INSTRUCTIONS
VHF ANALYST Model RF5
Autek Research

9/96

Price $3.00

Caution: RF5 diodes can be burned out instantly by RF voltages on the antenna exceeding 30 V pp--about 2 watts into 50 ohms. Thus, if used on a repeater tower, all transmitters which might couple 2W into the antenna being measured should be turned off. Nearby transmitters at much lower levels can also cause SWR and Z to read high . An external bandpass or notch filter might be needed to eliminate these, in severe conditions.

BATTERY INSTALLATION

Obtain a standard 9 volt ALKALINE battery. Battery life (6-12 hours with intermittent use) decreases drastically with a non-alkaline, and the battery must supply a high starting current. Using your thumb, slide back the battery compartment on the back. This may take some pressure. Don't pull it up and break it--it slides! Install the battery without pulling the battery leads excessively and replace the cover.

ON/OFF

Tap the on/off switch. The first number which flashes is the program code version, e.g. PC 5.0. A higher number may indicate later software, or a later date of manufacture.

FREQUENCY

When you turn your unit on it enters the FREQ mode. The frequency is changed by tapping or holding down the UP or DN (down) buttons. Tap the UP or DN button. The frequency changes DISCRETELY by about 1/240 of the total frequency range across each band.Now, hold down the UP or DN button.The frequency slews UP or DOWN, with a slight lag in the frequency readout.Note that when you reach the top of the band, the frequency jumps to the low end; similarly, it goes from bottom to top when going down. When changing bands (see below) the frequency always starts at the lowest point for the band (except for fine tune. see below). The quickest way to reach the high end of the band is to tap the DN button immediately after a band change. The unit can't go lower, so it switches to the highest frequency.

FINE TUNE

To reach frequencies between the discrete frequencies of the UP/DN buttons, use the FINE TUNE knob. The FINE TUNE knob changes frequency continuously, and much slower than the UP/DN buttons. Also, to reach the extreme high or low frequencies on each band, you must use FINE TUNE. For example, to find the lowest frequency on each band, set the FINE TUNE full counterclockwise, and cycle through the bands.

BAND BUTTON

Tapping the band button changes to the next of three bands.

SWR MODE

Tap the SWR button. An upper box appears 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 6. This is the mode you use to find the resonant frequency of your antenna.
Simply connect the transmitter end of your feedline to the RF5, select the SWR mode, and find the frequency of lowest SWR. See below for more details.

Z MODE

Tap the "Z" button. The meter is now reading the impedance of the meters stray output capacitance. A lower box appears in the left digit showing you're in the Z mode. If the impedance is greater than about 600 ohms, an "H" appears, meaning too high. However, the stray output capacitance will be lower than 600 ohms except at the lowest frequencies! In fact, at 440 MHz, Z will read under 100 ohms with nothing connected! This is normal, but does not mean the unit cannot measure much higher impedances at 440 MHz, as you will see when you connect a transmission line. Please read detailed measurement discussions below.

Unlike other brands which only measure resistance at resonance (X must be zero),the RF5 actually takes the ratio of voltage across the load to current through the load and divides them. This is possible because of the microprocessor. Specifically, if the load is R+ jX , it measures the square root of (R^2+X^2). It will accurately measure the impedance of even a pure capacitor or pure inductor (R=0)

INSTANT SWR™ MODE

This is a unique feature of the RF5, and is made possible by computer control of the RF5 frequency. To enter this mode, hold down the UP and DN buttons at the SAME TIME and release. Notice that most of the display blanks for a few seconds. During this time, the RF5 frequency sweeps across the entire current band, looking for the minimum SWR seen on the band. When the normal display reappears, the RF5 computer has jumped to the frequency where minimum SWR occurred. Thus, with an antenna connected, you can find its resonant frequency without having to manually tune. If you select the Z mode before holding down the UP\DOWN buttons, **the RF5 computer will find the frequency of minimum Z instead**, and jump there.

This mode will find the minimums most of the time. However, you will find that some fine tuning is required, and the unit may not always find the minimum. This could occur for several reasons:

1) To save time, the INSTANT mode only searches 120 frequencies across the band, instead of the 240 reachable by the UP/DN buttons. Set FINE TUNE to center before entering the INSTANT mode for a touchup.

2) Less smoothing of SWR and Z is used, again to save time. This is most noticeable when the Z is very low , or the SWR is fairly constant over a wide range. So the unit sometimes misses the minimum entirely.

3) Loose connections, or RF interference, can be a problem.

If you don't find the minimum right away, try again. In extreme cases, and this may happen for "mysterious" reasons, you will have to search the frequencies manually using the UP/DN buttons.

MODE CYCLING

The display will cycle between modes so you can watch them both. Hold down the FREQ and SWR buttons together,and release them together. Or tap both buttons very quickly in succession. Note that the display now cycles between SWR and FREQ readout. Try the same with the FREQ and Z buttons. Or tap FREQ, SWR and Z together to cycle between all three modes.

AUTO FREQUENCY DISPLAY AT BAND EDGE

Please note that if you are changing frequency in the Z or SWR mode and you reach the end of a band, the unit switches to the frequency mode to warn you. Try: 1) Select the Z mode 2) Change bands, which puts you at the lower end of the band. 3) Hold down the UP button. The unit is now slewing up the band, but you can't see the frequency. When the unit reaches top of the band and jumps to the low end again, you'll see the frequency, instead of Z, until you briefly release the UP button.(This works in reverse with the DN button.)

BATTERY

The first symptom of a low battery is that the highest frequency reachable on each band will be reduced drastically. All else will seem normal.

The unit has an "automatic off" feature to save the battery. It will automatically shut itself off after 15-20 minutes of no use-- no button pushed. To disable this feature: First turn the unit off. Then hold down the FREQ button. Then tap the on-off button ONCE, and release the FREQ button.You will not see the PC5.x indication, confirming that auto- off is disabled.

The unit is totally voltage-regulated as the battery drops to about 6V.The unit includes a step-up circuit--as much as 20 volts is generated internally to control the VCO's.

If you wish to use an AC adaptor note that: **The unit will NOT work properly with voltage above about 12 volts.** Use a 9V adaptor.The unit draws about 50 ma. but needs a MUCH higher starting current which may tax some adaptors. (Radio Shack #273-1552A and #273-1662 have been found to work.) Also, the unit may not turn on if an ammeter is in series with the battery since the meter limits the starting current. If you must drop the voltage to get below 12V, you may need a 100uF or larger capacitor across the RF5 battery input to supply starting current.

You should get in the habit of turning the unit off after a measurement to conserve the battery. If you have a problem with the unit turning on in transit , you may want to cut some plastic off the top of the on/off button.

VERY HIGH FREQUENCY OPERATION

Above about 250-300 MHz, accuracy begins to be limited by stray capacitances and inductances. This is discussed in detail below. If you are a casual user simply looking for lowest SWR or Z, this is of little concern, even at 440 MHz. Most of the instructions will assume a frequency below 250 MHz, and leave most discussion of very high frequencies until later.

SWR MEASUREMENT

SWR (standing wave ratio) is measured relative to 50 ohms. The accuracy tends to be a little better for large Z's than for Z below 50 ohms.

SWR is measured by connecting the feedline to the RF5 output. Antenna resonance occurs at the lowest SWR. The antenna is then made longer or shorter until it shows its lowest SWR at the frequency of interest. (The screw next to the coax connector is also connected to coax ground , but has undesirable extra lead inductance.)

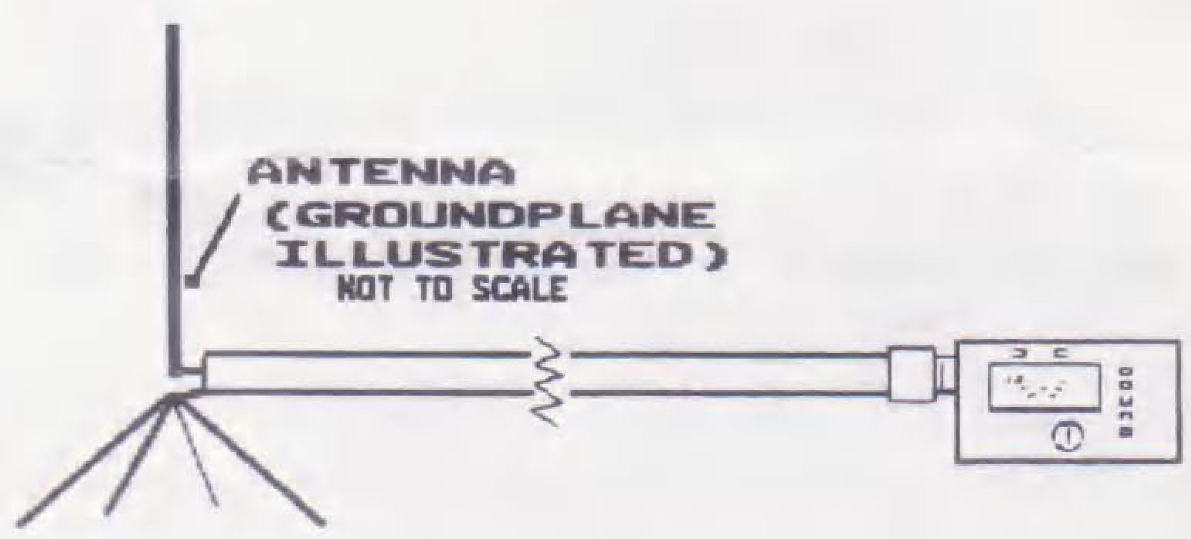

Fig. 1. Measuring at xmtr. end of line

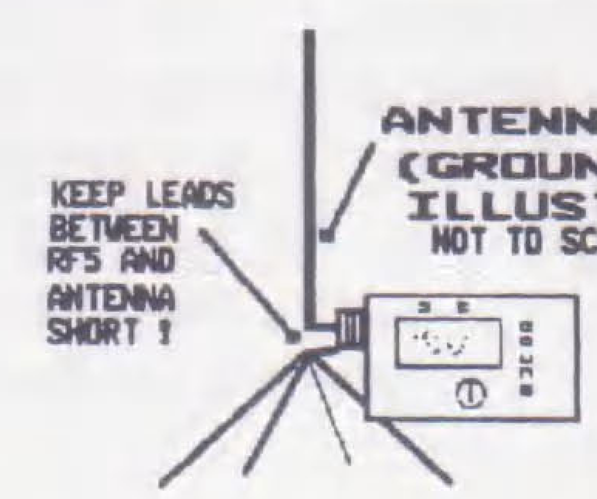

Fig. 2. Measuring at antenna
(Not recommended above 150 MHz. See text)

Measuring at the antenna will make the antenna appear longer than it really is, and produce a lower resonant frequency. For example, if the lead lengths are only 1/2", the leads will appear to be part of the antenna and the antenna may appear to be 1/2" longer than it is! At 440 MHz, where the antenna itself is only 6" long, such an error is unacceptable. At 50 MHz, where the antenna is several feet long, 1/2" of lead is negligible, or might be compensated by making the antenna itself 1/2" longer than indicated by the min. SWR reading with Fig. 2.

To measure **at the antenna** at high frequencies, you might disconnect the long feedline and connect a much shorter feedline only a few feet or inches long , connected in exactly the same way as the longer feedline. By watching the RF5 readings you can see if the nearness of your body has any effect on the antenna.

ADJUSTING ANTENNA LENGTH

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

(1) 1/4 wavelength , groundplane (in.) = 2700/F(MHz)

(2) 1/2 wavelength , dipole (in.) = 5400/F(MHz)

The formula for 1/2 wave of transmission line is:

(3) 1/2 wavelength (in.)= 5900 * VF / F(MHz)

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

Frequency (MHz)	1/4 Wave (in.)	1/2 Wave (in)	1/2 Wave Coax (VF=.66)
52	52"	104"	75"
146	18.5	37	26.7
222	12.2	24.3	17.5
445	6.1	12.2	8.75

Table 1. Some common lengths

Lengths will rarely agree exactly with Table 1 because of nearby objects, dependence on the thickness of the antenna, other variables, and **lead lengths** to the antenna or coax. So you should always initially make any antenna **longer** than Table 1...it is easier to delete wire than splice it on. Another trick is to fold the wire back on itself to make it appear shorter, without actually cutting it.

The procedure for adjusting the antenna length is best illustrated by an example: Say you build a 2M dipole and make it 41" long. Longer than shown in Table 1. You measure its resonant frequency using the hookup of Fig 1 or 2 and finding the frequency of minimum SWR . Lets say this frequency is 136 MHz. But say you want the antenna to resonate at 146 MHz. So your antenna is too long. The correct length should be:

(4) Desired length = Actual Lgth x Actual Freq. / Desired Freq.

For the example:

Desired length = 41" x 136 MHz/ 146 MHz= 38.2 "

So, in the example, the antenna is 2.8 " too long and should be shortened by removing, or folding over, 1.4 " from each side.

For a groundplane, the **vertical** element length is most critical, and the (near-horizontal) ground-plane wires need not be adjusted so long as they're close to correct. By the way, the droop angle, if any, of the groundplane is also not critical. More droop raises the Z of the groundplane. (Horizontal wires yield about 38 ohms theoretically, and drooping raises Z to the desired 50 ohms.) But don't believe the theory, make some measurements!

FINDING FEEDLINE LOSS

Loss in the feedline to your antenna can be very significant. It wastes your transmitter power by using it to heat up the coax before it reaches the antenna, and also makes all signals picked up by your antenna weaker at your receiver. For the first time, you have a way to accurately measure this loss using your RF5. The procedure is summarized below, so you don't have to totally understand the theory we'll present first .
Feedline loss is often negligible below 30 MHz, but increases drastically at 144 MHz and above, and is critical at 440 MHz.

The simplest way to measure line loss is to make measurements of your transmission line as shown in Fig. 3.

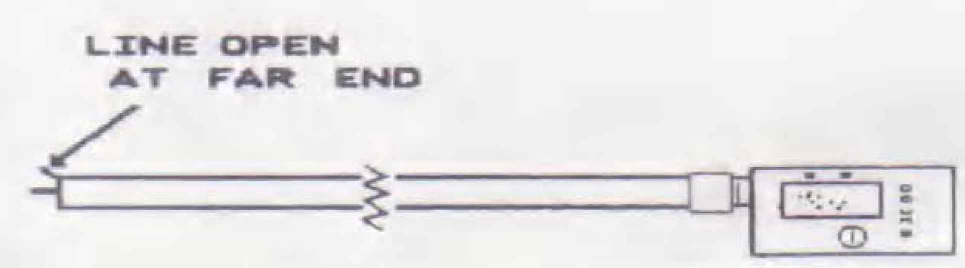

Fig. 3. Measuring line loss with an open line

(Textbooks say the line may be open or shorted, but limited tests with the RF5 show that opening the line yields a much lower loss result at VHF, and is simpler. You can verify.)

There are two methods to measure line loss, a quick way using SWR and a more accurate way using Z.

MEASURING LINE LOSS USING SWR

Simply hook up your RF5 as in Fig 3 and read the SWR. Then refer to Fig. 4 to determine the line loss at the frequency of the RF5. Loss is proportional to line length, so use a reasonably long line, say 20 ft or more. Also, loss rises as frequency rises, as you will see.

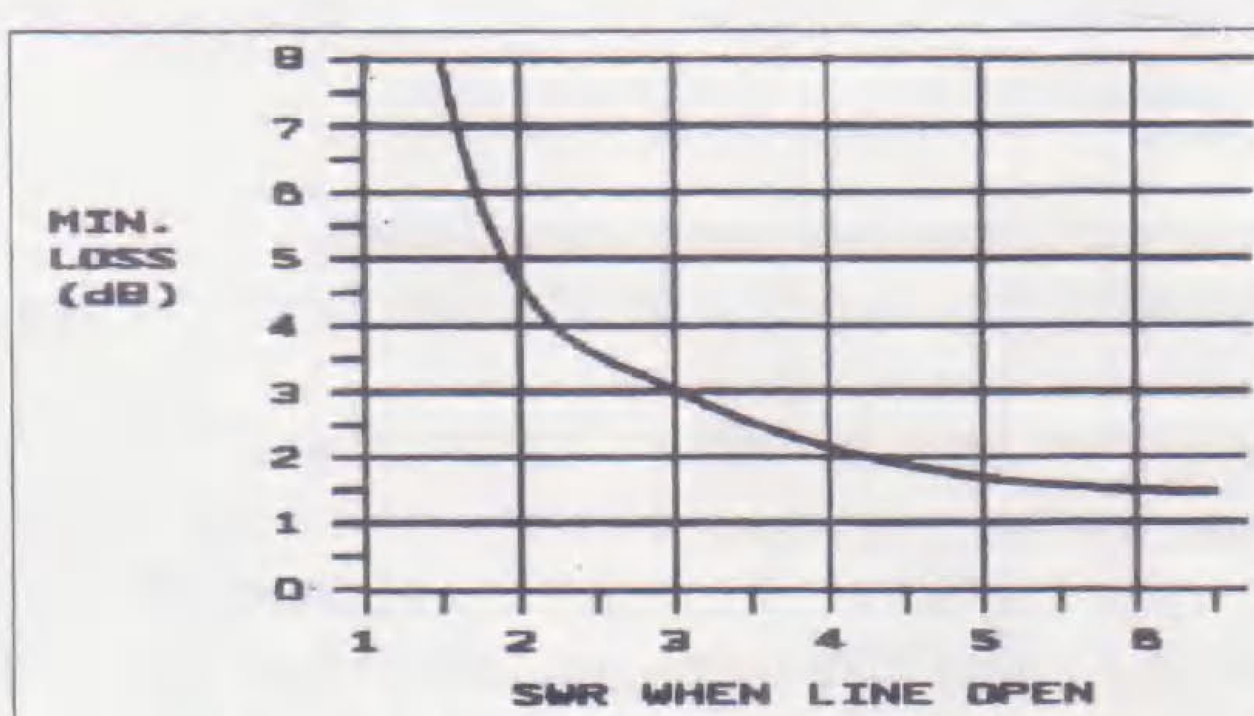

Fig. 4. Line loss vs. SWR of an open line (50 ohm line)

The SWR method is most useful for a quick sweep, since indicated SWR is somewhat sensitive to Z, and SWR accuracy suffers at high SWR. You should always average SWR readings near the frequency of interest.

MEASURING LINE LOSS USING Z

Fig. 5 shows how Z varies with frequency when the line is open or shorted and measured as in Fig. 3.

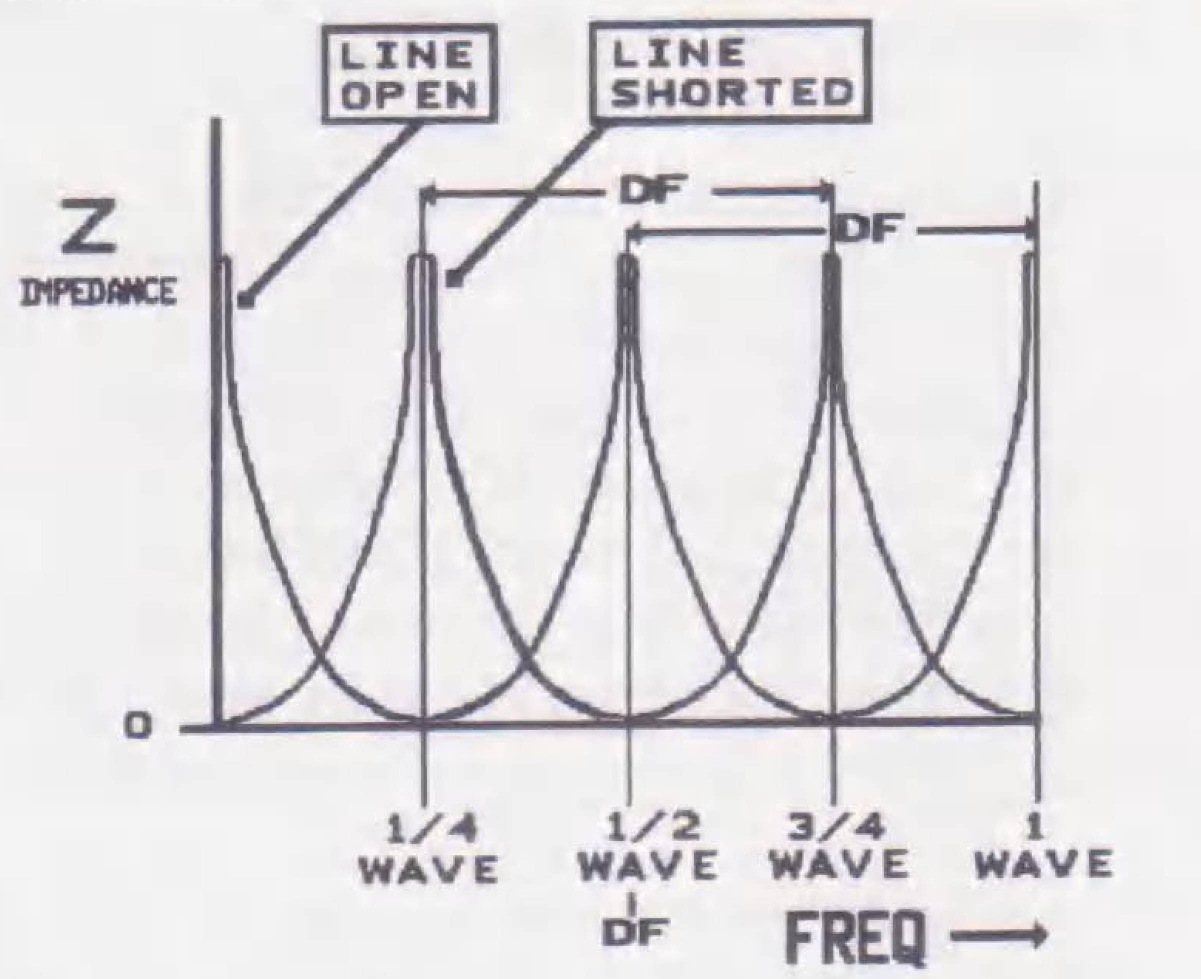

Fig. 5. Transmission Line Impedance

Note that Z shows peaks and nulls separated by a frequency DF, where:

(4) DF(MHz) = 492 x VF / Line Length (ft)

And VF is the velocity factor of the cable. (See Table below.)

For example, for 30 ft. of RG8 or RG58 cable, which has VF= 0.66:

(5) DF= 492 x 0.66 /30 = 10.82 MHz

So, if you connect your RF5 to the cable in the example, you would see nulls or peaks in Z every 10.82 MHZ, all the way up to 500 MHz, ideally. The minimum Z shows you the loss in your cable according to the formula:

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

This formula allows you determine loss for any cable impedance, even for open-wire line.

For 50 ohm line:

(7) Loss--50 ohm line(dB)= 0.17 x Minimum Z

Eqn. (7) is plotted in Fig 6.

So, to determine the line loss using impedance:

1. Disconnect your feedline at the antenna and leave the far end open as in Fig. 3.
2. Find the impedance nulls by varying the RF5 frequency near the frequency of interest, For best accuracy average 2 or 3 min. Z's near the frequency of interest.
3. Find the cable loss using equations 6 or 7, or Fig. 6.

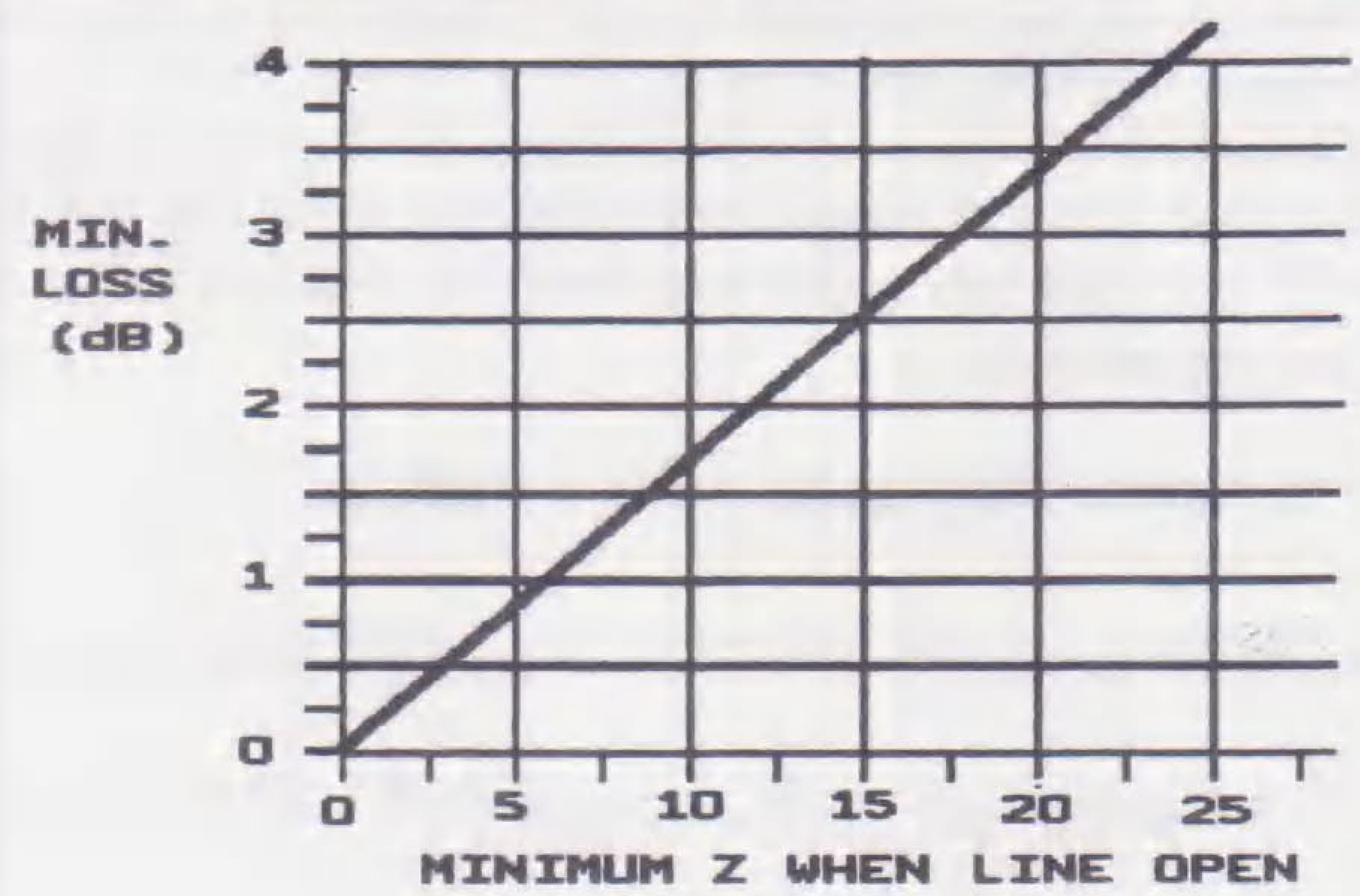

Fig. 6. Line Loss vs. Min. Z (50 ohm line)

TOTAL LINE LOSS AT ANY SWR

All the above loss values are in dB, and **all assume a 1.0 SWR when the antenna is connected.** That is why they are labeled min. loss. However, line losses increase further when SWR is greater than 1.0. **Figure 7 puts everything together** and shows how much of your transmitter power reaches the antenna (or how much of the received signal reaches your receiver.)

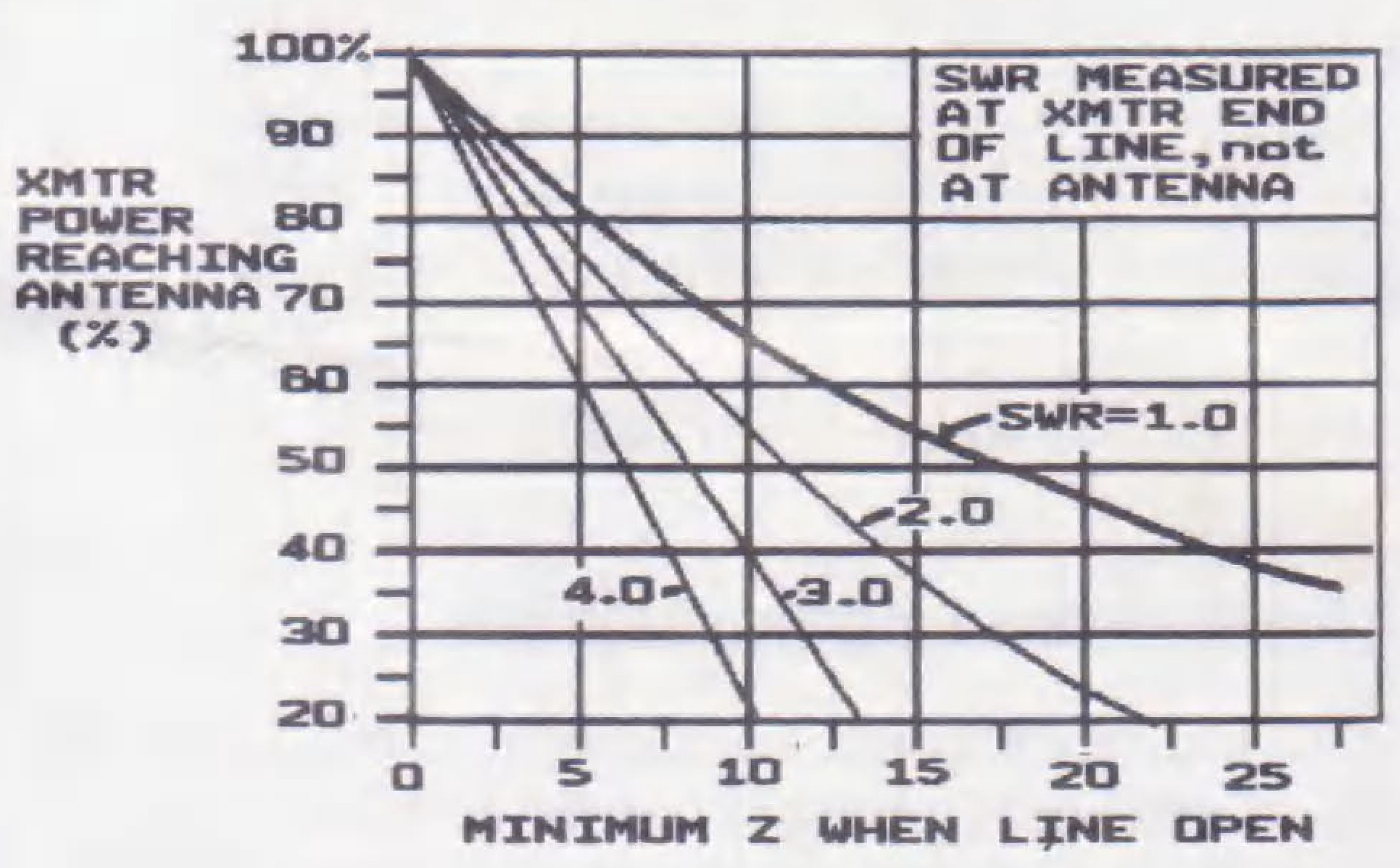

Fig. 7. Power Reaching Antenna

To use Fig. 7:

1. Determine minimum Z with an open line as described above.
2. Connect the antenna and measure its SWR at the **transmitter** end of the cable.
3. Read the percentage of power reaching the antenna from Fig. 7.

Any result over 80% on Fig 7 is considered excellent, but below 50% means you should consider investing in some lower loss cable. Most installations may fall between 50% and 80%, with lower values on the higher bands, especially 440 MHz.

Fig. 7 is not shown in RF1 instructions, but also applies to the RF1. You can convert the "x axis" of Fig. 7 to dB loss by using Fig. 6, if you wish.

Note that the SWR measured at the "shack end" of a line will always be lower than that measured at the antenna because of line loss, and Fig. 7 shows values of the (easier) SWR measurement at the "shack end."

DETERMINING CABLE IMPEDANCE

If you don't know your cable impedance, connect a 50 ohm resistor to the far end of the cable and measure Z at the cable input as you change frequency. If Z changes cyclically about 50 ohms as you change frequency(every DF..see Fig. 5,) then the cable is not exactly 50 ohms. Find a terminating resistor which produces the least change . The value of this resistor is the cable impedance. Do this on the **lowest band** if possible so that the resistor's inductance has minimum effect.

CHECKING BALUNS / OTHER TRANSFORMERS

If you have a 1:1 balun, connect a 50 ohm resistor to the balun output (where the antenna would normally go) and measure the Z at the balun input. It should be a fairly constant 50 ohms over the frequency range where you plan to use it. If you have a 75 to 300 ohm balun, connect a 300 ohm resistor to the output and verify a 75 ohm Z at the input, etc. Perfection is not required, and even a 20% variation, or more, may be acceptable. (This may not work well above 150 MHz because of resistor and RF5 inductance. See discussions below.)

MAKING 1/2 WAVE and 1/4 WAVE LINES

These lengths are often used for phased arrays, stubs, and have other uses. Using a loose length of cable connect it to the RF5 as in Fig. 3. (Except that you may sometimes want to short the far end.)

If you want a 1/2 wave cable, use equation (3) , and cut the cable slightly longer. Now, **short** the far end of the cable and find the first frequency of minimum impedance (see Fig. 5.). This is frequency where the cable is 1/2 wavelength long. The frequency should be low at first. Cut off some cable until the minimum Z occurs at the desired frequency.

A 1/4 wavelength cable should be about half as long. In this case, leave the far end of the cable **open**, and look for the frequency of minimum Z (see Fig. 5 .)

FINDING CABLE VELOCITY FACTOR

By manipulating equation (4):

(9) VF= DF(MHz) x Line Length (ft)/492

So, to find VF, connect the RF5 as in Fig. 3. Change the frequency and find the separation between nulls in Z (DF). (See Fig 5.) Also measure the line length and put these values in equation 9 to determine VF. Average several values of DF for best accuracy, if possible, and use a line at least 10 feet long if possible so DF is not too large. Accuracy to within 1% can be obtained using this method.

FINDING A SHORT OR OPEN IN CABLE

This problem often comes up in computer data cables. The cable is open or shorted somewhere , but how far down the line?

By manipulating equation (4), we find that:

(10) Distance to short /open (ft.)= 492 x VF/ DF(MHz)

To find the position of the open or short , disconnect the cable at the far end if possible (Fig. 3) to avoid feeding any spurious signals into the cable which could affect RF5 readings. Change frequency and find the separation between nulls in Z (DF). (See Fig. 5.) Determine the velocity factor of the cable from manufacturers specifications , or use a length of good cable of the same type and measure VF as in the paragraph above. Put these values in equation (10) to determine how far the short or open is from the RF5 measurement point.

Surprisingly, the same result is obtained with a short or open when DF is used. Examination of Fig. 5 shows that by knowing the exact frequencies , as well as DF, one could determine whether it is a short or open. But this is not usually required, and is not discussed here.

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 will change the impedance unless the SWR is 1.0. 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 effects such as line loss.)

When measuring antenna impedance be sure the "ground" end of the antenna is connected to the RF5 coax ground.

Be sure to disconnect the feedline from the antenna when measuring Z or SWR at the antenna ! Simply connect the RF5 where the feedline was connected to the antenna.

Note that, if you connect the RF5 at the antenna, the lead length of the connection will move the antenna resonant frequency down, but not affect the minimum Z significantly. So, when measuring at the antenna, look for the **minimum Z** near the frequency of interest.

At 440 MHz, and even at 220 MHz, you might want to construct a short length of 1/2 wave line using the method described above and measure at the other end of the 1/2 wave line to avoid problems with lead length. Also, and this is not obvious, when you measure and prune the 1/2 wave line using the RF5, you will automatically tend to cancel the coax connector length **and RF5 internal inductance,** which is very significant at 440 MHz. Still, measuring Z is tricky at 440 MHz.

MEASURING TRAP RESONANT FREQUENCY

A trap is usually a parallel resonant circuit. You could put the RF5 across the trap and look for the frequency where impedance is greatest, but this will not be accurate for two reasons: The impedance peak may exceed 600 ohms and be hard to measure, and the output capacitance of the RF5 and coax connector 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 Z is a minimum, as in Fig. 8.

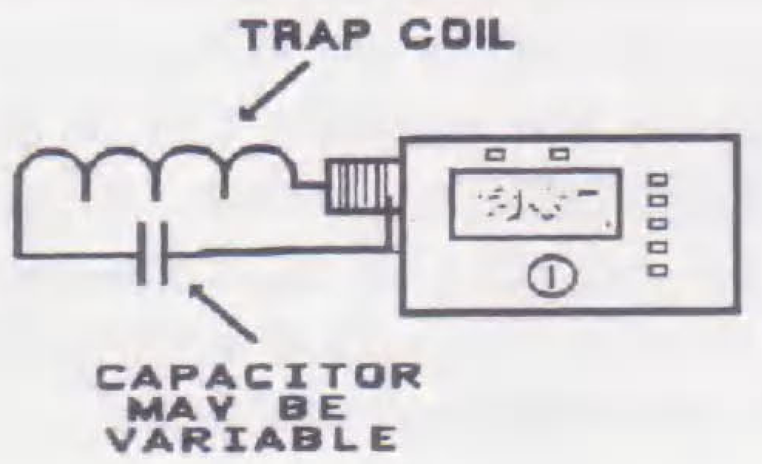

Fig. 8 . Measuring Trap Frequency

This method is very accurate, but you must allow for lead lengths, including leads inside the RF5. These may be significant at 140 MHz and above.

Another method might be to construct a 1/4 wave transmission line at the desired trap frequency, as described above, using the RF5 so that its internal inductance is cancelled. Connect the coil and capacitor **in parallel (not as in Fig. 8)** to the other end of the line. A 1/4 wave line converts high impedances to low impedances. So tune the trap to produce a **minimum** Z at the desired trap frequency.

TUNING YOUR TUNER WITHOUT TRANSMITTING

Antenna tuners are not usually used at VHF because of high line loss. If you measure your line loss leading up to Fig 7, then connect an antenna tuner at the **shack end** of the line, there is no change in the fraction of the power reaching your antenna! The only benefit is that your transmitter may put out more power into the lower SWR produced by the tuner. **A tuner in the shack does not reduce line loss.** Ideally, a tuner should be at the antenna, but that is inconvenient.

If line loss is low, or not important, tuners can be used in the Shack at VHF to present a 50 ohm load to the transmitter. Fig. 9 shows way to quickly switch between the RF5 and your transmitter.

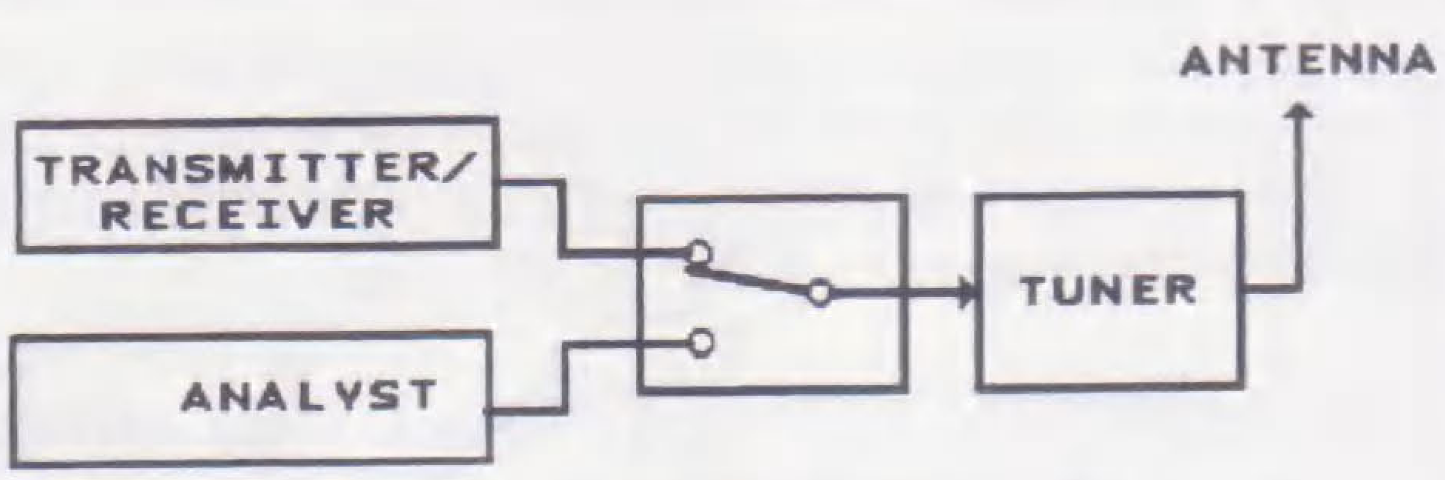

Fig. 9. Tuning an Antenna Tuner Without Transmitting

We don't make the switch, but you can use a coaxial switch, or fashion one with an ordinary SPDT toggle switch and some coax connectors in a small minibox. Everything from Radio Shack. Just be sure there is NO possibility that the transmitter could feed directly into the RF5. **THIS CAN BURN OUT THE RF5 INSTANTLY!**

Lead lengths in the switch box must be kept extremely short -- less than 1/4" at 440 mHz, and 2" at 50 MHz. Otherwise, they will affect the SWR reading. A coaxial switch should be used above 150 MHz. Of course, you can always **disconnect the coax from your rig, connect it to the RF5, and read SWR.**

USE AS A SINE WAVE GENERATOR

The RF5 uses commercial VCO's which have low harmonic distortion-- typically -20 dB or better. They are also **totally shielded** so your hand has no effect on frequency, and they are buffered so the load does not change their frequency.Their drift is low compared to RF5 readout resolution, and spectral purity is more than adequate for antenna measurements. However, they are not synthesized sources, and will sound noisy and drift in a narrow-band communications receiver! This is normal.

The RF5 has a nominal 50 ohm output impedance, but this can vary considerably above 300 MHz, especially. Its output is about 0.5 to 1.5 Vpp and varies about 2:1 over each band. The output is AC coupled through a .001 uF capacitor at the coax connector.

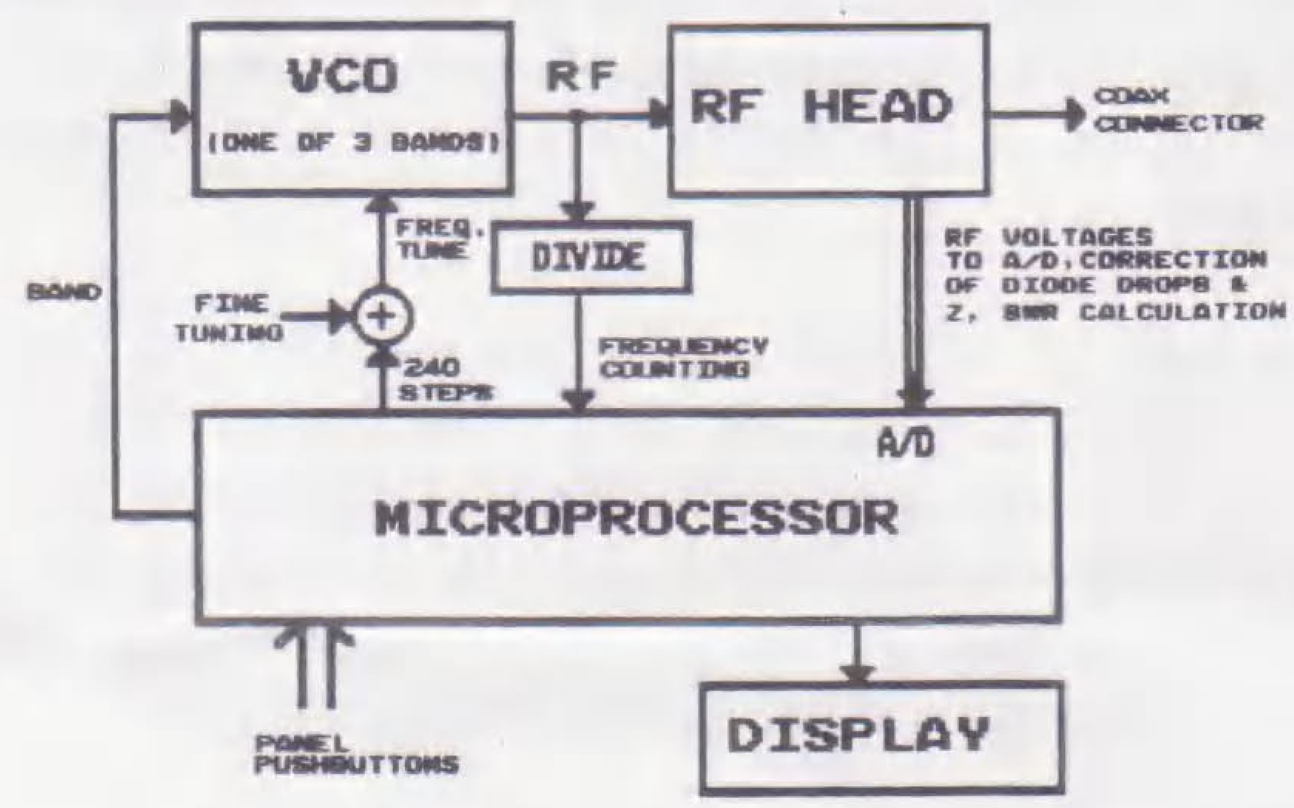

Fig. 10. RF5 Block Diagram

Fig. 10 is a simplified diagram. The microprocessor (uP) is the heart of the RF5. It controls the frequency, except for fine tuning. When you push the UP/DN buttons, the uP sends a voltage to the VCO's to change frequency. When you go into the INSTANT SWR mode, the uP tries frequencies across the entire band looking for the lowest SWR or Z.

A very important feature of the RF5 is the conversion of RF head voltages to digital values in the A/D converter, which has an effective resolution of 10 bits. Unlike analog designs with a fixed meter scale, the RF5 KNOWS the **values** of all voltages, not just their relative values. Voltage drops in the diodes in the RF head can be compensated extremely accurately this way. And, even after this compensation, there is a further compensation of SWR and Z values to take out any systematic error in diode compensation . All in software.

The uP drives the LCD directly, simplifying the design.

We're sorry, but because of the proprietary and advanced nature of the RF5 we cannot supply a schematic at this time.

ACCURACY

The RF5 uses 1% components in critical areas, expensive HP microwave diodes in the RF head, and extensive digital correction of known systematic error sources. Probably nothing similar under $1000 is as accurate. Errors occur due to:

1. Slight differences between detector diodes.
   These cause an SWR or Z reading to vary from unit to unit randomly. These errors tend to be constant, so you could make a correction table for your unit if you have accurate loads available.
2. Diode Thresholds.
   Diodes do not conduct at low levels. This creates a "suckout" effect below SWR's of about 1.2, and below Z=2 or 3 ohms, despite computer compensation.
3. Stray inductance and capacitance.
   These are almost negligible at 50 MHz, but very important at 440 MHz. These primarily affect Z, not SWR. See below.
4. User measurement techniques.
   A basic knowledge of VHF techniques is required. Important points are discussed throughout these instructions. Other examples: Simply sticking a 50 ohm resistor in the coax connector might work at 50 MHz, but a quality coaxial load is required at 440 MHz, and even these will vary. Verifying Z accuracy, even at 50 MHz, must take into account stray capacitance and inductance.

The basic SWR accuracy is 10% for SWR's less than 3; except that below 1.3, the unit will tend to read a little low at 250 MHz and below, and high above 300 MHz. Accuracy is 15% to an SWR of 6, and usually much better.

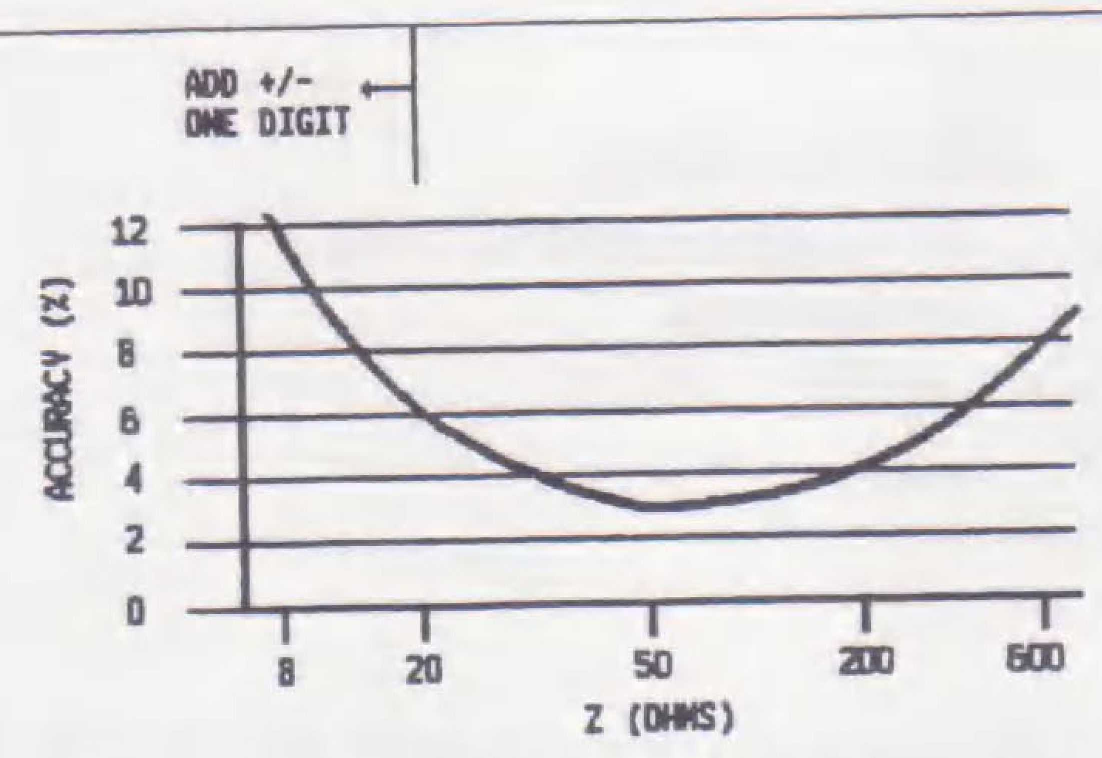

Fig. 11. Impedance (Z) Accuracy

Fig. 11 shows impedance accuracy . At 50 Mhz, this is the accuracy you can expect if your load has negligible lead length, say 1/4" or less, and the impedance is below a hundred ohms. At higher Z, the meter's output C makes the Z appear smaller.

At higher frequencies, Z measurement is affected by stray capacitance if Z is high, and by stray inductance if Z is low. Fig. 12 shows approximate values of these.(Incidentally, these values were measured using the RF5.) The total stray capacitance (5.4 pF) acts in parallel with the load, tending to reduce the apparent load Z at high Z. At low Z, the series inductance tends to increase the apparent Z. With an antenna, the strays shift the curve of Z vs. frequency slightly with little affect on the values of Z, except possibly above 300 MHz, i.e a slight frequency shift cancels the strays!

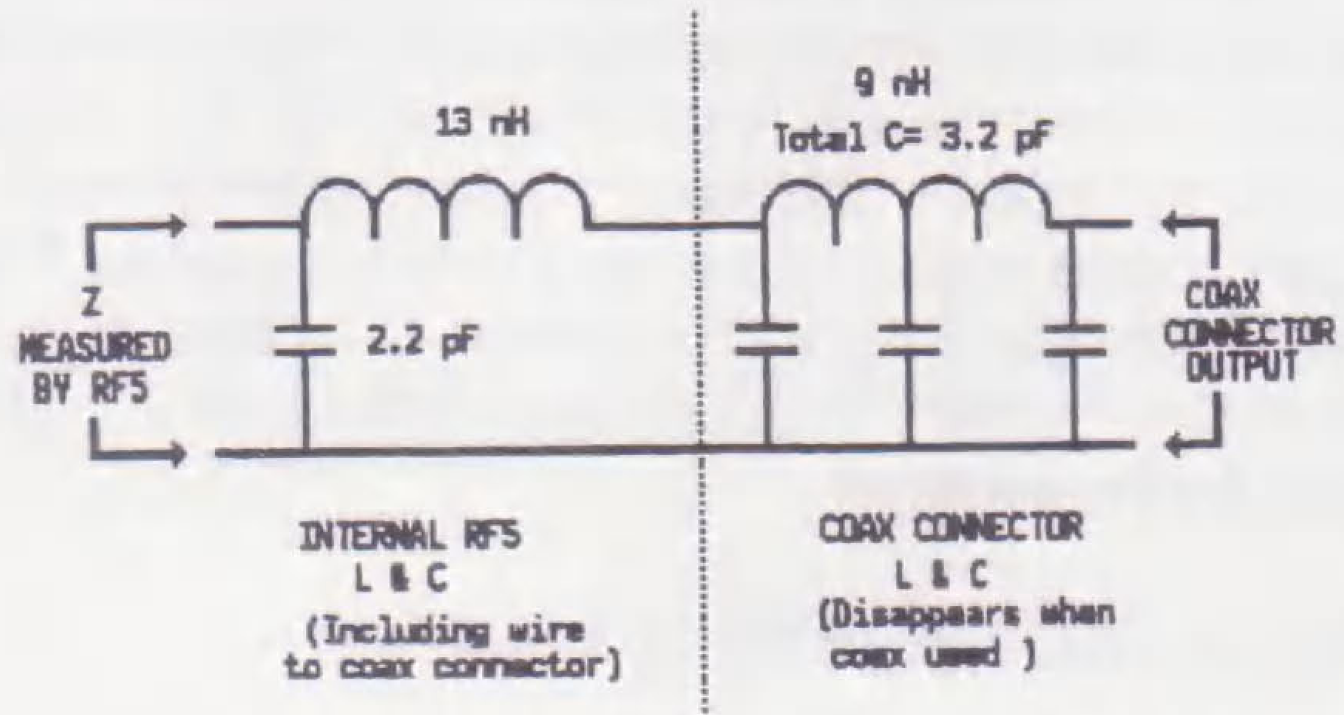

Fig. 12. Approximate Equivalent Circuit When Measuring Z.

Please note that when a coaxial line is connected to the RF5, the coax connector becomes part of the transmission line, and the coax connector L and C "disappear."

Also note that SWR measurements are made in a bridge circuit where internal RF5 L&C, including the lead to the coax connector, is compensated in the other leg of the bridge. So **Fig. 12 does not apply to SWR measurements.**

Note that all **the strays** shown in Fig. 12 **are cancelled** when making the "minimum Z" measurement used in Equations 6 and 7, and Figs. 6 and 7 ! The transmission line looks a fraction of an inch longer because of them, but that is all.

MEASUREMENTS ABOVE 300 MHZ

The affects of parasitic elements, such as stray inductance , capacitance,and even some lead radiation increase exponentially at the highest frequencies. Precise measurements above 300 MHz are almost an "art," rather than a science, and may be limited by your experience and method of hookup rather than the RF5 accuracy.For example, only 1/2" of wire (1/4" gnd lead, 1/4" hot lead) has an inductance of about 10 nH, and a reactance of 26 ohms at 440 MHz. This alone will keep the SWR above 1.5! Or, if measuring at the base of an antenna, the antenna will appear 1/2" longer than it really is, and seem to resonate lower. You should almost always measure at the far end of the coax on 440 MHz to avoid this. Also, the coax connector may not be capable of a 1:1 SWR no matter what the load. Trying various dummy loads may produce wildly different SWRs, since few loads are perfect here. The meter itself has an inherent minimum SWR of about 1.2 at 440 Mhz, and perhaps 1.4 at 520 MHZ, although this depends on the load. So, at these frequencies, any SWR less than 1.5 is usually considered good, and 2.0 is usually "acceptable." Thus, the search for a "perfect" 1.0 SWR here may be futile. You can see from Fig. 7 that a 1.5 SWR has little effect on line loss, for example.

You should tune the antenna for minimum SWR and note that the actual SWR on the line is undoubtedly lower, and it is the SWR on the line which increases cable loss. (For example, a "bump" in the SWR due to a "shack end" coax connector has negligible loss compared to a similar SWR occurring at the antenna end, since it does not increase standing waves on the much-longer line. We don't think replacing the RF5 connector with an "N" connector produces much practical improvement.)

DETERMINING R+jX

Advanced users may be interested in determining the two components of Z, R and X. For a simple antenna, R=Z at minimum SWR. Finding these components away from resonance becomes impractical at frequencies much above 50 MHz because of internal and lead L&C (see Fig. 11.) If X is inductive, you can insert a capacitor in series with the load to cancel X , producing minimum Z when the C is adjusted. This yields R. Also note that R typically varies much slower than X away from minimum SWR, so X can be inferred from Z and R at resonance by the equation:

(10) X= SQUAREROOT (Z^2-R^2)

The sign of X is usually negative (capacitive) at frequencies just below resonance, and positive above, assuming you are measuring at the antenna.

Another way is to use the equation:

$$(11)\ R = \frac{(2500+Z^2)(SWR)}{50(SWR^2+1)}$$

Measure Z and SWR using the RF5, use eqn.. (11) to find R, then use R and Z in eqn.. (10) to find X.

This equation is only accurate if R and X are about the same size. If one is much larger (4x or more), the smaller one cannot be determined. More importantly, above 50 MHz, the parasitic L&C (Fig. 12) will tend to make Z less accurate. Eqns. (10) and (11) are useless at 440 MHz, for example.

CABLE

Characteristics of some common cables are shown below.The loss is per 100 feet of cable. For 50 feet, multiply the loss by 1/2, etc. Note that foam- dielectric cable has less loss (and its size is the same as equivalent "non-foam.") However, foam is more subject to increased loss due to weathering...for example moisture. Otherwise, low-loss cable tends to be **much** thicker, and more expensive. All losses are at swr=1.0. See Fig 7 for an indication of how loss increases with SWR.

		Loss per 100 ft. (dB)		
Cable	~VF	50 Mhz	144 Mhz	440 MHz
RG58 Type	.66	3.2	6.0	12
RG58 (foam)	.80	2.6	4.7	8
RG8,RG 213-216	.66	1.7	3.0	5.9
RG8 (foam)	.80	1.2	2.0	3.7
9913 (Belden)	.84	0.9	1.5	2.7

Note: 1 dB loss= 79% of power reaches antenna. 2 dB= 63%
3 dB= 50% 4dB= 40% 6dB=25% 9 dB=12% 12 dB= 6%

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 to cover return shipping and handling 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.

As this writing, shipping and handling is $9 in 48 states and $36 overseas, but this may increase. Please call, E mail, or check our web page for latest S/H.

This warranty gives you specific legal rights, and you may have other legal rights which vary from state to state.

SERVICE OUT OF WARRANTY

At this writing, our **minimum** charge is $60 plus S/H as above. **Please call or E mail for the current rate**. 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 $60 plus S/H as above 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.

Most random failures can be repaired for the minimum. However some catagories such as exposing the unit to RF, severely botched major repair attempt, unit fell in water, etc. would probably be more.

REFERENCE

Most of the equations herein can be found in :

The ARRL Antenna Book
American Radio Relay League
225 Main St.
Newington, Conn. 06111
(203-666-1541)

This book is written for both novices and engineers, and is highly recommended to any RF5 owner.

IN CASE OF TROUBLE AND HINTS

Some common questions:

1. Impedance reads 50 ohms yet SWR is very high. Why?
   Remember, SWR is only 1.0 for a **resistive** 50 ohm load. When the load has reactance(X), this relationship does not apply. (A pure coil can have a Z of 50 ohms, yet SWR is infinity, for example.)
2. The display readings never seem to settle down, on large Z or SWR, for example.
   The RF5 smooths each reading 256 times; more smoothing would slow response. You should average any readings which vary. The multiplexed display may flicker a little, especially under indoor lights, and the displayed value may occasionally "hiccup." This is normal.
3. My brand X reads differently than the RF5.
   Many SWR meters read 1.0 even when the SWR is higher. This is the simplest design (no computer compensation required), and cuts down on customer complaints. Just think-- did you complain that the other meter reads **low**?
   The RF5 is a serious instrument, not some diodes and a panel meter, and we discuss accuracy at length. Does Brand X do this? Why not ?
4. Readings don't agree on the two bands where the bands overlap in frequency.
   The reading on the highest band should be more accurate . Oscillator output is higher . Also, oscillator output is higher when the 440 MHz frequency is approached by tuning UP from the low end of the band, rather than starting at 500+ MHz and tuning down. So tuning up can be a little more accurate.
5. I seem to get wrong readings when I measure..........
   Is something wrong with the RF5?
   The short answer is probably no. If in doubt, you need an accurate reference load, along with good measurement techniques to tell. You've entered the "twilight zone" of VHF measurements, where 1/2" wires can look like 25 ohms, and your wet hand can appear to be a decent antenna. The meter may be smarter than you are. Learn from it.

Please note: We make test equipment, and have described many typical applications in these instructions. However, we cannot give specific advice on your antenna problem, any more than a voltmeter manufacturer could help you fix or design your radio, since this could turn into a full-time job for a highly-paid engineer. We're sorry, but correspondence along these lines can't be responded to. More reading of the reference, or hiring of an antenna engineer is recommended in this case. If writing, always enclose an S.A.S.E.

LATE NOTES

These notes cover items which came up after the main instructions were written.

1.RUBBER DUCKIES / HANDHELD ANTENNAS

Antennas which connect directly to your handheld, **without a feedline**, may appear to measure too high or low in resonant frequency. This may be done on purpose to cancel lead inductance inside the handheld, or for other reasons. So you may not want to change their tuning based on RF5 measurements unless you use them at the other end of a feedline.