RESEARCH DEPARTMENT

HORIZONTALLY-POLARISED AERIAL FOR LOW-POWER TELEVISION STATIONS — RESULTS OF PRELIMINARY MODEL MEASUREMENTS

Report No. E-055

(1956/24)

THE BRITISH BROADCASTING CORPORATION
ENGINEERING DIVISION

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SUMMARY

This report describes the first stage in the development of the "Batwing V" aerial system, one of the proposals which has been considered for the low-power television stations at Rosemarkie, Londonderry, Blaen Plwy and Carlisle, operating in Channels 2, 3 and 4. Each tier of the aerial comprises two radial "batwing" elements fed in antiphase and arranged on two adjacent faces of the 4 ft (1·22 m) square lattice mast.

The measurements, made on a one-eighth scale model, show that similar elements may be used at all these stations, but that different settings of the slot length and width will be required for the three channels.

1. INTRODUCTION.

The third phase of the expansion of the television service is the provision of a number of stations equipped with 500 watt Band-I transmitters. Band-II transmitters of various powers will also be installed for radiating frequency-modulated sound programmes. A single mast will carry both the Band-I and Band-II aerial systems, and will be capable of supporting additional aerials radiating alternative television programmes in Bands III and IV if required. It will be of lattice construction with a cross section 4 ft (1·22 m) square.

This report summarises the results of a preliminary investigation into the horizontally-polarised aerial system proposed for the Band-I transmissions at Rosemarkie, Londonderry, Blaen Plwy and Carlisle. Sufficient work has been done, using a small-scale model, to enable a tentative engineering design to be prepared; further work will then be necessary to check the electrical performance of this design.

It is intended to use two-tier aerials at Rosemarkie (Channel 2), Londonderry (Channel 2), and Blaen Plwy (Channel 3). The use of two tiers at Carlisle (Channel 4) may not provide a sufficiently great e.r.p., and it is therefore proposed to provide four tiers with a reduced inter-tier spacing; results for both two-tier and four-tier arrangements are given in this report.

2. DESCRIPTION OF THE AERIAL.

It is assumed that the section of mast supporting the radiating elements will be 4 ft (1·22 m) square (measured between the heels of the leg angles), and will have horizontal bracing members 3 ft (91·4 cm) apart and one diagonal member crossing each 3 ft panel. Additional horizontal screening bars will be required mid-way between the horizontal bracing members; these may either be of angle material, similar to the bracing members, or thin strip about 2 in. (5·1 cm) wide. It is recommended that the screening should extend over a vertical aperture of 48 ft (14·6 m) for the two-tier aerials, and 69 ft (21·0 m) at Carlisle if four tiers are used.

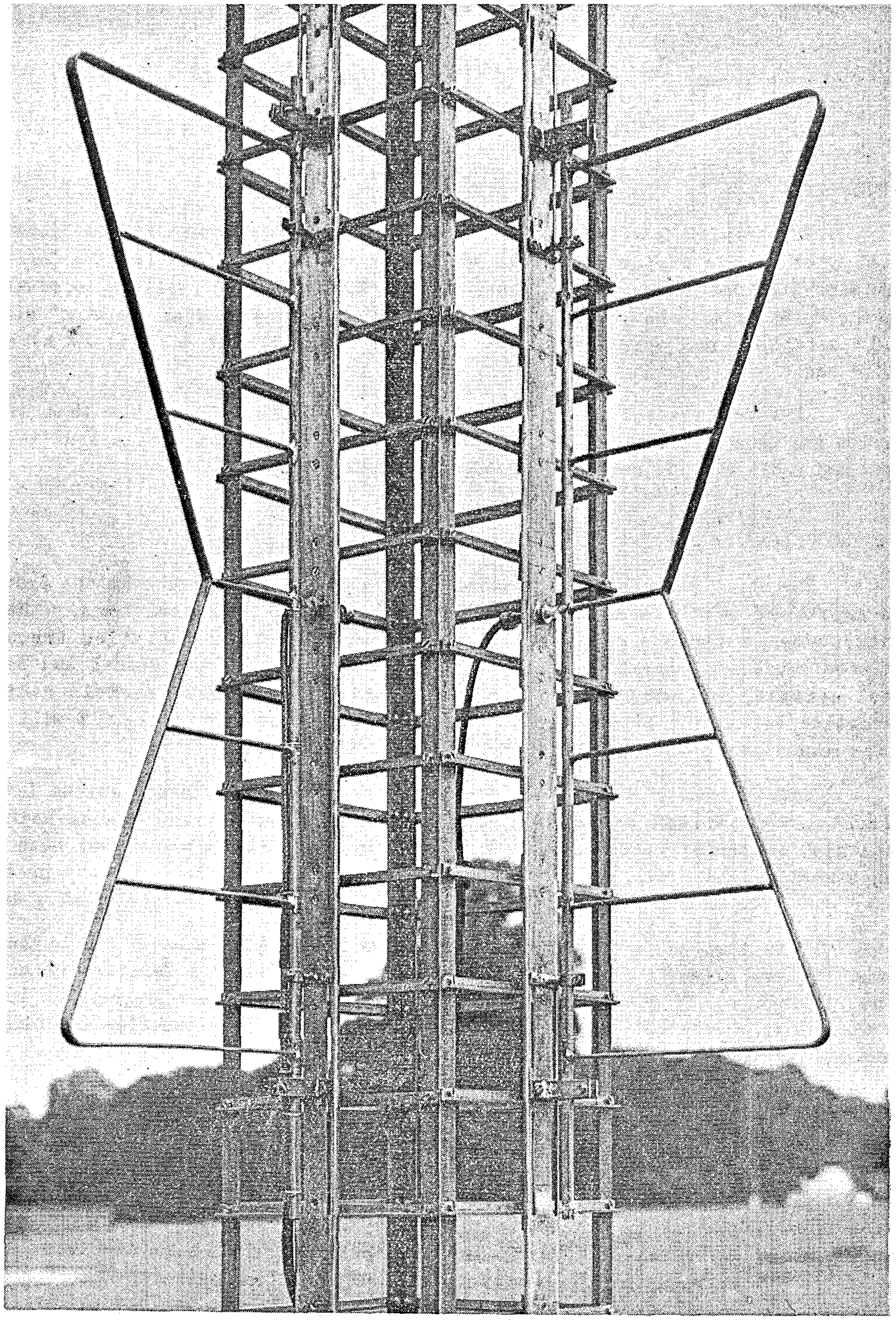
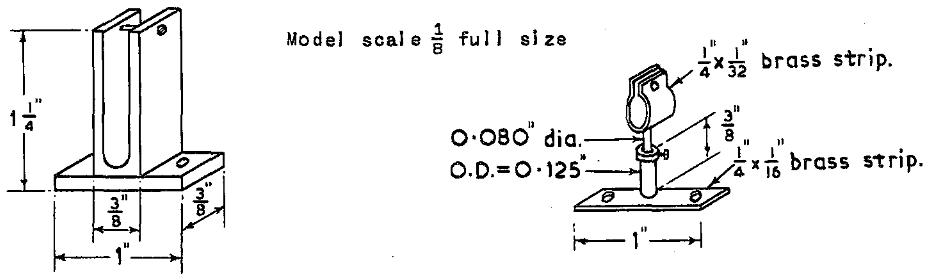


Fig. 1 - Model of one tier

Each tier of the aerial, which may be termed the "Batwing-V" aerial, consists of two batwing elements mounted radially on adjacent faces of the mast and fed in antiphase[1]. A vertical metal strip 9 in. (22·9 cm) wide, which may be stiffened by flanges to form a channel, is clamped to the outside of the screening members in order to form a support for the element, and to screen the interior of the mast from the field of vertical currents in the element.

The batwing element, which is the basis of the American R.C.A. Superturnstile aerial, may be regarded as a skeletonised slot; its use as a separate radiating element supported by a mast of large cross-section was first proposed for the Norwich Band-I television aerial[1, 2]. In the present application it has two advantages. In the first place, the bandwidth, as determined by the impedance/frequency characteristic, is sufficiently wide to enable the same elements to be used in all three channels. Secondly, the radiation pattern of each element resembles that of a pair of horizontal half-wave dipoles spaced approximately one half-wavelength apart. It follows that by using batwing elements instead of dipoles a higher gain can be obtained for a given number of feed points.

Fig. 1 shows the one-eighth scale model used in the experiments. The elements were fed in antiphase by means of equal lengths of PT1M cable whose outer conductors were bonded respectively to the vertical rod of one element and the vertical channel supporting the other element. The clamps supporting the batwing elements, and those provided for slot-length adjustment, are shown in Fig. 1 and, in



(a) Model element support (b) Model short-circuiting clamps

Fig. 2 - Model element support and short-circuiting clamp

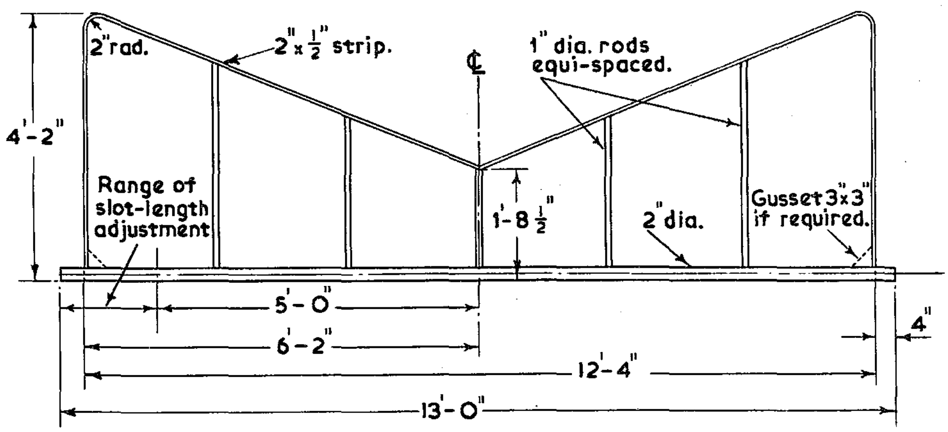


Fig. 3 - Full-scale dimensions of elements

greater detail, in Fig. 2. The model short-circuiting clamps were intended to represent the type of clamp proposed, in a fully-engineered design, for a reserve aerial of similar form at Divis. Fig. 3 shows the dimensions of the radiating elements at full scale together with the range of slot-length adjustment. The self-inductance of the short-circuiting clamps has an effect similar to an increase of slot length; a change in their design from that shown in Fig. 2 may therefore alter the range of slot-length adjustment.

For the two-tier aerials, the inter-tier spacing should be 21 ft (6·40 m). This spacing was chosen to be rather greater than that giving the highest gain in order to reduce the coupling between tiers. If four tiers are used at Carlisle (Channel 4), the inter-tier spacing should be 15 ft (4·57 m).

3. RADIATION PATTERNS AND GAIN.

3.1. Horizontal Radiation Pattern (h.r.p.).

Fig. 4 shows the h.r.p.s measured with a single-tier model at model frequencies corresponding to the vision carrier frequencies. They are in good agreement with h.r.p.s calculated by assuming the square mast to behave like a cylinder having a radius 0·6 times the side of the square. The effect of moving the elements across the faces of the mast was investigated but no worthwhile improvement could be obtained in this way.

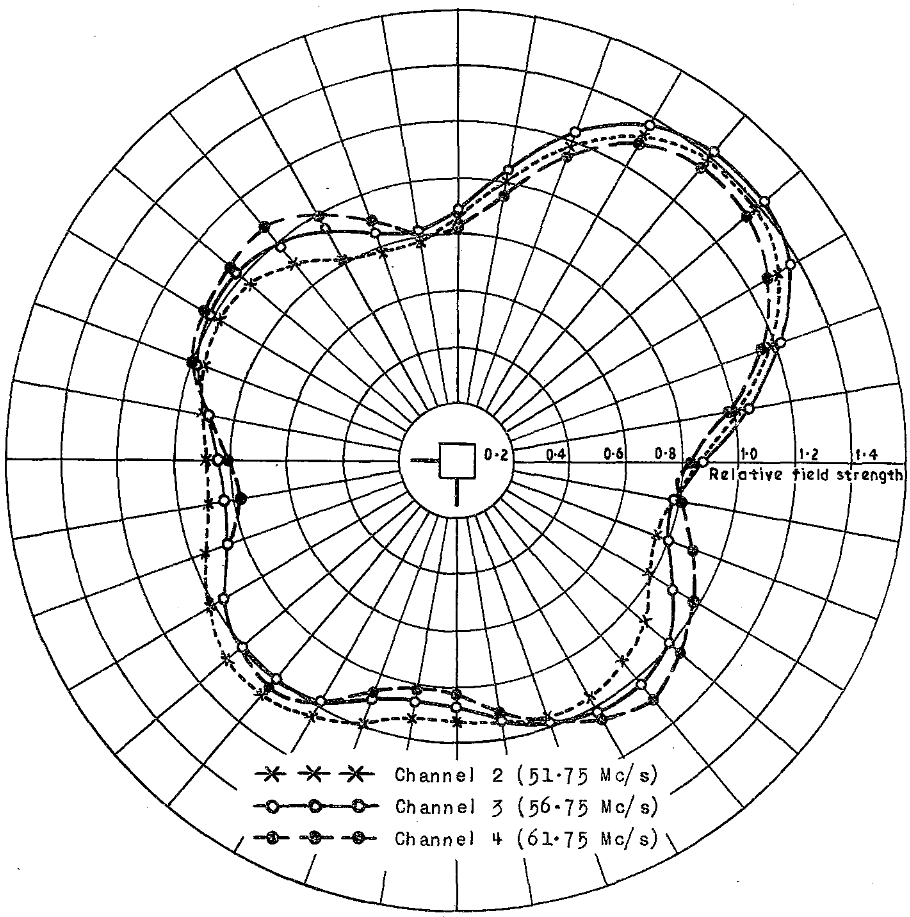


Fig. 4 - Measured horizontal radiation patterns

The curves in Fig. 4 are scaled so that each of them is equal in area to the unit circle. It follows that the mean gain of the aerial will be equal to the gain in any direction in which Fig. 4 shows the relative field strength to be unity.

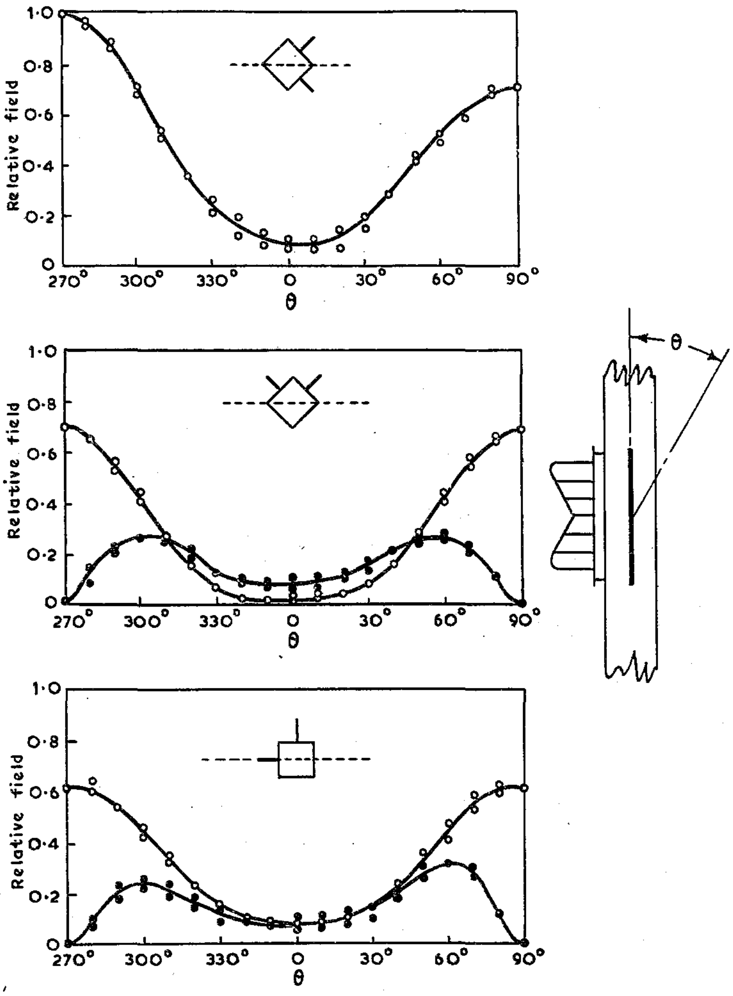
The maximum/minimum ratio is about 5 dB, although it is usually considered undesirable for this ratio to exceed 3 dB. In this case a less uniform h.r.p. can be accepted because there is a single predominant maximum rather than three or four equal maxima. This maximum can be oriented in the direction requiring the greatest e.r.p., and may be helpful rather than harmful. With three or four equal maxima it usually proves impossible to direct one maximum in an important direction without directing a minimum in another important direction. The required direction of the principal maximum shown in Fig. 4, which coincides with a mast stay, is as follows:

Blaen Plwy	0°
Rosemarkie	208°
Carlisle	230°
Londonderry	195°

3.2. Vertical Radiation Pattern and Gain.

The vertical radiation pattern (v.r.p.) of a single-tier model, measured at a model frequency corresponding to the vision carrier frequency of Channel 3, is shown in Fig. 5 for each of the diagonal planes of the mast and for a plane parallel to two faces of the mast. Similar measurements were also made at frequencies corresponding to the vision carrier frequencies of Channels 2 and 4.

From considerations of symmetry it may be deduced that the radiation from the aerial will be purely horizontally polarised in the vertical plane bisecting the angle between the elements, and in the horizontal plane. In other directions elliptically-polarised waves will be radiated, and the power associated with the vertically-polarised component must be



Channel 3 (56·75 Mc/s)

—o—o— Horizontally-polarised component

—●—●— Vertically-polarised component

Fig. 5 - Measured vertical radiation patterns

taken into account in assessing the gain. The v.r.p. was therefore measured separately for the two polarisations, and where appropriate the curves for vertical polarisation are included in Fig. 5.

From the measured v.r.p.s the total radiated power was determined, taking both vertical and horizontal components of the field into account, and the intrinsic gain (i.e. the gain ignoring all losses) calculated for each channel. The results, which are contained in Table 1, correspond to unit field in Fig. 4.

The aerial net gain is less than the intrinsic gain by the loss in the distribution feeders and that due to accidental misphasing etc.; these are assumed to be 0·1 dB and 0·2 dB respectively. The network loss is that in the sound/vision combining filter; the main feeder loss is that due to the required length of HM11A1 cable.

TABLE 1

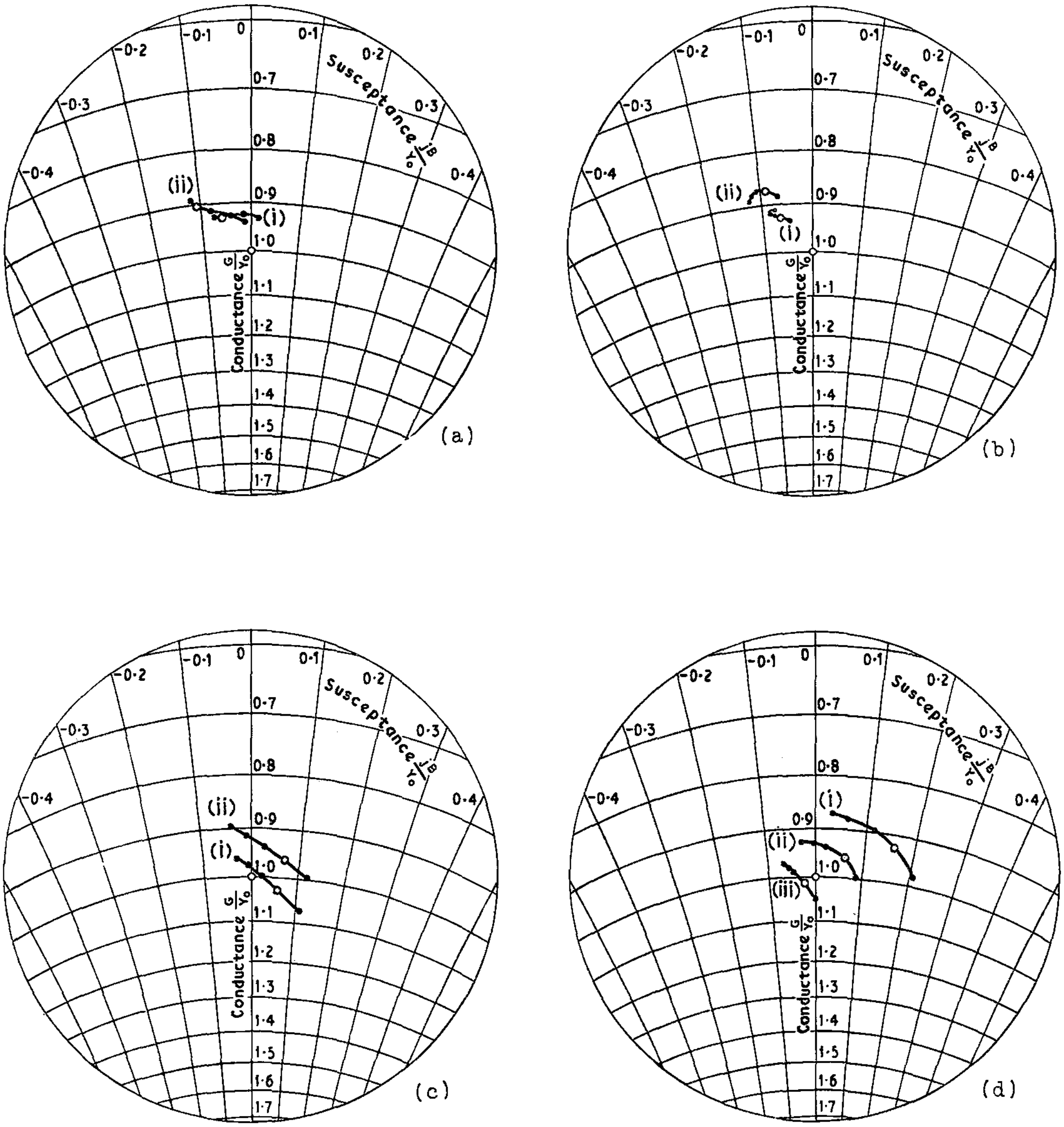
Channel	No. of Tiers and Spacing	Intrinsic Gain	Aerial Net Gain	Main Feeder Loss	Network Losses	Effective Gain	E.R.P.
2	1 2(21 ft)	+0·1 dB +3·3 dB	−0·2 dB +3·0 dB	0·6 dB	0·4 dB	−1·2 dB +2·0 dB	0·38 kW 0·79 kW
3	1 2(21 ft)	+0·3 dB +3·5 dB	0 dB +3·2 dB	0·9 dB	0·4 dB	−1·3 dB +1·9 dB	0·37 kW 0·77 kW
4	1 2(21 ft)	+0·3 dB +3·4 dB	0 dB +3·1 dB	0·9 dB	0·4 dB	−1·3 dB +1·8 dB	0·37 kW 0·76 kW
4	2(15 ft) 4(15 ft)	+3·4 dB +6·5 dB	+3·1 dB +6·2 dB	0·9 dB	0·4 dB	+1·8 dB +4·9 dB	0·76 kW 1·54 kW

4. ADMITTANCE.

4.1. Method of Measurement.

All the admittance measurements were made using a two-tier model. The four elements were connected through 10 ft (3·05 m) lengths of PT1M cable to a double quarter-wave transformer attached to a General Radio admittance meter modified for use with 70-ohm cable. The measuring system was calibrated by connecting to the transformer four terminated cables each 75 ft (22·8 m) long and noting the admittance read by the meter. As a result of attenuation the use of an approximately-matched termination resulted in an input admittance very close to the characteristic admittance of the cable. The cables were then cut to the required length and their electrical length and loss determined in a separate experiment.

Measurements were made at 10 Mc/s intervals over the frequency range 370 Mc/s to 520 Mc/s, and the results were referred to the feed point of an element. These experimental values of conductance and susceptance, normalised to the characteristic admittance of PT1M cable (13·8 ± 0·3 mmho), were plotted against frequency, and smoothed curves were used to obtain the admittance locus.



(a) Channel 2, inter-tier spacing 21 ft
(b) Channel 3, inter-tier spacing 21 ft
(c) Channel 4, inter-tier spacing 21 ft
(d) Channel 4, inter-tier spacing 15 ft

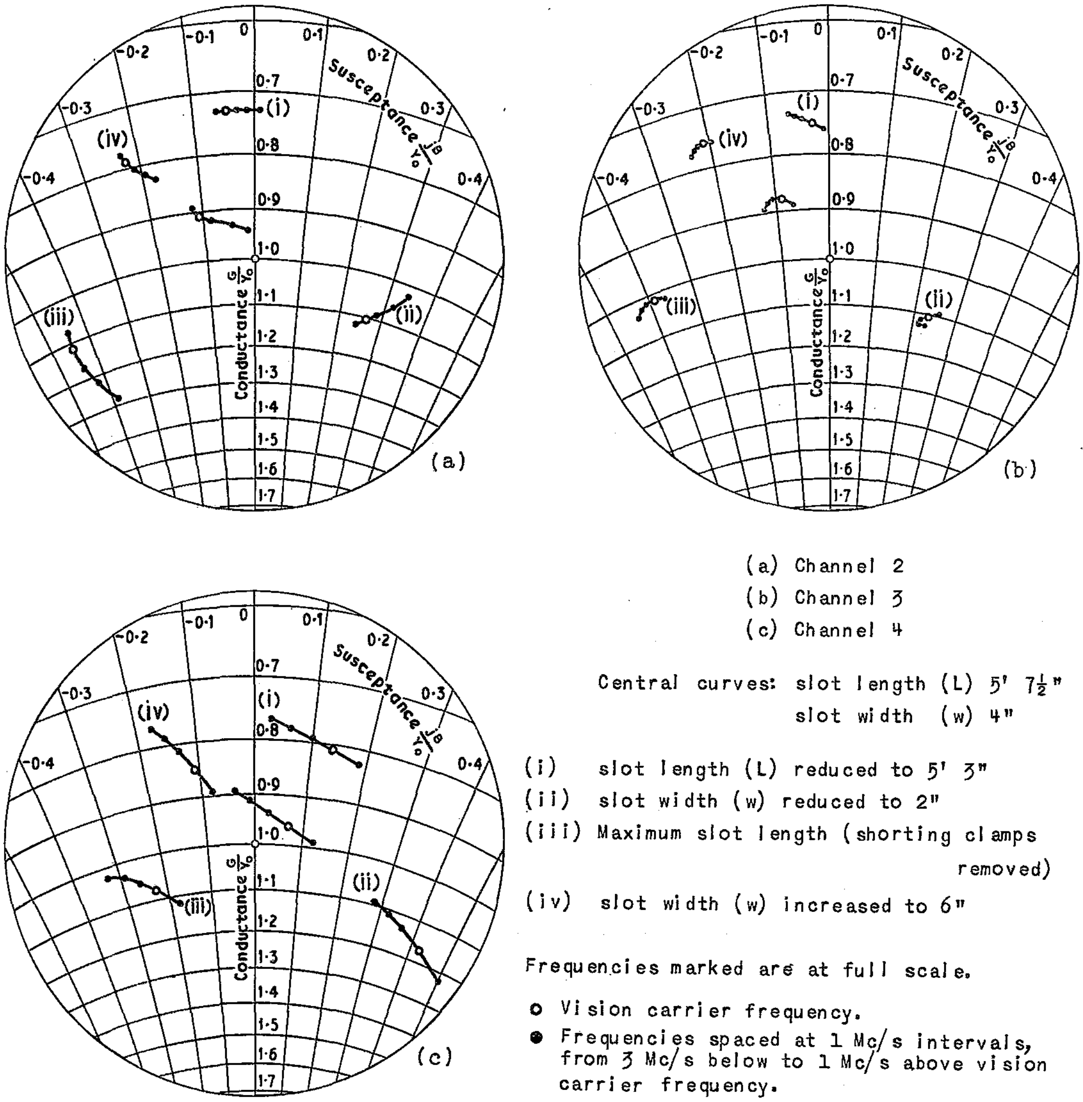
(i) 1 tier
(ii) 2 tiers
(iii) 4 tiers

Frequencies marked are at full scale.

o Vision carrier frequency.

● Frequencies spaced at 1 Mc/s intervals, from 3 Mc/s below to 1 Mc/s above vision carrier frequency.

Fig. 6 - Admittance loci of 1, 2 and 4 tiers



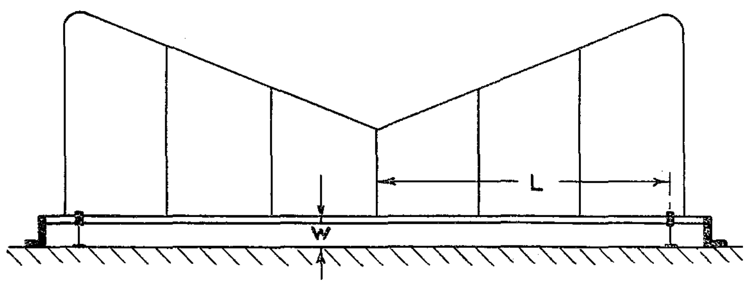
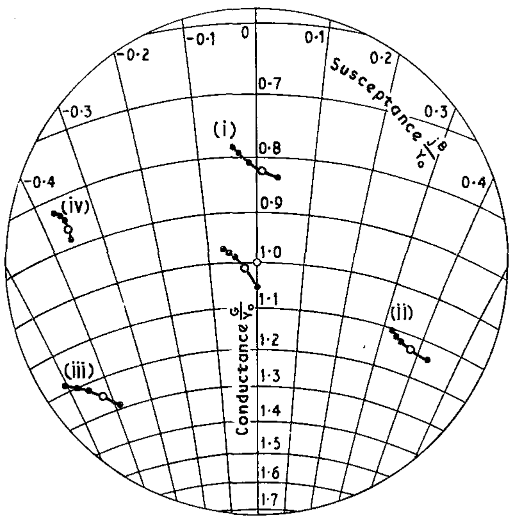


Fig. 7 - Effect of adjustments on admittance of 2 tiers spaced 21 ft

4.2. Mutual Admittance.

The admittance of two tiers driven in phase was measured directly; their mutual admittance was assessed by making a second admittance measurement with the connections to one tier reversed. In the case of the four-tier aerial proposed for Carlisle an additional pair of measurements was made with increased spacing between the tiers to assess the second-order mutual admittance. The third-order mutual admittance was found to be less than 2% and was neglected.

Fig. 6 shows the admittance loci for two-tier aerials in Channels 2, 3 and 4 respectively, together with the loci corresponding to a single tier. The single-tier admittances were obtained by subtracting the mutual admittance from the two-tier measurements. The admittance of a four-tier aerial in Channel 4, also shown in Fig. 6, was obtained by adding the measured mutual admittances to the two-tier admittances. The settings of slot length and slot width for these results are as specified for the central curves of Figs. 7 and 8.



Channel 4

Central curve: slot length (L) 5' $5\frac{1}{2}$"
slot width (w) 4"

(i) slot length (L) reduced to 5' $0\frac{1}{2}$"
(ii) slot width (w) reduced to 2"
(iii) Maximum slot length (shorting clamps removed)
(iv) slot width (w) increased to 6"

Frequencies marked are at full scale.

o Vision carrier frequency.

● Frequencies spaced at 1 Mc/s intervals, from 3 Mc/s below to 1 Mc/s above vision carrier frequency.

Fig. 8 - Effect of adjustments on admittance of 4 tiers spaced 15 ft

4.3. Method of Adjusting Elements.

A specification for the reflection coefficient of a television aerial is laid down in Research Department Report No. E-046[3]. This specification can be satisfied at all the sideband frequencies by adjusting the width and length of the slot for a match at the vision carrier frequency. Figs. 7 and 8 show the admittance curves obtained at the extremes of the proposed adjustments. The results shown in Fig. 8 were deduced from measurements made on two tiers spaced 15 ft (4·57 m). The second-order mutual admittance which was added was assumed to be negligibly changed over the range of adjustment shown.

The bandwidth of the two-tier aerial for Channel 4 (see Fig. 7c) is only just adequate and it follows that this aerial would require careful adjustment. A better admittance-frequency characteristic could have been obtained by adopting different dimensions for Channel 4 but this course was not recommended in view of the advantage gained by using identical elements in all channels. In any case, it is now proposed to use four tiers at Carlisle, the only station in Channel 4.

It may be desirable to stiffen the elements mechanically by the triangular gussets shown dotted in Fig. 3. If this is so, there will be a region in which the short-circuiting clamps cannot be placed when adjusting slot length. This difficulty may be overcome by placing the two clamps at different distances from the feed point, one nearer than the gusset and one beyond the other gusset. It has been verified that the performance is negligibly affected if the two short-circuit clamps are placed asymmetrically in this way; the two half-lengths of the batwing element may differ by up to 8 in. (20·3 cm) at full scale.

5. EMERGENCY CONDITION.

The mutual admittance between the halves of the aerial is shown as the difference between the admittances for one and two tiers in Figs. 6(a), 6(b) and 6(c), and the difference between the admittances for two and four tiers in Fig. 6(d).

If, as a result of a breakdown, only one half of the aerial is energised, a delayed signal will be radiated owing to the mutual impedance between the halves of the aerial. Its maximum amplitude will be about 29 dB below the primary signal in the case of the two-tier aerials and 23 dB below the primary signal in the case of a four-tier aerial on Channel 4. The latter figure corresponds to an appreciable ghost image, but this could be accepted in emergency.

6. CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER WORK.

The development has been taken to a point at which a fully-engineered design for the aerial and feeder system can be prepared.

Since the model design has been based, as far as possible, on engineering designs of similar aerial systems, the full-scale design should correspond very well with the model. If this is so, no further radiation pattern measurements will be required. It will, however, be necessary to make further admittance measurements in order to check that the range of admittance adjustment is satisfactory. These measurements could be made either on a new model (preferably with two tiers) or at full scale.

7. ACKNOWLEDGEMENT.

The experimental work was carried out with the assistance of Mr. R.C. Thoday.

8. REFERENCES.

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2. "Horizontally-Polarised Directional Band-I Aerial for the Norwich Medium-Power Television Station", Research Department Technical Memorandum No. E-1032, October 1954.

3. "Specification of the Impedance Characteristics of Television Transmitting Aerial Systems", Research Department Report No. E-046, Serial No. 1953/18, July 1953.

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