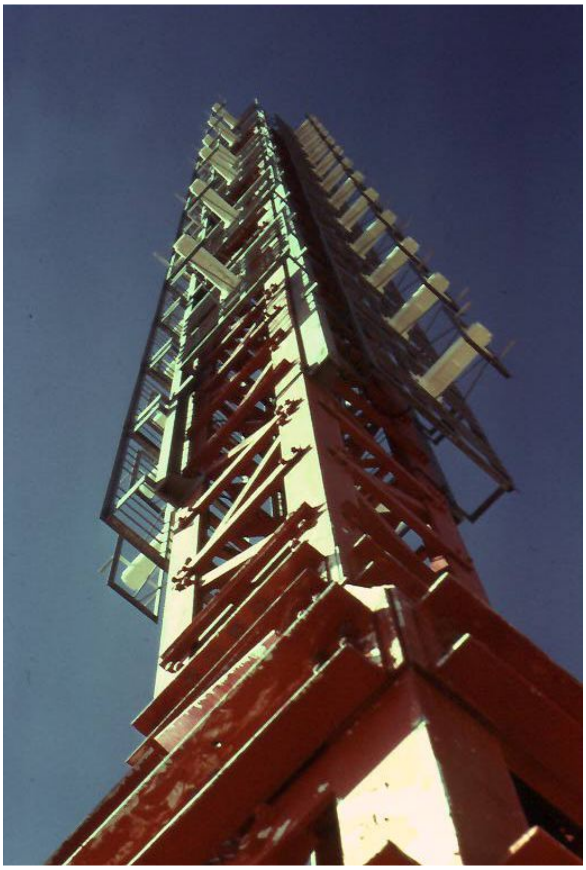
Antenna design

By B. S. COLLINS



THE PERFORMANCE requirements for every broadcasting antenna are different. This article indicates the methods used by the antenna designer to make sure the intended target area for a broadcasting station is fully served

The various design features are discussed in the order in which the designer will consider them. The design process is essentially one of successive approximation, as many of the features are interdependent.

A designer will generally have available a number of standard units from which to be able to build up an array for any requirement. On bands I and II these units will often be simple dipoles which must be set against the faces of a mast or tower.

On bands III, IV and V the unit will generally comprise panels of several dipoles or slot radiators together with a reflecting backscreen. A detailed knowledge of the radiation and impedance characteristics of these building blocks is vital and will be used to compute the performance of more complex arrays. As well as radiating panels, various broadband transformers and hybrids will be required. Except in band I, all components will normally be designed to cover the whole of the band in question with substantially constant. performance.

The initial object is to define the intended service area and to consider possible sites for the transmitting station. Except over completely flat ground — which does exist in some parts, of the world — some areas will be identified as potential trouble spots and possible solutions formulated

A site visit is essential. Maps are often misleading — an apparently gentle hill top is often found to be strewn with 8ft. boulders! Particular attention will be paid to access and suitable link paths for incoming signals and any relay stations intended. Local. information will often reveal areas which for various reasons must receive a good signal.

Sometimes it will be-found that the original objectives for coverage are unrealistic either because of the distances involved or because of topography. Alternative schemes may then have to be examined. Either the station will have to be moved, or perhaps a relay station considered for a remote town nestling unhelpfully behind a 1000m mountain..

In some areas it may be the quality rather than the quantity of signal which is unsatisfactory, as when paths have obvious alternatives by reflection from hills nearby. This problem of multi-path propagation must be particularly closely examined when siting relay stations which rely on off-air links.

Responsibility for the avoidance of co-channel interference to other stations is frequently placed on the designer as when maximum ERP limits are set in particular directions.

The channels allocated to a new station are generally established by the regional frequency plan, but the polarisation is often not specified. This leaves open the possibility of using orthogonal polarisations for reception and retransmission at relay stations in the interests of obtaining better isolation between the receiving and transmitting antennas.

Knowing the location of the station and the required coverage area the designer will compute the relative ERP (effective radiated power) required in every azimuth direction. The designer will then attempt to design an antenna tier (ie a plan arrangement) which will yield the nearest fit to this azimuth power distribution. In producing this design various constraints will also have to be considered.

1. Each tier of the antenna must contain no more radiating units than are absolutely necessary — complexity costs money.

2. The HRP (horizontal radiation pattern) must fit the requirement closely or power will be lost in unwanted directions. More tiers will then be needed to reach the required ERP.

3. It must be practicable to mount the tier which has been designed onto the support structure intended. In the case of existing stations the size and orientation of the tower must be carefully considered. Towers of large cross-section mean trouble.

4. Power dividing transformers with unequal power divisions are expensive and become difficult to realise if the ratio between outputs exceeds about 6 dB.

5. If possible a scheme should be devised in which the units of a tier are not cophased — this will lead to improved input impedance.

These restraints often conflict and compromise is necessary. Sometimes two or more tiers will be used to generate the basic HRP, especially when large power division ratios are otherwise required. It is unfortunately not possible merely to project the radiation pattern. of a proposed arrangement directly onto a map. The shape of an equal field strength contour on a map is not the same as that of the radiation pattern, which is essentially a plot of field strength at constant distance.

An increase in ERP of around 13 dB is needed to double the distance to a given contour. This contrasts with only 6 dB necessary in free space and is due to the combined effects of earth curvature and atmospheric refraction. The result is that to a first approximation - the square root of the (relative field) radiation pattern will indicate the shape of the constant field strength contours over level terrain.

A fundamental choice must now be made. If. the antenna is placed on a tall mast, say 300m, then less ERP will be required to produce a given field strength at a distance of 75km than if the antenna height is reduced to 150 or l00m.

A halving of the mast height requires around 6 dB. more ERP to serve the same area over reasonably flat terrain. This is why hilltop sites are so much favoured.

If the number of tiers in the transmitting antenna is doubled, the output power required from the transmitter is halved.

Sometimes these trade-offs are simple to analyse, but other factors such as the availability of local labour able to work at heights or the problems of transporting very large drums of coaxial feeder cable over poor roads may influence the choices made. Antenna masts seldom exceed 350rn in height and the vertical aperture of antennas is usually less than 24 wavelengths.

A further trade-off lies between antenna gain and main feeder size. A minimum size is determined by the power to be handled, but on a tall structure it may be economic to use a larger diameter rather than to compensate for the attenuation introduced.

A large aperture antenna confines the power radiated to a very thin 'wedge' in the elevation plane. A 16-wavelength long cophased array has a half power beamwidth of ±1.6 degrees about the horizontal. This has two undesirable effects:

1. The maximum of the VRP (vertical radiation pattern) is directed over the horizon and benefits no one.

2. Nulls at lower elevation angles fall within the service area — at angles of depression of 3.2, 4.8, etc degrees seen from the antenna. Moreover the exact position of the nulls varies with frequency, so viewers near the null positions may perceive the effects of a distorted frequency response.

The solutions to these problems are know at Beam-Tilt and Null (or Gap) Fill.

By the application of a phase shift across the whole antenna the VRP maximum is deflected downwards so that it is directed correctly towards the outer areas to be served. This tilt is frequently in the range 0.6-3.5 degrees. The smoothing of severe nulls in the VRP may be achieved by changing the magnitude and/or phase of the current fed to successive tiers of the antenna. A small loss of gain in the main lobe direction - is inevitable (0.5 - l.0 dB) but the designer will generally have anticipated the need for null fill when computing the antenna gain required.

Most broadcasting, requirements — especially TV — demand extremely low input reflection coefficients for an antenna systems. This is especially so when long low loss main feeders are used, when, the k-rating of the system may closely approximate the input reflection coefficient for the antenna.

Current demands are for multichannel capability with frequency spacings often in excess of 25 per cent. The required performance can only be obtained by designing all individual components to have reflection coefficients of less than 3 per cent over the- whole band required, and then ensuring that both horizontal and vertical distribution systems are designed so that very littLe of the remaining reflections reach the main feeder. This is often achieved by feeding blocks of elements in phase quadrature.

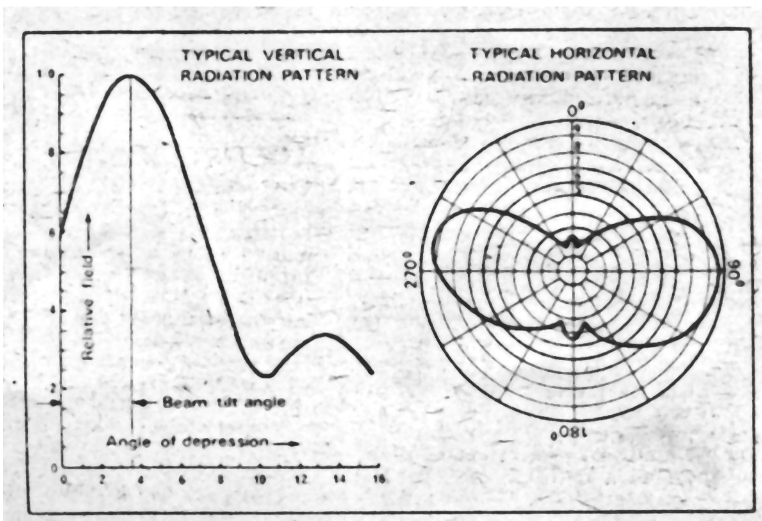
Current European practice for larger installations is to design antennas in two nominally equal halves, each fed by its own main feeder, allowing each half of the array to be used independently should a failure occur. This provides security but is costly and not universally followed overseas.

The main feeder is almost universally a semi-flexible helix insulated air dielectric cable and is terminated at its upper end by a unit whose function is to match the antenna precisely to the characteristic impedance of that particular piece of feeder.

The size of transmission lines chosen to feed the antenna will depend on the powers involved; as the system branches so the power level falls and the cables decrease in size.

Distribution feeder losses are not usually significant in high-power antennas as an ample diameter is ensured by the high power to be carried. the whole feeder system, from the main feeder up to and often including the radiating :panels, is pressurised with dry air to keep moisture out of the system.

It will be seen that antenna design is not an isolated activity but is related very fundamentally to the design of the whole-system. The antenna is a reliable and sophisticated piece of modern engineering and its development is keeping pace with the ever more stringent requirements with which it must conform.



B. S. Collins is Technical Manager, C&S Antennas Ltd.

Electronics Weekly, May 21st 1975