Tricks of the Trade

Dave Porter G4OYX and Chris Pettitt G0EYO

This issue of Signal **[1]** includes a piece by long-time contributor to ToTT, Alan Beech G1BXG, concerning the history of the 647/648 kHz frequency in the UK. Alan has been involved with the RF engineering for the new Radio Caroline 1 kW emrp (effective monopole radiated power) service on 648 kHz from the former Babcock site at Orfordness, Suffolk (**Figure 1**). The antenna currently employed at Radio Caroline is what was previously the low-profile, omnidirectional reserve 250 kW-rated mast. Seeing this in use prompted the authors to follow-on from the recent articles describing the developments in AM transmitter design by a similar series of articles concerning antenna developments from the early 1930s to the present day.

Figure 1. The Radio Caroline transmitter site at Orfordness. This image is a cropped photograph taken by John Fielding in January 2014 when the site had been flooded, and the Radio Caroline banner has been added. Reproduced here under a Creative Commons Licence (https://creativecommons.org/licenses/by/2.0/) and originally published on https://www.flickr.com/photos/john_fielding/11739241703

Introduction

One of us (G0EYO) was employed by Marconi Antennas, a part of MWT/MCSL at Chelmsford, in the early 1980s, when he wrote an article entitled "Antennas for Broadcasting" for the trade publication, IBE, in January 1981 **[2]**. In this article he described the time-line of developments and, of course, the antennas that were being marketed by MCSL. Information contained in this article was later re-used for MCSL sales publicity and this content, together with that from other MSCL sales documents, is reproduced here.

The antenna system (**Figure 2**) employed at Radio Caroline may be regarded as unusual so it was considered topical to describe it as a 'taster' for the series and the next ToTT will begin the historical account from the early 1930s to cover both BBC and, later, IBA developments.

Figure 2. The 250 kW-rated antenna for Radio Caroline

The Fixed Station MF Folded Umbrella

The Fixed Station MF Folded Umbrella antenna, to give it its full name, is effectively what is currently in use at Orfordness though, as we shall see later, not entirely to the classic design.

MCSL offered two designs of this antenna: the R5071 was for fixed service and the R5075 was a transportable type with fully tuneable MF band coverage. The R5071 featured the classic design of a single mast with a low physical height of 0.1 wavelengths; no base insulator was required and it was matched directly to 50 Ω without the need of an antenna tuning unit ATU. It was suitable for use at up to 50 kW with single spot frequency working as there was a fixed relationship between the operating frequency and the height of the mast. It provided a cost-effective alternative to conventional Tee and Inverted-L antennas with the added advantage of taking up less space on site.

Description

The general arrangement of the antenna is shown in **Figure 3**. In principle, the antenna is a short vertical radiator comprising three downleads supported by a galvanized tubular-steel triangular-sectioned mast with insulated stays.

The three downleads are connected directly to the top of the mast and come down spaced and are insulated from the ground at the bottom. The RF feeder is terminated and then connected directly to the bottom of the vertical downleads. The electrical height of the mast is increased effectively by capacity top-loading the vertical radiator using nine umbrella radials connected directly to the top of the mast and sloping at 37° to the horizontal. By making the antenna self-resonant, *i.e.* by making the capacitance of the umbrella top-tune with the inductance of the mast and vertical downleads in parallel, the input impedance is expected to be of the order of 15 Ω and purely resistive.

The actual input impedance can be raised to 50 Ω by using the three vertical downleads in a folded arrangement, thus making a direct match to the incoming RF feeder possible without the need for any extra matching components or a building or enclosure to hold them. Apart from the elimination of matching components, the use of a folded umbrella had the advantage of not requiring a mast base insulator or a mast lighting isolation transformer. Being directly earthed, the mast was further protected from damage in the event of a lightning strike and there can be no build-up of static charge.

To reduce ground losses, an earth mat comprising 72 radial buried wires, each approximately a quarter-wavelength long, is specified.

Typical Dimensions

The dimensions of the R5071 antenna for design frequencies across the MF broadcast band are given in **Table 1**.

Frequency	Mast height	Ground radius to umbrella anchor	Radial earth element radius
580 kHz	49 m	65 m	130 m
900 kHz	32 m	43 m	84 m
1500 kHz	19 m	26 m	50 m

Table 1. Dimensions of the R5071 antenna

Technical performance specifications

The R5071 antenna is usually rated up to 20 kW but higher powers could be specified with a bandwidth generally ±5 kHz for a 1.2:1 VSWR at design frequency. The efficiency was typically up to 84% but did depend on the actual ground conductivity and a good earth being provided.

The ORF Omni

As can be seen from **Table 1**, the mast should be *c*. 46 m high at 648 kHz, *i.e*. 0.1 x 464 m; in fact the FCO DWS-CED used a 60 m, *c.* 200-foot high mast so the mast at Orfordness is 15% higher than the usual 0.1 wavelength.

Broadcast engineer Andy Linton who works for BW Broadcast, servicing their Irish clients, has seen the antenna at Orfordness recently and was able to jog the memory of G4OYX who had not been there in a professional capacity since 2001.

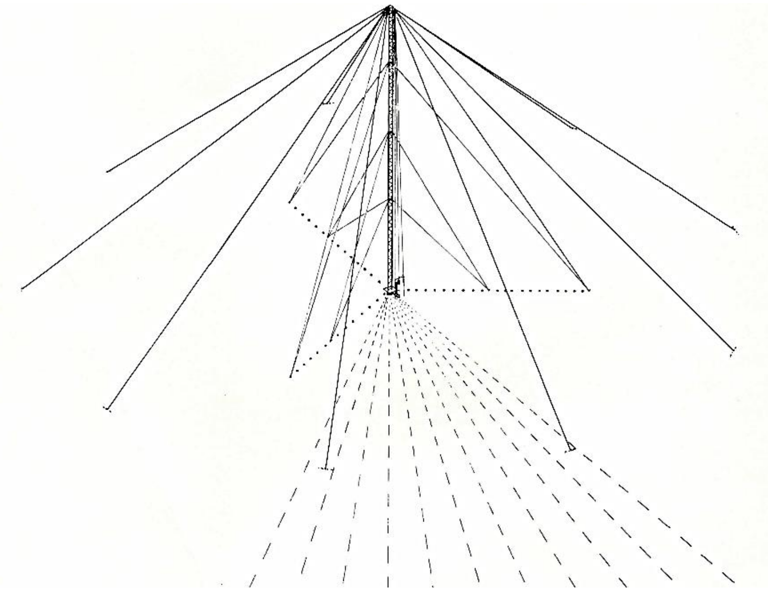

Figure 3. General arrangement of the R5071 antenna

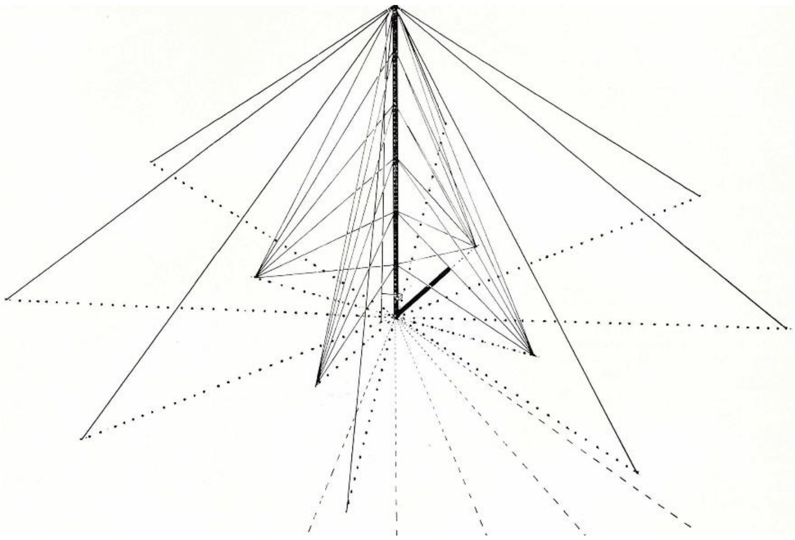

Figure 4. General arrangement of the R5075 antenna

Andy reports: “It’s a 60 m base-grounded mast, shunt fed to the top, with the skirt wires pulled out to a diamond shape. The angle of these wires is adjusted to achieve 50±j0 Ω, which it does present at 648 kHz – so there’s no ATU needed. In addition, there are vertical wires running down the outside of the mast to increase its electrical width and preclude any resistance across the tower section flanges. It is effectively a variation of the ‘Marconi’ antenna.”

So, with the exception of the overall umbrella loading being a diamond skirt arrangement, the rest of the build was as featured in **Figure 3** and the system bandwidth was recently checked by the engineering team of Radio Caroline and found to be well within the 1.25:1 VSWR limits at ±5 kHz. The 2.5 kW Canadian-manufactured Nautel transmitter has been set to 1.5 kW and produces a field strength of 300 mV/m at 1 km from the antenna, equating to 1 kW emrp; a system efficiency (feeder loss + antenna loss) of 66% has been confirmed by Ofcom.

This concept of an inexact 0.1 wavelength low-profile loaded antenna is illustrated by the MCSL R5075 antenna.

The R5075 10 kW Tuneable MF Umbrella Antenna

The R5075 was an antenna comprising a vertically polarized radiator and suitable for transmitter outputs of up to 10 kW and, in conjunction with its simple tuning unit, could radiate on any frequency from 531 kHz to 1602 kHz. It was transportable and, as advertised, featured rapid set-up and dismantling; however, this may not have been the whole story.

Description

The antenna (**Figure 4**) consists of a short radiator wire supported by, and insulated from, a 29 m lightweight aluminium guyed mast. An umbrella in the form of eight radial wires is connected to the vertical wire at the top of the mast; this umbrella increases the radiation resistance of the radiator and effectively the electrical height. The umbrella wires are drawn out to an angle of approximately 50° to the vertical and cover 80% of the mast height.

The number of radials used and their length are varied over the frequency band. For example, at 531 kHz, 7½ radial wires are used whereas, at 1602 kHz, only a quarter of one radial is used. A standard all-band earth mat comprising 32 copper radials each 62 m long is provided.

Two variable inductors in an inverted-L network (**Figure 5**) are provided to tune out the capacitive reactance of the antenna and match its base impedance to the 50 Ω input feeder.

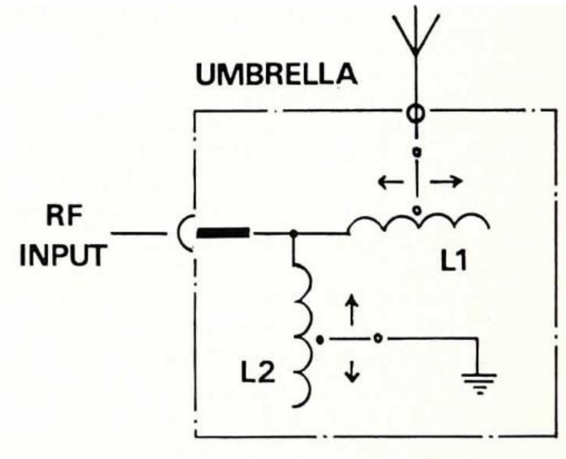

Figure 5. Circuit diagram of the ATU for the R5075 antenna

Antenna matching

Each antenna was accompanied by a set of tables which, by defining the number of umbrella radials to be installed, showed the relationship between the operating frequency and the amount of top-loading required. Each radial was broken in the middle by an insulator. The upper half of one radial was further sub-divided into four sections, each one an eighth of the length of a full radiator. This radial was attached directly to the downlead. The dividing insulators could be shorted out by joining wire tails. Thus, considerable flexibility could be achieved by adjusting the number of radials and their effective lengths.

The upper 27 m portion of the 29 m mast did not form part of the radiating section; it was used solely as a mechanical support for the downlead and was isolated by insulating connectors about 2 m up from the earthed base section. Settings for the variable inductors in the ATU were provided to allow tuning to the respective frequencies.

Technical Performance Specifications

The technical performance specifications of the R5075 antenna are given in **Table 2**. The antenna efficiencies are for the antenna with the standard earth radial pack.

Frequency	Bandwidth at VSWR		Efficiency
	1.4:1	2:1	
531 kHz	±2 kHz	±4.5 kHz	>50%
999 kHz	±3.25 kHz	±8 kHz	>70%
1602 kHz	±10 kHz	±27 kHz	>80%

Table 2. Technical performance specifications of the R5075 antenna

The R5071 and R5075 compared

The bandwidth and efficiency data given above really do show the differences between the fixed and transportable systems as the useable bandwidth of the 29 m transportable antenna at 531 kHz is only ±2 kHz at a VSWR of 1.4:1 with *c*. 50% efficiency. Modern solid state transmitters with progressive audio processing would shut down on VSWR with such a small bandwidth but a valve transmitter could be more accommodating. For the R5075 there would have been a need to have a static 'leak' had there not been the two variable inductors between the antenna and earth.

The prospect of having to engineer operationally an emergency R5075 installation, maybe in a time-pressure/limited situation in poor weather after a catastrophic failure, with all the fractions of a top-loading system to comprehend, rig and then attempt to secure a satisfactory VSWR, is most daunting. A possible 're-rig' to adjust the fractions of top-loading could have been time-consuming.

For a planned work situation then, yes, it would be possible to accomplish the rigging of the R5075 but, nevertheless, the setting-to-work would still be a heavy responsibility for the antenna engineer and the rigging team.

Often, in company sales literature, it is what is *not* mentioned that is of more interest and, in the case of both the antennas referred to in this article, it is the fact that they are exclusively single-frequency working when on power. At many sites, both at home and abroad, an MF radiator can be fed with up to six separate channels. This limitation became evident at Cotheridge in Worcestershire where, for the Independent Local Radio service Radio Wyvern, another manufacturer's version of the R5071 had been erected by the IBA for 1530 kHz. However, a few years later, the BBC wished to site-share on 738 kHz for their Radio Hereford and Worcester service and, of course, with only the 20 m or so maximum mast height available, it was not possible to use the antenna and an alternative site had to be found. Had the IBA erected, say, a 54 m vertical mast as a quarter-wave radiator for their 1530 kHz service originally, then it may have been conceivable to site-share.

The absence of an ATU with the R5071 means that, in the event of a legacy transmitter that may have a poorer harmonic suppression capability compared to a modern design being used, suppression of second and higher harmonics cannot be effected. A work-round in such a situation would be a low-pass filter, typically a π-network, in the outgoing feeder of the old transmitter.

Next time

We will start on the dual-channel London Regional Transmitter of 1929 with surprisingly tight aeronautical restrictions.

References

1. A Beech G1BXG. The History of 648 kHz in the UK. *Signal* 2018, **46** (February), 16–18.
2. C Pettitt. Antennas for Broadcasting, *The International Broadcast Engineer* 1981, **12** (January), No. 175.