The Inverted-L Antenna

You can't put up a low-band half-wave dipole for local work because you're cramped for space? Unable to lay out a good radial system for a vertical antenna to work DX? This antenna may be just what you're looking for — it has the performance advantages of both, without the disadvantages.

By Richard A. Lodwig,* W2KK, ex-W2IHJ, ex-W3GNK, ex-K2ODT

Amateur radio operation in the low hf bands has historically been a challenge, especially for those persons without large amounts of antenna real estate available. In order to operate on the 160-, 80/75-, and 40-meter bands in locations where either or both minimum space and few vertical supports are available, antenna compromises are usually required. Such compromises generally have a significant effect on the bandwidth, efficiency and direction of radiation of the signals. Many antenna types have been proposed and constructed which try to "optimize" the variables involved.

This paper introduces a new type of antenna which was developed and tested, including comparison tests against several other popular antenna types. The antenna has exhibited excellent performance characteristics during these tests and offers some interesting installation advantages, such as no requirements for ground radials and short physical span between supports. In addition, it has been intentionally designed to provide simultaneous low-angle radiation (vertical polarization) for DX work and high-angle radiation (horizontal polarization) for short-distance and local work via sky-wave signals. This article discusses some of the performance factors of this inverted-L antenna, as well as explains how and why it and some of the other popular 160-, 80-, and 40-meter antennas operate in a practical environment.

On the 40-meter band, the daytime D-layer absorption is even lower than on 160 or 80 meters, thus enabling communication up to about 1,000 miles during the day. Up to about 200 miles, the propagation is via high-angle vertically or horizontally polarized sky wave; from 200 to about 1,000 miles, moderate to low-angle vertically or horizontally polarized sky-wave signals provide the communications path. During the evenings, communication on 40 meters is possible from about 500 miles to as far as the limits of darkness permit; the signals are propagated as low-angle horizontally or vertically polarized sky waves. Communication over distances closer than 500 to 1,000 miles is usually impossible on 40 meters during the evening, because the high-angle signals for this distance (within the "skip distance") penetrate the normally reflective F-layer.

At this point, let us examine a principle which relates the propagation mode to the relative performance of several antenna types: The effectiveness of any efficient antenna system is dependent upon how well the particular system (including the surrounding environment) couples energy into an efficient mode of propagation between communicating stations.

Note that this principle implies several necessary conditions for maximizing the communicating efficiency: The antenna itself must be efficient (low losses, little energy dissipated b[y] coupling to nearby objects). One o[r] more efficient propagation modes mus[t] exist between the communicating sta[-]tions since no antenna is capable o[f] enabling communication when there i[s] no suitable propagation mode. The an[-]tenna must couple energy efficientl[y] into at least one of the propagatin[g] modes.

Taking all of these consideration[s] into account, some general conclusion[s] concerning the desirable properties o[f] antennas for the 160-, 80/75-, an[d] 40-meter bands can be drawn.

1) Close-in daytime communicatio[n] would be optimized by an antenn[a] which provides some degree of high[-]angle radiation (about 60-degrees eleva[-]tion angle on 160 and 80 meters, and 3[0] degrees on 40 meters). Either horizonta[l] or vertical polarization is suitable a[t] these angles.

2) Close-in nighttime communi[-]cation (where skip permits) would b[e] optimized by an antenna which provide[s] some degree of high-angle radiation (4[0] to 73 degrees) on 160 or 80 meters with either horizontal or vertical polari[-]zation suitable.

3) Distant nighttime communica[-]tion on any of the three bands require[s] low-angle radiation (40 degrees or less) in either polarization. Generall[y] speaking, the lower the elevation angl[e] that an antenna system provides (close[r] to the horizon), the better will be th[e] communication at extreme distances.

It is obvious that some of the mos[t]

*22 London Lane, Endicott, NY 13760

popular antenna systems used by amateurs provide efficient coupling to either high-angle or low-angle propagation modes, but not both simultaneously. This results in a compromise, whereby good results may be obtained for close-in daytime and nighttime communications, but not for distance or vice-versa. But there are certain antenna types which can be designed to provide efficient operation and coupling to both the close-in and distant propagation modes.

Simultaneous High- and Low-Angle Radiation

The configuration for the inverted-L antenna was arrived at through a process which asked the question, "Is there an antenna type possible which will provide high-angle coverage (for local and moderate distance communication) *and* low-angle coverage (preferably down to the horizon for DX communication) simultaneously in a compact configuration which is reasonably independent of ground loss (thereby obviating the need for an elaborate ground radial system)?" After much thought, a configuration was found which theoretically met these requirements. An 80/75-meter and a 40-meter version of the antenna were built and the 40-meter model was tested directly against other antennas in a set of "blind" experiments. The results of the experiments confirmed that the radiation properties of the antenna were noticeably better than the four basic antenna types used in the "average" type of amateur operation involving both local and DX communication on 160, 80/75, and 40 meters, namely a horizontal dipole, a quarter-wave vertical, a half-wave vertical, and an inverted V.

Fig. 1 illustrates the basic inverted-L configuration. The antenna consists of a quarter-wavelength vertical element and a quarter-wavelength horizontal element which are joined at the central coaxial feed point. The feed line can be run off at an angle away from the plane of the antenna (as in Fig. 1), in the plane of the antenna, or in a direction perpendicular to both legs. The height of the feed point should be at least a quarter-wavelength above ground (but can be higher if feasible) in order that the vertical radiating wire does not reach the ground. (A later section will discuss variations of the basic antenna to allow for installation of the antenna at heights lower than a quarter wavelength above ground.) In the basic configuration, the antenna can be considered to be either a horizontal dipole with one of the arms bent downward by 90° until it is vertical, or a half-wave vertical dipole with its top arm bent 90° until it is horizontal, or a 90° inverted-V antenna which is rotated in its plane by 45°.

Note several desirable factors which such a configuration results in. The vertical arm of the inverted L is a quarter-wave element above ground, but with the high-current end of the dipole located at the top of the vertical structure (not the bottom, as with a quarter-wave monopole). This results in relative independence from ground-loss coupling (since only the high-voltage, non-radiating end of the antenna is near the ground) and good low-angle vertically polarized radiation (since the active high-current radiating portion of the antenna is at a substantial height above ground).

The horizontally polarized section of the antenna, being located at least a quarter wavelength above the ground, provides good high-angle radiation in a manner similar to that of a full-sized horizontal dipole.

Naturally, the amount of signal radiated by the inverted-L antenna in low-angle vertical polarization is not as strong as that of a full half-wave vertical antenna, since we are only providing one of the two arms of the antenna. Similarly, the amount of high-angle signal radiated by the inverted L is not as strong as that provided by a full half-wave horizontal dipole antenna (again, because we are only providing one arm of the two which the dipole normally has). However, the inverted-L antenna provides a substantial amount of both types of radiation, and thus provides better "compromise" performance for the standard types of amateur communication which involves a mixture of high- and low-angle radiation requirements.

The approximate radiation patterns of the inverted-L antenna in the E-W and N-S direction are shown in Fig. 2. Note the relatively uniform amount of total radiated power in both the N-S and E-W direction, independent of the elevation angle. These are theoretical patterns, calculated for perfectly conducting ground, but calculations for an imperfect ground show that the patterns are relatively independent of the electrical properties of the earth. In directions other than the E-W or N-S direction, there is always both a substantial amount of low-angle vertical polarization and high-angle vertical or horizontal polarization. It can be seen by examination of these radiation patterns that the antenna should provide effective local and DX coverage for any of the three low frequency bands.

With a 50-Ω coaxial feed line the VSWR bandwidth of the inverted L is somewhat broader than that of an inverted V and slightly less than that of a dipole, primarily because of the stronger coupling between the adjacent arms of the antenna. About 180 kHz of the 160-meter band or 375 kHz of the 80/75-meter band can be covered with a VSWR of less than 3:1, and the full 40-meter band can be covered with a VSWR of less than 1.8:1. (Later, it will be shown how a short "tail" can be added to the vertical element to permit easy adjustment of the exact center frequency to any desired spot for 160- or 80/75-meter versions of the antenna.)

Theoretical and Experimental Comparison of Types

An experimental program was undertaken to try to verify the predicted radiation performance of the inverted L. Forty meters was chosen to be the frequency band for the test, since there are useful and stable local and distant foreign broadcast signals which could be used for signal strength comparisons. Use of a-m stations facilitated the signal strength measurements by enabling measurement of the received carrier level.

A horizontal half-wave dipole was erected as a reference antenna. Tested

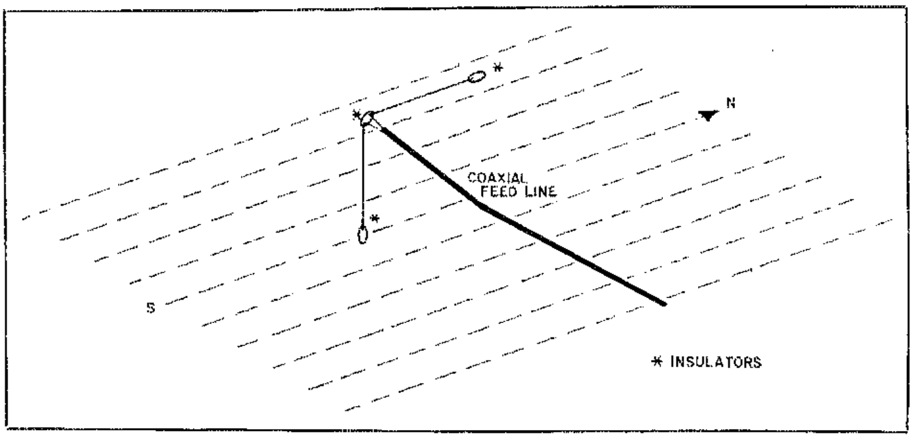

Fig. 1 — The inverted-L antenna. As an aid to discussing radiation patterns, the antenna is shown with the horizontal portion running north and south. The vertical and the horizontal sections are each a quarter wave in length for the frequency band of operation.

against this reference antenna were a quarter-wave vertical, a half-wave vertical, an inverted-V, and the inverted-L antenna. The method for measurement of the antenna performance was to select a local or distant a-m carrier for reception by a calibrated receiver, with the two antennas under test being fed to an spdt rf switch. The peak carrier level was recorded during a period of about 30 seconds for each of the two alternate antennas and was tabulated. The test was performed in a "blind" fashion, with a noninvolved party performing the connection of the two antenna connectors to the spdt switch prior to recording of data. Only after completion of the test were the antennas identified. Several hours of measurements were performed at different times during the day and night for local and distant signals. All of the results (for signals in various directions) were averaged in order to obtain the "average" effectiveness of each candidate antenna compared to the dipole standard. The results of the evaluations are summarized in Table 1.

Of particular significance is the performance of the inverted L with respect to all other antenna types (exceeded in performance by only the half-wave horizontal dipole for local contacts and the half-wave vertical dipole for DX signals). Note the effect of the radials on the performance of the quarter-wave monopole. The radials were physically removed for the "no radial" test, and only a minor VSWR effect was noted when comparing data before vs. after radial removal.

It should be noted that during the measurement series the general trends of the received signal measurements usually substantiated the average trends presented in Table 1. Of course, particular measurements taken at a particular time with a particular signal may momentarily show signal strengths which are different than that indicated in the table.

Table 1

Received Signal Level from 40-Meter Test Series

ANTENNA	*LOCAL (<1,000 MILES)*	*DISTANT (>2,000 MILES)*
Horizontal half-wave dipole λ/4 above ground	Reference	Reference
Quarter-wave monopole, 12 λ/4 radials	−8 dB	+2 dB
No radials	−10 dB	−4 dB
Half-wave vertical dipole	−15 dB	+9 dB
Inverted V, 0.2-λ vertex ht.	−3 dB	+3 dB
Inverted L	−2 dB	+6 dB

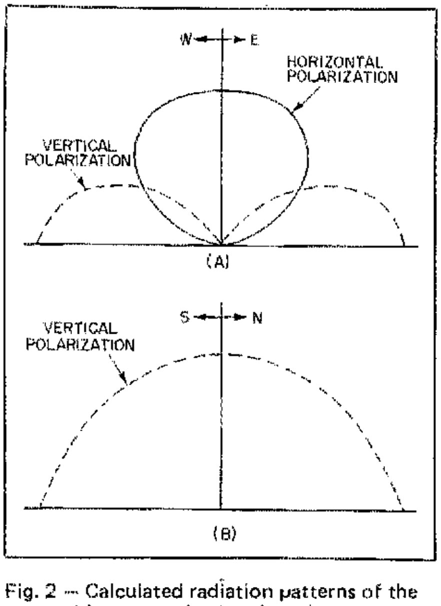

Fig. 2 — Calculated radiation patterns of the inverted-L antenna having the orientation shown in Fig. 1. These patterns show performance for a perfectly conducting earth, but calculations for imperfect ground indicate that the patterns are relatively independent of the electrical properties of the earth.

The relative effectiveness of the inverted-L antenna compared with the others evaluated for the average amateur operation is clear from the table. For local operation, the inverted L was not as effective as the horizontal dipole (2 dB worse), but it is slightly better than the inverted V (about 1 dB better) and significantly better than the quarter-wave monopole and half-wave vertical dipole. When used in providing long-distance communications, the inverted L is not as effective as the half-wave vertical dipole (3 dB worse), but is significantly better than the inverted V (by 3 dB), horizontal half-wave dipole (by 6 dB), and quarter-wave monopole (by 4 dB, even when the monopole had a radial system).

Variations on Basic Inverted L

For the basic inverted L, the approximate length of each leg (in feet) can be calculated by dividing the desired resonant frequency (in MHz) into 230. If it is desired to provide for a degree of adjustment of the resonant frequency (especially in the 160- and 80/75-meter versions of the antenna), an additional length of wire may be added at the accessible bottom of the vertical section. This additional wire can be either vertical or horizontal since hardly any radiation occurs at this point in the antenna. The tuning wire should not be a portion of the main antenna structure, so that its attachment can be accom plished rapidly. An alligator clip o other similar means of attachment i quite acceptable, since very little r current flows across the connection These tuning wires can be precon structed, such that with no wire addec the antenna is resonant near the high frequency end of a particular band Adding a particular wire will lower th resonant frequency to a preset nev frequency lower in the band.

If the geometry of a particular instal lation does not permit equal lengths fo the vertical and horizontal portions o the antenna, the legs may be made o unequal lengths (within reason) as lon as the overall antenna length is 46(divided by the desired resonant fre quency. As an alternative, the le lengths may be kept equal and the fee point located at a point other than the point at which the antenna bends by 90°. For most effective operation of the antenna, the feed point should b located at the junction of the horizonta and vertical sections of the antenna.

Electrically loaded (shortened) an tennas, which are commercially avail able from a number of sources, o continuously loaded types (such a Slinky Dipoles) can be employed wher space does not permit installation of full-sized antenna. Even trap dipole an tennas can be used to provide multibanc coverage in a single inverted-L antenna structure. Tuning of the antenna at the bottom of the vertical section (similar to the full-sized version) is practical for these alternative configurations.

The inverted-L antenna has been in use at the author's station since the spring of 1974. Performance of the antenna has been quite satisfactory, to the point where other antennas (in cluding horizontal and vertical dipoles have been removed and are no longer used. The particular advantage of the antenna (excellent local and DX cover age in a single antenna) is easily ob served when operating with this an tenna. The convenience of a single antenna usable for both local and DX work is noteworthy.

It should be mentioned that I am not aware of any previous disclosure of this particular antenna structure, but I am certain that it must be in use by others who have installations which dictated the particular horizontal-vertical configuration of the invertical L. It is not my intention to claim "discovery" of this antenna, nor to advocate its use in preference to other antenna types. The purpose of the article has been to enable the reader to gain a little more understanding of how various antenna types operate, especially the concept of effective antenna coupling to propagating modes in the 160-, 80/75- and 40-meter bands. QST