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(Planning and Installation Department, BBC Engineering Division)

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FOREWORD

THIS is one of a series of Engineering Monographs published by the British Broadcasting Corporation. About six are produced every year, each dealing with a technical subject within the field of television and sound broadcasting. Each Monograph describes work that has been done by the Engineering Division of the BBC and includes, where appropriate, a survey of earlier work on the same subject. From time to time the series may include selected reprints of articles by BBC authors that have appeared in technical journals. Papers dealing with general engineering developments in broadcasting may also be included occasionally.

This series should be of interest and value to engineers engaged in the fields of broadcasting and of telecommunications generally.

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CONTENTS

PREVIOUS ISSUES IN THIS SERIES

THE CRYSTAL PALACE BAND I TELEVISION TRANSMITTING AERIAL

SUMMARY

This monograph describes the design, testing, and installation of the eight-tier Band I transmitting aerial at the BBC's Crystal Palace Television Station. Structural considerations made it necessary to mount the upper four tiers and lower four tiers of the aerial on sections of the tower having very different cross-sections and this raised many electrical and mechanical problems which had not occurred in previous aerial designs.

Preliminary measurements at 450 Mc/s using scale models indicated that four dipoles per tier for the upper half and eight dipoles per tier for the lower half of the aerial would be necessary to give a sufficiently circular horizontal radiation pattern. These model measurements also predicted the spacing of the elements from the tower face and, in the case of the lower half of the aerial, from each other. Based on this information preliminary designs for a single-dipole radiating element for the upper half of the aerial and a double-dipole radiating element for the lower half of the aerial were prepared. These designs were developed at full scale and further model tests were carried out in parallel with the full-scale development work, thus enabling the effect of changes in design to be rapidly assessed. These prototype investigations enabled the behaviour of the complete aerial to be predicted with considerable accuracy and as a result the adjustment at site was carried out relatively easily.

1. Introduction

The economic considerations governing the choice of transmitter power and aerial gain for the Crystal Palace Television Transmitting Station resulted in a decision to use a Band I aerial consisting of eight tiers of vertical dipoles with a substantially circular horizontal radiation pattern.[1] Restriction of space available on the site, however, necessitated a self-supporting tower and not a stayed mast being used. The tower is illustrated in Fig. 1 and consists of a support structure 440 ft high of square cross-section tapering from 120 ft wide at the base to 14 ft 6 in. at the top. Above this are three parallel-sided sections, 9 ft 6 in., 6 ft 6 in., and 4 ft 4 in. square, each 72 ft high. Short, tapered assemblies interposed between these sections bring the total height to 672 ft and there is provision for erecting a 40-ft pole-mounted aerial above this level, bringing the total height to the maximum permitted figure. This form of tower was chosen since preliminary investigations had shown that it would be possible to erect the Band I aerial partly on the upper part of the tapered support tower (mean cross-section 17 ft × 17 ft) and partly on the parallel-sided section above (cross-section 9 ft 6 in. × 9 ft 6 in.) and thus leave the maximum possible space above the Band I aerial for higher frequency aerials. Fig. 1 also shows in outline the Band I aerial arrangement adopted.

The transmitting system adopted for the station consists of two separate chains each comprising a 15-kW peak-white vision transmitter and a 3·75-kW sound transmitter together with a vision/sound combining unit. The combined sound and vision output signals of the two chains are fed to the aerial switching arrangement shown in Fig. 2. The normal system of operation is with the two chains combined in the diplexer, the output of which feeds the two halves of the aerial via the splitter transformers. This system of normal operation is adopted, rather than that of feeding the output of the two chains independently to the two aerial halves in order to reduce distortion of the received signal which would otherwise tend to occur at minima in the field near the station.

In the event of a transmitter or combining unit failure the radiated field is reduced by 6 dB, but by switching out the diplexer the drop in field is reduced to 3 dB. In the event of an aerial failure both chains of transmitters are paralleled via the diplexer and connected to the remaining half of the aerial; the loss in radiated field is therefore once again 3 dB. Each half of the aerial system, both feeders and aerial elements, have therefore to be capable of carrying the combined power of both transmitter chains. In the initial planning it was decided to cater for a possible future increase of vision power to 50-kW peak-white for each vision transmitter, together with appropriate sound power. Each main feeder and half-aerial system, together with the relevant part of the feeder switching system, has therefore been designed to carry a total power of 100-kW peak-white vision and 25-kW sound carrier.

2. Mechanical and Electrical Design of the Aerial System

2.1 General

2.1.1 Practical Considerations

Initially, model tests at one-tenth scale (450 Mc/s) were carried out to determine an arrangement of dipole radiating elements which would give a sufficiently circular horizontal radiation pattern for each half of the aerial. The investigation showed that acceptable results would be obtained with an arrangement of four dipoles per tier for the upper half of the aerial and eight dipoles per tier for the lower half of the aerial (see Fig. 1). It was further determined that for both halves of the aerial the elements in each tier should be driven with currents of the same amplitude and phase. The tests showed that the dipole elements for the upper half of the aerial were required to be 0·2 λ from the tower face, whilst the two dipoles on each face used for the lower half of the aerial needed to be 0·5 λ apart and 0·2 λ from the tower face.

Since only one dipole per face per tier was required for the upper half of the aerial it was decided that each of these dipoles should be designed as a single self-contained ele-
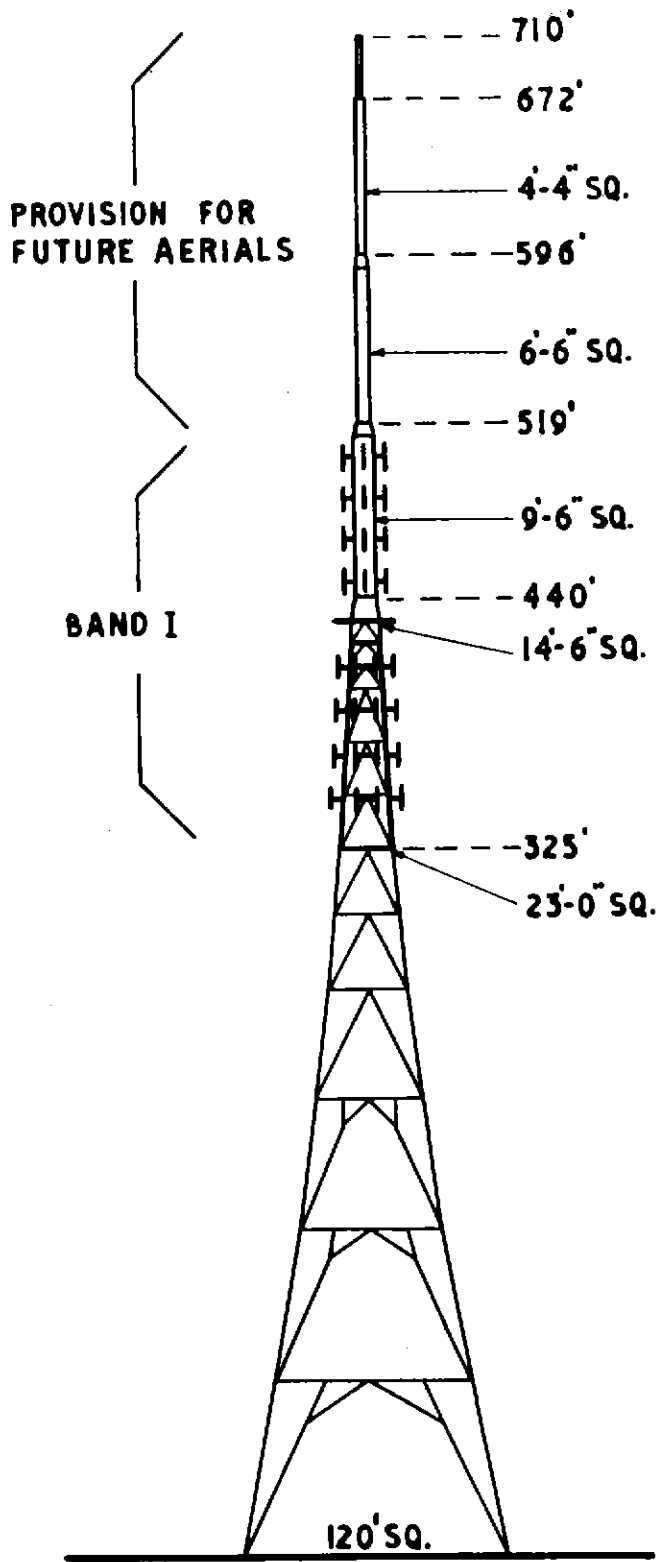
PROVISION FOR
FUTURE AERIALS

- - - - 710'
- - - - 672'
- 4·4" SQ.
- - - - 596'
- 6·6" SQ.
- - - - 519'
- 9·6" SQ.
- - - - 440'
- 14·6" SQ.

BAND I

- - - - 325'
- 23·0" SQ.
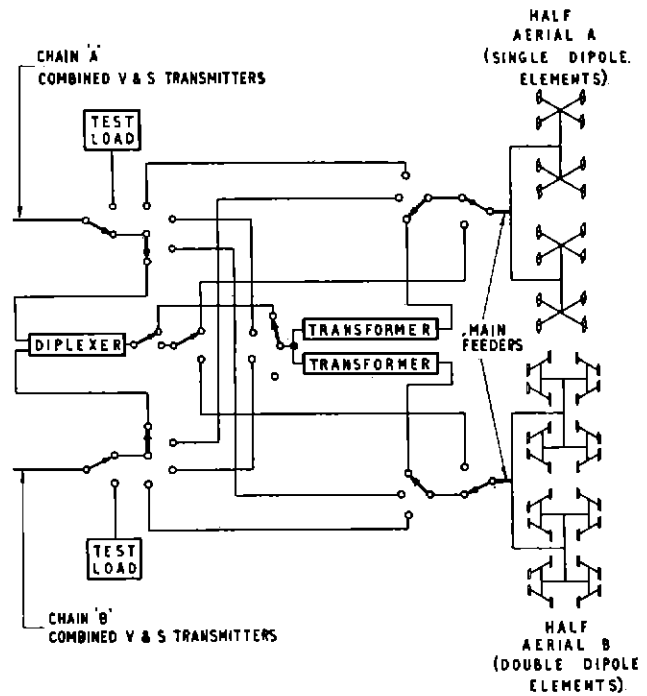
120' SQ.

Fig. 1 — Outline of the tower

Fig. 2 — Schematic of aerial, feeders, and switching

ment. For the lower half of the aerial, however, where two dipoles per face per tier were required, it was decided to develop an element comprising two dipoles fed by a common coaxial feeder.

The spacing necessary between tiers of vertical dipoles for optimum gain is approximately one wavelength. Due to mechanical considerations, however, it was necessary to reduce the spacing between tiers of the upper and lower halves of the aerial to $0·825 \, \lambda$ and $0·90 \, \lambda$, respectively. The gain varies very slowly with tier spacing in the region of the optimum and the loss of gain due to the reduction in tier spacing is negligible.

2.1.2 Theoretical Considerations

The variation of the conductance presented at the centre of a resonant half-wave dipole (either a single or a folded dipole) is determined by the effective cross-sectional area of the dipole limbs, and in practice it is found that no mechanical difficulty exists in achieving a limb cross-section resulting in a sufficiently constant conductance. The susceptance presented by the dipole varies considerably however, and has a negative slope over the band. To obtain a broad-band admittance it is therefore necessary to connect a parallel resonant circuit across the dipole feed point with a susceptance slope such that it cancels the dipole susceptance. This method of improving the dipole admittance characteristic is referred to as susceptance compensation. The design of each type of element was therefore based on the use of dipole limbs of sufficient cross-sectional area and the incorporation of the simplest and most compact arrangements possible for susceptance compensation.

6

2.2 The Single-Dipole Element for the Upper Half of the Aerial

The final design of the full-scale dipole element is shown in Fig. 3, together with a schematic diagram illustrating the principle of operation. The dipole limbs are skeletonized to give low wind-loading and their length can be varied by means of the adjusting tubes protruding through the end plates. The parallel resonant compensating circuit is realized by mounting the dipole limbs on short-circuited stubs which form an inductance, the required capacitance being provided by a short length of open-circuited coaxial feeder connected across the dipole limbs. As illustrated in Fig. 3, the short-circuited part of the structure is split into three in the practical arrangement, the outer arms forming the means of mechanical attachment to the tower legs.

The following controls are available for adjusting the dipole impedance to match its 2-in. diameter, 70-ohm feeder over the band:

(a) The dipole resonant frequency can be varied by adjusting the length of the dipole limbs.

(b) The conductance can be adjusted about a mean value of 14 m.mho (70 ohms) by moving the driving point horizontally relative to the dipole limbs. This is achieved by the provision of a telescopic joint in the 2-in. diameter feeder.

(c) The susceptance compensation can be controlled by simultaneous adjustment of the position of the short-circuits and the value of the coaxial capacitance.
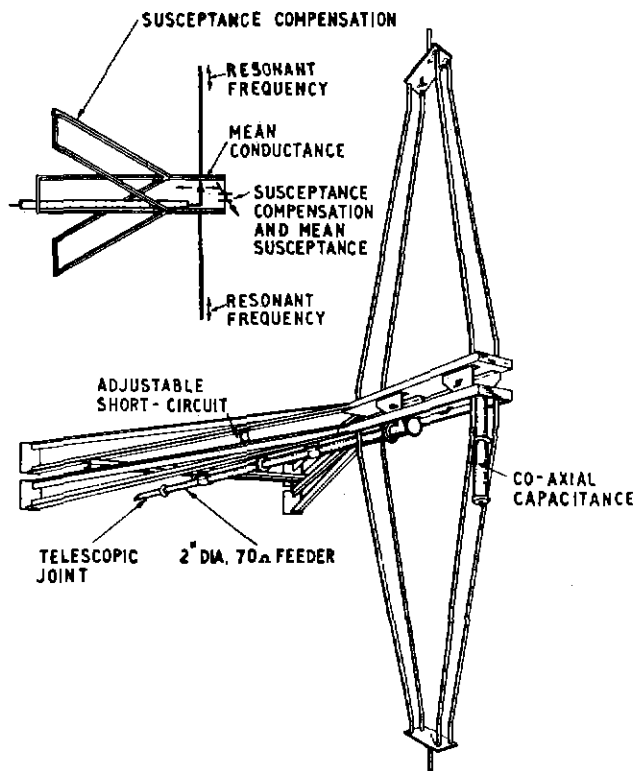

Fig. 4 — Double-dipole element for lower half of aerial

(d) The coaxial capacitance, in addition to controlling the susceptance compensation in association with the short-circuited stubs, may be adjusted to offset any excess or deficit of capacitance across the centre of the dipole. This is, in effect, an adjustment of the mean susceptance of the dipole.

De-icing heaters of tubular form are fitted to the base plate of each dipole limb, each heater being of 500-W loading, i.e. a total heating power of 1 kW per dipole.

2.3 The Double-Dipole Element for the Lower Half of the Aerial

The final design of the full-scale double-dipole element is shown in Fig. 4 together with a schematic diagram illustrating the principle of operation. As in the case of the single element the limbs are skeletonized to reduce the wind load. The dipoles are folded, each having a driving-point impedance of approximately 280 ohms, and derive a certain amount of compensation from the short-circuited transmission lines formed by the folded limbs. The 'dead' sides of the folded dipoles are attached to a beam, universally drilled, so that it can be attached to the tower at any one of the four tier levels by a pair of standard brackets. The driving points of the dipoles are connected together by a balanced transmission line consisting of two light angles supported from the beam on polythene insulators. The balanced transmission line is extended beyond the di-

Fig. 3 — Single-dipole element for upper half of aerial

pole driving points for approximately a quarter-wavelength and then short-circuited. A 1⅝-in. 70-ohm copper feeder is bonded along the lower of the two angles forming the balanced transmission line and is connected at the centre point of the line between the two dipoles. The dipoles are separated by a half-wavelength and, since the characteristic impedance of the balanced transmission line is 200 ohms, an approximate match to the 70-ohm feeder is obtained at the centre point.

The following controls are available to match the dipole element to its 1⅝-in. diameter, 70-ohm feeder:

(a) The dipole resonant frequency can be varied by adjusting the length of the limbs with the screwed rods protruding from the end-plates.

(b) The mean conductance can be adjusted by adding capacity plates on the balanced transmission line between the dipoles, thus changing its characteristic impedance. To ensure that an addition and not a reduction of capacitance is required a capacity sleeve is placed on the inner of the coaxial feeder an eighth-wavelength back from the drive point.

(c) The susceptance compensation can be controlled by the simultaneous addition of capacity plates across the dipoles and the adjustment of the balanced transmission line short-circuits.

(d) As in the case of the single-element the mean susceptance can be controlled by adjustment of the capacitance across the dipoles.

In order to increase the mechanical stability and simplify the distribution feeder system, the main supporting beams are extended so as to meet at the corners of the tower, thus forming a continuous cat-walk at each tier level.

As an experiment, it was decided not to fit the double-dipole elements with de-icing heaters, initially. The design, however, permits the installation of tubular heaters on the parallel transmission line in the region of the dipole driving points should this eventually prove necessary.

2.4 Screening of Tower

In order to prevent the feeders and steelwork internal to the tower from affecting the aerial impedance and also to reduce the possibility of any internal resonances within the tower, screening conductors are installed on all four faces of the tower over the aerial aperture. The screening consists of six equally spaced vertical conductors per face over the region of the upper half of the aerial and eight quasi-vertical conductors per face over the region of the lower half of the aerial. The number of conductors used is the maximum permissible on wind-loading grounds and each conductor consists of a ½-in. diameter S.C.A. cable bonded to the tower wherever it crosses a structural member.

2.5 Main and Distribution Feeder Systems
2.5.1 Main Feeders

In order to carry the maximum power ever likely to be employed and also to minimize losses, the two main feeders are 5-in. diameter coaxial copper air-spaced feeders of 51·5 ohms characteristic impedance. The performance of these feeders is as follows:

(a) Each feeder is capable of carrying simultaneously a vision power of 100-kW peak-white on 45 Mc/s and a sound carrier power of 25 kW on 41·5 Mc/s 100 per cent amplitude modulated. The loss in each feeder is less than 0·075 dB per 100 ft.

(b) With the feeders terminated in matched loads the input reflection coefficient is less than 1·5 per cent, which results in delayed signals caused by impedance discontinuities being well below the level of visibility.

2.5.2 Distribution Feeders

The use of two main feeders necessitates the provision of separate distribution feeder systems for the two halves of the aerial. The performance of these systems is as follows:

(a) Each half of the distribution feeder system is capable of carrying the same power as its associated main feeder.

(b) With each of the branch feeders leading to the aerial elements terminated in a matched load, the reflection coefficient of the input impedance of each half of the distribution feeder system is less than 1 per cent. This performance ensures that the degradation of aerial performance due to the distribution feeder system is negligible.

The distribution feeder systems for the upper and lower halves of the aerial use similar main transformers, but there are considerable differences in layout owing to the differences in the tower cross-section. To illustrate the method whereby the impedances of the aerial elements are transformed to match the main feeder, Fig. 5 shows a schematic layout of the distribution feeder system used for the lower half of the aerial.

For the upper half of the aerial the distribution feeder system is mounted axially in the tower but for the lower half of the aerial structural considerations made this form of layout impossible. In the latter case, therefore, the transformers are mounted at one side of the tower and lie in a plane parallel to one of its faces. The tapering section of the tower and the layout of the distribution feeder transformers resulted in a variation in the lengths of the 1⅝-in. feeders at each tier level and this, together with the need for special phasing due to the tapering of the tower, made it necessary to incorporate equalizing loops of feeder in each of the 2-in. 35-ohm feeders (shown in Fig. 5).

Throughout the system, screwed joints tightened by phosphor-bronze set-screws are used wherever possible to joint adjacent lengths of the inner conductor and, where spring contact joints are necessary, all contacts are heavily copper or silver plated. The outers of the feeders are flanged at the ends, bolted together, and sealed by synthetic-rubber rings. The system is supplied with dry air under pressure from a dehydrator to ensure that no moisture enters.

All horizontal feeder sections are protected against falling ice and, in the case of the lower half of the aerial, use is made of the open-mesh steel flooring of the platforms for this purpose.
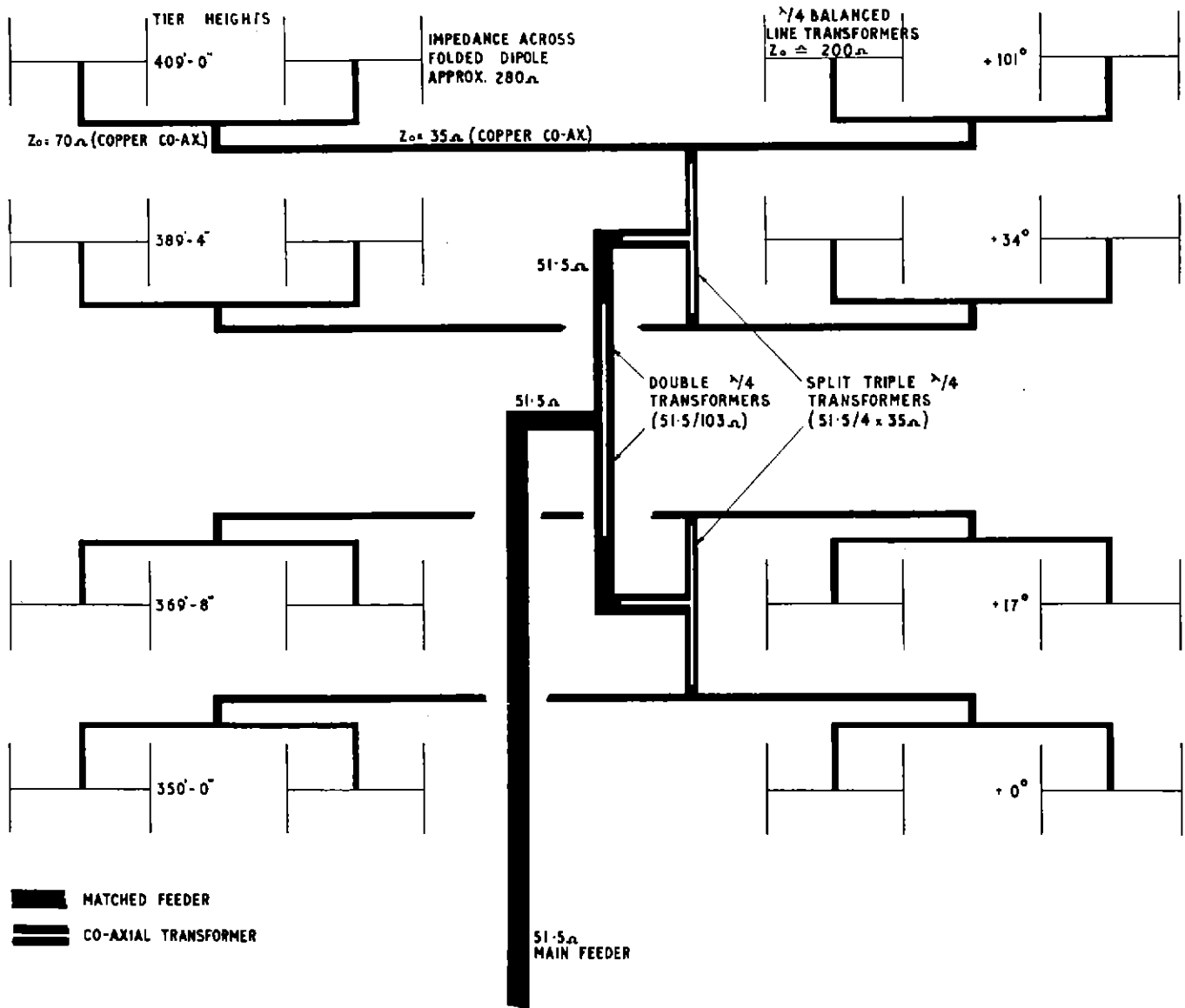
Fig. 5 — Schematic of distribution feeder system for lower half of aerial

3. Model and Full-scale Prototype Aerial Measurements

3.1 Scale Model Tests

The full-scale design of the elements for both the upper and lower halves of the aerial were checked by measurements made on model aerials which enabled bandwidth and impedance to be investigated. It was not possible, however, to predict the precise settings of the impedance matching controls due to the difficulty of scaling the full-size elements sufficiently accurately. The great advantage of the model measurements was that, due to the small size of the model elements, it was possible to try out design modifications in a minimum time and to build sufficient of the aerial system (i.e. more than one tier) to investigate the magnitude of the mutual impedances between elements. The latter measurements were of great assistance in setting up the aerial and it is no exaggeration to say that the accurate design of an aerial of this complexity would be virtually impossible without the aid of model measurements.

3.2 Single-Dipole Element

Initially, a mechanical design based on preliminary model measurements was prepared, and a full-scale single tier of four dipoles, mounted on a 40-ft tower simulating the relevant section of the final tower, was then erected. Measurements were carried out to determine precise mechanical dimensions and the range of the impedance adjusting controls was also investigated to ensure that sufficient range
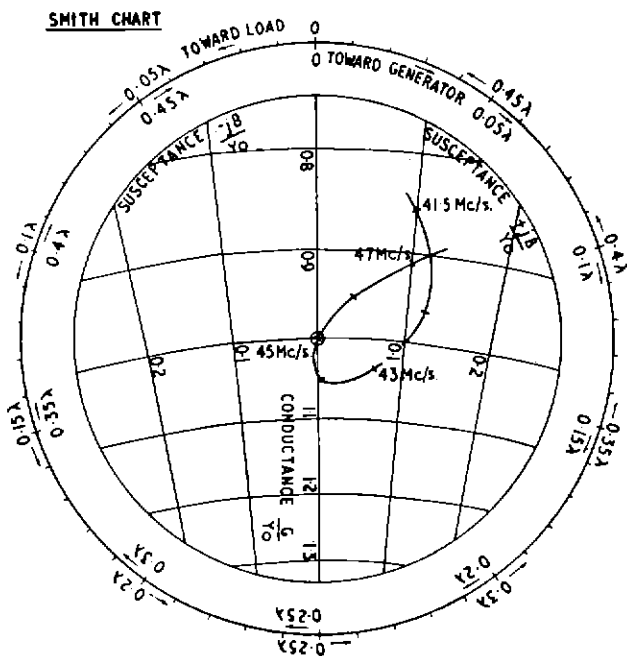
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Fig. 6 — Admittance characteristic of one tier of dipole elements for upper half of aerial

of adjustment would be available to take up effects of mutual impedance on site. Fig. 6 is a typical admittance characteristic obtained for the complete arrangement of one tier.[2]

3.3 Double-Dipole Element

The production of a full-scale prototype of a single tier of double-dipole elements would have required a structure approximately 20 ft × 20 ft × 40 ft high and four radiating elements. This would have involved considerable delay and expense, but model tests confirmed that tests on one double-dipole element mounted horizontally over a wire netting earth screen would be adequate to establish settings of the controls.

In view of the greater complexity of this element as compared with the single dipole, full-scale prototype tests were carried out in parallel with scale-model tests. In the original design the folded dipole limbs consisted of four tubes, two attached to the support beam (dead side) and two attached to the parallel transmission line (live side). Model tests indicated, however, that the driving point impedances of the dipoles were in the region of 800 ohms, instead of the expected value of 280 ohms. Nevertheless, further experiments on the model showed that the impedance of the folded dipole could be reduced to the required value by modifying the dipoles so that the 'dead' side of the fold consisted of one tube only (see Fig. 4). The reason for the unexpectedly high impedance of the folded dipoles has not been investigated in detail but it is thought to be due to the large area of the feed points of the dipoles and their association with the parallel transmission line.

The results of the prototype tests may be summarized briefly as follows:
(a) The mutual impedance between dipoles and the effect of the earth screen (i.e. the tower face) raised the resonant frequency of the dipoles by approximately 6 per cent. The length of the dipoles had therefore to be reduced by this amount.
(b) Model tests predicted that the mutual impedances between double-dipole elements in a given tier would not be greater than 5 per cent and it was found that the range of the controls could conveniently take up this amount during the final adjustment on site.

Fig. 7 shows a typical admittance characteristic of the prototype double-dipole element.[2]

4. Phasing of Aerial Tiers

In order that the maximum field strength is obtained from a multi-tier aerial it is necessary that, at any distant point, the contributions from all the tiers add in phase. In a system where all the tiers are similar electrically and mechanically, this means that all the tiers must be driven with equal, co-phased currents. This equal-amplitude, co-phased condition could not be used for the Crystal Palace aerial for the following reasons:
(i) Due to the location of the site in a densely populated area, minima in the vertical radiation pattern give rise to areas of low field strength near the transmitter, which result in distortion of the signal. It is therefore necessary to de-phase one or more of the aerial tiers to reduce the depth of the minima. This process is usually referred to as 'gap-filling'.
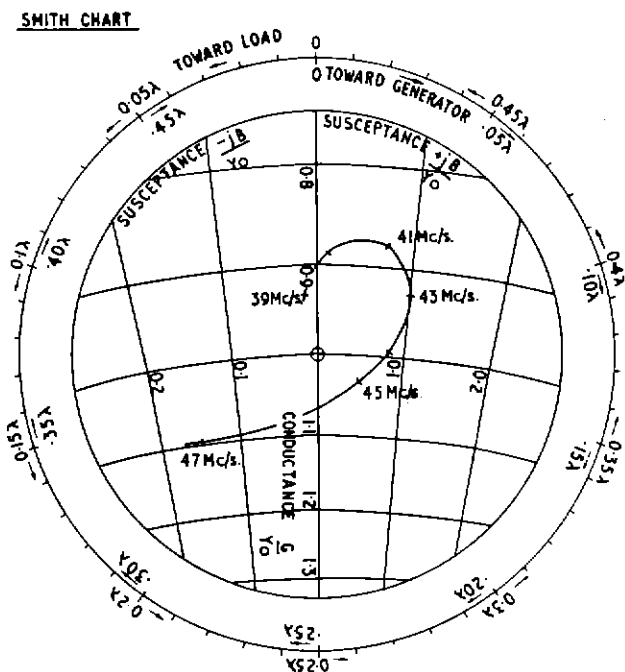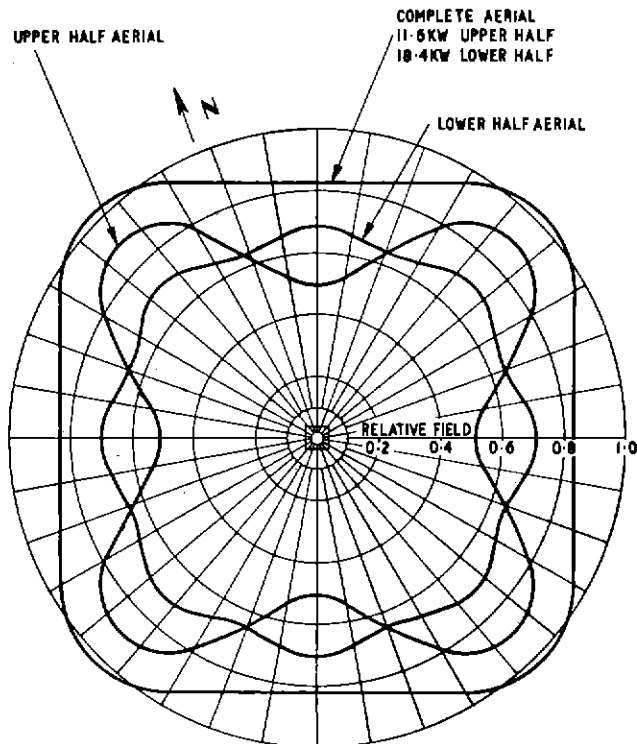
Fig. 7 — Admittance characteristic of one double-dipole element for lower half of aerial

10

(ii) Due to the dipoles of the upper and lower aerial halves being at different distances from the tower axis, a co-phased current distribution would not result in the contributions from the tiers being in phase at a distant point. The currents in the tiers of the lower half of the aerial are therefore phased to offset this effect.

(iii) The different arrangements of the tiers of the upper and lower halves of the aerial result in horizontal radiation patterns which differ both in amplitude and phase (see Fig. 8). It is therefore necessary to adjust the overall phases of the currents in the upper and lower halves in order to achieve the most uniform h.r.p. consistent with a high gain.

Calculations were made which showed that the optimum performance of the aerial would be achieved if the following conditions were fulfilled:

COMPLETE AERIAL
11·6KW UPPER HALF
18·4KW LOWER HALF

UPPER HALF AERIAL

LOWER HALF AERIAL

RELATIVE FIELD
0·2   0·4   0·6   0·8   1·0

UNIT CIRCLE CORRESPONDS TO AN E.R.P OF 200KW

Fig. 8 — Horizontal Radiation Patterns

(a) Adequate gap-filling would be provided if:
   (i) the phase of the radiating currents in the dipoles of the top tier of the lower half of the aerial were advanced by 50° relative to the phase of the currents which would be required for the contribution from this tier to be in phase with the contributions from the three lower tiers at a point in the distant field.
   (ii) the outputs of the two transmitter chains were combined in a diplexer and then divided between the upper and lower halves of the aerial in the power ratio of 0·63:1.

(This measure was not originally included in the aerial design. Experience in service showed, however, that the gap-filling was inadequate in certain directions and that this further step was necessary.)

(b) In order to offset the slope of the tower, the phases of the currents in the lower half of the aerial were advanced progressively by 17° per tier referred to the lowest tier; with the exception of the uppermost tier which would be advanced by a further 50° for gap-filling purposes as explained in (a) (i) above.

(c) The dipole currents in the upper four tiers were all co-phased.

(d) In order to achieve a compromise between uniformity of horizontal radiation pattern and gain the contributions from the two halves of the aerial were arranged to be in phase at a point in the distant field on a bearing of 17° to any one of the tower faces. This results in the best compromise between the conflicting requirements for radiation pattern and gain, conditions (a), (b), and (c) having been met.

The relative phasing of the currents in the lower four tiers was achieved by installing distribution feeders of the appropriate lengths, and the overall phasing of the two halves of the aerial by adjustment of the length of a loop of feeder installed at ground level in the main feeder supplying the lower half of the aerial. This loop of feeder, in addition to providing the necessary phase relationship between the upper and lower halves of the aerial for maximum distant field on bearings of 17° to the tower face, allows for the differing distances between the dipoles in the lower half of the aerial and those in the upper half of the aerial from the tower axis. The actual phases of the dipole radiating currents and the contributions of the tiers to the distant field are quoted in the table below:

Tier		Relative phase of radiating current DEGREES	Relative phase of contributions to distant field on a bearing of 17° to any face of lower DEGREES
1	Upper Half	0	0
2		0	0
3		0	0
4		0	0
5	Lower Half	−34	+38 Resultant
6		−101	−12
7		−118	−12 0
8		−135	−12

5. Lining up the Aerial System

5.1 *General Considerations*

Lining up the system involves two sets of adjustments:

(i) Matching the aerial impedance to the main feeders by adjustment of the individual elements.

(ii) Adjustment of the phases of the dipole currents to obtain adequate gap-filling, and the required horizontal radiation pattern and gain.

11

The prototype tests enabled the length of the dipole elements (dipole resonant frequency) and the susceptance compensation controls to be preset prior to erection. The adjustments at site thus involved matching the upper and lower halves of the aerial to the main feeders, using the mean conductance and susceptance controls (see sections 2.2 and 2.3). The matching was carried out at the vision carrier frequency and the variation of impedance over the band then checked to ensure that it was within the specified limits. In the case of both the upper and lower halves of the aerial the controls were set initially to values deduced from the full-scale prototype tests.

5.2 Upper Half of Aerial

The upper half of the aerial was matched in three stages:
(i) The top tier was measured by means of a calibrated transformer and the controls adjusted to give a match at the vision carrier frequency.
(ii) The upper two tiers were then measured together via the relevant part of the distribution feeder system, initially with the controls on both tiers set to the values determined from (i) above. Similar adjustments were then made on the elements in both tiers until a match at the vision carrier frequency was re-established.
(iii) All four tiers were measured simultaneously via the complete distribution feeder system, at first using similar settings on all tiers as determined in (ii) above. Similar adjustments were now made to the centre two tiers only, to rematch at the vision carrier frequency. This procedure was adopted as it was reasoned that the mutual impedance between the two centre tiers comprised the principal part of the total mutual impedance between the two halves.

5.3 Lower Half of Aerial

Fundamentally, the setting up of the lower half of the aerial was very much more complicated than that of the upper half for the reasons already outlined and the following procedure was therefore adopted:
(i) All four tiers were measured via the complete distribution feeder system and the admittance at the vision carrier frequency was found to be matched to within 5 per cent reflection coefficient, the compensation being satisfactory.
(ii) In the light of measurement (i) it was decided that the effects of mutual impedance and screening had been allowed for to a fair degree of accuracy by presetting the controls, and that it would be permissible to adjust all four tiers simultaneously by equal amounts to obtain an accurate match at the vision carrier frequency.

Due to the differences in distribution feeder lengths, the electrical length between the input to the distribution feeder system and the aerial driving point is different for each tier. This means that the adjustment of any given dipole control will result in the admittance characteristic at the input of the distribution feeder system moving in a different direction of the Smith Chart[2] depending on the tier in which the dipole is situated.

Tests were carried out to determine the direction of movement of the input admittance characteristic due to adjustment of the elements in each tier, and the dipoles in the four tiers were then adjusted so as to contribute equally to matching the characteristic at the vision carrier frequency.
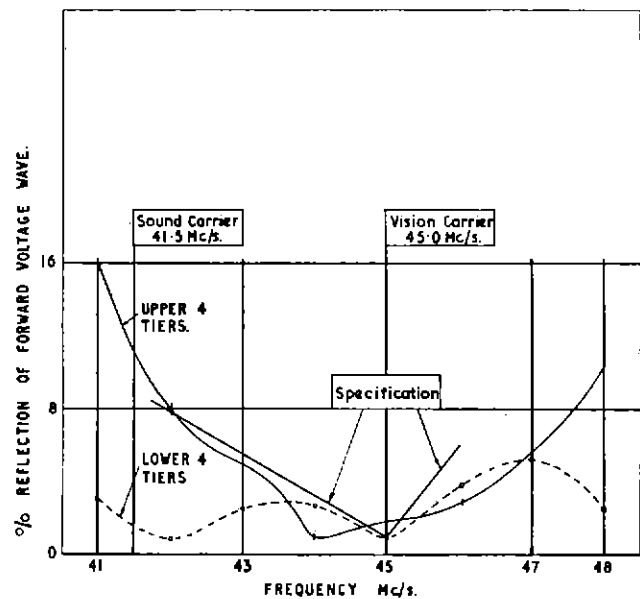

Fig. 9 — Reflection coefficients of both halves of aerial

5.4 Phasing of Upper and Lower Halves

The lengths of the main feeders were initially chosen so that the contributions from the dipoles of the upper four tiers and those in the lower three tiers of the lower half of the aerial on a given face were approximately in phase at a point in the distant field normal to that face.

The field strength received at a distant point on a bearing of 17° to one face of the tower was then measured, while the phases of the transmitter outputs were varied relative to each other by means of the drive phasing unit, and the phase difference for maximum signal noted. Finally, the main feeder supplying the lower half of the aerial was accurately adjusted in length, so that the aerial was correctly phased when the transmitter outputs were in phase.

5.5 Mutual Impedance between Halves of Aerial

The mutual impedance between the two halves of the aerial was measured and found to be less than 0·2 per cent. The two centre tiers of the aerial are separated from each other by 40 ft and screened from each other by a platform, which is designed to accommodate centimetric link equipment. There is little doubt that the relatively large distance between the tiers and the screening effect of the platform account for the relatively low figure of mutual impedance. The mutual coupling is such that operation on half the aerial causes a negligible impedance change and no increase in radiation of delayed images results.

12

6. Aerial Performance

(*i*) *Horizontal Radiation Pattern*

The horizontal radiation pattern of the complete aerial is shown in Fig. 8 together with the pattern for each half of the aerial powered separately with 15-kW peak-white. It is seen that under normal operating conditions the max. to min. ratio of the field strength is 1·8 dB.

(*ii*) *Gain*

The gain of an ideal aerial of eight identical tiers, energized in phase, is 9·1 dB relative to a half-wave dipole. To obtain the effective gain of the Crystal Palace system, however, the following losses must be subtracted from this figure:

Loss due to differing horizontal radiation patterns of the upper and lower halves	0·4	dB
Loss due to gap-filling	0·4	dB
Loss in distribution feeder system	0·1	dB
Estimated loss due to electrical and mechanical asymmetries	0·2	dB
Loss in Main Feeder	0·45	dB
Loss in Vestigial Sideband Filter and Combining Units	0·05	dB
Total Losses	1·6	dB

Subtracting these losses from the ideal gain the mean effective aerial gain is 7·5 dB, which is equivalent to a power gain ratio of 5·63. For the 30-kW peak-white total transmitter power at present used the mean e.r.p. is therefore 169 kW.

The above figures are averaged over the horizontal radiation pattern and the effective gain varies with bearing between 6·7 dB and 8·5 dB.

(*iii*) *Bandwidth*

The specification for admittance bandwidth was based on the fact that if an aerial is well matched at the vision carrier frequency, considerable latitude in the impedance match is permissible over the rest of the vison band.[3] The magnitude of the reflection coefficients achieved for the two halves of the aerial is shown in Fig. 9 together with the specified limit. The specification ensures that delayed images due to reflections caused by aerial mismatch will be at all times below the level of visibility.

7. Conclusions

The complete eight-tier transmitting aerial was commissioned on 21 December 1957 and since that date has operated satisfactorily.

The final stages of the work were completed on 21 May 1958, when the transformer system dividing the power unequally between the halves of the aerial was put into service. This also has operated satisfactorily and the filling of minima in the field (gap-filling) appears, from reports, to be satisfactory.

The measurements described indicate that the admittance characteristic of the double-dipole elements used for the lower half of the aerial is superior as regards bandwidth to the single-dipole elements of the upper half. It is thought that this improvement may be due, in part, to the constant cross-section limbs used for the lower half as opposed to the tapering cross-section limbs used for the upper half of the aerial, though mutual impedances between dipoles undoubtedly affect the performance to some extent. It is intended to investigate this aspect of dipole limb design further when time permits.

8. Acknowledgments

9. References

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A RECENT BBC TECHNICAL SUGGESTION

A SINGLE-GUN SELF-SWITCHING COLOUR TELEVISION DISPLAY TUBE

In any single-gun colour tube, the tube gun must receive information appropriate to the colour phosphor being excited at any instant of time. Two accepted methods of achieving this are either (a) cyclically switching the beam from one colour to another synchronously with gating appropriate colour information to the tube gun, or (b) gating beam colour information according to positional information received or inferred from the beam itself, notably by secondary emission strips laid near the fluorescent surface.

The particular tube to be described is in category (b) but utilizes screen luminescence to provide the information as to the beam position. Two methods of achieving this are suggested: (1) by using photo-conductive material as the controlling medium, and (2) by using photo-emissive material as the controlling medium.

Considering (1) (the photo-conductive case), refer to Diagram A.

A thin glass plate B is mounted to occupy the usual picture area in an exhausted envelope of conventional picture-tube shape and containing a single conventional electron gun.

Thin strips of coloured fluorescent material A, each one-third of the width of a picture element, are laid on the glass plate B in a repeating sequence, e.g. Red, Green, Blue—Red, Green, Blue, these strips being approximately at right angles to the scanning lines.

On the opposite face of the glass plate B are laid strips of transparent coloured conducting material C. These strips are insulated from each other, are parallel to strips A, and are laid so that they correspond both in colour and position with strips A.

Strips C are coated with a layer of photo-conductive material D in such a manner that electrical insulation between each of the strips C is maintained. A continuous sheet of transparent conducting material E is laid over the surface of all the photo-conductive surfaces of D.

All of the red-coloured conducting strips C are connected together, and similarly with the green and blue strips. There are thus three connections to the layer of strips C, one for each colour. A polarizing voltage is applied between each of these connections and the conducting layer E.

The principle of operation is as follows:

The fluorescent spot, when in any position on its scanning cycle, produces light of a colour depending upon which particular strip A is being struck by the scanning beam. This light passes through glass plate B and the associated coloured conducting strip C, strikes the photo-conductive layer D, and thus alters the resistance of this layer. This change in resistance produces a change in the current flowing between the strips C and the transparent conducting layer E.

This change in current is used to provide a gating pulse to switch the electron-gun control electrode to the appropriate colour information channel.

Considering (2) (the photo-emissive case), refer to Diagram B.

A thin glass plate B is mounted to occupy the usual picture area in an exhausted envelope of conventional picture-tube shape and containing a single conventional electron gun.

Thin strips of coloured fluorescent material A, each one-third of the width of a picture element, are laid on the glass plate B in a repeating sequence, e.g. Red, Green, Blue—Red, Green, Blue, these strips being approximately at right angles to the scanning lines.

On the opposite face of the glass plate B are laid strips of transparent coloured conducting material C. These strips are insulated from each other, are parallel to strips A, and are laid so that they correspond, both in colour and position with strips A.

Strips C are coated with a layer of photo-emissive material D in such a manner that electrical insulation between each of the strips C is maintained. All of the red-coloured conducting strips C are connected together and similarly with the green and blue strips. There are thus three connections to the layer of strips C, one for each colour.
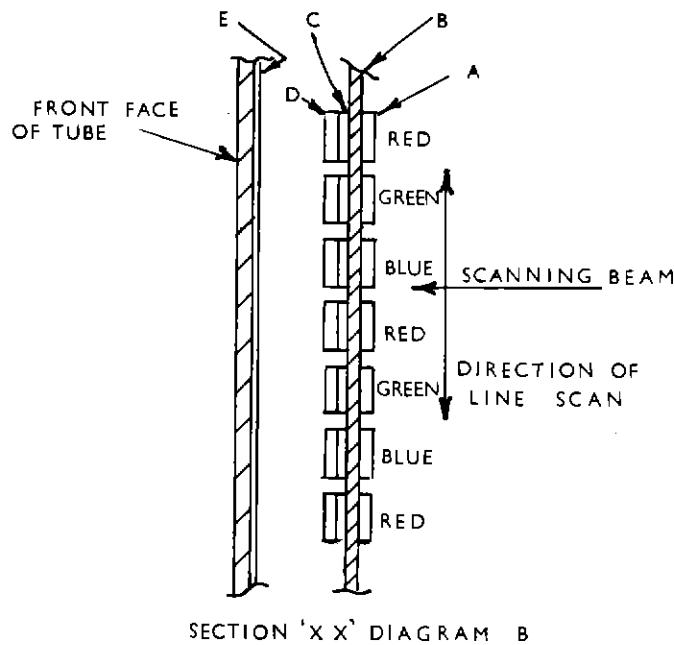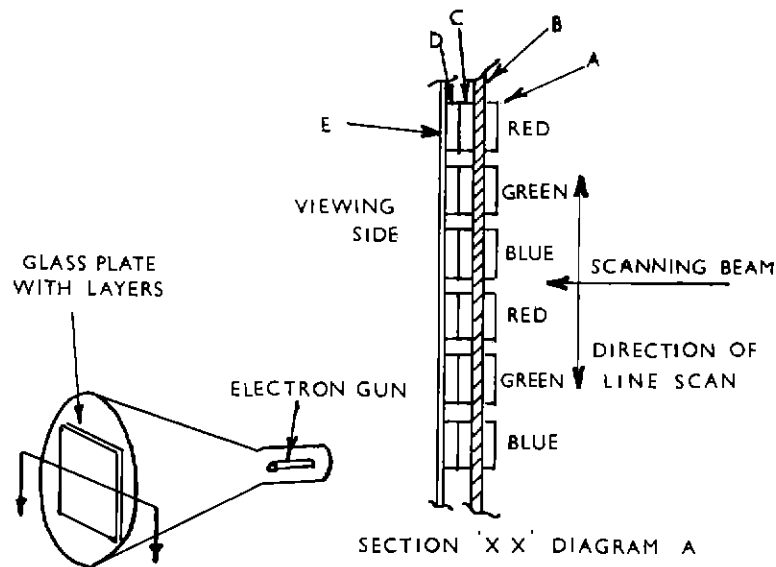
The inner face of the glass front of the tube is coated with a layer of transparent conductive material E which is maintained at a potential in excess of the fluorescent screen potential.

The principle of operation is as follows:

The fluorescent spot, when in any position on its scanning cycle, produces light of a colour depending upon which particular strip A is being struck by the scanning beam. This light passes through the glass plate B and the associated coloured conducting strip C, strikes the photo-emissive layer D, and causes the release of electrons which are collected by layer E. This results in a current through the strips C which correspond to the colour of the element being struck by the electron beam from the gun. This current is used to provide a gating pulse to switch the electron-gun control electrode to the correct colour information channel.

In both cases, the gating pulses produced by the strips would probably need to gate information for a colour one element removed, to allow for the delay in the video circuit. For example, the pulse derived from the red strip would be used to gate red information to the *next* red strip. It might also be necessary to run the tube with some residual brightness even in black periods to keep the gating pulses continuous.

An advantage of a tube of this type is that it could have built-in chrominance monitoring. A suggested method is

SECTION 'X X' DIAGRAM A

SECTION 'X X' DIAGRAM B

SINGLE GUN SELF-SWITCHING COLOUR TELEVISION DISPLAY TUBE

as follows: During the line suppression period a pulse at white level is injected into the video amplifier. This causes a white bar to appear along the edge of the display (suitably masked off). The particular strips under this white bar (there should be not less than one of each colour) are not paralleled to their equivalent colour neighbours—instead each output is compared with one of three voltages which are known to have the relative proportions to produce white when combined. The difference between each colour pulse and each known colour voltage becomes a colour error signal used to adjust the gain of each colour channel for the following line period. It may thus become possible to dispense with an overall gain control and, in any case, separate gain controls for each colour channel should not be necessary.

A further advantage of the tube is that there are no registration problems and indeed the strips need not necessarily be vertical since the beam only receives information relative to the colour it is at any instant displaying. Scan linearity and amplitudes are, by the same token, not critical.

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15