Tricks of the Trade

Dave Porter G4OYX

Last time in ToTT, we had arrived at the point in the development of broadcast HF arrays where the HRRS 4/4/1 reigned supreme. This status was no doubt due to its versatility having slew, reversal and the ability to use half the array, reducing the aperture but spreading a signal over a wider part of the globe.

Limitations

By the early 1960s, the limitations of the single band HRRS 4/4/1 array were becoming apparent as the BBC developed a dual-band array where two adjacent bands could be accommodated, typified by 41 and 49 m, often used for transmissions to East European countries during the Cold War. This arrangement saved real estate and permitted greater flexibility in transmission planning as well as for operational staff on the sites if arrays were damaged in severe weather.

VMARS Member Dave Gallop G3LXQ was a member of the BBC Transmitter Scheduling Unit at Bush House and involved with the use of these older designs. Below is a commentary that neatly describes the theory at the time and relates to a later improvement in the feed system.

G3LXQ writes,

"I was never fully convinced by the traditional feed system for HRRS 4/4/1 arrays. Vertical power sharing between the dipoles did not follow the theory for much of the intended frequency range, particularly when the BBC liked using band-edge frequencies (out-of-band frequencies). The take-off angle would have been raised for any but mid-range frequencies. The traditional feed system (bottom-up) was used for all of the single-band designs having two or more dipoles per stack but it was the HRRS 4/4/1 which particularly aspired towards DX performance by having the lowest theoretical take-off angle. It is only more recently, with the use of branch-feeding, that all of the dipoles have a chance of equal current feed and, therefore, predictable take-off angle over a wider frequency range."

Examples of the out-of-band frequencies referred to by G3LXQ were 7320, 7325, 9410, 9825, 9915, 12040, 12095, 15070, 17695 and 18080 kHz. The 9 MHz series was particularly troublesome to operational staff, requiring trips to certain arrays to apply different shorts to reflector curtain tuning stubs manually for the lower 9410 and the higher 9825/9915 combinations. It is interesting to note that now, following successive ITU/WARC conferences, most of these frequencies are included in the official HF broadcast bands, apart from 15070 and the amateur allocation of 18080 kHz. However, the BBC still has one in use, a late addition in 2006, and that is 5790 kHz.

Operationally switching the single band arrays

Before about 1970, it was an all-manual operation to effect slews, reversals and 'A'-condition switching on the arrays. Technical Assistants were rostered for turns on the senders, the control room and the antennas.

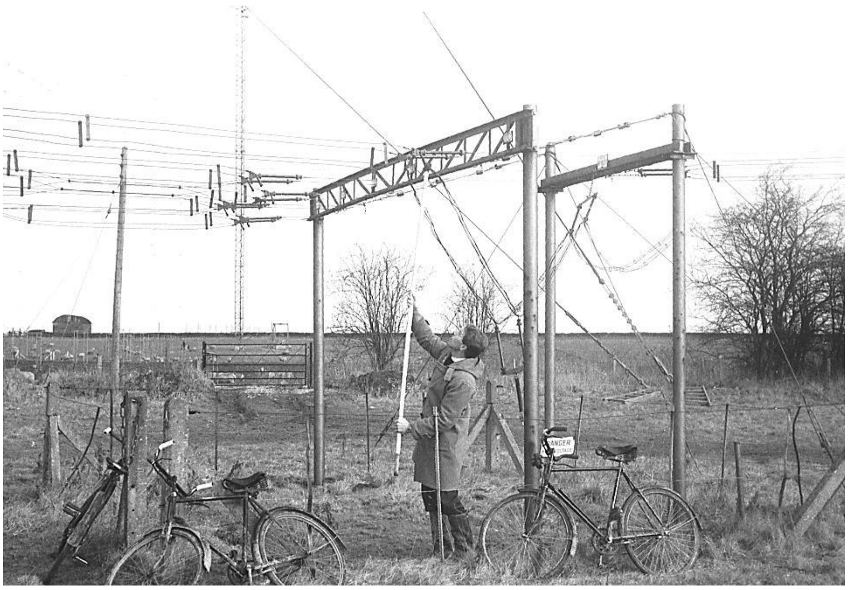

Figure 1. Photograph courtesy of Dick Buckby G3VGW from the Jeff Cant Archive showing antenna switching at Woofferton in the mid-60s

Figure 1 shows Technical Assistant Rod Viveash at Woofferton on antenna duty on what appears to be a dry day. He is sporting the standard, communal BBC-issue, brown 'one-size-fits-all' duffle coat and, no doubt, his personal issue 'Sea-Boot' woollen socks and (but maybe second or third hand) Wellington boots. The author's pair of boots (size 9) at Daventry had been 'previously enjoyed' by Keith Orchard G3TTC who is now a famous Islands-on-the-Air IOTA activator. This ownership is evident from his initials, KMO (but not his call-sign!), written in them in very large letters!

The author would guess that Rod was 'double-banking', that is to say, was learning the trade with the trainer Richard (Dick) Buckby G3VGW. Antenna switching was a solitary job and, in the dead of night, in the winter fog, it was quite disorientating at times. The author recalls, while on the control desk at Daventry, being called on VHF 141 MHz R/T at 0300 by the Technical Assistant outside in the fog (name withheld but he went on after a few years to a prominent Head Office job) asking for possible directions, from where he might have been, to the next switching operation. One of the 'old-timers' talked him through. It must have been even more difficult in the days when there were only a few fixed telephone points in the field from which to establish communications.

In **Figure 1** Rod is demonstrating the technique whereby the balanced feeder is switched from one set of 'eyes' to another using the hooked ends. This manoeuvre would be done within a few minutes of the feeder having carried up to 250 kW of modulated RF and was probably required to be on power again within 15 minutes. A safety procedure of 'getting a clear for switching' usually by R/T was in place and the Technical Assistant would talk to the control room engineer to obtain the permission. It was up to the Technical Assistant to establish for himself that he was at the correct array at the correct time. The control room engineer would lock out the array (so it could not be powered) and send the message by R/T that it was "clear for switching" He would hang the interlock key on a board with a red tally over it. After the switching was complete the Technical Assistant would confirm by R/T, the tally would be removed, the key would be restored and the array returned to service.

Tensions

There were times in the schedule when there could be up to four arrays spaced at considerable distances to switch by one man in 30 minutes. This requirement kept the individual on his toes and the stress to a new recruit could be considerable. That is why, on the photograph, 'antenna bikes' can be seen leaning on the sheep-proof fence. So, when joining the BBC staff on an HF station, one of the first questions asked was "can you ride a bike?" It was surprising how many young men and, during the War, Technical Assistants (Female) had to be taught to ride a bike.

Those hooks and eyes were tensioned by a long spring attached by 12 inch rod insulators (**Figure 1**) which made the arrangement heavy and, in high winds and rain with slippery conditions underfoot, it was easy for one of the hooks to become detached from the wooden switching pole. There was no choice but to bend over and, with one's leather rigger's gloved hand, retrieve the hook and replace it on the pole. Sometimes there was RF pick-up on the feeder and one could get a burn. After the correct antenna had been selected, the spring was pulled down and connected to a suitably placed ground anchor, tensioning up the feeder and completing the task. In view of the possible RF pick-up, it was customary to bang the feeders together with the switching pole prior to working on the array; the size of the sparks provided a clue as to whether it was still on power and how much, if any, pick-up there was.

Figure 2 shows a diagram of a manually switched array with a boresight condition of 47° and slews to 34° and 58°, and there is a reflector bearing of 227° with a single reversed slew option of 238°. Points S1 and S2 terminate the front curtain as λ/4 shorting positions to establish that curtain as a reflector. For normal boresight 47° operation, points S3 and S4 are where the Technical Assistant would clip on a short on the reflector tuning stub or operate a shorting switch (**Figure 3**). The position in **Figure 2**, where Rod would be standing, is the 'R' point where the main feeder enters.

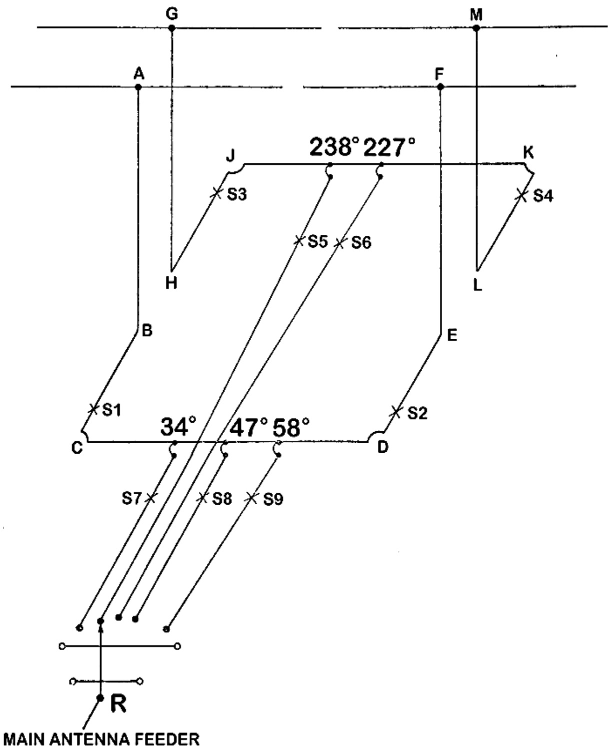

Figure 2. Perspective schematic of HRRS4 array and bay

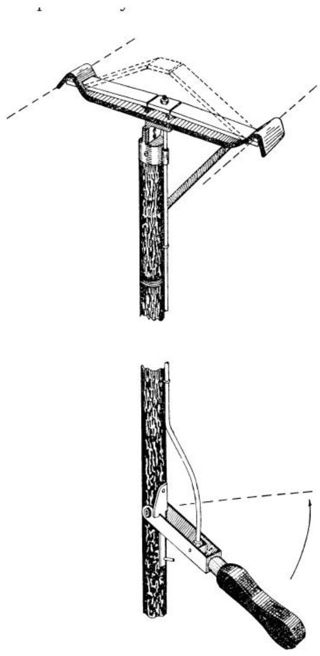

Figure 3. Short-circuiting switch

Partial Automation

It can be seen that hooks and eyes were a cumbersome, labour-intensive, time-consuming system and, following the introduction in 1963 of compressed air operated matrix switches to select senders to antennas, the logical transfer of the technology was to the antenna switching itself.

Daventry was the first station to be trialled and the author's former Babcock colleague, Pete Bairstow, the Babcock Technical Trainer, has kindly allowed the publication of a Powerpoint™ slide from his present training course that shows the switch arrangement adopted as **Figure 4**.

Power into the array enters at the bottom left hand corner of the diagram into Switch H whose position determines whether half or all the curtains are used. At Woofferton this switch is known as the A/Normal switch. In Normal condition, the power goes to both curtains and, as such, the array is slewable. In the A condition, only one set of curtains is used so the antenna cannot be slewed; only boresight or reverse boresight beams are possible.

S1 and S2 are the slew switches and allow the addition of a critical length of feeder that delays the phase of the RF to one curtain and so produces a slew to the beam of typically 12° to 15°.

The remaining switches, labelled A and B, are at the base of the four vertical feeders and select which pair of curtains are powered. At the same time fixed quarter wave shorts are applied to the switched reflector curtains.

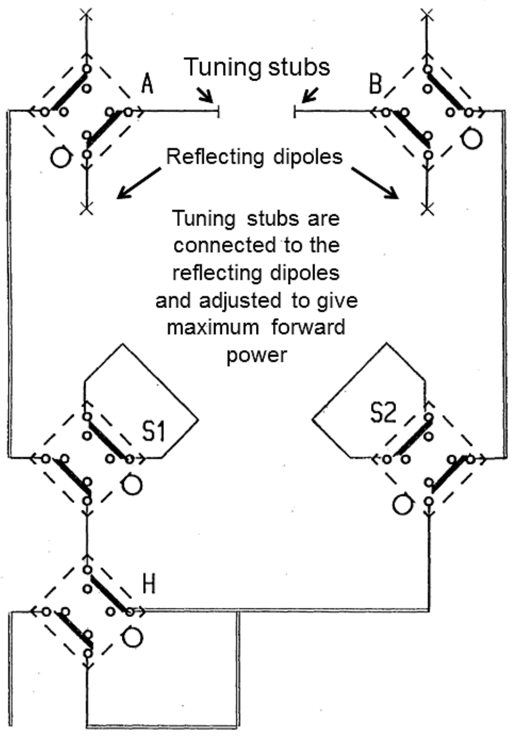

Figure 4. HF curtain antenna groundwork using rotary switches. Diagram courtesy of Pete Bairstow and Babcock Communications

It is interesting to note that, when these arrays are being set-to-work, the position of these reflector shorts is determined empirically. Temporary, moveable shorting lengths of wire are loosely connected, the array is powered at low power mid-band and, from a vehicle parked a half mile away behind the boresight bearing, a receiver indicating signal strength is used to define minimum signal rearwards. The riggers 'knock the shorts' to and fro with insulated rods to tune the curtain. When the exact position is found, the RF drive is switched off and a permanent connection made. UHF R/T was used to control the tuning operation.

For these arrangements, the array groundwork had to be altered but it was a prescient move as it paved the way to full automation later. Initially, the rotary switches were operated manually with a handle to two labelled positions. The antenna Technical Assistant selected, and then carried a Traffolyte™ engraved plate for each array with the positions required for all the conditions. The actual switching was now much easier and safer.

Full Automation

By 1978 at Daventry, Skelton and Rampisham, it was possible to switch many of the arrays remotely from the main station as compressed air actuators and DC micro-switch tell-back revertives had been added to the previously manually operated switches. Woofferton, being primarily a Voice of America site, did not benefit from this BBC initiative and so it was not until about 1983 that some arrays were fitted with switches. Only after 1986 did changes to full automation commence; it was very much a piecemeal transfer and was expedited as funds and time allowed.

International Telecommunications Union ITU

The ITU is the central official agency for World communications including broadcasting and, as such, publishes technical reports and recommendations. While preparing this article, reference was made to a document "Transmitting Antennas for HF Broadcasting" by Pham Nhu Hai of the ITU Radiocommunication Bureau. Within the document are three superb diagrams of broadcasting antenna arrays. The first (**Figure 5**) is a single band array with an aperiodic (wire-mesh) reflector screen and is based on the classic HR type array.

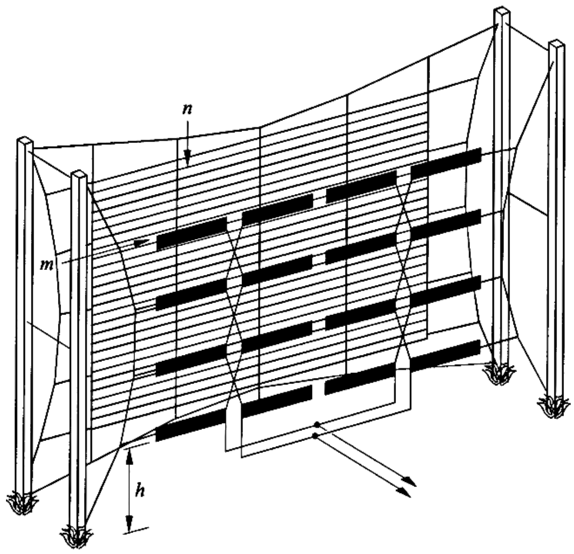

Figure 5. End-fed dipole array with aperiodic reflector. Diagram reproduced from D011 Rec. ITU-R BS.705-1 with permission of the ITU

The second diagram (**Figure 6**) shows a dual band end-fed curtain antenna array with tuned dipole reflector. BBC dual band antennas use fan dipoles, similar to UHF TV 'Bow-Tie' antennas and are not quite the same as on the ITU diagram but, of course, serve the same purpose.

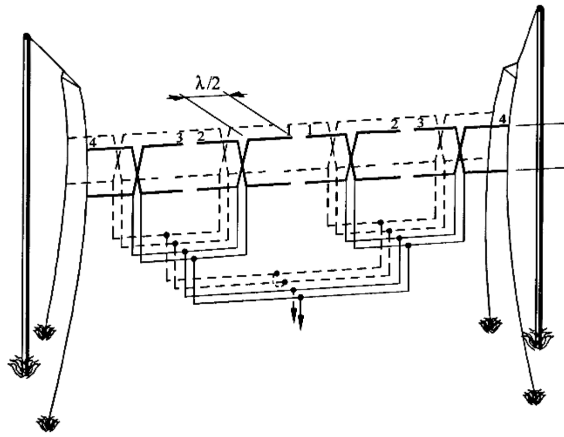

Figure 6. Dual band, end-fed curtain antenna array with tuned dipole reflector. Diagram reproduced from D012 Rec. ITU-R BS.705-1 with permission of the ITU

In the previous ToTT, it was shown that an unslewed HR 4/4/1 antenna produced, in addition to the major lobe on the boresight bearing, two minor side lobes of little consequence at *c*. 40° on each side.

To achieve slewing, both of the above array types introduce off-centre feed at the first stage of branching so that two stacks of end-fed half-wavelength dipoles are fed together in phase and in advance of the other two stacks, also fed together in phase.

The result of this two-step phasing is that, as the slew angle is increased, the power in the side lobe also increases until the worst-case scenario is reached. Here, two identical lobes, symmetrically disposed at *c*. ±20° are produced, each containing approximately half the power of the unslewed antenna. A practicable limit of 12° slewing has been set, resulting in an acceptable reduction of only 1 dB or so in the major lobe.

Multiband (wideband) antennas

With the introduction of computer-aided design, it became possible by the mid-1970s to design multiband arrays; typically, models covering a 2:1 frequency ratio could be produced. The most common designs were in three groups namely 6, 7, 9 and 11 MHz, then 9, 11, 13, 15 and 17 MHz and, finally, 15, 17, 21 and 26 MHz. Woofferton was the first UK station to have four such antennas made by the American TCI Company. They were part of the US-funded, Voice of America modernisation program of 1980. After the BBC had seen that the design and concept were satisfactory, it purchased mainly Marconi manufactured antennas, but some TCI designs for Rampisham and other sites. In 2007 VT Comms purchased two Thomcast brand, of German design and make, Croatian-installed arrays for Woofferton.

Dave Gallop G3LXQ alluded to the method of feeding the folded wideband dipoles on these arrays by the use of the word 'branched' and **Figure 7**, the third diagram from the ITU, shows the technique.

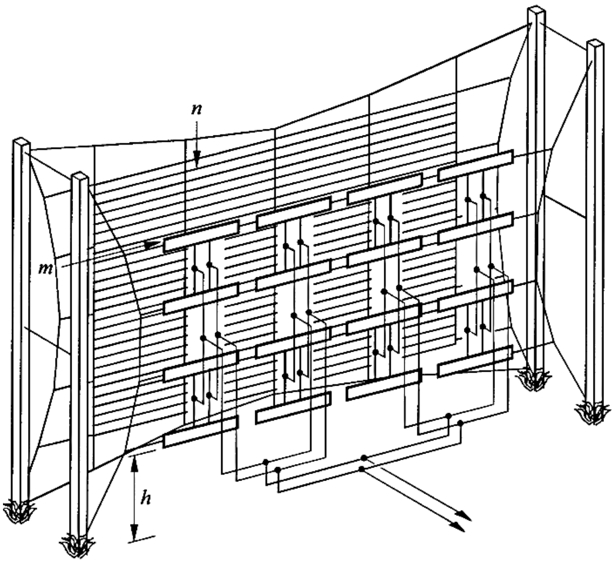

Figure 7. A multiband curtain array with centre-fed dipoles and an aperiodic screen reflector. Diagram reproduced from D010 Rec. ITU-R BS.705-1 with permission of the ITU

The RF feed to the 16 folded dipoles is achieved by successive feeder 'branching', both horizontally and vertically, so that the dipoles receive equal shares of power with identical phasing. Because the RF feed to each of the four stacks of centre-fed folded half-wavelength dipoles may be controlled at the relevant feeder-branching points, slewing is achieved by advancing the relative phase of each stack in equal steps. By this method, slews of up to ±30° are obtained before side-lobe problems are incurred and intermediate slew bearings of ±15° can be added if required. A photograph of the slew loops on a TCI array is shown in **Figure 8**.

Figure 8. Slew loops for one stack of dipoles on a TCI four-band array. The conductors are just copper 'plumbing pipes' but have the correct diameter and spacing, giving the correct impedance for the signal. Their length gives the correct signal delay for the particular slew bearing required. Photograph courtesy of Pete Bairstow and Babcock Communications

The principle of (progressive) slewing of a wideband array is illustrated in **Figure 9**.

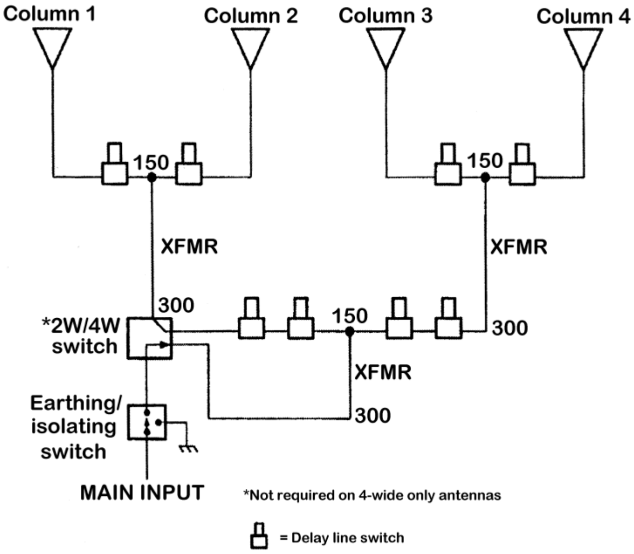

Figure 9. Schematic diagram of the HRS 4/2 or HRS 4/4 slewing system. Feeder impedance (150 or 300 Ω) is indicated at relevant points. The delay to the signal can be adjusted to each column allowing the beam to be slewed by up to 30° from the fundamental direction. The fundamental bearing is at 90° to the radiating curtain. The 2W/4W switch can be used to select full curtain (as shown in the diagram) or half curtain so that the beam-width can be changed. Diagram courtesy of Pete Bairstow and Babcock Communications

Conclusion

All the designs described so far have relied upon fixed support structures, guyed masts or towers, to fix the required boresight bearing. In the late 1980s a French/German consortium approached the selection of a bearing in a different way. In fact, the entire concept was turned on its head. Called Alliss™, after the two French transmitting sites Allouis and Issoudun (where installation was originally intended), an integrated construction housed just one sender (typically 500 kW) above which was a rotatable antenna assembly comprising a low HF band array on one side and a high HF band array on the other. **Figure 10** shows such an installation.

The French continue to use them at their HF complex near Issoudun where, on 'Google Maps', 12 Alliss™ facilities can be seen dotted around an area of countryside. In Germany there are installations at Nauen, near Berlin. The land use is minimal, which was probably a deciding factor in their installation. However, there still has to be provision of substantial mains electricity capacity to each site and programme delivery and control. In addition, if an Alliss™ cell fails with antenna or sender faults, then the scheduled service would have to be transferred to another cell but, of course, any desired bearing is available from this type of transmitter site.

Acknowledgements

The author is grateful to Dave Gallop G3LXQ for permitting use of his commentary, for proof-reading the original manuscript and offering suggestions and improvements. These amendments have been incorporated diligently.

In addition, thanks are due to Pete Bairstow and Babcock Communications for the use of his training slides and for his encouragement in the preparation of this article.

Next time

Dave Gallop, G3LXQ has kindly offered to produce the next ToTT, subtitled 'A Winter's Tale' which recounts a few days at Daventry.

Figure 10. Thomcast rotatable HF antenna. This antenna comprises two 'curtains' of rigidly-supported folded dipoles with a central reflecting screen. The white dipoles are shorter and work at higher frequencies than the darker coloured dipoles. The whole antenna can be rotated to 'point' in the required direction. Photograph courtesy of Pete Bairstow and Babcock Communications

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