Tricks of the Trade

Dave Porter G4OYX with Trevor Brook G3WBQ, Doug Fisher G3SAK and Tony Preedy G3LNP

Regular readers will no doubt be familiar now with the words of wisdom from the BBC publication TT.5 with regards to *Medium Wave* Matching Networks, *etc*. **[1]**. As a diversion from MF we start this time from an LF perspective and, in particular, the LF and MF station at Ottringham, near Hull, which was known as Overseas Service Extension 5, OSE5 in its BBC wartime coding.

OSE5

BBC Instruction TT.9 **[2]** describes OSE5 as follows: Each of the four Marconi transmitter units is Class-B modulated with a manufacturers' carrier power rating of 150 kW but capable of continuous operation at 200 kW output on any frequency in the band 550–1600 kHz or 160–250 kHz, but note that the LF range quoted was after certain modifications had been made during the war after the installation.

The original plan provided for parallel operation on the transmitter units on both LF and MF wavebands; the plan also provided for both horizontally and vertically polarised radiation on MF.

(Horizontally polarised radiation was to prevent the enemy using the site as an aid to DF and had been employed at Droitwich with 400 kW on 1149 kHz in 1941 following earlier trials at Start Point.)

Changes in the war situation rendered it unnecessary to put the full plan into operation. Combining circuits for parallel operation on MF were not installed and similarly the LF antenna system was only ever deployed in a Tee configuration for vertically polarised transmissions. The original single Tee antenna was replaced later by two Tee antennas of simpler construction which were connected in parallel in the antenna tuning house (ATH) to form a single radiator of relatively low Zo again for LF use with a drive point impedance (dpz) now of 8 –j40.6 Ω.

For a period, the station was in operation with three transmitter units, paralleled on LF to 600 kW on 200 kHz with the remaining transmitter on 767 kHz for the Home Service covering the East Riding of Yorkshire and Lincolnshire at 30 kW using a pair of adjacent masts as a vertical array.

For a period just after the end of the war, the site was in operation with two transmitter units on 250 kHz at 400 kW. Problems were caused to shipping with the second harmonic, 500 kHz being the International Distress Frequency and the station changed to 271 kHz and later in 1946 to 167 kHz, but with a power restriction to 200 kW. During this same time, there were MF overseas services on 977 kHz at 100 kW and later 1122 kHz. With the loss of the 167 kHz channel following the Copenhagen Plan implementation in March 1950, OSE5 then became a relief site for maintenance at Aspidistra on 1295 kHz with LF transmissions ceasing completely. The entire site was closed in February 1953 and dismantled with much plant placed into storage. The author, who was one year old at that time, actually worked on all four OSE5 transmitters as they were re-engineered, upgraded and installed at Droitwich in 1962 and ran until the mid-1980s.

The LF antennas at OSE5

The first Tee antenna was used on 200 kHz in January 1943 and was suspended between two of the 500-foot masts; the dpz at 200 kHz was 6.4 –j66 Ω. A revised arrangement, described below, was implemented in October 1944 and was rated to 600 kW.

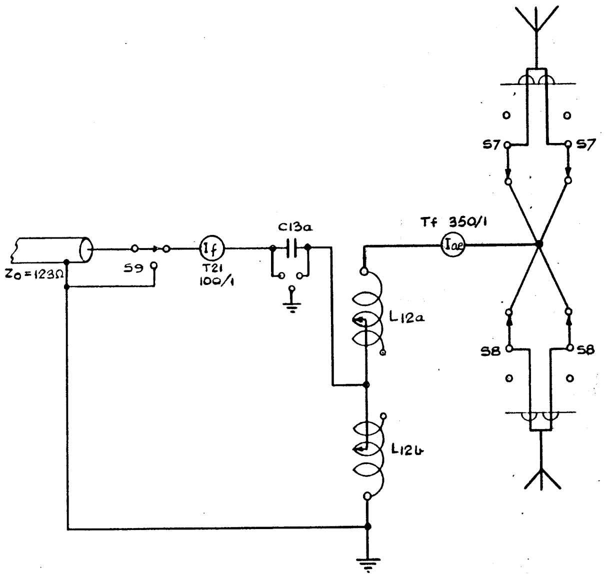

Figure 1. LF antenna ATU at OSE5. Measured performance at 200 kHz: antenna current 253 A, dpz 8.0 –j40.6, input power to ATH 512 kW, mean field strength 1220 mV/m at 5 km, mean Ed 6100, power radiated 414 kW, antenna efficiency 82%.

Here a further pair of 500-foot masts was used to support this second Tee antenna. The separation between the side-by-side antennas was 200 feet, that is 0.04 λ. Each of the twin antennas consisted of a flat top-hamper composed of four 7/.161-inch steel-cored aluminium (SCA) wires spaced approximately 21 feet apart and carried on spreaders, the overall length being 451 feet. The pair of down-leads consisted of four similar wires, spaced again at 21 feet and about 450 feet long. These were terminated at a height of 10 feet above the ground by insulators supported on a steel frame. Connection to the ATH was made by means of a horizontal line 50 feet long; formed by bunching the four wires together to a 4-inch spacing. The 50-foot horizontal leads were introduced deliberately and were made of as high a characteristic impedance as possible in order to reduce the capacitative reactance presented to the ATH without appreciably reducing the resistive component, the resulting dpz being now 8 –j40.6 Ω.

It will be apparent that the *R*-term is, in both cases, below 10 Ω with the expected substantial capacitive reactance term; this presents a considerable necessary impedance transfer up to the Zo of the transmitter output feeder of 123 Ω. Accordingly, a standard LF matching circuit was used as shown on **Figure 1**. Measurements were taken by BBC Research Department and are documented above in the text for **Figure 1** for 200 kHz.

At Droitwich after 1945, the wartime antenna arrangements were normalised and a four-wire Tee antenna was used on 200 kHz at 400 kW. With the masts at 700 feet high and spaced about 800 feet, the dpz was 11 –j85 Ω. This illustrates the difference that an increase of 200 feet in antenna height can make to the *R*-term compared to 500 feet at OSE5 on the same frequency.

Scaling up and down

For low-power MF relay or fill-in stations, it is uneconomic to employ massive antenna structures such as would be used at the higher powered main stations and so it was established practice to use, typically, Tee antennas often held up by simple Cubro and Scrutton poles or Adastra cigar sectional masts of around 110 feet high and spaced at 150 feet. The Tees could be single or twin wire. In the BBC/Govt Deferred Facility initiative for Civil Defence broadcasts during the Cold War; frequencies at the HF end of MF were used, typically 1457, 1484, 1546 and 1594 kHz. There were a few sites assigned to 1295 kHz.

These higher MF channels made matching more simple. All was to change though in the later re-purposing of some of these sites for BBC Local Radio starting in the 1970s when a low MF channel was assigned. Many had a new antenna system installed with a pair of 45-metre masts and a twin-Tee or a single mast radiator.

Towards the end of the expansion of BBC local radio, it was decided to have an MF introductory period on a temporary licence to establish the service and then *ease the listeners over* to FM and the then new up-coming DAB service.

603 kHz in Gloucestershire - 1

In 1988, the former 1950's DF station at Twigworth, Gloucester was re-purposed to be a temporary LR intro-service on 603 kHz. The wartime BBC/RCA ET4336 transmitters were wavechanged and the 110-foot masts were supporting a brand-new twin-wire Tee antenna.

The author was involved in this project as regards the transmitter and programme input equipment, but the antenna, earthing system, ATH and matching was the responsibility of the Woofferton Antenna Engineer Andy Savage. He had taken preliminary measurements of the dpz at 603 kHz and, at 7 –j215 Ω, he had not a lot of *R*-term to work with.

Use of TT.5 showed that, for a Tee or L matching network, very large value capacitors in the region of 10,000 pF were needed and relatively high-value inductors; these requirements rang 'alarm bells' regarding *Q* and associated bandwidth restrictions.

Like many of us, Andy had passed through Droitwich as a Technical Assistant and was no doubt familiar with the 11 –j85 Ω dpz on 200 kHz and the matching circuits used as, in the main transmitter hall, were wall-mounted, glass-fronted, wooden-edged framed prints of most if not all of the transmitter and antenna circuits. He proposed to use the standard LF twin-coil arrangement but on MF! This makes sense really as we have now a scaled down LF antenna with a low MF channel.

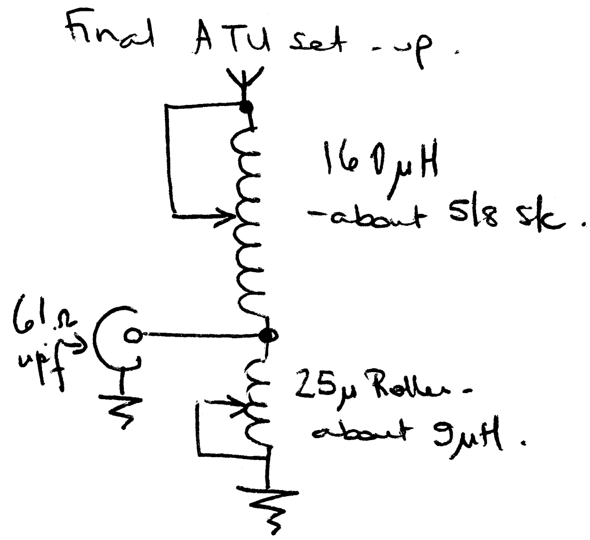

Figure 2. Original sketch from 1988 by G4OYX of the matching circuit by Andy Savage

With reference to **Figure 2**, the inductors used for a 61 Ω match were one of 160 µH total for the antenna side coil with about 5/8 of it short-circuited out and a 25 µH ex-ET4336 roller coaster set to about 9 µH between the 61 Ω input and earth. The coils were arranged in the wall-mounted alloy-boxed and screened ATU at right angles to each other. An SO-239 input socket was used for the 61 Ω feeder to combiner output to prevent any 50 Ω regular N-connections being made! Using a vector impedance bridge it was possible to view the results on the Smith chart display and adjust the top L and roller to achieve 61 Ω unity power factor (upf).

A good useable RF bandwidth of 12 kHz was available and no sideband cutting was evident. Luckily though, the twin-813 PA-valved ET transmitters were far more accommodating in this respect than their much younger solid-state cousins.

There was just the one problem that is usually associated with twin coil LF matching, and that is the lack of any harmonic attenuation within the ATU itself. It was noted that a 1206 kHz signal did extend to about 500 m from the site but was soon swallowed up in the sideband mush of the Radio 3 service on 1215 kHz.

BBC Local Radio… on the cheap!

By 1989, the final few BBC LR stations were in the process of being built; these included for Wiltshire, 1332 and 1368 kHz, Hereford and Worcester 819 and 738 kHz and a replacement MF antenna for the already long-established 1116 kHz service from Radio Derby which had to be relocated from the Burnaston aerodrome site when the Toyota vehicle manufacturing plant was established. Derby City Council had made a site in Burnaston village itself, nearer the city centre, available to the BBC.

For the these other temporary MF services, sites had been found by the BBC Site Acquisition Section. Doug Fisher, G3SAK was one of the engineers in that department and, in a former BBC life in the BBC Capital Projects Department TCPD MF Unit, he had been heavily involved at Droitwich in September 1972 with a directional antenna system for the combined 150 kW R4 1052 kHz service and the 30 kW 1214 kHz R1 service. The need for a directional antenna was to prevent too much radiation to the south west as 1052 kHz was shared after September 1972 with Start Point and the 1214 kHz caused a mush area in Gloucester with Washford in Somerset. It was here at that time that the author first met Doug who seemed to be on permanent nights! His four-wire box *c.* 200 kW dropper from a triatic off the northern-most mast was the solution, but to achieve a successful final working arrangement was not easy particularly considering the large input power difference of 30 kW *vs.* 150 kW between the two channels.

It was fortunate that Doug was in the BBC Site Acquisition Section for this later MF expansion, as he was able to take on board the wishes of the various District Planning Departments regarding antenna constraints and those of BBC LR who had very little money for what were supposed to be only temporary (6 to 18 months) installations, anyway. The major requirement was to be as close as possible to the major centre of population.

Prior to all this MF work in Site Acquisition Section, Doug had been involved in the Phase 2E UHF relay station expansion, where 17-metre wooden poles were used as a cheap and easy solution and usually (but not always) preferred by planning officers. No doubt the prospect of three (regular looking) telegraph poles (even though they were 17 m high!) were maybe an easier thing for the planners to take than a steel lattice mast or two.

Doug came up with the idea of a three pole low-profile Tee antenna for MF.

G3SAK explains:

The idea of three poles was to avoid the sag of a conventional Tee and allow a matching unit to be pole-mounted, well off the ground for security and flooding issues, just like an electricity board pole-mounted 3-phase transformer.

It would have been possible, by designing the Tee to be resonant on the desired frequency, to present a purely resistive load. An elevated feed could then raise the feed point impedance to 50 Ω so no matching unit would have been required but this was considered too difficult to engineer by TCPD. Whatever method is used, the adjustment always comes down to getting the antenna resistive and the reactive component to appear as 50 Ω so it's inevitable that there are two things to adjust but the trick is to make them as less interactive as possible. It is quite easy to do by the right choice of matching circuit.

Of course, I wasn't in TCPD MF Unit at the time and didn't have any input into the details as there was a bit of a 'not invented here' syndrome and some in TCPD thought I shouldn't be designing MF antenna systems. Anyway, I pressed on regardless and actually Marconi Antenna Systems were approached with possibly taking on the design for which I had applied for a patent (since lapsed) whose front page is shown as ***Figure 4****.*

In the event, Doug need have had no worries as to the actual implementation of his idea by TCPD, as the powers-that-be handed it over to another talented BBC antenna specialist Tony Preedy G3LNP for his attention. Tony was fresh from his Droitwich 200/198 kHz 500 kW antenna redesign and combining/matching installation.

G3LNP issued a set of instructions and diagrams and it appeared that Woofferton (WOF), basking in the financial limelight from the £33k under-budget installation at Gloucester the previous year, was to be the go-to-site for installation effort for the first site at Hereford. This was a fair point as WOF was geographically in exactly the right area for Hereford and Worcester and the two sites in Wiltshire were within fairly easy commuting distance as was Derby. There were also some 'spare' staff just arrived on site straight from their engineer training and, of course, the Old Duffer G4OYX to oversee the engineering of the transmitter Portakabins, a full LF to SHF rigging team and Senior Antenna Engineer. Tony's design is shown in **Figure 3** as a schematic and in **Figure 5** as a mechanical / electrical layout.

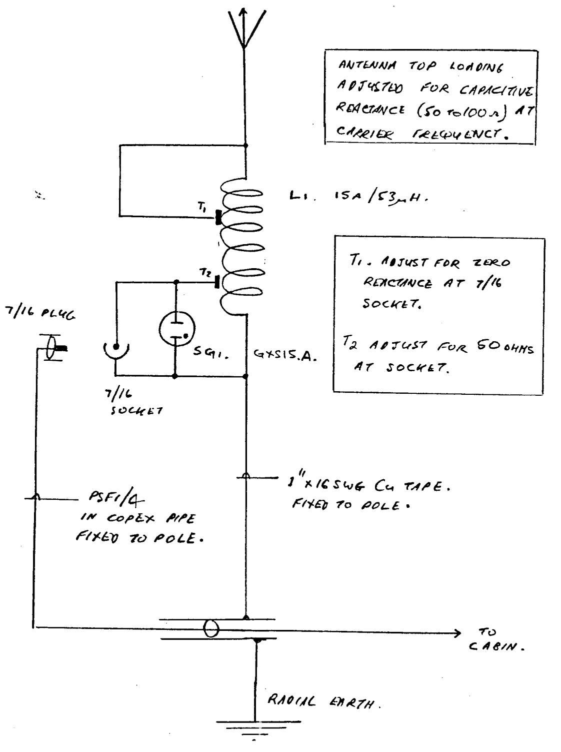

Figure 3. Tony Preedy's original sketch of the matching unit

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H01Q 9/20 9/26

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(56) Documents cited
GB 0474384 A GB 0348852 A GB 0223537 A
US 4423423 A

(58) Field of search
UK CL (Edition J) **H1Q QDN QDP QDX**
INT CL^{4} **H01Q**

(54) **T-shaped antenna**

(57) A T-shaped antenna comprises an upper element (22) extending between supports (24, 26), and a vertical element (30) extending from a position near the mid point of the upper element (22) to ground (32). The antenna can be a folded antenna. A feeder is connected to the vertical element (30) at a feed point (38) elevated from the ground.

Fig. 5

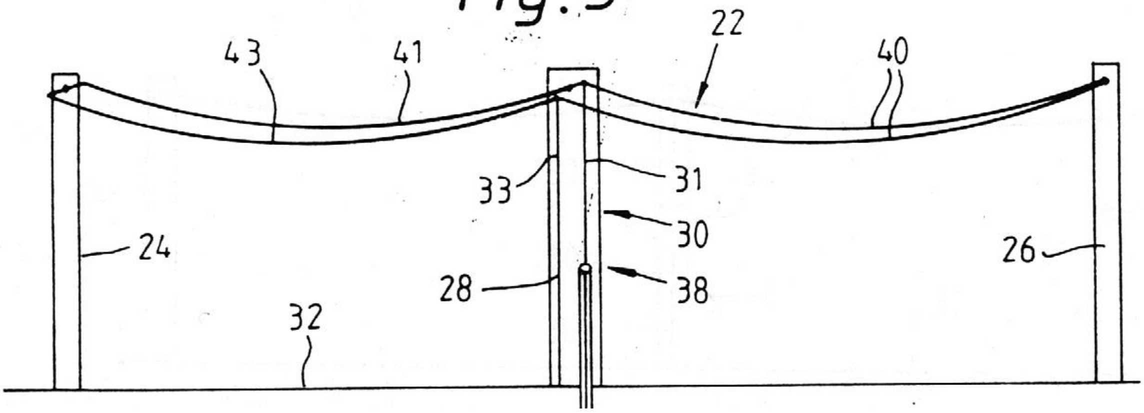


Figure 4. Front page of Doug Fisher's patent application

For the rigging staff, the mechanical/electrical engineering was fairly simple though at Worcester the laying of a considerable length of URM67/RG213 was not easy as the trench continually filled with water rather than flowing away to the seemingly always in-flood River Severn some 50 m away at Bennett's Dairies "Manor Farm". The WOF ground-crew were not happy with that as it overflowed their Wellington boots but they did enjoy the overtime… At least the earth mat was bathed in an almost permanently wet environment there.

G3SAK's **"Low Profile MF Tee Antenna"** was described by G3LNP as follows:

Introduction

A simple matching arrangement is employed which reduces the mast loading where this is remote from the transmitter or reduces the space requirement when mounted in a Portakabin (directly below the Tee).

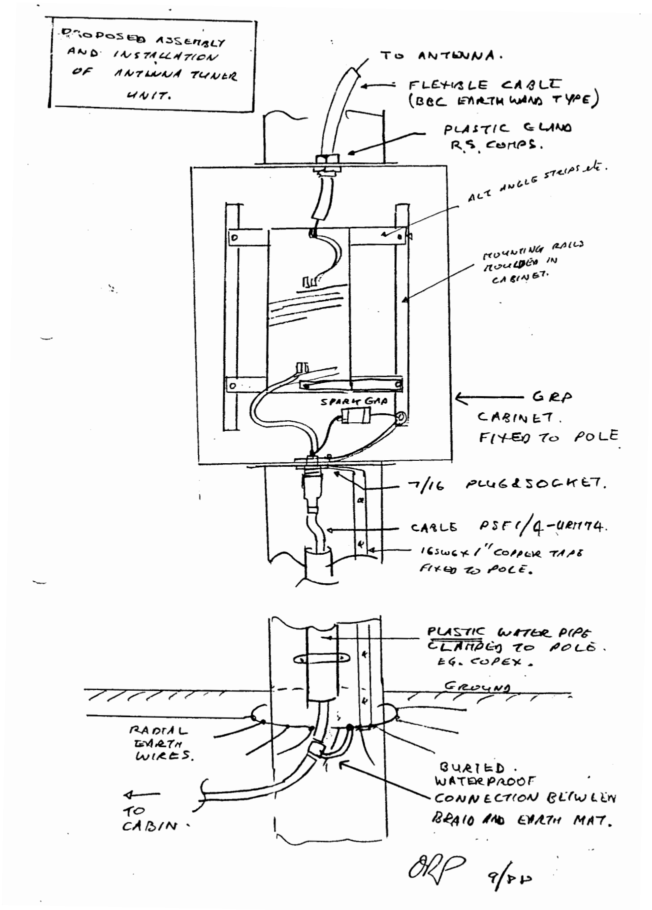


Figure 5. Tony Preedy's original sketch of the proposed assembly and installation of antenna tuner unit, dated 9/88

Description

The circuit is a tuned auto-transformer which uses a tapped inductor to provide a 50 Ω feeder termination at the carrier frequency. The inductor resonates with the antenna reactance which must be made capacitive (by reducing the length of the horizontal section if the operating frequency is above 1 MHz). The auto-transformer eliminates capacitors and a static leak and offers least susceptibility to environmental influence on transmitter load impedance.

Adjustment

*1) Ensure that the feeder braid is joined to the earth mat at the base of the antenna if pole mounted (**Figure 5**).*

2) Symmetrically adjust the antenna top length to present a feed capacitance preferably of 50–100 Ω measured between the antenna and feeder braid if pole mounted and between the antenna wire and chassis if mounted in the isolator cabinet. Note: on low MF channels all of the top span will be in use and the capacitive reactance may exceed –j100 Ω.

3) Connect the lower coil tap about two turns from the earthy end and connect this to the impedance bridge. Connect the antenna to the upper coil tap.

4) Adjust the upper coil tap for zero reactance between lower tap and feeder braid.

5) Adjust the lower coil tap for 50 Ω.

6) If the upper coil tap is more than half-way down the coil arrange for the unused turns to be short-circuited. Repeat 4) and 5) until 50 Ω upf is obtained.

Hereford, 819 kHz was one of the first sites on air and the Eddystone B6038 1 kW transmitter was at the Welsh Water Broomy Hill Water Treatment Works in a rather grand-sounding "Expansion Chamber Room".

Worcester, 738 kHz was at Manor Farm in a Portakabin right next to an enormous open slurry pit that appeared to contain at least 10 million litres of this most disgusting material.

Both Wiltshire sites were "agriculturally" in the clear with Lacock, 1332 kHz on the outskirts of the beautiful mediæval village and Swindon on 1368 kHz, both in Portakabins.

Martin Watkins of the mb21 web site **[3]** has made available to the author illustrations of the general arrangements at WR and LA and high quality photographs, kindly provided for *Signal* by Ian Chalmers G8HON and Mark Carver, are included as **Figures 6–8**.

Figure 6. Lacock MF antenna. Photo: Mark Carver

Tony G3LNP did provide the author at the time with some extra information including the explanation of the need for a gas-filled spark gap on the ATU input; this was a standard requirement on these Eddystone transmitters to prevent high voltages, particularly static-derived, finding their way into the solid-state output stages. In the same vein, G3LNP stated that for this ATU arrangement the transmitters must have their spurious output checked as there is no harmonic suppression within the ATU due to the 'LF-match' design. Of course, due to the 1206 kHz output at Gloucester, we were well aware of that already.

Figure 7. Lacock MF antenna termination. Photo: Mark Carver

Figure 8. Worcester MF antenna termination. Photo: Ian Chalmers G8HON

One last point mentioned by G3LNP was that the vertical mounting of the single 53 μH coil was essential as the RF field on it does add to that radiated thereby increasing the efficiency. The extra RF was able to 'escape' from the actual ATU as it was specified as a Glass Reinforced Plastic (GRP) structure and as such was not screened. It is important to note that the use of a single 53 μH coil with two taps rather than two separate coils, maybe spaced at 90° as was used at BBC Gloucester MF, did make the setting-up more 'tricky' due to their expected mutual interaction.

Initial results

Field strength measurements at Worcester on what was to be the lowest allocated channel of 738 kHz showed that, to comply with the licence conditions of 37.5 W emrp (effective monopole radiated power), 400 W of transmitter output power was needed. Allowing for the loss on the not inconsiderable length of RG213 it would appear the Tee was about 10% efficient. As an aside, the licence here was odd in that it had been set at 150 W emrp in the service planning data some 15 years previous but, allegedly, following representations from the IBA and their existing service provider on 1530 kHz it was knocked back by 6 dB for BBC LR use to just the 37.5 W.

However the BBC did 'win' with the original 603 kHz Radio Gloucestershire service as the measured emrp was indeed 100 W as licenced and, compared to the ILR fairly directional service on 774 kHz, the 603 kHz field strength was up to 6 dB higher throughout the whole county rather than being all concentrated in the actual city!

Hereford was better at around 15% efficient and the transmitter ran at 500 W output.

The Wiltshire sites came in at around 25% and ran the full 1 kW transmitter output to achieve 250 W emrp. One would guess that Derby was around 20% on 1116 kHz.

Another Tee-antenna design

As is often the case great minds think alike and we have Doug G3SAK with his low profile Tee-antenna in 1988/9 and actually a similar design had been offered by C and S Antennas Ltd of Rochester, Kent illustrated in their data sheets **[4]** published in July 1983. These are reproduced as **Figure 9 and Table 1**. Reference to them shows that the antenna arrangement is quite unlike G3SAK's idea for a centre-pole support and high level ATU but rather the C and S design uses a ground-mounted conventional enclosure. These deviations probably account for the fact that Doug's later, significantly different, design did qualify for a patent.

603 kHz in Gloucestershire - 2

For some 40 years the author, G4OYX, has been in contact with friend and colleague Trevor Brook G3WBQ, often concerning broadcast audio equipment as he was the MD of Surrey Electronics in Cranleigh and as such a renowned and well regarded supplier to the BBC and many others. He was also very experienced in RF circuitry and, for example, he redesigned and incorporated many improvements to the Yaesu FRG-7700 receiver making it into a professional monitoring unit for broadcast stations and organisations including BBC World Service and British Forces Broadcasting Service amongst others.

Many VMARS members may recall the speech-based, technical emphasis broadcast station "Radio Fax" that had a four-year life on HF 1988–1992 and, for many years after closure, was seeking to be given a licence to operate legally on HF from within the UK. Trevor was the main mover in this application. It was a great shame that his application(s) were unsuccessful as the UK authorities, managed to circumvent many UK and Euro Court decisions and rulings with appeal after appeal.

'T' Antennas

Types TA 3/3/30 and TA 3/3/70

3 Wire 'T' antennas
For MF/LF broadcasting
and beacon applications

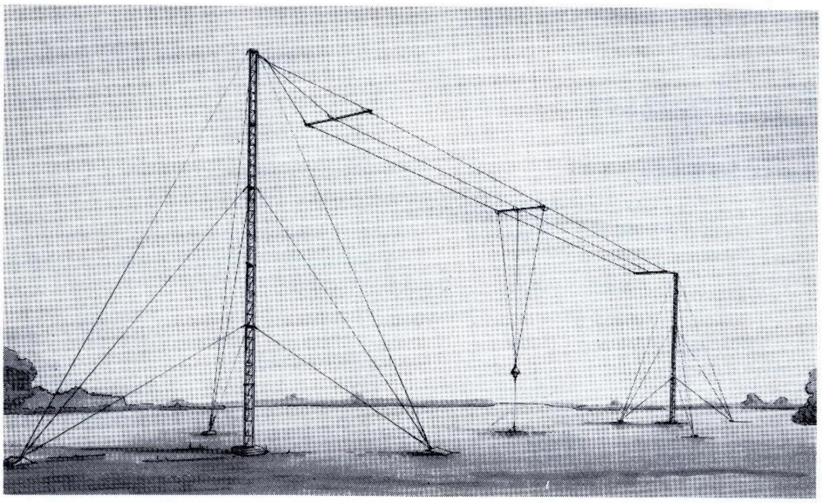
These 'T' antennas have a wide application in MF and LF for navigation beacons and broadcasting. TA 3/3 antennas are used when the height of the antenna for practical reasons must be restricted to $\lambda/8$ or less, and for transmitter powers of up to 10kW.

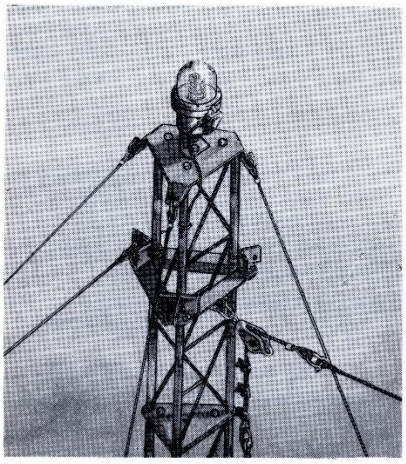
With a suitable earth mat, antenna efficiencies of up to 80% are typical in the MF broadcast band.

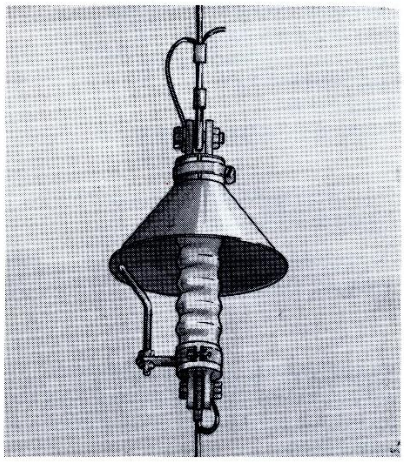
The horizontal section of the 'T' serves to increase the radiating current in the upper part of the vertical section of the antenna, increasing its effective height and radiation resistance. Top loading also reduces the capacitive reactance which must be matched by the antenna tuning network. Thus the radiation efficiency of the antenna, the efficiency of the antenna tuning unit (ATU) and the bandwidth of the system are all enhanced. The horizontal radiation pattern is substantially omnidirectional.

A complete antenna comprises prefabricated elements, insulators, bridles and spreader poles. The strain insulator at the lower end of the downlead is protected by a rain-shield and arcing horn. These reduce the change in input impedance caused by severe environmental conditions and help to protect the ATU and transmitter from damage.

The antennas described in this leaflet are supplied in fully finished sub-assemblies which can be assembled and erected with the minimum of 'on site' time.







General Specification

Materials

Insulators:	Porcelain or alumina ceramic
Antenna wires:	Cadmium copper
Earth mat:	Soft copper wire
Spreader poles:	Galvanised mild steel
Small fittings:	Stainless steel/ galvanised steel

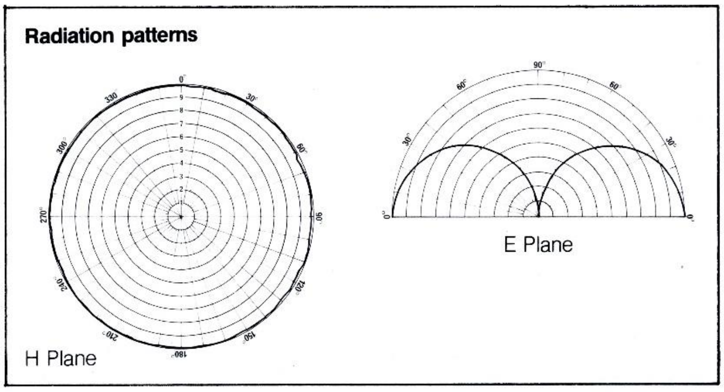


Figure 9. Extract from C&S Antennas Ltd datasheet

Typical characteristics

Type	Height	Length	Frequency	Feed impedance ohms
TA 3/3/30	15m	30m	200 kHz 500 kHz 1000 kHz	0.4 - j750 2.75 - j300 9 + j43
TA 3/3/70	45m	70m	200 kHz 500 kHz 1000 kHz	0.9 - j650 4.5 - j130 14 + j111

A complete antenna system comprises:

Type	Description	Recommend mast	Earth mat*
TA 3/3/30	3 wire 'T' antenna 30m top length 15m rigging height	LTSH 15	EM48/30
TA 3/3/70	3 wire 'T' antenna 70m top length 45m rigging height	LTSH 45 or HTS 45	EM48/45

* These earth mats are for average soil conductivity of 10 mS/m.

Table 1. Data for the antenna described in Figure 9

Trevor's considerable and proven skills in all matters RF must have come to the attention of a group in Cheltenham. This group had been allocated the former BBC LR 603 kHz 100 W emrp channel when the BBC's temporary licence came to an end and had employed the local (to them) contractor Alan Dick & Co. Ltd to build and commission the transmitter site, masts and antenna.

On his website **[5]** G3WBQ describes what was required to upgrade this transmitter installation following many problems, most of which appeared to be due to the physically very small low-profile Tee-antenna system.

G3WBQ has most kindly agreed to publication in Signal of the full story of this exercise. His notes have been edited slightly to be in the house style.

G3WBQ writes:

Fixing Cheltenham Radio 603 kHz which tripped off during drivetime

In 1996, the Independent Local Radio (ILR) service for Cheltenham, running a 250 Watt transmitter for its 100 Watt Effective Monopole Radiated Power (EMRP) licence, developed a commercially disastrous propensity to fall off the air during the busy listening time of 1700 to 1900.

The transmitter would trip for two seconds and then reapply power. If three trips occurred within a short period it stayed off permanently until somebody drove up from the studios in Cheltenham, out to the site in a far flung corner of the racecourse which was once a rubbish tip, opened the cabin and pressed a reset button.

*It seemed that large numbers of starlings congregating on the Tee antenna (**Figure 10**) at dusk, before flying off to roost, were detuning the antenna sufficiently to upset the modern solid-state transmitter. This power at MF is harmless to birds but if a bird has the sad misfortune to land on a high power short wave antenna or open-wire feeder the RF would blow off its legs.*

*On auspicious days, someone would be positioned at the site to scare birds. Marc Bond, station manager at the time, needed help. To win a few weeks of time to devise a plan and obtain parts, my first action was to climb the east mast and install at the top a large decoy eagle owl **(Figure 11)** I'd bought from a field sports shop.*

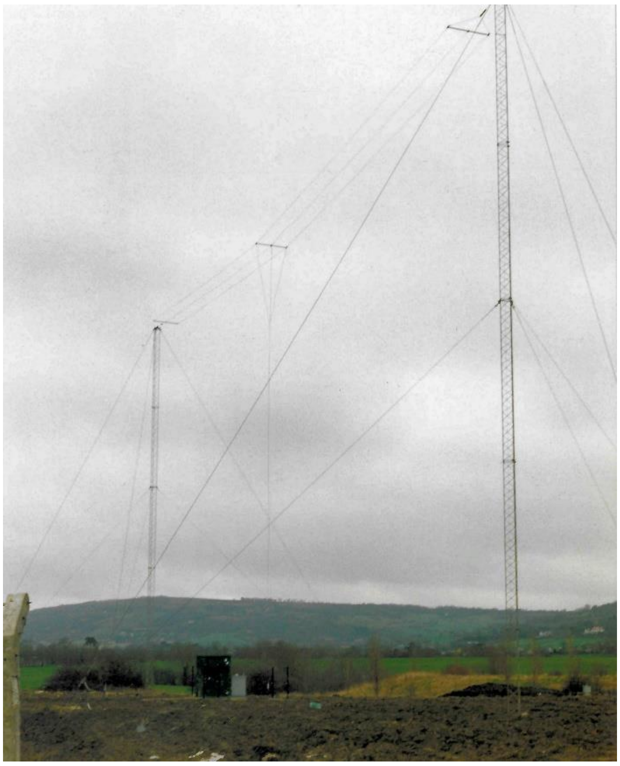
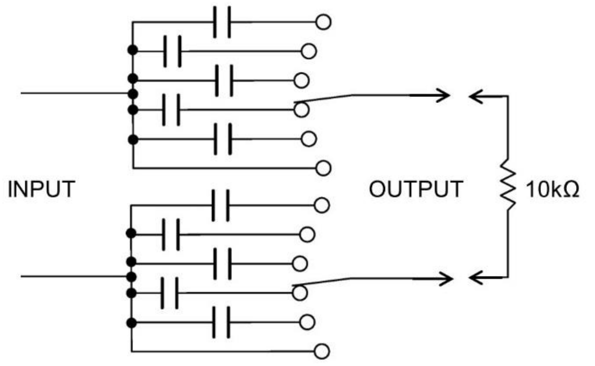


Figure 9. The Tee aerial favoured by starlings Photo: David Thorpe

Figure 11. The half-metre tall eagle owl decoy

*Optimod audio processors don't really do low frequency roll-off so, in the studio racks room, I also installed a balanced jack switch box **(Figure 12)** which could insert various capacitors into the audio feed going out through the jackfield to the transmitter. Selecting an appropriate LF roll-off crispened up the muddy sound of the station caused by losing treble due to poor return loss and sideband cutting in the narrowband transmitting aerial.*



	Measured into 10 kΩ load		Capacitor value
	At 50 Hz	At 100 Hz	
Direct	0 dB	0 dB	s/c
LF1	–1.5 dB	–0.4 dB	1 μF
LF2	–2.8 dB	–0.9 dB	680 nF
LF3	–4.6 dB	–1.8 dB	470 nF
LF4	–6.7 dB	–2.6 dB	330 nF
LF5	–10.5 dB	–5.5 dB	200 nF

Figure 12. Balanced LF roll-off switch box

Figure 13. The original aerial matching system Photo: David Thorpe

*That same night I took the station off the air at 0100 to take antenna bandwidth measurements and examine the antenna matching unit **(Figures 13 and 15)** properly. The ATH was installed beside the centre of the Tee aerial drop, with the transmitter cabin **(Figure 14)** directly beside it. There were a range of suspects, most ranging from non-optimal to simply wrong:-*

- *Even when adjusted for zero reflected power at carrier frequency, the transmitter was seeing significant reflections on treble in the sidebands.*
- *The two 27-metre masts were physically too short, which was a planning constraint.*
- *At 56 metres, the masts were too close together, especially given their height.*
- *None of the steel supporting-stay wires were broken up with insulators.*
- *Worse still, shackles attaching the stays to the masts were not strapped across, meaning variable contact resistance.*
- *Given the short length, the three-wire hamper should have been wider with more wires.*
- *Instead of tapering, the Tee drop should have remained wide to nearly the bottom.*
- *The buried earth mat was too deep at 30 cm, so the earth above it drying out would affect tuning more than it should.*
- *The five coils in a matching unit, intended to widen bandwidth, were achieving no more than an L-network, as well as being lossy.*
- *The inductors were small and undesirably close to each other or the enclosure's aluminium side panels, reducing their Q.*
- *The matching unit was assembled with steel washers between joints of silvered copper straps, which is lossy.*
- *A similar arrangement of washers in the riser from the earth system was also lossy.*

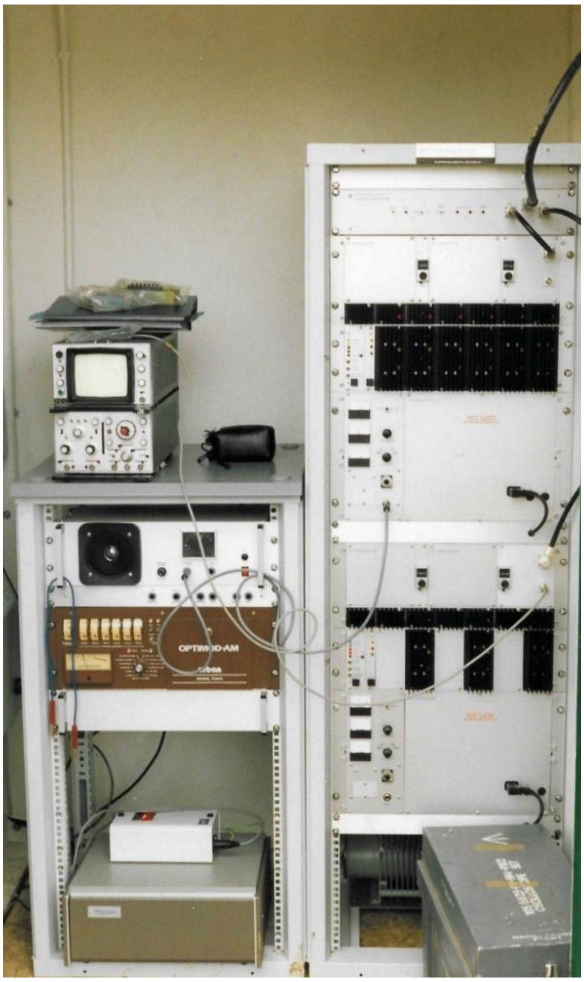


Figure 14. Main and reserve transmitters in the cabin. Photo: David Thorpe

*The 1993 antenna system design and installation was by local Cheltenham company Alan Dick & Co Ltd **(Figure 16)**. Whatever their undoubted skills in VHF and UHF antennas and combiners it has to be said that Medium Wave engineering did not appear to be their forte.*

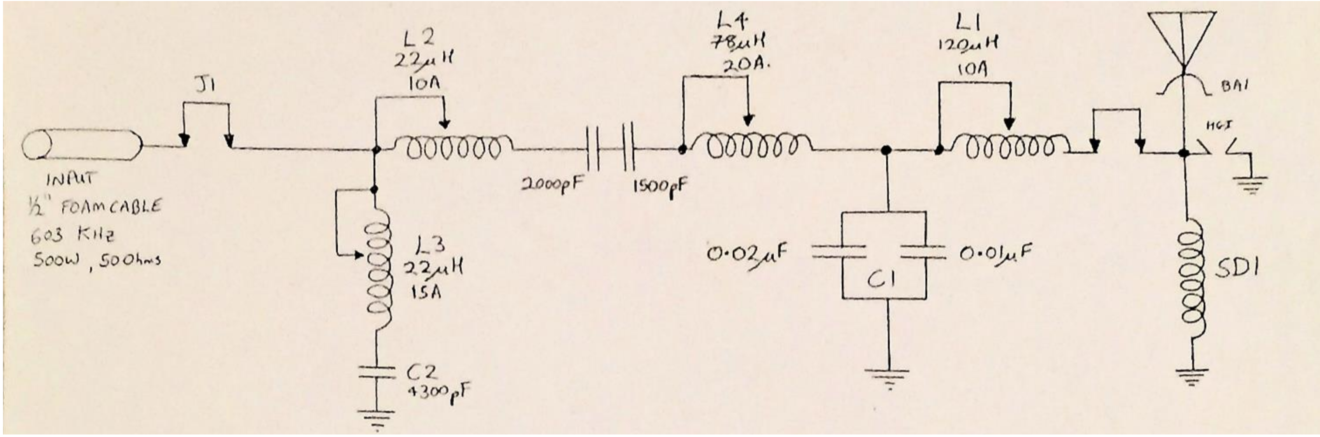


Figure 15. Original drawing of the Cheltenham Radio ATU circuit diagram dated 22/2/93

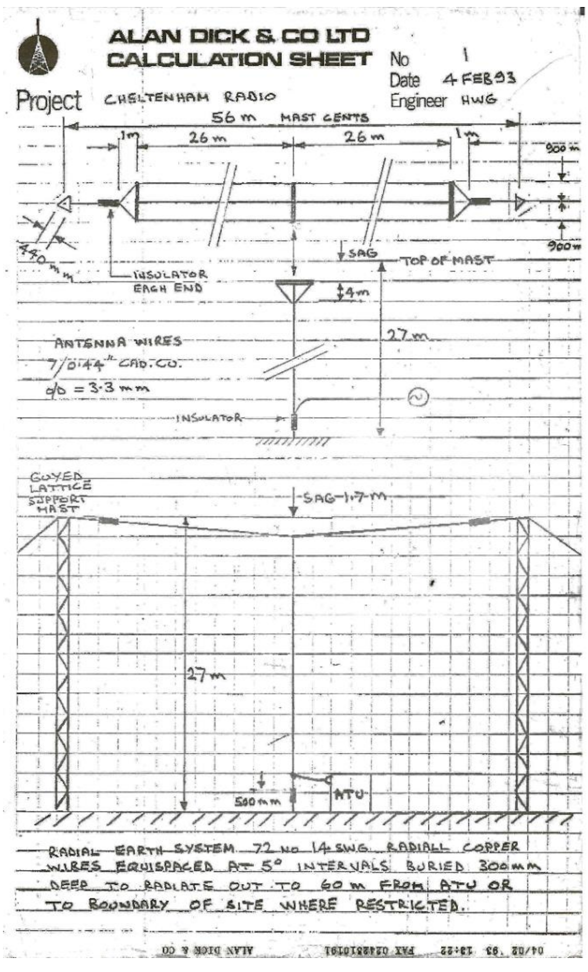


Figure 16. Original drawing of the design of the Cheltenham Radio Tee antenna

In the preparation of this article the author, G4OYX did ask Tony Preedy for his comments on the original US-inspired Alan Dick matching unit and G3LNP replied as follows:

*Referring to the original Cheltenham ATU circuit **(Figure 15)** it looks like L3 and C2 are a harmonic trap. L2, L4 and the capacitors of 2 nF and 1.5 nF could be replaced by a single component unless they were series resonant at 603 kHz. In that case, they would have restricted the sidebands. L1 and C1 look like an L-match. SD1 is obviously a static leak.*

I would have replaced all of these components with a single inductor forming an auto transformer. This usually gives good bandwidth and, because the bit of coil below the tap has only the difference between antenna and feeder currents, it wastes less power compared to a two inductor L-match and requires less total inductance because the mutual inductance between the two parts of the transformer is included without adding any loss resistance. The single inductor also provides a static leak.

If the bandwidth from the autotransformer was not sufficient a pi-circuit or length of feeder could be added between transformer and transmitter to rotate the Smith chart plot to make the load on the output devices symmetrical. That is, one sideband = R +jX and the other = R –jX. At carrier, the load is still resistive but, by making the parallel equivalent of R less that the carrier frequency resistance, the antenna will suck out more power as the modulation frequency increases. This is what we did at Droitwich LF after the 1984 refit.

G3WBQ continues: *The main transmitter was a 250-watt HCD Research Ltd. unit with a 125-watt HCD as reserve **(Figure `14)**. The manufacturer had no suggestions, so going through the circuit diagrams and output device specifications I devised circuitry changes to the transmitters aimed at making the installation more tolerant of reflected power, without risking damage.*

After doing modifications on the standby transmitter and testing it into a dummy load, it was put on the air while I modified the main 250 W unit, luckily with dry January weather while working on the ground at the cabin door.

After an evening meal in Cheltenham I again took the service off the air at 0100 and proceeded to dismantle the matching unit completely. I then rebuilt the match as an auto transformer. Providing no harmonic attenuation, it's a technique which normally comes into its own on Long Wave but it looked like a promising solution for this antenna, also dispensing with the need for a static leak. Each connection, including tap points on the silver-plated coil, was made in the lowest-resistance way possible.

***Figure 17** shows my special purpose-built rechargeable return-loss bridge, crystal tester and precision 100 mW source covering 130 kHz–20 MHz.*

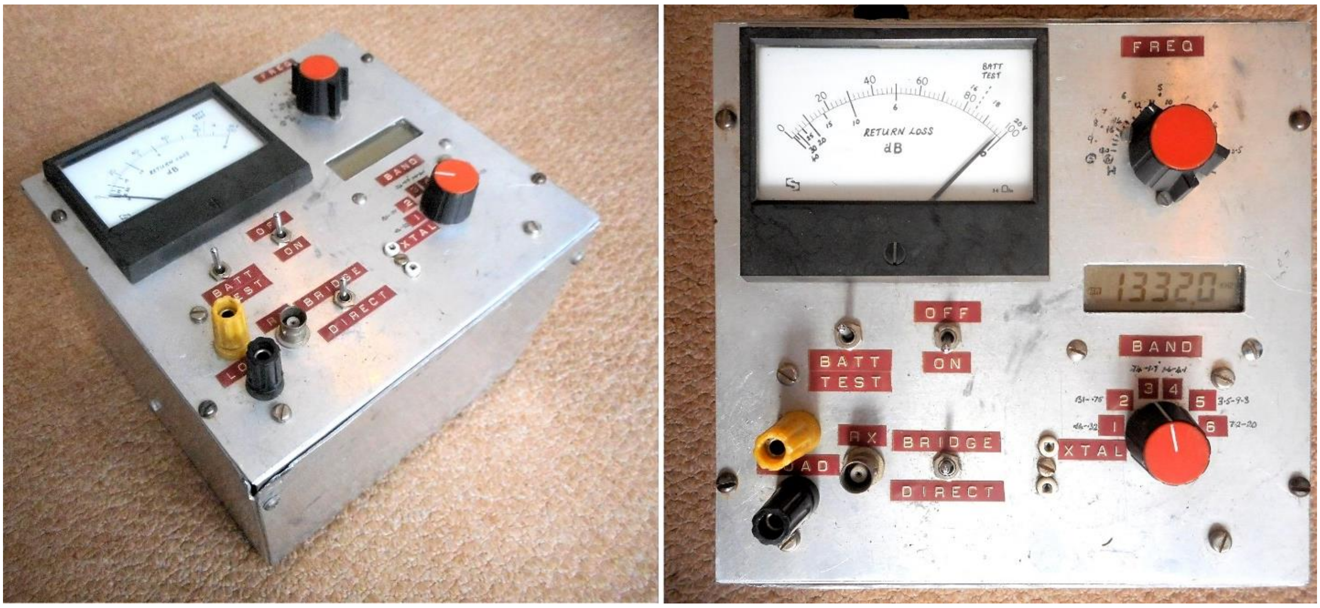


Figure 17. Rechargeable return loss bridge, crystal tester and precision 100 mW source covering 130 kHz–20 MHz

Once I had the new arrangement matched to 50 Ω at better than 30 dB return loss on the 603 kHz carrier frequency, the moment of truth came by sweeping the return loss bridge up and down by 5 and then 10 kHz. What a transformation in bandwidth!

A mast stay could now be banged hard to shake the structure without any flicking of the return loss. The re-powered transmitter with 100% tone modulation at 6 kHz displayed only modest reflected power. Cheltenham Radio 603 now had proper treble with nicely symmetrical sidebands.

603 kHz was shared with Invicta Radio in Kent, 116 km away. After the rebuild Cheltenham, 140 km away, became predominant in Surrey.

Apart from the jump in sound quality, it became obvious that the field strength was almost embarrassingly better. Confident that these measures were a permanent fix for birds, as well as ice, fog, wet soil or dry soil, it was noted during and after the drive back to Surrey, where Invicta Radio from Littlebourne in Kent had been the predominant signal on the channel, Cheltenham Radio was now the stronger.

I had notified all the details of changes to the Radio Authority, as required by the licence. Perhaps recognising that the site had always underperformed, the power was never regulated downwards and so it continued until the station obtained one of those supposedly non-existent VHF/FM frequencies in 1998.

Interestingly, Littlebourne was one of the sites where the IBA used aluminium, rather than copper, radial earth wires. It was unique in the UK for running 200 W by day and 400 W at night, leading to naughty station staff covering over the IBA's light sensor!

More difficulties

Regrettably it wasn't just Cheltenham Radio that had been experiencing difficulties with matching drift, birds and VSWR trips when a low-profile Tee-antenna was used.

With the BBC LR temporary services on these systems from 1989, it was noted that at Derby and Lacock in particular there would be shutdowns caused by VSWR trips to lockout. When the maintenance team visited to effect a reset they were often greeted by the sight of many starlings or other large birds roosting on the antenna. Rough measurements seemed to equate that one starling produces 1 W of indicated reflection by the simple expedient of counting 100 birds and seeing 100 W of backward power!

Luckily, BBC Transmitter Head Office Engineer Eric Reeves (licenced but now SK) had investigated the variable matching phenomenon before in 1987 with the Eddystone B6038 and a replacement VSWR monitoring and executive control PCB of his design had been incorporated in the transmitter that folded back the transmit output power as the VSWR increased, keeping the reflected power to a level that prevented a trip and also any damage to the output transistors.

Another early investigation involved the employment of the Derbyshire Fire and Rescue Service on a BBC-sponsored 'Training Exercise' at Burnaston, spraying water on the wooden central support pole and again it was noted that, when very wet, the system again de-tuned.

Even after these modifications, Lacock and Burnaston continued to suffer trips to lockout and, in 1993, Field Engineer Bob Day from BBC Head Office Transmission Technical Investigations was tasked with finding out why and reporting on same.

Bob noted that the B6038 transmitters were normally set to trip at a reflection coefficient (RC) of 17%; that is a VSWR of 1.4:1. A re-designed VSWR board put the transmitter to half power when the RC reaches 15% and trips the transmitter at 33%. If the RC rises above 15%, but does not reach the trip level and then falls below 12%, the transmitter resumes full-power working.

Even with these changes in place at Burnaston, trips still occurred so further modifications were done to increase the RC trip level to 55%. This was achieved by reducing the transmitter output power in the reduced power condition from half to quarter power. In the quarter-power condition, the transistors will tolerate a much higher RC before the VSWR trip circuit needs to operate. Tests at Burnaston showed that the transmitter could tolerate a RC of 65% to 70% in the quarter-power condition; however, setting the trip to 55% or 60% was recommended to give a safety margin.

The agents responsible for these RC variations were as follows:

Wind-induced variations at Lacock showed that the RC had changed by up to 8% from 2% to 10% during windy weather. This was higher than recorded at Burnaston and was believed to have been caused by movement of the four antenna dropper wires. The tension in these wires was noted to be low. Increasing the tension in these was the solution.

Wet weather had produced variations from a typical dry weather condition of 5% RC to a maximum of 13% RC but had not produced any periods of reduced power. These wet weather variations alone were not considered to be a problem. However in conjunction with birds or thunderstorms some periods of reduced power could result. The solution was to move the dropper wires further away from the centre pole where water on pitch-impregnated poles has caused trips previously.

Bird-induced variations were successfully managed by the revised monitoring board and it was noted that typically the activity of birds was short-term anyway, mostly to a maximum of 10 minutes.

Transmitter spark-gap units could be a source of trouble. Fitted by Eddystone Radio and manufactured by EEV, they contain a small amount of Tritium. Tritium is the only radioactive isotope of hydrogen and is an ionising gas. They were to protect against high induced voltages reaching the transistors in the output stage. Care was be taken to replace these regularly and routinely as, over time, the rated flashover voltage will decrease and the RC could rise.

In the BBC Internal Report, Bob Day **[6]** documented the arrangements of the original antenna build and the recommended modifications and these are illustrated below **(Figure 18)**. His conclusion made for interesting reading in that, after the Lacock modifications, three bird-triggered shutdowns within a six-week monitoring period had been avoided. Bob was helped in this monitoring by then recent introduction of laptop computers with logging software and Programmable Logic Controllers by Mitsubishi that were available at the time.

Water, water everywhere! One other more specific, local difficulty was at Broomy Hill, Hereford in the Welsh Water Expansion Chamber Room where the B6038 was situated. The WOF team arrived one day to find the transmitter off and locked out with a full set of front panel overloads. Normally. such an indication could involve much head-scratching to begin with. In this case it was blindingly obvious as the front panel and areas partly inside were completely soaked-through as the transmitter appeared to be a victim of the expansion chamber operation where the excess water had escaped and sprayed literally all around.

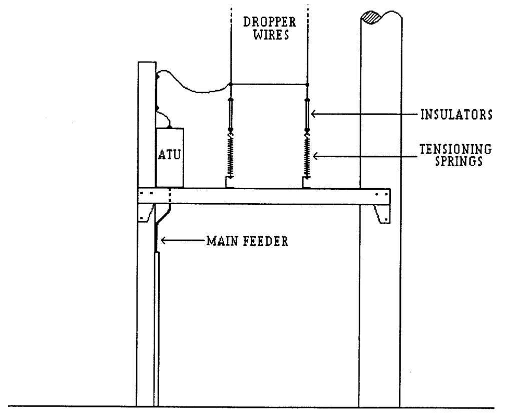


Figure 1. Antenna Feed Point Before Modification.

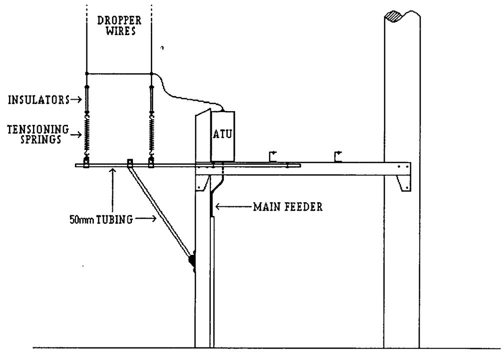


Figure 2. Antenna Feed Point After Modification.

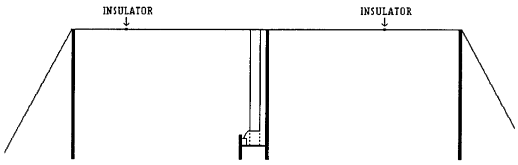


Figure 3. Antenna Outline Before Modification.

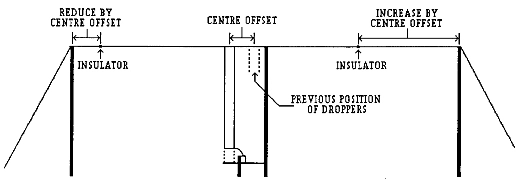


Figure 4. Antenna Outline After Modification.

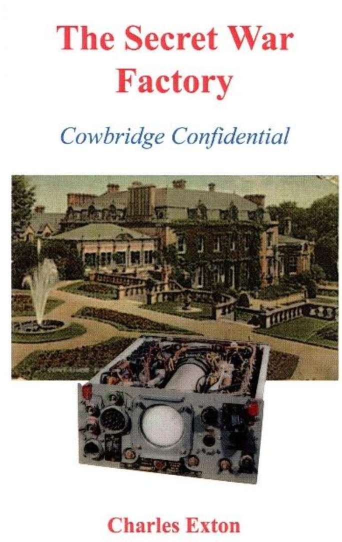
Figure 18. Extract from BBC Internal Report: A53R-1291: Final, Lacock Antenna

Some careful drying out with cloths and a hot air gun did result in normal operation being resumed. The longer term fix was to cover the vulnerable parts of the TX in a plastic sheet. Luckily for the WOF team this service did follow the intended temporary route and the MF lead-in service for Hereford closed after about 18 months.

Continued on page 79 after the book review

Book Review: Charles Exton. *The Secret War Factory*, AuthorHouse UK 2007. ISBN: 978-1-4343-0224-3 (sc). pp 158

Ken Brooks G3XSJ



This gem was spotted some years ago purely by chance during a trip to Malmesbury, site of the wartime Ekco factory. This account was written by someone who experienced events first hand and describes how a converted country house in a tiny Wiltshire town produced secret radio equipment for the war effort. The style of writing gives readers a feel of immediacy of the problems faced setting up a radar factory from scratch, largely using what were effectively conscripted and inexperienced workers. That the equipment they produced was cutting edge and built to the highest standards added to the difficulties.

The author sets the scene in pre-war days and moves on to the early part of the war, outlining all the restrictions that were introduced. Although not the authors' chosen career, he, like most workers was directed to the works where each of the various production functions are colourfully described. Where so many books focus on the boardroom, this one takes the reader behind the scenes and observes life on the factory floor in considerable detail. We get to hear about mundane daily gripes like the irritations of shift patterns and grumbles about the canteen. Where the author really scores is his detailed recollections of the petty rivalries and resentment between the imported, largely urban, labour force and the much more reserved (and suspicious!) rural population. All these sources of friction were sufficiently interesting for the factory to be the subject of Mass Observations' report “War Factory”. The technical side is well catered for and I especially enjoyed reading the painstaking efforts applied to trace the cause of mounting failures at test, finally traced to “painting” resistors. There are a number of excellent books by the distinguished developers of radar and this account from a different perspective has delivered an enjoyable and informative book.

Continued from Page 78

Postscript

It was not the same for the others as Lacock, Swindon and Worcester went on for many years with Lacock closing in January 2018 and Worcester in May 2021 – not bad for a temporary set up! Swindon’s low profile Tee-antenna was closed in June 2003 and the service transferred to the ILR/INR site that was carrying Absolute Radio by then on a shared facility. The BBC output was closed in January 2018.

At Droitwich, Doug’s combined 1052/3 kHz and 1214/5 kHz service antenna lasted until the mid-1980s when more land was acquired to the north of the station site. On this were built by Marconi Antenna Systems two 100-metre masts, correctly orientated to produce a directional null on now 1053 kHz and 1215 kHz to the south west and a peak through Birmingham and out across Leicestershire and into Lincolnshire.

Derby’s low profile antenna Tee lasted until 2003 when it was replaced by a 61-metre lattice mast radiator on the same site and it continues to this day on 1116 kHz; being one of the few remaining BBC LR outlets still on MF. Apparently it percolates through the hills and along the dales in the Peak District where VHF/FM and DAB are topographically severely attenuated!

Next time

We will look at the Radio 1 Main/Reflector and Reserve ATH installations at Brookmans Park in 1978 and see why certain contributors to “Wireless World” became rather ‘hot under the collar’...

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5. http://radiofax.org/radiooddities.html
6. BBC Transmission Technical Investigation (Internal) A53R-1291: Final, Lacock Antenna. Bob Day February 1993.

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