimum Z at the nulls (See Fig. 7). The cable loss at that frequency is given by (Ref. 1)

(10) Loss(dB) = 8.69 * Minimum Z / Cable Impedance

For 50 ohm line, the loss is

(11) Loss--50 Ohm Line (dB) = 0.17 * Minimum Z

For example, if you measure a 4 ohm minimum Z, the loss is 0.68 dB.

The Z method works for any line impedance, even for a 600 ohm line. Its disadvantage is that it only can measure at frequencies where the impedance goes to a minimum. But, by opening and shorting the line,many frequencies can be measured and in-between loss interpolated. An estimate of loss as low as 0.17 dB (1 OHM) can be obtained.

Overall, we recommend the Z method, since extreme values of Z can be measured more accurately than extreme SWR's, and lower loss values can be measured. The SWR method can be used for a quick sweep.

Please note that this is the loss when the line is terminated in its impedance (has 1:1 SWR). The loss will be higher at higher SWR's, but not significantly higher unless the SWR is well above 2:1.(Ref.1).

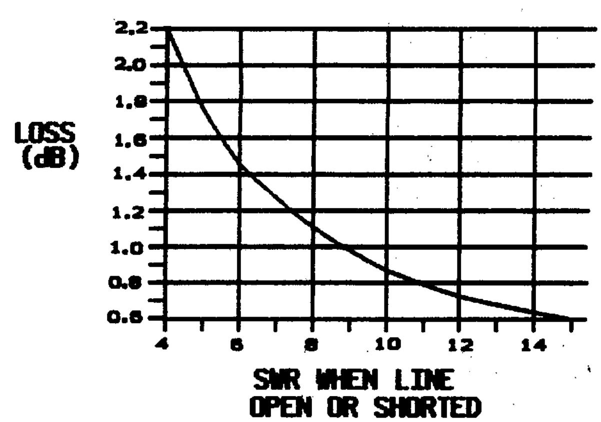

Fig. 8. Measuring Line Loss Using SWR

DETERMINING CABLE IMPEDANCE

Lets say you don't know whether you have 75 or 50 ohm line. Simply connect a 50 ohm resistor to the far end of the cable and measure its input impedance as you change frequencies. If it is about 50 ohms at all frequencies, then it's 50 ohm cable. If the impedance swings cyclicly with frequency, it's some other impedance. Find the terminating resistor value which gives constant impedance as you change frequency and you've found the cable impedance. (Be sure you don't use a wirewound resistor for these tests, since they're inductive at RF.) This also works for 300 and 600 ohm lines, etc. The line doesn't have to be coaxial, it can can be twinlead. There is negligible imbalance to ground because of the plastic case. Just connect the twinlead to the coax connector with SHORT leads.

CHECKING BALUNS AND OTHER TRANSFORMERS

If you have a 1:1 balun, connect a 50 ohm resistor to it's output (where the antenna would normally go) and measure the impedance at the balun input (where the feedline brings in the tranmitter power.) This should be a fairly constant 50 ohms, at least over the frequency range where you plan to use it. If you have a 75 ohm to 300 ohm balun, connect a 300 ohm resistor to its output and verify a 75 ohm input impedance over frequency.

Perfection is not required, and even a 20% variation, or more, may be acceptable.

Testing of a balun at high power is necessary to see things such as core saturation (toroid too small for the power), arcing, etc. To be safe, you should also use an in-line SWR meter, such as our WM-1, which works at 1 or 2 watts,and watch for any change in SWR as the power is increased.

MEASURING ANTENNA IMPEDANCE

The impedance of the antenna must be measured AT THE ANTENNA, not at the far end of a feedline. This is because the feedline can change the impedance unless the SWR is 1:1. One exception: If the feedline is 1/2 wave or a multiple (1 wave, 1.5 wave, etc.) the antenna impedance will be accurate at the other end of the feedline. (Except for second-order affects, such as line loss.)

When measuring antenna impedance be sure something is connected to the ground part of the coax also. Simply sticking a wire in the center of the coax connector may show some resonance, but your hand may be the other end of the antenna! When measuring at the antenna, simply look for an impedance minimum, which shows resonance.

Be sure to disconnect the feedline from the antenna when measuring Z or SWR at the antenna ! Simply connect the RF-1 where the feedline was connected to the antenna.

MEASURING SWR ON LINES OTHER THAN 50 OHMS

This is easy if you can reach the center of the antenna. Simply measure the antenna impedance at resonance-- the frequency where the impedance reaches a minimum. Then the SWR at resonance is given by:

(12) SWR= Minimum Z / Feedline Z
or
Feedline Z / Minimum Z

whichever is larger.

For example, if you measure a minimum antenna Z of 200 ohms and you're using 300 ohm twinlead, the SWR at resonance (where the Z is 200 ohms) is 300/200 = 1.5:1. Yes, the RF-1 can also measure twinlead as accurately as coax. Just keep the leads short.

If you can't reach the center of the antenna, you could measure Z if you have a multiple of 1/2 wave feedline, as discussed above.

In fact, it is possible to determine antenna Z for any length of feedline (Smith chart or equations). And, by assuming that the antenna resistance doesn't change much with frequency, but its reactance does (usually true), one can calculate the reactance from the measured impedance, and use the reactance to calculate SWR as well. But all that is beyond the scope of these instructions.

CHECKING THE AFFECT OF ADDING RADIALS TO A VERTICAL

You put up a vertical antenna (1/4 wave). You have a few radials. Now you want to boost your signal, so you add more radials. But how do you tell how much good they did? Should you add more? Have you reached the point of diminishing returns? This is hard to tell without accurate field-strength measurements (very difficult to reproduce). But the impedance of the antenna at resonance tells you a lot.

A 1/4 wave vertical has a theoretical base impedance of about 38-40 ohms, with hundreds of radials. Lets say you measure the base impedance (SWR doesn't tell you impedance) and find that it is 60 ohms--the minimum Z at resonance-- measured at the base of the antenna or at the other end of a 1/2 wave feedline. This means that you have about 20 ohms (60 minus 40) of ground loss. So about 1/3 of the antenna's Z is in the ground loss, and so 1/3 of your power is lost. Now, you add a few radials. You may find that the resonant frequency is changed a little, but there is also a lower impedance at resonance. If it's been reduced to,say, 50 ohms, you've gotten rid of 1/2 of the ground loss.

This method is not perfect, but your RF-1 gives you some indication of what is happening...puts some numbers on it.

Many caviats: The 40 ohms only applies to a 1/4 wave vertical with radials at right angles, and in the clear. If the radials slope a lot, such as on a steep roof,the radiation resistance increases. Nearby objects (trees, structures) usually reduce Z . So, you can't be too precise in applying this technique. However, it could also be very useful for short loaded verticals, where most of the power vanishes in ground loss.

TUNING YOUR TUNER WITHOUT TRANSMITTING

This a necessity for SWL's, or for tuning up on a frequency without transmitting. The figure below shows how to do it.

We don't make the switch, but you can use a coaxial switch, or fashion one with a 5 or10 amp ordinary SPDT toggle switch and some coax connectors in a small minibox. Everything from Radio Shack. If you keep the leads short (a few inches), it will work fine. Just be sure there is NO possibility that the transmitter could feed DIRECTLY into the RF-1. **THIS CAN BURN OUT THE RF-1 INSTANTLY!**

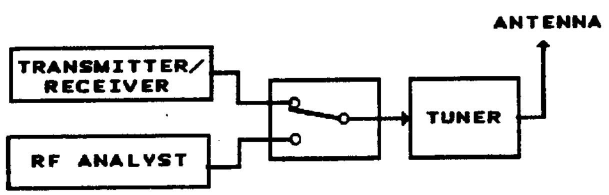

Fig. 9. Tuning an Antenna Tuner Without Transmitting

MEASURING COIL Q

The Q of a coil can be found using the RF-1 by measuring its impedance at resonance. The figure below shows the method:

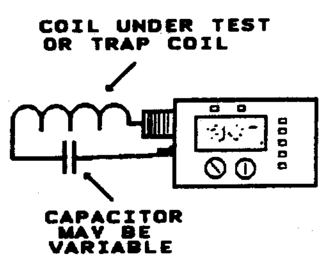

Fig. 10. Measuring Coil Q, or Trap or Tuned-Circuit Frequency

You must supply a capacitor which resonates with the coil at the frequency of interest, or close to it. You know where it resonates by finding the minimum Z, which will probably be in the range of a few ohms. There will be a VERY sharp dip in Z at resonance.

You must also measure the impedance of the coil alone (with no series capacitor.)

Then the Q is given by:

(13) $Q = \text{Coil } Z / \text{Minimum } Z \text{ in tuned circuit.}$

For example, you connect the coil across the RF-1 and measure its impedance as 430 ohms at the frquency of interest. Then you add the series capacitor as in Fig. 10, and find a minimum Z of 4 ohms.So the coil Q is

$$430 / 4 = 107.5.$$

(This asssumes the capacitor Q is much higher than the coil Q, which is almost always true.)

Note that this method is most accurate if the minimum Z is more than a few ohms. You could calibrate your individual RF-1 by measuring small, known, 1/4 watt resistors, but the 1 ohm resolution remains.

Also note that the minimum impedance represents the coil loss in a mobile antenna loading coil, which is what you're trying to minimize. So Q is an incidental parameter. Minimize R.

MEASURING TRAP RESONANT FREQUENCY

A trap is usually a parallel resonant circuit. You could put the RF-1 across the trap and look for the frequency where impedance is greatest, but this is not very accurate for two reasons: The impedance peak may exceed 2000 ohms and be hard to measure, and the 7 pF output capacitance of the RF-1 will pull the trap lower in frequency. But, you can disconnect the trap capacitor from the coil at one end and measure the frequency where impedance reaches a minimum, as in Fig. 10.

With this method,the RF-1 output capacitance doesn't matter, and the dip is **extremely** narrow and precise when read out on the RF-1 frequency counter. Just keep the leads to the RF-1 short.

SWL APPLICATIONS. SIMPLE ANTENNAS

We discussed tuning an antenna tuner above.

It is very interesting to check the resonant frequencies of common objects already in place, such as gutters, non-grounded window frames, door frames,etc. Often these can make interesting receiving antennas. (Just remember to connect something to the grounded (outside) part of the RF-1 coax or the measurement is meaningless.). The screw is also "ground."

Indoor dipoles and other indoor antennas often deviate greatly from the values in Table 1. But they are easily trimmed using the RF-1.

Look for a dip in Z to find resonance, rather than using SWR.

If there's no digital readout on your radio, you can find a stations exact frequency by tuning the RF-1 until you hear the RF-1 signal on top of the station you're listening to, then read out its frequency on the RF-1. You can even use harmonics of the RF-1 frequency to determine frequencies well above 35 MHZ. Stick a few feet of wire inside the RF-1 coax connector to make it louder, or hold the RF-1 near the radio if necessary.

USE AS A SINE-WAVE GENERATOR

Unlike most inexpensive RF generators, the RF-1 output is a true low-distortion sinewave. In addition, it's output is fairly constant as frequency is varied (AGC is used), and it has a digital frequency readout. These features alone makes it unique at its price.

Its output is about 2 Vp-p (open circuit) with an output impedance of 150 ohms. To maintain lowest distortion you should load it down as little as possible. We recommend a pad consisting of a 150 ohm series resistor,with a 60 ohm resistor to ground. This would yield an output of about 400 mv. p-p with an output impedance of 50 ohms.(If harmonic distortion is not critical, the pad is not needed.)

WHAT IS IMPEDANCE?

Briefly, impedance (Z) is simply AC resistance. A DC voltmeter measures resistance, which is the impedance at DC... zero frequency. As the frequency is increased the resistance changes because of reactance (X). Reactance is either inductive (like a coil), or capacitive (capacitor). X is always present, but you don't notice it until the frequency is high. At 1 MHZ and above, it is very apparent.

An antenna is an extreme case of Z. The impedance of a dipole at DC is infinite (the two sides aren't connected together), yet its impedance at RF resonance is near 50-70 ohms or so. The impedance of a resistance (R) and reactance(X) in series is

$$Z = \sqrt{R^2 + X^2} \quad (14)$$

or,

$$X = \sqrt{Z^2 - R^2} \quad (15)$$

Advanced owners may have noticed that the RF-1 is a modern replacement for the RF noise bridge, widely used in the past. But it doesn't have a way to measure reactance directly (R-X noise bridge.)

However, by using the above equation, X can often be accurately determined. Some examples:

1.We measure Z for a dipole or vertical, etc. At resonance, X disappears, leaving only R (radiation resistance.) Now, for a small (3%) change in frequency away from resonance R hardly changes at all. Virtually all the impedance change is caused by X changing.

So, we can put the measured values of Z and R in the equation 15 and solve for X.(This also allows calculation of SWR (Ref.1), but this gets messy.)

We also know that a dipole or 1/4 vertical has capacitive reactance below resonant frequency, and inductive reactance above, so we know the sign of Z as well.

2. For a short vertical or wire (much shorter than 1/4 wave), R is much less than 40 ohms, and X is large. A stub (open or shorted tranmission line) has almost zero R. In both of these cases, Z=X , to a close approximation.

You could even connect the RF-1 to the base of your short antenna, switch over to the L mode, and read out the coil value, in uH, needed to base-load the antenna! (Yes,the short wire has a capacitive reactance, but, as discussed above, the RF-1 converts between C and L.)

3. In general, if the reactance is inductive, you can tune out the inductance with a capacitor. The minimum Z gives you the R part, and you can calculate X from Z and R using eqn. 15.

ADJUSTMENTS

There are two adjustments on the unit, neither of which should need attention. However, here they are:

1. LCD brightness pot
Turn this to make the LCD brighter or dimmer. If too high you will see "8888." If too low, the display will be too dim and eventually the microprocessor will stop.

2. Distortion adjust pot.
This determines the purity of the sine-wave and primarily affects minimum SWR. If SWR can't be brought to zero, or if the SWR doesn't read "H" with a direct short across the coax connector, this could need adjustment. However, this adjustment is VERY tricky, and user misadjustment is not covered by warranty.

We adjust it by connecting a series-tuned circuit, similar to Fig. 10, except with a 50 ohm resistor in series with the L and C. At resonance (we use about 8 MHz) the circuit looks like a pure 50 ohms (plus coil loss.) But any distortion on the sine wave increases the SWR. Simply adjust the pot for minimum SWR at resonance.

In a pinch, an antenna matched through a tuner could be used as a load connected to the RF-1. The key is that the load must have an SWR near 1:1 at the RF-1 frequency, but a high SWR at harmonics of that frequency. So a tuned circuit is needed. A 50 ohm resistor **WILL NOT DO.**

One board must be unsoldered from the coax connector to make these adjustments.... another reason we don't recommend it. Sorry, we cannot supply a schematic, since this is proprietary.

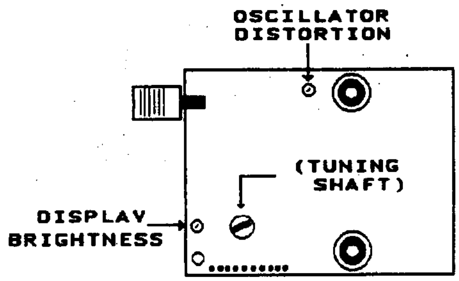

Fig. 11. Adjustments .Made through holes in board with oscillator board mounted in cabinet. The unit will not operate until reassembled unless a special jumper is used to connect boards, so small changes must be made and checked after the boards are connected again. Removal of the oscillator board from the cabinet may break components/wires to the coax connector, and is strongly discouraged..

LIMITED ONE YEAR WARRANTY

Autek Research warrants this product against manufacturing defects for one full year after the original date of consumer purchase. This warranty does not include damage resulting from accident, misuse, abuse, or unauthorized alteration. This product is not weatherproof, so the owner must use reasonable care to protect it against the elements outdoors. Autek Research will not be responsible for consequential damages to person or property cause by use of our products. This warranty is in lieu of any other warranty expressed or implied.

If the product becomes defective during the warranty period we will repair or replace it , at our option, parts and labor included, if it is mailed to us postpaid with a check for $8 to cover return postage and handling ($34outside USA) enclosed **in the package**. We have records of your name and date of purchase, but **you must state your purchase date** (within a month) to find these and verify warranty. Include a description of the problem **in the package** also.

If a unit is returned without the $8 ($34) return shipping, there is an additional $3 charge for corresponaence asking for the payment. **We're here to help you**, but we cannot maintain a high level of service at low cost if excessive correspondence is required. This warranty gives you specific legal rights, and you may have other legal rights which vary from state to state.

SERVICE OUT OF WARRANTY

Our minimum charge is $60 plus $8 shipping and handling (USA), or $28 outside USA. If you should damage the unit during the first year, or the warranty has expired, this charge applies. We cannot give estimates, or even look at the unit ,unless a check for $68(USA) is **enclosed in the package**. Also enclose a detailed description of the problem, a way to induce any intermittent, etc. If the unit appears to have nothing wrong with it, the minimum charge still applies for checkout. We can fix 95% of failures for the minimum.

REFERENCES

1. **The ARRL Antenna Book**, American Radio Relay League, 225 Main Street, Newington, Conn. 06111 (203-666-1541) 736 pages. At this writing, $20 plus $5 S/H. Charge cards accepted.

This handbook has gotten progressively better over the years. Antennas are discussed from the beginner and practical level all the way through topics normally seen only at the graduate engineering level. In our opinion, anyone who's bought an RF-1 should also invest in this "classic" antenna book.

There are many other excellent books covering specific topics listed in Ref. 1.

If you are an author writing about the RF-1, please let us know. If you write a book "101 Uses for The RF Analyst," we'd especially like to talk to you. We'll eventually have a bibliography on all articles, and don't want to leave you out. (We also have glossy photos available for authors. Just write or call.)

IN CASE OF TROUBLE AND HINTS

This section covers common misconceptions and explains normal operation more thoroughly.

1.Impedance reads 50 ohms, yet the SWR is very high, or off scale. What's wrong?

Remember, SWR is only 1:1 for a **resistive** 50 ohms. Any reactance means a higher SWR. As an extreme example, a capacitor can have an impedance of 50 ohms, yet it can't take power, and its SWR is infinity.

2. The displayed values never seem to settle down on large-value readings, for example large Z or C.

First be sure that the connection is not loose. It is **normal** for readings to change several times a second if the last digit (or even two) exceed the measurement tolerance. Simply use the average reading. The multiplexed display may also show occasional "ghost" segments, especially at large viewing angles.

3.When I listen to the unit on my radio, it has a raspy tone.

This is normal. The microprocessor is FM modulating the oscillator, and some of the coils are affected by 60 Hz AC . While it sounds strange, this has no effect on the accuracy of the unit, since the effective bandwidth of the oscillator is much narrower than your antenna, and the oscillator has little harmonic distortion, which is what counts. We didn't design it as a VFO.

4. I seem to get wrong readings when I measure........Is something wrong with the meter?

The short answer is probably no. In testing the meter we often came across readings that "couldn't be right." Yet, once we understood what the load was doing, the meter was always vindicated. It is easy to verify SWR and impedance with resistors. For example, connect a 150 ohm resistor with short leads and verify about 150 ohms and 3:1 SWR. You've now entered the "twilight zone" of RF measurements, where 1" wires can look like 20 ohm resistors, and the meter may be smarter than you are. Learn from it.

Please note that we cannot give specific advice on your antenna problem, any more than your voltmeter manufacturer would help you fix a TV. We're sorry, but any correspondence along these lines can't be responded to. We hope you understand that this could turn into a full time job otherwise. If you do write, enclose a self-addressed stamped envelope (S.A.S.E.) for quicker response.

LATE NOTES

These notes were written after several months of production and reflect user experience and some points not covered above.

MEASURING VERY SMALL Z

The RF-1 has a "suckout" below 4 ohms due to diode drops and the A/D. 3 ohms or less may read zero, or 1-2 ohms. However, accurate measurements are easily made by inserting a small resistor in series with the load.For example, insert a 10 ohm resistor in series, and a 2 ohm load will read 12 ohms. Note that this only works with non-reactive Z , but this is the case when measuring feedline loss, 1/2 wave etc. lines, coil Q, small resonant loops, or anything at its resonant frequency. **We now recommend a larger series resistor (about 50 ohms) for coil Q and other sharply resonant low-R measurements to minimize effects of oscillator distortion.**

MEASURING VERY SMALL L

Software PC2.2 increased L resolution to as low as .001 uH. The meter easily measures below .04 uH by using a few inches of lead wire, measuring at 30-35 MHZ, and subtracting lead inductance. However, note that the last digit of L may exceed A/D accuracy, so this digit may skip several values, or even "go backwards" for tiny L changes.This is normal.

TUNING YAGI AND QUAD PARASITIC ELEMENTS

The general procedure is to break the parasitic element and insert the RF-1.For example, break the quad reflector wire and insert the RF1 where the wire was broken. Then adjust the RF1 frequency to find minimum impedance,and hence resonance. This should be about 5% below the transmitted frequency for a reflector, and 5% above for a director. These may not be best because of interaction with the driven element, so several tests at different parasitic resonant frequencies may be needed. The advantage of the RF-1, as opposed to a grid-dip or SWR meter, is its narrow Z dip, and frequency accuracy. You can make extremely accurate and repeatable measurements as you proceed.

USE OF Z FOR RESONANCE MEASUREMENTS

Many owners are still in the habit of using SWR only, even though Z has a sharper "dip" because of its 1 ohm resolution and total lack of "suckin."
In most cases, the minimum Z will indicate the resonant frequency.(This does not apply to the input of a tuner or matching network, however, just most "bare" antennas.)

METER BURNOUT

The meter can withstand 50+ VDC , and about 50 v p-p RF. This is 2 watts of RF power (into 150 ohms). At this writing, only one owner has had this problem, which is NOT covered by warranty. But, please use caution:

1. Discharge all capacitors. Don't measure circuitry where high DC or RF voltages are present.
2. Never leave the meter connected to ANY antenna while transmitting high power on a VERY CLOSE antenna. This might induce more than 2 watts into the RF1. Beware of very close antennas on Field Day, and never leave the RF1 on one element of a phased array or yagi/quad while transmitting on another element. (2M handhelds should be no problem.)
3. If you suspect your antenna may have built up a large static charge, briefly discharge the static before connecting the RF1.

Also, extremely high power broadcast stations nearby can disrupt meter readings, although not burn it out. If you live within a few miles of a 50 KW station you may see high SWR, etc. if your antenna is large. (A series L/C trap is a possible solution.)

DETERMINING R + jX

As discussed above, R can be determined by cancelling X with a series capacitor or inductor.But, R & X can also be calculated directly using SWR and Z measured by the RF1! The formula is:

$$R = \frac{(2500+Z^2)\,(SWR)}{50\ (SWR^2+1)} \qquad (16)$$

where **SWR** is relative to 50 ohms,as in the RF1,and **R** is in ohms.

Then , X is determined by equation (15), above. The **sign** of X is easily determined by increasing the frequency **slightly** and watching Z. If Z **decreases** when the frequency **increases**, then X is negative (capacitive). If Z increases, X is positive (inductive.) Use a **small** frequency change so that Z does not go through a maximum or minimum...the sign of X changes at a max. or min. Z. (Remember that a feedline can also change the sign of X.)

We believe this simple method of determining the sign of X will work in all cases, but there could be a rare exception due to a rapid change in R with frequency...perhaps when R is very large. As a double check, you could connect a small (5 pF?) capacitor in **parallel** with the load. If Z increases, then X is positive. If it decreases, X is negative. Use the smallest C that shows a measurable Z change .

Equation 16 is error-free, and your RF1 is the most accurate SWR and Z measuring device available unless you have a laboratory impedance bridge. However, a small error in SWR or Z can cause a large error in R. You can only depend on equation (16) when:

a. SWR is greater than 1.2 but less than 6:1, preferably less than 4:1,
and
b. The ratio of R/X is not too large or too small. This ratio should be between 0.2 and 5, or the impedance will be dominated by either R or X, and the other will be inaccurate.

However, even outside these limits, equation 16 can give sufficiently accurate estimates for many purposes. Just use caution. (This note was first included in RF1 instructions about Sept. 1994. If you know of owners with older instructions, please inform them of this new use for the versatile RF1 that they're probably not aware of.)