The 'Screwdriver' Rapid QRV Antenna

by Dr Louis Stuyt, PA3BTN*, and Hans Spits, PD0NCF

*An updated version of the article in Electron (NL) 3/97 on a 10-80m continuously tuneable vertical for mobile and portable use, translated and edited by Erwin David, G4LQI**.*

MANY AMATEURS NEED antennas which are small in comparison with the longest intended wavelength of operation, be it because of restricted space at home or for portability at a holiday location.

The quest for 'the-best-for-us' car portable holiday antenna prompted a literature search; 15 different Dutch, English and German-language books and articles were consulted, though only English ones are quoted here.

We formulated the following wish-list:

- Easy to transport
- All bands, 3.5-29MHz
- Easy to resonate and match without an ASTU
- Reasonable radiation efficiency
- Assemble in 10 minutes
- No skyhook required

Wire dipoles and loops were ruled out from the beginning: those tall trees always seem to be in another camper's pitch or across a road with overhead power lines. That left small loops and short verticals, on both of which there is plenty of amateur literature. The loops cover a frequency range not exceeding 5:2, hence two loops would be required, of which the largest is difficult to fold into a boot-sized bundle without introducing additional, efficiency-damaging resistance losses [1]. Therefore we concentrated on finding the best vertical.

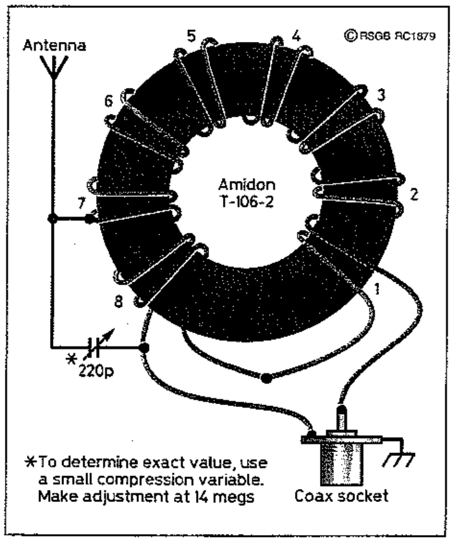

Fig 1: The latest version of W6AAQ's 3.5-30MHz impedance transformer for the DK3 antenna. The capacitor is significant only above 10MHz.

W1ICP's practice-oriented book [2] introduced us to the writings and products of Don K Johnson, W6AAQ [3], who has developed mobile HF radio since 1948. His DK3 model, the 'ultimate centre-loaded HF whip' and his latest and apparently third design bearing his initials is described, along with earlier material and many dos and don'ts, in a 1997 book [4].

Don has licensed one US company to make these antennas commercially and will himself supply any or all parts. He encourages other amateurs to duplicate or improve on his design, but warns that machine shop facilities and skills are required. As we use this antenna mostly stationary at campgrounds and only occasionally while mobile, we made provisions not only for installation on our van [5] but also on a rapidly deployable earth mat of our own design.

DESIGN CONSIDERATIONS

WHAT WE HAD READ provided several rules:

As the height of mobile antennas is limited both by statute and practicality (think of underpasses and overhead wires), its height will be much less than a quarter wave on the lower bands and its radiation resistance much less than the 36Ω of a 'standard of comparison' ground plane vertical. Ours is of the order of only 5.5Ω at 3.5MHz. If efficiency is to be maximised, losses, which mainly (but not exclusively) result from earth and loading coil resistances, must be minimised. The latter translates into a high-Q coil; 200 or better; that is easy on the bench, but difficult after exposure to condensation and dirt.

As the antenna height represents the smallest part of a wavelength on the lowest fre-

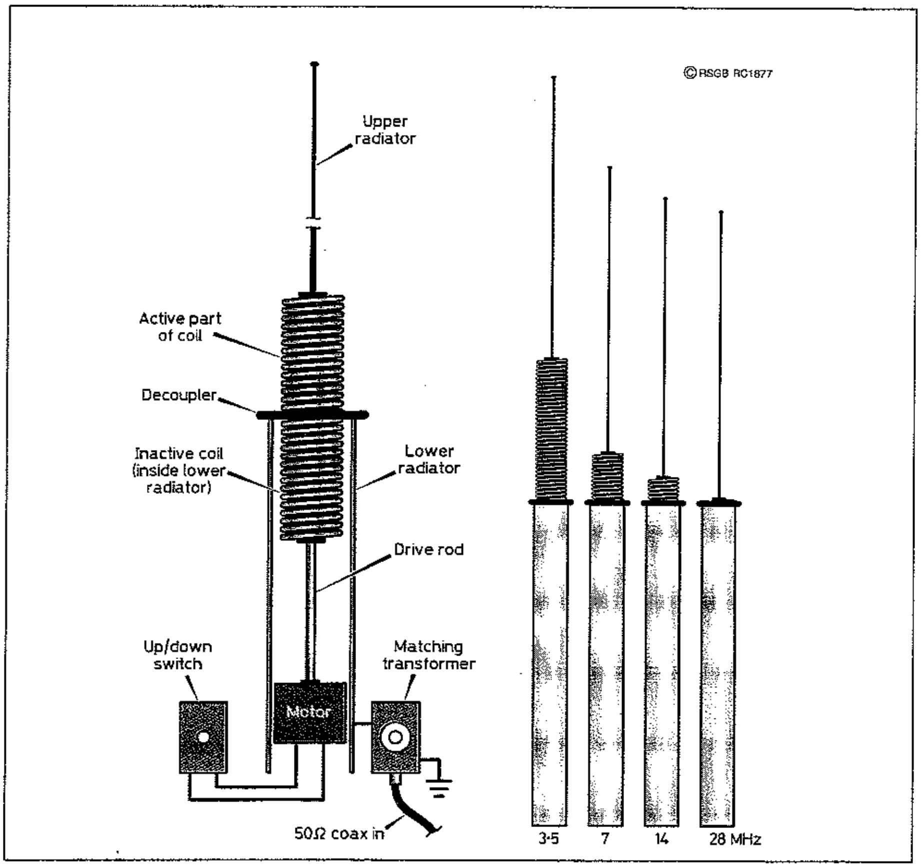

Fig 2: The principle of W6AAQ's DK3 continuously tuneable 3.5 - 29MHz mobile antenna.

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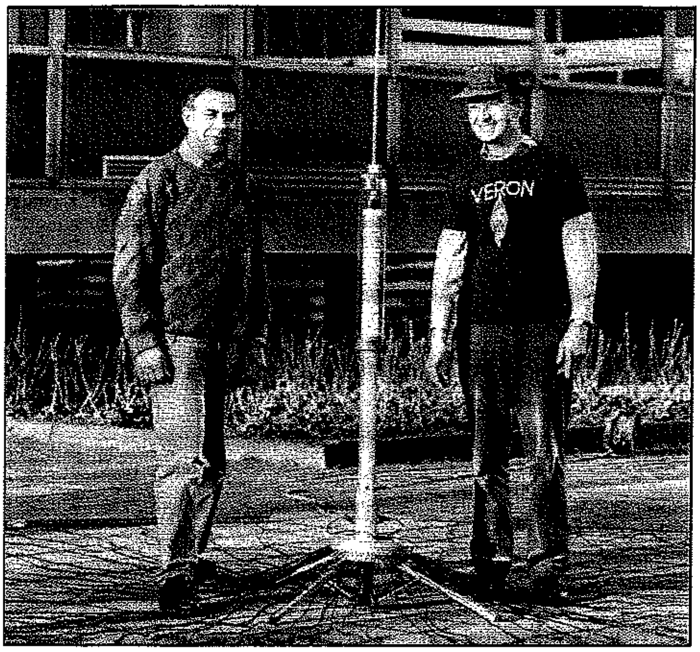
quency, 3.5MHz, one should strive for maximum attainable efficiency on that band; higher bands will then take care of themselves.

Inductive centre loading is better than bottom loading, and top loading is mechanically impractical. A small top hat can be practical and is beneficial, provided it is at the top, ie well above the centre loading coil. One frequently sees a capacity hat directly above the coil but that is counter-productive, as it diverts part of the RF current from the top of the coil through the non-radiating capacity hat back to the counterpoise, ie without flowing through the upper radiator where it does contribute to the desired radiation. Shorted coil windings resulting from some band-switching schemes represent a lossy load on the active part of the coil, while open coil windings invite arcing.

The antenna should be capable of being tuned to the operating frequency without the use of a tuner inside the vehicle.

At 29MHz, the feed-point impedance of a resonant quarter-wave whip with the vehicle body as a counterpoise can be expected to be close to 36Ω resistive. At lower frequencies, the radiation resistance will be lower, but the inductance required to tune out the capacitive component of the feedpoint impedance and the less adequate counterpoise introduce losses which show up as extra resistance at the feedpoint.

A wide-band transformer at the feedpoint is adequate to match the antenna to the transceiver, ie 50Ω. The transformer shown in **Fig 1** can give a good all-band match; its 9:16 turns ratio would imply an antenna feed-point resistance of only 16Ω; that is about right at the lowest frequencies; the shunt capacitor is supposed to keep the impedance down towards the higher frequencies, but in our case this proved unnecessary: the SWR is below 1.5:1 on all bands without this capacitor.



Dr Louis Stuyt, PA3BTN, a scientist (R), and Hans Spits, PD0NCF, an instrumentation engineer, at the Winand Staring Centre for Integrated Land, Soil and Water Research, where both work. Between them the DK3 antenna, which wears an over-size top hat for the occasion.

Design procedures for short vertical antennas are well described in [6].

THE DK3 SOLUTION

W6AAQ'S CONTRIBUTION to the art is the design of a centre loading coil of which the self inductance is continuously and remotely variable from zero to the approximately 150μH required to tune a 2.5m mobile whip to 3.5MHz without compromising the Q. A patent disclosure was dated 18 March 1991.

Fig 2 is W6AAQ's sketch of the basic construction. The antenna consists of a tubular lower radiator, a centre loading coil and a whip as the upper radiator. The coil can slide up and down in the top of the lower tube by means of a motor-driven threaded rod. A 'decoupler', consisting of a ring of finger stock around the rim of the lower radiator makes contact with the lowest turn of the coil which protrudes above the top of the lower radiator. The flow of antenna current from the feed point is up the outside of the lower radiator, through the protruding part of the coil winding and up the whip; none of it flows through the coil turns below the finger stock, so these are electrically non-existent. One might think that the upper rim of the lower radiator is itself a shorted turn coupled to the active part of the coil, but it would have almost zero resistance and therefore create virtually no losses.

A wide-band matching auto-transformer can be wound on a powder-iron toroid mounted near the feedpoint, either inside the lower radiator or in a small box near it.

The drive motor is operated by an up/off/down switch at the operating position. Ours is an AEA stepper motor with LC2 'loop controller'; unnecessarily expensive, but left over from a magnetic loop project. Some constructors, at the suggestion of WB6MNX, use a cordless electric screwdriver motor, hence the name 'screwdriver' antenna.

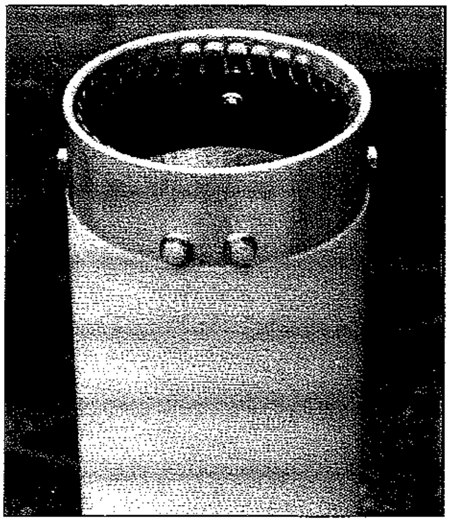
OUR CONSTRUCTION

FOR RELIABLE operation away from home, especially in a moving vehicle, only the very best mechanical construction will do. A complete construction guide is available from W6AAQ, but availability of a well-equipped and stocked machine shop and Hans' expertise made us decide to detail and manufacture most pieces from raw stock.

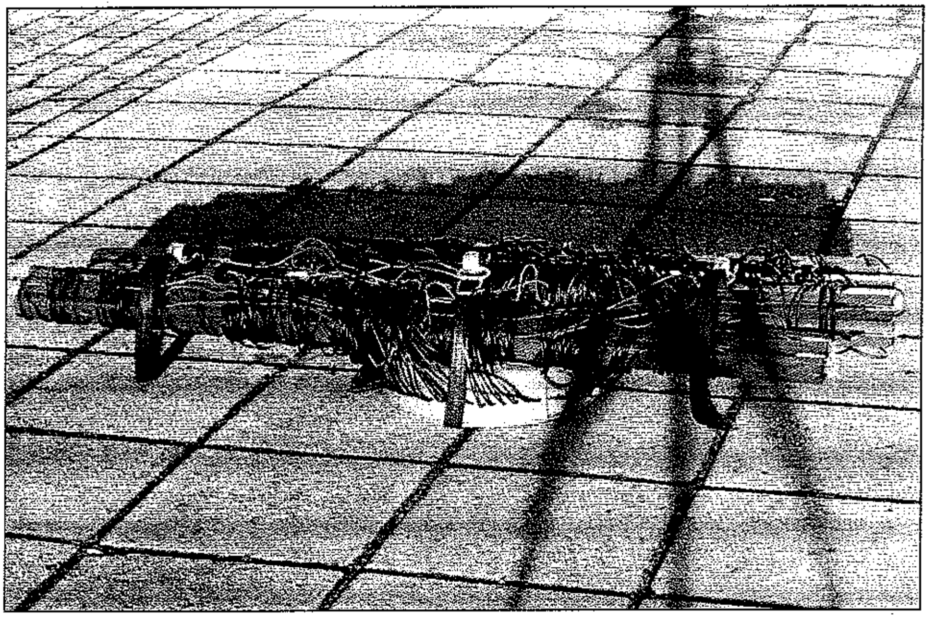
From the bottom, there is a PVC base rod, then a short aluminium tube which serves as a housing for the motor and the matching transformer. On this the connectors for the counterpoise, coax feeder and motor wires are mounted. Following this is the PVC base insulator, which carries the lower radiator, an aluminium tube 900mm long x 54mm outside diameter (51mm inside diameter).

Within this tube, there is a stainless steel rod, threaded M12, which is keyed to the motor shaft. The coil carrier, a PVC tube, has a Delrin [7] M12 nut fixed in its lower end, which makes the coil carrier, coil and upper radiator go up and down as the motor shaft turns one way or the other. The lowest 25mm of the M12 rod are undercut to 10mm to disengage the nut from the thread on the rod when the nut comes to its lowest position. A foam rubber bumper on top of the base insulator prevents the nut with all that it carries from dropping down further. The M12 rod is too short to push the coil completely out of the lower radiator. The coil carrier is kept centred in the lower radiator by two PVC rings.

The coil itself is the most difficult part to make. A lathe and good craftsmanship are essential. 1mm-deep grooves in the coil former are needed for 150 turns of 1.5mm diameter silver-plated copper wire. Other constructors have used PVC tubing for the coil former but we thought that too flimsy, especially after cutting grooves into it. Also, PVC has rather high RF losses; we therefore used a solid polyethylene core, in spite of the extra weight. For best Q, the turn spacing should be roughly equal to the wire gauge. We used a pitch of 2.54mm. The estimated Q of this coil is 275.



The decoupler. Finger stock at the top of the lower radiator makes contact with the loading coil wire. No RF current flows in the coil turns below the point of contact.



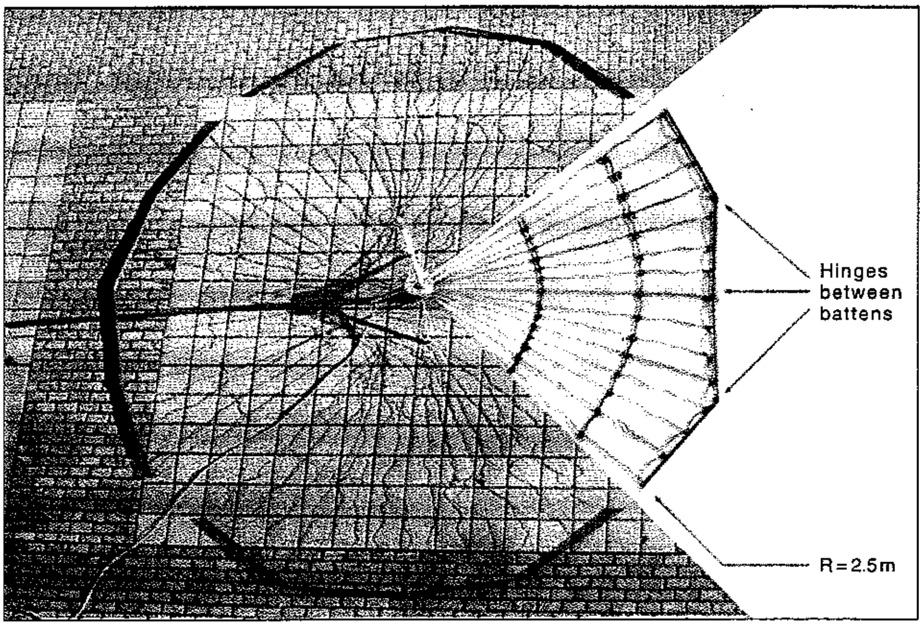
The earth mat, ready for transportation.

The exact diameter of the coil former can be determined only after the finger stock has been fitted into the upper rim of the lower radiator. Our beryllium-copper finger stock, the kind used to make the doors of shielding cabinets RF-proof, was ordered from the USA. To fit the 51mm inside diameter of the lower radiator, we used a 158mm long strip with 34 fingers, each 7mm long x 4mm wide. The strip is fastened with five stainless M2 bolts, heads inside, with washers and nuts on the outside, as shown in photograph 2. A plastic ring protects the fingers from external damage. The coil diameter now must be chosen so that both the outside of the windings as well as the spaces between turns are within the spring travel of the fingers. There also must be clearance between the five M2 bolt heads and the coil wire.

Having tried with a sample first, we ended up with a former of 46mm diameter and wire grooves 1mm deep for an over-the-turns diameter of 47mm.

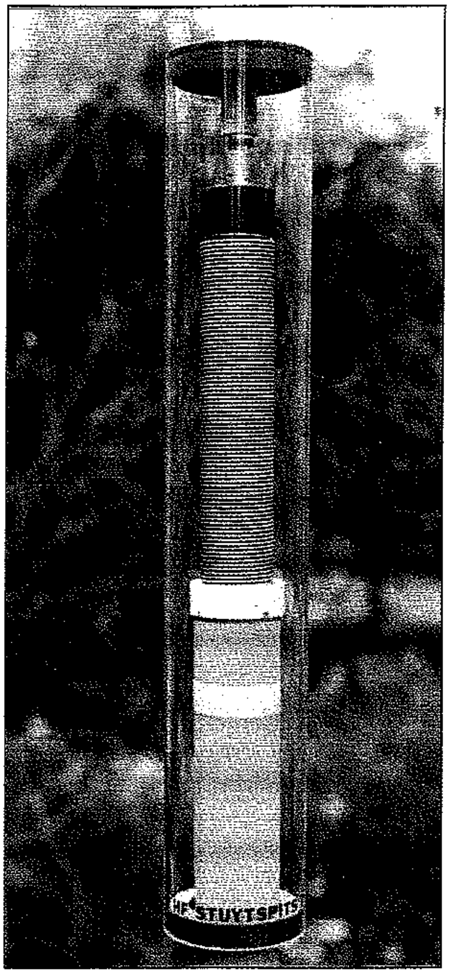
One end of the coil wire is fixed in a small hole drilled into the former at the low end of the wire groove; the wire then is wound into the groove under tension (from a gloved hand!) on the lathe. The top end of the wire runs straight up through a slot in the former to a brass ring which is held in place on top of the coil by a Hustler QD-2 quick-disconnect coupling; the latter provides for easy installation and removal of a selection of upper radiators. The coupling is firmly threaded into the coil former, as this connection must withstand the considerable bending moment exerted on it by the upper radiator in strong winds. A plexiglass cover keeps rain, dirt and insects off the coil and finger stock. The photograph right shows the completed coil.

If an N-type coax connector is used on the antenna, it may be considered weatherproof.



The earth mat, deployed under the DK3 antenna. One quadrant is drawn for clarity.

[G4LQI can provide would-be constructors of the PA3BTN and PD0NCF version of the antenna with a detailed illustration of the construction, plus annotated text. A hard copy is available in exchange for a SASE and a First Class stamp to cover the cost of photocopying. Soft copies, DK3MECH.JPG and README.TXT, are available in exchange for a pre-formatted 1.44MB diskette and a SASE. Finally, the illustration and text may be found on the RSGB web site (www.rsgb.org/news/radcom/screw.htm) - Ed*]*



The centre-loading coil in its plexiglass cover. Only half of its 150 turns are visible and in the RF current path.

COUNTERPOISES

WE HAVE PROVIDED three ways of erecting the antenna. The base rod fits the socket of the XYL's rotary clothes line on our patio. Away from home, a fold-up stand for such a clothes line makes a light but sturdy pedestal as shown in the photo on page 17.

For use with these two methods, we designed and made an earth mat which can be quickly deployed without having to untangle a mass of wires, and repacked for transport. It features 60 radials of insulated stranded wire, each 2.5m long, to go with an antenna height of 2.5m. See photos left and top left. The radials are divided into four groups of 15, with their ends stapled to four battens, each of which is articulated in three places to permit folding into a W-shape. The 15 radials in each group are interconnected at the battens and at two intermediate distances between the centre and the battens. At the centre, all radials are terminated on a saucepan which has a hole for the antenna base rod.

Also attached to this saucepan are two heavy straps to connect the earth mat to the earth point of the antenna.

The third way of erecting this antenna is on the steel roof of our van by means of a Tennamast quad mag mount.

The implications of a metal vehicle roof as a counterpoise are well described by G6XN in [8].

EXPERIMENTS

WE HAVE TWO upper radiators: a 1.55m maximum telescopic whip and a 1720mm x 10mm diameter aluminium tube, on top of which we can fit a capacity hat of four horizontal spokes 500mm long x 4mm diameter, or a 0.8m whip, or both.

With the antenna installed on the described earth mat in our garden, measurements were taken with an MFJ-259 SWR Analyser installed 300mm from the antenna feedpoint. The results are plotted in **Fig 3** and **Fig 4**.

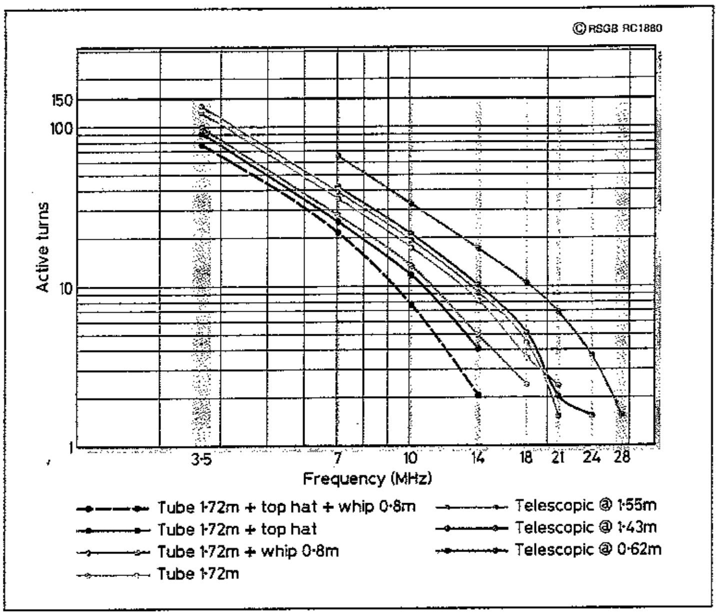


Fig 3: Active coil turns required vs. frequency with various upper radiator configurations.

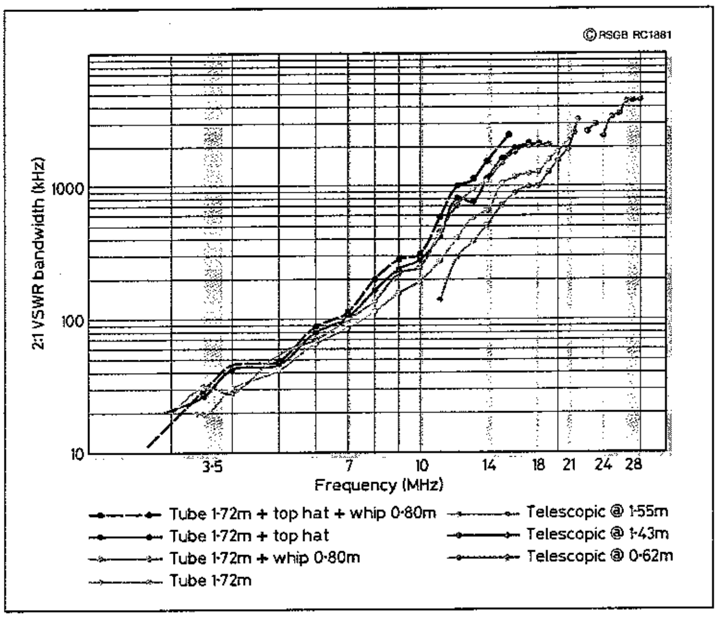


Fig 4: 2:1 SWR bandwidth vs. frequency with various upper radiator configurations.

Fig 4 shows the number of active coil turns vs. frequency for each of the seven upper radiator configurations mentioned. With either the 1.55m telescopic whip or the 1.72m tube, all bands 3.5 to 21MHz are within the coil range. 28MHz requires the whip to be telescoped down to 0.62m. The latter is shorter than we expected, but that does not interfere with the way we operate.

Fig 4 shows that at 3.5MHz, the only band where the SWR bandwidth is narrower than the band itself, a taller radiator and/or a capacity hat increase the bandwidth, and also that the whip above the capacity hat has little effect.

Performance measurements on the DK3 antenna are scarce. Mobile field trials, such as are occasionally held in California, compare complete mobile installations in a variety of vehicles, not just antennas. Of 17 entries in one 1995 75m trial organised by W6KKT, six were DK3s. These were significantly outdone only by a single-band design with an enormous funnel-shaped top hat. DK3s equalled or bettered single-band designs of similar dimensions.

RESULTS

OUR DK3 HAS been extensively used with up to 100W in QSOs with other nearby holiday makers as well as for DX, the latter mostly with CW. Performance was entirely satisfactory.

Does the convenience of quick remotely controlled band-hopping and retuning after QSY in the 3.5MHz band justify the effort and expense of making a DK3, as compared with a design featuring interchangeable centre loading coils for each band and a small bottom loading roller-coaster or moving a powder-iron core into and out of the low-band coil [9] for in-band tuning? We think so.

REFERENCES

[1] See *Eurotek* (PA2JCB) in *RadCom* May 1993, p69.

[2] L McCoy, W1ICP, *Lew McCoy on Antennas*, CQ Communications, Hicksville, NY, USA.

[3] PO Box 595, Esparto, CA 95627-0595, USA. Tel: 001 530 787 3905.

[4] DK Johnson, W6AAQ, *Everything You Forgot To Ask About HF Mobileering*, Worldradio Books, PO Box 189490, Sacramento CA 95818, USA 1997.

[5] JS Belrose, VE2CV, 'Short Coil-Loaded HF Mobile Antennas: An Update And Calculated Radiation Patterns', *ARRL Antenna Compendium* Vol 4 (RSGB).

[6] *The ARRL Antenna Book*, eg 17th ed. ch. 16.

[7] A hard-wearing low-friction plastic made by Dupont.

[8] Les Moxon, G6XN, *HF Antennas for all locations*, 2nd ed. (RSGB).

[9] TD Forrester, G4WIM, 'A 1.8MHz Auto Tuning Vertical Antenna', *RadCom*, November 1986, or the *HF Antenna Collection* (RSGB).

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