Small-Loop Receiving Antennas

The late Joe Carr K4IPV looks at antenna design for a receiving antenna. With the ability to null-out local interference, it might allow you to work stations that are otherwise lost in the noise.

Let's face it, the bands are crowded today. In fact, they have been crowded for quite some time, and with more and more wireless services coming on line every day the situation doesn't look promising. We can, fortunately, do something to reduce the apparent QRM on the bands from the viewpoint of the receiver.

For the low frequency bands the situation can be ameliorated by the use of a small-loop antenna. At frequencies up to about the 6MHz band, the small-loop antenna may be the key to reception.

The problem is not so much gain as it is the directivity of the antenna. On the low frequency bands directivity is hard to get, if you count size as important and who owns enough land to put up a 3.5MHz three element Yagi beam? The directivity of the small-loop antenna could be ideally suited to such operations.

Small Loop Antenna

So what is a small-loop antenna? And how does it differ from a large-loop antenna? The difference is primarily one of wavelength. One textbook lists a small-loop antenna as a loop antenna with an overall wire length of less than 0.18λ, while another textbook lists the overall length as less than 0.10λ. The illustration **Fig. 1** shows the concept of a small-loop antenna.

I have shown the square type of loop, although they're circular, hexagonal and octagonal styles as well. The square loop is a little bit easier to build than the others, so I chose that one to illustrate the point. The comments are appropriate to all small-loop antennas, however.

A large-loop antenna, on the other hand, has a length of at least 0.5λ (λ/2), with most being either one or two wavelengths long. A consequence of the difference in size is that the r.f. current flowing in the small-loop antenna is uniform…it's the same throughout the antenna, no matter where you look at it. The large-loop antenna, on the other hand, produces distinct voltage and current nulls and maxima throughout the length of the wire.

There may be one or more turns of wire in a small-loop antenna. The length of the sides is **A**, and the depth of the winding is **B** in Fig. 1. The only constraint is that the length of A must be at least five times the length of the loop winding (B).

The winding turns can be either planar wound (all in one plane) or solenoid (one layer) wound. Of these, the planar wound results in a sharper null (theoretically that is, as it's difficult to achieve in practice!), while the solenoid wound form is often a little easier to implement.

The tuning capacitor in Fig. 1 is optional, but is highly recommended. The reason is that the output voltage of the loop is increased markedly by the presence of the capacitor. I've seen some books quote that the output voltage is increased by the *Q* of the capacitor, which can be 100 to 500. The capacitor should resonate the loop inductance to the frequency being received.

Radiation Pattern

The radiation pattern of a small-loop antenna is the standard figure of eight pattern with the nulls aligned broadside to the plane of the loop (the maxima are off the ends of the loop). This points out another difference between the large-loop antenna and the small-loop antenna.

The pattern of a large-loop antenna is just the opposite of the small-loop one. The nulls are off the ends and the maxima are broadside to the plane of the loop. It is those nulls that make the antenna an exciting prospect for receiving on crowded bands. The gain of the small-loop antenna is less than that of a dipole, although larger than an isotropic antenna.

But the gain is not the real issue. The real issue is the depth and sharpness of those nulls. By placing the nulls (in their deepest extent) on the offending interfering station you increase the signal-to-noise ratio (S/N) of the situation.

And radio reception is a game of S/N period! This works if there is a difference in azimuthal direction of more than a few degrees between the two stations. Even though the desired signal is not in the maxima of the

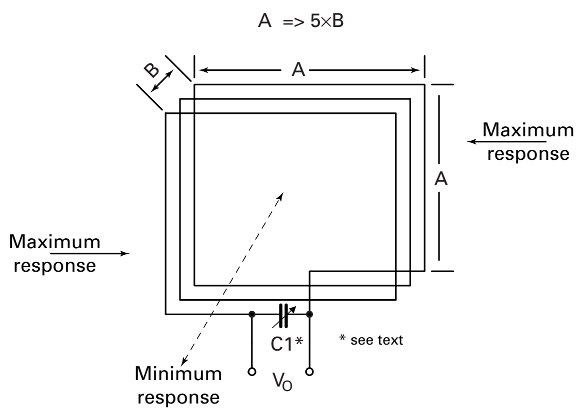

Fig. 1: The small-loop antenna is physically small in relationship to the wavelength, but has many advantages. See text for more detail..

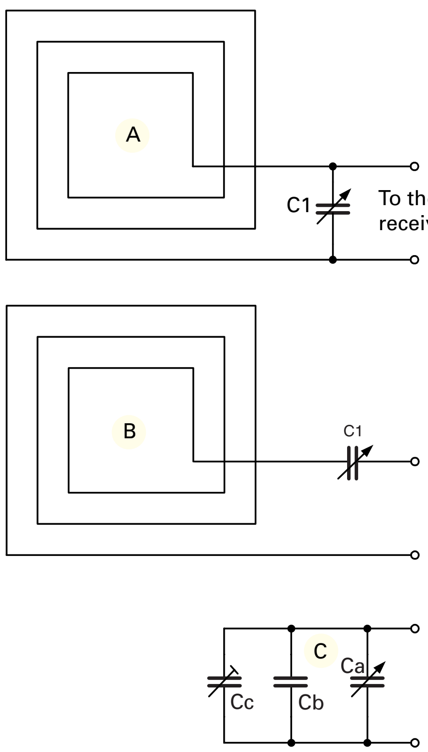

Fig. 2: The various loop tuning schemes: A parallel tuned loop is shown above a series tuned loop, and below them both, is a scheme for padding the capacitor value.

loop, it will perform wonders on the desired signal if the ratio between the two signals is improved (made bigger).

Works Wonders

Not only does the small-loop antenna work wonders on the reception of weak signals on the low frequency bands, it also improves the performance of some receivers on those bands. If the dynamic measures of the receiver's performance are at all compromised by the crowded conditions, then the loop is the answer.

Those dynamic performance parameters include the dynamic range, the third-order intercept point and the desensing signal levels required. The problem is too much r.f. at the r.f. amplifier and the mixer stages, and that drives these stages beyond their capability, producing increased intermodulation distortion noise (IMD) products. This is especially likely to affect the receiver is the third-order difference products ($\{2F_1\}-F_2$ and $\{2F_2\}-F_1$) are present.

Tuning Schemes

Look now at **Fig. 2**, which shows two different tuning schemes for the main loop. The parallel tuned version is shown at the top, while the series tuned version is shown just below. There are apparent differences between series and parallel resonant circuits, but the practical difference is not audible.

Getting the capacitance range needed, does not depend on the availability of the exact capacitor. The lower part of Fig. 2, shows a parallel arrangement in which a trimmer capacitor and a fixed capacitor are used to pad the value of the variable capacitor. Any series, parallel, or series-parallel combination of capacitors can be used in this application.

Loop Impedance

The loop impedance of the loop in Fig. 1 is typically very high, but your receiver wants to see a low impedance feed (a value of 50Ω is a popular choice). The answer to the problem is to use a coupling loop within the main tuned loop.

The coupling loop as shown in **Fig. 3**, is concentric with the main loop, a multi-turn tuned loop similar to Fig. 1. The coupling loop may be one or two independent turns of wire that forms a low impedance coupling to the receiver.

Sometimes, the smaller coupling loop is also tuned, as shown by the additional coloured capacitor in Fig. 3. But the capacitance value required for resonance is typically several times the capacitance needed to tune the main loop. For that reason, one only occasionally finds the coupling loop tuned as well.

Shielding The Loop

Shielding the loop in its own Faraday cage, makes good sense, even if it can be a pain doing it. Shielding the loop, reduces capacitance coupling to nearby voltage sources minimising local noise pickup.

Shielding, or screening the loop has another beneficial effect, as the loop interacts with its environment. The benefit is of reducing the effects of the distortion to the loop's radiation pattern.

The distortion differences are due to capacitance coupling to the environment and their effect is to reduce the sharpness of the nulls. Indeed, in extreme cases the small-loop antenna can show very shallow nulls.

Reduction of nulls, affects the signal-to-noise ratio that can be obtained with the loop! I've seen loop nulls deteriorate from better than –40dB in the direction of a null (maximum being 0dB), to less than –15dB. the change of 25dB (or more) is a significant deterioration of the loop's pattern!

The shielding of the loop antenna is shown in **Fig. 4**, in this case a circular loop is used, but

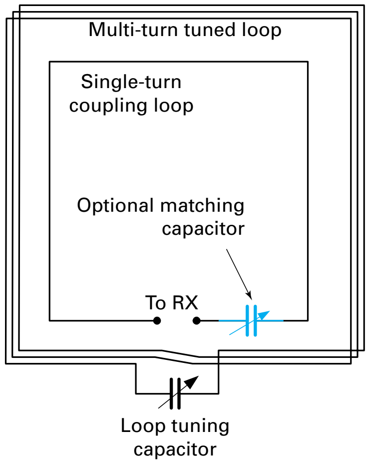

Fig. 3: The use of a coupling loop can make matching to the input of the receiver much better. Although the coupling loop may be at resonance, it's unusual because the value od the capacitor is often much larger than the main loop tuning capacitor.

the same discussion could apply to other forms as well. In the drawing of Fig. 4, the loop only has one loop for sake of simplicity, but it may have many turns.

Note that the shielding is not continuous. There is a gap in the shielding that can be as little as a few millimetres width. The effect of the loop is preventing the shielded loop from acting as a single-turn loop in its own right.

The shielded loop antenna then is sensitive only to the magnetic field component of the electromagnetic signal, rather than the electric field component, the typical wire or tubing antenna responds to the electric field rather than the magnetic one.

Peeking Through

By shielding the loop, allowing only a small segment to peek through the shield, you allow the magnetic field vector to affect the antenna, but not the electric. The noise generated by lightning and man-made spark oriented interference on the band, tends to be electric field oriented so, the shielded small-loop antenna also tends to discriminate against this form of unwanted noise

So, small-loop antennas are

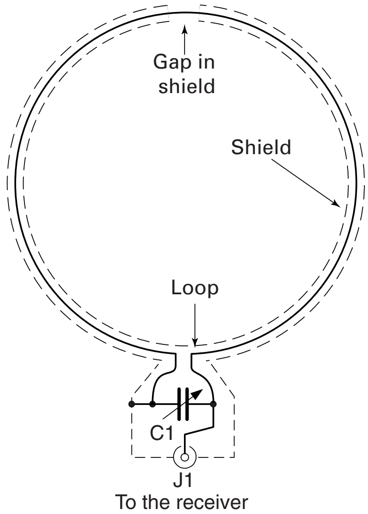

Fig. 4: A shielded loop has many advantages over an unshielded one. (see text for more detail).

antennas with an overall wire length less than 0.18l or 0.10l. The result of the small size of the antenna is that the current flowing is the same at all points within the antenna.They have advantages over large-loop antennas which shows distinct voltage and current nulls and maxima.

Try a small loop out and I'm sure you'll come to the same conclusion: that small-loop antennas with their figure of eight radiation pattern can be used to null out interference, increasing the S/N of the desired signal. Try it…you'll like it. **PW**

When Joe wrote this article for us, he added the following postscript: "I would like to thank those who welcomed me as a columnist for *Practical Wireless* after my first column. It's truly an honour to be named to this post, and I will endeavour to be worthy of the honor the magazine has done me".

Sadly Joe became a silent key on the 25 November 2000. A loss, not only to his family, but to the whole of Amateur Radio. An obituary appeared on pages 10 and 11 of the March 2001 issue of *Practical Wireless*.