9811

INSTRUCTIONS
VECTOR RX ANTENNA ANALYST™
MODEL VA1

Autek Research

Price $3.00

Caution: VA1 diodes can be burned out instantly by RF voltages on the antenna exceeding 30 V pp—about 2 watts into 50 ohms. Thus, 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.

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BATTERY INSTALLATION

Obtain a standard 9 volt ALKALINE battery. Battery life (6-12 hours with intermittent use) decreases drastically with a non-alkaline .Using your thumb, slide back the battery compartment on the back. Don't pull it up and break it--it slides! Install the battery without pulling the battery leads excessively and replace the cover.Tap the on/off switch. The first number which flashes briefly is the program code version. A higher number may indicate a later date of manufacture.

The unit draws about 50 ma., rising to 80 ma. at 30 MHz. It has an "auto-off" feature to save the battery. The unit automatically shuts off after about 20 minutes on nonuse. 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 brief program code at turnon, confirming that auto-off is disabled.An AC adaptor , 9-12 V at 200-500 ma. may be used. Radio Shack #273-1552A and #273-1662 are suitable. Replace the battery when the display dims noticeably.

The screw near the coax connector is an alternate ground.

MODES

FREQUENCY

When you turn your unit on it enters the FREQ mode. The "tune" knob changes the frequency. The "fine" knob also changes frequency, but much slower.

BAND BUTTON

Tapping the band button changes to the next band. If you hold down the band button, the unit continuously cycles between bands.

FUNCTIONS

The measurement summary drawing on the next page summarizes the VA1 functions. Function 1 measures SWR, Rs and Xs. Function 2 measures Z, L and C, etc. When you turn the unit on it always starts in Function 1. To change functions, tap the Function switch until the desired function number appears. Then tap <u>any other button</u> (except on/off) to stay in that function. If you get confused about which function is selected, simply tap the function button ONCE to see the function, then tap any other button to stay in the function.

SPECIAL DISPLAY SYMBOLS

Each measurement mode has a special symbol on the left which further tells you what function you're in. For example, SWR has a little box in the upper left, the C mode has a small c on the lower left, etc. Sometimes this symbol is written over if the number is too large, however. The sign of a number, if it is minus, is shown by a minus sign in the upper left. Xs, Xp, L and C can all be minus. No sign is shown for "+."

If a number is too big, a large "H" appears on the right, meaning too HIGH to measure. This usually occurs when Z is larger than 1000 ohms, in which case all modes read high , except C reads "L." But other conditions can cause this.

MODE CYCLING

Hold down the SWR and frequency buttons, and release them at the same time. Notice that the meter now cycles between the FREQ and SWR modes. If you tap the buttons in VERY QUICK succession, cycling will also occur. By tapping all mode buttons very quickly you can even cycle through all 4 modes in each function. *Cycling is very handy.*

SWR

This mode displays SWR relative to 50 ohms, so that a 50 ohm resistor will read close to 1.00 SWR. The "H" appears for any SWR above about 20:1. This is the mode you use to find the resonant frequency of your antenna. Simply connect the transmitter end of the feedline to the RF5, select the SWR mode, and find the frequency of lowest SWR. Or measure at the antenna. See below for more details.

CHANGING LINE IMPEDANCE FROM 50 OHMS

You may be using 73 ohm line,or some other impedance, not 50 ohm line, and wish SWR to be referenced to this impedance.To do this : HOLD DOWN THE SWR BUTTON FOR ABOUT 1 SEC and release (in function 1.) The display reads "L 50" , showing that 50 ohm line is selected. Now tap the SWR button until you see "L 73" for 73 ohm line, or whatever line you want. To keep this, tap any other button, such as frequency. If you ever want to verify the setting, hold the SWR button down for 1 sec again, and release. Then tap any other button. Just as with the Function button, the LAST reading you see is used.

The unit always starts at 50 ohms on powerup. So you must change the reference at each powerup if desired.This impedance also affects the Rs ant and Xs ant calculations, discussed below, but has no effect on any others such as Rs or Xs.

Rs and Xs

Amazingly, any (linear) load can be *completely* described by its equivalent series resistance (Rs) and series reactance (Xs) at each frequency. (See the drawings on Page 3.) This means that knowing Rs and Xs, the VA1 can calculate SWR. (See equations in the Appendix.)

IMPEDANCE (Z) and PHASE

Rs and Xs are are right angles to each other (see the triangle on page 3) . So they don't add directly. Z is similar to DC resistance, in that it obeys ohms law . Instead of E= I R at DC, we use E=I Z at RF frequencies. But E and I are not necessarily in phase with each other, and the phase angle shows the difference. A phase angle of 0 degrees means the load is pure R with Xs=0, while + or - 90 degrees indicates a pure X, with R=0. Other angles indicate a mix of R and X.

L & C

The L and C functions convert Xs to its equivalent C and L value at the measurement frequency, which saves much calculation. Most L/C meters operate at some low frequency, such as 100 kHz or 10 kHz. The VA1 measures at the RF frequency of interest for a much more realistic value, especially for coils. For example, a toroid inductor has a totally different L value at RF because of core characteristics, and distributed capacitance changes the apparent L value of any inductor with frequency.

When measuring a lumped L or C it is important to keep Z between about 30 to 200 ohms for best accuracy. This is done by varying the frequency and watching Z. Also, lead lengths are very important, especially at the higher frequencies.

MEASUREMENT SUMMARY

NOTE: "LOAD" REFERS TO WHATEVER IS CONNECTED TO THE METER'S COAX CONNECTOR--AN ANTENNA OR A FEEDLINE OR DISCRETE COMPONENTS.

SWR

STANDING WAVE RATIO RELATIVE TO 50 OHMS (AT EACH POWER TURNON.)

TO CHANGE FEEDLINE TYPE, HOLD DOWN SWR BUTTON FOR 2 SECS, RELEASE, AND SELECT NEW FEEDLINE TYPE.

(SEE PAGE 2)

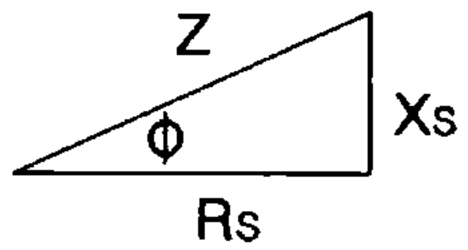
Z

MAGNITUDE OF LOAD IMPEDANCE (OHMS)

$$Z=\sqrt{Rs^2 + Xs^2}$$

Φ

PHASE ANGLE OF LOAD (DEGREES).



A MINUS SIGN IN THE UPPER LEFT DIGIT MEANS NEGATIVE PHASE, NEGATIVE X, AND A CAPACITIVE LOAD. OTHERWISE THE LOAD IS INDUCTIVE.

$F_{1/4}$

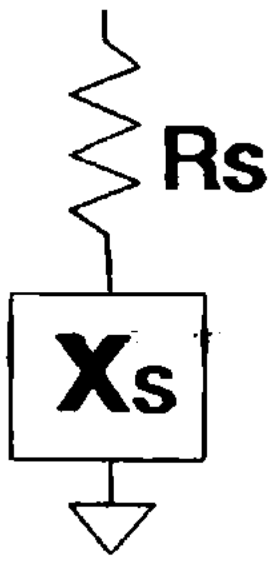
THE FREQUENCY WHERE THE FEEDLINE TO THE ANTENNA IS 1/4 WAVELENGTH. CAN BE MEASURED BY USER SO THAT Rs ant AND XS ant (BELOW) CAN BE CALCULATED.

THIS FREQUENCY YIELDS THE ELECTRICAL LINE LENGTH FOR THE SELECTED FEEDLINE AT ANY FREQUENCY.

(SEE PAGE 8)

Rs

LOAD SERIES RESISTANCE (OHMS)



L

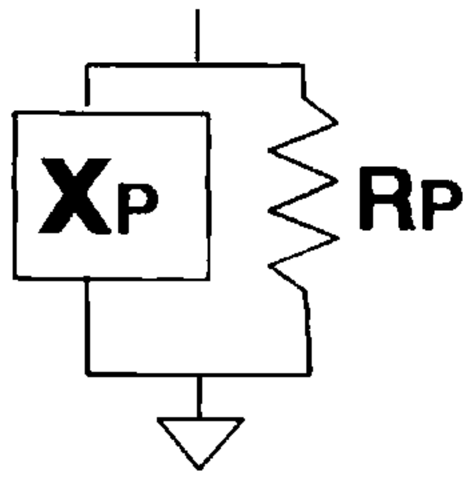
INDUCTANCE IN MICROHENRYS (Uh)

EITHER:
1. THE VALUE OF A PURE INDUCTOR (COIL), OR
2. WHEN MEASURING AN ANTENNA, THE VALUE OF Xs CONVERTED TO AN INDUCTANCE.

IF L IS NEGATIVE, THE LOAD IS CAPACITIVE, AND THIS IS THE VALUE OF THE COIL NEEDED TO CANCEL THE CAPACITANCE.

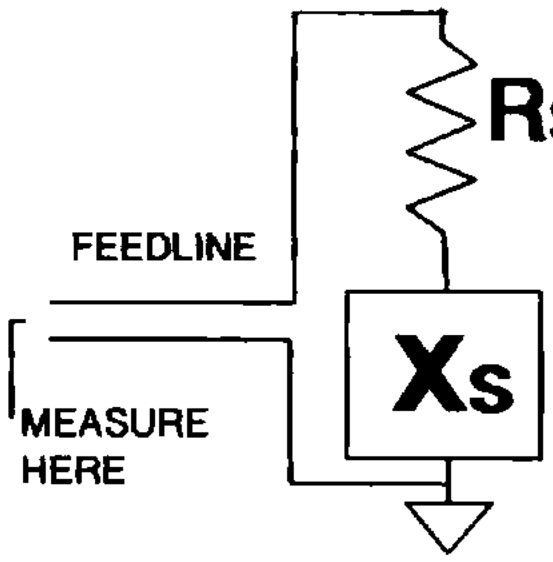
Rp

EQUIVALENT LOAD PARALLEL RESISTANCE (OHMS)



Rs ANT

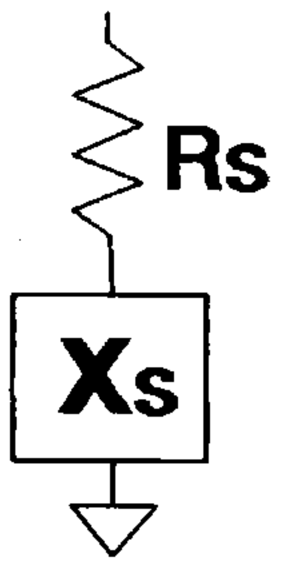
RESISTANCE OF ANTENNA (OHMS) CALCULATED BY MEASURING AT OTHER END OF FEEDLINE.



Xs

LOAD SERIES REACTANCE (OHMS)

A MINUS SIGN IN THE UPPER LEFT DIGIT MEANS CAPACATIVE, OTHERWISE X IS INDUCTIVE.



C

CAPACITANCE IN PICOFARADS (pF)

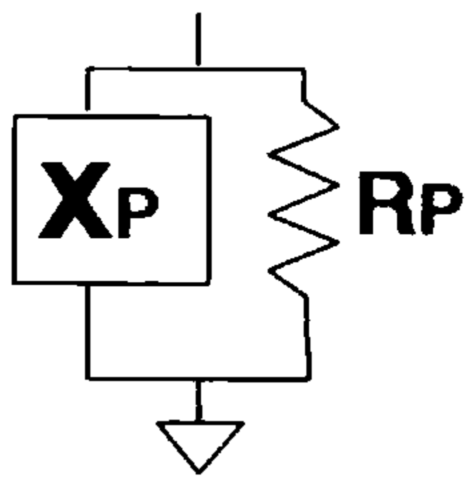
EITHER:
1. THE VALUE OF A PURE CAPACITOR, OR
2. WHEN MEASURING AN ANTENNA, THE VALUE OF Xs CONVERTED TO A CAPACITANCE.

IF C IS NEGATIVE, THE LOAD IS INDUCTIVE, AND THIS IS THE VALUE OF THE CAPACITOR NEEDED TO CANCEL THE INDUCTANCE.

Xp

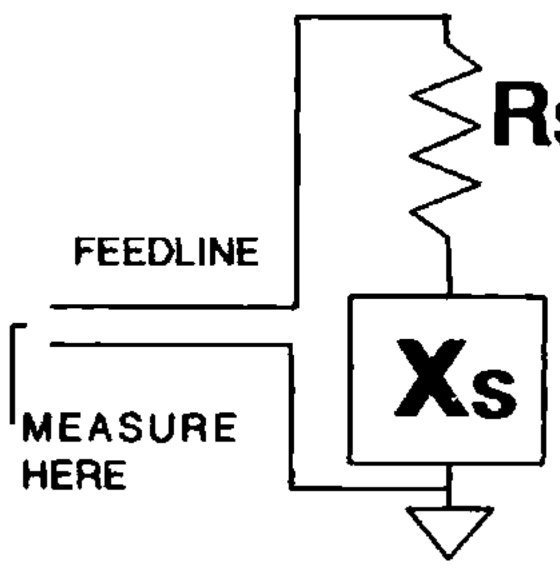
EQUIVALENT LOAD PARALLEL REACTANCE (OHMS)

A NEGATIVE SIGN MEANS CAPACITIVE. OTHERWISE Xp IS INDUCTIVE.



Xs ANT

REACTANCE OF ANTENNA (OHMS) CALCULATED BY MEASURING AT OTHER END OF FEEDLINE.



1	2	3	4
SWR, Rs, Xs	Z, L, C	Φ, Rp, Xp	$F_{1/4}$, Rs ANT, Xs ANT

FUNCTIONS

To eliminate lead inductance, measure L with test leads shorted to get the inductance of the test leads. Then connect the test leads to the coil, read L, and subtract the test lead inductance to get the true L of the coil.

When measuring a lumped capacitor, keep leads short, especially with capacitors over 100 pF or so. If leads are long, the positive reactance of the leads will cancel some of the negative reactance of the capacitor and make the capacitor appear larger.

The above discussion applies to lumped L or C. When measuring an antenna, the VA1 also converts Xs to its equivalent L or C. (See equations A10 and A13 in the appendix.) For example, you read

Rs = 70
Xs = 50
F = 7 MHz

Because Xs is positive, the series reactance is inductive, not capacitive. Switching over to the L mode, you read

L = 1.14 uH

So, your load looks like a 70 ohm resistor in series with a 1.14 uH inductor at 7 MHz. Switching over to the C mode at the same frequency you read

C= -455 pF.

There is a minus sign in front of the C. This is the capacitor value which has Xs = -50 ohms. This tells you that , at 7 MHz, 455 pF has the same reactance as 1.14 uH, but opposite sign. In other words, this L/C combination has a *resonant frequency* of 7 MHz.

Similarly, if Xs is negative, C will read positive since the series reactance is capacitive, but L will read negative and yield the series value of L required to cancel C.These applications are discussed in more detail below (matching.)

Rp & Xp

Just as any load can be described by Rs and Xs, there is an equivalent parallel combination of resistance and reactance, called Rp and Xp which is just as valid and occasionally more convenient.

See the MEASUREMENT SUMMARY on page 3. Rp and Xp are calculated from Rs and Xs using equation A8 and A9 in the Appendix. Some uses for Rp and Xp are discussed in more detail below (matching.)

F-1/4 , Rs ant , Xs ant

A feedline can drastically change Rs and Xs unless it is 1/2 wavelength long or a multiple. These functions yield Rs and Xs at the antenna for ANY LENGTH feedline, so you can measure at the transmitter end of the feedline. Briefly, F-1/4 is the frequency where the feedline is 1/4 wavelength long.These modes are discussed in detail below. (Advanced Applications)

BASIC APPLICATIONS

As shown in Fig. 1 and 2, the VA1 can be used to measure at the antenna, or at the far end of a feedline. For SWR, measuring at the end of the feedline may be preferred since it is often more convenient and the feedline may affect the antenna resonance. However, initial adjustments are often made at the antenna if possible.

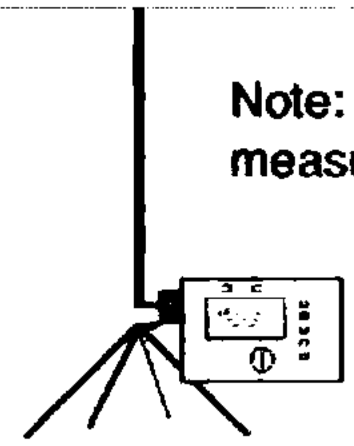


Fig. 1. Measuring at Antenna
For SWR & Accurate Rs and Xs .

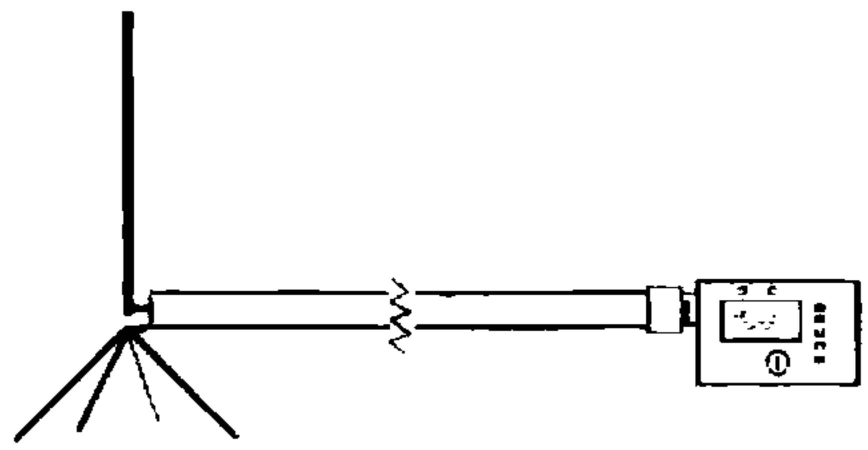


Fig. 2. Measuring at End of Feedline.
For SWR. Use Rs ant and Xs ant for R and X .

Frequency (MHz)	1/4 Wave Vert. (ft.)	1/2 Wave Dipole(ft.)	1/2 Wave Coax (VF=.66)
1.83	123	256	177.4
3.75	60	125	86.6
7.1	31.7	65.9	45.7
10.15	22.2	46.1	32
14.1	16	33.1	23
18.1	12.4	25.9	18
21.1	10.7	22.2	47.6
24.9	9	18.8	13
28.5	7.9	16.4	11.4

Table 1. Some Common Lengths

ADJUSTING ANTENNA LENGTH

The formulas for common antennas are:

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

(2) 1/2 Wave Dipole (ft.) = 468 / F (MHz)

Table 1 shows lengths for some common frequencies.

The recommended procedure when erecting an antenna is to make it 2% to 5% longer than the calculated value... it's easier to delete wire than splice it on. The calculated values 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 SWR is lowest. If this frequency is too low you need to shorten the antenna; if too high, you need to lengthen it.

The procedure for changing the antenna length can be illustrated with an example. Say you erect a 40M (7.1 MHz) dipole and cut it a little long at 70 feet (35 feet per side.) You raise the antenna and measure the antenna as in Fig. 2. The lowest SWR occurs at 6.521 MHz. So, you antenna is too long. The correct length should be:

(3) Desired Length = Actual Length x Actual Freq./Desired Freq.

For the example:

Desired Length = 70 ft. x 6.521 / 7.1 = 64.29 ft.

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

MAKING 1/4 and 1/2 WAVE LINES

The lengths are often used for phased arrays, stubs, and have other uses. Formulas are:

(4) 1/2 Wave (ft.) = 492 Vf / F(MHz)

(5) 1/4 Wave (ft.) = 246 Vf/ F(MHz)

Using a loose length of cable (not connected to your antenna), connect the meter to the cable (Fig. 3.) You can either short the other end of the cable or leave it open. Now, measure the Z of your cable vs. frequency. You'll get a curve like Fig. 4.

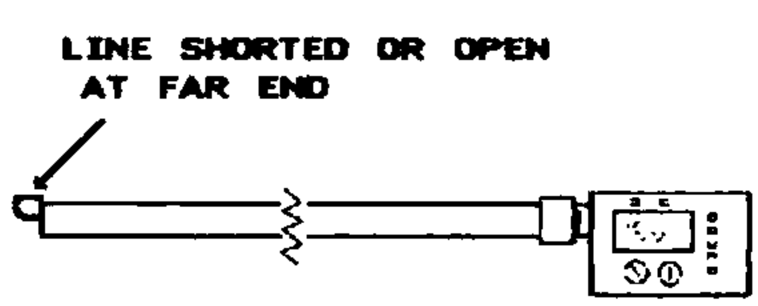


Fig. 3. Measuring Transmission Lines
Note: Disconnect any antenna.

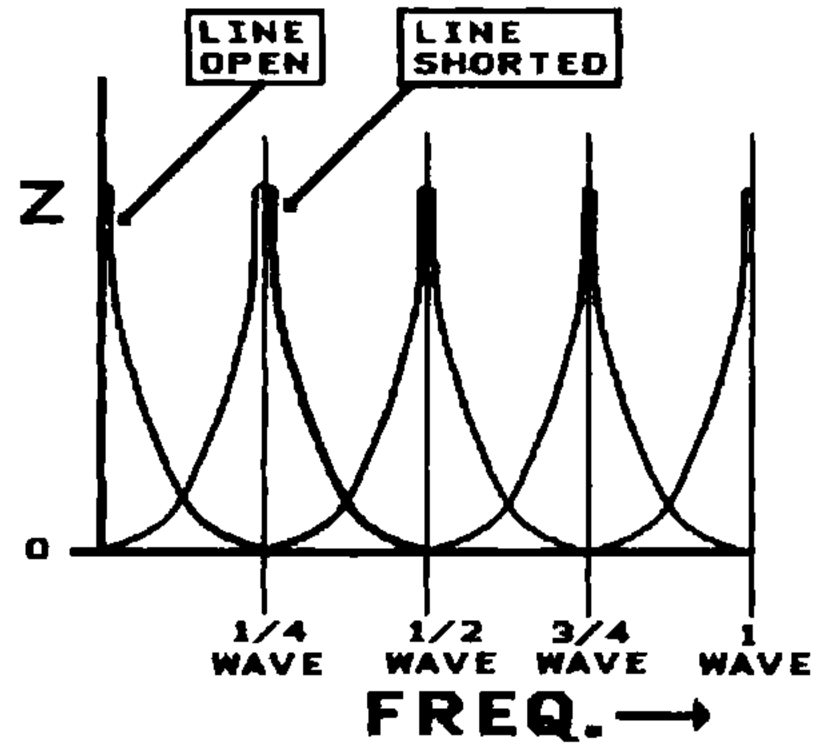


Fig. 4. Transmission Line Impedance vs. Frequency

Since maximum Z is probably off scale, we recommend looking for the minimum Z. So, to measure :

1/4 Wave Line: Open the line
1/2 Wave Line: Short the Line

In either case, look for the lowest-frequency minimum Z.

As an example, lets say we have 50 ft. of line. We short the far end and measure Z starting at 0.5 MHz. We see 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. This is the *First Null Frequency.* The line is exactly 1/2 wave at this frequency. By manipulating eqn. (4), the velocity factor of the cable is:

(6) Vf = First Null Frequency x Cable Length (ft.) / 492

So, in the example,

(7) Vf = 6.48 MHz x 50 ft. / 492 = 0.658

Now that we know Vf, we can calculate the appropriate length using eqn. 4. (Or Eqn. 5 if we want a 1/4 wave line.) Using eqn. 4, a 1/2 wavelength of this line would be:

(8) 492 x 0.658 / 14.2 = 22.8 ft.

If we cut the cable to 22.8 ft. and short the far end, we should see the minimum Z at 14.2 MHz now, confirming that we have 1/2 wave of line.

If we had cut a 1/4 wave line at 14.2 MHz (11.4 ft for this cable), we would OPEN the line and confirm that we had a minimum Z at 14.2 MHz and, thus, a 1/4 wave line.

These measurements are remarkably accurate with only a slight discrepancy between maximum and minimum Z frequencies due to second-order effects.

FREQUENCY WHERE LINE IS 1/4 WAVE (F-1/4)

This frequency is needed to use the Rs ant and Xs ant functions of the VA1, and can also be used to determine line impedance. (see below.) To find F-1/4 for a random length of line, simply **open** the far end of the line (Fig.3) and find the **lowest** frequency where Z reaches a minimum.(See Fig. 4) This is F-1/4.

You should mark each line by, say, wrapping a piece of masking tape around the near (shack) end and writing F-1/4 on the tape.

MEASURING LINE LOSS

How lossy is your transmission line? Has weathering ruined it? Now you can tell with a very simple measurement. In fact there are two ways to do it. **In both cases, connect the meter to either an open or shorted line** as shown in Fig. 3. (We've found more accurate results with an open line.) Line loss increases with frequency (often as the square root of frequency.) So you may see twice the loss at 28 MHz as at 7 Mhz. Use a reasonable length of line, say 25ft. or more, since loss is proportional to length. The longer the better.

1. SWR METHOD

Simply measure the SWR of the cable versus frequency. If you get H, the SWR is greater than 20, or Z is greater than 1000. If SWR displays, simply read the loss at the frequency of use from Fig. 8.

One problem with this method is that Z varies widely as you vary frequency, and SWR accuracy degrades at small and large Z. So the SWR will appear to vary widely. Note: You must select the appropriate line impedance also. If you're using 50 ohm line there is no problem. If not, see page 2..CHANGING LINE IMPEDANCE.

2. IMPEDANCE (Z) METHOD

Either open or short the line and find the minimum Z at the nulls (See Fig 4.) The cable loss at that frequency is given by:

(9) Min. Loss (dB) = 8.69 x Minimum Z/ Line Impedance

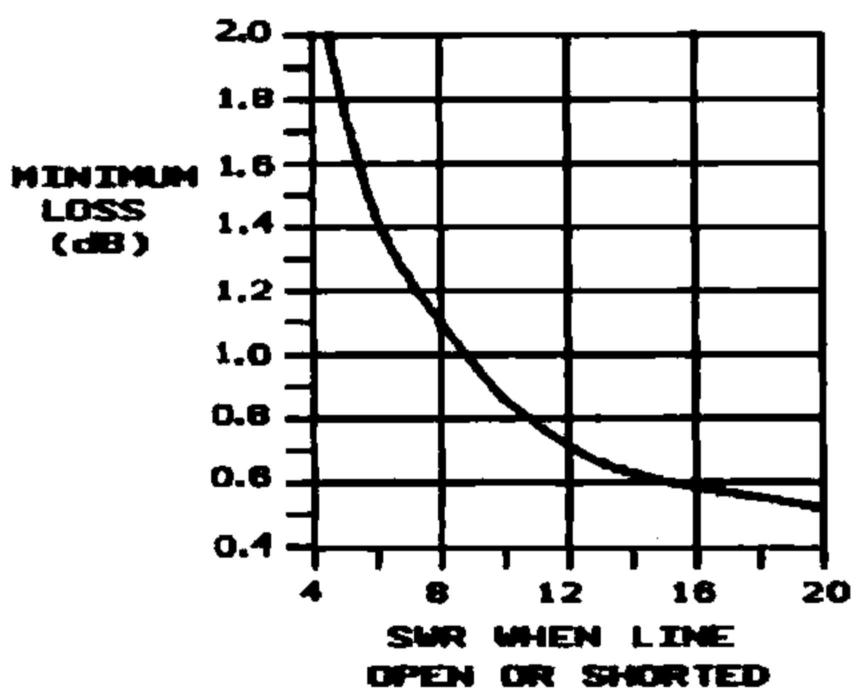


Fig. 5. Measuring Line Loss Using SWR

(Note: You need not change the VA1 line impedance for this measurement, since Z does not depend on line impedance.)

For 50 ohm line the loss is

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

For example, if you measure a 4 ohm minimum Z with 50 ohm line, the loss is 0.68 dB.

The Z method works well for any line impedance. Overall, we recommend the Z method for its greater accuracy. The SWR method can be used for a quick estimate.

Please note that **all loss values are for a line terminated in the line impedance (SWR = 1.)** The loss is higher at higher SWR's .

POWER REACHING THE ANTENNA

Fig. 6 shows the effect of SWR on power reaching the antenna. For example, if you measure 6 ohms minimum Z with 50 ohm line, or calculate 1 dB loss with any line impedance, Fig. 6 shows that about 80% of a transmitters power reaches the antenna if the SWR is 1. However, if the SWR is 4, only 55% reaches the antenna. The lost power mostly heats up your transmission line. Lossier lines are affected more by high SWR. Note that SWR is always lower at the transmitter end of a transmission line because of line losses. This is where the SWR of Fig. 6 is measured.

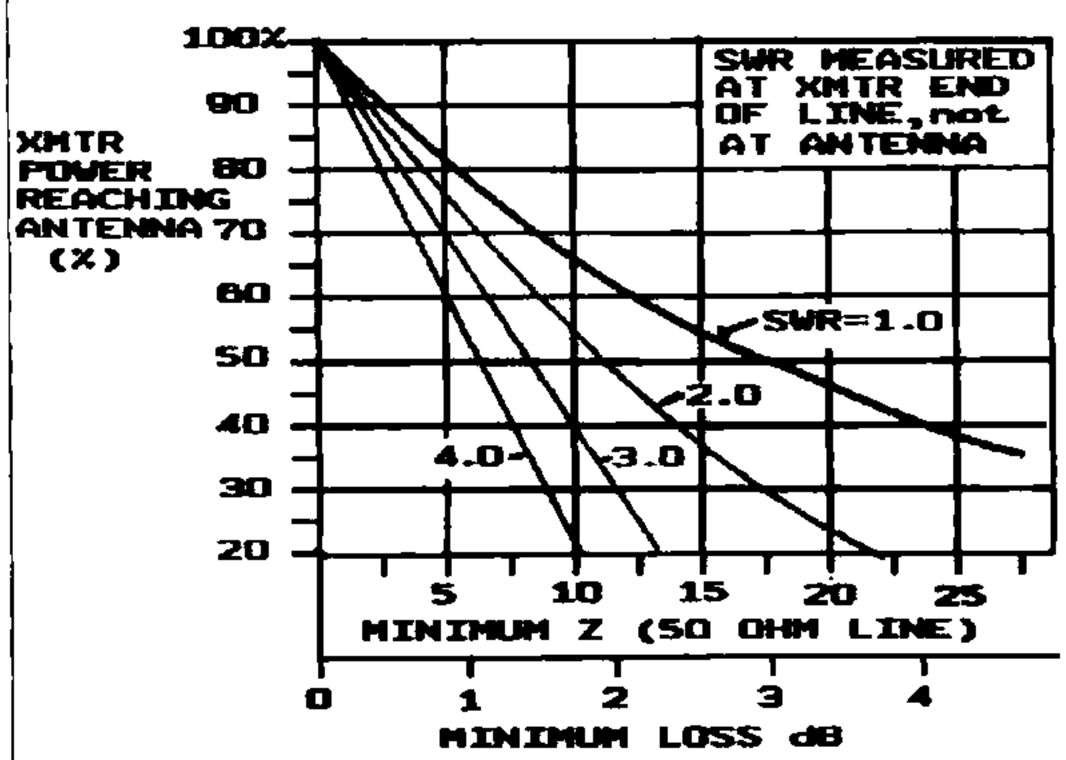


Fig. 6. Power Reaching Antenna

DETERMINING FEEDLINE IMPEDANCE

One way is to terminate the far end of the line with a resistor and measure its impedance as you vary frequency over a wide range. If the impedance stays the same as the resistor, or close to it, the line has the same impedance as the resistor. For example, for 50 ohm line, connect a 50 ohm resistor to the far end of the line.

If the resistor does not have the same impedance as the line, the measured Z will vary cyclically as in Fig. 4 but the peaks and nulls will not be as pronounced. Let:

Zo = Line Impedance

R t = resistor terminating the line

If you measure the minimum Rs at the frequency F-1/4 discussed on Page 6, the line impedance is very close to:

(11) Zo = square root of (Rt x minimum Rs)

This equation ignores line losses and any small "imaginary" part of Zo. For best accuracy, Rt should be close to Zo.

CHECKING BALUNS & TRANSFORMERS

If you have a 1:1 balun, connect a 50 ohm resistor to its output (where the antenna would normally go) and measure Rs, Xs, and SWR at the balun input. This should be a fairly constant 50 ohms with little X. (First check any variation R, X, and SWR of the VA1 by connecting the resistor directly to the VA1.) If you have a 50 ohm to 200 ohms (4:1) balun connect a 200 ohm resistor to the balun output and check for 50 ohms at the input. Expect a higher SWR at the highest and lowest frequencies .

Testing of a balun at high power is necessary to see such things as core saturation, arcing, etc. To be safe, you should use an in-line SWR meter, such as our WM-1, which works at 5 watts, and watch for any drastic change in SWR as power is increased.

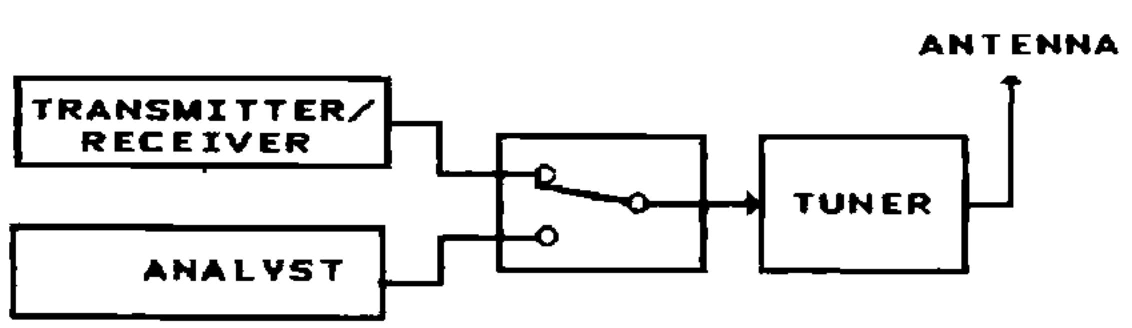


Fig. 7. Tuning an Antenna Tuner Without Transmitting

TRAP

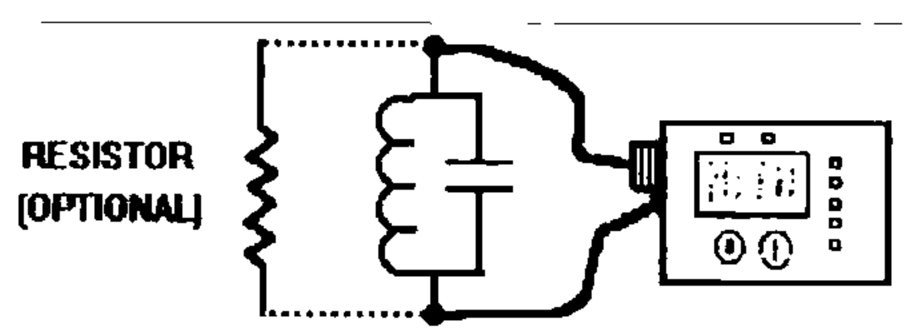


Fig. 8. Measuring Trap Resonant Frequency

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?

A 1/4 wave vertical has a theoretical base impedance of about 38 ohms at resonance (Rs=38 , Xs =0) with hundreds of radials. Lets say you measure the base impedance at 58 ohms. This means you have about 20 ohms (58-38) of ground loss. So about 1/3 of the antennas Z is in ground loss, and so 1/3 of your power is lost. Now, you add a few radials and find a lower impedance at resonance. You can now see how much your ground loss has been reduced.

Many caveats: The 38 ohms depends on antenna thickness and assumes an antenna in the clear, and radials that don't slope. So you can't be too precise here. But the method is also useful for very short loaded verticals, where most of Z is ground loss.

TUNING A TUNER WITHOUT TRANSMITTING

Figure 7 shows how to do this. We don't make this switch, but an ordinary 5 to 20 amp SPDT toggle switch in a small minibox will work fine. Just keep leads short..a few inches. Be sure there is **no** possibility that the transmitter can feed directly into the Analyst. **This could burn out the analyst instantly!**

MEASURING TRAP RESONANT FREQUENCY

Connect the Analyst across the trap as shown in Fig. 8. Keep the leads widely spaced so stray capacitance is not added.Tune the frequency until the highest impedance occurs. This is the resonant frequency of the trap. At resonance, Z will probably read "H" so you may have to average two frequencies on each side of resonance where Z reads the same, say 800 ohms. To avoid "H," you could connect a resistor , say 500 to 1000 ohms, across the trap. The highest Z still indicates resonance.

USE AS A SINE WAVE GENERATOR

The VA1 output is a low distortion sine wave , about 2 V p-p with no load, and an output impedance of 140 ohms; a 140 ohm load cuts its output in half.

ADVANCED APPLICATIONS

BASIC PRINCIPLES

There are some basic principles you should have in mind:

1. **Changing the length of a feedline does not change SWR... to a first approximation.**
Changing the length of a feedline can drastically change **Rs and Xs** if the SWR is high, and this might make your transmitter or tuner happier, but the SWR is virtually unchanged, except for the effects of transmission line losses.

2. **The SWR is always a little lower at the transmitter end of the feedline than at the antenna** ; due to line loss.

3. **An antenna tuner does not change SWR on the line.**
It only makes your transmitter happier since it sees the lower SWR. However, all the line losses caused by SWR (See Fig. 6) are still there. In addition, the tuner introduces **additional** loss, which can be significant. The popular "T" configuration tends to be the lossiest. If you can, put an efficient matching network right at the antenna and avoid all these losses.

4. **If Xs = 0 , SWR is Rs / Zo or Zo/Rs , whichever is > 1**
For example, 25 and 100 ohms both yield an SWR of 2 on a 50 ohm line. Any Xs always *increases* the SWR. (Eqn. A6)

Many antenna myths are humorously discussed in a series called Aerials, by Kurt N. Sterba, available from Worldradio, Box 189490, Sacramento, Ca. 95818. (916) 457-3655.

USING Rs ant and Xs ant

If your antenna is 100 ft in the air, you can't usually measure Rs and Xs at the antenna. In addition, the feedline often becomes part of the antenna and changes Rs and Xs, at least slightly. Rs ant and Xs ant allow you to measure at the transmitter end of the feedline. There are a series of equations that the VA1 solves to do this. First, you must enter:

1. **The Feedline Impedance.**
This is 50 ohms at turnon, but can be changed by holding down the SWR button as described on Page 2.(If your feedline is 50 ohms, nothing need be entered.)

2. **The Feedline Electrical Length via F-1/4**
This is entered by determining the frequency where the line is 1/4-wavelength long , and entering this frequency into F-1/4.

Once these values are entered, the VA1 compensates for the length of the feedline and calculates the RS ant and XS ant **at the antenna**, even though you might be measuring at the other end of 100 feet of feedline.

The best way to determine F-1/4 is to **measure** it. See Page 6. The value is somewhat critical, especially near frequencies where the line is 1/4 wavelength long or a multiple. If the line is many multiples of 1/4 wave you may want to measure, say, the 3/4 wave frequency (See Fig. 4) and divide by 3 to get F-1/4. A less accurate way is to calculate F-1/4 using:

(12) F-1/4 (MHz) = 246 Vf / (Feedline Length, ft.)

Where Vf is the velocity factor of the cable. (Also see Page 6.)

For example, if you have 50 ft of RG8, RG213, or RG58 cable, Vf is approximately 0.66. So:

F-1/4 = 246 x 0.66 / 50 = 3.247 MHz

ENTERING F-1/4

The VA1 has no numeric keypad, but F-1/4 is easily entered by tuning the unit to F-1/4.

To enter F-1/4, first tune the VA1 to the approximate frequency desired. Then select Function 4 and press the F-1/4 button. You will see "----", meaning that F-1/4 has not been entered. Press the button again, and you will see a display exactly like the display in Frequency mode. Now, adjust the frequency display so it reads the desired F-1/4, **without changing bands.** When you have the desired F-1/4 on the display, press any other mode button, such as Rs ant. Pressing the other button saves F-1/4 until the unit is turned off.

To verify that you have saved F-1/4, go to the frequency mode and change frequency. Then tap the F-1/4 button **once.** You will see the frequency saved above. Then, again, tap any other mode button to keep this value of F-1/4.

Just as with Line Impedance and Function, the last value you see is the one saved and used in the calculations.

To change to a different F-1/4, tap the F-1/4 button twice. After the first tap you see the last value saved. After the second tap, tune to the new desired F-1/4 **without changing bands** and save by tapping any other mode button as before.

For Vf = .66, and a frequency range of 0.5 to 30 Mhz, lines between 5.4 feet and 324 ft. can be entered.

INTERPRETING Rs ant and Xs ant

See the drawing on page 2. With this measurement, it is as if you were standing where the coax is connected to your antenna. The readings will seem to bear no resemblance to Rs and Xs, except at frequencies where the feedline is 1/2 wave or a multiple, where they should be equal (except for some possible roundoff in the computer.) Xs can be highly reactive (large Xs), yet Xs ant will can be zero. Or vice-versa.
Rs can be very low, yet Rs ant is very high, or vice versa.

These measurements can be used to determine what matching network to try at the antenna. Please note that the VA1 calculations do not take line loss into account. If your line loss is small there is little effect. Line loss usually acts to bring Rs closer to the feedline impedance. For example, Rsant might read 110 ohms at resonance, but , because of line loss, the actual value is 125 ohms. Usually the error is small and resonance is not affected.

We recommend a program called "TLA" which comes with the ARRL Antenna book. ARRL, 225 Main St., Newington, Ct, 06111 . (888-277-5289)

With this program you can enter Rs and Xs and it calculates RS ant and Xs ant, including losses. But each frequency needs a separate entry, so the VA1 is much more convenient.

MATCHING BY CANCELLING Xs

All matching methods below can be used at the antenna (preferred) or at the transmitter end of the feedline, which is more convenient and could avoid adjusting a tuner for the antenna in question and have less loss than a tuner.

Fig, 9 shows an easy way to cancel Xs. Simply connect a component (L or C) with the opposite sign in series with the load. The component **value** can even be read by selecting the L or C mode.

For example, your antenna or other load measures:

Rs = 35
Xs = +30
at F = 14.1 Mhz

L and C read:

L = 0.34 (uH) (= Xs)
C = - 376 (pF) (= -Xs)

So, if you add a 376 pf capacitor in series with the load, as in Fig. 9, the load will now look like 35 ohms, ideally, and SWR will be:

SWR = 50/35 = 1.42 for a 50 ohm line

Not bad, but you can do better with parallel matching, as shown in Fig. 10.

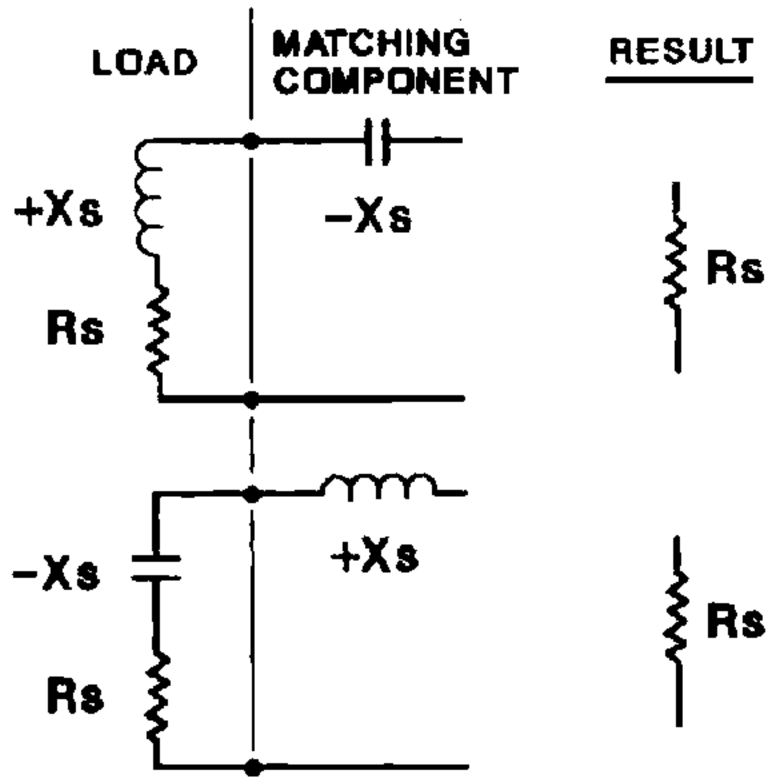


Fig. 9 . Series Component Cancels Xs

MATCHING BY CANCELLING Xp

Recall that the load also has an equivalent Rp and Xp which are not the same as Rs and Xs in general. As shown in Fig. 10, Xp is cancelled by connecting a component with the opposite sign in parallel with the load.

Continuing the example , you switch to Function 3 and read:

Rp = 61
Xp = 71

So you need to add a capacitor with X= -71 ohms at 14.1 MHz in parallel with the load. Unfortunately, the VA1 only converts series X (Xs) to a C value, so you have to do the calculation:

(13) C (pf) = 1,0000,000 / (6.283 F X)

C = 1,000,000 / (6.283 x 14.1 x 71)
= 159 pF

So if you put the 159 pF capacitor in parallel with the load, you should have a pure R of 61 ohms.

This yields an SWR of 61/50 = 1.22 for 50 ohm line, which is lower than if a series capacitor were used.

Note: If Xp were negative, a parallel inductor (coil) would be needed for matching. The value of this coil would be:

(14) L (uH) = - Xp / (6.283 F)

Since coils don't usually have their their values labeled as capacitors do, it might be simpler to adjust taps on a coil and measure it with the VA1 until it has the desired X.

Examining equations A8 and A9 in the appendix you see that: Xp is always greater than Xs, which means a smaller capacitor but a larger coil is needed. But more significantly, **Rp is always greater than Rs**. If you measure Rs less than 50 ohms (or whatever value you're trying to achieve), then be sure to check Rp also, since it may have a more suitable value.

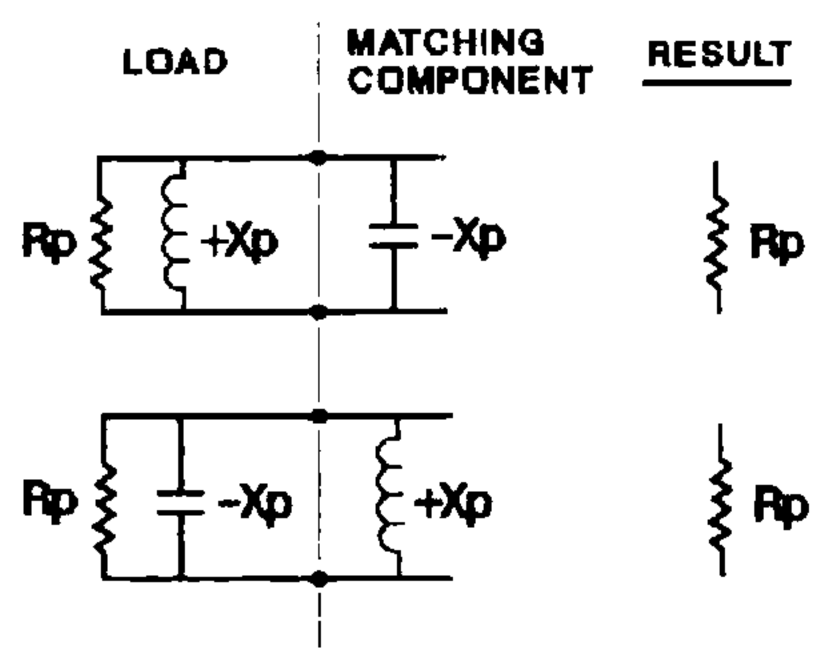


Fig. 10 Parallel Component Cancels Xp

MATCHING WITH A BALUN OR TRANSFORMER

After cancelling Xs or Xp you could next add an impedance-changing device to bring the impedance to 50 ohms, or whatever is desired.

MATCHING WITH AN ARBITRARY LINE

A little understood fact is that a length of 50 ohm transmission line can transform virtually any Rs into 50 ohms by selecting the proper length of line. For example, Rs might be 200 ohms or 15 ohms at your antenna or at the "shack" end of your transmission line. By selecting a proper length of line to add on, you can achieve Rs= 50 ohms, with some Xs which can be cancelled as shown in Fig. 9. The result is a 1:1 SWR at the point this is done. The added feedline need not be longer than 1/2 wave, and in fact there are two lengths in this range which yield 50 ohms, but their Xs have opposite signs.

We don't want to keep cutting and adding feedline, but the VA1 can tell us the result if we did. It turns out that Rs ant with a particular F-1/4 tells how much line to *subtract* to produce that Rs. But everything is symmetrical about 1/2 wave, so the length of added line can be calculated also. The procedure is:

PROCEDURE	EXAMPLE
1. Measure R/X at the desired operating frequency (Fo)	Rs= 22 Xs=113 (Func 1) Frequency= Fo = 10.1 MHz
2. Set F-1/4 to 1/2 Fo	F-1/4 set to 5.05 (Func 4)
3. Return to Fo and measure Rs ant. Should be same since this is 1/2 wave line.	Rs ant = 22 at 10.1
4. Set F-1/4 a little higher	Set F-1/4 = 5.5
5. Return to Fo for Rs ant	Rs ant = 121 at Fo = 10.1
6. Keep increasing F-1/4 until Rs crosses 50 ohms.	Rs ant already > 50 ohms
7. Zero-in on 50 ohms	When F-1/4 = 5.3 Mhz Rs ant = 50 Xs ant= 175

Then the length of feedline to subtract is:

(15) Length to subtract (feet) = 246 Vf / F-1/4

For the example & Vf = .66, length = 246 x .66 / 5.3 =30.6 ft.

If we subtract this length, then add a series C to cancel Xs, SWR drops from about 15:1 all the way down to 1:1. Equivalently, we can *add* a length :

(16) Length to add (feet) = 492 Vf / Fo - 246 Vf /F-1/4

For the example: 492 x .66 / 10.1 - 30.6 = 1.55 ft.

Try an added line a little longer than this, and cut it until the desired Rs =50 ohms is achieved. Then measure Xs and cancel it as in Fig. 9.

Sometimes a 50 ohm line is not always the best , even though we want 50 ohms at the end. You could also see what happens to Rs ant with other impedance lines. For example, a full-wave loop, which has a resonant Rs of about 100 ohms is often matched with a 75 ohm line whose F-1/4 is the same as the operating frequency. To use 75 ohm line and Function 4, you have to change line impedance to 75 ohms (See page 2.)

Line loss causes the actual value to be slightly different than Rs ant, so some final fine adjustment of line length may be needed. The bandwidth of matching may be estimated by observing Rs ant and Xs ant once F-1/4 is found. Also, loss in the transmission line can be high if the line is long and lossy. Even though a 1:1 SWR occurs at the matching point the line could still have a high SWR.

OTHER MATCHING METHODS

A very popular matching method is the L network, which has only a single L and C, yet can match almost anything with low loss. Again, the TLA program which comes with the ARRL Antenna book, allows you to input Rs and Xs and it gives you L and C network values. Other popular methods such as stubs, gamma match, traps, and the list goes on, can be adjusted easily with the VA1. There are many more uses for the VA1 than we have room for without writing an Antenna Handbook.

ACCURACY

The computer compensates for known systematic errors such as diode drops, phase detector nonlinearity, and stray capacitance. Note that because the VA1 knows the *sign* of X it can compensate for strays, which can give very large errors at high frequencies, especially with an inductive load. The VA1 measures Z and phase, and derives all other results, including SWR, from these. (See equations in the Appendix.)

In the range 20-200 ohms, Z accuracy is typically about 3-4% and and phase accuracy (rms) is 2 to 4 degrees to 16 MHz and increases to 8 degrees at 30 MHz due to phase detector limits and strays. Most measurements are within the rms limit, but some will statistically be larger. Error also increases at very high and very low Z.

Because of tolerances on phase, most error is to be expected on the smaller of Rs or Xs. For example, if Xs is very large, as it may be on a short antenna, the value of a small Rs can't be determined accurately without cancelling Xs. (See Fig. 9.) Coil Q measurement is also "iffy" even if Xs is cancelled, since harmonic distortion in the VA1 sine wave will appear to lower the Q. For example, measurement of coil Q of 100 using Rs would require oscillator distortion much greater than 40 dB down, and few RF oscillators are that pure .

Trying for an SWR of exactly 1.00 is meaningless. Anything less than 1.1 (or even 1.4) is virtually the same. The 0.01 SWR readout *can* help to find the exact minimum, however.

Purists can use 1% resistors to calibrate out small errors. For example, if your VA1 reads Rs= 51 ohms and Xs = 2 on a 1% resistor *with short leads* at a certain frequency, you could subtract 1 ohm from R and 2 ohms from X for values near 50 ohms to increase accuracy.

When measuring Rs ant and Xs ant, remember these are derived from Rs and Xs. If Rs and Xs are in a region of lower accuracy , such as very small or large Z, then Rs ant and Xs ant will be less accurate. .

SERVICING

ADJUSTMENTS

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

1. LCD Brightness

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

2. Phase Adjustment

The LCD brightness has a small effect on phase, so LCD brightness should be adjusted first.

To adjust phase:

1. Connect a capacitor of about 100 pF to the VA1 coax connector.
2. Set the VA1 at approx. 7 MHz.
3. Select the Rs mode.
4. Turn the phase adjustment until Rs reads 1 to 10 ohms. Try for 1 to 3 ohms.

Note: Theoretically, Rs should read zero ohms. However, the VA1 shows "negative ohms" as zero. So, if you try to set it to Rs=0 ohms, you may go too far on the adjustment. But zero is also acceptable. The phase adjustment sets the phase angle at 90 degrees. It is not as critical at smaller phase angles since a 5 degree error at 90 degrees produces only a 1/2 degree error at 9 degrees, for example.

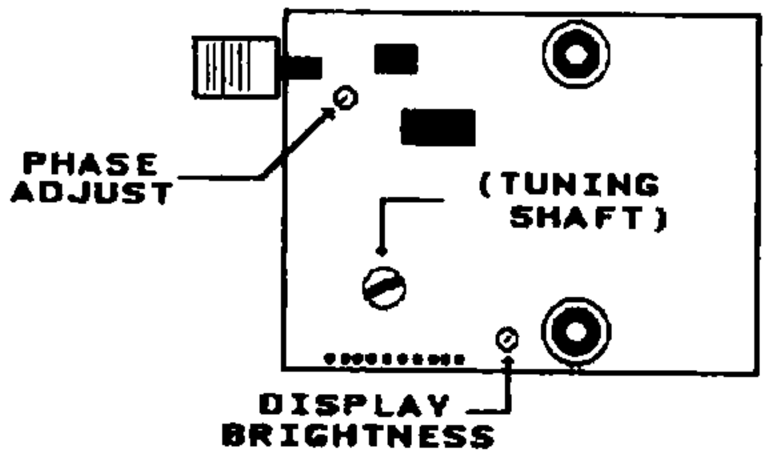


Fig. 11. Adjustments.

Made through holes in board with oscillator (lower) 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. With care, it may be possible to bend the lower board up without breaking leads to the coax connector, but this is discouraged.

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 ($20 outside 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 ($20) return shipping, there is an additional $3 charge for correspondence 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 $40 plus $8 shipping and handling (USA), or $20 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 $48(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. On the rare occasion when the charge will be more, we will get your permission before proceeding. The service charge also applies to any unit returned within one year which simply needs calibration or has no problem; **be sure there is a defect before returning.**

FREQUENTLY ASKED QUESTIONS

1. Impedance reads 50 ohms, yet the SWR is very high.
SWR is only 1.0 for a resistive 50 ohms (X=0). Any X will raise the SWR. (See Equations A5 and A6 in the Appendix.)

2. The display never seems to settle down, especially on large-value readings.
The VA1 smooths each reading ; more smoothing would slow response excessively. You should average any readings which vary. This is common at high readings. Also, the multiplexed display may show some ghost segments at large angles.

3. The display occasionally "hiccups" and shows a strange reading very briefly. Is something loose?
Probably not. The microprocessor is very busy. Occasionally it will be interrupted to take a frequency measurement and make a momentary mistake.

4. When I listen to the unit on the radio it has a raspy tone.
This is normal, due to small currents generated in the microprocessor, and has NO effect on accuracy since the oscillator bandwidth is much narrower than the antenna. The oscillator has very low *harmonic* distortion, which is what counts. Note: An AC adaptor greatly increases the raspy quality because its hum feeds through on the "fine tune" line, which is not regulated. But, accuracy should not be affected.

6. My "brand X" reads a lower SWR than the VA1.
Most people don't like bad news, so they like the meter which reads lower. You must test the VA1 with some 1% resistors, say 50 ohms (1:1) and 60 ohms (1.2 SWR) to convince yourself . Most SWR meters have "suckout" and read 1.0 below 1.2 or so. For extreme differences, see Caution on Page 1, and check your connections. Often, even a 5 watt transmitter can "heal" a corroded connection temporarily, but the joint opens up when the power is removed. This has been observed!

If you habitually twist the *inner* conductor of the coax plug when attaching, the wire between the coax connector and the board may have broken. Check this.

APPENDIX – EQUATIONS

The VA1 directly measures F, Z, Φ (phase angle.) ,and the sign of the phase angle.Its microprocessor then uses these quantities to calculate and display other values using the equations below:

(A1) $Z = \sqrt{Rs^2 + Xs^2}$ = Impedance , ohms (Directly measured)

(A2) $Rs = Z \cos(\Phi)$ = Series resistance , ohms

(A3) $Xs = Z \sin(\Phi)$ = Series reactance , ohms (+ inductive, - capacitive)

(A4) $\Phi = \mathrm{atn}(Xs / Rs)$ = Phase angle (Directly measured)

(A5) $SWR = (1 + p)/(1 - p)$ = Standing wave ratio

(A6) $p = \sqrt{\dfrac{(Rs - Zo)^2 + Xs^2}{(Rs + Zo)^2 + Xs^2}}$ = Reflection coefficient

(A7) Zo = Transmission Line impedance (50 ohms at power on ; can be varied by holding down SWR button)

(A8) Rp = Equivalent parallel resistance = $Z^2 / Rs = Rs + Xs^2 / Rs$

(A9) Xp = Equivalent parallel reactance = $Z^2 / Xs = Xs + Rs^2 / Xs$

(A10) C = 1,000,000 / (2 pi F Xs) , picofarads ,pF (F in MHz)
= Series capacitance , or value of pure capacitor

(A11) pi = 3.14159265

(A12) F = Measurement Frequency , MHz

(A13) L = Xs / (2 pi F) , microhenrys , uH (F in MHz)
= Series inductance , or value of pure inductor (coil)

Note: Displayed values may not *exactly* correspond to these equations due to roundoff and other computational factors.

LATE NOTES

None to date