A Door-Loop Receiving Antenna

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THE TUNED LOOP HF receiving antennas described here are intended for use indoors such as in a bed-sit or loft, where space is at a premium and the installation of a normal antenna impractical.

The loops are unobtrusive, effective, directional, and very easy to make using inexpensive hook-up wire. The wire loop antenna is simply wound on self-adhesive or self-suction plastic hooks stuck on whichever face of the door is convenient. This method of attachment avoids damage to the door itself, and the hooks can eventually be removed without trace.

Details are given for a range of antennas to cover the full short wave band from 1.5 to 30MHz, and one for the 136kHz LF band. From the details given here, a loop can be selected for and tuned to the frequency band of interest. Also described is a simple but functional loop-signal amplifier, the output from which is taken via coaxial cable to the radio receiver.

ABOUT THE LOOPS

STRICTLY SPEAKING, a 'loop' antenna has but one single turn, whereas a 'frame' antenna has two or more turns. Most of those to be described here are multi-turn and hence are actually 'frame' antennas. However, to call them door-frame antennas might be confusing because they are *not* wound around the door-frame, but on the door-face. So, for this article, they will be called loop rather than frame antennas.

And now to the directivity feature that makes the door-loop antenna unique. The response pattern of a loop antenna is a figure-of-eight similar to that of a dipole, but with one important difference. With a dipole antenna, maximum response is when it is broadside on to the signal, and minimum response when in-line. But with a loop antenna, *minimum* (not maximum) response occurs when it is broadside on to the arriving signal. *Maximum* pick-up of received signal is when the plane of the door is in line with the signal. Similar to the dipole however, maximum and minimum responses are bi-directional. In other words, when a loop antenna is positioned for maximum received signal, the signal could be coming from either of two opposite directions. The same applies to a null.

This means that the all-round response of any loop antenna is obtainable by rotating it through no more than 135 degrees. This is exactly what the door hinges provide free of charge, simply by opening or closing the door to give a nearly complete directional response from signal maximum to minimum. Elegant simplicity? Obviously, the realisable response pattern depends upon the extent of available door swing. A door that can swing through 180 degrees will give a full response pattern, whereas if its swing is restricted to say 90 degrees (as with my own), then the pattern is also restricted, but only marginally, so don't be put off by that.

Here is an novel indoor receiving antenna that will appeal to SWLs and licensed amateurs alike. Mounted on the back of an internal wooden door, its bi-directional response pattern can be rotated by opening the door!

Regarding the diameter of a loop antenna, theory has it that, for optimum performance, the loop diameter must not exceed $\lambda/8$ at the highest frequency in use (ie 1.25m at 30MHz), so the standard domestic door fits that bill nicely. It should be pointed out, however, that these particular door-loop antennas are all of rectangular or square section, not circular, the different geometry being of no practical significance!

Considering now the Q-factor of the loop, the use of thin PVC-covered stranded wire means that the Q cannot be as high as might be achieved by using thicker or more specialised wire such as Litz. In favour of a modest Q, however, the tuning of the loop is not critical, which means that the receiver can be tuned across an entire frequency band without having constantly to re-tune the loop. Furthermore, any loss of signal level due to a lower Q is more than made up for by the signal amplifier to be described later.

Any wire loop, whether it be of one or more turns, constitutes an inductance which would need to be tuned to the frequency-band of interest. No normal tuning capacitor will have a big enough swing to tune any one loop across the entire short-wave band, which means that a range of loop inductance values is required to give the required frequency coverage. The HF loops described here have inductance values in the microhenry range, to be tuned by the 2 x 126pF AM sections of a low-cost miniature AM/FM tuning capacitor of the type used in transistor radios. Note that in this balanced loop arrangement, the two 126pF sections of the tuning capacitor are actually in series (*not* parallel) with the loop, hence the maximum capacitance swing is only 63pF. This limits the tunable frequency range for any one loop, but that could be doubled by using instead a 2 x 500pF tuning capacitor.

One must bear in mind that any loop antenna will have a self-capacitance determined by its dimensions. That self-capacitance, typically a few picofarads, will act in parallel with the loop's inductance to form a resonant circuit which will give the as-yet unconnected loop a self-resonant frequency. When a tuning capacitor is connected across the loop antenna, the loop's self-capacitance will act in parallel with the tuning capacitor, thereby changing its apparent value. So, a knowledge of the self-capacitance value can be useful when calculating the tuning range of a variable capacitor connected across a given loop-inductance. The self-capacitance of these HF loops was measured and found to range from about 6pF to 30pF from smallest to largest loop.

Approximate values of inductance to be expected from loops of different sizes and numbers of turns are shown in **Table 1**, based on the use of 7/0.2mm wire. It will be appreciated that these values can only be approximate because of the

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Loop size (m)	One turn		Two turns		Three turns		Four turns	
	L (µH)	f (MHz)	L (µH)	f (MHz)	L (µH)	f (MHz)	L (µH)	f (MHz)
0.6 x 0.3	2.4	***11.9 - 30.0***	8.0	***6.3 - 13.2***	15.4	4.4 - 8.7	24.3	***3.4 - 6.4***
0.6 x 0.6	3.2	10.2 - 24.3	11.1	5.3 - 11.0	23.0	3.5 - 6.2	39.0	3.0 - 4.3
0.6 x 1.0	3.9	8.6 - 21.2	15.3	5.6 - 8.4	31.0	3.0 - 5.2	52.6	***2.2 - 3.6***
0.6 x 1.75	7.0	7.0 - 16.2	23.1	3.5 - 5.9	47.8	2.3 - 3.6	83.7	***1.7 - 2.7***

Table 1: Showing the frequency ranges to be expected from different sized loops, based on the use of 7/0.2mm PVC-covered hook-up wire and a 2 x 126pF variable capacitor.

differences in door design, but they will be near enough for practical purposes. The tuning capacitor will make up for any modest differences in finished loop inductance.

There is of course no reason why heavier gauge wire such as 16/0.2 or 20/0.2 should not be used, especially for the HF loops as opposed to the 20-turn 136kHz loop, the limit being the size and strength of the support hooks. The inductance (and hence the tuning range) of the finished loop would not be markedly different from that of the thinner wire and the extra cost would be negligible.

CONSTRUCTION

ASSUMING AN average-sized wooden internal door of dimensions 2m high by 0.6m wide, the height of these loops has been restricted to 1.75m, to leave space at the lower part of the door face for the amplifier box and outgoing coaxial cable.

A maximum of twelve plastic self-adhesive or self-suction hooks is needed, the larger the better (especially for the 136kHz loop) because the smaller ones tend to break easily. Such hooks are readily available at very low cost from most hardware shops or street markets.

Refer now to **Fig 1** which shows the hook-method of winding for the loops. Decide which face of the door is to be used for the antenna, then stick the hooks on the door face. The hooks are numbered 1-12 in Fig 1. For HF use, all 12 hooks may be used, but for 136kHz only hooks 1,2,10,11,12 are needed. Be careful to position each hook with its open side facing up or down as shown on the drawing. Hooks 7,8,10,12 are inverted for ease of loop winding. Hooks 9 and 11 serve as fastening points for the wire tails of the various loops (and maybe even as a suspension point for the amplifier).

Loop Size		Use hooks	Start/finish at hook number
Width (m)	Height (m)		
0.6	0.3	7, 5, 6, 8	9
0.6	0.6	7, 3, 4, 8	9
0.6	1.0	7, 1, 2, 8	9
0.6	1.75	10, 1, 2, 12	11

Table 2: Information on using the hooks shown in Fig 1 for loops of different sizes.

To decide on a loop size for a given frequency range, use Table 1. The figures in bold italics suggest that the entire short-wave band could be covered with five loop antennas, but that could be reduced to two or three by using instead a 2 x 500pF tuning capacitor. Once this size has been chosen, **Table 2** can be used to recover information about which hooks to use and where to start and finish the loop.

Fasten one end of the wire by a half-hitch or elastic band on the central fastening-hook (9 or 11), leaving a tail of about 75mm, then wind the chosen number of turns around the four hooks given in Table 2, and back to the fastening hook. Again, fasten the wire leaving a 75mm tail as before. Strip back the wire tails and connect them to the loop-terminals on the amplifier assembly. Your first door-loop antenna is now finished and ready for action.

Details of the amplifier for use with the loops are given in **Fig 2**, **Fig 3** and **Fig 4**. It is mounted on the door, together with the tuning capacitor, as shown in Fig 1.

136kHz DOOR-LOOP ANTENNA

THIS LONG-WAVE antenna is offered as an experimental project. It has been included to embrace the recently-released amateur band where the length of even a quarter-wave antenna would be about 550 metres. But first, a small change needs to be made to the loop-signal amplifier for use at this frequency. Because of the increased reactances of the three 1nF coupling capacitors C4, C5 and C6 at 136kHz, it is necessary to replace them by capacitors of value 10nF. Changes to the tuning capacitor, VC1, are mentioned later in this section.

The antenna consists of 20 turns of 10/0.1mm hook-up wire (equivalent to about four 25m reels) wound on hooks 11, 10, 1, 2, 12, 11, to produce an inductance of about 1.8mH. To tune that 1.8mH to about 136kHz would require an effective parallel capacitance of 750pF. That figure would include the self-capacitance of the loop. Measurements indicate that the very narrow 136kHz band could be

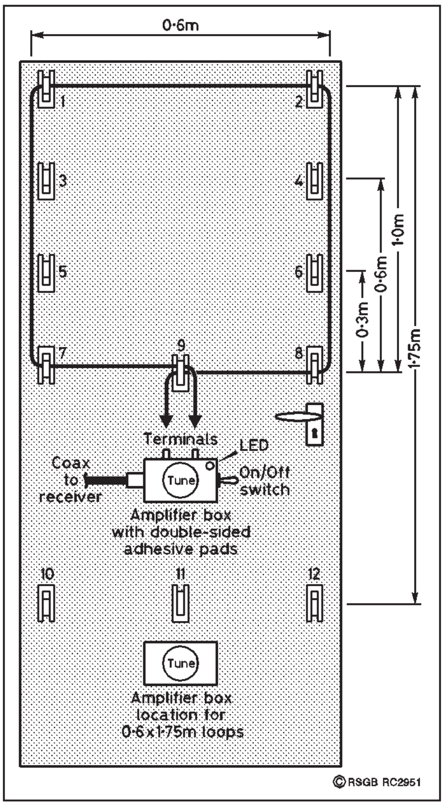

Fig 1: Disposition of hooks, amplifier and tuning capacitor on the side of a standard door.

covered by using the same 2 x 126pF mini AM/FM tuning capacitor as used with the HF loop antennas, but with a 590pF capacitor soldered across each of its 126pF sections to give a tuning range of approximately 132 - 139kHz. Alternatively, using a 2 x 250pF variable capacitor with 470pF padding capacitors would give a tuning range of about 139 - 145kHz; a range of about 132 - 158kHz is available from a 2 x 500pF variable with 270pF padding capacitors. Swinging the tuning capacitor through its range whilst listening to 136kHz on the receiver would soon let you know if the loop is tuning to that frequency. The noise peak is quite pronounced.

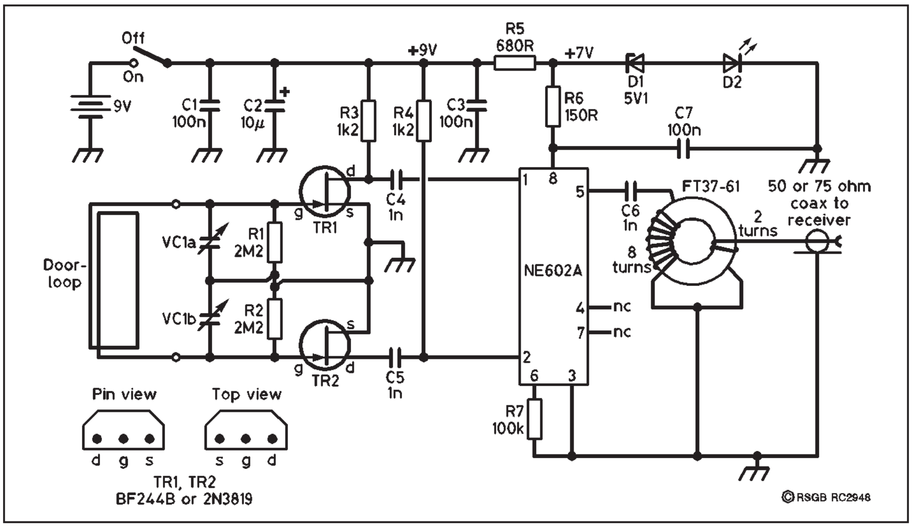

Fig 2: Circuit diagram of the loop antenna and amplifier.
Notes: (a) see Tables 1 and 2 for loop details;
(b) for HF use, VC1a, b = 2 x 126pF variable;
(c) for 136kHz use, VC1a, b = 2 x 500pF variable and C4, 5, 6 = 10nF.

LOOP-SIGNAL AMPLIFIER

THE CIRCUIT DIAGRAM of an HF tuned loop and its signal amplifier is shown in Fig 2. The battery-powered amplifier uses two field-effect transistors in a balanced input configuration. This arrangement preserves the electrical balance of the loop about ground potential, and the high input impedance ensures that the Q-factor of the loop is not unduly damped. The RF gain of the FET input stage is quite low, but this receives a boost from the NE602 integrated circuit to give an overall signal voltage gain of at least 10 (20dB).

Power supply to the amplifier is from a PP3 9-volt battery at about 15mA. The transistors each take about 6mA and the NE602 draws about 2mA. The maximum voltage supply rating for an NE602 is 8V. It is therefore fed from a stabilised 7V supply, derived from the 9V rail by using a 5V1 Zener diode in series with a light-emitting diode. The LED also serves as a battery 'ON' indicator light.

The NE602 is perhaps best known as a double-balanced mixer/amplifier, but in this application its internal local oscillator circuit is made inoperative by R7. The NE602 amplifier then acts in a cascode mode, with an output available at either pin 4 or 5. Either of these pins can be used to give an unbalanced output, with an output impedance of about 1500Ω. This is transformed down to about 50 - 70Ω by means of a toroidal ferrite transformer, so allowing the use of coaxial cable to feed the output signals into a short wave receiver. Although many receivers have a 50Ω antenna input socket, 75Ω TV coaxial cable would be quite suitable.

AMPLIFIER CONSTRUCTION

THE COMPONENT layout for assembly of the amplifier on perforated 0.1-inch matrix stripboard is shown in Fig 3, and also shows where holes should be cut in the copper tracks on the reverse side of the board. The use of a proprietary track-cutter (sometimes listed as a 'Spot Face Cutter') is recommended. It can save a lot of frustration and is a good long-term investment! Alternatively, a 3mm twist drill operated gently between thumb and forefinger works well.

The 4:1 turns ratio (theoretically 5:1 but 4:1 worked better) output matching-transformer is very simple to wind. It consists of an eight-turn primary winding and a two-turn secondary, using single-strand PVC-covered wire such as from telephone cable, wound on a ferrite ring type FT37-61 (0.37-inch outside diameter, number 61 mix).

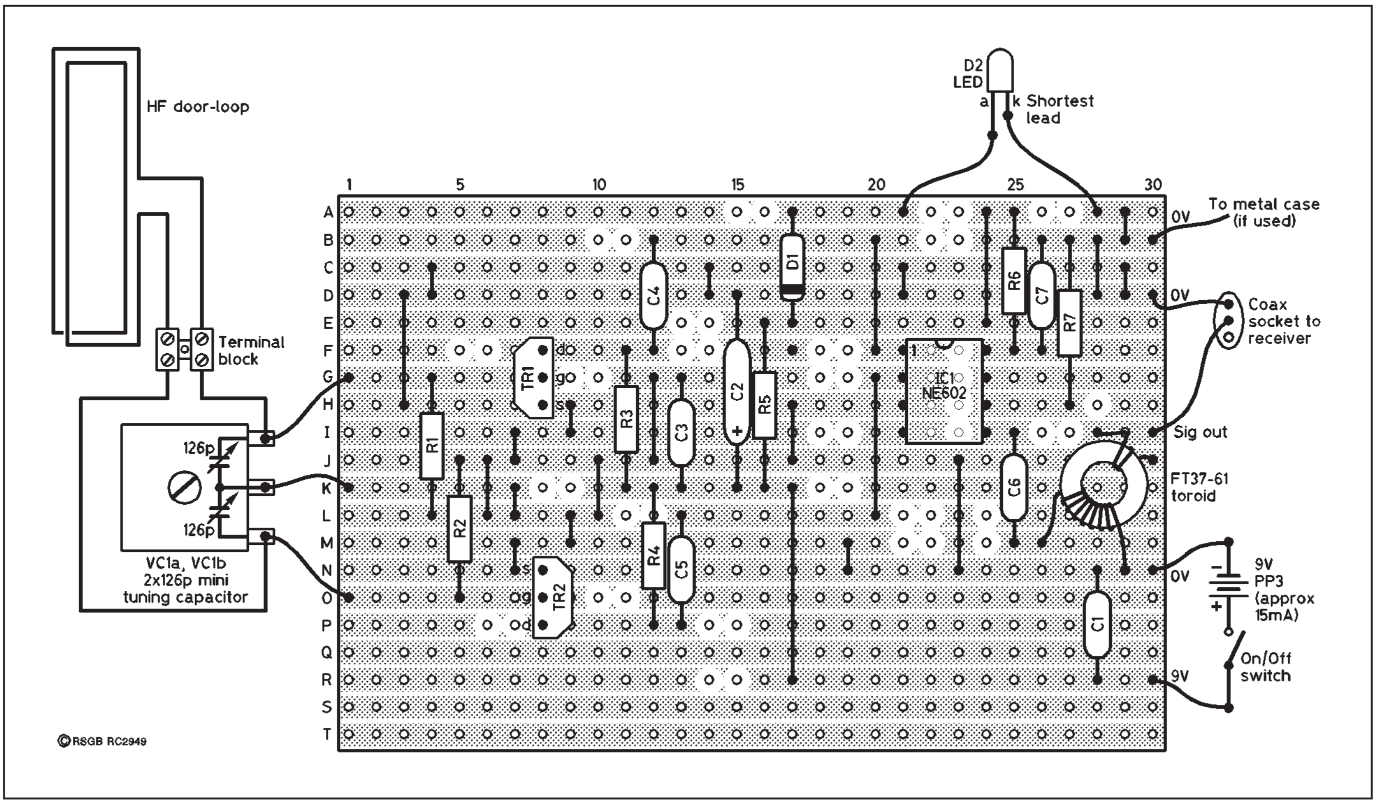

Fig 3: Layout of components on the stripboard, showing connections to off-board components.

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A twin section of screw-type electrician's terminal block is used for the loop connection. The finished board and its external components could be fitted into any convenient metal or plastic container, although it must be said in truth that in my own set-up, the amplifier assembly was left uncased and simply suspended from the loop's central fastening-hook... and it worked fine! If a metal box is used, be sure to strap the metal to the 0-volt rail of the board.

The miniature tuning capacitor can be mounted on the front panel of the box, with its spindle protruding. Two M2.5 fixing screws are required. Some tuning capacitors are sold complete with an extension spindle to accommodate a standard knob, which should be fitted. A tuning dial is not really necessary, because the loop antenna will simply be tuned by ear (or S-meter) for maximum signal strength on the frequency band in use.

A Belling-Lee (TV type) coaxial plug and socket would be suitable at the amplifier end of the coaxial cable, but a plug to suit the receiver's antenna socket should be fitted to the other end. Although its length is not critical, the coaxial cable should be kept as short as possible.

The finished box can be secured to the door face by means of double-sided adhesive tape or pads, just below the loop's fastening-hook, or maybe even just hung on the hook itself!

USING LOOP ANTENNAS

SIMPLY CONNECT the coaxial cable between the loop-signal amplifier and the short-wave receiver's antenna socket, switch on the amplifier, tune the receiver to the frequency band appropriate to the loop antenna, and adjust the loop's tuning capacitor for maximum signal or noise level in the receiver. You can now use the receiver anywhere on that band without having to tune the loop again. If needs be, try opening and closing the door to peak the loop on any selected signal, or perhaps to minimise an interfering signal. ♦

FURTHER READING

'An Introduction to Variable Tuned Circuits', G3PMJ, *RadCom* March 2001, pp34/35.
Backyard Antennas, by Peter Dodd, G3LDO (RSGB Shop).
HF Antennas for All Locations, by Les Moxon, G6XN (RSGB Shop).
Practical Antennas for Novices, by John Heys, G3BDQ (RSGB Shop).

A note for the academic experimenter: although classical theory states that inductance is directly proportional to the number of turns squared ($L \propto N^2$), experience with these loops suggests that the power of N is nearer 1.8 than 2 ie ($L \propto N^{1.8}$ not N^2). That might not seem much of a difference but take, for example, the 0.6m x 1.75m loop antenna whose 1-turn inductance was measured at 7µH. Now for this 20-turn loop of the same dimensions, its inductance should be

$$7\mu H \times N^2 = 7 \times 20^2 = 7 \times 400 = 2800\mu H,$$

compared with the measured value of 1800µH. This would equate to

$$7\mu H \times N^{1.853} = 7 \times 257.5 = 1802\mu H.$$

You would need to use the x^y function on a scientific calculator to check this. However, armed with that knowledge, it becomes easy to calculate what the inductance would be for a different number of turns on any one of the loops.

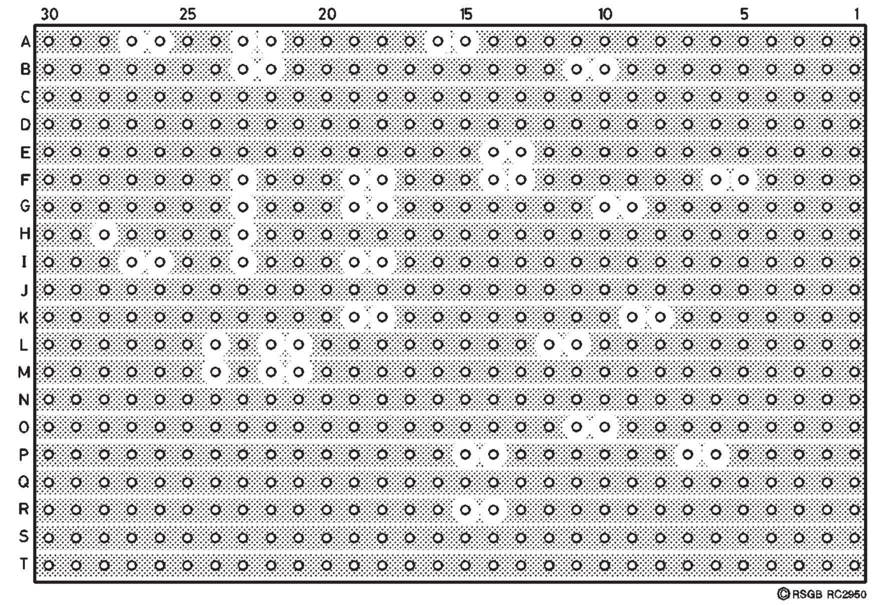

Fig 4: Showing the track-cutting positions from the track side.

COMPONENTS LIST

Resistors

R1, 2	2M2
R3, 4	1k2
R5	680R
R6	150R
R7	100k

Capacitors

C1, 3	100nF, ceramic
C2	10µF, electrolytic 25V
C4, 5, 6	1nF, ceramic (10nF for 136kHz use)
VC1a,b	2x126pF miniature AM/FM variable capacitor, eg Maplin AB11M

Semiconductors

D1	5V1 Zener diode
D2	Light emitting diode, red
TR1, 2	BF244B FET
IC1	NE602A or SA602AN, double-balanced mixer

Additional Items

12 off	Self-adhesive/suction hooks
2 off	Screw M2.5 x 6mm
1 off	8-pin DIL socket
4 off	25m reel 10/0.1mm light duty connection wire
2 off	10m pack 7/0.2mm hook-up wire
1 off	Strip 2A terminal block, screw type, eg Maplin FE78K
1 off	Ferrite ring type FT37-61
1 off	Vero stripboard, 0.1in hole spacing, 30 x 20 holes
1 off	Switch, SPST miniature
1 off	PP3 battery
1 off	Connector for PP3 battery
1 off	Belling-Lee coaxial plug and socket