Magnetic Radiators – Low Profile Paired Verticals for HF

The antenna described in this article consists of paired vertical radiators made from wire. The system does not require ground radials, nor does it require loading coils. The system provides ample bandwidth and it is fed directly with coaxial cable. It is an efficient radiating system which presents a very low profile.

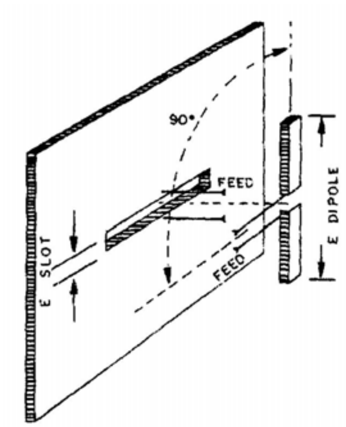

Figure 1 - Insight into magnetic and electric radiators can be gained by considering the slot antenna. The slot is a magnetic radiator made by cutting a thin sliver from a large sheet. To the right, a complimentary electric dipole is made from the sliver. Near the antennas (near field), the H field component of the slot is proportional to the E component of the dipole. The H component or the dipole is proportional to the E component of the slot. Although the slot is horizontal, polarization is vertical. For comparison, the dipole is rotated 90 degrees to a position of vertical polarization. (See notes 4, 5 and 6.)

Electric Versus Magnetic Radiators

Ordinary antennas such as dipoles and verticals are classified as *electric radiators.* These antennas generate a very high E component and a very low H component in the fields close in, near the antenna. Boyer shows that the E component creates ground losses and that the H component is virtually lossless (see note 1). Electric radiators exhibit a relatively high voltage at the antenna ends.

The magnetic radiator generates a very low E component and a very high H component close in to the antenna. Losses in the ground and in nearby objects are therefore minimized. Magnetic radiators exhibit a low voltage at the antenna ends and a relatively high current flowing within. See Fig 1. In the case of the electric radiator, Boyer shows that the radiation field with a fixed E/H ratio of 377 ohm, predominates beyond ½ wave from the antenna. In the case of the magnetic radiator, the predominance of the radiation field occurs beyond 1½ wave from the antenna. Magnetic radiators can therefore be efficient and desirable in many applications.

Laport classifies the U antenna as a magnetic radiator (see note 2). In Fig 2, four U antennas are connected together and evolve into Dellinger's "coil aerial." (see note 3) The coil is rectangular in shape and, although made from wire, is derived from Boyer's DDRR doublet.

The four U antennas forming the rectangular coil are referred to as a multiple U, or simply MU. The four vertical ends of the rectangle are the prime radiators. The horizontal wires produce two minor high-angle lobes. Note that there are no loading coils or radials used. The bottom horizontal runs of the antenna are located about 2 feet above ground.

The vertical ends of the antenna are 30 electrical degrees high. This is less than 0.1 wave, and indeed presents a low profile. This translates to about 11.5 feet for 40-m operation and about 21.5 feet for 80-m operation. (Although the wires at the far end cross at a small angle, these wires are referred to as vertical.)

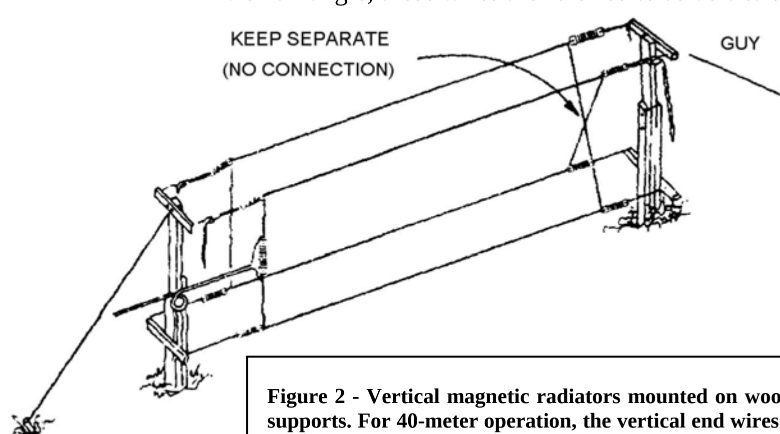

Figure 2 - Vertical magnetic radiators mounted on wooden supports. For 40-meter operation, the vertical end wires are 11.5 ft high and the horizontal wires are 58.2 ft long. Wire spacing is 18 in. The coiled feed me is an RF choke and impedance-matching segment (see text). The antenna is mounted near ground level

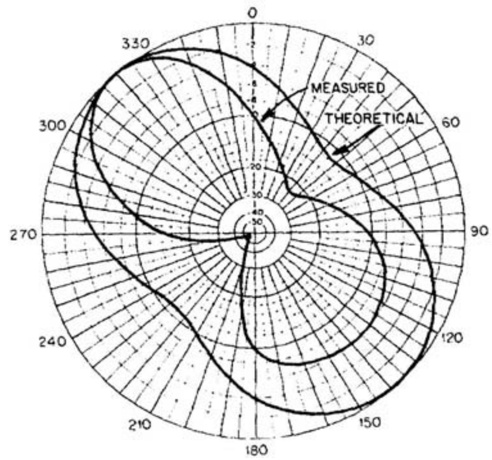

Figure 4 - Azimuth-pattern plot of the 21-MHz MU antenna. Zero degrees represents north. The horizontal wires run northeast-southwest.
The lower end is 12 in. above ground. Field measurements are at ground level. Antenna dimensions are Lv = 4, Lh = 19, S = 0.3 (all values in ft).

The horizontal runs are approximately 150 electrical degrees long. This is about 58.2 feet for 40-m operation and 109.2 feet for 80-m operation. The total wire length is approximately 2 wave at the desired frequency. The configuration of the wire in the rectangular coil is such that the currents in the four vertical end wires are co-phased. Both the magnitude and phase of these currents are virtually constant throughout their 30 degree height.

Radiation Pattern

Fig 3 shows a plot of the radiation field of a model MU operating at 21.4 MHz. This plot, although made from crude measurements, resembles the theoretical free-space pattern for this type of antenna, also shown in Fig 3.

The measurements were made at sites ranging in distance from 0.8 to 1.5 miles and located at 45 degree intervals around the antenna, beginning in the suspected direction of the main lobe. All measurements were normalized to 1 mile. The deep null to the southwest is possibly the result of a nearby steel tower that is in this direction and directly in line with the MU model. The smaller main lobe to the southeast is possibly the result of the measurement sites in this area being well below the antenna horizon. The plane of the model is oriented northeast-southwest. Maximum radiation is broadside, as it is from ordinary co-phased verticals.

Design and Construction

The following expressions were developed for use in designing the MU antenna.

Lt = 1988/f
Lv = 82/f
Lh = 415/f
S = 125/f

Where

Lt = total wire length required, ft
Lv = height of each vertical wire, ft
Lh = length of each horizontal, ft
S = wire spacing, inches.
f = center freq of operation, MHz

For example, for a center frequency of 3.8 MHz, the following values are obtained from the expressions above.

Lt = 523.2 ft
Lv = 21.6 ft
Lh = 109.2 ft, and
S = 32.9 in.

The length of the horizontal runs, Lh. will usually give resonance at a slightly lower frequency such that the antenna can be pruned to resonance. The antenna should be pruned by clipping four short segments, equal in length, from the center of each horizontal run. Attempting to prune the antenna at the feed point will require the re-rigging of the eight corner insulators (see Fig 2).

For efficient operation, the antenna should be made from no. 14 or larger wire. Since the antenna is frequency sensitive to stretch in the horizontal runs, stranded wire is recommended. Good results have been reported when using no. 12 copper-clad steel.

Figs 4 and 5 show some of the construction details of the wooden supports used here for various MU antennas. On the 40-m model, it is recommended that the spacing between the cross arms on each support be made 14 feet. This will permit vertical tension to be applied to the vertical wires. For the same reasons 24-foot spacing is recommended for the 80-m model.

If the bottom two horizontal runs are placed within a few feet of ground level, these runs should be protected or adequately marked to prevent someone from falling or becoming burned. If the 80-m model is mounted with the bottom near ground, two short supports bearing cross arms with insulators on the tips should be used to prevent the lower horizontal

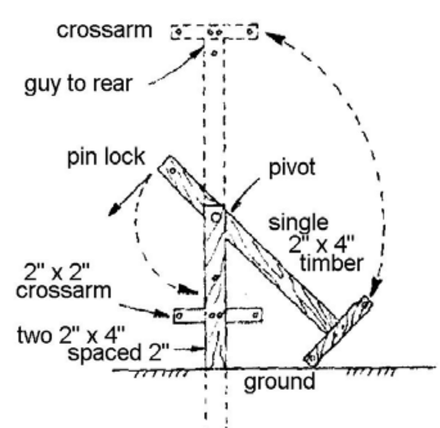

Figure 3 - Typical wooden support. Setup and takedown can be accomplished by one person (use help if possible). Use treated lumber. To determine dimensions, see text.

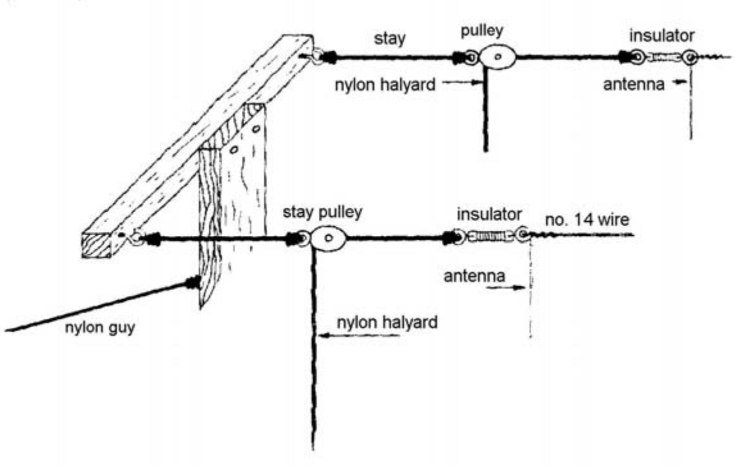

Figure 5 - Upper cross-arm detail. Upper and lower cross arms are vertically spaced greater than Lv. (See text.)

runs from sagging into the grass. These supports should be placed one-third of the distance between the end supports.

Feeding the MU

At resonance, the 40-m MU presents a measured input impedance of 115 + j0. (The impedance will change somewhat with different antenna heights above ground.). This load is ideally matched to 50 ohm coaxial cable by ¼ wave of 75-ohm cable acting as a transformer. Since currents in the MU must be held equal, top and bottom, the 75 ohm cable should be made into an RF choke by winding it into a flat coil about 12 inches in diameter. This coil can then be taped or strapped together.

The 80-m MU presents a measured input impedance of 150 + j0 at resonance (again, subject to minor change with antenna height). This load is matched by using a series segment of good 300 ohm ribbon. Feed the antenna with 50 ohm coaxial cable. Cut the cable at a point 16.9 feet from the antenna. At this point insert a 6.66 foot length of 300 ohm ribbon in series with the 50 ohm cable. This arrangement matches the 150 ohm load to any random length of 50 ohm feed line. (A velocity factor of 80% was assumed for both ribbon and cable. An operating frequency of 3.75 MHz was also assumed.) The 16.9-foot segment should be wound into a flat coil to form an RF choke as was done with the 40-m MU. Additionally, it is well to form a second RF choke by winding another flat coil in a portion of the 50-ohm cable on the transmitter side of the ribbon, right at the ribbon.

With the feed arrangements just described, system bandwidth is about 4% of the center frequency. This is approximately 280 kHz on 40 m and 150 kHz on 80 m. The term bandwidth as used here refers to the frequencies between which the SWR rises to a ratio of 2:1 on the 50 ohm cable feeding the system.

A “20-Degree” MU

Joe Logan, WA4CPN, and Dr Tom McLees, WF5I, both aircraft pilots, became interested in the low-profile performance of the MU antenna. Hence a design for an 80-m “20 degree” MU was made with the vertical ends being but 14.5-feet high. Thus Joe, with Doc’s assistance, built the first 14.5-foot MU for 80 m and erected it near Joe’s flight strip. The advantage of low profile in this application is obvious.

On 3.75 MHz, Doc and Joe measured the input impedance of the 14.5-foot MU to be 110 + j0. Hence, the 75 ohm transformer match was used. Shortly thereafter George McCulloch, WA3WIP, built the second 14.5-foot MU for 80-m operation.

For the lower profile 20 degree antenna, use the following.

$L_v = 54.67/f$

$L_h = 442.33/f$

$S = 125/f$

Operating Results

With the 14.5-foot MU on 80 m, Joe consistently receives good reports from Europe and Africa. George reports equally good results to Europe and to Australia via long path. On one test George reported that upon switching to a dipole antenna, neither the European nor the Australian via long path was able to hear him.

From this location, using the 21.5-foot verticals on 80 m, good reports are consistently received from South Africa and New Zealand, as well as from other continents. Using the 11.5-foot MU on 40 m, a daily schedule was maintained for a 4-month period with Paul Stein, G8NV/MM. Paul was aboard a cargo vessel operating in the South Atlantic, the Indian Ocean and the Far East. On 85% of the days, Paul reported that signals from the MU were S9 or more. Although the MU is not the best for local contacts, it has been found to be surprisingly effective as a long haul, low profile, radiating system.

Many thanks go to Dave Atkins, W6VX, Joe Boyer, W6UYH, Bob Lewis, W2EBL, and Paul Stein, G8NV. They generously donated their time and talents to the project.

Notes

1. J. M. Boyer, “Surprising Miniature Low Band Antenna,” Parts I and II, 73, Aug and Sep 1976.
2. K. Henney, Ed., *Radio Engineering Handbook,* 4th ad. (New York: McGraw-Hill Book Go, 1950), p 660.
3. J.H. Dellinger “Principles of Radio Transmission and Reception with Antenna and Coil Aerials,” *Bureau of Standards Sci Paper 354,* June 1919.
4. H. Jasik. *Antenna Engineering Handbook,* 1st *ad.* (New York: McGraw-Hill Book Cc, 1961), p 2.5 and Chap 8.
5. *Reference Data for Radio Engineers,* 6th *ad.* (Indianapolis: Howard W. Sams & Cc, subsidiary of ITT, 1975), pp 27-14, 27-15.
6. J. D. Kraus, *Antennas,* 1st *ad.* (New York: McGraw-Hill Book Ca, 1950), Chap 13.

	30 degrees			20 degrees		
Lt	1988/f			1988/f		
Lv	82/f			54.67/f		
Lh	415/f			442.33/f		
S	125/f (inches)			125/f (inches)		
10 meter MU	28.300 MHz	feet	inches		feet	inches
Lt	70.25	70	3	70.25	70	3
Lv	2.90	2	11	1.93	1	11
Lh	14.66	14	8	15.63	15	8
S	4.42”		4 ½”	4.42”		4 1/2 “
12 meter MU	24.930 MHz	feet	inches		feet	inches
Lt	79.74	79	9	79.74	79	9
Lv	3.29	3	3	2.19	2	2
Lh	16.65	16	8	17.74	17	9
S	5.01”		5”	5.01”		5”
15 meter MU	21.200 MHz	feet	inches		feet	inches
Lt	93.77	93	9	93.77	93	9
Lv	3.87	3	10	2.58	2	7
Lh	19.58	19	7	20.86	20	10
S	5.90”		5 7/8”	5.90		5 7/8”
17 meter MU	18.118 MHz	feet	inches		feet	inches
Lt	109.73	109	9	109.73	109	9
Lv	4.53	4	6	3.02	3	0
Lh	22.91	22	11	24.41	24	5
S	6.90”		6 7/8”	6.90”		6 7/8”
20 meter MU	14.150 MHz	feet	inches		feet	inches
Lt	140.49	140	6	140.49	140	6
Lv	5.80	5	10	3.86	3	10
Lh	29.33	29	4	31.26	31	3
S	8.83”		8 7/8”	8.83”		8 7/8”
30 meter MU	10.120 Mhz	feet	inches		feet	inches
Lt	196.44	196	5	196.44	196	5
Lv	8.10	8	1	5.40	5	5
Lh	41.01	41	0	43.71	43	9
S	12.35”		12 3/8”	12.35”		12 3/8”
40 meter MU	7.150 Mhz	feet	inches		feet	inches
Lt	278.04	278	1	278.04	278	1
Lv	11.47	11	6	7.65	7	8
Lh	58.04	58	1	61.86	61	10
S	17.48”		17 ½”	17.48”		17 ½”

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80 meter MU	3.800 MHz	feet	inches		feet	inches
Lt	523.16	523	2	523.16	523	2
Lv	21.58	21	7	14.39	14	5
Lh	109.21	109	3	116.40	116	5
S	32.89”		32 7/8”	32.89”		32 7/8”

160 meter MU	1.900 MHz	feet	inches		feet	inches
Lt	1046.32	1046	4	1046.32	1046	4
Lv	43.16	43	2	28.77	28	9
Lh	218.42	218	5	232.81	232	10
S	65.79”		65 ¾”	65.79”		65 ¾”