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Title: Better Results with Indoor Antennas
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Better Results with Indoor Antennas

Limited to an antenna hidden under the roof? Then make the most of it. The W6HPH approach can help you optimize that attic-bound aerial and even lead you to a coveted DXCC certificate!

By Fred Brown,* W6HPH

Beyond any question, the best place for your antenna is outdoors and as high and in the clear as possible. Some of us, however, for legal, social, neighborhood, family or landlord reasons, are restricted to indoor antennas, a consequence of being denied the privilege for so much as a flagpole vertical outside.[1] Alternatively, having to settle for an indoor antenna (IA) is certainly a handicap for the amateur seeking effective radio communication, but that is not significant enough reason to abandon all operation in despair. In fact, worldwide communication leading to the acquisition of the prized DX Century Club award has been accomplished with an IA.

This article goes into some of the fine points of IAs and shows how the best possible results can be obtained. Understandably an inside antenna will not enable a station to offer real competition against another that has a tribander at 60 feet (18 m), but a few hours spent on optimizing IA performance can add many decibels to your signal at the receiving end.

First of all, we should be aware of the reasons why indoor antennas *do not* work well. Principal faults are (1) low height above ground — the IA cannot be placed higher than the highest peak of the roof, a point usually quite low in terms of wavelength at hf; (2) the IA must function in a lossy rf environment that involves close coupling to electrical wiring, guttering, plumbing and other parasitic conductors, besides dielectric losses in such nonconductors as wood, plaster and masonry; (3) sometimes the IA must be made small in terms of a wavelength and (4) usually the IA cannot be rotated. These are appreciable handicaps. Nevertheless, global communication with an IA is still possible.

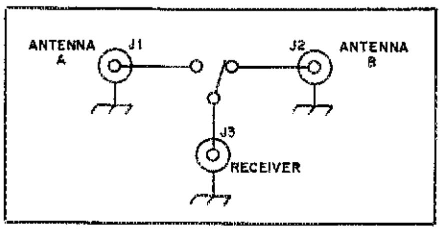

Fig. 1 — Certainly no one should be discouraged by the complexity of this circuit! When antennas are compared on fading signals, the time delay involved in disconnecting and reconnecting coaxial cables is too long for accurate measurements. A simple slide switch will do well for switching coaxial lines at hf. The four components can be mounted in a tin can or any small metal box. Leads should be short and direct. J1 through J3 are coaxial connectors.

Some practical points *in favor* of the IA include (1) freedom from weathering effects and damage caused by wind, ice, rain, dust and sunlight (the SWR of an attic antenna, however, can be somewhat affected by a wet or snow-covered roof); (2) indoor antennas can be made from materials that would be altogether impractical outdoors, such as aluminum foil and thread (the IA need support only its own weight); (3) the supporting structure is already in place, eliminating the need for antenna masts and (4) the IA is readily accessible in all weather conditions simplifying pruning or tuning which can be accomplished without climbing or tilting over a tower.

Empiricism

A typical house or apartment involves such a complex electromagnetic environment that it is impossible to predict theoretically which location or orientation of the IA will work best. This is where good old-fashioned cut-and-try, use-what-works-best empiricism pays off. But to properly determine what really is most suitable requires an understanding of some antenna-measuring fundamentals.[2,3]

Unfortunately, many amateurs do not know how to evaluate performance scientifically or compare one antenna with another. Typically, they will put up one antenna and try it out on the air to see how it "gets out" in comparison with a previous antenna. This is obviously a very poor evaluation method because there is no way to know if the better or worse reports are caused by changing band conditions, different S-meter characteristics or any of several other factors that could influence the reports received.

Many times the difference between two antennas or between two different locations for identical antennas amounts to only a few decibels, a difference that is hard to discern unless instantaneous switching between the two is possible. Those few decibels are not important under strong-signal conditions, of course, but when the going gets rough, as is often the case with an IA, a few dB can make the difference between copy and no copy.

Reciprocity

A very common misconception in antenna work is that the use of a

[1]References appear on page 21.

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transmitter is necessary in order to properly evaluate an antenna. This is not true and not even desirable. Testing with a transmitter can cause needless QRM. Because of reciprocity, only a receiver is needed.[4] An important consequence of the reciprocity theorem is that any given antenna will perform exactly the same whether receiving or transmitting. Gain is the same, impedance is the same, losses are the same and the radiation pattern is the same. In short, practically any antenna measurement can be carried out in the receiving mode.

Very little in the way of test equipment is needed for antenna evaluation other than a communications receiver. You can even do a qualitative comparison by ear, *if* you can switch antennas instantaneously. Differences of less than 2 dB, however, are still hard to discern. The same is true of S meters. Signal-strength differences of less than a dB are not usually visible. If you want that last fraction of a dB, you should use an ac VTVM at the receiver audio output (with the agc turned off, of course).[5]

Ideally, the received signal should be a steady, unmodulated carrier from a source close enough to avoid fading. Now that a-m is obsolete, steady carriers are not so plentiful on our bands, but we do have cw and Teletype signals. Sometimes foreign broadcast carriers can be used. Sideband signals are not very useful because of their intermittent and fluctuating nature.

In order to compare two antennas, switching the coaxial transmission line from one to the other becomes necessary. No elaborate coaxial switch is needed; even a simple double-throw toggle or slide switch will provide more than 40 dB of isolation at hf. See Fig. 1. Switching by means of manually connecting and disconnecting coaxial lines is not recommended because that takes too long. Fading can cause strength changes during the changeover interval.

Whatever difference shows up in the strength of the received signal will be the difference in performance between the two antennas in the direction of that signal. For this test to be valid both antennas must have nearly the same feed-point impedance, a condition that is reasonably well met if the SWR is below 2.0 on both. If it is not, a matching device, such as any of many that have been described in *QST* or the *Handbook*, can be inserted in the coaxial line to bring the SWR down.

On ionospheric-propagated signals (sky wave) there will be constant fading and for a valid comparison it will be necessary to make an average of the difference between the two antennas. Occasionally, the inferior antenna will deliver a stronger signal to the receiver, but in the long run the law of averages will put the better antenna ahead.

Of course with a ground-wave signal, such as that from a station across town, there will be no fading problems. A ground-wave signal will enable the operator to properly evalute the antenna under test in the direction of the source and will be valid for ionospheric propagated signals at low elevation angles in that direction. On 10 meters, all sky-wave signals arrive and leave at low angles. But on the lower bands, particularly 80 and 40 meters, we often use signals propagated at high elevation angles, almost up to the zenith. For these angles a ground-wave test will not provide a proper evaluation of the antenna and use of sky-wave signals becomes necessary.

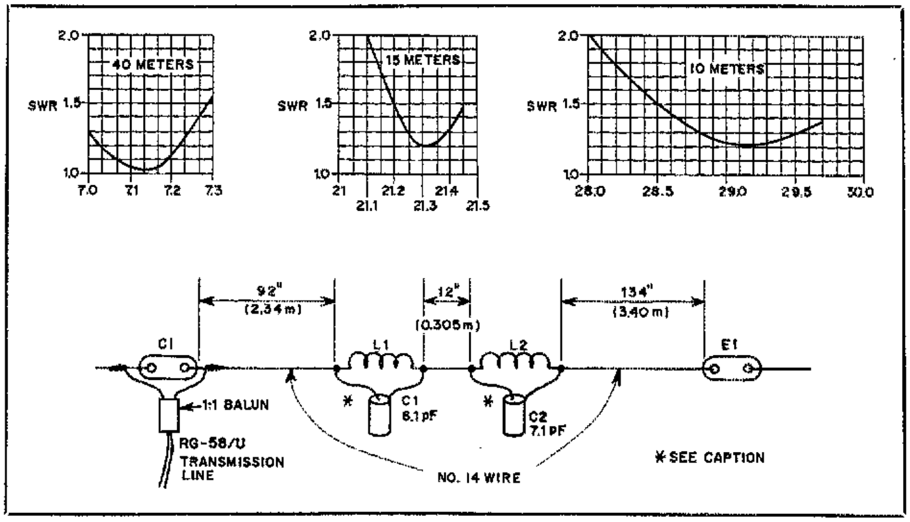


Fig. 2 — The author's attic antenna is a trap doublet designed for operation on 10, 15 and 40 meters. Only the right half of the doublet is shown here. The left half is identical to the right. C1 and L1 resonate at 29 MHz, while C2 and L2 resonate at 21.2 MHz. The graphs show the SWR behavior on the three bands.

C1 — 2.5-inch (64-mm) length of RG-8/U solid-dielectric cable.
C2 — 2.9-inch (74-mm) length of RG-8/U solid-dielectric cable.
L1 — 4.9 µH; 9-1/2 turns of coil stock having 2-in. (51-mm) dia and 10 turns per inch (0.39 turns per mm). Suitable stock is B&W 3907-1, Air-Dux 1610T or Polycoils 1771.
L2 — 7.6 µH; 13 turns of same coil stock specified for L1.

Trap Dipoles

At hf the most practical IA is usually the dipole. Any attempt to get more gain with parasitic elements will usually fail because of close proximity of the ground or coupling to house wiring. Beam-antenna dimensions determined outdoors will not usually be valid for an attic antenna because the roof structure will cause dielectric loading of the parasitic elements. It is usually more worthwhile to spend time optimizing the location and performance of a dipole than to try to improve results with parasitic elements.

The trap dipole, Fig. 2, is an easy way to get multiband performance. For good SWR bandwidth, the traps should have a high L-to-C ratio. The capacitors can be made from short lengths of coaxial cable. Tuning is accomplished by snipping the cable to the proper length.[6] The author's coils are wound on short lengths of 1-inch (25-mm) thinwall PVC pipe. PVC has a bad reputation as a dielectric.[7] At power levels up to 100 watts, however, the writer has experienced no problems with these coil forms.

In addition to providing multiband operation, the traps inductively load the dipole, making possible a resonant length shorter than a full half-wavelength on the lowest band of operation. Even with this loading, however, most attics are not long enough to accommodate a doublet for 75 meters. Many are not even large enough for a 40-meter aerial. This means some folding of the dipole will be necessary. The final shape of the antenna will depend upon the dimensions and configuration of the attic in which it is to be installed. Remember that the center of the dipole carries the most current and therefore does most of the radiating. This part should be as high and unfolded as possible. Because the dipole ends radiate less energy than the center, their orientation is not very important. They do carry a maximum voltage, nevertheless, so care should be taken to position the ends far enough from other conductors to avoid arcing. The dipole may end being L shaped, Z shaped, U shaped or some indescribable corkscrew shape, depending on what space is available.

In any event, some pruning to establish minimum SWR at the band center will be required. Tuning the antenna outdoors and then installing it inside is usually not feasible. The behavior of the antenna will not be the same when placed in the attic. Resonance will be somewhat affected if the antenna is bent. Even if it is placed in a straight line, parasitic conductors and dielectric loading by nearby wood structures will affect the impedance. When properly tuned, the minimum SWR should be near the band center and well below 2.0. If the SWR does not drop below 2.0, it is advisable to use one of the aforementioned matching devices placed in the transmission line.

Orientation

Theoretically a vertical dipole is more effective at low radiation angles, but practical experience usually shows that the horizontal dipole is a better indoor antenna. Perhaps the theory fails because it assumes a perfectly conducting ground or because it does not take into account scattering from nearby structures in a typical urban environment. Also, of course, a given roof height permits the center of a horizontal dipole to be placed higher than the same dipole vertically polarized.

A horizontal dipole, however, exhibits directional effects. Theoretically there are nulls off the ends, especially at low radiation angles. Your dipole, therefore, should be broadside to directions in which you are interested in working. If you want 360-degree coverage, place two dipoles at right angles to each other with provision in the shack for switching between the two. In fact, this is a good idea even if you are not interested in 360-degree coverage, because the radiation patterns will inevitably be distorted in an unpredictable manner by parasitic conductors. There will be little coupling between the dipoles if they are oriented at right angles to each other as shown in Figs. 3A and 3B. There will be some coupling with the arrangement shown in Fig. 3C but even this orientation is preferable to a single dipole.

You may find that one dipole is consistently better in nearly all directions, in which case you will want to remove the inferior dipole, perhaps placing it someplace else. In this manner the best spots in the house or attic can be determined experimentally.

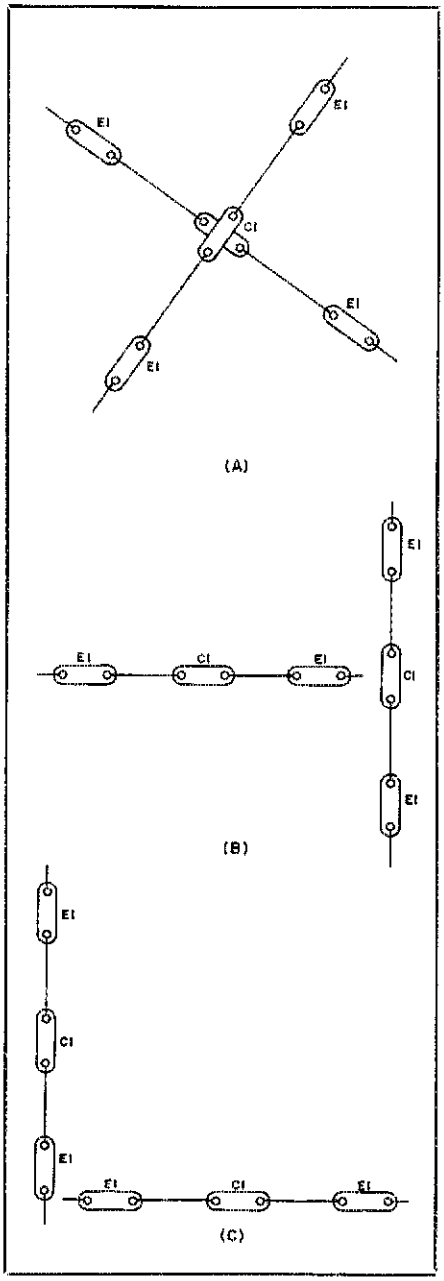


Fig. 3 — Ways to orient a pair of perpendicular doublets for 360-degree coverage. The orientations of A and B will result in no mutual coupling between the two dipoles, but there will be some coupling with the configuration shown at C. End (EI) and center (CI) insulators are shown.

Parasitic Conductors

Inevitably, any conductor in your house near a quarter wave in length or longer will be parasitically coupled to your IA. The word *parasitic* is particularly appropriate in this case because these conductors will sap energy from your transmitter and leave less for radiation into space. Unlike the parasitic elements in a beam antenna, conductors such as house wiring and plumbing are usually connected to lossy objects such as earth, electrical appliances, masonry or other objects that can dissipate energy. Even where this energy is reradiated, it is not likely to be in the right phase in the desired direction.

There are, however, some things that can be done about parasitic conductors. The most obvious is to reroute them at right angles to the IA or close to the ground, or even underground — procedures that are usually not feasible in a finished home. Where these conductors cannot be rerouted, other measures can be taken. Electrical wiring can be broken up with rf chokes to prevent the flow of radio-frequency currents while permitting 60-Hz current (or audio, in the case of telephone wires) to flow unimpeded. A typical rf choke for a power line can be 100 turns of no. 10 insulated wire closewound on a length of 1-inch (25-mm) dia plastic pipe. Of course one choke will be needed for each conductor. A three-wire line calls for three chokes.

The Resonant Breaker

Obviously, rf chokes cannot be used on conductors such as metal conduit or water pipes. But it is still possible, surprising as it may seem, to obstruct rf currents on such conductors without breaking the metal.

You may suspect there is a bit of legerdemain in resolving the problem of rf on those conductors. Fig. 4 discloses how this is done. A figure eight loop is inductively coupled to the parasitic conductor and is resonated to the desired frequency with a variable capacitor. The result is a very high impedance induced in series with the pipe, conduit or wire. This impedance will block the flow of radio-frequency currents. The figure-eight coil can be thought of as two turns of an air-core toroid and since the parasitic conductor threads through the hole of this core, there will be tight coupling between the two. Inasmuch as the figure-eight coil is parallel resonated, transformer action will reflect a high impedance in series with the linear conductor.

Before you bother with a "resonant breaker" of this type, first be sure that there is a significant amount of rf current flowing in the parasitic conductor. The relative magnitude of this current can be determined with an rf current probe of the type shown in Fig. 5.[8]

The current probe also uses a figure-eight coil. The principle of operation is very simple. Rf magnetic fields from *distant* conductors will induce equal voltages in the two loops of the coil. Because these two loops are wound in opposite directions, the resulting two induced voltages will cancel and not be detected by the germanium diode. But when the loop is placed against a conductor as shown in Fig. 5, the magnetic field surrounding the conductor will induce voltages in the two loops, which, instead of subtracting, will add in phase. As a consequence, presence of the field will be detected and indicated on the meter.

In this way measuring relative rf currents on parasitic conductors is possible with immunity from radiation that comes directly from the antenna. According to the rule of thumb regarding parasitic conductor current, if it measures less than 1/10 of that measured near the center of the dipole, the parasitic current is generally not large enough to be of concern.

The current probe is also needed for resonating the breaker after it is installed. Normally, the resonant breaker will be placed on the parasitic conductor near the point of maximum current. When it is tuned through resonance, there will be a sharp dip in rf current, as indicated by the current probe. Of course, the resonant breaker will be effective only on one

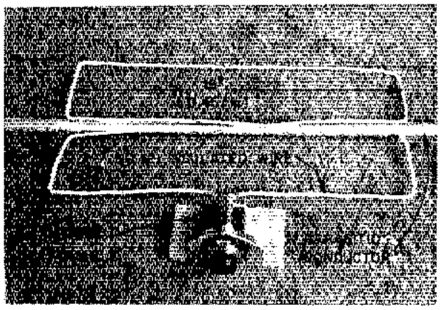


Fig. 4 — A "resonant breaker" such as shown above can be used to obstruct radio-frequency currents in a conductor without the need to break the conductor physically. A vernier dial is recommended for use with the variable capacitor because tuning is quite sharp. The 100-pF capacitor is in series with the loop. This resonant breaker tunes through 10, 15 and 20 meters. Larger models may be constructed for 40 or 80 meters.

band. You will need one for each band where there is significant current as measured by the probe.

The current probe is also handy for other uses such as a field-strength meter or wavemeter. To use it as a field-strength meter, the figure-eight loop is replaced with a large circular loop of wire. When employed as a wavemeter, the figure-eight coil is replaced with a calibrated parallel-tuned circuit.

Power-Handling Capability

So far, all our experiments have been limited to the IA as a receiving antenna, except for the current measurements where it is necessary to supply a very small amount of power (1 watt is more than enough) to the antenna. These measurements will not indicate the full power-handling capability of the IA. Any tendency to flash over must be determined by running full power or preferably somewhat more than the peak power you intend to use. The IA should be carefully checked for arcing or rf heating before you do any operating. Bear in mind that attics are indeed vulnerable to fire hazards.

VHF

At 2 meters and above, the IA is small enough to be rotated easily; it is also small enough to be readily mounted on a stick and moved around the house or attic. This makes probing for the best location possible. Often just moving the IA a few feet can make a 20-dB difference in signal strength. The optimum location will usually be optimum in only one direction. Therefore it should be determined for the most difficult direction or the direction you are most interested in working. To determine the best location will require a steady carrier in the direction of interest. This can be provided by a station across town or by a signal source in your car which can be parked a few blocks away in the desired direction.

By way of conclusion, I heartily recommend that if you are among the "underprivileged" amateurs who have relegated Amateur Radio equipment to the closet for want of an antenna, pull the heap from those dust-covered boxes and go IA. The world could be waiting for you! QST

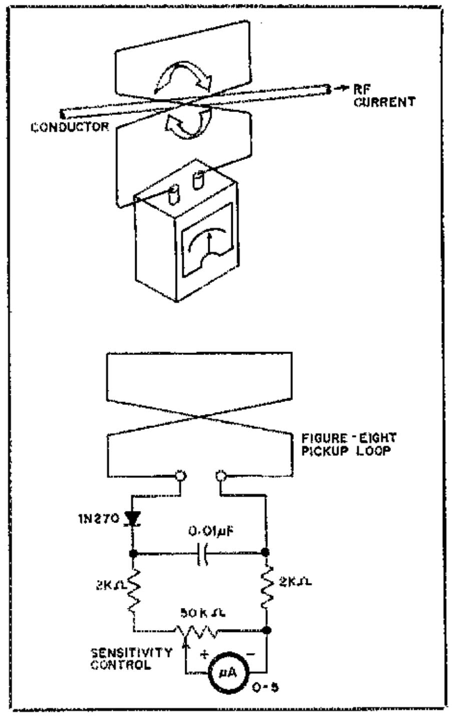
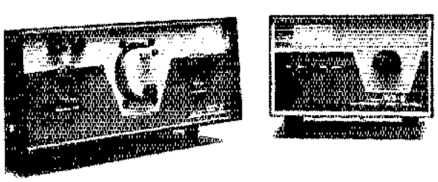


Fig. 5 — This current probe, constructed in a 3 × 4 × 5-inch (76 × 102 × 127-mm) enclosure, can be used to measure relative rf current in any conductor. The instrument may also serve as a field-strength meter or a wavemeter. Arrows show how the magnetic field surrounding the conductor threads through the figure-eight loop. The author's model contains a 5-µA meter but a less expensive meter movement, such as a 50-µA unit, may be employed. If a 0- to 1-mA meter is used, the sensitivity control should be changed to 10 kΩ.

References

[1]Schnell, "The Flagpole Deluxe," *QST*, March 1978.
[2]Brown, "How to Measure Antenna Gain," *CQ*, November 1962.
[3]Overbeck, "Measuring Gain with Amateur Methods," *QST*, October 1977.
[4]Jordan, *Electromagnetic Waves and Radiating Systems*, Prentice-Hall, 1950, p. 327.
[5]See ref. 3.
[6]Mathison, "Inexpensive Traps for Wire Antennas," *QST*, February 1977.
[7]"A Dielectric No-No," Hints and Kinks, *QST*, April 1977, p. 56.
[8]Brown, "RF Current Probe," *Ham Radio*, October 1968, p. 76.

Strays



Fred Hurteau, WD4SKH, designed the cabinets of his Ultimate Transmatch and Wattmeter to match his Drake R-4A. The cabinets were built out of sheet-metal scraps. The wattmeter was constructed as a complete unit instead of with a remote sensing head, so it could be placed inside the larger cabinet with the coax switch. The wattmeter can be removed from the cabinet, allowing it to be used remotely. *(WD4SKH photo)*

Elsewhere in this issue you'll find all the news that's fit to print about Field Day 1979. Here's a glimpse of Field Day 1946, the first postwar event. During the past 33 years, the ranks of those participating in Field Day have swelled from 1936 to 23,612, but some things have stayed about the same. Sam Arn, who was then W9KWX and president of the group in the photo, the Elgin (IL) ARS, is now K6TSD and president of Swan Electronics. Our thanks to him for the use of this photo.

I would like to get in touch with . . .

☐ anyone who has experimented in the 1750-meter band. Contact K1JDJ, P. O. Box 1003, Fairfield, CT 06430.

☐ chessplayers for check-ins to the international Chessplayers net every Sunday at 2100 UTC on 14.320. For info, send s.a.s.e. to Rick Wentworth, WB9ZJW, 100 St. Marys Blvd., Green Bay, WI 54301.

Wisconsin's new license plates, perhaps the first to state *Amateur Radio*, help Winfred A. Ross, WB9SQJ, proclaim his interest in the hobby. *(WB9SQJ photo)*