Joe Carr's Radio Tech-Notes

Using the Small Loop Antenna

Joseph J. Carr

Universal Radio Research
6830 Americana Parkway
Reynoldsburg, Ohio 43068

Using the Small Loop Antenna

Joseph J. Carr

Small loop antennas have an overall wire length ≤ 0.15λ. They exhibit deep nulls perpendicular to the plane of the loop, and broad maxima off the ends of the loop. The pattern of these small loop antennas is a variant of the classic "Figure-8" pattern. Although the loop has less gain than a dipole, the radiation pattern and small size make the antenna quite useful for certain situations.

One common use for small loops is in *radio direction finding* (RDF). The maxima are too broad for effective RDF, but the nulls are sharp. The target station is tuned in when the maxima are aimed in its general direction. The precise line-of-direction to the station is then found by rotating the loop until the null is at its deepest. This position is found when the signal strength drops to a minimum level.

Positioning the loop so that the null is on the line-of-direction to the station produces an ambiguous situation because the loop is bilateral. The actual direction of the station could be in either direction on the line-of-direction. In some RDF systems a vertical sense antenna is positioned near the loop to discriminate the null direction, although at the cost of some null depth.

The most common use for small loop antennas on crowded bands is interference reduction of off-axis signals. Consider the situation in Fig. 1A. The antenna here has an omnidirectional pattern, so receives equally well in all directions. Suppose that two signals, SIG1 and SIG2, are on the same frequency, but arrive from different directions. Even if they are of the same power level (see inset to Fig. 1A), they will overwhelm the receiver, and cause considerable interference with each other.

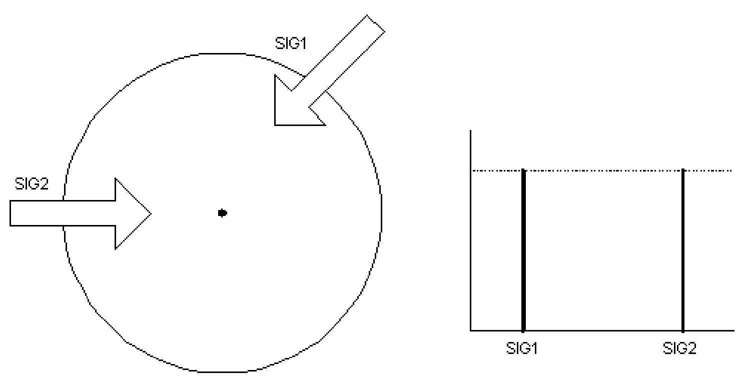

FIG. 1A

And if one signal is considerably stronger than the other, then it may overwhelm the other, preventing reception. However, even if the weaker signal cannot be easily heard (or heard at all), it may still cause problems. In my locale, we have an AM BCB station on 780 KHz. For years, sensitive AM BCB receivers (auto radios, for example) would exhibit a 10

KHz heterodyne when tuned to that signal. The problem was another station on 790 KHz 100 miles away. And while we were in the "deep fringe" area of its ground wave pattern, there was sufficient signal from this adjacent channel station to interact with the 780 KHz signal and create a 10 KHz beat note. It seems that the radio regulatory authorities muffed that one; the 790 KHz station eventually changed frequency or went off the air, I am told.

Figure 1B shows the situation where a loop antenna is used to null out one of the stations. Although maximum sensitivity occurs when the maxima lobe is pointed at the desired signal, this isn't always the best approach. Assume that we want to monitor SIG2, and need to be rid of SIG1. By pointing the deepest part of the antenna null at the unwanted station (SIG1), we can considerably reduce the signal level seen by the receiver (see inset to Fig. 5B), even if the signals are the same strength. Indeed, even if SIG1 is considerably stronger than SIG2, a considerable improvement in signal-to-noise ratio (SNR) is possible by correct loop pointing.

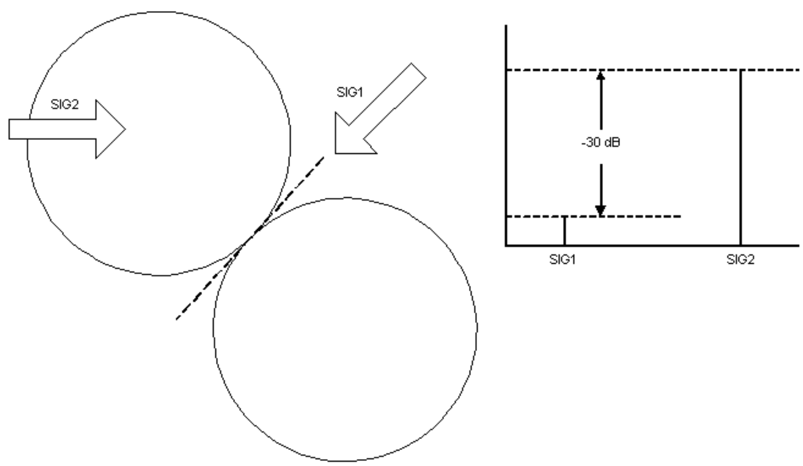

FIG. 1B

The depth of the null, used to null the offending signal, is usually far more important than the lost signal occurring because the maxima is off-axis to the desired station. SNR is, at the end of the day, what's important. Most people agree that an SNR of around 10 dB is necessary for what is described as "comfortable" listening.

Deploying the Loop - With Rotation

Unless a loop is used for reception of a single station, it will be necessary to reorient the nulls and maxima in order to accommodate different situations, different frequencies, etc. As most loops are desktop affairs, one could simply shove the loop around as needed. But that's not a terribly elegant solution. A bit less messy is the method shown in Fig. 2. The "rotator" in this case is nothing more than the bit of furniture we call a "Lazy Susan" in the

USA. About one yard in diameter, it sits in the center of a dining table, and can be rotated to bring food items right to the diner.

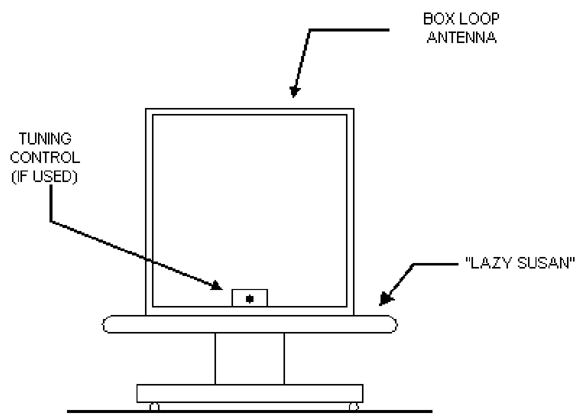

FIG. 2

Although new Lazy Susans might be a bit expensive for this use, used ones (not antiques, of course) are often quite reasonable. Also, DIY woodworking supplies shops often carry the mechanisms at a low cost, and these could be pressed into service without the decorative wood pieces. Also, I've seen an "unfinished" Lazy Susan kit advertised in a magazine. To reorient the loop, one merely rotates the table portion of the Lazy Susan.

I've seen a variation on this theme that would permit remote rotation of a loop antenna. There are small rotating platforms available that are used by merchants to create rotating merchandise or advertising displays. Typical rotation speeds are on the order of 1 to 12 RPM. Some of them use a 12 VDC motor, and these could be used to rotate a loop placed in the attic or at some other remote site (120 VAC motors are not recommended for this use). Of course, some sort of end-of-travel stops, limit switches, or electro-optical sensors would be needed to prevent full rotation of the table. Otherwise, the feedline would soon become entangled and snap off.

Deploying the Loop - Where To Install It

For most people, the question of where to install a loop is quite simple: right at the receiver table, of course. But this might not always be the right answer. A friend of mine uses an AM BCB loop to pick up WSM, Nashville, TN (650 KHz) from a site on the east coast of Virginia. He has a house with two stories above ground, and an attic, and is not constrained as to where in the house the antenna could be placed (a long suffering, tolerant wife helps). Experimenting showed that the best siting was on the ground floor, where signal levels were weakest. But, as it turns out, the co-channel sky wave and adjacent channel ground wave and sky wave signals were considerably weaker on the first floor than above ground. Again, the issue is less one of signal strength, but rather of signal-to-noise ratio. For that particular case, with the angle of arrival of the various signals, the best solution was the lowest point in the house.

Deploying the Loop to Boost Portable Radio Performance

Most portable radios use either an internal loopstick or built-in telescoping whip antenna. Neither antenna is a top performer, with the loopstick being sufficient mostly for local reception only. Of course, if distant interference is a problem at your location, then this is not a bad attribute, but for other purposes it is a problem. Fortunately, the loop antenna can come to the rescue of marginal performing AM and MW portable radio receivers.

Figure 3 shows the use of a box loop to enhance the performance of a small portable radio that uses a built-in loopstick antenna. The loopstick (see insert) is an inductor wound on a ferrite rod, usually about 1 to 1.3 cm in diameter and several cm long. Unlike the box loop, the maximum pick-up on a loopstick occurs broadside to the ferrite rod, with the nulls being off the ends. The placement of the loopstick in this particular radio is shown in the inset. For any given radio, the set must be positioned within the box loop such that the maxima and nulls of the two antennas coincide. This requirement means that the loopstick will be perpendicular to the plane of the box loop. This is seen in Fig. 3 by the fact that the loopstick in end view is perpendicular to the loop plane.

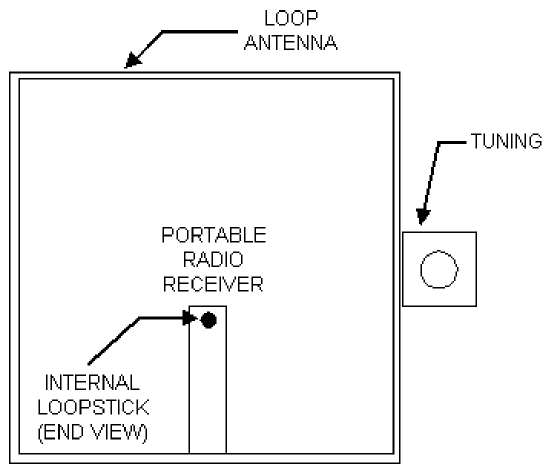

FIG. 3

The box loop is 60 to 100 cm on each side, and is resonant at the frequency desired. A typical loop, designed to resonate in the AM BCB with a 365 pF variable capacitor, would have ten turns of wire, spaced across 1 cm depth, on sides of 61 cm. When the radio and the box loop are tuned to the same frequency, energy picked up by the larger aperture box loop is coupled into the loopstick, resulting in a large increase in signal strength received.

This loop is popularly known as the "Sports Fans Antenna" because it was once used by a lot of sports fans to pick up distant ball games. It is the practice of baseball and football teams to not broadcast a game in the vicinity where it is played (i.e. 75 mile radius), unless the stadium is sold out. These blacked out games might, however, be broadcast over AM stations >75 miles away, and the Sports Fans Loop permits the fan to use the portable radio to hear the game.

Shortwave receivers usually have a telescoping whip antenna, rather than a loopstick. Figure 8 shows this same concept for receivers with the whip style of antenna. The concept is shown schematically in Fig. 4.

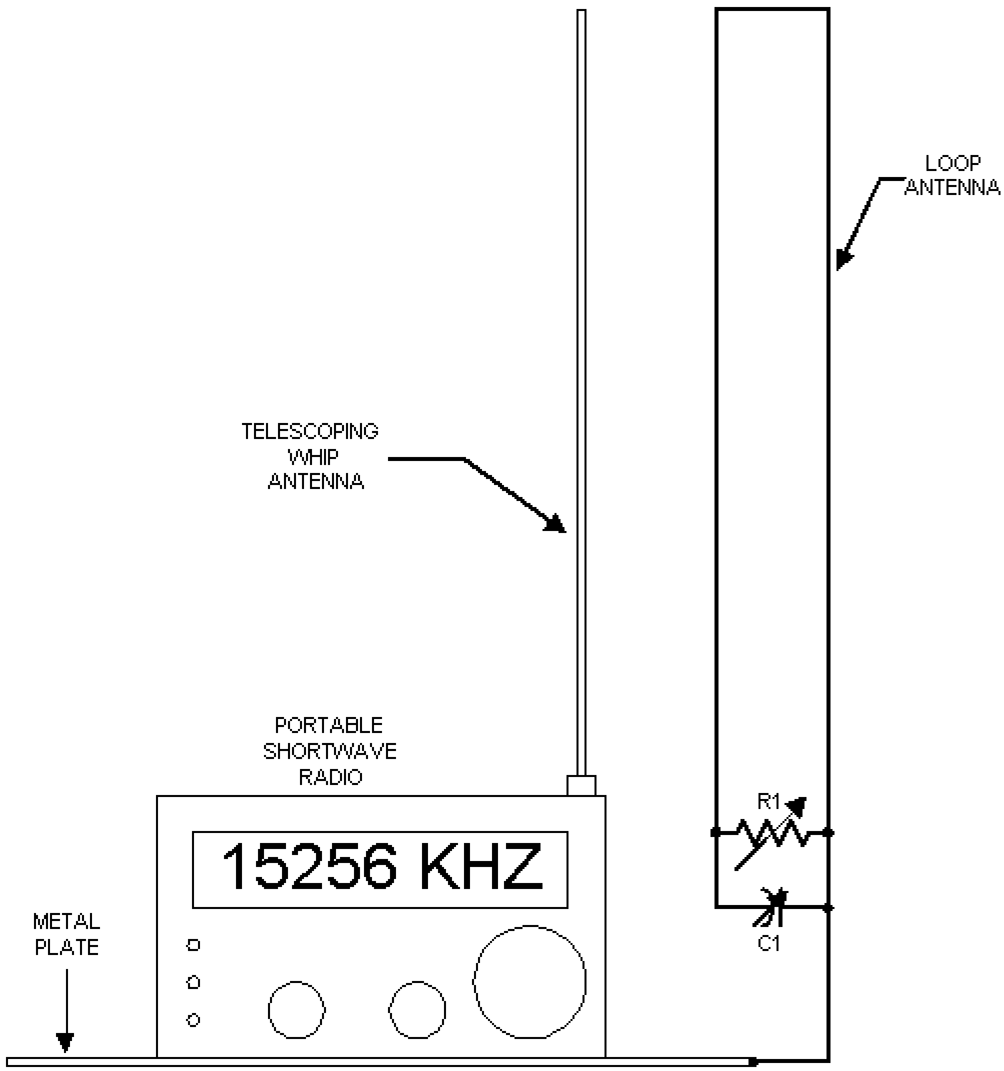

FIG. 4

Deploying the Loop for Co-Axis Stations

The ability of the loop antenna to null interference results from the fact that the maxima and the nulls are separated by 90 degrees. Thus, the loop antenna has two nulls 180 degrees apart. Although some less-than-ideal loops have different null depths on the two sides, most well constructed loops have a balanced situation unless there is some local object distorting the pattern. This geometry means that the best null occurs when the undesired signal arrives from a direction that is 90 degrees with respect to the desired signal. In that ideal situation, the maxima is aimed at the desired station and the null at the interfering station.

But what happens when the interfering station and the desired station are on the same axis? If both are in the same direction, the answer is "not much" unless there are different sky wave components that can be used to discriminate by tilting the loop.

If the two signals arrive from exactly opposite directions, then there is quite bit we can do. One solution is to use a loop in conjunction with a sense antenna to produce a heart shaped pattern. Another approach is to place a spoiler loop (such as the Sports Fan's Loop above) behind the receiver loop.

Figure 5 shows the use of a spoiler loop placed between the receiver antenna (a loopstick) and the offending station. The spoiler loop is a box loop of similar dimensions to the Sports Fans Loop above. It is skewed on the axis 60 to 90 degrees, the exact amount being determined experimentally for each situation.

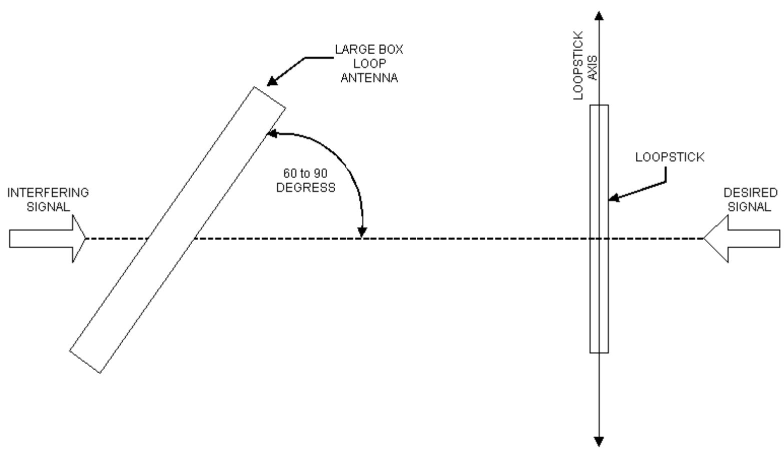

FIG. 5

The spoiler is placed 30 to 90 cm behind the receiver antenna, again the exact amount being determined experimentally. Although the use of a loopstick is shown (the assumption being that a portable AM BCB radio is being used for reception), a box loop can also be used for the receiver. Indeed, when a communications receiver is used, both loops will be box loops.

References

ARRL (1988). The ARRL Antenna Book. Newington, CT.: American Radio Relay League.

Carr, Joseph J. (1994). "Small Loop Antennas for MW, AM BCB, LF and VLF Reception - Part 1." Elektor Electronics (UK), June 1994, pp. 58 - 63.

Carr, Joseph J. (1994). "Small Loop Antennas for MW, AM BCB, LF and VLF Reception - Part 2." Elektor Electronics (UK), July/August 1994, pp. 104 - 109.

Carr, Joseph J. (1994). Joe Carr's Receiving Antenna Handbook. Solana Beach, CA:HighText Publications.

Carr, Joseph J. (1994). Practical Antenna Handbook - 2nd Edition. Blue Ridge Summit, PA:TAB/McGraw-Hill.

Jasik, Henry, editor (1960). Antenna Engineering Handbook. New York: McGraw-Hill Book Co.

Kraus, John D. (1950). Antennas. New York: McGraw-Hill Book Co.

Lankford, Dallas (1981). "Loop Antennas Theory and Practice." National Radio Club (USA). Reprint A-37.

Moxon, Les (1982). HF Antennas for all Locations. Potters Bar, Herts., England: Radio Society of Great Britain.

Nelson, Gordon P. (1965). "Improving Loop Antennas Part II." National Radio Club (USA). Reprint A-1.

Nelson, Gordon P. (n.d.). "Patterned Controlled Loops for the Medium Wave DXer." National Radio Club (USA). Reprint A-6.

Nelson, Gordon P. (1965). "High Precision Direction Finding of Medium Wave Skywave Signals." National Radio Club (USA). Reprint A-1 (repeat number, different paper).

Nelson, Gordon P. (n.d.). "The Vertical Pickup Pattern of the MW Loop Antenna." National Radio Club (USA). Reprint A-12.

Swain, Paul (n.d.). "Loop/Longwire Combined Antennae." National Radio Club (USA). Reprint A-36.

The small loop antenna is a loop as shown in Figure 1. The antenna feed points would be in series with the loop, such that a small loop looks somewhat like a short circuit across the antenna feed. These antennas have low radiation resistance and high inductive reactance, so that their impedance is difficult to match to a radio impedance (often 50 Ohms). As a result, these antennas are most often used as receive antennas, where impedance mismatch loss can be a bit more easily tolerated in some systems. The radius is a, and is assumed to be much smaller than a wavelength (a<<). The loop I The small loop antenna is akin to an uncut diamond. It has been around a long time, and has only recently been cut and polished to reveal a shining new gem. This antenna is small, operates well when mounted at ground level, and exhibits performance that competes with almost any HF antenna except a multielement beam at a wavelength or more above ground. This article explains how the wrapper was taken off this antenna, and why. History. A small loop antenna is basically just a very large parallel tuned circuit or tank circuit. The loop can be veiwed as a large single turn loop of this circuit. Due to the large (relatively speaking) size of this inductor, radiation very easily takes place.Â There are a lot of misconceptions about small loop antennas. Small loop antennas are often referred to as magnetic antennas. This is because they mostly respond to the magnetic component of an electromagnetic wave and transmit a large magnetic component in the near field. In the far field (>1 wavelength distance*) the RF from a small loop is the same as that from any other antenna, electromagnetic. It is often believed that magnetic antennas will not respond to local noise because local noise is mostly electrostatic. Wideband small magnetic loops (WSM loop) are used already 3-4 decades and I was curious to see what can be reached with them and to evaluate their usefulness as a wideband SDR input. The WSM loop should work in short circuit mode in order to reach flat frequency response in wideband frequency range. The antenna should be used with an amplifier since the loop current is very small. This amplifier must be with very low input impedance. [1, 2, 4, 6, 12]. Schematics and Construction. A circuit diagram of active WSM loop antenna is shown on Fig.1. The antenna specification is given for 1m diameter Small transmitting loop antennas are very useful when space for a full size antenna is limited. When care is taken during the construction to minimize resistive losses, performance can be very respectable. Users of this antenna, including the military, have reported very good results even when mounted close to the ground. I have used small transmitting loop antennas close to the ground, leaning up against wooden fences, and indoors with very acceptable results. Beware however that the fields near this antenna are very strong so do not plan on using any more then QRP power levels unless you can