antenna systems for 80 and 40 meters

Some interesting ideas for efficient broadband antennas for the lower-frequency amateur bands

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You often hear references to antenna resonance, but with a lack of indication that the resonant frequency ever was adjusted or measured. Perhaps it is a good thing, for it might lead to confused thinking about the problem.

resistive mismatch

Take a very simple example—a half-wavelength antenna fed directly with 50-ohm RG-213/U coaxial cable (or 52-ohm RG-8A). The antenna is presumed to present a resistive load of about 72 ohms to the line or $R_R = 72 + j0$. The 50-ohm line needs a load of $R_0 = 50 + j0$, but it is not getting it. The result, 72/50, is a standing-wave ratio of 1.44:1.

The amateur, it is presumed, doesn't actually know that his antenna is at resonance, and doesn't like the resulting swr, so he proceeds to run a curve of changing swr with frequency. Somewhere, at a nearby frequency, the swr bottoms out to a minimum that satisfies him, so he trims the antenna length to put this minimum swr at the desired frequency. Then, he claims that the system is "resonant." Why?

Had the line been a 72-ohm coaxial cable, the antenna load resistance $R_R = 72 + j0$ would equal the characteristic impedance of the line, Z_0, and everybody would be happy. The original antenna would *still* be resonant, and the line would be "flat." That is, regardless of points along the line, or its length, the swr would be 1:1, it would load the transmitter well, and putting in a little more coaxial cable would not change anything.

The original antenna length, fed with the 50-ohm coaxial cable, would worry this chap because of the 1.44:1 swr. He might even add coaxial cable to improve the loading at some new cable length. What he really needs is something to transform 72 ohms at the middle of the antenna to the 50-ohm characteristic impedance of the line. With the transformation the swr at the sending end of the line would be 1:1, and again it would load well. This transformation could have been done in one of several ways, including a transforming bridge balun[1], tapping the line slightly up on a grounded (or ground-plane) vertical, with a stub, with an LC matching network, or with a quarter-wave transmission-line transformer.

finding resonance

How do you determine the resonant frequency of an antenna if the swr dip does not give it? One quad manufacturer says to insert a one-turn coil in the antenna and grid-dip it; but this may move the resonant frequency down a hundred kHz or more. *The grid-dip frequency must be* checked accurately, such as with a calibrated receiver. And it must be done so the grid-dipper doesn't come too close to the antenna, because that can lower the frequency too.

There are other ways. One is to feed the antenna when it is a continuous dipole, or a grounded vertical, and determine that the currents on both sides of a feed line are identical. A way to do this is to put two rf ammeters in a loop of wire, couple it inductively to an rf source to check meter calibration, and jumper this loop of wire, stretched out with the ammeters in the middle, across part of the antenna with the feedline connected between the meters (**fig. 1**). The frequency that produces identical current in both meters is the resonant frequency.

This method works when the antenna is folded in the middle to produce a tuning or matching **stub**, as shown in **fig. 2**. However, it is also satisfactory to make a pick-up loop of several small turns of insulated wire, with ends about a foot long, and jumper this across two feet of the antenna. Then a grid-dip oscillator can be coupled to the small coil without it being in series with the antenna. The result is much more accurate. It works on quads, too.

reactive loads

You may have a resonant antenna with a load impedance (resistive) that is not equal to the characteristic impedance of *the feedline. This results in standing* waves although the line will present a resistive load to the transmitter when it is any multiple of an electrical half wavelength long. This load will be that of the antenna, which may or may not make the transmitter happy.

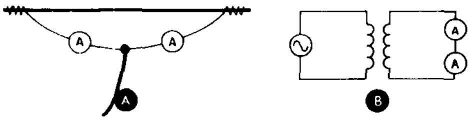

fig. 1. Determining resonance with rf ammeters. When the current through each ammeter in A is the same, the antenna is resonant. In B, the ammeters are placed in series to check that both instruments read the same.

At any intervening length of feedline the actual impedance will be complex—that is, it will have a resistive and a reactive component. Some lengths of line may produce a combination of resistance and reactance that the transmitter cannot load because of matching network limitations. In this case, you can live with the high swr by adding sections of coaxial line until a length is reached that provides a more satisfactory load to the transmitter. The actual swr, however, remains the same.

Another solution is to add a series or parallel capacitor or inductor to the line to cancel the reactance.

When my Henry 2K is used on the wrong end of the 80-meter band, the tuning and loading controls no longer are where they were when feeding a dummy load; the tuning control is at maximum, and the loading control alone is adjusted for a plate-current dip, allowing no control over loading. As coaxial cable is added to the line the loading improves and the controls on the amplifier move toward the setting when feeding the dummy load.

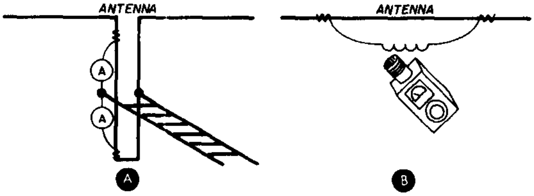

fig. 2. Determining antenna resonance with series rf ammeters in a matching stub, A, and with a grid-dip oscillator, B.

bandwidth

If a dipole is used over a 12 to 14 percent bandwidth in the 80-meter amateur band there are problems due to the change in complex antenna impedance presented to the feedline as the frequency is moved from one end of the band to the other. When the antenna itself is mistuned in order to terminate the line with a suitable amount of reactance to minimize the swr it may operate at a point on its reactance curve where small changes in frequency create large changes in reactance. This results in a narrowing of bandwidth, which might be defined as the bandwidth for an acceptable swr. A result of this condition was the development of in-band rf traps,[2] the use of coil switching at the antenna,[3] end clip-on wires, and other means of enabling the antenna to be used over the entire 80-meter band. One approach[4] used series capacitors, a stub of fanned-out wires to create a real 10 percent bandwidth or more with a 1.5:1 swr.

In the case of the inverted-V antenna, fortuitous height and apex angle may cause the antenna to present a 50-ohm load at resonance.[5] Some increase in bandwidth may result as compared with a horizontal dipole in the absence of matching or broad-banding. Broadband impedance-transforming bridge baluns have been developed[1] for use when the antenna impedance at resonance does not match the transmission line properly. However, solutions by step tuning or by true broadbanding continue to be required, particularly for those whose antenna facilities are limited. Many of us need an antenna that covers 40 meters and both ends of 80 meters. We now have simple solutions for the 40-meter band and for spot frequencies of 3525 and 3825 kHz more or less, using the in-band traps or dual 80-meter wires, but we must develop a more general approach.

With the current 5-band DXCC interest in 80 meters, better solutions are needed. Frequently, one is caught with the end loading wires clipped on or off, presenting a 15-to-1 swr or worse at the necessary operating frequency. The system can be loaded with a suitable matchbox, or addition of coaxial cable, or lumped reactance, but there are added losses with such a high swr.

stub matching

Before leaving the general comments, let's take a quick look at some of the simple theory of stub matching. If an antenna is resonant and presents a satisfactory resistive load equal to the characteristic impedance of the line, there is no problem. However, if the length of the antenna (or frequency) is changed it becomes reactive. If this length is selected to bring the resistive component of the complex impedance of the antenna, $Z_R = R + jX$ to a point where the R is equal to the characteristic impedance of the transmission line, Z_0, a reactance (equal and opposite to the antenna's reactance) placed across the line will result in a match. The necessary reactance can be a stub. Usually a shorted stub is preferred. If you know the $R + jX$ at the center of the antenna,[6] the stub length that can provide the cancelling $-jX$, can be calculated, read from a graph, or obtained from the Smith chart.

Let's look at the situation in another light; **fig. 3** shows a quarter-wavelength stub with a line attached at a point that gives a proper termination to the transmission line. The impedance of the shorted stub in one direction from the transmission line tap, **a**, is equal to that of the open stub in the other direction, **b.** The current flowing in one wire of the stub will be equal just below the line tap, and just above the line tap, when the stub is resonant. The open part of the stub can be bent out to form a dipole antenna, with the feedline conveniently located at the bend. This form of stub may shorten the dipole.

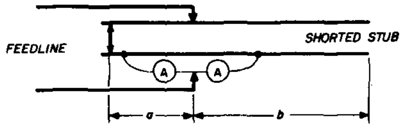

fig. 3. Line matched to stub; the reactance of the shorted section (A) at the line taps equals the reactance of the open section (B).

On the other hand, if you have an arbitrary length dipole and wish to feed it you may back down the line to the one or two points, **a** in **fig. 4,** in the first half-wavelength toward the transmitter which has a resistive component (in $R + jX$) equal to the characteristic impedance of the line. At that point, attach a stub, **b,** which has an equal and opposite $-jX$ reactance, thus cancelling the reactance and matching the line with the resistive load from that point back to the transmitter.

smith chart

The Smith chart[7] is a useful tool. A circle on it, centered on the center of the chart, is an swr circle for a lossless line. Points around this circle, which covers a half wavelength, gave the resistive and reactive components of the complex impedance along the transmission line.

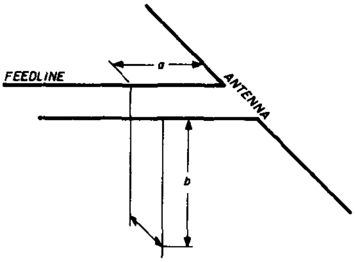

fig. 4. Method of stub-matching a reactive antenna. All lines can be coaxial cable.

In reverse, any value $R + jX$ complex impedance can be plotted on the chart, such as the changing resistance and reactance as some circuit is fed at different frequencies. When these impedance points are connected together with a line it will be seen what range of frequencies falls within an acceptable swr. The Smith chart also facilitates adding reactances in order to bring some part—or a greater part—of the connected points within the acceptable swr circle, by moving a plotted point along a resistance curve by the amount of the added reactance.[8]

So far we have dealt with resistance, impedance and reactance. Sometimes problems are more readily solved in the reciprocals (these values divided into 1) called conductance, admittance and susceptance. Whichever form is used, it is sometimes convenient to divide R + jX by the characteristic impedance of the line, use the result in chart work or calculations, and then multiply again by the line's Z_0 to obtain the actual values of R + jX. This process is called "normalizing." One advantage of normalizing is that the value applies equally to lines of different Z_0 without replotting. Smith charts are available with a normalized 1 at the center for normalized data, and others are available with 50 at the center for direct use with 50-ohm systems.

about four turns were added; for 80-meter cw, about 9 turns were added.

An swr bridge showed something like 1.5:1 but there was no transmission line to have a standing wave. This actually was a measurement between the normal 52-ohm termination in the swr bridge, and the actual resistive load presented by the antenna. At any rate, the Heathkit SB200 and Henry 2K both fed the antenna easily, which was only 15 feet above ground at its midpoint. Nevertheless, cw and ssb contest contacts were made into far South America, Malaysia, Singapore, and the like on 80 meters.

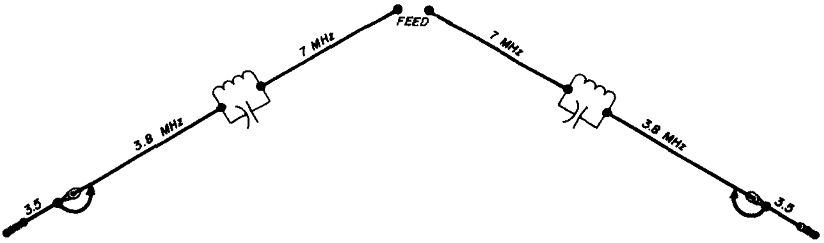

fig. 5. Trapped inverted-V with clip-on ends. Coaxial connectors are more reliable than alligator clips.

simple two-band antenna

When I was becoming more active in amateur radio after retirement, I didn't appreciate that the problem of coax-fed antennas for the lower bands might be *difficult. With some memory of a chap* named Marconi, and disregard for the 200-ohm resistance between rods driven *in the ground ten feet apart, I put up an* L antenna which was resonant at 5/4 wavelengths to the 40-meter trap, and at 3/4 *wavelengths on 80 meters to the far* insulator. The antenna was led to the transmitter output terminal with **no** coaxial cable at all, and **no** matching or coupling device. The wire was trimmed for the high end of both bands. Then, to move it to the low end of both bands, about ten turns of two-inch Air-Dux coil were mounted on the wall, and provided with a shorting clip. For 40-meter cw,

The main problem was the necessity to put 16 bypass capacitors and one rf choke in the electronic keyer, and to use RG-58/U cable instead of shielded audio cable to the exciter key jack to prevent rf from interfering with the keying. The antenna system was so simple, really, that it was a pity that use of the land was prevented by a building program. With the local decomposed granite soil, and pavement over almost all of the ground, all proposals that I use a vertical antenna and a radical ground were quickly rejected without a fair test.

two-band dipole types

The common two-band inverted-V or dipole is the trapped wire, **fig. 5.** This antenna may have considerable interlocking tuning between the sections. Furthermore, *if any dead-end wire is twisted back* around itself, thus providing more wire if needed, it may load that section of the antenna unless it is shorted to the active wire by soldering or clamping with a Kearny clip. Even a loose fold-back may change the tuning by acting like a "fat" wire.

Another version is the use of two wires, each being a dipole for one of the bands; these wires can be at different angles, or spaced by dowel-rod spreaders, using a single support at each end, as in **fig. 6.**

These antennas may provide adequate coverage of the 40-meter band, but the width of the 80-meter band may be too much for them unless there is excessive loss in the line or balun. Line losses can be compared with those existing during earlier measurements, by logging the swr when the far end of the line is shorted.[10]

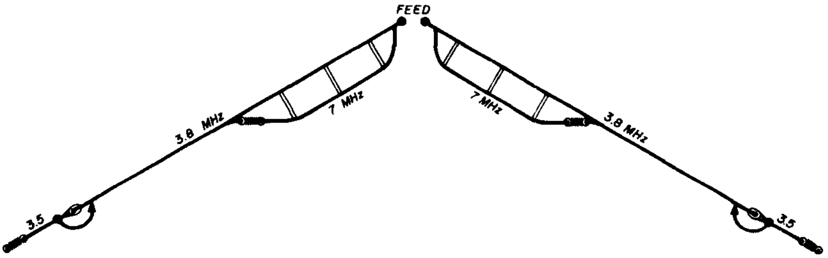

fig. 6. Two-wire, two-band inverted-V with clip-on ends.

broad-banding

On one band only, there are several ways to broaden the antenna. One way is to make the wire fat, in effect, compared with the length. Several spaced wires can be used, including the old "cage."[11] A remarkably effective and convenient form is to use several wires, held apart half way between the center insulator and the end by some type of light-weight spreader, forming a diamond in each quarter-wavelength. Still another way is to fan out two wires, or three, supporting the far ends from different points. All these tend to shorten the resonant length by as much as 20 percent.

Everett[9] goes through the design of a fat antenna with a bandwidth of about 30 percent within an swr of 1.25:1. The length/diameter ratio of the conductor was selected for a resistive component that matches the transmission line; then a shorted stub was connected across the line at the antenna to cancel out the reactance.

John Kraus, W8JK,[12] gives the resistance of fat antennas which runs in the vicinity of 80 ohms at the center of a half wavelength, to 200 to thousands of ohms for the center of a full wavelength. These lengths are much shortened due to the shape. The convenient impedance explains why many very broadband fat antennas actually are vertical half-waves or horizontal full-waves.

Coleman[4] has investigated the use of parallel or series reactances in the form of capacitors, inductances or line segments, to obtain more bandwidth in a particular antenna. In connection with parallel-resonant stubs (usually slightly longer than a quarter wavelength) placed across the line at the antenna, he says: "The broad-banding property seems not to have been exploited. A resonant antenna has a negative susceptance (1/X) slope with respect to frequency, which can be cancelled with a properly chosen circuit over a considerable range of frequencies. The most favorable antenna curve is one which has a resonant conductive component (1/R) just less than 2. The stub portion of a bazooka (quarter-wavelength-line type of balun) is ideally suited for bazooka matching and balancing of a balanced resonant circuit to an unbalanced line." Linear baluns thus formed of coaxial or triaxial[13] cable may be very useful in broad-banding an antenna without added hardware.

Meier[4] has put together the work of Coleman on the use of capacitors or inductors, and stubs, to obtain broad-banding. With simple antennas, and using a two-element broadening arrangement consisting of a series capacitor and a parallel stub, he obtained bandwidths far greater than our 80-meter band. Then, he explored the use of fan elements (**fig. 7**) which are physically short, and found that it was necessary to use only the parallel stub in order to obtain adequate broad-banding. Three wires, connected together at their far ends, were satisfactory; the length of the center wire plus half the length of the wire connecting the ends, was approximately a quarter wavelength.

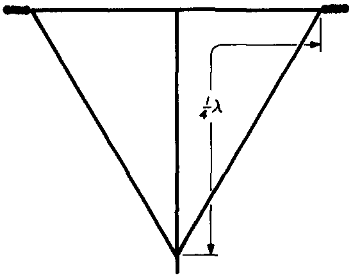

fig. 7. Fan monopole, physically short as shown. Two can be used as a dipole.

The unusual bandwidth resulted partly from the complete loop that the antenna impedance makes on the Smith chart. The spiral locus is also typical of a series line transformer with a length that exceeds a quarter wavelength.[9]

It is customary practice in broadband designs to sacrifice a perfect match at the midfrequency in order to gain bandwidth within the acceptable swr. For a fanned-out antenna and linear balun giving an swr less than 2.5:1 over the 80-meter band, (see the Radio Handbook, 17th Edition).

double-humping

Somewhat like broad-banding is the design of an antenna that will produce an acceptable swr at two different frequencies within the 80-meter band. One way is to clip additional wire on the ends of the antenna, but this sometimes proves to be inconvenient. A second way is to use in-band traps to do the clipping-on automatically.[2] It may be possible to use line sections as automatic switches[14] even if a coiled coaxial line is used on only one side of the center of the antenna to perform the switching function, such as shorting a series capacitor or changing the length of a stub to its shorting bar or shorting line. I have tried separate dipoles cut for two frequencies in the 80-meter band (**fig. 8**). This worked satisfactorily except for the amount of wire in the air.

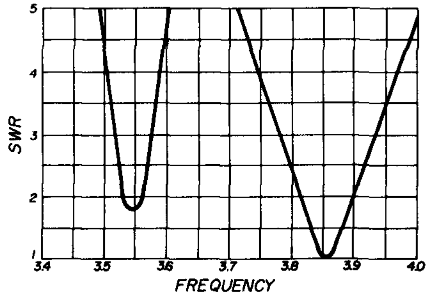

fig. 8. 80-meter antenna using two dipole wires within the band producing a double-humped swr curve.

Two tests were made to solve the problem of midband operation. With the clip-on ends, leaving one on and one off, put the antenna swr dip in midband. This has not yet been tried with the in-band traps, but clip-on wires hanging from the inside end of the traps successfully moved the position of the swr dip. This idea was first considered as a means of lowering the frequency of the ten- or fifteen-meter sections of the driven element of a Telrex Yagi without affecting lower bands appreciably, and without adjusting the aluminum tubing.

two bands broad-banded

Many of us have the more difficult problem of covering the 40-meter band at both ends, and the 80-meter band on both cw and phone. This tends to make the problem more difficult. The trapped 40/80 inverted-V with clip-on ends for the 80-meter cw frequencies which has been in use at K6KA for several years is somewhat difficult to adjust initially because of the loading effects of the 80-meter sections upon the 40-meter section inside of the 40-meter Hy-Gain traps.

The need for clipping on wires was found unnecessary when an 80-meter phone dipole was placed in parallel with the old 80-meter cw dipole which was trapped for 40 meters. However, there continued to be some interlocking adjustments.

An alternate plan used one dipole from the center of the antenna to the 40-meter trap, and then two fanned wires from the trap cut to different lengths for the ends of the 80-meter band. This caused a remarkable shortening of the wire length in addition to that caused by the inductive reactance of the trap, and only one swr dip was located within the transmitter's frequency range. The narrow frequency range of current exciters makes it difficult to locate the swr dips when they fall well outside a band.

Using two dipoles spaced six inches by dowel rods, the 40-meter wire below the 80-meter wire, and in-band traps near the end of the 80-meter wire, W6JKR found no interaction and fully satisfactory operation.[2]

Obviously, the in-band traps can be eliminated, too, by using three wires: one for 40 meters, one for 80 cw, and one for 80 phone. Such an arrangement was put up at WB6ITO and WA7NAR using a wooden mast and a four-wire cage dipole on X-shaped spreaders. The wires are not connected at the far ends, but the lengths are cut for different frequencies in order to produce a fairly flat swr over the entire 80-meter band. One wire presumably can be cut for 40 meters. The problem of adjustment might be simplified by clipping extension wires on the three (or two) 80-meter dipoles not being adjusted, in order to move them out of the range of the dipole being adjusted. Actually,

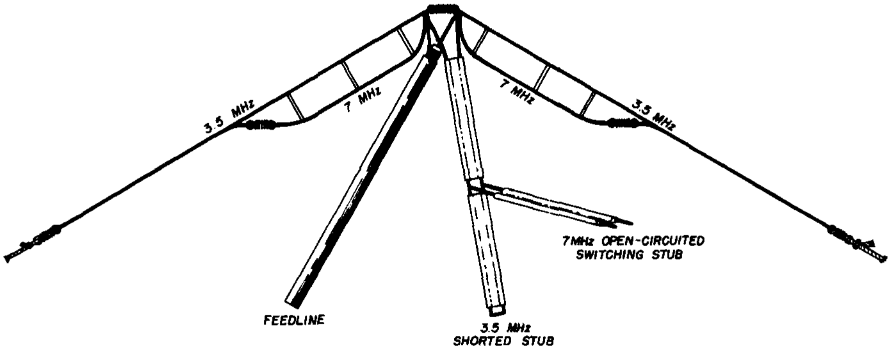

fig. 9. Broadband 80- and 40-meter inverted-V with tv shielded foam line shorted stub, and quarter-wave 7-MHz switching stub. This can be part of a bazooka balun.

the adjustment is not to "resonance," but to a low swr at the dipole's assigned frequency in the band.

general solution

So far several satisfactory one-coaxial-cable two-band antennas have been mentioned, including those with a separate wire for 40 meters, and two-point or wideband coverage of 80 meters. If two coaxial cables are considered, the problem of obtaining broadband coverage of 80 meters is not difficult if a quarter-wave stub or bazooka balun is used for broadening.

For full coverage with a single feedline, other than the two cage dipoles described by Covington,[11] or a single cage which might permit trapping one wire for 40 meters, it appears that the most satisfactory design will use a combination of methods such as those discussed above and will be useful throughout both 40 and 80 meters with an acceptable swr. The most promising possibilities appear to be:

1. A 40-meter wire and an 80-meter wire, broadbanded by a parallel quarter-wavelength (or slightly longer) stub or bazooka whose length is automatically switched between bands by applying a quarter-wavelength open-circuited line at the position that will shorten the stub to the 40-meter length (**fig. 9**).

2. A fan dipole with 40-meter traps in all of the wires, and a parallel quarter-wavelength stub (or slightly longer, possibly made of shielded tv foam cable coiled up) or bazooka with the automatic switching discussed above (see **fig. 10**).

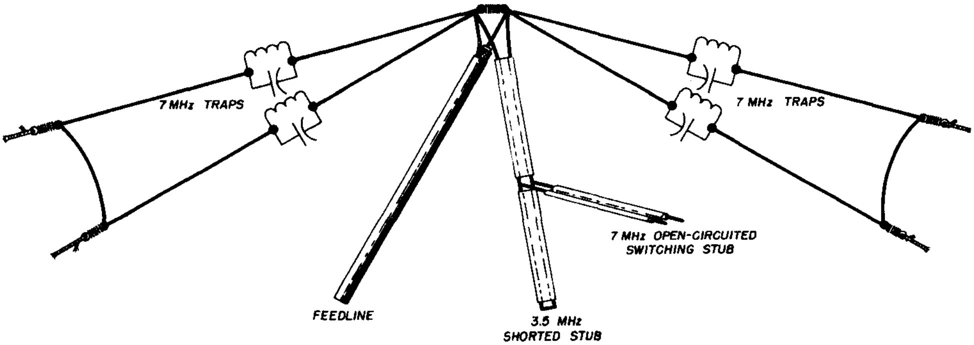

fig. 10. Broadband 80- and 40-meter fanned inverted-V, trapped for 40 meters. Stubs perform the same as in fig. 9.

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ham radio