Tricks of the Trade

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Readers of the last ToTT **[1]** (The Blaw Knox tower at Lisnagarvey) may recall that mention was made of a second Blaw Knox tower in use by the BBC. It was at Droitwich and was erected in the Second World War on the US Lease-Lend Program and was used on 1013 kHz and 583 kHz. After 1950, it was used on 1088 kHz at 150 kW. For this article, reference is made to the line in [1] – "it was used on 1013 kHz and 583 kHz"; what is of interest here is that signals on *both those frequencies were radiated from it simultaneously*.

Two into one will go!

As far as can be established, this was the first time in the UK that a combining technique for a dual channel antenna had been employed. In 1946, Droitwich found itself in the position of having three services to transmit, rather than the two for which it had been designed. The transmitter site is actually at Wychbold and was not particularly large and consequently there was not any provision at the time for a separate, third, antenna.

The 350-foot high Blaw Knox mast was 'bridged' on 25th September 1946 and at 593 kHz the driving point impedance (dpz) was measured at 13–j2 Ω, while at 1013 kHz it was 178+j47 Ω. The 25 kW transmitter for 583 kHz was (most likely) one of the pair of 150/200 kW MWT Class B-modulated units called High Power Medium Wave (HPMW) in a separate building (OSE6) erected during the War. OSE6 was on the opposite, south side, of the antenna field and had been on 1149 kHz at 400 kW. The feeder was a 120 Ω open 12-wire coaxial type. For 1013 kHz, the pre-war 5GB 50 kW MF unit was used and had a 5-wire 300 Ω open-wire coaxial feeder.

Figure 1 shows the circuit diagram of the antenna tuning hut (ATH) components as provided by the BBC Design and Installation Department.

Rejectors

Consider a situation where an antenna serving two transmitters, the HPMW transmitter on 583 kHz (BBC Third Programme) and a 5GB transmitter on 1013 kHz (BBC Home Service), is located close to the antenna of a transmitter producing 150 kW at 200 kHz (**Figure 1**).

L3 and L4, in conjunction with C3 and C4, both 2000 pF, comprise a 200 kHz parallel tuned circuit rejector in series with the antenna (**Figure 1**). This is required to prevent local pick-up of the high power 150 kW 200 kHz radiation finding its way on to the anodes of the MF services transmitters. It is known as 'throw-in voltage' and its existence was checked for on the MF transmitter anodes using a valve voltmeter. It is generally accepted that 10 V peak-to-peak is the maximum that can be tolerated before RF cross modulation products are generated on the MF transmitters and re-radiated.

For the 25 kW Third Programme transmitter on 583 kHz, a rejector comprising L2 and C2 (1500 pF) and resonating at 1013 kHz, keeps the output of 5GB transmitter away from the anodes of the HPMW transmitter.

For the 50 kW Home Service on 1013 kHz, a rejector comprising L5, L6, C5 and C6 (both capacitors 2000 pF) and resonating at 583 kHz, keeps the output of the HPMW transmitter away from the anodes of the 5GB transmitter.

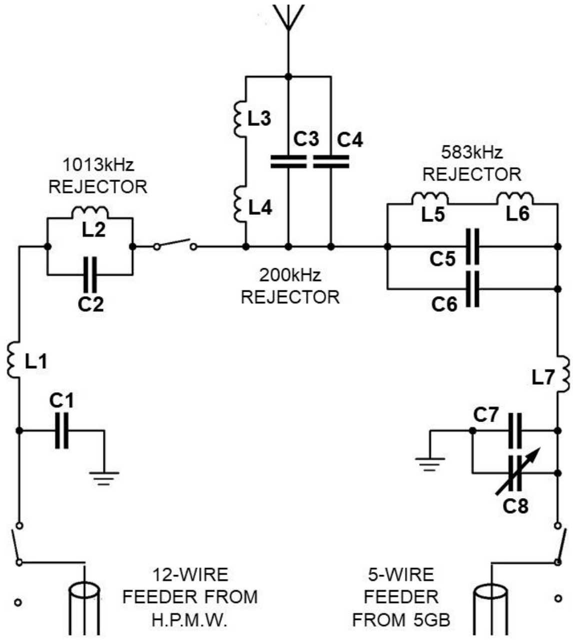

Figure 1. Circuit diagram of the ATH components

L-Matches

The 120 Ω feed from the HPMW transmitter needs to be matched to the antenna: L1 and C1 (6600 pF) are configured as an L-match downwards transforming the 120 Ω feeder impedance to that of the antenna *via* the residual reactive components of the rejectors. Below 1013 kHz, the combination of L2 and C2 behaves as an inductor and the combination of L3 and L4 with C3 and C4 behaves as a capacitor.

Considering next the 300 Ω feed from the 5GB transmitter, L7 with C7 and C8 are again configured as an L-match downwards transforming the feed impedance to that of the antenna *via* the residual reactive components of both rejectors; both L5 and L6 with C5 and C6 and the 200 kHz rejector behave as series capacitors as they are both resonant below 1013 kHz.

The Copenhagen Plan came into force at 0200 on 15th March 1950 At Droitwich, the Light Programme transmitter in OSE6 building, now known as HPLW (High Power Long Wave), came into service at 400 kW on 200 kHz and the 5GB transmitter radiated the Home Service running 50 kW, after being wave-changed from 1013 kHz to 1088 kHz. Work to convert the 150 kW 5XX transmitter from 200 kHz to 1088 kHz started immediately and, on June 25th, it became the main Midland Home Service transmitter running 150 kW, with the 5GB transmitter now acting as a reserve.

The Third Programme was transferred to an ex-Forces 20k W transmitter as a temporary measure on 647 kHz until the Plan was fully implemented. The Third Programme eventually left Droitwich on 8th April 1951 and was taken over by the new 647 kHz, 150 kW installation at Daventry, where it remained before returning to Droitwich in November 1978 on 1215 kHz.

Post-War stagnation on MF in the UK

There will be many VMARS members who recall that, from the early 1950s after the Copenhagen Plan, that the UK use of the MF band was very staid and very few changes were implemented in terms of transmitters on the air and frequencies used. The BBC occupied the UK-assigned high power channels and most of the former Regional sites had at the most a two frequency operation for Light and Home services with separate antenna systems. Solo sites catered for the Third Programme and that was that.

It was only after 1967, with the increased use of 1214 kHz for the Radio 1 service, that Droitwich again transmitted on three frequencies and the 30 kW service was run using what had been the reserve 1088 kHz antenna from twin parallel wires hanging off a triatic from the southern mast with the mast itself being a parasitic reflector to prevent too much radiation in the south-westerly direction.

BBC and Independent Local Radio

At the start of the 1970s with the introduction by the Government of licencing for local commercial radio, the Independent Broadcasting Authority (IBA) was created out of the Independent Television Authority (ITA). One of its first remits was to engineer local radio services. The BBC already had a few local stations but only on VHF/FM. At the time, there was a perceived need for the Independent Local Radio (ILR) and BBC services now to be simulcast on MF and FM.

Whilst the early ILR city MF sites were solo-service sites *i.e.* not shared with the BBC, there came a time when site sharing on MF became necessary. This engineering facility site-sharing was not new as, since the start of UHF TV services in 1964, the BBC and ITA shared the sites on a landlord and tenant basis so, for example, at Sutton Coldfield, BBC was the landlord and ITA tenant and at, say, Winter Hill, BBC was tenant and ITA landlord – good engineering common sense.

Tees, towers, masts

The IBA had used the 'industry standard' insulated base-fed guyed mast at many of their ILR stations as it was economic to install and required little maintenance. As a single channel radiator, it provided a reasonable load impedance when over 60° high (where one wavelength is 360°). At lower heights, sideband cutting can be noticeable and seasonal ground conductivity can lead to earth mat impedance instability.

Self-supporting tower radiators were not used by the IBA since their capital cost was considerably higher than that of a guyed mast of comparable height. The fact that a tower occupies a much smaller site area than a mast and its stay-blocks is of little advantage at MF since both require the installation of a large copper wire earth mat, typically 100 m in diameter. However, for dual or multi-frequency use, towers may well be preferable as their larger cross section results in their load impedance being less frequency-sensitive.

The low power, local radio 'Tee' antenna consists of a pair of vertical copper wires typically spaced 800–1000 mm apart, feeding the centre of a similar pair of conductors suspended horizontally between, but insulated from, a pair of supporting masts. The masts themselves are normally open-circuited at their bases, being supported on base insulators. This minimises the flow of RF current in the masts themselves – assuming they are electrically short, which is normally the case. The Tee antenna produces a nominally omnidirectional horizontal radiation pattern and the groundwave radiation is vertically polarised.

For MF, the Tee has the major advantage of requiring a much reduced height compared with that needed by an unloaded mast or tower. The electrical top-loading produced by the top horizontal conductors shifts dramatically the current distribution on the antenna. The result is that the resonance point, and thus the dpz, is shifted downwards in frequency compared to a mast of the same overall height. For example, the resonant frequency of a 45 m mast is about 1370 kHz but it is 820 kHz for a 45 m Tee antenna. For a mast to be resonant at 820 kHz, it would need to be about 75 m high.

It is interesting to note that two 45 m masts are needed for a Tee, complete with stays, base insulators and stay blocks. This represents more metal and hardware than would be needed for a 75 m mast to achieve the same resonant point. However, the Tee results in increased bandwidth of the system and so its ability to cope with two or more frequencies simultaneously.

By 1975, the BBC had Tees in service running on up to five frequencies. Lisnagarvey was a particular higher power example and was by 1978 taking four services (on 720, 909, 1089 and 1215 kHz) each running 10 kW to a single *c*. 45 m 4-wire Tee antenna.

High resistance and reactance slopes across the pass band of each channel degrade the overall VSWR performance and the factors that increase these slopes are

- antennas with steep impedance characteristics – caused by electrically thin elements or shunt feeding
- rejectors with large L to C ratios
- operation at comparatively close frequencies.

These problems can be compounded if planning restrictions prevent a structure based on technical requirements being used and a smaller one has to suffice. The IBA documented a case study of a dual frequency antenna system in use at Littlebourne, near Canterbury. Here, the lower frequency of 603 kHz was allocated for ILR with the BBC on 774 kHz. Owing to planning restrictions, a considerably-lower-than-ideal mast height had to be used. The structure chosen was a base-fed mast 81 m high, triangular in cross section and slim, having a 390 mm face-width. Electrical top-loading was not used. 81 m corresponds to 58° at 603 kHz and 75° at 774 kHz. The dpz was 15–j78 Ω at 603 kHz and 25+j30 Ω at 774 kHz.

Using these impedances as the basis for the diplexer design, it became apparent that the low dpz at 603 kHz would give rise to sideband cutting. Without any form of pre-matching and using rejectors with standard L/C ratios of 10,000 Henries/Farad and Qs of about 300–500, a VSWR of not better than 2.7:1 could be expected at the lower channel's sideband frequencies. The performance at the higher channel frequency would be better since the dpz at 774 kHz is more favourable.

Much improved performance at 603 kHz was achieved by transforming upwards the dpz before presenting it to the output of the 774 kHz rejector. This was achieved by adding a 12 µH inductor in series with the antenna to increase the net positive reactance at the 774 kHz channel, while maintaining a small negative reactance at 603 kHz. A parallel L/C combination of 4 µH and 12,500 pF was then placed in shunt so as to transform the resistance of both frequencies to higher values. This L/C combination is a low-Q circuit, the resonant frequency of which lies between 603 and 774 kHz. At the junction of the 12 µH coil and the parallel L/C combination is connected the rest of the circuitry. It is essentially as used at the Droitwich 1946 diplexer with L/C matching for the 603 kHz and a Tee network for 774 kHz.

Quite what could have been required at Droitwich in 1946 if the Blaw Knox tower had not been such an accommodating antenna in terms of bandwidth by virtue of its height of 350 feet and substantial base area, remains a mystery.

Offshore use

The IBA published data **[2]** on Littlebourne seemingly made its way on to the Radio Caroline Ross Revenge vessel where, in the mid-1980s, Peter Murtha G3ZGO (a.k.a. Peter Chicago) made a similar ATU incorporating comparable pre-matching, which he named 'The Animule', to diplex up to 35 kW of 963 kHz and 5 kW of 558 kHz on to the 300-foot high tower.

Redmoss MF near Aberdeen

Figure 2 shows the combining arrangements used at Redmoss near Aberdeen, where the outputs of six transmitters on 693, 810, 990, 1089, 1215 and 1449 kHz were combined with powers in the range 2–5 kW. It would appear that acceptors had been used on some legs rather than rejectors and provision had been made for possible spurious outputs at 1825 and 1332 kHz to be eliminated. The top of the Tee antenna appears to be a four-wire box section, no doubt to improve the bandwidth and certainly there was a need for it at this site with these channels.

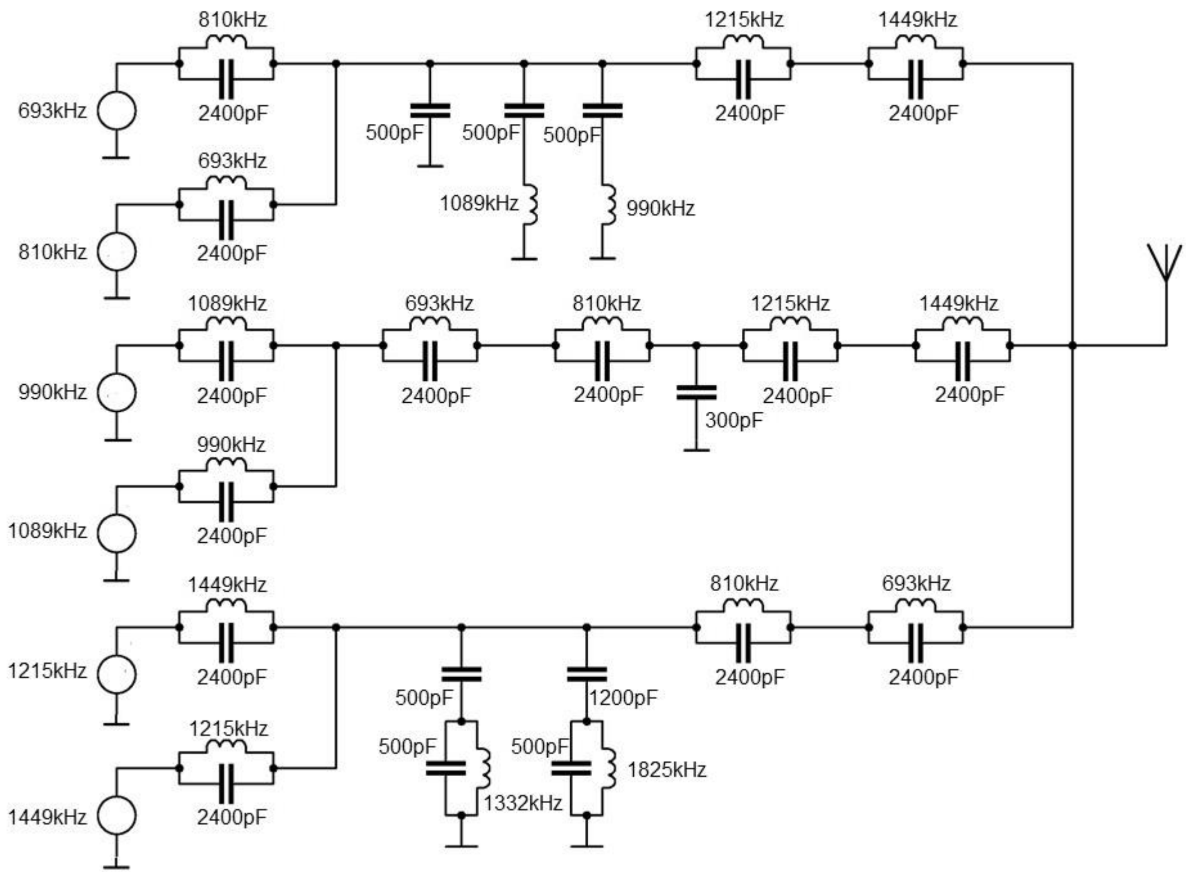

Figure 2. Circuit diagram of the duplexer at Redmoss

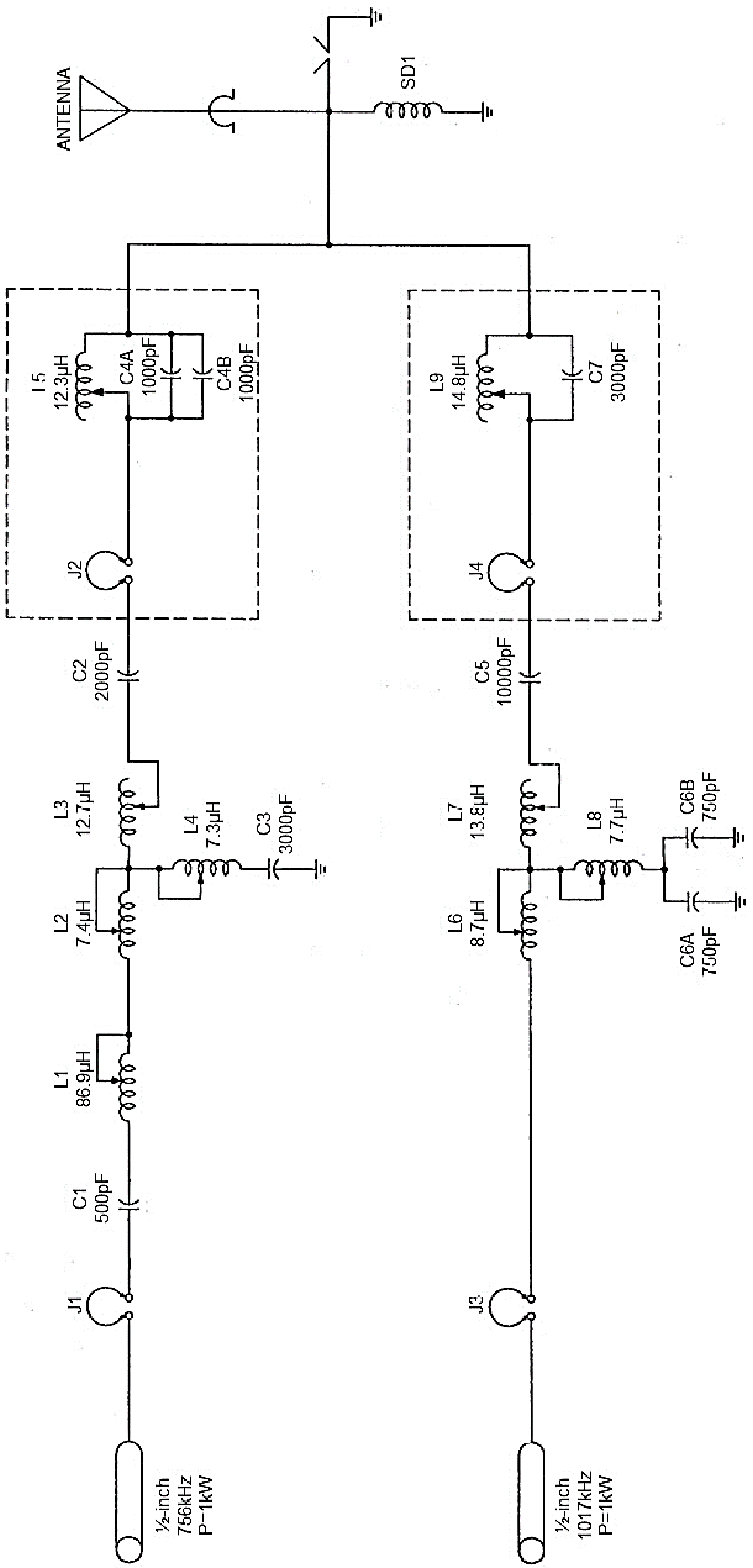

Figure 3. Circuit diagram of an MF diplexer for 756 kHz and 1017 kHz

Shrewsbury MF

This former Deferred Facility site at Nobold on the outskirts of Shrewsbury was upgraded to modern standards in 1987 for BBC Local Radio. The two Cubro and Scrutton 110-foot masts and single-wire Tee antenna were removed and replaced by a shunt-fed 61 m guyed lattice mast. An ATU manufactured by the Daventry company Matheran Products was used for the 1 kW Eddystone B6038 transmitter; the ATU contained a simple Tee network of series input coil, shunt capacitor to earth and a second series coil and a shunt static leak choke to the antenna for 756 kHz.

In 1991 came the need for site sharing and a new ATU was required for the ILR 1017 kHz 1 kW service. A pre-fabricated American unit by Vector Technology of Daylestown, Pennsylvania was procured and the circuit is shown as **Figure 3**. It appeared that the 'prefabrication' extended only to the design, the mechanical/electrical construction but not to the tuning of the components in the unit. All the inductors and rejectors needed bridging and setting to work.

Working back from the antenna lead-out, there is a static leak (RFC) to earth as SD1, then the two rejectors: for 756 kHz rejection (3000 pF and 14.8 µH) and for 1017 kHz rejection (2000 pF and 13.3 µH); so far so good. There is nothing new here as there are no ‘tricky’ dpz to deal with as the antenna is 25–j49 Ω at 756 kHz and 61+j99 Ω at 1017 kHz.

Tee matching networks of series L and shunt C are used for the feeder to rejector legs. In addition, L4 (7.3 µH) and L8 (7.7 µH) are in series with the shunt capacitors C3 and C6A/C6B respectively. This technique of a small value inductor in series with a fairly large capacitor was new to most of us. The idea was to make what is a fixed component, the shunt capacitor, variable in value by alteration of the inductor. Vacuum variable capacitors were available at the time but, in terms of cost, there was ‘no competition’ particularly for C3 (3000 pF), as a high voltage component at, say, 10 kV would have been expensive.

Note that both networks do have series capacitors in circuit; C1 (500 pF), C2 (2000 pF) and C5 (10000 pF). In BBC training and normal BBC Transmitter Department practice, the use of series-C was to be avoided if at all possible, so this innovation was quite alien to us.

The use of ‘Jumpers’ labelled J1, J2, *etc*. was also new; jumpers were a plated copper blade into a pair of slide contacts. An insulated handle was fitted to the blade allowing one to break easily into the circuit for simple access if test equipment needed to be connected. However, for the previous 60 years, the BBC just used bolted connections.

The entire combiner was in use for a few years until the BBC were required by Ofcom to surrender the MF channel for use by ILR at Newtown, Powys. The 1017 kHz side of the network continues.

BBC Research Department

Mention was made earlier of the 1960’s stagnation of UK MF use but actually BBC Research Department published a paper in 1969 detailing the diplexing of 1088 kHz and 1052 kHz to a common antenna. These frequencies represent just a 3% frequency difference and show what can be done but, of course, one wonders why in practice this would ever be required. The receiver selectivity demands would be challenging.

The diplexer design was for 1 kW transmitters and an antenna dpz of 24+j50 Ω at the 1070 kHz centre channel. The design arrived at was like the simple one used in 1946 and pre-matching was not required. The report is available on the internet for further reading **[3].**

The reader will have no doubt guessed that the construction of diplexers involves some ‘heavy engineering’ and **Figure 4** provides an example of a rejector with the capacitor components in the rack and the inductor in the foreground.

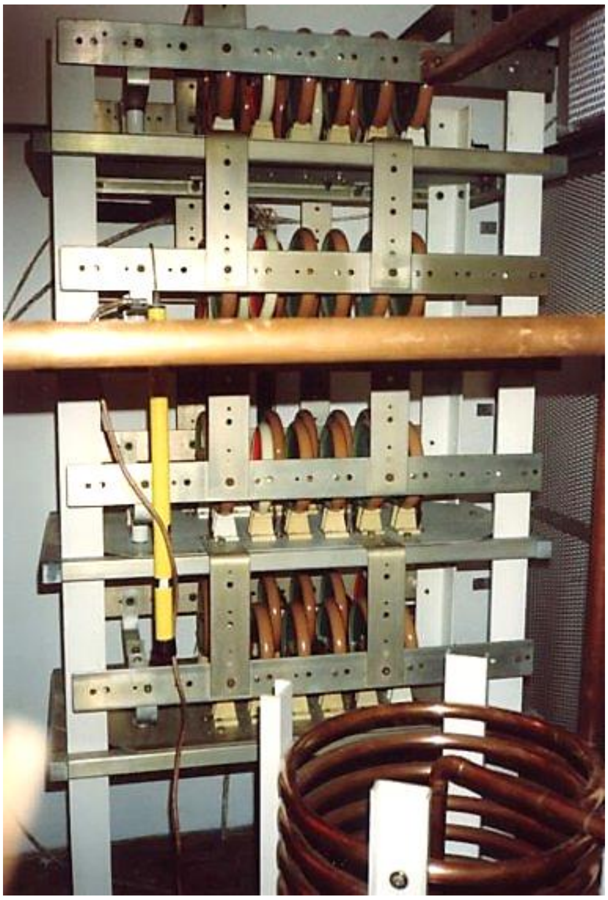

Figure 4. Physical realisation of a rejector. (www.waniewski.de/MW/Murcia/id293.htm)

Next time

We will continue to examine more MF systems and deal with directional arrays, starting with developments at Moorside Edge in 1946.

References

1. D Porter G4OYX and A McKibben. Tricks of the Trade. *Signal* 2019, **51** (May), 37–41.
2. D Cowans. Dual-Channel MF Aerials. *IBA Technical Review* 1985.
3. RDC Thoday and P Knight. The design of combining circuits for MF transmitters working into a common aerial. *BBC Research Department 1969/6*. www.bbc.co.uk/rd/publications/rdreport_ 1969_06.