Multi-Band Vertical Aerials

In last month's issue we gave details of a vertical aerial for the 14MHz amateur band which had been developed in the US. In this article the author describes two somewhat more flexible multi-band vertical aerial systems which he has developed locally and found to give good results, both for short-wave listening and for amateur transmission.

by IAN POGSON

Aerials for short wave use are many and varied. The variations are generally dictated by a number of factors, some of which are the frequency of operation, cost, simplicity or otherwise of construction, ease of erection, directivity required, amount of real estate available, and so on.

The factors to be considered will also vary according to the user. A short wave listener will possibly need an aerial, or aerials, for many bands according to his particular interest. These aerials will generally be required to respond to signals ideally from all directions. On the other hand, a transmitting amateur would have quite a different set of requirements. His aerial system would more than likely centre around the frequencies allocated to the Amateur Service. In addition, he would probably require some sort of directivity characteristics, either fixed or rotatable. Angle of radiation would also be of interest to the amateur. These are just a few of the possible considerations.

The above points are mentioned in passing, as being of general interest. No active radio amateur would need to be told any of these factors, as he has possibly spent quite a lot of time and effort in determining the best aerial system to suit his requirements. The writer can be listed with this group, having spent many years looking for an aerial system to meet his particular needs.

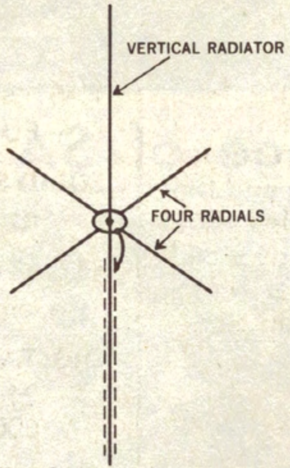
We have no intention of entering into any controversy as to which is the "best" aerial for amateur use, particularly the quad versus the Yagi!! In the opinion of the writer, they are both excellent systems, when properly used.

The writer has a two-section crank-up tower 50 feet high, and the need has been for aerials for the 3.5, 7, 14, 21 and 28MHz bands. We will forget about the two lower frequencies for the present and concentrate on the three higher bands. Over the years, many different types of aerial have been tried, all more or less satisfactory from the radiation point of view. The problem has been associated with the means of rotation.

A disposals type cowl gill motor has been used and is quite capable of doing the job. The real problem lies in the means of coupling the motor drive shaft to the shaft of the aerial to be rotated. The requirement here is always very stringent, as the coupling has to stand up to the high torque which strong winds impose from time to time. Other amateurs no doubt have had similar experiences and may well be looking for a way out.

Short of spending quite a lot of money etc., a solution seemed to lie in some sort of compromise with the situation. After much thought on the subject, consideration was given to the possibility of trying a ground plane. This aerial is relatively simple to make, has a low angle of radiation and as it is omni-directional, dispenses with the need for any rotating device. Points which may not be in its favour are the fact that it does not beam the signal in any particular direction, with its implications. Vertical aerials also have a reputation for picking up somewhat more noise than a horizontal system. Also, under some circumstances, problems with BCI and TVI can be experienced.

The pros and cons were weighed up and we decided to "give it a go". Initially, we roughed up a simple unit, similar to the basic ground plane as shown in the sketch. Each of the four radials and the vertical section were made of 1in diameter duralumin tubing, 13ft 6in long. Details of the actual construction will be given later on.

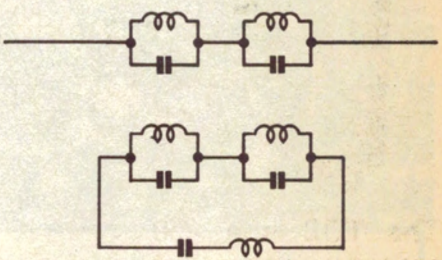


A basic ground plane aerial.

With the four radials actually on the ground, we connected a coaxial cable with the braid to the radials and the inner conductor to the vertical element. The cable, about 50ft long, was connected to a full coverage receiver. In case you were wondering, the aerial in this form resonated at about 16MHz. A listening test was very encouraging. Strong signals were received over a wide range of frequencies. These included international broadcast stations on frequencies between about 7MHz and 21MHz, together with amateur signals on the three bands included in the same frequency range. On 14MHz in particular, amateur signals were excellent from interstate as well as overseas, including British and European.

Listening over a period of a couple of weeks showed that this was an aerial which would be ideal for many short wave listeners. Naturally, the performance would be best around the resonant frequency of 16MHz but results showed that it is quite satisfactory over at least the frequency range originally quoted and if some fall off in response can be tolerated, it can be used right down to the broadcast band. In point of fact, a fortunate situation exists here, in that most receivers are more sensitive on the lower frequencies and so they do not need such an efficient aerial as for higher frequencies.

Within the limits which we have already quoted, we can confidently recommend this simple ground plane aerial to short wave listeners who may not have the space or other facilities for something more ambitious.

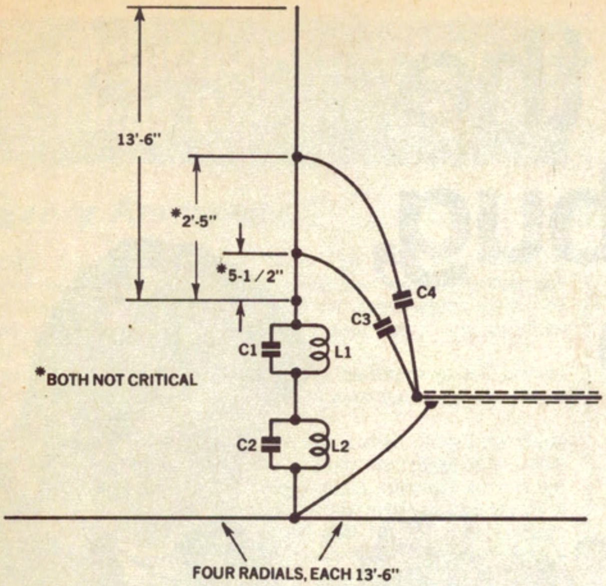


Top. A half-wave dipole with two parallel resonant circuits in series inserted at the centre. Above. The equivalent circuit, which is resonant at three different frequencies and no others.

Our findings thus far were such that we were encouraged to develop this aerial for use as a transmitting and receiving aerial for the top three HF amateur bands. What was required then was some means of making this aerial resonant on 14, 21 and 28MHz, together with a method of feed which meets the requirement of a low SWR.

For many years the writer has made use of the multi-band aerial tuning system as developed by Hans Ruckert, VK2AOU. Briefly, this system consists of splitting a dipole and inserting one or two parallel or series resonant circuits between the two halves.

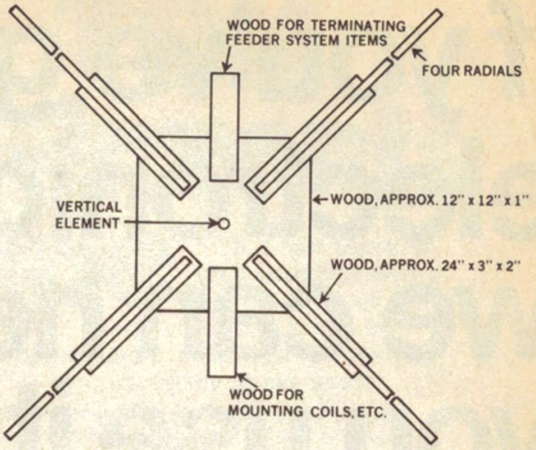
It can be shown that a resonant half wave dipole is equivalent to a series resonant circuit at the same frequency. Also, let us consider that we have two parallel resonant circuits, in series, connected into the centre of the dipole. Again, it can be shown mathematically, that this is equivalent to two parallel resonant circuits in series, with a series resonant circuit connected across them and that the system is resonant at three different frequencies, not necessarily harmonically related.



L1 : Mainly affects 14MHz : 6-1/2" long, 14G, bent into semi-circle.
L2 : Mainly affects 21MHz : 2T, 14G, 1-1/2" DIA., 1/2" long, leads 2" and 4" long.
C1 : Mainly affects 21MHz : 160pF.
C2 : Mainly affects 28MHz : 60pF.
C3 : Mainly affects 28MHz : 55pF (Adjustment fairly critical).
C4 : Mainly affects 14MHz and 21MHz : 52pF (Adjustment fairly broad).

Note: Space gamma 2" from radiator, to 2'-5" tap, otherwise SWR on 28MHz will be seriously affected.

The circuit of the aerial system for the 14, 21 and 28MHz bands.



(Above.) The layout of the base constructed by the author to support the vertical element and the four radials for the aerial system covering the 14, 21 and 28MHz bands.

A very interesting exercise is to mock up an arrangement using two equal lengths of wire, strung horizontally and broken in the centre. Add two parallel resonant circuits as shown and then investigate it with a grid dip oscillator. Couple the GDO into each of the coils in turn, and you will find three resonances. It is also interesting and important to note that this system will not resonate at any other than the above frequencies. This is a useful feature, in that it helps to reduce harmonic radiation. For readers who wish to read more on the findings of Ruckert, a list of references is given at the end of this article.

In order to apply this tuning system to our ground plane, we have to insert the two parallel circuits between the ground planes and the vertical element. This is shown schematically in the appropriate diagram. By now many readers will be asking how the three wanted resonances are obtained. The answer in general terms is that 14MHz is largely determined by L1, 21MHz by both C1 and L2, and 28MHz by C2. If you stick to the element lengths which we have used, then the values of L and C may be obtained from those we quote. Otherwise, you will have the interesting task of finding them for yourself.

It may be noticed that the element lengths used fall between a half wave on 14MHz and a half wave on 21MHz. This means that the system is shortened for 14MHz, somewhat lengthened for 21MHz and rather longer again for 28MHz. From practical considerations, the element lengths which we have used are about the longest for the frequencies involved, whereas the radials and the vertical radiator could possibly be reduced to a lower limit of 11 feet. This may lead to some drop in overall efficiency and it would certainly mean a new set of values for L1, L2, C1 and C2.

Having arrived at a set of values for the two capacitors and two inductors, by means of a grid dip oscillator, the next move is to find a satisfactory means of feeding the system on all three bands. This can be done by means of a link coupling arrangement into one or both of the inductors. However, a method which we found to be very satisfactory closely resembles the familiar "gamma" match.

The feedline used is 75 ohm coaxial cable, with the braid terminated at the junction of the four radials. From the centre conductor, a lead is taken via a capacitor to a tap 2ft 5in up the vertical element. This serves for both 14Mhz and 21MHz. For 28MHz, another lead is taken via a capacitor, to a tap 5½in up the vertical element. This arrangement can be adjusted to give a low SWR on all bands. The values which we found to be optimum again apply only when the same element lengths are used. No doubt these adjustments will have to be modified if shorter elements are used.

From a constructional point of view, it may be better to leave most of this to the devices of the individual. At the same time, a few remarks as to how we went about it may be of assistance.

Whereas we used 1in OD dual tubing, with radials and vertical element each 13ft 6in long, other materials and diameter may be used according to individual needs and circumstances. We would suggest however, that the original element lengths be adhered to, unless there is a good reason for making a change.

Our construction was based on a "chassis" consisting primarily of a piece of board, about 1ft square and 1in thick. Four pieces of 3in x 1in about 2ft long were added to the board, as shown in the sketch. These are to provide a fixing for each of the radials, the radials being held in place with two saddles for each. In addition to the four pieces of 3in x 1in just mentioned, we added an extra two pieces as shown, about 1 ft long. These are handy to accommodate stand-offs, terminations, etc, for the tuning items and the feeder system.

Having fixed the radials in place, the question of fixing the vertical element can pose some problems. We screwed a stand-off ceramic insulator to the centre of the board, the diameter of the insulator being such that it was an easy fit inside the end of the tubing. The vertical element was then stabilised by using four guys, one to each of the radials. We used stranded galvanised wire for the radials, broken by egg insulators about 2ft apart. A point about 4ft up the vertical and about the same distance along the radials from the centre would be satisfactory. In the construction, we made use of clamps intended for TV aerial use.

Inductor details, capacitor values, method of feeding, may all be obtained from the table and drawings. Most of this information should be self-explanatory and the small details are left to the initiative and particular requirements of the individual.

It will be noted from the inductor details that L1 is not a coil but a short length of wire, bent into a semi-circle. This may need a bit of juggling to get the 14MHz response correct, but no trouble need be anticipated. It would seem that this inductor virtually determines the maximum length of the vertical and radial elements. If they are increased beyond the length which we have used, then this inductor would approach vanishing point. On the other hand, with shorter elements, this inductor will increase and will then assume the shape of a coil.

All of the capacitors, C1, C2, C3 and C4, which we used, are of the miniature variable type. When they have been adjusted, each one is put into a protective plastic container, to protect it from the weather. The containers which we used were originally used for pharmaceutical products, such as tablets, etc. These are not hard to come by. In each case, we drilled two small holes in the case to pass the leads through, these holes were waterproofed later by a drop of Bostik or similar adhesive.

Although we used miniature variable capacitors in the finished job, it may be possible to use coax cable, to give the requisite capacitance, once it has been finally determined with a variable capacitor. This may be worth investigating.

The capacitors C3 and C4 are mounted close to the end of the coax feedline. The lead from C3 should be a heavy gauge of wire and is run directly to the tap point which is only 5½in up the vertical element.

This point did not appear to be critical. Much greater care must be taken with the lead from C4, to its tap 2ft 5in up the vertical element. Steps must be taken to run this lead parallel with the vertical element, starting from an inch or two from the bottom. The distance of the lead from the element is necessarily a compromise, as the closer it is the better, for 14Mhz; but it should be spaced at least ¾in for 28MHz.

In fact we found that ¾in spacing was about the best compromise. If the spacing is too little, it will be impossible to get the SWR down for 28MHz. Following from this condition, it is necessary to maintain the spacing constant against weather conditions and to this end, spacers must be provided to achieve this. Although we used wire, which needs to be supported, it may be a proposition to use a small diameter tube, which would be rigid enough, when supported only at each end.

Having completed the assembly, with L1, L2, C1 and C2 connected up, the feed components are best left off at this stage. C1 and C2 are then set to approximately the capacitance given in the table. We will also assume that the radials are at least 12in or so above the ground. With a grid dip oscillator, couple into L1 or L2, the latter will probably be more convenient, check for the three resonance frequencies. While there will be a certain amount of interaction, L1 is varied to set the 14MHz point, both L2 and C1 may be varied to set the 21MHz point and C2 will control mainly the 28MHz point.

Even at this stage, the precise band-centre frequency should be aimed at in each case. Actually, such centre frequencies as 14.2MHz, 21.3MHz and 28.6MHz may be selected. Having done this, the feeder components are added and the series capacitors are set roughly to the values given in the table. These are simply quoted as a guide. We can now start the serious business of setting the centre frequencies accurately, together with adjusting the SWR to a minimum for each band.

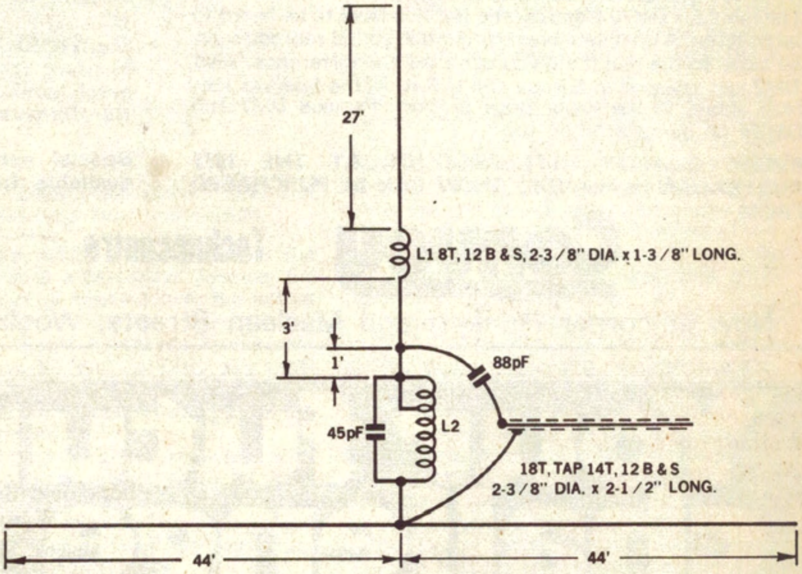
To do this, we need an SWR bridge and a transmitter set to deliver only enough power to actuate the bridge properly. A power input of about 20 watts or so should be sufficient. The bridge is connected in series with the line, as closely as possible to the feed point at the aerial, ie, within about 3 feet. The transmitter is then set to the desired centre frequency in the 14MHz band and a small amount of power loaded into the feedline. The SWR bridge will quickly tell its own story and this will indicate what has to be done to improve matters.

With the SWR bridge set for reflected power, check for centre frequency by introducing a piece of ferrite aerial rod into L2. If the meter drops, then L1 may need to be increased. Conversely, the opposite would be true. But at this stage, it would be well to leave L1 alone and attempt to reduce the meter reading by adjusting C4 for minimum.

The transmitter is now set to the chosen centre frequency in the 21MHz band and loaded up as before. Check the SWR again and attempt to bring the reading down by adjusting precisely to frequency with C1. This should bring the SWR to a very low value and although the SWR on this band is also largely determined by adjustment of C4, the adjustment already carried out for 14MHz should be very close.

The transmitter is again changed and set to the centre frequency for the 28MHz band and loaded up lightly once again. Adjust precisely to frequency with minimum reading, by C2. A further reduction in SWR is now effected by adjusting C3 and this should also result in a very low SWR. However, as intimated earlier, there is a compromise here between 14MHz and 28MHz and a complete reduction to zero reading may not be achieved.

With these preliminary adjustments made, we are now faced with a similar situation to that used for aligning a superhet receiver. The whole procedure must be repeated for each band, until all adjustments are correct. On the second time around, it may be determined whether L1 and L2 will need any adjustment. Adjustment of L1 is clearly indicated at this stage, if the frequency of the 14MHz band needs to be changed one way or the other. Adjustment of L2 will only be necessary if the 21MHz band can only be adjusted with C1, thereby markedly upsetting either of the other two bands.



A ground plane aerial system for 3.5 and 7MHz.

Having completed all adjustments, full power may be fed into the system. Even with the aerial about 12in above ground, it is remarkable just how well it performed at the writer's location. Although is was difficult to judge performance at this level, compared with the aerial raised to 28ft above ground, there did not seem to be a great deal in it, at least on listening tests. Even with the radials at 50ft above ground, little difference could be detected. In short, it would seem that the low angle of radiation for which the ground plane is reputed, is virtually unchanged by height above actual ground. At the same time, it is axiomatic that any aerial system should be well in the clear of all obstacles which could result in absorption of the signal.

The writer is also of the opinion that when a ground plane in particular, is raised as high as possible, the amount of noise pickup could well be reduced and any tendency to a strong ground wave which may be conducive to TVI and BCI, would be substantially reduced.

Since the tri-band ground plane has been erected at the writer's location, it has survived a very strong southerly blow at the 28ft level, showing no signs of distress. At the same time, considerable damage was done to property elsewhere. The performance of the aerial has been very satisfying, with good signal reports given by stations as far away as England and Europe. At the same time, we would not presume to compare it under poor conditions, with a high gain system. In spite of any shortcomings which such a simple aerial system may have we think that it has been worthwhile and we have no hesitation in commending it to those whose interests are in this direction.

Having had considerable success with the 14MHz, 21MHz and 28MHz amateur band ground plane aerial system we thought that it would be worth a try to produce a similar system for 7MHz and 3.5MHz, particularly as we had a use for such a system. Most of us have the usual suburban building lot and this does not allow sufficient room to erect a full size aerial for 3.5MHz. Even one for 7MHz can be somewhat of a squeeze.

Surely no one would dispute the efficiency and desirability of a full size aerial, even some sort of beam but for those of us who find this to be quite impractical, we must look elsewhere for an answer to the problem. As surprisingly good results are obtained with vertical whip aerials in mobile work, even on the 3.5MHz band, we reasoned that at least as good results could be obtained from a fixed vertical aerial system.

With these thoughts, we considered that it would be worth starting off with just two radials and see how this worked out. A suitable length for these radials would be somewhere between a quarter wavelength on 3.5MHz and 7MHz, or between 67ft and 33ft. We chose a starting length of 44ft as being about right to fit into the space we had available.

Turning to the vertical element details, we already had on hand a 20ft length of 3in x 2in oregon timber. Also, a piece of galvanised conduit, 5/8in diameter and 11ft 6in long was available. The conduit was clamped to the top of the timber, with about 18in overlap. Wire could then be run from the conduit down to the bottom of the pole, thus giving a vertical length of about 30ft. The pole was then pushed up and screwed to a selected post — actually part of a side paling fence. In my case, this is all that was necessary to make a solid fixing for the pole. In some cases, it may be necessary to guy the pole, with guys suitably broken up with insulators.

From the base of the pole, we tacked one of the radial wires along the bottom rail of the fence. When fixing the second radial, we came to the corner at the back of the building block and so the radial was simply tacked for the rest of its length, along the bottom rail of the back fence.

With the three elements in place, the next job was to make a resonant system. As the radials were each 44ft long and the vertical element was only about 30ft, we decided that to make a reasonably balanced system, this element should be loaded to bring it to about an equivalent of 44ft. As shown in the diagram, this has been done by introducing a loading coil L1 at a point 3ft from the bottom.

This coil consists of 8 turns of 12 B&S enamelled wire, 2¾in diameter and 1¾in long. We wound ours on "air" but if you have a suitable former, it could be used, provided that it is of low loss material and proofed against the weather. Two porcelain stand-off insulators were used to mount the coil. In fact, we used several of these insulators for terminations, at such points as the bottom of the vertical section, which is just a few inches above the ground level.

The 27ft length between the bottom of the conduit and the loading coil is provided with a reasonably heavy gauge of copper wire, say between about 12 and 16 gauge. The 3ft space between the coil and the bottom end of the vertical element is also a piece of the same gauge of wire.

Assuming now that the vertical element and the radials are in position, the next task is to tune the system to the 3.5MHz and 7MHz bands. Another coil is required (L2) and the one which we used consisted of 18 turns of 12 B&S enamelled wire, wound on a 2¾in diameter ceramic ribbed former, the winding being 2½in long. When the system was finally tuned, we had shorted out the top 4 turns, thus reducing the number effectively to about 14.

With the L2 connected, a variable capacitor of about 100pF is connected in parallel with it as a temporary measure. The initial tuning is done with a GDO, coupled into L2. The variable capacitor is adjusted to bring the resonance right for the 7MHz band. The exact frequency will be up to individual choice, but it may be in the vicinity of 7.075MHz. The 3.5MHz frequency is adjusted with L2 itself, turns being added as required. Again, the exact frequency may be set to 3.6MHz, or thereabouts.

Having initially found the two wanted frequencies, it will be necessary to go back and forth, as before, until both frequencies are correct.

At this point, we are again ready to start on the more serious business of coupling the feedline into the system and adjusting it for minimum SWR. The coaxial line from the transmitter is connected with the outer conductor to the junction of the radials and the bottom of the vertical. The inner conductor is run via another variable capacitor of 150pF or so, to a point 12in above L2. The series capacitor should be set to approximately 88pF as shown in the diagram, this being the value which we finished up using.

The transmitter is now needed and should be set to the 3.5MHz band centre frequency and lightly loaded into the system at first. An SWR bridge should be connected into the line, close to the aerial feed point. If the bridge is not available, then a field strength meter may be used.

Set the SWR bridge for reflected power and check for centre frequency by introducing a piece of ferrite aerial rod into L2. If the meter drops, then L2 may need to be increased. Conversely, the opposite would be true. In cases where a field strength meter is used, adjustment would be made for maximum meter reading. Continuing, the series feed capacitor is now adjusted for minimum SWR, or maximum field strength.

The same procedure is adopted for the chosen frequency of the 7MHz band; but this time, any adjustment in resonant frequency should be made with the variable capacitor across L2. The series capacitor is checked and adjusted if necessary, for minimum SWR or maximum field strength. The process must be repeated on each band, until adjustments are complete. If the series capacitor setting is not the same for both frequencies, then a compromise will have to be made and individual circumstances will dictate what this might be. However, the setting should be fairly close for both bands.

Having completed the final adjustments, the two variable capacitors may be installed permanently, provided that they are protected from the weather. An alternative, and one which we adopted, is to replace the two capacitors, each with a piece of coax cable. To do this, carefully remove one capacitor at a time and accurately measure its capacitance. A piece of coax cable is then cut to length to give exactly the same value of capacitance. The cable is then connected into the place of the former capacitor. This method has the advantage that the cable is better able to withstand the rigours of the weather.

At this stage, the new vertical is ready for service. If the experience of the writer is any indication, readers will find that although the system occupies a minimum of space, it will give a good account of itself. An important point which should not be overlooked is the fact that the aerial as described only has two radials. This would be a bare minimum and there is little doubt that if space is available to add extra radials — the more the better — results would be improved accordingly.

Just one final point. The thought has crossed the mind of the author that it may be possible to achieve some measure of directivity by switching in and out radials, as required. It has been established that one, two, or even three radials of the high band system can be disconnected, without upsetting the SWR. I have not checked the idea for directivity at the time of writing. If any reader tries it, I would be interested to hear of the findings.

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