Tricks of the Trade

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A 'Winter's tale' about a few days at Daventry and consideration of some of the related factors to be considered in designing and maintaining short-wave curtain arrays.

Figure 1. A bleak outlook through freezing fog at Woofferton. January 1979. Photograph by courtesy of Jeff Cant

I'm dreaming of a white Christmas

The severity of this last Winter has drawn comparison with the one 50 years ago. The snowfall started in earnest on Christmas Eve 1962, it was a White Christmas and the snow persisted for weeks during which travel was considerably disrupted. **Figures 1 and 2** give an impression of the bleak landscape of freezing fog and snowdrifts surrounding an HF transmitting station in severe winters.

The author had joined the BBC in 1962 and, like many other 'new-boys', his first posting was to Daventry transmitting station. Being a trainee, he had the Christmas holiday period off as leave and would be returning to a spell of day shifts and any other relief cover duties as they arose.

Instead, upon returning from the break, the author was told that he would be attached to aerials, working for GF Turner, a quiet, unassuming but very affable man who commanded respect by his knowledge and experience in antennas **[1]**. 'GF' was in charge of aerial maintenance at Daventry, and Bob Tyler was his doughty assistant **[2]**. They had the support of a rigging team who stoically worked hard and without complaint in all weathers, conscientiously keeping abreast of all the required maintenance. In addition, the riggers seemed to accept all 'half-cracked' ideas from the engineers whilst probably keeping their thoughts to themselves.

Also on site at the time were Ken Tink, from London Planning and Installation **[3]**, and Allen Herbert, both of whom were involved with the development of the new dual-band arrays. It was a very friendly and entertaining group who made the author feel quite welcome, with warm protective clothing and dry over-boots as well as Ken's dry waggish humour. All in all, the camaraderie did help to get the work done and, in fact, it could have been the words of a soothsayer, what had been told was correct because the author did become quite attached to aerials.

Figure 2. Drifting snow in Woofferton antenna field. January 1963. Photograph by courtesy of John Chantler, from the Jeff Cant archive

Not only were there hoar frosts and freezing fog making antennas, masts and rigging as well as the few trees on Borough Hill very photogenic, but also there had been much damage to dipoles and other wirework from the ice build-up on all surfaces. The additional weight on the arrays had been lifting the halyard balance blocks. These concrete counterweights, located at one end of each antenna bay, set a safe maximum tension in the triatic catenary from which the arrays are suspended, thus safeguarding the structure of the curtains as much as possible in times of excessive ice-loading and high winds. However, much of the copper-work was too frail to support extreme build-up of ice.

A lethal working environment was created at ground level where spears of partially-thawed ice would fall without warning from a great height at alarming speed. But, as soon as it was safe to work beneath damaged arrays, it was a case of 'all hands to the pumps' to release the aerials from service, lower the curtains, replace broken parts and raise them again without tangling at any stage.

Visual inspections were carried out across the site each morning, wherever it was safe to do so, any damage could be assessed using binoculars from ground level and the required parts prepared ready for the reinstatement work. Teams would have been fully employed pre-fabricating whenever possible.

The BBC had a 'filing system' for the miscellany of aerial parts which greatly assisted operations particularly if there was a race against time for fabrication and repairs.

SAP's and sub-assemblies

The mechanical design of BBC curtain antennas had evolved slowly since the Empire Service of the 1930s and there was obvious commonality between array components used at the several short-wave sites as well as copper-work sized for the frequency band to be used. For instance, insulators of various sizes and their end-caps, spacers, dipole end- and centre-fittings, wire-clamps and a host of mechanical parts were all given Standard Aerial Part (SAP) reference numbers or identified as part of sub-assemblies. As an example, dipoles could be pre-fabricated according to operating frequency in readiness for repair work or even for a new array project. Working drawings would then present almost a graphical version of a Mrs Beeton recipe calling up the required number of SAPs as ingredients with assembly diagrams showing the method.

The use of SAPs greatly eased re-ordering of large quantities to meet necessary specification requirements as well as simplifying the handling of parts and their storage on site. The size of SAPs varied from nuts, bolts, washers, split pins, *etc*. as well as small fittings such as line-taps and spacers, up to the spreaders used to maintain correct separation of the radiator and reflector curtains of an array, *i.e*. a nominal quarter wave for each broadcast band. However, a spreader for 49 m with an overall length of 41 feet and weighing *c*. 200 lb (or *c*. 90 kg) would, for convenience, have been manufactured in two identical halves to be bolted together when required on site.

With the increased use both of dual-band antennas and of switches in the groundwork, either manually operated or remotely by electro-pneumatic actuation, there was an increasing need for 'corners' in feeder runs. Bob Tyler devised a frame containing a right-angle bend with equal lengths of feeder whilst also maintaining correct phasing. Yet another sub-assembly, this was inevitably known as a Tyler-Frame.

Theory into practice

In the early design stages for a bay of curtains between two masts, drawings would be produced to show vertical loadings of the arrays to be suspended from the triatic catenary spanning the masts. Mechanical stress and force diagrams would be developed which could be translated into a working physical space diagram showing the complete bay of antennas in terms of component specifications and dimensions including the correct length of all support and straining wires. There is then a very good chance that the eventual array curtain would 'hang right' on site with only moderate tension applied by tie wires.

A generous safety factor is always necessary in the design of mast and array structures to ensure that the breaking load is well above the maximum stress which will be experienced in practice. However, the problem of ice is a difficult one. Ice formations up to a diameter of 2–3 inches on a 0.25 inch diameter wire have been experienced and, in addition to the dead-weight loading of ice, there is loading due to windage. A mast collapse at Rampisham, noted in a contribution to GP Lowery's collection of short-wave reminiscences **[4]** as occurring during the extreme winter of 1947, should be a warning against complacency.

There is no corroboration for this event by Pawley in his BBC engineers' bible **[5]** although he has recorded several similar incidents. However the contributor to Lowery's reminiscences was quite familiar with arrays and their support structures. He was the son of 'Jock' Cunningham, the aerial engineer at Skelton, and for 15 years lived with his parents in one of the farm houses on the site. Among some amusing memories, John Cunningham relates that, on a warm, still summer afternoon there was no more pleasant spot to be than with a good book on the top platform of the 300 and 325 foot high masts. He had not climbed them all but, by the age of 16, he had ‘notched’ up a good selection, and then his dad found out.

Reaching for the sky

The antennas used in the 1930s, 40s and 50s employed single vertical feeders, bottom upwards, to connect each element of a vertical stack of dipoles. However, in the desire for higher antenna gains as well as lower radiation angles to enable broadcasts to reach the far corners of the empire, the vertical feeders became longer as more dipoles were added at the top.

Assume, for simplicity, a '2-high' stack of elements, at the frequency where dipole spacing is an electrical half-wavelength. The impedance of the upper dipole will be 'seen' in parallel with that of the lower dipole and feeder current from the transmitter will divide equally between the elements vertically. Such an array, if in free space, would radiate perpendicularly or 'broadside' to the stack.

If the frequency of operation is now changed so that the feeder length is no longer an exact half-wavelength, the true impedance of the upper dipole would not be seen in parallel with the lower dipole and the feeder current from the transmitter could not then divide equally between the two elements, resulting in a vertical slew in the free-space antenna. The vertical slew resulting from the use of three, four, five, or six dipoles in a vertical stack fed in this manner would have been greater still because of the cumulative phase differences between top and bottom dipoles. Each of these various array formats has been utilised at BBC sites at some time in the past.

With his dual-band arrays developed in the 1960s, Allen Herbert introduced branch-feeding of dipoles in each stack to maintain correct current and phase relationships, a feature even more important in the more recent wide-band designs.

Serendipity rules OK!

The theoretical values of radiation angle given in the textbooks for different formats of curtain array are obtained by mathematical analysis of ideal circumstances. However, real-life take-off angles are also influenced by the lay of the land in the direction of intended maximum radiation. Daventry transmitting station was built on the site of an iron-age hill fort, eminently suitable for 5XX on long-wave, the first transmitter in service there in 1925. But, over the years since the introduction in 1932 of long-distance short-wave broadcasting, the copper tentacles have spread inexorably towards the slopes bounding the hill-top plateau.

Many HR 4/4 antennas were erected with their lowest dipoles one wavelength above ground level. But, for all long-distance curtain-type antennas, the radiated beam is not formed within the immediate near-field area but is likely to be the result of 'averaging' across acres of terrain in front of the array. Back-of-envelope trigonometrical sums suggest that, for long-distance broadcasting where take-off angles of five to ten degrees are required, reasonably level ground is necessary ahead of the array for at least 10–20 wavelengths, equating to approximately a kilometre at 6 MHz. Taking this into account, the take-off angles from Daventry were likely to have been lowered by the falling terrain surrounding Borough Hill which would counter, to some extent, the vertical slewing referred to above. This is not to recommend an attitude of complacency about the whole construction. The physical arrangement of array air-work and ground-work should follow as closely as possible the intent of the established theories in order to minimise cumulative departures from the intended, or predicted, antenna performance. But sometimes by happenchance one strikes lucky.

What has been achieved so far?

The HRRS 4/4/1.0 array format is still seen as a good solution to achieving long-distance broadcasting. By a range of ploys, the format has been greatly improved during its long history. The dual-band version introduced caged fan elements to extend the operating frequency range. The radiating stacks were coupled by branch-feeding so that all elements were fed equally and in-phase, overcoming the problems incurred by using frequency-critical half-wavelength feeder sections.

However, one weakness in the generic design of dual-band antennas having 'tuned' reflector curtains concerned the sometimes high strength of signal towards the reverse bearing, or back-radiation, occurring at certain transmission frequencies. This resulted from the method used for initial commissioning of each array. Reflector curtain stub tuning points would first be determined separately for the mid-frequency of each band, as in principle described for single-band arrays by Dave Porter G4OYX in previous 'Tricks of the Trade' articles **[6]**.

Bearing in mind that tuning would have been carried out at around a half- to a full-wavelength beneath the lowest dipoles of each stack, the relevant tuning points would have been odd multiples of quarter-wavelengths from the corresponding bottom dipole. The final setting adopted for minimising back-radiation from dual-band antennas was then, albeit a compromise, midway between the closest pair of tuning points obtained for upper and lower frequency bands but preferably as close to the vertical feeder as possible. In practice operationally, front-to-back ratios as low as 10 dB were measured at some operating frequencies, sufficient in some circumstances to cause interference in the service areas of other broadcasters.

The concept of wide-band antennas adopting half-wavelength radiating elements, successive feeder 'branching' and progressive slewing **[6]** brought the requirement for stronger support structures, in turn providing the opportunity to employ aperiodic mesh reflector screens. Self-supporting towers with cantilevered crossheads have been used in recent years for fixed antennas, allowing a reduced structure height to be used for a given antenna load, while the rotatable 'Alliss'-type of installation brings new rules to the game, such as a post-mill turning into the wind.

Nevertheless, Allen Herbert's dual-band antennas probably reached the limitations of the existing stayed masts at the short-wave sites in terms of head-loading and windage. But his work set the pattern for a new generation of antenna designs which were a valuable stepping stone to the more recent computer-modelled wideband arrays. Any further logical development at that time would have been constrained by the nature of the 20–30 year-old lattice masts.

The domesticated curtain array

Closer to home, the author found a commercially manufactured TV receiving antenna of a type very commonly seen in mainland Europe but not so in the UK.

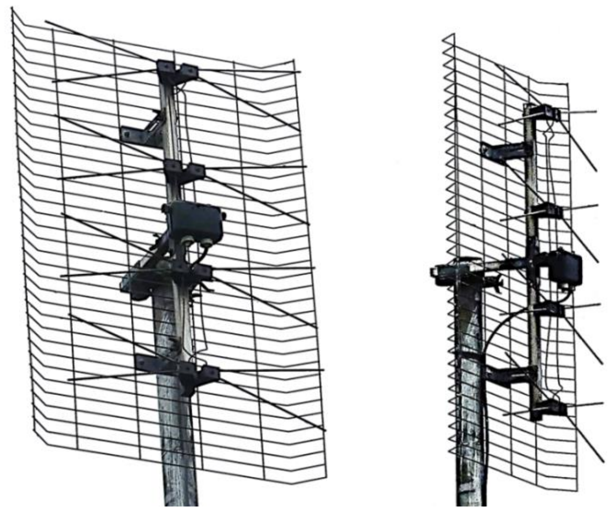

Figure 3. A Band 4/5 TV receiving antenna showing the layout of elements and the parallel line feeder

Known as a stacked bow-tie antenna in TV circles (**Figure 3**), it is clearly the domestic species of a broadside collinear dipole curtain array with an aperiodic mesh reflector screen. The reader will recall that curtain arrays comprise an arrangement of half-wave dipole elements which may either be centre-fed or end-fed, and which may be of a shape to make them less frequency-selective. In this case (**Figure 3**), two fan-shaped half-wave elements are end-fed 'in-line' at their adjacent apex ends using balanced feeder. This enables stacking of other similar element pairs to provide the required directional performance. Each element pair presents a high impedance to the feeder and so a parallelled stack of four pairs reduces the overall feed impedance by a factor of four. No doubt a small ferrite-cored balun-transformer is employed at the antenna termination box to finally match into unbalanced 75 Ω coaxial downlead.

It will be seen that a measure of compromise has been used in the feeder arrangement. Branched feeding is used between the inner two element pairs, from the middle outwards, while half-wavelength parallel line sections are employed for the top and bottom element pairs, each section transposed to maintain correct phasing. This arrangement allows all splitting and feeding to be achieved physically in a single plane, simplifying the mechanical structure of the antenna. Any compromise in vertical reception pattern across the UHF TV band is, at least, symmetrical.

Of strong mechanical design, this HR 2/4 antenna would also appear to be less attractive to birds than a long yagi-type. More usefully, it probably achieves a gain of around 12–14 dBi across the Band 4/5 frequencies.

Next time

Dave Gallop G3LXQ finds out if rhombic antennas can be used for high-power broadcasting and how one of the world's big broadcasters got on the air.

References

1. An Obituary to G F Turner appears at www.guardian.co.uk/theguardian/2008/sep/25/secondworldwar.military.
2. Bob Tyler was not known to be related to MWT engineer VJ (Vic) Tyler who devised the Tyler high-efficiency circuit used in the BD228A transmitter at Brookman's Park. See Tricks of the Trade in *Signal* 2010, **17**(November), 18–24 and 2011, **18**(February), 22–30.
3. Ken Tink went on to Radio Engineering at Broadcasting House where he was involved in the provision of studio control desks for the newly numbered national networks, one of the consequences of the Marine Broadcasting Offences Act 1967.
4. Captain John Cunningham MA CEng FIEE (the aerial engineer's son). 'Skelton-Home Sweet Home'. Section 4 of 'Skelton Transmitting Station 1942 to 1998 – Over half a century of short wave broadcasting'. Written and compiled by GP Lowery in 1990. Updated by Chris Garlick in 1998. Pictures provided by Russell W Barnes in 2007. Edited for bbceng.info by Martin Ellen in 2007. http://www.bbceng.info/Operations/transmitter_ops/Reminiscences/skelton/sk1.htm
5. Edward Pawley OBE, MSc(Eng), CEng, FIEE. BBC Engineering 1922-1972. BBC Publications. 1972. ISBN 0 563 12127 0
6. Dave Porter G4OYX. Tricks of the Trade, *Signal*, 2013, **27** (May), 33-37