The Huff-Duff Seven practical loop antenna

Geoff G3XGC poses with the completed prototype Huff Duff 7 loop project.

This version (above) of the Huff Duff 7 was built by Derek Brooks M0BNZ, who co-operated with Geoff G3XGC to take bearings on GB75PW.

High frequency (h.f.) direction finding is usually known by its acronym h.f./d.f., pronounced Huff-Duff. This has become the common name for a radio direction finding (d.f.) system and was coined during the Second World War, particularly for the high speed system used to detect enemy submarines that very briefly transmitted c.w. Morse signals back to their base while surfaced.

During the Second World War, the Huff-Duff system became very efficient and semi-automated versions, using multiple monitoring stations were able to obtain accurate bearings on moving targets that could re-submerge again rapidly. Many submarines were destroyed by aircraft that had been vectored on to the plotted positions.

There has been a recent outbreak of microphone scratchers and whistlers on the 7MHz band (see the Keylines Editorial *PW* May 2007). Apart from lowering the tone of genuine Amateur Radio operations, such transmissions cause trouble and the operators are in violation of the conditions their Amateur Radio licence (if indeed they possess one).

The *PW* Editor **Rob Mannion G3XFD** asked me to look into making a simple Huff-Duff antenna project (heading photographs and **Fig. 1**) to help reduce interference or to d.f. and locate the scratchers. Hence the name of this project is the Huff-Duff 7.

With a few people dotted around the country using the Huff-Duff 7, it should be possible to triangulate the position of offenders and hopefully get some action taken. The Huff-Duff 7 is also an excellent construction project for a short wave listener and can also be used as an aid to reduce unintentional interference (QRM) or electrical noise (QRM).

Into Service Quickly

The requirement was for a loop antenna which, when needed, can be brought into service quickly and used to take the bearing of a source. I have concentrated on a small hand-held loop that can be rapidly connected to a main station or portable receiver. The d.f. loop antenna is a very old idea and it consists of a parallel tuned circuit with inductor and capacitor values

Geoff Cottrell G3XGC describes a useful and extremely practical loop antenna system designed to counteract unintentional or deliberate interference to QSOs on the 7MHz band. The project's name pays tribute to an efficient direction finding system used in the Second World War to help detect enemy submarines when they transmitted while on the surface.

Fig. 1: Close up view of Huff Duff 7 number 1 (G3XGC prototype).

chosen to resonate at the required frequency, in this case 7MHz.

Why is a loop directional? To discover why, let's consider a radio frequency (r.f.) wave travelling towards an upright loop exactly along the loop's axis. The wave front is parallel to the plane of the loop and the electric field of the wave excites equal and opposite alternating current (a.c.) currents in its left- and right-hand halves.

There is no phase difference between the induced currents so they cancel giving a null output. But when the wave front is at any off-axis angle to the loop, there is a phase difference between the two halves. Cancellation of the two induced currents is no longer complete and a signal appears at the loop's terminals. The loop's response has a broad maximum when oriented edge-on to the source.

The Huff-Duff 7 relies on the sharp on-axis nulls for its d.f. ability. A nulled-out signal indicates that the r.f. wave is coming either from the forward or the backward direction. But from which direction is it coming? To resolve this ambiguity, I've also included an omnidirectional sense antenna that can be added to the loop signal. When the sense signal level balances that in the main loop, one of the two nulls vanishes and the loop has a cardioid response.

A push button and separate variable gain control determines how much of the sense signal is added to the main loop to achieve balance. With this, the forward and backward directions can be distinguished. Having found a null, a simple magnetic compass is used to measure the direction bearing of the source.

Initial Tests

My initial tests of a prototype two-turn loop of diameter 180mm, tuned to 7MHz, showed directional behaviour. But the received signals were quite weak when used with my Elecraft K2 receiver.

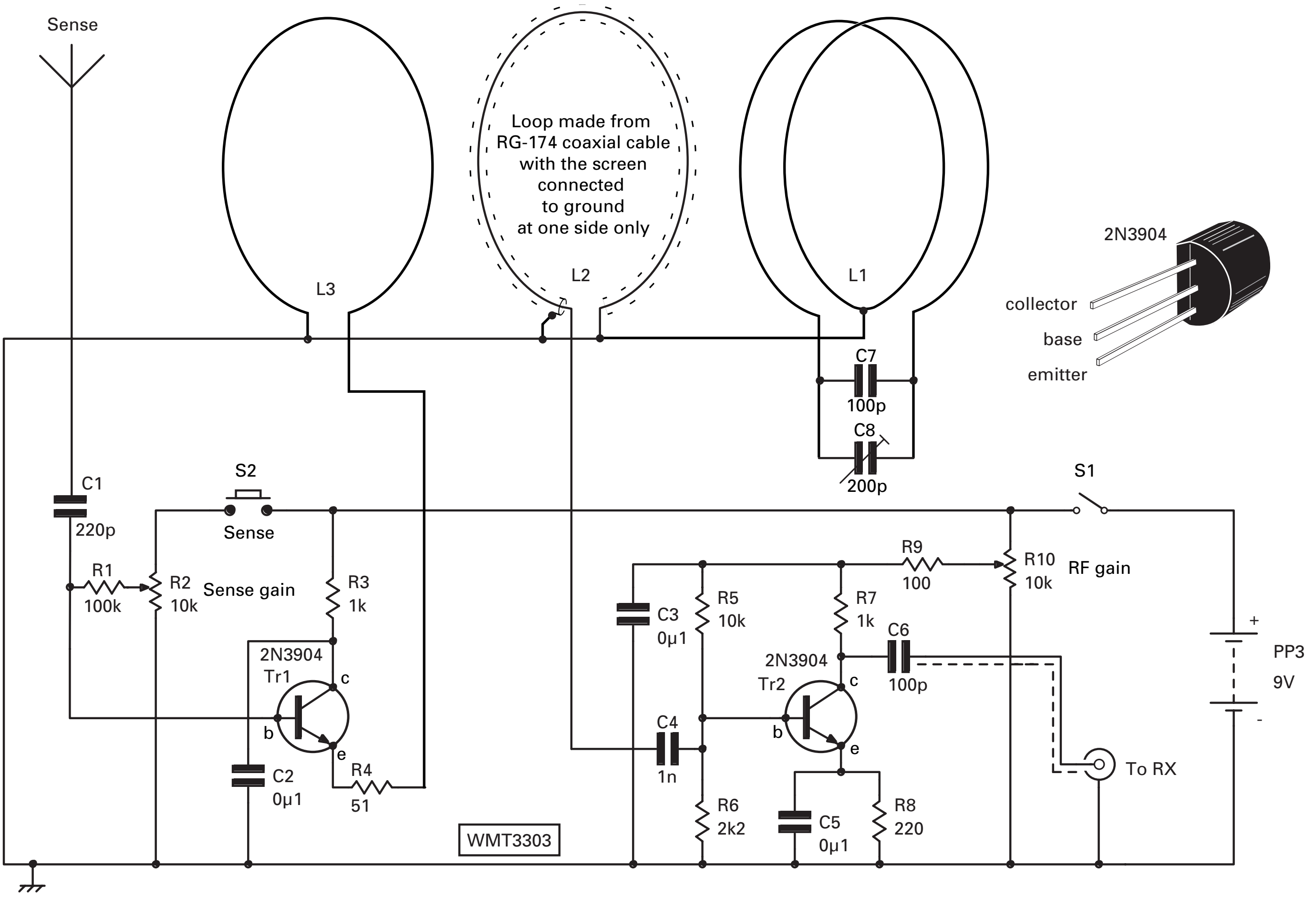


Fig. 2: The loop amplifier circuitry.

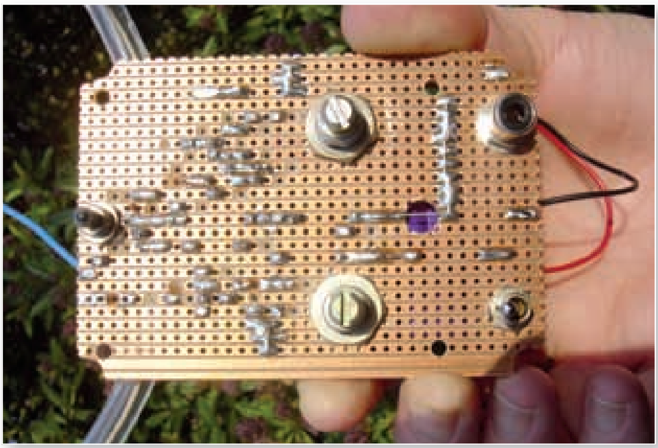


Fig. 3: Close up view of copper track side of the board.

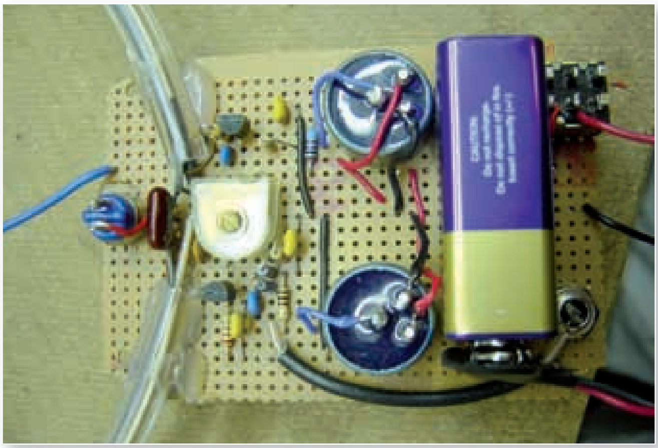


Fig. 4: Upper side of the board, showing loop ends secured with hot melt glue.

The loop is small, so its low output was not too surprising.

I added a single-stage variable-gain r.f. pre-amplifier (based on Tr2 in **Fig. 2,** onto Veroboard, **Fig. 3, 4** and **5**). The loop feeds r.f. to the pre-amplifier via a screened coupling turn, L2. The pre-amplifier increases the signal by up to 12dB and makes the band really comes to life. The sense antenna circuit consists of a short pick-up wire feeding a single-stage variable-gain amplifier (Tr1 in Fig. 2). The sense signal is coupled into the input circuit via an extra single turn (L3).

Construction Straightforward

The construction is relatively straightforward and the main d.f. loop (L1) consists of two complete turns (centre tapped to ground) of thin pvc multistrand wire. The pick-up turn (L2) is a single shielded turn of RG174 coaxial cable wound along with L1, as shown in Fig. 1.

The single sense coupling turn, L3, is grounded at one end. All the wires lie inside a plastic tube, bent into a circle. I had a spare length of plastic rod, used to adjust a venetian blind. This has an outer hexagonal shape and inner 4mm diameter hollow circular section.

I discovered that by immersing the rod in very hot water for a short time, it became very soft. So much so, that I was able to easily bend it around a circular former (the base of a saucepan!).

On cooling, the plastic tube retains its new circular shape. Any suitably sized plastic tube will do provided it's rigid enough to keep its shape. Whatever you do here, try to make sure that the loop is not warped. (Out-of-plane windings will degrade the d.f. properties of the loop.

Next, I prepared A 650mm long bundle of wires to form L1, L2 and L3 and this fed into the circular tube, leaving about 50mm dangling free at each end to form connections. At this stage, L1 consists of two separate wires – these could be identified later with an ohmmeter. The wires should be tensioned a little inside the tube to maintain geometry.

The Huff Duff 7 board was then fitted in a small plastic box (Fig. 1). A rectangular piece of matrix board, with the copper strips aligned with the long direction, was shaped to fit inside the box's lid, attached using four M3 bolts. After pre-drilling the board for major components, the plastic loop tube was attached to it with hot melt glue (Fig. 4).

The wires from the loop were then soldered to the board, keeping leads short. One central copper strip of the matrix board was chosen as ground. The two wires of L1 were grounded centrally to this strip, so forming a single centre-grounded and balanced main loop. The shield of the coupling loop L2 is grounded at only one side of the loop. The other end of the shield is not connected but the coaxial cable inner core is grounded at this end.

The r.f. output is taken from the inner coaxial conductor at the end where the shield is grounded. The sense antenna is an 180mm long insulated wire running from the board up to where it is attached at the top of the plastic loop. The positioning of the sense antenna is not critical. Once the large components (C8, S1, S2, Variable resistance R1 and R2, r.f. socket) have been fitted to the board (leaving space for the battery), the small components can be added. To complete this simple circuit, the copper tracks are segmented as required. A hand-held 4mm twist drill was used to remove a small amount of the copper.

Testing The Project

The first step is to connect the loop output to a suitable 7MHz receiver. The pre-set capacitor C8 then has to be adjusted for maximum received signal strength. (Loop resonance was obtained with a total capacitance, C7 + C8, of around 200pF).

Next, the r.f. gain has to be adjusted to give a satisfactory output. The 7MHz band should sound lively with many stations audible if all is well. Then, it's time to check that the loop's two nulls are present. (Find a strong and fairly continuous signal for this stage). Keeping the loop upright, rotate it about a vertical axis to confirm that the two nulls, (forward and backward) are present. They should be 180° apart and fairly sharp.

To calibrate the loop, the Huff Duff 7 I connected it to my Elecraft K2 transceiver. For a steady signal source, I set up a K1 transmitter, 50m away (using **very low power)** coupled into a 1.5m vertical wire. With the K2's automatic gain control (a.g.c.) switched off I measured the audio output voltage using a digital multimeter (DMM) set to a.c. volts. I then rotated the loop through 360°, noting the bearing, and plotted the received power in the diagram, **Fig. 5**. As can be seen in the diagram, the two nulls are clearly visible, 180° apart.

Setting up the Sense Circuit

Here it's important to balance signal levels by carefully adjusting the sense r.f. gain control. **Note:** I found that some experimentation is required to find the optimum setting.

When a null is found (using only the main loop) pressing the sense switch should remove the signal null in one direction, but not the other, where the signal should still be audible. In this state, the ambiguity of the loop can be resolved. Correct operation can be checked by rotating the antenna by 180°.

With the sense button depressed, the remaining null is fairly broad and imprecise. Therefore, the sense circuit should only be used to resolve the direction **and not the actual bearing**. The ear is good at hearing nulls as can be proved by gently oscillating the loop from side-to-side.

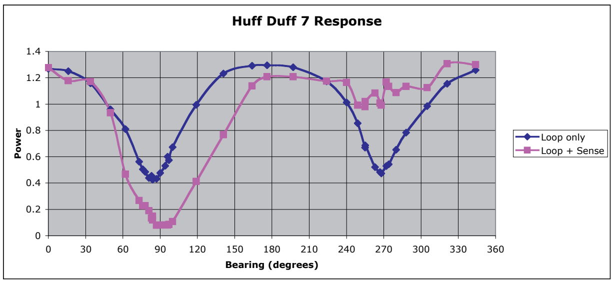


Fig. 5: Measured directional response (receiver power) for a full rotation of the loop at 7MHz using a test signal. For the main loop (dark blue) the forward null is seen at a bearing of 87° and the backward (rear) null is at 267°. With the sense antenna added (purple) the forward null is broader and remains while the backward (rear) null has vanished. The use of the sense antenna resolves the forward/backward ambiguity of the simple loop.

Huff Duff 7 Operations

To radio-locate an interfering station, a co-ordinated approach by two (or preferably more) operators, equipped and ready to use their loops, is required and this method is suggested in **Fig. 6**. During an agreed break in legitimate transmissions, leaving only the offender transmitting, each of the loop operators will take bearings. These bearings, and the locations of each receiving station, are then reported back to a co-ordinator who can use the data to fix the offender's location.

During this break in transmission, each operator switches their loop into their receiver and rotates the loop about a vertical axis until a null is found. Using a magnetic compass the bearing of the loop's axis, in degrees from magnetic North, is found and noted.

If there is time, the sense switch can then be deployed to fix which of the two possible directions the signals are coming from. This last step is, however, not essential because the triangulation method automatically results in an unambiguous fix on the source location. Nevertheless, it will help in giving some credibility to the measurement.

The loop should be kept in the null position while the bearing is taken. When this is done, it's important to remember that that the compass should not be placed near iron or other magnetic objects which can influence the reading and cause errors.
Apart from the ground-wave tests, I have also assessed the loop on air both during the day and after dark when the skip distance changes. It is quite easy to produce nulls on signals as far away as Germany and Russia. However, when fading is present this can sometimes deceive the ear into finding false nulls. So, care and practice is needed to get the best out of the Huff Duff 7!

Finally, I must gratefully acknowledge the help provide by my friend **Derek M0BNZ**, from Mullion in Cornwall. He built his version of the Huff Duff 7 and we both obtained test bearings on GB75PW when it was active from the **Poole Amateur Radio Club** in Dorset, as part of the development process. The Huff Duff 7 operates well with team work!

Component list:

These components were used in my Huff-Duff Seven. Other possibilities abound, depending on what's in your junk box!

Resistors (all 0.25W 5%):

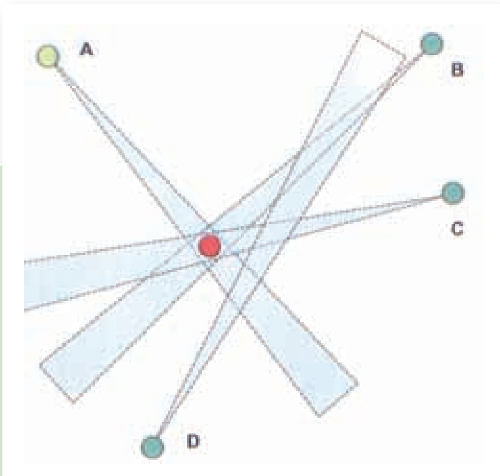
51Ω	1	R4
100Ω	1	R9
220Ω	1	R8
1kΩ	2	R3, R7
2kΩ	1	R6
10kΩ	1	R5
100kΩ	1	R1
Variable 10kΩ small linear		R2, R10

Capacitors (miniature ceramic, unless otherwise stated):
C1 220pF
C2, C3, C5 0.1μF
C41nF
C6 100pF
C7 100pF silver mica
C8 200pF trimmer

Other:
Tr1, Tr2, 2N3904
S1 Small push-to-make switch
S2 Small toggle switch
L1, L3, sense antenna. Thin stranded wire
L2 RG174 coaxial cable (500mm)
PP3 battery with snap-on connector
Phono socket (r.f. out)
Matrix copper strip board (90 x 67mm)
Knobs (2)
Plastic enclosure box (100 x 75 x 40mm)
4 M3 nuts and bolts.
600mm plastic tube about 4mm inner diameter (see text).

Further Reading
I have found some reference sources on the Huff Duff system
http://en.wikipedia.com
ARRL Handbook 2005 p.1319
QST Sept. 2005 p.36.

Fig. 6.



Technique

To plot a transmitter's position on a map, multiple directions are taken from stations A, B, C and D. The transmitter should be within an area, bounded by the overlapping beam-headings from stations (± heading errors). Directions from stations A, B and C agree fairly well but the heading from station D doesn't. It might be that station D has local objects causing beam distortion in that direction. The greater the number of stations, the more likely the result will be accurate.