Tricks of the Trade

Dave Porter G4OYX

The subject of the use of a directional antenna (DA) for MF has been partly explored in recent ToTT. We started first with the Droitwich and then Start Point simple two-element systems, essentially to concentrate the radiation in a general direction, then to Moorside Edge where the system was designed to radiate in a figure-of-eight pattern. It is pertinent now to examine the different reasons for having a directional service.

Reasons for directional antennas

Option 1: A DA may be used to enhance the field strength in a general direction.

Option 1 could be used for city coverage; an omnidirectional service would technically be excellent but it is normally impossible to site a high power MF station in the middle of a city. So a site on the edge of a conurbation with a directional antenna would cover the city. In addition, there may be the opportunity to use the gain of the antenna to reduce the amount of transmitter power required to cover said city.

In 1939, BBC Start Point was an example of such an arrangement; why waste power over the sea? Much use was made of DAs in the USA as seen by examples of high power 50 kW stations where the transmitter site is between a city and a mountain range. In such situations it would be pointless to send RF towards the mountains and a DA would effect that requirement.

Option 2: A DA may be used to limit RF radiation in a general direction

A good example of Option 2 is the Droitwich 1214 kHz 30 kW Radio 1 facility after September 1967, as Washford in Somerset was co-channel running 60 kW. It was found that there was significant interference to reception in Bristol. The addition of a simple reflector at Droitwich moved the ‘mush’ area to the countryside around Gloucester and, of course, gave a little more field strength to Birmingham.

Option 3: A DA may be used to enhance the field strength in a specific direction

Directional antennas were used widely by both ‘sides’ of the Cold War. Following on from an original WWII three mast 'Arrow-head' array at Aspidistra and 500 kW output, Orfordness in Suffolk became the classic UK example of the use of a DA when a six-mast array was proposed and contracted out. The main bearing was to be 110° east of true north (ETN) and the carrier input power was to be 600 kW. In the event, modelling at Marconi Antennas Ltd indicated that a five-mast array was all that was required to deliver the requested field strength into the designated Eastern Bloc countries.

Option 4: A DA may be used to limit RF radiation in one specific direction

An early UK example of Option 4 was at Trowell in Nottinghamshire where the former Deferred Facility site situated equidistant between Nottingham and Derby was used for BBC Local Radio (LR) in the early 1970s. The site had a standard 110-foot Tee antenna with isolated-from-earth steel pole supports (for 1950’s DF use), giving an omnidirectional pattern and covering both cities. For 1520 kHz BBC LR use, the antenna was altered such that the east and west masts were made to radiate and a horizontal section for top loading was added at the top of each mast to make, in effect, two inverted-L antennas. Power splitting of the transmitter output, with a fraction going to each mast, enabled a pattern to the east to be generated with little towards Derby.

However, when Derby’s 1115 kHz MF service came on, it was from Burnaston Airport using an omnidirectional Tee antenna from a BBC caravan and ‘cigar masting’. Maybe they were not too bothered about the good people of Nottingham receiving their service.

Option 5: A DA may be used to limit RF radiation in more than one direction for one radiated service

A particular example of Option 5 was the IBA system at Ashton Moss, Manchester. The four masts are a highly directional array, radiating the signal in a tight pattern west across Manchester. The transmitter input power is around 350 W and the directional gain of the antenna produces 1.5 kW effective monopole radiated power (EMRP) in the direction of maximum power, 250°ETN originally on 1151 kHz, now 1152 kHz.

The IBA built such highly directional antennas to avoid interference to other Independent Local Radio (ILR) stations using the same frequency. In the case of 1152 kHz, directional antennas were installed by the IBA at Langley Mill (Birmingham), Saffron Green (Barnet, Herts. for London, see below), Greenside (Newcastle) and Dechmont Hill (Glasgow).

Option 6: A DA may be used to limit RF radiation in more than one direction and with more than one radiated service.

One example of Option 6 was the IBA’s 1975 system at Saffron Green in Hertfordshire where 1151 kHz and 1546 kHz were combined and radiated on a four mast system. This was one of the most technically challenging antenna systems commissioned by the IBA.

Engineering the options

Option 1 (with shades of Option 6) is best illustrated in a Marconi Antennas technical brief from 1982 where the upgrading of the antennas and services from Start Point was detailed **[1].** Before the antenna changes, the site was solo frequency, 1053 kHz at 100 kW. Since it lies on the coast, from 1939 it was given a directional pattern to reduce radiation seawards by constructing a main director and a parasitic reflector. This was achieved by a two-mast system giving essentially a cardioid radiation pattern as illustrated by **Figure 1**.

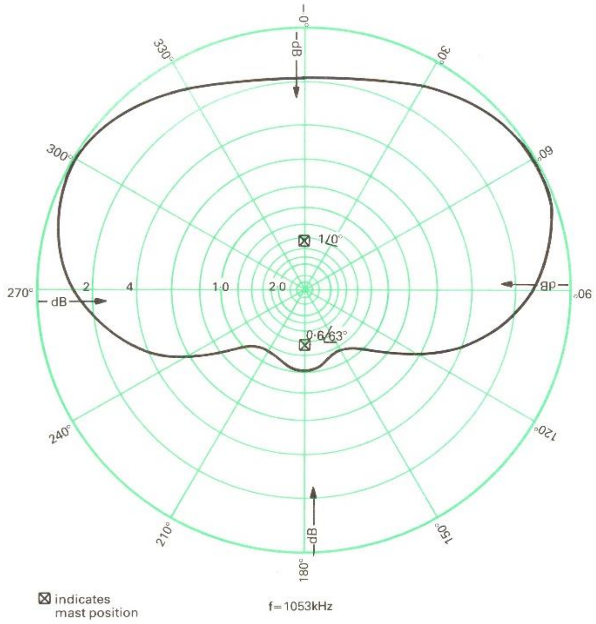

Figure 1. 1053 kHz radiation pattern

When the requirement arose for a 50 kW service on 693 kHz, it was again required that the pattern be a directional one, partly to save energy as before, but also to provide a deep minimum in the direction (257° ETN) of a co-channel station in the Azores (**Figure 2**). It was found that the same two masts could be used given the appropriate current amplitude and phase distribution. At the same time it was decided to replace the 1053 kHz matching circuits so that an optimum dual-frequency circuit could be provided. The associated current distributions are shown in **Figure 3**.

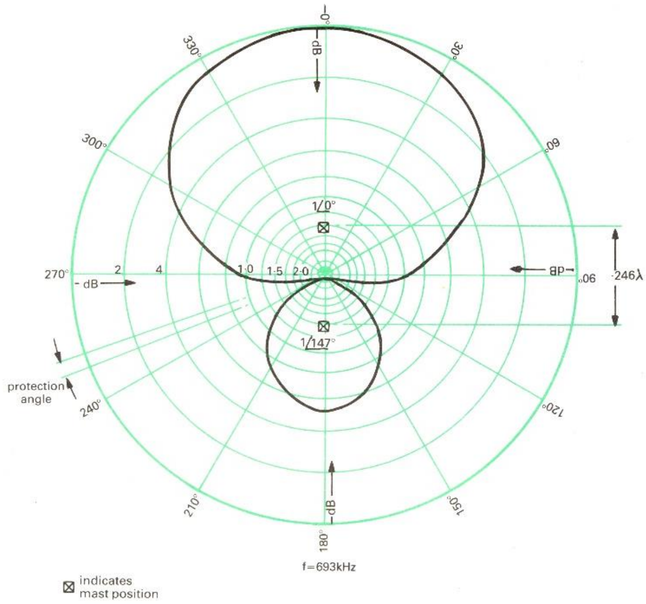

Figure 2. 693 kHz radiation pattern

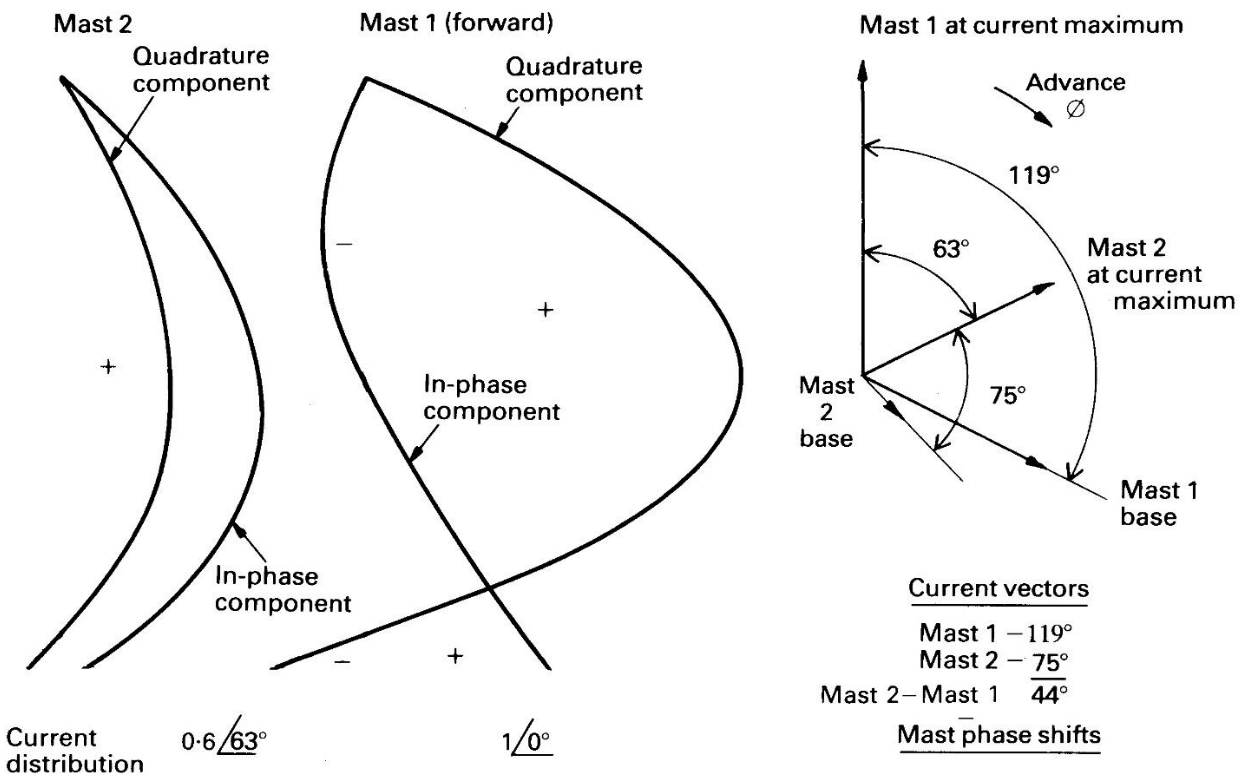

Figure 3. Calculated current distribution and phase at 1053 kHz

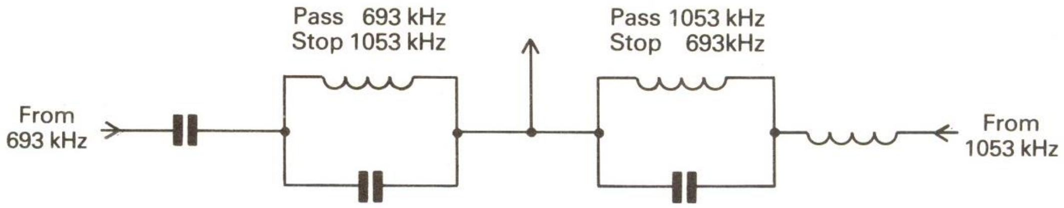

Figure 6. Filter circuit diagram

Required performance

The problem, therefore, lay in feeding a set of two masts 137 m high, 76 m apart with a prescribed set of currents at either of the two frequencies together with the necessary filter circuits to prevent mutual interference between the two channels. A further requirement was that it should be possible, by means of switching, to feed the services to one mast only. The other mast would then be grounded and available for maintenance. The patterns in this condition would be approximately omnidirectional.

Figure 4 shows the basic setup to establish the directional pattern condition; there are six basic stages.

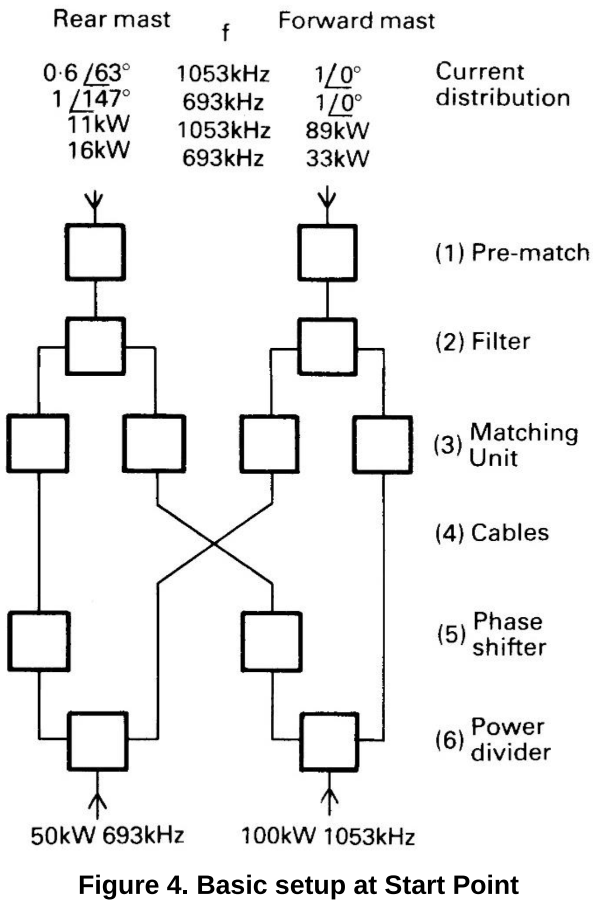

Figure 4. Basic setup at Start Point

The **pre-match circuit** shown in **Figure 5** is placed immediately at the mast base. It is required because the mast impedances have high series reactances at both frequencies, resulting in high voltages. Reducing these beforehand considerably simplifies the design of the filtering. The pre-match consists of two parallel resonant circuits placed in series and both in series with the mast. One circuit resonates above the upper working frequency, the other below the lower working frequency. The net result is a pair of reactances at the working frequencies which are of opposite sign and approximately equal in value to the mast reactances.

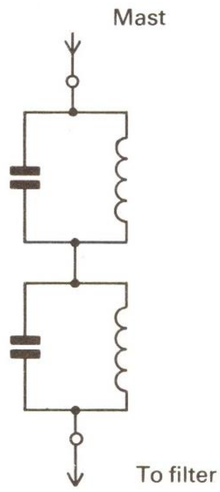

Figure 5. Pre-match circuit diagram

With the reactive component largely removed from the antenna impedance the **filter circuit** required to isolate the two transmissions can be a fairly simple one, a parallel circuit, resonant at the other frequency, with a series reactance added to give a net zero reactance at the working frequency as shown in **Figure 6**.

The measured values of driving point impedance (DPZ) for each mast are 200+j250 Ω at 693 kHz and 90–j215 Ω at 1053 kHz. The reactive values are relatively little changed by the mutual impedance and the resistive component reduces to about 150 Ω at 693 kHz and 60 Ω at 1053 kHz by stray capacitances in the pre-match and filter circuits.

The **matching circuits** are simple L-networks which bring the above values to 50 Ω to match the incoming feeders from the power dividers situated in the transmitter hall.

The components which need to be changed, according to whether single or two mast working is required, are selected by a motor-operated, multi-contact switch. The above equipment is contained in screened metal cabinets housed in the brick-built antenna tuning hut (ATH) at the base of each mast.

Four runs of coaxial cable are used between the transmitter building and the mast base huts, two to each hut. RFS Cellflex™ foam-filled 50 Ω cable of 1.625 inches in diameter is used for all runs; care being taken at the terminations to maintain the HV rating of this cable to 12.5 kV peak.

Although the currents in the masts may be the same in amplitude, the powers will be different because of the mutual impedance between the masts. The ratio of the powers is determined theoretically. For the present case the values are as follows:

Frequency 693 kHz
Rear mast 16.5 kW
Forward mast 33.5 kW

Frequency 1053 kHz
Rear mast 11 kW
Forward mast 89 kW

(Note the rear, southern mast is nearer to the sea)

The power divider network chosen is where the input impedance equals each of the output impedances and no transformation is required (**Figure 7**). The components, roller coaster inductor and vacuum variable capacitor are made variable on power.

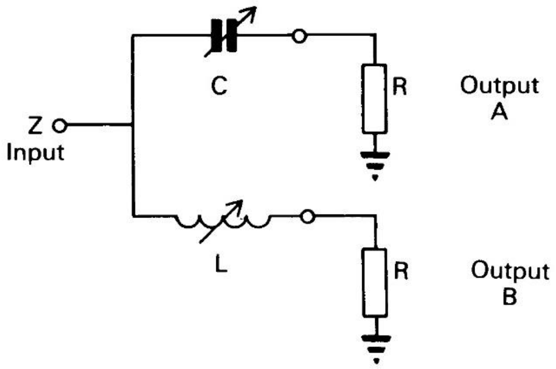

Figure 7. Power divider circuit diagram

A variable phase-shifter is placed in one output of each power divider to give a ±15° variation of phase on power. It consists of a Tee-network with two ganged variable inductors in the series arms and a variable vacuum capacitor as the shunt element.

The ability to be able to vary the current distribution to the masts whilst on power ensures optimum adjustment of the required null on about 257° ETN towards the Azores (**Figure 2**).

The current monitor is housed next to the power divider cabinet. By operating the amplitude and phase controls on the latter it is possible to set the mast current amplitudes and phases.

System monitoring

The ultimate success of a DA system relies on being able to monitor the currents and phases on the masts. For a quarter wave antenna, the mast current may best be monitored by sampling with a coupling loop at the mast base or by a current transformer in the mast feed. However for half-wave antennas it is necessary to measure near the current maximum, approximately half-way up the mast. At Start Point, the mast height varies from 0.32 λ at 693 kHz to 0.48 λ at 1053 kHz, so the sampling loop is placed about one third way up each mast, this being reasonably near to the current maximum for both frequencies. The sampling loop output is brought down the mast in small diameter RFS Flexwell™ cable. On passing into the ATH through a lead-in insulator, it is formed into an isolating coil, the lower end of which can be grounded and then on to the monitoring set in the transmitter hall.

Setting to work

Getting it all to work is effectively equivalent to solving two simultaneous equations. The correct phase shifts in the circuits and also the power division only hold when these circuits are matched; the circuits cannot be matched until the mast currents are correct, that is, the power division and phase shift are correct.

The power divider and phase shifter networks were initially set up in to dummy matched loads. The masts were matched individually and the whole circuit put together. Then, by alternately adjusting the power divider and phase shifter and re-matching the antennas, the system was brought within 1% in phase and 1% in current.

Up to the present day

The dual frequency arrangement from 1980 continued at the site until the Radio 1 1053 kHz frequency was relinquished to Independent National Radio (INR) in 1992. The INR operator decided to use low-power relays on 1053 kHz to cover specific regions of the south coast and close the high power 1053 kHz service. The BBC Radio 5 Live 50 kW 693 kHz service continued.

Around 12th January 2016 the top stay on the NNW side of the northern (forward) mast at Start Point snapped, the point of failure being the highest in-line insulator on the stay. The top 150’ of the mast, *i.e*. the section above the old break-insulator, was now leaning at about 25–30° off-vertical, roughly towards the south.

After seventy-six years with two masts side by side, the skyline at Start Point changed dramatically on Thursday 21st January 2016.

At approximately 10.45 the 693 kHz service was switched off and, an hour later, Arqiva riggers brought down – with great skill – the north mast, after fifty-eight years of service. The demolition went exactly to plan; the mast folded with meticulously planned neatness and 693 kHz was back on the air by 14.00.

By January 2017, work had progressed well to bring its replacement into service. No doubt Arqiva specified an exact or almost exact copy of the fallen mast as a replacement as the re-matching and adjustments to the 693 kHz phase and current parameters would have been tricky had it been significantly different.

Next time

Having covered Option 1 and to a degree Option 6, we can examine the rest of the options, again with specific examples.

Reference

1. SU Nolan, EJ Lee. Two-frequency MF directional antenna for BBC Start Point. *Communication and Broadcasting*, The Marconi Co., 1982, **7** (3), 41–45.

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