Cheap and Easy:

The Accommodating Wire Antenna

By Joseph J. Carr

There are three reasons why wire antennas have remained popular amongst SWLs and hams for the entire century or so of radio history: they are cheap, they are easy to erect and they work. Ever since "Gug" Marconi stretched some wire across his father's garden in his native Italy, or wired his backyard in his adopted England, or raised a long wire with a balloon or kite in Newfoundland, wire antennas have been a mainstay for both receiving and transmitting systems. But there are several types of wire antenna that you may either be unaware of, or have overlooked in the glitz of the modern commercial "store bought" antenna.

Two Basic Forms of Wire Antenna

There are three basic categories of wire antenna: Marconi, Hertzian, and loop (Note: some texts list loops as special cases of the Hertzian). Although the details differ from one design to another, nearly all antennas can be fit into one of these classes.

The Marconi antenna is shown in Fig. 1A. Its characteristic feature is that it is unbalanced to ground, i.e. the receiver or transmitter ("generator" in antenna terminology) is operated relative to ground and a single radiator element. The Hertzian antenna (Fig. 1B), on the other hand, is balanced; i.e. it uses two radiator elements, neither of which is grounded. Thus, if one side of the receiver or transmitter must be grounded for the antenna to operate, then it is a Marconi; if neither side is grounded then it is a Hertzian.

The horizontally polarized, half wavelength dipole is an example of a Hertzian antenna, while random length and long wire antennas are examples of Marconis. The vertical antenna, which can be made with either wire or piping, is also an example of a Marconi antenna.

The loop antenna (Fig. 1C) is similar to a Hertzian antenna in that neither side is grounded, but differs from the Hertzian in that the ends of the radiator elements are connected together forming a closed circuit.

Now that we've defined the basic categories, let's take a look at some practical examples.

Half-Size Dipole (Hertzian Antenna)

The standard dipole (Fig. 2A) is horizontally polarized, is half wavelength long, and is fed in the center. The wire radiator elements are made with #14 or #12 copper wire (either hard drawn solid, multiwire stranded, or Copperweld® in ascending order of preference). The dipole is center fed with 75-ohm coaxial cable. The classical "figure-8" pattern of the dipole is usually distorted if only coax is used, so most advanced users of dipoles install a BALUN (BALanced/UNbalanced") transformer at the feedpoint. You can buy several varieties, but for standard dipoles it should have an impedance ratio of 1:1.

The overall length of the antenna's wire radiator element is found from:

$$L_{feet} = \frac{468}{F_{MHz}} \qquad (1)$$

Where: L_{feet} is the overall length in feet, and F_{MHz} is the operating frequency in megahertz (1 MHz = 1,000 kHz). Each element of the dipole (lengths marked "A") is one-half the length of Equation[1]. It is the usual practice to cut a dipole for the center frequency in the band of interest. For example, if you want to cut an antenna for the 9.5 to 10 MHz shortwave band, then use the frequency 9.75 MHz as the halfway point. If you work the equation, you will find that the overall antenna length for 9.75 MHz is 48 feet, so each element is one-half that length, or 24 feet.

The half wavelength antenna has a bidirectional radiation or reception

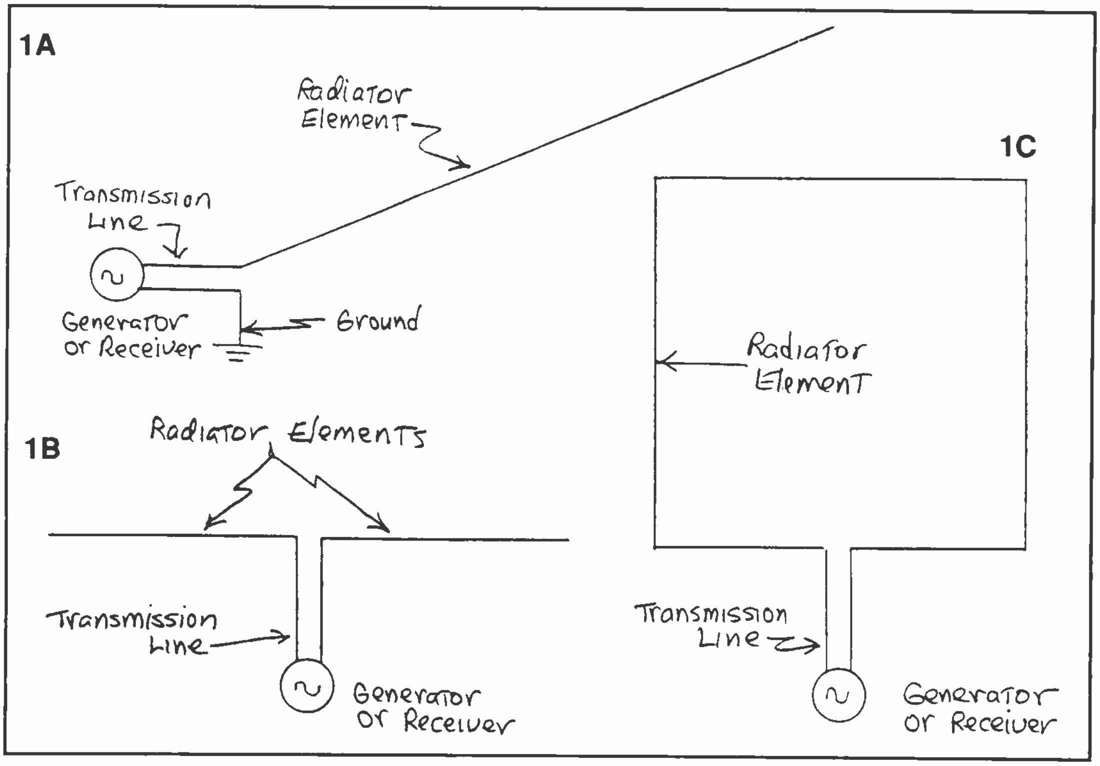

Fig. 1: A) Marconi (unbalanced) antennas; B) Hertzian (balanced antennas; B) Loop antennas.

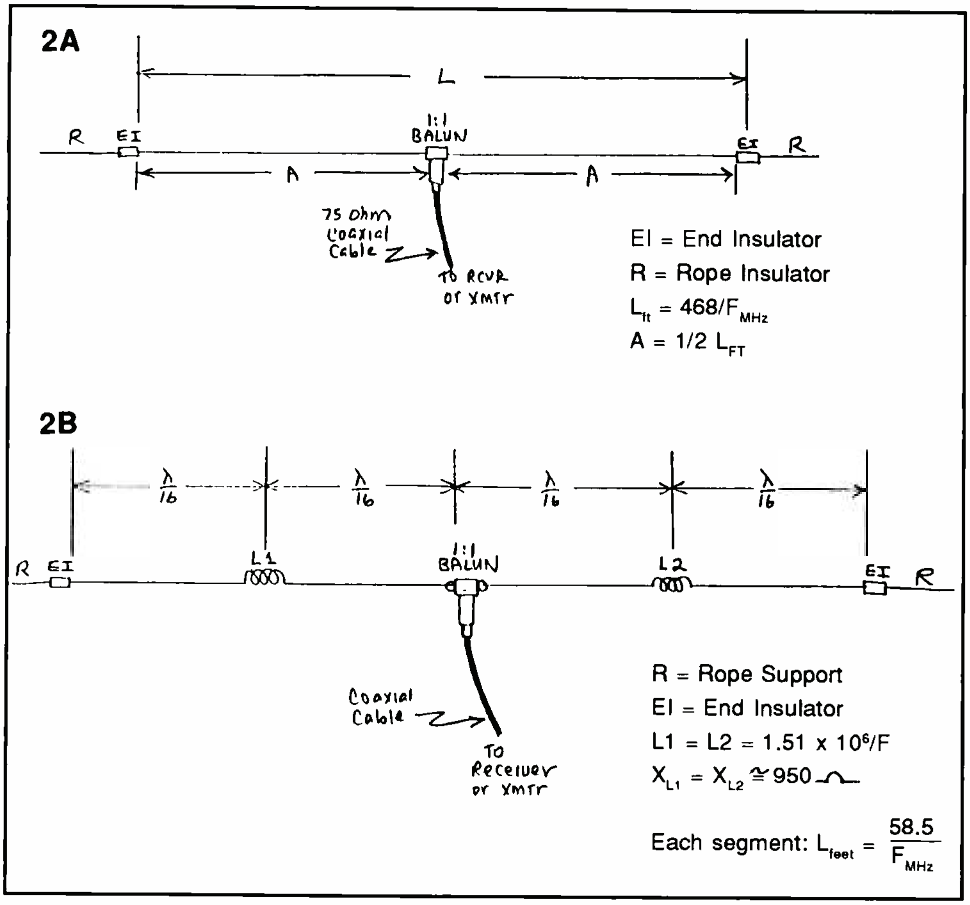

Fig. 2: A) Conventional dipole antenna; B) Half-size loaded dipole antenna.

pattern, so is good for maximizing operation in one direction, or (more importantly) nulling interfering signals from the directions "off the ends" of the antenna. But what if the antenna is too long for your property? For years I lived in houses or apartments that restricted my antenna possibilities. Even today, I can get a 7 MHz antenna (approx. 66 feet) only in one orientation, and would find a 3.5 MHz antenna impossible without the permission of a neighbor.

There is hope: the loaded, short dipole (LSD), shown in Fig. 2B. Although the LSD can be as small as 10 percent of the length of a full length dipole, the half-size (i.e. quarter wavelength) LSD is probably the smallest that is practical for most people, especially since the shorter the antenna the narrower the tuning range (Q). The overall length of the antenna is quarter wavelength (as opposed to half wavelength), and it is made up of four wire segments that are each one-sixteenth wavelength long:

$$L_{feet} = \frac{58.5}{F_{MHz}} \qquad (2)$$

The missing length is made up using an inductor in each leg. The reactance (X_L) of the inductor is a function of the overall length of the dipole (usually expressed as a percentage of the full-sized dipole length); for a half-size LSD the value is about 950 ohms. Make an inductor that has an inductive reactance of 950 ohms at the frequency in the center of the desired operating band. This value is:

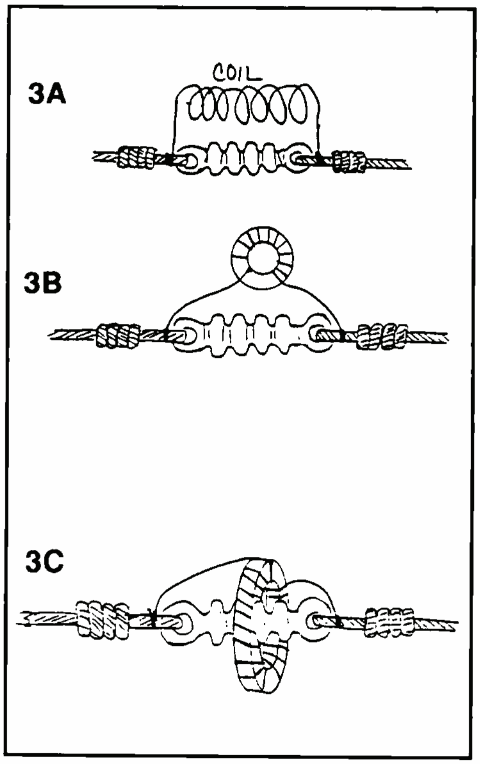

Fig. 3: Methods for mounting loading coils:
A) solenoid wound coils;
B) small toroidal coils;
C) large toroidal cores.

$$L_{\mu H} = \frac{151}{F_{MHz}} \qquad (3)$$

If you work Eq.[3] for 9.75 MHz, the inductance is 15.5 H. Figure 3 shows several ways the inductor coil can be installed on an antenna. Figure 3A shows one way to mount a regular "solenoid wound" coil, i.e. one that is wound in a cylindrical form with length greater than diameter. The wire element sections are tied to an ordinary ceramic or plastic end/center insulator, and tied off with several wraps back on themselves (and then soldered) for the sake of strength. The coil is hung from the insulator, or alternatively, the insulator is placed inside of the coil on the same axis. The mounting of toroidal coils is shown in Figs. 3B and 3C, and follows the same ideas as the solenoid wound coils.

The Random Length or Long Wire (Marconi Antenna)

Random length and long wire antennas (the two are sometimes confused with each other) are easily built Marconi-style antennas. They consist of a radiator element consisting of a length of wire supported by end insulators and ropes. An insulated wire downlead is routed through a window or wall to the receiver. If the antenna is used with a transmitter, then an antenna tuning unit (ATU) is required at the transmitter end of the downlead. If the antenna has an unknown length, then it is a random length and may or may not offer directivity (depending on frequency). The long wire has a length that is at least two wavelengths long (2λ), and offers directivity on the lowest operating frequency (2λ), and higher frequencies.

A lightning arrestor is absolutely essential on any antenna, so don't overlook it on this type of antenna! The ground terminal on the arrestor should be connected to an 8-foot ground rod that is driven into the earth, through a short length of heavy wire (consult local electrical codes).

A problem sometimes seen on long wire antennas is static electricity build up. The electricity comes from local fields, including distant lightning, and other physical phenomenon. It can reach hundreds of kilovolts, and can seriously damage the input circuitry of the receiver (even though not generally harmful to humans, unless you're startled by the shock and fall off your ladder).

The solution to this problem is to place a resistor between the ground and the downlead. Many people place the resistor across the lightning arrestor because the arrestor makes a decent mounting support for the resistor. Use a value of resistance between 200 kohms and 2 megohms. However, in constructing the resistor use at least ten 2-watt resistors in series; i.e. for a 1 megohm resistor use ten 100 kohm, 2-watt resistor connected in series. The reason for this is to prevent the static electricity from arcing over the resistor...we want to drain it off, not zap it to ground (Yes, Virginia, resistors have voltage ratings).

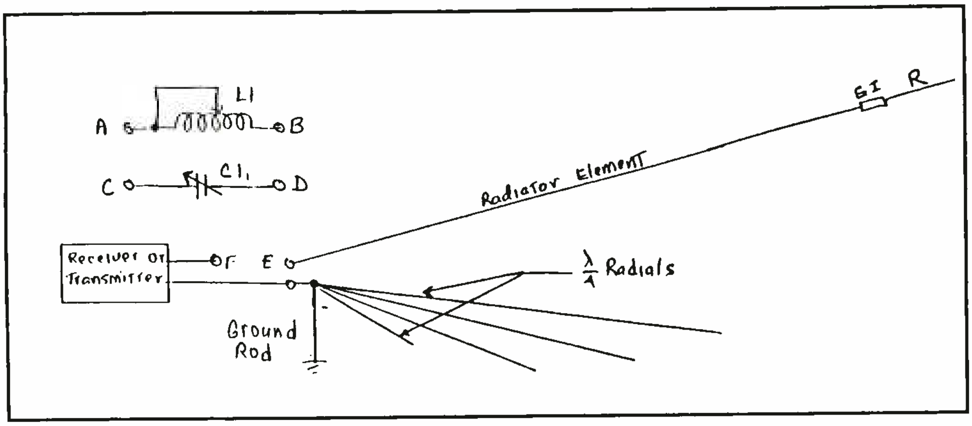

Fig. 4: Tuned random length antenna.

Tunable Random Length or Long Wire Antenna (Marconi Antenna)

The random length antenna is not usually resonant at a wide range of frequencies, but that situation can be rectified by using a tuning circuit at the feed end (Fig. 4). If an inductor (L1) is inserted into the circuit in series, i.e. by connecting B-to-E and A-to-F, then the antenna will act as if it were longer than the actual length (for any given frequency). Alternatively, if a capacitor (C1) is inserted in series with the wire, i.e. connecting D-to-E and C-to-F, then the antenna will act as if it were shorter than the actual length on any given frequency. Conversely, we can build a simple L-section antenna coupler by connecting A-to-F, B-to-D-to-E, and C-to-ground.

For the upper end of the HF region (>14 MHz) use a variable or tapped inductor of 18 µH (or so), and a capacitor of 140 pF. For the entire range of the 3 to 30 MHz HF band, then use a 365 pF capacitor and a 28 µH inductor (for less than 3 MHz, try up to 1100 pF of capacitance, which can be built using a two or three section "broadcast variable" capacitor).

Any long wire is enhanced by using a series of quarter wavelength radials connected to the ground point. The ground rod is also used (for lightning protection), but the radials improve the performance on the bands for which the radials are cut. The length of each radial (in feet) is $492/F_{MHz}$. Use at least two radials for each band of interest (although, up to 120 "the more the better" ...but two to four is a practical limit). For the sake of pedestrian safety in your yard, bury the radials a few inches underground. A spade or shovel blade can be used to "slit" a trench that is wide enough to press a wire into it, without the need for digging holes.

The random length antenna can sometimes be tuned by watching the S-meter on the receiver, but the effect is small (so tune slowly and watch carefully). A better solution is to use a noise bridge, or an SWR meter (if you're licensed to transmit), to tune the antenna. Once the dials connected to the rotary inductor and the capacitor are marked for band and frequency, they can be re-tuned without the need for the instrument.

Terminated Long Wire (Marconi Antenna)

Real long wire antennas (not merely "random length" antennas) are resonant at some frequency that is set by the physical length of the antenna. A terminated long wire (TLW), Fig. 5A, is non-resonant, but is nonetheless directional. The TLW antenna is at least two wavelengths (2λ) long, but the longer the better. The directivity pattern is

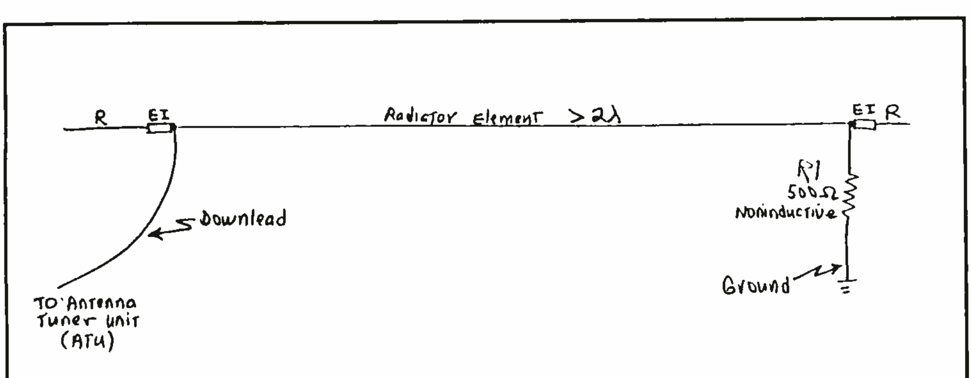

Fig. 5A: Conventional terminated long-wire antenna

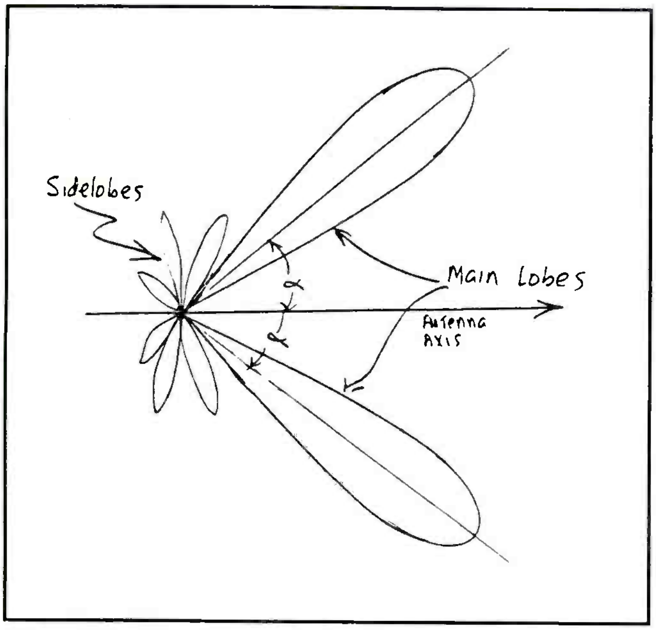

Fig. 5B: Directional pattern

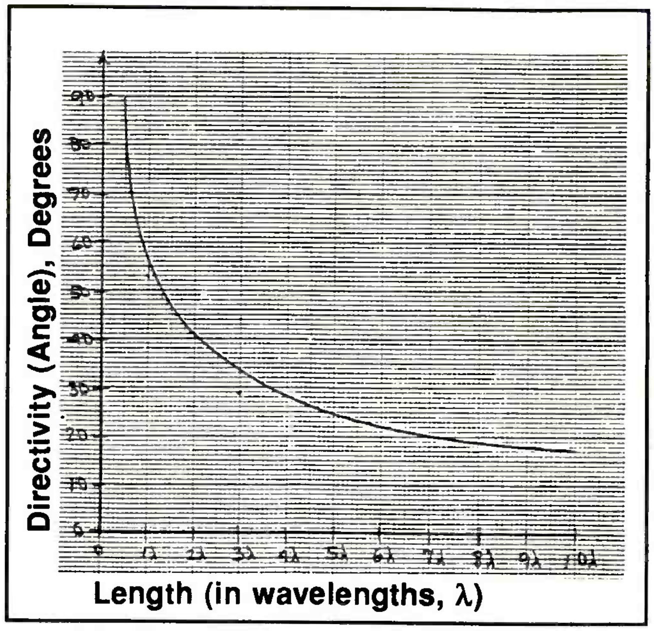

Fig. 5C: Radiation angle as a function of length (in wavelengths).

shown in Fig. 5B, while the angle of directivity (α) is shown as a function of length (in wavelengths) as shown in Fig. 5C.

The termination resistor (R1) has a resistance that is a function of height above ground, but for practical antennas the range is normally 470 to 600 ohms. The resistor must be a nonindnductive type. The power rating for resistors in transmitting antennas must be at least one-half of the applied RF power, but for safety's sake use the full-power rating. For receive-only antennas, a one or two-watt resistor is satisfactory. It is reasonable to use a 470 ohm, 510 ohm or 680 ohm resistor for receive antennas.

There is a bit of a problem on practical long wire antennas: the distance from the ground to the resistor is too long for practical use when a wire must connect the two together. Figure 6A shows a practical solution to this problem: use a counterpoise ground made up of several quarter wavelength radials. The radials tend to make the antenna less "nonresonant," but that problem is overcome by using two or more radials for each band of interest. Thus, we have a non-grounded grounded antenna because of the counterpoise "ground" made with the radials. The resistor can be mounted across an end insulator, in the form shown in Fig. 6B.

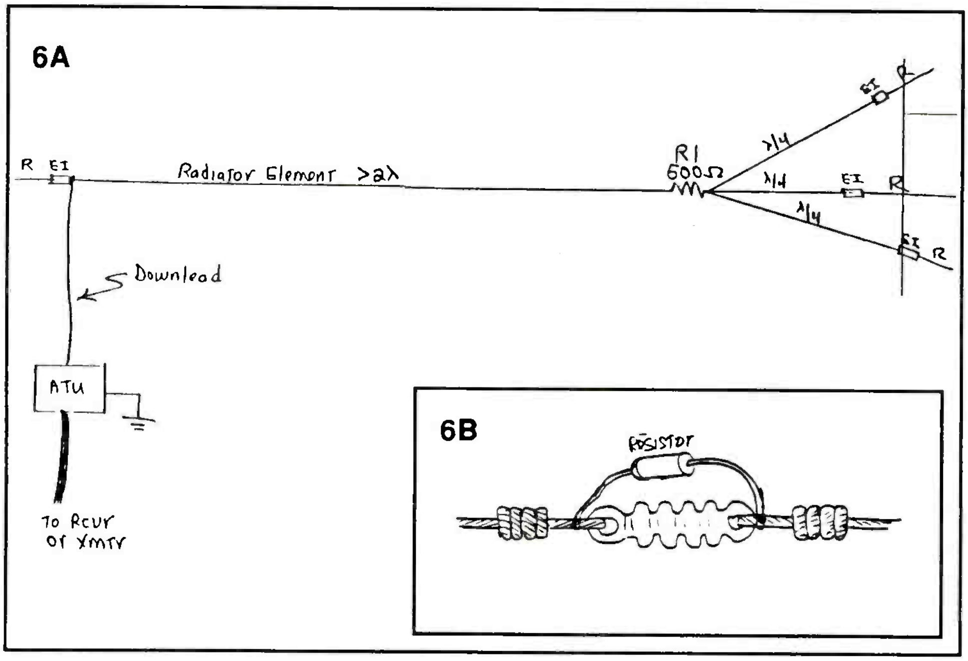

Fig. 6: A) Practical terminated long-wire antenna;
B) mounting the termination resistor for receive antennas.

Tilted, Center Fed-Terminated, Folded Dipole (Loop Antenna)

Figure 7 shows the tilted, center fed-terminated, folded dipole (TCFTFD) antenna, which is a special case of a loop antenna and a folded dipole antenna. The inventor, Navy captain G.L. Countryman (W3HH), once called it a "squashed rhombic" antenna. The antenna is a widely spread folded dipole, and is shorter than a conventional folded dipole. It must be mounted as a sloper, with an angle from its upper vertical support of 20 to 40 degrees.

The feeding of the antenna is conventional, with a feedpoint impedance close to 300 ohms. A 75-ohm coaxial cable is connected to the bottom half of the antenna through a BALUN transformer that has a 4:1 impedance ratio. At the top side of the antenna, the "feedpoint" is occupied with a termination resistor of 370 to 430 ohms (390 ohms, 1 or 2 watts, makes a good compromise for receiving antennas).

The spread (D) of the antenna wire elements is found from:

$$D_{feet} = \frac{9.8}{F_{MHz}} \qquad (4)$$

The spreaders are preferably ceramic, strong plastic or thick-walled PVC pipe. The spreaders can be made of wood (1X2 stock or 1-inch dowels) for receive antennas, if the wood is properly varnished against the weather.

The overall length of the antenna is calculated a little differently from most antennas. We need to calculate the lengths from the feedpoint to the middle of the spreaders, which is also the length from the middle of the spreaders and the terminating resistor. These lengths (A1-B, A2-B, C1-D and C2-D) are found from:

$$L_{feet} = \frac{164{,}000}{F_{kHz}} \qquad (5)$$

Four sections of wire, each with a length defined by Eq[5], are needed to make this antenna. The lengths also must include the lengths calculated for D in Eq[4] above.

The height of the upper antenna support is determined by trigonometry from the length of the antenna from end-to-end (not the length calculated from Eq[5], but approximately twice that length), and the angle. For example, at 7 MHz the lengths are 23.4 feet, and the spreaders are 1 foot. Thus, the overall physical length, counting the two element lengths and half of both spreader lengths, is [2 X 23.4 feet - (2 X 0.5)] foot, or 45.8 feet. If the angle of mounting is 30 degrees, then the antenna forms the hypotenuse of a 60/30 right triangle. If we allow 6 feet for the lower support, then the upper support is:

$$\text{Height(ft)} = 6 + L \cos\phi = 6 + (45.8 \cos 30) = 45.7 \text{ ft}$$

This antenna has a low angle of radiation, and at a tilt angle of 30 degrees (considered ideal) it is nearly omnidirectional.

Loopstick Receive-Only Antennas (not loop, but Hertzian)

A loopstick antenna (Fig. 8) is a tiny, directional antenna that is built on a ferrite rod core, using a wire wrapped around the rod. Most AM and MW portable radios use an internal loopstick antenna. For the shortwave bands, use a 7 inch rod made of #61 ferrite material such as the Amidon Associates (12033 Otsego Street, North Hollywood, CA 91607; 1-818-760-4429) model R61-050-750.

Wrap the entire length of the ferrite rod with a single layer of black plastic (not cloth) electrical tape; do not use "friction tape." Start at the center, and wrap #22 or #24 insulated wire clockwise until only about 1/4-inch of rod is left. Next, wrap the same number of turns from the center to the other end, but wind in a counterclockwise direction. Tie off the ends and the center with electrical tape to keep the assembly from coming unraveled. Solder the two wire ends at the center to the center conductor of a piece of coaxial cable (52 or 75-ohm); the coax shield is not connected to the antenna. If the signal level is low, then also do not connect the shield to the receiver chassis (experiment with the shield grounded and floating for best results).

The loopstick antenna can used either indoors or outdoors, but its main use is to place a null on the direction of an interfering strong station. When you null out these powerhouse blowtorches, it is surprising what weak stations are lurking beneath them.

Conclusion

Wire antennas are a low cost, effective and simple to build alternative for both ham radio operators and shortwave listeners. They work well, and don't cost an arm and a leg. Although you can stick with the old fashioned dipole and vertical designs, these designs offer you some alternatives to work on.

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More information on wire antennas can be found in J. Carr's book Practical Antenna Handbook (TAB Books, Blue Ridge Summit, PA, 17294-0850; 1-800-233-1128; Cat. No. 3270, $21.95).

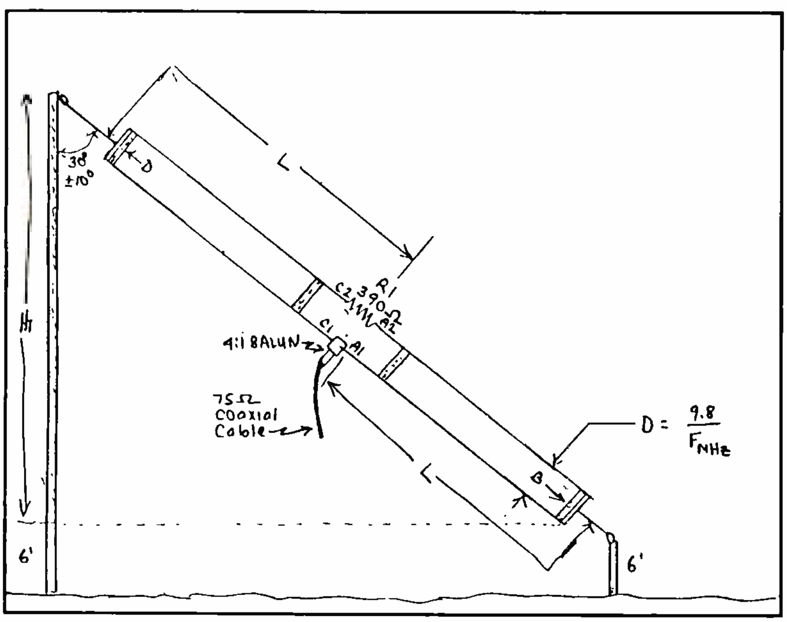

Fig. 7: Tilted center fed/terminated folded dipole loop antenna.

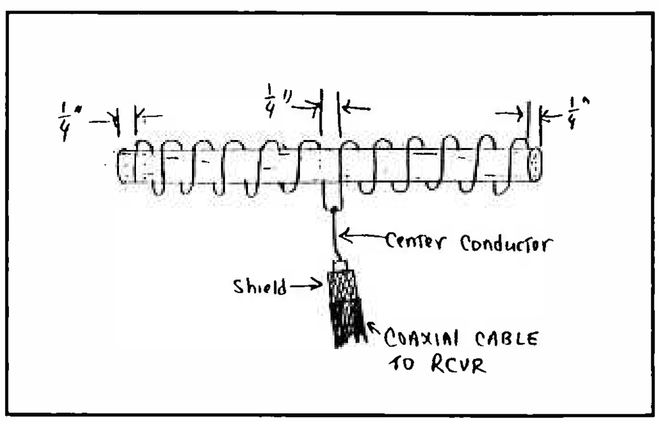

Fig. 8: Loopstick antenna.