Top-Drive

for the Lower Bands

Part one, by Tony Preedy, G3LNP *

I RECENTLY came upon an interesting old engineering report, published in 1964 by the Research Station of the General Post Office, in which the authors effectively demonstrated why the antennas then used on board ships for 500kHz emergency communication were more efficient radiators than their designers had anticipated:

The typical ship MF installation consisted of multiple-wire-T or inverted-L antennas supported between masts or between mast and funnel, driven from a transmitter located in the radio cabin. The radio cabin was traditionally placed high on the superstructure because, historically, the wireless installation was a late arrival and for the practical reason of permitting unobstructed and safe clearance for the antenna feed wire which was, until then, believed to be the main radiator, with its necessarily very high voltage.

After describing the results of extensive testing on vessels named the *Beaver Ash* and the *Senorita* plus one-tenth scale 5MHz model tests, the GPO report concluded that the effective height of the antenna and hence the effective length of the radiating feed wire was more than could be expected from consideration of the height of the antenna relative to the superstructure of the ship. In fact, the metal hull of the ship extended the radiator down to the sea. An effective antenna could therefore still be installed if the top loading wires were no higher than the radio cabin or the vertical feed wire did not exist! In this case the hull was the radiator.

Relatively compact emergency antennas for 500kHz operation could, therefore, still be installed on vessels that had no other MF capability. This requirement has now been superseded by satellite systems, but the principle is still relevant to amateur operation on the lower frequency bands.

We see this effect in an HF mobile installation, where the vehicle body forms an appreciable part of the radiator and its electrostatic capacitance provides a ground connection.

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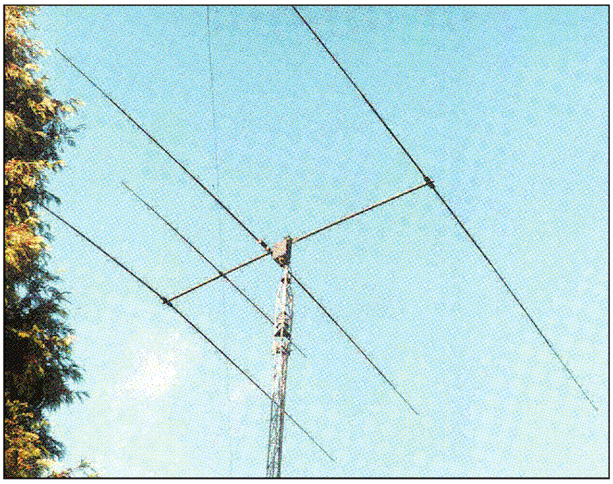

The finished antenna with top-feed tuner, based on a Hy-Gain 14MHz Yagi and Strumech tower. The long Yagi elements, two half-waves in phase on 28MHz, are 11m. The short element, used only on 24 and 28MHz, is 5.3m and the boom, which houses the relay-selected tuning lines, is 4.9m. The number of active elements varies from one at 10MHz to seven at 28MHz.

GROUNDED-TOWER RADIATORS

MANY ATTEMPTS have been made to use grounded metal towers, usually supporting rotatable VHF and/or HF antennas, as radiators for HF. Typical arrangements are sloping wires insulated from the top of the tower [1], sloping wires joined to the tower and forming, with the ground, a triangular loop [2], and wires outrigged running nearly parallel to the tower for shunt-feeding [1].

I have tried them all and had good results on 160m using shunt-feed with a pair of wires attached at the rotator cage fixing bolts of a P60 Versatower and extending to the ground, where the wires were terminated and insulated, 1m apart and 1m from the tower. A series capacitor of 250pF, connected to the pair of wires, gave an impedance transformation to 50Ω. However, my tower is generally retracted and, in each case, the wires became a nuisance, both obstructing the garden and tangling with the tower as it was being raised.

Shunt-feeding of towers with the feed wires connected other than at their tops, forming a folded monopole, is usually not as efficient as base-feed, because the ground return current consists both of that causing radiation and that due to the feed. The effect is to increase the energy dissipated at the ground connection. A low-resistance ground connection is therefore important with shunt-feed, and this is not easily achieved in a typical domestic setting. In the shunt-fed arrangement, the HF Yagi beam antenna, supported by the tower, forms an effective non-radiating top, which enhances the radiation efficiency of the tower by making the current distribution throughout its length linear rather than triangular. The same effect can be obtained in theory by breaking the tower and driving it above the base… not very practical!

Obviously, some form of inverted-L antenna can be made by adding a horizontal wire and driving this via a remote-controlled tuner [3] against the top of the tower-plus-beam. In practice, life is not that easy, because optimum performance requires another support. With height comparable to that of the beam, the wire interferes with the directivity of the beam and requires a back stay, with an attendant compression load via the tower lifting tackle, to balance the head load on the tower.

A much more convenient drive point is the junction between the tower and the HF antenna which it supports, because there is already a coaxial feeder terminating at this point and it should be relatively easy to insulate the HF beam from the tower without loss of mechanical integrity. This is analogous to the old ship installations described in the GPO report. In this case, the HF beam replaces the multiple-wire top, the tower replaces the hull of the ship, and the remote tuner replaces the elevated radio cabin.

The potential for using an existing tower and HF beam for lower frequencies without adding any significant extra hardware or requiring further planning approval was immediately attractive, and prompted an investigation using the computer. To reduce the time taken to obtain the data, I simplified the antenna by making it representative, electrically, of a typical tri-band beam mounted on a 20m telescopic tower.

I obtained the data of **Fig 1** from the computer by using *ELNEC*, simulating the

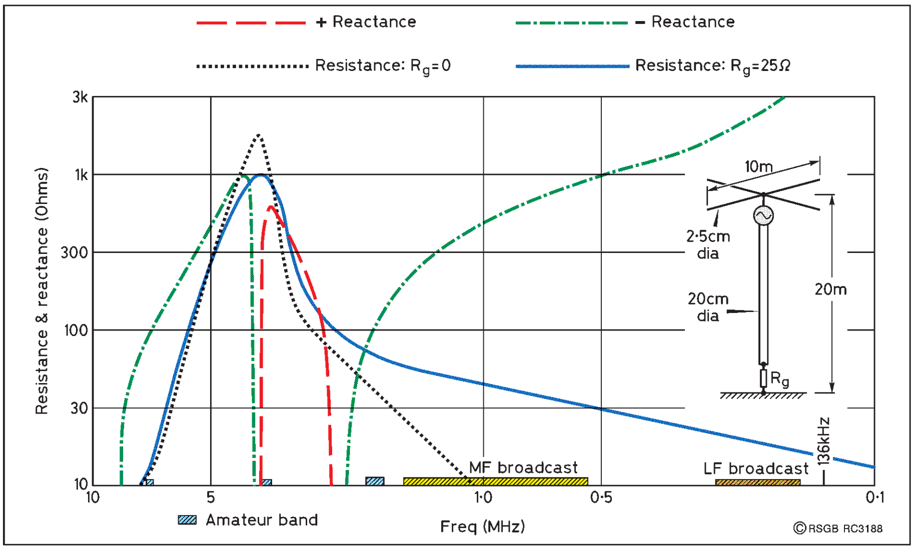

Fig 1: Computed impedance at the elevated feed point between an HF Yagi and a grounded telescopic tower.

typical grounded-tower lattice structure with a 20cm tube and simulating the electrostatic capacitance of a typical HF Yagi beam with a pair of crossed 10m horizontal metal tubes, of diameter 2.5cm.

FEED IMPEDANCE

ELNEC GAVE quite reasonable drive-impedance curves, for a generator located between tower and beam, not too far from those expected with base-feed. For example, at 1.85MHz the resistance was either 23Ω or 56Ω for a ground resistance (R_g) of zero or 25Ω respectively, each with a capacitive reactance near 165Ω. A series inductor coil, of about 15µH would, therefore, give a VSWR below two on the original 50Ω feeder. 25Ω was taken to be the best ground connection resistance likely to be achieved in a residential setting, incidentally. Primary resonance occurred at 2.3MHz, indicated by a pure resistance near to 80Ω. Above this frequency, a capacitor was required for tuning.

At 3.6MHz, where the system was electrically a half-wave, the impedance was 1800 or 1100Ω resistive, for R_g of zero or 25Ω respectively.

The above are within the capability of standard automatic tuners intended for random length wires or whip antennas. At 136kHz, the drive impedance was 16.5Ω with 5094Ω reactance for an R_g of 25Ω while, down at 73kHz, the corresponding drive impedance was 16.4Ω with 9500Ω reactance. In either of these two LF cases, the anticipated tuning inductor losses would be expected to make the resonant impedance close to 50Ω.

RADIATION PERFORMANCE

OPTIMUM LOW-ANGLE radiation was maintained up to 5MHz, above which the angle started to increase, reaching 34° at 6MHz and 50° at 8MHz. For DX working, the top-fed antenna, based on a 20m tower and HF Yagi, was, therefore, suitable only for amateur frequencies of 3.8MHz and below. **Fig 2** shows some computed 'gain' figures for top-feed relative to base-feed at the major lobe of radiation, for different values of R_g, over ground of average conductivity. From this, we see the potential advantage of top-drive for frequencies below the predicted resonance frequency of 2.3MHz. Base-drive would be superior from 2.3 to 6MHz, where R_g is less important, but this is academic with a grounded tower.

Operation on 136kHz required a tower-mounted tuning inductor of approximately 6mH . Assuming constant coil, feeder and ground-connection losses, the gain advantage at 136kHz over base-feed was substantially 3.6dB for any value of R_g significantly greater than the radiation resistance. The grounded tower makes it impossible to verify this, although it should not cause surprise because, in the extreme case of infinite R_g, the base-driven antenna has zero current and cannot, therefore, radiate. The top-driven antenna is still viable, however, as an unbalanced vertical dipole. Even at 1.85MHz, as Fig 2 shows, there is worthwhile gain to be had with top-feed, particularly if you cannot achieve a low ground-connection resistance. There are likely to be problems keeping RF out of the shack if the ground connection is eliminated, however.

At 73kHz, a tuning inductor of approximately 20mH was required but, even here, 3.8dB gain over base-feed was available at the cost of installing a dustbin-sized inductor just beneath the HF antenna! To put this in perspective, 3.8dB is equivalent to increasing the height of a base-driven antenna by a factor of 1.55, eg from 20m to 31m!

INSULATING THE BEAM FROM THE TOWER

THE INSULATION REQUIREMENTS at the gap between HF beam and tower for the 73kHz to 3.8MHz amateur bands can be seen in **Table 1**, on the assumption that we will be operating within the ERP limitations of our licence. The equivalent parallel resistance, derived from the series values of impedance in Fig 1, together with the computed gain figures, are used here to obtain drive voltage. The specified insulator, assuming a conservative voltage gradient of 400V/mm will allow up to 1kW input at 73kHz. At any higher frequency, an insulator of this size is not likely to restrict input power.

In view of the computed results, I decided initially to try adapting my installation to cover the bands 1.8 to 28MHz only, by using a commercial automatic tuner. I reserved the prospect of attempting to top-drive on the LF bands for the future, by building-in the 95mm insulation path. The practical arrangements were considered next .

IN PRACTICE

'DISCONNECTING' THE BEAM would be easy if I could find a piece of 2in-diameter insulating rod to extend the rotating mast by the amount required by Table 1. Such electrically-suitable materials are available at prices from £16 to £220 plus VAT for a 50mm rod of typically 1m. Many of these materials can be eliminated because of their susceptibility to ultra-violet radiation, atmospheric pollutants or water absorption. Many are just not strong enough for the torsional loads anticipated. None of the available insulation materials was considered to be hard enough not to yield when gripped by the teeth of the typical boom clamp of a full-

Freq (MHz)	Power (dBW)	Gain (dBi)	Tuning & feed (dB)	Input (dBW)	Input (Ω)	Parallel R(Ω)	Potential (Vrms)	Gap (mm)
0.073	0	-24	-6	30	$1.0x10^3$	$1.4x10^6$	$3.7x10^4$	93
0.136	0	-18.7	-3	21.7	$1.5x10^2$	$7.9x10^5$	$1.1x10^4$	28
1.85	26	-0.8	-0.5	26.5	$4.5x10^2$	$4.7x10^2$	$4.6x10^2$	1.2
3.6	26	-0.2	-0.8	26.8	$4.8x10^2$	$1.1x10^3$	$7.3x10^2$	1.8

Table 1: Determining mast insulator length with Rg of 25Ω. For higher Rg values the LF power input can be appropriately increased to maintain ERP without significant change in insulator voltage stress.

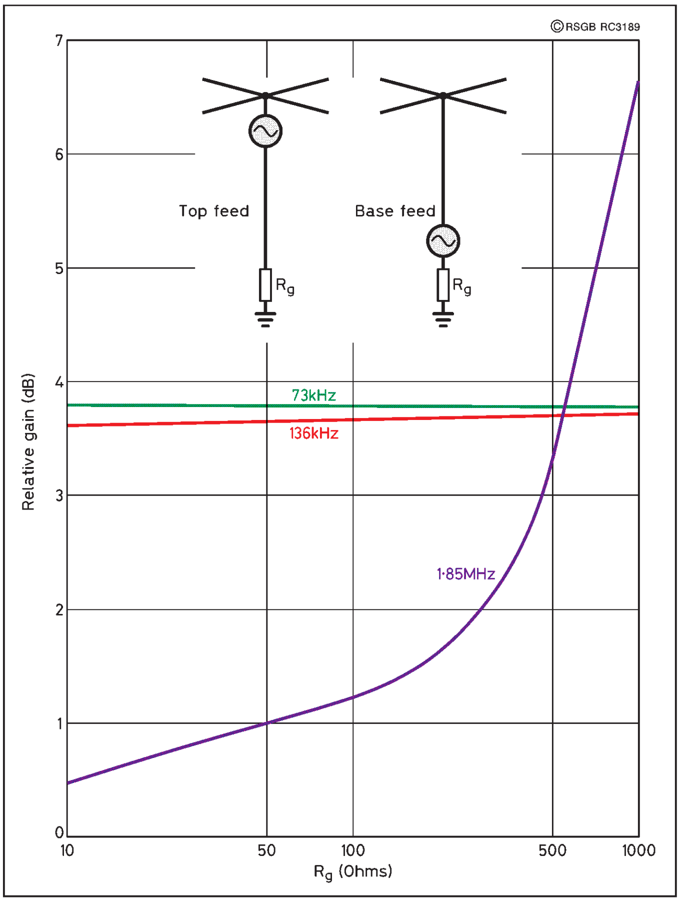

Fig 2: Computed gain of top-feed relative to base-feed for the antenna in Fig 1 for different values of ground connection resistance, R_g.

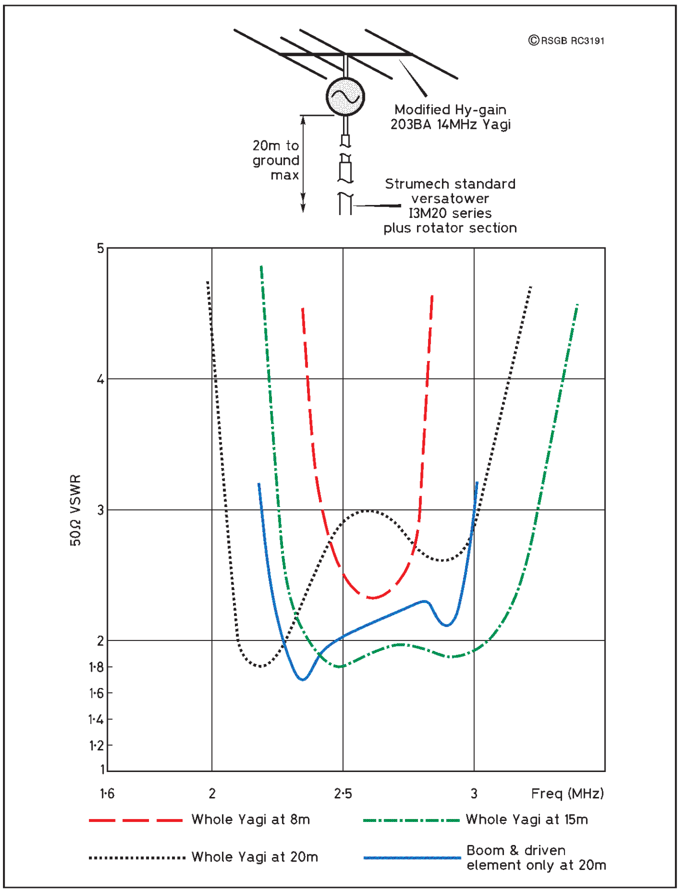

Fig 4: Measured VSWR, without any attempt at tuning, for the author's top-fed system in the vicinity of resonance at different heights and with some elements isolated.

sized 20m Yagi. A sleeve of tube cut from the rotating mast is thus necessary to prevent the antenna working loose.

Through-bolting and epoxy adhesive were desirable because of the requirement not to slip while the antenna is swinging in a gale. A reasonable choice is phenolic resin-bonded fabric (Whale brand, Tufnol. 50mm diameter. RS Catalogue. No 374-346). This tried-and-tested material comes in a nominal 585mm length, at a total cost of approximately £70, but will make two insulators. **Fig 3** shows the detail for modifying the top mast of a large tower system. The total length of top mast should allow for installation of a tuner below the insulator if this is to be added.

If you want to follow my design and lack appropriate workshop facilities, have the whole rotating mast assembly modified professionally, because the consequences of failure are frightening.

The measured VSWR referred to the radio-end of the 50Ω transmission line for top-feed in the vicinity of resonance on my installation, before tuning, is shown in **Fig 4**. I was quite elated by these results, because they confirmed my earlier input data assumptions, chosen for the computer analysis. The curves show the

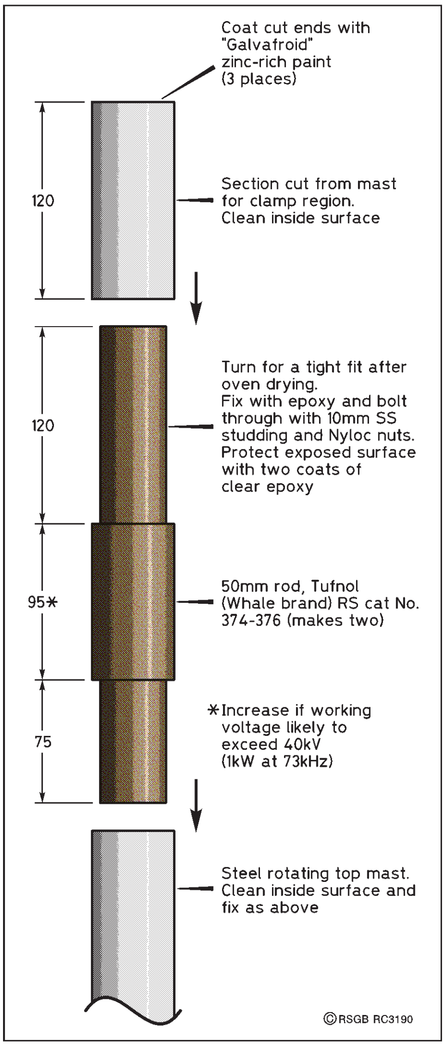

Fig 3: Detail of the insulator required to isolate a large HF beam from the rotating top mast of a tower.

effect on resonant frequency of changes to tower height and number of elements. ie where VSWR is minimum. Extrapolation of the resonant-frequency/height relationship indicates that an increase in height by 2.5m would cause self-resonance at 1.85MHz. Similarly, extrapolation of the resonant-frequency / number-of-elements relationship confirms that self-resonance at 1.85MHz could also be achieved with a larger antenna on the existing tower. With the tower at its minimum height of 8m, a good impedance was obtained over the 80m band with a minimum VSWR of 1.5 at 3.6MHz. The antenna was more effective at the lower frequencies than any other I had tried at this location, and a manual tuner permitted the antenna to be used in advance of installing the automatic tuner at the top of the tower.

REFERENCES

[1] *ARRL Antenna Book*, (ARRL), 16th edn, chapter 4.

[2] 'Half Delay Loop Antenna', *The Handbook of Antenna Design*, Vol 2.

[3] 'PicATUne - the Intelligent ATU', by G3XJP, *RadCom* Sep 2000ff. ♦

In the concluding part next month, G3LNP considers the use of remote tuners in some detail.

Top-Drive

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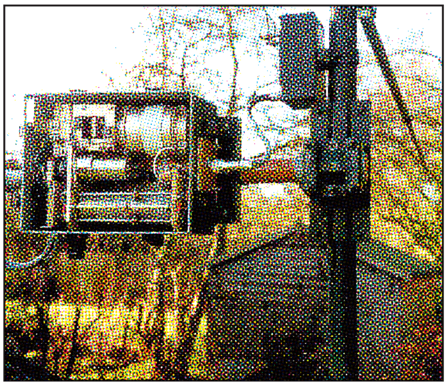
*Concluding part, by Tony Preedy, G3LNP **

AT THE START of this project, I obtained an American SGC-237 tuner PCB, but decided that its 40W power limitation (100W PEP) and 2:1 input VSWR (before re-tuning) would not be appropriate for my station. The 237 was useful when getting a feel for remote top-feed operation and now serves in a transportable station. **Fig 4** shows how to add an automatic tuner to enable multi-band operation.



The upper part of the author's top-fed antenna, tuner open and tower luffed. It provides all-band coverage, 1.8 to 30MHz at full power, with tower at any height. The photograph shows the insulating plate with HN output connector, Tufnol rod insulator and HF balun. The vacuum relay is hidden between the variable inductor and ceramic variable vacuum capacitor. The 'sardine tin' (top left) contains silica gel desiccant.

The photograph shows the top of my full-power multi-band arrangement, where a remote automatic tuner is used for driving either the six-band modified rotatable Yagi on the bands 30m to 10m, or the 20m Versatower on the bands 160m to 40m. However, on 40m, the radiation pattern is not ideal for DX contacts unless the tower height is reduced.

The full tower does result in optimum take-off for contacts a few hundred kilometres distant, however. The tower is motorised and controlled from the shack, so there is no problem slewing the beam elevation on 40m! A remote tuner should offer the advantages of maintaining a low VSWR, even at the band edges, maximising the power out of the radio and minimising feeder attenuation. It also allows operation to continue in bad weather, with the tower partially retracted or if the antenna is detuned by accumulated ice. The overriding benefit is that it saves a lot of hard work, raising and lowering the tower for optimisation of impedance transformation circuits for multiple bands. My system has a unique feature, which is one of the reasons I deferred using the tower on 136kHz. The insulator is bridged by a trifilar-wound 100µH choke, necessary with my unusual electrically-tuned HF antenna, both to get band switching voltages to the beam and to provide a static discharge path [1].

The rotating tuner I eventually chose (or rather was given by someone who did not know what it was for), is a US surplus item, MSR 40-20 made by ITT/Mackay. This is typical of those early designs, employing an aluminium case and intended for use on ships (and built like one), where occasional immersion in salt water is inevitable. It appears to be quite happy with the output power from my SSB linear amplifier, although it lacks the sophistication of more recent designs in that it needs to be told when to tune and consumes 1.5A at 12V while doing so. However, once tuned, the supply can be removed without loss of settings.

Other features are; a pair of signal outputs, derived from forward and reflected power couplers that are used to drive a cross-needle instrument showing VSWR at the tuner input, and a 3dB attenuator that is introduced until tuning is complete, to prevent the transmitter seeing an excessive VSWR. Another remote marine tuner that can sometimes be found on the surplus market is the Redifon ACU15. However, this requires a multi-core interfacing cable carrying an isolated 220VAC supply for the synchronous drive motors and anti-condensation heater, 24V coded telemetry and rela-

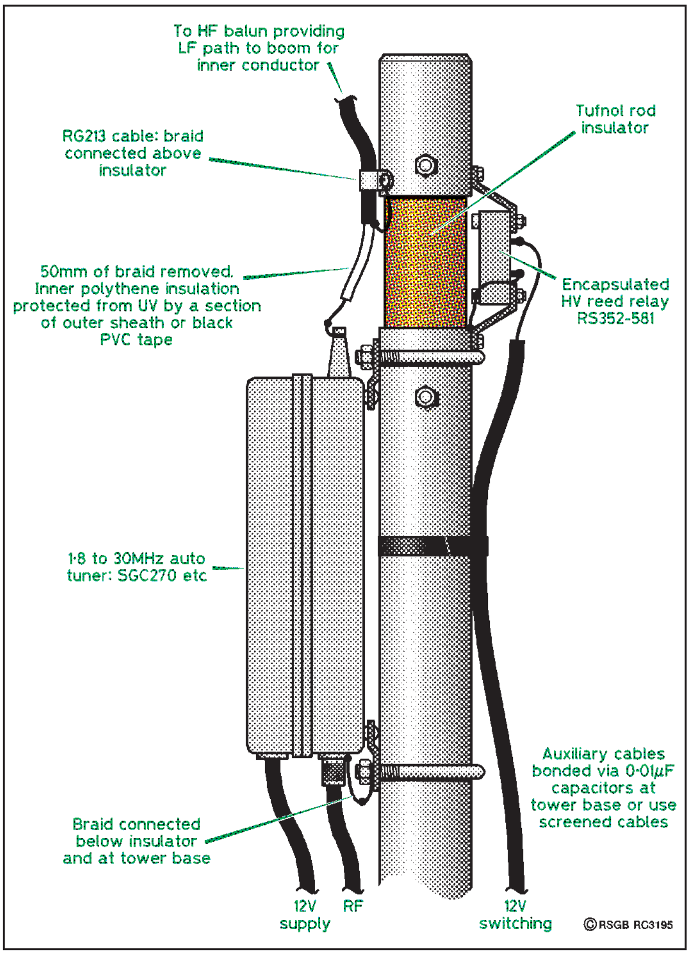


Fig 4: Basic arrangement for using a proprietary automatic tuner to allow a combination of top-feed plus normal operation of the beam antenna.

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tively complex interfacing electronics at the operating position. There are some ex-aircraft tuners, notably by Collins, but these are likely to be less amenable to exposure and have restricted tuning range. The recent SGC tuners are particularly attractive because they have all processing on board and can be operated over a single coaxial cable if the 12V supply is diplexed with the RF signal. They have low wind-loading, particularly if mounted with the major dimension horizontal. Icom supply a similar tuner.

My Mackay tuner is modified to include a vacuum relay and an insulated-type HN waterproof coaxial output socket in place of the original porcelain output terminal. Note that an HN- or N-connector is required, rather than the common SO239 or UHF-type socket, because the latter will compromise the weather sealing of a tuner package. The single changeover contact of the added vacuum relay is arranged to lift from ground the outer conductor of the output socket, whilst shorting it to the inner conductor when required to drive the tower. The Mackay tuner worked as expected on the 1.8 to 7MHz bands at full power, with a VSWR less than 1.2 when driving the tower at any height. The Yagi could be similarly driven, 7 to 30MHz, except that the balun restricted input to 100W if using the driven element of the multi-band

Simple modification to allow LF top feeding by changing the feed cable between LF tuning coil and HF balun.

Yagi on 7MHz. The tuner was, in fact, able to tune the Yagi on 1.8 and 3.6MHz, but I suspect very little power left the tuner!

Because of the high RF voltages expected on the 136 and 73kHz bands (Table 1, last month), conventional relays must be replaced by high-voltage vacuum switches or, alternatively, HF / LF operation will have to be selected on, say, a seasonal basis. For example, retracting and tilting the tower is necessary to allow disconnection of the RF feeder from the balun of the Yagi and plug it into the LF coil. The photograph (below, left) shows such a simple system. In this example, the top of the coil is connected to the boom of the Yagi, the lower end is connected to the inner contact of a coaxial socket and the outer contact or shell of the socket is connected to the rotating mast.

If you are worried, the practical difficulties associated with remote tuning on the LF bands are not insurmountable. Adjusting tower height is not the only way! Because at the lower frequencies the coaxial cable between top and base of the tower can be considered to be of negligible electrical length, and losses due to mis-termination over extremes of a single amateur band are also negligible, it is only necessary for the top inductor to bring the tower to resonance somewhere just above the upper band edge frequency. Final tuning is by means of the tower inductor, located within the shack.

For top feeding, it is necessary to provide electrical connections between feeder braid and tower, both just below the insulator and the tower base. The braid will automatically get connected to the tower if the tuner's 'earth' terminal is connected at the tower. Generally, to prevent RF feedback to the radio, the rotator wires and tuner supply cables will also have to be bonded to the tower via capacitors at the base. For 80m and 160m, 0.01µF 250VAC is suitable but about 0.22µF is required for the LF bands. In my situation, bonding was simplified because I had anticipated this when previously using shunt feed, by using overall screened rotator cable, which facilitated bonding without capacitors. If building from scratch, I recommend using a single multi-core cable with an overall screen for all auxiliary circuits. We have to assume that there will be electrical continuity between the tower sections and through the rotator bearing. This is not unreasonable, in view of the weight of the materials. In my experience this continuity is reliable with no sign of poor contact except whilst the tower is being actively telescoped.

Similarly, continuity to the boom and elements of the HF antenna is required either via the balun, hairpin match etc to the antenna input connector. I use a home-made bifilar 4:1 balun to enable the trapless driven element of the beam antenna to be used in the range 10 to 30MHz. This ensures a low-frequency path between both halves of the driven element, boom and both sides of the input connector. The finished antenna consisting of top fed tower and six band yagi was shown in the photo last month.

TOP-FEEDING A GUYED MAST

FIG 5 SHOWS a typical lightweight HF installation, as frequently used for DXpeditions and field days, modified for top-feed by replacing the rotating stub mast with a short piece of 50mm Tufnol rod. The tuner and relay have been fixed below the rotator in order not to increase stress on the bearings by lifting the antenna. The relay recommended is the high-voltage reed type stocked by RS. The effective encapsulation of this relay eliminates the requirement otherwise to protect the live parts by installing within a non-conducting box. As an alternative to the metal brackets shown, an adhesive can be used to fix the relay to the case of the tuner or a plastic angle bracket used to fix it to the mast. If you decide to design a top-fed system around the SGC tuner PCB, saving more than half the cost of the completed item, it can be packaged in a weatherproof box with space for the relay and an insulated coaxial output connector incorporated. If your Yagi does not have a balun, this can be included in the tuner box. Incidentally, my SGC-237 for portable use is housed with all these items in an Icom tuner box and is used to drive a short inverted-V dipole, either as a dipole or as a top-fed T.

The circuit is as shown in **Fig 6**, and can be used to convert any HF beam or inverted-V system for multiple HF band coverage as a dipole plus top feed. The balun consists of six turns of PTFE insulated twisted pair on a 40mm diameter FX1588 ferrite toroid. It is important to make sure that the flexible cable between tuner and beam does not make contact with either rotator or guys because, on the lower bands when top-feed is being employed, the braid is

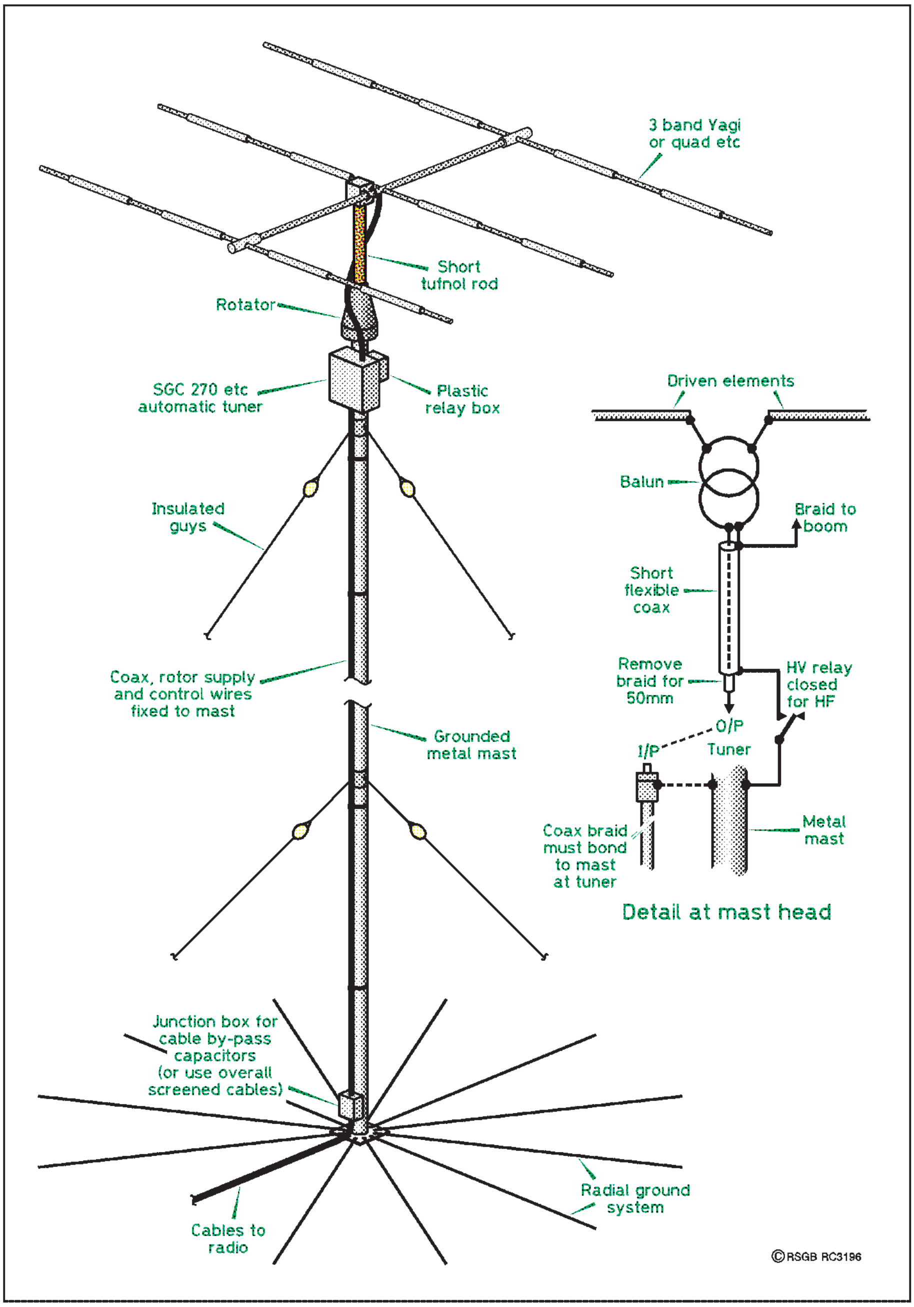

Fig 5: All band antenna system with top-feed, based on a guyed mast.

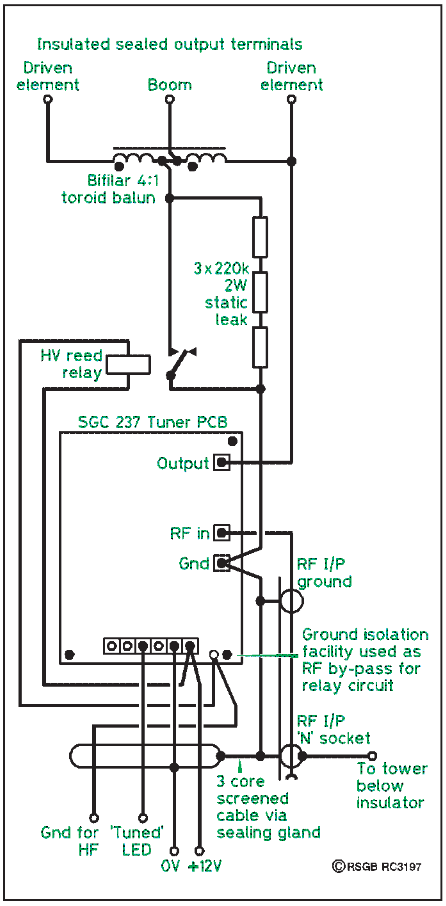

Fig 6: How to integrate an SGC tuner board with other components to make a 100W PEP self-contained dipole plus top-feed unit. This can be used to add extra bands to a triband Yagi, monoband Yagi or G5RV type inverted-V, and allow top-feed on 160m, 80m and 40m. A suitable sealed enclosure is the polycarbonate type, such as RS 138 - 177, with overall dimensions 200 x 150 x 75mm. The transparent lid allows the monitoring of moisture penetration, status LEDs etc, without opening.

live. If necessary, additional insulation can be added over the sheath of the cable and the guys re-attached below the tuner, as shown.

The feeder, rotator, tuner supply and relay cables must remain close to the mast throughout its length, and they will require bonding at its base, as described earlier. If buried or running at ground level, they act as additional ground radials.

The remote tuner offers another advantage. Depending on the feed arrangements at the driven element, any triband or monoband beam can be driven as a rotary dipole on the WARC bands, where the tuner eliminates the otherwise prohibitive feeder losses and transmitter power reduction caused by a high VSWR.

MULTI-BAND COVERAGE WITH A TV ANTENNA

I AM SURE the technique recommended to drive a grounded tower on the low bands could be applied to a chimney- or gable-end-supported amateur VHF or large domestic TV antenna array. The transformation range of the tuner and size of the TV array will determine how low in frequency the system will tune. This has the potential of making an effective but clandestine HF radiator for those with planning problems for amateur antennas. The TV antenna must obviously be of the type with parasitic elements connected electrically to the boom. In this application, the TV coaxial feeder would form both the HF feeder and, jointly with the tuner supply wires, the radiator, whilst the combination of domestic water and heating pipes plus electrical power wiring, to which they should be bonded, could provide the 'ground' or ship's hull effect. Although a separate RF ground is preferred, it is not practicable to separate this safely from the domestic system if using a mains-powered radio. If 75Ω feeder is acceptable, you can use inexpensive low-loss satellite antenna feeder which incorporates power supply conductors. The remote tuner now poses as a TV mast-head pre-amplifier! It would be advisable, for obvious consideration of EMC or TVI problems, to dedicate the 'TV' antenna to amateur radio, and to receive TV via cable or satellite.

REFERENCE

[1] 'Electrically-Tuned Six-Band HF Beam', by Tony Preedy, G3LNP, *RadCom* Jan 1999. ♦