The Coplanar-Twin-Loop Antenna

Build this compact, unidirectional HF receiving antenna for ground- and sky-wave interference rejection and direction finding!

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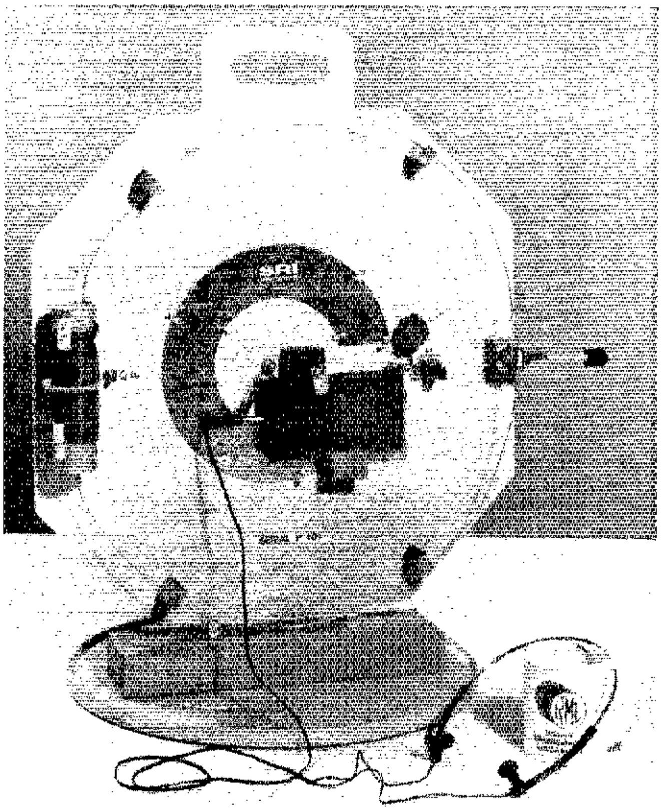

Conventional, compact loop receiving antennas exhibit little directivity on certain sky-wave signals because some signal components arrive at different vertical angles. As a result, directional bearings obtained with conventional loop antennas can be blurred, and can fluctuate with time.

This article describes the design and construction of a compact, portable receiving antenna with a unidirectional null. Null depth is 20 dB or so. I call this antenna the *coplanar-twin loop* (CTL) because of its physical configuration. It consists of two concentric loops instead of one (see the title photo). When station bearings are reasonably well separated, a CTL is capable of greatly reducing sky-wave interference, even if an interfering signal is on exactly the same frequency as the desired signal. This is something a notch filter or Q multiplier cannot do. Accordingly, the designation "spatial notch filter" seems appropriate for the CTL's function. The CTL also adds a new dimension to "fox hunts": *sky-wave* direction finding (see the sidebar entitled "How the CTL Responds to Propagation Modes").

CTL Description

The CTL works, no matter how many vertical-plane modes are present, as long as all the modes travel along the shorter great-circle path from the transmitter to the receiving site, and their arrival angles are below 45 to 50°. (This is usually the case when the received signals originate more than 400 km from the receiving site.)

For receiving ground-wave and low-angle sky-wave signals, the azimuth-plane pattern of the CTL is basically cardioidal (a heart-shaped, unidirectional pattern). The pattern is somewhat sharper than a classical cardioid, though, and has nulls (or near-nulls) at 90°, 180° and 270°. These low-angle nulls can be seen in Fig 2 (slightly filled in, as this pattern shows CTL response at a somewhat higher wave angle). This added directivity is especially helpful in locations such as cities, where there are multiple local inter-

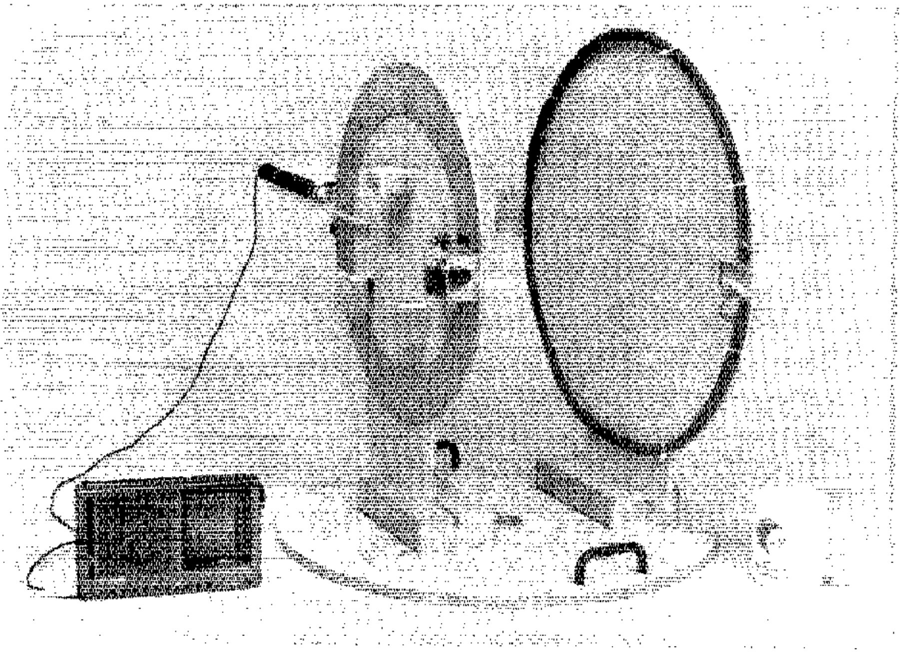

Fig 1—Photograph of an offset-twin-loop antenna for 15 MHz. This model uses offset loops and a coaxial-choke balun to isolate the feed line from the antenna.

Sky-Wave Signal Characteristics

Ionospheric propagation complicates direction-finding and signal rejection by nulling because of polarization rotation and the presence of signal components at multiple vertical angles. These circumstances are more troublesome when, for practical reasons, an antenna's size must be small compared with the wavelength (which must be the case if the antenna is to be portable).

Near most types of ground, the vertically polarized component of an incoming sky-wave signal is considerably stronger than the horizontal component. Nevertheless, the horizontal component cannot be ignored, especially when operating in the upper floors of wooden buildings or other tall structures with relatively low signal attenuation. Many antennas, such as conventional loops, will respond to both vertically and horizontally polarized signals, but their directive patterns are usually quite different for the two. A null in the pattern in one plane is not generally a null for the other. With the CTL, however, in the null direction the component loops are oriented end-on. The planar design makes CTL sensitivity to horizontally polarized signals in this direction so low that it can be ignored.

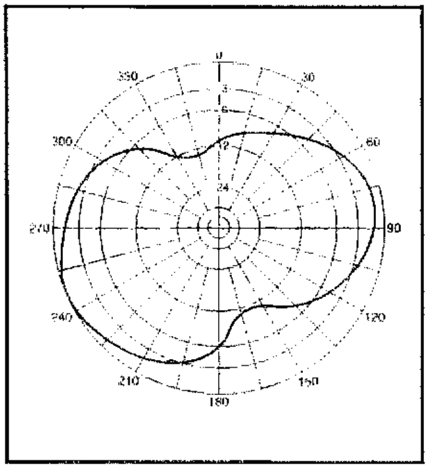

Fig A—Measured azimuth-plane radiation pattern of a conventional loop antenna receiving a multimode signal. This pattern was measured during the same period and on the same signal as the CTL pattern shown in Fig 2.

CTLs do respond to horizontally polarized sky-wave signals from other directions. This response does no harm beyond filling in the pattern nulls which would otherwise appear at 90° and 270° (these are observable in the reception of ground-wave signals).

When the I loop is detuned, the R loop functions as a simple vertical-loop antenna.[†], [††] Fig A shows the polar pattern of a simple vertical loop when receiving a sky-wave signal. Nulls are filled in when signals are horizontally polarized.

[†] O. G. Villard, Jr, K. J. Harker and G. H. Hagn, "Interference-Reducing Receiving Antennas for Shortwave Broadcasts," Final Report, Jan 1987, Contract IA 22082-23, US Information Agency, Voice of America, 601 D St NW, Patrick Henry Building, Washington, DC 20547.

[††] O. G. Villard, Jr, "Portable Unidirectional HF Aerial for Reducing Co-Channel Multihop Sky-Wave Interference," *Proceedings of the Fourth International Conference on HF Radio Systems and Techniques*, April 1988, pp 141-144, Institution of Electrical Engineers, London, England.

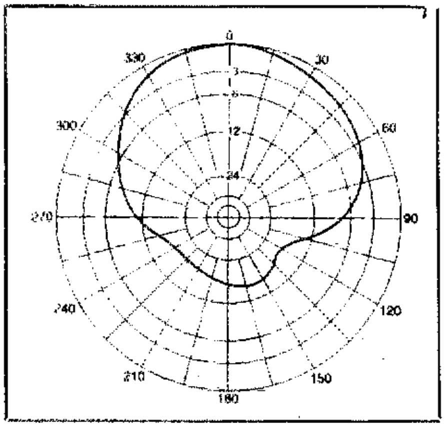

Fig 2—Measured azimuth-plane radiation pattern for a coplanar-twin-loop antenna while receiving a ground-wave signal from an elevated local source. The antenna was located 3 feet above ground for this measurement.

ference sources in different directions. In addition, the ability of the CTL's 180° null to reject signals over a wide range of vertical angles often makes possible near-complete rejection of ground-wave signals that consist of several vertical components.

A hybrid schematic diagram of the CTL shown in the title photo appears in Fig 3. For convenience and portability, a small receiver is included with the loop. This combination is particularly convenient for exploration of local signal fields, both indoors and out. It is especially useful for finding the best location for reception indoors, where both direction of arrival and directional discrimination are strongly affected by reradiation from conductors. Since reradiation fields depend on the details of building construction and furnishing, the best location for receiving must be found by trial and error. This is particularly easy to do when the receiver and loop are a single package.

Advantages of a self-contained device—apart from portability—include the avoidance of feed-line pickup or RF energy conduction along power lines. Larger receivers than that shown can be used with a CTL, if the loops are scaled up appropriately in size. It is desirable—though not essential—that the radio be only an inch or so thick, because this keeps most of the electrical components in the plane of the loops.

The CTL design does have drawbacks. The penalties of good performance in an antenna structure of small size include the reduced sensitivity that results from increased losses, and diminished aperture (energy-collecting area). Relatively narrow bandwidth is also a characteristic of reduced-size antennas, and the CTL exhibits this trait. The effects of losses and small aperture are compensated in the CTL design by making the loops resonant. Reduced bandwidth is overcome by using tunable loops.

How the CTL Works

The CTL consists of two resonant loops, one inside the other, having a common center and lying in a common plane. (It is also possible to use two loops of nearly the same size, concentric and side-by-side, as shown in Fig 1.) The smaller loop is connected to the receiver (as explained later) and is therefore called the *R* (receiver) *loop*. The outer loop is not connected to anything else, thus it's dubbed the *I* (independent) *loop*. It is roughly analogous to a parasitic element in a two-element broadside array or Yagi antenna, but its action is quite different.

The R loop of a CTL is a single-turn, low-impedance loop made of a wide strip of metal. It is tuned by means of a standard medium-wave-band tuning capacitor (350 to 600 pF—C2 in Fig 3). R2 is included in the R-loop assembly to allow variation of the amount of signal supplied to a receiver, as I'll explain later.

The R loop responds primarily to magnetic fields. The I loop, on the other hand, has a relatively high impedance. The I loop responds well to both electric and magnetic fields. Its tuning capacitor has a maximum capacitance of about 20 pF. Both loops are tuned to resonance at the operating frequency. The low-impedance (R) loop is set first and needs no further adjustment for a given band. The I loop, however, must be retuned whenever the operating frequency is altered by more than 10 kHz or so, depending on the desired null depth. The I loop is loaded by L1 and tuned by C1. The Q of the I-loop assembly is controlled by R1.

Directional Properties of the CTL

The null direction of a properly adjusted CTL is in the plane of the loops (instead of

How the CTL Responds to Propagation Modes

There are two fundamentally different situations encountered in practice with sky-wave signals: single and multimode propagation. (Polarization effects and upper-ray propagation are less important and can be ignored here for simplicity.) In the first situation, an ordinary loop—or the R loop of a CTL by itself—will give deep bidirectional nulls suitable for discriminating between two signals when their directions differ. The only difficulty is that this propagation mode is not encountered most of the time. When two or more modes are present, an antenna such as the CTL is needed to give good unidirectional rejection.

The way in which single and multimode propagation varies with time is illustrated in Fig B. This shows a typical daily variation of the major modes for a fixed distance on two bands (14 and 28 MHz). Path length is assumed to be about 4000 km. In the early morning, 28 MHz is usually not open and 14 MHz generally supports only one-hop propagation. (The elevation angle of this hop is small, because of the path length). Under such conditions, a simple loop—especially one with its tuning capacitor in a horizontal segment of the loop—gives a figure-eight pattern†, and is therefore useful for DFing. This is because a single-mode, low-angle, sky-wave signal is—as far as a simple loop is concerned—equivalent to a ground-wave signal.

As the sun rises farther, 14 MHz supports multimode propagation. Under such conditions, a simple loop antenna will give bearings that "wander." This is a situation in which the CTL works very well.

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†H. Whiteside, and R. W. P. King, "The Loop Antenna as a Probe," *IEEE Transactions on Antennas and Propagation*, Vol AP-12 (May 1964), No. 3, pp 291-297.

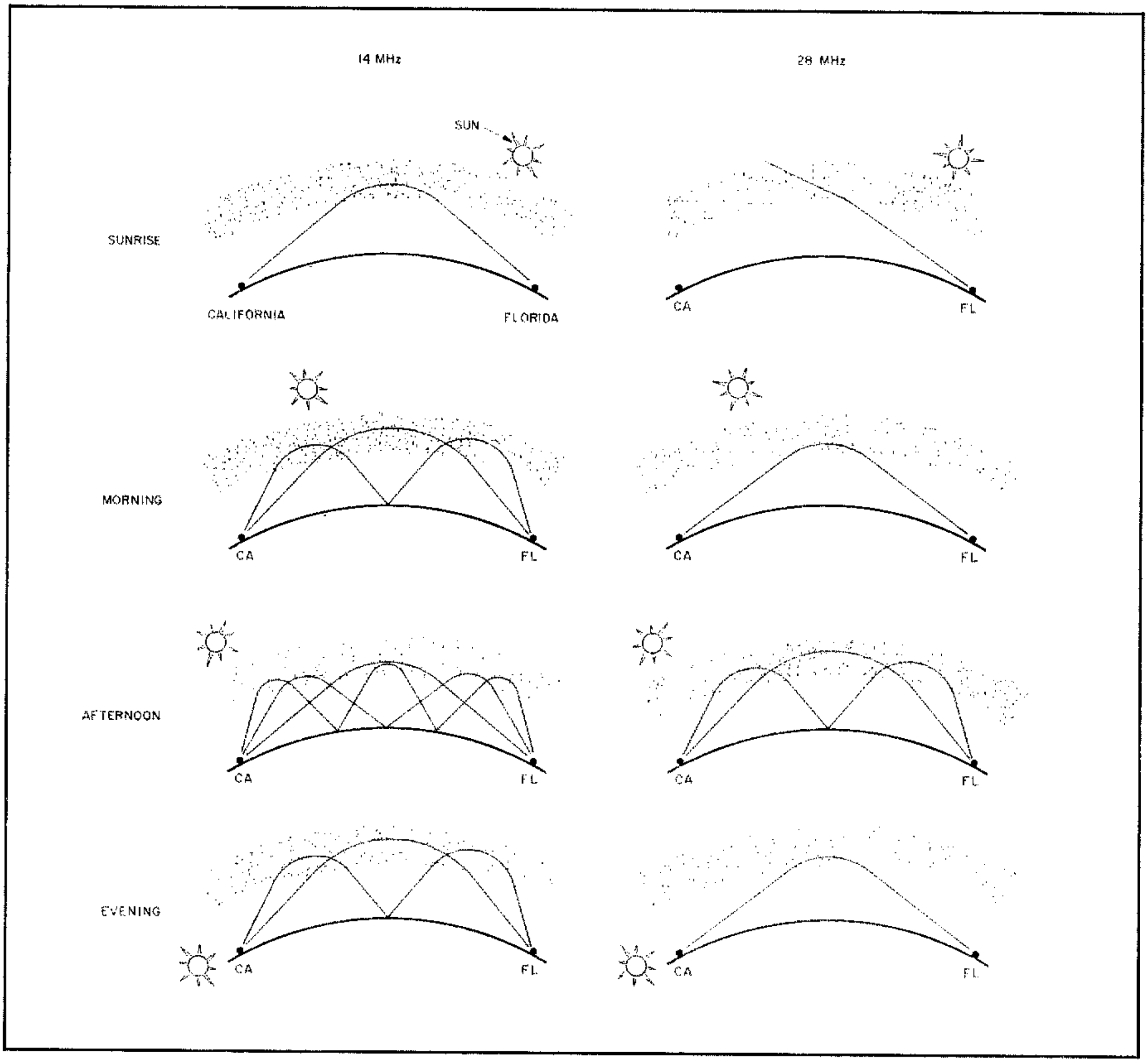

Fig B—Typical vertical-angle propagation modes on 14 and 28 MHz over the course of a day. A CTL antenna performs considerably better than a conventional loop antenna for receiving signals with more than one vertical mode.

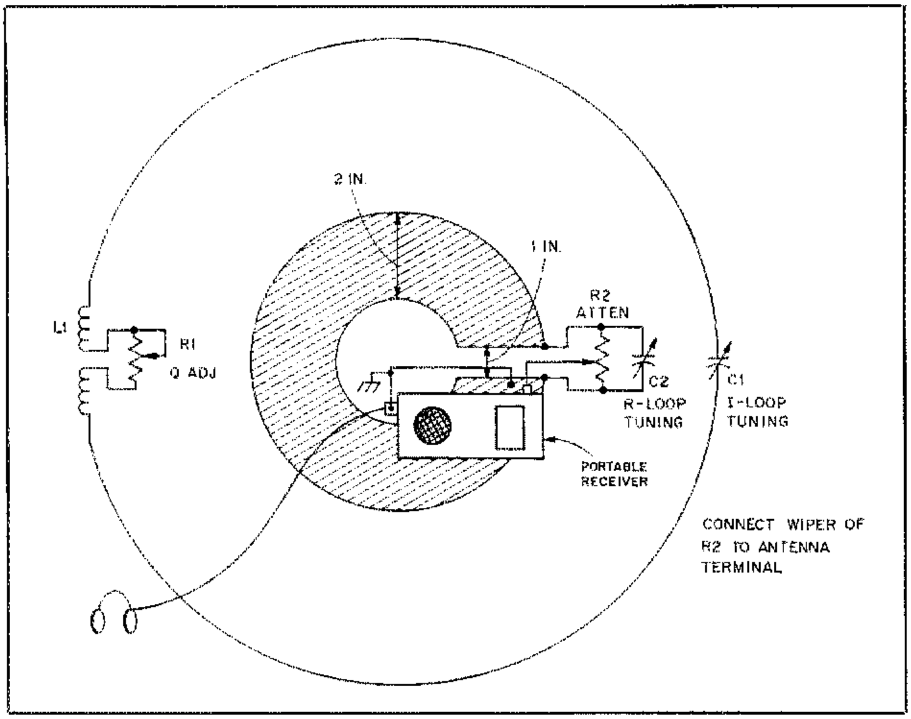

Fig 3—Hybrid schematic of a CTL antenna. The loops can be supported by a single sheet of plywood (or any lightweight nonconductor), or they may be built as shown in Fig 1. A small portable receiver can be connected directly to the R loop (as shown in the title photo) or operated separately from the CTL. If the antenna and the radio are mounted independently, the radio ground must be connected to the end of the R loop as shown. In either case, all other antennas (such as built-in whips) should be disconnected from the radio when the CTL is in use.

Parts list for a 7- to 21-MHz CTL antenna

C1—5- to 20-pF receiving variable.
C2—300- to 600-pF receiving variable (RS 272-1337).
L1—23 turns of no. 18 insulated wire wound on a 1-inch diam wood core approx 6 inches long (approx 8 μH for 15-MHz reception). Open at center for connection of R1.
R1—50-Ω carbon-composition potentiometer.
R2—5-kΩ carbon-composition potentiometer.
I loop—Approx 50 inches of no. 18 insulated wire.
R loop—9-inch OD, 2-inch wide piece of thin sheet metal.

Relative Loop Positions in a CTL Antenna

It is easiest to obtain a good front-to-back ratio when the two loops of a CTL are concentric, of roughly the same size, and spaced apart a distance of one third or one half their diameter, with their planes parallel (see Fig 1). However, with the coplanar arrangement shown in the title photo, the loops are less disturbed by field gradients associated with standing waves created by nearby reflecting objects. (This is because when coplanar loops are in a field having an intensity gradient along a line roughly perpendicular to the plane of the loops, both component loops respond to this gradient in more nearly the same manner than if they were parallel and spaced some distance apart, as in Fig 1.)

As an example of insensitivity to local effects, the portable antennas shown in the title photo and Fig 1 can be used to estimate signal arrival direction when operated inside a small car!

being at right angles to that plane, like conventional loop antennas). Let's assume that a signal arriving from the null direction has vertical components whose elevation angles are no higher than 50°. The function of the I loop is to generate a local magnetic field that cancels the incident field and produces a "shadow" in the total magnetic field at the position of the R loop. When I-loop tuning and station direction are correct, this shadow completely surrounds the R loop (as shown in Fig 4) so that the R-loop output goes to zero.

The position and depth of the shadow (the region of field cancellation) at the R loop depend on the azimuth direction of the incoming signal. Once a magnetic-field shadow has been generated around the R loop, that loop is effectively isolated from the outside world insofar as the nulled signal is concerned. When changes occur either in signal direction or in loop direction with respect to the signal, the I-loop current changes, the region of incident-signal cancellation around the R loop becomes incomplete, and energy can be picked up by the R loop.

For relatively small changes in vertical angle of arrival in the null direction, the I loop's output, and the shadow "darkness" (the degree of incident-signal cancellation), change very little. As a result, once adjustments are made to produce a null in a given direction, the null is independent of elevation angle over a considerable range of angles (Fig 5). At sufficiently high elevation angles, however, the null depth decreases (as it must if there is to be a useful reception in the direction opposite to the null).

Incident signals cause current to flow in the I loop. This current generates a magnetic field. When the I loop is tuned near resonance, the local magnetic field it generates has the correct phase to cancel the incident magnetic field at the position of the R loop. For this cancellation to occur, the locally-generated field must also be of the correct magnitude. This is controlled by either adjusting the axial spacing between the loops, or the Q of the I loop (by adjusting R1).

The I loop generates a local electric field in addition to the desired magnetic field. The electric field of the I loop (which could disrupt the R-loop response) is kept from affecting antenna performance by keeping the R-loop impedance low.

Building the CTL

The parts that make up each loop of the CTL should be as nearly in the same plane as possible (see the title photo and Fig 1, and the sidebar entitled "Relative Loop Positions in a CTL Antenna"). Physically small components are preferable to large ones. C1 should have a relatively small capacitance, although the exact value is not critical—10 pF at 15 MHz is about right for the middle of the HF range (from about 7 to 21 MHz). C1's value can be altered proportionally as the frequency is changed. Once C1 is set, L1 is adjusted by adding or removing turns so that resonance can be found in the middle of the range covered by C1. Band changing with the CTL is discussed in detail later.

The I loop should have only one turn. Improved front-to-back ratio can be obtained if the I-loop conductor is made of two wires spaced roughly an inch apart, and connected at the ends. This increases the electrical width of the conductor and improves the I loop's sensitivity to electric fields. The I loop should be larger than the R loop; the size difference is not critical. Loop spacing can be much closer than that shown in the title photo; 1½ to 2 inches is a good distance.

Since high Q is needed, plug-in loading coils are probably best for L1 if the antenna is to be used over a wide frequency range (more than a 3:1 ratio). Switch-selected separate coils are preferable to one coil of which turns are short- or open-circuited when frequency is changed.

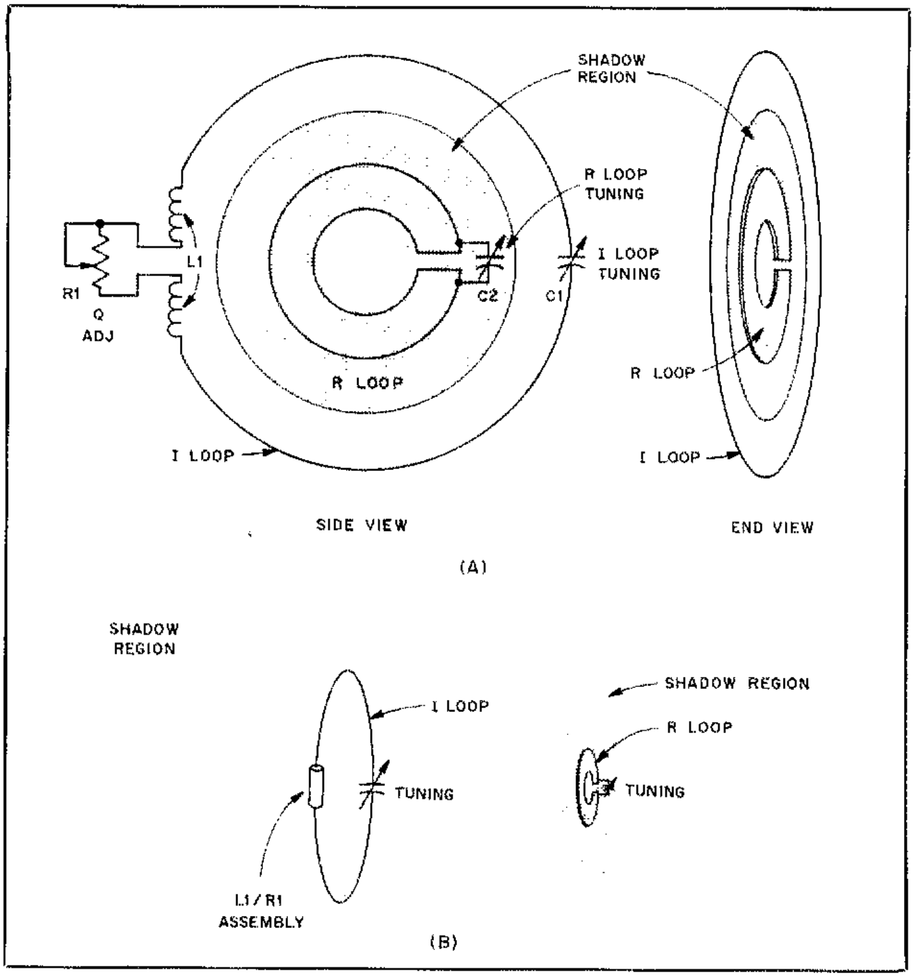

Fig 4—Current flowing in the I loop as a result of an incoming signal creates a shadow in the magnetic field around the inner (R) loop. If the I and R loops are in the same plane (as shown at A), the magnetic-field shadow only occurs around the R loop itself, inside the I loop. If the loops are offset, however, shadow regions exist around the R loop and in a position the same distance away from the I loop as the R loop, but in the opposite direction, as shown at B.

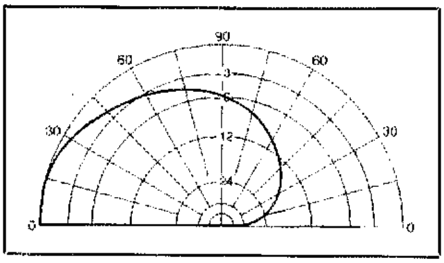

Fig 5—Measured elevation-plane radiation pattern of a CTL antenna located near ground level.

It is important that the tuning capacitors be located in the center of one of the vertical sides of each loop, and that these sides be adjacent to each other. The R loop can have multiple turns if desired, although one should be wide, as shown in the title photo.

Building a CTL is straightforward. Plywood and dowels are about the easiest materials to use for constructing the framework. A hand saw and a drill make the frame building easy. Small blocks of plywood can be used to set the I loop away from the board (giving clearance for the loop and L1, and keeping losses to a minimum). A dab of silicone sealant where the I loop crosses each block will hold the loop in place. Use the title photo and Fig 1 for reference in building the CTL.

Adjusting and Using a Coplanar-Twin-Loop Antenna

The use of lightweight, good-quality headphones—such as those shown in the title photo—is strongly recommended. Changes in signal level resulting from loop and receiver rotation can more readily be distinguished when headphones are used. (Headphones provide an acoustic path of constant length and attenuation.) Because the R loop has a low impedance, there is little hand-capacitance effect, and presence or absence of the headphone wires has little or no effect on receiver and antenna operation. Even touching the R loop with a finger has little effect. The general proximity of the body to the assembly can, for all practical purposes, be ignored, as long as nothing comes within a few inches of the I loop.

The antennas shown the title photo and in Fig 1 are designed for the 15-MHz broadcast band, and will cover the 14-MHz amateur band without modification. The loops are usually operated in the vertical position. To prepare the CTL for operation at a given frequency, first detune the I loop by means of C1 by setting it to maximum or minimum capacitance (see Fig 3). Initially, set R1 to minimum resistance. Then, tune the R loop (with C2) to peak the desired signal. Usually, no further adjustment of C2 is needed unless the operating frequency is changed by a few hundred kilohertz.

Next, tune the I loop to resonance at the signal frequency as follows: Assume that the direction of the received station is known. Orient the loops with their common plane in that direction, and with the loading coil of the I loop on the side closest to the desired station. A pronounced dip in receiver output will occur when C1 is correctly tuned. With the CTL pointing in the opposite direction, the decrease in signal strength is all but unnoticeable. Because the dip will be deepest when the loop plane is precisely aligned with the station direction, readjust loop direction as you approach a signal-strength null while tuning C1. Signal-strength null depth can be in excess of 20 dB, so C1 must be tuned with care to get the best rejection.

Increase the value of R1 from minimum

CTL Performance with High-Angle Signals

The CTL rejects incoming vertical-plane signal components very well from 0 to about 45° in elevation (see Fig 5). This range usually includes the most important angles from the standpoint of long-distance propagation. From 45 to 90°, the amount of rejection falls off. Signals from transmitters at short ranges, delivering only high-angle components, are not rejected as well. In those cases, it is possible to obtain signal rejection by placing the CTL on its side. The antenna is then sensitive to horizontally polarized signals. In that position, the antenna can be rocked or tipped so that its null provides the best rejection. The pattern null is wide in azimuth in this configuration.

Because vertical-plane modes fade independently, the strongest one at any given time will usually yield a good drop in signal strength when the antenna is positioned and tuned correctly. By successive observations, frequently you can estimate which propagation modes are active at a given time, even when there are several present simultaneously. Low-angle signals from distant stations are easily identified in this way. The amount of attenuation on low-angle signals resulting from nearby obstacles, such as trees and buildings, can also be estimated this way.

(while readjusting loop direction and I-loop tuning slightly, if necessary) until the null depth on a particular station is as deep as you can make it. An R1 value of a few ohms is about right. Outdoors, with favorable propagation, the null can be made extremely deep. As propagation conditions change over the course of a minute or so, the null depth typically decreases somewhat. Once the proper setting for R1 is found, there is usually no need for readjustment unless the operating band is changed.

As C1 is tuned through its range, sometimes there is a setting at which the receiver audio output increases. This is most noticeable if R1 has been initially set to zero. When this happens, increase the value of R1. When R1 is close to the optimum value, only a dip in signal strength will be found as C1 is tuned through its range.

As mentioned previously, the purpose of R2 (Fig 3), is to vary the amount of signal supplied to the receiver. (Unfortunately, few broadcast receivers have provisions for disabling the AGC and controlling gain manually. AGC smooths out amplitude changes and makes direction judgement difficult, especially in the case of sky-wave signals with fluctuating amplitudes.) When the CTL is initially adjusted, R2 should be set to reduce signal input to the receiver to somewhere below the point at which AGC action is pronounced. Once the antenna has been adjusted, R2 can be set to minimum resistance, and need not be adjusted further. If your receiver has defeatable AGC, there is no need to adjust R2; just disable the AGC during antenna tuning.

Proximity of the radio to the metal comprising one side of the R loop capacitively couples the radio ground to that side of the loop. Improved results can sometimes be obtained if the radio's ground is physically connected (with a piece of wire) to the same side of the loop. The best point of connection is close to the tuning capacitor, C2. The radio's chassis ground can usually be accessed at either the earphone jack or the external power-supply jack. Some small portable radios become unstable when operated in close proximity to metal. If this is a problem, move the radio to the space between the loops and install a separate ground connection to the radio as previously described.

Once tuning is complete, turn the antenna so that the desired signal lies in the direction of maximum response. Alternatively, the antenna can be rotated so that the null direction coincides with that of an undesired signal. Useful sky-wave signal discrimination can usually be obtained when the angular separation between stations is as small as 45°.

As a result of the resonant-loop, wide-metal-strip design, the sensitivity of the setups shown in the title photo and Fig 1 is surprisingly high—in fact, it is comparable to that of the receivers' built-in whip antennas. To prevent overloading in areas where very high field strengths are encountered, it may even be necessary to couple the radio's antenna connection to the loop via a small (10-pF) capacitor in series with the wiper of R2.

Indoor and Outdoor CTL Operation

Best results are obtained when the antenna is operated outdoors, in a location that is reasonably clear of reflecting objects. Familiarize yourself with the CTL tuning procedure outdoors; it is not necessary to go more than a few feet outside a building. A "reasonably clear" area can be a parking lot—proximity to automobiles has surprisingly little effect at HF, because cars are usually small compared with the wavelength, and are insulated from the ground by their tires.

CTL height above ground is not important. Best interference rejection is often obtained when the antenna is physically close to the ground. (Indoors, this means close to the floor of a room, especially when the building is made of reinforced concrete.) Indoors, the best place to operate a CTL is close to outside walls and, above all, to windows. If there are several windows side by side, the best place for reception is in the middle of the window area.

Although CTL performance—as measured by directional discrimination—suffers when the antenna is used indoors, the degradation is not as serious as you might expect. In general, some degree of directional discrimination is possible wherever a signal of usable strength can be found indoors using a receiver with a built-in antenna.

When a CTL is operated indoors, the following performance changes usually occur, in addition to a reduction in average signal level:

- The indicated direction of arrival may be more related to the direction to the nearest window than the direction to the station.
- Once a null has been obtained on a particular signal, it will tend to drift more rapidly than when outdoors—that is, the amount of rejection decreases appreciably over a minute or two. This is caused by reflections from local conductors. The original rejection level can be restored, but a slight change in azimuth and/or tuning setting is usually required.
- More than one null (often two) in the otherwise unidirectional pattern may be observed.

Move the CTL around and find the spot where these effects are least noticeable. Many reflections encountered indoors have a surprisingly short range. A location change over a distance of a few feet often makes a significant difference.

Band Changing

The R loop can be tuned over about a

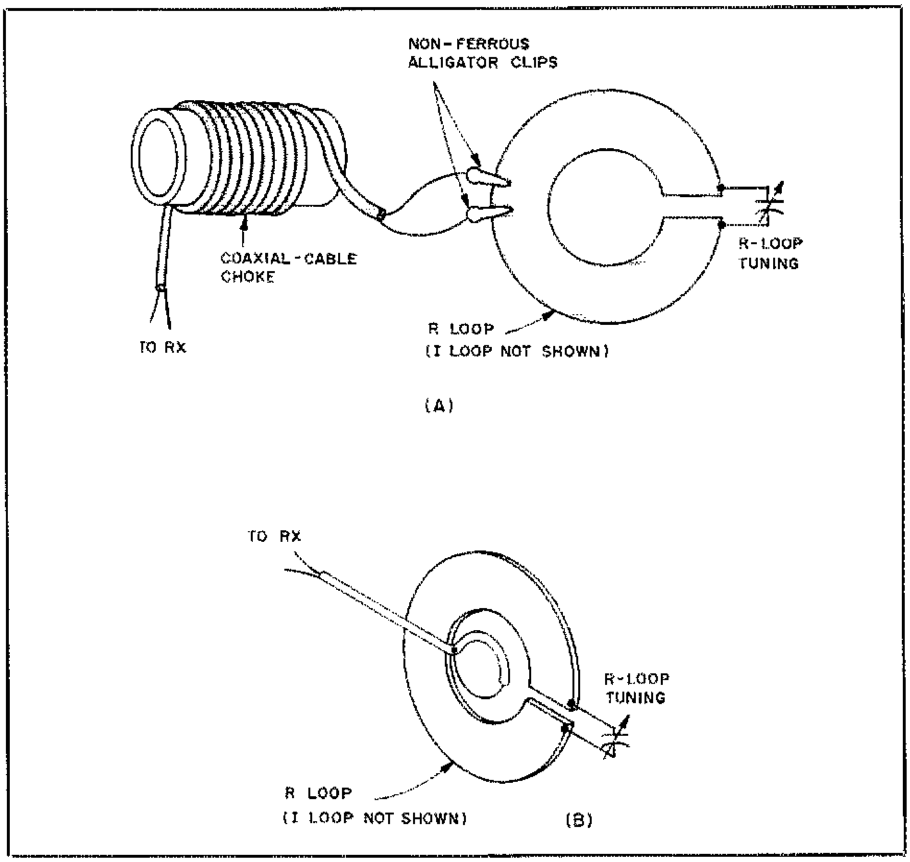

Fig 6—Two methods of connecting a coaxial feed line to a CTL antenna. At A, the feed line is wound over a wooden dowel in solenoidal form. At B, a shielded link is used to couple energy from the loops into the feed line. No direct connection to the CTL is required for this feed method.

three-to-one frequency range (such as 7 to 21 MHz), without band switching, because its tuning capacitor is quite large. For operation at lower frequencies, switch-selected additional turns made of insulated hookup wire can be added to the R loop. These can be wound right over the metal strip, if desired.

Using the CTL with a Separate Receiver

If you want to use the CTL with a separate receiver (instead of a small portable receiver like that shown in the title photo), there are a few approaches to use in attaching a coaxial feed line. One approach is to connect a coaxial cable across the high-current part of the R loop, as shown in Fig 6A. A convenient means for reducing RF current flow on the outer conductor of the coax is to use a small-diameter coax and to wind a portion of it in the form of a solenoidal RF choke, also shown in Fig 6. A coupling loop like the one shown in Fig 6B is another good way to attach a coaxial feed line.[1]

Summary

Although the amount of energy received by a coplanar-twin-loop antenna is considerably less than that of a good Yagi antenna on a tall support, the CTL performs adequately for most amateur HF interference rejection and DF work. If desired, a CTL can be operated by remote control on a rooftop or tower much more easily than a Yagi can be brought indoors!

Acknowledgment

I am grateful to Dr Robert R. Everett for drawing to my attention the instability of some small receivers when operated in contact with sheet metal.

Reference

O. G. Villard, Jr., "Interference-Reducing Antennas for Short-Wave Broadcast Listeners," *IEEE Transactions on Broadcasting*, Vol 34 (Jan 1988), pp 159-166.

O. G. "Mike" Villard is a Senior Scientific Advisor at SRI International, a Professor Emeritus of Electrical Engineering at Stanford University and a former trustee of the Stanford Amateur Radio Club, W6YX. Mike has authored more than 22 QST *technical articles over the last 38 years. Mike earned the ARRL Merit Award in 1955 for "...technical contributions in the fields of wave propagation, single sideband telephony, and selective circuits." Mike has been associated with developments in meteor-scatter propagation, backscatter sounding, long-delayed echoes, magnetospheric HF propagation and ionospheric radar. He was instrumental in the widespread growth of SSB after World War 2, and designed a tunable AF circuit commonly known as the Select-o-Ject.*

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[1] D. E. Barrick, "Miniloop Antenna Operation and Equivalent Circuit," *IEEE Transactions on Antennas and Propagation*, Vol AP-34 (Jan 1986), pp 111-114.

New Products

PACKET RADIO PLUG-IN TNC AND HF MODEM FOR IBM PCs

☐ Digital Radio Systems, Inc (DRSI) has introduced the PC*Packet system for the IBM® PC/XT/AT and compatible computers. PC*Packet consists of a half-length, plug-in PC board that provides the capabilities of two conventional TNCs. The PC*Packet board has two ports. One port has a 1200-bps CMOS crystal-controlled AFSK modem that connects directly to a VHF FM transceiver; the second port is configured for use with an external modem that uses RS-232-C or TTL signal levels. When used with the DRSI HF*Modem, the PC*Packet system provides two-port (HF/VHF) operation, featuring the ability to connect to stations on both ports—simultaneously. A version of PC*Packet with two built-in VHF 1200-bps modems is also available.

The software included with the PC*Packet system features a split-screen, menu-driven terminal program, TSR background AX.25 device driver, a stand-alone TNC emulator and a calibration utility program. The terminal program offers pop-up windows, on-line help information, a scrollable buffer to review received text, ASCII and YAPP binary file transfer, printer support and more. For the more technically inclined, the PC*Packet system includes the developer's software documentation for the low-level TSR driver, and information on how to write an original software application for the system. Prices for the components of the PC*Packet system are: PC*Packet system (including PC board, terminal program, AX.25 protocol support software, RS-232-C serial port and 1200-bps modem), $139.95; HF*Modem with LED bar-graph tuning indicator and selectable 200, 600 or 1000-Hz shift, $79.95; TNC-232 (RS-232-C adapter for TNC-2 and clones), $24.95. Cable sets for the PC*Packet system are also available. A package of two cables (a 5-foot shielded RS-232-C cable and a cable for connecting the PC*Packet board to the HF*Modem) is $12.95, and a cable for connecting the PC*Packet board to a VHF FM transceiver is $12.95. The PC*Packet system is available from DRSI, 2065 Range Rd, Clearwater, FL 34625, tel 813-461-0204 or 800-999-0204.—*Rus Healy, NJ2L*