**A Reconsideration of DX and Contesting Antennas for the Low Bands**

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**Introduction**

The Quartz Hill User Group Committee has for some time been looking for a site near Wellington for a DX or Contesting location to replace the Makara site (now occupied by the Meridian Energy Wind Farm).

Guidelines for any new site have included factors such as location, access, lease cost, elevation above surrounding terrain and near line of sight to the horizon in critical DX directions (NW, NE, and SE), low level of man-made RF noise, and site size. Several of us are beginning to rethink the last of these parameters. The reality is that we probably don’t need as big a site as we had at Quartz Hill (around 100 acres).

This paper considers alternative antenna designs to Vee Beams for the low bands, as designs have in the past influenced thinking about site size.

**DX antenna requirements**

Members will be aware that any DX path out of New Zealand requires a very low angle to the horizon to be effective. An antenna that has a maximum gain at an elevation angle of 30-45 degrees may be fine for working within New Zealand, but is not useful for DX. Most dipole and Yagi antennas mounted so as to comply with the typical NZ local body height restriction of an 8m envelope will simply not be efficient radiators between 0 and 30 degrees of the horizon except on the highest bands. A half-wave dipole does not have useful low angle radiation until it is mounted at least half a wavelength high, unless it is on the side of a hill in the intended contact direction. It is not optimal until over a wavelength above ground.

For DX communications, maximum radiation should ideally be maximised at the horizon or just above the horizon (certainly less than 20 degrees). To work stations in Europe or North America, a maximum gain at 5 degrees elevation would be ideal for effective communications. Such a low angle minimises the number of bounces required between earth/sea and the ionosphere on any DX path. Of course, in most practical situations gain at such a low angle of maximum gain is difficult to achieve.

Directivity is the natural result of producing any gain in an antenna. However, highly directive antennas are not really practical unless fast directional changes can be made. The Rhombic at Quartz Hill was generally not better than the EU Short Path and Long Path Vee Beams even though it was partially steerable. The very narrow lobe led to the antenna not being able to hear stations that were just off beam. A broad lobe, low to the horizon with high front-to-back and front-to-side ratios represents the ideal antenna pattern for HF DX out of New Zealand. Maximum overall gain is not the most important consideration. Gain at 5 degrees is a more useful indicator of effectiveness for DX paths. Fast switching of direction is also important during a contest, as anyone who has used a rotator will know.

**Vee Beams**

Quartz Hill members were keen on the Vee Beams at Quartz Hill that seemed to work well for us on DX paths. This was for good reason – they worked better than any of our backyard antennas. The Vee Beams at Quartz Hill were typically mounted on a centre pole of 20m with end poles of between 3m and 20m. Higher end elevation was more effective. Vee angle was typically around 35 degrees, which provided reasonable patterns on all bands from 40m through 10m. Leg lengths were around 300m.

A key advantage of the Vee Beam is its simple construction, leading to easy replication and low maintenance costs. A collection of power poles strategically placed can result in a high performance station with suitable space. The downside, is that a large piece of land is required to be able to maintain Vees for both SP/LP Europe and Stateside and for multi-station use. With multiband multi-operator stations, separation distance between antennas is very important.

With leg lengths like those at Quartz Hill, the Vee antenna was two wavelengths in length on 160m (although the low height of 1/8 wavelength at the centre led to poor efficiency on this band), 3 or 4 wavelengths on 80m (with ¼ wavelength centre height), and 5 to 8 wavelengths on 40m. The Vee Beams were typically 10-30 wavelengths in leg length on all higher bands (30m and above).

It was discovered towards the end of our period operating at Quartz Hill that simple elevated Yagi antennas actually performed better on the higher bands than the Vee Beams. The reasons for this are more readily seen when you use a modelling programme (such as EZNEC). The long Vee Beams generate very complex radiation patterns with sharp lobes and lots of nulls in both azimuth and elevation patterns at high frequencies. Much of this radiation is still skyward in patterns that resemble egg trays or undulating dunes.

Without terminations, Vee Beams are also reasonably bidirectional, with the advantage of being useful over both Short Path and Long Path directions, but they also tend to pick up more QRM and QRN than an antenna with a good Front-to-Back ratio.

Vee Beams have much simpler lobe patterns when they are only 2-4 wavelengths in leg length and they have larger and reasonably broad beams at lower radiation angles. However, even at two wavelengths leg length they start to have multiple lobes and deep nulls. Note that some gain is realised at only one wavelength leg length, but gain is comparable to a dipole (although at a slightly lower angle and with a lobe that extends down to below 10 degrees at the 3dB point).

The conclusion is that shorter Vee beams for the higher bands may work better. They also take up less space. However, on the higher bands, there are lots of alternative options, and mounting antennas at least a half wave above ground is realisable on all bands at 20 metres and above.

**DX antennas at 20 Metres and above**

On the higher HF bands, a variety of antennas can be deployed on pretty much any site. Even a ¼ acre (1000 m2) section unencumbered by a dwelling would allow for steerable Yagi, quad or log periodic antennas at these frequencies and quite complex wire arrays to be built. A small low-noise site that is affordable and within easy reach of downtown Wellington should be fine at these frequencies as an operating station. The biggest limitation is likely to be consent requirements for any pole exceeding 8m in height.

I don’t propose further consideration of antenna options for 20m and above in this paper, as there would be plenty of opportunity to experiment with antennas on pretty much any selected site.

**DX antennas for 160m through 30m**

For 160m through 30m, rotatable antennas are much more difficult to construct and maintain, particularly on an exposed site, such as those around Wellington. This suggests vertical or wire arrays represent available options. Devising antenna systems within a height restriction of 8m is also difficult at these frequencies. Regrettably, with the departure of key Quartz Hill members the club lacks the ability to regularly scale towers and high masts.

***So what alternative antenna systems exist to provide the necessary gain, directivity and low angle radiation that we desire for transmit on the low bands?***

**Horizontal and Vertical Arrays**

A study of alternatives for low band antennas throws up antennas such as horizontal broadside arrays (ZL special, W8JK, Sterba curtains, etc.) and phased vertical arrays.

In my experience, phased arrays are not commonly deployed in New Zealand. They are, of course, a mainstay of high-power HF broadcasters and extensively used by cellphone companies at UHF frequencies.

Horizontal arrays require elevated antennas requiring high masts and at times require scaling during maintenance. For a similar amount of gain, they are more compact than Vee Beams. However, phased horizontal arrays generally need to be at least a quarter wave above ground and to work effectively should be mounted even higher.

In modelling a range of simple wire designs (such as the Half Square, Double Extended Zepp, etc.) amateur operators will find that a simple Vee Beam has the advantage. The Vee is inherently a multi-band antenna offering low angle radiation on all bands for a sufficient leg length (2 or more wavelengths) and it has been proven to work at Quartz Hill even when the antenna is mounted below a half wavelength in height. Several antennas suspended from high poles would be required to achieve two or three operating directions on the four low bands and provide for multiple operating stations. It is not possible to escape the inevitable – horizontal antennas mounted below a half wavelength in height tend to have high angle radiation patterns unless they are over ground sloping in the intended beam direction. Only exceptionally long antennas can overcome this obstacle. My modelling suggests vertical Vees and Rhombics have an advantage over horizontal vees in terms of angle of radiation. However, they all require acres of ground.

In analysing antennas in terms of fitness for purpose (i.e. DX use within New Zealand) that overall gain figures are not the point of reference, but real gain at or near the horizon over a poor earth. This is the true test of DX worthiness in the NZ context where almost all stations will be 6,000Km or more away.

Vertical arrays show promise. They all generate radiation patterns low to the horizon while providing some gain when using an efficient radial system. Gain may not be as high as certain other types of antennas, but the gain is realised at or near the horizon. Verticals, therefore, tend to provide more effective gain for DXing than say a horizontal Yagi, doublet or zepp antenna, unless the horizontal antenna is mounted on high structures.

Bob ZL2AMI had indicated in his presentation on Contesting in 2013 to Wellington Amateur Radio Club members that the Four Square Array had become quite popular with DXpedition teams. It is clear why these types of arrays have become popular: they do not need to be scaled, they use light weight materials, they have gain close to the horizon, they have good front-to-back ratios, they provide fast directional switching and wide beamwidth and bandwidth, and most importantly perhaps, there are commercially available solutions readily available.

**Vertical Phased Arrays, Vertical Parasitic and Log Periodic Arrays**

A range of vertical antennas could be suitable for DX operation from a site in or near Wellington. These include vertical dipoles, vertical parasitic (Yagi) arrays, vertical log periodic and vertical half-wave arrays and half square arrays.

None of the half-wave or 5/8 wave options are of much practical use for our purposes on the lower HF bands, as they need to be mounted above ground (ideally by around ¼ wavelength) and they are at least twice the height of quarter wave vertical radiators. They are of more interest on the higher HF bands as they would be of relatively low cost and more easily fed and erected. Horizontal polarisation is, however, more likely to be deployed for reasons of convenience and lower receiver noise.

Turning to quarter-wave vertical antennas working against ground, the options are:

* Simple vertical quarter wave monopoles fed through a phasing system
* Vee beam (which looks like a sloper fed from the lowest end) and vertical half rhombic (looks like an inverted vee but is fed from the lowest end and terminated at the far end)
* Parasitic arrays (basically one side of the boom on a Yagi mounted vertically) fed against ground (at 90 degrees).
* Log periodic arrays (similar to half a log periodic mounted vertically and operated against a counterpoise).

Parasitic and log periodic arrays are uni-directional and mounted against ground and they are, therefore, non-rotatable. Three would need to be built to get the three directions of interest to contesters in NZ (NW, NE, SW). Yagi antennas could have traps incorporated in their design to make them multi-band antennas and loading could be used to reduce the height of the longest elements (with some loss in efficiency). A log periodic could be designed to work over the 160m to 30m bands (or two or more of them could be built to achieve greater gain over a narrower bandwidth).

A log periodic can also be constructed from wire elements suspended along a catenary curve created when a wire is hung between a high pole (reflector end) and a shorter end pole (director end). The antenna is fed from the director end. These antennas use right angle or fishbone style earthing radials. The reflector pole could be used (in common) for 3 antennas for the three directions of interest.

At 20m and above, these types of antennas become interesting, as height above ground become modest (5.5m) and for quite modest catenary lengths it would be possible to build quite high gain broadband antennas without the complications of raising horizontal arrays. These types of antennas don’t seem to be commonly used amongst amateurs, but are commonly used by professional users. I suspect that amateurs have not used them because of the lack of ability to steer them directionally and because of the complexity of construction.

For the low bands a four square array would be much simpler, giving similar gain for the same area and in 90 degree segments covers the full 360 degrees. The cost of guyed lightweight monopoles is likely to be lower than the installation cost of a power pole to support a log periodic, particularly when resource consent costs are factored in.

**Why verticals**

The rest of this paper focuses on multi-element vertical ¼ wave arrays. There are a number of reasons for focussing on these types of antennas. The advantages include:

* Guaranteed low angle radiation (with a good radial system) and at -3dB points have a broad radiation pattern in terms of elevation (approaching 0 to around 30 degrees)
* Moderate gain (6 dBi over a monopole with a Four Square array). This is comparable to a mast mounted Yagi antenna at a much greater height
* Similar front-to-back ratios (25+ dB) to a Yagi at low angle to the horizon
* A single broad lobe in the forward direction (almost 90 degrees at the -3dB points for a four square)
* Fast direction switching (c.f. rotatable arrays)
* Relatively easy to construct the elements or able to be purchased off the shelf
* Phasing/switching/mixing units can be purchased off the shelf, or constructed with access to suitable test equipment
* A 30m antenna fits within any local body height limit
* A shortened verticals that meets the height limit of NZ local bodies should work fine on 40m.

The disadvantages include:

* Vertical arrays only provide for a vertical polarisation pattern (c.f. Vee Beams that provide a combination of vertical and horizontal radiation and a small amount of circular radiation)
* A short vertical fitting within NZ antenna height limits (without resource consent) would be inefficient on 80m and 160m. Some fudging of height restriction is possible with tall thin structures such as verticals. A 15 metre high radiator would be reasonably efficient on 80m (with top loading and a capacity hat). It would be difficult to get efficient antennas for 160m without access to a high tower (30m or more high).
* Costs of the phasing and vertical elements would be significantly higher than the costs of a Vee Beam (but the cost of installing telephone poles may well be higher when resource consent hearing costs are factored in)
* For receive, verticals suffer higher noise. Directional arrays with good front-to-back and front-to-side reduce noise dramatically. The practical balancing of lower noise using horizontal antennas versus lower noise from phased verticals is not known, but DXpeditions speak favourably about vertical arrays.

**Vertical primer**

Any vertical antenna system needs to be located over a near perfect ground to be an efficient radiator. A vertical antenna can be mounted at ground level with radials at the surface or buried just below the surface. Alternatively a vertical can be elevated above ground with elevated radials. Verticals mounted above ground tend to require fewer radials. That’s just as well, since installing large numbers of elevated radials would be challenging.

Practically, most verticals are ground mounted and deploy buried radials. While it takes time to bury the radials, this would not be a demanding activity for QHUG members. The cost of robust copper conductors has to be considered. One possibility could be copperweld for MIG welders or separated TPS (lighting) power cable for cheap radial wire.

Most amateurs know that verticals have radiation patterns that radiate well at low angles to the horizon. With a poor radial system the radiation lobe is raised considerably above the horizon. By way of contrast, over perfect ground, vertical antennas have maximum radiation towards the horizon with a 3dB point at around 30 degrees making for very effective DX operations.

For a ground mounted vertical, four, eight or perhaps even 16 radials may simply not be enough to work with a phasing unit. In order to achieve the desired low feed-point impedance (around 36 ohms) indicating an efficient radiator it may be that you need more than 20 radials. There will be diminishing returns at some point, but experts differ on just how many radials are required. Too few radials means that phasing units do not function correctly to achieve gain or good front-to-back ratio.

When using more than one vertical at close spacings (less than two wavelengths) there will be appreciable cross-coupling between antennas. These second round effects in the design of phased arrays are important and are often not taken into account in amateur antenna design. Simple solutions to feeding may not work as anticipated.

Efficiency of a vertical varies according to whether the vertical is full sized or is loaded with either inductance or capacitance. Shortened verticals will be essential on 160m and likely on 80m for practical reasons, but radiation efficiency will be lowered.

Vertical height is highly manageable in the high bands (20m and above) and becomes increasingly an issue with council planning requirements for 40m and below. For example, a full size vertical on 40m would not be permitted in any of the local bodies at this end of the North Island. An 8m high restriction on antenna height would require some capacitance loading on even a 40m vertical.

As a guide, it would seem that antennas that are around 2/3 of the height of a full quarter wave or more are likely to be adequately efficient radiators. Efficiency issues rapidly worsen below this threshold. Top loading by capacitance (e.g. using top sections of guy wires) is preferable to inductive loading as this will not further lower the radiation resistance of the antenna. Capacitance loading in aluminium or steel is more challenging in terms of wind loading, but lightweight wire guys can be just as effective in providing capacitance near the top of the radiator.

If we were to abide by planning requirements (without access to an existing tall structure), then we would have to accept some level of compromise in performance in any vertical antenna for 160m and 80m. If we were willing to stretch the rule a bit, we could possibly get an efficient antenna perhaps on 80m.

**Two vertical Arrays**

The simplest phased vertical array consists of two vertical quarter wave antennas spaced a quarter wavelength apart. The antennas can be fed in a number of ways, but a typical approach is to feed the two antennas using a 90 degree phase difference (i.e. in quadrature). This results in an end-fire arrangements with around 3dB of gain over a single vertical and 10dB – 25dB of front-to-back ratio. The pattern achieved is the classic cardioid pattern, with a null along one end of the two antennas and a lobe on the other end. Strong local and medium distance stations (i.e. VK stations) will have very reduced signals (-25dB typically).

Remote switching normally provides for switching direction and for a third position where the array is fed in phase for a broadside array (with 3dB of gain broadside to the two antennas and about the same front-to-back ratio). The beamwidth of such arrays is typically around 165 degrees at the -3dB points.

Phasing requires a 90 degree phase shifter. This can be achieved in a number of ways – potentially with a simple LC circuit, with a hybrid coupler, or with Christman phasing lines. With hybrid couplers, the antennas are fed from the phasing unit to the antennas with ¼ wave 50 ohm coax, to achieve “current forcing” of the antennas.

Commercially available couplers all use a Collins hybrid coupler to achieve the phase shifting required. The Christman method is cheaper and results in lower losses in the coupler circuitry (losses are limited to coax cable losses only) providing calculations reflect actual measured antenna impedances, and take into account cross-coupling. Computer programmes are available to compute phasing line lengths or a programmable delay line box can be used for coupling. Because the Christman method requires calculations specific to a particular setup, this approach is not able to be commercialised.

**Four Vertical Arrays (The Four Square)**

Four vertical monopoles are arranged in a square and separated by a quarter wavelength. The antennas can be fed in a number of ways. Generally the front antenna is fed at 180 degrees in relation to the rear antenna, and the two side antennas are fed at 90 degrees in relation to the rear antenna. This results in a radiation pattern in just one quadrant of the compass (and a small rear lobe), with around 6dB of gain over a single vertical and 25dB front-to-back ratio. Beamwidth is about 80 degrees at the three dB points. A switching system means that the beam can be rotated quickly between the four points of the compass. In New Zealand the centre of the beams would be aligned to NW, NE, SW, and SE.

Phasing requires a 90 degree phase shifter and a 180 degree phase shifter. This can be achieved in a number of ways. Commercially, all circuits now use hybrid couplers and a toroidal 180 degree transformer. The antennas are fed from the phasing unit to the antennas with ¼ wave 75 ohm coax, to achieve “current forcing” of the antennas.

Again it is possible to use the Christman method with two specifically calculated phasing lines or variable delay line boxes and a 180 coaxial delay line or transformer. Coaxial delay lines can be quite long at 40m and below, and this tends to suggest the Christman method is better suited to the higher bands from 30m and above where other antenna systems may prevail.

**Other vertical arrays**

There are many other types of vertical phased arrays including:

* Rectangular arrays
* Five vertical arrays
* A circle of six or eight verticals with various phasing options
* Two sets of Four Square Arrays fed in phase

All add some gain and much greater complexity. There seems to be limited benefit from implementing more complex arrays beyond a Four Square. Feeding two Four Square arrays in phase would probably be the easiest way of realising greater gain.

In conclusion, the Four Square array, is the way to go for better gain in portable situations. Contest and DXpedition stations prefer these arrays on the low HF bands. The club’s vertical antenna (Hustler 6BTV) is quick and easy to set up and requires no climbing. While it would take four times as long to set up, a Four Square array (using single band elements) should be able to be assembled by the same amateurs in a portable situation without any greater level of expertise. A few more helping hands would increase the speed of assembly.

Note that two vertical dipoles are often used by DXpeditions for the higher bands. These can be phased or parasitic arrays. Vertical dipoles can also be used in a four square configuration for additional gain on the higher bands.

**Area requirements for Phased Vertical Arrays**

Phased vertical arrays for 160m through 30m require far less land area than Vee Beams or horizontal arrays. But they still require more area than any antenna for the higher bands.

A 160m Four Square, using shortened vertical radiators (say 20-30m radiators deploying top loading and a capacity hat on the guy wires) would exceed the 8m height restriction, but would be somewhat efficient. Heights below this should not be considered. Spacing at a ¼ wavelength between verticals would place antennas at 40m apart. Guying of the antennas would require a further 5m to 8m around the edges and a good radial system would extend out to a 40m radius around each radiator. In other words an 80m x 80m area (6400 square metre site) would accommodate a ¼ wave spaced 160m Four Square Array. This is an area of around 1 and half acres. This compares with the requirement for a single Vee Beam with 300m leg lengths of at least 45,000 square metres (or about 12 acres). Two Vee Beams mounted on the same pole would require around 90,000 square metres (or about 24 acres). Larger areas could be required depending on orientation of the land. A North/South orientation is preferable for building multiple Vee Beams in New Zealand. A Four Square Array for 160m, therefore, requires less than 10% of the land area required for two Vee Beams (covering EU long and short path and short path USA) similar to those installed at Quartz Hill.

Note that ¼ wave spacing is not essential for a phased array. Either higher gain or higher front-to-back ratios can be achieved when using different spacing. Commercially available equipment requires ¼ wavelength spacing to function as phase shifts required are specific to spacing of antennas. Quadrature phasing is also easier to achieve with hybrid couplers and transformers. Spacing between complete arrays should ideally be at least 2 wavelengths minimum for two similar antennas on the same frequency in order to avoid difficulties with cross coupling. Spacing between antennas that are not resonant on the same band will be less critical. Co-locating antennas on different bands would allow for closer spacing.

An 80m Four Square, again using shortened vertical radiators (say 8-10m radiators with top loading and capacity hats) spaced at ¼ wavelength between verticals would require placement of the two antennas at 20m distance apart. With 5m additional radius required for guying around each vertical and 20m for buried radials, an 80m Four Square could be accommodated within a 1600 square metres (or in an area of under half an acre).

40m and 30m antennas require less space again (around 400 square metres and 180 square metres respectively when using full size radiators).

Assuming that antennas are built for all four bands (160m, 80m, 40m, 30m) and antennas are arranged carefully (see Annex A for a possible layout) then total land area required is much smaller than that available at Quartz Hill. The example in Annex A requires about 1Ha (2 ½ acres). This involves reasonably close spacing between arrays and may result in some detrimental cross-coupling, but reflects the kind of real world spacing seen in DX stations, as demonstrated in photos or diagrams found on the internet.

Acquiring access to a parcel of land of this size would be much easier than a full size farm of 100 acres plus. It would also be possible to locate potential sites much closer to Wellington, including possibly some that the Quartz Hill User Group has already investigated. A smaller land requirement could also open up the possibility of land purchases in the Wairarapa or Horowhenua (with prices around $115k – 250k).

**Costs of Constructing Phased Vertical Arrays**

Phased verticals will inevitably cost more than simple wire antennas. However, the Vee Beams at Quartz Hill relied on access to a collection of 20m high poles. Installation of a similar set of poles on any large site could be quite expensive and may be as expensive as an investment in phased arrays.

*Commercial Options for Phasing Units*

There are two main commercial options for phasing units for vertical arrays (with three different brands). DX Engineering markets their own 160/80/30/40m Four Square and Two Vertical phasing units. They also market older (and slightly less effective) Comtek designs covering all non-WARC bands. Note that Comtek is now a subsidiary of DX Engineering. Units range in price from US$439 to US$695 for each combination of shack controller and phasing unit. Additionally, each unit requires the addition of tuned quarter wave coax phasing lines, which represents an additional cost and a feedline.

Array Solutions make Four Square phasing units as well (US$595 each covering 160/80/40m bands). These have some additional advantages, in that they can be fine tuned for maximum forward gain and can be remote controlled. It is suggested that the Array Solutions option would be preferable for QHUG use.

*Commercial options for Quarter Wave Vertical Antennas*

Vertical antennas can also be purchased off the shelf. A range of options for 80m, 40m and 30m exist for under US$200 per antenna for full-size or shortened loaded antennas. These costs need to be multiplied by four to install a Four Square array. Not surprisingly, costs for 160m antennas tend to be quite a bit higher. Given these require resource consent to deploy, I have not looked into the costs of a 160m array. I suspect that a 160m array would not be of highest priority for the Quartz Hill User Group.

*Home made alternatives*

Another option is to construct our own phasing units and antennas.

There are a number of design options for phasing units, with various pros and cons of each option. There are some very good papers on the internet about different types of phasing arrangements.

The Christman method has the lowest cost as it only requires relay switching and coaxial phasing lines. This method is based on the principal that you can feed two antennas at any point on the feedlines where there are matching voltages in order to ensure similar currents in the radiators.

The Christman method is subject to greater error in construction and in antenna resonance/impedance mismatching. Losses are limited to those in the coaxial lines. Other circuits are more complex and involve L/C combinations, hybrid combiners, and 180 degree transformers in addition to the switching equipment. These approaches introduce losses. For a portable unit, the hybrid switcher is the way to go. For a permanent installation, other methods may be cheaper and just as achievable, providing access to feedpoint impedance measuring equipment and computer programmes for setting up is available. Long coax phasing lengths on the low bands may suggest Collins hybrid couplers would be the better option as they would be more compact.

A Swedish supplier can supply circuit boards for Four Square hybrid style phasing systems. Construction of phasing units and remote switching equipment could be an interesting club project. However, this may not save a lot of money and could lead to frustrations with underperforming units in the absence of a suitable test environment.

Antennas located in windy locations around Wellington will probably need to be home made. Steel, rather than aluminium construction, may be desirable to ensure they remain upright in sustained high wind locations. However, corrosion will require regular inspection and eventual replacement of steel structures. The challenges of home construction are primarily in the areas of base isolation and top loading, particularly when using capacitive loading.

*Other costs*

There are other costs associated with using verticals including guy ropes and anchors, feedlines, switching cable and most importantly radial wire. A 160m Four Square would require around 5Km of radial wire if 32 radials per antenna were to be installed. A 30m Four Square, by way of comparison, would require almost 1Km of radial wire if 32 radials were to be installed.

**Conclusion**

Nothing in this paper represents anything new in terms of antenna science or construction. However, research and modelling of antenna types may assist in rethinking a core assumption held by the Quartz Hill User Group - that a large site is required for effective DX low band antenna operations. Good performance is likely to be achieved with phased vertical arrays for the low bands. Options for 20m and above do not take up much acreage and are therefore not as relevant to site area considerations. Verticals are readily able to be installed and maintained and unlike Vee Beams require no climbing of poles. They would, however, be a bit more costly to install, unless 20m power poles have to be erected on site. In this case, costs involved in vertical arrays may be lower. Existing Quartz Hill funds would permit a good start to building a new antenna farm and additional fund raising could allow for expansion of antennas systems over time.

Sites such as the previously identified and close-in Pukerua Bay hilltop location or the former Wellington Radio location on Tinakori were earlier rejected for their lack of site area for large antennas. There may still be other good reasons to reject these sites. The Pukerua Bay site is prone to extreme winds and uplift effects and requires four wheel drive vehicle access. Tinakori Hill is likely to be subject to man-made RF noise given its proximity to the city. Security would also be a key concern with this site. However, all previous sites need to be reviewed in light of the demonstrated potential for vertical arrays to represent viable options for the lower HF bands.

Other sites located near water should also be considered given the increased efficiency and effectiveness of verticals over sea water. The Quartz Hill Committee will consider the issues raised in this paper at its next meeting.

**Useful reference material**

1. ARRL Antenna Handbook
2. A very detailed study of Phased Arrays <http://vss.pl/lf/11.pdf>
3. The Simplest Phased Array System that works, by W7EL: <http://www.i1wqrlinkradio.com/antype/ch69/chiave34.htm>
4. TK5EP page with the design and construction of a Four Square Array. <http://www.egloff.eu/index.php?option=com_content&view=article&id=4&Itemid=136&lang=en>

**Annex A: Possible Four Square layout for all bands 160m through 30m**

80m

Possible Operating Location

120m

40m

80m

30m

160m