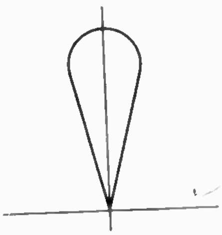
Television Aerials

Close-Spaced Arrays

By N. M. BEST and R. D. BEEBE, B.Sc. (Eng.), A.C.G.I.
(Antiference Ltd.)

IN considering the design of a television aerial array for domestic receivers a number of conflicting factors arise. The electrical requirements are maximum discrimination against interference, good forward gain, and wide bandwidth acceptance. Mechanically, the aerial needs to be of light and rigid construction and as compact as possible. In view of the fact that the spacings and reflector lengths giving maximum forward gain are not the same as those giving maximum discrimination, and that in general the high-gain arrays have considerably narrower bandwidths, a compromise has to be arrived at in designing an aerial for universal use.



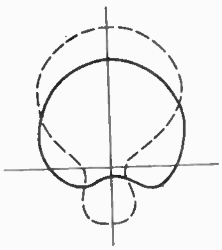


Fig. 1 (left). Ideal directional pattern obtainable only with multi-element array. Fig. 2 (right). Specimen patterns obtainable with single reflector.

In most practical cases these requirements are met by using a dipole and parasitic reflector, and it has been common practice to use a reflector element spaced at approximately a quarter-wavelength from the dipole. Experience showed, however, that closer-spaced reflectors appeared to give equal results, and in view of the mechanical advantage obtained it was decided to investigate the performance of this type of array over the bandwidth required for television reception, and to ascertain the optimum spacing and element lengths.

To overcome interference the aerial needs a directional reception pattern so that by rotating the aerial to a suitable position the direction of minimum reception may correspond with that of the interference. As this interference usually comes from a distributed source, such as motor vehicles passing along the road, rather than from a single point, an array having a sharply defined minimum reception position is not as generally useful as one which has reduced signal pick-up over a wide angle. Good forward gain also helps in improving the signal-to-noise ratio. These considerations do not apply, of course, in cases where both the interference and signal are coming from the same direction, for advantage cannot then be taken of the directional properties of an aerial.

An ideal polar diagram is shown in Fig. 1, but such patterns are only obtainable with multi-element arrays which are not practicable for domestic installation. The patterns usually obtained with a single reflector approximate to the general shapes shown in Fig. 2. It is difficult to express the performance of an aerial in terms of its polar diagram, and it is usually more convenient to specify the ratio of the signal received from the front to that received from the rear. This front-to-back ratio, while not giving a complete picture, is a fair guide to the discriminating efficiency of the aerial.

Fig. 3 shows the gain of a reflector array over that of a simple dipole plotted against reflector spacing when the reflector lengths are adjusted in each case for optimum front-to-back ratio.[1] It will be seen that the maximum gain is obtained at a spacing of 0.175 wavelength, but the overall variation in gain for spacings between $\frac{1}{8}$ wavelength and $\frac{1}{4}$ wavelength is less than 0.5 db, which may be considered negligible for all practical purposes. In view of the necessity for maintaining the front-to-back ratio as high as possible for maximum interference discrimination, it would appear that spacings of less than $\frac{1}{8}$ wavelength are not desirable owing to the steep drop in forward gain.

The effect on the front-to-back ratio of varying the reflector length is shown in Fig. 4 for $\frac{1}{4}$-wavelength and $\frac{1}{8}$-wavelength spacing. Reflector spacings between these two values give curves lying between the two shown. It will be seen that for reflector lengths of between 0.49 wavelength and 0.57 wavelength the front-to-back ratio is greater for the eighth-wave array than the quarter-wave. Below 0.49 wavelength the ratio falls away very sharply, but the slope is more gradual for increasing reflector lengths. It would appear,

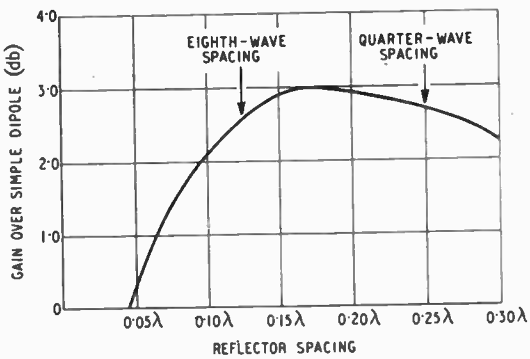


Fig. 3. Variation of gain of dipole and reflector over dipole alone with reflector spacing when the reflector length is adjusted for the optimum front-to-back ratio.

[1] "Some experiments on linear aerials." McPetrie and Saxton, *Wireless Engineer*, April 1946.

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therefore, that for good signal-to-noise ratio using the closer spacing the reflector length should be at least 0.49 wavelength at the lowest frequency to be received. The bandwidth required for television reception is from 41.5 to 48 Mc/s, and if advantage is to be taken of the higher front-to-back ratio possible with $\frac{1}{8}$-wavelength spacing, the reflector length should be at least 0.49 wavelength at 41.5 Mc/s. This length is equivalent to 0.57 wavelength at 48 Mc/s, giving a front-to-back ratio over the band of from 9 db at 41.5 to 6.8 db at 48 Mc/s. It has been common practice to make the reflector length about 0.51 wavelength at the vision frequency of 45 Mc/s. This corresponds to a length of 0.47 wavelength at 41.5 Mc/s, and should result in a considerable drop in signal-to-noise ratio on the sound frequency. Table I shows the approximate front-to-back ratios corresponding to these lengths and spacings. Comparing the arrays, the $\frac{1}{8}$ wave-length spaced aerial appears to give a maximum front-to-back ratio between 41.5 and 45 Mc/s, which falls slightly at 48 Mc/s. The $\frac{1}{4}$-wavelength array has its maximum at about 44-45 Mc/s, falling away at each end of the band.

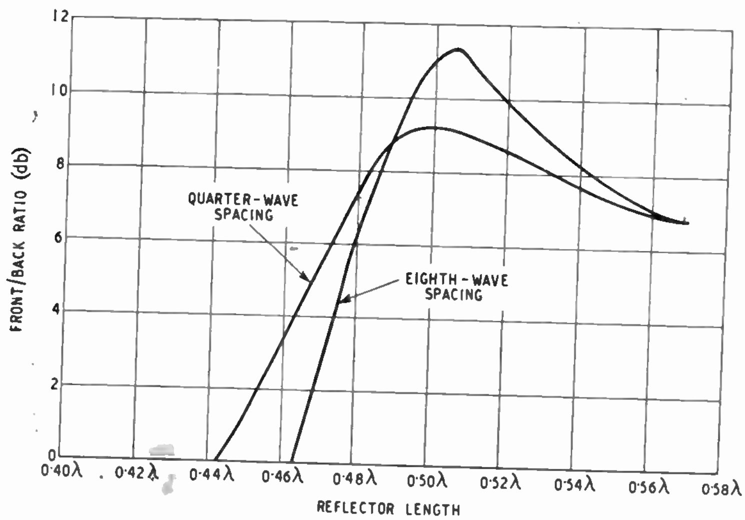

Fig. 4. The effect of the reflector length on the front-to-back ratio is shown here for reflector-aerial spacings of λ/8 and λ/4.

TABLE I

Array	Freq. (Mc/s)	Length	Spacing	Front/ Back (db) (Approx.)
Typical commercial quarter-wave with 133-inch reflector.	41.5	0.47λ	0.23λ	5.4
	45.0	0.51λ	0.25λ	9.0
	48.0	0.54λ	0.27λ	7.6
Eighth - wave with 139-inch reflector ...	41.5	0.49λ	0.115λ	9.0
	45.0	0.53λ	0.125λ	9.0
	48.0	0.57λ	0.133λ	6.8

To verify the above conclusions an experimental confirmation was planned. A low-power oscillator was connected to a vertical half-wave dipole erected at a height greater than 1.25 wavelength at the lowest frequency to be used. The dipole elements were constructed of $\frac{3}{8}$-in diameter aluminium tubing. One hundred yards of coaxial cable of 75-ohm impedance joined the oscillator to the dipole, enabling the operator to stand well outside the field of the dipole. About three wavelengths away at the lowest frequency used, a similar dipole was erected connected by a similar cable to a field strength meter calibrated directly in db with a reference level of 1 millivolt. The calibration was checked against a high-grade signal generator through an equal length of cable to that used in the tests and found to be accurate within plus or minus 0.5 db, enabling direct readings to be taken. The frequency of the oscillator was varied in 0.5 Mc/s steps from 41.5 Mc/s to 48 Mc/s, the aerial current being kept constant. The field-strength meter was tuned to the oscillator frequency at each step, the db readings being recorded against frequency. The resulting curve showed slight cyclical variations over the band, but a mean curve could be drawn with a fair degree of accuracy.

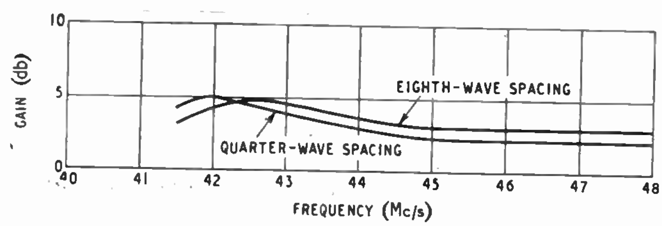

Fig. 5. Measured forward-gain curves of λ/8 and λ/4 spaced reflectors.

A quarter-wave spaced reflector of 0.51 wavelength was then added to the receiving dipole and a similar set of readings obtained, and this was repeated for various element spacings and reflector lengths. At spot frequencies of 41.5, 43.5, 45, 46.5 and 48 Mc/s, polar diagrams were taken by rotating the receiving array in angular steps of 30°. For each array a mean curve of signal against frequency was drawn, and by subtracting from these the mean curve obtained with the dipole alone the forward gains for each array were calculated. The front-to-back ratios were obtained from the polar diagrams.

The forward-gain curves obtained by this method for ⅛-wavelength and ¼-wavelength spaced arrays are shown in Fig. 5. It was found that spacings between these values gave curves

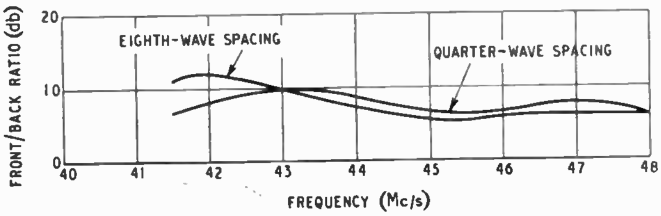

Fig. 6. Measured front-to-back ratios for λ/8 and λ/4 spaced reflectors.

lying approximately between those shown and that no greater overall gain was obtained. The optimum length of reflector for the ⅛-wavelength spaced array was 0.49 wavelength at the lowest frequency; shorter lengths giving considerable loss at 41.5 Mc/s. The reflector length for the ¼-wavelength spaced array was less critical, and a value of 0.51 wavelength at 45 Mc/s appeared a good compromise. The curves of Fig. 5 appear very satisfactory, and, assuming that the dipole alone gives a symmetrical bandwidth, the ⅛-wavelength spaced array gives a response curve flat within approximately 1 db over the television band.

Fig. 6 shows the front-to-back ratios of the same arrays. These agree with the figures expected except that the maxima for both curves occur at rather lower frequencies. The polar diagrams for 41.5, 45 and 48 Mc/s are plotted in Fig. 7, from which it would appear that there is little to choose between the two arrays on the score of discrimination. The familiar cardioid pattern only appears in Fig. 7 (c), and the asymmetrical shape of this is probably due to the use of coaxial-feeder cable.[2] Arrays having spacing between ¼ wavelength and ⅛ wavelength gave similar diagrams when the reflector lengths were suitably adjusted.

No adverse effects were produced in practice through the lack of an impedance-matching device between the cable and aerial when using the close-spaced arrays. The figures given include any losses due to mismatch at this point. Eighth-wave spaced arrays have given satisfactory reception with all types of commercial television receivers, and the test results have been confirmed in a large number of practical installations, including many on the fringes of, and beyond, the generally recognized television service area. No cases of ghost images due to reflections up and down the feeder cable have been encountered, and tests made by introducing a large mismatch at the connection of aerial to cable show no adverse visual effects.

In general, it can be concluded that the advantages of the more sturdy and lighter construction of the close spaced array may be utilized for television-receiving aerials with the additional benefit, in so far as the ⅛-wavelength spacing is concerned, of more even gain over the bandwidth, and better signal-to-noise ratio on the sound channel.

[2] "Dipole with unbalanced feeder." D. A. Bell. *Wireless Engineer*, January 1947.

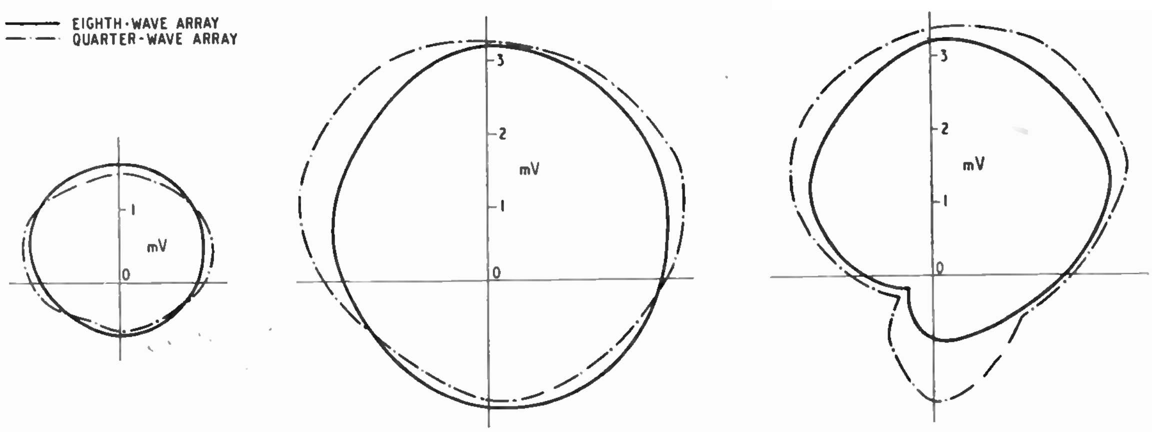

Fig. 7. Polar diagrams of λ/8 and λ/4 spaced reflector systems at 48 Mc/s (a), 45 Mc/s (b) and 41.5 Mc/s (c).