Unipole Antennas—Theory and Practical Applications

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When properly designed, constructed and tuned, the folded unipole has the potential of having many advantages over more traditional antennas. It is often utilized as an "afterthought" antenna, sometimes installed on the tower or pole supporting a beam and/or VHF or UHF antennas. Compromises made to suit the particular situation may have negative effects on its ultimate performance, its advantages not being fully realized. While it is most familiar in the form of a vertical antenna for use on the HF bands, the same principles of tuning and performance apply regardless of polarization or frequency.

The folded unipole antenna has been said to be the same as a gamma-matched or perhaps a shunt-fed antenna. While there are similarities on the surface, a properly designed, constructed and tuned folded unipole is far superior to the other two mentioned in many respects.

In this paper, several properties are discussed and compared to the series-fed antenna as well as to the gamma- and shunt-feed methods. At the outset it should be said that a folded unipole is a truly tunable antenna. The dimensions for a standard series-fed antenna must be carefully calculated and then the ends sometimes pruned to get optimum performance from it. The dimensions on the unipole to be described are not critical, the input impedance being a function of how the stubs between the fold wires and the supporting structure are set.

Fig 1 is an illustration of the antenna. Compared to other antennas, it has broad bandwidth and low Q, and is inherently stable with changes of weather and season. Finally, it appears to be less ground-system dependent; that is, it still performs well even if the ground system is not ideal or real-estate boundaries limit the length of ground wires.

Geometry is often overlooked in the design of an antenna, sometimes for convenience and sometimes for economics. Length-to-diameter ratio has been known for many years to affect both the bandwidth and propagation velocity of an antenna.[1] This ratio is easily improved (decreased) by the application of good unipole design.

[1]Notes and references appear on p 38.

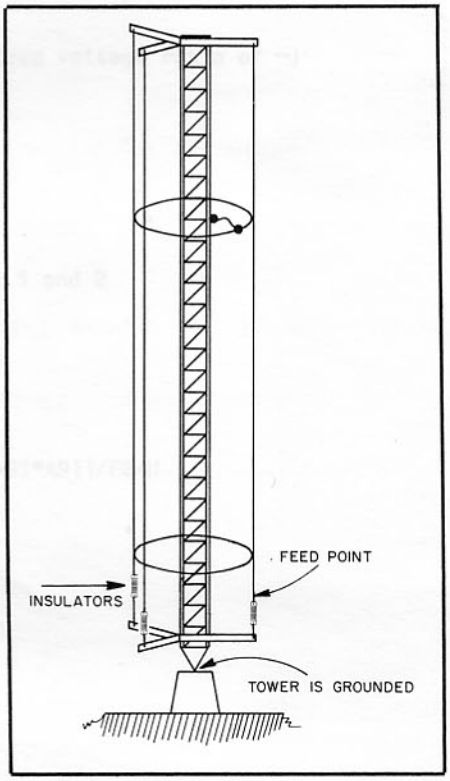

Fig 1—Used commercially for AM broadcasting, the folded unipole antenna can be adapted fairly easily for Amateur Radio use. Tuning may be accomplished by separate jumpers or one jumper and a commoning ring, as shown.

A good unipole uses several skirt wires rather than just one for both symmetry and effective diameter increase. A single wire may help establish a desired input impedance, but it does little to increase the effective diameter of an antenna. On the other hand, if three or more wires are equally spaced around a supporting structure, such as a tower, the effective antenna diameter approaches the diameter of the circle encompassing those wires (Fig 2). Additionally, each wire has an effect on the input impedance of the total antenna. A further effect is a reduction in the velocity of propagation within the antenna.

The folded unipole has been described as a "transmission line antenna." It might be viewed as a length of skeletonized coax cable, with the center conductor grounded while the outer conductor (wire skirt) becomes the feed point. Measurements

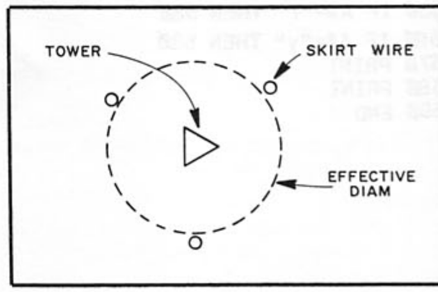

Fig 2—This top view shows placement of skirt wires that serve to increase the antenna's effective diameter.

made on model antennas indicate that the velocity may be on the order of 0.88c rather than the factor of 0.95c which is used in the rule-of-thumb formula for ¼ λ.

$$h = \frac{234}{f}$$

(approximately ¼ λ for a series-fed antenna; velocity is assumed to be 0.95c)

where
h = height, feet
f = frequency, MHz
c = the velocity of EM radiation (such as light)

Using the value of 0.88c, the formula becomes

$$h = \frac{216}{f}$$

(approximately ¼ λ for a unipole)

This makes a ¼-λ unipole about 7 to 8 percent shorter than a series-fed antenna, which may provide a slight advantage when building an antenna. However, we will see that there is nothing magic or sacred about a ¼-λ unipole antenna. With a series-fed antenna, the ¼-λ point is merely the first dimension at which the reactance goes through zero and the resistance is a manageable value. It makes input matching simple, but by a bit of juggling, we can make the folded unipole give us a good match without having to be concerned with precise height or length dimensions.

In the process of tuning, stubs are placed between the inner conductor (often a tower or pole) and the skirt wires. The location of the stubs can provide a wide variety of input impedances, depending on what is desired. Since most ham equipment has adopted a universal value of 50 Ω and zero reactance (50 + *j*0 Ω), that's the value that will be discussed here. Bear in mind, however, that almost any other value can be matched by proper design and tuning.

Theory: Superposition of Two Currents

During the latter years of the Vietnam War, our military wanted an antenna system that would quickly tune to any frequency between 2 and 30 MHz. The forces in the field were using a special version of the Collins KWM-2 which operated in this range. They wanted a quick QSY in the event of jamming, QRM or enemy listeners. Today's transceivers have optional autotuners to quickly match into any antenna input impedance (within reason), but they were not available back at that time. General Dynamics developed an antenna called the "Hairpin Monopole" which, with a special auto-tuner, attempted to accomplish this.[2] For an antenna only 14 feet in height, they were able to effect a good impedance match and reasonable coverage throughout the HF spectrum. What is important here is their analysis of the currents within the antenna.

Looking at the lower frequencies, it is obvious that a 14-foot antenna is electrically very short. *Superposition* is a math term that can lead to great complexity, but we will avoid equations and look at it graphically. What it means is that we must analyze the antenna as having two currents flowing in it simultaneously (Fig 3).

The first is a transmission line current, I_L. It enters the antenna terminal, flows upward to the top and then downward in the other conductor of the antenna toward ground. Note that its value is constantly changing to conform to transmission line theory, but if the trip from input terminal to ground terminal is much less than 180 degrees, it never reaches a value of zero or reverses direction.

The second current is the antenna current, I_A. It enters the antenna terminal in phase with I_L and remains so to the top of the antenna (or the tuning stub). However, it does not follow I_L when it turns and starts down the other conductor of the antenna. The other conductor, being in the very near field of the one connected to the input, has a current induced into it the way that a transformer primary winding induces a current into a secondary winding. Thus, in this "secondary" portion of the antenna, the two currents, I_L and I_A, are no longer in phase. But because their amplitudes and phases are not the same, they do not entirely cancel each other.

Superposition allows for the analysis of the resultant current. We may say that the current in the antenna "secondary" is less than in the "primary," but at no two points on the secondary will the resultant current be the same. It gets complicated, but

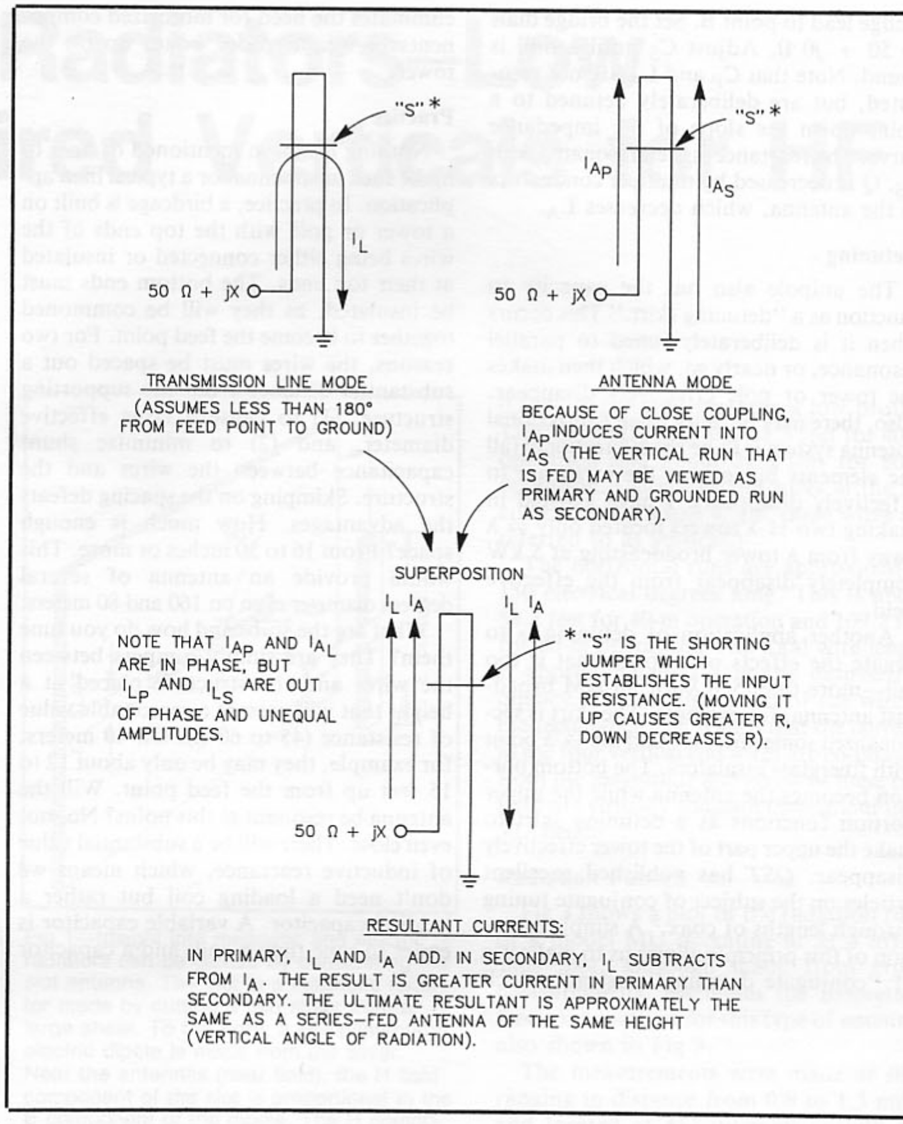

Fig 3—Current distribution on a folded unipole.

knowledge of such details is not necessary to construct a practical antenna. Most of the current will be in the skirt wires and a smaller portion in the supporting structure, such as a tower. The antenna will appear to have skin effect with most of the current being effectively in the form of a sheet on the effectively large outer diameter. The EM flux density will be much less than that surrounding a small-diameter conductor.

Tuning

I have built a two-capacitor tuner for my 48-foot tower, and it works perfectly (see Fig 4). I tested it on 1610 kHz (±28 degrees) and on several points in the 160-meter band (± 33 degrees), and in each case got the optimum match. The tune-up procedure I used may prove helpful.

To tune for 50 + *j*0 Ω, connect a bridge from point A to ground. Set the R dial of the bridge to 50 Ω and leave it there. Adjust C_P and the reactance dial of the bridge until a null is found. Move the

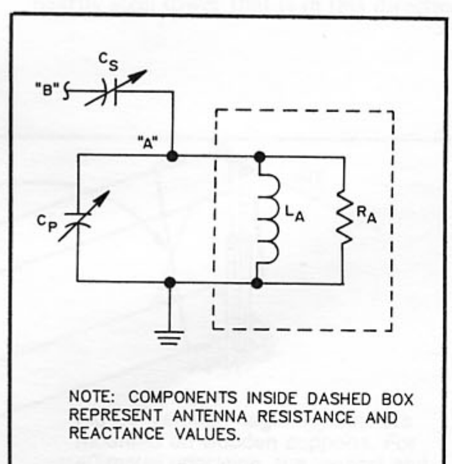

Fig 4—Tuner circuit for the author's "Hairpin Monopole" antenna. Components inside the dashed box represent antenna resistance and reactance values. See text for adjustment procedure.

bridge lead to point B. Set the bridge dials to $50 + j0\ \Omega$. Adjust C_S until a null is found. Note that C_P and L_A are not resonated, but are deliberately detuned to a point down the slope of the impedance curve. The reactance is then resonated with C_S. Q is decreased by multiple conductors in the antenna, which decreases L_A.

Detuning

The unipole also has the capacity to function as a "detuning skirt." This occurs when it is deliberately tuned to parallel resonance, or nearly so, which then makes the tower or pole effectively disappear. Also, there may be times when a directional antenna system is to be omnidirectional (all the elements but one in the array are to effectively disappear). I have assisted in making two ¼-λ towers located only ¼ λ away from a tower broadcasting at 5 kW completely disappear from the effective field.

Another application of detuning is to negate the effects of a tower that is too tall—more than 5/8 λ for an AM broadcast antenna, for example. The skirt is sectionalized somewhere around the ¼-λ point with fiberglass insulators. The bottom portion becomes the antenna while the upper portion functions as a detuning skirt to make the upper part of the tower effectively disappear. *QST* has published excellent articles on the subject of conjugate tuning through lengths of coax.[3] A simple extension of this princ̓ple allows us to make use of "conjugate detuning" instead, which eliminates the need for motorized components in weatherproof boxes up on the tower.

Practice

Nothing has been mentioned of how to make such an antenna for a typical ham application. In practice, a birdcage is built on a tower or pole with the top ends of the wires being either connected or insulated at their top ends. The bottom ends must be insulated, as they will be commoned together to become the feed point. For two reasons, the wires must be spaced out a substantial distance from the supporting structure: (1) to cause a large effective diameter, and (2) to minimize shunt capacitance between the wires and the structure. Skimping on the spacing defeats the advantages. How much is enough space? From 16 to 30 inches or more. This would provide an antenna of several degrees diameter even on 160 and 80 meters.

What are the stubs and how do you tune them? They are simply jumpers between the wires and the structure placed at a height that will present a reasonable value of resistance (45 to 60 Ω). On 40 meters, for example, they may be only about 12 to 15 feet up from the feed point. Will the antenna be resonant at this point? No, not even close. There will be a substantial value of inductive reactance, which means we don't need a loading coil but rather a loading capacitor. A variable capacitor is easier to tune than a coil, and a capacitor is an inherently lower loss device than a coil.

In practical applications I have installed an air-variable capacitor in a weatherproof housing in series between the center conductor of the coax from the transceiver and the wire commoning the bottom ends of the skirt wires together. Conjugate matching might be done by calculating the length of the feed line to an appropriate length. However, I haven't gotten that far yet.

Conclusion

There is more to building a good antenna than just stringing up some wires of certain dimensions. Geometry is very important, and proper application of geometric principles can make the difference between a high-Q, narrow-band and sometimes unstable antenna and one of low Q, broad bandwidth and good stability in varying climatic conditions. The cage antennas of the early decades of ham radio very likely helped in settling down transmitting and receiving equipment that would have been wild had it been connected to antennas that were also difficult to deal with.

Notes and References

[1]See J. Devoldere, *Low Band DXing* (Newington: ARRL, 1987), p II-21.

[2]See J. A. Kuecken, *Antennas and Transmission Lines*, 1st ed. (Indianapolis: Howard W. Sams and Co, 1969).

[3]M. W. Maxwell "Another Look at Reflections," *QST*, Apr, Jun, Aug and Oct 1973, Apr and Dec 1974 and Aug 1976.

J. H. Mullaney, "The Folded Unipole Antenna," *Broadcast Engineering*, Jul 1986.