Tricks of the Trade

Dave Porter G4OYX

This ToTT marks the end of the series on directional antennas for MF that started in November 2019 in *Signal* Issue 53 **[1]**. It has been a long saga and, not surprisingly, some errors have crept in; these will be corrected in a final, included corrigenda. While much on complex directional antennas for single and multi-frequency use has been covered, the remaining topic is comparatively simple. Early in the introduction to this subject, six options for directionality were outlined. The final design to be described here, fits neatly into two of these options as, in Option 1 it may be used to enhance the field strength in a certain general direction or, as Option 2, it may be used to limit RF radiation in a certain general direction.

Directional MF antennas with sloping wire reflectors

Directional MF antennas with sloping wire reflectors first appeared in the UK at the start of Independent Local Radio ILR and was a firm favourite with the IBA. Use was made of it later by the BBC and it became an industry standard. Marios Zapitis described their operation in an IBA Technical Review published by their Engineering Information Department **[2]** which forms the basis of the following.

The system comprises a single guyed mast supporting a parasitically-tuned sloping wire reflector. When the mast is fed at its base and the reflector is tuned passively, this system produces a directional cardioid horizontal radiation pattern (hrp) and is an economic solution to a two mast array as there is a saving in costs of about 20% by dispensing with the second mast.

The sloping wire reflector consists of a parallel pair of thin multi-strand wires, typically 4–6 mm in diameter, spaced about 1 m apart and slung *via* a halyard from near the top of the mast, but insulated from it. The slope angle is usually about 45° as shown in **Figure 1**.

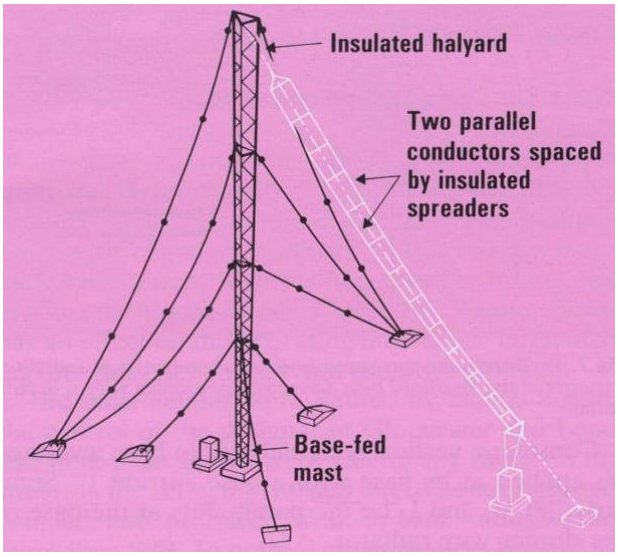

Figure 1. A directional MF antenna with base-fed mast and sloping twin-wire reflector

By inserting a passive tuning reactance in series between the base of the reflector and its own specific earth mat, a cardioid pattern can be achieved with a maximum front-to-back ratio typically between 13–17 dB. Measured forward gains of up to +2.5 dB over the theoretical short monopole, normally used as a reference for MF antennas, are possible. As touched on above, to minimise ground system losses, both the mast and reflector have their own radial earth wire systems consisting of 72 or 90 buried copper 12 SWG, 2.6 mm, wires extending out to a minimum distance of λ/6.

The electrical height of both the mast and sloper are important in determining the amount of directionality achieved in the hrp.

At the start of ILR, the most geometrically-compressed antenna was at Gloucester where a 60° mast and a 72° reflector (where one wavelength in this case: 388 m 773 kHz, equals 360°) exhibited a mere 8 dB front-to-back ratio with a forward gain of +1 dB whereas, at Coventry, 220 m, 1358 kHz the use of an electrically taller mast of 93° and 84° reflector led to a maximum front-to-back ratio of 24 dB and a forward gain of +2.4 dB being realised.

Very much like some early BBC experiments on MF antennas for the evaluation of the first station at Bradford, the IBA employed $^{1}/_{60}{}^{th}$ scale models and measured the field strengths so, for example, for broadcasts on 1.5 MHz, a test frequency of 90 MHz would be used.

Interestingly, theoretical calculations showed that the sloping wire radiator cannot be used as a director with more than a 2.0 dB front-to-back ratio, whatever value of tuning reactance is inserted in series with it.

Analysis of antenna performance

Although a careful choice of geometrical arrangements can result in front-to-back ratios as high as 25 dB, it should be noted that the ground-wave hrp follows a well-defined shape; that is the null to the rear does not form a narrow notch but is maintained over a broad azimuth arc to create what may be described as an 'apple-shaped' pattern. The suitability of a sloper at any site would depend on the acceptance of this pattern shape.

For a given pattern shape and front-to-back ratio, there are a number of parameters within the control of the designer. These include the electrical height of the mast and the length of the reflector, their electrical spacing and the reflector's base tuning reactance. **Figure 2** shows the effect of the reflector tuning reactance versus MF gain for various reflector lengths including the length actually used at Coventry.

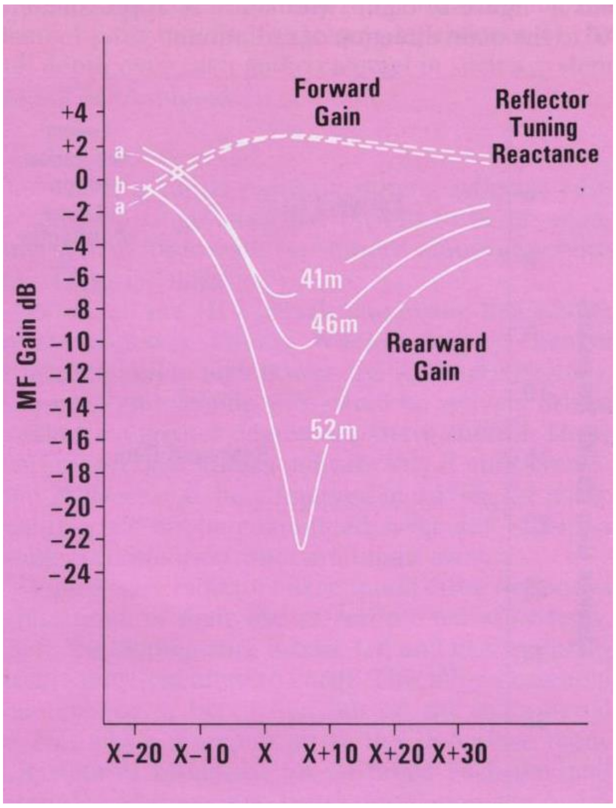

Figure 2. Computer prediction showing the variation of MF gain with reflector tuning for various reflector lengths for the Coventry MF antenna

A careful choice of antenna geometry and sloper tuning reactance can control the amplitude and phase of the reflector current to produce a range of null depths. At Coventry, the maximum front-to-back ratio occurs when the current in the reflector is 30% greater in amplitude than that in the mast. This is because the mast generates 30% more radiated field than the reflector for a given current at its base and the favourable phase to centre spacing between reflector and mast results in almost complete field cancellation to the rear.

For a given sloper length, it can be seen from **Figure 2** that the null-depth is adjustable (at Coventry it was set to 9 dB in operational service) by adding passive tuning reactance at the base of the sloper. Tuning away from resonance decreases the amplitude of the current flowing in the wire and alters the phase and hence the null depth. Tuning away from the deepest null with positive reactance will produce a normal cardioid pattern, whereas tuning away with negative reactance will produce a major back lobe which, with further negative tuning, will produce a 'figure-of-eight' pattern. Passive tuning of the sloper has an effect on the driving point impedance of the mast so the mast's ATU components will need to be adjusted to cope.

Limitations

At some sites, for example Gloucester and Leeds, the mast heights were limited by factors (often planning permission, *etc*.) and the antennas were electrically short. In this case, the slopers turned out to be strongly over-coupled and produced front-to-back ratios of not more than 8 dB. In normal circumstances, the mutual coupling can be reduced by shortening the radiator but, when it is already as short as say 67°, any further reduction in its length causes the self-resistance to drop at the same rate as the mutual impedance, thus the over-coupling remains. When this was tried at Leeds (mast 60°, sloper 67°) the pattern developed into a 'figure-of-eight' with the nulls at approximately 90° to the main direction of radiation.

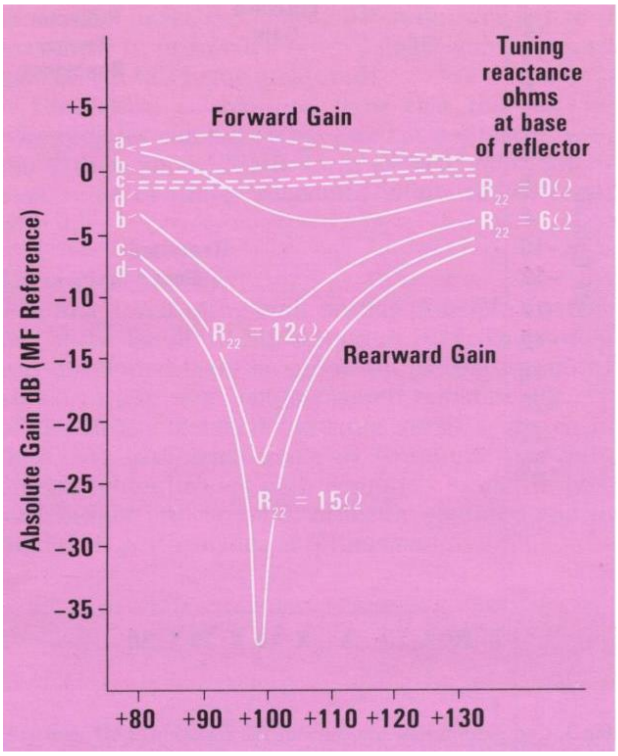

Figure 3. Computer predictions showing the variations in forward and rearward gain for Gloucester MF antenna with different values of earth mat-loss resistance

Another way that the current in the reflector can be attenuated without changing the phase is the insertion of additional loss resistance at its base. **Figure 3** shows the theoretical effect of adding varying amounts of loss resistance to the base of the reflector at Gloucester. Very deep nulls could be obtained at the expense of forward gain since some of the transmitter power is dissipated as heat in the resistor. At three stations with short masts, it was necessary to use a 6 Ω resistor in series with the variable tuning reactance. Although this may be seen as undesirable it did not create a problem because the transmitter powers were very low and had been specified originally with spare power in hand to cover in the event of using low-efficiency antennas. For high power (say >5 kW) high efficiency requirements, resistive damping would be unacceptable. To overcome this, slopers with adjustable lengths have been used.

Options 1 and 2

The first ten stations with slopers had nulls ranging 5–17 dB in depth. These nulls were not intended to provide co-channel protection but were intended to adjust the size of the service area to conform with the programme editorial boundaries so, in effect, they covered both the options as outlined at the start.

In some installations, for example at IBA Brundall near Norwich, the sloper there was used to prevent signal going towards Birmingham on the co-channel of 1152 kHz.

The feed point VSWR of the antennas at ±6 kHz from carrier can vary from 1.05:1 for sites with front-to-back ratios of 5 dB such as Bury St Edmunds to 1.3:1 for systems with front-to-back ratios of 17 dB such as Bradford and Preston.

Sloping wire radiators

A sloper can also be used as a radiator to provide a reserve transmission capability. If, for example, the mast or its ATU networks need to be maintained, the sloper can be used as the driven element whilst the mast itself is short-circuited to earth. Under these conditions, the directionality of the system is changed and it becomes nominally omnidirectional if the electrical height of the mast is substantially less than λ/4, that is, the mast is non-resonant. For mast heights greater than λ/4 some directionality remains.

This reserve use of a dedicated sloper has been discussed in the previous pieces on Saffron Green for the London ILR MF services **[3]**.

Dual-channel operation

The IBA antenna at Kempston, Bedford was one of very few converted for dual frequency operation when the BBC came along with a site-sharing request. The existing ILR channel had a front-to-back ratio of 14 dB and a forward gain of +2.4 dB at 792 kHz; the new BBC channel was to be 1161 kHz. Computer studies had shown that the sloper would be considerably off-tune at the new, higher frequency and carry only a small base current relative to the mast current with a 2 dB front-to-back ratio. However, in this instance this was an acceptable situation and, indeed, the measured service area was in agreement with the prediction. In cases where directivity is required on both channels then the sloper could be tuned independently on both frequencies by fitting rejector filters in each channel path, but the frequency dependence of the null depth over each audio channel in such a system has not been studied.

The audio problems

Where a deep co-channel protection null is required in typically higher power installations but also at low power sites, both mast and sloper could be actively driven with RF from a power splitter in the transmitter building or in one of the ATUs. Theoretical studies indicate that, if more than 25 dB were to be attempted in service, then the audio quality could not be guaranteed in the null region; a problem common to other multi-mast arrays.

This audio distortion phenomenon was well known and could be troublesome. The worst case noticed by the author was at Orfordness; oddly not on the 648 kHz five-mast system but actually on the six-mast (2 x 3) antenna system for 1296 kHz. Whilst on-call over a weekend, but not on site, the author had occasion to drive along the coast, continuing northerly from Orford village having joined the A12. The 1296 kHz 500 kW plant had just started to be rented out, when not required by the BBC, to the Dutch “Radio Nationaal” station 0400–1830 daily, so it was prudent to keep a check on the continued output. What immediately became apparent was the horrendous sound of the reception at certain narrow points along the A12 passing through Wickham Market, Saxmundham, Yoxford and then deviating off to Dunwich and Southwold. When the multitude of nulls was passed through, there would be fading that was so typical of night-time MF reception of Radio Luxembourg with their selective fading as the sidebands became separated and were individually lost and re-found. No doubt, going south from Orford the effect would be duplicated.

For an overseas service on the main beam this is not at all a problem as reception was not intended for the UK.

However, consider the case for the IBA where a highly directional antenna had been specified to cover a particular editorial area. Thinking about Saffron Green for example, where the main beam is towards London, no doubt there would have been listeners in cars travelling to the capital from towns such as St Albans, Potter’s Bar, Hatfield, Cheshunt and Enfield, all to the north west, north and north east of the transmitter site situated near to Borehamwood. Without a doubt, there would have been the received audio distortions on programme which, though transitory in nature, could be rather annoying.

In the same geographical area, there was a known null line of received audio distortion present on the similarly directional BBC Radio London 1458 kHz service from Brookmans Park which ran along a certain road. Travelling it was a useful maintenance tool in checking that all was OK with the DA and was exploited to that end. Roy Hatton (now SK), the Engineer-in-Charge, took it upon himself to check that null as it was on his way home to Harpenden, albeit *via* a small detour.

BBC use of slopers

The author recalls the use of a temporary sloper at the Shrewsbury MF BBC site one July night in 1994 when mast maintenance was scheduled. A very rudimentary earth system was installed overground, terminated on a temporary ATU with a length of URM67/RG8 coaxial cable to the transmitter building. A two-wire sloper was in place to be connected to the ATU. All this had been rigged on a closedown a few days previous. Come the official shutdown for changeover at 2100–0600 overnight, the riggers and an antenna engineer along with the author and a colleague attended. The weather was appalling with heavy rain and, at 2200, there came a very heavy thunderstorm with much lightning. An ‘informed decision’ (*i.e.* educated guess) was made by the riggers when to make the connection of the sloper to the temporary ATU, as previous to this the sloper had been isolated and un-terminated to prevent detuning the regular mast. The termination was made immediately after one stroke of lightning and before the next one, having timed the intervals between previous strokes.

It’s fair to say that the whole project did not get off to a good start and the omens were not positive as the riggers then had to sort out what was their temporary, now non-aligned and unpegged, earth mat and check the entire length of the on-ground UR67 as no one had told the farmer NOT to put the cattle back in the field after their pre-rig a few days previous.

By 0030 the storm had passed, the ATU was matched to the single frequency of 1017 kHz at 500 W and a round-the-town field strength check did indicate a roughly omnidirectional pattern from the <λ/4 system.

Wet feet

Enhancements to the BBC Radio Wales service in English were made in 1985 with two new stations; both had identical buildings and transmitter/diesel plant. The first at Llandrindod Wells, deep into mid-Wales, used a text-book BBC standard-design twin-wire Tee antenna supported by a pair of 45-metre masts for what was an omnidirectional 1 kW service on 1124 kHz, 266 m.

Its near twin at Forden, only a few miles from the English border south east of Welshpool, employed just a single mast with a tuned sloper, directionally orientated to ensure that coverage into England on 882 kHz was attenuated; so Option 2 was the order of the day here. Granted that more RF, Option 1, would have been sent on the forward bore-sight into Wales but, with low or almost zero population there, that option was not the main priority. However, the two main population centres of Newtown to the south west and Welshpool to the north west of Forden were well served as intended.

Operationally, Forden was an interesting site as it was literally on the flood plain of the River Severn; while the generally damp conditions ensured the efficiency of the earth mat, it was a tricky site to manage as, after the first flood of The Severn, the ATUs were themselves flooded and the service was off due to VSWR trips to lockout. The emergency raising of the ATUs above ground on stilts fixed that problem but it would appear that due regard had not been taken initially of the effect of a parasitic sloper on the driving point impedance, dpz, of the driven mast. Whilst a base-fed 63-metre mast would be fine on its own at 882 kHz; the effect of the sloper was to lower the dpz; again that is not a problem under normal conditions as the matching could be configured to cope typically with 20–j50 Ω. But here, with the ever-present river threat and subsequent ever-changing earth mat resistance, it proved difficult to find a mid-point match that suited winter and summer extremes; the usual fix of accommodating earth mat variations engineered in the spring or autumn was not effective.

The author had been heavily involved in the operation of the site and proposed to the Head Office-bound powers-that-be that three top-loading wires between the existing stays be connected to the top of the mast and come down to ground anchors *via* insulators; the lengths to be two-thirds wire from the top and then a one-third length of insulating Parafil™ rope to the anchor.

Hopefully, just this one modification should have raised the dpz of the mast but, if that had not effected enough of an increase, then a further change would have been to earth the mast and connect to the top of the mast an additional pair of wires and drive those to create a folded unipole arrangement. Then, with the higher value of resistance on the dpz, the river-induced changes in the earth resistance would have been a much smaller percentage of the total.

This re-engineering suggestion was sent to the BBC Transmitter Masts and Towers Department but it was concluded that the mast was not of a sufficiently substantial mechanical construction to stand any more physical loading.

Luckily for all involved, this problem of varying VSWR and tripping off on a certain transmitter (a solid-state Eddystone B6038 1 kW unit) was well-known by then as there had been roosting bird problems on Tee antennas as well as some earth mat variations at other sites. A Head Office engineer, Eric Reeves (licenced and now SK) had researched this problem and had designed and developed a new VSWR monitoring and control board for the transmitter that effectively throttled back the RF power output of the service so as to provide a reduced level of derived VSWR voltage, sufficient not to cause a transmitter trip-to-lockout and off. This was an ideal solution for both transient and slow varying conditions. So there was no need to consider a better antenna arrangement at Forden.

Both sites closed in April 2020 as a result of BBC cutbacks as Radio Wales was now available on DAB.

Sloper to the rescue?

During the planning by officials of The Radio Communications Agency (as it was in 1991 prior to it becoming The Radio Authority) for the South Shropshire ILR MF service, suggestions were made as to the frequency. 756 kHz was a likely possibility as the BBC had been requested to close their Shrewsbury transmitter. They had already closed what had been a temporary start-up service for BBC Hereford and Worcester at Hereford on 819 kHz; that too was a possibility, as was the Worcester output of BBC H and W on 738 kHz. The author was involved in this ILR set-up as a volunteer and so had to buy crystals and set up the transmitters on all three possible channels.

819 kHz was eventually settled upon, until someone realised that Wolverhampton had a BBC service on 828 kHz. With Ludlow being a lot nearer to Wolverhampton than Hereford, it was suggested that a sloper be provided for the Ludlow service to keep the adjacent channel RF splash on the sidebands off the 828 kHz service. However, with that sloper, a large amount of coverage would have been taken out of the 819 kHz editorial service area for south Shropshire and consequent listener loss. The solution was to allocate a new frequency of 855 kHz, which was new to ILR, being in use already by 1 kW BBC stations at Preston, Postwick (Norwich) and Plymouth. 150 W emrp was permitted, resulting in a single mast being possible, no interference problems and a considerable sum of money saved in re-engineering the 54 m mast and extra earth mat.

Conclusion

With the rise in the number of local radio stations in the 1970s and 1980s, and the need for transmitters on the edge of population centres, the sloper did provide an economic and cost-effective means of concentrating an MF signal into a town or city centre.

There is one final point about the use of a sloper rather than a two-mast directional array in that it is more acceptable for planning considerations as, from a distance, it has just the appearance of a single mast, the reflector being scarcely more obtrusive than the guy wires.

Marios Zapitis **[2]** has already featured in this series of DA articles **[4]** being in a later engineering involvement with the BBC Antenna Engineer Bill Barrow when they were wrestling with matching problems caused by the tidal River Thames at Lots Road, London.

Corrigenda and updates

In no particular order, here is a series of corrections and updates with regards to recently published articles:

In the Start Point DA piece in Issue 54 of Signal **[5]** there were a few final paragraphs headlined "Up to the present day" where the failure and subsequent replacement of the northernmost mast was described. The information there was not attributed to the source **[6]** which was the mb21 website and its many contributors. That was an omission on the part of G4OYX but Martin Watkins of mb21 has granted forgiveness and has permitted the author to contribute to their pages since; with appropriate credits one might add.

When mention has been made by the author of the services from Orfordness over recent issues of Signal, the incorrect bearings had been given for the two frequencies. For the 648 kHz DA the correct bearing was 130° (rather than 110°) and for the 1296 kHz DA the bearing was 96° (rather than 90°). With mention in the current article about the Radio Nationaal 1296 kHz service, it is pertinent to add that a slew was introduced for their transmissions to 106° from 96° to better cover The Netherlands, which was switched out when the BBC were using the service.

Ray Cooper, who kindly contributed to the story of The Buzz Factories and The Zoo at Sutton Coldfield in Issue 57 of *Signal*, proof-read and approved the piece in question. After the publication deadline, he added the following anecdotes in his own inimitable style regarding some more information about Trowell MF near Nottingham.

Ray's piece follows:

If you look at the mb21 page on Trowell **[7]** you'll see that there is some comment that the masts are dissimilar. Well, they used to be the same, early 1950's 110-foot Coubro and Scrutton pole masts: but one fateful morning, the studios were on the blower PDQ, complaining that their MF was off. It was a filthy morning: there had been a blizzard the day before, then a brief thaw, then a hard frost. The journey over there was not at all pleasant, lorries performing graceful pirouettes before our bonnet. But we got there, to find that we were minus one mast.

The east mast was lying in the field, imitating a corkscrew. It still had a very healthy thickness of ice upon it and evidently ice-loading had been the source of the collapse. Not much we could do there and then (the local B&Q didn't seem to stock 110-foot masts) so we called out the rigging team from Woofferton. They managed to jury-rig a sloping-wire aerial from the remaining mast and that carried the service for quite a while until the replacement was fitted. And the replacement was a lattice; perhaps they'd run out of poles by that time.

On the other occasion: it was a rigger's 'beanfeast' down there, an outage had been arranged for mast inspection and maintenance. So we shut down the system, put on the earthing switches and handed over the mast. Didn't want to waste time hanging about while they did their stuff, takes a couple of hours or so, so we left a junior engineer on site to keep an eye on them, with instructions to de-earth and re-power when the thing was handed back. In the meantime, the rest of us sloped off to some small UHF site and did a maintenance visit there, followed by lunch.

After lunch, the R/T was alive from Trowell: they'd finished, re-powered, but the studios claimed that they couldn't hear a thing.

Back at Trowell, the transmitter meters indicated something amiss with the aerial match. A quick inspection revealed that one of the riggers (no names, no packdrill) had on his own initiative applied an extra earth, by putting a G-cramp across the spark gaps. But he'd forgotten to remove it. Removal of said G-cramp, application of a few words of advice to the rigger and re-powering brought smiles back to everyone's faces (well, almost everyone's).

And did the MWT B6023 1 kW noise box complain about this? Not a whit.

Ray's piece ends

The final correction is again from ToTT in Issue 57 of *Signal* **[8]** where the author wrote that the IBA Langley Mill site, to which the BBC Radio Birmingham 1457 kHz MF service was transferred to spare BBC Sutton Coldfield the interference problem, was to the north west of the city, well actually no, it is on the north east side of the city just directly east of The Royal Town of Sutton Coldfield, adjacent to the M6 Toll Road.

References

1. D Porter G4OYX. Tricks of the Trade. *Signal* 2019, **53** (November), 33–35.
2. M Zapitis. Directional MF Aerials with Sloping Wire Reflectors in: Developments in Aerials for Broadcasting. *IBA Technical Review No. 23.* 1986 (March), 27–31.
3. ET Ford. A Dual-Frequency Highly-directional MF Aerial for ILR London. In: Latest Developments in Sound Broadcasting. *IBA Technical Review No. 14*. 1981 (June), 44–47.
4. D Porter G4OYX. Tricks of the Trade. *Signal* 2020, **56** (August), 39–42.
5. D Porter G4OYX. Tricks of the Trade. *Signal* 2020, **54** (February), 33–36.
6. http://tx.mb21.co.uk/gallery/gallerypage.php?txid=1474&pageid=1641
7. http://tx.mb21.co.uk/gallery/gallerypage.php?txid=1561&pageid=1267
8. D Porter G4OYX. Tricks of the Trade. *Signal* 2020, **57** (November), 17–21.

~ ~ ~