Inverted-V Radiation Patterns

A Theoretical and Experimental Study

BY DALE W. COVINGTON,* K4GSX

The antenna now known in amateur circles as the inverted V, not being one of the "standard" forms, has not been analyzed in any of the current antenna texts. K4GSX undertook to work out the patterns mathematically and experimentally, with the results given here. A cage-type construction for increasing the bandwidth is also described.

One of the handiest antennas for the low frequency bands is the inverted V. Its simplicity makes it particularly useful for Field Day or fixed-portable installations. Despite the antenna's popularity [1,2,3] little seems to have been written about its radiation characteristics. The following note considers a few patterns in both the horizontal and vertical planes of the far *E*-field radiation of an inverted V. Some practical details of a broad-band V for 40 and 80 meters are also included.

Patterns

Perhaps a couple of points should be made before launching into the radiation patterns. First, the term "inverted V" actually describes two types of antennas. One is a half rhombic in the vertical plane,[4] fed at one end and terminated through a resistor to ground at the other end. More recently, use of the term implies resonant dipole antenna with its ends drooped. It is this latter type, with the approximation of sine currents on the V legs, that is treated here — not the travelling-wave rhombic antenna.

Second, the patterns of the inverted V are a function of the *E*-field polarization. There is no change of polarization effect for the field in the vertical plane perpendicular to the plane of the V. This field is horizontally polarized regardless of the angle of elevation. The radiation pattern in the horizontal plane about the antenna is not so simple. Fig. 1 illustrates the far fields that might be measured for the case of a 90-degree angle between the legs of the V. If one walked around the antenna with a short sensing dipole horizontally oriented, the field observed would have the characteristic figure-8 pattern of Fig. 1A. Maximum signal would occur broadside to the antenna, and at a point in line with the V a null would be seen. Rotating the sensing antenna to the vertical direction would yield no change in this null for a horizontal antenna with no droop, but the slope of the legs of a V introduces a completely different pattern, with a maximum somewhat smaller than before and positioned in line with the V. This new pattern is shown in Fig. 1B. The final field is therefore the sum of both horizontal and vertical *E*-fields being all horizontal broadside, all vertical off the ends, and a mixture in between.

The far *E*-field patterns were derived with suitable coördinate transformations from expressions given in a previous paper by Wells.[5] Two cases were solved. One was the total field magnitude in the horizontal plane perpendicular to the plane of the V and parallel to ground. The other was radiation in the vertical plane perpendicular to the antenna and ground. Computed values for the latter case were corrected to include the effects of earth that was perfectly conducting. Relative patterns are plotted in Figs. 2 and 3 for inverted V's with included angles between the legs of 120,

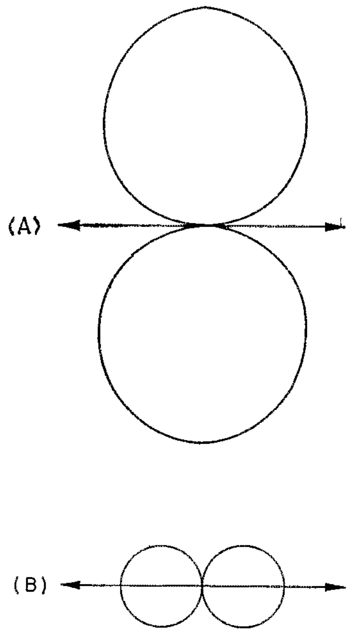

Fig. 1—Theoretical field patterns of an inverted V having a 90-degree apex angle for (A) horizontally-polarized component of radiation and (B) vertically-polarized component. Arrows indicate V leg directions.

* 1/Lt., Hq. and Hq. Co. U.S.A.S.A., Box 028, Ft. George G. Meade, Md.

[1] Glanzer, "The Inverted V-Shaped Dipole", *QST*, August 1960, p. 18.
[2] Allred, "E-Z Up Antenna for 75 and 40", *QST*, October 1961, p. 52.
[3] Dzambik, "Multiband Antenna", *QST*, November 1961, p. 55.
[4] *The A.R.R.L. Antenna Book*
[5] Wells, "Quadrant Aerial", *J. Inst. Elec. Engrs.*, Pt. III, 182 (1944), p. 91.
[6] Zawacki, "An 80 and 40 Meter Inverted V", *CQ*, March 1962, p. 32.

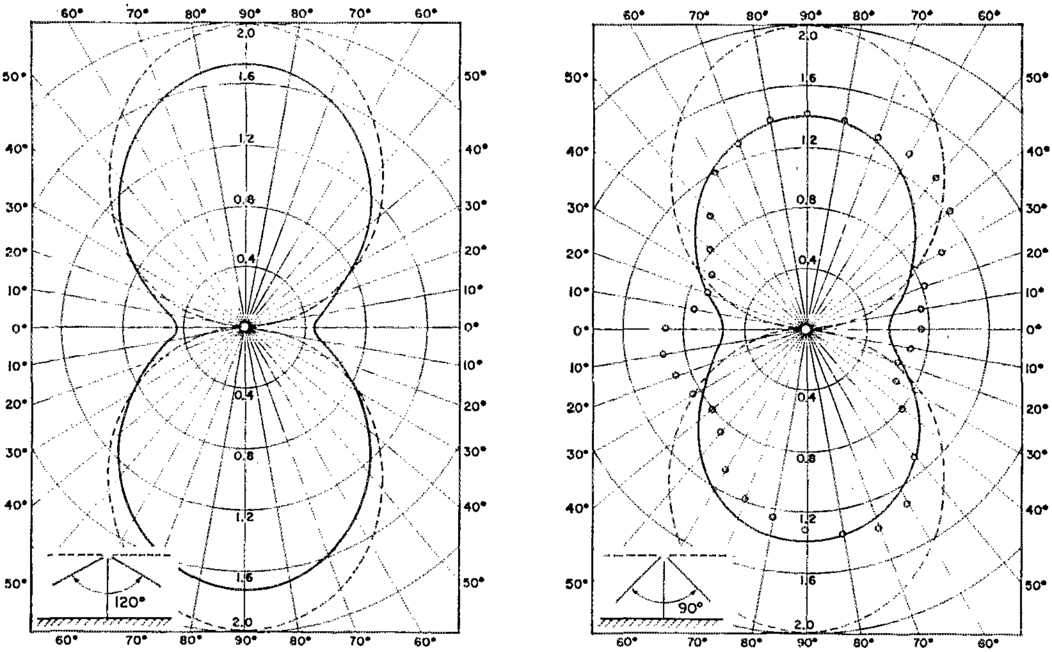

Fig. 2—Total relative field intensity in horizontal plane from inverted-V antennas having three different apex angles. This is the theoretical azimuthal pattern of the antenna irrespective of polarization. The legs of the V lie in the 0-0 direction. Dashed line shows pattern of a linear half-wave antenna for shape comparison.

90, and 60 degrees. For comparison purposes the angular multiplying factor of the horizontal half-wave antenna is also shown on the plots by a dotted line.

The horizontal patterns of Fig. 2 reveal a number of interesting features. First, the antenna behaves much like a horizontal dipole until the ends have been drooped a considerable amount. The plot for 120 degrees is quite close to the half-wave antenna. For the same *current* input the radiation along the axis of the V (0-0 direction) is greatest for the 90-degree V. Further droop does increase the net *percentage* of radiation off the ends to that broadside, as in the 60-degree V. In all three V's the *E*-field is at a 45-degree angle with respect to the horizon before θ of 27 degrees is reached. Thus V radiation is predominantly of horizontal polarization for all but the smallest V angles.

Experimental Measurements

There are always problems associated with accurate modeling and plotting of fields of low-gain antennas. Changes in polarization increase these difficulties. Nevertheless a small u.h.f. model of an inverted V was constructed. A u.h.f. oscillator excited a separate transmitting antenna that could be rotated in both polarization and orientation about the receiving V. Baluns were used to transform the coaxial feed to the balanced impedance of the antenna terminals. By using this simple rig, measurements were made of the total radiation in the horizontal plane. Some 20 wavelengths separated the two test antennas, so near-field effects were minimized. The small open circles in Fig. 2 are the experimentally measured field values. Although there was some distortion even for the dipole, the most obvious disagreement occurred off the ends of the 90-degree V. A recheck of the data revealed that the nulls were not particularly sharp for horizontally-polarized radiation. The response to vertical radiation alone at the horizontal null was some 12 percent greater than the theoretical patterns indicate. The general shape of both polarizations individually followed closely the predicted patterns shown in Fig. 1.

Vertical-Plane Patterns

Vertical-plane patterns of V's do not differ greatly from dipoles. Fig. 3 presents the vertical patterns of inverted-V antennas when the apex is located ½ wavelength above ground. Immediately striking is the similarity to the patterns of horizontal dipole also ½ wavelength from ground. The patterns, while close, are not quite identical. Actually there is a slight increase in V radiation for the lower angles of elevation and a slight decrease for the higher angles. Again for the 90-degree condition, the increase in radiation at 10 and 20 degrees is 0.3 and 0.5 percent, respectively, over that of a half-wave dipole normalized to 30 degrees. The decrease for the higher angles of 70 and 60 degrees is in about the same ratio.

The above theoretical patterns in all instances are the angular factor of the radiation-field expres-

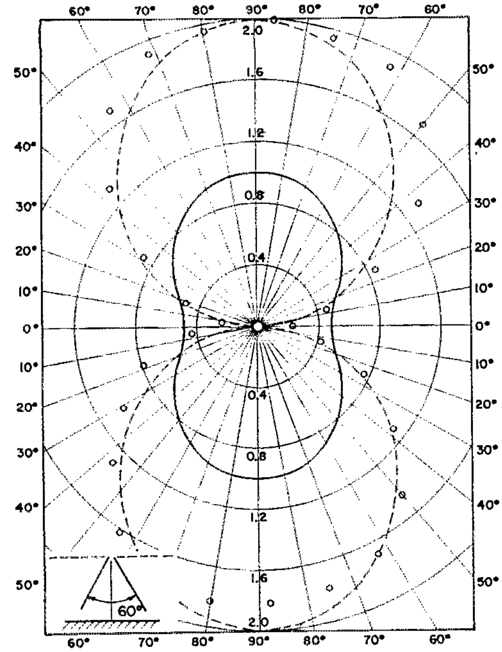

Fig. 2—Continued

sions. Actual field-strength comparisons between the various antennas for a constant input *power* would also require the inverse square root of the radiation resistance of the V. As the leg angle sharpens, this term does decrease, which compensates in part for the reduced angular factor.

Construction Details

On the more practical side, some details are included of a broad-band V for 40 and 80 meters that my father, W4LKB, built. As Fig. 4 indicates, two trees were used instead of a center support mast. Plastic clothesline strung between the trees was tied to a phenolic center insulator. The clothesline is light, strong, and slippery enough to permit easy raising and lowering of the antenna. Several techniques were tried in getting a light line into the trees, including the slingshot-fishing line approach. The best luck was obtained with a bow and featherless arrow.

Fig. 5 shows the center insulator, made with a ½ × 2½ × 3½ inch phenolic block and a U bolt. A coax terminal should be mounted on the block for 52-ohm RG-8/U coax. If RG-58 is used, a knot will keep the coax from pulling through the insulator and reduce the strain on the soldered connections.

Three wires in the cage were considered to be a good compromise between bandwidth and wire cost. Tee braces were constructed of light poplar, ½ × 1⅛ × 11 inches for the upright and ½ × 1⅛ × 12⅜ for the horizontal member. Holes were bored 7/16 inch in from the brace ends to receive the antenna wire. These dimensions will yield an equal wire spacing of 11½ inches. The braces were treated to baths of hot paraffin before assembly with brads or screws. End braces should be especially sturdy. The total length of the wire elements was 121.5 feet for 80 and 65 feet for 40. A good flexible wire — 7 strands of No. 22 copper is excellent — greatly facilitates stringing the cage. Spacing the braces 5 to 6 feet apart seemed to work well. Short lengths of copper or brass wire tightly twisted around the ends of the braces will keep the braces in position along the antenna wire.

Once the legs had been fanned out beneath the center section, it was easy to raise the antenna into position. The 40- and 80-meter antennas ran approximately perpendicular to each other to insure minimum interaction.

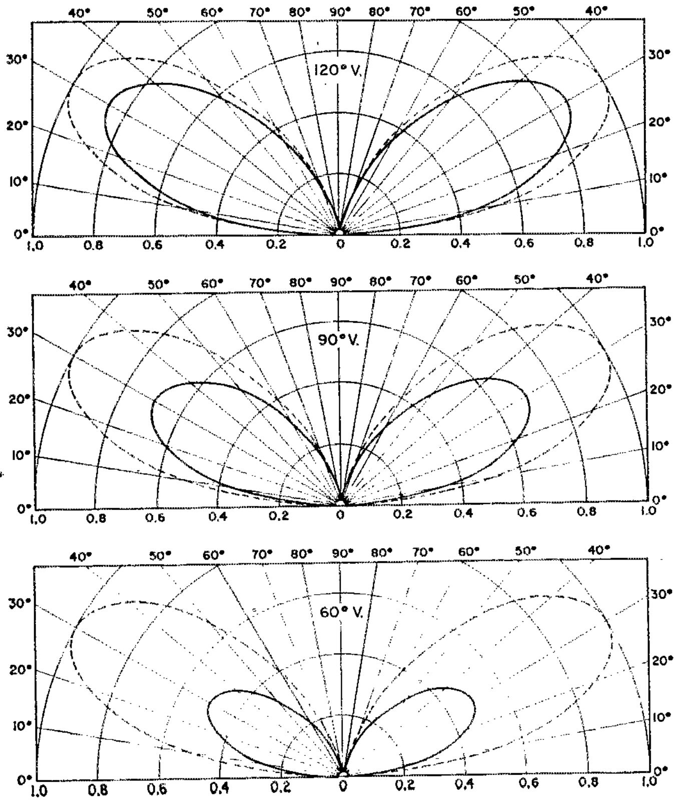

Fig. 3—Vertical-plane radiation patterns for V antennas having three apex angles. The antenna apex is assumed to be one-half wavelength above perfectly-conducting ground. Corresponding vertical pattern of a linear half-wave antenna is shown for shape comparison.

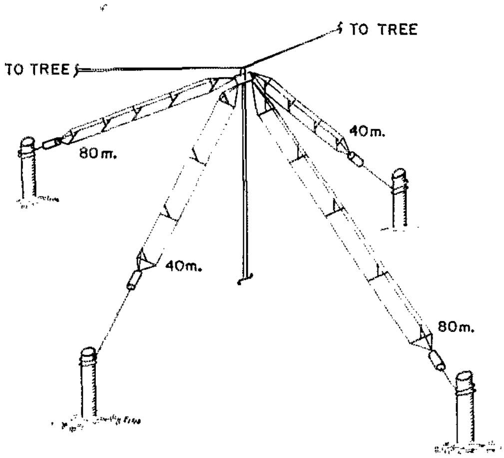

Fig. 4—Inverted-V antennas for two bands suspended from one support. Three-wire cages constructed as described in the text are used for widening the s.w.r. bandwidth. The two antennas are installed at right angles to each other to minimize interaction.

Results

Results from the cage V have been most encouraging. The angle formed by the legs of the 80-meter V is approximately 110 degrees, and is about 95 degrees for the 40-meter V. The apex of the antenna is around 45 feet above ground. This is less than ¼ wavelength for 80, and contacts here have been characteristic of high-angle radiation associated with antennas installed close to the earth. Several QSO's have been made across the U. S. and in Europe on a NW-SE oriented 40 while running 250 watts input. A portable 20-meter inverted V in a N-S direction gave consistently better coverage to the West than to the South.

Plots of the s.w.r. and final lengths are given in Fig. 6. As can be seen, the cage provides a broard-band antenna that maintains less than 2:1 s.w.r. over 80 and less than 1.3:1 over 40. Allred [2] and also some local hams have found that the bandwidth for single-wire V's was limited to around 200 kc. on 80 meters for an s.w.r. of less than 2:1. The over-all bandwidth might be improved by adjusting the angle of the V[6]. Finally, it had been mentioned [1] that the lengths of the V legs should be slightly greater than those for a horizontal antenna. However, it would appear from the above that a shortening of the leg length by roughly 3 percent yields a length closer to the desired resonant frequency.

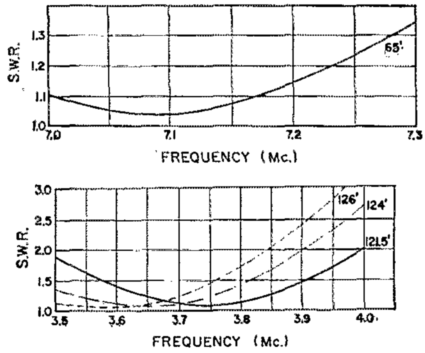

Fig. 6—Measured s.w.r. vs. frequency for the cage inverted-V antennas. The upper graph shows the effect of varying the over-all length of the 80-meter antenna.

In conclusion, the inverted V is an effortless and compact way of radiating. Basically, the V is a close relative of the horizontal dipole. Thus some thought should be given to orientation for low-angle DX use. Radiation at the higher angles is probably omnidirectional. Obviously the unbalance feed with 52 ohm coax will undoubtedly distort the radiation patterns unless care is exercised to cancel currents on the coax braid. At any rate an inverted V is certainly worth a try if that 40 or 80 band switch hasn't been used because of antenna problems.

It is a pleasure to acknowledge the stimulating influence of my father's keen interest in antennas and to present his cage construction hints. QST

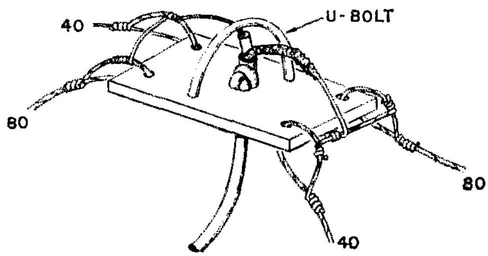

Fig. 5—Details of the center insulator used to support the two cage antennas.

Strays

ITU Centenary Operation

On May 16 and 17 the International Amateur Radio Club at Geneva, Switzerland, will be on the air around the clock in commemoration of the one-hundredth anniversary of the founding of the International Telecommunications Union on May 17, 1865.

Six stations, signing 4U1ITU through 4U6ITU, will be in operation on the following frequencies:

Transmitting	*Listening on transmitting frequency and*
1810, 1830	1810–1835
3503, 3797	3803–3810
7003, 7045	7203–7210
14,113, 14,292	
21,050, 21,400	
28,050, 28,625	
145,100	144,000–146,000

These stations will be manned by visiting operators from all parts of the world, who will be issued special certificates for their participation. Distinctive commemorative QSLs will be issued to all stations worked. If you'd like to be one of the operators on this occasion, or if you'd like a schedule at some special time during the operating period, get off a letter right away to the International Amateur Radio Club, P.O. Box 6, Geneva 20, Switzerland.