Tricks of the Trade

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Again we continue the examination of the development of the antenna systems primarily used in the UK for MF and LF broadcasting. In the Marconi Antennas sales documentation **[1]** of 1980, G0EYO describes some practical MF antennas and the ways of feeding them.

Ways of feeding the radiator

There are two basic methods of feeding the RF energy to the radiator, whether it is a self-supporting tower or a guyed mast. These are illustrated in Figure 1 (a) and (b). The most common way is to apply the power across the base insulator placed between the bottom of the radiator and the ground (earth) system. This is known as the base-fed configuration. The other method is the shunt-fed system where the base is connected directly to ground and the energy is fed to the radiator part of the way up its height *via* a slanted wire. The system can then be considered as a single-turn, three-sided loop that consists of the slant wire, the bottom section of the radiator and the ground plane. Substantial copper straps connect the bottom of the radiator to the earth side of the unbalanced transmission line to reduce circuit losses.

Both approaches have their advantages and disadvantages; the base-fed method is the more conventional and gives a better vertical radiation pattern when used as a (high-power) anti-fading radiator. However, the radiator is required to be insulated from the ground and the insulator must be strong enough to support both the weight and downward thrust of the mast. An insulator is, of course, required in each leg of a tower. Mast lighting circuits on the radiator must also be isolated from ground and this necessitates the use of a mast lighting transformer. Base-fed systems are more difficult to protect from lightning strikes and the build-up of static electricity, requiring extra mechanical and electrical components, for example: upgraded stay insulators and static-leak chokes.

The shunt-fed method has the advantage of not requiring a base insulator or lighting transformer and gives better protection to the broadcast plant from lightning and static. In theory, it is possible to determine a connection point on the radiator for the slanted-wire so that the resistive component of the radiator input will be equal to the characteristic impedance of the transmission line. The reactive component can be tuned out with a capacitor or inductor connected in series with the slanted wire. In any event, the radiator input impedance of the shunt-fed method will permit the use of much simpler matching circuits. There are disadvantages though: the correct connection point is not always easy to determine theoretically and (stray) radiation from the slanted wire may also be a problem and distort the vertical radiation pattern.

A variation in the shunt-fed arrangement is the folded monopole method, **Figure 1 (c)**. Here, the shunt feed is connected to the top of the radiator. The monopole is usually in a cage around the radiator. **Figure 2** shows a typical folded monopole tower system which is used at higher powers, typically 100 kW to 2 MW and which can be matched directly to the characteristic impedance of the transmission line thus avoiding the expense of matching circuits.

Other methods of feeding the antenna were developed by the BBC for anti-fading radiators and are known loop-fed and doubly-fed systems but first a word of explanation on top-loading radiators is required.

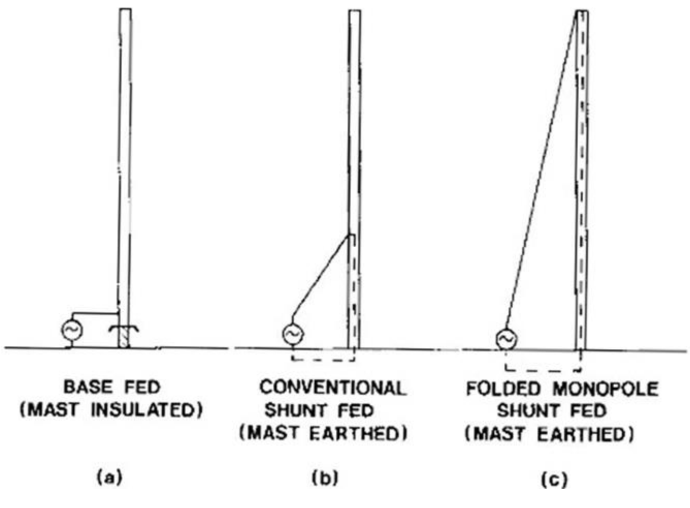

Figure 1. Methods of feeding a monopole antenna

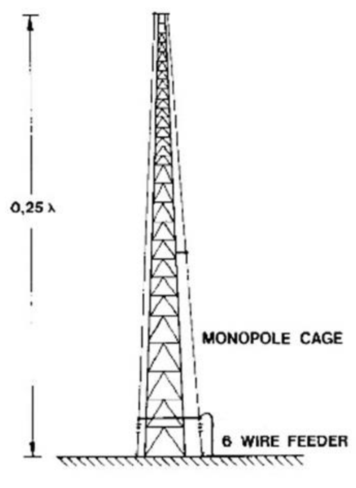

Figure 2. Quarter-wave high-power MF monopole

Top-loading and sectionalised radiators

It will be recalled from a previous *Signal* article **[2]** that the ideal radiator that gave the maximum field strength at ground level and the minimum radiated energy at skywave angles was one of just slightly more than half a wavelength high (190°). As the height increases beyond this, so the high angle lobe caused by the current phase reversal at 180° becomes larger and results in more skywave being produced. 190° radiators are, in practice, large structures at the lower frequencies at MF. One way of achieving the same anti-fading properties of the larger radiator with something physically smaller is by *top-loading.*

There are three methods of achieving top-loading:

- the capacitor-top
- a sectionalised mast
- a combination of both.

In an ordinary radiator the current is effectively zero at the top of the masts simply because there is nowhere for it to flow. Actually, the current is not exactly zero because there is always some capacitance between the top of the radiator and the ground. Thus, by mounting a large capacitance disc, insulated from the mast and series resonated by an inductance connected across the insulator, at the top of a shortened mast there will be a substantial current at the top as shown in **Figure 3**. The top-loaded radiator looks electrically like a taller radiator in as much as the point of maximum current is higher above the ground. Other arrangements where the capacity top is in the form of horizontal spikes and connected to it, have been used.

The capacity-top 'Umbrella'

An alternative is to use a number of wires in the form of an umbrella, a subject that was touched upon in *Signal* **[3] [4]** and is fully explained now. The wires emanate from the top of the radiator and are connected directly to it and are secured *via* insulated stays or rope to ground anchors. Umbrella-loading is particularly valuable with thin, light-weight masts as it requires no heavy top structure, while the base voltage is reduced by the heavy capacitive loading. Theoretically, loading to resonance should increase the radiation resistance of a short mast by a factor of four. However, both the out-of-phase radiation from the umbrella coupled with the screening effect on the mast can seriously reduce the radiation resistance. In practice a compromise is obtainable giving roughly a doubling of the radiation resistance and reducing the base voltage several times. The optimum dimensions of the umbrella are somewhat critical and vary with frequency and mast height.

The sectionalised radiator

The second method of top-loading is the sectionalised radiator. Here, the mast itself is broken by an insulator at about 80% of the height, usually at a point of zero bending moment. The upper portion of the mast then acts as the top capacity and is resonated by an inductance connected across an insulator. Additional loading can be obtained by a small capacity top of adjustable radial rods, often six in number, connected directly to the top of the mast. Full anti-fading characteristics may be obtained with a radiator height of 135° – a significant saving and the arrangement is illustrated in **Figure 4 (a)**.

The loop-fed system

The vertical radiation pattern, VRP, was further improved by a BBC Research Department initiative in the mid-1950s; **Figure 4 (b)** shows the radiator broken by an insulator at a point near to the loop-current maximum and energised at this point by a transmission line contained within the lower portion of the mast. The VRP was controlled by connecting an adjustable reactance between the base of the mast and ground.

The 'Doubly-Fed' radiator

Figure 4 (c) shows the mast fed at the base and the break simultaneously creating the doubly-fed radiator; even more control over the VRP is now obtainable.

Any sectionalised radiator has a number of disadvantages over a conventional 190° anti-fading radiator; the break in the mast imposes additional complexity in the mechanical design. Changing an insulator up the mast can be a very costly and difficult exercise. Of course, insulator failure would be disastrous, necessitating regular inspection and the subsequent service outage which on a 24/7 service is not what the programme makers wish for.

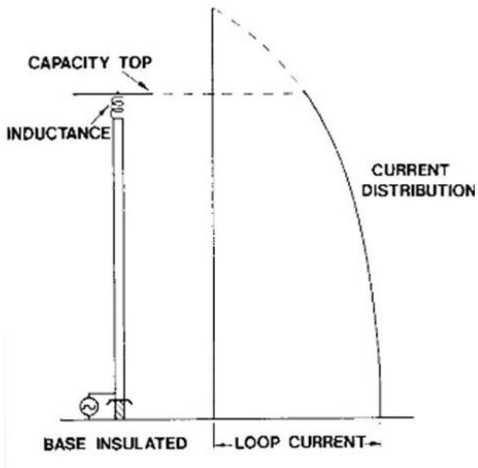

Figure 3. Current distribution on a top-loaded radiator

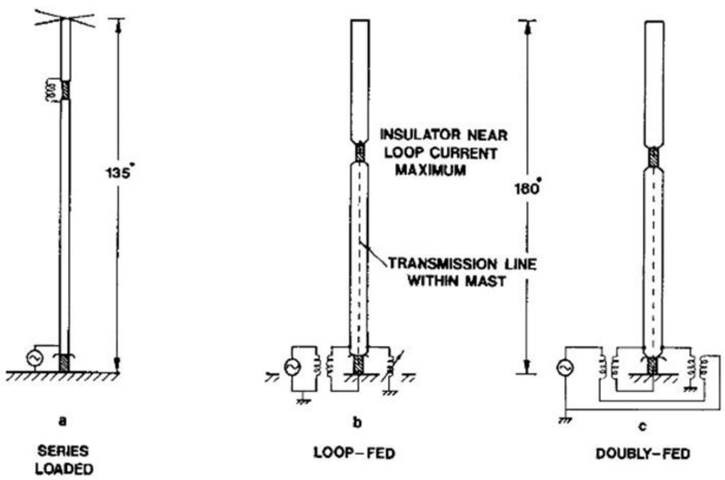

Figure 4. Alternative methods for energising sectionalised radiators for anti-fading radiation patterns

The resulting reduction in height (from 190° to, say, 135° or more) is limited by the reductions in the driving point impedance and particularly the radiation resistance. An economic point is reached where the saving in capital cost of the doubly-fed mast over a simpler version is equal to the capital cost of supplying the additional RF input power to overcome the losses.

Daventry and the loop-fed system

The 'classic' version of the loop-fed system was used at Daventry for the post-war 647 kHz Third Programme service. During the Dodford mast service life from 1951 until 1978, changes were made, notably the shorting out of the mast break insulator for a good few years and then its alleged re-instatement. There may have been Cold-War factors at play as, during certain of the hours of darkness, the antenna was used for the BBC European Service as essentially a sky wave generator, a task for which it was not originally intended!

"Well, there was this sort of rushing sound behind us as we went to lunch"

Brookmans Park had a mast-break and top-loading was incorporated on the 500-foot Mast "F" 908 kHz radiator at some point after the war but, during scheduled stay maintenance in the Spring of 1956, it fell down whilst in the care of the contractors and was replaced by a 'previously-enjoyed' 500-foot mast recovered from the closed WWII Ottringham LF/MF station. Subsequently, no mast-break was incorporated and the F1 mast is still in service today.

LF developments at Droitwich

Mention was made in the last ToTT **[5]** of the National LF service which began at Droitwich in October 1934 or, more geographically correct, Wychbold station, Wychbold being some 3 miles due north of Droitwich.

The then new 150 kW Long Wave 200 kHz service had been transferred from Daventry and was radiated from a Tee antenna. Much work had been conducted by BBC Research Department as to the best antenna for this service. The ideal antenna was one which did not exhibit an appreciable change of resistance or reactance over the range of frequencies represented by the carrier ±7 kHz.

BBC Research Department calculated various options and tests were conducted at the BBC Receiving Station at Tatsfield in Kent using one-tenth and one-seventh scaled-down models with 70-foot masts having insulated stays and bases and the wavelengths scaled up to 150 m (3 MHz) and 200 m (1.5 MHz), respectively. For actual transmissions, it had been decided to use two 700-foot base and stay insulated masts situated 600 feet apart and a single-wire Tee antenna, the reasons for the choice being simplicity and mechanical strength, a satisfactory frequency characteristic (but see later), lower antenna current for a given power and a slightly higher radiation efficiency.

The down-lead consisted of 630 feet of 19/0.64-inch silicon-bronze cable and the horizontal portion of 550 feet of 19/0.128-inch silicon-bronze cable.

It had been ascertained on the tests that there was serious attenuation of the modulated frequencies above 2 kHz if the antenna was connected, albeit with some simple matching, directly to the output circuits of the transmitter. So a network (**Figure 5**) was designed to achieve a sensible bandwidth of 14 kHz around 200 kHz. **Figure 6** shows part of the Rs/Xs curve of the actual antenna; the varying impedances are visible as is the lack of symmetry.

The provisos were as follows: provide correct impedance matching for transmitter, the 550 Ω balanced feeder and Tee antenna, suppress any harmonics from the transmitter to the satisfaction of the Radio Regulations and, most importantly, reduce the attenuation of the sideband response to maintain a flat audio response by correcting for the considerable lack of symmetry around the carrier frequency.

The final arrangement that was arrived at (**Figure 5**) shows both the actual components used and a dissected diagram. The transducer networks were all unbalanced π-sections in series, with a parallel/series LC network prior to the ATU within which were three inductors to do the first transformation.

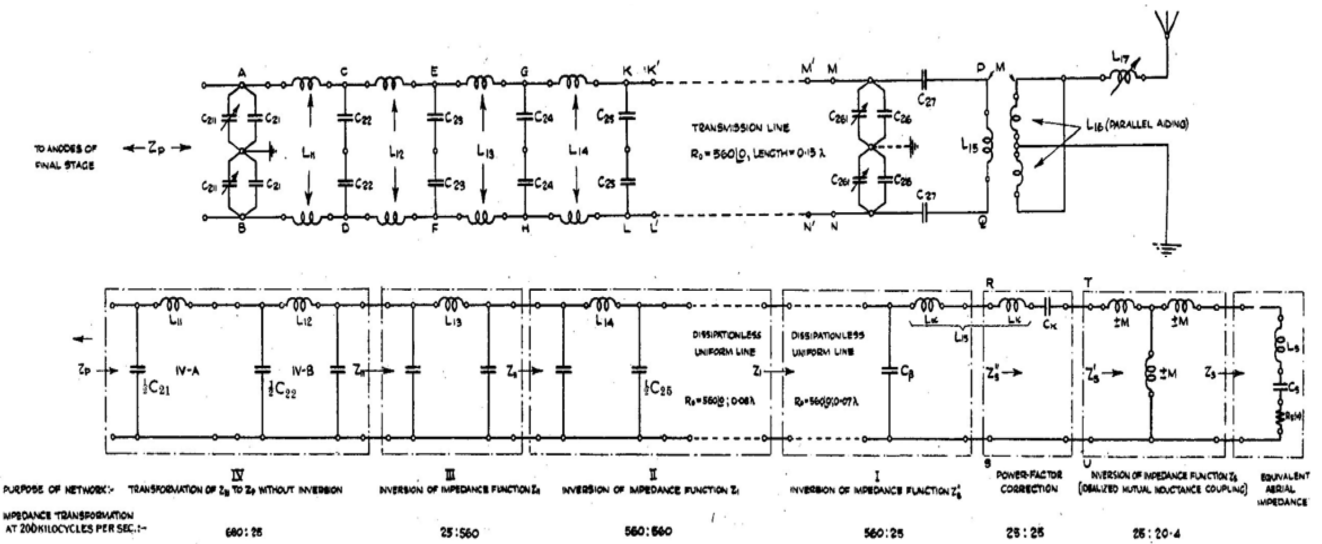

Figure 5. Actual (above) and dissected (below) diagram of antenna and coupling circuits

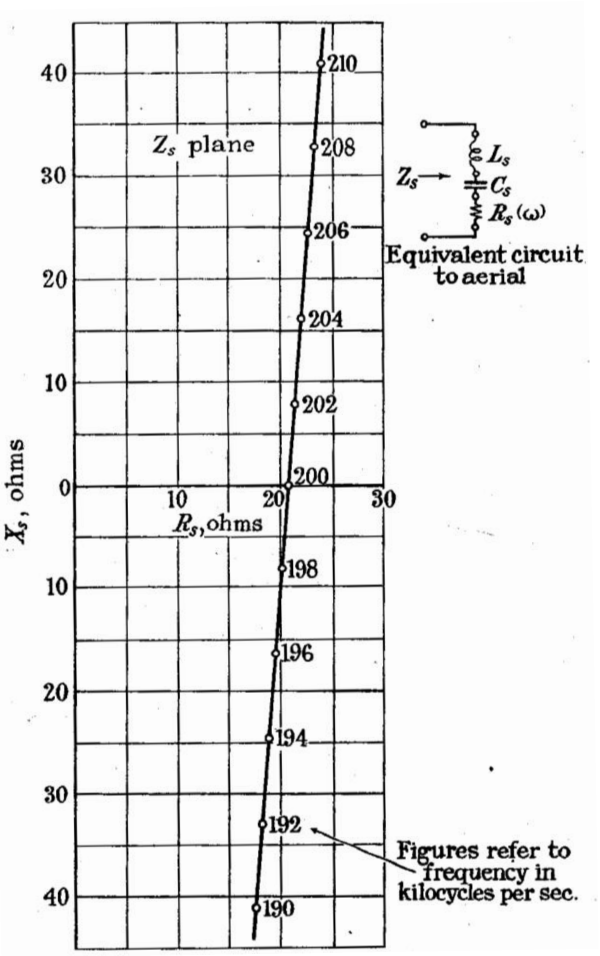

Figure 6. Impedance of antenna circuit of Droitwich national transmitter

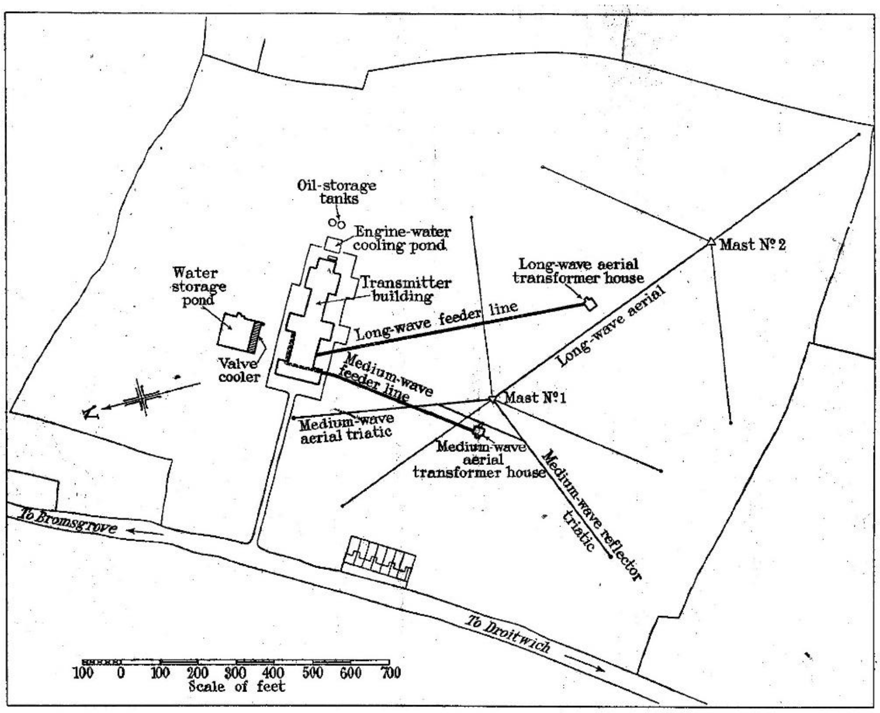

Figure 7. Layout of the Droitwich transmitter site in 1935

MF Developments at Droitwich

With the planned transfer of the 1013 kHz Midland Regional MF service from Daventry to Droitwich, arrangements were made for an MF antenna at Droitwich. The only masts on site were the 2 x 700-foot masts supporting the LF Tee. **Figure 7** shows the site plan by 1935. The MF antenna was a λ/2 type and consisted of a single vertical wire 450 feet long supported by a triatic (essentially a support wire broken up by egg insulators attached to the top of the mast and out to a ground anchor) slung from the top of the more northerly mast. A driven reflector to increase radiation in the northerly direction was supported by a separate triatic.

This was the first use on any BBC Regional station of a directional antenna. Mention ought to made of the earth system as, reviewing the original specification, it now appears to be somewhat lacking. It was composed of 72 off 16 SWG copper wires buried approximately 9 inches below the surface. The method of laying the earth wires was by ploughing a series of furrows radiating from the antenna tuning house, inserting the wire and turning the turves back. Each wire extended to a maximum of 700 feet from the hut or to the extremity of the available field.

For the MF service, a copper strip extended some 300 feet in either direction from the associated hut across the radial wires to which it was connected. A number of additional buried wires extending in both directions were also connected to the strip to reduce the resistance of the earth connection. An earth system of this type was reported to have an extremely low resistance with the added advantage of being relatively simple to install and not particularly expensive.

In the next ToTT Chris G0EYO will be describing the earth systems as employed by the 1980s and a typical 50 kW set-up for both the mast radiator and the ATU. Noted deficiencies of earth systems in high power VLF systems will also be documented.

References

1. C Pettitt. MF Broadcast Antenna Systems R5100. Marconi Communications Systems Limited 1980, pp 3–4.
2. D Porter G4OYX and C Pettitt G0EYO. Tricks of the Trade. *Signal* 2018, **47** (May), 31–33.
3. A Beech G1BXG. The History of 648 kHz in the UK. *Signal* 2018, **46** (February), 16–18.
4. D Porter G4OYX and C Pettitt G0EYO. Tricks of the Trade. *Signal* 2018, **46** (February), 26–29.
5. D Porter G4OYX and C Pettitt G0EYO. Tricks of the Trade. *Signal* 2018, **48** (August), 33-35.

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