the offset drooper
an improved ground plane

Reduce antenna effect and still achieve a 50-ohm feedpoint resistance

The original "ground plane" omnidirectional antenna was developed in the late 1930s jointly by Dr. George H. Brown, J. Epstein and R. F. Lewis, W2EBS, all of RCA Laboratories. It consists of the long-familiar configuration of a vertical quarter wave "spike" working against four resonant radials at 90 degrees to the mast. In the original version, patented in 1941, the feedpoint impedance is matched to the coaxial feedline by means of a quarter wave coaxial "Q" section. A typical Amateur adaptation is shown in **fig. 1**. In 1942 Dr. Brown patented, solely, the version shown in **fig. 2**, which has several advantages over that of **fig. 1**.

These basic "ground plane" antennas exhibited less antenna effect (surface current) on the mast and feedline than did other omnidirectional VHF antennas widely used at the time. However, the four radials at 90 degrees to the mast are somewhat "transparent" and definitely resonant. For this reason they may be considered more a part of the antenna than a virtual ground plane for the "spike." Semi-infinite ground plane characteristics would allow little radiation below zero degrees elevation. Such a pattern might be unsuited to a mountain top location or a swaying freestanding mast.

Because of the direction of current flow in the radials, the resultant radiation from the individual spikes results in good cancellation, and there is little net radiation from them. The fact that one may touch the tip of one radial with little effect on VSWR doesn't mean that the radials do a good job of simulating a large, flat conductive sheet. Because of the quarter wavelength of the radials, pinching the tip of one elevates the impedance at the opposite end and effectively isolates it. The remaining three radials simply take over, with only moderate detuning of the antenna.

The result of all this is as follows: the performance of a "90 degree" ground plane represents an improvement over several previously popular base station antennas. However, while orienting the resonant radials at 90 degrees does reduce inductive coupling to the coaxial line and mast, it doesn't effectively eliminate it. The coupling is sufficient that the resulting antenna effect may be found undesirable for some applications.

Long popular among hams for VHF and upper HF is the "droopong" ground plane, a simplified, less elegant, low-cost descendant of the Brown ground plane. Simply bending down the horizontal radials to about 45 degrees raises the radiation resistance to 50-52 ohms. This permits direct connection of the coax without use of a matching device. A more appropriate description might be "skeleton skirt dipole," because the resonant drooping radials don't do a very good job of serving as a virtual ground plane. Instead, they exhibit more inductive coupling to the feedline than do radials at 90 degrees.

Nearly 40 years ago, in the *Antenna Manual*, I pointed out that while the drooping ground plane or "drooper" is simple and works well, the configuration aggravates antenna effect. For the benefit of those not familiar with the term, *antenna effect* (transmit case) can be described briefly as follows:

Antenna effect on a two-wire line: refers to line radiation as a result of "common mode" current. Part of the power (energy) fed to the feedline travels on it as though the two wires were tied together and were working against ground. Usually it results from load imbalance and/or excessive coupling from one side of a balanced antenna to the line. Common mode current adds in one wire and subtracts in the other. This in-phase component of the total power fed to the line acts as though the two wires were in parallel. So it gets radiated.

Antenna effect on a coaxial line refers to radiation from a coaxial feedline as a result of current flowing on the outside of the outer conductor. The current often is shared with the surface of a metal mast supporting a bottom-fed vertical antenna. Usually it results from either or both of the following:

- The outer conductor of the coax is directly connected to a point on the antenna not precisely at

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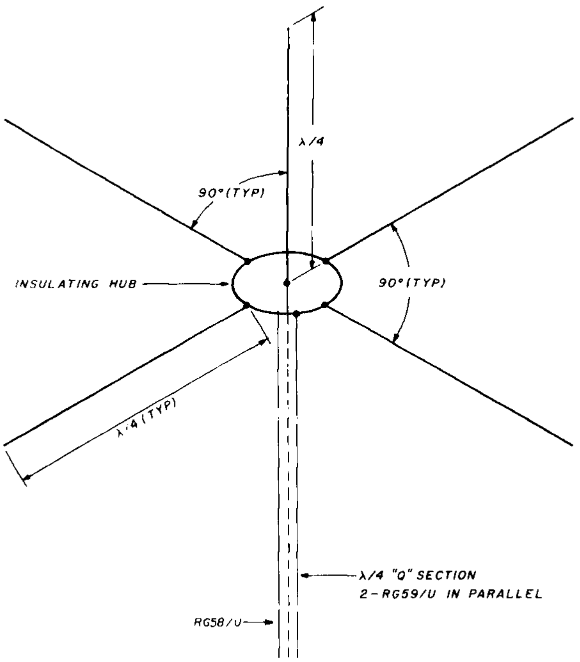

fig. 1. Typical Amateur adaption of the classic (original) Brown ground plane antenna, suitable for upper HF use on a flat roof, or for upper VHF use on a mast.

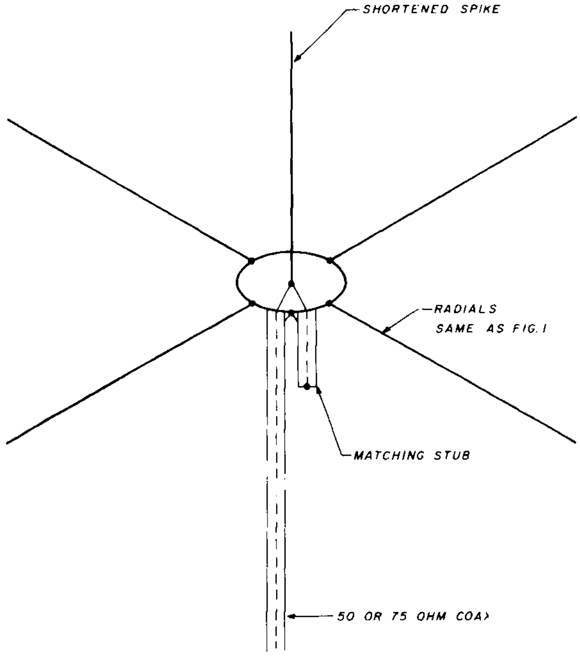

fig. 2. A later version by Brown eliminates the Q section and allows easy tweeking for a perfect match at a spot frequency. Useful where the antenna must be side-mounted on a shared mast of large cross section, or is other wise subjected to unpredictable detuning.

ground potential. As a result, current flows not just to the antenna, but is encouraged to flow back down the *outside* of the coax shield to a virtual ground as well. The "ground" can be a cabinet at VHF or house wiring at HF, for example.

- Excess inductive coupling exists from one half of the antenna to the outside of the coax or metal supporting mast (or both). The radials of a drooping ground plane are a case in point. If the coax is enclosed by a metal mast, spurious current flows on the surface of the mast. If the coax is draped along the outside of a metal mast, current flows on the surfaces of both and *both* radiate. To complicate things, the mast can have its own virtual ground.

is antenna effect all that devastating?

At just what point antenna effect becomes serious enough to be concerned about is debatable. The amount of current that can be tolerated on the outside of a coax line or mast or both depends to a great extent upon the following:

On transmit, let's first consider a well elevated, vertically polarized, omnidirectional VHF antenna with a feedline many wavelengths long. What is the result of antenna effect? Normally little of the power (energy) radiated with vertical polarization from such a long feedline (and the mast) will be directed at the horizon. For this reason, little of the spurious radiation will either add to or subtract from the energy being radiated effectively towards the horizon by the antenna proper.

So at VHF the end result of antenna effect on *transmit* is primarily a waste of power. But even if as much as 20 percent of the total radiated power is radiated by the coax, mast or both and thereby wasted, the resulting 1 dB loss is hardly anything to get worked up about. This is especially true when it buys worthwhile simplicity, convenience, or economy. However, if the radiating coax passes close to a TV receiver feedline, TVI may result if the TV coax suffers from poor shielding, or if the TV twinlead feeds a poorly balanced receiver front end.

On *receive*, the situation is different. Consider a coax line running through a localized area of high ambient noise. Antenna effect can cause noise picked up by the outer conductor of the coax to travel up to the antenna proper, then back down the coax to the receiver input just like a desired signal.

baluns vs. resonant isolators

Baluns of the type used with HF dipoles to minimize antenna effect are not suited for use with vertically polarized VHF antennas of the omnidirectional type. Instead, resonant detuning sleeves, cones, and radials are widely used as isolators or decouplers to "cool off" the mast and feedline. To what extent these produce any practical benefit in a particular installation by reducing antenna effect often is open to question. The use of coiled coax, ferrite beads, or a ferrite sleeve to choke off or dissipate surface current on the coax does not solve the metal mast problem.

Granted, no startling increase in transmitted signal strength will be noted when a resonant isolator of some kind is added to a simple VHF drooping ground plane. But even so, suppose it were possible to achieve a big reduction in antenna effect on the drooper without adding a resonant isolator. Suppose the various resulting advantages (such as they are) could be achieved by simply altering the dimensions and the droop angle.

something for nothing?

It's not only possible; it's *simple*. And there are no additional parts or materials, and without any additional manufacturing, construction, or assembly labor. Here's how: take the case of a conventional drooper that's supported by a metal mast enclosing the coax. Current is induced on the mast as a result of inductive (mutual impedance) coupling to the radials. If the coax exits the hub external to the mast (offset antenna mount), spurious current also appears on the outside of the coax.

This detrimental inductive coupling can be reduced somewhat by reducing the droop of the radials (the angle they make with the horizontal). The remainder can be compensated for by deliberately introducing a critical amount of conductive coupling of opposite phase. This is done by drastically offsetting the feedpoint from the voltage node.

The offset required for good cancellation is accomplished by simply making the radials as much as 30 percent (yes, thirty percent!) longer than the spike. Because precise cancellaton is somewhat frequency-sensitive, the effectiveness will vary a bit over the 2-meter band. However, in spite of the fact that optimized coupling neutralization is less than perfect over the whole band, the practical results obtained are most worthwhile.

Offsetting the feedpoint from the voltage node raises the feedpoint resistance. On the other hand, lessening the droop angle lowers the feedpoint resistance (by lowering the radiation resistance). By proper choice of these two values, it's possible to reduce antenna effect dramatically while at the same time achieving a 50-ohm feedpoint resistance. With an offset represented by a 28-30 percent radial-to-spike length differential, a 27-29 degree droop angle provides both maximum reduction in antenna effect *and* a 50-ohm feedpoint resistance. To some extent the optimum values vary with conductor diameter, mast diameter, and hub geometry. Less important is whether the coax departs the hub inside or outside the tubular mast.

Neither the 1.5 VSWR bandwidth nor the antenna gain is noticeably degraded by drastically offsetting the feedpoint and reducing the droop of the radials. And in case you're skeptical about the horizon gain comparisons, it's true that the spike is slightly shorter on an offset drooper. Likewise, the resultant vertical component or vector of the drooping radials is a little shorter for an offset drooper than for a regular drooper. But careful measurements show this does not affect the gain significantly. Increased current throughout the antenna resulting from the lower radiation resistance (about 35 ohms) compensates. Also, power wasted by line and mast radiation is reduced to insignificance.

Out of curiosity, a check was made to see just what would happen if the feedpoint of a classic 90-degree ground plane were deliberately offset. When the resonant radials were lengthened, an arbitrary 12 percent and the spike length and matching adjustment were re-optimized, antenna effect was virtually eliminated. However, overall performance was no better than that of an offset drooper, which has the advantage of requiring no matching device. Because of the latter, no further work was done with 90 degree ground planes. It is interesting to note that when resonant radials at 90 degrees to the mast were shortened experimentally by no more than a few percent, antenna effect was markedly aggravated.

improvement over what?

A check was made on drooper dimensions given in various handbooks and past magazine articles. Also, two different commercially manufactured 2-meter droopers were purchased and the dimensions measured. The effective radial length ranged from slightly longer than the spike to slightly shorter. All were series-fed at the hub without benefit of a matching device. None employed a resonant decoupler, such as an extra set of radials below the antenna oriented 90 degrees to the mast.

The reduction of antenna effect provided by drastically offsetting the feedpoint of a drooping ground plane depends, among other things, upon how bad the antenna effect is to begin with. This varies somewhat with location of the voltage node on the regular drooper used for comparison. For instance, antenna effect definitely will be worse if the radials of a regular drooper are significantly shorter than the spike, as was the case with one of the name brand antennas tested. This makes an offset drooper appear just that much better by comparison.

a spurious top-fed Marconi is the culprit

The degree of improvement will also vary with the length of the coax. This is explained as follows: the outside of the coax shield will do its best to act like a "harmonic Marconi" fed at the top instead of the bottom. Just how effective (and therefore how objectionable) this is will depend to a great extent upon the electrical length of the coax shield in wavelengths from "virtual ground" to the point of attachment to the radials.

Unfortunately, with 40 feet of coax, QSY from 144 to 148 MHz can change the electrical length of the shield substantially. This in turn affects the feedpoint impedance of the spurious "upside down harmonic Marconi." The variation can affect the amount of line radiation by 10 dB or more in the case of a conventional drooper. Things get even more involved when comparing an offset drooper to a regular drooper for antenna effect simply by swapping them at the end of the same feedline. The radials of a 2-meter offset drooper are longer than a quarter wave and their impedance to ground at their feedpoint therefore is affected. This was taken into account when designing the antenna and making comparison measurements.

the test set-up

For reference, a 2-meter drooper with optimized offset feed was constructed with four radials 30 percent longer than the spike and having a droop angle of 28 degrees. For starters for those who might like to experiment, the 1/8 inch diameter spike measured 18 3/8 inches and the 3/32 inch diameter radials 24 inches, all of brass welding rod. Size and configuration of the hub will affect the lengths, especially that of the spike. Note that while the spike of an offset drooper is only slightly shorter than normal, the radials are much longer. The result is that the overall length of the spike plus a radial is nearly 10 percent longer than for a conventional drooper. This involves the integral coupling neutralization and impedance transformation process, and a rigorous explanation is not within the scope of this article.

The offset drooper reference antenna just described was compared to four different conventional 2-meter droopers for antenna effect, 1.5:1 VSWR bandwidth, and field strength at zero elevation angle. One of the conventional droopers was constructed to dimensions specified in a magazine article. Two were dissimilar name brand units. None employed a detuning sleeve, cone, or extra set of radials. Measurements were taken near 144, 146, and 148 MHz with four feedline lengths differing by 1/8 wavelength.

Tests were first run with the coax leaving the hub contained within a 3/4 inch O.D. mast for the first 5 feet. The tests then were repeated with the hubs offset from the top of the 5 foot upper mast section. With the hubs offset, the coax was brought down snugly against the outside of the mast for its entire length. Next, the hub was mounted concentrically atop a 12-foot section of aluminum tubing strapped to a steel vent pipe, with the coax brought down inside the tubing. While these changes did cause the readings to change, the overall improvement exhibited by the offset drooper did not change significantly. The coax employed was RG/8X-8M 0.25 inches OD, 52 ohm.

test results

A spurious RF current sniffer was improvised to quantify the amount of improvement exhibited by the offset drooper. The sniffer was provided with a plastic spacing fixture that allowed choice of two spacings in order to increase the useful range. It was checked for directional effect (by reversing it) and the directivity was found to be negligible. Relative calibration in dB was accomplished by simply varying the measured power fed to a leaky dummy load which was space-coupled to the sniffer.

The reduction in antenna effect when using the offset drooper exceeded 11 dB for three of the comparison antennas tested. The improvement obtained over the fourth regular drooper (the one with the longest radials) measured 10 dB. The greatest improvement was observed when the offset drooper was compared to the regular drooper having the shortest radials (about 5 percent shorter than the spike). The improvement figures reflect those obtained or exceeded with the worst case combination of frequency, line length, and mast and feedline configuration.

This article is not intended to show the reader how to build something exactly like the author's, but instead to explain a simple method of improving the performance of the venerable drooping ground plane. Just make the spike a little shorter, the radials a lot longer and bend the radials up a bit. It is applicable to modification of existing antennas as well as to new construction. To approach the maximum possible improvement, all you need is a VSWR meter. Just make the radials 30 percent longer than the spike and droop them 28 degrees (or as close as you can). Optimum length for the spike is usually about 6 percent shorter than for a regular drooper that uses similar hub and element diameter.

If this doesn't result in equal VSWR at the band edges, the spike is too long or too short. Once the radial length and droop are optimized, the center frequency can be fudged about 1 percent just by trimming the spike.

The reader will notice that no VSWR numbers are given for an optimum offset drooper. The reason for this is that a conventional drooper with bad antenna effect can give specious VSWR readings, making any offset drooper comparisons meaningless. The deceptive readings obtained with a standard drooper will change with coax and mast lengths, and the readings

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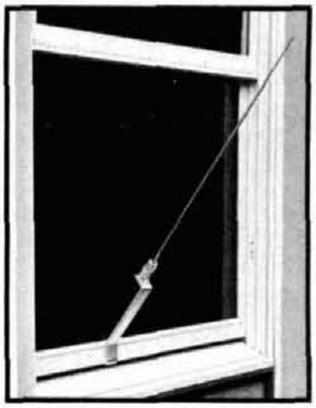

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can be considerably better (or worse) than the true antenna VSWR. To a lesser extent this applies also to a classic 90 degree ground plane. But with an optimized offset drooper, readings will change little with line and mast lengths (except as reduced by line attenuation), and can be relied upon. The true VSWR of a properly optimized 2-meter offset drooper will approach 1.0:1 over much of the band, and be found very low at the band edges.

so why not?

In closing, I hope the reader accepts the fact that while a bad case of antenna effect on a VHF drooper isn't necessarily disastrous, minimizing it certainly can't hurt. It's easy to do and all it can do is good — so why not?

references

1. *Ground Plane Antenna*, U.S. Patent 2,234,333, issued March 11, 1941, to G.H. Brown, J. Epstein, and R.F. Lewis of RCA Laboratories.

2. *Improved Ground Plane Antenna*, U.S. Patent 2,275,342, issued March 3, 1942, to G.H. Brown.

3. Woodrow Smith, *The Antenna Manual*, Editors and Engineers, Ltd, Santa Barbara, California, 1948.

bibliography

Vance, Harold C., Sr., K2FF, "The Ground Plane Antenna: Its History and Development," *ham radio*, January 1977, page 26.

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