THIS MONTH'S LEADING PROJECT

Seven Antennas On One Tower

The first of three parts by Tony Preedy C Eng MIEE, A45ZZ

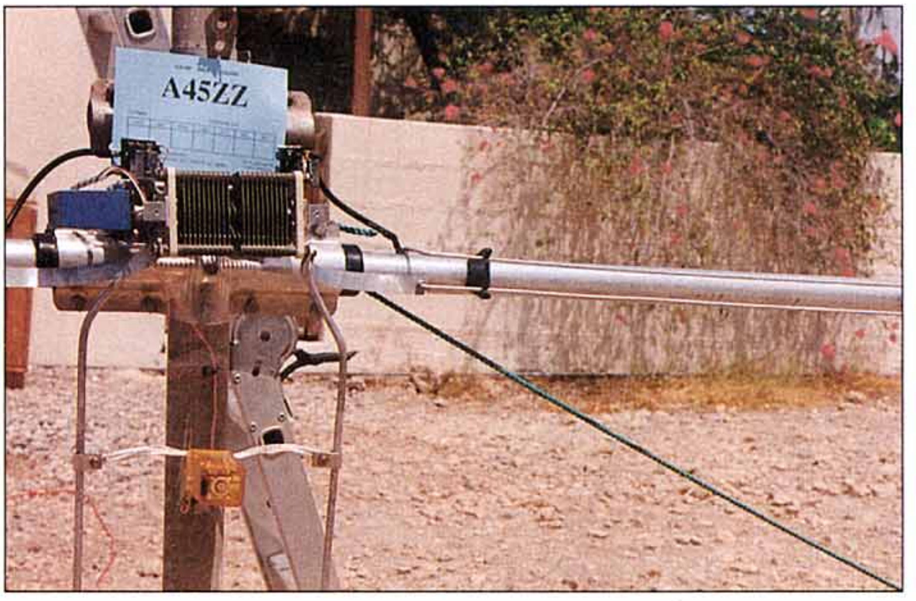
THIS ANTENNA, COVERS all of the amateur bands from 7 to 28MHz, and is the result of my efforts to make a reproducible high performance multiband rotatable beam which does not use traps for tuning or matching.

Although traps have allowed compact two and three band rotary beam antennas to be built commercially, suitably weatherproofed types of appropriate precision are difficult for the home constructor to make. Commercial attempts to cover more than three bands using traps generally result in whole elements being redundant on some bands. Traps do in any case result in a compromise because they are inherently lossy, restrict antenna bandwith, add windage and weight to the elements and worst of all, as with log-periodic and multiband quad antennas, they result in a high proportion of the exposed hardware being unused on most frequencies covered by the antenna.

The use of traps in a beam antenna for the seven HF bands is not practicable for home construction. A new approach was therefore necessary. Although my antenna operates down to the 7MHz band the boom is not much longer than a conventional tri-bander; although the elements are longer. As far as visual impact goes the longer elements are offset to some extent by the absence of traps (particularly if you were using traps in a seven-band design).

You need not be this ambitious if planning difficulties are anticipated. For example any monoband beam could be adapted on the same lines as my antenna by having the element centres insulated and made tuneable from the original band through each higher frequency one. My first attempt to prove the principle used a Hygain type 203 BA, 14MHz 3-element beam, with additional centre insulators, as used on the driven element, fitted at reflector and director. Relays were mounted inside the ends of the boom and connected across the insulators of the parasitic elements. The relays were closed for 14MHz and open on 18MHz, where the capacitance of the insulators conveniently provided the necessary tuning reactance. Initially the standard driven element was tuned midway between the two bands but later I replaced it with a folded dipole to give a better impedance match over both bands.

After this success I was inspired to add some more bands without adding extra elements or lengthening the boom the boom length being a limiting factor in my domestic situation.



A front element tuning assembly sitting on the locally made plastic cover. The housing can be kept to a reasonable size, about 160 x 100 x 75mm inside dimensions, if the servo is mounted outside on the end of the box and the 'O' ring seals supplied with it are used to keep out the weather. No attempt was made to seal the enclosure where conductors pass through the base because this provides a drainage route for the inevitable condensation.

EXTENDED ELEMENTS

THE GAIN OF A DOUBLET varies with length as shown in **Fig 1**. The maximum gain of 3dB over a halfwave dipole (available when in extended double Zepp form in which each half is 5/8 wavelengths long) can be used to advantage in a beam antenna. For a given antenna height, this colinear gain is equally effective over any communication distance whilst gain obtained from either vertical stacking or additional parasitic elements is only effective over specific paths. The usable frequency range of a doublet is typically that where the length lies between 1/3 and just over 2 x 5/8 wavelengths. That is over a frequency ratio of 3.8. The lower frequency is limited by losses in the loading inductor, typically as shown in the dotted curve of Fig 1, whereas the upper frequency is limited by side lobes taking power from the main broadside lobe of radiation.

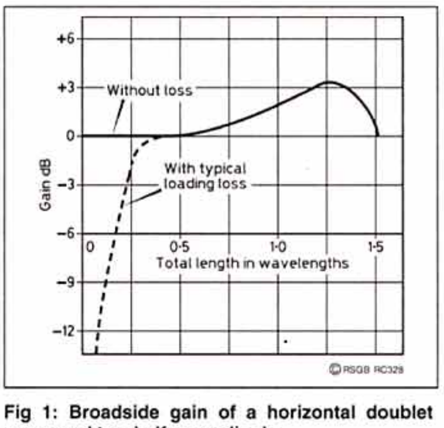


Fig 1: Broadside gain of a horizontal doublet compared to a half-wave dipole.

A single nominally 14m element should therefore be expected to perform efficiently in a directional antenna throughout the amateur bands 7 to 28MHz if precautions are taken to minimise losses on the lower band. Transmission lines can make much more efficient loading inductors than coils and these were therefore chosen for the successful Hygain/Telex design which provides the basic mechanical structure for my antenna. The reactance necessary to tune an extended element of typical tubular form, to make it perform as a reflector, can be calculated approximately by treating the element as a section of transmission line of characteristic impedance 250Ω and using a frequency 5% lower than the working frequency. Similarly for a director a frequency 3% above the working frequency is used in the calculation.

To be more precise we should also consider element spacing and the effect of extra

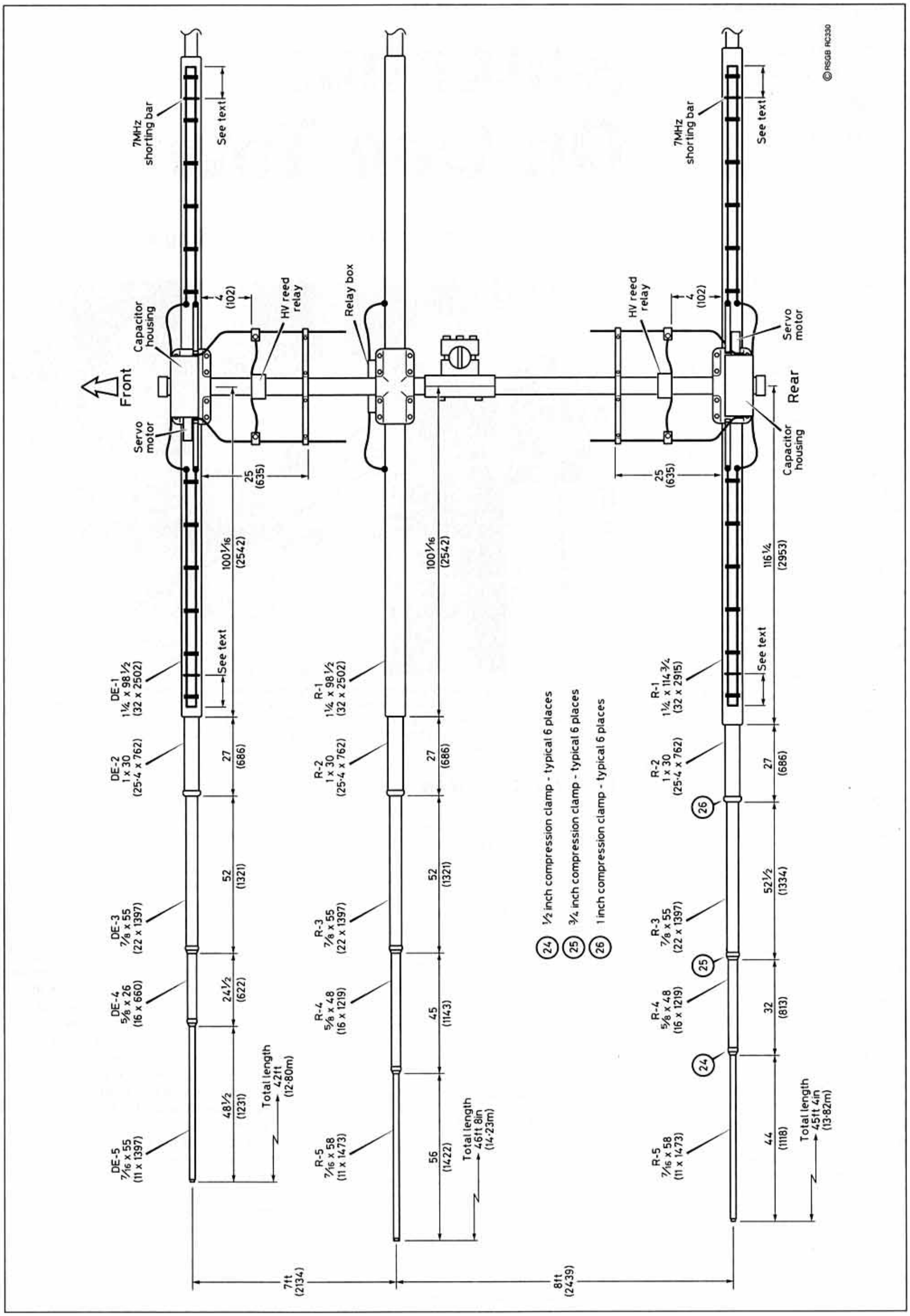


Fig 2: General view of the Hygain 402BA-S antenna modified for seven bands.

radiation resistance on the phase of the current in an extended element. However in this design it is not important to know exact measurements because with the exception of the reflector on 7MHz all tuning is optimised from the operating position. How many readers can be confident that the parasitic elements of their antennas are optimally tuned *after* they have fixed the antenna on to the tower? The required tuning reactance X is given by:

$$X = \frac{j \times 2 \times 250}{\mathrm{Tan}(L)}$$

Where L is the electrical length of *half* the element in degrees (unless you're familiar with j notation ignore this symbol which provides the signs of the reactance).

For example, a 2 x 5/8 wavelength doublet when used as a reflector at 28.5MHz must resonate in the 1.5 wavelength mode at say 27MHz where the electrical length L is 5/8 x (27/28.5) x 360 = 213°.

The tangent of 213° is +0.65. Therefore the reactance required is 2 x 250 divided by 0.65 = 769Ω inductive. The formula will show that below the frequency where the element is a half wavelength, inductance is again required but between 1/2 and 1 wavelength, as on 14 and 18MHz in this case, the tuning reactance for resonance in the full wavelength mode will be provided by a capacitor.

The required range of reactance in this design was calculated to be obtainable from a section of transmission line (hairpin) shunted by a variable capacitor.

This arrangement incorporates capacitance attributable to the insulation at the centre of the element. The effect of centre capacitance is to increase circuit Q and hence the potential for dissipation by current circulating in the hairpin. This can be accommodated by making the hairpin from thick conductors. The hairpin also serves more conventionally to raise the otherwise very low feed resistance at the front, driven, element on the 7MHz band.

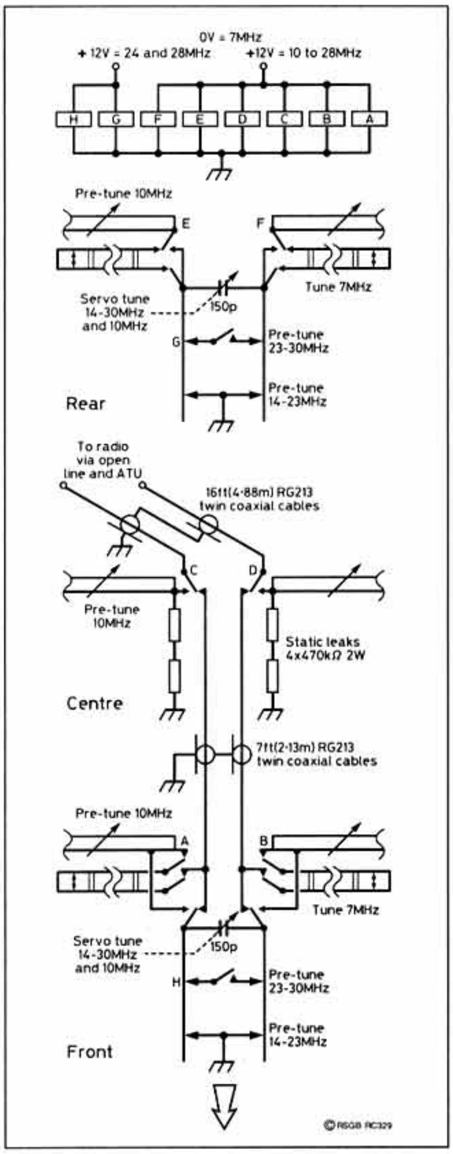


Fig 3: Concept and tuning of the 7-band antenna

MATERIALS

MOST OF THE HARD WORK and component sourcing usually associated with home construction has been eliminated from this project because the aluminium tubes, stainless steel parts, insulators and fixings are standard items from Telex/Hygain which I borrowed from their type 402BA-S, 40m two-element Yagi design. Even if you fail to make my antenna work you should still have a worthwhile asset!

Because of the relatively long elements this structure (shown in **Fig 3**) uses concentric heavy gauge tubing near the centre which is obviously necessary for both appearance and rated survival in severe weather. There is good reason to use a proven mechanical design for antennas of this size. This adaptation requires one standard antenna plus an additional set of parts, listed below, to form a third element.

It will no doubt be less expensive to obtain the standard fixings from a local source if you can. I managed to obtain all of the fixings and stainless steel clamps from a local marine chandler. The extra element is supported just to one side of the mast so that it imposes minimal additional loading on the boom.

Alternatively if the mast has a diameter of exactly 2 in it may be more convenient to fix the centre element to the mast. Precautions will then be necessary to prevent any tendency for the centre insulator clamp to slip.

The only other mechanical items which need fabrication are a relay/junction box, some simple brackets, shorting bars, capacitor boxes and drive couplings. Precise assembly details are not given here because these will depend on what tuning capacitors you can obtain. The layout of the relay wiring will also have some influence on the final tuning. Always be aware of the need to minimise weight and windage at the ends of the boom or you may have to add some support for the sake of appearance. A simple remote band selector using a proven circuit based on 555 timer ICs and other standard components is described later.

THE PARASITIC ELEMENTS

THE ELECTRICAL CONFIGURATION and tuning functions at the elements is shown in **Fig 2.** The front one is driven on 7MHz and becomes a director or pair of directors on bands 10 to 28MHz. Generally it is possible to tune each band without upsetting another. The mode of operation on 7MHz is conventional when the relays are not energised:

The element length is about 1/3 wavelength loaded to an electrical 1/2 wavelength by sections of transmission line supported on insulators along the element. A hairpin match (the original Beta match with 760mm removed from each leg for use at the reflector and for making shorting bars) results in a low driving impedance on this band. The element length plus hairpin provides resonance somewhat above 10.125MHz, resulting in a parasitic director.

The total length in metres is obtained from the formula 138/f. Shorting bars on the linear loading are then used for tuning to the required 7MHz band sector. These each consist of two 35mm lengths of 6.3mm diameter aluminium rod (beta rod offcuts) drilled at their centre and clamped with a 2.5mm nut and bolt. The variable capacitor, which is ineffective on 7MHz, provides remote fine adjustment of director performance when the antenna is on 10MHz.

The 402BA antenna lends itself to easy conversion for 10MHz operation, where the element size is a half wavelength, simply by short-circuiting each half of the linear loading to the element at the centre. Unfortunately this places a doublet, formed by the loading lines, in parallel with the feed point of the elements.

Although it has little effect on 10MHz, this doublet is resonant in the 24 to 28MHz region, causing it to detune the extended element and to become the major radiator as the working frequency is increased. The benefits of the extended element would therefore be lost.

Effective elimination of the linear loading on the HF bands requires either that it be shorted to the element at both centre and outboard ends or that it be completely disconnected. The former is impractical and therefore the rather inelegant relay disconnection system of Fig 2 was adopted. Whilst the loading is disconnected each half of the element is 5/8 wavelength on 28MHz, 1/2 wavelength on 21MHz, etc, and thus the colinear gain mentioned earlier is realizable on the bands above 10MHz.

To tune as a director or reflector on 24 and 28MHz a centre loading inductor is provided by the shorter section of hairpin loop as selected by relays G and H, high voltage reed types obtained from RS Components (Electromail). Relays G and H have their own control circuit.

The necessary reactance to resonate the element at the right frequency for best director performance on the bands 14 to 28MHz is found under final working conditions by varying the tuning capacitance with the aid of a remote controlled servo motor.

Settings are stored at preset resistors for future rapid band selection. The choice of capacitance range was influenced by the relatively high capacitance of the centre insulators (about 37pF) and the need to keep the Q of the circuit low to maintain a wide bandwidth.

A tuning range of 14.2 to 31MHz, director or 13.4 to 27MHz, reflector was achieved in two bands with modified 500pF 2kV capacitors from the junk box (EF Johnson type 500E20).

. . . to be continued

RADCOM TECHNICAL FEATURE

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The final part by Tony Preedy CEng MIEE A45ZZ*

SWITCHING TO 7MHZ is achieved by using S3 to remove both the 5 volt control and 12 volt relay supplies. The antenna therefore automatically defaults to this band. If the 12 volt supply is common to the radio it will ensure that you don't start calling on an HF band with the antenna tuned to 7MHz!

The servo motors are driven only when changing bands, by pressing S2 for a few seconds, after making a selection at S1. This prevents any tendency for the electronics of the control system to respond to RF from the transmitter and similarly we avoid the possibility of the control system causing interference when receiving.

If you need to listen 'off beam' simply select another band to effectively remove the parasitic elements. Because of the narrow beam, which results when the parasitic elements are in use on the higher frequencies, this mode will help when making a general search for signals. Also it may enable you to hear a third station who is on a different bearing to the station with whom you want to have contact, such as a DX net controller, without having to rotate the antenna.

PRELIMINARY TUNING

SLACKEN THE CAPACITOR drive couplings and check the band switching controller for correct output voltages as S1 and S3 are operated. If you do not have an oscilloscope a pair of headphones or an analogue DC meter can be used for checking the pulse outputs. As the preset resistor value is increased the buzz will alter in tone or the meter indication should rise linearly over a range of 3 to 1. Connect the controller to the servo motors and relays and confirm that they can be controlled by the resistors VR1 to VR6 and the switches respectively.

Set VR1 and VR6 and the capacitors to minimum. Lock the capacitor couplings and check that the tuning resistors provide full 180° rotation of the capacitor shaft without either exceeding the range of the servo feedback potentiometer or hitting any endstop on the capacitor. R7 determines maximum rotation by reducing the effective value of the tuning resistors to about 150kΩ.

Check that the relays function correctly. Find a site clear of electricity supply cables and other conductors. Erect, one at a time, the front and rear elements on their respective (vertical) 2 inch half boom sections so that they are clear of the ground and large conductors. Set the element lengths as shown in Fig 2 (in Part One) and connect the band selector. Energise the relays A to F with + 12 volts. Use a dip meter to check for resonance by coupling close to the end of the hairpins. Adjusting the capacitor should produce a weak dip at 10.4MHz at director or 9.8MHz at reflector.

Check that at maximum capacitance strong dips occurs at or below 14.5MHz, director and 13.4MHz, reflector. You will need to energise the hairpin relays G and H to confirm resonance at 31MHz, director or 27MHz, reflector with the capacitor at minimum. In this case couple the dip meter near the reed relay. Switch off the relay supply and either short the feed end of the quarter-wave 100Ω feeder or disconnect it from the front element.

Tune with the shorting bars and check at the front element hairpin for a weak dip in the selected part of the 7MHz band. The capacitor has no effect on this band. However, 7MHz tuning of this front element is not critical to overall performance and a reasonable discrepancy can be taken up in the ATU.

As explained earlier, the reflector plus hairpin length is set for optimum 10MHz operation and the linear loading is adjusted for the sectors of the 7MHz band by moving the shorting bars symmetrically along the loading lines. Look for resonance at the hairpin on 6.8, 6.9 or 7.0MHz. (A shift of shorting bar position of approximately 180 mm is required for a 100kHz tuning increment). These correspond with low, mid or high band sectors respectively. If you want to operate on the whole band 7 to 7.3MHz this can be done at the expense of gain and back to front ratio at the high end by using the low band settings for reflector and mid band settings for front element. A subsequent change of 7MHz tuning will not influence the other bands. Do not attempt to tune the elements with a dip meter after assembly of the antenna because the results will be confused by mutual impedance.

To summarise the tuning procedure:

1) Element length, 10MHz

2) Linear loading, 7MHz

3) Hairpin length, 14MHz

4) Hairpin tap, 28MHz

FINAL ASSEMBLY

THE ANTENNA SHOULD be assembled using both Fig 2 and the makers' instruction

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SEVEN ANTENNAS ON ONE TOWER

THE PHOTOGRAPH, which was taken early in the development period, shows my home-made tower with an experimental antenna attached. The boom length was not finalised at this time and it was still supported by stays from an extension of the mast. In final form these stays were not required. Also the rotator, an Emoto type 1105MS, was not yet fitted. The front and rear elements of the seven band antenna are in their final positions but the driven element is not fitted. The other elements belong to a 17m monoband antenna which was being systematically replaced by the seven band antenna without unbalancing the boom.

Because of the severe working conditions, with temperatures sometimes exceeding 50°C in the shade, it was necessary for most of the construction and development to take place by moonlight. During daytime no part of the antenna or any tools could be handled unless kept in an ice box!

The mast is constructed from 16m of 100mm steel tube pivoted on the parapet wall of the bungalow about 4m above the ground. A falling derrick consisting of 8m of 56mm steel tube is permanently attached and shares the mast pivot.

The derrick and mast have stays of 6mm steel wire rope terminated on the walls of the bungalow. Two mast stays are permanently attached to the top of the derrick which is itself fixed to the opposite parapet wall via a bracket when the mast is vertical. A 500kg boat trailer winch, fixed to the wall, is used for single handed control of the mast.

The mast also supports both one end of the author's 160m inverted-L and the Double Delta antenna for 80m, which was described in *Radio Communication* November '93. Readers will appreciate that the municipal authorities in Muscat do not discourage the construction of amateur radio antennas.

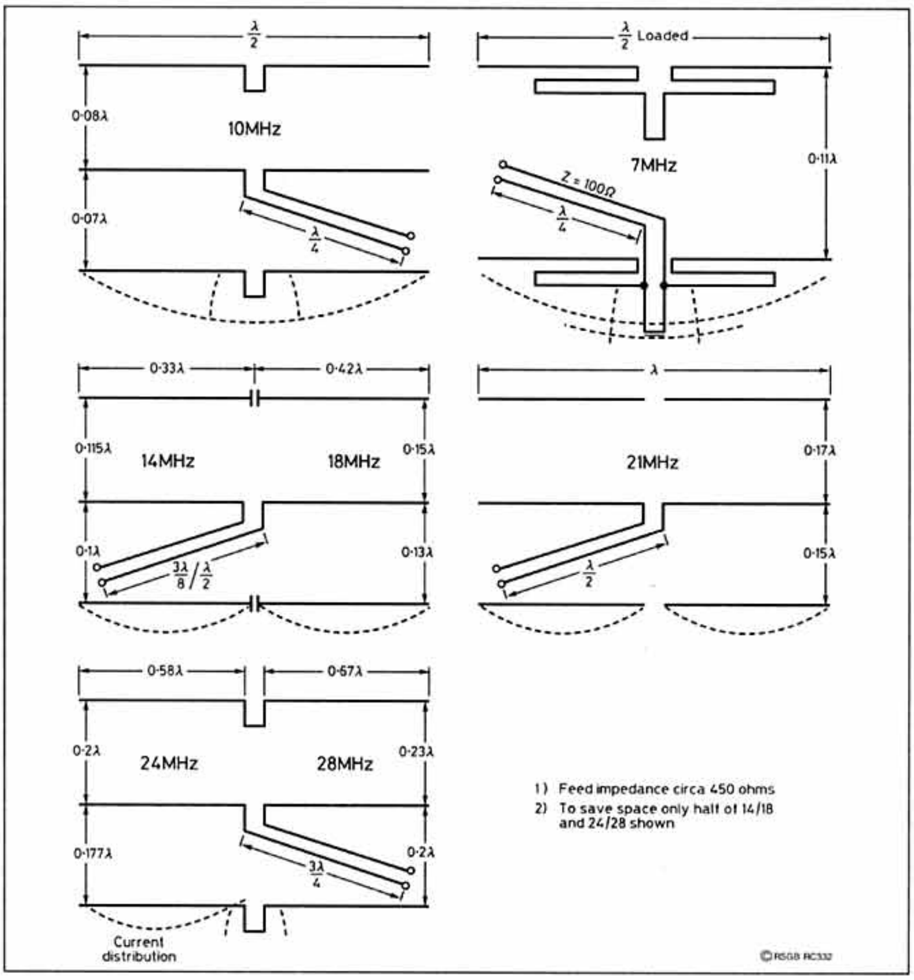

Fig 8: Current distribution of the antenna on each of the seven bands.

manual. Again be very careful of electricity supply wires and make sure that the screens on the sections of dual coaxial feeder and those on the control cables are bonded to boom and tower at each end where appropriate. With an antenna of this size it is necessary to give some thought to handling. If your tower is fixed it will be necessary to use a crane or extension mast and lifting tackle. Either of these will require a rigger working overhead. The centre element need not be attached until last because it is accessible from the tower. However it will be necessary to support the tubes until the insulator clamp bolts are tight.

My preference is for tilt over towers because they allow one to work single handed from the safety of the ground. My method is first to align the rotator and attach the boom and cables whilst they are horizontal. Then to raise the tower slightly to permit 90° rotation before fixing the centre element whilst working on steps. Back on the ground the director is fixed 7ft (2.13m) below the centre element. The tower is raised again and the antenna rotated 180°. Next the tower is lowered and the reflector fixed 8ft (2.44m) from the centre element. This method has the advantage of not requiring a large ground area near the tower on which to assemble the antenna and it is inherently safe, particularly if the boom takes some of the weight off the tower whilst you're working below. Also it is easy to check the relays and servo system as construction proceeds.

Although, as indicated below, the vertical radiation pattern is relatively broad, making antenna height not very critical, 20m is preferred for best compromise performance on all seven bands.

PERFORMANCE

THE CURRENT DISTRIBUTION of the antenna is illustrated in **Fig 8** for each of the seven bands. The antenna works, as was originally intended, as a two element Yagi on 7MHz giving 4.9dBd gain and 15db back to front radiation ratio (makers' figures). On 10MHz it is a close spaced full sized three element Yagi capable of about 7dBd gain and over 30db back to front ratio. The antenna becomes an extended Yagi with wider spacing on the other bands. For example on 21MHz there are effectively six elements. On a test range I measured 19.6dBi (11.5dBd) peak gain on 24.95MHz on the first prototype of this antenna. This was about one decibel more than anticipated. Back to front radiation ratio exceeded 20dB at that time.

The beam is impressively narrow in azimuth on the higher frequencies, rather like the conventional 8-element Yagi that one might use on VHF. The vertical beam width should still be that of a 3-element antenna however. Minor lobes each side of the main beam will be apparent on 28MHz. Gain on the 28MHz band will be reduced if you tune for coverage of the whole band 28 to 29.7MHz. I have tested the antenna at 1kW input on all but 28MHz, where I could only produce 100 Watts.

FINAL TUNING

THIS IS WHERE YOU will really appreciate the servo system because of the flexibility it allows when tuning. You can choose to optimise back to front radiation ratio or gain within a band to suit the preferred mode or current interest. Tuning from the operating position requires a steady local signal off the back of the antenna. For general operating activity within the wider bands (14, 21 and 28MHz) it may be advantageous to adjust the reflector tuning preset resistor for minimum received signal at a frequency near the low end of each band. Adjust the director similarly at a frequency near the high end. The narrow WARC bands can have both elements tuned at the band centre. Beware that it is possible on some bands to interchange director and reflector functions. A very low power wideband noise source driving a short high horizontal dipole a few wavelengths away is ideal for tuning because it saves having to leave the operating position to change frequency (I used the noise radiated from a defective 11kV power line insulator).

If required the antenna can be set up on non-amateur frequencies within the tuning range. If you find that a null is found only at the extremes of adjustment it will be necessary to alter the hairpin tuning. For example if the 14MHz null is achieved only above 14.3MHz then the main hairpin tuning requires lengthening. After establishing optimum directivity, only now do we sort out settings for the balanced type of ATU.

To avoid the problems associated with running open wire or slotted line into the house, I suggest removing the balun from the ATU and installing it outside in a suitable container. The shortest practicable length of coaxial cable can then connect the balun to the ATU. At least one manufacturer of tuners includes an optional kit for this purpose. You should have no grounds to envy those amateurs with monoband beams and multiple towers because, as Fig 8 shows and as the tile implies, if you complete this project you will have effectively seven monoband beams and not have to rely on multiple towers to prevent their mutual interaction!

At the time of writing amateurs do not have access to the 10MHz band so I cannot put the antenna to work on that band yet in the Sultanate of Oman. ♦

RADCOM Helplines FOR MEMBERS

● Eric, G3VRU, is seeking any information for a **Mk 19 Set**, especially schematic and component layout. Also any help in clearing a fault in an Amtor program for a Commodore C64 for use with the AMT-1 Terminal. Please contact him by writing QTHR.

● Keith, G0OZK, needs a circuit diagram for an old **Venner 4-digit counter/timer**, type TSA6634A/2 and/or any information of any surplus cards or PCBs. If you are able to help, then contact Keith QTHR.

● Mike, G3OOQ, needs any advice/information for a **semi-conductor laser (0.4mW) assembly,** possibly from a printer, to use as a pointer? No make, roughly the size of TO3 transistor case, with four flat supply leads, yellow, blue, white and red with polarised flat yellow socket. Sub-assembly carries numbers 24Z57, s 708, KSS-121A, 107702S. Contact Mike on tel: 0789 205973.

● John, G3OQC, is seeking any information/circuit diagram for a **PACE Fleetmaster FM 3625** modified to accept and fitted with CTCSS board. Has Tx working but cannot open the Rx. Expenses reimbursed or information purchased. If any one can help, then contact him by telephoning 0705 380705 or write to G3OQC, QTHR.

● Any information of a supplier or other source of **Aluminium tubing** to replace a Jaybeam TB2 Mk 2 Tri-bander driven element, the original sheared in a storm. Dimensions are - Length, 250cm/8ft 4in; OD, 32mm/1.25in; ID, 30mm/1-1/8inch. Anyone able to help to contact Stuart, GM0CAQ, (NOT QTHR) on 0261 833298.

● Len Iceton, G0IIL, is seeking any alignment procedure/information or the possible loan of such material, for an **Airmec Type C864**. Anyone able to help please contact him tel: 0642 559845 or write QTHR.

● Don, G0PRZ, needs manual/circuit diagrams, etc for a **Standard Signal Generator** TF144G No B192, Marconi Instruments Ltd. Unit also marked ZD00390 Signal Generator No 1 Mk3 - Marconi's Service Division have manual back to TF144H but no earlier. All expenses will be reimbursed. Contact Don on tel: 0703 261877 or write QTHR.

● Harjo, DK3VF, need a circuit diagram for a **Sinclair MTV1** - TV Receiver or an address where to get one. All expenses reimbursed. Contact him by telephoning (Germany) 40 7374246 or write to: H Schroeter, DK3VF, Moorfleeter Deich 503, 21037 Hamburg.

● Mr F A Law, G6RHP, wants a circuit diagram and/or service manual for an **Olivetti Dm105 S 9pin Printer**. All expenses paid. If any one can help, then contact him by writing to: 47 Springcroft, Hartley, Longfield, Kent DA3 8AR. ♦