SHORTWAVE DIRECTION FINDING: GETTING STARTED

Joe Farley Mitch Sams

If you told me five years ago that it would be possible to obtain an accurate DF bearing on Bhutan on 60 meters using a relatively small loop antenna indoors I might have suggested that you join the queue at the ticket window for the Disoriented Express. Of course, some fortuitous scheduling by the frequency management staff in Thimpu did not hurt, but this previously absurd feat has been accomplished by both authors. And, we hope, you may be able to do it also.

A loop possesses a number of desirable properties which taken together makes it an attractive candidate for serious DX work. A compact loop coupled with a suitable amplifier will exhibit sensitivity in its resonant bandwidth which will rival or exceed wire antennas occupying significantly greater real estate. A small loop tends to be quieter than a wire antenna of comparable output. These two factors taken together can give a decided edge to a loop in marginal reception conditions.

Most importantly, a small loop can exhibit enough directionality at shortwave frequencies to make it useful where controlled reception is desired . Attenuation of both local and distant sources of QRN is possible under many circumstances. This can offer the "edge" necessary to extract precious audio from a signal near the noise floor. Additionally, a small loop can provide enough discrimination to allow more than casual determination of the azimuthal bearing of a wave's arrival. This opens a lot of possibilities to the serious DXer, and Mitch will discuss this in a later section.

All of this does not come without a price, and the price may be substantial in terms of dollars, time, and effort. To get into this area, you will have to do a bit of homework and determine the most efficient design. Luckily, loops are flexible and forgiving. With a little research and experimentation you should be able to design and build one to suit your needs.

To do accurate DFing at shortwave with a loop, one must be able to make judgments on signal strength at various loop positions while working at or near the receiver noise floor. These loops will exhibit null depths of only 30 dB or so, and as such, an S-meter is virtually useless as a null detector in the presence of fading. The receiver noise floor and your ears are used to determine the null position, and an artificially high noise floor (due to local QRN) will limit the quality of signals you can hear. More importantly, this noise will severely limit your ability to make judgments. At this time, DF loops are being used by Mitch Sams, Guy Atkins, and myself. Only Mitch appears to be in an environment with local house noise low enough to allow the DFing of weak signals indoors on a steady basis. Guy and I are able to DF the more powerful stations, but this is very frustrating.

The following sections are intended to give you a better understanding of SW loops and the various tricks (DFing in particular) which are possible with them. I hope to also give you a better understanding of the obstacles you must overcome to be successful in your pursuit of this exciting technique. Rather than being a connect-the-dots approach to building a DF loop, I hope that this compendium of selected topics will better serve the majority of DXers. In the absence of comparable commercial offerings, you will undoubtedly be forced to "roll your own".

ABOUT DF LOOP CONSTRUCTION

A brief description of the loop which Mitch and I are using is now offered so that you may better visualize the following sections.

The loop and frame are similar to those described in [3]. The loop itself is an "air-core" winding and consists of 6 turns of 20 AWG insulated wire wound into an 18 inch square coil. Adjacent turns are separated by 1/2 inch. The loop is electrostatically balanced; the two ends of the loop connect to the inputs of a balanced FET amplifier, while the loop center-tap is at ground potential. The loop is supported on a conventional X-shaped wooden frame as detailed in [3]. This loop frame needs to be rigid. In practice, the nulls are extremely sharp, and sloppy frame construction could possibly decrease one's ability to determine nulls. Wood frame construction is the usual approach, but PVC frame construction should also work nicely.

The loop amplifier mounts to the lower frame arm with a patch of hook and loop fastener and cable ties. The wire length between the loop windings and the amplifier was kept to a practical minimum to eliminate stray pickup. This amplifier will be dealt with in greater detail in a later section.

The loop frame is mounted on a support arm which is (roughly) C-shaped. The upper end of this support arm is forked, and the lower arm of the loop frame is held in this fork by a bolt. This forms a pivot which allows the loop to be tilted in elevation. To the lower end of the support arm is attached a 1/2 inch steel shaft (about 10 inches long) which extends vertically downward. This shaft is the azimuthal pivot point of the loop and support arm.

An azimuth pointer was fashioned from a piece of acrylic sheet (scrap window glazing available at most hardware stores). It was scribed with a sharp knife, and was mounted on the bottom of the loop support arm so that the scribe line was perpendicular to the plane of the loop.

The base for the loop is fashioned as a small table. The table top is made from a 10 x 12 inch piece of 3/4 inch thick plywood. On this table is mounted an azimuth scale and also the loop control (tuning) box. The table is in turn bolted to a pedestal which is made from two 3 inch PVC closet flanges joined by a 7 inch length of 3 inch PVC tubing. A ball bearing was mounted in the table top in the center of the azimuth scale; a second bearing was also installed in the pedestal near the bottom of the PVC tube. These bearings accept the 1/2 inch steel shaft and allow for exceptionally smooth loop rotation. As the loop is rotated, bearings can by read off the azimuth scale through the pointer.

This arrangement solves most of the problems I had encountered with loops I had made previously. It is relatively compact and does take up precious desk space. Most of the mass in the loop is concentrated towards the bottom which of course aids its mechanical stability. The overall balance of the loop is good enough that the lower flange will prevent the entire loop from tipping over in all operating positions. The use of ball bearings results in a very nice "touch" when adjusting the loop in azimuth.

Remember that this loop and frame represent my preferences in construction. They are also a reflection of what was in my junk box and wood scrap bin. You can choose any construction methods with which you feel comfortable. Just keep in mind the desirable attributes of a good DF loop: rigidity and stability of both the loop and base, freedom of rotation in both the azimuthal and elevational planes, and a good amplifier to allow the DFing of that elusive DX. You should also try to keep the elevational pivot point vertically aligned with the center of azimuthal rotation, and try to minimize the overall height. Both of these will aid mechanical stability. At some point you will become aware that your loop is more than just an antenna but is also a sensitive instrument for measuring the arrival angles of incoming radiation.

I recommend strongly that you consult relevant National Radio Club publications such as [2] and [4]. These publications contain a wealth of ideas which may guide your construction. In particular, either the 2 or four foot NRC loop frames can be scaled to the 18 inch dimension suggested for shortwave. Also offered are several noteworthy approaches to building a base. A catalog of available NRC publications is also available from the National Radio Club, Publications Center, P.O. Box 164, Mannsville, New York 13661.

THE FARLEY LOOP: A USER'S REVIEW by Mitch Sams

Over the past two years Joe Farley and myself have spent a fair amount of time on the phone discussing directional antennas for shortwave. We traded ideas and opinions about just what would be a reasonable approach to a directional antenna system for shortwave. Joe's article in PROCEEDINGS 1989 [3] laid the groundwork for the exceptional loop antenna which he has now built, and which I have had the opportunity to use for the past three months.

I was very impressed with the professional quality of work which Joe had put into the loop. Heavy duty wood construction in the loop with countersunk screws, beveling, wooden dowels, and everything. The electronics (amplifier and tuner) were custom made and looked like they had just come off the assembly line at JRC. Even the ball bearing assembly used to swing the antenna in azimuth was smooth as silk.

I reconstructed the loop and hooked it up. Turning it on with my receiver I noticed no signal level being reported at the receiver. "No problem, just need to tune the antenna preamp and I should see a little gain out of it". Boy was I surprised. My S-meter on the FRG-7 came to life; this loop was hot! At the time all I had was a 65 foot longwire running east-west, and a 65 foot longwire running north-south. When I switched between the loop and either of the longwires, the loop outperformed both by 1-3 dB! I couldn't believe it. Later I was able to compare the loop to a 100 foot and a 200 foot longwire. The loop put the S-meter about 3 dB below where the longwires did, still surprisingly good and not that noticeable to the ear.

I remembered a user review of Joe's loop by Mike Nikolich. Mike pointed out that the loop seemed quieter than the longwire. I agree, the loop at times is quieter than the longwire. In my case I think the noticeable difference in the levels of noise present on the longwire versus what is present on the loop is due to some low-level background that the loop is able to reject.

I should also point out that in the three months I have owned the loop I have only used it indoors. I have the loop on the second floor of our wood frame home. I have also used the loop while inside a metal exterior trailer home. The results I will report were obtained while indoors at both locations. I would expect some amount of improvement if I were to move the loop outdoors.

AZIMUTH DIRECTIONALITY. The Farley loop tunes from 120 meters to just below 49 meters, but it is still useful outside of that range. Two nulls exist broadside on both sides of the plane of the loop, with the peak of the pattern occurring when the edge of the loop is pointed at the station. One shouldn't get the idea that the loop nulls are extremely deep and pronounced; this is not always the case. Depending upon the mode (number of hops, etc) and signal-to-noise ration at the receiver, the nulls may be very noticeable or difficult to find.

I first tried the nulling capability of the loop by tuning a strong Latin on 60 meters. No problem finding the null; the station was attenuated by about 40 dB. As I swung the antenna back and forth across the station I could see the S-meter dip again and again. On weaker stations the null would put the signal into the noise, completely eliminating the audio.

But this is not always the case. On very weak signals the null can be difficult to find and is hard to hear. Fading also makes nulls extremely difficult to locate. It is hard to tell the difference between a fade down and a null while scanning with the loop. Fading also changes the phase relationship of the incoming signal, which sometimes makes the null move around.

With practice I can achieve about 5 degrees of accuracy in azimuth for determining the bearing of a station.

ELEVATION DIRECTIONALITY. It is possible to tilt the loop in elevation as well as azimuth. At first this didn't seem to be very useful, however, I've since learned that this is very effective against local noise. In most cases, this noise is very directional, even in elevation. For example, when the TV is on at night I can point the loop broadside to where the TV is located downstairs and at the other end of the house and the TV interference will go completely away. This is a help later in the morning when the tropical bands begin to fade and are overtaken by local noise. I can delay the complete washout of the band a bit by using the loop.

As far as elevation directionality for shortwave stations, I've not had much success there. However, there is one interesting thing that can be deduced from the elevational directionality that is a big help. I believe that I am able to tell the difference between a one hop station and a multi-hop station by tilting the loop in elevation. The one hop station usually peaks about +10 degrees while long distance stations with multiple hops are near +3 degrees. When the higher elevation angle peak is detected I can assume, under normal conditions, that the received signal is probably within a 2000 mile radius of my location.

EXAMPLES. Now, let me relate some specific loggings and how the loop performed.

At 0140 UTC with my longwire switched in, I tuned to 4755 kHz and the Brazilian, R. Educacion Rural, Campo Grande. There was a pulser ute interfering with the Brazilian on this frequency. I switched in the loop and swung the antenna around to the southeast. At a bearing of 140 degrees, the S-meter dipped to its lowest point. I looked on my azimuthal-equidistant map plotted with my QTH (Wichita) in the center, thus providing a straight line path to any other point in the world along an angular bearing in azimuth. Campo Grande was at 144 degrees; I was off by only 4 degrees! The most significant thing about this logging, though, is that the pulser ute on this frequency was nulled enough to where it was not a problem anymore. I swung the null around looking for the ute's bearing. I found it ti be at 250 degrees. This was the ideal case for an interfering station; it was 90 degrees away from the desired station. A null could be put on the pest while the desired station would be near the peak of the loop response.

Other stations were checked. Rebelde, Cuba, on 5025 kHz was right on with no error at 130 degrees. R. Tarma, Peru, was at 150 degrees with a 2 degree error. Buenas Nuevas, Guatemala, was right on target at 160 degrees.

UNIDENTIFIED STATIONS. What a help this loop is in gathering clues to the identity of unidentified stations. For example, I tuned to a Brazilian at 0230 on 4815. There is more than one Brazilian listed here and I didn't have an ID yet. The null was at 145 degrees which was very close to the city of Benjamin Constant, home of a Radio Nacional outlet. The other listing on 4815 in Londrina is much further east and is located at 138 degrees.

The loop can save a lot of time by giving you strong evidence as to the identity of an unknown station which may turn out to be something you are not interested in DXing. For example, another unidentified station was on 4840, a Latin at 0235. Should I waste my time here? "Not if it's Radio Valera. But if it's the Ecuadorian or Peruvian, that might be worth sticking around for" I thought to myself. Swinging the antenna around I found the null at 145 degrees which ruled out Valera. Later it turned out to be the Peruvian.

It is now easy to tell which Canadian regional I have on 6160, Vancouver or St. Johns, because the angular spacing between the two is so great.

One morning I came across a carrier on 3277 during a good opening to the subcontinent. I was naturally interested in this one since Kashmir is active on this frequency, but I didn't want to waste time here if it was Jakarta while other Indian regionals were coming through elsewhere on 90 meters. A null check with the loop revealed just what I had hoped; the bearing was right on for Kashmir, not Jakarta. I stuck with it and sure enough it was Kashmir. The loop did a good job of clueing me in on some potential DX and allowed for more efficient use of my time.

TRIANGULATION. Recently I wrote a simple computer program which allows me to take two bearings for the same station from two different locations and triangulate the location of the received station. If the station is located near broadside to a line drawn between the two DXers' locations then the accuracy of determining the station's latitude and longitude is within 0.5 degrees. If the station is more parallel to the imaginary line then the accuracy gets pretty bad. If there were a group of DXers strategically located across North America then it should be possible to accurately determine the position of received signals.

It is particularly interesting to find the location of a clandestine station. So far my results have pretty much matched the published locations of some clandestines. I'm waiting for a new one to come on the air to test out the system. (I guess this capability might make pirate broadcasters shudder a bit!)

SUMMARY. I am extremely happy with the performance of this loop, and I am surprised. Nulls are about 40 dB deep on average and about 20 degrees wide. It has sufficient gain, effective noise reduction capability, it's portable, works indoors, and of course is directional and steerable. I find that the loop is now used a majority of the time when I am DXing the tropical bands.

GETTING STARTED

You might be tempted to dive right in and begin assembling a DF loop of your own, and that is understandable. Before you do, however, it would be very worth your while to investigate your listening environment, solidify your expectations, and gauge how much time and money you wish to invest in this project.

Without a doubt, the first step is to gauge the intensity of noise pollution in your listening shack. In the ideal situation you would like to be able to both hear and DF tough DX in the comfort of your shack. The loop described will have enough sensitivity to hear DX indoors. But sensitivity is a double-edged sword as the loop will also be able to hear the local QRN emitted by appliances in your house. In my experience, noise has been traced to most of the classic QRN sources such as the refrigerator, furnace, lamp dimmers, VCR digital readout, etc. This is not a major problem; just pull the plugs during DF sessions!

More serious is the noise which is apparently and mysteriously conducted along and radiated by the house infrastructure. This includes house wiring and conduit, gas and water pipes, telephone wires, and possibly even the CATV cabling. In many houses (including mine) electrical service is just plain noisy from the service entrance on. Filtering outlets IS effective in reducing noise in the receiver when an external antenna is employed. An indoor antenna still sees the noise radiated by conduit et al, and this type of noise seems to be the major obstacle to serious DFing here. It is a pernicious type of noise that appears in bands coinciding roughly with the 120, 90, and 60 meter bands. Watch! The intensity and "signature" of the noise varies daily, but it is typically at S9 or better with an indoor loop. It is always inaudible with a similar loop sited outdoors about 30 meters from the house. The noise seems to take vacations; typically one day in fourteen is quiet enough to do any serious work.

You might benefit from this hindsight by surveying your listening environment for noise sources with a portable receiver tuned to a clear channel in a band of interest while it is active. Gauge the stations that can be simultaneously heard on that band, and their strength relative to the noise. Do this over a period of several days if possible.

Alternatively, you might wish to install a temporary antenna consisting of a 10-20 foot length of wire near the ceiling in your shack. Use a wire antenna tuner if you have one. Try to DX with this antenna, while gauging the relative reception of both DX and noise. Try also to compare noise pickup to the external antenna with which you normally DX. If you do this over a period of time, you should be able to get a fairly good idea of the noise in your shack relative to outdoors.

If the results of your surveys indicate that you are consistently able to hear modest DX with a relatively low amount of noise, I think that you should consider building an indoor loop. A good approach would be to obtain or build a loop amplifier, and to build a test loop on an 18 inch square cardboard box or scrapwood frame. Use the dimensional guidelines cited in [3], but don't be overly concerned about getting the dimensions exact. The idea here is to make a crude test loop. DX with it and try to obtain nulls on a variety of stations by steering it with your hand. Try using the loop in different rooms in your house if possible, and by all means, give it a try outdoors. Gauge whether its performance indoors justifies the construction of a good frame and base. Gauge the outdoors performance; would it justify the time and expense of putting the loop on a rotor? Think again about your goals and expectations, and use the solid facts you learn along the way to determine the course corrections you must make.

If the results of your surveys indicate that you are consistently unable to hear modest DX with a relatively low amount of noise pickup, your choices are more limited. The probability that a DF loop will work well for you indoors is not very high. If you are intent on DFing, you could assemble the makeshift loop and analyze its performance indoors and outdoors. If it does perform to your expectations indoors, that is great; the decision to build a frame is yours. If it does not perform well indoors but does work outside, you might still wish to build a good frame so that you could DF outdoors or on DXpeditions.

You may decide that your only recourse is to mount the loop outdoors and use a calibrated rotor to steer it. Personally speaking, this is the course of action which will best solve the noise problems in my particular environment.

A light duty commercial ARO rotor such as the HyGain AR-40 (about $180) should easily be able to steer this loop in azimuth. I cannot comment as to its accuracy, but a rotor of this type should be suitable for low accuracy DF work. It might also be useful for those who wish to investigate the possibilities of using a loop to avoid co-channel QRM or local QRN.

Radio Shack and Handy Andy (or similar DYI superstores) carry a light duty rotor meant for FM and TV antennas. These run in the neighborhood of 50 to 60 dollars and are a bargain. Other names in the rotor market include Alliance and Daiwa, and you can check the catalogs of amateur radio supply houses for more details.

GETTING YOUR BEARINGS

As I scan the bands I find a signal which gets my heart pumping. It is weak and is fading periodically. It shows a fair carrier, and a trace of audio. Let's see how to go about getting a bearing on it.

I like to spend the first couple of minutes slowly scanning the loop panoramically (rotating a full 360 degrees and then back) while watching the S-meter and listening for clues to a tentative null bearing. It is not easy to find a null, but after several full scans I become convinced that the signal strength always decreases as the loop pointer crosses 4 degrees and 180 degrees approximately. The null at 4 degrees is more pronounced, and I mentally log this as my tentative null location. I do a few more scans and I note that the signal always seems to peak near 89 degrees and 273 degrees. My confidence is bolstered, as the loop seems to be showing a good response pattern. I <u>could</u> accept this bearing as being the wave arrival, but I do not have much confidence that the null is found at this singular bearing; the best I can guess is that it is in the general area of 4 (possibly plus/minus 5) degrees. I want to get a more accurate bearing by doing some "fine" scans.

I swing the loop around to 89 degrees (one of the signal peaks) and ensure that the loop tuning is peaked. I then switch off the receiver AGC and preamp (if on) and set the audio gain to maximum. I swing the loop around to the tentative null at 4 degrees and adjust the receiver RF gain so that the signal is <u>barely perceptible as audio</u>. I sweep the loop through a small arc between 340 and 20 degrees while riding the RF gain control. I make several passes through the tentative null while adjusting the RF gain between scans to account for periodic fading. What I am trying to find is a setting for the RF gain which will cause the audio to disappear at one precise loop position. I am watching the loop pointer only as I swing the loop, while listening to the audio. I find that if I park the loop near the suspected null that I can deepen the null by adjusting the loop's elevation. I continue scanning while I keep a mental average of the azimuth at which the audio disappears on each pass. I disregard any apparent nulls which seem to be caused by a sudden fade down, and try to use only those nulls which are caused <u>by loop rotation alone</u> in my mental average. As the data accumulates I realize that my initial estimate was not that bad; the majority of the nulls on these fine scans show up at about 2 degrees. I decide that I really do have a high confidence level in this bearing; into the logbook it goes!

This technique requires much manipulation of your loop and receiver RF gain control. Alternatively, the loop tuning control can be used to make fine gain adjustments, especially if you used a ten-turn pot for the tuning control. If you mount the control box on the loop base then everything you need to make these fine bearing measurements is right there in front of you. There is nothing to distract you from what is important, and that is taking good data!

ABOUT CALIBRATION

I do not think that you can discuss DFing geographically distant stations without mentioning how to calibrate your loop to global geographical coordinates. Your DFing results obviously cannot be accurate if your calibration is not accurate. There are several methods available, and you must experiment to find one which suits you.

It would appear that the simplest method would be to use a magnetic compass (mounted on your loop table) to align the 0 degree bearing of your azimuth scale to magnetic north. To do this, you must account for the fact that in most areas in the world magnetic north does not coincide with geographical north. Also, you must compensate for the fact that in most locations the magnetic north you measure on a compass does not coincide the the north magnetic pole. It generally differs by a small value known as the local magnetic declination. I do not recommend this approach except for a quick DF check in which accuracy is not that critical.

A better method is to use stations with known transmitter sites (operating in your band of interest) as references. Before a DF session, you can take bearings on two or more known stations with the loop (and therefore the azimuth scale) in a fixed position. You can then obtain theoretical bearings on these reference stations from your azimuthal-equidistant map or from a bearing generation program such as the one supplied in the <u>Low Band DXing</u> software package (by John Devoldere, ON4UN, available from the ARRL, 225 Main Street, Newington, CT 06111). Your loop (or scale) can then be rotated so as to give a best fit between the theoretical bearings and the bearings you measured. Or, you can leave the loop where it is and add or subtract an offset (the amount you would have to rotate the loop) from all subsequent DFs. This method allows you to know the station location while you are nulling it.

All DXers are aware that it is quite easy to imagine a station ID; given the speaker's language, a scrap of music, and a frequency/time/propagation fit, you will hear an ID no matter what was said! Similarly, if you do your calibration before you DF, I guarantee that you will always hear a null at the precise bearing at which you hope it will show up! Within a few days of starting DFing you will have memorized the arrival bearings of all your favorite quarry. It will be quite difficult to keep this knowledge from biasing your results, and this fact suggests a third method of calibration.

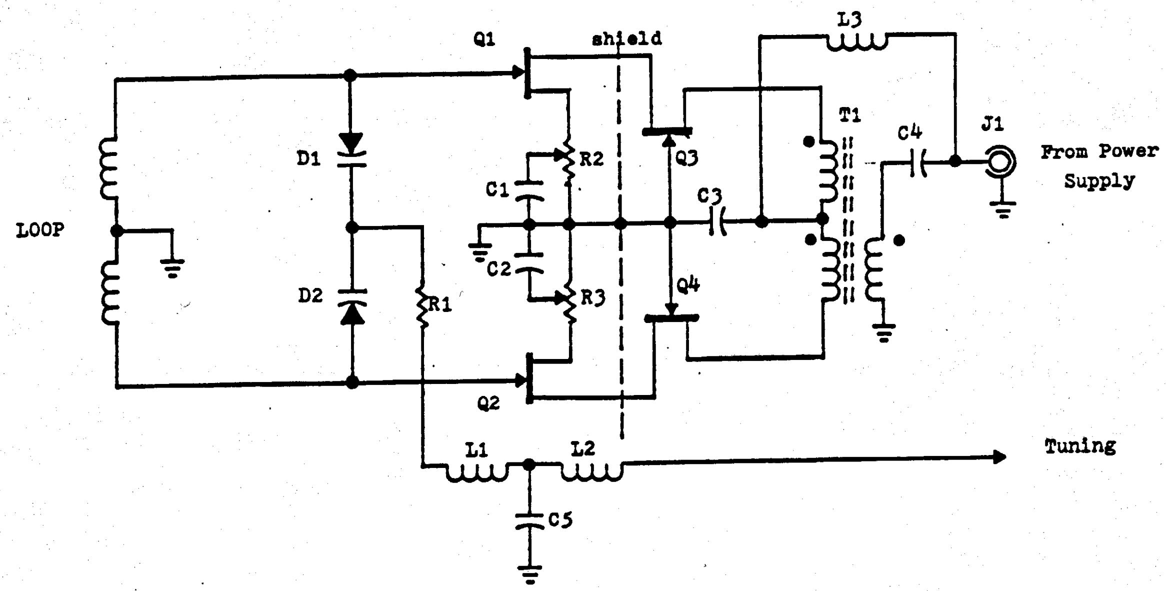
In this method you do your DFing first, with the loop and azimuth scale firmly fixed in a random position so that the scale bearings <u>do not</u> correspond to world coordinates. After DFing, you calibrate against known stations as previously discussed. The azimuthal correction factor that you derive from this calibration is then used to correct any bearings you took in the DF session. The major advantages of this method of "blind calibration" are:

1) In the event of a band opening (especially a quick one) precious time is not wasted in calibration.
2) You have no concrete knowledge of the actual bearings you are trying to determine; bias is minimized.
3) In the event that you take no "high confidence" bearings in a session, no calibration is required!

A "UNIVERSAL" LOOP AMPLIFIER

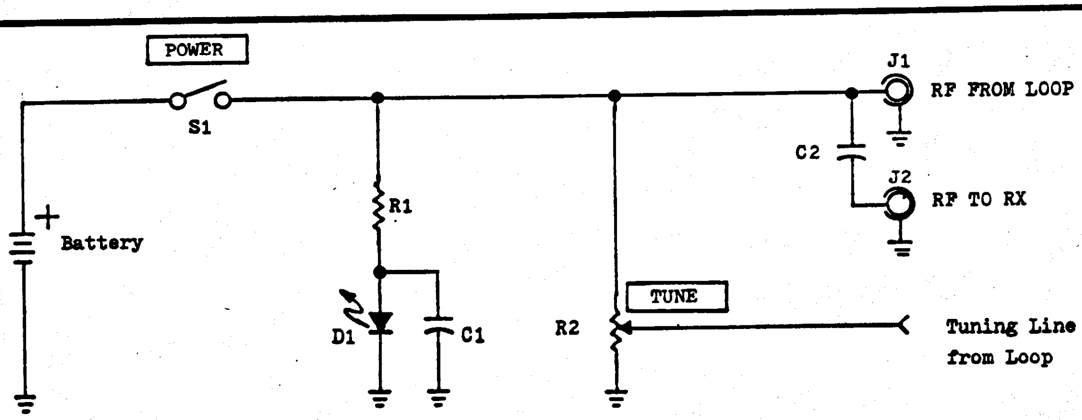
The amplifier described in [3] is suitable for use in a DF loop. With a loop inductance of 32 uH, a coverage of 1800-5200 kHz will typically be possible. "Remote" tuning is used in this scheme, and only a single coaxial cable is required between the control (power supply) and the loop amplifier.

Fig. 1 and Fig. 2 illustrate an improved amplifier and control scheme which I recommend for anyone wishing to experiment with DF loops. Fig. 1 describes an amplifier in which the coaxial cable is used to return RF to the receiver via the simplified controller described in Fig. 2. This coax is also used to bring a fixed +18 volts to the amplifier. The tuning voltage has been segregated from the drain supply; a separate wire is used for the tuning function. This circuit arrangement offers the following advantages:



C1-4	.05 uF, 50V ceramic disc	Q1,2	MPF102 JFET
C5	.01 uF, 50V ceramic disc	Q3,4	MPF102 JFET (U310 JFET may be substituted)
D1,2	MVAM115 (NTE618) tuning diode	R1	22K, 1/8W, 5%
J1	BNC bulkhead jack	R2,3	200 ohm trimpot
L1,2	270 uH molded inductor	T1	10T #32 AWG trifilar on Amidon FT-50A-77
L3	270 uH (15T on Amidon FT-50A-77)		

Fig. 1 LOOP AMPLIFIER



Battery	18V (three 6V lantern cells in series)	J1,2	BNC bulkhead jack
C1,2	.05 uF, 50V ceramic	R1	10K, 1/8W, 10%
D1	any LED	R2	10K, 10-turn pot
		S1	any SPST switch

Fig. 2 LOOP CONTROL BOX

1) The overall circuit power dissipation is significantly reduced. Battery operation is feasible, and three 6 volt lantern cells in series will help to ensure quiet amplifier operation, and they will have a long life. Battery operation will also allow the loop to be used on DXpeditions.

2) The control box is greatly simplified; both cost and construction complexity are minimized.

3) This circuit will produce a tuning voltage of 0-18 volts. Although it is not a recommended practice, running the varistors at a reverse bias of 0 volts will result in a tuning minimum of approximately 1400 kHz. MW stations of known location may then be used for azimuthal calibration points. The MVAM115 (NTE618) diodes are specified for a 15 volt reverse bias maximum operating, and 18 volts maximum. The controller described in Fig. 2 will allow operation up to the 18 volt limit. This does not appear to pose any threat to the diodes; every unit that I have tested withstood 21 volts reverse bias ("high temperature") without degradation. Practical experience suggests that the ability to tune a couple of hundred kHz higher (to 5400 kHz typ) is worth pushing the limits on these devices.

4) This circuit will work nicely for either an indoors DF loop or for an outdoors loop on a rotor.

The amplifier should be built along the guidelines outlined in [3], and should be housed in a metallic enclosure. I like to use a 3.6 x 1.5 x 1.0 inch aluminum diecast box (Hammond Manufacturing #1590A or Bud #CU-123) that has tight-fitting lid which is secured by four machine screws. This enclosure helps to make the amplifier a compact and rugged unit, and it can be easily waterproofed for external use.

The MVAM115 diodes will be difficult to find in small quantities. A suitable replacement is the NTE618, which is an aftermarket replacement for the Motorola part. Mouser Electronics distributes the NTE line, and although they do not currently list the '618 in their catalog, they should be able to get them for you. The price should be about $2.50 each. Information on this and other amplifier parts can be found in the reference section at the conclusion of this article.

The MPF102 JFET pairs should be selected and matched for zero-gate drain current (Idss) as described if [3]. Using these FETs, the amplifier gain should be suitable for most applications and listening environments. If you have access to some U310 JFETs, you may try them instead of the MPF102s at Q3 and Q4. This will result in a somewhat "hotter" loop, and it may be useful in areas free from local RF pollution. If you wish to go this route, keep the U310 gate leads in your layout as short as possible. Also, choose Q1 and Q2 to have the highest matched Idss possible; a value of 12-15 mA would be acceptable.

The control box is quite straightforward to construct, and it may be built in an enclosure of your choosing. The ten-turn pot and counting skirt (optional) may be obtained from Digi-Key Corporation.

Connectors and cabling are not critical, and should reflect your preferences. The loops I built use RG-174 miniature 50 ohm coax for the RF path between the loop amplifier and control, with BNC connectors at the loop amplifier and control enclosures.

EPILOGUE

The potential for DFing with small loops has barely been explored in the shortwave hobby. Many questions remain unanswered, and there are many areas yet to be explored. Among the most interesting are:

1) For the most part, the null patterns observed in practice are consistent with simple theory. In some instances, "pattern skewing" (and/or degeneration into single or multi-lobed response patterns) is observed. Why is this so?

2) These loops generally produce the classic "figure 8" response, and a station which shows an arrival null at a given bearing will generally show another 180 degrees away also. The accumulated knowledge of propagation, band openings, and station identifiers will usually allow the easy elimination of one of the possibilities. For example, there is probably not much reason for a Slavic language numbers transmission to be arriving from the far southern Pacific rim at 0500! It is well known that the pattern of an omnidirectional an-

tenna (short vertical?) can be combined with a loop response to generate a pattern with a single null (cardioid). This would be a great area for some individual research.

3) Improved calibration methods are needed, and a larger user pool will allow a better determination of the accuracy which is possible.

4) More research into elevational arrivals is needed. Such information is vital in attempting to reconstruct a hypothetical transmission path back to the transmitter.

5) I make no pretenses that the loop and amplifier combination is ideal; it simply works. The loop area, number of turns, loop Q, tuning range, winding spacing, and amplifier have settled into a recipe which I tend to duplicate with each new loop. Card holding members of the Tinkerers Union are welcome!

ACKNOWLEDGEMENTS

The authors wish to acknowledge those members of the medium and longwave community who pioneered the use of loops and hobby DFing. In view of this, our current work is but a footnote to their endeavors.

REFERENCES

[1] Connelly, Mark, WA1ION, "RT-1 Remotely Controlled Antenna Tuner", I.R.C.A. Reprint A66, 1984, International Radio Club of America.

[2] Edmunds, R.J., ed. N.R.C. Antenna Reference Manual, Vol. I and II, 1982. National Radio Club.

[3] Farley, Joe, "A Remotely Tuned Loop Antenna", fine tuning's PROCEEDINGS 1989, 1989, FT Special Publications.

[4] Knitter, Michael G., ed. Loop Antennas Design and Theory, 1983, National Radio Club.

SOURCES OF SUPPLY

Amidon Associates
12033 Otsego Street
N. Hollywood, CA 91607
-Ferrite and iron powder toroids

Digi-Key Corporation
701 Brooks Avenue
P.O. Box 677
Thief River Falls, MN
56701-0677
-Electronic components

Mouser Electronics
P.O. Box 699
Mansfield, TX 76064
-Electronic components

To help to support your efforts, I will be able to supply the "universal" loop amplifier described in this article in kit, partial kit, or assembled and tested form. For details, send an SASE to Joe Farley, 910 Westwood Avenue, Addison, IL 60515 USA.