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Pulling a Quart

It's spring time – time to start thinking about your antenna farming! Steve Ireland describes how to build a cheap and efficient ground screen for the low bands that will fit in a suburban garden.

Perhaps the biggest problem for those of us who are interested in the 1.8 and 3.5MHz bands and want to use a vertically-polarised antenna lies underneath our feet. Engineering a large vertical antenna is looked on by many 'low-banders' as being a breeze compared with the construction of the ground screen to prevent the antenna from coupling to the lossy earth beneath its base and thus reducing the near-field efficiency of the antenna.

The electrical conductivity of the soil/rock/sand beneath you will determine how much of a ground screen your antenna requires for the lowest ground losses and maximum efficiency. As this conductivity can vary considerably over a small area and is relatively difficult to measure, the best solution is to put down a ground screen that will produce maximum efficiency *whatever the type of soil that lies under the antenna.* For those lucky low-band enthusiasts with lots of land, time and money, this has traditionally meant laying down or burying 120 quarter-wave (or longer) pieces of wire [1], equally spaced at their tips, in a radial (bicycle-wheel spoke) fashion around the base of the antenna, electrically connected together at the antenna base (ie at the wheel's hub). This is not only a lot of hard work and expense, but for most of us is impossible, given the practicalities of suburban living. Instead, we usually try to get away with burying relatively few pieces of wire and sundry bits of metal as an earth system for our vertically-polarised antennas (resulting in earth losses and poor antenna system performance) or give up the whole idea and instead put up a horizontally-polarised antenna, often with mixed DX success. The author had tried both of these approaches, ultimately settling on the latter as the best compromise, but still longed to have an efficient vertical antenna.

Below: A trench with the radial lying to its side waiting to inserted using the 'radial needle'.

Bottom: The aluminium disk at the centre of the earth screen. The W2FMI unun is placed inside an empty swimming pool chlorine bucket mounted on top of the disk.

When I analysed why I had settled for a 'second best' earth system (and as a result had almost given up on vertical antennas) it came down to three practicalities:

- The space required for a full-sized ground screen
- The cost of a full-sized ground screen
- The physical energy required for a full-sized ground screen.

Whilst it was difficult to do much about the first of these, I had some good ideas about the second and a few inklings about the third. Firstly, even though I did not have the room for one, I worked out how much wire would be needed for 120 quarter-wave radial screen for 1.8MHz, the lowest frequency band of interest (see **Fig 1**). This came to almost 5km of wire – a very large and potentially expensive amount.

A few years ago, in the process of building an elevated ground system, in the manner of the W3ESU Mini-poise [2], for a 3.5MHz vertical antenna, I had learnt the cheapest way to buy copper wire was by weight, from either an electric motor re-winding company or direct from a wire maker. What I had also learnt was that thin wire was as good as thick wire for ground screens when there were relatively large numbers of radials involved.

As a result, I decided to work out how much it would cost to buy enough 22 gauge copper wire – which had proved to be quite durable for my version of the Mini-poise – for a full-sized 1.8MHz screen. This wire would cost around £3.50 per kg, plus tax and from my previous purchase of this wire, I knew that about 0.625 of a mile (1km) of it weighed just over 3.5kg. After getting out the calculator and doing a couple of simple sums, my maths showed that a full-sized 1.8MHz 'broadcast station-style' ground screen would cost over £60. Although the cost of 5km of wire was painful in financial terms, actually burying it sounded even worse, in terms of the huge physical effort involved.

The VK6VZ location, some 30km east of Perth in the Darling range of hills, is a beautiful place to live but the soil is a very tough mixture of gravel/red clay, interspersed with granite boulders. Planting anything in the earth – trees, shrubs, flowers or ground radials – requires the use of a pickaxe. What this meant was digging a trench and burying a mere 20m-long radial took up to an hour of hard labour – meaning that burying the 5km or so required for a full sized 1.8MHz ground screen could take up to 240 hours or about a month's worth of hard labour! My back was aching just at the thought of it.

Of course, there was also the other snag to frustrate me further – I didn't have the room for the 5km of wire anyway, so all this pain was strictly in my head. Maybe I should just stick to my inverted-Vee dipole?

A PRACTICAL SOLUTION

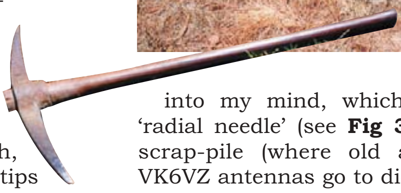
What followed was several months of reflection and reading a large number of articles on the theory and practice of building ground screens. There were two sources of encouragement in particular – a series of articles written by Jerry Sevick, W2FMI, during the 1970s [3] and the more recent work by Eric Gustafson, N7CL, and John Devoldere, ON4UN, featured in the latter's *Low-band DXing* book [4].

What I discovered was that to make

from a Pint Pot...

a wholly effective near-field ground screen, using wires connected together at a single central point, the ends of the radials making it should be spaced around 0.015 of a wavelength (around two metres on 1.8MHz, or around one metre on 3.5MHz). However, if the spacing between the ends of the radial spacing were doubled to 0.03-wavelength, substantially fewer radials were required but the ground screen was only around 0.5dB lower in effectiveness from a full-density one (ie the ground losses would increase by 0.5dB). Even more significant was the assertion that if the radius of a ground screen was reduced from a quarter to an eighth of a wavelength, the smaller ground screen was only around 0.3dB down on the larger one.

At this point, I purchased some graph paper and made plans for the radial system using a compass and ruler. What this meant was a mere 30 radials of 20m in length, spaced around 4m at their tips would be less than 1dB down on a full-size quarter-wave-radius ground screen - good news for me as this would fit within the VK6VZ backyard and also cut-down on the backache and expense (see **Fig 2**).



Although I only needed around 600m of wire for my pint-sized ground screen, I decided to buy at least a third more than this (about 1km) to give myself the latitude to put down a few more radials if I got energetic. After all, 1km of 22 gauge wire for £12.80 sounded much better than paying £64 for 5km!

The 1km of 22 gauge wire was purchased from an electric motor wire supplier. At the same time, I bought a 1m diameter disk of 4mm-thick aluminium for £6.60 from a local scrap yard, to serve as the centre of the ground system. As aluminium screws are hard to find in Western Australia, 30 M6 diameter stainless screws were purchased to fasten the radials to the aluminium disk, along with a similar number of Bosch 6mm ring terminals to which the radials could be soldered.

There was still something bothering me. Burying 600m of radials was a lot better than 5km, but was still a lot of work, particularly in the 30°C heat of Perth. Some kind of tool was needed to speed up the process and stop VK6VZ from expiring.

After some thought, an idea came into my mind, which I called a 'radial needle' (see **Fig 3**). From my scrap-pile (where old and broken VK6VZ antennas go to die), I selected a 1.2m length of 15mm diameter aluminium tubing. Using a small rat's-tail file, all the sharp edges at one end of the tubing were carefully rounded. Then, using a wooden mallet, about 10cm of the aluminium tubing at the filed end was *almost* flattened, so as to reduce the circular hole at the end to a long slit, about 2.5 mm wide. This meant that this end of the aluminium tubing could be dragged easily along the bottom of a slit cut into the earth/grass with a pickaxe, allowing a piece of wire threaded through the needle to be dragged/deposited neatly at the bottom of the slit.

Left: VK6VZ using his 'radial needle' to lay a radial into a 10 - 15cm deep trench which has been dug using a pickaxe.

A test run was carried out using the radial needle on a 20m-long piece of 22 gauge wire. The trench took about 15 minutes to dig using the pick axe and the wire took only a further 15 minutes to bury in the trench, cutting the time to bury each radial by at least half from the previous method using just a pick-axe and trowel. Not only was the time cut in half, but the strain on the VK6VZ back and knees was cut by about 80%, as I could place the wire on the bottom of the trench using the radial needle while hardly having to bend at all. There was another bonus: placing the wire on the very bottom of the trench using the needle, and covering it over by pressing the earth back into the trench with my foot at the same time meant that the wire tended to stay buried much better than when I was using the pickaxe-and-trowel method.

RUNNING THE RADIALS

To speed up laying down the ground screen further, I fabricated a couple more mechanical aids, the first of which (see **Fig 4**) was the VK6VZ 'wire unwinder' [5]. This simple device, made from scrap timber and a piece of 2.5cm diameter aluminium tube, allows the wire used for radials to be easily pulled off the drum without kinking.

The second aid was even simpler, made from a 2m length of dowel. As each of the radials was to be spaced about 4m at their far ends, this made measuring the distance an easy two-step process; much simpler than continually having to extend a tape measure.

My radials were laid out, one at a time, working in a clockwise direction from where the centre of the ground system was to be sited, in the fashion described earlier. The aluminium hub, drilled with 30 6mm holes for the radials around its rim (see **Fig 5**), was placed on a square support made of four house bricks mounted around a shallow hole in the ground filled with pebbles (see **Fig 6**), preventing grass growing over the hub and allowing drainage.

After six or so radials had been laid (ie after around three hours hard graft), I would stop work, have a long drink and a short rest and then rub the varnish off the hub-end of the radials (using emery paper) and solder a terminal to each one. This meant a half day's work for every six radials – and, believe me, half-a-day burying radials is as long as you want to do at a time.

The process of laying a ground screen is a laborious one, in this case about six full working days in total, but seeing it take shape is very satisfying. The secret is to do no more than one half-day a weekend at a time and if you get fed up, come back and do some more another day.

The radial needle proved an excellent tool and the more I used it, the quicker I became. By the time I had done the last of the 30 x 20m-long radials, the 'burying time' had been reduced to around 20 minutes per radial.

Some of my radials cross a raised area of rocks, covered in honeysuck- ▶

Fig 1: VK6VZ pint-sized 1.8 MHz ground screen.

Fig 2: The VK6VZ 'radial needle'.

Fig 3: The VK6VZ 'wire unwinder'.

Fig 4: Hub for radial system used at VK6VZ.

Fig 5: Mounting the radial hub over a hole filled with pebbles (to prevent grass growing over the aluminium hub and to allow drainage). The aluminium hub is mounted on the four bricks, above the ground surface.

Fig 6: 1.8MHz Marconi-T quarter wave antenna used at VK6VZ.

le, involving threading the wires under the vine. To my pleasure, I discovered I could use the radial needle in the manner of a sewing needle and use it to thread radial wires underneath the vines. In a matter of minutes, I could thread a wire under six to nine metres of matted undergrowth, a few centimetres below its surface.

CONNECTING UP

The radial wires were attached to the centre aluminium hub, using 6mm ring terminals and stainless steel screws/nuts after these had been liberally coated with aluminium oxide inhibiting compound (Aluminox or Burndy Penetrox A). A connection was made from the centre of the hub to the earth side of the antenna matching unit using a 10mm ring terminal/stainless steel nut/screw combination. As a final touch, the soldered connections between the ring terminals and the radials were weather-proofed using bitumen roofing compound bought from the local hardware store.

After some thought, a wire 1.8MHz Marconi quarter-wave T-antenna with a 21m vertical section was erected above the earth system, suspended between my telescopic tower and a nearby pine tree. Assuming that my ground screen was working in an efficient manner, with very little earth losses in the near-field of the antenna, its impedance should be close to the theoretical figure of about 22 Ω (for this shape of antenna).

To match the RG213 feeder to this impedance, I decided to use an Amidon multi-output 'unun' (mounted inside an old sealable chlorine bucket). The unun provides the facility to match unbalanced antennas, such as the Marconi, with impedances varying from about 12.5 to 38Ω. In the past, my vertical antennas had often had feed impedances that were considerably higher than the theoretical figure, indicating large earth losses and an inefficient ground screen/earth system.

To my surprise the antenna was a perfect 1.0:1 match at resonance using the 22.5Ω tap on the unun and only needed trimming a metre or so to be resonant on my favourite frequency of 1.830MHz. The Marconi-T displayed a narrow 2:1 bandwidth of 80kHz, only two-thirds of the bandwidth of my inverted-Vee dipole with its apex at 27m, also indicating the ground screen was working efficiently and the 'Q' of the entire system was high.

The on-air results confirmed the good match and efficiency of the ground screen, with the Marconi-T being competitive with the inverted-Vee dipole after sunset when working into North America. A few weeks later the Marconi-T and ground screen netted 3D2CI on Conway Reef for a new 1.8MHz country which was unreadable on the inverted-Vee dipole.

The Marconi-T is also the noisiest 1.8MHz antenna I have ever used. A good sign that a vertically-polarised antenna system is working well is the amount of noise it receives, as noise is, in general, vertical in polarisation.

Ground screen of 30 radials	Length of each radial	Distance from one tip of a radial to another tip of a radial
3.5MHz	10m	2m
7MHz	5m	1m

Dimensions of the VK6VZ pint-sized ground screen scaled for 3.5 and 7MHz.

CONCLUSIONS

The ground screen of 30 one-eighth wavelength radials, spaced 0.03 of a wavelength at their tips, is the best 1.8MHz earth system that has been used so far at VK6VZ. This screen can easily be scaled down for those who are interested in 3.5 or 7MHz DXing (see the table below) and is, of course, totally invisible.

Future plans include feeding a 3.5MHz quarter-wave wire vertical over the same earth mat and replacing the ferrite-cored unun with a series matching coil, made from copper brake pipe.

One day, I'll move to a five or 10-acre block where there is room for a full-sized quarter-wave ground screen, but for now I am very happy with my pint-sized one that gives a quart-sized performance.

Don't forget, when it comes to the low-bands and verticals, what you put underneath the soil is at least as important as the antenna you put over it.

REFERENCES

[1] The classic work on buried ground radial systems was carried out by Dr George Brown in 1937 and became the basis for engineering vertical broadcast station antennas around the world, up until today. Brown's research led him to believe that a broadcast station should use at least 120 radials, at least one quarter-wavelength long. As a result, for many years, the dream of those radio amateur interested in 1.8, 3.5 and 7 MHz bands was to have a 120-radial ground system...

[2] 'An Elevated Earth System Made Easy' by Steve Ireland, VK6VZ, *Radio and Communication*, December 1998, published in Australia. W3ESU's Mini-poise was originally described in *CQ* magazine, April 1984.

[3] Jerry Sevick's articles are collected in *The ARRL Antenna Anthology*, published in 1978 by the ARRL.

[4] *ON4UN's Low-Band DXing* by John Devoldere, ON4UN, published by the ARRL in 1999.

[5] Originally described in the article [2] above. ◆

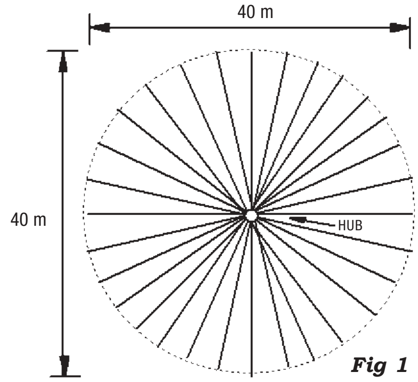


Fig 1

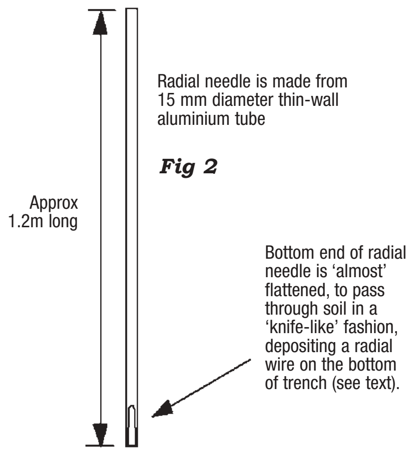


Fig 2

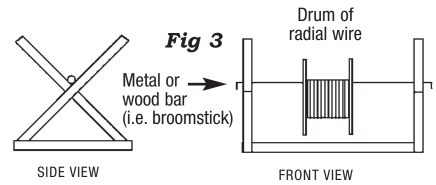


Fig 3

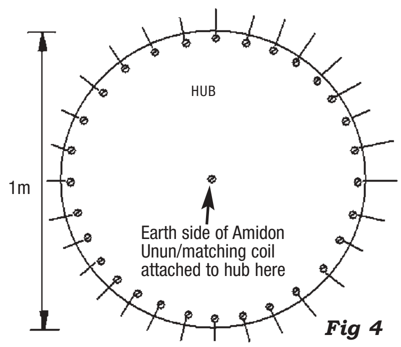


Fig 4

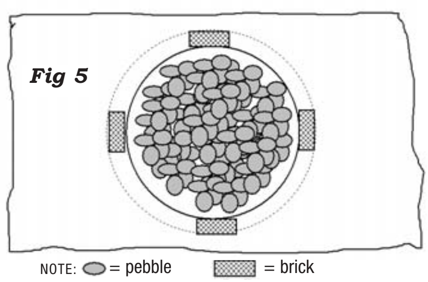


Fig 5

Dotted line shows the position of the aluminium plate, used to attach the radials

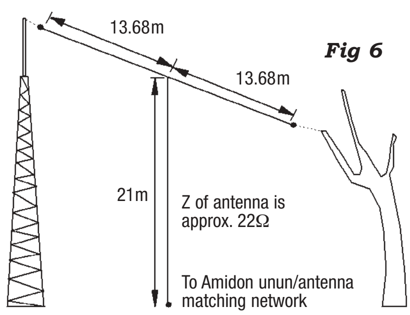


Fig 6