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.

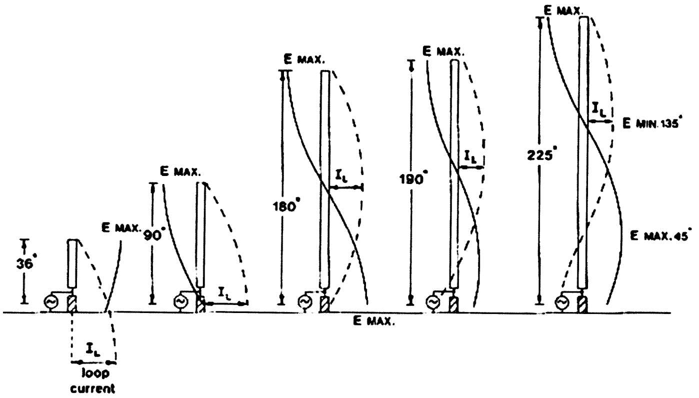

Figure 1. Theoretical current and voltage distribution for monopoles for 0.1 λ (36°), 0.25 λ (90°), 0.5 λ (180°), 0.53 λ (190°) and 0.625 λ (225°).

It may be prudent to start with some antenna theory which Chris G0EYO neatly described in his 1981 article for the International Broadcast Engineer **[1]**. He has updated his original article and begins by outlining the accountant's aspect as follows:

The cost effectiveness of a broadcast system can be measured (a) by its ability to convert input power to radiated power and (b) by choosing the right antenna to give the coverage required. The antenna is a major part of any broadcast system both in terms of its capital cost and its impact on system efficiency. How strange then that it appears to be such a neglected part of the broadcast system. Its theory gets no more than cursory attention in our universities and colleges and its practice is almost never taught. Ultimately, it is the interface between the programmes and the signals the broadcasters make and generate and the public who are meant to receive them.

The supply of broadcast antenna products and services involves a number of engineering disciplines:

- Electromagnetic.
- Mechanical: as all antennas are mechanical structures.
- Structural: as antennas are usually supported above ground level.
- Civil: with foundation design and preparation.

And to these can be added the discipline of wave propagation and coverage predictions.

Such a multi-disciplined subject demands a large investment in trained personnel and facilities resulting in relatively few companies supplying the majority of the World's antenna systems. In fact, there are very many more manufacturers of studio and transmitter equipment than there are antenna suppliers.

MF broadcast antennas

Even after the introduction of VHF/FM broadcasting, MF was guaranteed a place in the overall scheme of things by the arrival of the cheap battery-operated transistor radio making it a reliable means of mass communication at a low capital cost.

The basis of all MF antennas is a vertical radiator called a monopole standing on and insulated from the ground with the transmitter output connected between the base of the monopole and ground. The physical height of the monopole varies typically between 0.1–0.6 λ.

The horizontal (azimuth) radiation pattern is omnidirectional and is unaffected by the height of the monopole. The radiated field (vertical pattern) is determined by the current distribution in the antenna and is, therefore, affected by the height of the monopole (**Figures 1 and 2**).

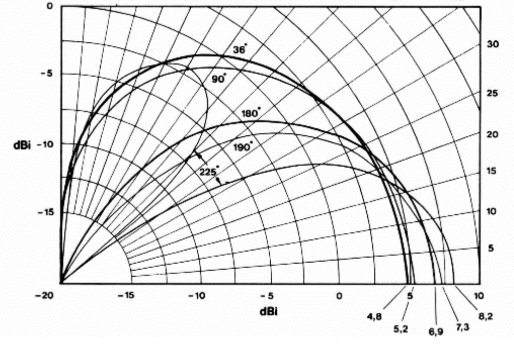

Figure 2. Theoretical vertical radiation patterns for the monopoles shown in Figure 1.

It will be seen that there is very little difference between the short 36° monopole and the λ/4, 90° monopole. This does not mean that they both radiate the same amount of power for a given input. This is because for the power to be radiated, a radiating or loop-current must flow through a resistance. This is known as the loop-radiation resistance and is measured were the loop current is maximum, *i.e*. 90° from the top of the monopole. The amount of power radiated is proportional to the square of the loop-current and the radiation resistance, *i.e*.

$$P = I^2R_L$$

Where P equals the radiated power, I equals the loop current and R_L equals the radiation resistance at the loop current point. **Figure 3** shows the relationship between monopole height and loop radiation resistance. It can be seen that the loop radiation resistance is very low for a 36° monopole and peaks for a monopole just less than 180° high. Therefore, for a given antenna current, the short monopole will radiate less total power than the larger monopole.

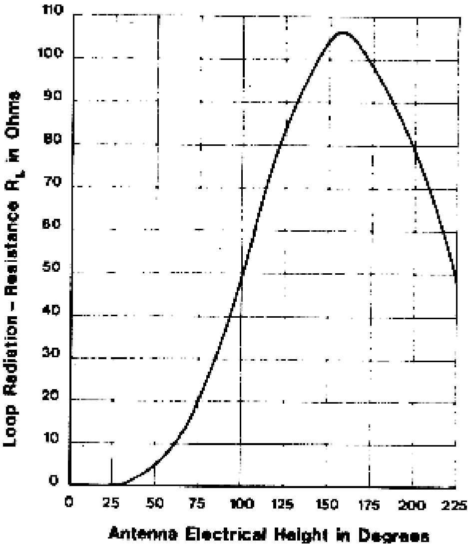

Figure 3. Relationship between monopole height and loop radiation resistance

The efficiency of the overall antenna system depends on the matching circuit transferring all of the available transmitter power to the antenna. The monopole base impedance (Z) is a complex term containing resistance and reactance. It is expressed as

$$Z = (Re + Rr) \pm jXr$$

where Rr equals the radiation resistance which is proportional to the loop radiation resistance, Re equals the earth and current loss resistance and Xr equals the reactance. This is also known as Driving Point Impedance, DPZ.

Figure 4 shows a typical relationship between antenna height, radiation resistance and reactance. For monopoles of less than λ/4 the reactance is negative *i.e*. capacitive. As the height increases, the capacitive reactance decreases until just below quarter-wave when it drops to zero. The graph for resistance shows it increasing with height until a second maximum is reached at the second resonance when the reactance is again zero at 150°.

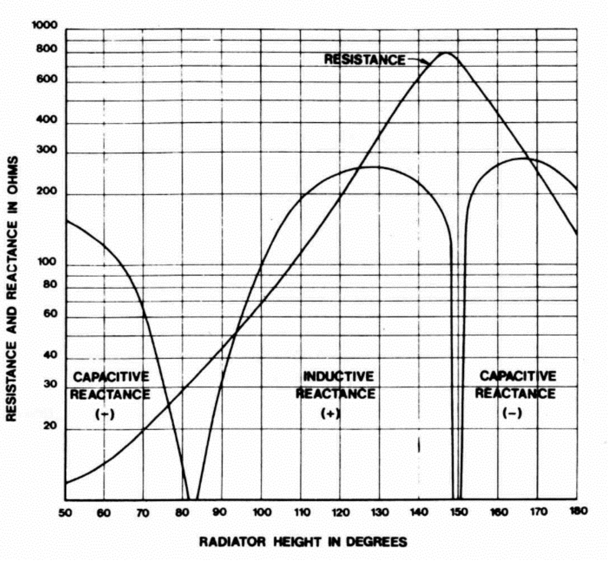

Figure 4. Theoretical monopole base impedance

The ratio of reactance to resistance determines the Q and, therefore, the bandwidth of the antenna. In general, monopoles which are electrically short have high reactance and require components in the antenna matching unit to tune them out, resulting in an overall system with high Q and narrow bandwidth.

Another aspect of base impedance which is of interest to the System Engineer is the variation over either side of the carrier frequency. As the base impedance varies with frequency, so a mismatch occurs between it and the characteristic impedance of the transmission line. At MF this is not always a problem but at LF then it is significant and the design of the AMU will incorporate components to correct this variation.

On MF it can be significant if short antennas are employed and poor bandwidth can result when there is a very high step-up ratio between the resistance of the antenna and the impedance of the feeder or when the matching circuits contain acceptor and rejector circuits whose dynamic component values change with frequency.

The reflected voltages caused by mismatches over the sidebands set up standing waves on the transmission line. Thus, the limits of bandwidth are in effect determined by the maximum VSWR allowed on the transmitter. The bandwidth of a short monopole may be ±2 kHz with a VSWR of 1.4:1 and 2:1 at ±4 kHz. The RF bandwidth for typical AM is 9–11 kHz. However the power levels in the sidebands are usually much lower than that of the carrier and, therefore, in terms of reflected power, the levels are low.

That said, the high-Q antenna is best to be avoided if at all possible as besides the bandwidth limitations there are the seasonal variations of ice, fog, antenna field earth system drying out/flooding changes.

The start in the UK

Experimental sound broadcasting began in the British Isles as far back as 1919 by the Marconi Company and other large electrical engineering manufacturers. The British Broadcasting Company came into being in 1922 and took over the three 1½ kilowatt transmitters: 2LO in

London, 5IT in Birmingham and 2ZY in Manchester. Regular daily broadcasting on MW from these stations commenced during November 1922. Expansion continued and, by 1925, over twenty MW stations were in operation. These were all low-power local services and situated in large towns and cities.

The first LW transmitter, 5XX, opened at Chelmsford in July 1924 and was transferred to Daventry a year later to carry an alternative programme that was the forerunner of The National Programme. Coverage from this 25 kW service extended to 150 miles or so on crystal set receivers.

On 1st January 1927 the British Broadcasting Company was dissolved and the British Broadcasting Corporation was constituted under a Royal Charter. The Regional Scheme was executed with the low power stations being replaced by new studio centres and high-power transmitters, initially serving five regions of the British Isles. Daventry 5GB (1927) was the prototype design of the 50 kW MW transmitter.

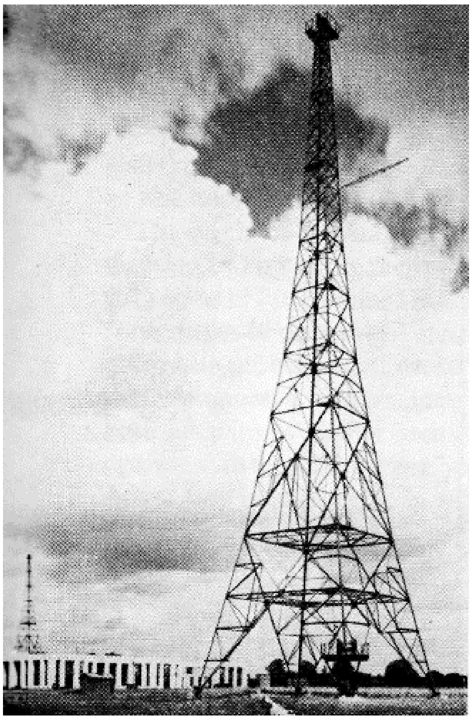

Figure 5. Antenna towers at Brookmans Park 1929

The antennas for all the original low-power stations appear to be simple Tee types, suspended between two masts or even wooden poles. Daventry 5XX LF had a wire Tee antenna between a pair of 500-foot masts.

The Regional Scheme

Brookmans Park, 20 miles north of London, was the first in the Regional Scheme in 1929 but the operating of two (up to) 60 kW MF services from the same site was uncharted territory; from the north side of the building ran the Regional Service with the same plant on the south side, for the National Service. There was no direct connection between the two as concerns were raised about the possibilities of cross-modulation. In the event, this was not a problem and a common RF earth system could be used.

Four 200-foot fully base-insulated, self-supporting steel lattice towers (**Figure 5**) were used to support two Tee antennas. Each Tee antenna had a top hamper of four wires about 450 feet long and originally with a two-wire drop to the ATU termination. After the War, they were re-engineered to a four-wire drop. Given the geometry of the systems, it is fair to assume that the maximum height of the central vertical multi-wire drop was about 150 feet, at best.

The original 1928/9 planning restrictions with Government aeronautical limitations on mast/tower height of 200 feet were relaxed in 1938 and a 500-foot base-insulated mast (Mast F) and ATU were erected in an adjacent field for the 877 kHz service. The North Tee was then a reserve antenna. It was not used again in permanent peacetime broadcast service until November 23rd 1978. It was noted in wartime documentation that the most if not all the towers were used throughout the hostilities to radiate various channels including even 200 kHz LF transmissions.

The South Tee was used on 1149 kHz until 1950 and then on 1214 kHz. In order to produce an enhanced field strength into London a 350-foot Wincharger™ mast and ATU was added post-war on the south side to act as a passive reflector to the 1214 kHz Light Programme service. The Home Service was then on 908 kHz into the 500-foot F-mast.

In 1973, 1457 kHz was added at 20 kW and the South Tee/ Wincharger ATU circuits were altered to combine the 1214 kHz and the 1457 kHz services but the latter was severely attenuated towards the Midlands as the Radio Birmingham service from Sutton Coldfield shared the same frequency of 1457 kHz.

RF Fire!

The variation of loop radiation resistance over the MF band has been explained above. This variation was to prove challenging at Brookmans Park after the 1978 changes as a new, fourth, frequency was added, namely 1089 kHz at 150 kW. The North Tee Antenna Tuning House (ATH) was re-engineered and the circuits had to cope with the fact that, at this frequency, the antenna behaves almost as a perfect half-wave, having a high loop resistance, *etc*.

G4OYX and many of his colleagues saw the three new MCSL transmitters tripping on VSWR due to problems in the ATU. The only way to find the cause was for some volunteer to be sitting (for what could be hours at a time) in the ATH observing the circuits through the viewing windows. The flashover area was seen eventually and essentially it was not easy to modify! What was easier was to modify the Tee antenna itself; so it was lowered on a summer overnight outage to have less top-loading in use and the wires were broken up with additional end insulators. This moved the resonance point away from 1089 kHz. This effected a permanent cure. Around 1980, a mini-Tee antenna on 150-foot poles was erected to the north of the North Tee to act as a reflector southwards for the 1089 kHz service.

Lessons learned

The next station was Moorside Edge in Yorkshire and here the experiences at Brookmans Park were employed into an alternative arrangement.

These and further developments will be explained next time.In addition, the post-1985 problems with antenna bandwidth, modern transmitters and audio processing will be detailed.

Reference

1. C Pettitt. Antennas for Broadcasting, *The International Broadcast Engineer* 1981, **12** (January), No. 175.