The folded unipole antenna

By John H. Mullaney, P.E.

The folded unipole antenna offers several advantages for stations with inefficient arrays or deteriorating ground systems.

The folded unipole antenna has been around for a long time. Yet many engineers are not familiar with its design. Even so, the unipole AM antenna offers a number of advantages, making it worth consideration by stations that have old and inefficient arrays, deteriorating grounding systems or that simply would prefer to have a grounded tower. These advantages are especially important when the station wants to add an FM antenna or reduce the problems associated with lightning and ungrounded towers.

Compared to both series-fed vertical and toploaded antennas, the unipole offers several specific benefits. The unipole has greater radiation resistance. For those stations concerned about AM improvement, the folded unipole antenna provides greater system bandwidth than does a series-fed antenna. The folded unipole antenna's base impedance can be varied, making coupling and bandwidth easy to control. Conversely, the base impedance for a series-fed antenna cannot be easily changed.

For those installations that suffer from instability in inclement weather, the folded unipole can be a real blessing. The antenna maintains its operating characteristics in most types of weather with few of the problems found in some series-fed installations.

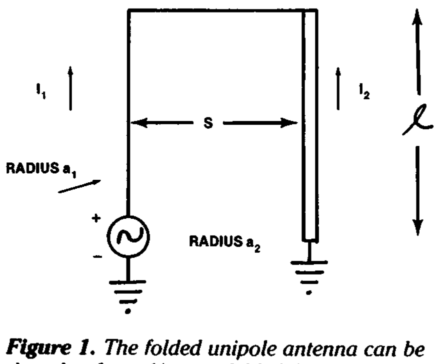

***Figure 1.** The folded unipole antenna can be thought of as a ½-wave folded dipole antenna perpendicular to the ground and cut in half.*

Mullaney is a consulting engineer and president of Mullaney Engineering, Gaithersburg, MD.

Unipole theory

The folded unipole antenna is really a grounded vertical structure with one or more conductors folded back parallel to the side of the structure. It can be visualized as a half-wave folded dipole perpendicular to the ground and cut in half. (See Figure 1.) This design makes it possible to provide a wide range of resonant radiation resistances by varying the ratio of the diameter of the folded-back conductor in relation to the tower. Toploading can also be used to widen the antenna bandwidth.

The folded unipole antenna could be called a modification of the standard shunt-fed system. Instead of a slant wire that leaves the tower at an approximate 45° angle (as used for shunt-fed systems), the folded unipole antenna has one or more wires attached to the tower at a predetermined height. The wires are supported by standoff insulators and run parallel to the sides of the tower down to the base.

The tower is grounded at the base. The folds, or wires, are joined together at the base and driven at this point through an impedance matching network. Depending upon the type of folded unipole antenna used, the wires may be connected to the tower at the top and/or at predetermined levels along the tower with shorting stubs.

The folded unipole can be used on tall (130°) towers. However, if the unipole is not divided into two parts, the overall efficiency or unattenuated field intensity will be considerably lower than the normally expected field for the electrical height of the tower. (See related article, "Tall Towers," page 68.) For shorter towers, however, the folded unipole design is less involved.

Calculating the impedance and operating characteristics of a folded unipole antenna is quite complex and will not be covered here. Instead, this article will examine some of the other important aspects of the system.

Most broadcast folded unipole antennas use three folds on tower widths from

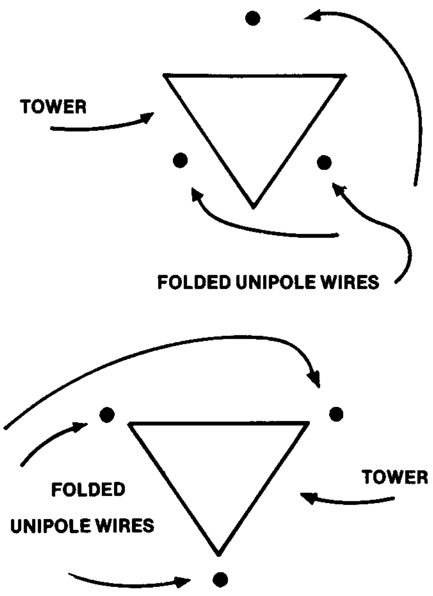

***Figure 2.** The folds of the antenna are arranged either near the legs of the tower or near the faces of the tower.*

15 inches to 48 inches. The folds are arranged either near the apexes of the triangle of the tower or near the sides of the tower, as shown in Figure 2.

The various equations related to folded unipole antennas reflect the number of factors that affect the antenna's impedance. Not apparent from the equations, however, are the structural and environmental problems that can be encountered. For instance, the spacing of the folds from the tower can cause a windloading problem. Furthermore, the accumulation of ice on the bottom of the fold wires and in the strain insulators can cause the VSWR to increase, detuning the transmitter as the base impedance changes.

These problems can be addressed by a triangular brace on the top of the tower cross-arm at the termination of the folds. (See Figure 3.) The arm's spacing should not exceed four times the tower's width or side dimension. The best way to keep ice from building up around the base insulator termination is through the use of a shield-shaped funnel made from copper or sheet metal. This can be used to cover

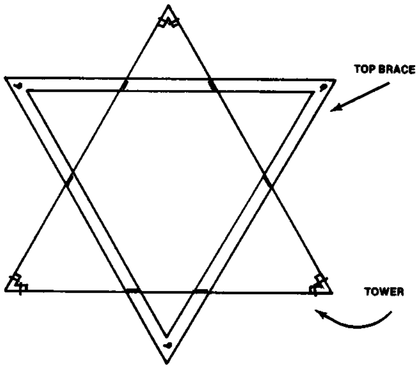

Figure 3. The top brace supports the entire weight of the folds, which are anchored near the base.

the top of the strain insulator.

The funnel not only protects the strain insulators from ice accumulation, but also acts as a corona shield. These funnels should be approximately four to eight inches in diameter.

Ground system losses

If you compare a series-fed antenna with a folded unipole antenna of the same height and similar ground system, you'll find that the unattenuated field efficiency is identical. However, if a series-fed system is many years old and suffering from a deteriorated ground system, the results may be quite different.

In cases in which the ground system has deteriorated from weather, chemical action or vehicle traffic, the folded unipole antenna can provide an increase in unattenuated field intensity. This occurs because the antenna currents divide in accordance with the impedance of the line portion and the tower. Therefore, less current flows in the ground resistance portion of the system, resulting in higher efficiency.

The folded unipole antenna is not a panacea to eliminate ground systems, but it does have the capability to work with a deteriorated ground system. The overall tower height determines the maximum efficiency you can expect from an antenna system and the folded unipole antenna can only work within these limits.

Bandwidth and coupling

Bandwidth and RF coupling to an antenna go hand in hand regardless of the method used to excite the system. All elements between the transmitter output circuit and the antenna must be analyzed, first by themselves, then as part of the system bandwidth. In any transmission system, the total *system bandwidth*, not only the bandwidths of individual components, is of primary concern.

The antenna's bandwidth depends upon its base impedance and the rate at which its reactance changes with frequency. The antenna bandwidth is considered to be the frequency band within which the power is equal to or greater than one-half the power at resonance. It is expressed in equation form as follows:

$$\Delta f = \frac{2Ra}{\frac{dx}{df}}$$

Where: f = bandwidth in kilohertz between half-power points
Ra = measured antenna resistance in ohms
$\frac{dx}{df}$ = slope of reactance curve at the resonant frequency

The effective bandwidth doubles when the generator is matched to the antenna circuit. The Q of a folded unipole antenna can be determined from the equation:

$$Q = \frac{f_o}{\Delta f}$$

Where: f_o = operating frequency in kilohertz
Δf = bandwidth of antenna in kilohertz

Antenna bandwidth is the difference in frequency between two points at which the power output of the transmitter drops to one-half the midrange value. The points are called half-power points. A half-power point is equal to a VSWR of 5.83:1, or the point at which the voltage

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response drops to 0.7071 of the midrange value.

In broadcasting, equal power in the sidebands is desirable. Because power is proportional to the square of the amplitude of modulation, power is equal to one-fourth that of the unmodulated carrier. In actual practice, a sideband VSWR of less than 1.2:1 within the bandwidth of the program content would be preferable.

A typical situation

The following example should provide a better idea of how a folded unipole antenna design can be used to improve a station's signal. The information was obtained from an actual operating station, so the problems and solutions represent real-life situations.

The station was operating with 1kW at 730kHz with a non-directional antenna system. The 300-foot series-fed tower was unstable, especially during inclement weather. The antenna system was more than 18 years old and the ground system was in questionable condition.

Over the years, several buildings had been built on top of the ground system, causing it to further deteriorate. A side-mounted FM antenna had been installed near the top of the AM tower, thereby requiring the use of a coaxial isolation transformer. A preliminary study indicated that it was not possible to replace the ground system. The station wanted to know if a folded unipole antenna might help solve the coverage problem.

The first step in any redesign is to fully

Tall towers

The fact that 50Ω or some other usable drive point can be obtained on a tall tower does not necessarily make the tower an efficient radiator. For this discussion, consider anything over 130° a tall tower.

Generally, an AM station that increases its tower height by locating on an FM tower is not allowed to operate with the efficiency that would be expected from the taller tower. The FCC requires that the station reduce the input power to the antenna so that it will produce the same unattenuated field efficiency for which it is presently licensed. This requirement is based on a mutual assumption that the station's efficiency has not changed.

Unfortunately, in a majority of the cases in which an AM station has moved to a tall FM tower, the station finds that it has increased its bandwidth, but with a noticeable reduction in signal level. The move often causes instability too. Some stations even find that the AM signal appears on the FM carrier at plus or minus the AM frequency.

The installation of a folded unipole antenna is a complex process, especially on a tall tower. Although the math indicates that a series-fed tower can usually be modified, there are a few tricks of the trade *that must be followed.*

Often, the folds on tall tower installations have been run either to the top of the tower or just below the FM antenna. This may not be the best solution. Sometimes, it's better to use an upper and lower set of folded unipole antennas. In these cases, the bottom section would start at the base, going up approximately 90° where the folds are bonded to the tower.

On some tall towers a second set of folds would start at the top and go down the tower to approximately the 90° point. Here, the top three folds would be connected and tuned through a variable vacuum capacitor connected to the tower. The upper section tends to couple into the lower folded unipole, so some adjustment may be required. This capacitor would then be tuned by remote control to obtain maximum field strength. After the maximum field intensity is obtained through this adjustment, the station power can be adjusted to the licensed unattenuated field intensity.

Folded unipoles can also be used to detune tall towers if reradiation is a problem. Detailed information on this process is available from the author. Write John H. Mullaney, P.E., 9049 Shady Grove Court, Gaithersburg, MD 20877.

understand the characteristics of the current system. The base impedance was measured and carefully documented. A series of four radials, every 90° from the tower, were marked out and field-strength measurements were taken at 10 locations along each radial.

Modifying the tower

Based on the results of the measurements, the station's antenna system was found to have a low unattenuated field efficiency. The station decided to use a 3-wire folded unipole antenna to improve the efficiency.

The first step was to reduce the transmitter power to 500W so the riggers could install the three folds on the tower. The tower had a 36-inch face, making the installation fairly straightforward. The riggers were warned to be careful and to not allow the folds to come into contact with the tower during the installation process. The folds were spaced 24

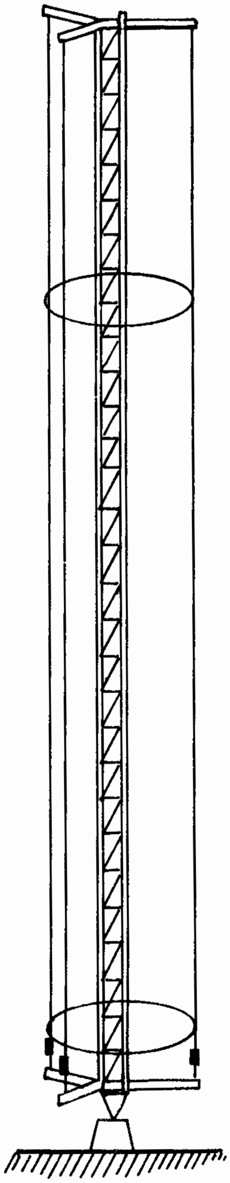

Figure 4. A 3-wire folded unipole installation.

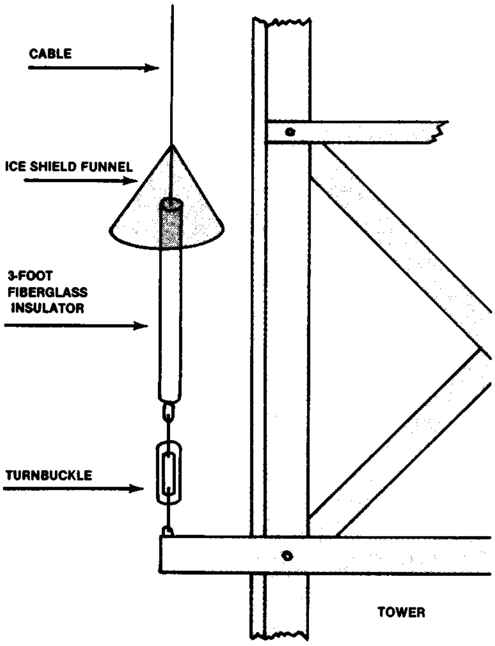

***Figure 5.** The lower ends of each fold are insulated with a fiberglass rod and protected with a funnel-shaped ice shield.*

inches out from the tower face and run from the 300-foot level to the tower base. (See Figure 4.)

After sign-off, three pieces of 4-inch copper strap were installed across the base insulator and soldered to the ground system and tower. The lighting chokes and FM isolation transformer were removed and the FM transmission line was bonded to the tower every 20 feet. The lighting system neutral wire also was bonded to the base of the tower and again at the obstruction lamp level. The three folds were then bonded to the top of the tower.

At the base, the folds were terminated with 3-foot fiberglass strain insulators, as shown in Figure 5. Because the station is located in snow country, funnels were placed on top of the insulators to prevent ice from detuning the system. The three fold wires were then bonded together and a single wire was run from the tower to the coupling house.

The folded unipole antenna design had a characteristic impedance of 50Ω, so the folds were shorted to the tower at 160 feet from the top of the tower. The design stage predicted an impedance of $50+j122\Omega$. The actual measured impedance was $50+j135\Omega$. The distance between the coupling house and the tower accounted for the additional inductive reactance.

After modifications were completed, it was time to again measure the field intensity. The same 10 points along all four radials were checked, and the results were encouraging, showing an increase of approximately 11% in field intensity. The station sounded louder, had better frequency response, and to the listener, seemed to have broader tuning. The change from a series-fed to folded unipole antenna was a success for this station.

The folded unipole antenna is a useful device for many stations. It can solve problems in a relatively inexpensive manner, often making construction work unnecessary. The grounded nature of the folded unipole tower is a real advantage to stations that are plagued by lightning or that plan to install an FM antenna. For many installations, the folded unipole antenna is equivalent to or better than an identical height series-fed antenna.

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