Using Tuned Passive Loop Antennas

I've heard it said that successful medium wave DXing is 50% antenna and 50% receiver. In order to get the most out of the antenna factor, those with sufficient real estate will erect a EWE, Beverage, KAZ or other outdoor antenna. For those like me with little space or who have restrictive homeowners associations, one of the antennas of choice will likely be an indoor loop antenna. This might be a home-made box loop or a desktop ferrite loop such as the Quantum Loop. Those whose passion lies in using portable receivers, including the popular Ultralights, rely on the ferrite loop inside the receiver.

An often-overlooked asset is a tuned passive loop used to augment the primary loop antenna. A tuned passive loop is readily available commercially from manufacturers such as DXTools.com, Terk, Select-A-Tenna and others. Alternately, one can be made quickly by the home hobbyist. This article is a summary of several techniques by which a tuned passive loop antenna can help DXers solve common problems.

<u>1. Signal Enhancement</u>

<u>Facing Orientation</u>

Signal (gain) enhancement is probably the most typical use of passive loops. For maximum gain, one possible orientation is to align the coils of the passive loop so that they face those of the windings on the ferrite antenna in your receiver. This allows the magnetic lines of flux from both loops to couple together (see also Attachment 1).

For example, the Sony ICF-SW7600GR and Terk Loop are in facing orientation at right. I have found that placing the receiver inside the loop also works well, with the receiver resting next to the tuning dial housing as if in a cradle. A Quantum "Q-Stick" in this orientation would be parallel with the top of the receiver.

<u>Adjacent Orientation</u>

Equal and often superior results are obtained if the loop is positioned adjacent to the receiver, seemingly in the end-fire null of the receiver's ferrite antenna. What makes this work is that the magnetic field flux lines from the passive loop feed into the coils on the receiver's tuning coil as if the two coils were mounted on the same ferrite bar. This same principle is employed on the receiver's loopstick itself in order to transfer signal from the tuning coil to the sense coil. In adjacent orientation, shown at left, you should make sure that the receiver's ferrite is somewhere near the horizontal center of the passive loop; otherwise, the two coils involved may not couple very well. This can be done by flipping down the stand (if the receiver has one) or placing the receiver on a book.

In general, good results are obtained in using passive loops to augment both internal ferrite loopsticks in portable receivers and the small air-core loops supplied with modern home entertainment receivers. Additionally, all passive loops will work in either orientation. I have found that finding the proper position with a ferrite passive loop such as the Quantum Stick can be more difficult, especially in adjacent orientation, whereas air-core loops generally have a wider "sweet spot". Also bear in mind that signal gain at night may not be very noticeable, since signal levels are much higher than during the day, and with your receiver's AGC circuit limiting gain increases, finding the right position may be more challenging.

Generally, the closer the receiver is to the passive loop, the higher the gain transferred to the receiver. The results can be impressive: a Sony SRF-59 UltraLight receiver, up next to a Terk loop, is more sensitive than a fully-aligned Sony ICF-S5W. Remarkably, even the mighty Sony ICF-2010 registers two more LEDs when matched with a 4-inch ferrite antenna/coupler. Conversely, a Quantum Loop requires about a 15x15 inch box loop for appreciable gain increase, and a 36x36 loop works well for longwave reception. In any event, a general rule of thumb is: the bigger the passive loop, the better the gain.

If you want even *more* gain, try putting two passive loops next to each other. As depicted at right, you can use a Terk Loop or Q-Stick in as an intermediary loop between a larger box loop and the receiver.

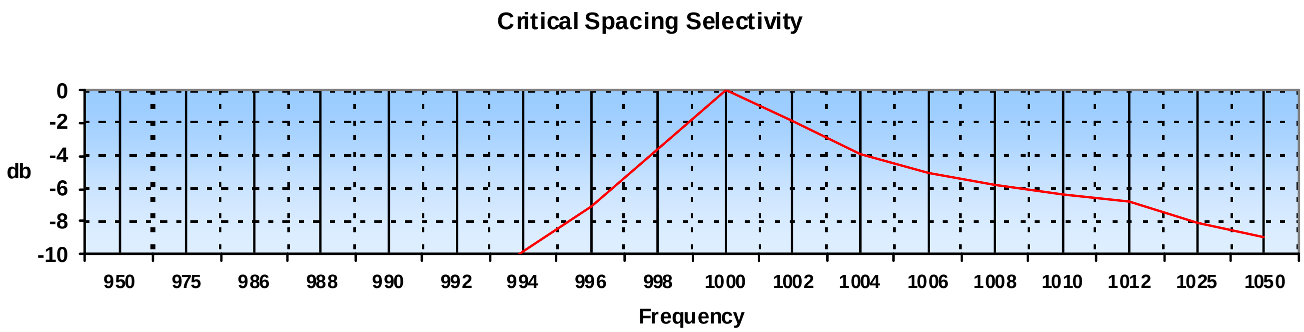
When the receiving and passive loops are identically matched or nearly so, the two loops may not compliment each other. For instance, when I use one Terk Loop as the receiver's main antenna and another as a passive loop, there is usually no orientation by which I can get any signal gain – in fact, all I can do is degrade it! Similarly, Gerry Thomas reports that his Q-Stick passive ferrite loop does not work well with the Panasonic RF-2200, both of which have 8-inch ferrite loopstick antennas.

2. Selectivity Enhancement

Critical Spacing

A technique to increase the selectivity of the receiver consists of simply pulling the receiver away from the passive loop in either orientation. At a critical point, the loop will still be close enough to provide signal gain, but the high-frequency content and adjacent-channel interference are reduced. Electrically, the two coils are now decoupled to a large degree. With the Sony M37V, the critical point is about 3 inches away from a Terk Loop and about 10 inches away from a 15x15 inch box loop. With a receiver employing a larger ferrite loopstick, the critical distance will be further away.

By simulating the resultant loopstick/passive loop circuit on Gene Preston's AC.EXE program (see Attachment 1 for more details), the results of a typical critically-spaced coupling are shown below:



In this graph, the signal is decreased about 6 decibels at 3.5 kHz on either side of the desired frequency, making this roughly equivalent to a 7 kHz filter. Compared to the filtering in many portable receivers, this can be a major improvement. Continuing to separate the receiver and loop will narrow this figure even more. However, past a certain point, the two will be decoupled to such a degree that the passive loop no longer will affect the selectivity. Also, if your receiver has decent IF filtering, or if the passive loop has very low Q, the effects of this strategy may be negligible.

You can also experiment with using more than one passive loop. For instance, I find success putting an intermediate loop such as the Q-Stick near the receiver for gain enhancement in addition to a much larger passive loop for selectivity control. As is shown in the picture on the right, the intermediate loop is pulled away just a bit, which helps to further tighten the selectivity.

The reverse of this selectivity control strategy is also generally true, in that if you place the receiver quite close to the passive loop, this will generally result in a broadening of the bandwidth. This is more pronounced with a larger passive loop.   At a certain point, though, the receiver and passive loop will be too close together. In that case, the two coils will start to decouple, and tuning of the passive loop will not significantly affect the receiver.

Critical Angle

An alternate way to decouple the receiver and passive loop is to place them at approximately a 45 degree angle to each other. By doing so, the coils are in neither facing nor adjacent orientation, but rather half-way in between. At this point, the two are completely decoupled, regardless of the actual distance between them. To find this point, place the receiver and passive loop in this orientation and move the receiver or loop until you find a point at which tuning the passive loop has no effect on the receiver. You can then move the loop or receiver anywhere along an imaginary 45 degree line, and the two units will remain decoupled. Selecting a point just on either side of the imaginary 45 degree line will begin to loosely couple the receiver and loop in one orientation or the other, and the receiver's bandwidth will be narrowed as with critically-spaced decoupling. This is often more convenient with receivers with large loopstick antennas, since the distance required for critical spacing is often correspondingly quite large.

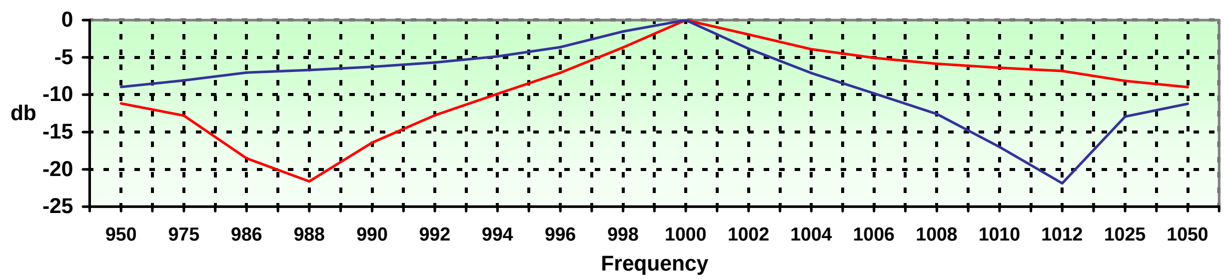
Detuning of the Passive Loop

The tuning of the passive loop will change depending on how far away the receiver is. To verify this, try tuning to a certain frequency on your receiver, and then tune the passive loop for a peak while the receiver is loosely coupled in facing orientation. Bring the receiver closer and closer to the loop and continue to adjust the tuning of the loop tuning to maintain the peak. With facing orientation, you will find that you must tune the loop higher and higher in the band to maintain the peak, and lower and lower with adjacent orientation. Therefore, depending on the technique you are using, slight retuning of the passive loop may be required.

3. Adjacent channel notching

You may have noticed that a passive loop will both peak and notch a particular frequency, depending on the tuning capacitor's setting. For instance, try peaking a station at 1000 kHz or so using facing orientation with the loop pulled back a couple of inches. Then, slowly rotate the passive loop's tuning capacitor up-band a bit – you should notice a definite notch when the passive loop is tuned to 1020 kHz or so. In other words, in facing orientation, the passive loop will induce a notch below its tuned frequency! With adjacent orientation, just the opposite occurs – a notch will be placed above the passive loop's tuned frequency. In the chart below, the critically-spaced response from earlier is extended down to -25 db to show that there are definite notches about 12 khz away in both orientations.

Up-band and Down-band Notching



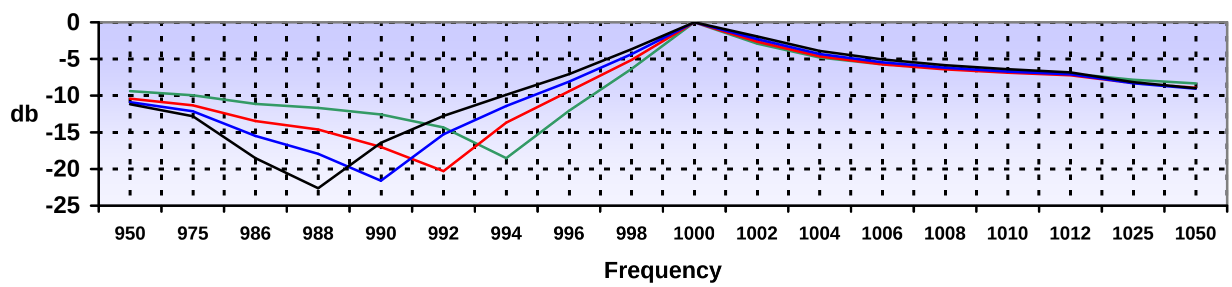
Because of the way the receiver's loopstick and the passive loop interact, there will *always* be a lower notch in facing orientation and an upper notch in adjacent orientation. Therefore, if you want to put a notch up-band from the desired target to attenuate interference on the neighboring channel, use adjacent orientation, and use facing orientation for notching down-band from your target. As a memory aid, I use the phrase "face down, this side up" to remember the relationships. While not reflected in theoretical calculations, in actual practice there is a more pronounced notch in adjacent orientation.

As an example of using this technique, I have a strong local on 1000 kHz which makes reception of 990 and 1010 a challenge. In facing orientation (down-band notch) I can listen to 1010 much more easily, and the same for 990 using adjacent orientation (up-band notch). If I get the orientation wrong, as the chart above shows, the interference is 20 decibels worse than when I started!

Notch Depth vs. Notch/Peak Spread

As you decouple the receiver and passive loop, in addition to tightening the selectivity, the "spread" between peak and notch will narrow. The graph below shows the effect of progressively decoupling the receiver and loop.

Notch Depth vs. Notch/Peak Spread



The trade-off here is that not only does decoupling decrease the gain imparted to the receiver, the depth of the notch gets shallower as well. As with the critically-spaced selectivity technique above, an intermediary loop between the main passive loop and the receiver will help restore gain should you need it.

Notching an Interfering Station

For the DXer, the optimum situation is where the peak and notch are spread exactly 9 or 10 kHz apart (and even narrower for transoceanic split-frequency DXing) so that the target is peaked and the interfering station is notched. A casual placement of the loop and receiver may result in a 20-30 kHz spread, and a critically-placed loop for selectivity alone might still put the notch up to 15 kHz away from the peak.

By moving the receiver even further away from the loop, the spread between peak and notch decreases, and at a critical point, the spread will be exactly 10 kHz. The spacing will depend on the receiver and passive loop being used. For instance, with a Sony M37V and a 15x15-inch box loop, the distance is usually around 12 inches with either orientation. You will need to experiment to find the distance that works for each receiver/loop combination, and the distance in one orientation may be different than the other. As above, the use of an intermediary loop can help provide extra gain if needed.

A recommended approach to find the critical placement for a 9 or 10 kHz spread is as follows:

1. Select the orientation based on where the co-channel interference is (i.e., adjacent orientation for upper notch and facing orientation for lower notch).
2. Tune the desired target frequency on both the receiver and loop for maximum gain, with the receiver a few inches away from the loop.
3. Tune to the interfering frequency on the receiver *without touching the tuning on the passive loop*.
4. Move the receiver either closer to or away from the loop along the imaginary perpendicular line until the notch on the interfering station is found; it may disappear or perhaps the background noise will elevate. If you have trouble discerning any notch effect, try orienting the receiver and passive loop to place a simple directional null on the interfering station so that you can better hear the notch.
5. If you end up moving the receiver further away from the loop in Step 4 to minimize the interfering station, that means you started out too close in the first place. Similarly, moving the receiver closer to the loop for the notch means you started out too far away. In either case, come a little bit back towards where you started and repeat steps 2-4 until the target peak and interference notch coincide.

For example, in order to receive a semi-local on 620 kHz under a strong local on 630 kHz:

1. Select adjacent orientation to put a notch above the desired target.
2. Tune the receiver to 620 and place the receiver several inches away from the loop, then find the peak on the loop. For this example, assume the initial distance is 14 inches away.
3. Tune the receiver to 630 (the interfering station).
4. Move the receiver either closer to or farther from the receiver to find the notch. For this example, assume that the receiver is moved closer, to 10 inches away, for the notch on 630.
5. This means that the distance was too great to begin with, so come back a little towards the original distance (say, to 11 inches away) and retune both receiver and loop for a peak on 620. If repeating steps 3 and 4 shows that no further movement is required, the desired 10 kHz spread has been found.

Notching out split-frequency interference is much easier. In this case there will generally be a heterodyne as an indicator, so you don't need to actually tune to the interfering station in Step 3. Rather, adjust the tuning on the loop to minimize/notch the heterodyne while tuned to the desired target, and then increase or decrease the distance between the receiver and loop (followed by slight retuning of the loop) until you find the position of maximum clarity of the target and minimum heterodyning. This becomes a very quick process with a little practice. In many case, notching of the interfering carrier will cause the receiver's AGC to increase gain for the target, resulting in an apparent increase in sensitivity.

Once you have found the desired notch, depending on the situation you can then:

- Move the receiver or loop a little, either closer to or further away, to see if there is a better relative position, rather than trying to fine-tune the loop's tuning
- Retune the loop *slightly* away from the interfering station (e.g., tune the loop slightly down-band when listening to 620 under a local on 630) while keeping the distance between the receiver and loop the same. This will maintain the 10 kHz spread, but will put the peak on the target's sideband which is furthest away from the interference and the notch on the closest interfering sideband.
- Move the receiver a little closer to the loop in order to increase the peak/notch spread (say, to about a 12 kHz spread for domestic DXing) and then retune the loop slightly to the point of best clarity. The result is that you will peak the sideband of the target which is away from the pest while keeping the notch on the carrier of the interfering station.

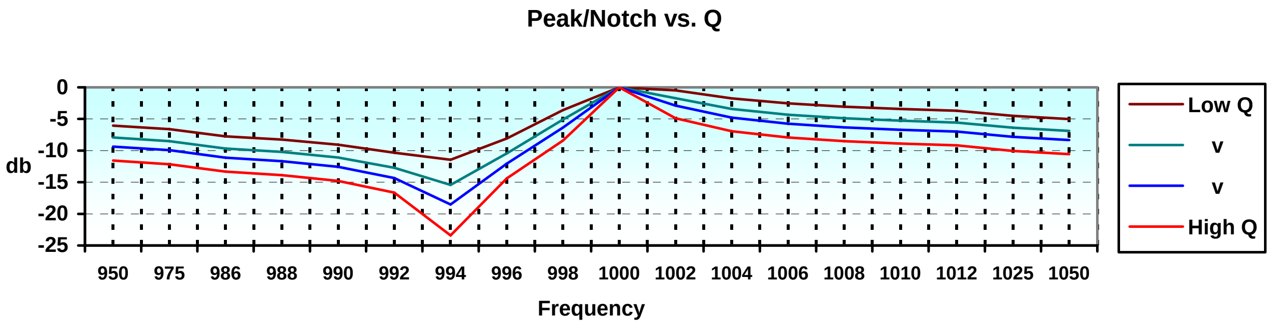
Dealing with IBOC Digital Noise

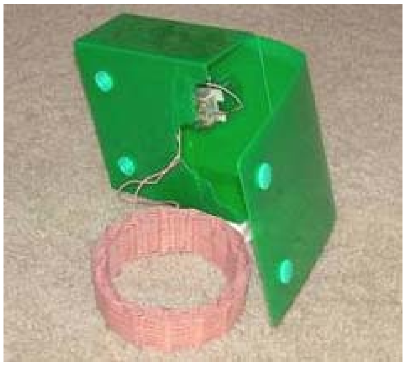
One variation to the orientation rule above is in dealing with IBOC noise. This stems from the fact that the digital sidebands which produce the noise are centered about 12 kHz away on either side of the station's actual carrier frequency. For example, if my 630 kHz local were using IBOC, the digital noise would be centered at 618 and 642. Therefore, to tune in 620, one must actually use facing orientation to put a notch below on 618, even though the interfering station itself is above on 630.

Of course, by doing so, the analog sidebands from the main signal on 630 will cause interference, although the decoupled passive loop may provide increased selectivity in addition to the notch. In any event, my experience has been that notching out the noise associated with IBOC broadcasts results in a more readable signal, especially with weak DX targets that would otherwise be completely buried in the noise. Unfortunately, if there is an IBOC station on the other side as well (in this case on 610, with the upper digital sideband on 622), then there isn't much that can be done, since both sidebands of the target on 620 would suffer from the noise.

Notch Depth and Q

The “Q” of a passive loop, which essentially describes the tuning sharpness of the loop, also influences the peaks and notches achieved. Specifically, both the peak and the notch are more pronounced as the loop’s Q increases: therefore, a higher the Q of the loop, the better.





While the above graph depicts results from using the high-Q loop in facing orientation, the principle applies in either orientation. For example, to listen to 1200-WOAI some 1750 miles away on a Sony M37V, I need to deal with IBOC noise from a strong semi-local on 1190 and a strong local on 1210. Using the IBOC strategy above, I must use adjacent orientation to avoid 1190’s upper digital sideband on 1202. Favoring the lower sideband of 1200 in this way, interference from 1210 is reduced, but 1190’s upper analog sideband will interfere: a tight situation indeed.

Using a 9-inch Terk loop, I can barely make out 1200-WOAI amidst the various sources of interference. With a small (3.5 inch) basket-woven Litz wire loop with very high Q (at right), there is a definite peak of intelligibility: even though the gain isn’t as great as with the Terk loop, 1200-WOIA comes in just fine!

4. Adjacent channel interference – Fixed Channel “Detuning”

If your receiver only tunes in fixed 9 or 10 kHz increments, as with many UltraLights and other portables, DXing split frequencies can be difficult. For example, tuning to a trans-oceanic signal on 774 kHz next to a local on 770 would be much easier if you could slide over to 775 or 776. Such “detuning” is also common practice with domestic stations spaced 10 kHz apart; for instance, to hear 780 under local 770, you might tune up to 782, placing 12 kHz between you and the problem. In both of these cases, you will be favoring one sideband over the other in order to avoid interference.

The peak/notch technique above can provide considerable help with fixed tuning receivers. It is probably impossible to move the receiver far enough away to effect a 1 or 2 khz spread between peak and notch. However, you can move the receiver out to a point of extreme tuning sharpness in order to increase the slope of the peak-to-notch curve to the maximum extent possible.

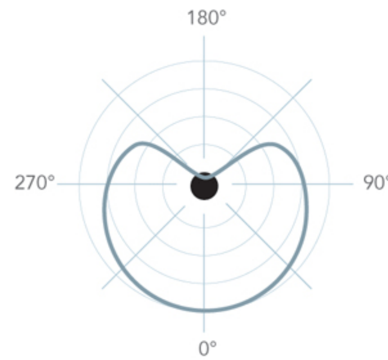
In looking at the “Notch Depth vs. Notch/Peak Spread” graph several sections earlier, as the notch draws closer and closer to the peak, the depth of the notch is more shallow. However, the slope of the line is significantly greater. Therefore, in tight situations you can take advantage of this steep slope to significantly favor one station, or one sideband, over the other. In doing so, you will either peak the target or notch the adjacent interference; let your ear be the judge.

For example, my semi-local on 1190 kHz has substantial man-made interference which renders the lower sideband (centered around 1188) completely inaudible, while the upper sideband at 1192 is clean. While my higher-end communications receiver can simply be placed in USB mode for clean reception, an UltraLight with only fixed-tuning AM (dual sideband) mode receives both sidebands, and the overall result is an unintelligible signal. Using well-separated facing orientation to favor the upper sideband over the lower, I can first tune the loop for a peak on the interference (so I know where I’m at), then tune slightly up-band to notch out the noise. While not necessarily isolating the desired sideband, it is now emphasized in the receiver’s passband compared to the other sideband.

But wait, there’s more! By using a second passive loop as an intermediate, the results are even better. In my test on 1190 khz above, I started out with a Sony ICF-SW7600GR receiver and a 15x15 inch box loop. Separating the two units enough to increase the slope of the peak-to-notch curve meant that signal gain was rather low. By first placing a tuned Q-Stick in between the units, about 1 inch away from the receiver, I was able to provide more gain to the receiver. The intermediate loop also further enhanced the rejection of the lower sideband – tuning on the box loop was much sharper, corresponding to an even steeper peak/notch slope. As a result, the upper sideband of 1190 was loud and clear with just a hint of the noise from the lower sideband. While this is not actual exalted carrier single sideband (ECSS) reception which eliminates the offending sideband altogether, it is probably about as good as you can do with an AM-only receiver, and it can make a huge difference.

This can be a valuable strategy even if your receiver is able to tune off-channel. For example, on a recent DXpedition I used an Eton e100 UltraLight in Alaska to listen to Asian split-frequency stations. The e100 not only tunes in 1 kHz increments, but also has surprisingly tight filtering. However, in situations such as an Asian on 972 kHz next to a domestic on 970, the e100 was not able to produce decent audio, even if I tuned up to 974. Using a Terk Loop in loosely-coupled facing orientation, I was able to not only provide extra gain, but also strongly attenuate the domestic on 970. By thus favoring the upper sideband of the target on 972, it came in loud and clear.

5. Co-channel interference – Passive Phasing



When a passive loop is oriented such that its signal for a given station is precisely out of phase with the signal generated by the receiver's antenna, the two will cancel each other out. As a result, an otherwise dominant station will delightfully disappear, allowing you to hear what was lurking underneath. This technique produces a reception pattern in the shape of a cardioid (right), with a pronounced null in one quadrant and virtually undiminished reception in the other three.

Either orientation can be used for passive phasing, although adjacent orientation often seems to work better than facing orientation. Here is a basic procedure for passive phasing (paraphrased from Gerry Thomas' Q-Stick phasing procedure):

1. Tune the passive loop to maximize the frequency of interest using the selected orientation, then set it well away from the receiver.
2. Orient the receiver to place a simple null on the station to be eliminated. If possible, tilt the radio up or down (i.e., azimuth change) to get an even better null, using a tripod for stability if desired.
3. With the passive loop still tuned to the desired frequency, position it a few inches away from the receiver. Then, begin rotating it about its vertical axis as you also change the distance from the receiver. At a certain distance and angle, you will hear the unwanted station's signal level go down, or see it on the S-meter of the receiver. If you don't have an S-meter, try decreasing RF gain so that you can better hear the null.
4. Once you have found the general distance and angle, try going off-axis a bit (i.e., not at a 90-degree angle from the receiver) to see if there is an even better orientation of the loop, or try the other orientation. Some phased nulls may be found with the loop at nearly a 45-degree angle from the receiver. Elevating the passive loop an inch or two may make a big difference. Also, with adjacent orientation, the passive loop might have to be tuned slightly up-band to account for decreased coupling; facing orientation may require re-tuning slightly down-band.
5. Once you have found the right distance and angle for the passive loop, *slightly* adjust the passive loop's tuning or the receiver's position to fine-tune the null.

Facing Orientation - Eton e100 and Terk loop

Adjacent Orientation - Quantum Loop and 15" box loop

If you get a decent directional null in Step 2 above, you may notice that the audio becomes distorted. As a result, the eventual phased null may not be very good because the out-of-phase signal produced by the passive loop is now significantly different than the distorted signal produced by the receiver's directional null. In this case, try to lessen the directional null a bit and then re-do the phased null.

In phasing out the undesired station, the strength of the remaining stations on that channel will depend on the levels present in the receiver antenna and passive loop individually. In other words, the final result will only be as good as the weakest antenna. For example, the M37V has a very small ferrite antenna, and the limited in-phase signal it produces doesn't need much opposite-phase signal from the passive loop to cancel it out; therefore you will have to decouple the loop a significant amount, resulting in less gain for the DX targets underneath. To remedy this, use an augmenting passive loop for gain, then use a second loop for the phased null – it really works well! In the case of an M37V with a Q-Stick (right), I am essentially phasing the Terk loop with a receiver with an 8-inch ferrite antenna, so there is sufficient gain to hear the remaining stations.

With a high-Q passive loop, you may find that its narrower opposite-phase signal doesn't phase very well with the broader contribution of the receiver's loopstick. In such a situation, you can use an intermediate loop with the receiver to narrow its selectivity, then apply a larger high-Q loop for a phased null. In the picture just above, the opposite occurs: the Q-Stick causes the receiver component to have a narrower bandwidth than the component supplied by the low-Q Terk loop, so a higher-Q passive loop would work better in this situation.

Once you have nulled the unwanted station to the extent possible, you can then employ a second passive loop and move it around either the receiver or the first passive loop until you find an even deeper null. This "double phasing" technique can be very effective, and has allowed me to hear stations under fairly strong locals that would have been impossible with single passive phasing alone.

Another application for phasing is to reduce co-channel interference. For example, a target on 810 may be sitting alone on the channel, but a local powerhouse on 820 is completely obliterating the target. In this case, use adjacent orientation and tune the passive loop to 810, and then tune to 820 on the receiver and passively phase 820 to the extent possible. Then tune the receiver back to 810 - the co-channel interference will be significantly reduced.

6. Images and spurs

Images are created when a strong station causes the receiver to generate a phantom signal of that station two IF bandwidths down from where it actually is. Since most receivers use either 450 or 455 khz IF stages, the phantom image will show up 900 or 910 khz down-band. For example, I have a local station on 1590 khz, and many of my receivers have a very strong image on 680 or 690 khz which itself sounds like a local!

Spurious mixing products ("spurs") are produced when two strong local signals mix together to produce a third signal, which is comprised of the arithmetic difference between the two local signals' frequencies or some other combination. For example, my strong locals 1590 and 1000 produce a huge spur on 590 (1590 - 1000 = 590), which is a "second order" product, and 1000 combines with another strong local on 880 to produce a third order product on 1120 (1000 + 1000 – 880 = 1120).

The notching technique is very effective in eliminating these artificial signals, tuning the passive loop to place the notch on the offending station which is causing the image or spur. As discussed earlier, the notch produced with adjacent orientation is much deeper than that produced with facing orientation, therefore use adjacent orientation for image and spur notching.

In order to find the correct tuning position on the passive loop for an image/spur notch, place the passive loop in adjacent orientation close to the receiver, and tune the passive loop in order to maximize the image or spur in order to get close to the final spot on the loop's dial. Then, tune the loop *slightly* down-band for the notch – the image or spur should disappear or be substantially reduced. Once you get the hang of this, you can skip the peaking step and simply listen for and tune to the notch.

Some receivers like the super-sensitive Sony ICF-S5W are so prone to images that, on a night with decent propagation conditions, I can get a heterodyne on just about every frequency in the lower part of the band, meaning that even moderate-strength distant stations are enough to cause the S5W to produce an image. Using a passive loop in adjacent orientation, as I tune up and down the band on the receiver, I can tune the passive loop up and down as well to make the images disappear.

An added advantage to image and spur notching is that you can use another passive loop in facing orientation for gain. For example, with the Sony ICF-SW7600GR, during the day my strong local on 1590 creates an image on 680, obliterating a weak semi-local on this frequency. By notching out 1590 with an adjacent loop and peaking 680 with a facing loop (see picture at right), the weak station is easily heard, a feat I can't accomplish with just one loop, regardless of the orientation.

Summary

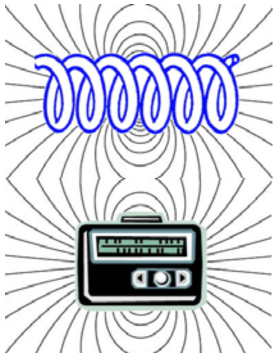
Whether you are using a stock UltraLight or the Sony ICF-2010, judicious use of a passive loop (or two!) can make a huge difference. Additionally, for those like me who like to use a Quantum Loop or similar as the primary antenna for a communications receiver, all of these techniques are available. Optimum results are typically obtained when you employ the largest, most selective (highest Q) loop possible, your space and budget allowing. However, as described above, even an inexpensive commercial loop can be very effective. To find out more about loop design and construction, the document "Air Core Loop Designs" provides information on and links to a variety of different designs, and is available at the DXer.ca web site in the Ultralight File Area. With all these tools in the toolbox, hopefully one or two will work for you in a given situation.

Good DXing to you!

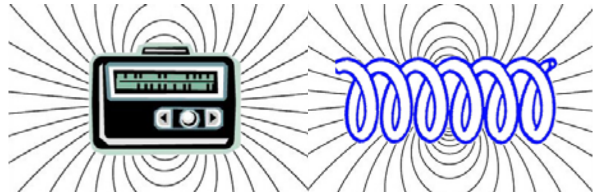
Kevin S.
Bainbridge Island, WA
October 2008
satya(at)sounddsl.com

Attachment 1

Below are depictions of the inductive coupling of receiver and passive loop in facing and adjacent orientations:



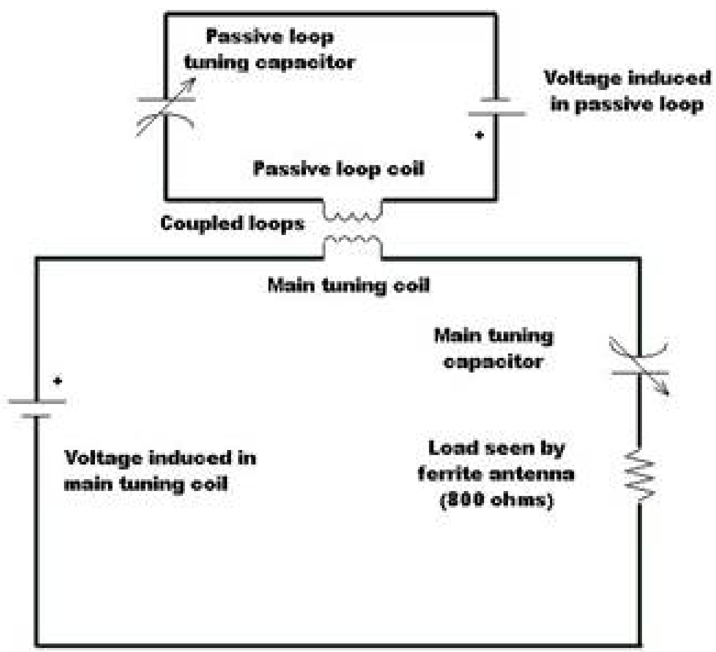
Facing Orientation



Adjacent Orientation

Mutual inductance occurs when the magnetic flux lines intersect. When the two coils are properly tuned, energy is transferred to the receiver's tuning coil from the passive loop's coil as the latter induces a voltage in the tuning coil.

<u>The Circuit</u>



The equivalent circuit of a receiver in proximity to a passive loop is shown at right. The two coils, when inductively coupled, act as a transformer to transfer energy from the passive loop to the receiver. As a result, the inductance and capacitance in the passive loop is "seen" by the receiver's antenna as a load which is in parallel with the sense coil load.

When in facing orientation, the dots on the transformer are on the same end, and in adjacent orientation they are on opposite ends. When the two units are decoupled, the mutual inductance factor (M) is zero, meaning that the circuit reduces to the simple RLC series circuit in the bottom of the diagram; otherwise, M appears to be on the order of 0.05 or less.

<u>Circuit Evaluation</u>

The resultant circuit was evaluated using Gene Preston's AC.EXE program, varying the tuning capacitance of the passive loop and the coupling of the two loops to simulate the various strategies. Below is an example of a loosely-coupled facing orientation simulation, which resulted in a peak/notch spread of approximately 10 khz:

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* Linear plot at node 5, 100 lines of data, max voltage of 15000, ranging from 950 to 1050 khz
LI 5 100  15000  9.5E5  10.5E5
*Receiver tuning coil induced voltage at Node 1, max voltage is 1000 units of voltage
VS 1 0    1000.   0
*Passive loop coil induced voltage at Node 4
VS 4 0    1000.   0
*Receiver tuning coil 250 uH
TF 1 2   250E-6  0
*Passive loop coil 250 uH, mutual inductance factor = 0.02
TF 3 4   250E-6  0.02
*Receiver capacitor tuned to 1000 khz
RC 2 5   2.    101.38E-12
*Passive loop capacitor tuned to 1000 khz
RC 3 0   2.    101.38E-12
*Sense Coil Load – assume the sense coil "sees" 800 ohms and transforms it to 50 ohms for the RF stage
R  5 0  800.    0.
```