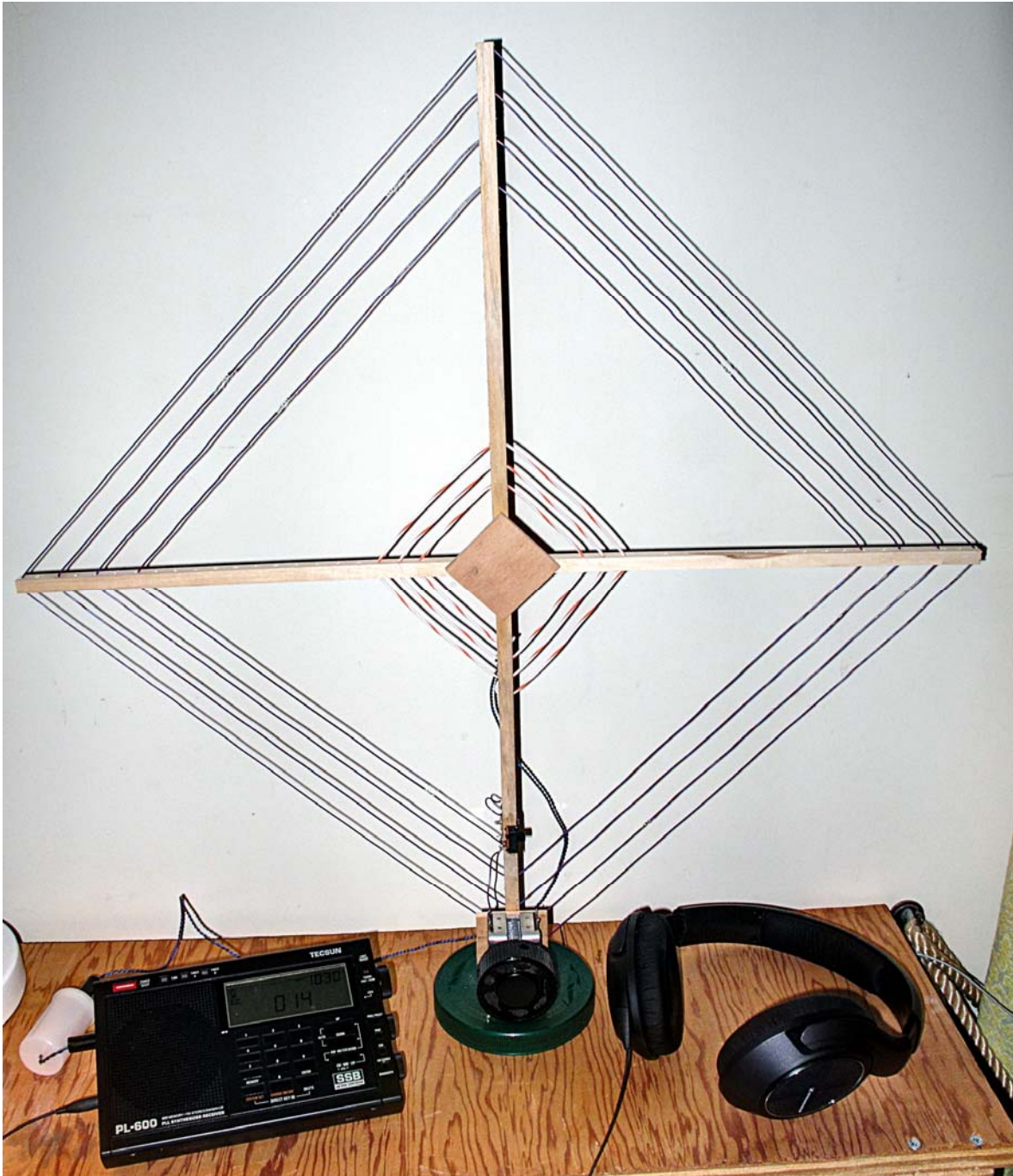


# ***ELECTRICALLY SMALL RESONANT LOOP ANTENNA FOR SHORTWAVE***

**BY BOB COLEGROVE**



# Electrically Small Resonant Loop Antenna for Shortwave

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## Introduction

A good antenna is as useful for what it rejects as for what it detects. A loop antenna is a delight; it gives you the sensation that you are really tuning your radio and not just pressing buttons. A well-designed, tunable antenna can be played like a fine musical instrument.

In the early 1980s, I had access to a large engineering library and availed myself of its wealth of electronic information, particularly regarding loop antennas. Much of the early research and theory was available. My primary interest at the time was medium wave, although I designed and constructed resonant loops operating at long waves and short waves.

There are several properties of loop antennas which make them attractive. Amazing things happen when you take a straight, modest length of hookup wire, wind it into a coil of suitable

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dimensions and resonate it with a capacitor. Properly constructed, the combination will produce a signal+noise-to-noise ratio comparable or better than random-wire, electric-field antennas. Initially, you may be discouraged that radio is not as *loud*. However, careful tuning and some practice learning how to *play* the antenna will uncover signals that are not otherwise detectable.

Tuned loops are highly-selective, narrow-band antennas. They must be tuned as you move up or down the band. Sometimes, retuning the antenna after a change of just 5 or 10 kHz in the receiver will produce noticeable increase in signal strength. Thus, loops of the type described here are *preselectors*. By allowing only a very limited band pass to reach the input of the receiver, they greatly relieve the receiver's susceptibility to overloading and intermodulation.

Loop antennas are directional. In many cases it will be possible to produce total nulls of an interfering signal or locally-produced noise. Since noise and interference are often in opposing directions to that of the signal, it will be possible to greatly reduce these annoyances. These features give the loop a distinct advantage over random wire antennas.

This article documents fabrication of resonant loop antennas which cover a large portion of the shortwave spectrum. It is easily possible to tailor the design described here to optimize reception of a specific portion of the shortwave spectrum. Four variants, all having the same size of the outer turn of 17" square (24" diagonal) have been built and tested having the upper frequency limits as follows.

**2 Turn - 22 MHz; 3 Turn - 16 MHz; 4 Turn - 10.5 MHz; 7 Turn - 5.2 MHz**

The lower frequency is determined by the maximum amount of capacitance you choose to add. Thus, each antenna can be made to tune through the lowest shortwave frequencies. For antennas having fewer turns in the primary coil, however, performance at lower frequencies will be compromised. The reason for this is described below in the Theory Section.

### Theory

Much can be said about how I arrived at the concept. Suffice it to say, there is nothing new here. It is, I feel sound application of the basic theory laid out almost 100 years ago. This is an *electrically small* loop, meaning the overall dimension of the primary coil is much smaller than the wavelength of the received signal. This is a *tuned loop*, meaning the primary coil is made to resonate at a specified frequency. This is accomplished by placing a capacitor in series with a coil of wire (inductor). The coil is the antenna proper and the capacitor is used to tune or resonate the circuit. At resonance, the current flowing through the circuit is greatly increased and other frequencies are attenuated. Thus, the antenna is also a preselector. The circuit can be made to resonate through an entire band of frequencies by changing the value of the capacitor or inductor. It is normally more practical to change the value of the capacitor.

### Coil Design

The capacitor's only function is to provide resonance. The values of capacitance and inductance can be varied inversely to resonate at the same frequency. The coil is responsible for capturing the field of the incoming signal; and it makes sense for the inductance to be large and the capacitance small. Inductance and, consequently, the antenna's *effective height*, increases by making the cross-sectional area of the coil larger or increasing its number of turns. Effective height for a non-resonant loop is calculated by the formula  $h_e = 2\pi NA/\lambda$ , where  $N$  is the number

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of turns,  $A$  the area of the turns (or average area for a flat coil having different areas for each turn), and  $\lambda$  the wavelength. For resonant loops,  $h_e$  is multiplied by  $Q$ , the figure of merit.

I have chosen to impose a limit on the size of the loop. Two 24" lengths of strip wood joined at a 90-degree angle at their centers produce a suitably strong framework, which can be mounted on a simple base and located on a desktop in close proximity to the radio.

If we keep capacitance of the circuit constant, lower frequencies will require larger inductances than higher frequencies. But, there is a limit to the size of the inductor. Unfortunately, there is no such thing as a perfect coil. The amount of useful inductance produced by the coil in a resonant circuit is in part limited by its *distributed* or *self-capacitance*. For example, two turns of a coil in close proximity have a slightly different potential, and therefore act as a capacitor. This capacitance is cumulative and *distributed* along the coil windings. It acts with the value of inductance of the coil and will form a circuit resonant at some frequency, beyond which the coil is useless as a tuned circuit. This physical barrier quickly comes into play at shortwave frequencies and limits the size of the loop to just a few turns of wire.

The question is then, how do you minimize distributed capacitance? It is reduced by increasing the distance between each turn in the coil. In addition, distributed capacitance is minimized by winding the coil in a single plane rather than in a solenoid shape. Each turn of the coil is separated a suitable distance from adjacent turns. The separation distance is limited by the coil's geometry. If the dimensions of the coil are kept small, the number of turns must be increased to achieve the same value of inductance, and these turns must necessarily be wound more closely.

There is one more characteristic, at least in theory, which has some impact on the antenna we are building, namely wire gauge. At resonance, two of three impediments to current flow in the circuit are cancelled, the inductive and capacitive reactances. That mainly leaves the resistance of the wire itself to limit current flow. Low resistance will increase the figure of merit or "Q" of the circuit. Heavier wire or stranded wire has less resistance and will make a better conductor, particularly at radio frequencies.

Many air- and ferrite-core loop antenna coils are formed from Litz wire. This is based on the theory that, as frequency increases, most of the current flow gravitates to the outer surface of the wire. By using multiple strands of insulated wire, this outer surface is increased and the resistance to current flow is lowered. Litz wire may be fabricated from several strands of wire insulated by enamel or fabric.

In practice, AWG 22 stranded wire is a convenient point of diminishing returns. Even at longwave frequencies requiring very large coils, this wire is large enough to produce extremely high Qs in very large coils. The benefit of heavier wire will be lost with the added distributed capacitance and mechanical drawbacks it produces.

### ***Capacitor Characteristics***

From the explanation above, it also makes sense to consider the characteristics of the capacitor you use to resonate the coil. In order to maximize the amount of inductance you can use, you want to minimize the amount of capacitance you add to tune the highest resonant frequency. A tuning capacitor set at minimum capacitance (rotor and stator plates open) does not

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have zero capacitance; rather it is typically on the order of 10 to 20 picofarads. This value, plus the value of the distributed capacitance of the coil acting in parallel, will determine the highest resonant frequency for the circuit. Unlike distributive capacitance, we have some control over the minimum added capacitance, and can reduce it by methods that are described below.

### *Secondary or Pickup Coil*

Now you have a tuned circuit consisting of a coil and capacitor, which will resonate through a band of frequencies. How do you channel the energy to the receiver? You simply build a transformer by adding a secondary (pick-up) coil. The secondary coil develops its current from the inductive field produced by the primary coil and delivers this to the receiver by a transmission line. The secondary circuit is not resonant and produces a low-impedance current to the receiver.

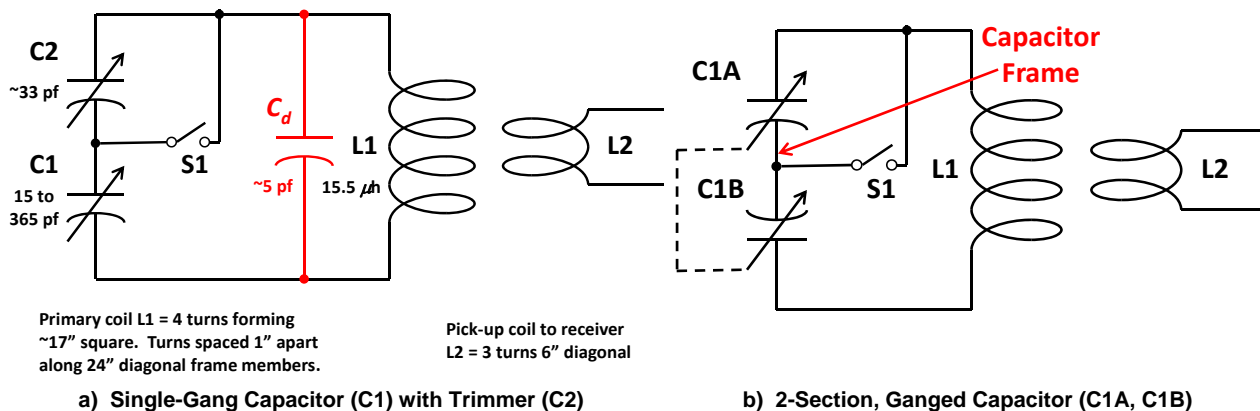
The size of the secondary coil is, with some limitations, not critical. Two to four turns of hookup wire wound on a form 3 to 5 inches in diameter will work quite satisfactorily. However, its location within the field of the tuned circuit is important. The secondary coil should be mounted coaxially with the primary coil and in the same plane, in other words, in the center of the loop antenna. That places all portions of the pickup coil in proper phase to detect the field produced by the tuned primary circuit. At other locations, portions of the pickup coil will be out of phase with the field and pickup will be diminished.

Overcoupling between the two coils must be avoided. A secondary coil which is overcoupled will load the primary resonant circuit and effectively lower the Q. This typically happens if the secondary coil is made too large in diameter with respect to the primary coil.

### *The Circuit*

Figure 1 shows the basic diagrams for the antenna. Figure 1a shows the circuit with a single gang tuning capacitor and trimmer. The component values shown are typical for a 4-turn primary coil. The effect of distributed capacitance is represented in red.

High band - 6.9 to 10.5 MHz – S1 open;  
Low band - 9.0 to 2.1 MHz – S1 closed.



**Figure 1. Basic Loop Antenna Schematic Diagram**

C2 is a trimmer capacitor added in series with the main tuning capacitor, C1. It has two purposes. First it effectively lowers the minimum capacitance of C1 resulting in an extension of the upper operating range by about 1.5 MHz. Second, it provides some bandsread across the

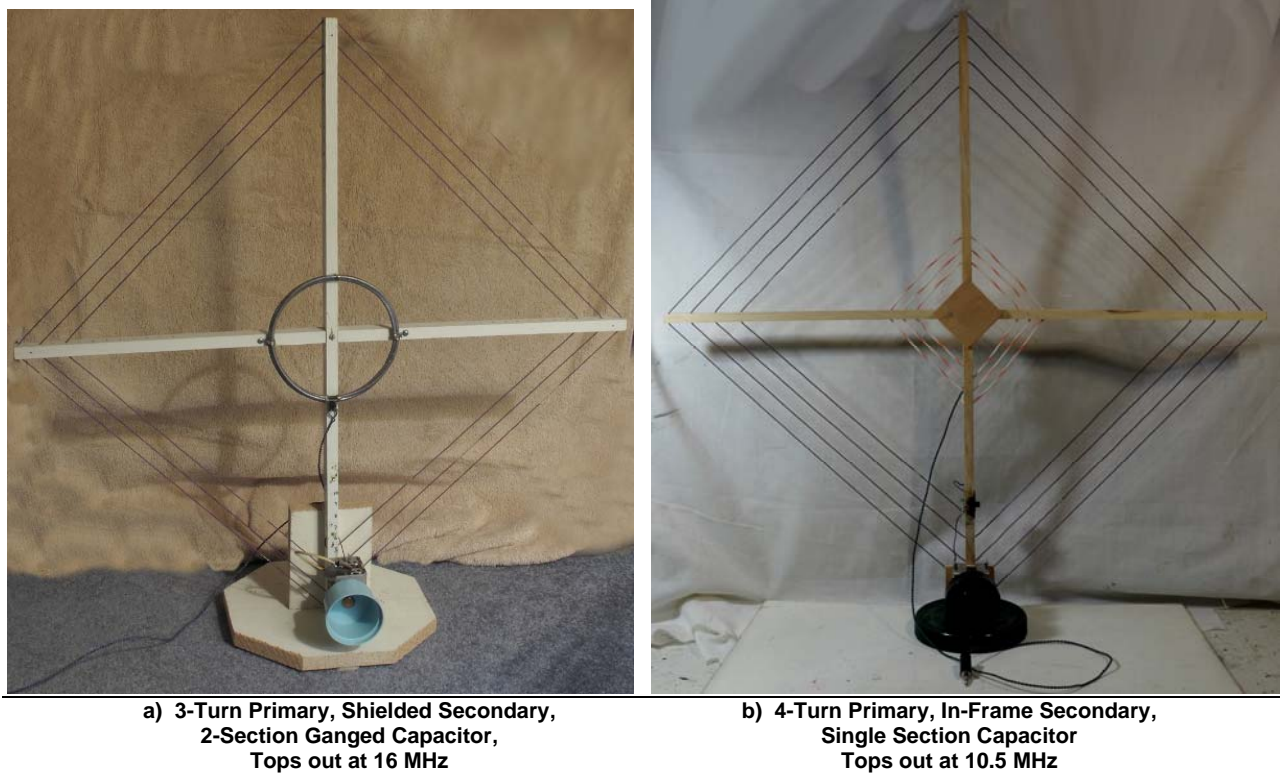
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tuning range by limiting the lower range of C1. Adjusting C2 will have much greater effect at the low end of the tuning range. S1 is added to remove C2 from the circuit, thereby restoring the full range of C1. When open, it is in the 'high band' position; closed, the 'low band.'

Figure 1b shows the circuit using a 2-gang tuning capacitor. The dotted line indicates the sections are tuned simultaneously. Assuming each gang to be 15 to 365 pf, with the gangs open minimum capacitance would be  $\sim 15/2 = 7$  pf. With the gangs closed, the maximum capacitance is  $\sim 365/2 = 183$  pf. S1 provides a shunt across one section of the capacitor. This effectively increases the total capacitance. The range would then be 15 to 365 pf, and the circuit would tune to much lower frequencies, with some overlap between the two bands. Distributed capacitance still exists in the coil, but is not shown in the diagram.

### Description and Construction

Figure 2 shows photographs of two loop antenna variants for shortwave. As indicated above, I have arbitrarily imposed a physical size limitation of the coil. It is square, oriented in the shape of a diamond. The diagonal measurements are 24" resulting in sides of approximately 17".



**Figure 2. Resonant Loop Antennas for Shortwave**

As described above, the number of turns will determine the upper frequency tuning range. You may choose from among four variants of this design: 2 turn, 3 turn, 4 turn and 7 turn. These will have, in turn, upper frequency limits of approximately 22 MHz, 16 MHz, 10.6 MHz and 5.2 MHz, respectively. For this discussion, I have focused on the 4-turn loop, as it provides an upper range extending through the 31 meter band and will have the highest inductance/capacitance (L/C) ratio and, consequently, the greatest effective height at that frequency. The

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lower range of any antenna is limited only by the amount of capacitance you add. 365 pf will tune any of these antennas down to 2 or 3 MHz or lower.

### *Frame*

The primary coil consists of 2, 3, 4 or 7 turns of AWG 22 wire, depending on the highest frequency you intend to tune (see Page 2), and is wound on a cross frame of wood, tennis racket style. The two cross members are 24 inches long. The frame cross members can be made from either  $\frac{1}{2}'' \times \frac{5}{8}''$  or  $\frac{3}{8}''$  square strip wood.  $\frac{3}{32}''$  holes are drilled at 1'' intervals for the 2-, 3-, and 4-turn loops and  $\frac{1}{2}''$  intervals for the 7-turn loop. Extra holes, providing a future capability for modification, may be drilled from the ends of the cross members inward to approximately 2 inches from the center.

The center of each member is notched to mate with the opposite member.  $\frac{1}{4}''$  plywood pads, 2'' or 3'' square are used, one at the center to reinforce the joint between the two cross members and one at the end of one of the cross members to mount the variable capacitor and base. The strip wood joint and pads are bonded with wood glue.

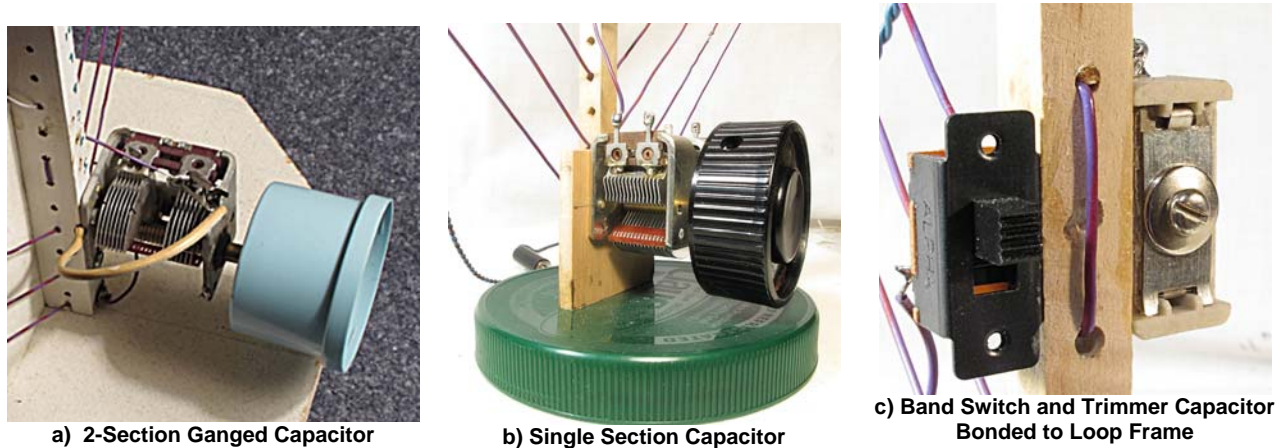
The tuning capacitor is mounted to the plywood pad at the end of the frame member. Be careful when mounting the capacitor. The frame is probably threaded, usually for 6-32 machine screws. The screws must not penetrate much beyond the inner surface of the frame; otherwise they could contact the stator or rotor plates. A solder lug can be used under the head of one of the screws to serve as a terminal point for the coil.

The base can be made out of any non-conductive material such as wood or plastic. I have used large plastic jar lids. With the capacitor mounted at the bottom of the primary coil, the center of gravity is quite low and the base doesn't have to be very large. This makes it convenient to rotate. The frame is mounted to the base with wood screws through the bottom of the base into the pad at the end of the frame member.

### *Tuning Capacitors*

Unfortunately, air-dielectric, variable capacitors have pretty much gone the way of slide rules and buggy whips. A good source is an old radio. These tuning capacitors customarily had two or three sections or 'gangs,' as they variously tuned oscillators, mixers and possibly RF stages within the radio. Although a single gang capacitor is perfectly acceptable, a 2-gang capacitor does have the advantage that you can connect the gangs in series to reduce the normal minimum capacity (two capacitors in series) and thus extend the range to cover higher frequencies. Some sources for air-dielectric, variable capacitors are listed in the Sources for Air Dielectric Variable Capacitors Section.

Figure 3a shows an example of a 2-section, ganged capacitor; the schematic diagram is shown in Figure 1b. In the high-band range, each stator gang is connected to an end of the primary coil, and the metal frame 'floats' in the center. Connecting the frame to the stator plates of either gang, shorts out that gang and leaves only one gang in the circuit. As shown in the figure, this can be done with a short wire and alligator clip, or, you can get elegant and use a switch.



**Figure 3. Variable Capacitor Arrangements**

Figure 3b shows a single-gang capacitor. Yes, the green base is the plastic lid from a pickle jar. The operating range of this capacitor is 15 to 365 pf, which is typical for capacitors of this type used in radio circuits. In order to reduce the minimum capacitance, a separate trimmer capacitor is added in series; the schematic diagram is shown in Figure 1a. In this example, the trimmer capacitor is adjusted to ~30 pf and not changed during normal operation of the antenna. A slide switch is used to shunt the trimmer capacitor for the ‘low band,’ extending the tuning range to use the full 365 pf of capacitance.

The capacitor shown in Figure 3b is also produced in a variant having an 8:1 planetary reduction mechanism built into the shaft. Separate 6:1 planetary reduction mechanisms are available for attachment to standard ¼” shaft capacitors.

If a trimmer capacitor will be used, mount it, along with a ‘band switch’ to the lower frame member just above the point where the primary coil terminates. Figure 3c shows a typical installation. These parts were bonded to the frame with contact cement.

Note that the knobs on the tuning capacitors are relatively large in diameter. This provides easier tuning; this is very convenient, as the tuning peaks will be quite sharp. In addition, body capacitance will tend to detune the circuit, if your hand is placed too close to the capacitor frame. This is discussed further in the Operation Section. The “knob” in Figure 3a is actually a plastic cap from an aerosol can. Larger knobs can be fabricated by bonding these caps or plastic jar lids to small knobs intended for ¼” shafts.

### ***Primary Winding***

Run the AWG hookup wire loosely through the holes around the frame. When the desired number of turns has been wound, check their spacing through the correct holes, and then solder the outer end at the bottom of the lower frame member to the variable capacitor. For a single-gang capacitor, this will likely be the frame. For a 2-gang capacitor, this will be one of the stator gangs.

Pull the wire snugly around the loop working your way from the outer turn to the inner turn. Lace the end of the last turn back through the next inner hole in the frame. This will provide some tension to hold the last turn in place. You may go back a second or third time to



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pull out some slack. The turns should be tight, but not have excessive tension. In addition, ensure the frame members retain their position normal to one another.

Figure 4 shows a detail of the primary windings passing through a frame member. When using holes spaced 1" apart, this results in an actual separation of approximately  $\frac{5}{8}$ " between turns. Now solder the remaining (inner) lead of the primary coil to one terminal on the trimmer capacitor or the remaining stator terminal on a 2-gang capacitor. If a 2-gang capacitor is used, you can solder the 'band switch' across the frame and one gang of stators. If a trimmer capacitor is used, don't forget to connect it's remaining terminal to the stator terminal of the single-gang capacitor.



**Figure 4. Detail of Primary Winding**

### ***Pick-up Coil***

Figure 5 shows three various designs for pick-up coils. Distributed capacitance is not an issue, since this is a low-impedance, non-resonant circuit. The turns of the secondary can be closer than the primary – with insulation from adjacent turns in direct contact, if necessary.



**Figure 5. Pick-up Coils**

Figure 5a may be the simplest approach, as it makes use of the center portion of the frame. The turns are wound through holes in the frame similarly to the primary coil. It consists of three turns, with the outer turn 6" along the diagonals and the turns spaced  $\frac{1}{2}$ " apart along the frame.

Figure 5b shows a 3-turn coil wound on a  $2\frac{5}{8}$ " plastic jar lid. The threaded flange was drilled with two pairs of closely spaced holes. See the inset in Figure 5b. The wire is held in place by lacing each end through one pair of holes, and covering the remainder of the flange and coil turns with tape. A hole in the center of the lid provides a point of attachment to the center of the loop frame.

One useful feature of this coil bears mentioning. Since, it is easily removed from the antenna frame, you can manually move it around the field created by the resonant circuit to see its effects in various positions.

Figure 5c is an artifact from the author's days in constructing medium-wave antennas. This coil is shielded, and follows the same principles as old-time radio direction-finding coils. Shielding was used in early low-impedance radio direction finding antennas, as it provided high

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directional capability, as well as minimizing noise. A shielded pick-up coil is probably unnecessary at shortwave frequencies and is only presented here for information purposes to complete the discussion. Properly constructed, this antenna will produce nulls, particularly for locally generated noise, without shielding the secondary coil. Anyway, at shortwave frequencies, signal nulls are problematic, particularly at night when multi-path skywave propagation is common.

If you decide to fabricate a shielded pick-up coil, the wire consists of three turns of AWG 14, the kind used in Romex house wiring, and the coil is 5" in diameter. For the coil shown, the shielding was formed by wrapping conductive foil tape around the three turns of wire. This tape is used around windows and doors for security systems. The tape shown here is lead, which is probably no longer available. Current tape is made from aluminum or copper. Copper is probably more suitable, as it is solderable. Ground lugs were soldered at 180-degree intervals and used for mounting the coil to the frame. It is absolutely essential that there be a gap in the shield. This is most convenient at the end points. One end of the coil is soldered to the shield and the other end of the shield is left unattached.

### *Transmission Line*

It is not necessary to use coaxial cable as a transmission line. A twisted pair of wires will achieve the same result and be more flexible, see Figure 6. Take two pieces of AWG 22 stranded wire, clamp an end of each wire in a vise, connect the remaining two ends to the chuck of a hand drill, and twist the pair until you have 8 to 10 turns per inch. The polarity of the secondary coil does not matter; either end can serve as the ground side, relative to the radio. I have used transmission lines in excess of 6' in length with negligible loss. Since this antenna is intended to operate on a desktop next to the radio, there is no reason why the transmission line can't be kept under 2' in length for mere convenience.



**Figure 6. Twisted Pair and Plug**

### *Options*

#### *Lowering the Frequency*

The best way to lower the tuning range of this antenna is to add more turns to the primary coil. Using the same maximum diameter of the outer turn, 7 turns at  $\frac{1}{2}$  the turn spacing will produce a range between approximately 160 meters and 60 meters. You can add more capacitance to a coil with fewer turns to produce the same result, but, as explained above, the effective height of the antenna will be greater if you increase the size of the coil.

#### *Raising the Frequency*

Removing one turn from the loop described above will raise the maximum tuned frequency, but it will also raise the minimum tuned frequency. Again this can be compensated with more capacitance, but at a price of a lower effective height.

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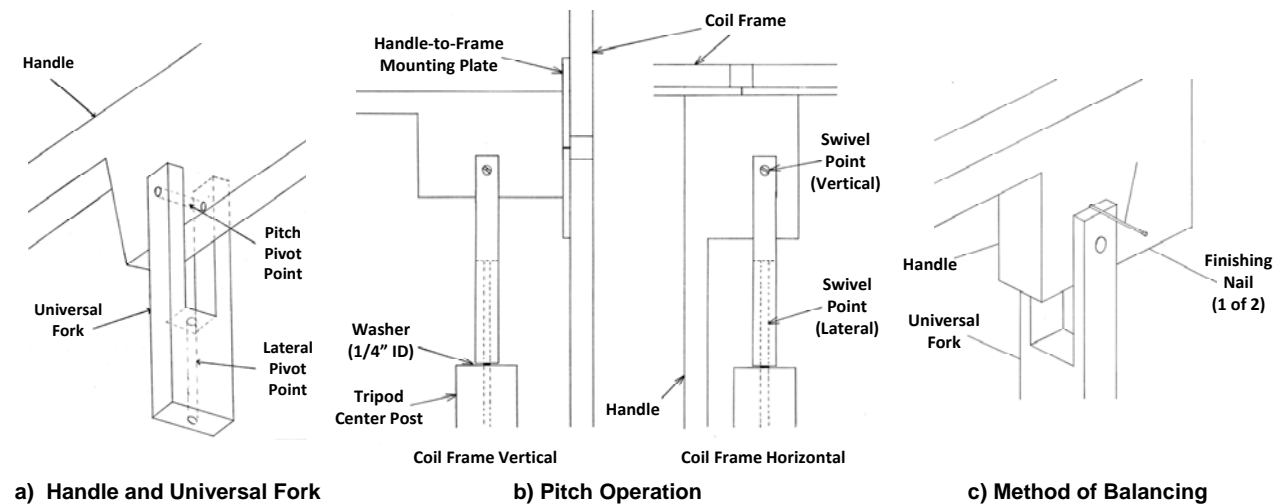
## *Improved Directional Response*

An optimum design for directional response permits a minimum 180-degree horizontal rotation with the plane of the loop normal to the ground and 90-degree vertical rotation with the plane of the loop parallel to the ground. This is useful for peaking or nulling so-called “skywave” signals bouncing off of the Earth’s ionosphere. Addition of vertical capability will require construction of a more extensive mechanism.

In the 1980s, the author designed a wooden tripod for operation of long- and medium-wave loops. The cross frame of the loop was fitted with a wooden handle which extended normal to the plane of the loop and served as a counterbalance as the antenna was rotated in the pitch direction. A pivot point in the handle near the loop was connected to a universal fork which was free to rotate on a pin in the top of the tripod. The handle and loop were mechanically balanced so any vertical orientation of the loop could be maintained with a minimum of mechanical resistance. Thus the loop could be rotated a full 360 degrees laterally and 90 degrees vertically.

Figure 7 shows the concept. Figure 7a shows the handle and the universal fork. Not shown are the antenna frame, which would be attached to the handle at the right side and the tripod for mounting the assembly. The tripod was fitted with a 1/4” pin to receive the universal fork. Figure 7b shows the antenna frame oriented vertically (left) and horizontally (right). The center post of the tripod can be seen at the bottom.

Figure 7c shows the method of mechanically balancing the loop antenna and handle assembly. Finishing nails were installed on each side of the handle and the assembly temporarily balanced at the top of the fork. When perfect vertical rotational balance is achieved the pitch of the assembly can be held at any position without any clamping. The finishing nails were repositioned by trial and error until this was achieved.



**Figure 7. Concept for Vertical Pitch Control**

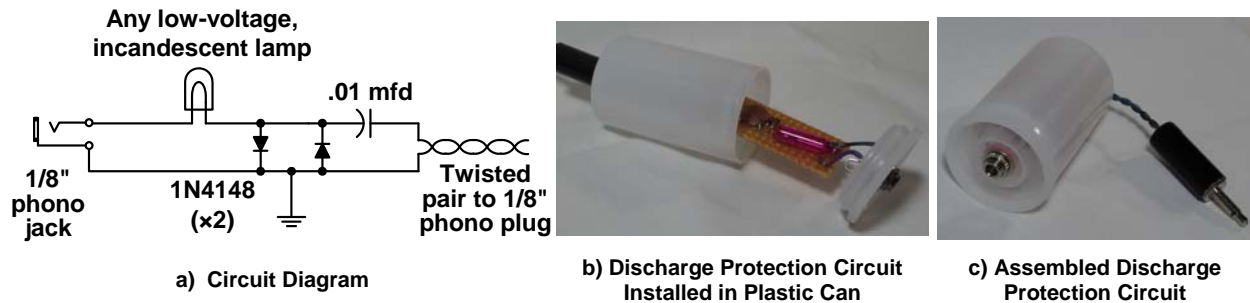
## *Protection and dc Isolation Circuit*

First of all, some understanding of what this is and what it isn’t. This is a circuit intended to prevent accidental coupling of high voltages to the external antenna input of portable radios. Such discharges can damage the input stage of your radio. These voltages may be generated through electrostatic buildup along the external antenna, or may come from bodily discharge through contact with the antenna. This device does *not* provide protection from lightning.

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The danger of electrostatic discharge using the loop antenna described here is minimal, certainly not the concern it should be if end-fed antennas, particularly outdoor antennas are plugged into the receiver's external jack. The pick-up coil of the loop antenna has very low inductance and represents a dc short across the external antenna jack. However, the possibility of bodily static discharge still exists when connecting or disconnecting anything from the external jack, particularly during winter months when the air is dry.

The circuit is shown in Figure 8a. Voltage is limited by the two diodes. Depending on the polarity of the discharge, one diode will be reverse biased and not limit voltage. Meanwhile, the remaining diode is forward biased and will conduct current sufficient to limit voltage to about 1 Volt. The light bulb is optional. It presents low resistance to the incoming signal and acts as a fuse which will blow if the voltage across its filament exceeds its rating.



**Figure 8. Static Discharge Protection Circuit**

The .01 mfd capacitor serves another purpose. It decouples dc voltage which may be present on the external antenna input jack of the radio. This applies to the Tecsun PL-660, the Sony ICF-SW-7600GR and possibly other receivers. This voltage is used to turn on certain active antennas, such as the Sony AN-LP1, when they are connected to the radio. There is no danger to the radio if another antenna is connected across the external antenna jack on the radio. The Sony ICF-SW-7600GR has a 470-Ohm resistor, which will limit current. However, a low-resistance antenna circuit will cause a small but unnecessary drain on the radio batteries. This would include a low-impedance loop having its terminals connected between the antenna input and ground. This is effectively a dc short across the antenna output leads.

The circuit was constructed on a piece of perfboard (Figure 8b). The case may be an old plastic film can or medicine container. The antenna end is terminated on a  $\frac{1}{8}$ " jack or other suitable terminals used to accommodate the connection to your antenna. This is mounted through a hole in the cap of the case. The input to the radio exits through a hole in the bottom of the case via a twisted pair and is terminated in a  $\frac{1}{8}$ " plug.

Figure 8c shows the assembled circuit board and case. The circuit presents negligible impedance to rf signals from the antenna and will not result in any noticeable signal attenuation.

### Operation

The antenna has a very high Q, meaning, at resonance, it has very low resistance in the resonant circuit, resulting in a very narrow bandpass. There may be a complete absence of signals with the antenna tuned slightly off resonance.

1. Tune the receiver to the desired frequency. Bandwidth and use of a synchronous detector may be applied as desired after the antenna is tuned.

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2. Tune the antenna capacitor to peak the tuned frequency of the radio. Tuning will be very sharp. Sometimes it will be easier to tune the antenna with the receiver first tuned to background noise 5 or 10 kHz off frequency, particularly if the signal is fading rapidly.
3. Rotate the antenna to a point where the overall signal+noise-to-noise ratio is the best. This should be somewhere within a 180-degree arc.
4. Adjust the bandwidth and synchronous detector of the receiver for best response.

### *Intermodulation*

Some receivers are capable of occasional intermodulation, that is, reception of strong signals at frequencies where the station is not transmitting. It is possible that intermodulation will still be present when operating with this antenna. Intermodulation may peak by tuning the antenna to a point removed from the receiver's tuned frequency. However, it can be totally eliminated or significantly reduced when the antenna is tuned to resonate at the receiver's tuned frequency.

### *Stability*

Stability refers to the variation of the tuned frequency over time. With some radios, particularly old vacuum tube radios, this was a problem where the resonant frequency of tuned circuits would drift, particularly as the radio warmed up and thermal change caused component values to change. The result was that the station would slowly detune over several minutes.

The resonant loop described here may demonstrate a stability problem, though this has a different cause. This antenna is a victim of its own success. First, it operates at a very high Q. It has a very narrow bandpass at resonance. In order to maximize its effective height, the size of the coil has been made as large as possible. Together with the capacitance required to bring it into resonance, it has a very high inductance-to-capacitance (L/C) ratio. At the top end of its frequency coverage, it operates very close to its resonant or natural frequency. The addition or subtraction of 1 or 2 picofarads (pf) will detune it and the resulting signal strength to the receiver will decrease noticeably.

There are two likely causes for this. It may be a loosely wound primary coil, where the turns tend to wobble, their separation distances changing if the antenna is repositioned or jarred. The remedy for this is simply to tighten the turns in the primary coil as described in the Description and Construction Section. The more likely cause is body capacitance introduced when you operate the main tuning capacitor. This adds to the total capacitance of the tuned circuit and tends to lower the resonant frequency.

Even with reasonable care taken in the design and fabrication of your antenna, you may still notice that body capacitance causes the antenna to detune when you pull your hand away from the tuning knob. The final remedy is to detune the capacitor very slightly toward in the lower frequency direction (more capacitance). Then when you remove your hand, the correct amount of capacitance will be applied and you should detect an increase in signal strength near peak.

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### **Sources for Air Dielectric Variable Capacitors**

MTM Scientific, Inc., <http://www.mtmscientific.com/capacitor.html>

Borden Radio Company, <http://www.xtalman.com/potsvaricaps.html>

The Xtal Set Society, <http://www.midnightscience.com/catalog5.html>