Tricks of the Trade

Dave Porter G4OYX and Aubrey McKibben

In recent ToTT we have been looking at the different antenna systems as used in the UK and abroad for MF and LF broadcasting. In this issue of *Signal* an antenna installation unique to a particular BBC station is considered. G4OYX has been most ably assisted in this piece by a significant contribution from Aubrey McKibben who now lives in Australia but, as will be seen, has first-hand knowledge of this set-up near Blaris in Northern Ireland.

Aubrey can now take up the story. He writes:

Why am I writing this?

It might seem rather odd that an article on Lisnagarvey Transmitting Station could possibly turn up from the land 'down-under'. However, all will make more sense in light of the fact that my parents were born and lived in Ulster for some years. I was actually born in what is now Zimbabwe but, as a family, we returned to Ulster in the mid-1950s. This was just long enough for the magnificent 'Blaw-Knox' styled tower at the Lisnagarvey site (**Figure 1**) to inspire great wonder in a young boy's memory and hence start a lifelong interest as to the station's history, and a career in electronics.

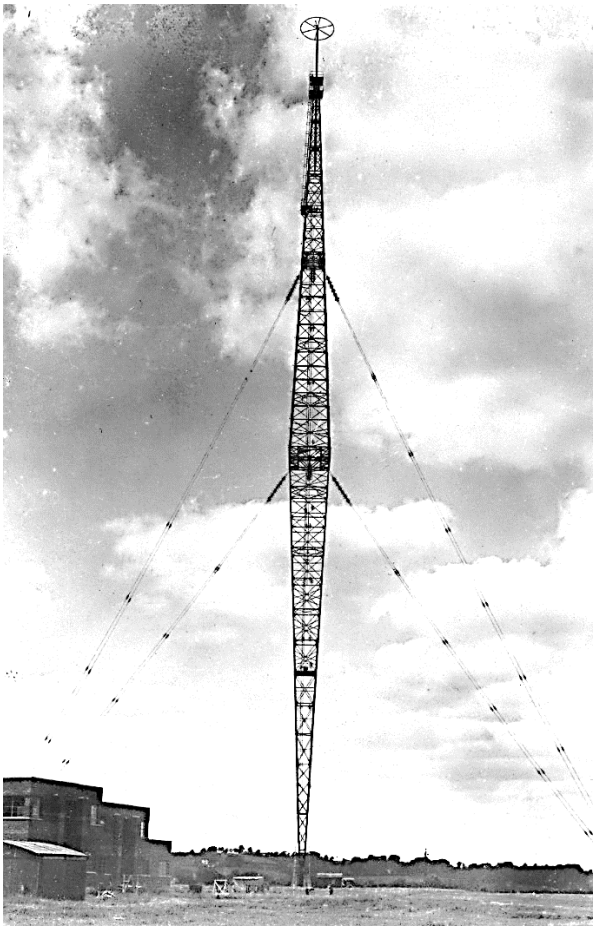

Figure 1. Lisnagarvey 'Blaw-Knox' styled tower

This interest was given a massive boost when, in 1968 at age fourteen, I was fortunate enough to join my mother on a return trip to Northern Ireland. Needless to say, a pushbike was keenly ridden out to the site. It was only my 'Aussie accent' and boyish appearance that got me past the front entrance, as Ulster's political turmoil of the late sixties was well and truly under way. An engineer spent some considerable time giving me a tour of the whole site, allowing me to absorb most of its former glory before the major changes to sites such as this that started for the BBC in the 1970s. Indeed, I was fortunate to see the original 'Marconi' transmitter still in use. It had been installed for the March 1936 opening and was still running well; up to the mid-1970s, in fact.

In the 1980s, I shared some brief correspondence with the then-current transmitter manager, Norman Marsden G4BQN and also with some other BBC people in England. This all allowed me to accumulate further and add to what little history I have on the station. It is heartening how it has all 'added together' though.

So it is that someone 'at the antipodes' would be able to perhaps add to the history of one of the first transmitting sites of the 'Regional Scheme'.

Opening ceremony

The BBC 'Lisnagarvey Transmitting Station' was opened on the 20th March 1936 in a rather overpowering ceremony held, unbelievably, at the actual transmitter site. It was attended by various high-ranking BBC and local dignitaries such as AC Norman, Chairman of the BBC, Sir John Reith, Director General and BBC Regional Director GL Marshall. Civil dignitaries included Lord Craigavon, Moderator of the Church of Ireland, the Archbishop of Connor and many others. In today's world, a gathering such as this is inconceivable for the opening of a 'mere' broadcast transmitter. However, it must be borne in mind the political significance of Northern Ireland as part of the United Kingdom and the demand for broadcasting at the time.

The Regional Scheme

The station was to be part of the BBC's Regional Scheme conceived by PP Eckersley in 1924, the aim of which was to give listeners a choice of programmes at good signal strength and covering most of Britain. Transmitters needed to provide good reception on inexpensive receiving apparatus within about an 80-mile radius of the site. Northern Ireland became the sixth region to have a

new high-power transmitter installed. With its 100 kW Marconi Class B high-level modulated transmitter, Lisnagarvey was the most powerful medium-wave transmitter in the UK at time of commissioning. Prior to this, Belfast had been served by a low-power 1 kW transmitter (callsign 2BE) operating from the Belfast Power Station, which closed the day of Lisnagarvey's opening.

The new high-power transmitters produced very high local field strengths 'blanketing' the wireless front ends of the era, meaning that nearby listeners had difficulty tuning in any other stations. High-power sites like Lisnagarvey were, therefore, best located in sparsely populated areas.

The site development and considerations

Five sites were considered and the townland of Blaris, just outside the 'Irish Linen' town of Lisburn, was chosen, thereby putting the station nine miles southwest of densely populated Belfast. A 'Marconi' 100 kW transmitter was ordered in mid-1935 and Lisnagarvey was to be distinguished by the erection of what was to become the UK's only 'Blaw-Knox' style of mast. The massive new mast radiator aerial had an overall length of just over 500 feet and made a strong visual statement in the local countryside (**Figure 1**). It still stands out boldly against the sky and one is strongly impacted by its 'cigar-shape', being considerably thicker in the middle than at either at either of its ends – like two elongated diamonds.

The 'Blaw-Knox' mast and the 'anti-fading' characteristic

From an engineering point of view, the *big fat middle* of the Blaw-Knox mast, just near the *point of maximum aerial current*, seems just ideal, as any radio engineer will confirm. Its original design frequency was 977 kHz and the overall physical height of the mast at commissioning was just a little over 500 feet.

It was commissioned as the BBC's first anti-fading aerial. The anti-fading characteristic is often associated with the strong visual impression that these Blaw-Knox shaped radiators impose upon one's psyche. Ostensibly, it seems completely logical that the radiator's complex and unique mechanical shape would be the reason for such desirable anti-fading properties. Incredibly, this is not the case.

In fact, no aspect is more misunderstood about the whole Lisnagarvey site than this very point. Any anti-fading characteristics that the tower may have had nothing in the least to do with its cigar shape. In fact, the 'unique shape' of such radiators was later proven to actually degrade their performance instead of enhancing their characteristics.

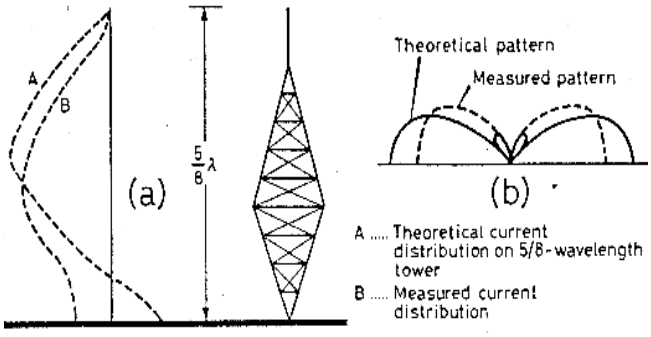

Figure 2. (a) The non-sinusoidal current distribution that was found to occur with towers of non-uniform cross-section. (b) Field strength measurements made on WABV from aircraft that showed how the vertical radiation pattern differed from theory (*Rad. Comm*. January 1986)

The true reason for the mast's anti-fading characteristic

One factor alone imparted the anti-fading characteristic: quite simply, its electrical length, which was adjustable. It was the first BBC vertical radiator that had an easily adjustable electrical length. At this point of the story, it is helpful to consider the evolution of the vertical broadcast radiator with respect to anti-fading characteristics.

In December 1924, Stuart Ballantine of the Harvard University Physics Department released two historic papers to the Institute of Radio Engineers (IRE). His second paper is particularly relevant because he specified a height of 0.64 wavelengths (accepted as 5/8λ or 225° of a wavelength) for producing the maximum radiation in the horizontal, broadside direction.

Towers henceforth erected at Ballantine's suggested height were to prove his theory of increased radiation in the horizontal direction as he had predicted.

Confluence of two factors

Due to a most unfortunate confluence of two hitherto unknown and unrelated factors, the broadcasting industry soon uncovered problems with the early 5/8λ Blaw-Knox towers; these were 'Fading Ring' and 'Smaller Service Area'. A defined severe fading ring existed within the expected coverage area so, at 5/8λ, the towers were too tall.

The first discovery was that there existed an unwanted high-angle minor lobe at 58° elevation to the main lobe (**Figure 2**) which caused a severe fading ring within what should have been the station's coverage area.

To quote Maxwell's book "Reflections" **[1]**, "the radiation from this high angle lobe returned to ground from the ionosphere at night. At the distance where the signal from the ionosphere was the same strength as that of the direct ground wave of the major lobe, wave interference occurred between the two signals and caused fading."

Further study disclosed that maximum ground-wave field gain and best anti-fading characteristics would not be obtained at the same height. The 5/8λ height gave the best field strength but had the secondary lobe of high-angle radiation.

As Maxwell states in his book **[1]**, "The solution to the problem was the reduction of the tower height to 0.528λ (190°), which nearly eliminated the minor lobe, while reducing the radiation level by only 1.03 dB."

The service area was smaller than expected *i.e.* a departure from expected theoretical field patterns (the unique shape of the Blaw-Knox changed expected field patterns).

This second discovery was revealed as a result of George Brown and Herman

Gihring (members of the Broadcast Engineering Section of RCA) responding to a request by WCAU staff in 1934 to 'investigate the poor performance' of their big 500-foot Blaw-Knox tower. Brown convinced Gihring to join him in constructing and testing a scaled-down model of the WCAU antenna. Their model investigations were to prove conclusively that these massive 'mechanical structures' would never yield the expected theoretical field patterns without some modification. It all boiled down to the shape of the tower. As he put it: the bulge in the centre was the culprit as it modified the current distribution along the radiator's length.

The dimensions and design criteria specific to Lisnagarvey

The overall length of the main tower body was 475 feet to the apex of the top elongated pyramid, then there was a further extension; a sliding top mast which had a maximum height of 75 feet. Furthermore at the top of the mast was a capacity ring mounted on a supporting mast, (**Figure 1**) which could be raised or lowered to alter the electrical height of the whole mast.

This means that, overall, the length of the mast was very close to λ/2 in length physically. However, because of the capacity hat, the electrical length of the radiator would, by very design, have been considerably longer than the visible (and easily verifiable) physical half wavelength.

So, this adjustable electrical length was the only factor imparting any of the magic anti-fading characteristics, despite the mast's interesting cigar-shaped appearance. It would have allowed engineers to experiment with the electrical length, thereby fulfilling the overall aim of installing such a massive and expensive antenna, *i.e.* to obtain the greatest coverage area.

To quote from the 'BBC Annual of 1936': "The height of the top mast is used to adjust the electrical length of the mast to suit the operating wavelength".

What electrical height would they have been experimenting with prior to commissioning? In the months prior to Lisnagarvey's commissioning in March 1936, engineers must have spent quite some time adjusting the sliding mast for what they considered to be the best coverage area. Blaw-Knox towers in the USA, on which Lisnagarvey was very much based, had a height in conformance with Ballantine's 'optimum-height' formula, which was 5/8λ.

RCA's George Brown had been intimately involved with the early radiators and, therefore, had authority to state with some accuracy: "Conventional antenna theory of the period [the early 1930s] had shown that for the largest service area free of night-time signal fading, the transmitting antenna should be 59% of the operating wavelength in height".

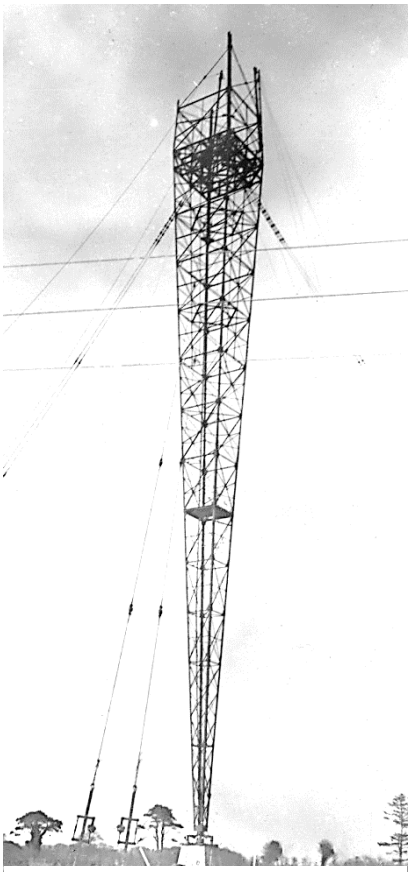

Figure 3. Part-built Lisnagarvey tower with the additional stays in place

The early towers of WSM and WLW were exactly 59% of a wavelength long when first erected, being shortened in later years. It may well be, therefore, that BBC engineers based their original experiments on 59% of a wavelength as Lisnagarvey's nominal electrical length, as Brown described. Indeed, would BBC antenna engineers have been aware of the need to use a radiator adjusted to an electrical length of 190° (53%), considering the context of a mid-thirties timeframe?

In his book published in 1952 **[2]**, Edmund Laport states: "By about 1934, the modern broadcast radiator had evolved to its present state". This statement seems to indicate that knowledge of the requirement for a 190° radiator may have been known by the time the Lisnagarvey radiator was in the planning stages? Without access to the station's original engineering documentation, it is difficult to know precisely what 'electrical wavelength' they were experimenting with. Nevertheless an accurate range of wavelengths can be still be extrapolated from available information. For instance, we have determined that the tower would have been electrically longer than a half wave (180°) and likely to have been adjustable to be as long as a 5/8λ electrically. In the United States, it appears that 190° modifications were not carried out to the original 5/8λ Blaw-Knox towers until the late 1930s.

Referring to the WSM Blaw-Knox still standing in Brentwood near Nashville, Chief Engineer Watt Hairston states **[3]** that, by 1939, it was determined the tower was electrically long. Note that the WLW 5/8λ *tower* in Mason Ohio was also modified back to 190° at some stage.

The timeline for commissioning the Lisnagarvey radiator

It is now known that the site plans for the Lisnagarvey site would have been under way by late 1934, considering the extensive mechanical and electrical engineering required (**Figure 3**). Brown and Gihring's paper criticising the design of these radiators was only released in April 1934 by which time the Lisnagarvey radiator may have been decided upon. The paper's findings may have taken some time to disseminate within the broadcast engineering industry worldwide; therefore, BBC engineers were most likely unaware of this most recent of papers.

The very least one can assume is that there were not enough reasons for the BBC to continue using such elaborate towers. The Lisnagarvey mast was expensive to build and undoubtedly field strength tests indicated a lack of any special attributes over normal straight towers. Perhaps they even discovered deficiencies with predicted field patterns as predicted by Brown and Gihring.

Figure 4. Some promotional literature in the US

With time, Brown and Gihring's 1935 findings would have eventually made it into the hands of BBC Research Department for them to mull over before ordering any more towers of the same design for the BBC. Indeed, when one considers all the factors – very high erection costs, confusing and maybe disappointing field pattern results and, in time, papers proving inherent design flaws, it is easy to understand why the Lisnagarvey radiator was not repeated in the UK.

The BBC's first and last Blaw-Knox twin pyramid mast

As one BBC engineer commented to the author: "As far as I can recall, marketing had quite a lot to do with their popularity in the United States. The Blaw-Knox company really pushed their towers **(Figure 4)**. I'd be prepared to bet that someone believed the hype and we tried one. It would also be logical to assume that BBC Research Department checked the performance – and that would be why we never bought any more (rather a lot of unnecessary steel work)."

It's interesting to note that the Lisnagarvey style of radiator was the only one of its type to be erected in the whole of the UK. Burghead, the Scottish Regional Site commissioned about seven months later, had a 'normal', straight-sided radiator.

Lisnagarvey today

A somewhat sad-looking, decapitated radiator still exists today on the original Lisnagarvey site. About a quarter of the top pyramid of the mast has been removed as the result of a number of frequency changes at the station over the years. Without this severe pruning, the radiator would be much too long for its present electrical wavelength/frequency. This would increase the emission of unwanted high-angle sky-wave radiation, thereby reducing the desired coverage area.

Figure 5. Lakihegy Tower

It perhaps also demonstrates that RF antenna engineers have absolutely no sense of aesthetic sensibility, having initiated such barbarism to this exceedingly grand old lady from 1936.

Blaw-Knox towers worldwide

Many Blaw-Knox towers, of both conventional (uniform cross-section) and diamond design, remain in use in the United States. Few of the diamond towers were built and several remain; all transmit AM radio signals:

Nashville, Tennessee: 808 feet (246 m); originally 874 feet (267 m); tower located in Brentwood, Tennessee.

Cincinnati, Ohio: 747 feet (227 m); originally 831 feet (253 m); tower located in Mason, Ohio.

Charlotte, North Carolina: three towers, 428 feet (130 m) each (one original, two reproductions from the original plans after the originals were destroyed in a hurricane).

Manchester, New Hampshire: 400 feet (121 m)

Columbus, Ohio: 380 feet (116 m)

The following Blaw-Knox diamond-cantilever towers remain standing in Europe:

Lakihegy Tower (constructed: 1933) 1030 feet (314 m) Budapest-Lakihegy, Hungary **(Figure 5**)

Vakarel Transmitter (constructed: 1937, 1158 feet (353 m) Vakarel, Bulgaria

Stara Zagora Transmitter at Stara Zagora, Bulgaria (dismantled 2014)

Riga LVRTC Transmitter at Riga, Latvia

Comment from G4OYX

G4OYX thanks Aubrey for that well-researched and documented piece. Others who have read it have commented and their submissions are shown below starting with one from G4OYX:

There was actually another BBC site with a Blaw-Knox base-insulated tower. It was not the style of LIS though, the tower was of the shape more akin to a pylon, certainly not the double pylon of the Lisnagarvey configuration but rather like the four 1929 towers at Brookmans Park. It was erected at Droitwich in the Second World War on the US Lease-Lend Program and used on 1013 kHz and 583 kHz. After 1950 the tower was used on 1088 kHz at 150 kW and the matching to the 120Ω feeder required just a few µH of coil in series with only minor adjustment for the 36 kHz move to 1052 kHz in 1972.

The tower was dismantled in the mid-80s when the two MF masts were erected to the north of the site to gain directivity more easily.

John Peacocke writes:

The part played by Lisnagarvey staff in the critical period of the Ulster (Electrical Power Station) Workers` Strike in 1974 should get a mention. The Marconi transmitter was, for much of the country at certain times, the only communication between Government and people who were trying to keep businesses, farms and schools alive. This was because the high-powered diesel alternator and MW transmitter could be kept going and could always be received on battery portables. Engineer [name removed] was effectively locked in for days (and nights) and hostile pickets made it very unpleasant for the engineers who came to relieve him.

(Note from G4OYX: I was on a UHF Course at BBC Woodnorton in December 1974 with said anonymous engineer and he was grateful to be away from 'The Troubles' and the site for a while)

I (John Peacocke) was the Site Engineer at Lisnagarvey in 1981, when BBC TCPD set about demolition of the old original transmitters. The Marconi railway carriages and crypt full of cooling coils were junked and a BBC Doherty design supplied its replacement. The mighty H&W marine diesel was dragged away to finish its days in a sawmill. The high-tension rotary generator was cut up for its brass and copper. Harris 10 kW units were imported and installed with a new two-masted centre fed T-array for the other MF services. The Blaw-Knox mast was jacked up and its ceramic high voltage supporting insulators were washed and put back again. The result was a station which required a very minimum of maintenance, with a resident mobile maintenance team who serviced TV and FM transmitters in conjunction with a similar team based at Sheriff`s Mountain, Londonderry.

The place was full of ghosts and echoes, there were archaeological moments such as a magpie`s hoard of small gold and silver items and a highly polished light switch which for generations had afforded a periscopic view of the senior engineer's approach. There was a glorious Imperial-themed sculptured facade to the building with flying boat and steel tracery. I believe it was taken away subsequently and preserved. I worked for a while in Northeast England and I can confirm that the sky wave coming from Lisnagarvey did actually provide useful coverage there. I recall that the BBC Northern Ireland material in the 1960s was very much in plummy received pronunciation and would have been quite intelligible anywhere in Britain. Not really so anymore….

Kevin Halpenny writes:

Aubrey McKibben's engineering recollections, specifically the Lisnagarvey MW transmitter, have just recently been forwarded to me and I certainly remember it well. I grew up in the 'fifties living in rural Northern Ireland about 40 miles from the site. My family were big radio fans and I remember clearly the local programmes especially the news and the very popular soap "The McCooeys" broadcast on Saturday evenings.

The mast was pointed out to me any time we drove past it en-route to Belfast and the signal was really strong and broke through if the car radio was on another frequency.

The only snag was that the transmission was shared with the north of England and, for example, the local news was preceded (or followed, I'm not sure) by "News from the North" *i.e.* the north of England, with accent and content accordingly theirs. I presume this sharing was due to a shortage of frequencies, or post-war economies of some sort. I remember the announcement of the shift to a new frequency and the programme sharing ended. At the same time, the mast was shortened and its elegant cigar shape was gone.

(Note from G4OYX: The Lisnagarvey mast started on 977 kHz with capacity top-hat loading and, while during the war the mast was on 767 kHz as part of the Northern Synchronised Group, the subsequent frequency changes have been upwards, *i.e*. post-war in 1946 to 1050 kHz and, after March 15th 1950, to 1151 kHz shared with Stagshaw. After the closure of the BBC relay on 1295 kHz at Norden in West Germany in November 1962, the 1295 kHz channel was transferred to Crowborough for European Service at 600 kW releasing 1340 kHz that Aspi had previously used. 1340 kHz was used by Lisnagarvey from January 1963. However, as a holding operation, Brookmans Park used it at 20 kW from November 1962, still with BBC European service until the official Northern Ireland Home Service start date at Lisnagarvey. This operation was presumably to ensure that what could have been a blank clear channel was not seized upon by another broadcaster – such were the politics of MF at the time. 1341 kHz is in use now at 100 kW from a pair of MWT B6034 50 kW transmitters.)

References

1. MW Maxwell. *Reflections: Transmission Lines and Antennas*. American Radio Relay League, Newington, CT.1990.
2. EA Laport. Radio Antenna Engineering. McGraw Hill Book Company Inc., 1952.
3. Courtesy of Jim Hawkins' Radio and Broadcast Technology page: http://hawkins.pair.com/blaw-knox.html

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