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Experimental Determination of Ground System Performance for HF Verticals

Part 7

Ground Systems With Missing Sectors

Here is the author's research on radial systems that do not make a full circle around the vertical antenna.

A very common problem with vertical ground systems is the impracticality — in many situations — of laying down a symmetric circle of radials. Some object, frequently a structure or a property line, may make it impossible to place radials in certain areas around or near the base of the antenna. I have received many questions on this subject so I decided to do some experiments where I compared the signal strength (S_{21}) of a ¼ λ vertical antenna that has a full 360° radial fan to one with a substantial portion of the radial fan missing in one sector.

The first part of the experiment was done at four frequencies: 7.2, 14.2, 21.2 and 28.5 MHz. The second part the experiment was done at 7.2 MHz only.

Radial Fan Configurations

For this series of tests I chose to use a symmetric 360° radial fan with thirty two 33 foot radials (¼ λ on 40 m) as the reference configuration (C1). As shown earlier in this series, a radial system with thirty two ¼ λ radials is usually pretty good. You can add more radials, but the gain is relatively small, so a 32-radial system is a good compromise, and probably more typical of amateur installations. The radials were close to ¼ λ on 40 m. Figure 1 shows a plan view of the initial radial fan geometries.

The four 180° sectors were arranged in relation to the receiving antenna as follows:

1) Radials toward (C2),
2) Radials away (C3),
3) Radials to the left (C4), and
4) Radials to the right (C5).

Both right and left configurations, which ideally should be identical, were run as a check on the consistency of the measurements.

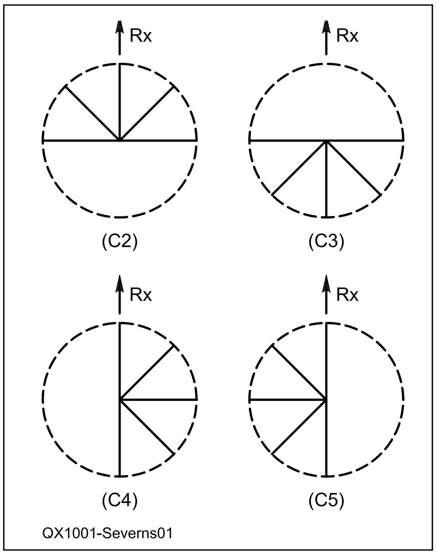

Figure 1 — Missing sector radial layouts.

After running tests using configurations C1 through C5, I realized that some additional radial configurations might be interesting. In particular I wanted to see how much adding some short radials in the missing sector would improve things.

I added the configurations shown in Figure 2 to the experiment:

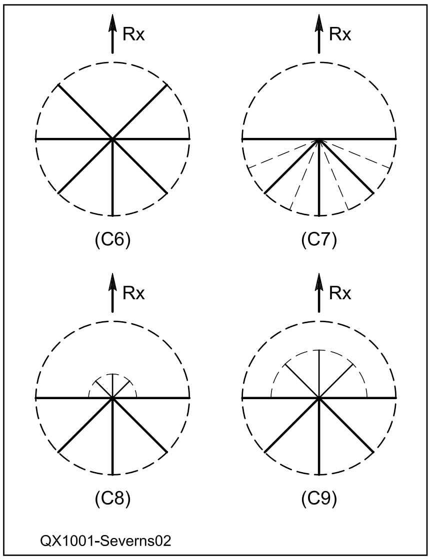

Figure 2 —Additional asymmetric ground systems.

Table 1

Effect of a 180° Sector Ground System on Signal Strength (S_{21}) in a Given Direction Relative to the Receive Antenna

Frequency (MHz)	*C2 Toward RX (dB)*	*C3 Away from RX (dB)*	*C4 Left (dB)*	*C5 Right (dB)*
7.2	–0.42	–1.91	–0.82	–0.94
14.2	–0.57	–2.42	–1.20	–1.24
21.2	–0.69	–3.00	–1.24	–1.33
28.5	–0.55	–3.23	–1.26	–1.58

Table 2
S_{21} Test Results for the Added Radial Configurations

Radial Configurations	*$|S_{21}|$ Referenced to C1 (0.0 dB)*
C6	–0.44
C3	–1.91
C7	–1.39
C8	–1.52
C9	–0.34

5) A 90° missing sector (7 radials removed, 25 radials remaining) (C6). The axis of the missing sector was pointed at the receiving antenna.

6) To C3, which has 17 radials facing away, I added an additional sixteen 33 foot radials between the seventeen already there (33 radials total) (C7). The missing 180° sector was facing the receiver.

7) To C3 I added fifteen 8.5 foot radials in a fan towards the receiving antenna. These are 1/16 λ radials on 40 m (C8). C9) To C3 I added fifteen 17 foot radials in a fan towards the receiving antenna. These are ⅛ λ radials on 40 m.

Test Results

Modeling ground systems with missing sectors using *NEC* indicates that compared to a full 360° system we should see both a reduction in the peak signal and a distortion in the pattern; in other words, a front-to-back ratio not equal to 0 dB.

Experimental results are given in Tables 1 and 2. Note that Tables 1 and 2 show the *difference* in dB from the 360° radial fan (C1), which is the reference.

Clearly sector radial systems have an impact on the radiated signal. In the direction of the remaining radials the signal loss is on the order of 0.5 dB, but in the direction of the missing sector the loss is from 1.9 to over 3 dB. If you have a 3 dB loss, that means you have lost half your power. Not good!

The test results qualitatively agree with *NEC*, the peak amplitude is reduced and the pattern is distorted when only a partial radial fan is employed. The radial system used for the tests reported in Table 1 has 33 foot radials, which of course are long for frequencies above 7.2 MHz. As we saw in the discussion for multi-ground systems (Part 6), the system with all 40 m radials gives the best performance, even better than if we used thirty two ¼ λ radials tailored for each band.

The test results for radial configurations C6 through C9 are given in Table 2. All of these tests were done at 7.2 MHz.

The first thing we see is that omitting the seven radials in a 90° sector (C6) does not seem to do too much harm, only –0.44 dB. Eliminating all the radials in a 180° sector (C3) is not good, however (–1.91 dB). The loss jumps by almost 1.5 dB over the 90° case!

Taking the radials removed from C1 (to form C3) and adding them between the remaining radials in C3 (C7) helps a little bit, reducing the loss by 0.5 dB. If, instead, we add fifteen 1/16 λ radials (C8) in the missing sector we get a similar improvement, about 0.4 dB. Despite some improvement, the signal loss for both C7 and C8 is still substantial. What really seems to help is to put fifteen 1/8 λ radials (C9) in the missing sector. Unfortunately, that may not always be possible.

Some Closing Comments

Overall, it’s pretty clear both from modeling and experiment that sector ground systems can reduce your signal substantially in some directions and produce a distorted pattern.

What can we do about this? The first thing is to remember that the field intensity around the vertical increases rapidly as we get near the base of the antenna.[1] If we move the base of the antenna away from the obstacle as little as 1/16 λ or better yet 1/8 λ, so that we can have at least some radials in the sector towards the obstacle, the losses will be reduced. As shown above, 1/8 λ spacing can be quite effective. In the process of moving the base away from the obstacle you may have to shorten some of the other radials on the side away from the structure but that may be acceptable. Another possibility would be to move the base from the side of the building to a corner which might allow the radial fan to be increased from 180 to 270°. As the test data shows, this can be very helpful.

These experiments were done in an ideal situation. There was no actual structure next to the antenna. In addition to the losses we see in this idealized situation, it is very likely that the structure blocking the radial fan will increase the loss. It is difficult to estimate how much the loss will increase, but it's not likely that the building will improve your signal! Another factor to consider is the soil characteristics. My soil, over which these tests were conducted, would be rated as good or even very good, depending on the time of year. Poorer soils would result in even larger negative effects due to the use of a sector ground system than those shown in Tables 1 and 2.

What I have shown here represents only a few of many possibilities. It's not possible to experimentally examine all possible situations, but *NEC* modeling should give you a good qualitative feeling for your particular situation. One common situation that I did not have time to examine experimentally is the case where the base is alongside the house but not too far from a corner. The conventional wisdom is that you should run the radials along the side of the house to the corner and then fan them out from there. I don’t think that can hurt but keep in mind that the farther you are from the corner, the less effective this scheme is likely to be.

Rudy Severns, N6LF, was first licensed as WN7WAG in 1954 and has held an Extra class license since 1959. He is a consultant in the design of power electronics, magnetic components and power-conversion equipment. Rudy holds a BSE degree from the University of California at Los Angeles. He is the author of three books and over 90 technical papers. Rudy is an ARRL Life Member, and also an IEEE Fellow.

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[1] Rudy Severns, N6LF, “Verticals, Ground Systems and Some History,” *QST*, Jul 2000, pp 38-44.