Compact Hybrid Dipole-Loop Antenna for the 1.8-2.0 MHz (160m) Band with Full HF Tunability

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Abstract— **This paper describes a novel approach to successful emulation of half-wave dipole performance on the 160-meter amateur radio band (1.8 - 2.0 MHz) with a hybrid wire antenna comprising a dipole part and a loop part, requiring a real estate length component of only 140 feet (42.7m) for deployment. Further, via a switching circuit near the transmitter, the loop and dipole can be routed to separate antenna tuning units (e.g., two identical Nye Viking Model MB-VA ATUs) and individually tuned over all eight amateur bands between 3.5 and 30 MHz.**

I. INTRODUCTION

This article reports a novel solution to the practical need for an effective communications antenna for the 1.8-2.0 MHz (160m) amateur radio band subject to a restricted available land area. Atmospheric noise on the 160m band drops dramatically in the late fall, and 160m becomes a popular and impressive radio communications resource (typically) from early November through mid- to late-April in North America. A resonant full half-wave dipole for 160m is about 250 feet (76.2m) long and, in this case, the longest dimension of the available land was along a line due North-South and with pine tree supports available that are separated by approximately 144 feet (43.9m).

For the Winter 2004 operating season, an experimental trial was conducted with a conventional half-square configuration. Namely, a 140 foot (42.7m) horizontal wire was supported between the available supporting trees at the N-S property line at a height of 50 feet (13.7m) and center-fed with open wire transmission line of characteristic impedance 600Ω. At both the North and South ends, the antenna wire was extended vertically down to a height of about 3 feet (1m) above ground. This trial configuration exhibited three significant shortcomings: (a) it was found that most man-made electrical noise in this frequency range is vertically polarized and, together with vertically-polarized local AM broadcasting, cumulatively produced objectionable interference on receive, (b) extensive operating experience indicated that the antenna was performing, in an overall sense, at a level approximately 6 dB below that normally associated with a horizontal half-wave dipole at height 50 feet (15.2m), and (c) wiring and electronics in residences in close proximity exhibited a greater susceptibility to vertical versus horizational transmit polarization, which was becoming a significant factor with the vertical end wires as described above.

A replacement 160m antenna with better performance was sought. For detailed analysis, numerical modeling with EZNEC version 4.0 [1] was applied throughout this engineering study. For all EZNEC results reported here, real/high accuracy ground was selected with $\sigma = 3$ mS/m and $\epsilon_r = 12$, typical of west central Alabama soil conditions. Also, "copper" wire loss was selected, so the results here include conductor loss.

II. HYBRID DESCRIPTION

Before the Winter 2005 operating season began, a new center-fed 174 foot (53m) horizontal dipole, tunable 3.5-30 MHz with a Nye Viking MB-VA ATU, was installed between the North end tree support and a third tree some 180 feet (54.9m) distant on a bearing 37° West of South. The dipole is center fed with 600Ω ladder line, has end support heights of approximately 45 feet (13.7m), and notably uses the same overall North-South property length of 43.9m as above; the Southwestern end dipole support is a third tree at the South property line and displaced about 105 feet (32m) West of the rear N-S property line.

Also in the interim a triangular loop was installed. The loop feed point is at a height of just nine feet (2.7m) above ground, just outside the radio room's eastern wall. From the feed point, the loop first has a leg approximately 90 feet (27.4m) long to a point at sixty-five feet (19.8m) high on the South end support tree, then proceeding approximately 140 feet (42.7m) to a point forty feet (12.2m) high on the North end support, then continuing a length approximately seventy-two feet (22m) back to the feed point. The geometry details of the loop and dipole described above can be seen in Figures 1 and 2.

Both antennas are fed with 600Ω ladder line. There is a short length, about eleven feet (3.4m) between the Nye Viking MB-VA balanced line antenna terminals and an outside box containing eight SPDT blade switches, which allows the antennas to be separated into separate loop and dipole antennas fed by two separate ATUs, and also allows the four wires comprising the two ladder lines to be grounding during periods of nearby lightning activity. More details on the switching box are given later, and suffice it to note that this represents the common feed point for the 160m antenna for analysis purposes. Parenthetically, the MB-VA circuit is a balun followed by a traditional tee network with one variable inductor and two variable capacitors.

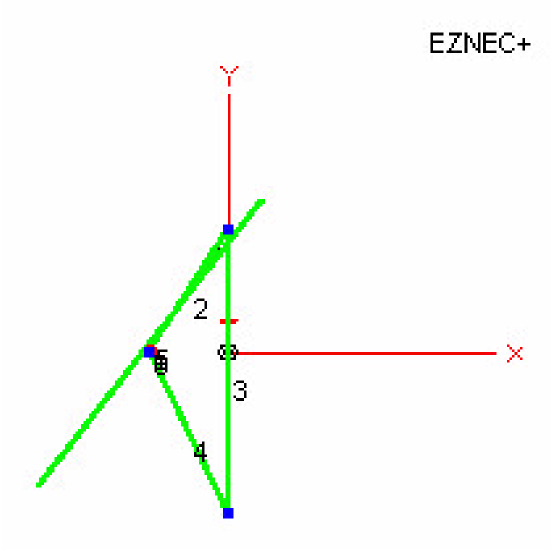


Figure 1. Dipole and loop antennas, top view down the z axis; +y is North.

Note in Figure 2 below that the dipole has a thirty-three foot (10.1m) ladder line section connecting its center feed point to the common feed at the switch box. This appears as a wire (#5) and not a two-wire structure because the two conductors of the ladder line are shorted together by the switch box and fed as a single wire comprising one side of the hybrid antenna (that is, connected to one wire of the ladder line coming from the ATU balanced line terminals).

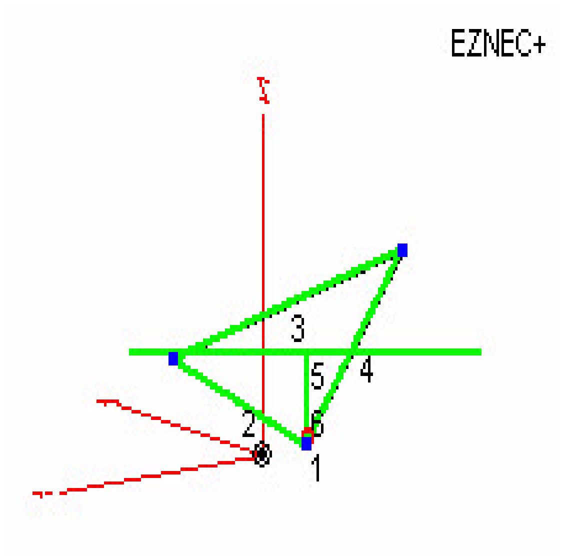


Figure 2. Dipole and loop antennas, oblique view.

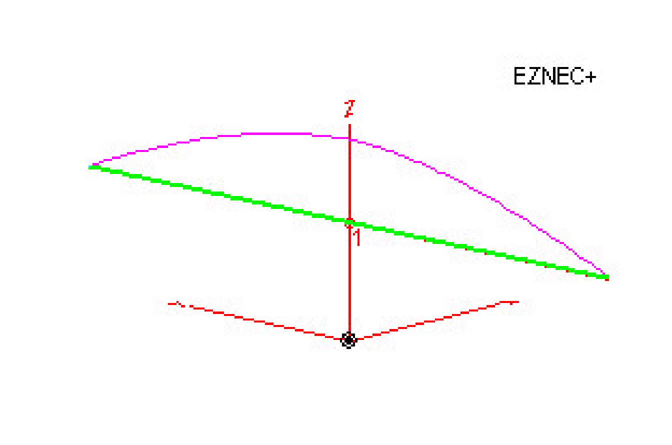


Figure 3. Comparison 160m half-wave dipole at 40 feet (12.2m) height, with current distribution.

III. 160m Hybrid Performance

In contrast to the dipole side of the hybrid configuration, which has the ladder line wires shorted to effectively give a single-wire feed at the dipole center in “Marconi" manner, as described above, the loop side of the hybrid is different. Namely, one side of the loop feed point is left open. The remaining ladder line wire from the ATU is connected to the side of the loop feed point that goes to the southern end support. The side of the loop feed point that is created by the return of the loop from the northern end support is left open. Therefore, this “half” of the composite hybrid antenna is the full length of the triangular loop wire, slightly more than three hundred feet (about 93m). An experiment was done with shorting the loop ladder line wires together to give a single wire feed to the loop similar to that used with the dipole, but it was found that the resulting impedance was not tunable with the MB-VA ATU. In the configuration described above, the hybrid antenna is easily tuned to 1:1 SWR over the entire 1.8 - 2.0 MHz band.

The essence of the hybrid’s performance at 160m, which was quite satisfactory to impressive in all aspects, may be presented succinctly. Qualitatively, the antenna garnered signal reports throughout the Winter 2005 prime operating season fully equivalent to other nearby stations running comparable power into full half-wave dipoles at heights of 40-65 feet (12.2 - 19.8m), inverted L’s and Vees. Only after several months of on-air operating experience was gathered was an EZNEC comparison to a full-sized horizontal dipole performed. The analysis indicates that a full-sized horizontal dipole is at a disadvantage to the hybrid at heights below 40 feet (12.2m) but has an increasing advantage with height above that level. It is interesting to note that the hybrid geometry and wire lengths are quite different from a regular dipole, but the average height of the composite hybrid configuration is itself on the order of 40 feet.

Figure 5 shows an East-West elevation plot of the hybrid, with the full-sized dipole at 40 feet overlayed. In the plot, East is to the right and West is to the left. The maximum gains for the two antennas are virtually identical and, as can be seen in the figure, the patterns are very similar. Figure 6 is the corresponding result for an elevation plot on a North-South line, with North to the right. Again, the full dipole and hybrid have virtually identical maximum gain, but in this case the hybrid has a perceptible gain advantage at intermediate elevation angles.

It is noteworthy that the hybrid exhibited a high degree of immunity to incoming vertically-polarized noise. Local AM broadcast and power line noise interference were no longer an issue, as they were with the predecessor half-square antenna.

IV. HF SPECTRUM FLEXIBILITY

It was noted earlier that there is a switch box in the system to allow combining the loop and dipole into a hybrid antenna, fed through one ATU, or separating the dipole and loop into separate transmitter connections through two separate ATUs. Figure 4 is schematic depiction of the switching circuit:

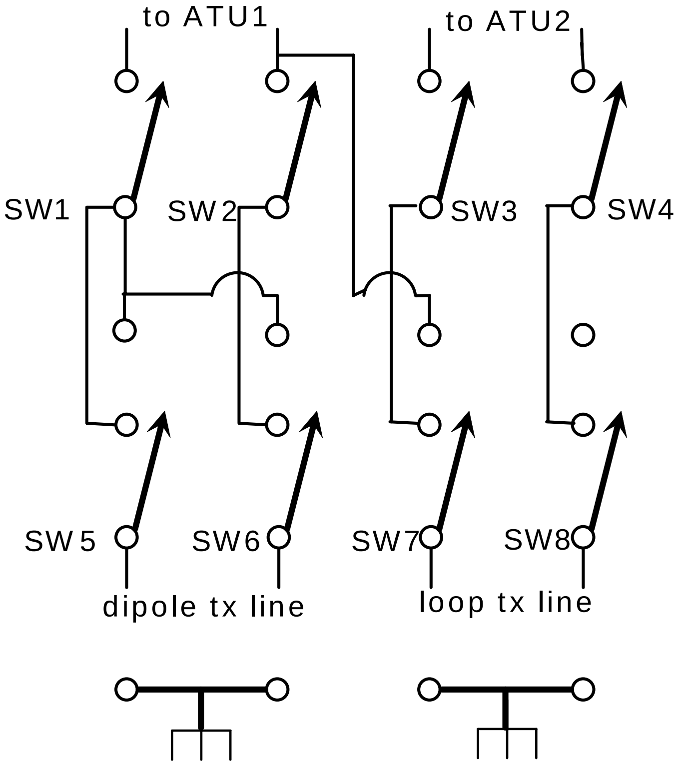


Figure 4. Antenna switch box.

All switches are SPDT, knife blade type. In normal operation, switches SW5 - SW8 are in the up position, as shown. These four switches are connected down to ground the ladder lines for lightning protection. When the four switches SW1 - SW4 are in the up position, as shown, the dipole and loop elements are connected through to separate ATUs 1 and 2. For hybrid operation, the three switches SW2 - SW4 are moved to the down position. One sees that downward movement of switch SW4 creates the desired open circuit on the return line from the triangular loop antenna. Simultaneously, downward movement of SW3 connects the “hot” leg of the loop over to ATU1, while downward connection of SW2 causes the two conductors of the dipole ladder line to be shorted together and connected as the other side of the hybrid antenna feed out of the switch box.

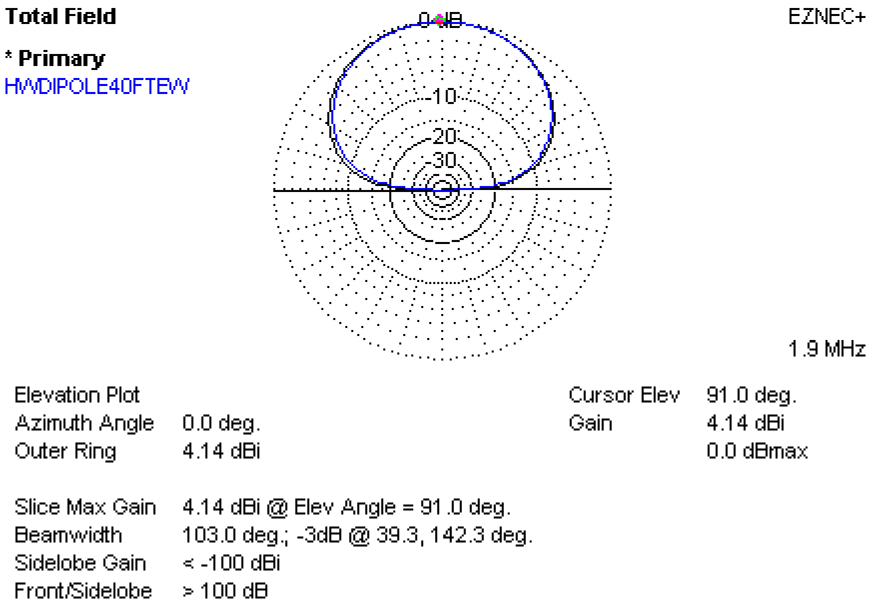
Because the two wire element antennas provide three possible operational modes through different switch selections and all three possibilities are tunable to 1:1 SWR on all the HF ham bands, a variety of radiation pattern possibilities are available to the radio operator. To illustrate, sample azimuth plots at elevation angle 30° have been prepared with EZNEC. For clarity, the three antenna possibilities are given in individual plots, where the pertinent data/quantitative results can be seen clearly. In these plots, North is the positive vertical axis and East is to the right (the positive horizontal axis). Figures 7 through 9 are for 7.3 MHz, at the upper end of the popular medium-range 40m band, and Figures 10 through 12 are the corresponding plots at operating frequency 18.1 MHz (the so-called 17m band). Elevation angle 30° was selected as a medium-distance single hop propagation path compromise between the longer paths associated with lower elevation angles on the order of 10° and more regional links associated with elevation angles on the order of $60 - 70°$.

Note that the respective maximum gain values for the dipole, loop, and hybrid at 7.3 MHz from Figures 7 - 9 are 8.46 dBi @ azimuth angle 143°, 5.97 dBi @ azimuth angle 330°, and 5.96 dBi @ azimuth angle 333°. The qualitative pattern shape differents are best appreciated by visual inspection. At 18.1 MHz, for comparison, the maximum gain numbers are 2.24 dBi @ azimuth angle 21° for the dipole, 4.08 dBi @ azimuth angle 272° for the loop, and 6.46 dBi @ azimuth angle 39° for the hybrid.

V. CONCLUDING REMARKS

A specific case study is reported here, and the resulting wire antenna configuration is not intended to be a general (160m) low-frequency solution that will fit many potential users. However, it does serve well to illustrate the benefits of unconventional thinking applied to wire antenna needs in the HF radio spectrum.

The straightforward deployment of a horizontal dipole of length 250 feet (76.2m) at a height of 60 feet (18.3m) and fed with low-loss ladder line is clearly the most simple and a highly desirable antenna implementation for routine 160m operation (conceding that the standard of excellence in a transmitting antenna for this band is a vertical radiator at least a quarter-wave tall and accompanied by a full, AM broadcast band quality ground radial system, but at the same time recognizing that such a deployment is beyond the means



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Elevation Plot                                     Cursor Elev    91.0 deg.
Azimuth Angle    0.0 deg.                          Gain           4.14 dBi
Outer Ring       4.14 dBi                                         0.0 dBmax

Slice Max Gain   4.14 dBi @ Elev Angle = 91.0 deg.
Beamwidth        103.0 deg.; -3dB @ 39.3, 142.3 deg.
Sidelobe Gain    < -100 dBi
Front/Sidelobe   > 100 dB
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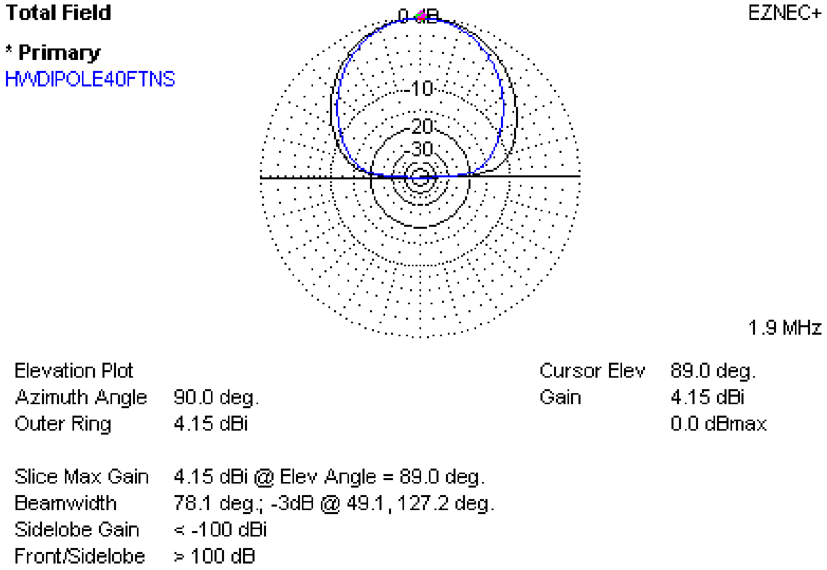
Figure 5. 160m hybrid vs dipole at 40 feet, E-W elevation plot.



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Elevation Plot                                  Cursor Elev    89.0 deg.
Azimuth Angle    90.0 deg.                      Gain           4.15 dBi
Outer Ring       4.15 dBi                                      0.0 dBmax

Slice Max Gain   4.15 dBi @ Elev Angle = 89.0 deg.
Beamwidth        78.1 deg.; -3dB @ 49.1, 127.2 deg.
Sidelobe Gain    < -100 dBi
Front/Sidelobe   > 100 dB
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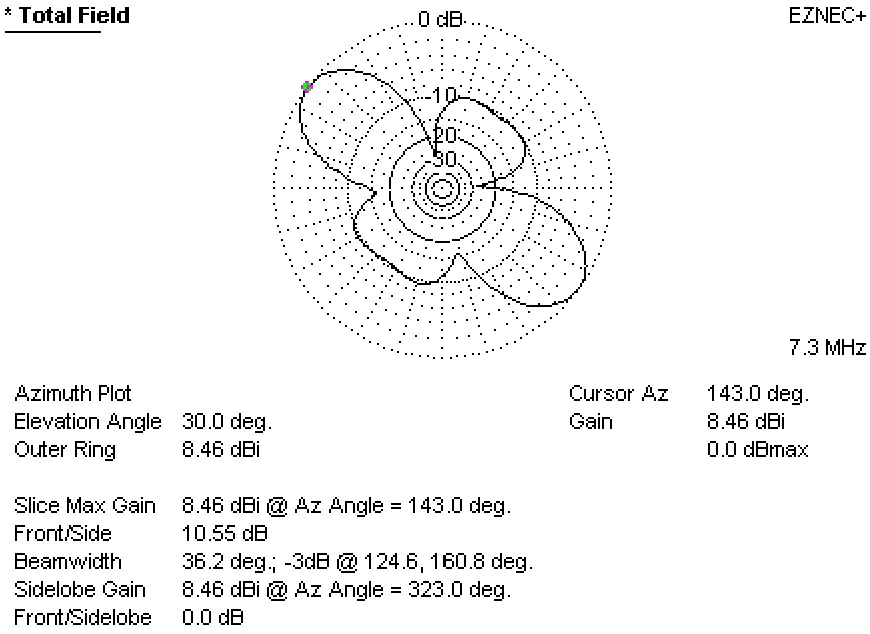
Figure 6. 160m hybrid vs dipole at 40 feet, N-S elevation plot.



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Azimuth Plot                                     Cursor Az   143.0 deg.
Elevation Angle  30.0 deg.                       Gain        8.46 dBi
Outer Ring       8.46 dBi                                    0.0 dBmax

Slice Max Gain   8.46 dBi @ Az Angle = 143.0 deg.
Front/Side       10.55 dB
Beamwidth        36.2 deg.; -3dB @ 124.6, 160.8 deg.
Sidelobe Gain    8.46 dBi @ Az Angle = 323.0 deg.
Front/Sidelobe   0.0 dB
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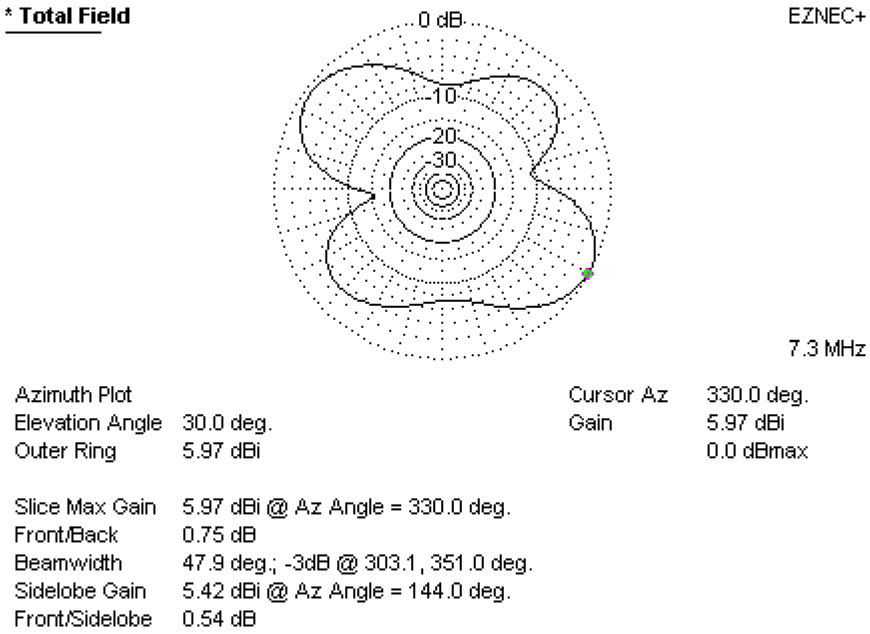
Figure 7. Dipole element azimuth plot at 7.3 MHz.



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Azimuth Plot                                     Cursor Az   330.0 deg.
Elevation Angle  30.0 deg.                       Gain        5.97 dBi
Outer Ring       5.97 dBi                                    0.0 dBmax

Slice Max Gain   5.97 dBi @ Az Angle = 330.0 deg.
Front/Back       0.75 dB
Beamwidth        47.9 deg.; -3dB @ 303.1, 351.0 deg.
Sidelobe Gain    5.42 dBi @ Az Angle = 144.0 deg.
Front/Sidelobe   0.54 dB
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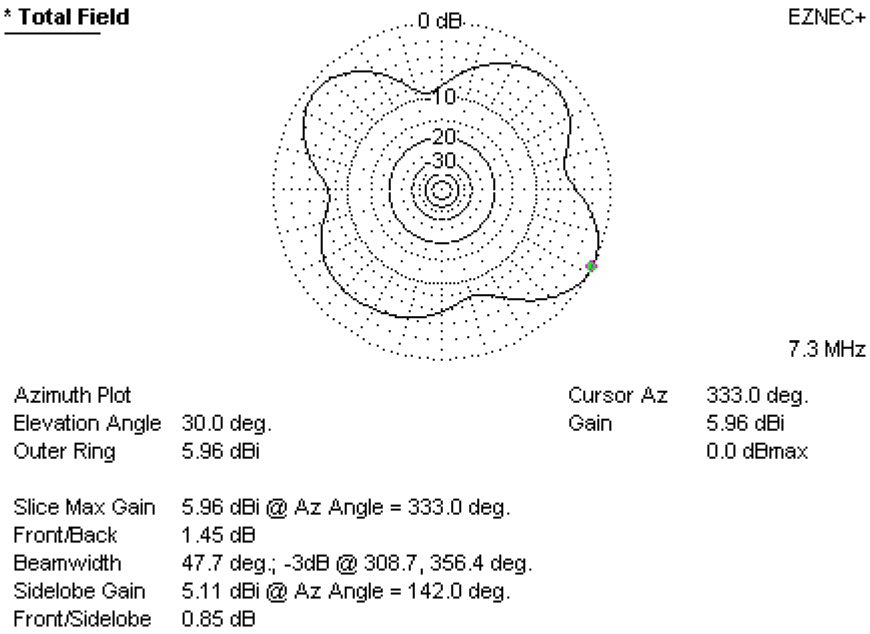
Figure 8. Loop element azimuth plot at 7.3 MHz.



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Azimuth Plot                                         Cursor Az      333.0 deg.
Elevation Angle   30.0 deg.                          Gain           5.96 dBi
Outer Ring        5.96 dBi                                          0.0 dBmax

Slice Max Gain    5.96 dBi @ Az Angle = 333.0 deg.
Front/Back        1.45 dB
Beamwidth         47.7 deg.; -3dB @ 308.7, 356.4 deg.
Sidelobe Gain     5.11 dBi @ Az Angle = 142.0 deg.
Front/Sidelobe    0.85 dB
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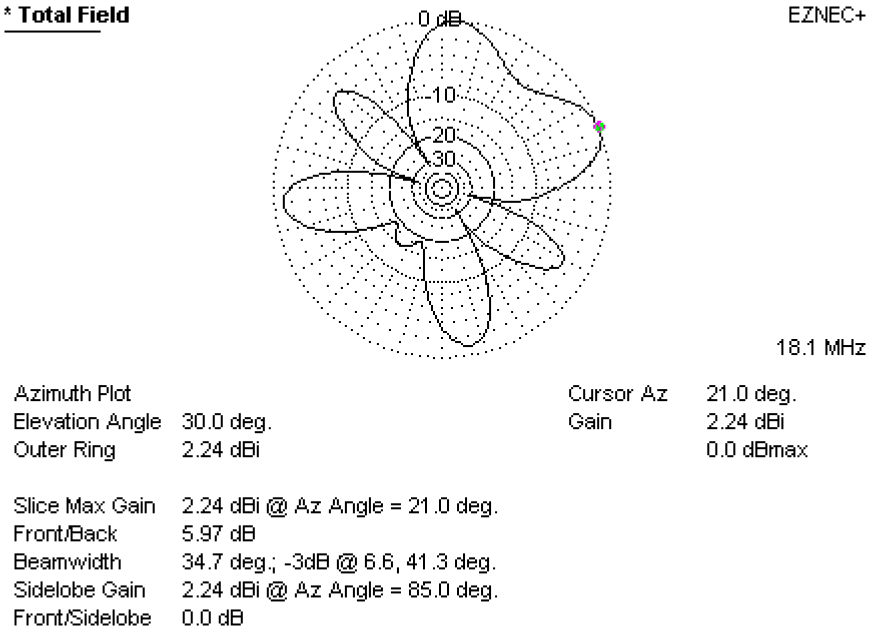
Figure 9. Hybrid antenna azimuth plot at 7.3 MHz.



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Azimuth Plot                                         Cursor Az      21.0 deg.
Elevation Angle   30.0 deg.                          Gain           2.24 dBi
Outer Ring        2.24 dBi                                          0.0 dBmax

Slice Max Gain    2.24 dBi @ Az Angle = 21.0 deg.
Front/Back        5.97 dB
Beamwidth         34.7 deg.; -3dB @ 6.6, 41.3 deg.
Sidelobe Gain     2.24 dBi @ Az Angle = 85.0 deg.
Front/Sidelobe    0.0 dB
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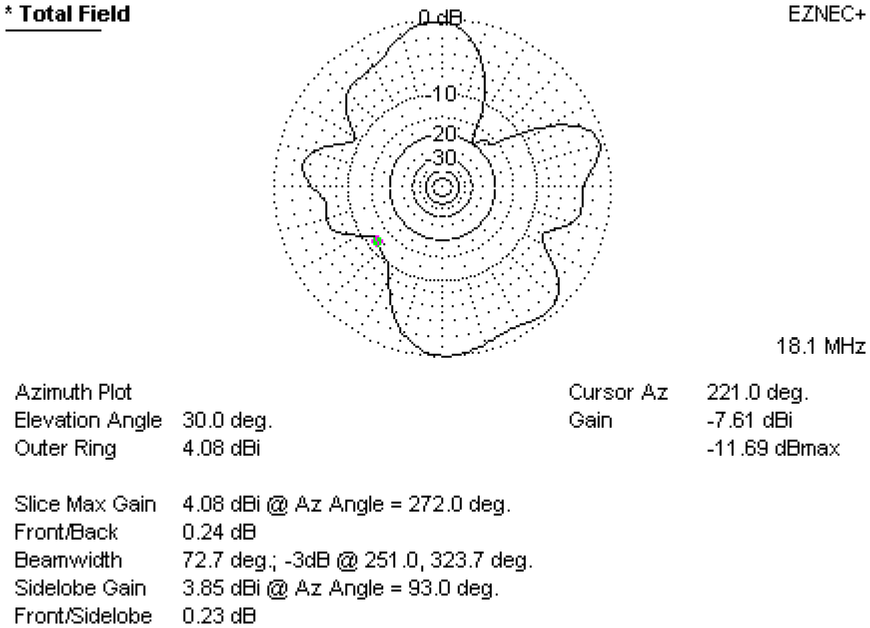
Figure 10. Dipole element azimuth plot at 18.1 MHz.



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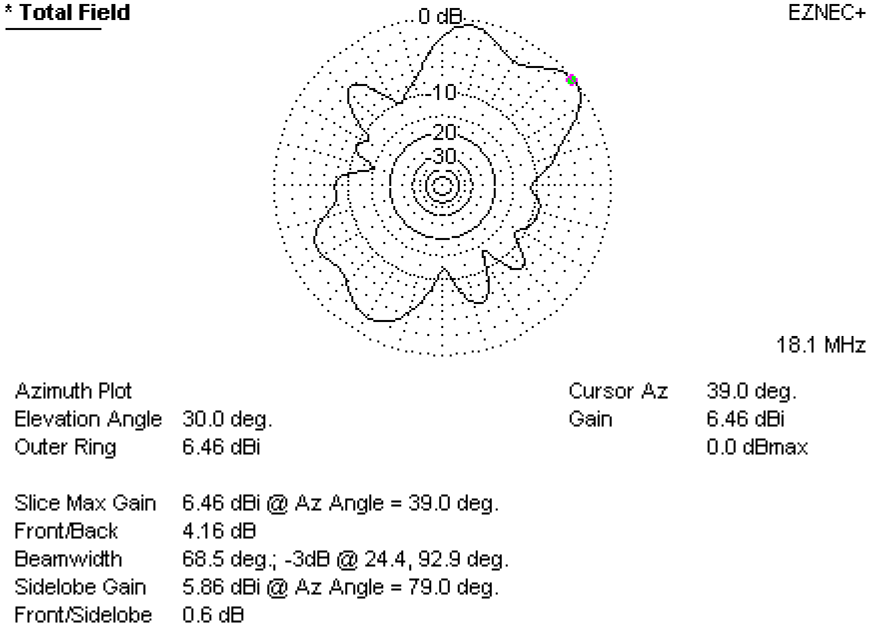
Azimuth Plot                                          Cursor Az    221.0 deg.
Elevation Angle  30.0 deg.                            Gain         -7.61 dBi
Outer Ring       4.08 dBi                                          -11.69 dBmax

Slice Max Gain   4.08 dBi @ Az Angle = 272.0 deg.
Front/Back       0.24 dB
Beamwidth        72.7 deg.; -3dB @ 251.0, 323.7 deg.
Sidelobe Gain    3.85 dBi @ Az Angle = 93.0 deg.
Front/Sidelobe   0.23 dB
```

Figure 11. Loop antenna azimuth plot at 18.1 MHz.



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Azimuth Plot                                          Cursor Az    39.0 deg.
Elevation Angle  30.0 deg.                            Gain         6.46 dBi
Outer Ring       6.46 dBi                                          0.0 dBmax

Slice Max Gain   6.46 dBi @ Az Angle = 39.0 deg.
Front/Back       4.16 dB
Beamwidth        68.5 deg.; -3dB @ 24.4, 92.9 deg.
Sidelobe Gain    5.86 dBi @ Az Angle = 79.0 deg.
Front/Sidelobe   0.6 dB
```

Figure 12. Hybrid antenna azimuth plot at 18.1 MHz.

and physical capabilities of most individuals). When available property is an active constraint, one should not hesitate to experiment with non-traditional configurations and can have confidence in the predictions afforded by readily available MoM numerical codes such as EZNEC.

It is true that a land width requirement was introduced in this case. However, the area under the composite hybrid antenna detailed in this paper is less than 0.2 acres, a land requirement that is generally not preclusive. The results of this study, both the numerical analysis outputs and the experience of on-air use, agree and conclude that the hybrid antenna is fully equivalent (and even superior at some spatial angles) in electrical performance to a full sized half-wave dipole at 40 feet height.

Not only are the received/transmitted signal strengths noticeably better with this configuration in comparison its half-square predecessor, but the susceptibility of the half-square to local vertically polarized noise sources is considerably reduced. Indeed, it would be a fair characterization to describe the hybrid described here as a quiet receiving antenna.

A significant bonus is that, since the hybrid was the product of judiciously combining two already existing antennas, the two "element" antennas remain available for use by introducing a switching box as described above.

The author would welcome reports from any practical communicators of similar developments they achieve that are either derived from, or at least inspired by, the contents of this paper. In addition to the work email address furnished as part of the paper title, interested parties may also contact the author via email address k4cww@comcast.net.

REFERENCES

[1] EZNEC is a software product of Roy Lewallen, as described at http://www.eznec.com/.