Tricks of the Trade

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We continue the examination of the development of the antenna systems primarily used in the UK for MF and LF broadcasting.

RF current distributions in monopoles

In Issue 47 of *Signal* **[1]**, we considered some of the electrical parameters of masts and, in particular, the current flows and distributions on masts having a uniform cross section when used in broadcast applications. In a sales document for Marconi Antenna Systems **[2]** G0EYO expanded the discussion for masts of different shapes and construction.

All the introductory information presented in **[1]**, related to theoretical antennas which have a sinusoidal current distribution and where the ground is a perfectly conducting medium. Terminal resistance and reactance are modified by mast design, *i.e.* diameter, column shape, *etc*. Both the R and X terms are modified by shunt and stray capacitance at the base of the mast. The practical performance of the antenna depends on the effects of mast guys, the capacitance across guy and base insulators, the losses in the matching circuits and the earthing system. Also, because the propagation velocity along a monopole is less than the free space propagation velocity, the resulting increased electrical length must be taken into account. The velocity of propagation along a mast used as a monopole depends on its diameter, its lattice configuration and the way it is fed.

Figure 1 shows several different structure shapes and the typical current distribution on each **[2]**. If the mast were infinitely thin, the current distribution would indeed be very nearly sinusoidal. When the mast has a uniform cross section, the current distribution is still nearly sinusoidal. It starts to deviate noticeably from sinusoidal behaviour when a self-supporting tower is used as the radiator. In general, the current tends to increase with tower cross section, particularly near the base and together with the greater shunt capacitance this has the effect of increasing the electrical height. As the monopole reaches a half-wavelength, the base impedance becomes critical and the effects of the radiated energy must be taken into account to avoid errors in calculating the current distribution.

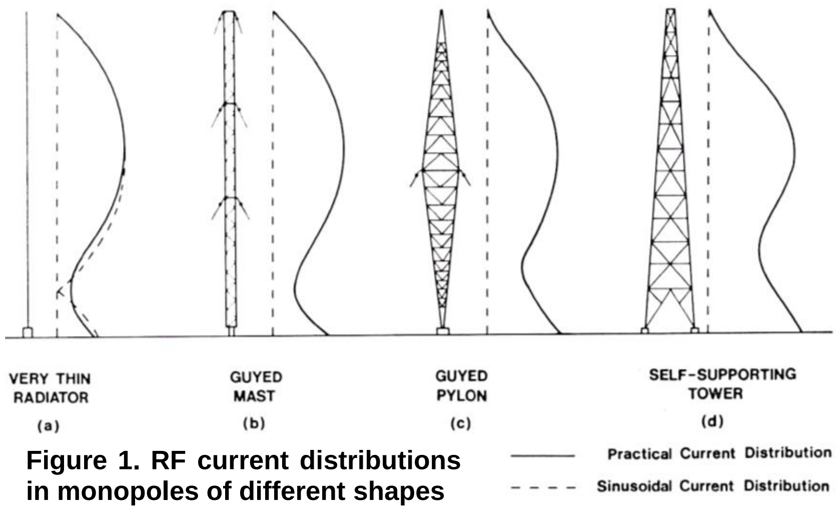

Figure 1. RF current distributions in monopoles of different shapes

MF and LF Propagation

MF and LF broadcast transmissions propagate *via* groundwave and skywave. The groundwave component of field strength is constant with time of day and, thus, is present day and night. It depends on:

a) The vertical radiation pattern, *i.e*. the more power that is radiated along the ground at 0° elevation the better.
b) The conductivity of the ground over the signal path; sea paths support groundwave propagation considerably better than dry ground.
c) The frequency; low frequencies propagate better than high frequencies.

The skywave component is the field radiated at angles of elevation and occurs when power is reflected by the ionosphere and is returned to the earth. It is present only during the hours of darkness. During the day, the lower layers of the ionosphere which are activated by the sun absorb MF. The skywave reaches a much longer distance than the groundwave. However, depending on the electrical height of the radiator and the groundwave propagation path, the skywave may return to earth a signal of similar magnitude to that of the groundwave at some 50–500 km from the antenna. Because the ionospheric conditions are continually changing, the magnitude and phase of the skywave changes with respect to the groundwave and severe fading can occur in receivers within the ‘night fading zone’. It is to extend this zone beyond the limit of a receivable groundwave that ‘anti-fading’ radiators (190°–200°) are used.

The normal minimum field strengths required for broadcast reception which are expected to overcome man-made noise are shown in **Table 1 [1]**.

There is no point in having an anti-fading antenna if the transmitter power is less than 100 kW as the fading zone is beyond the range of the useful groundwave service area with antennas operating on the lower MF channels. Also, and this is crucial, the anti-fading antenna requires a very large structure which is an expensive proposition considering the heights of the radiator (**Table 2**).

MF	Northern Hemisphere	Equatorial Zone	Southern Hemisphere
Daytime groundwave service	63	73	66
Night groundwave service			
–Rural areas	71	81	74
–Urban areas	77	87	80
Low power channels	88	88	88

Table 1. Nominal usable field strengths dBµV/m

Frequency	90°	190°
500 kHz	150 m	320 m
750 kHz	100 m	230 m
1000 kHz	75 m	150 m
1250 kHz	60 m	130 m
1500 kHz	50 m	105 m

Table 2. Heights of quarter wave (90°) and anti-fading (190°) radiators at MF

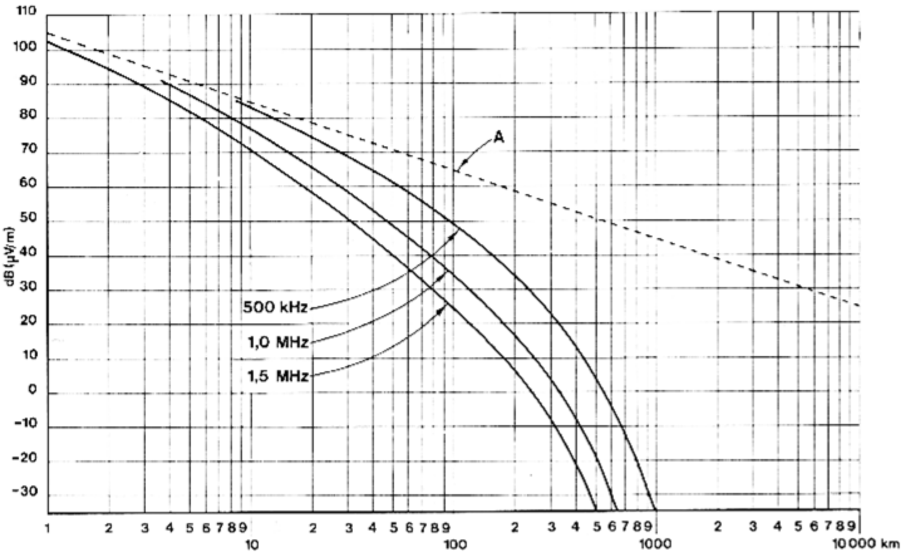

Figure 2. Groundwave field strength in dBµV/m at 500, 1000 and 1500 kHz for a 1 kW transmitter over a good earth. The line marked A is the 'inverse distance curve'

Figure 2 [2] shows the groundwave field strength in dBµV/m at 500, 1000 and 1500 kHz for a 1 kW transmitter over a good earth. The graph assumes no antenna gain. To determine the groundwave field strengths for antennas of differing electrical heights and transmitter powers, add the antenna gain in dBi and the power gain (dB relative to 1 kW) to the field strength (in dBµV/m) indicated.

Practical examples of the above theory are neatly illustrated by the arrangements in use for many years at Radio Luxembourg on 1439 kHz, 208 m where, for the daytime German service, a simple two-mast array was used to exploit the maximum groundwave but, for the UK and Ireland (English) service during the hours of darkness, a three-mast, arrow-head-shaped directional system was employed to generate the maximum skywave and little groundwave. Even with that antenna and 600 kW output, or following an increase in output to 1200 kW later in the 1970s, mid-summer reception at the start of the service at 1800 GMT into the UK could be challenging. Deutschlandfunk from Neumünster on 1268 kHz fared a little better and took advantage of the direct sea path at least to South-East England, East Anglia and the Midlands for the English service. No doubt the same strategy was employed at Aspidistra for the wartime services into Germany.

Pre-war UK developments

By 1930, the second of the regional transmitting stations was nearing completion on a 31-acre site at Moorside Edge, five miles to the east of Huddersfield at a height of 1117 feet ASL. The site was chosen after extensive tests had been made with a mobile transmitter to find a location where suitable land was available and where intervening hills (the Pennines) would not screen the large areas of Lancashire and Yorkshire that it was planned to serve. The regional service was assigned the lowest frequency available to the BBC under the 1929 Prague Plan; 626 kHz, 479 m. Since the effective range on MF is greater the longer the wavelength, this channel was chosen to serve what was to become the North Region.

While the design of the buildings and transmitters followed closely that of Brookman's Park **[1]**, advantage was taken of the experimental work that had been started in 1928 on the design of antennas. This work had shown that a λ/2 antenna was considerably better than the 200-foot Tee antennas at Brookman's Park where, of course, there had been the aeronautical restrictions placed by the Air Ministry.

For Moorside Edge, three 500-foot stayed steel lattice masts were erected in an arrow-head formation with a multi-wire Tee antenna between masts 2 and 3 for the 626 kHz service and a vertical wire antenna, *i.e.* effectively the same construction as a Tee but without the additional horizontal top-loading, between masts 1 and 2 for the National service on 995 kHz, 301 m. Services began in 1931.

The extremes of weather on this bleak and wind-swept, exposed site must have been familiar to the designers from the start, as provision was made for the station 220 VDC supply to be passed through the antenna wires out of programme time to prevent icing of the antennas.

Unusual arrangements?

Considering these historical arrangements, one wonders why the vertical wire antenna was used; why not just base-feed the single mast No. 1 and save all the disadvantages of a wire antenna? G4OYX recalls some BBC training information where the pros and cons of various MF/LF antennas were detailed and one observation was "Wire antennas fall down in winter".

In later years, more work was done on the antennas at Moorside Edge and these will be detailed when we discuss directional systems.

The third regional station to be built was to serve Glasgow and Edinburgh and the densely populated Forth-Clyde belt. It was hoped, and later established, that it would also cover Dundee and much of the rural Scottish Lowlands. The selected site was called Westerglen and was about 2½ miles to the south-west of Falkirk.

It is interesting to note that, as the site was not really near Falkirk or any local villages, the name of a *nearby* farm was used for the location, rather than the name of the *nearest* farm. One can imagine Lord Reith calling the site on the telephone to hear them say "Hello, Scottish Regional, Rottenstocks".

Two 500-foot stayed, steel lattice masts were erected to support two 'umbrella' antennas; one mast/umbrella was for the 797 kHz, 376 m regional transmitter and a second on the other mast for the national transmitter on 1040 kHz, 288 m. Services began in 1932.

The Umbrella antenna

The umbrella antenna was a new technical departure and consisted of three radiating wires suspended by a short length of steel wire rope attached to but insulated from the top of the mast. The wires were equidistant between the normal insulated mast stays and pulled out to a distance of 150 feet, this distance being greater than the outermost stay, secured to a ground anchor and then back to nearly the main mast where the ends were joined and from where the termination to the Antenna Tuning Unit was made. The mast was base-insulated as usual for the time. The RF arrangement and consequent current/voltage distribution here would not be dissimilar to that of the self-supporting tower as illustrated in (d) of **Figure 1**.

The fourth station clone

A fourth station was planned to serve the populous areas of South Wales, Bristol and as much of the West of England as possible. In order to take the advantage of the low-attenuation path over the sea to the South Wales coastal towns, it was decided to build the station on the southern shores of the Bristol Channel, not too far from Bristol. The site selected was at Washford Cross, some three miles inland from the port of Watchet, Somerset. Two 500-foot stayed, steel lattice masts were erected exactly as at Westerglen, from which most, if not all, the site's design had been copied; two umbrella antennas were built, one around each mast. The West Regional service started in May 1933 on 968 kHz, 310 m and the National service soon after on 1148 kHz, 261 m. The latter channel was already in use so it was synchronised with Brookman's Park by tuning fork drives linked by audio correction down General Post Office lines.

The Lucerne Plan

On 15th January 1934, new channels were implemented after the international conference in Lucerne a year or so earlier; a year or so later on 17th February 1935 there were more BBC-only changes resulting in Brookmans Park being on 877 kHz, 342 m and 1149 kHz, 261 m; Moorside Edge on 668 kHz, 449 m and 1149 kHz, 261 m; Westerglen on 767 kHz, 391 m and 1149 kHz, 261 m with Washford on 804 kHz, 373 m and 1149 kHz, 261 m.

In July 1937, as Droitwich National was now on Long Wave, Washford lost its National service and became a dual Regional site with separate West and Welsh services.

With Start Point coming on in June 1939, Washford became just single frequency Welsh Regional. During the War it would again become a dual frequency site but afterwards, it again reverted to single service (Welsh Home Service) until the start of Radio 1 in September 1967.

G4OYX worked at Washford in 1974 and then at Westerglen in 1975. Upon starting at Westerglen, the Assistant Engineer-in-Charge, David Dove, greeted the author with the words, "I see you have worked at Washford; well, this place is just the same except for the RCA 50E 50 kW transmitter that's carrying the Radio 1, so there's no need for a tour".

At some point between the start of both Wasford and Westerglen in the 1930s and the 1960s, a four-wire drop-Tee antenna and Antenna Tuning Hut were added between both masts and used for 809 kHz at Westerglen and 881 kHz at Washford. Quite when this happened is unknown, but a good guess would be 1949 when both sites were upgraded to 100 kW with the addition of a ST&C CM10 transmitter. The presence of an unused umbrella antenna would have been useful for reserve service if required. Even now Washford has the original 1933 masts, both umbrellas and the Tee. Westerglen has been altered significantly having gained Long Wave in 1978.

References

1. D Porter G4OYX and C Pettitt G0EYO. Tricks of the Trade. *Signal* 2018, **47** (May), 31–33.

2. C Pettitt. Antennas for Broadcasting, R5100 Marconi Antenna Systems Ltd, 1980.

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