RF Ground, Counterpoises, and Elevated Radials

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Ground is ground,right?

Not really! There is a notion of 'ground' as the 'big zero', a charge reservoir that is so huge that no matter how much current is sunk into it, the electrical potential cannot be raised above zero volts. This does apply at DC and at Power Supply frequencies. But the full story is more complex. Amateurs will use ground connections for three main purposes:

- To earth the rig in power supply terms
- To earth antennas to protect against static charge build up
- To act as a substitute limb of an unbalanced antenna

Earthing the rig may generally use the power supply ground. Very often this involves a connection to earth through a stake driven into the ground. Actually, there can be some issues with this too but that's a different story. Earthing antennas against charge build up can also be achieved with stakes driven into the ground and the addition of a spark gap of some kind. We will return to this.

Where ground needs special thought is when we seek to sink or source RF current into it.

RF flows along the surface

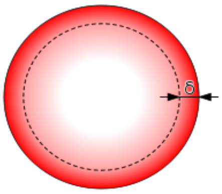

Fig 1

Because of eddy current produced by AC, current is forced to flow close to the surface of conductors. At power supply frequencies 60Hz/50Hz the depth δ in fig 1 above is about 9 to12mm in copper. The higher the frequency the smaller is δ. The actual value depends on the permittivity and permeability of the conductor.

In unbalanced antennas such as a 1/4λ vertical, or derivatives like the inverted L and T, the RF currents in the aerial element use ground as a virtual element, i.e. identical currents must flow in the ground. This leads to a misunderstanding, perhaps caused by typical illustrations as shown in fig 2. taken from the RSGB Handbook. Ground is shown, and the above ground element is complemented by a mirror element in the ground.

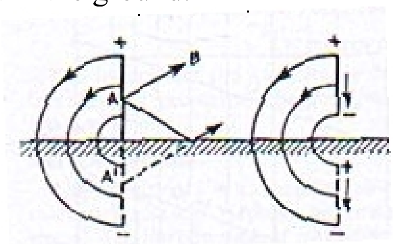

Fig. 2

This leads us to think that the ground is a perfect conductor and is not affected by skin effect. Neither of these are true.

The RF 'balancing currents' needed to make the antenna work actually flow horizontally, close to the surface. At Top Band or even 80m, the conductivity,permeability and permittivity of typical ground will result in the **RF currents only flowing within a few inches of the surface.**

How does this affect my 'Earthing' method?

Firstly, the notion of driving one or more earth stakes into the ground is seriously flawed. At RF only the top couple of inches of the rod will be effective. The rest is a waste of time (and of rod!). Also we want to make a 'good' low resistance earth connection to keep losses down and increase radiation efficiency. If we use: vertically driven in; virtually 2 inch long earth rods, they are not going work very well at all.

In normal circuitry, if we only have a given resistor but want half the value, what do we do? We use two in parallel. To reduce the loss inherent in a ground connection we could also use more than one! Also, burying longish wires just under the surface would be an answer. But the questions are : how many radials? And how long must they be. See Fig 3 below.

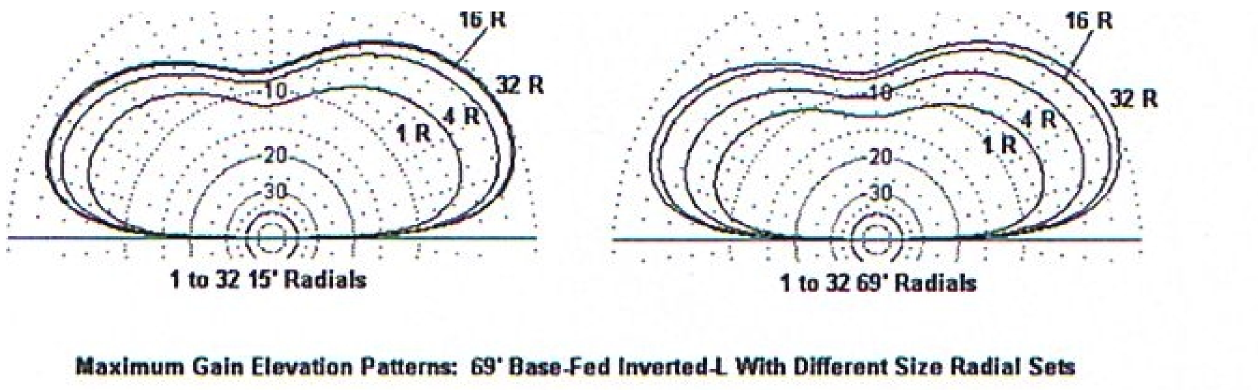

Fig. 3 (Cebik W4RNL)

L.B.Cebik, W4RNL was a great experimentalist and analyst of antenna systems. In a highly detailed and complete analysis of the Inverted L worked against ground for 80m, part of his published result is shown in Fig 3. Generally the advice you will get from antenna handbooks says that ideally 120 long radials are needed. These figures are historically rooted in the engineering of broadcast station antennas on medium wave and are not entirely relevant. Cebik shows that you will get out with just one radial 15 feet long You will be 6dB down (1 's' point) on a 32 radials of 15ft. Interestingly, there is clearly a law of diminishing returns and the difference between 16 and 32 radials is small. Going from 1 radial to 4 however does give a 3dB gain (½ an 's' point). That is worth having. The results for longer (69 ft) radials show little difference from 15 ft radials.

Given that amateurs usually have space restrictions and have to compromise on antenna systems, it seems that for an inverted L operating at 80m and upward in frequency, Four 15ft radials will do quite well. Cebik's average soil results suggest you will be just 2dB down on a dipole but this may be acceptable if you have squeezed everything into a small garden. The size of wire used for radials is not critical, nor does it matter if they are insulated or not, (more on this later).

Must I dig up my patio?

The best way to bury radials is to slit the ground and push the wire down an inch or two. However, radials can be left running along the surface. Dangerous for pets, children and lawn mowers but it will work. Why is this? What happens is that the wire capacitively couples to the earth and RF bridges the problem easily. This is also why it doesn't matter if insulated wire is used. Now we have suggested that an antenna ground need not be in the ground we soon encounter the term 'counterpoise'. This term is a problem because it does not describe anything in particular. The thesaurus offers counterbalance to mean the same, so any way of providing the balancing earth return for an antenna worked against ground is a counterpoise. Since we have to have a name for each technique we use, I will use it to describe a substitute earthing system of radials that are up to 0.05 wavelengths above the ground. For 80m, this is 9 to 12 feet! The reason for this is that the ground still has more influence through capacitance than the wire has the properties of an independent aerial element.

Counterpoises

Where it is difficult to bury wires the slightly elevated radials of a counterpoise system will do the job. Bearing in mind that it is a good thing to make the capacitive reactance of the wires to ground as low as possible i.e. capacitance to be as high as possible, the system should be a low to the ground as reasonable and of the greatest cross sectional area (capacitance is proportional to AREA and inversely proportional to DISTANCE). Between a few inches and 18 inches is common though it has been shown that it all still works up to the 9 to 12 feet mentioned before. This has some practical benefits, for instance, the counterpoise wire can be run along a fence.

Counterpoise wires need not be resonant because the close coupling to ground swamps this out. This is why 15' radials perform very nearly as well as 69' (resonant) radials in Cebik's experiments.

Elevated Radials

I shall use this term to describe radials that are well above the ground, for example, at a height above say 0.1 wavelengths or more above ground. At this height the radials are an integral part of the antenna and the ground is far less effective than the other properties of the antenna. A classic example of this type would be the ground plane. See fig. 4

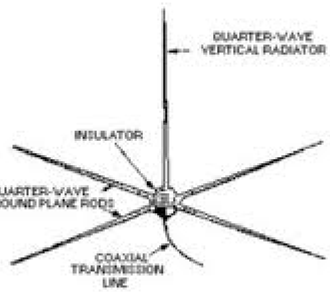

Fig. 4
Ground plane normally mounted on a mast

Note that the radials will resonate when they are well above physical ground. This then means they need to be cut to be quarter waves.

What about Static build up and Lightning Protection

This can be done with earth stakes! As no AC is involved an earth stake system will be effective as a separate circuit. Do not use elevated radials for this whatever their height above ground. However, an additional component is needed and that is a spark gap. These can be bought built in to a coax connector about the size of an adapter. Alternatively, you can build your own as demonstrated in the RSGB Handbook, see fig 5, a design for an open wire feeder.

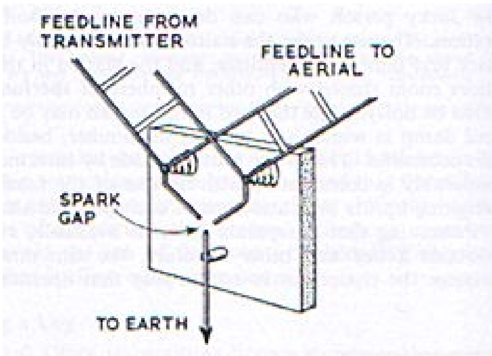

Fig.5 Spark gap for open wire feeders (RSGB Handbook)

How do I know if my ground system is working?

In an antenna worked against ground, the current flowing in the actual antenna wire can only be as good as the balancing current flowing in the ground itself. Therefore, measuring the antenna current at the base of the antenna will be an excellent indicator. For this you need an RF ammeter. Alternatively it is just possible to measure the field strength using an absorption wave-meter or a hand-held receiver, though it must be appreciated that the local or proximity field will be very strong and if using a receiver it would be best to measure the radiation field a couple of wavelengths from the antenna, probably with the attenuator switched on! The preferred method though is current measurement because the interpretation of field strength is extremely difficult.

What conclusions can be drawn?

The term 'counterpoise' has been used and abused and since it describes nothing in particular it is an unhelpful word.
When using antennas worked against ground, we can used radial wires buried shallowly (ground rods or stakes are fairly useless for this RF purpose).

If this is inconvenient we can use insulated or non-insulated wires mounted above ground, up to about 9-12 feet, to couple capacitively with the ground and thus act like shallow buried radials.
We can, at the higher end of HF, have resonant radials well above ground.
In all of these cases the number of radials used is subject to a law of diminishing returns. Using 4 radials gives a good advantage over a single wire but after about 16, little further gain in efficiency will be had. As far as the length of radials goes, there is no critical length and no great advantage past 15-20 feet except for the case of elevated radials well above ground where they must be tuned (a quarter wave).

Static charge build up is essentially DC, so earth stakes will work but you need to use a spark gap.

References

http://w4rnl.net46.net/

The RSGB Handbook

The ARRL Antenna Handbook