Small Receiving Loops

Small loops are often referred to as "magnetic radiators". Folklore claims a small "shielded" loop antenna behaves like a sieve, sorting "good magnetic signals" from "bad electrical noise".

Nothing is further from the truth! At relatively small distances a small magnetic loop is more sensitive to electric fields than a small electric field probe.

Field Impedance

The ratio of electric to magnetic field sensitivity is sometimes called or can be described as the "field impedance". In the near field region, a ***high field impedance*** indicates a dominant electric field. A ***low field impedance*** indicate has a dominant magnetic field. The field impedance actually varies with distance when close to the antenna, and it can also vary with direction or angle.

Although fields have different ratios close to the antenna, at distances of ***about λ/2 the field impedances of all but very large antennas are virtually indistinguishable from each other***. Once we understand the basics, we might picture our antennas differently. We might find antennas don't respond to signals and noise like we thought. Best of all, we won't be as susceptible to the "noise" caused by rumors and folklore!

Loop Antenna Fields

It is the induction field response within λ/10 distance from the antenna that gives small "magnetic loop" and "electric dipole" antennas their names.

Very close to a small loop antenna (but not necessarily near the open ends of the small loop where the tuning capacitor is) the magnetic field dominates. Current is essentially uniform all around the loop circumference, while voltage has a nearly straight-line increase as we move to the tuning capacitor area. Since most of the loop area has uniform current and only a small concentrated area has the highest voltage, the magnetic field clearly dominates over most of the loop area.

Magnetic fields are effects derived from the actual moving of charges (current flow). The magnetic effect is related to current, and if it is proportionally large compared to voltage or capacitive coupling the field is described as having a "***low***" impedance. This is similar to the description used in circuits, where a system with high current and low voltage is said to have "low impedance".

Short Dipole or Vertical Fields

Near a small open-ended dipole or monopole the electric field dominates. A short antenna has very high voltages (compared to current) all along it's length. It normally has highest current only near the feedpoint, with current tapering or reducing in a straight line (linear fashion) to zero at the antenna's open end. It is the electrical compliment of a small closed loop. The dominant coupling to objects immediately next to the antenna is from the very high voltages that appear all along the antenna, which we can also consider as capacitive coupling. We say the antenna has a "***high field impedance"*** right next to the antenna, and we might call it a voltage probe or e-field probe antenna.

In the electrically small antennas, such as the loop antenna and the sort dipole or vertical described above, the dominant field descriptions only apply within λ/10 distance! You'll see why as you read further.

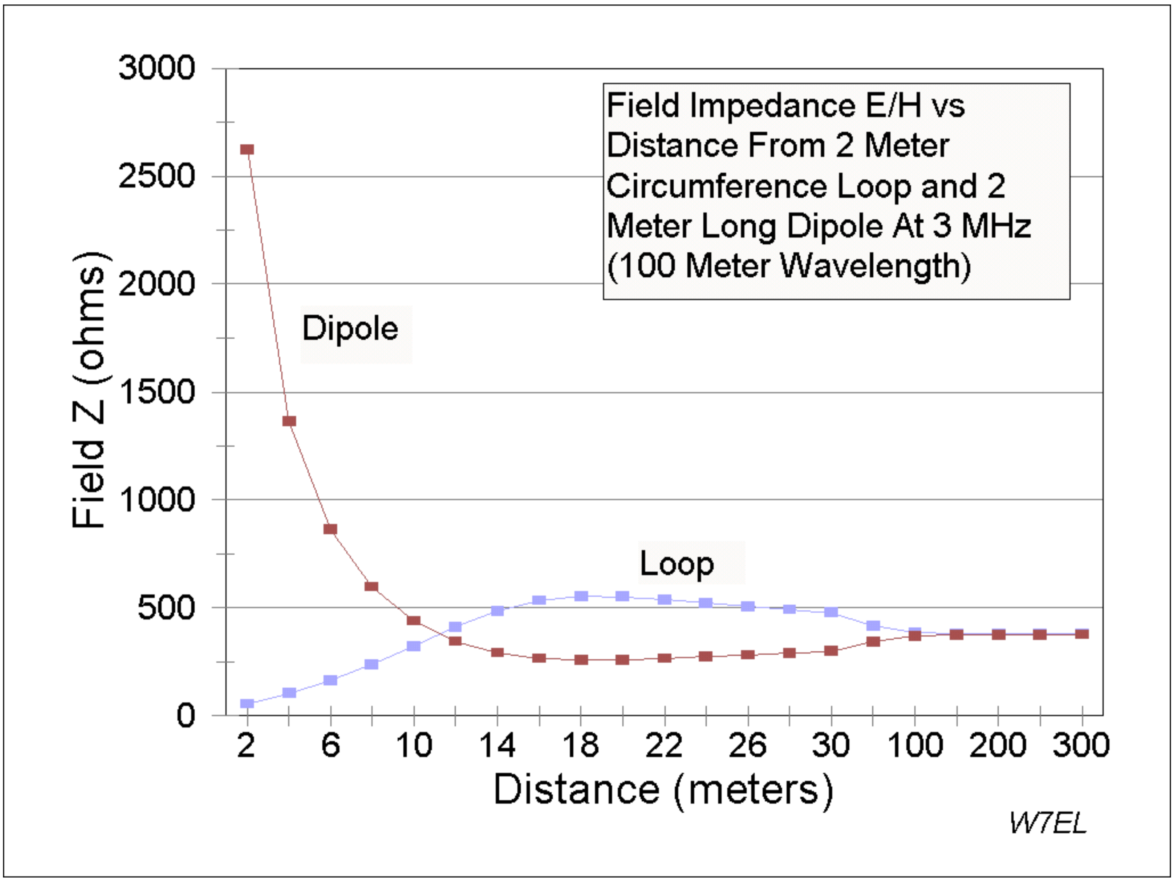
Radiation

The induction fields very close to the antenna that I described in the text above are NOT what radiates or receives at a distance. The induction effects are a necessary and unavoidable result of:

1. Uneven charge distribution (a difference in voltage) causing a physical force on other charges. We call this effect the **electric field.**

2. Moving charges (a current) causing a force on other charges. We call this effect the **magnetic field.**

Signals from any real distance are coupled by a third totally different charge interaction at distance. ***Acceleration*** of charges causes a very unique force on other charges in the Universe. We call this effect ***electromagnetic radiation*. I**t is a totally different effect, and it is **independent of induction fields.** This is the only effect or force that works to move charges at a very large distance, and it cannot be created by mixing induction fields. (See CFA or EH antenna hoaxes.)



This graph shows the field impedance at various distances near a small dipole or loop. Since the distance of a wavelength in the above graph is 100 meters, we can considered the bottom scale as the percentage of a wavelength. We can see at about 11 percent of a wavelength (which would be about 60 feet on 160 meters), there is no difference in field impedance between a small loop and a small dipole. At distances beyond 11 percent of a wavelength or about 60 feet on 160 meters, the magnetic loop actually has a ***higher*** field impedance than a dipole. That means a magnetic loop is actually electric field dominant at a very modest distance in the near field area.

If the noise source is coupled to the antenna within a distance of about 1/2 wl or so, you might find a difference in noise coupling between the short dipole and small loop systems. At larger distances, only directivity and polarization would make a difference.

So much for the myth that a receiving antenna can sort good signals from bad signals (noise) by virtue of being "magnetic"! We not only don't have the field response we might have imagined, we also almost certainly have no idea if close-by unwanted noise or signal sources are radiated from electric or magnetic field dominant sources. Successful noise reduction by virtue of by antenna "style" would mostly be a matter of hitting a lucky combination through experimentation.

Loop Shielding and Balance

Loop shields do not sort noise out, nor do they prevent electric fields from affecting the antenna. They do not change the field impedance of the antenna. For a description of how shields work, look at the Concentric and Coaxial Transmission lines page and also **skin depth**. You can also read a few pages of **"Transmission Lines, Antennas, and Waveguides"** (no longer protected by copywrite) that deals with loop shielding and balance.

From those pages you will see the shield actually becomes the antenna in a "shielded" loop.

There are many construction articles about small loop antenna available. It is *VERY* important that all conductors exit the loop at the ground point of the shield, and that the loop is grounded exactly at the electrical center of the shield. The loop must also be symmetrical, each side must be excited equally, and you must mount the loop so the feedline and any metallic supports leave the center area of the loop with maximum symmetry. If you DON'T do this, the loop can actually use the feedline as the antenna. This can greatly increase sensitivity of the loop to conducted noises! Improper design or construction can also distort the pattern.

Remember the following guidelines:

- The shield is the actual antenna
- The shield must be perfectly symmetrical away from the inner wire exit point
- The gap in the shield must be exactly opposite the grounded point
- The ground must be at the inner wire exit point
- The shield will not make an unshielded loop that is properly balanced any quieter
- ***The shield only is a tool to help you balance the system IF the shield is properly implemented***

Examples of Small Loops and Analysis of Loop Construction

From my 1988 ARRL Handbook

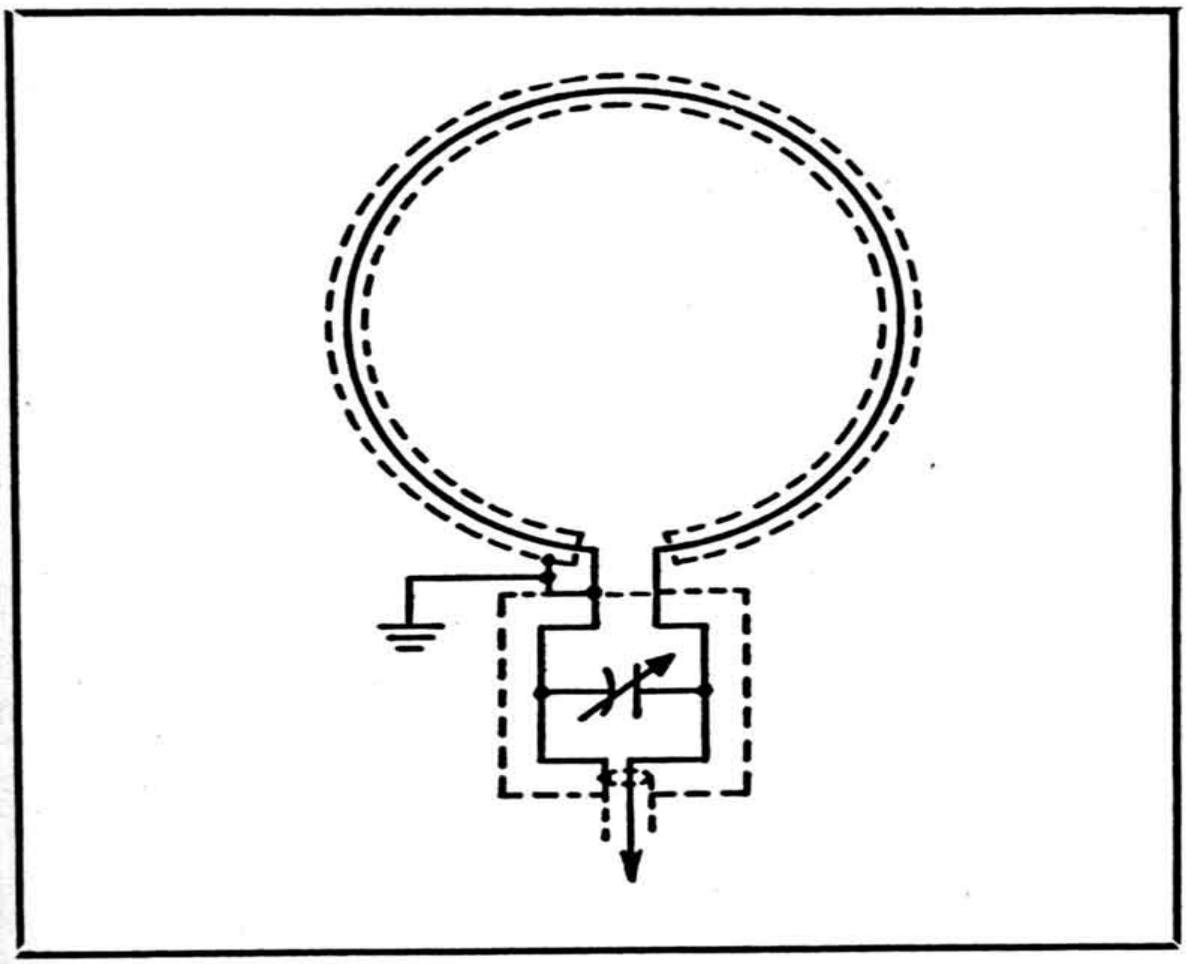


Fig. 2 — Shielded loop for direction finding. The ends of the shielding turn are not connected, to prevent shielding the loop from magnetic fields. The shield is effective against electric fields.

Good Points:

A moderately good feed system, although no ability to match impedances is included. Notice the coaxial feedline feeds each terminal of the center conductor in differential. It does not feed the terminals in parallel or with one terminal hanging loose as some loop designs do.

Bad Points:

Overall, this is actually a ***poor design*** and it includes a very ***poor description of operation***.

First, the shield doesn't shield or filter the time-varying electric field. It cannot do so without also removing the magnetic field. Since neither the electric or magnetic field passes through the many skin depths of shield wall thickness, any claim the shield passes one field and limits the other is wrong. The mechanism of field behavior is described in detail in Concentric and Coaxial

Transmission lines and **skin depth**. pages.

- **EM fields excite the shield's outer wall.**
- **Skin effect isolates the outer shield wall from the inner shield wall.**
- **The current on the outside of the shield produces a voltage (EMF) across the open gap in the shield, and that voltage in turn excites a current flow on the inner wall of the shield.**
- **The current flowing on the inner wall of the shield creates a current in the inner conductor through induction field coupling, and that current (and voltage) is coupled to the receiver feedline.**
- **The inside of the loop is a simple transformer, the gap is the feedpoint, and the outside of the shield is the antenna.**

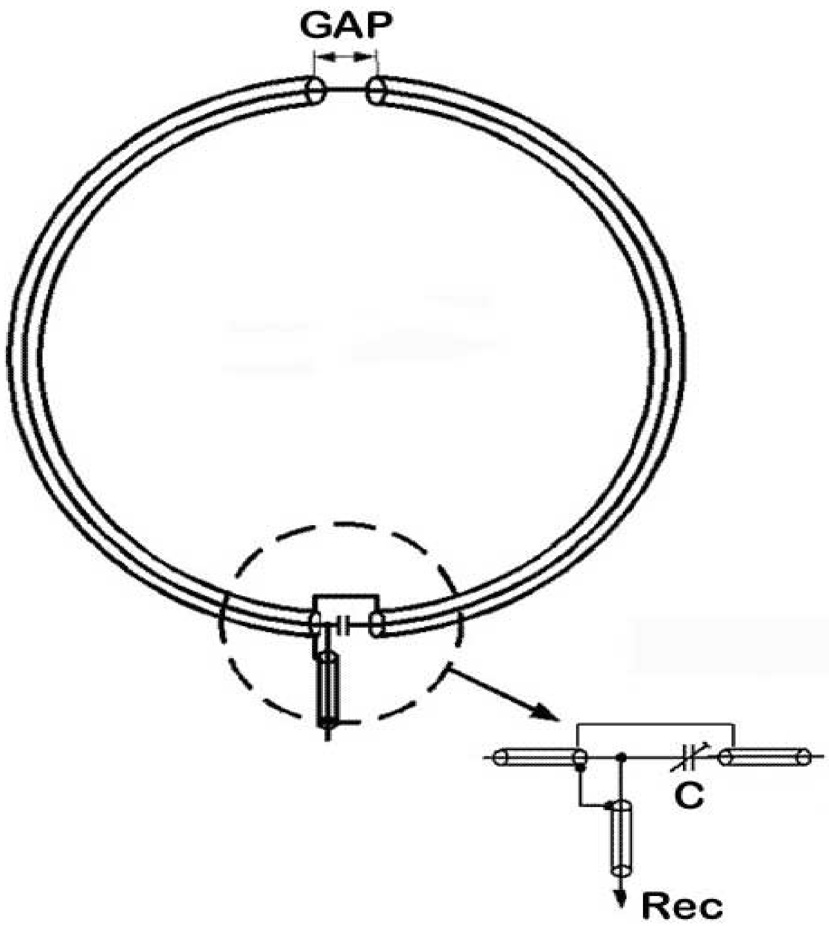
The flaw with the ARRL Handbook's DF loop pictured above is the shield is not symmetrically placed with reference to ground, and so it is susceptible to common mode or parallel currents. The shield arrangement in this case actually ***unbalances*** the loop.

This loop could be corrected by moving the shield gap to a point exactly opposite the feedpoint "ground". Each half of the loop would be symmetrical on the outside.

The next design cures the shield symmetry problem, but creates an additional unnecessary problem inside the cable in the process.

Typical Magnetic Loop (found on Internet and other places)

This loop probably works better than the ARRL Handbook loop above, although still not optimally designed.



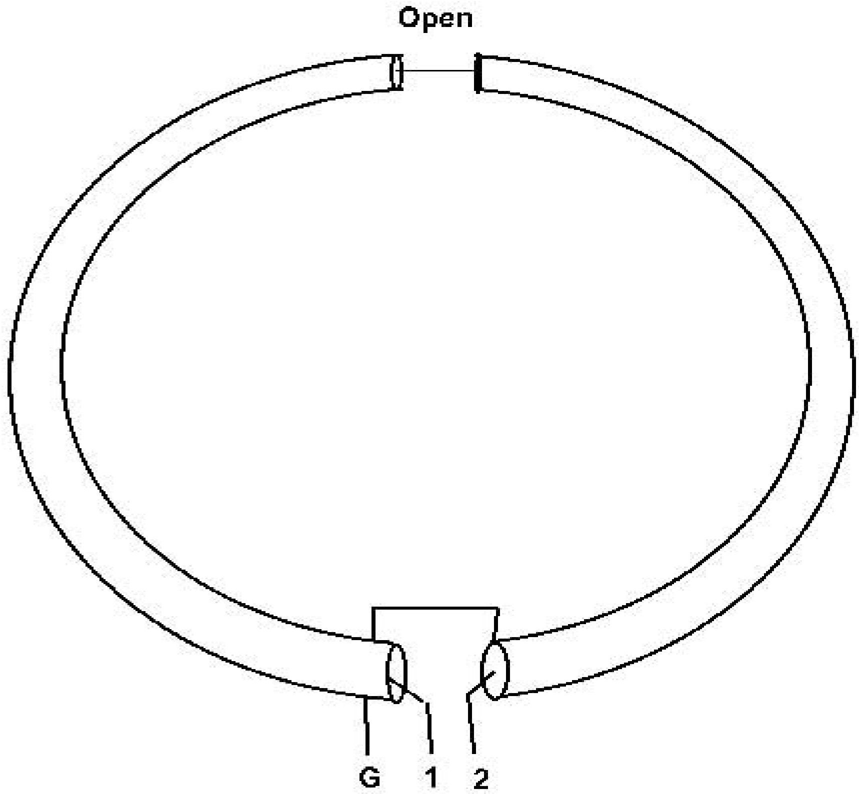
Good Points:

The shield is symmetrical in reference to the ground point. Since the shield is the actual coupling mechanism or antenna, it must be symmetrically distributed to prevent acting like an extension of the feedline. Shield design is excellent.

Bad Points:

- No impedance matching
- Susceptible to cable variations since the coax connection to inner link conductor depends on capacitance inside cable for coupling.

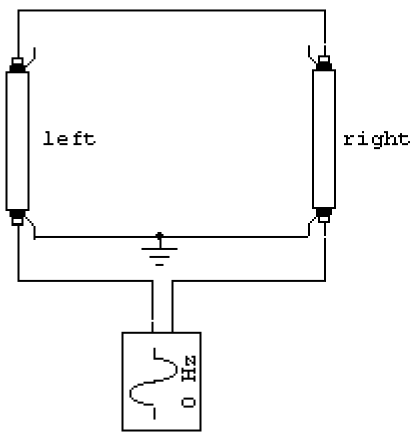
If we look at how energy transfers from the inner conductor to the feedline closely, we see an inherent design problem. Let's look at the ideal coupling method:



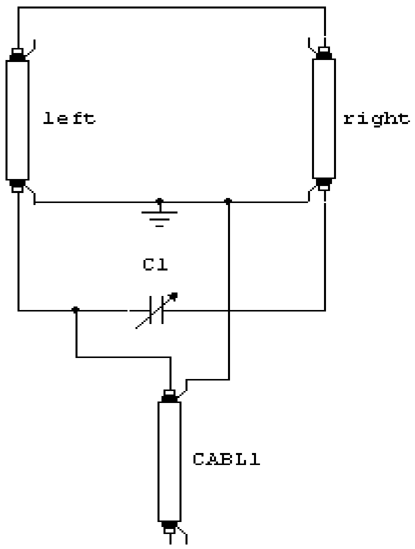
G always has to be referenced to ground or an electrical neutral or zero voltage point.

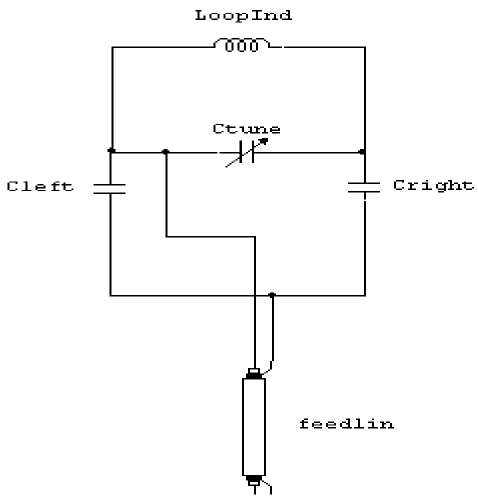
1 and 2 are fed differentially. It is the voltage difference between 1 and 2 that causes current to flow around the internal conductor. Ideally terminals 1 and 2 should have about the same voltage level with respect to G but opposite polarity voltages (balanced) in reference to G. This would ensure each half of the loop exterior wall is excited with reasonable symmetry.

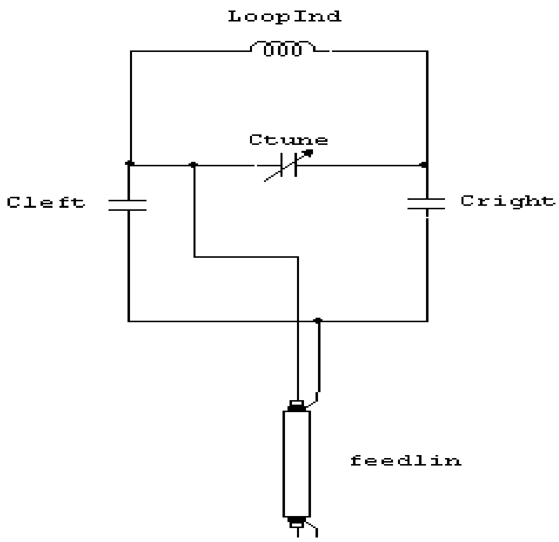
Circuit Representations of Shielded Loops



Shown above, ideal differential excitation of the inner conductor

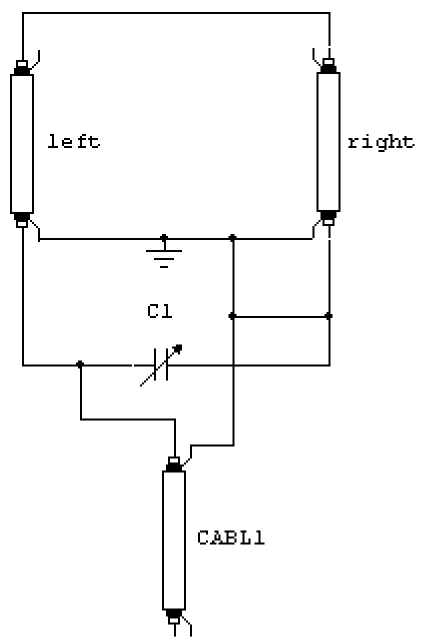


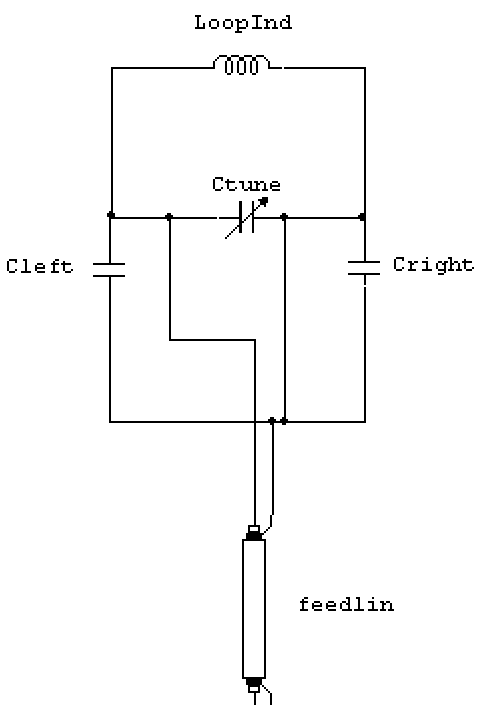




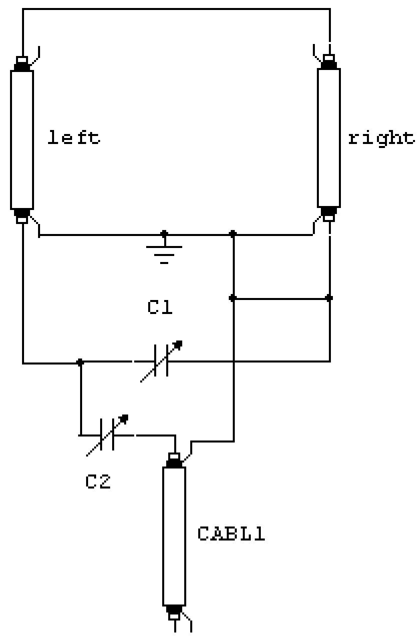
Shown above left, unbalanced stray capacitance excitation of the inner conductor. Note the lack of a clear return path for the inner wire current to the feedline. The differential current path exciting the inner conductor is actually through the stray capacitance of the right cable only, although both sides can affect SWR. This has the potential to unbalance the loop shield currents and cause energy transfer problems. The feed system SWR is critically dependent on loop coaxial length and loop coaxial impedance (distributed capacitance).

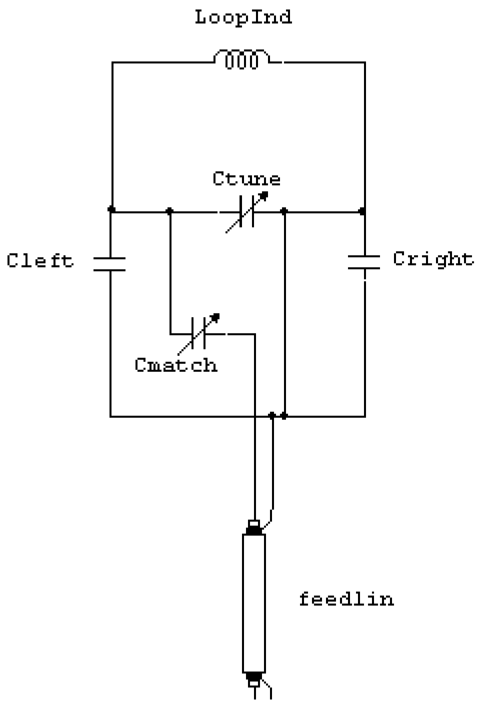
Above right, electrical equivalent. This system depends on cable capacitance to form a voltage divider that excites the inner conductor and matches the loop impedance to the feedline impedance. C right has a very high impedance compared to C left, since C right is shunted by the very low feedline impedance



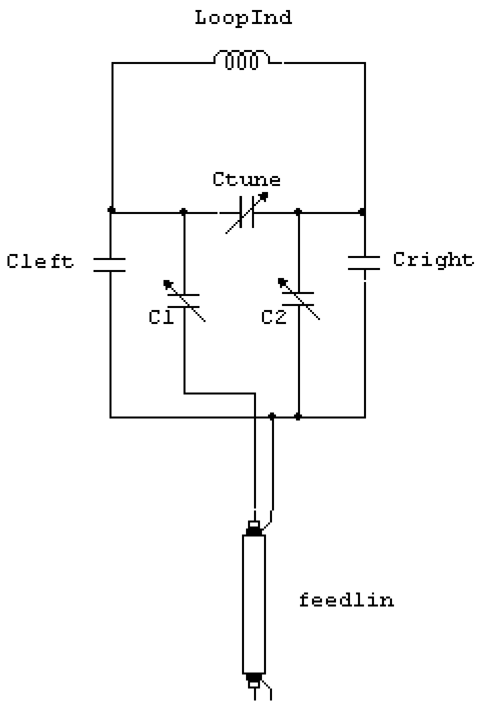


Shown above, unbalanced differential mode excitation of the center conductor without SWR adjustment. This is still distributed capacitance critical with the left side having limited primary control of SWR, but it has better balance than the system with a floating center conductor and more symmetrical shield currents.

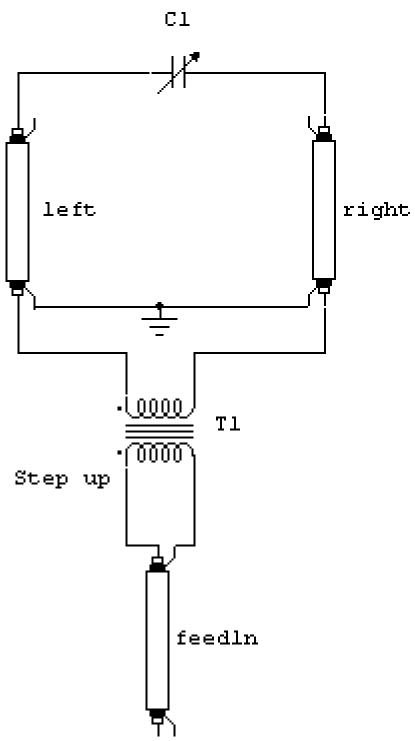


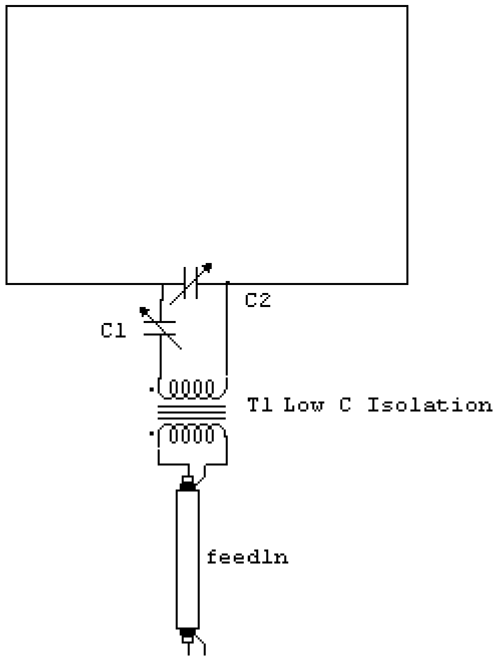


Above, feedpoint with adjustable matching. Impedances shunting C left and right are both low, but impedance balance is slightly flawed.



Above circuit would balance both loop sides, assuming matching capacitances C1 and C2 are nearly equal





Above, isolated unshielded with matching.

I hope this article is useful in helping you select a GOOD design, or to experiment and find a better system.

You might also research older antenna textbooks, like "Transmission Lines Antennas and Wave Guides" by King, Mimno, and Wing