Crystal Radio Engineering
Antenna Matching

by Kenneth A. Kuhn
March 1, 2008 (draft)

As discussed in an earlier chapter the ten to thirty meter antenna used for crystal radios has a very low resistance and a high capacitive reactance. The ground resistance discussed previously is typically in the several tens of ohms and is effectively in series with the antenna. As an example, an antenna/ground system may have an impedance of 20 –j1000 ohms at 1 MHz. For maximum power transfer from the antenna to the resonant circuit the input impedance of the set should be a conjugate match – that is have similar resistance but the reactance will be equal in magnitude but opposite in sign. For the example this means that the crystal set should have an input resistance of about 20 ohms and a reactance of about +j1000 ohms (160 uH) at 1 MHz. The positive reactance is obtained by an inductance in series with the antenna circuit. This inductance should be variable to tune out the capacitive reactance of the antenna across the AM broadcast band. Tuning is not sharp as the Q of resonance is low. Table 1 shows some typical values. Note that the inductance tuning range becomes wider for longer antennas since the capacitive reactance drops rapidly as the length approaches one-quarter wavelength at the upper end of the AM band. It is important that this series inductance have very low losses or the advantage of using it will vanish – a lossy inductor could be worse than nothing.

Antenna Length	**Typical Antenna XC @ 550 kHz**	**Typical Antenna XC @ 1.7 MHz**	**Antenna series Inductor tuning range**
10 m	-j4040 ohms	-j1250 ohms	1200 – 120 uH
15	-j2680	-j780	780 – 70
20	-j1990	-j530	580 – 50
25	-j1580	-j360	460 – 30
30	-j1290	-j240	370 – 20

Table 1: Antenna series inductance tuning range

One effect of not tuning out the reactance of the antenna is that the resonant frequency of the tuned circuit will shift because the antenna becomes a reactive load. One way to know if the series inductance has been tuned to the right value is that the station is received at the calibration point – assuming the radio tuning was calibrated.

The next issue is creating a low input impedance of several tens of ohms. There are two ways to do this and they are essentially the same. One method is wind a turn or so of wire near the ground end of the coil of resonant circuit – one end of the wire goes to the series inductor to the antenna and the other end connects to ground. This small winding transforms the low antenna/ground impedance to a high impedance across the coil. The other method is to make a tap a turn or so above the ground end of the coil of the resonant circuit to accomplish the same effect. If the winding or tap is too few turns then there is an impedance mismatch and a weak signal will result although selectivity will be relatively sharp. If the winding or tap has too many turns then the coil is overloaded by the antenna/ground impedance which also results in weak signals and the selectivity will be broad. The optimum is the point of proper impedance match although it is not very critical. The issue is how to determine the proper point. A second issue is that the required impedance level varies across the AM broadcast band. Thus, the tap should be variable.

If the coil is wound on a ferrite toroid core which enables a high degree of flux coupling from turn to turn then it is fairly easy to calculate at what turn a tap should be for the desired impedance transformation. However, our coil is typically an air-core solenoid which has a complicated flux relationship. Calculation is difficult and very error prone. The best way is to make a variety of taps and measure the impedance using laboratory methods and note the results. I will present the data of just such an experiment on a typical coil for crystal radios when this article continues …