Measuring the Antenna from the Shack

The half-wavelength feedline and how to get it.

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Perhaps the two most common measurements that you can make on an antenna are its resonant frequency and its impedance at the place where the feedline is connected. Measuring the resonant frequency of the antenna is important in assuring that the antenna will efficiently radiate a signal; measuring the impedance is important in assuring that the feedline will transfer the signal to the antenna.

Making reliable contacts requires transferring maximum signal to the antenna, and radiating maximum signal from the antenna to other receivers. Unfortunately, most of us are in a hurry to get on the air so we cut the antenna to length with a tape measure, connect a piece of coax long enough to reach the shack, and begin to operate. Only after antenna erection do we realize that the SWR is not what we would like it to be. An antenna tuner or transmatch will not resonate the antenna nor improve the power transfer at the feed point to the antenna.

You can also prune the feedline, or lengthen it, to get a different SWR reading. This will not really change anything either. The SWR reading is most accurate when it is telling you the worst possible information it can tell you: the highest SWR reading it can give you. A low reading may be accurate, but it may also be way off base. If the SWR is very high, there will be maxima and minima all along the feedline. If the feedline length is such that your SWR bridge is at a minimum voltage point, the SWR bridge is not telling you how bad things are.

To maximize radiation from the antenna and power transfer to the antenna, we must resonate the antenna and improve the match of the feedline to the antenna.

There are many good instruments available. A dip meter or antenna bridge will give resonant frequency measurement. A noise bridge or a resistance and reactance bridge may be used for impedance measurements. Such measurements must be made at the feed point (see Reference 1) and, to get true readings, we can only make these measurements with the antenna at its operating position.

Making the Measurements

We cannot stand in the air at the feed point with the antenna at its operating height and make measurements. We must use a length of feedline that is an electrical half wavelength at the operating frequency. (Actually, this is even better than standing in the air at the feed point next to the antenna because it reduces body capacitance.)

The half-wavelength piece need not be heavy-duty cable. Any small cable, even twin lead, will do. If a half wavelength will not reach the antenna, use two or three half wavelengths or any integer number. However, replacing the feedline and making multiple measurements and adjustments can be tedious.

The standard method requires many steps:

1) Lower the antenna.
2) Replace the feedline with a half wavelength piece (or two, or three, etc.).

LOOP

3) Raise the antenna to regular operating height.
4) Measure the resistance, reactance, and resonant frequency. If the resistance is within 10% of the feedline impedance and the reactance is between +5 and -5 ohms (a good match), and the resonant frequency within 5%, you have good power transfer and radiation. Go to step 8.
5) Otherwise, lower the antenna again.
6) Adjust antenna length and/or matching section.
7) Go back to step 3.

END OF LOOP

8) Replace half-wavelength feedline with your regular feedline.
9) Raise the antenna.

My method replaces steps 1, 2, and 3 and reduces the loop with an incremental adjustment of the existing feedline. Incremental adjustment is a way to extend your existing feedline to a true half wavelength of feedline (or multiple), without lowering the antenna

CHART 1
TABLE OF LENGTHS OF COAXIAL CABLE YOU CAN USE FOR INCREMENTS OF A WAVELENGTH AT EACH AMATEUR BAND.

FREQUENCY	.01	.02	.04	.08	.16	.32
28.3 MHZ	0' 2.75"	0' 5.5"	0' 11"	1' 10"	3' 8"	7'4"
24.96MHZ	0' 3.1"	0' 6.25"	1' .50"	3' 0"	4' 2"	8' 4"
21.2MHZ	0' 3.6"	0' 7.5"	1' 2.7"	2' 5.4"	4' 10.9"	9' 10"
18.13MHZ	0' 4.3"	0' 8.6"	1' 5.2"	2' 10.4"	5' 8.8"	11' 5"
14.3MHZ	0' 5.4"	0' 10.8"	1' 9.8"	3' 7.6"	7' 3.25"	14' 6.5"
10.12MHZ	0' 7.7"	1' 3.4"	2' 6.8"	5' 1.6"	10' 3.25"	20' 6.5"
7.2MHZ	0' 10.8"	1' 9.6"	3' 7.3"	7' 2.6"	14' 5.3"	28' 10"
3.75MHZ	1' 9"	3' 5.5"	6' 11"	13' 10.6"	27' 8.7"	55' 7"
1.875MHZ	3' 5.5"	7' .2"	14' .5"	28' 1"	56' 2.5"	112' 5"
OTHER PRACTICAL UNITS WHICH MAY BE USED						
ENGLISH UNITS						
(18 - 28MHz.)	3"	6"	1'	2'	4'	8'
(7 - 14 MHz.)	9"	1.25'	2.5'	5'	10'	20'
(1.8- 4 MHz.)	2'	4'	8'	16'	32'	64'
METRIC UNITS						
(18 - 28MHz.)	12.5 CM.	25 CM.	50 CM.	1 METER	2 METERS	4 METERS
(7 - 14 MHz.)	37 CM.	75 CM.	1.5 METERS	3 METERS	6 METERS	12 METERS
(1.8- 4 MHz.)	1 METER	2 METERS	4 METERS	8 METERS	16 METERS	32 METERS

or replacing the feedline. It requires a little patience and some time, but very little expense.

This method requires five or six pieces of coax, each with an inexpensive slide-on coax connector. These are easy to put together. They should have a binary relationship in length, such as 1, 2, 4, 8, 16, or possibly 32. Make up combinations of pieces to convert your existing feedline to a true half wavelength for the time you are measuring it, and remove the pieces when you want to operate. (You still have to lower the antenna once to make the final adjustment.)

You can use any scale you want for finding the sizes of the pieces of coax. I wanted to find the resonant frequency at 3.750 MHz, so I calculated the sizes for 0.01, 0.02, 0.04, 0.08, and 0.16 wavelength at that frequency. Later I added 0.32 wavelength. Chart 1 shows both the actual sizes I used and the corresponding sizes for other frequencies. They are called increments because each small piece (a fraction or increment of a wavelength) can be added to other small pieces to reach a half wavelength.

Instead of fractions of a wavelength, you can "scale" the pieces of coax according to inches or centimeters; these are included in the table. Any scale will work, as long as it is small enough and you have enough pieces. Chart 1 gives a number of examples of lengths that may be useful, and indicates that other measurements may be used. The increments are to be added to your existing feedline as explained below.

To use these pieces of coax:

1) Assemble them into every possible combination of lengths, as shown in Chart 2.
2) Try each combination, adding it to the shack end of the existing feedline.
3) Use your noise bridge or resistance bridge and impedance bridge to determine resistance and reactance at that combination. Write down your readings.
4) Plot these points on graphs.

CHART 2 COMBINATIONS OF INCREMENT UNITS
INCREMENT OF A WAVELENGTH AT EACH BAND

MEASUREMENT NUMBER	.01	.02	.04	.08	.16	.32
1	X					
2		X				
3	X	X				
4			X			
5	X		X			
6		X	X			
7	X	X	X			
8				X		
9	X			X		
10		X		X		
11	X	X		X		
12			X	X		
13	X		X	X		
14		X	X	X		
15	X	X	X	X		
16					X	
17	X				X	
18		X			X	
19	X	X			X	
20			X		X	
21	X		X		X	
22		X	X		X	
23	X	X	X		X	
24				X	X	
25	X			X	X	
26		X		X	X	
27	X	X		X	X	
28			X	X	X	
29	X		X	X	X	
30		X	X	X	X	
31	X	X	X	X	X	
32						X
...						
40				X		X
...						
50		X			X	X
...						
63	X	X	X	X	X	X

The above combinations are assembled and connected (in series).

My antenna was long for the 80 meter band, and I wanted to adjust it to resonate at 3.750 MHz. At the flat portion of the curve on my graphs there is an equivalent half wavelength of the feedline. This is halfway between the peaks of the one-quarter and three-quarter wavelengths. That shows the ideal increment, the amount of added feedline that makes a half wavelength equivalent out of your existing feedline, without lowering the antenna! With that added length in place, you can measure the real resistance, reactance, and resonance.

In my case, the half wavelength was reached by adding 0.34 wavelength. The resonant frequency was 3.025 MHz, and the resistance was 21 ohms with a reactance of +1 ohm. The SWR was 2.5:1 at this point, but the SWR wandered all over the place as the feedline length was changed! The only accurate SWR reading was the one at the half wavelength point. If I had chosen to, I could have made the antenna and feed point match look pretty good by adding 0.45 wavelength of feedline permanently to make the SWR read 1.6:1! But I would only be fooling myself.

The resonant frequency of 3.025 MHz

called for a reduction to 81% of the original length to get to 3.750 MHz (3.025/3.750). I lowered the antenna one time, cut it 19%, and raised it back up. It resonated at 3.740 MHz; the resistance was 48 ohms and the reactance was +1 ohm. The SWR was 1.1:1. That was close enough for me, so I stopped right there.

I removed the extra feedline, and operated with the assurance that I was transferring maximum power to the antenna, and radiating maximum signal. My signal strength reports are up about 10 dB. Best of all, I know that my antenna is operating at peak efficiency! 73

References:

1. *ARRL Antenna Book,* 16th Edition, 1991, pp. 2-6.

2. *Antenna Impedance Matching,* Wilfred N. Caron, 1989, pp. 2-9.

Velocity Factor

The equation I used for calculating the feedline lengths, including the velocity factor (coaxial cable propagation factor), was: Feet = (486/MHz) x VF x N/50, where VF = velocity factor and N = number of hundredths of a wavelength you want. For example, for 0.02 wavelengths, N = 2; for 0.04 wavelengths, N = 4. The velocity factor I used was 0.70, determined by measurement.

The standard reference tables (from the *ARRL Antenna Book,* 16th Edition, pp. 24-19) of characteristics of transmission lines indicate the following values for the velocity factor in common transmission lines:

Transmission Line	Velocity Factor
RG-8X	0.75
RG-8	0.66
RG-8 Foam	0.80
Belden 9913	0.84
Belden 9914	0.78

I determined the velocity factor of my length of coax with a noise bridge and a general-coverage receiver. I used the simple formula: VF = Lf/984 x N, where VF = velocity factor, L = line length in feet, f = frequency in MHz., and N = number of electrical wavelengths in the line.

To use this formula, select a piece of the coaxial cable you are going to use. It should be equal to, or slightly longer than, either one-quarter wavelength or one-half wavelength for the frequency of greatest interest. Attach a PL-259 coax connector to one end. If it is about one-quarter wavelength long, leave the other end open; if it is one-half wavelength long, then short circuit the other end. Attach it to the noise bridge. Set the noise bridge to zero resistance and zero reactance (R = 0 and X = 0). Tune the receiver for a null in the noise bridge signal, and you have found the frequency (f) to plug into the formula above. N will be either 0.25 or 0.50, according to whether you chose a quarter or a half wavelength. Determine L with a good tape measure.

My calculations showed the VF of the RG-8X I was using to be 0.70, rather than the 0.75 shown in the table. This was probably taking into account the connector used and other unknown factors.