Building a CCD Antenna

By Joel C. Hungerford, KB1EGI

INTRODUCTION

This month I set out to build a CCD antenna, consisting of several series tuned circuits all resonant at the same frequency, but with each section L/C ratio varying along the antenna to mimic the effective impedance of a dipole: high impedance at the open end, and low impedance at the center.

The first section I built was the one representing the open end, using a small C and a large L wound on the end of the PVC pipe. The pipe is about four feet long and I envisioned an antenna wound on the pipe and fed in the center. At about the same time, the antenna discussion forum featured comments about the capacitance of a sphere in space: A capacitor is a region of space that contains energy stored in an E field.

The conducting charged sphere in space is a capacitor with one terminal at infinity and the other at the sphere. If I change the charge on the sphere somehow, the "news" of that change propagates outward at the speed of light as a change in the E field. That sounds like an antenna to me—so I built a spherical end as the capacitor in the highest impedance section of the antenna.

A TESLA COIL EMERGED

I then found that 42 turns of wire wound on the pipe resonated nicely at 7 MHz. The combination is a "Tesla Coil" resonating at 7MHz! I connected the coil wire to the center connection of the antenna analyzer's input and it tuned to 7 MHz with an impedance of around 30 ohms resistive and 20 ohms reactive!

Next, I considered the middle of the antenna, where the reactance is lowest. The series tuned circuit has a low L/C ratio—at the extreme, it is a big capacitor and a few inches of wire. The shortest possible antenna would result if just these two tuned circuit sections were connected on each side of a dipole configuration –with a big mica capacitor for tuning. It turned out that making the wire half the distance left on the pipe after the two Tesla coils are wound required about 400 pf to resonate at 7 MHz.

But that resonant circuit would normally be regarded as just a coupling capacitor! It has very low Q, stores no energy, and contributes nothing to the antenna selectivity.

At that point I began to think rather abstractly about Tesla coils, devices with terminals at infinity, the functional parts of a dipole, and the many variations of capacitor antennas like the Isotron, etc. My cats would wake up with the first birds at some very early hour and decide that I needed to feed them, so they would hold a convention in my bedroom (Dogs have owners—Cats have staff!).

Once awake, I pondered the subject while delaying getting up. The dipole is a resonant, lossy (thru radiation) structure. As such, lots of energy is stored reactively in the surrounding fields, with half the stored energy held in the E field of the capacitor on the dipole ends and half the energy stored in the magnetic field associated with current in the center. The center current is all going in some unique direction during the RF cycle — there is no almost canceling counter current like in a loop antenna because the dipole has electric energy storage regions at each end to send or absorb the current. The dipole achieves what is otherwise impossible — an isolated region of current going in one only direction. Like the sphere, it stores energy in the surrounding space and another wire at infinity can "know" of the presence of the center current magnetically. That also sounds like an antenna!

DIPOLE ESSENCE

I began to realize that the dipole gets its high efficiency of radiation because the energy from a transmitter is stored sequentially in the fields of the dipole alternately as electric energy, then as magnetic energy, then electric etc., and all of these fields terminate or exist at infinity due to the nature and shape of the storage structure. The unique way the dipole makes the unidirectional current element by cycling the current between two electric storage elements forces the dipole to be an AC radiator because the current in the center cannot continue at a static level—the electric storage regions reach a finite high voltage level during the AC cycle limited by the energy of the transmitter. So the dipole is doing more than just the impedance transformation of the CCD antenna — it is also transforming the method of storage from electric (voltage) to magnetic (current), whereas the impedance transforming of the CCD concept is only a change in the voltage level. Hence, we need a circuit that does both.

The circuit placed in the center should be the **dual** representation of the Tesla coil. A dual of a circuit is another circuit that results when one replaces the circuit elements with new elements whose admittance (=1/impedance) is the same numerical value. Thus, high resistance devices become high admittance devices, inductors become capacitors and capacitors become inductors. Resonators stay at the same frequency. After sorting out the equations, series circuits become parallel admittances. Needed in the center is a parallel tuned circuit, not a series tuned circuit.

It became clear that, by themselves, Isotrons, Tesla coil antennas and loops are only half of the dipole process. They are missing the duality conversion and the unidirectional current and therefore are low efficiency radiators—only working at all if the dual element is added by a radiating feed cable or structure.

I wound a small 5 turn coil in the center of the PVC pipe — it tuned to 7 MHz with an available variable C in parallel with the coil — and clip-lead connected it to the Tesla coils — the combination resonated to 7 MHz with a 9-ohm resistance at resonance.

I made the coil a transformer by adding a second coupled coil and a balun to change the drive from unbalanced to balanced. The whole device could easily be adjusted to a 50-ohm resistive match by changing the turns ratio. At resonance, the analyzer “transmitter” can be touched and nothing changes, but all the other storage parts of the antenna are very “aware” of the presence of nearby objects that change the storage of energy. (The Tesla coil ends changed tuning 400 kHz when I brought them up from the crowded basement and put them on a plastic table in the open living room.)

Where am I going with all this? I am looking for “cookie cutter” functions that can be looked for in a candidate design for an antenna to assess its probable efficiency. The same criterion can assist making the design of a “new” antenna complete. I will use the functions I have outlined to design an antenna; the appropriateness and completeness of the functions idea will be shown or disproved by how well it works.

Figure 1

Figure 1 shows the dipole simulating CCD antenna on the plastic table in the living room. **Figure 2** shows one of the Tesla coil ends, surrounded by 2 members of the engineering staff. The sphere diameter is 14 inches (35 cm), made of hoops of #6 copper wire. These were the wire loops used in the loop study. The ends of the wire are bent to form a 1 cm “hook” sticking out from the loop circle. I found that the 8 ends of four hoops would fill a ½ inch copper pipe to ½ inch threaded pipe adapter. The 4 hoops are arranged about 45 degrees apart and the lot soldered together. The tops of the loops are also soldered together. The result is a nice conducting sphere that can be screwed into a threaded end adapter fitting the PVC pipe. The adapter and sphere can be pushed onto the pipe containing the coil, and easily removed to enable working with the pipe and coils alone.

Figure 2

Figure 3 shows the center resonating coil (white) and the primary of the transformer (black) along with the tuning capacitor, the balun, and the antenna analyzer. **Figure 4** shows the circuit diagram of the antenna.

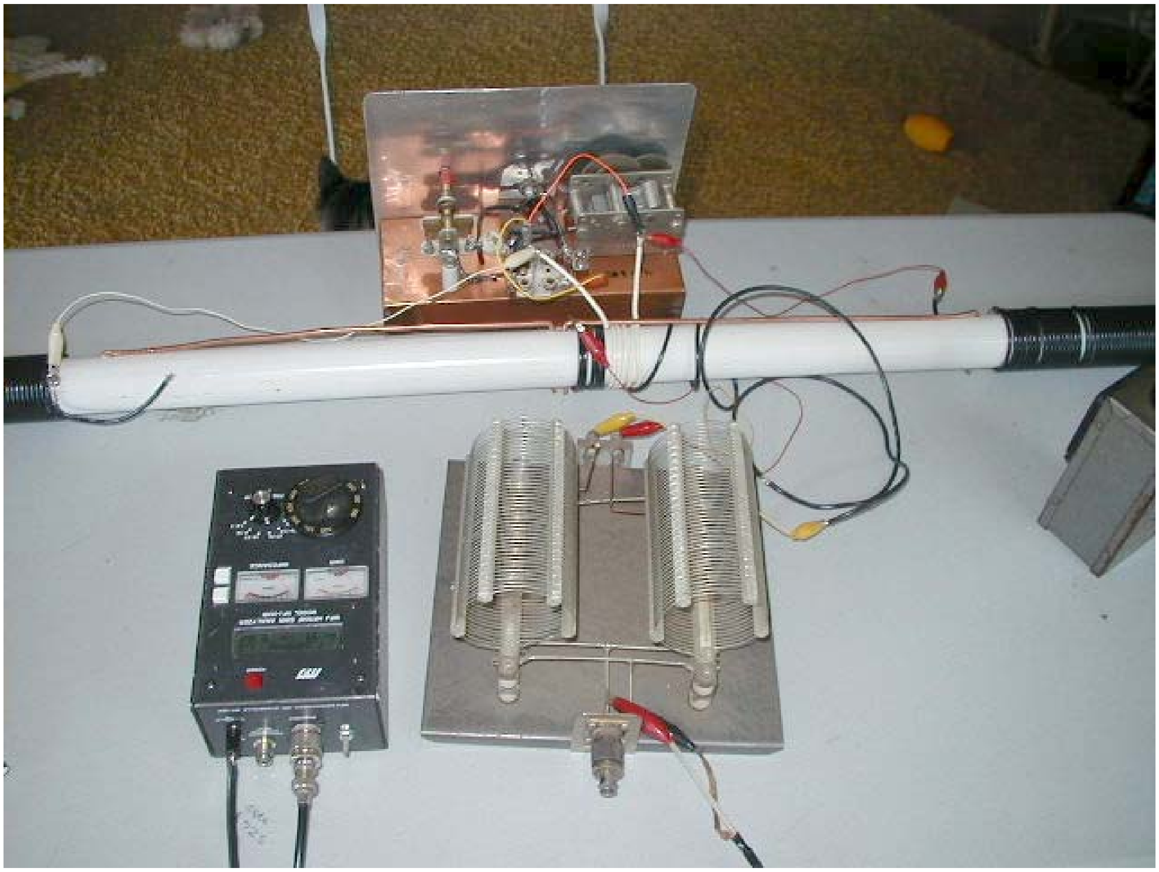

Figure 3

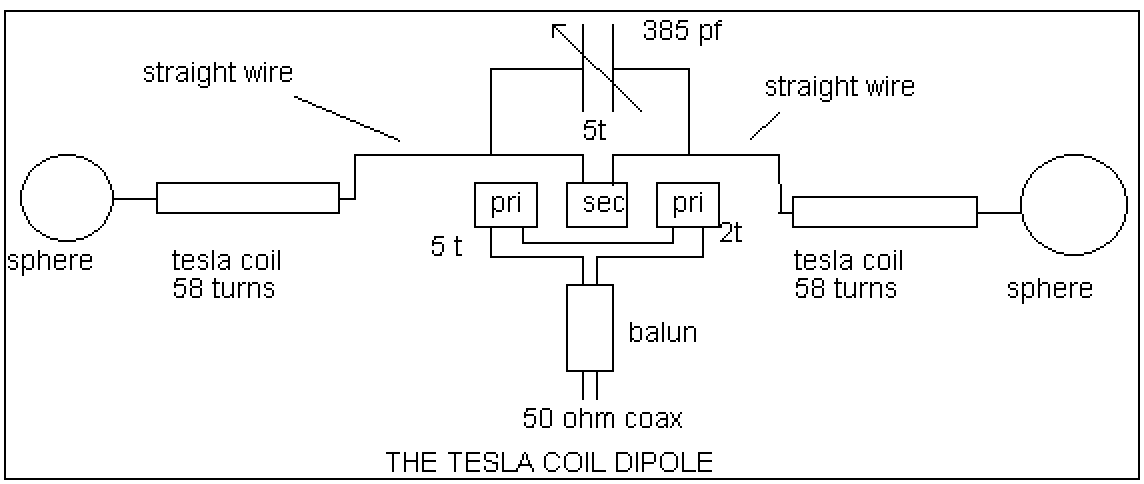

Figure 4. The schematic of the Tesla coil dipole antenna

The resonating coil has merged with the white pipe in **Figure 3**, but the two leads can be seen pointing toward the tuning capacitor. The primary of the parallel resonating transformer is split, and half (5 turns) wound on each side of the tuned coil, with one additional turn passing over the white tuned coil to link the two sides of the primary. The two straight pieces of #6 copper wire lying along the pipe will connect the ends of the resonating parallel tuned circuit with the Tesla coil ends, and function as the unidirectional current regions of this antenna. The small gaps in the Tesla coil happened because 16 more turns had to be added to re-resonate the Tesla coils to 7 MHz when they were brought into the open living room.

One strange thing happened when the transformer primary was changed to adjust the match to the balun. Eleven turns resulted in a matched resistance of 34 ohms loading the balun. I computed that 2 more turns would increase the turns ratio between primary and secondary to give the desired 50 ohms match. Putting on the turns resulted in a **decrease** in the impedance as seen at the balun input instead of an increase. I then unwound turns on the side of the primary to the right in **Figure 3** until the balun input read 50 at resonance. Evidently the balun inverts the change in impedance — lowering impedance at the balanced output raises impedance at the unbalanced input.

I was curious how much the two Tesla coils coupled. In this data, they are not matched, and the two coil inputs were just tied together at the antenna analyzer input. The two tuning curves were plotted, then one coil was carefully disconnected at one end, and the coil rewound in the opposite direction, all without moving the whole assembly (it’s sensitive to its surroundings). The tuning curves were then re-plotted. **Figure 5** shows the data. Reversing one winding, which would increase or decrease the net inductance, moves the frequency about 100 kHz, much less than the resonance moved when the whole thing was moved to the open living room. The single spot data shows the effect of touching the antenna analyzer box at resonance, showing that the parallel tuned circuit and balun are necessary to stabilize the antenna tuning and allow any length of coax feed.

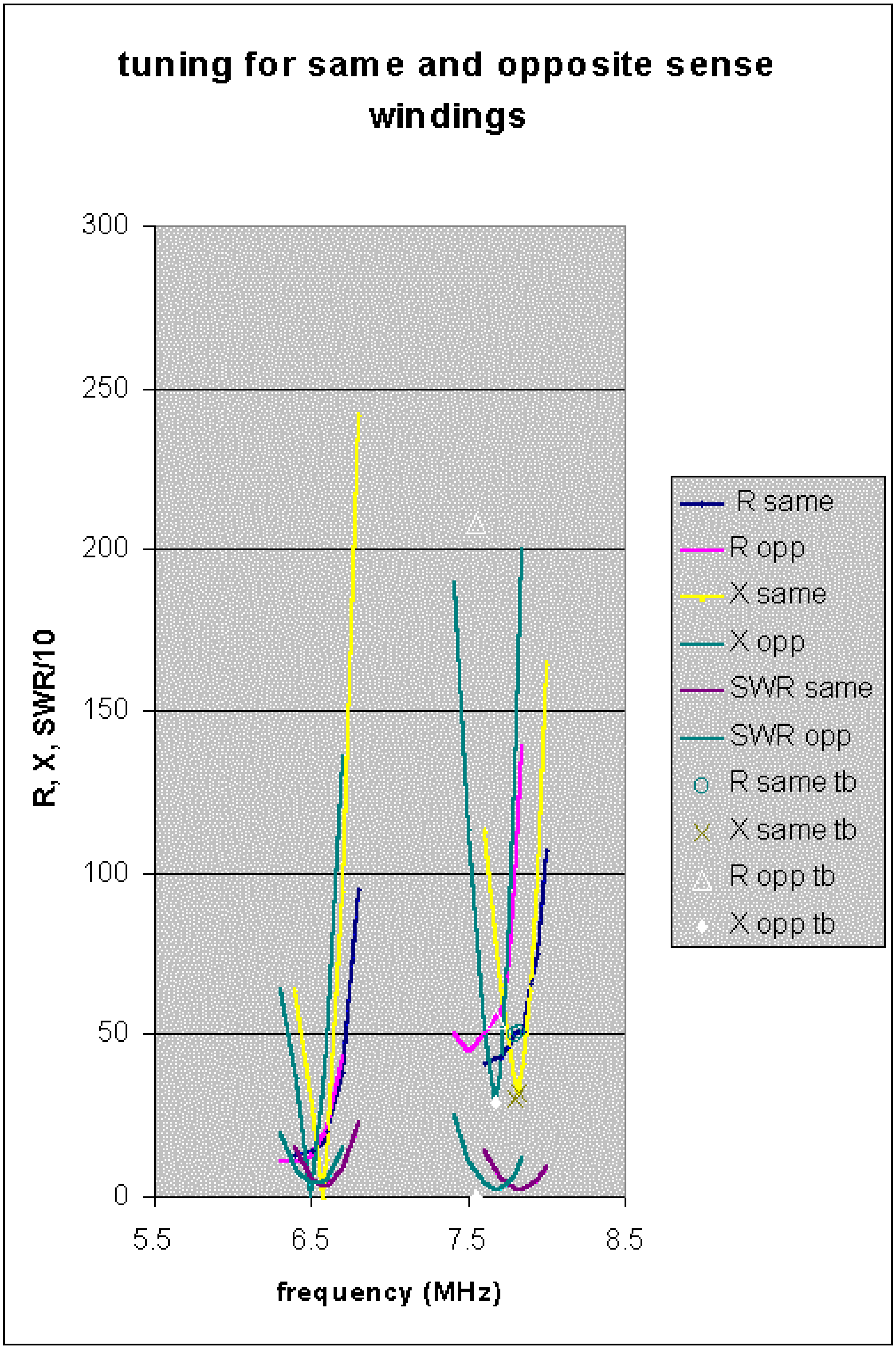

Figure 5. This figure shows that there is a small amount of coupling between the coils "tb = touch box"

The antenna at this time is wired together with clip leads.

COMING UP

Next I shall harden it so it can be hung in space on a rope to see if it will radiate and how well. **–30-**

Brief Biography of Author: Joel C. Hungerford, KB1EGI
1958, Bachelor of Science Degree at Massachusetts Institute of Technology
1962 Masters in Science at Purdue University

Worked for 16 years designing electronic countermeasures against monopulse and pulse compression radars, including remote means of bending the radar's antenna pattern, and have designed and built an instrumentation radar.

Worked for about 15 years as an electronic consultant designing and troubleshooting microwave anechoic chambers using chamber simulation computer programs I wrote for the purpose. Designed and built (I have a machine shop) test fixtures to measure the electronic properties of materials and absorbers. Have written computer programs to do stock market analysis and to encrypt documents using simulated rotor machine coders.

Was first licensed as W9TPH in 1952, then K1ZLJ but let it lapse in the 1960's. Later, retested and passed General Class and then Extra Class a few months afterwards. After relocating from the East Coast to the West Coast in Oregon, USA, now, having put the ocean on the left instead of the right. Am interested in compact antennas to fit in my postage stamp of land looking out over the Pacific Ocean.

Active member of the GARDS since 1999 involved in research of smaller devices with this International group.

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