Demonstration of 10 metre & 40 metre EH Antennas by VK5BR at a meeting of the CW Operators QRP Club (Photo by Don Callow VK5AIL)

The EH Antenna - Out of Balance Current or Longitudinal Mode Current in the Coaxial Cable causes radiation from the coax. But how large a proportion of the total power is radiated or lost from this Current?

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(Figures redrawn for AR Journal by Bill Roper VK3BR)

Introduction

A lot has been said about radiation from the coax feeding the EH antenna. This occurs because a longitudinal or common mode current flows when the antenna is directly connected to the cable. There are those who have claimed that radiation from the coax is the primary means by which the EH antenna works. So let's take some measurements and really find out what proportion of the total power might come from the coax.

In this article, I describe how measurements were taken to determine the longitudinal mode current for a given transmitted power at certain points in the coax cable and the resistance component at those points. This enabled me to derive the proportion of power radiated or lost because of this current.

What causes the Out-of-Balance Current in the coax and why does it Radiate?

The out-of-balance or longitudinal mode current will occur for any dipole arrangement fed by a coaxial cable without some means of isolating the antenna circuit from the unbalanced transmission feeder.

The result is current (the out of balance result) which can produce a magnetic field along a conductor which runs from the transmitter output to the extremities of the dipole antenna and acts as an antenna itself against ground.

To simulate this as an antenna itself, we have to model a conductor against ground which follows the route of the coaxial cable and ends at the extremities of the antenna.

Figure 1 has been prepared to illustrate how the out of balance currents occur when feeding a balanced antenna from an unbalanced source. The diagram shows a balanced dipole fed via 50 ohm coax cable. Matching elements are not shown and the load presented to the termination of the cable is a resistance of 50 ohms. The cable length, for the purposes of the discussion, is small compared to a wavelength to avoid complicating with varying current distribution due to standing waves. So current along the length of the line is assumed to be constant over the cable length.

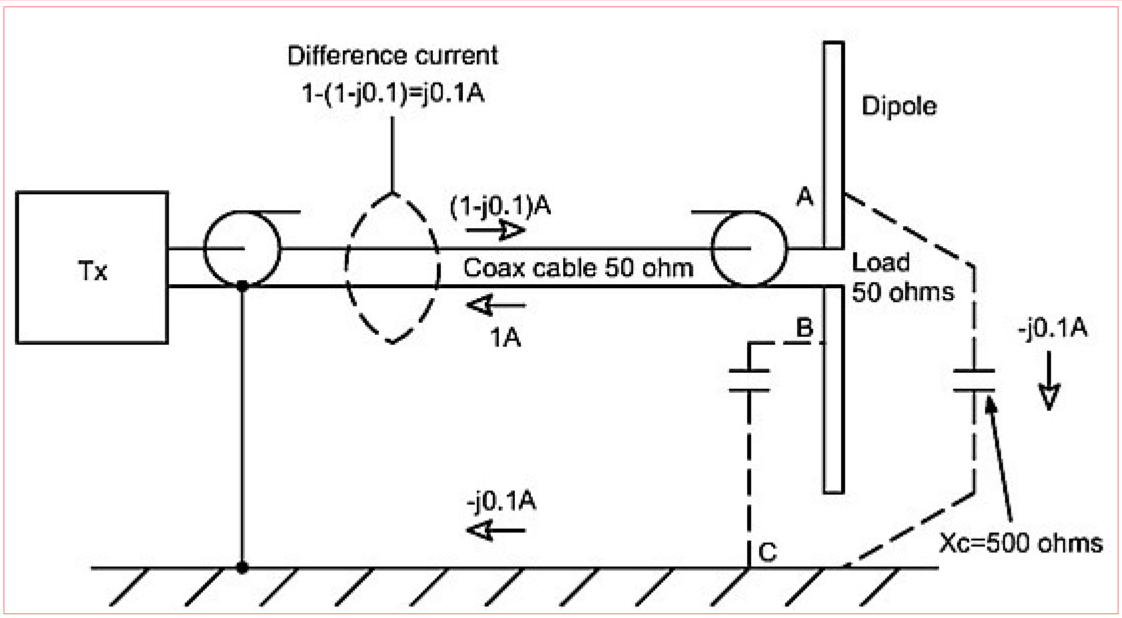


Figure 1 - Out of Balance Currents in Coaxial Cable

At this point, I will also assume no radiation from the cable although the end point is resulting radiation.

I will feed 50 watts down the cable and because the load is 50 ohms, the current is 1 amp. This is shown traveling in the outer conductor in the diagram.

I have assumed a reactance of 500 ohms from each half of the dipole elements to ground for the purposes of the demonstration.

Points B and C are at virtual ground potential and we can assume little current flows via the lower half dipole capacitance to earth. However the upper half dipole capacitance is across A and C and, in effect, is across the 50 ohm dipole load. Since its reactance is 500 ohms, a current will flow of around -j 0.1 amp and this is returned to the transmitter source via earth conduction.

The vector sum of the currents in the three conductors (inner coax, outer coax and earth) must be zero, and hence there is a difference current between the inner and outer conductors of the coax of j 0.1 amp.

Since there is a difference current, there is a magnetic field and the coax can radiate. Of course if there is radiation, there is radiation resistance and the difference current must become more complex than the simple reactive current I have used for the explanation. However I hope the diagram has filled the purpose to explain how radiation from the coax can occur.

Particular case of the EH Antenna

In the previous example we depicted a current between a dipole element and ground of 0.1 amp. To do this we needed 500 ohms reactance and for 20 metres, this implies a capacitance to ground of around 20 pF. With such small sized elements, the EH antenna is not likely to exhibit such a a high value. However, the effect is multiplied because of voltage gain in the resonant circuits of the EH matching system.

Take the case of the L+L matched antenna which I described in reference 1. The loaded Q of the matching system is around 7 and hence the voltage across each cylinder to reference ground is seven times that at the unbalanced 50 ohm input of the matching circuit. To achieve a current with this voltage, we only need a capacitive reactance of 500 x 7 = 3500 ohms. This now implies a capacitance of less than 3 pf between the 20 metre EH antenna element and ground to produce 0.1 amp.

The matching circuits of the L+T and Star EH antennas are different (refer Appendix), but voltage multiplication, as referred to earth, between the top dipole element and the 50 ohm input can also be shown.

Of course we can stop the current out-of- balance with the right interface.The purpose of the balun choke or tuned trap in the coax line is to force equalisation of the two currents in the inner and outer conductors so that there is no magnetic field and radiation from the coax line is reduced or eliminated.

But how much power is radiated or lost from the coax when when you don't use the interface? - First the very short cable.

Short Coax Cable Lengths

For a coax feeder line within the length of 0.15 wavelength, its radiation resistance as a radiator is unlikely to be greater than 10 ohms. In fact not raised fully above the ground it will probably be much less.

Let’s look at the possibility of such a feedline radiating. Take the case of 1 amp being fed up the cable differentially into its 50 ohm EH antenna load. Power = I squared x 50 = 50 watts.

Radiation from the coax can only occur from the magnetic field created from the difference current of that of the inner and outer conductors. In making measurements of these currents, the worst case scenario I have seen is when the difference current is around half the current fed to the 50 ohm load. So for the case above, our difference current is 0.5 amp and fed into the radiation resistance of 10 ohms discussed above gives a power of 0.5 squared x 10 = 2.5 watts. This represents a mere 5% of the radiated power of 50 watts.

So you can see that if your feeder cable is within 0.15 wavelength long you are not going to loose much power from feeder radiation. So for these short cable lengths, you do not need a balun choke or trap to reduce feeder radiation loss. In this case, the reasons you might decide to install one is because of too much RF in the shack or you are bugged because of interaction of the antenna tuning with the coax. Whilst these are nuisance things, they will not inhibit your antenna radiating most of the available power in the EH mode at the antenna.

But let’s now turn to the longer cable. The antenna height and cable length is the same as I used for the 20 metre air tests described in a previous article. (At time of writing that article, we were describing the longitudinal current as shield current whereas now I am saying the current is due to the out-of-balance between the inner and outer conductor currents).

Longitudinal Current Tests

The following describes how measurements were carried out to measure the magnitude of longitudinal current on the coax line feeding several EH antennas operating without a choke balun or line trap. The tests were essentially concerned with the 20 metre antennas to derive information for power measurement. Tests were carried out on a 20 metre L+L matched antenna and a 20 metre Star matched antenna. The currents for a 40 metre L+L matched antenna were also recorded but not processed further.

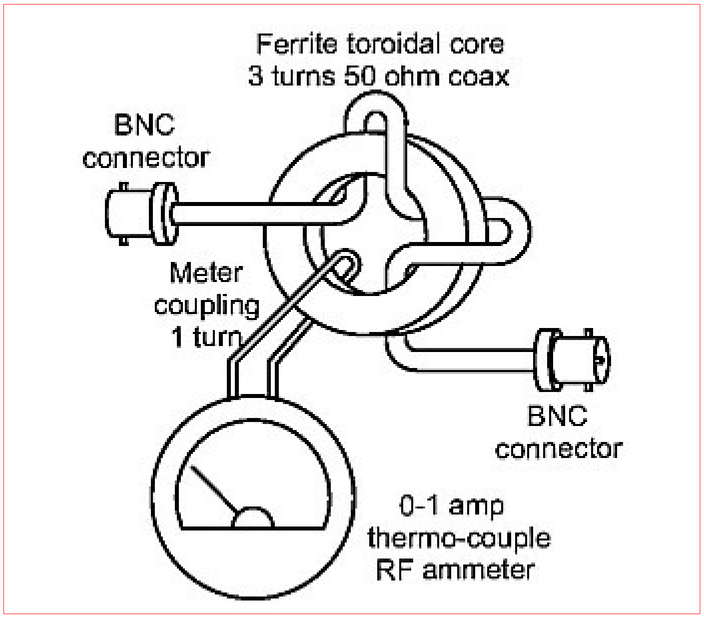


Figure 2 - Longitudinal Current Measuring Device

Longitudinal Current Measuring Device (Refer Figure 2)

Ferrite Core OD = 40mm
ID = 20mm
Width = 11mm
Ferrite type - Not known
The device was calibrated by connecting to an RF source in directly in series with another 0-1 Amp RF ammeter.
Reading = 1.2 x actual current (for 20 metres) & 2.5 x actual current (for 40 metres)

Measurement Results

Antennas fitted approximately 2.5 metres high.
50 ohm cable to antenna - 17.5 metres.
Power fed to antenna - 50 watts.
Calculated differential line current for 50 watts - 1 amp
Longitudinal current measurements taken at:
(1) 1.5 metres from antenna.
(2) At transmitter end.
No choke balun or line trap is fitted for the tests.

L+L matched 20 metre antenna

At 1.5 metres - 0.26A
At Transmitter - 0.17A

Star Matched 20 metre antenna

At 1.5 metres - 0.25A
At Transmitter - 0.2A

L+L matched 40 metre antenna

At 1.5 metres - 0.6A
At Transmitter - 0.08A

An interesting result is that despite the fact that the method of developing the two fields in the Star matched 20 metre antenna is quite different to that for the L+L matched 20 metre antenna, they produced similar results of longitudinal current. One might have expected that as only the secondary field of the L+L antenna operates in a longitudinal mode, a different reading might be recorded. The results give support to a theory which has been growing on me that the longitudinal current is more to do with the unbalance caused when you connect any dipole directly with an unbalanced line (without an isolating device to block the common mode currents) rather than due to the specific characteristics of the EH antenna.

Resistance in the Longitudinal circuit & the Power Consumed

Measurement Arrangement

So that power radiated could be derived in the longitudinal mode, the coax was broken at the same points as the previous current measurement to measure the resistance component. The inner and outer conductors of each open coax end was paralleled and measurement was taken between these ends. A noise Bridge was used for the resistance measurement isolated by a series choke and candelebra circuit as shown in Figure 3. The coax break points were connected where "Balanced Line" is shown on the diagram.

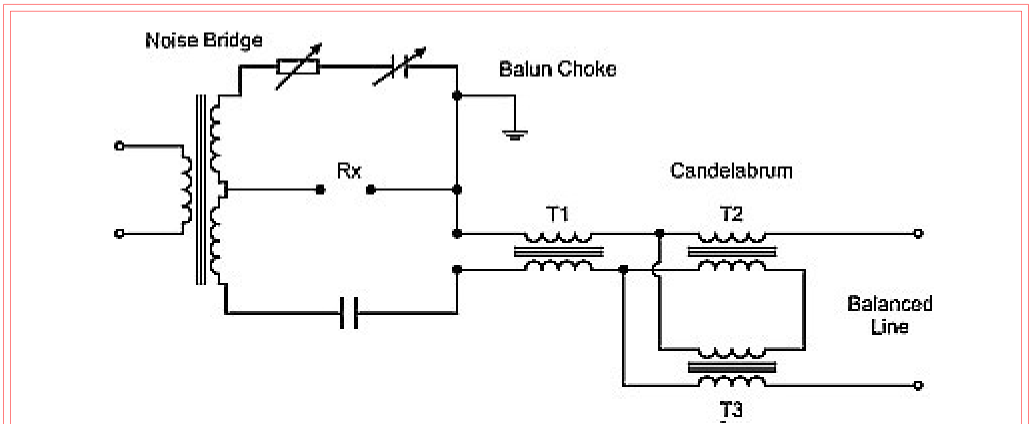


Figure 3 - Candelebra circuit to isolate unbalanced measuring instrument

Measurement were carried out on the 20 metre L+L antenna with the 17.5 metre coax feeder as described before.
Measurements were taken at 1.5 metres down from the antenna and at the transmitter.

Results of Measurements

Resistance measured at 1.5 metres - 104 ohms
Current from previous measurement at 1.5 metres - 0.23 A
Power at 1.5 metres = 0.23 squared x 104 = 5.5 W

Resistance measured at transmitter - 252 ohms
Current from previous measurement at transmitter - 0.15 A
Power at transmitter end = 0.15 squared x 252 = 5.6 W

The previous current measurements were made with 50 watts of power fed from the transmitter.
Hence close to 11% of the power is being consumed in the longitudinal circuit.

Summary & Conclusions

I have described how a longitudinal current component can occur when you feed a balanced antenna from an unbalanced transmission line such as a coax cable. The phenomenon is dependent on current flowing through capacitance between the antenna elements and ground. In the case of the EH antenna, its elements are physically small, implying low capacitance to ground and low capacitive current. However in offset to this, the capacitive current is amplified by voltage gain in the tuned matching circuits of the EH antenna.

For a short coax, the radiation resistance of the coax as a radiator in the longitudinal mode is too low to produce significant radiation. For a longer coax, the power radiated can increase and my tests show such a case where the longitudinal radiation resistance at the transmitter is a high 250 ohms. However multiplied by the current squared at that point, a mere 11% of the power is consumed due to the longitudinal current component.

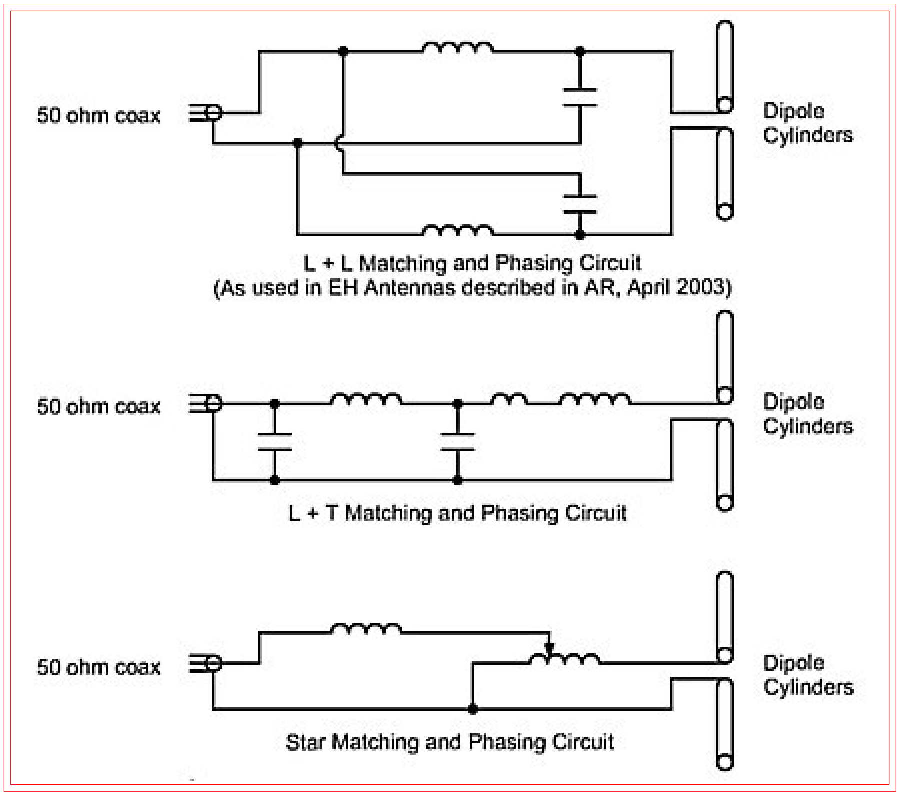
Radiation from the coax of the EH antenna is a nuisance in that it has the effect of making the antenna tuning adjustment dependent on the length of the coax and its proximity to the antenna. It is also a nuisance because of RF getting into the radio shack. If these things are a worry, then the coax radiation can be easily prevented by using a suitable trap as I have described in a previous article. **However my tests show that coax radiation is hardly the primary source of radiation in the EH antenna (as some sources have claimed) and amounts to but a minor proportion of total power radiated.**

Other relevant articles in AR

(1) EH Antennas for 20 and 40 metres - Lloyd Butler VK5BR, Amateur Radio, April 2003.

(2) The EH Antenna - More Information on how it works and how it has performed. - Lloyd Butler VK5BR, Amateur Radio, Date?

APPENDIX - EH Antenna Matching & Phasing Circuits



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