Some Observations on the K9AY Receive Directional Antenna

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The K9AY antenna is a popular, compact receive directional antenna commonly used on the 80 and 160 meter amateur bands to improve the signal-to-noise ratio[1]. Some people have assembled this antenna, but have had difficulty in achieving an acceptable front-to-back ratio. This monograph provides a couple of suggestions that may improve the operation of the antenna. Test results by K5QY have confirmed the utility of these suggestions.

The K9AY antenna is a small antenna configured like a loop, with one end grounded. It is terminated with a resistor. Typically two such loops are erected, at right angles to each other. Only one loop operates at any instant in same time, the operator switches between the two loops to select perpendicular receive directions. The simplified operation of one loop (see Figure 1) is as follows:

1. If we consider the termination resistor to be open, then the antenna acts as a shortened monopole fed against ground. The pattern of this antenna is omni-directional.
2. If we consider the termination resistor to be shorted, then the antenna acts as a loop with an incidental ground connection. The pattern of this antenna is figure-eight.
3. A properly chosen value of termination resistor sums the two patterns above, and when chosen correctly produces a cardioid pattern – which is the desired receive pattern.

Over average ground, the cardioid pattern has a rearward null at about 45 degrees rear elevation. Attempts to use local sources to tune the antenna lead to frustration, because these local sources usually enter the antenna at a low elevation angle from the rear. Changing the optimum resistor value turns out to change the elevation angle of the rear null, but unfortunately also dramatically degrades the pattern of the antenna. Again, changes to the termination resistor value prove difficult to evaluate.

Simulations in NEC2 show that the pattern distortion induced by the resistor value can be compensated by introducing a series capacitor or a series inductor (depending on whether the resistor is decreased or increased from the nominal value. By adjusting the value of the resistor to alter the rearward notch elevation angle and simultaneously adjusting the series compensating reactance, a good cardioid pattern can be achieved over quite a range of resistor values.

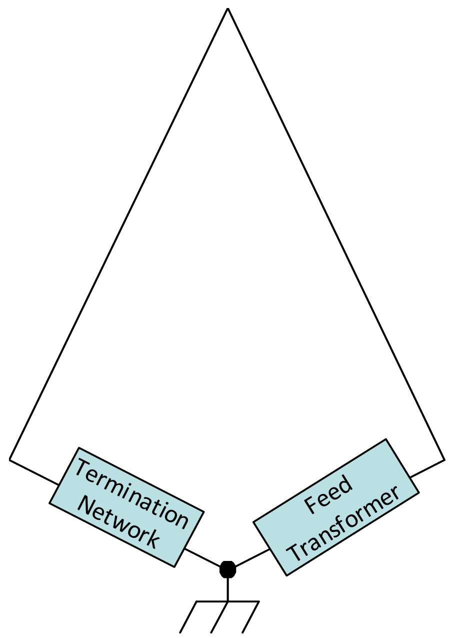

Figure 1 – K9AY receive loop – showing one of the two loops, and wiring to select only one of the two directions.

The choice of rearward elevation rejection angle may be desirable, or may be of personal preference. Figures 2, 3, 4, 5, and 6 show the pattern of the antenna for four different values of resistance and the corresponding value of reactance which has been chosen to clean up that pattern. These simulations were done on 160 meters. Simulations on 80 meters were not quite a good, and possibly the antenna dimensions may be slightly too large for 80 meter operation.

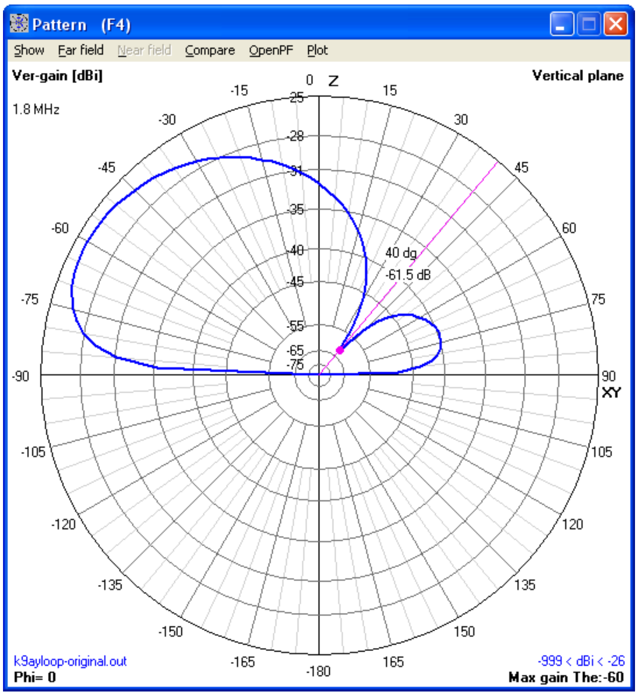

Figure 2 – Termination 420 ohms with no reactance.
Null angle is 50 degrees elevation (40 degrees below zenith).

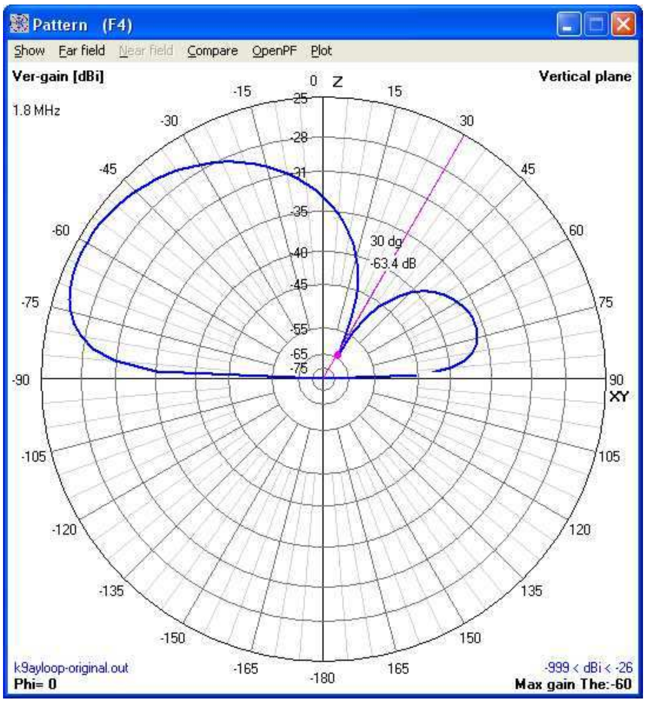

Figure 3 – Termination 500 ohms + 9 uHy in series.
Null angle is 60 degrees elevation (15 degrees below zenith).

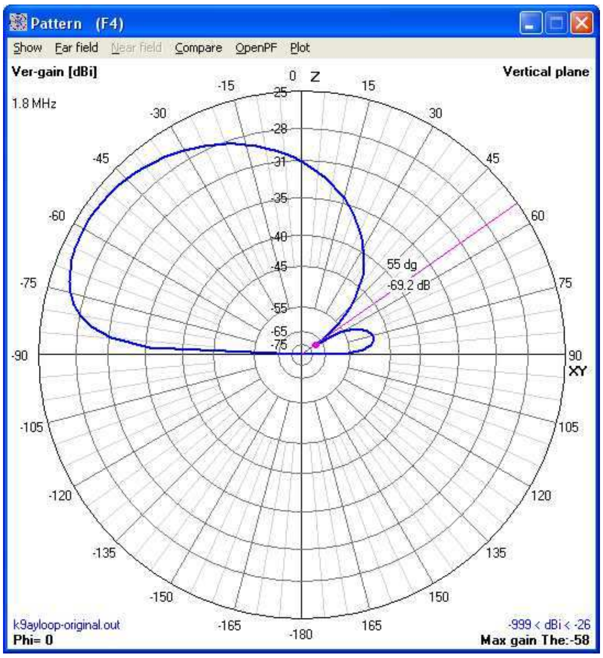

Figure 4 – Termination 350 ohms + 1000 pF in series. Null angle is 35 degrees (55 degrees below the zenith).

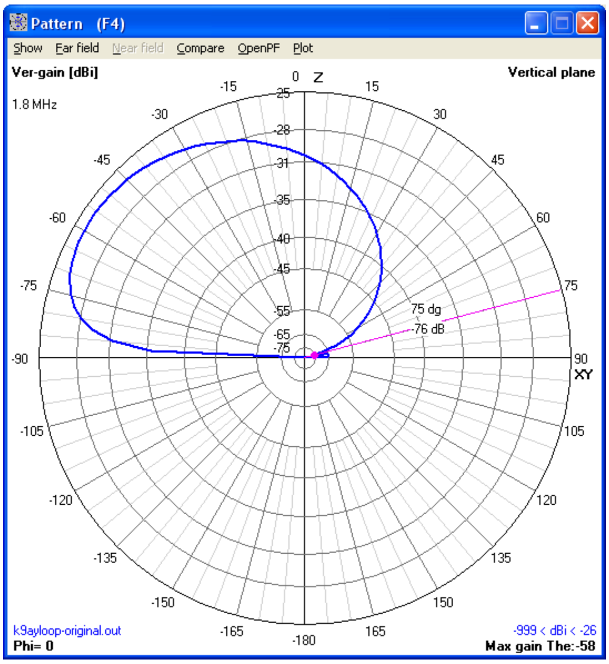

Figure 5 – termination 350 ohms + 750 pF in series. Null angle is 15 degrees (75 degrees below the zenith).

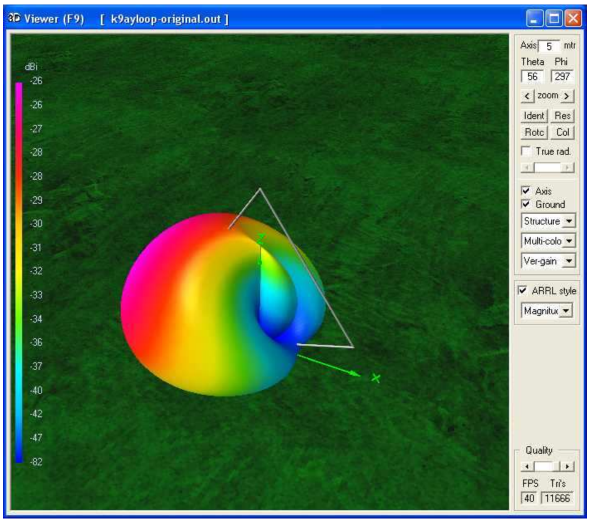

Figure 6 – Termination 350 ohms + 1000 pF in series. 3D pattern view. The pattern has a rear-null starting about 35 degrees rear elevation.

Another common problem is the method chosen to feed the K9AY antenna. Because the signal level from the loop is quite low, care must be taken to exclude other effects from overwhelming the loop response. One such effect is the choice of transformer used to couple the feedline to the antenna. A long length of feedline is itself a longwire antenna, although its efficiency is usually low since many times it's lying on or under the ground. Specifically, an autotransformer couples the K9AY response and the feedline-as-longwire antenna response together thus corrupting the pattern of the antenna. A fully isolated transformer is needed to assure that the feedline common-mode current has difficulty coupling into the feedline differential-mode response. Secondly, the winding style of the transformer is important at low frequencies to avoid adding a large amount of loss due to high leakage flux (and thus high leakage inductance) in the transformer.

The feedline is typically grounded at the receiver end, and the braid is grounded out near the antenna. If we ignore the center conductor for a moment, we see that the braid forms a wire antenna the looks pretty much like a terminated beverage antenna itself, although the height above ground is close to zero.

Figure 7 shows a typical receive antenna setup along with the feedline connecting back to the shack. A K9AY loop requires a ground connection. Typically, it's difficult to get less than about 10-25 ohms of ground resistance when putting in a ground rod, and this resistance in fact is common between the beverage antenna and the feedline.

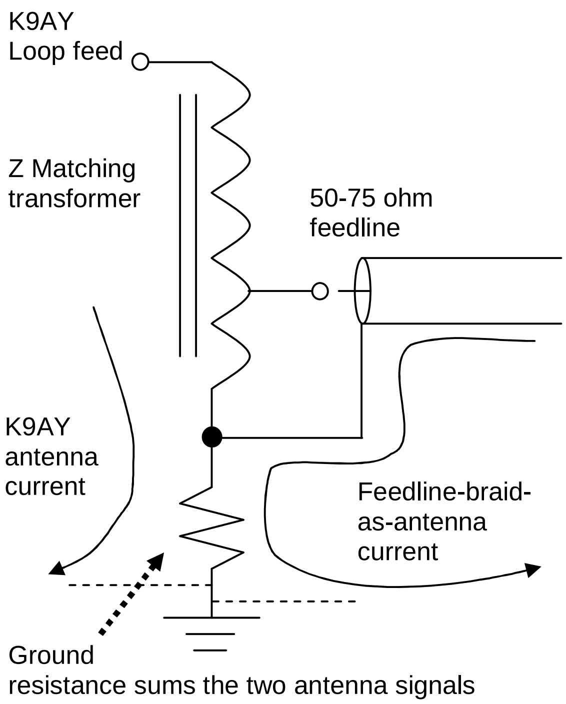

Figure 7—Poor approach to connecting feedline to antenna.

The K9AY antenna current and the feedline-as-antenna current both travel through the ground resistance, and thus resistively sum up at the input to the feedline. At that point nothing can distinguish between the desired antenna signal and the undesired feedline-as-antenna signal. We've destroyed the nice pattern of our receive antenna because the two antenna patterns overlap, and the front-to-back of the desired antenna is swamped with undesired signals.

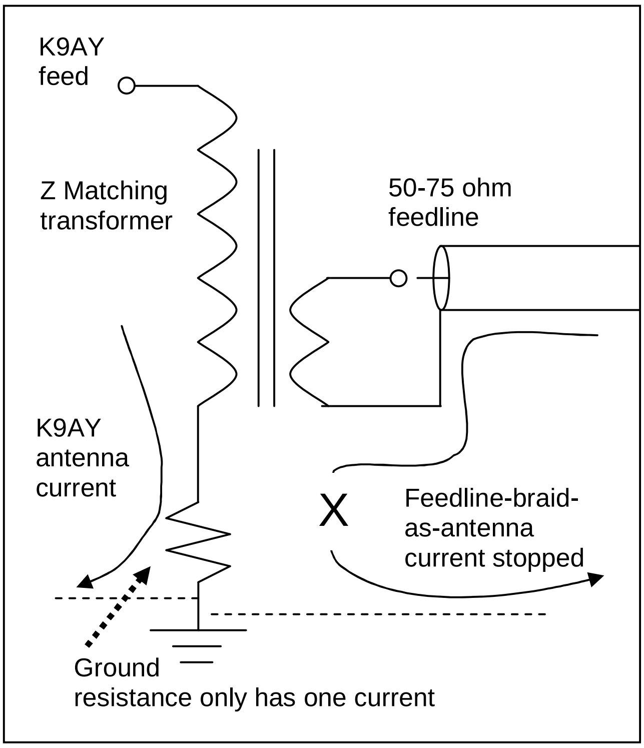

Figure 8—Better method to connect feedline to transformer.

We need to prevent the feedline from acting like an antenna. There are a couple of ways to do this, they rely on isolating the antenna ground current from the feedline ground current. One good approach is to use an isolation transformer to float the end of the feedline up from ground out at the beverage antenna. This same approach works for a K9AY antenna, which is also a ground-referenced antenna. Figure 2 shows the transformer connections that reduce common ground currents.

In figure 8, the transformer is wound as an isolation transformer rather than as an autotransformer. This means that the connection between the feedline braid and ground at the antenna can be cut loose, resulting in stopping the flow of feedline braid current through the common ground resistance of the ground rod earth.

While the design of the transformer is not too critical, there are some common misconceptions about preferred winding methods for isolation transformers, and one of the common techniques turn out to somewhat poorly suited for use on top-band.

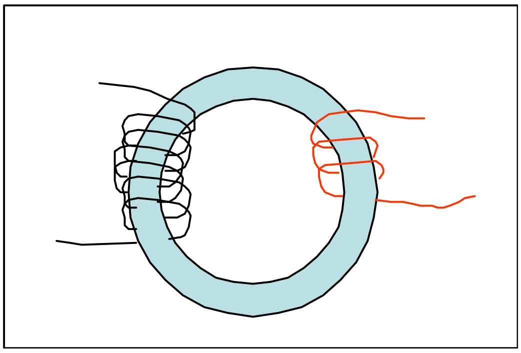

Figure 9—Lossy transformer winding method.

Figure 9 shows a transformer wound with the primary on one side of the core, and the secondary on the other side of the core. The idea here is that the stray capacitance between the two windings is reduced thus reducing undesired coupling. However in this type of transformer the magnetic flux couples poorly between the two windings, and thus a lot of leakage inductance is introduced into the circuit.

The leakage inductance acts as a series inductance and this forms an attenuator with the load impedance. The net result is that the loss through the transformer is very high—sometimes as much as 10-20 dB of loss at low frequencies. If the received signal is strong enough, this loss may not be noticed; sometimes it can be a problem.

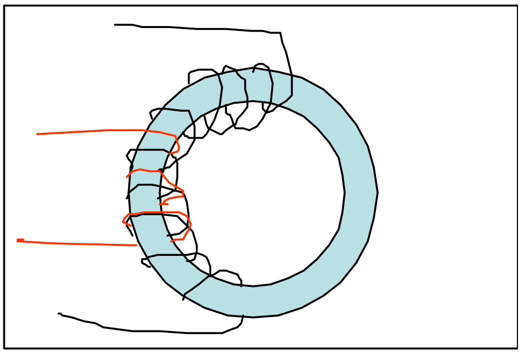

Figure 10—Less lossy transformer winding method.

Figure 10 shows a less lossy method to wind the transformer. The overlapping windings reduce the leakage flux substantially thus reducing the loss of the transformer due to leakage inductance. The inter-winding capacitance is slightly increased, but at 160 meters, it does not have too much impact (1 pF is about –j88,000 ohms which causes minimal leakage).

For the transformer to work well the core losses should be low and the permeability of the material should be relatively high in order to minimize the number of turns needed on the transformer core. If more than about 15-20 turns are used in an RF transformer the performance often suffers.

Type 61 or type K ferrite material would be a good choice for this application due to the low losses and the high permeability of the core. Type 31 ferrite material might not be as good a choice since it is intended primarily for EMI suppression applications and thus has a high resistive loss component in this frequency range.

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[1] "The K9AY Terminated Loop—A Compact, Directional Receiving Antenna" QST, September 1997, pp 43-46, Gary Breed, K9AY.