ground screen — an alternative to a buried radial system

Using a ground screen to complement or replace the wire radial system to reduce ground losses

As an alternative to a radial system, the ground screen consists of a wire mesh of sufficient size to act as a capacitive connection to the earth, similar to a counterpoise, but laid on the ground instead of suspended overhead. It can consist of hardware or construction mesh, welded fencing, or even chicken wire, although the latter is less durable. I have been using a screen for fifteen years as a replacement for a radial ground system and find that it works quite well, although until recently I had been unable to make quantitative measurements on its efficiency.

A 1/2-wavelength wire radial system is a very effective ground return, although it has certain practical disadvantages. First, a lot of work is involved in installing the radials, especially if you move very often. Second, the area required for a low-band system is quite large and hurriedly-buried wires are prone to damage by the lawn mower. The ground screen has none of these drawbacks. My first ground screen was installed under a 60-foot (18.3m), base-insulated tower erected in my parent's back yard in suburban Cincinnati, Ohio. I tried this system since the driveways on each side of the tower left room for nothing else. The screen then consisted of two 15 by 5-foot (4.6x1.5m) lengths of construction mesh, one on each side of the tower.

I also tried a 1/4-wavelength flat top but found a single wire has such a small cross-section that it was an ineffective loading system for the tower. After many variations, I finally settled on a 65-foot (19.8m) sloping vertical wire with a 1/8-wavelength flat top. This system worked quite well both stateside and into Europe and was an effective testimony for the ground screen. Unfortunately, my beautiful base-insulated tower was a bust on 160 meters.

Several years later, I had my own home in Denver, Colorado, and could hardly wait to erect an extensive antenna system. Finances were short, however, so I settled on a 48-foot (14.6m) vertical made from 1-inch (25mm) aluminum tubing. A good radial ground system

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could not be installed under this vertical either, since the house and patio blocked the area to the South and the lot line was only 25 feet (7.6m) away to the North.

As before, I decided to install a ground screen due to the limited space available. I bought a 20 by 3-foot (6.1x0.9m) length of 1/2-inch (13mm) hardware mesh which was woven with no. 18 AWG (1mm) steel wire and then heavily dip galvanized. It was laid out along the house right under my 48-foot (14.6m) L-network-fed vertical, and the results were excellent on 40 and 75 meters.

table 1. Ground screen configurations under the test vertical.

1	10 x 3 feet (3x0.9m) with vertical centered
2A	20 x 3 feet (6x0.9m) with vertical centered
2B	20 x 3 feet (6x0.9m) with vertical 5 feet (1.5m) from one end
3	30 x 2 feet (9x0.6m) with vertical centered (same area as no. 2)
4	50 x 2 feet (15.2x0.6m) with vertical centered
5A	75 x 2 feet (22.9x0.6m) with vertical centered
5B	75 x 2 feet (22.9x0.6m) with vertical 25 feet (7.6m) from one end
6	75 x 2 feet (22.9x0.6m) + 20 x 3 feet (6x0.9m) in a 90° cross with vertical centered
7	45 x 2 feet (13.7x0.6m) + 20 x 3 feet (6x0.9m) in a 90° cross with vertical centered
8	45 x 2 feet (13.7x0.6m) + 30 x 2 feet (9x0.6m) in a 90° cross with vertical centered (same area as no. 7)
9	45 x 2 feet (13.7x0.6m) + 25 x 5 feet (7.6x1.5m) in a 90° cross with vertical centered
10	45 x 2 feet (13.7x0.6m) + 30 x 2 feet (9x0.6m) + 20 x 3 feet (6x0.9m) in 60° radial strips with vertical centered
11	45 x 2 feet (13.7x 0.6m) + 30 x 2 feet (9x0.6m) + 20 x 3 feet (6x0.9m) in overlapping parallel strips with vertical centered
12	30 x 2 feet (9x0.6m) + 30 x 2 feet (9x0.6m) + 20 x 3 feet (6x0.9m) + 15 x 2 feet (4.6x0.6m) in overlapping parallel strips with vertical centered

About a year later the vertical came down in an ice storm — I replaced it with a 50-foot (15.2m) tower and a four-element, 20-meter beam. For 40 meters I suspended a 45-foot (13.7m) vertical wire 5 feet (1.5m) from the side of the tower and tuned it with an L network, as I had done with the previous vertical. The tower affected the feed impedance of the wire, but did not seem to degrade its radiation since the wire vertical worked as well as a 40-meter inverted Vee.

A year and a half later the 40-meter wire vertical was replaced by a 40-meter beam on a 20-foot (6.1m) mast above the existing 20-meter antenna. With the additional top-loading provided by the 40-meter beam, it was now possible to use the existing 20 by 3 foot (6.1x0.9m) ground screen to shunt-feed the tower system on 160 meters. According to an article in *ham radio*,[1] the 65-foot (19.8m) tower with a two-thirds size 40-meter beam at the top and a four-element 20-meter beam 15 feet (4.6m) below should have an electrical length of about 110 feet (33.5m). The radiation resistance, however, is lower than that of a wire that long, so my ground screen was put to the test again. The tower ground-screen system was quite effective on 160 meters, and it allowed me to maintain weekly schedules through the 1976 season until May, over the 1100 mile path between Denver and Cincinnati. Reports up to 20 dB over S9 that were received from K1PBW made me decide that more quantitative data had to be obtained on the ground-screen idea.

In May, 1976, I went to WØSPM's farm with my GR916A rf bridge, GR1001-A signal generator, Drake R-4C receiver, three lengths of tubing for an antenna, and 210 square feet (20m^2) of new chicken wire for a ground screen. While chicken wire is no rival for mesh or fencing in a permanent system, it was much cheaper to cut it up into different lengths for experiments.

A 36-foot (11m) high, 1 inch (25mm) constant cross-section aluminum tubing vertical was erected and used for all of the following tests. This length was chosen since it was easy to install and could be part of an easily built phased array. Antenna impedance measurements were made on 1.8, 3.6, and 7.2 MHz. Various shapes and sizes of ground screen were tested under the vertical including a single strip, two lengths in a 90° cross, radial strips at 60°, and different overlapping lengths laid parallel to each other. The fourteen arrangements of screening are listed in **table 1**, while **table 2** gives the resistive and reactive antenna measurements for each case.

resistive changes

Since no significant change in reactance was noted beyond 60 square feet (5.6m^2) of ground screen, only resistive changes will be discussed. These resistive values consist of the radiation resistance R_r plus the ground loss R_g. When a single two-foot (0.6m) wide strip was used, the lowest total resistance (R_r + R_g) occured with a screen length of 50 feet (15.2m) on 1.8 MHz and 3.6 MHz, and 30 feet (9.1m) on 7.2 MHz. With greater lengths, the radiation resistance (R_r) probably increased as the screen departed from a lumped capacitance and began acting as part of a dipole leg. There was a similar occurrence with the long cross in **case 6** which resulted in a larger R value than with the smaller screen area of the **case 7** cross. **Case 9** yielded the lowest total R on all three bands.

table 2. Impedance measurements for the 36 foot (11m) vertical with the different ground screen arrangements.

	1.8 MHz	3.6 MHz	7.2 MHz
1	25.0 − j730	28.0 − j286	85 + j67
2A	18.7 − j739	22.0 − j285	80 + j72
2B	17.7 − j739	23.0 − j278	80 + j71
3	13.5 − j728	18.5 − j281	78 + j81
4	11.0 − j719	20.0 − j274	81 + j81
5A	12.8 − j711	21.7 − j276	82 + j71
5B	12.6 − j717	21.5 − j275	81 + j81
6	11.2 − j714	18.0 − j281	74 + j77
7	8.8 − j717	16.6 − j278	74 + j76
8	8.8 − j719	15.7 − j279	72 + j78
9	7.9 − j717	14.6 − j279	71 + j76
10	8.2 − j717	15.6 − j279	72 + j76
11	8.2 − j717	14.5 − j279	73 + j78
12	8.5 − j717	14.8 − j279	72 + j76

The radial strip configuration of **case 10** had a resistive component slightly higher than in **case 9**, which was somewhat surprising. I thought it would have been equal to or better than that of the cross, but since more of the screen overlapped itself in this configuration, it is probable that the decrease in area caused the increase in R. The ground resistance of the overlapping parallel strips was also slightly higher than the **case 9** cross. I decided not to make the strips shorter and more numerous because of the difficulty in keeping all the pieces bonded together.

As would be expected, there were greater percentage changes on 1.8 and 3.6 MHz due to the ground losses (R_g) being a larger part of the R component. With approximately 200 square feet ($18.6m^2$) of screening, the cross (with one leg at least 5 feet [1.5m] wide) yielded the lowest ground loss. A single 30 by 3-foot (9.1x0.9m) strip of half that area, however, was only 38 per cent less efficient. This is the layout I am using under my tower at the present time.

A GR-916A rf-impedance bridge was used to make the impedance measurements. The chicken-wire mesh can be seen laid on top of the ground.

theoretical losses

Now, compare the theoretical impedance of a 36-foot (11m) vertical over a perfectly conducting ground with that of the test installation. This will enable the ground losses to be calculated. The following data, for 36-foot (11m) verticals, is from the *ARRL Antenna Book* graphs:

7.2 MHz	0.277 wavelength	100° = 48 ohms
3.6 MHz	0.139 wavelength	50° = 9 ohms
1.8 MHz	0.069 wavelength	25° = 2 ohms

Subtracting the theoretical from the measured values yields the following ground losses and efficiency

7.2 MHz	23.5 ohms	67%
3.6 MHz	5.6 ohms	62%
1.8 MHz	5.9 ohms	25%

The ground losses are higher on 7.2 MHz than were expected, but are probably due to the lower conductivity of the earth at this frequency. On the other hand, to obtain more than 60 per cent efficiency for a 1/8-wavelength vertical on 3.6 MHz is quite encouraging and might foster some interest in phased arrays on 80 and 75 meters, using only a ground screen instead of wire radials.

The 25 per cent efficiency on 160 meters is not spectacular, but compare it with the results of Brown, Lewis, and Epstein[2] using eight 135-foot (41m) radials on 3 MHz. With a 25 degree antenna they obtained only 27 per cent efficiency and a 5-ohm ground resistance, but a 50 degree antenna gave a 51 per cent efficiency with an 8.5-ohm ground resistance. The efficiency goes up because the radiation resistance increases 4.5 times, yet the ground resistance also goes up because the taller radiator induces currents into the earth at a greater distance from the antenna.

Using fifteen 135-foot (41m) radials on 3 MHz, Brown measured a ground resistance of 3.2 ohms. When he added a 9 by 9-foot (2.7x2.7m) copper screen the resistance dropped to 1.6 ohms. One hundred and thirteen radials 135 feet (41m) long (0.4 wavelength) brought this down to 1 ohm, but, unfortunately no information is available on the ground screen alone. One might use the parallel resistor equation however, to extrapolate from his data a probable ground screen resistance of 5 to 6 ohms. These values are very similar to the 5.6 and 5.9 ohm reading obtained on 3.6 and 1.8 MHz with my test system.

With ground losses as low as 6 ohms obtainable by using only 200 square feet ($18.6m^2$) of ground screen, efficient vertical radiators are within the reach of most amateurs. While good efficiency is obtained with a 36-foot (11m) radiator on 80 meters, some sort of top loading is advised on 160. A 2-ohm radiation resistance is just too low for good efficiency with most amateur ground systems.

I feel the ground screen is a good alternative to the wire radial ground system. I've used it for a long time and am glad to see test measurements that confirm its effectiveness.

An additional aspect of wire screening is that its application does not have to be limited to one type of installation. If you have the room and initiative to install a radial ground system, add a screen, too. If the antenna is approximately 1/4 wavelength or shorter, a screen will reduce the ground losses in the high-current zone at the base of the antenna. For your next vacation or Field Day project, a screen made of chicken wire offers the added benefit of being as easy to roll back up as it was to unroll. It is available almost anywhere, so you do not have to bring it with you. The next time you erect a new vertical, or plan to improve an existing one, consider a ground screen as either a substitute for radials, or as an adjunct to an existing radial ground system.

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references

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