Tricks of the Trade

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Readers will recall that we have been looking at the six various options for MF Directional Antennas (DA) detailed in a recent ToTT **[1]**. In the current issue, we re-visit the reasons for the Options 4, 5 and 6 in UK use. The author is fortunate in having a copy of an article written by Pat Hawker G3VA (SK) for the Marconi Co. publication "Communication and Broadcasting" **[2]**. At the time, G3VA was an employee of the IBA in their Engineering Information Department. Reference 2 was, in effect, a trade publicity and sales vehicle for MWT/MCSL outlining their latest products and projects. This has proved most useful in the preparation of this piece. It describes how the Independent Broadcasting Authority (IBA) and the BBC had to employ highly directional antennas when the requirement for Independent Local Radio (ILR) and BBC services on MF had to be fulfilled. This was after the publication of the Government White Paper in 1971 detailing "An Alternative Service of Broadcasting".

Prior to 1973

Since the war and prior to 1973, the BBC had used the MF band for all the AM Radio 4 (*aka* Home) services; Northern Ireland Radio 4 (R4) used 1340 kHz, Wales R4 881 kHz and Scotland R4 809 kHz for country-wide coverage. England was regionalised with 692 kHz for the North, 908 kHz for London and the South East, 1052 kHz for the South West, 1088 kHz for The Midlands and East Anglia, 1151 kHz for the North East and Cumbria and 1457 kHz for Central Southern England and Bristol. Short bulletins of regional news, 'opt-outs' were carried on these services two or three times a day, with Network R4 from London the rest of the time.

With the IBA needing some MF channels, R4 was re-organised and, on Saturday September 2nd 1972, England became one R4 national network with no local opt-outs on just three frequencies 692 kHz, 908 kHz and 1052 kHz.

1151 kHz was made available exclusively to the IBA for ILR, 1457 kHz was similarly for exclusive BBC Local Radio (LR) use and 1546 kHz, that had been used for the BBC Radio 3 city fillers, was given over to both BBC LR and ILR. 1088 kHz was transferred to Aspidistra at Crowborough for External Services at 500 kW.

Economics

It is important to realise that, for these high power main services that had been running since the early 1930s, the cost of the transmission plant on the ground was in proportion to the cost of the antenna and earth system. To achieve high efficiency and ensure a reliable field strength to the target areas, substantial (meaning large!) antenna and earth systems were employed together with tens or hundreds of kW of input power.

For the post-war low power filler stations say, Radio 3 on 1546 kHz, experience of the Wartime Group H 1474 kHz low-power stations and the later Civil Defence Deferred Facility sites, indicated that rather than massive masts of 300–500 feet, a much smaller (meaning cheaper!) installation was all that was required. Typically 110-foot Coubro and Scrutton pole-type masts spaced about 150 feet apart with a two-wire Tee antenna and a (up to) 2 kW transmitter was satisfactory for the reduced, modest coverage required. A simple 72-wire earth mat was the norm.

Put simply, the antenna and earth system provision matched the transmitter power in terms of installation cost.

Now, in 1973 with the requirements of multi-city coverage and limited frequencies based on the map as **Figure 1**, it was clear that some innovative solutions were needed as the same frequencies were to be re-used many times.

All change

The IBA were new to MF and, as such, must have had a rather steep learning curve.

The Government's requirement was for (up to) 60 stations broadcasting on MF in what was already a very crowded band.

The initial problem was how could a new system be set up without recourse to a large number of available frequencies? It had been proposed by some of the supporters of commercially financed local radio that much more effective multiple use of channels could be made by adopting directional antenna techniques. Very little was known in Europe about the practical aspects of such arrays. As a first step, a visit to the US and Canada was made by senior IBA engineers.

MF broadcasting in North America

During this visit, particular attention was paid to the use being made of directional antennas; it was found, for example, that the tight control exercised made it possible for very large numbers of stations to operate on each channel without mutual interference. On some single channels, there were as many as 200 stations spread throughout the continent. Some of the DAs had extremely complex polar diagrams, sometimes being varied between day and night operation and sometimes containing nulls 30 dB down on the mean power and consisting of up to 12 mast radiators.

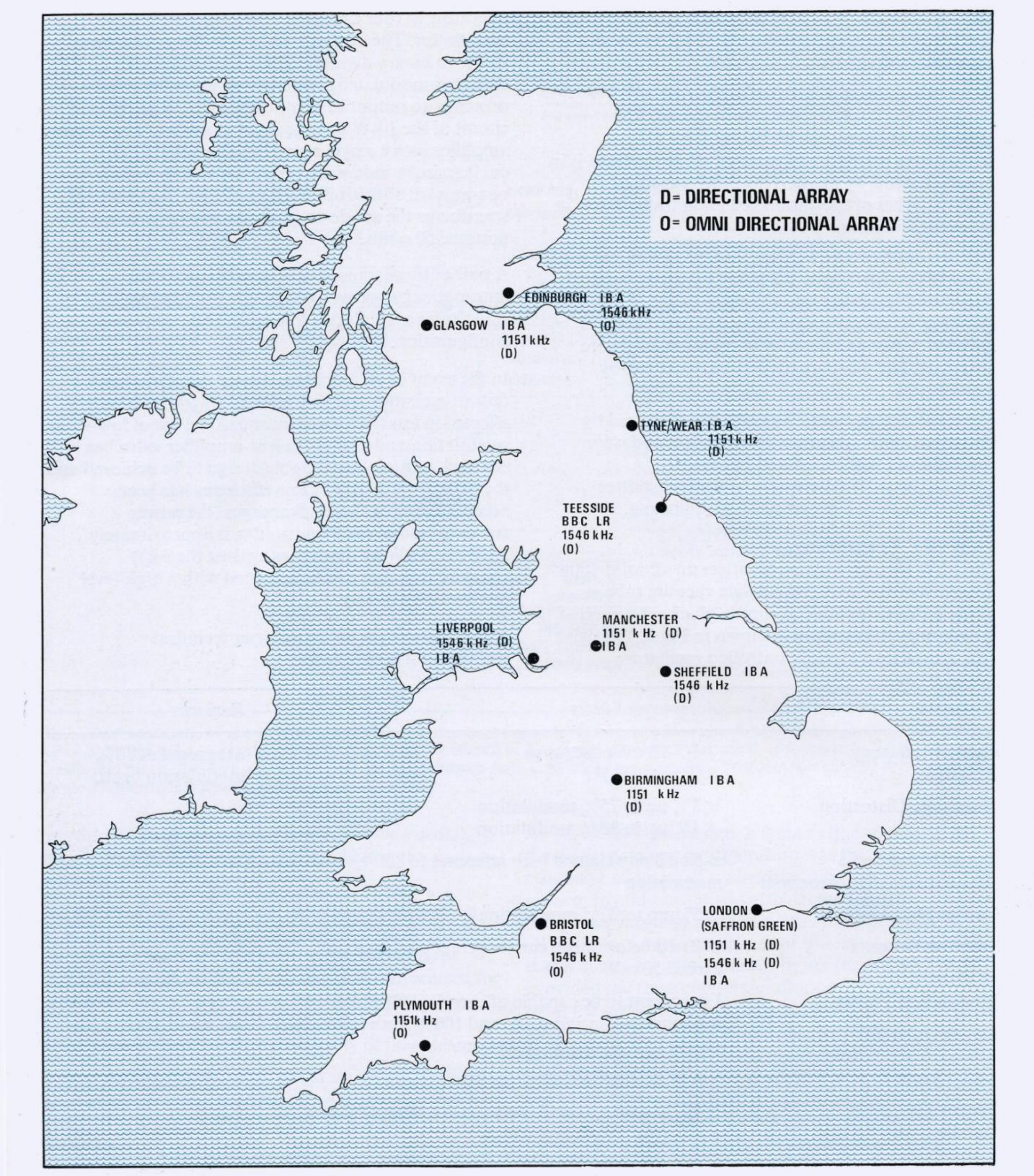

Figure 1. UK Map showing provision of ILR and BBC LR sites for 1151 and 1546 kHz

MF broadcasting in North America

It soon became clear to the IBA engineers that North American MF broadcasting had developed along very different lines from that in Europe, where the emphasis had so often been on high single masts and high power, on sky wave as well as ground-wave coverage.

It was found that the US and Canadian broadcasters accepted that the costs of a sophisticated polar diagram may represent a substantial proportion of total installation costs, although often the buildings and lightweight masts were to a more economical standard than in Europe.

A detailed appraisal of the advantages and disadvantages offered by DAs to ILR planning outlined the design philosophy on which ILR has been established; an interesting example of how the adoption of a completely new system can provide an unrivalled chance to break loose from traditional practices.

Advantages of directional antennas to the IBA

1. It would be possible to achieve greater use of the limited number of UK-assigned frequencies since the sites could be more closely spaced geographically.

2. It would be possible to avoid the use of closely synchronised transmitters.
3. Since power would be directed mainly to where it was most required, greater signal strengths could be provided where needed (for example in heavily built-up areas).
4. A DA would allow the use of sites outside the urban centres; these might be more readily obtainable even though larger sites would be needed.
5. The possibility of higher signal strengths could be expected to improve night-time as well as day-time coverage.

Disadvantages of directional antennas

1. The cost of a multi-mast system would inevitably be much greater than using omnidirectional antennas comprising a single-mast radiator or Tee antenna with two supports; conversely a DA would allow the use of a lower cost, lower power transmitter.
2. The design and setting-to-work of DAs was likely to need for expertise not readily available outside North America where a long tradition, often involving specialised engineering consultancies, had been established since before WWII.
3. It was also recognised that the time it would take to obtain planning permission for the use of multiple masts, the location and purchase of suitable sites, the technical adjustments to prove the patterns would all be longer – a not insignificant factor when there was a need to establish ILR in the major cities as quickly as possible.

ILR directional arrays

By 1976, the IBA had brought into service DAs at 10 of its 19 stations. The US firm of Cohen and Dippell PC from Washington DC, were employed as consultants and Marconi Research Laboratories were contracted for the frequency planning, coverage predictions and subsequent coverage measurements. Many sites had Marconi transmitters.

The arrays differed in design and complexity but all met the required pattern successfully despite the absence of detailed ground conductivity data; in practice this was conservatively estimated with the result that it has often been found possible to obtain the required performance with less, rather than more, transmitter power than predicted.

The earth systems employed usually consisted of 120 copper wires per mast of typically 12 SWG, 2.6 mm. An extensive earth system is required not only to improve efficiency but also to ensure stability of the radiation pattern, particularly the null areas.

It was decided at an early stage that end-fire arrays offered an arrangement that would provide suitable rejection nulls for skywave as well as groundwave radiation.

Long-term stability could be anticipated with null depths of 26 dB over arcs of 20° in azimuth and co-channel protection nulls at angles not less than 7° from the main lobe. These requirements are modest compared with US arrays where up to 12 masts are used. Arrays with more than four masts require very large sites and become extremely expensive. For example, four-mast end-fire arrays are used at Birmingham, Manchester and at Saffron Green, near Borehamwood for London.

The Saffron Green array with four guyed 71 m radiators was operationally the most complex since it is required, simultaneously, on two different frequencies 1151 kHz and 1546 kHz, to provide appropriate nulls on each channel. All four masts are actively fed on both frequencies to achieve null control.

The recurring ‘First Served Problem’ for London

With the two channels and the need for high power, it was unfortunate for the IBA that, as usual, the London area was to be ‘first-served’ with commercial radio.

This was an exact repeat of the BBC Regional Scheme in 1929 with Brookmans Park, 405-line TV from Alexandra Palace in 1936, VHF radio from Wrotham in 1954, Band 3 ITV from Croydon in 1955 and Band 4 UHF TV from Crystal Palace in 1964; London and the South East always seemed to catch for the new, untested technology.

Fortunately for the rest of the country, it was clear to the IBA that for the service and coverage planning, the majority of their MF stations would require a transmitter power of less than 1 kW (**Table 1**) with just a few needing up to 2 kW., which would make for easier systems engineering.

	MF	VHF	
	Nominal Transmitter Power (kW)	Transmitter Power (kW)	Max. ERP (kW)
1. London General	1·0* 25·0	0·4	2·0
2. London News	0·5* 8·0	0·4	2·0
3. Birmingham	0·8	1·0	2·0
4. Glasgow	2·0	1·0	4·0
5. Manchester	0·35	0·3	2·0
6. Swansea	0·8	0·7	1·0
7. Tyne/Wear	1·0	1·0	5·0
8. Sheffield	0·4	0·1	0·1
Rotherham VHF Relay	—	0·05	0·05
9. Liverpool	1·2	1·0	5·0
10. Edinburgh	2·0	0·45	0·5
11. Plymouth	0·5	1·0	1·0
12. Teesside	0·8	1·0	2·0
13. Nottingham	0·25	0·3	0·3

* Temporary station

Table 1. List of transmitter powers used at the first thirteen stations

With its two channels and higher power, Saffron Green was a considerable engineering undertaking and it was unlikely to be completed before the agreed on-air time. Accordingly, a pro-tem solution was enacted; namely an omnidirectional site at the then London Transport Executive’s power station at Lots Road. Between the two 90-metre high chimneys was erected a two-wire Tee antenna and temporary frequencies of 557 kHz and 719 kHz were allocated.

It was on-air for the start of legal UK Commercial Radio on October 8th 1973 for London Broadcasting Company (LBC) and October 16th for Capital Radio. Being in Chelsea, central London, with some of the earthing being in a creek adjacent to the River Thames, it was expected that good coverage would be obtained.

King Canute (*aka* Cnut) strikes again

Coverage was good… for most of the time but considerable effort had to be expended to solve one problem, that of the tidal River Thames. For it was noticed that the VSWR on the combined services altered with the tide. The transmitters would trip on high VSWR so provision was made to set the ATU components at mid-tide to better cope with the variation.

In later years, after the commissioning of Saffron Green in May 1975 and closure of Lots Road, the original frequencies were again re-used, first by the BBC with 720 kHz for R4 in November 1979 and then by National Transcommunications Limited, (NTL), the privatised successor to the IBA, in June 1990 for Spectrum Radio on 558 kHz. The tidal problem was still evident, possibly even more so with solid-state transmitters, and a BBC antenna engineer Bill Barrow, based at Woofferton, was heavily involved along with his NTL counterpart Marios Zapatis. The author recalls Bill returning to base saying that despite trying servo-controlled components for 'active tuning management' it still wasn't 100% reliable. It became known affectionately as "The Lots Road Lash-Up" Bill later left both the BBC and the UK and became a Roman Catholic priest abroad; whether or not the 'lash-up' had been a factor in his career change decision is not known. We heard later that allegedly he had renounced the faith and got married.

The Lots Road transmitter site closed down for good on 25th September 2001 with the two services transferred out to Crystal Palace and the site is now being redeveloped for shops, offices and flats.

The London array

There are four lattice masts each with a triangular cross-section of 430 mm, 17-inch face width, equally spaced 61 m, 200 feet apart in a line orientated 161° ETN to form an end-fire array towards central London 12 miles to the south. Each mast has an earth mat of 120 radials of 2.6 mm diameter copper wire extending up to 65 m from the base of the mast except where restricted by the site boundaries. The wires are buried 300–450 mm, 12–18 inches deep.

All four masts are fed at both frequencies. There is a combining unit at the base of each mast consisting of a pair of pass/reject filters; these provide isolation between the transmitters and also prevent any significant interaction between the two groups of antenna tuning circuits, occurring. Thus, there are eight buried 50 Ω coaxial feeders between the masts and the transmitter building.

In the building is a RF phasing and splitting cabinet, divided in two sections, one for each channel.

In the horizontal plane, the main lobe of the radiation pattern at 1151 kHz has a half-power bandwidth of about 90° total included angle. At 1546 kHz the masts are electrically significantly further apart giving rise to a broad flat-topped main lobe with a half-power bandwidth approximately 115° and thus lower antenna gain. It is the combination of lower gain and higher groundwave attenuation that brings about the large difference in transmitter power requirements to provide the same service are, namely 5.5 kW at 1151 kHz and 27.5 kW at 1546 kHz.

After allowing for losses in the splitting, phasing, feeder and matching networks, 30 kW is needed at 1546 kHz and about 7 kW at 1151 kHz.

Three Marconi B6029 10 kW transmitters are used with a triplexer on 1546 kHz and two more B6029 are used either/or for the 1151 kHz service down-rated to 7 kW.

There was provision for a demountable 45° sloping twin-wire antenna from the top of mast 1 to a ground anchor on the southern boundary of the site, to be used as a reserve. In this configuration the four masts behind it would be a substantial reflector.

A final on the economics

Readers will note that reference to costs and expenditure has been a thread running through this article. Saffron Green was installation-wise a very expensive site due to the complex antenna requirements. Mention must be made of a further point – the running cost of this site for London. The Marconi B6029 10 kW transmitters were a standard workhorse solution at the time and were a development of the earlier B6023.

The B6023 was a 1 kW unit; these were known in The Trade as the "One-kilowatt-noiseboxes" by the fact that the cooling fan by the Derby-based British Organ Blowing Company for the Eimac 3CX3000F7 single tube was somewhat stentorian.

The reason for the powerful fan was that there was a great deal of heat to lose as the power conversion efficiency was very low at only about 18–20%. So for 1 kW out about 5 kW went in and the same ratio for the B6029, about 50 kW in for 10 kW output.

The culprit was the triode output stage, which took in low-level modulated RF drive at 15 W and amplified it in a linear stage, just as the MWT Regional Transmitters at Brookmans Park, *etc*. had done in 1929. So, for Saffron Green, it is fair to assume that for a total site RF output of 36 kW, some 180 kW was drawn with about 144 kW as waste heat. The advantages of these transmitters were that they were extremely reliable and required very little maintenance and the building was warm in the winter

These days, with solid-state transmitters, over 85% efficiency will be realised rather than 18%.

Next time

We will look more at the engineering at Saffron Green, move on to Manchester and Birmingham and then, amongst other things, explore the trappings and contents of "The Zoo" at BBC Sutton Coldfield and all the mayhem that was caused by one very unwelcome occupant.

References

1. D Porter G4OYX. Tricks of the Trade. *Signal* 2020, **54** (February), 33–36.
2. P Hawker, Using Directional MF Transmitting Antennas. *Communication and Broadcasting*, The Marconi Co., Summer 1976.