Some Notes on Antenna Bandwidth

L. B. Cebik, W4RNL, QRPARCI #2572, 1434 High Mesa Drive, Knoxville, Tennessee 37938-4443 cebik@utk.edu

For most of us, the antenna's bandwidth is the number of Hz for which the antenna will exhibit a less than 2:1 SWR. We usually measure bandwidth at the transmitter output, and hence put a large pile of variables on top of the basic idea of SWR bandwidth. So let's begin again and see how the concept actually works.

An antenna--for example, a resonant half-wavelength dipole operated on its fundamental frequency--has a natural feedpoint impedance. For a lossless wire dipole in free space, that figure is just about 72 ohms. In fact, NEC-2 models of just such an antenna using wire diameters from #30 to over 2.5" show less than 1 ohm variation in the 72-ohm feedpoint impedance.

Relative to that impedance, a 2:1 SWR will occur as the feedpoint impedance (off resonance, a complex of resistance and reactance) reaches or 144 ohms at points higher or lower than resonance. The number of Hz (of kHZ or MHz) between those frequencies is the 2:1 SWR bandwidth of the antenna. The bandwidth will vary with the diameter of the antenna element in a regular but nonlinear manner.

2:1 SWR bandwidth is approximately (but again, nonlinearly) proportional to frequency. For a given wire size, a resonant dipole at 28 MHz will have (about) twice the bandwidth of a resonant dipole at 14 MHz.

Table 1 Selected 2:1 SWR Bandwidths for Wire Antennas

Frequency	3.5 MHz	7 MHz	14 MHz	28 MHz
Wire Size (diameter)			2:1 SWR Bandwidth in MHz	
#28 AWG (0.013")	0.17	0.35	0.73	1.63
#12 AWG (0.081")	0.19	0.40	0.86	1.91
#4 AWG (0.204")	0.22	0.46	0.98	2.18
(1")	0.30	0.63	1.35	3.06

To help you gain a reasonable expectation of the 2:1 SWR bandwidth of resonant half-wavelength dipoles, I am attaching a small BASIC utility program that will produce bandwidth tables for any HF frequency for wires from #30 (0.01" diameter) to 2.5" diameter. It is roughly calibrated to NEC- 2 models for lossless wire resonant dipoles in free space and to 72 ohms. The algorithms are generally accurate to about 5%, with some matrix-center variations reaching about 10%. The figures are roughly applicable also to resonant quarter-wavelength vertical antennas.

Table 1 sumarizes a few data points for thin, medium, and thick antenna elements on 80, 40, 20, and 10 meters. The increase of bandwidth with frequency for a given wire size is evident. Notice also *that it takes nearly* a 100:1 wire size increse to double the bandwidth of the antenna on any given frequency.

The degree of error in the program is of no concern, since real antennas and antenna systems will introduce larger variations that no table can account for in advance. Hence, the program is only for getting some reasonable expectations, not for predicting bandwidth wit precision. The bandwidth you actually measure will vary with the following variables:

1. Antenna type: Low impedance antenna types will generally (but not always) have wider bandwidths than high impedance antennas.

2. *Antenna material: Copper and aluminum* have losses that affect antenna bandwidth, especially with small diameter wires (less than #20).

3. Antenna environment: Placing an antenna some height above ground less than about 2 wavelengths will alter both the natural feedpoint impedance and the bandwidth at that impedance. Ground clutter in the near field of the antenna will affect both in ways that are for practical purposes unpredictable.

4. Feedline mismatch: Feeding a 72-ohm antenna with our common 50-ohm coax starts us out at 1.4:1 SWR, hence decreasing the 2:1 SWR bandwidth. The reduction of SWR bandwidth is a function of a complex curve that begins with a shallow decrease, narrows to the inverse of the SWR at the 1.4 SWR point and then decreases rapidly toward zero as the basic mismatch SWR grows to 2. Hence, for the case of the dipole fed with 50-ohm coax, we should expect *about 70% of the program's* estimated bandwidth. (This fact explains is why some claim a slightly wider band width for inverted Vee configurations: being closer to 50 ohm natural feedpoint impedance, Vees introduce less bandwidth narrowing due to the slight mismatch).

5. Feedline losses: Even well-matched transmitter-feedline-antenna systems introduce some losses in the feedline. The effect of these losses is to reduce the SWR at the transmitter end of the line, thus giving a wider 2:1 SWR bandwidth. This wider bandwidth is usable, so long as we understand and evaluate the acceptability of the power losses involved.

6. Antenna shortening and loading: Although antenna loading for the sake of shortening reduces the feedpoint impedance, it introduces components that raise antenna Q and narrow the bandwidth. As a rule of thumb, bandwidth is reduced by the percentage of shortening of the antenna. For example, a 33' *vertical on 80 meters is about half size, and* its bandwidth is about 70 kHz for most common loading schemes--just about half the bandwidth of a full size quarter-wave vertical.

Understanding these bandwidth-altering factors along with the basic output of the program can give us reasonable expectations for antenna bandwidth for the various bands. If our antenna system is more than about 20% off the mark, then we begin to search for possible problems.

Remember that these notes do not apply to antennas fed with parallel feedline and an ATU: those we always tune for 1:1 SWR and maximum power output to the line and antenna.

Finally, if you do not like typing BASIC programs or converting them to C, a version of the program will appear in VE3ERP's HAMCALC collection, available in the Lehigh.edu archives or directly from Murph. Address: **Mr. George Murphy, VE3ERP;** 77 McKenzie Street; Orillia, Ontario; L3V 6A6 Canada.

Program Listing

```
10 ' BW.BAS
20 CLS:SCREEN 0: COLOR 2,,4:CLS
30ER$=STRING$(70,32):BW$="###.###":WIRE$="#.###":S$=
STRING$(10,32): T$=STRING$(6, 32)
40 ' Estimates 2:1 SWR bandwidth of halfwavelength dipoles for
a range of common wire and tubing sizes. Algorithm is based on
NEC models of lossless wire dipoles in free space and is based on
a feedpoint
50 ' impedance of 72 ohms. Program does not account for
material losses, feedline losses, mismatches, or the antenna
environment. Accuracy averages 5%.
60 PRINT " Estimated 2:1 SWR bandwidth of half-wavelength
dipoles at any HF frequency"
70 LOCATE 2,25:PRINT "by L. B. Cebik, W4RNL"
80 LOCATE 3,15:INPUT "Enter any frequency from 3 - 30 MHz:
",F 90 IF F>30 OR F<3 THEN LOCATE 3,5: PRINT ER$:GOTO
80
100 PRINT "Wire size","Wire dia.","Bandwidth";S$;"Wire
dia.";T$;"Bandwidth"::PRINT " AWG ","inches"," MHz ";S$;"
inches",T$;" MHz "
110 FOR J=30 TO 2 STEP -2
120 AWG$=MKS$(J):N=J:AWG=J
130 K#=(.46/.005)^(1/39):WIRE=.46/K#^(N+3):DIA=WIRE
140 DIA2=DIA-((.4343*LOG(30/F))*(DIA/(2*(2.56/DIA))))
150 BWBASE=(.0469+(((F/3)-1)*(.0116/9)))*F
160 BW=((SQR(DIA2))+.9)*BWBASE
170 PRINT AWG,:PRINT USING WIRE$;WIRE,:PRINT"
",:PRINT USING BW$;BW
180 NEXT
190 FOR J=.375 TO 2.5 STEP .125
200 DIA=J
210 DIA2=DIA-((.4343*LOG(30/F))*(DIA/(2*(2.56/DIA))))
220 BWBASE=(.0469+(((F/3)-1)*(.0116/9)))*F
230 BW=((SQR(DIA2))+.9)*BWBASE
240 K=(J*8)+3:LOCATE K,50
250 PRINT USING WIRE$;J,:PRINT S$;:PRINT USING
BW$;BW
260 NEXT
270 LOCATE 23,5:PRINT "Another <F>requency or <Q>uit"
280 A$=INKEY$
290 IF A$="f" OR A$="F" THEN 10 ELSE IF A$="q" OR
A$="Q" THEN 300 ELSE 280
300 END
```

THE QRP WORKBENCH

By Bruce O. Williams, WA6IVC, MXM Industries, Rt 1 Box 156C, Smithville, TX 78957

PART I. THE WORKBENCH AND TEST EQUIPMENT

QRP operators ARE different from other Amateur Radio Operators. Their interests are not different from the rest of the ham community, but they lean toward simplicity of operation coupled with a desire to build and test their own equipment. Commercial ham equipment is extremely complicated, both from a construction and technical standpoint. As a result, prices for commercial Amateur Radio equipment have become, for most of us, prohibitive. QRP operation offers the experienced and the inexperienced operator the opportunity to not only acquire reasonably priced equipment, butto take an active part in the design, construction and testing of it.

The interest in QRP operation over the past ten years has created a new set of requirements. Equipment must now be simple, and the technical requirements for QRP operation demand the highest performance for the most cost effective design and construction.

QRP operation is, by definition, weak-signal work. As such, receivers must be highly sensitive, extremely selective, and devoid of most features such as noise blankers, memories, dual VFOs, digital processing, etc., that drive up the cost of commercial equipment, but do not necessarily make a radio more useful for the ultimate purpose, COMMUNICATIONS!

This series will talk about some of the things that I have found needed for home construction and testing of simple QRP equipment. We will discuss the QRP experimenter's workbench, tools and test equipment, troubleshooting and repair of simple transmitters and receivers--the kind that are provided in kit form, or are designed by the experimenter for his own use. I'll try to make it interesting, also. If you have specific questions that you'd like to see covered, write to me at the above address, and I'll try to answer them.

First in a series!

Lets all give a big welcome to **Bruce Williams, WA6IVC**.

Have you ever wondered what tools and equipment you would need to build that kit you have been looking at? What will it take to get it going once it's built?

This is the place for you. **Bruce** will be covering all that and more in the coming months.

de **Ron, KU7Y**

Costs

A word about costs. Amateur Radio is a hobby--it should be fun. One sure way to take the fun out is to find out you can't afford what you need or want. I estimate that to properly set up a workbench, with minimum tools and test equipment, will cost in the neighborhood of $500. This is not a one-time, start-up investment, like a set of golf clubs, but can represent the investment over several months, or even years. Of course, like any hobby, you can spend as much as you want. Where possible, I'll note typical costs for each item I describe.

Choice of Workplace

Choosing a working space for your experimenting is a real