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Chapter 20

Stealth and Limited Space Antennas

The biggest challenge facing many hams today is putting up an effective antenna. Many homes come with severe restrictions or even prohibitions on external antennas of any sort. Apartment and condominium dwellers have even more limiting circumstances. The traveling ham faces a new set of challenges at every stop. Yet many persevere and have rewarding experiences in Amateur Radio without big towers and high wires. The secret? According to Steve Ford, WB8IMY, author of the ARRL's *Small Antennas for Small Spaces*, it's "using the best antenna possible for a given circumstance." That may be a wire in an attic or dangling from a high-rise window but you can get on the air and make lots of contacts. In fact, Joe Gregory, W7QN, moved to an apartment building several years ago and has been making thousands of contacts with nothing more than a mobile antenna clamped to his balcony railing. Enjoyable hamming — even DXing — is very achievable without the traditional "aluminum farm" and that is the focus of this chapter.

Much of the material in this chapter is collected from WB8IMY's book mentioned above and Steve Nichols, GØKYA's RSGB book *Stealth Antennas*. In addition, several projects from the pages of *QST* and other sources are provided. It is not expected that you will be able to exactly duplicate these designs. Use them as a starting point for adaptation to your particular circumstances and learn to adjust and work with the resources available. You may also find the **Portable Antennas** chapter interesting reading.

The goal of presenting this collection of antenna designs is to inspire imagination and innovation on the part of the reader. As you review these antennas, think about how you might apply the same styles and approaches to your station. Perhaps these antennas will answer the question, "Would antenna X work in my situation?" Give your imagination free reign!

Once you have selected a design, be prepared to experiment and adjust. The *antenna analyzer* described in the **Antenna and Transmission Line Measurement** chapter is an invaluable tool for this type of antenna building.

20.1 INSTALLATION SAFETY

Why start with a discussion of safety? Because your antennas will likely be a lot closer to power wiring and power lines than the traditional dipole in the trees. In addition, you and your family and possibly your neighbors will be a lot closer to the antenna than if it is installed outside and well above the ground. The *ARRL Handbook* contains additional information on electrical and RF safety and grounding.

20.1.1 ELECTRICAL SAFETY

Before installing or even designing an antenna, check the area around your home and property for power lines, including the household voltage "service drops" to your house. Don't mistake a power line for a cable TV or telephone line. Working on building roofs or lowering wires and cables over the edge of a building or out a window can place you or a wire or cable in contact with hazardous, even lethal, voltages. Here are some rules to live by:

- Keep all objects — including masts, poles, ladders, tools, and antennas far away from power lines at all times. If in doubt — stop. You can be electrocuted if you are touching anything even a little bit conductive that comes in contact with a power line. High voltage electricity does not need much conductivity to create hazardous currents.

- Antennas and masts should never be closer than 10 feet to a power line or your electrical service wiring.
- If you are moving an antenna or taking one down, look for new power lines that may have been installed or rerouted since the antenna was first put in place.
- Never assume that any power line is insulated — any contact may be lethal.
- Don't rely on fiberglass or wooden poles to act as insulators.
- Know first aid for electrical shock and don't work alone if possible.

Installing indoor and otherwise stealthy antennas invariably means drilling holes through and driving fasteners into walls and ceilings. Before drilling or hammering or driving, be sure that you are not about to come in contact with an electrical wire or a water or gas pipe. If you are in doubt, stop and get professional help. The cost and small delay are minor compared to that of a fire or leak. Remember that detectors designed to find metal piping or conduits will not find plastic pipe.

20.1.2 PERSONAL SAFETY

You may have seen comedy sketches where someone puts a foot through the ceiling but it isn't very funny when it's your or your friend's ceiling! Take steps to be sure that you are working safely and not placing yourself in a risky position. When working in unusual spaces in, around, or on top of your home, someone else should be at home in case you become stuck or fall.

When working in an attic or crawl space, make sure you have adequate lighting. If you plan on working in these areas frequently, consider installing permanent lighting. At any rate, an ac "trouble light" with a florescent or CFL bulb will provide plenty of light. (Incandescent bulbs have a habit of breaking the filament when a trouble light is dropped or bumped into something.) Carry a strong flashlight with fresh batteries since it is inevitable that you'll be working in the shadows at some point. A head-mounted LED lamp works well.

Do not attempt to walk on attic joists as they make poor footing, leading to the aforementioned ceiling damage and possible injury. Use boards placed across the joists to support your weight. Again, if you expect to be working in the attic regularly, permanently install boards or plywood sheets.

Glass wool insulation is an irritant as the fibers break off and can stick in skin or be inhaled. Wear gloves, long-sleeve shirts and pants when working around insulation. If the insulation is loose (not in batts or rolls) wear a face mask. A face mask is also a good idea in crawl spaces to avoid inhaling rodent or insect droppings, dust or mold spores.

If you are working on a pitched roof, consider using a safety harness sturdily anchored to a tie point or chimney. Review basic climbing safety techniques and equipment in the chapter **Building Antenna Systems and Towers**.

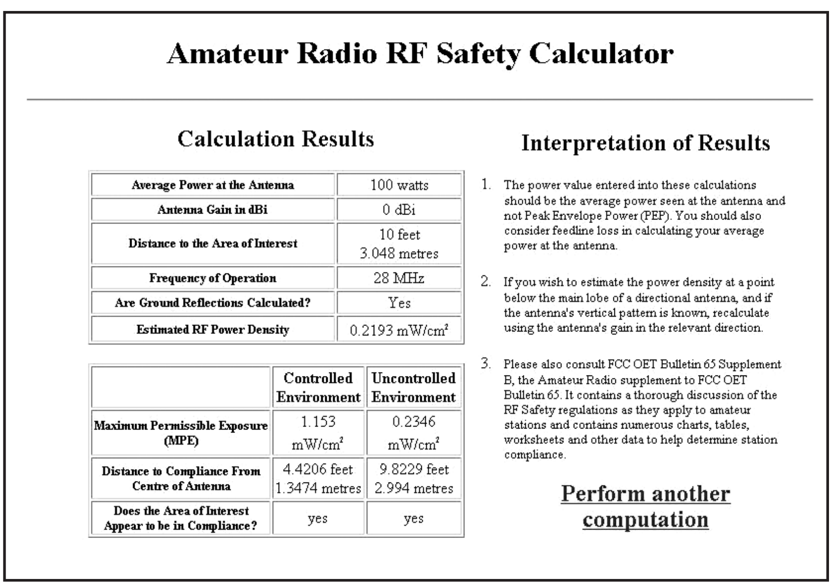
20.1.3 RF SAFETY

It is a good assumption that the antennas in this chapter will be installed fairly close to people. As such, you should consider the potential effects of your transmitted signal and are required to evaluate your station for RF exposure.

The evaluation procedure — required of all FCC-licensed amateurs — isn't as involved as you might think. No test equipment is required and no paperwork must be submitted to the FCC although you need to log your evaluation results and keep them at your station. An RF safety evaluation amounts to entering some values into an online calculator to determine whether your station is in compliance — it's that simple.

Figure 20.1 shows the RF Power Density calculator created by Paul Evans, VP9KF at **hintlink.com/power_density.htm**. For many of the antennas in this chapter, you can assume the gain is 0 dB. If you use a directional antenna, be sure to use the maximum gain figure and be aware of where the antenna is likely to be pointed.

The calculator mentions *controlled* and *uncontrolled* environments. These terms refer to whether people know RF is present and can take steps to control their exposure. (The **Antenna Fundamentals** chapter defines these terms and includes a large section on RF exposure and RF safety and the ARRL publishes the book *RF Exposure and You* for more information.) Assuming other people live in your home and nearby, the uncontrolled environment should be used. Even so, you will probably find that in most cases your station is in full compliance when transmitting with 100 W or less and for separations of approximately 10 feet. You will find that you must be running a fair amount of power at VHF or UHF and be fairly close to the antenna to exceed the RF level for compliance. As you use the calculator, print the screen images to create your evaluation record.



Amateur Radio RF Safety Calculator

Calculation Results

Average Power at the Antenna	100 watts
Antenna Gain in dBi	0 dBi
Distance to the Area of Interest	10 feet 3.048 metres
Frequency of Operation	28 MHz
Are Ground Reflections Calculated?	Yes
Estimated RF Power Density	0.2193 mW/cm^2

	Controlled Environment	Uncontrolled Environment
Maximum Permissible Exposure (MPE)	1.153 mW/cm^2	0.2346 mW/cm^2
Distance to Compliance From Centre of Antenna	4.4206 feet 1.3474 metres	9.8229 feet 2.994 metres
Does the Area of Interest Appear to be in Compliance?	yes	yes

Interpretation of Results

1. The power value entered into these calculations should be the average power seen at the antenna and not Peak Envelope Power (PEP). You should also consider feedline loss in calculating your average power at the antenna.
2. If you wish to estimate the power density at a point below the main lobe of a directional antenna, and if the antenna's vertical pattern is known, recalculate using the antenna's gain in the relevant direction.
3. Please also consult FCC OET Bulletin 65 Supplement B, the Amateur Radio supplement to FCC OET Bulletin 65. It contains a thorough discussion of the RF Safety regulations as they apply to amateur stations and contains numerous charts, tables, worksheets and other data to help determine station compliance.

Perform another computation

Figure 20.1 — The RF Power Density calculator created by Paul Evans, VP9KF, at hintlink.com/power_density.htm.

20.2 LOCATIONS FOR ANTENNAS

If you live in an apartment or condominium, do you have an attic space overhead? If so, find the access door. It is often hidden away in a closet or utility room. With a ladder or step-stool, grab a flashlight, open the hatch and take a look around. If you can easily (and safely) climb into the attic, go ahead and take some measurements. How much height is available? How much horizontal length? What does the insulation look like? Is it blown-in material or paper-backed batts or do you see sections of insulation with reflective metallic backing? Metallic-backed insulation acts as a shield and rules out such spaces for antennas. The same concern applies to metal buildings or buildings with metal siding or roofing.

As a test, take a portable radio into the space and try to receive signals. If you have a "world-band" shortwave radio, this is a great use for it. Start outside the space by tuning in a signal near a frequency at which you will want to operate. Then enter the space with the radio operating. If the signals stay the same level or get louder, an antenna will probably work well in the space. If the signal levels drop, the space will probably not work well for whatever reason. For VHF/UHF operation, a hand-held radio can be used in the same way.

If you don't have an attic, check out the inside of the apartment. Are there any rooms that might accommodate an antenna secured to the ceiling? If so, how much space is available? If you are considering VHF/UHF antennas, don't neglect the windows, especially if you live above the ground floor or have multiple floor levels. If the windows have metal screens, can they be removed? It is quite possible to be successful in pointing directional VHF/UHF antennas through windows.

Even apartment and condominium dwellers should examine the property for nearby trees. Depending on how restrictive the landlord or condo association might be, trees provide excellent opportunities for discreet long-wire antennas.

If you live in a house, your antenna location options expand considerably. Take a walk around the yard and make some measurements. Look for convenient supports such as trees and note their distances from each other and your house. Make a simple map from your measurements for planning.

Don't neglect the roof of your home. A chimney can support small VHF antennas but is not designed to handle the stresses of larger antennas. You may wish to consider a roof tripod such as are available for large TV antennas. (See the **Building Antenna Systems and Towers** chapter for examples.)

It cannot be over-emphasized that you will likely need to be inventive to a degree not required of the traditional outdoor antenna builder. Browse websites, read magazine articles and books, and ask other club members about their experiences. The more information you have, the more likely it is that you'll be able to find an acceptable solution for your particular situation with a little experimentation.

20.3 RF INTERFERENCE

Because your antenna is likely to be close to your living quarters, it will also be close to the many electronic devices in use today, including appliances and security systems. Realistically, you should expect some interference when operating at (or above) the 100-W level. You will probably also experience interference *from* these devices and systems. *The ARRL RFI Book* is an excellent resource to help you deal with interference as is *The ARRL Handbook*.

Nevertheless, many interference issues are quite manageable. Perhaps you can operate with low power. Keep the antennas as far as possible from your electronics and those of your neighbors. Learn how the radiation patterns of your antennas might be used to direct your strongest signal away from them. Study how to apply ferrite chokes to keep your signal out of electronics and vice versa — Jim Brown, K9YC has written an on-line tutorial (see Bibliography) about the use of ferrites to fight RFI.

Be especially aware that indoor antennas often couple very strongly to nearby or adjacent power wiring, telephone and network cables, security system wiring, etc. The best solution is to avoid placing antennas in close proximity to other wiring. If that is not possible, be prepared to mitigate interference with chokes and other measures such as the "Resonant Breaker" described in "Better Results with Indoor Antennas" by Fred Brown, W6HPH, on this book's CD-ROM.

Another option is to use modes that concentrate your power into narrow bandwidths, allowing you to communicate with a minimum amount of power. For example, Morse (CW) and the various PSK modes pack the entire signal into a bandwidth of less than 100 Hz. In addition, PSK is a *constant-power* mode and does not cause clicks and thumps and garbled voice in equipment receiving the signal unintentionally. In fact, PSK31 is used by many hams with antenna restrictions to make contacts around the world at powers of just a few watts.

20.4 INDOOR ANTENNAS

20.4.1 INDOOR HF WIRE ANTENNAS

The basic antennas presented in the chapters **Dipoles and Monopoles** and **Loop Antennas** can be adapted to many styles of installation. Most of them are quite forgiving of being bent and folded although you will have to make adjustments from the full-size antenna to achieve resonance at the frequency you want. Remember that the more an antenna is folded or coiled, the less efficient it becomes because the radiation from the different parts of the antenna tend to cancel out. Keep as much of the antenna in a straight line as you can.

The common λ/2 dipole in **Figure 20.2** is a very tolerant antenna. At 14 MHz, it is approximately 33 feet long and can be bent to fit many different rooms, under a roof line or eaves, in a hallway, etc. Very thin wire can be used at low power such as #30 AWG solid wire-wrap wire that comes in a number of colors to blend in with the surrounding material. You can use adhesive tape or hooks to hold it against the wall or ceiling. **Figure 20.3** shows a multiband antenna fed with ladder line. You can also use the clear 300-Ω twinlead sold for use with FM radio antennas.

Loop antennas can also be used as long as they are not too much smaller than one wavelength. (Very small transmitting loops are covered later in this chapter.) **Figure 20.4** shows how a loop extended around a ceiling can be fed with low-loss ladder line or twin-lead on multiple bands. Making the loop as large as possible allows it to be effective on the lowest possible frequencies. A loop can also be installed in an attic as described in the section below.

Attics and upper-story bedrooms under peaked roofs can make a good home for inverted-V style antennas. Support the feed point at or near the peak of the roof and run the legs down the roof joists or to the floor joists. A dual-band inverted-V can be installed with the pairs of legs connected in parallel and run at right angles to each other. Inverted-V wire Yagi antennas for 20 meters and higher frequency bands can also be made if the attic has a desirable orientation.

If you are working in an attic-type space, the simplest way to hold wire against wooden trusses and joists is a plastic coaxial cable clip of the sort used for cable TV wiring. Avoid attaching bare or enameled wire directly against wood. PVC-insulated wire can be carefully stapled directly to wood supports.

To get the feed line from the attic to your transmitter, you may be able to find the cap for an internal wall and drill a hole in it for the feed line to drop down between wall studs. You can then install an "old work" electrical box and an appropriate plastic cover plate for a professional-quality installation. Do not run feed line through the same hole as ac wiring or in conduit carrying ac wiring as that is an unsafe practice as well as increasing the probability of RF interference.

An Indoor Stealth Loop

Ted Phelps, W8TP, wrote an article in *The ARRL Antenna Compendium Vol 7* describing his attic-mounted wire loop

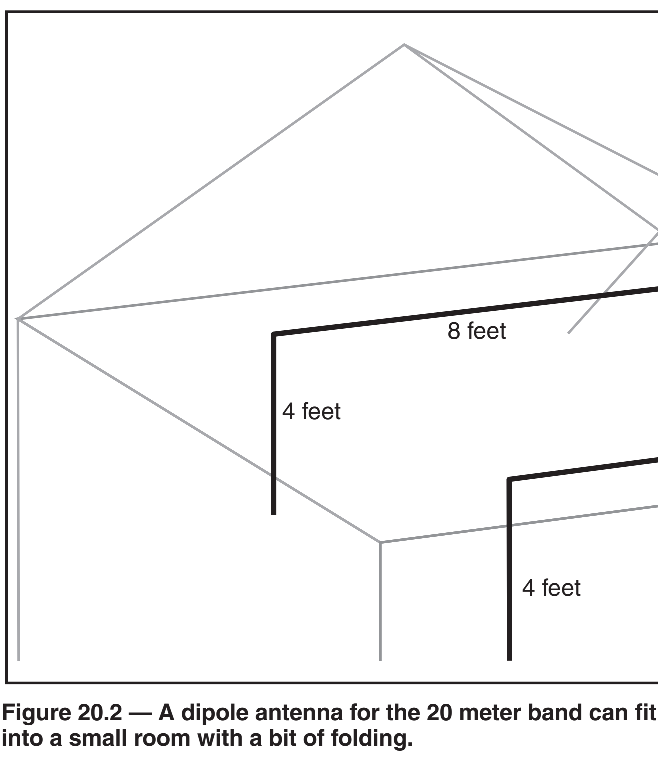


Figure 20.2 — A dipole antenna for the 20 meter band can fit into a small room with a bit of folding.

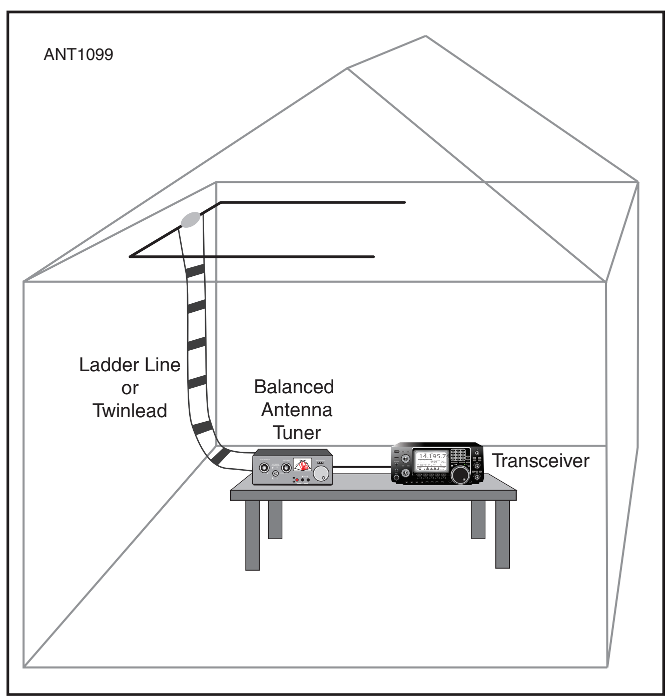


Figure 20.3 — A multiband ceiling dipole fed with ladder line or twinlead. Unlike a tuned dipole, the length isn't critical. As a rule of thumb, make each leg of the dipole as long as the space allows and make sure both legs are of equal length.

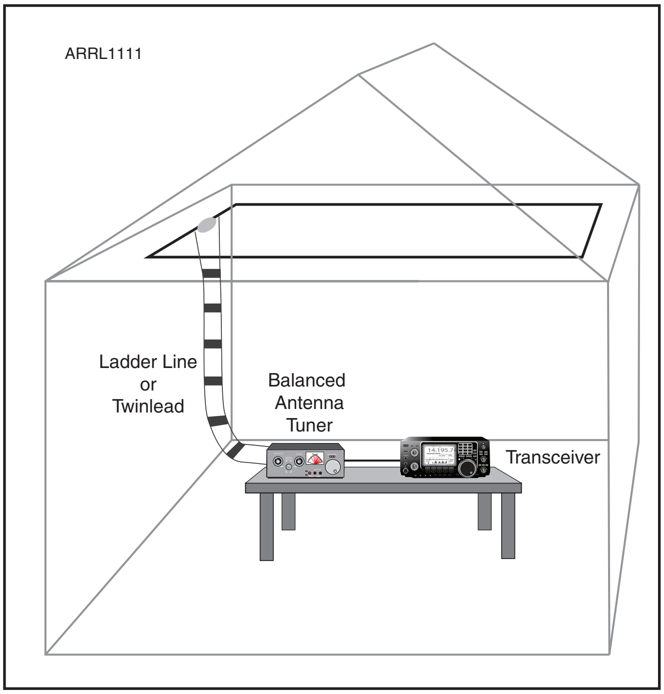


Figure 20.4 — A loop installed around the ceiling of a room and fed with balanced feed line and a tuner for multiband operation.

antenna, fed with an automatic antenna tuner. The full article is included on the CD-ROM accompanying this book.

Figure 20.5 shows the final dimensions of the loop hidden the attic of his condo. The antenna is a single-turn rectangular loop, erected in a north-south vertical plane and made from nearly 78 feet of #6 AWG stranded, aircraft primary wire in a PVC jacket, held taut at the lower corners and supported by a pulley and guy rope at each upper corner. The antenna will provide a mix of vertical and horizontal polarization on the different bands, covering many directions at a wide range of vertical angles.

The Slinky Antenna

If folding an antenna reduces its effectiveness, what about coiling it? This is just what happens when a Slinky™ toy is used as the antenna element! The Slinky Antenna was first described in an Oct 1974 *QST* article by W7ZCB (see Bibliography and this book's CD-ROM). As you might imagine, the antenna is nothing more than a dipole made out of two metal Slinky toys and stretched out until resonance is reached. W7ZCB was able to use his version on 80, 40, and 20 meters. It has been reported that the standard Slinky's quarter-wave resonance occurs on 40 meters when stretched to about 7.5 feet, so a full half-wave dipole would be about 15 feet long. This is well within the space available in a good-sized room. If you try this antenna, be sure to get a metal version as there are plastic models, as well.

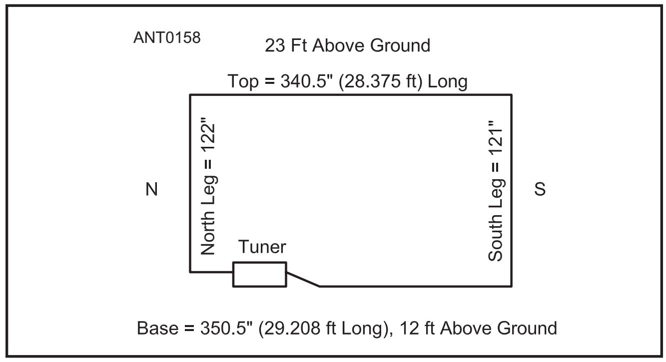


Figure 20.5 — Diagram showing layout of W8TP's indoor hidden loop antenna.

All-Band Attic Antenna

This design by Kai Siwiak, KE4PT, describes an inverted L antenna installed in the attic of his home. The system uses an automatic antenna tuner, similarly to the antennas shown in Figures 20.3 and 20.4. The full article is available on this book's CD-ROM.

The L is horizontal and laid out as shown in **Figure 20.6**. It comprises two parallel lengths of #9 AWG aluminum wire connected together at the far end, and spaced about 38 inches apart. The horizontal portion is about 48 feet long and a bit more than 14 feet above the ground, under the roof of the house. The horizontal length is approximately one wavelength at 21 MHz so the antenna pattern is very nearly omnidirectional from 20 meters down to 80 meters.

The parallel wires are brought together and emerge from the ceiling on a far wall of the house in a storage closet, as shown in **Figure 20.7**. Both of the parallel wires are joined together and connected to the antenna post of the AH-4 tuner. Connecting the wires together in this way creates a "thick" radiating element for which the feed point impedance varies more smoothly with frequency and eases the job of the antenna tuner.

A copper ground wire runs from the tuner ground connection to an outside 8-foot ground rod. The antenna shares this ground rod with a conductive mast supporting a 2 meter J-pole that tops out at 21.7 feet. This mast also functions as part of the HF radiating system.

A length of 50-Ω coaxial cable connects the tuner through an eight-turn, 5-inch diameter choke balun to the transceiver at the operating position in the ham shack on the other side of the wall of the storage closet.

Indoor antennas should be very carefully considered from the RF exposure point of view, especially for those within the dwelling. A spot check of near fields of the antenna both near the vertical and near the horizontal parts of the wires shows that for this antenna, the 6 meter band *4nec2* result of 3.3 feet gives sufficient compliance distance safety margin on all lower frequency bands. Evaluate unusual antennas very carefully, especially if a ground or ground post is part of the system!

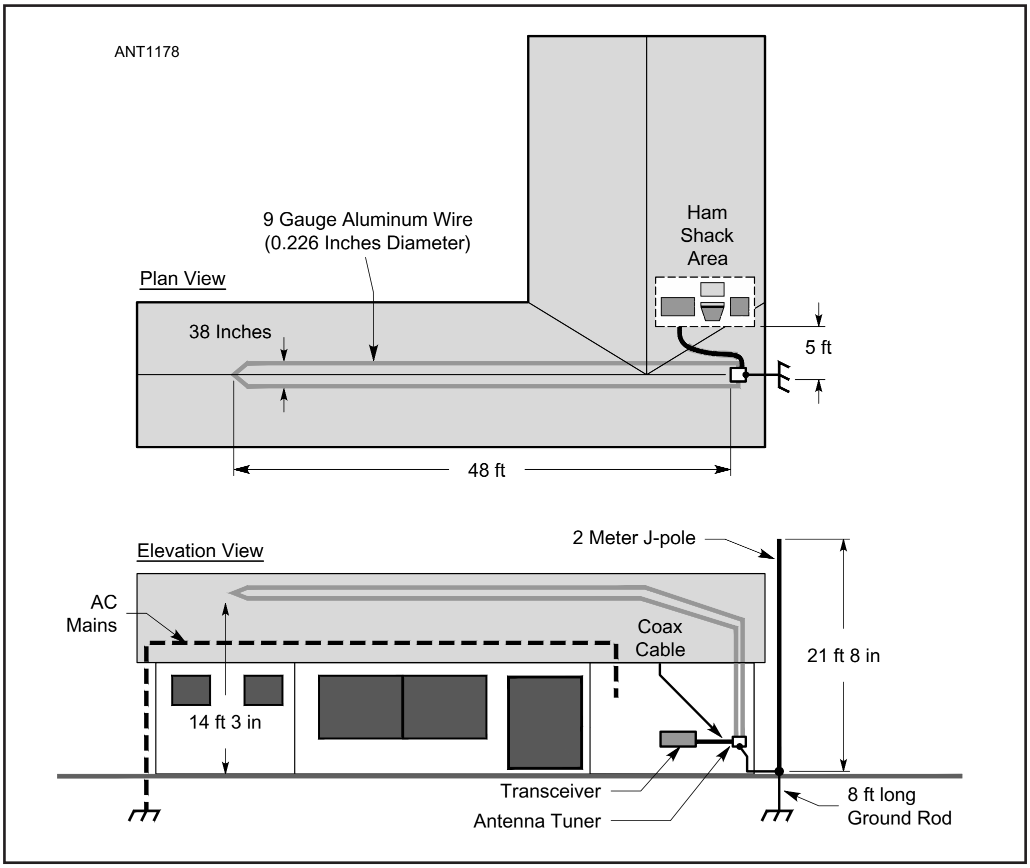


Figure 20.6 — Plan and elevation views of the attic inverted L antenna.

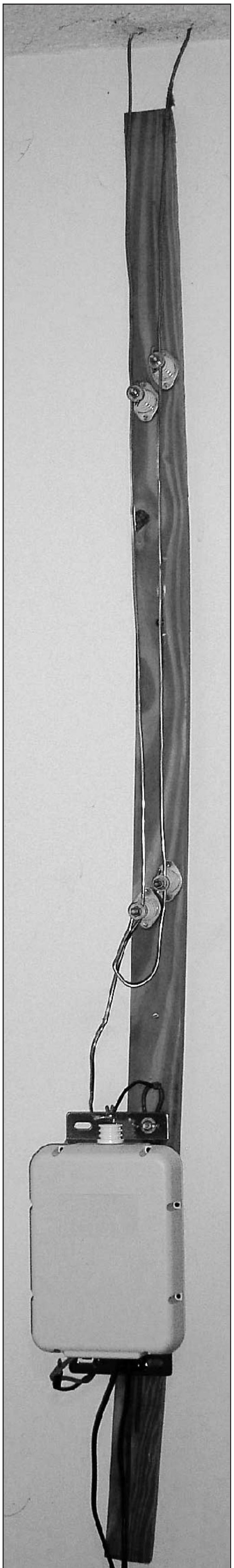


Figure 20.7 — The aluminum wires are brought through the ceiling and connected to the Icom AH-4 automatic tuner shown at the bottom of the photo.

20.4.2 MOBILE HF ANTENNAS INDOORS

Another popular option for indoor HF use is antennas intended for mobile operation. After all, mobiling is certainly another example of a limited-space application! (See the chapter **Mobile and Maritime HF Antennas** for more information about the mobile antennas described in this section.)

The same general concerns for mobile antennas mounted on vehicles apply to mobile antennas used indoors regarding the importance of how the antennas are mounted and having a large conductive surface to act as a ground plane. A mobile whip can be used quite effectively when mounted on a sufficiently large metal surface. For example, a windowsill (see **Figure 20.8**) or balcony railing will suffice. If those metal structures are also tied into a building's steel frame, the antenna will be very effective.

When using a mobile antenna in this way, if the metal item to which the antenna is clamped is not sufficiently large, a counterpoise wire should be added to the system. The counterpoise should be approximately $\lambda/4$ long at the frequency of operation and acts as the "missing half" of the antenna in lieu of a full ground plane. The counterpoise in this case is actually a radiating element and should be kept away from the operator and any electronics. If above the ground floor, the counterpoise can be allowed to hang down alongside the building. There may be significant RF voltage present at the end of the counterpoise so place it where it

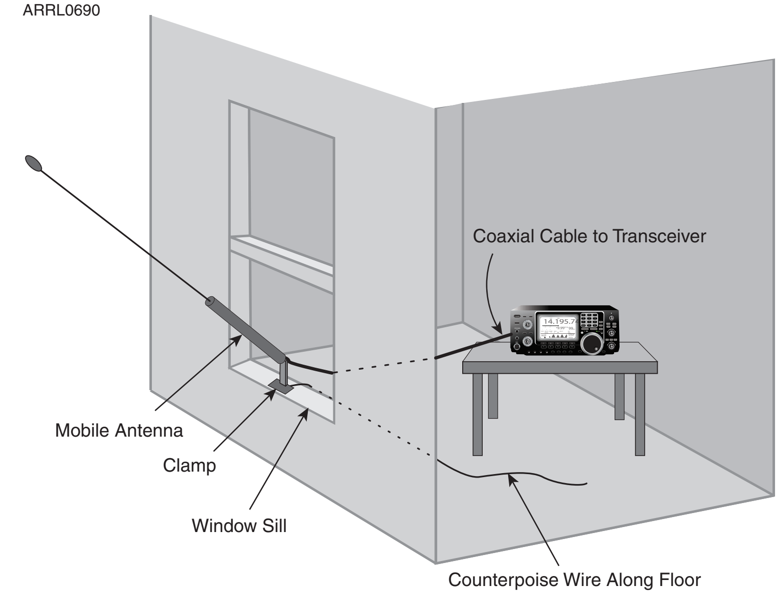


Figure 20.8 — A mobile antenna can be clamped to a windowsill or balcony railing. A counterpoise wire approximately λ/4 long at the operating frequency provides an additional radiating element for the RF "return" current. For multi-band operation, a counterpoise cut for each band should be used. If the frame or railing is tied into the building's metal structure, the counterpoise may not be necessary.

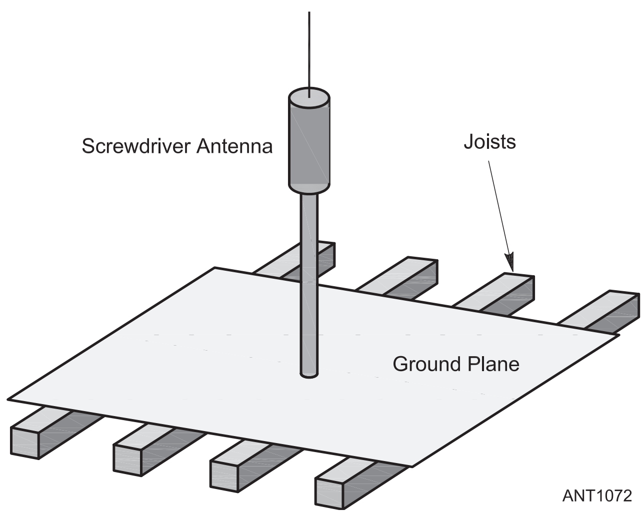


Figure 20.9 — A screwdriver antenna can be mounted on a ground plane for an effective, tunable attic antenna.

cannot be touched or arc to another surface.

The popular "screwdriver" mobile antenna can also make an effective and tunable HF antenna in an attic or unused room. **Figure 20.9** shows the screwdriver mounted on a ground plane that in turn rests on the ceiling joists. Shorter models are small enough to fit comfortably under a peaked roof. Along with sheet metal any mesh will do for the ground plane, such as hardware cloth or chicken wire. Even aluminum foil could be used. The more extensive the ground plane, the more effective the antenna will be. Screwdriver antennas also have the advantage of being tunable with a remote controller for use on all HF bands.

It is also possible to use mobile whips configured to form a dipole as in **Figure 20.10**. Many antenna parts dealers sell brackets with an SO-239 coax connector and tapped fittings for the popular 3/8-24 threaded antenna base. A pair of mobile whips can be attached as in the figure and supported on a camera tripod or other suitable base. This makes an excellent portable antenna, too.

Figure 20.10 — This pair of CB mobile antennas were trimmed slightly to resonate on 10 meters then attached to a mounting bracket. This created an effective apartment-sized antenna.

20.4.3 INDOOR VHF AND UHF ANTENNAS

Operating with indoor antennas for VHF and UHF operation is much less difficult than creating an effective HF antenna indoors. For example, placing a simple mag mount whip on top of a refrigerator or filing cabinet makes a reasonable base station antenna for local FM contacts. Any of the designs for ground-plane antennas in the **VHF and UHF Antenna Systems** chapter is easily adapted to indoor use.

Creating an effective installation for SSB and CW operation — the so-called *weak signal* modes — is more challenging. Horizontal polarization is required for sustained success but it is not always necessary to have multi-element beams. On 6 meters, for example, relatively omnidirectional antennas such as a horizontal "halo" (**Figure 20.11**) or dipole can make many contacts, including with distant stations when sporadic E propagation is occurring. (See the **Radio Wave Propagation** chapter.) The Lindenblad and turnstile antennas described in the **Antennas for Space Communications** chapter will also work.

Figure 20.12 — The 2 meter PortaQuad by National RF isn't intended for permanent outdoor use, but it would be a fine directional antenna inside a room or attic.

Figure 20.11 — A typical 6 meter horizontal full-wave loop antenna can be used either indoors or outdoors. The radiation pattern is omnidirectional with horizontal polarization.

Nevertheless, if you can manage an antenna with some directivity, it will help. Quad beams for VHF and UHF are fairly small antennas, even on 6 meters where quad elements are only 5 feet on a side. A 2-element quad for 6 meters can fit many attic spaces or be suspended from a ceiling mount. The 2-element Moxon design for 6 meters described by Allen Baker, KG4JJH (see Bibliography) measures 84 × 31 inches and being flat, is a natural candidate for ceiling mounting.

Quads and small beams for 2 meters and higher frequencies are even smaller as **Figure 20.12** shows. A light-duty TV rotator can turn any of these antennas. A note of caution — the higher the frequency of operation, the higher the attenuation from building materials as well as rain and snow on roofs, especially at UHF and microwaves.

20.5 OUTDOOR ANTENNAS

This book contains plenty of candidates for outdoor antenna designs in spaces of limited size. The antennas in the chapter **Portable Antennas** address similar limited-space needs as the amateur with a limited fixed space. The builder should start with a good idea of the available supports or ground area, decide on a horizontal or vertical antenna, and begin reviewing the antenna books and articles.

The main challenge addressed in this chapter, however, is how to put up such an antenna in the face of restrictions against them or when esthetics just don't permit the usual construction techniques. There are two basic approaches to putting up such a stealth antenna; invisibility and disguise.

20.5.1 INVISIBLE ANTENNAS

An invisible antenna is one that is constructed so as to be difficult to see. Many amateurs have been able to operate for long periods using invisible antennas without being detected. The secret to making an antenna invisible is to think small and thin. Thin wire, small coax, placing the antenna in trees or other foliage — all of these are time-tested techniques for making an antenna "disappear."

Thin wire can be used up to surprisingly high power before its resistance becomes an issue. Assuming you'll be using power levels of 100 W or less, you can use wire as small as #30 AWG. For sizes below #24 AWG, however, the challenge

Making Radials Disappear

How do you create an effective ground screen of the recommended 32 or more radial wires without an unsightly mess covering your lawn? The answer is to let the lawn do the work for you!

Get a large pizza cutter — it will be ruined for kitchen use so don't use the family's prize pie divider. You'll also need a spool of thin stiff iron wire - rebar tie wire will do fine. Cut at least a half-dozen 6-inch lengths of wire for each radial you plan on installing and bend them in half to form a narrow U — these are radial pins. Your radial wire can be any convenient type although a dark insulation or enamel coating will help with the disappearing act. Bare wire is fine, too.

Start by mowing the grass as short as you reasonably can. Attach a radial to the base of the antenna and cut a narrow slot in the grass into which you lay your radial wire. As you move away from the antenna, hold the radial down with the radial pins every few feet. The cost of each pin is quite low so use as many as you need.

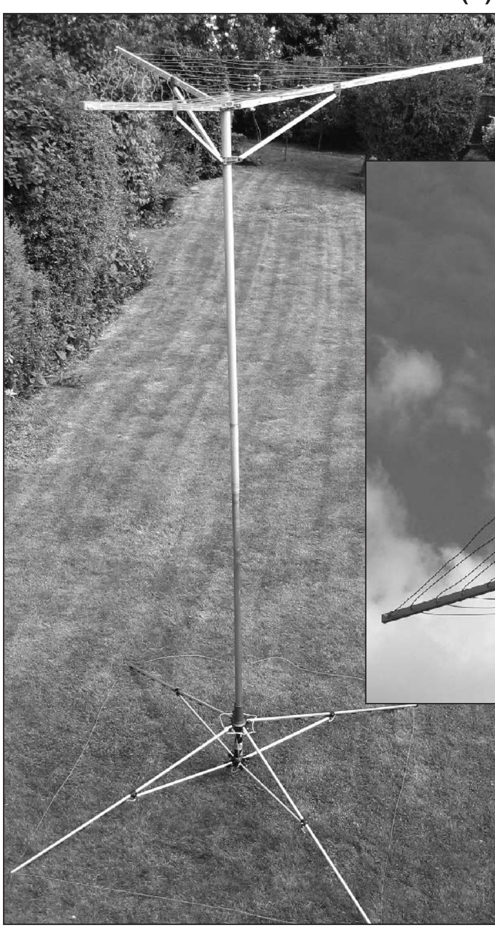
Once all of the radials are in, water the grass well. A little fertilizer won't hurt. In a matter of days, the grass will have grown high enough to completely hide the radial wires — you won't be able to see them even if you know they are there! Over time, the grass (and the worms) will conspire to pull the wires deeper toward and even below the surface of the ground. The radial pins will also quickly rust away and disappear if you used iron wire. The only thing sticking up out of the yard will be the ends of the radials at the antenna.

of keeping it up due to breakage becomes the bigger issue. Use stranded wire for better flexibility and be careful not to tension the wire too heavily — it will stretch, then break.

Think "small," too. Insulators, feed points, supporting lines, and coaxial feed line all need to be small so as not to attract the eye. Insulators and feed points can be homebrewed from scrap plastic or fishing supplies. Woven fishing line is usually tough, UV-resistant, and very hard to see against the sky or foliage (just ask the fish!). If possible, use colors that blend in to the surroundings.

Small diameter coax such as RG-174 can be dismayingly lossy (see the table of coaxial cable parameters in the **Transmission Lines** chapter) and should only be used for very short runs. RG-58, RG-59, and RG-6 can be used for longer runs and have the added benefit of looking very much like the cable TV service drop. Parallel-wire lines have much lower loss and are lighter than coax but are much harder to conceal. If you get a good deal on a long length of subminiature Teflon-insulated cable such as RG-393 or similar, it makes a very good miniature feed line.

(A)



(B)

Figure 20.13 — Martin, G8JNJ, converted a scrap laundry drying rack into a stealthy HF vertical. At A is the complete antenna showing the top and bottom counterpoise and capacity hat, respectively. B shows the upper capacity hat. (Photos courtesy of the RSGB and Martin Ehrenfried, G8JNJ)

20.5.2 DISGUISED ANTENNAS

A disguised antenna is an antenna that is easy to see but the viewer doesn't recognize it as an antenna! The classic example of the disguised antenna is a flagpole antenna such as that described by Geoff Haines, N1GY in the December 2010 issue of *QST*. To the non-ham, it's a basic flagpole. To the ham, it's a 23-foot ground-plane vertical with an automatic tuner at the base. Albert Parker, N4AQ took a different tack by hiding a Hustler 4-BTV 4-band trap vertical inside a flagpole made of PVC pipe (see Bibliography).

Another long-time favorite method is hiding the antenna near an approved structure such as a drain pipe or gutter. Hams have even used metal gutters and downspouts as antennas with a variety of results but it can be difficult to maintain good connections at joints. With plastic guttering so common, why not put a wire antenna directly into the gutter? With horizontal gutters, pooling water can be a problem but most vertical gutters are immune. Put your antenna in the gutter itself! The challenge will be to get the feed line to the antenna and keep water out of the feed line.

If your gutters or downspouts are metallic, try loading them up as described by Craig LaBarge, WB3GCK at **www.qsl.net/wb3gck/spout.htm**. Craig's example is just one way of using an automatic antenna tuner and counterpoise wires to create a surprisingly effective, yet completely invisible antenna.

Take a look around and see what metal objects are outside in your yard or around your home. Almost anything can be made into an antenna as the photo in **Figure 20.13** shows. Martin Ehrenfried, G8JNJ (**www.g8jnj.webs.com**) converted an outdoor drying rack into a vertical dipole with end loading. Lawn chairs, garden tools, sports equipment — any metal object can be made to radiate. The Ventenna (**www.ventenna.com**) is a roof-mounted antenna for VHF or UHF that looks just like an ordinary drain pipe.

Don't forget about "re-purposing" an approved antenna such as for TV broadcasts. The CD-ROM folder for the chapter **VHF and UHF Antenna Systems** contains an article describing the conversion of a regular VHF TV antenna to one that can be used on the VHF amateur bands!

20.6 SMALL TRANSMITTING LOOPS

The theory of these small loops is presented in the **Loop Antennas** chapter. The following material was adapted and updated by Domenic Mallozzi, N1DM, from content provided by Robert T. (Ted) Hart, W5QJR.

Small receiving loops are common but are not efficient enough to handle transmit power levels. There are serious challenges to designing a loop that is small and also efficient enough to be useful. This section addresses some of those challenges in the context of two designs. Construction details for both of these designs are provided on this book's CD-ROM.

20.6.1 PRACTICAL SMALL TRANSMITTING LOOPS

The ideal small transmitting antenna would have performance equal to a large antenna. A small loop antenna can approach that performance except for a reduction in bandwidth, but that effect can be overcome by retuning.

As pointed out above, small antennas are characterized by low radiation resistance. For a typical small antenna, such as a short dipole, loading coils are often added to achieve resonance. However, the loss inherent in the coils can result in an antenna with low efficiency. If instead of coils a large, low-loss capacitor is added to a low-loss conductor to achieve resonance, and if the antenna conductor is bent to connect the ends to the capacitor, a loop is formed.

Based on this concept, the small loop is capable of relatively high efficiency, compared to its coil-loaded cousin. In addition, the small loop, when mounted vertically, can radiate efficiently over the wide range of elevation angles required on the lower frequency bands. This is because it has both high-angle and low-angle response. See **Figure 20.14**, which shows the elevation response for a compact transmitting loop only 16.2 inches wide at 14.2 MHz. This loop is vertically polarized and its bottom is 8 feet above average ground, which has a conductivity of 5 mS/m and a dielectric constant of 13. For comparison, Figure 20.14 also shows the responses of three other reference antennas — the same small loop flipped sideways at a height of 30 feet to produce horizontal radiation, a full-sized ¼-λ ground plane antenna mounted 8 feet above average ground using two tuned radials, and finally a simple ½ λ flattop dipole mounted 30 feet above flat ground. The considerably smaller transmitting loop comes to within 3 dB of the larger ¼-λ vertical at a 10° elevation angle, and

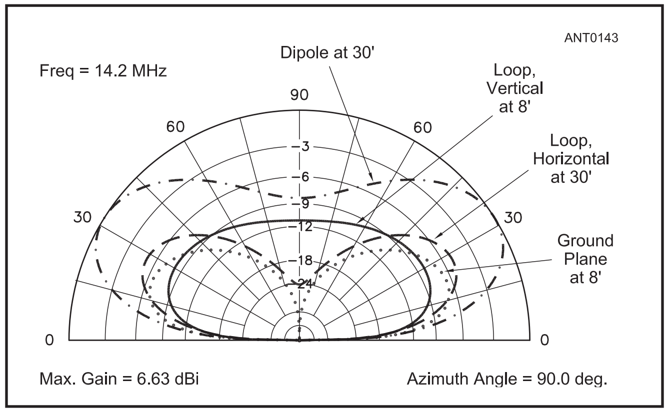


Figure 20.14 — Elevation-plane plot at 14.2 MHz, showing response of an 8.5-foot circumference octagonal copper loop (width of 16.2 inches), compared to a full-sized λ/4 ground-plane vertical with two elevated λ/4 radials, the same small loop flipped horizontally at a height of 30 feet, and lastly, a λ/2 flattop dipole also at a height of 30 feet. Both the λ/4 ground-plane vertical and the vertically polarized loop are elevated 8 feet above typical ground, with σ = 5 mS/m and ε = 13. The low vertically polarized loop is surprisingly competitive, only down about 2.5 dB compared to the far larger ground plane at low elevation angles. Note that the vertical loop has both high-angle as well as low-angle radiation, and hence would be better at working close-in local stations than the ground-plane vertical, with its deep nulls at higher angles. The simple flattop dipole, however, is better than either vertical because of the poor ground reflection for a vertically polarized compared to a horizontally polarized signal.

it is far stronger for high elevation angles because it does not have the null at high elevation angles that the ground plane has. Of course, this characteristic does make it more susceptible to strong signals received at high elevation angles. Incidentally, just in case you were wondering, adding more radials to the λ/4 ground plane doesn't materially improve its performance when mounted at an 8-foot height on 20 meters.

The simple horizontal dipole in Figure 20.14 would be the clear winner in any shootout because its horizontally polarized radiation does not suffer as much attenuation at reflection from ground as does a vertically polarized wave. The case is not quite so clear-cut, however, for the small loop mounted horizontally at 30 feet. While it does have increased gain at medium elevation angles, it may not be worth the effort needed to mount it on a mast, considering the slight loss at low angles compared to its twin mounted vertically only 8 feet above ground.

A physically small antenna like the 16.2-inch-wide vertically polarized loop does put out an impressive signal compared to far larger competing antennas. Though somewhat ungainly, it is a substantially better performer than most mobile whips, for example. The main deficiency in a compact transmitting loop is its narrow bandwidth — it must be accurately tuned to the operating frequency. The use of a remote motor drive allows the loop to be tuned over a wide frequency range.

For example, for fixed-station use, two loops could be constructed to provide continuous frequency coverage from 3.5 to 30 MHz. A loop with an 8.5-foot circumference, 16 inches wide, could cover 10 through 30 MHz and a loop with a 20-foot circumference, 72 inches wide, could cover 3.5 to 10.1 MHz.

Through computer analysis, the optimum size conductor was determined to be ¾-inch rigid copper water pipe, considering both performance and cost. Performance will be compromised, but only slightly, if ⅝-inch flexible copper tubing is used. This tubing can easily be bent to any desired shape, even a circle. The rigid ¾-inch copper pipe is best used with 45° elbows to make an octagon.

The loop circumference should be between ¼ and ⅛ λ at the operating frequency. It will become self-resonant above ¼ λ, and efficiency drops rapidly below ⅛ λ. In the frequency ranges shown in **Table 20.1**, the high frequency is tuned with a minimum capacitance of about 29 pF — including stray capacitance.

Controlling Losses

Contrary to earlier reports, adding quarter-wave ground radials underneath a vertically polarized transmitting loop doesn't materially increase loop efficiency. The size of the conductor used for a transmitting loop, however, does directly affect several interrelated aspects of loop performance.

Note that the efficiency is higher and the Q is lower for loops having a circumference near ¼ λ. Larger pipe size will reduce the loss resistance, but the Q increases. Therefore the bandwidth decreases, and the voltage across the tuning capacitor increases. Rigid ¾-inch copper water pipe is a good electrical compromise and can also help make a small-diameter loop mechanically sturdy.

The equivalent electrical circuit for the loop is a parallel resonant circuit with a very high Q, and therefore a narrow bandwidth. The efficiency is a function of radiation resistance divided by the sum of the radiation plus loss resistances. The radiation resistance is much less than 1 Ω, so it is necessary to minimize the loss resistance, which is largely the skin-effect loss of the conductor, assuming that

Table 20.1
Design Data for Loops

Loop Circumference = 8.5' (Width = 32.4"), Vertically Polarized

Frequency, MHz	10.1	14.2	21.2	29.0
Max Gain, dBi	–4.47	–1.42	+1.34	+2.97
Max Elevation Angle	40°	30°	22°	90°
Gain, dBi @10°	–8.40	–4.61	–0.87	+0.40
Total Capacitance, pF	145	70	29	13
Peak Capacitor kV	23	27	30	30

Loop Circumference = 8.5' (Width = 32.4"), Horizontally Polarized, @30'

Frequency, MHz	10.1	14.2	21.2	29.0
Max Gain, dBi	–3.06	+1.71	+5.43	+6.60
Max Elevation Angle	34°	28°	20°	16°
Gain, dBi @10°	–9.25	–3.11	+2.61	+5.34
Total Capacitance, pF	145	70	29	13
Peak Capacitor kV	23	27	30	30

Loop Circumference = 20' (Width = 6'), Vertically Polarized

Frequency, MHz	3.5	4.0	7.2	10.1
Max Gain, dBi	–7.40	–6.07	–1.69	–0.34
Max Elevation Angle	68°	60°	38°	30°
Gain, dBi @10°	–11.46	–10.12	–5.27	–3.33
Capacitance, pF	379	286	85	38
Peak Capacitor kV	22	24	26	30

Loop Circumference = 20' (Width = 6'), Horizontally Polarized, @30'

Frequency, MHz	3.5	4.0	7.2	10.1
Max Gain, dBi	–13.32	–10.60	–0.20	+3.20
Max Elevation Angle	42°	42°	38°	34°
Gain, dBi @10°	–21.62	–18.79	–7.51	–3.22
Capacitance, pF	379	286	85	38
Peak Capacitor kV	22	24	26	30

Loop Circumference = 38' (Width = 11.5'), Vertically Polarized

Frequency, MHz	3.5	4.0	7.2
Max Gain, dBi	–2.93	–2.20	–0.05
Max Elevation Angle	46°	42°	28°
Gain, dBi @10°	–6.48	–5.69	–2.80
Capacitance, pF	165	123	29
Peak Capacitor kV	26	27	33

Notes: These loops are octagonal in shape, constructed with ¾-inch copper water pipe and soldered 45° copper elbows. The gain figures assume a capacitor unloaded Q_C = 5000, typical for vacuum-variable type of tuning capacitor. The bottom of the loop is assumed to be 8 feet high for safety and the ground constants are "typical" at conductivity = 5 mS/m and dielectric constant = 13. Transmitter power is 1500 W. The voltage across the tuning capacitor for lower powers goes down with a multiplier of

$$\sqrt{P / 1500}$$

For example, at 100 W using the 38-foot-circumference loop at 7.2 MHz, the peak voltage would be

$$33 \text{ kV} \times \sqrt{100 / 1500} = 8.5 \text{ kV}$$

the tuning capacitor has very low loss. Poor construction techniques must be avoided. All joints in the loop must be brazed or soldered. Do not use clamps or screws.

However, if the system loss is too low, for example by using even larger diameter tubing, the Q may become excessive and the bandwidth may become too narrow for practical use. These reasons dictate the need for a complete analysis to be performed before proceeding with the construction of a loop.

There is another source of additional loss in a completed loop antenna besides the conductor and capacitor losses. If the loop is mounted near lossy metallic conductors, the large magnetic field produced will induce currents into those conductors and be reflected as losses in the loop. Therefore the loop should be as far from other conductors as possible. If you use the loop inside a building constructed with large amounts of iron or near ferrous materials, you will simply have to live with the loss if the loop cannot otherwise be relocated.

The Tuning Capacitor

Figure 20.15 demonstrates the selection of loop size versus tuning capacitance for any desired operating frequency range for the HF amateur bands. This is for octagonal-shaped loops using ¾-inch copper water pipe with 45° copper elbows. For example, a capacitor that varies from 5 to 50 pF, used with a loop 10 feet in circumference, tunes from 13 to 27 MHz (represented by the left dark vertical bar). A 25 to 150-pF capacitor with a 13.5-foot loop circumference covers the 7 to 14.4-MHz range, represented by the right vertical bar.

Air Variable Capacitors

Special care must be taken with the tuning capacitor if an air-variable type is used. The use of a split-stator capacitor eliminates the resistance of wiper contacts, resistance that is inherent in a single-section capacitor. The ends of the loop are connected to the stators, and the rotor forms the variable coupling path between the stators. With this arrangement the value of capacitance is divided by two, but the voltage rating is doubled.

You must carefully select a variable capacitor for transmitting-loop application — that is, all contacts must be welded, and no mechanical wiping contacts are allowed. For example, if the spacers between plates are not welded to the plates, there will be loss at each joint, and thus degraded loop efficiency. (Earlier transmitting loops exhibited poor efficiency because capacitors with wiping contacts were used.)

There are several suitable types of capacitors for this application. A vacuum variable is an excellent choice, provided one is selected with an adequate voltage rating. Unfortunately, those capacitors are very expensive.

W5QJR used a specially modified air-variable capacitor in his designs. This had up to 340 pF maximum per section, with ¼-inch spacing, resulting in 170 pF when both sections were in series as a butterfly capacitor. Another alternative is to obtain a large air variable, remove the aluminum plates, and replace them with copper or double-sided PC board material to reduce losses. Connect all plates together on the rotor and on the stators. Solder copper straps to the capacitor for soldering to the loop itself.

The spacing between plates in an air-variable capacitor determines the voltage-handling capability, rated at 75,000 V per inch. For other power ratings, multiply the spacing (and voltage) by the square root of the ratio of your power to 1000 W. For example, for 100 W, the ratio would be = 0.316.

Short articles describing two other methods of constructing tuning capacitors ("A Teflon-Insulated Trombone Variable Capacitor" and "A Cookie-Sheet and Picture-Frame-Glass Variable Capacitor") are provided on this book's CD-ROM. This issue is discussed further by Brian Cake, KF2YN in the book *Antenna Designer's Notebook* (see Bibliography) along with another loop design.

20.6.2 TYPICAL TRANSMITTING LOOP CONSTRUCTION

After you select the electrical design for your loop application, you must consider how to mount it and how to feed it. If you wish to cover only the upper HF bands of 20 through 10 meters, you will probably choose a loop that has a circumference of about 8.5 feet. You can make a reasonably sturdy loop using 1-inch diameter PVC pipe and ⅝-inch flexible copper tubing bent into the shape of a circle. Robert Capon, WA3ULH, did this for a QRP-level transmitting loop described in May 1994 *QST*. **Figure 20.16** shows a picture of his loop, with PVC H-frame stand. (The complete construction article is provided on the CD-ROM accompanying this book.)

This loop design used a 20-inch long coupling loop made

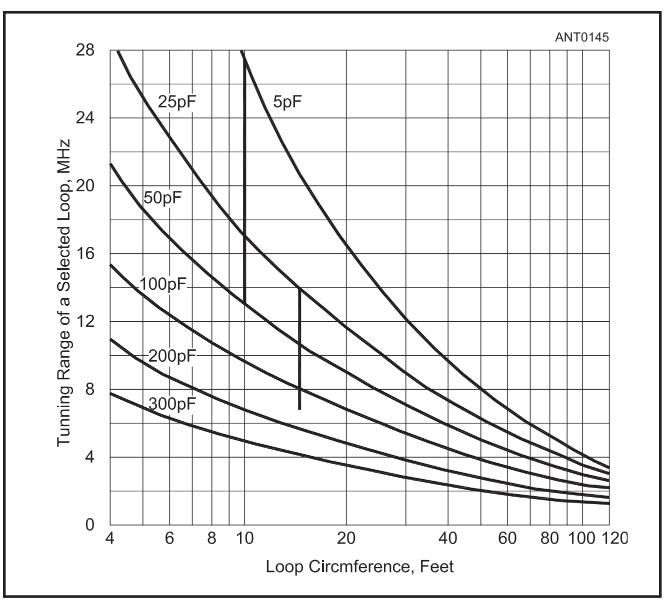


Figure 20.15 — Frequency tuning range of an octagon-shaped loop using ¾-inch copper water pipe, for various values of tuning capacitance and loop circumference.

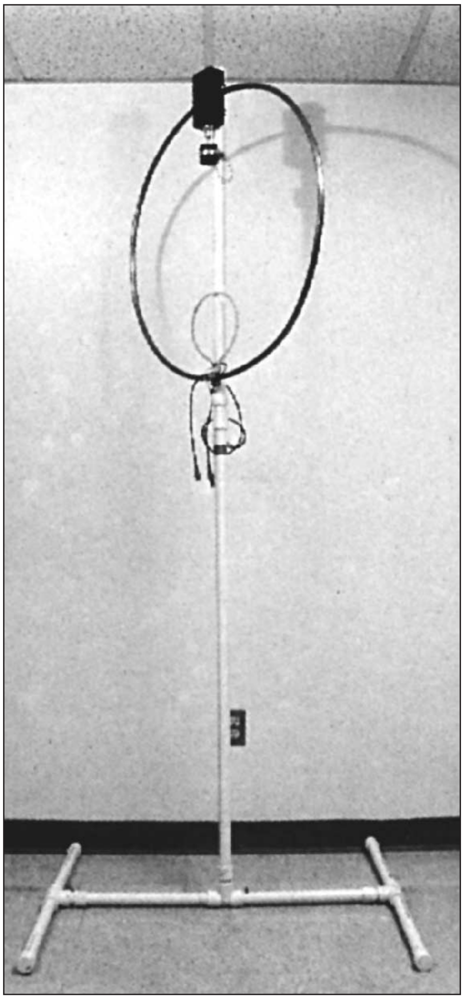


Figure 20.16 — Photo of compact transmitting loop designed by Robert Capon, WA3ULH. This uses a 1-inch PVC H-frame to support the loop made of flexible ⅝-inch copper tubing. The small coupling loop made of RG-8 coax braid couples the loop to the coax feed line. The tuning capacitor and drive motor are at the top of the loop, shown here in the ARRL Laboratory during testing.

of RG-8 coax to magnetically couple into the transmitting loop rather than the gamma-match arrangement used by W5QJR in his loop designs. The coupling loop was fastened to the PVC pipe frame using 2-inch long #8 bolts that also held the main loop to the mast.

A more rugged loop can be constructed using rigid ¾-inch copper water pipe, as shown in the W5QJR design in **Figure 20.17**. (See Bibliography and this book's CD-ROM.) While a round loop is theoretically a bit more efficient, an octagonal shape is much easier to construct.

If there is metal near any small transmitting loop, the additional loss will reduce the Q and therefore the impedance of the loop. In those cases it will be necessary to increase the length of the matching line and tap higher up on the loop to obtain a 50-Ω match.

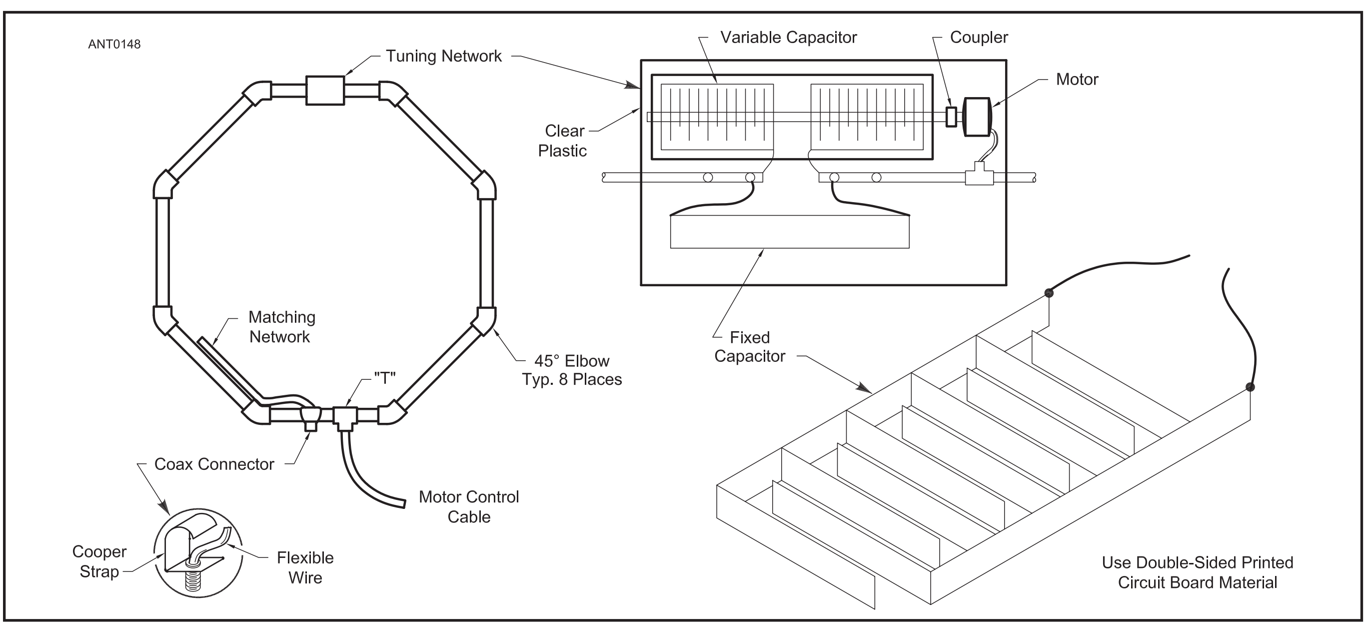


Figure 20.17 — Octagonal loop construction details. See the full article on this book's CD-ROM for more construction information and dimensions for different HF bands.

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