Using a Radial, Switchable, Sector Ground Screen to Produce Azimuthal Directivity for a Monopole Antenna

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Abstract **─** Ground-mounted monopole antennas are usually driven against a radial-wire ground system to control their input impedance and to improve their radiation efficiency. This results in a radiation pattern that is uniform in azimuth angle with a front-to-back ratio of 1, or 0 dB. The use of a sectorial ground screen, one whose radial or angular extent is varied to produce a radiation pattern having azimuthal directivity has received some attention. An alternate approach also is explored in this discussion. It involves exploring the effect of varying the number of "active" radials in an otherwise uniform ground system of radial wires, an active radial being one that is electrically connected to the base of the monopole. A "passive" radial on the other hand is one that is separated from the monopole by a switch. By varying the number and angular locations of the active and passive ground wires, the resulting azimuth pattern can be varied in angle and directive gain. This arrangement makes possible a steerable pattern, something not usually associated with ground-mounted monopoles. The antenna and ground screen are modeled using the well-known NEC package. For convenience in modeling, active radials are made into passive ones by adding a large resistance between the base of the monopole and a given radial. Directive gains of more than 5 dB are found to be possible.

Index Terms **─** Directivity, ground screen, monopole antenna, steerable pattern, switching radials.

I. INTRODUCTION

Sectorized ground screens have been examined previously using either a disk [1] or an arrangement of radial wires that are limited to a specified angular sector [2,3]. The approach taken here is to generalize [2] to a ground screen comprised of uniformly spaced wires that cover 360 degrees around the base of the monopole. This is illustrated in Fig. 1 for the 30 radial-wire system used to obtain the results presented below.

A sectorized ground screen is made here by inserting a 10-MOhm resistor at the connection points of one or more radials to the base of the monopole to create a passive, or loaded, radial. The unloaded radials are denoted as active radials. The resultant pattern can be steered in azimuth by rotating the loading arrangement in angle. The number of passive radials is varied from 0 to 30, with 0 loads denoted as the reference case. The input powers are normalized in the pattern comparisons that follow.

Some more recent publications somewhat related to this general problem are [4-6]. A comprehensive review of ground screens can be found in a book devoted to monopole antennas [7]. A discussion on the effects of elevated and buried ground screens on monopole-antenna performance can be found in [8]. The results presented in [2], [8] and here have been obtained using NEC, the Numerical Electromagnetics Code [9].

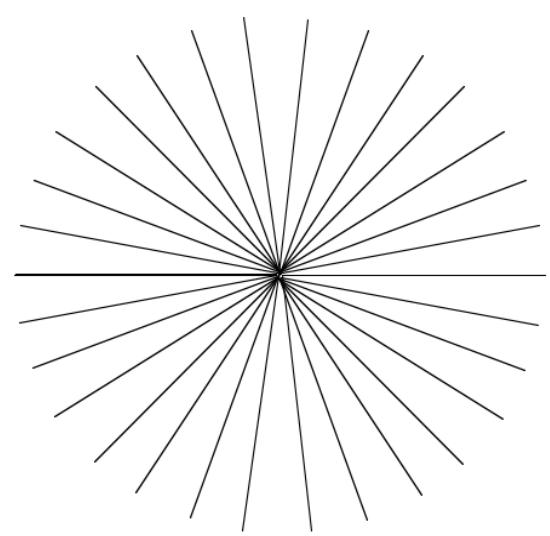

Fig. 1. A 30-wire radial ground screen.

The nominal model parameters are:

- Operating frequency of 10 MHz (30-m wavelength).
- Wire radius of 0.001 m (3.33x10-5 wavelengths).
- Monopole height of 7.5 m (¼ wavelength).
- Radials are 9-m long (0.3 wavelengths), and are 0.1 m (3.333x10-3 wavelengths) above the interface.

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-- A ground conductivity of 10-3 mhos/m and relative dielectric constant of 4.

-- Segment lengths throughout are 0.75 m (0.025 wavelengths).

II. REPRESENTATIVE RESULTS

Varying the number of loaded radials from 0 to 29 yields the elevation-pattern peak plotted in Fig. 2. The elevation pattern in Fig. 3 is obtained using 13 active radials whose effect is to provide a peak at about 5.7 dB at an elevation angle of about 35 degrees.

The azimuth pattern for 13 active radials is plotted at 35 degrees of the elevation pattern in dB in Fig. 4 and on a linear scale in Fig. 5, where the latter plot deemphasizes the sharpness of the pattern minimum.

The input and radiated powers for a 1-V source are plotted in Fig. 6 as a function of the number of loaded radials. Both the radiated and input powers monotonically decrease as the number of active radials is reduced from 30 to 1. The radiation efficiency also decreases from about 52% of 0.0115 w to 37% of 0.0052 w when the number of active radials is reduced from 30 to 12, as exhibited in Fig. 7.

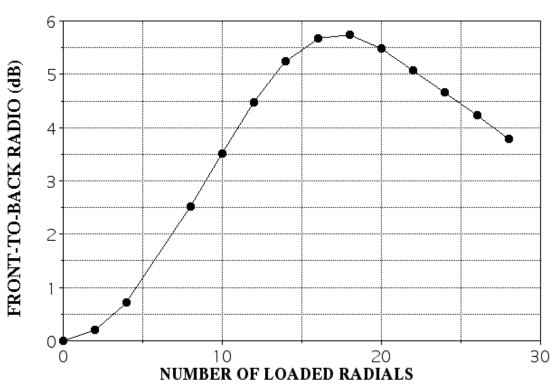


Fig. 2. The directive elevation gain as a function of the number of loaded radial wires.

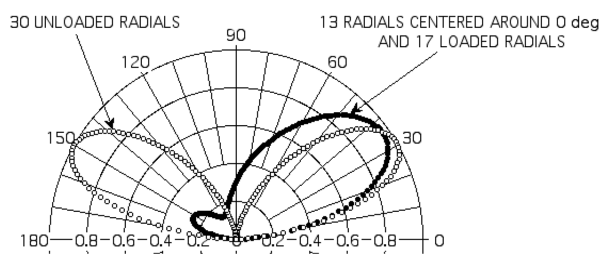


Fig. 3. The elevation patterns for 30 and 13 active radials respectively for equal input powers normalized to the reference pattern of 30 active radials.

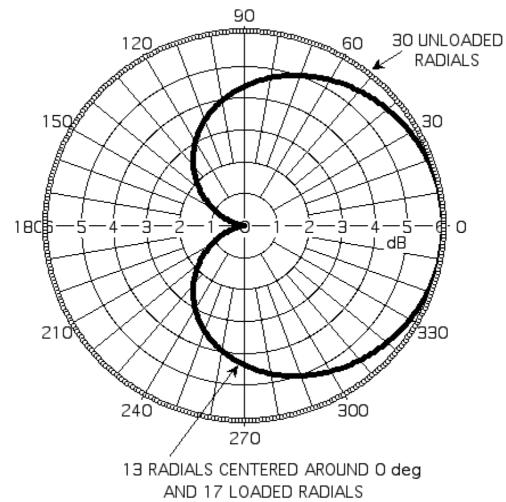


Fig. 4. The azimuthal pattern in dB for 30 and 13 active radials respectively, at the peak of their respective elevation patterns for equal input powers.

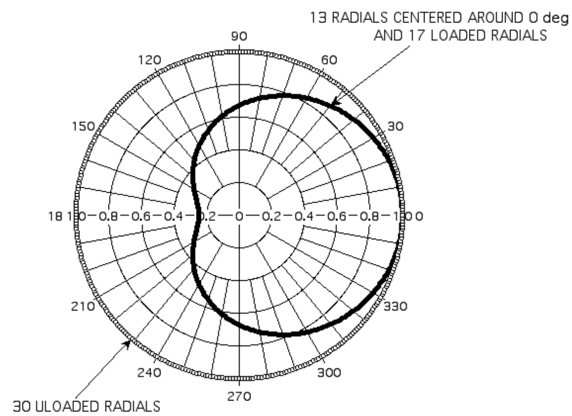


Fig. 5. The patterns of Fig. 4 plotted on a linear scale.

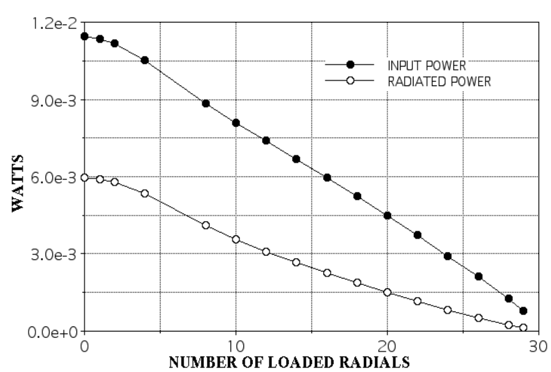


Fig. 6. Input and radiated power variation as a function of the number of loaded radials.

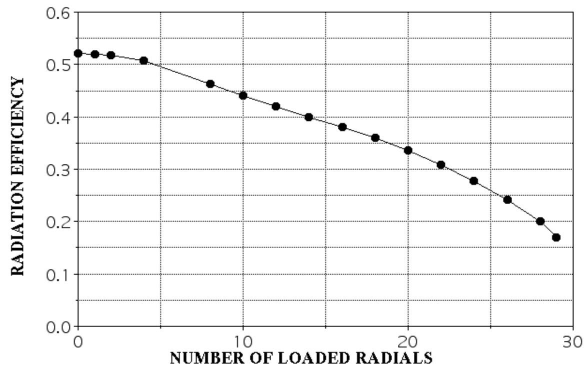


Fig. 7. Radiation efficiency as a function of the number of loaded radials.

The monopole and total ground-wire currents are shown as a function of position in Fig. 8 for case of 30 active ground wires. While the currents are equal at the base of the monopole it is interesting to see that the sum of the ground-screen currents otherwise exceeds that on the monopole.

The spatial distribution of power radiated by the monopole and 30 active radials as obtained from FARS [10] is shown in Fig. 9. More than 90% of the radiated power comes from the monopole in spite of the sum of the current on the 30 active radials exceeding that of the monopole. The total power coming from the monopole and radials is 4.53×10^{-3} w and 3.44×10^{-4} w respectively.

The monopole admittance is found to vary monotonically as the number of loaded radials is increased as shown in Fig. 10. The directivity is plotted as a function of the ground-wire lengths in Fig. 11 for the nominal case of 17 loaded radials and maximizes at about the length of 0.3 wavelengths used in this study.

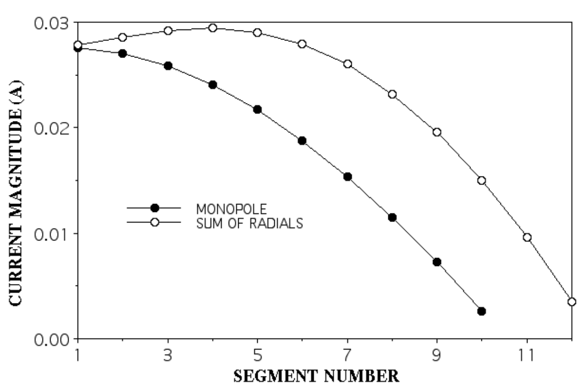


Fig 8. The current magnitudes on the monopole and sum on the 30 active radials.

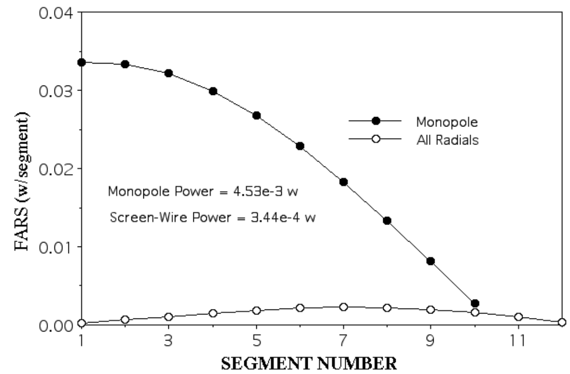


Fig. 9. The distribution of the radiated power from the monopole and 30 active radials.

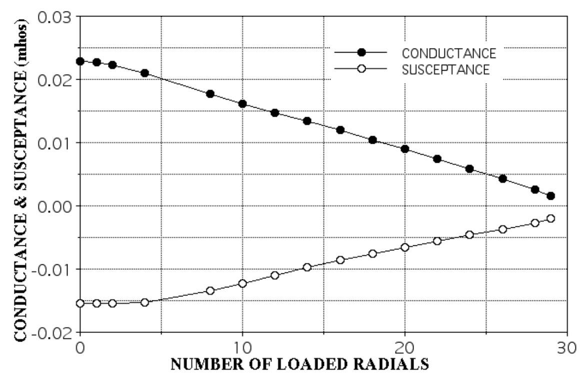


Fig. 10. The conductance and susceptance of the monopole as a function of the number of loaded radials.

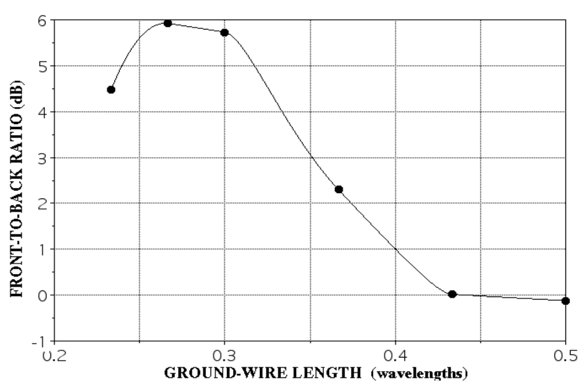


Fig. 11. The dependence of the directivity on the length of the ground wires.

III. CONCLUDING COMMENTS

The sectorized ground system has some interesting properties:

1) It maintains approximately the same far-field power flow in the direction of the unloaded radials.
2) It reduces the far-field power flow in the direction of the loaded radials due to increased ground loss.
3) It permits the pattern to be rotated in azimuth by switching the loaded sector.
4) However, loading the radials to produce directivity does reduce the overall radiation efficiency.

Other arrangement might be worth exploring. One possibility is to vary the lengths of some of the radials in a fashion similar to what is done above at the base of the monopole. Another would be to connect the ends of the radials to grounding stakes. In addition to providing more pattern control, such arrangements might also improve the radiation efficiency.

REFERENCES

[1] J. R. Wait, et al., "Antenna performance influenced by the finite extent and conductivity of ground planes: A collection of reprints," *Mitre Corporation, M90-79, AD-A232 132*, September 1990, including: James R. Wait and Lillie C. Walters, "Influence of a sector ground screen on the field of a vertical antenna," *U. S. National Bureau of Standards*, Monograph 60, April 1963.

[2] E. K. Miller, J. N. Brittingham, and J. T. Okada, "Explicit modeling of antennas with sparse ground screens," *Electronics Letters*, vol. 14, no. 19, pp. 627-629, 1978.

[3] J. R. Hallas, "Vertical monopoles can indeed be directive," *American Radio Relay League QST*, pp. 59-60, April 2015.

[4] M. Hirose and M. Miyake, "Pattern control of a 1/4 λ monopole antenna on a handset by passive loading," *Universal Personal Communications: Gateway to the 21st Century, Conference Record*, vol. 1, pp. 44-48, October 1993.

[5] J. F. Janek and J. J. Evans, "Predicting ground effects of omnidirectional antennas in wireless sensor networks," *Wireless Sensor Network*, vol. 2, pp. 879-890, 2010.

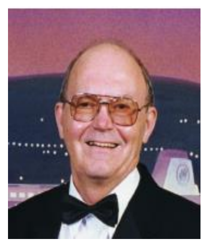
[6] L. Kibona, "Analysis of the effects of rectangular ground plane on radiation pattern of the monopole antenna," *Int. J. of Scientific and Research Publications*, vol. 3, no. 11, November 2013.

[7] M. M. Weiner, *Monopole Antennas*. Marcel Dekker, Inc., 2003.

[8] G. J. Burke and E. K. Miller, "Numerical modeling of monopoles on radial-wire ground screens," *IEEE Ant. and Propagat. Society Int. Symp.*, vol. 1, pp. 244-247, 1989.

[9] G. J. Burke, E. K. Miller, and A. J. Poggio, "The numerical electromagnetics code (NEC) – A brief history," *IEEE AP-S Int. Symp. and USNC/URSI National Radio Science*, Monterey, California, June 20-25, 2004.

[10] E. K. Miller, "Development of the incremental IEMF method as an analytical proof for the validity of FARS (far-field analysis of radiation sources)," *IEEE Ant. and Propagat. Society Magazine*, vol. 52, no. 6, pp. 46-54, December 2010.



Edmund K. Miller earned his Ph.D. in Electrical Engineering at the University of Michigan, and since has held a variety of government, academic and industrial positions. These include 15 years at Lawrence Livermore National Laboratory and 4+ years at Los Alamos National Laboratory His academic experience includes holding a position as Regents-Distinguished Professor at Kansas University, Stocker Visiting Professor at Ohio University, Physics Instructor at Michigan Technological University and Research Engineer at the University of Michigan. Miller has been appointed as an AP Distinguished Lecturer for 2014-2016, and wrote the columns "PCs for AP and Other EM Reflections" from 1984 to 2000 for the Magazine of the Antennas and Propagation Society. He received (with others) a Certificate of Achievement from the IEEE Electromagnetic Compatibility Society for Contributions to Development of NEC (Numerical Electromagnetics Code) and was a recipient (with others) in 1989 of the Best Paper Award given by the Education Society for "Computer Movies for Education." He is a Life Fellow of the IEEE and an ACES Fellow.