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"To promote the advancement of radio, electronics and kindred subjects by the exchange of information in these branches of engineering."

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REPORT OF THE THIRTY-FIRST ANNUAL GENERAL MEETING

THE INSTITUTION'S THIRTY-FIRST ANNUAL GENERAL MEETING (the twenty-third since incorporation) was held at the London School of Hygiene and Tropical Medicine, Gower Street, London, W.C.1, on Wednesday, 31st October, 1956.

The Chair was taken by the President, Rear-Admiral Sir Philip Clarke, who was supported by other officers of the Institution and members of the General Council. Twenty-eight corporate members had signed the Minute Book when the meeting opened at 6.5 p.m.

The Secretary read the notice convening the meeting which was published on page 413 of the August *Journal*.

1. To confirm the Minutes of the 30th Annual General Meeting held on October 26th, 1955

The Secretary stated that a report of the last Annual General Meeting was published on pages 533-536 of the November 1955 *Journal*. Admiral Clarke's proposal that these Minutes be signed as a correct record of the proceedings was approved unanimously.

2. To receive the Annual Report of the Council (Published in the September *Journal*)

Admiral Sir Philip Clarke believed that members would agree that the 30th Annual Report reflected the wide diversity of activities undertaken by the Council and its Committees, as well as the growth of the Institution, both in stature and in influence. He felt that all members would wish to be associated with the thanks he extended to all those members who gave their services to the Institution. In particular, Admiral Clarke thanked those members who were now retiring from the Council and its Committees.

Referring to the section of the Report dealing with "Section Activities," the President regretted his inability to visit all the Local Sections of the Institution during his term of office. He had, however, met all the Chairmen of the Sections at Council meetings, as well as some of the Chairmen of Sections overseas.

Admiral Clarke continued: "I hope that considerable success will attend the new venture of setting up an Indian Advisory Council and that the experience thus gained will pave the way towards extending such operations to other overseas Sections.

"The Officers of the Institution are particularly grateful for the response given to the Building Appeal by so many Companies in the British Radio Industry as well as by the membership. Support has not been confined to Great Britain alone; members from all over the world have shown great enthusiasm for the project, and I am confident that the Council will secure the large amount required for a suitable building."

Referring to the work of the Standing Committees, Admiral Clarke felt that members would again be pleased to see from the report of the Membership Committee the steady increase in membership, particularly in the corporate grades.

Important work had been undertaken by the Education and Examinations Committee, particularly in the major task of revising the Graduateship examination. The Institution welcomed the co-operation readily being given by teaching establishments in providing courses covering the syllabus of the examination or of other examinations recognized for exemption from the Institution's examination. This work was of outstanding importance in providing facilities for recruiting and training more engineers.

Members should give careful consideration to the report of the Papers Committee. The procurement and consideration of papers entailed much time and work by this Committee which was anxious to secure the assistance of all members.

The Technical Committee worked very closely with the Papers Committee in preparing technical reports covering a wide range of subjects; such work was often slow and tedious, but members serving on this Committee could receive satisfaction knowing that such reports were appreciated far beyond the membership, and brought considerable prestige to the Institution.

The report dealt in detail with the work of all the Standing Committees and provided every member with valuable information on Institution affairs and management.

Commenting on his own participation in Institution affairs, the retiring President stated: "In conferences I have strived to foster and develop co-operation between our own Institution and other engineering societies, the Services and industry."

The President's proposal that the 30th Annual Report of the Council be adopted was seconded by Professor Emrys Williams and unanimously approved.

3. To elect the President

Admiral Clarke proposed that Mr. G. A. Marriott, B.A.(Cantab.) be confirmed President of the Institution for the coming year, and said that Mr. Marriott had served on the Council and on important standing committees for a number of years, and had been Chairman of Council and Chairman of the Finance Committee. First elected a Vice-President in 1954, Mr. Marriott was very active in the Institution's interests. The motion to elect Mr. Marriott the fourteenth President of the Institution was carried with acclamation.

4. To elect the Vice-Presidents

The President next proposed the re-election of Messrs. L. H. Paddle and J. L. Thompson, and Professor E. E. Zepler, and the election of Professor Emrys Williams as Vice-Presidents. Professor Williams had been Chairman of Council for the past two years, and had ably represented the Institution at many important meetings. The proposal was approved unanimously.

5. To elect the General Council

The Council's nominations for the vacancies on the General Council had been published in the Agenda and, since no other nominations had been received, Admiral Clarke stated that he had pleasure in declaring that the following three members were elected:—

Members: A. D. Booth, D.SC.
E. M. Eldred.

Associate Member: R. H. Garner, B.SC.(ENG.)

In addition, the following retiring members of Council were re-elected:—

Members: F. G. Diver, M.B.E.
H. J. Leak.
Captain A. J. B. Naish, R.N., M.A.

Associate Member: E. W. Pulsford, B.SC.

6. To elect the Honorary Treasurer

Admiral Clarke moved that Mr. G. A. Taylor be re-elected Honorary Treasurer for a further year, and said that in making this recommendation, the General Council re-affirmed its confidence in Mr. Taylor. The motion was carried unanimously.

7. To receive the Auditor's Report, Accounts and Balance Sheet for the year ended March 31st, 1956

The President called upon the Honorary Treasurer, Mr. G. A. Taylor, to present the Accounts.

Mr. G. A. Taylor first thanked the members for giving him a further opportunity of serving the Institution in the capacity of Treasurer.

In presenting the Accounts he pointed out that again almost all items of expenditure showed significant rises over the previous year. Labour and material costs continued to increase and had it not been for additional income provided by an increasing membership, it would have been difficult to maintain service to members at the standard they now enjoyed.

Drawing attention to individual items in the General Accounts Mr. Taylor said that administration expenses would have been much higher if it had not been for the strenuous efforts of the secretarial staff in keeping costs down to the absolute minimum. Under the heading "Institution Premises," lighting and maintenance expenses had been mainly responsible for an increase of about £500.

"The printing and publishing of the Institution's *Journal* has this year shown a marked increase, amounting to £1,100. Some of this expense, of course, is due to the higher printing order necessary for an increasing membership, but printing, paper and postage costs have risen steeply, and although advertising revenue has been a little higher, this has not been sufficient to offset these increases. The full effect of increases in costs of printing, paper, telephone and postal rates will be even more fully realized during the next twelve months and it is estimated that the total increase in these charges alone will be about £2,000 in a complete year.

"Under the item 'Section Expenses,' members will again observe significant increases; overall the total is about £850 greater than for 1954-5."

"The Finance Committee has given very careful consideration to the position which is revealed by this year's accounts, and also those for previous years, and has been compelled to advise Council that, if we are to maintain services to the existing membership, it is essential that we increase our income over the next twelve months by at least £4,000.

"Unfortunately, this can only be achieved by an increase in the subscription rates, and Council has accepted and approved the Finance Committee's recommendation that subscriptions be modified in accordance with Table 4 in the Annual Report.

"We hope very much that members will support the Council in its efforts to maintain and to increase the status of the Institution, particularly during these vital years which will mean so much to us all in our endeavours towards becoming a Chartered Institution."

Mr. Taylor next discussed the Balance Sheet and said that it showed the difficulties experienced in trying to build up assets to finance future services, to provide a reserve for future development, and to meet contingencies.

The Building Appeal donations were doing much to stabilize the Institution's financial position; the members had made a fair contribution towards capital endowment through the Building Appeal, but the main contributions came from British radio and electronics organizations and the Council was especially grateful to them for their generous support. The donations were included in the Balance Sheet under the two headings "Investments" and "Cash at Bank" and Mr. Taylor particularly pointed out that these sums did not include two major covenants which, when fully paid, would increase the Building Appeal to just over £20,000. Very much more was required before a building could be acquired and the continued response by members was still urgently needed.

Mr. Taylor then drew attention to the economies being made which were demonstrated by the reduction of £500 in stationery and similar stocks. He emphasized that since the end of the year under consideration the trend of rising costs had continued and would occupy the attention of the Finance Committee, both now and in the immediate future.

Mr. Taylor then moved that the General Accounts and Balance Sheet for the year ended 31st March, 1956, be adopted, and this was carried unanimously.

8. To appoint Auditors

The President proposed the re-appointment of Gladstone Jenkins & Co. as the Institution's Auditors, and the proposal was approved unanimously.

9. To appoint Solicitors

The President moved that Messrs. Braund and Hill be re-elected as Solicitors to the Institution, and the proposal was approved unanimously.

10. Awards to Premium and Prize Winners

The President said that he was very pleased to award Premiums to the authors of outstanding papers published in the *Journal* in 1955, and to successful candidates in the Institution's Graduateship Examination during the year. He congratulated all the recipients, whose names were given in the Annual Report, and personally presented the awards to those resident in the British Isles and able to attend the meeting.

11. Any other Business

The Secretary stated that he had not received notification of any other business, and the President then closed the 31st Annual General Meeting.

REPORT OF THE ANNUAL GENERAL MEETING OF SUBSCRIBERS TO THE Brit.I.R.E. BENEVOLENT FUND

The Meeting was held on 31st October, 1956, and the Chair was taken by Rear-Admiral Sir Philip Clarke, K.B.E., C.B., D.S.O.

1. To confirm the Minutes of the Annual General Meeting of subscribers held on 26th October, 1955.

The Minutes of the Annual General Meeting dated 26th October, 1955, had been published in the December 1955 *Journal*. The President's proposal that those Minutes be signed as a correct record of the proceedings was approved unanimously.

2. To receive the Annual Report of the Trustees, and

3. To receive the Income and Expenditure Account and the Balance Sheet of the Benevolent Fund for the year ended 31st March, 1956

Sir Philip first thanked all members who had supported the Fund, and expressed the Trustees' gratitude to Electric and Musical Industries Ltd., and the Radio Industries Clubs of London and Manchester, who continued to subscribe so generously.

The President felt that the report of the Trustees adequately conveyed to members the ways in which the Fund's resources were being used, particularly in the matter of educating fatherless children. During his Presidency, he had been pleased to have the opportunity of visiting Reed's School, and had been most impressed with the work done for fatherless boys. The Institution always remembered with considerable affection the way in which Reed's School had received the children nominated by the Institution. Sir Philip was quite sure that all the schools mentioned in the Trustees' report deserved continued support; indeed, it was the particular hope of the Trustees that the grants made should be increased to meet the full cost incurred by the Schools in educating and boarding the children sponsored by the Institution.

Referring to the Accounts, the President felt that these were quite self-explanatory, although a comparison of income for the year with that for 1954 might indicate that there had been a considerable drop in donations. He reminded members, therefore, that in 1954 the Fund had benefited by a gift of £1,000 from Sir Louis Sterling; so far as normal revenue was concerned, the donations showed an increase of £125.

The Balance Sheet showed that investments were steadily increasing, and the income received from this source was of great value in supplementing the revenue received from subscribers.

Sir Philip Clarke then formally moved the adoption of the Annual Report of the Trustees and the Accounts of the Benevolent Fund for the year ended 31st March 1956. The motion was carried unanimously.

4. To elect Trustees for the year 1956-57

The President stated that the present Trustees of the Benevolent Fund were listed in the Agenda published in the September 1956 *Journal*. Subscribers had indicated their satisfaction with the way in which the affairs of the Fund were carried out, and he could personally testify to the sympathetic consideration which the Trustees gave to every deserving case.

The re-election of the Trustees was approved unanimously.

5. To appoint the Honorary Solicitors, and

6. To appoint the Honorary Accountant

Sir Philip Clarke felt that all subscribers would wish to be associated with the Trustees' thanks to Mr. Charles Hill and Mr. R. H. Jenkins for the help and guidance given in their respective capacities as Honorary Solicitor and Honorary Accountant. The President's proposal that Messrs. Braund and Hill, and Mr. R. H. Jenkins of Gladstone, Jenkins and Company, be re-appointed was carried with acclamation.

7. Any other business

The Secretary confirmed that he had not received notice of any other business. The President again thanked all subscribers for their support and closed the meeting.

COLOUR TELEVISION*

by

G. N. Patchett, Ph.D., (Member)†

Based on a paper to be presented at a meeting of the Institution in London on November 28th, 1956. Previously read at Local Section meetings in Manchester and Treforest.

SUMMARY

The theory of colour mixing and of colorimetry is discussed briefly. Various systems for colour television are outlined and studio and receiver equipment described. The N.T.S.C. system and its modification to British standards are discussed.

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1. Introduction

As many of the basic ideas used in colour television depend on the theory of colour some space will first be devoted to this extensive subject. In this paper it is not possible to do it justice but it is hoped to summarize a number of fundamental points which are essential to the understanding of colour television.

2. Colour Theory

The principle of all colour printing, colour photography and colour television is that of mixing a number of colours, usually three, to obtain all the other colours in the original. The colours that are used are termed primary colours. Although it is possible to obtain a tolerable colour picture by using only two colours (usually red-orange and green-blue) the resulting picture is not satisfactory and three colours are now universally used. It is found possible to reproduce all colours occurring in nature by suitable mixing of three primary colours. Although this statement is not scientifically correct it is sufficiently accurate for general colour picture reproduction.

It is extremely important to distinguish processes which mix colour lights from those which mix coloured pigments or paints. The former process is known as the additive colour

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† Head of the Electrical Engineering Department, Bradford Technical College.

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system whereas the latter is termed the subtractive colour process. Not only are the principles of the two systems quite different but so are the results.

2.1. *Additive Colour Mixing System*

Although it is possible to use any three primary colours (so long as the third cannot be produced by a mixture of the other two), red, green and blue (or blue-violet) are universally used. In Fig. 1 is shown the result of adding these primary colours in the form of lights, i.e. projecting light from two coloured lamps on to a common screen. Red and green produce yellow, green and blue produce a particular blue, known as cyan, while red and blue produce a particular red known as magenta.

RED + GREEN	= YELLOW
GREEN + BLUE	= CYAN
RED + BLUE	= MAGENTA
RED + GREEN + BLUE	= WHITE

Fig. 1.—Additive colour mixing process using coloured lights.

These three resulting colours are known as complimentary colours. The addition of all three primary colours, in correct proportions, produces white. This colour mixing system is the principle of certain colour photographic processes and of present colour television systems.

2.1.1. Principle of additive colour photography

The basic principle of colour photography is similar to that of colour television, and is shown in Fig. 2 (p. 595). The object to be copied is photographed by three cameras: in front of the first camera is placed a red filter, in front of the second a green filter and in front of the third a blue filter. (In practice, of course, the object must be photographed from one position either by successive exposures or by a special camera with a light splitting device—a one shot camera.[1]) The white background, the red sails and the orange sun reflect red light which will pass through the red filter and illuminate the focusing screen of the first camera and also fog these portions of the plate. There will be no red light reflected from the green boat and blue sea and this part of the plate will not be fogged. The resulting plate, when developed, will be as shown at (c) and a positive transparency is made from this as at (d). A similar action takes place in the other cameras. A colour picture may now be built up from these separation positives, as they are called, by placing them in three identical lanterns, with corresponding colour filters, arranged so that the projected pictures are in register. Considering the sky portion it is seen that light is projected by all three lanterns and the combination results in white, as in the original. The sail will appear red since, over this portion of the picture, only red light is projected from the "red" lantern. In the case of the sun, light is projected from the "red" and "green" lanterns, the mixture of the two giving yellow, as shown in Fig. 1. If a more complex picture is photographed in this way all shades of colour are produced by varying the relative amounts of light from the three lanterns.

Although this method can produce satisfactory results it is obviously not a practical system. On the other hand it is very closely allied to use of three projection units in colour television. A practical embodiment of this principle is the Dufay colour photographic process.[1]

In place of the three plates of the last process a fine filter screen or *réseau*, composed of tiny red, green and blue elements, as shown in Fig. 3a (p. 595), is used. This is placed in front of, and in close contact with, the emulsion. The film is exposed in the normal manner and a portion exposed to a green section of the picture is shown in Fig. 3b. The green light passes through the green elements of the filter and fogs the emulsion. On the other hand green light cannot pass through the red and blue elements and the emulsion behind these elements is not fogged. When the film is developed the result is as shown at (c) and this is converted to a positive by the process of reversal development[1] with the result shown at (d). It is seen that the film is now black behind the red and blue elements but clear behind the green elements. If this is now viewed in white light (or projected in a lantern with a source of white light) only green light is allowed to pass and this portion of the picture, therefore, appears green, corresponding to the green light originally falling on the film. A similar action takes place for red and blue light. Mixtures of the colours are obtained by partial blackening of the film behind the various elements. If the elements are small enough (in this case about

,200 elements per square millimetre) they are nvisible to the eye. This idea is similar to hat used in the tricolour tube which is lescribed later.

2.2. Subtractive Colour Mixing

It has been shown that white light is a nixture of red, green and blue lights and that cyan is a mixture of green and blue. Thus cyan may be produced by subtracting red light from white light. In a similar way yellow is produced by subtracting blue, and magenta by subtracting green, as shown in Fig. 4. Thus, a

Additive

WHITE = RED + GREEN + BLUE

Subtractive

CYAN	= GREEN + BLUE	= WHITE − RED
YELLOW	= RED + GREEN	= WHITE − BLUE
MAGENTA	= RED + BLUE	= WHITE − GREEN

Fig. 4.—Principle of colour subtraction. The addition sign in the subtractive portion indicates combinations of filters or pigments, not lights.

yellow filter is one which is opaque to blue and a magenta filter one opaque to green. If these two filters are placed one after the other in a beam of white light they will subtract both blue and green light and the result will be red. (Fig. 5, p. 595). A similar action takes place if other combinations are used and if three filters are used of yellow, magenta and cyan all three primary colours will be absorbed and the result will be no light or black. The combinations are shown in Fig. 6.

of filters or pigments, is known as subtractive colour mixing. This process is, of course, that used by artists and the three complementary colours cyan, magenta and yellow (often loosely called blue, red and yellow) are called artists' primary colours or often, incorrectly, primary colours.

This process is used in colour printing and in most colour photographic processes (e.g. Kodachrome, Ilford Colour and Agfacolour[1]). The basic principle is to obtain three separation positives as explained in Sect. 2.1.1, and shown in Fig. 2. These positives are reproduced in Fig. 7 (p. 595), with the original. In colour printing superimposed prints are made with these separation positives in the three complementary colours on to white paper, i.e. the red separation positive is printed in cyan, the green in magenta and the blue in yellow. The sky will be white as no printing ink falls on the white paper over this portion. The sails are red because this section has been printed in magenta and yellow and from Fig. 6 it is seen that this combination results in red. Similarly with all the other colours. In subtractive colour photography three emulsions are used and later dyed to produce cyan, magenta and yellow filters the density of these varying over the picture so producing the required colours. (Ref. 1 gives further details of these processes.)

It is not possible to use this system for colour television since it would require a screen composed of three filters, in the complementary colours, whose density could be controlled electronically, and no such method has yet been developed, although it is possible that such a device may at some time be devised.

YELLOW + MAGENTA	=	WHITE − BLUE − GREEN	=	RED
YELLOW + CYAN	=	WHITE − BLUE − RED	=	GREEN
CYAN + MAGENTA	=	WHITE − RED − GREEN	=	BLUE
YELLOW + MAGENTA + GREEN	=	WHITE − BLUE − GREEN − RED	=	BLACK

Fig. 6.—Subtractive colour mixing. The addition sign indicates combinations of filters or pigments, not lights.

A similar action takes place when coloured pigments or paints are mixed together. Thus, a yellow pigment appears yellow because it absorbs blue light and a magenta pigment appears magenta since it absorbs green. When the two pigments are mixed they still absorb these two colours and the result is red. This process of mixing colours, either in the form

2.3. *Colorimetry*

2.3.1. Brightness, hue and saturation

Suppose that sources of the three primary colours are placed at the corners of a triangle as shown in Fig. 8 (p. 596), then the complementary colours are produced at the centre of the sides of the triangle. Since light from all three sources falls on the centre this will be white. It is now necessary to explain the meaning of three terms which will be used later, namely hue, saturation, and brightness. If a circle is considered with its centre at the centre of the triangle then the hue, or colour of the light, varies as one travels round the circle, e.g. the hue is red, green or magenta. The saturation of a colour is its dilution with white light. If one moves along a line such as R–W, at R the light is all red and said to be saturated, but, as one moves towards W white light is added and the colour is then said to be unsaturated, until at W all the light is white. All points on this line have the same hue (i.e. red) and unsaturated colours are often referred to as pale or pastel shades. This is shown in another way in Fig. 9. In the case of neutral or grey colour, light of all wavelengths is present in approximately equal amounts. With a saturated red only light of wavelengths close to red is present, while in the case of an unsaturated red light all wavelengths are present but there is a predominance of light around the red wavelength.

The brightness is the amount of light and may be considered as an axis at right angles to the colour triangle (Fig. 8). It is also, of course, the height of the curves of Fig. 9.

2.3.2. Tricolour analysis

It is necessary to go further into the theory of colour mixing but this section must, of necessity, be brief and refs. 2, 3, 4 and 5 should be consulted for further information. It must be remembered that colour is a physiological sensation of the human eye and therefore, involves the response of the eye to various colours. Unfortunately all eyes are not alike and no scientific measurement can be made in the same way as the response of a photo-electric cell. To overcome this the response of a standard eye (standardized in 1924 by International Commission on Illumination) is used, and this response is shown in Fig. 10 (p. 596). This shows the relative luminosity at various wavelengths for a constant radiated power. It is seen that the eye is most sensitive at a wavelength of 550 millimicrons (yellow-green) and drops off greatly at the red and particularly blue ends of the spectrum.

Suppose that equal energy white light (W) (light in which the energy output is the same at all wavelengths) is matched by adding the three primary colours, and it is found that one lumen of white light requires u lumens of re[d] v lumens of green and w lumens of blue ligh[t] then this may be expressed as an equation:–

$$1_W = u_R + v_G + w_B \qquad \ldots\ldots\ldots(1)$$

The quantities u, v and w will not be equa[l] due to the relative sensitivities of the eye, bu[t] since the total of lumens is equal to the sum o[f] the lumens of each colour then $u+v+w=1$ This difficulty of the quantities not being equa[l] is overcome by adopting a new unit called th[e] trichromatic unit (or T unit). If eq. (1) is now written in trichromatic units the result is:—

$$1_R + 1_G + 1_B = 3_W = 1 \text{ lumen of white light.}$$

It follows then that:—

1 T unit of red $= u$ lumens of red light,
1 T unit of green $= v$ lumens of green light,
1 T unit of blue $= w$ lumens of blue light,

or, if we express our equation in terms of 1 T unit of reference white, then:—

$$1_W = 0{\cdot}33_R + 0{\cdot}33_G + 0{\cdot}33_B \qquad \ldots\ldots\ldots(2)$$

Using these units, suppose that one trichromatic unit of colour C is matched by the three primary colours. The result can be expressed as:—

$$1_C = x_R + y_G + z_B \qquad \ldots\ldots\ldots(3)$$

where $x+y+z=1$. This implies that colour C is matched by adding x T units of red, y T units of green and z T units of blue. The quantities x, y and z are known as the Trichromatic Coefficients of this colour. This equation may be converted to lumens by using the relationship between T units and lumens given above. The total luminance would be:—

$$x.u + y.v + z.w \qquad \ldots\ldots\ldots(4)$$

Since the sum of x, y and z is unity it is only necessary to quote the values of two of these to specify the colour. The quantities are conveniently plotted on a RGB diagram (Fig. 11, p. 596), x and y being two of the axes, the third quantity z following by subtracting $x+y$ from unity. For example, at point P $y=0{\cdot}6$ and $x=0{\cdot}2$ and, therefore, $z=0{\cdot}2$. From eq. (2) it follows that equal energy white must be the centre of gravity of the triangle, i.e. point $x=0{\cdot}33$, $y=0{\cdot}33$ (and $z=0{\cdot}33$). Since, at the origin of the diagram $x=0$ and $y=0$, then $z=1$ and this point corresponds to saturated blue. The complementary colours are formed along the sides of the triangle by combinations of two of the primary colours.

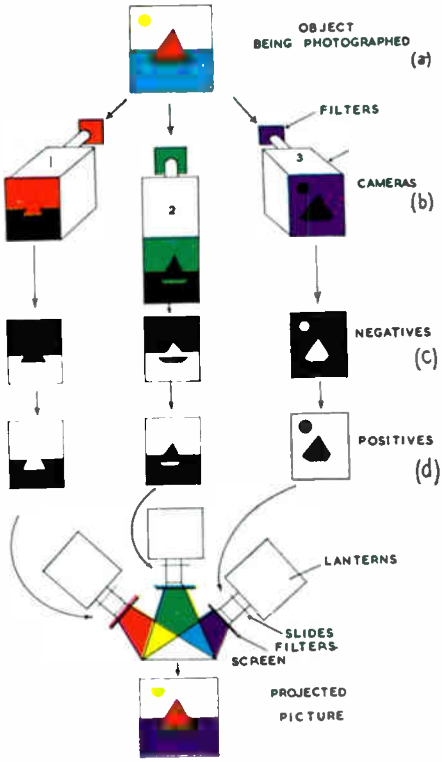


Fig. 2.—Principle of additive colour photography. (No allowance has been made for the fact that the camera images would be inverted.)

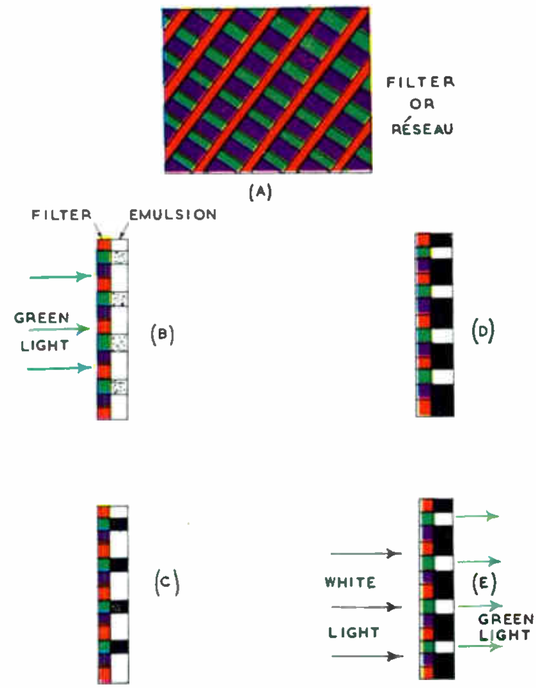


Fig. 3.—Principle of Dufay colour photographic process. The filter is shown greatly enlarged.

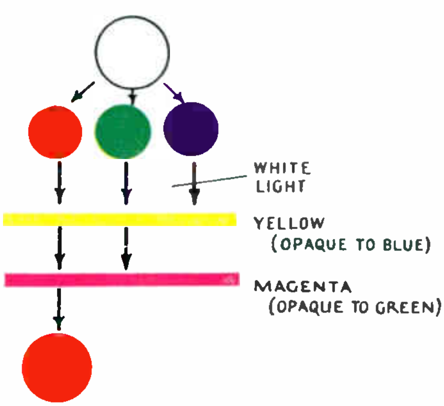


Fig. 5.—Principle of subtractive colour mixing.

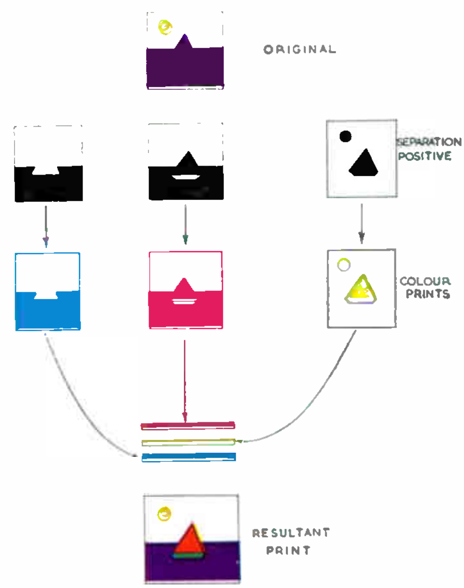


Fig. 7.—Principle of subtractive colour printing or photography.

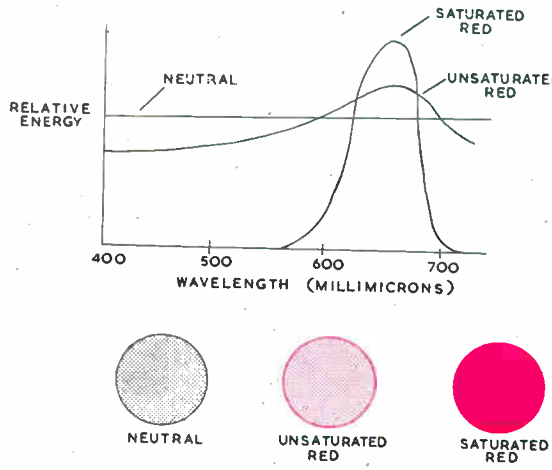
Fig. 8 (top left).—Colour triangle showing hue, saturation and brightness.

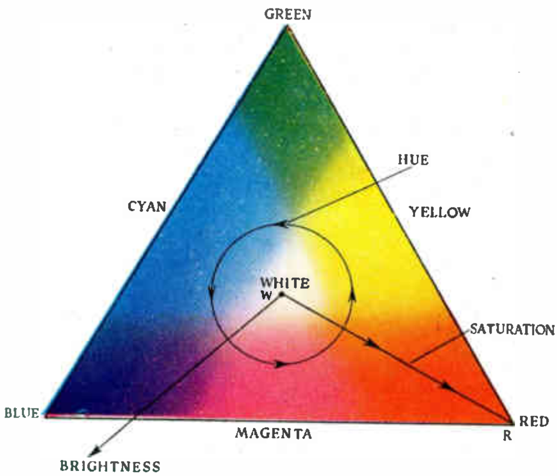
Fig. 9 (top right).—Diagram showing the difference between saturated and unsaturated colours.

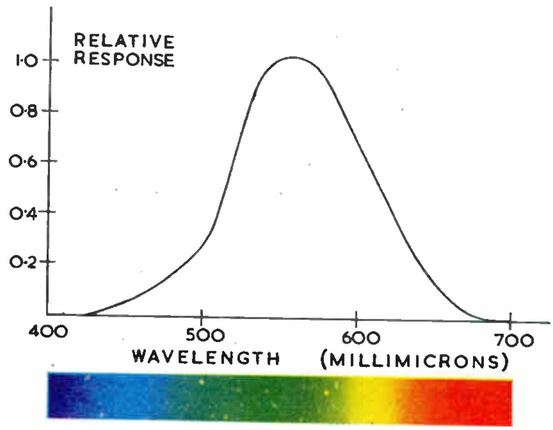
Fig. 10 (centre right).—Response of standard eye (I.C.E.).

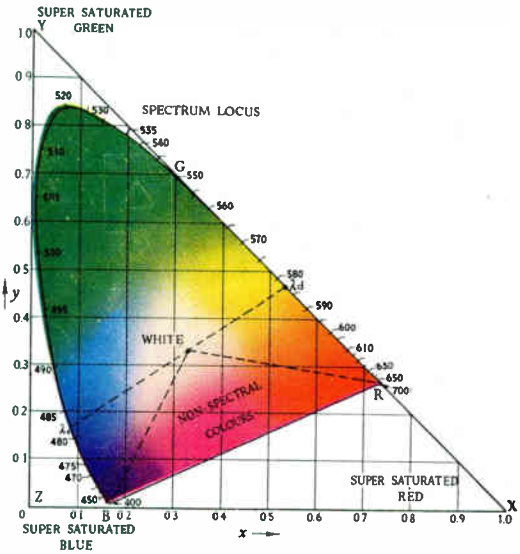
Fig. 11 (bottom left).—R.G.B. diagram.

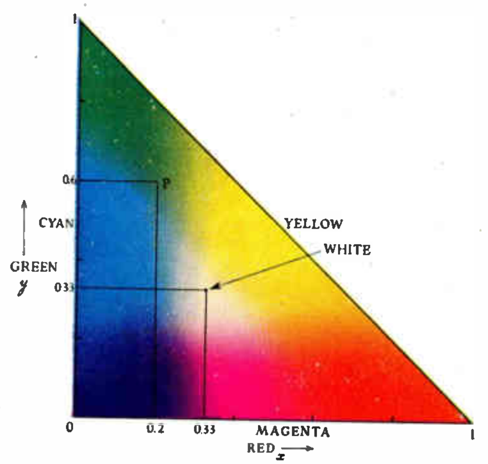
Fig. 12 (bottom right).—Chromaticity diagram.











The exact colours in the triangle will depend on the chosen primary colours but it is found that with physical realizable primary colours a *true* colour match can only be obtained of certain colours by using negative amounts of the primaries. A negative quantity of light has no significance and means that this amount of primary must be added to the standard to obtain a match. To overcome this difficulty the C.I.E.* (Commission Internationale de l'éclairage) chromaticity diagram was introduced. In this diagram use is made of three fictitious supersaturated primaries, and the diagram is shown in Fig. 12. On this are shown the spectrum colours and the area which includes all the colours occurring in nature. White, as before, corresponds to co-ordinates $y=0{\cdot}33$ and $x=0{\cdot}33$. Using this diagram it is possible to specify any colour by quoting the x and y co-ordinates. There are many useful features of this diagram which cannot be considered here. (See refs. 2, 3, 4 and 5.)

3. Colour Television

3.1. *Need for Colour Television*

The need for colour in a television programme depends greatly on the particular programme. In fashion displays and many variety shows much of the pleasure of the programme is lost if the colour is not present. In certain sports, e.g. snooker, colour is necessary if the game is to be followed without a commentator. On the other hand in many programmes, such as talks and interviews, it is quite unnecessary to use colour.

3.2. *Requirements of a Colour Television System*

If a television service was just being started in this country, and there was plenty of space allocated for television so that a wideband system could be used, many of the problems associated with colour television would be solved. Unfortunately this is not the position and there are two basic alternatives:—

(*a*) To couple the new television service to the present monochrome service.

(*b*) To use a completely separate system which must operate on a different band from those already used and may operate on different standards.

If (*a*) is to be adopted the system must be what is termed compatible. This means that the system must be such that it will operate with the same bandwidth as the monochrome system and use the same standards. Further, the system must produce a satisfactory monochrome picture on a standard monochrome receiver without any modification. If this system is used colour may be introduced into the normal programmes at any time, those with monochrome receivers being able to receive the programmes exactly as before the introduction of colour and those with colour receivers being able to enjoy the advantage of colour when this is transmitted. Since it is unlikely that all programmes will be in colour for a long time, if ever, it is also essential that a colour receiver will produce a satisfactory monochrome picture when fed with a normal monochrome signal. This need for compatibility obviously ties the system to the standards used for monochrome and also greatly adds to the complications of the system as will be seen later.

On the other hand if (*b*) is adopted there are many difficulties. Band I is already completely filled and all the channels of Band III (when available) are, no doubt, provisionally allocated and this would mean that the colour system would have to operate on Bands IV (470-585 Mc/s) or V (610-960 Mc/s). Little experience has been obtained using monochrome systems at these frequencies, and none on colour. There will be many difficulties in the design of receivers for these frequencies and there may be severe problems due to reflections and ghosts. If this scheme is adopted new transmitters would have to be erected and only those with colour receivers (and this is likely to be a small number at first due to the high cost of receivers) would be able to receive the programmes. It would also appear to be necessary to have special programmes for this system and it would be difficult to make these programmes available for the monochrome transmissions, since it is unlikely that the standards of such a system would be the same as the monochrome. The result is that, at the first, expensive programmes would have to be produced (the cost of producing a colour programme being considerably more than a monochrome programme) and these would be available to a limited number of viewers. The advantage of such a system is that different standards could be used, say 625 lines, with the resulting increase in definition.

* Also known as the I.C.I. diagram (International Commission on Illumination).

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It is largely a matter of opinion[6,7] as to which solution is likely to be the most satisfactory but it is interesting to see that the Americans have adopted a compatible system and that the B.B.C. are making experimental tests of such a system.[8,9]

3.3. *Possible Defects in a Colour Picture*

As well as the many defects which can occur in a monochrome picture there are others which are peculiar to a colour television system. Some of these defects[10] are:—

Colour Flicker.—This is similar to the flicker occurring in a monochrome system but is more complex. It is caused by the different luminances of the three separation pictures and, depending on the system, may be important in large or small areas of the picture.

Colour Fringing.—On moving objects the three separation pictures are not identical and result in moving objects having colour fringes.

Lack of Registration.—This is again caused by the separation pictures not being exactly similar even when the picture is stationary and results in a general lack of definition, and colour fringes on objects in the picture.

Lack of True Colour Rendering.—This is caused by incorrect relative brightnesses and/or contrasts of the three separation pictures. This results in all, or parts, of the picture being of incorrect hue or colour.

3.4. *Basic Principle of Colour Television*

The basic principle of colour television is that of superimposing three separation pictures, similar to the additive system of colour photography. Before proceeding further it is important to indicate the differences in the separation pictures. In the case of a simple picture as shown in Fig. 2, the differences in the three colour pictures are quite obvious. When a normal picture is being considered the differences are quite small. In Fig. 13 are shown the red, green and blue separation positives of a typical colour picture which contains a fair amount of colour but is not artificial in this respect; they have to be examined carefully in order to detect any differences. This shows the importance of maintaining the correct relative brilliance (or black level) and contrast of the three pictures.

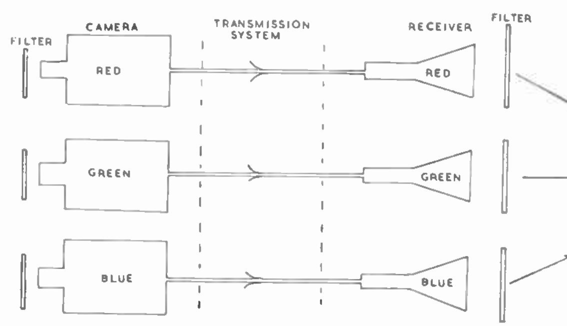


Fig. 14.—Basic principle of colour television.

The basic principle of colour television is shown in Fig. 14. The object is viewed by three cameras (in actual fact a single camera must be used to avoid parallax errors), one camera viewing the scene through a red filter, one through a green filter and one through a blue filter. The outputs of the three cameras are the electrical signals equivalent to the separation positives. These signals are transmitted over three channels in the conventional manner to three monochrome receivers. The pictures on the receivers correspond to the

Fig. 13.—Red, green and blue separation positives of a colour photograph.

separation positives of the scene and are converted to the corresponding primary colours by the use of colour filters as shown (or colour phosphors). The three pictures are superimposed optically by suitable means so that the viewer sees the pictures in register and, therefore, a colour picture. The system is in many ways the simplest and most satisfactory system. It has the serious disadvantage that it makes poor use of bandwidth. Assuming that each separation picture must have the same definition as the corresponding monochrome picture, the total bandwidth is three times that of monochrome. At one time, since a colour picture contains more information than a corresponding monochrome picture, it was considered that this increase in bandwidth was the price that must be paid for colour and that little could be done about it.

3.5. *Methods of Reducing Bandwidth*

The requirement for three times the bandwidth of monochrome no longer holds true and three methods may be used to reduce the bandwidth.

(1) Reducing the definition of the blue separation picture.

(2) Use of "mixed highs" principle.

(3) Use of frequency interlace system.

These will be explained as they are introduced later in the paper.

3.6. *Simultaneous and Sequential Systems*

A simultaneous system may be used as described in Sect. 3.4 in which the three separation pictures are transmitted continuously or simultaneously. Alternatively a system may be used in which the separation pictures (or parts of a picture) are seen in rapid succession and, if the repetition rate is high enough, the pictures will be combined by the retentivity of the eye. This is known as a sequential system.

3.6.1. Simultaneous systems

It has been seen that three channels may be used each with a bandwidth the same as for monochrome, but such a system is extremely wasteful of bandwidth. A modification of this idea, devised by R.C.A.[11] is shown in Fig. 15. Considering the video signal as shown at (a) the green signal is transmitted with a full bandwidth of 4·5 Mc/s. The blue signal is reduced in bandwidth to about 1·3 Mc/s and this is then modulated on to a sub-carrier of 6·25 Mc/s using vestigial sideband modulation. The red signal is transmitted with full bandwidth and modulated on to a sub-carrier of 8·25 Mc/s. Finally the whole complex signal modulates a vision carrier using vestigial sideband transmission as shown at (b). It has been found[12] that the bandwidth of the blue signal and hence definition of the blue picture can be reduced without making a noticeable difference to the picture, the eye being rather insensitive to blue light. Even with this reduction of blue bandwidth the video band extends to 13 Mc/s.

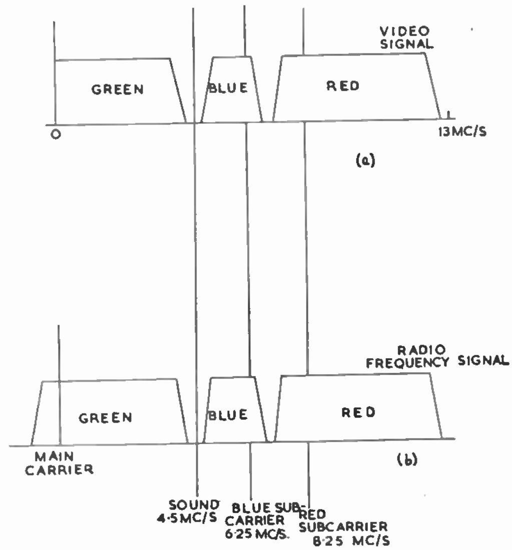


Fig. 15.—R.C.A. simultaneous system of colour television.

If the system uses the same standards as monochrome it is partly compatible since the green separation picture results in a tolerable monochrome picture, but not a truly panchromatic picture. The system is not used owing to the large bandwidth.

Another system (the N.T.S.C. system) which is a simultaneous system will be described later in Sect. 3.9.

3.6.2. Sequential systems[13-16]

Frame sequential system.[17-25]—In this system one complete colour frame is scanned in one primary colour, the next frame in another colour and so on. This is shown in Fig. 16 (p. 605). In the first frame the odd lines are scanned in red, in the second frame the even lines are scanned in green while in the third frame the odd lines are scanned in blue. This is continued until at the end of six frames all the lines of the picture have been scanned in all three colours—termed a colour picture. If this system is used with the same standards as monochrome (say 50 frames per second) there will be only 50/6=8·33 colour pictures per second. This low colour picture rate results in intolerable colour flicker due to the fact that the brightness of the separation pictures will, in general, appear quite different due to the colour content of the picture and due to the different sensitivity of the eye to the different primary colours. If it were possible to use the same standards the system would be compatible but to overcome the colour flicker the frame frequency must be raised to, say, 150 frames/second and, of course, the system is no longer compatible.

If the frame frequency is raised to 150 frames/second one may:—

(*a*) Keep the number of lines the same, in which case (for the same horizontal and vertical definition) the bandwidth will be increased by a factor of three, the definition remaining the same as for 50 frames/second.

(*b*) Reduce the number of lines to maintain the same bandwidth. This results in reduced definition.

In the case of moving pictures considerable movement often takes place between separation pictures, with the result that the pictures are slightly different and this causes colour fringing on moving objects. The camera and receiver are basically simple and a normal camera may be converted to this system by the use of a rotating colour disc, divided into red, green and blue segments, rotated synchronously with the scanning. A similar arrangement may be used in front of a normal monochrome receiver. With the rotating colour disc there are no registration problems which will be seen to be a difficulty with some other arrangements.

The system has been tried with a number of different standards and much work was done by C.B.S. in America and is at present being used in Russia.[26]

Although the system is not compatible and makes poor use of bandwidth and, therefore, unlikely to be used for domestic colour television, it has many advantages for industrial colour television where the bandwidth (on closed circuit) is not so important and th problem of compatibility does not arise.

A modification of this system, known as th dot interlace frame sequential system, give approximately twice the resolution for a given bandwidth[27] but it still has the other dis advantages of frame sequential scanning.

Line sequential system.—This system de veloped by C.T.I.[14, 28] in America is a sequentia system but the colour changes occur at lin frequency. One method of scanning is shown in Fig. 17 (p. 605). In the first frame, line 1 is scanned in green, line 3 (i.e. the second line in this frame) in blue, and line 5 in red. This sequence is repeated until the whole frame is scanned. In the next frame the same lines (i.e odd lines) are scanned again but starting with red, followed by green and blue. The third frame is similar but starting with blue. During the next three frames the even lines are scanned in all three colours in a similar manner. Thus at the end of six frames, all the lines of the picture have been scanned in all three primary colours. The basic method of producing the signal is shown in Fig. 18 (p. 605). Three separation images are projected side by side on a single camera tube and the electron spot scans across the three pictures producing three successive lines, red, green and blue. The various frames are produced by arranging that the scan starts at different positions. A similar arrangement may be used at the receiver, the three pictures being combined optically.

Since the system may be used with the same standards as a monochrome picture it is compatible. Unfortunately, due to the large time between scanning of the same line in the same colour (1/10th second with a frame frequency of 60 per second), small area and interlace flicker is bad. Further the phenomenon of line crawl occurs particularly with a bright picture. The system also suffers from registration difficulties since it is obvious that the three separation pictures must be in exactly the correct position relative to the scanning at both transmitter and receiver.

Colour dot sequential system.[29-33]—This system, developed by R.C.A., makes use of a much higher rate of colour change, the changes occurring more or less between elements of the picture at a frequency of 3·58 Mc/s. The scanning principle is shown in Fig. 19 (p. 605). It is seen that on the first frame odd lines are scanned but each line is divided into a large number of elements and a colour change takes place between elements. On the second frame the even lines are scanned in a similar manner. On the third frame the odd lines are again scanned but the position of the elements has been moved to fill up the space between those scanned on the first frame (dot interlacing). A similar action takes place for the even lines on the fourth frame.

In the case of frame sequential scanning, since the frequency of the colour change is low (say 150 c/s), the change may be made mechanically by a rotating colour disc. With line sequential scanning the rate becomes

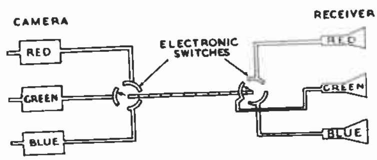


Fig. 20.—Basic R.C.A. dot sequential scanning system.

approximately 15,000 per second and some electronic means of switching must be used, this being done by the scanning beam of the camera and of the receiver cathode ray tube. With the dot sequential scanning system the frequency is still higher and electronic switches must be used. The basic principle is shown in Fig. 20. The electronic switch is arranged to select signals from the appropriate camera tubes at the transmitter and the signal is fed to the corresponding cathode ray tube at the receiver, the two switches being maintained in synchronism. It may be considered that the electronic switch is taking samples from the three camera tubes and the system is really a sampling system. Space does not permit further details of this and the reader should consult the references given for further information.

Into this system is introduced the second method of bandwidth reduction given in Sect. 3.5, namely "mixed highs." It has been shown[34, 35] that the eye does not perceive detail of the picture in colour and a satisfactory picture is obtained if the detail is shown in grey (i.e. monochrome) so long as the luminance is the same as that of the original picture. In the R.C.A. system the signal from the camera is divided into two bands 0–2 Mc/s and 2–4 Mc/s. The 0–2 Mc/s band is fed to the electronic switch as already described and this produces a colour picture with detail corresponding to about 2 Mc/s. The 2–4 Mc/s band is mixed from the three camera tubes (see Fig. 21) in correct proportions to produce a single signal which supplies the detail of the picture and is fed to all three receiver tubes, so producing detail in monochrome.

The system results in a compatible system with good definition when used with a monochrome receiver since the 2–4 Mc/s band is transmitted as a monochrome signal. The definition of the colour picture is the same as a monochrome but with colour only up to 2 Mc/s. The flicker is similar (apart from small area) to monochrome and, due to the high rate of change of colour, colour fringing is small. The system makes good use of the bandwidth since

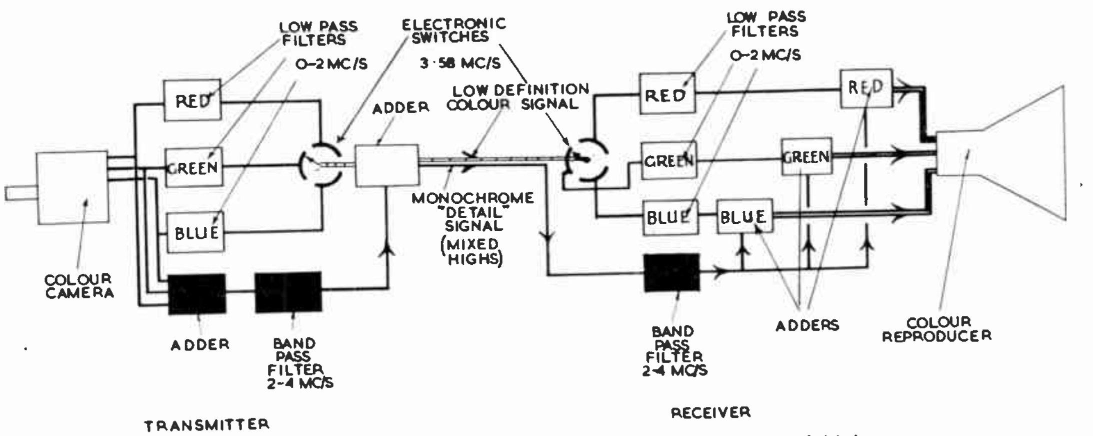


Fig. 21.—R.C.A. dot sequential scanning system with mixed highs.

it uses the dot interlace principle (or time multiplex transmission) together with mixed highs. Registration of the three pictures is difficult and colour fidelity may suffer as a result of phase shifts in the electronic switches.

3.7. *Apparatus at the Studio*

Having described the principles of a number of systems it is convenient to describe the type of equipment which may be used at the studio and in the receiver.

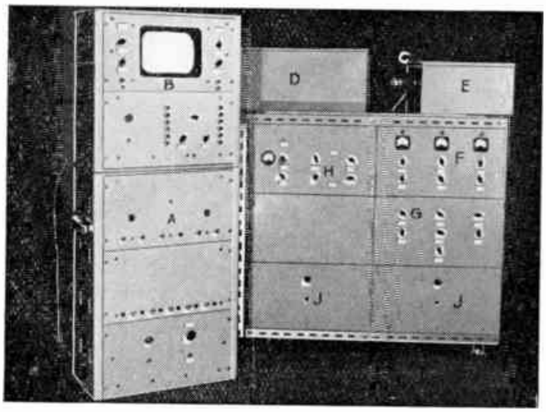


Fig. 23.—Colour slide camera with pulse generator and monochrome monitor.

A. Master pulse generator.
B. Monochrome monitor.
C. Lens and slide carrier.
D. Flying spot tube.
E. Dichroic mirrors and photomultiplier.
F. Video amplifiers.
G. Colour slide camera.
H. Time bases.
J. Power supplies.

3.7.1. Colour disc camera[25]

This has already been mentioned; it results in a simple camera since it is only necessary to add the rotating disc to a suitable monochrome camera. There are no registration difficulties and the camera is therefore easy to adjust. Unfortunately it is limited to use on a frame sequential system.

3.7.2. Flying spot slide camera[36-41]

This apparatus can only be used for reproduction of colour slides and films. The principle is shown in Fig. 22 (p. 615). The raster of the flying spot tube T1 is focused on to the slide S by the lens L1 and light passing through it is collected by the condenser lens L2 and converted into an approximately parallel beam. The light now falls on two dichroic mirrors M1 and M2. These are special mirrors manufactured so as to reflect one part of the spectrum and pass the remainder.[42] The first dichroic mirror M1 reflects blue light and passes red and green. The blue light is focused by lens L3 on to a photo-electric multiplier P1 which gives a signal output corresponding to the blue separation picture. The red light passing through the mirror M1 is reflected by mirror M2 into the photoelectric multiplier P2 which gives a "red" output. Mirror M2 allows green light to pass through it on to the photo-multiplier P3 which gives a "green" output. In order to correct for the light output of the flying spot tube (which has a predominance of green), the responses of the photo-multipliers and errors in the mirrors, correcting filters F1, F2 and F3 are used. The apparatus gives simultaneous outputs and may be used on any system. It has the advantage that there are no registration difficulties. An experimental flying spot colour slide camera constructed by the author is shown in Fig. 23.

3.7.3. Three tube camera[43, 44]

The arrangement of the R.C.A. three tube camera is shown in Fig. 24. A lens turret L1 contains four lenses of different focal lengths and the camera is focused by movement of the turret. In order to obtain sufficient space for the dichroic mirrors, a relay lens system, consisting of field lenses L2 and relay lens L3, is used. The blue light is reflected by dichroic mirror M1 and mirror M3 so as to produce a blue image of the scene on the face of the camera tube T1. Similarly red light is passed by dichroic mirror M1, and reflected by dichroic mirror M2 and mirror M4 so as to produce a red image on camera tube T3. The green light passing through both dichroic mirrors forms a green image on tube T2. Coloured filters F1,

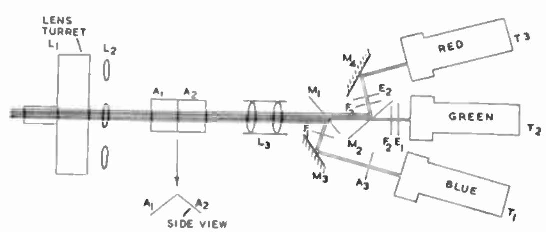


Fig. 24.—Colour camera using three camera tubes (R.C.A.)
(Note.—Not to scale.)

F2 and F3 are used to correct for the response of the mirrors and camera tubes and neutral density filters E1 and E2 are used to adjust the intensity of light on the camera tubes so that they all operate over the same portion of their characteristics. To correct for astigmatism caused by the dichroic mirrors M1 and M2 (since the displacement is not the same in horizontal and vertical directions), astigmatism correcting plates A1 and A2 are placed in front of the relay lens. A further astigmatism correcting plate A3 is necessary in the blue path so that light of all colours passes through the same total thickness of glass. Image orthicon camera tubes are used although the same principles are being applied to cameras using vidicon camera tubes.[48]

A camera of this complexity is, of necessity, larger and heavier than its monochrome equivalent. In order to prevent colour fringing due to lack of registration great care is necessary in setting up the camera so that not only are identical images produced on the three camera tubes but also that the three scanning systems are identical and similarly related to the three images.

3.7.4. Two tube camera[45-47]

This camera developed by Marconi's Wireless Telegraph Co. Ltd., is composed of two camera tubes. One camera tube produces a monochrome output of high definition (3 Mc/s) while the other tube produces two colour outputs of lower definition (1·5 Mc/s). The two outputs are obtained by using a colour grid on the screen of the tube. Since the colour signals are not required to the same definition as the monochrome signal the grid need not be so fine as would be required if this tube were producing a three colour output which would later be mixed to produce a monochrome signal. It will be seen later that this monochrome output and the two colour signals of lower definition are required by the N.T.S.C. system. It has the advantage that the fine detail is produced directly by the monochrome tube and not by a combination of three signals as in a three tube camera.

3.7.5. Single tube camera[48]

A new type of colour camera tube has recently been demonstrated by R.C.A. This is known as a tri-colour vidicon and has the advantage that since a single image and single scanning beam are used there are no difficult registration problems. The signal plate is divided into approximately 900 vertical strips. In front of these are placed red, green and blue filter strips. The appropriate signal plate strips are connected together so as to form a signal plate corresponding to one colour. Thus there are three signal plates and three simultaneous outputs corresponding to the separation pictures.

3.7.6. Chromacoder

It is relatively easy to produce a frame sequential camera but this method is not suitable for transmission. The idea of the

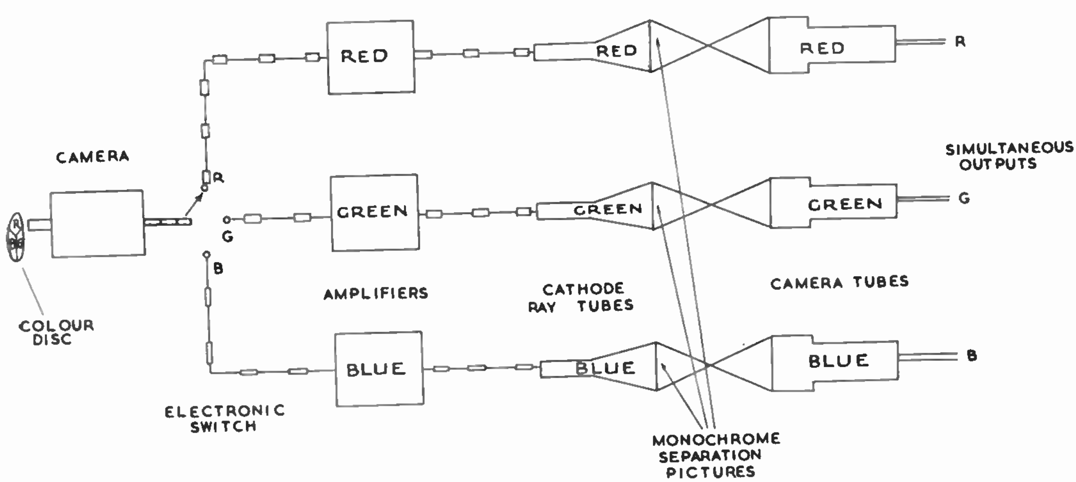


Fig. 25.—Chromacoder.

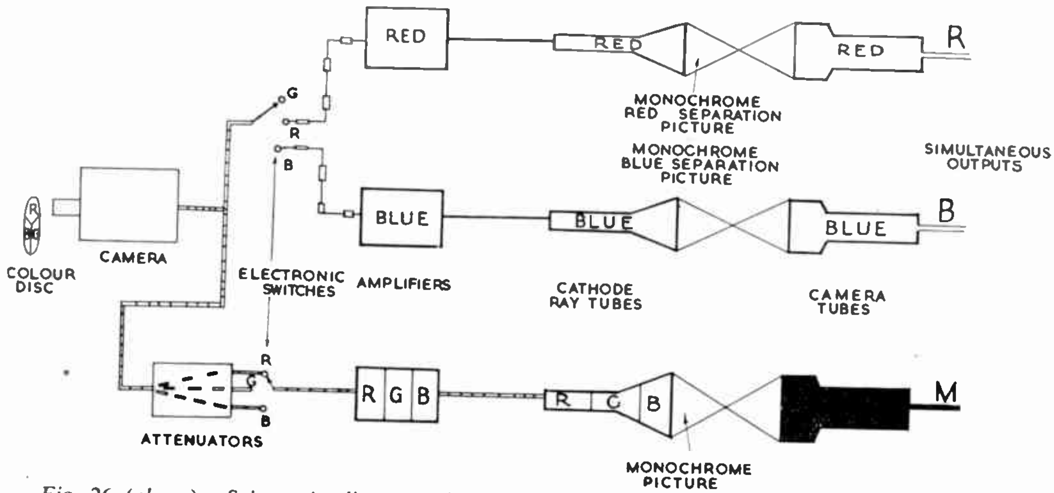
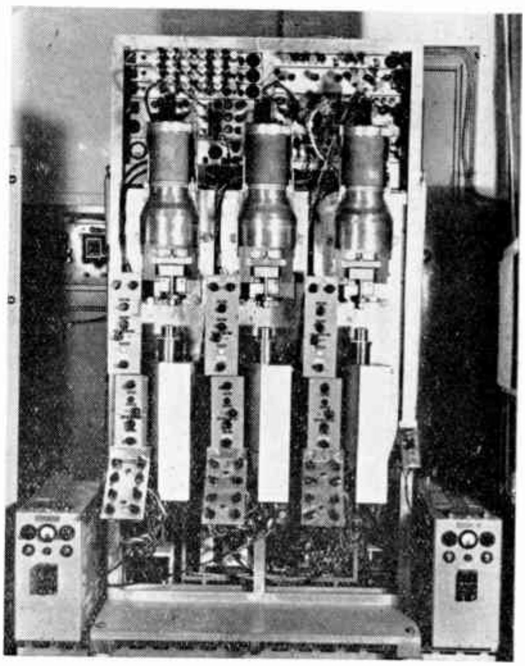


Fig. 26 (above).—Schematic diagram of the E.M.I. signal converter.

Fig. 27 (right).—Photograph of E.M.I. signal converter.



chromacoder is to convert the frame sequential system to a simultaneous system and the principle is shown in Fig. 25. The frame sequential camera runs on any convenient standard, say 405 lines, 150 frames per second using a bandwidth of 9 Mc/s and its output is fed to the chromacoder. In the chromacoder the signal is fed, by means of an electronic switch operated in synchronism with the rotating colour disc of the camera, to three cathode ray tubes which display monochrome pictures corresponding to the separation picture. This is really a complete frame sequential system. The cathode ray tubes are viewed by three cameras which may be operated on any required standard, say 625 lines, 60 frames per second. By use of spot wobble and the storage effect of the camera tubes, continuous output is obtained from the camera tubes although the pictures on the cathode ray tubes are of sequential nature. Obviously there are registration difficulties between the cathode ray tubes and the camera tubes but these difficulties have been removed from the camera to the chromacoder which is static and not limited in size.

3.7.7. E.M.I. signal converter[49, 50]

A signal converter of the chromacoder type has been developed by E.M.I. and is shown in Fig. 26. In this case the red and blue signals are produced as previously but, in place of the green channel, suitable outputs from all three tubes are fed to a cathode ray tube which displays a picture corresponding to a panchromatic monochrome picture. This is viewed by a camera and produces a signal corresponding to that which would be produced by a monochrome camera viewing the actual scene. Thus the output from the converter consists of a monochrome signal and two colour signals and fits in admirably with the requirements

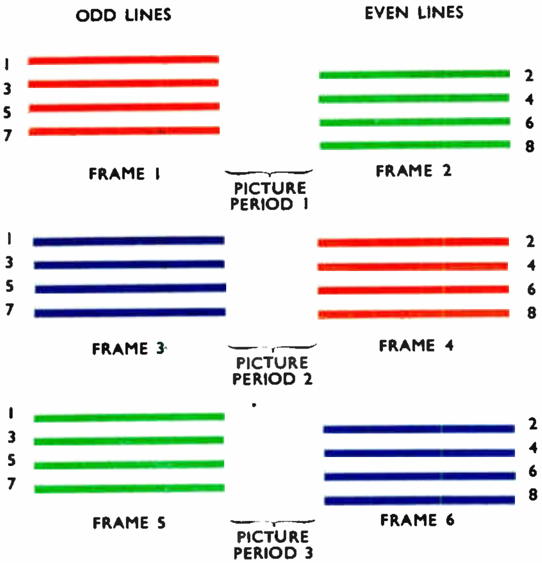


Fig. 16.—Frame sequential scanning.

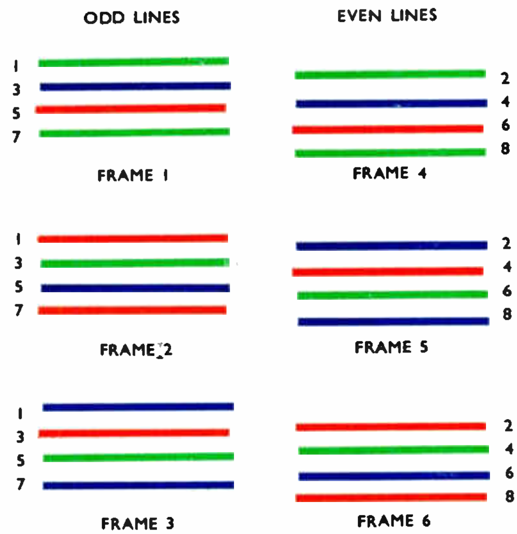


Fig. 17.—Line sequential scanning.

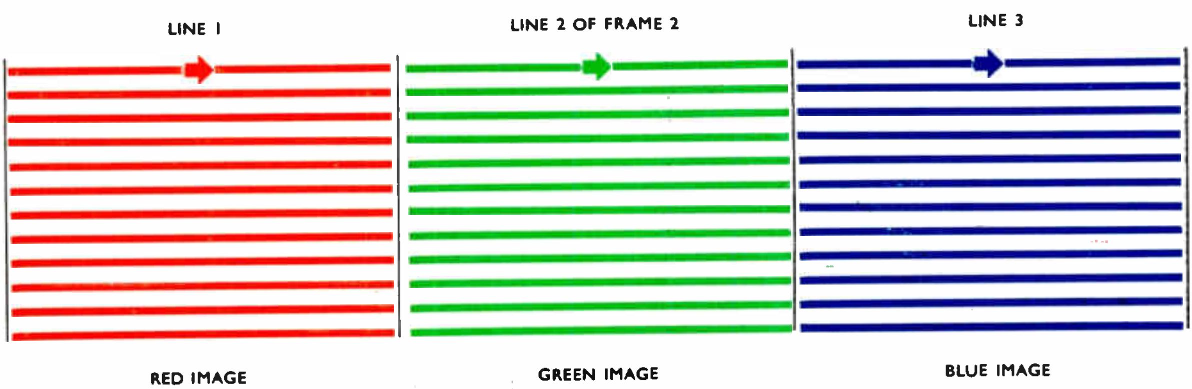


Fig. 18.—Method of producing line sequential scanning.

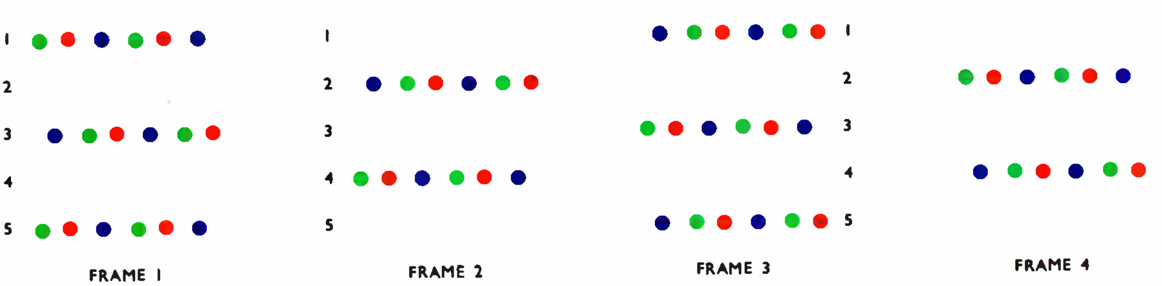


Fig. 19.—Dot sequential scanning (only a small number of dots being shown).

Plate III

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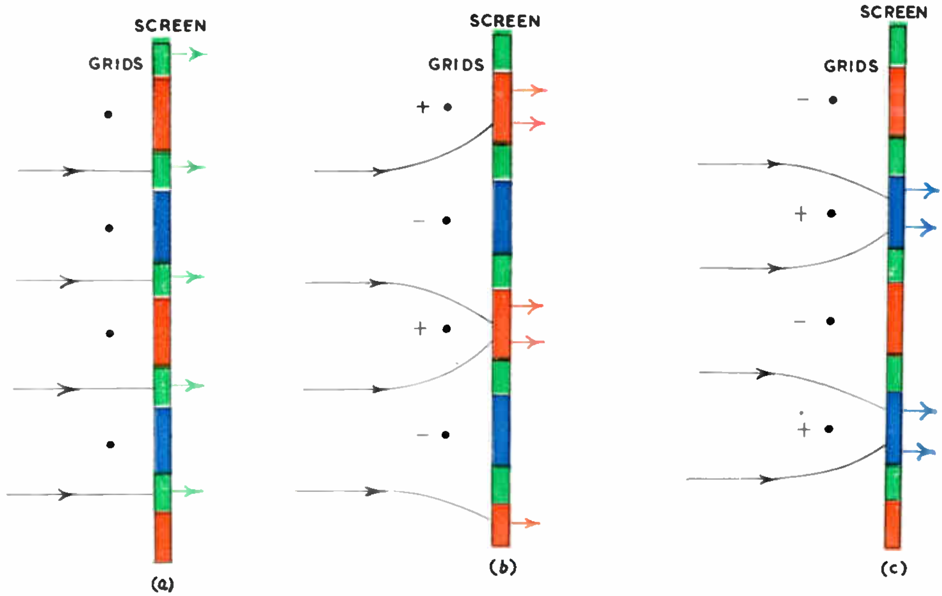
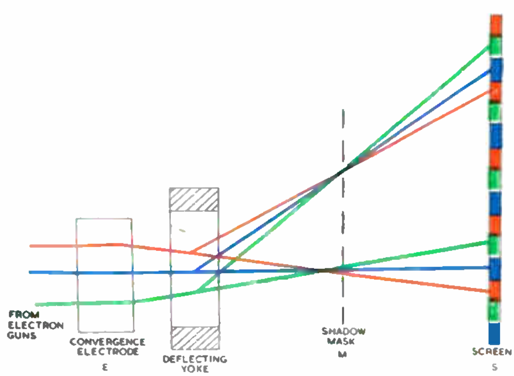
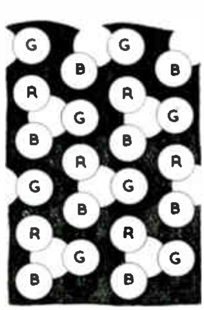


Fig. 31.—Grid type multicolour tube.



(a)



(b)

Fig. 32.

(a) Principle of tri-colour or shadow mask tube.

(b) Shadow mask and colour phosphor dots.

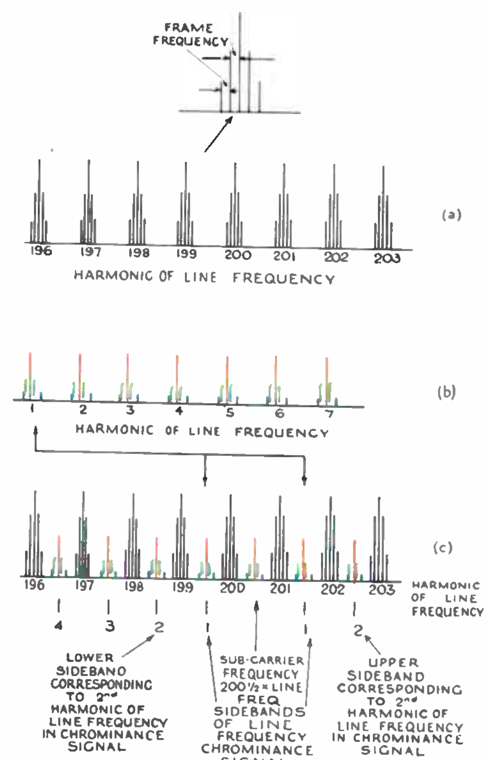


Fig. 34.—Principle of frequency interlace.

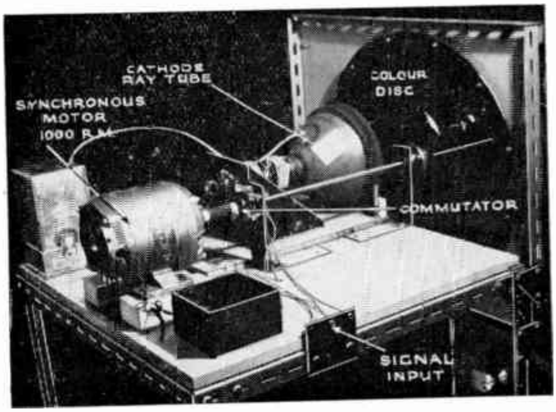


Fig. 28.—Rotating colour disc receiver.

of modern television systems as will be seen later. The arrangement has the advantage that the monochrome signal is produced directly and not obtained by registration of three images as in the original chromacoder. A photograph of the E.M.I. converter is shown in Fig. 27.

3.7.8. Pattern and picture generators

As well as cameras, pulse generators, pattern and picture generators are required for test purposes. For details of these see references 51-53.

3.8. *Apparatus at the Receiver*

3.8.1. Rotating colour disc receiver

Probably the simplest method of producing a colour picture is the use of a rotating colour disc, divided into red, green and blue sectors, in front of a monochrome cathode ray tube. This system can, of course, only be used with a frame sequential signal, and with a small tube say 9–10 in. in diameter, owing to the size of the rotating disc (approximately 22 in. diameter for a 9 in. tube). Although the system is simple it is useless for domestic television because:—

(*a*) A frame sequential system is most unlikely to be used.

(*b*) A rotating colour disc is not suitable for domestic use due to noise and difficulties of maintenance.

(*c*) Public desire for large size pictures.

Although it cannot be used for domestic colour television it has possibilities for industrial colour television where the above disadvantages do not apply. It has the important advantage that there are no registration problems.

An experimental rotating colour disc receiver built by the author is shown in Fig. 28. This operates on 405 lines, 50 frames per second and was built to show the principle and also to show the resulting colour flicker. It is fed from the colour slide camera shown in Fig. 23, the signals being selected in order by a commutator on the shaft rotating the colour disc.[40, 41]

3.8.2. Three tube receiver[54]

The basic idea is shown in Figure 29. The three tubes displaying the separation pictures may have a black and white phosphor screen and be converted to coloured pictures by coloured filters or suitable coloured phosphors may be used on the screens. The latter is the most efficient. The three separation pictures must now be combined by mirrors M1 and M2.

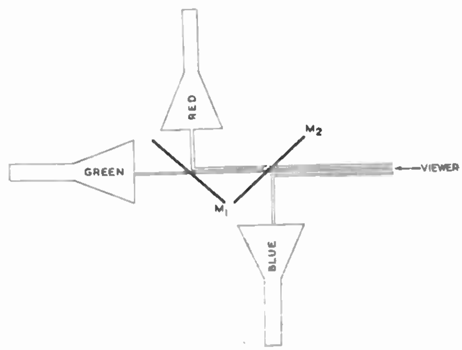


Fig. 29.—Three tube receiver.
(Note.—Not to scale.)

These mirrors may be half-silvered (for projection only), semi-silvered or dichroic mirrors. The latter are the most efficient but large mirrors of this type are difficult to manufacture and are extremely costly. The general principle may be used with direct viewing tubes as shown in Fig. 29 or with projection units. The use of three large direct viewing tubes with associated deflecting circuits is expensive, takes up a large amount of space and, at present, the cost of dichroic mirrors is prohibitive (for domestic use) so semi-silvered mirrors would have to be used with a corresponding loss of light. The projection system offers possibilities but the equipment is expensive and the light output is limited. Both systems suffer from the difficult problem of registration. It must be remembered that, not only must the pictures be exactly the same size and be arranged to coincide exactly, but the scanning must be linear to a much higher degree of accuracy than is necessary in a single tube. Quite large errors are not noticeable on a single tube, particularly on a normal programme as distinct from a test card, but small errors in linearity show up with three tubes in the form of colour fringes in certain parts of the picture. If one takes one picture as reference there are at least two height, two width, two vertical movement, two horizontal movement, two frame linearity and two line linearity controls to adjust to obtain registration of the pictures.

A photograph of an experimental colour projecting equipment[55] built by the author at the College is shown in Fig. 30. In this case only one mirror is used, the blue unit being offset. This is possible when the throw and picture size are large (in this case 40 × 30 in.) but not when a small picture is required.

3.8.3. Multi-colour tubes

Many ingenious ideas have been devised to obtain a colour picture from a single tube either using three electron beams or a single beam. The use of a single tube in a receiver is probably desirable since it overcomes the problem of registration of the three pictures (although there may still remain a registration problem of a different type associated with the tube) and takes up less space. On the other hand replacement costs are likely to be large. In a paper of this type it is not possible to deal with all the arrangements and the reader should consult references 56 to 66 for details. Two types only will be described.

Grid Tube.[67-69]—The basic principle of this tube is shown in Fig. 31 (p. 606). The screen of the tube is divided into a large number of colour phosphor strips, these strips being in the three primary colours. Behind the screen is placed a series of grid wires, one grid wire to each group of three colour phosphor strips. If there is no potential applied between adjacent grid wires the electron beam will be focused (the grids having a suitable potential relative to the screen) on to the green phosphor and a green picture will result. If a potential is applied between adjacent grid wires as shown at (b) the electron beam is bent so that it falls on the red phosphor. When the potential is reversed as at (c) the beam is bent in the opposite direction so that it excites the blue phosphor strips. Thus, by applying suitable potentials to the grids red, green and blue pictures may be obtained. The main difficulty with this type of tube is the large capacitance between the grid wires which would appear to limit the tube to use on frame sequential systems but by resonating this capacitance with a suitable coil the tube may be used on the N.T.S.C. system with a switching rate of 3·58 Mc/s. The tube has the advantage that the grid wires only intercept about 15 per cent. of the beam current due to the focusing action produced by the voltage between grid wires and screen.

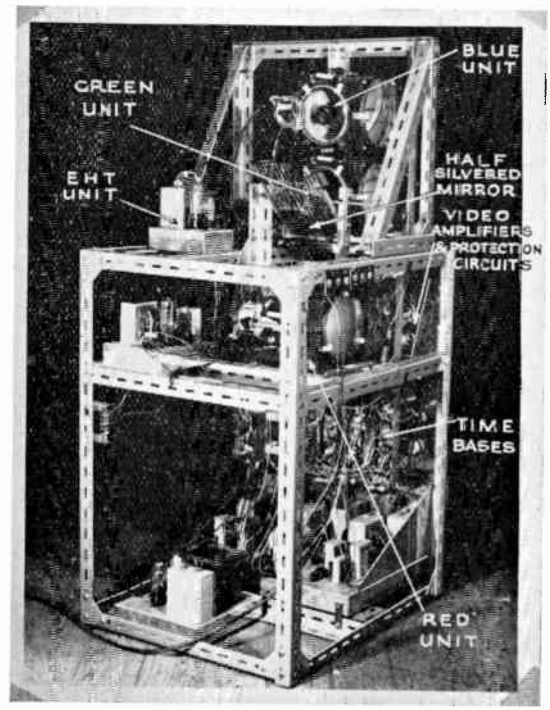


Fig. 30.—Three tube projection receiver.

Tri-colour or shadow mask tube.[70-82]—The principle of the tube is shown in Fig. 32 (p. 606). The screen consists of a large number of red, green and blue phosphor dots and behind the screen is situated a mask M, which is perforated with a large number of holes. The electron gun assembly consists of three electron guns but with common deflecting coils D. The holes in the mask are so positioned with respect to the phosphor dots that the beam from one gun aways falls on the same colour of phosphor dot, whatever the deflection. One beam is arranged to fall on red phosphor dots, one on green and one on blue. This is achieved by a convergence electrode E so that the three beams converge on the mask. Thus by controlling the relative intensities of the beams all colours can be produced. In many respects the tube is the electronic equivalent of the Dufay colour process. Fig. 32b shows the arrangement of the shadow mask relative to the phosphor dots.

In a 15-in. tube there are 195,000 holes in the shadow mask which is placed ⅜ in. behind a phosphor screen consisting of a glass plate fitted inside the tube. In the later 21 in. tube the phosphor dots are deposited on the tube face and a mask with 357,000 holes is used. In order to obtain correct convergence throughout the screen it is necessary to vary the convergence with the deflection (dynamic convergence). In the 15-in. tube a suitable voltage is applied to the convergence electrode but in the 21-in. tube three permanent magnets are used which are situated around the neck of the tube. The magnets may be adjusted for static convergence but they also have coils which are fed with suitable currents from the deflecting circuits to obtain dynamic convergence.

Although the principle of the tube is simple there are many difficulties in its practical use. Carefully designed deflecting coils are necessary if correct convergence and colour purity are to be obtained. A correcting coil (or magnets) is also necessary to overcome the effect of the earth's magnetic field and other stray fields. Owing to the large number of adjustments of convergence, etc., the setting up of the tube takes considerable time and skill. Much of the beam is lost (approximately 80 per cent.) by hitting the mask, which causes loss of brilliance, and final anode voltages up to 25 kV are used.

The advantage of the arrangement is that of a single tube but, due to the high mechanical accuracy required in the tube and deflecting coils, the equipment is expensive. It would appear to have the disadvantage that the failure of any part of the tube will make the tube useless and need a replacement whereas with three separate tubes a fault in any one tube only means the replacement of that tube.

3.9. *Principle of Luminance and Chrominance Signals*

Instead of dealing with colour television as the transmission of three colour separation pictures the problem may be considered as one of transmitting a monochrome picture and supplying additional information in the form of a chrominance signal to convert this to a colour picture. The idea is of great importance as it is the basis of the latest colour television systems.

The transmission consists of two sets of information:—

(*a*) A monochrome transmission which is identical to the signal transmitted in a monochrome system and known as the luminance signal.

(*b*) A chrominance transmission which contains the additional information to convert the picture to colour but does not contribute to the luminance of the picture.

Obviously transmission (*a*) will produce a monochrome picture and, therefore, so long as transmission (*b*) does not interfere with transmission (*a*), a satisfactory compatible system will result. The arrangement has the further advantage that the definition of the colour of the picture may be made any required value, independent of the monochrome definition. This principle is the basis of the N.T.S.C. system.

3.10. *N.T.S.C. System*[83-100]

3.10.1. Constant luminance principle

The N.T.S.C. system of colour transmission was developed by the National Television System Committee in America and was first demonstrated in October 1953. The system is one which is compatible with American monochrome transmissions, i.e. 525 lines 60 frames per second, 4·5 Mc/s vision bandwidth with 6 Mc/s total bandwidth. The monochrome signal is transmitted in the normal manner and the chrominance signals are transmitted by simultaneous amplitude and frequency modulation of a sub-carrier within the video band.

Assuming that the camera and receiver circuits are linear (i.e. no gamma correction is necessary) then the three outputs of the camera are proportional to the trichromatic coefficients of the colour being scanned (see Sect. 2.3.2). Thus, when the camera views equal energy white the three outputs will be equal. Similarly equal voltages fed to the three receiver tubes (or guns) will produce white. It has been shown in Sect. 2.3.2 that:—

1 T unit of red $=x$ lumens of red

1 T unit of green $=y$ lumens of green

1 T unit of blue $=z$ lumens of blue

$$\text{where } x+y+z=1 \qquad \text{........(5)}$$

The monochrome signal which corresponds to the luminance (or number of lumens emitted), is obtained by adding the three outputs in suitable proportions. Let the camera outputs be V_R, V_G and V_B. Then the relative luminances of the three colours will be

$$x.V_R,\ y.V_G \text{ and } z.V_B.$$

The monochrome signal which is proportional to the luminance will be:—

$$V_M = x.V_R + y.V_G + z.V_B \quad \text{.........(6)}$$

Using the primary colours specified in the N.T.S.C. system the following values are obtained:

$$x = 0{\cdot}30,\ y = 0{\cdot}59 \text{ and } z = 0{\cdot}11$$

Thus V_M is obtained by adding or matrixing suitable fractions of V_R, V_G and V_B and the resulting signal is modulated on to the vision carrier in the normal manner. The chrominance information consists of three signals which may be termed the colour difference signals. These are:—

$$V_R - V_M \quad \text{.........(7)}$$
$$V_G - V_M \quad \text{.........(8)}$$
$$V_B - V_M \quad \text{.........(9)}$$

By substituting for V_M (from equation 6) then:—

$$V_R - V_M = V_R(1-x) - y.V_G - z.V_B \quad \text{...(10)}$$
$$V_G - V_M = -x.V_R + V_G(1-y) - z.V_B \quad \text{...(11)}$$
$$V_B - V_M = -x.V_R - y.V_G + V_B(1-z) \quad \text{...(12)}$$

There are two important facts about these colour difference signals:—

(*a*) When there is no colour in the picture they are zero. When the scene is grey (no colour) $V_R = V_G = V_B$ and

$$V_R - V_M = (1 - x - y - z)V_R$$

but, from (5), $x + y + z = 1$ and, therefore,

$$V_R - V_M = 0.$$

Similarly with $V_G - V_M$ and $V_B - V_M$.

(*b*) These colour difference signals are fed to the red, green and blue tubes at the receiver. At the receiver a signal V fed to the red tube will produce a light output proportional to x lumens and a similar voltage fed to the green tube y lumens and so on. Thus a signal $V_R - V_M$ fed to the red tube produces $x(V_R - V_M)$ lumens, $V_G - V_M$ fed to the green tube $y(V_G - V_M)$ lumens and $V_B - V_M$ fed to the blue tube will produce $z(V_B - V_M)$ lumens.

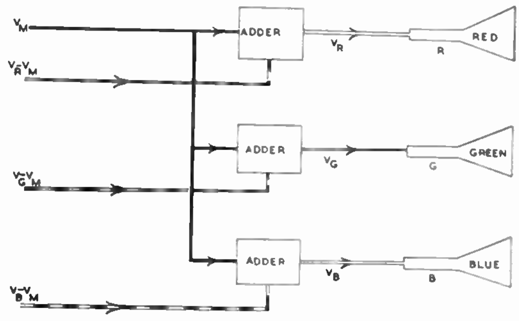
Thus the total lumen output is:—

$$x(V_R - V_M) + y(V_G - V_M) + z(V_B - V_M) \text{ ...(13)}$$
$$= xV_R - xV_M + yV_G - yV_M + zV_B - zV_M$$
$$= xV_R + yV_G + zV_B - (x+y+z)V_M.$$

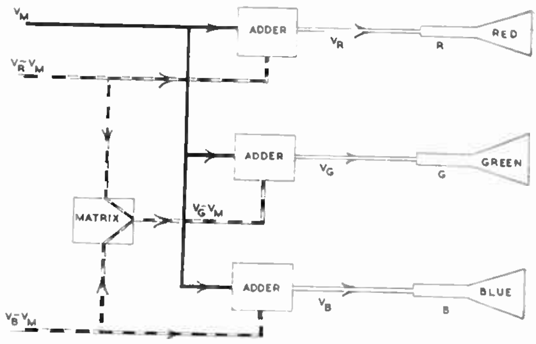
But $x + y + z = 1$,

hence total lumens $= xV_R + yV_G + zV_B - V_M$.

But from eq. (6) $V_M = xV_R + yV_G + zV_B$ and therefore the total lumens equal zero. Thus the chrominance signal does not contribute to the luminance of the picture. For this reason the system is often known as the constant luminance system.[101] †



(*a*)



(*b*)

Fig. 33.—(a) Principle of colour difference signals. (b) As (a), using only two colour difference signals.

The colour signals V_R, V_G and V_B are easily recovered at the receiver by adding V_M to each of the colour difference signals $V_R - V_M$, $V_G - V_M$, $V_B - V_M$. This is shown in Fig. 33a. From this diagram it would appear that four signals are actually necessary, the luminance signal and three colour difference signals. In

† Only true when no gamma correction present.

actual fact only two colour difference signals are required. It can be shown that:—

$$V_G - V_M = -x/y(V_R - V_M) - z/y(V_B - V_M) \quad \ldots\ldots\ldots(14)$$

Thus the $V_G - V_M$ signal may be produced by a suitable combination of the other two colour difference signals at the receiver. This is shown in Fig. 33b.

If the values of x, y and z are substituted in equations (10), (11) and (12) we have

$$V_G - V_M = 0{\cdot}70V_R - 0{\cdot}59V_G - 0{\cdot}11V_B \ldots(15)$$
$$V_B - V_M = -0{\cdot}30V_R - 0{\cdot}59V_G + 0{\cdot}89V_B \ldots(16)$$
$$V_G - V_M = -0{\cdot}30V_R + 0{\cdot}41V_G - 0{\cdot}11V_B \ldots(17)$$

or, substituting in equation (14),

$$V_G - V_M = -0{\cdot}51(V_R - V_M) - 0{\cdot}19(V_B - V_M) \quad \ldots\ldots\ldots(18)$$

3.10.2. Combination of luminance and chrominance signals—frequency interlace

The problem of fitting in the sub-carrier (which is modulated with the chrominance signals) within the normal video band (without interference with the luminance signal) will now be considered. In a general way the whole of the band is already occupied by the luminance and sound signals. At first it would be thought that, when a band of 4·5 Mc/s is allocated for the luminance signal, all frequencies within this band would be generated by the camera. It is found that the only frequencies generated,* are those which are multiples or near multiples of the line frequency, e.g. if the line frequency is 10,000 c/s only frequencies near 20,000, 30,000 —100,000, 110,000—1,000,000, 1,010,000 c/s are produced.[105] This is shown in Fig. 34a (p. 606) where it is seen that there are groups of frequencies separated from the harmonics of the line frequency by multiples of frame frequency. In other words, the band is not being fully utilised. The chrominance signals are similarly related to the line frequency (Fig. 34b) and the idea of frequency interlace is to fit in the chrominance information in the spaces of the luminance signal. This is achieved by modulating a sub-carrier with the chrominance information which has a frequency half way between line harmonic frequencies, e.g. a frequency of 200½ times line frequency (see Fig. 34c). This means that the sub-carrier must be an odd multiple of half the line frequency (i.e. 200½ is 401 times half line frequency). The effect of this subcarrier on the luminance signal at a receiver is shown in Fig. 35. The sub-carrier will modulate the intensity of the beam and during the first picture scan will produce a pattern (consisting of fine dots) as shown at A

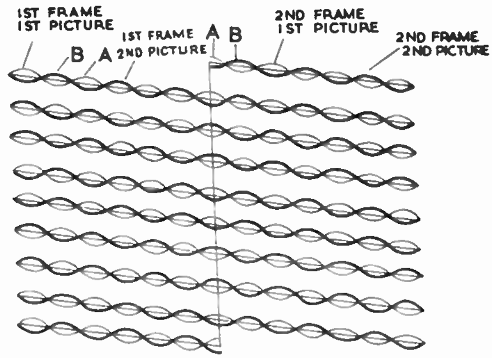


Fig. 35.—Diagram showing cancellation of sub-carrier modulation.

on the figure. At the end of the picture there will be an odd half cycle of this modulation so that on the next picture scan the modulation will be in antiphase as at B and cancellation will occur. In practice the cancellation is not complete due to:—

(*a*) The retentivity of the eye not being complete over the period of one picture.

(*b*) Non-linearity in the intensity modulation.

A similar action occurs for the sidebands of the carrier since these are all spaced from the sub-carrier by multiples of line frequency, i.e. they will be 199½, 198½, 197½, etc. times the line frequency.

Choice of sub-carrier.[106]—This is a complex problem and cannot be considered fully. The main points are that the higher the sub-carrier:—

(*a*) the finer the interference pattern,

(*b*) the less the response of the set at this frequency,

(*c*) the smaller the band which can be allocated to the upper sidebands of the sub-carrier.

To prevent the possibility of an objectional beat pattern between the sound carrier and the sub-carrier, the latter is also frequency interlaced with the sound carrier. Since the sound carrier is frequency modulated this frequency interlace is far from perfect but it has been

* On a stationary picture.

shown that it does make an appreciable reduction in the interference pattern. For this to occur the sound and vision carriers must be separated by an even multiple of half line frequency. The separation is 4·5 Mc/s (settled by present monochrome standards) and the line frequency is derived from this. Half the line frequency is 1/572 of the 4·5 Mc/s or line frequency is 1/286 × 4·5 Mc/s or 15,734·264 c/s. The figure 572 is chosen so as to give a line frequency nearest to the monochrome value of 15,750 c/s and it is within 0·1 per cent. of it.

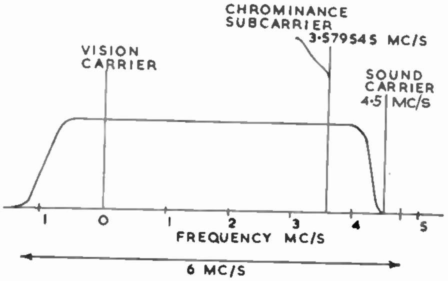


Fig. 36.—Position of sub-carrier in video band.

The frame frequency is, of course, 2/525 × 15,734·264 = 59·94 c/s. The sub-carrier is chosen (as a compromise) as 445 × half line frequency or $227\frac{1}{2} \times 15{,}734{\cdot}264$ c/s = 3·579545 Mc/s. The sub-carrier is the master frequency (accuracy ±0·0003 per cent.) and line and frame frequencies are derived from it by suitable frequency divider circuits, the transmissions being non synchronous with the supply mains. The position of this sub-carrier relative to the other frequencies is shown in Fig. 37.

3.10.3. Transmission of two chrominance signals on a single sub-carrier

It is now necessary to see how the two chrominance signals can be transmitted on a single sub-carrier. One may consider that the sub-carrier is simultaneously amplitude and frequency modulated, but in actual fact the resultant carrier is produced by amplitude modulation of two carriers of the same frequency but in phase quadrature. Suppose one sub-carrier is $V_1 \sin \omega t$ and that this is amplitude modulated by the chrominance signal $B \sin pt$. The resultant output would be $K_1(A + B \sin pt)V_1 \sin \omega t$ which when expanded gives:—

$$K_1V_1 \left\{ A \sin \omega t + \tfrac{1}{2}B \cos (\omega - p)t - \tfrac{1}{2}B \cos (\omega + p)t \right\} \quad \text{......(19)}$$

The first term is the carrier, the second the lower sideband and the third the upper sideband. This is represented by the vector diagram of Fig. 37a. Suppose that a similar modulator is fed with the same carrier and modulation but both in anti-phase with the first, then the resulting output would be $K_1V_1(A - B \sin pt)(-\sin \omega t)$ which expands to:—

$$K_1V_1 \left\{ -A \sin \omega t + \tfrac{1}{2}B \cos (\omega - p)t - \tfrac{1}{2}B \cos (\omega + p)t \right\} \quad \text{.........(20)}$$

shown in Fig. 37b. If the two modulators are arranged to have a common load (commonly called a balanced modulator) it is seen that the carried terms cancel and the sidebands add. The result is shown in Fig. 37c and is represented by:—

$$K_1V_1 \left\{ B \cos (\omega - p)t - B \cos (\omega + p)t \right\} \quad \text{...(21)}$$

The second sub-carrier is $V_1 \cos \omega t$ which when modulated with the other chrominance signal $D \sin qt$, results in

$K_1 (C + D \sin qt)V_1 \cos \omega t$ which expands to:—

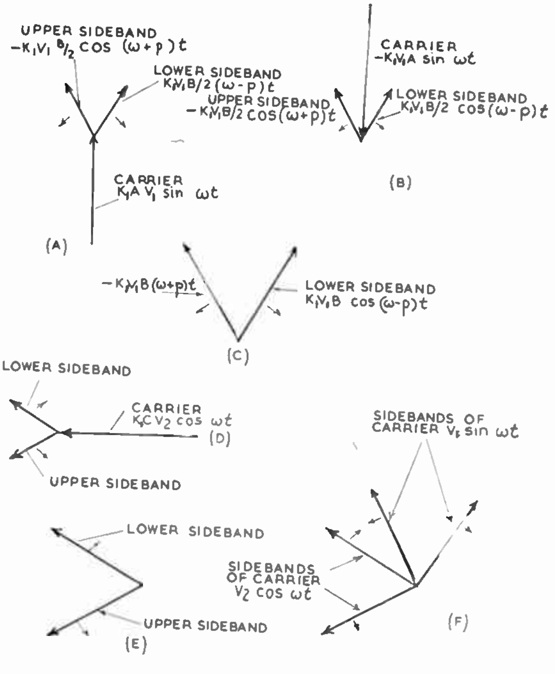


Fig. 37.—Diagram showing modulation of two carriers in phase quadrature.

$$K_1V_1\{C\cos\omega t+\tfrac{1}{2}D\sin(\omega+q)t-\tfrac{1}{2}D\sin(\omega-q)t\} \quad \ldots\ldots\ldots(22)$$

This is shown in Fig. 37d. When a balanced modulator is used the result is:—

$$K_1V_1\{D\sin(\omega+q)t-D\sin(\omega-q)t\} \ldots(23)$$

and shown in Fig. 37e. The resulting signal transmitted is the sum of equations (21) and (23) and is represented by the four vectors of Fig. 37f. Thus four sidebands are transmitted.

At the receiver the two sets of information are separated by a special detector or demodulator known as a synchronous detector,[107-111] one detector being used for each set of information. The process may be considered as one of re-introducing the sub-carrier frequency and using an amplitude detector, or of modulating the re-inserted sub-carrier by the sideband frequencies. In order to reinsert the sub-carrier it is necessary to have a local oscillator at the receiver not only of the same frequency as the sub-carrier but also in phase with the corresponding sub-carrier at the transmitter. Let one of the voltages from the oscillator be $V_3\sin\omega t$. In one arrangement this is modulated by the sidebands in a mixer valve so that the resultant output is:—

$$K_1V_1\{E+B\cos(\omega-p)t-B\cos(\omega+p)t+ +D\sin(\omega+q)t-D\sin(\omega-q)t\}V_3\sin\omega t$$
$$=K_1V_1V_3\{E\sin\omega t+B\sin\omega t\cos(\omega-p)t- -B\sin\omega t\cos(\omega+p)t+D\sin\omega t\sin(\omega+q)t- -D\sin\omega t\sin(\omega-q)t\} \quad \ldots\ldots\ldots(24)$$

When this is expanded the result is:—

$$K_1V_1V_3\{E\sin\omega t+\tfrac{1}{2}B(\sin(2\omega-p)t+\sin pt)- -\tfrac{1}{2}B(\sin(2\omega+p)t-\sin pt)+ +\tfrac{1}{2}D(-\cos(2\omega+q)t+\cos qt)- -\tfrac{1}{2}D(-\cos(2\omega-q)+\cos qt)\} \quad \ldots\ldots\ldots(25)$$

It will be seen that the cos qt terms cancel, and the first term and those containing the second harmonic term (2 ω) are removed by filters (they all being high frequency terms), leaving $K_1V_1V_3\,B\sin pt$ which is proportional to the original modulation of sub-carrier $V_1\sin\omega t$.

In a similar way, by modulating a voltage $V_4\cos\omega t$ by the sidebands, the original modulation of $V_1\cos\omega t$ is recovered.

Thus so long as both sidebands of each chrominance signal are transmitted the modulation may be recovered without mutual interference. On the other hand, suppose that one sideband of each signal is suppressed so that the resulting signal is:—

$$K_1V_1\{B\cos(\omega-p)t-D\sin(\omega-q)t\} \ldots\ldots(26)$$

If this is fed into a synchronous detector with a sub-carrier frequency represented by $V_3\sin\omega t$ it can be shown that the output is:—

$$K_1V_1V_3\{E\sin\omega t+\tfrac{1}{2}B(\sin(2\omega-p)t+\sin pt)- -\tfrac{1}{2}D(-\cos(2\omega-q)t+\cos qt)\} \quad \ldots\ldots\ldots(27)$$

Eliminating the high frequency terms the result is:—

$$-\tfrac{1}{2}K_1V_1V_3(B\sin pt-D\cos qt) \ldots\ldots(28)$$

Thus both sets of modulation are obtained in the output and it is impossible to separate the two sets of information.

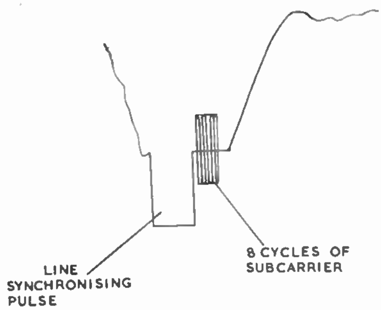


Fig. 38.—Sub-carrier synchronizing burst.

It was stated earlier that it was necessary to have a local oscillator in phase with the sub-carrier at the transmitter.[112, 113] The permitted error in phase is only about 5 deg. and to maintain this phase relationship 8 cycles of sub-carrier frequency are transmitted during the time of the back porch of the line synchronizing pulses as shown in Fig. 38. At the receiver a gating circuit picks out these cycles and compares them with the phase of the oscillator in a phase discriminator. Any error results in an output which is fed to a reactance valve to correct the phase of the oscillator. The phase of the reference burst of sub-carrier is shown in Fig. 39.

It has been shown that in order to be able to separate the two chrominance signals it is necessary to transmit both sidebands but when Fig. 36 is examined it is seen that it is only possible to use the upper sidebands to about 0·5 Mc/s without going outside the permitted video band. This difficulty is overcome by transmitting both sidebands of one signal up to 0·5 Mc/s and using vestigial sideband modulation for the other signal extending to 0·5 Mc/s for the upper sideband and 1·5 Mc/s for the lower. Interference does not occur because over the frequency band where both signals are present both sidebands of both signals are present. Interference from 0·5 Mc/s to 1·5 Mc/s on the first signal by the second is prevented by removing these frequencies after the synchronous detector. Thus, there are two chrominance channels available, the one high definition and the one low definition. It has been found that the eye can distinguish most detail in colours between orange to cyan via white. This axis is shown in Fig. 39 and is at an angle of 33 deg. to the $V_R - V_M$ vector.

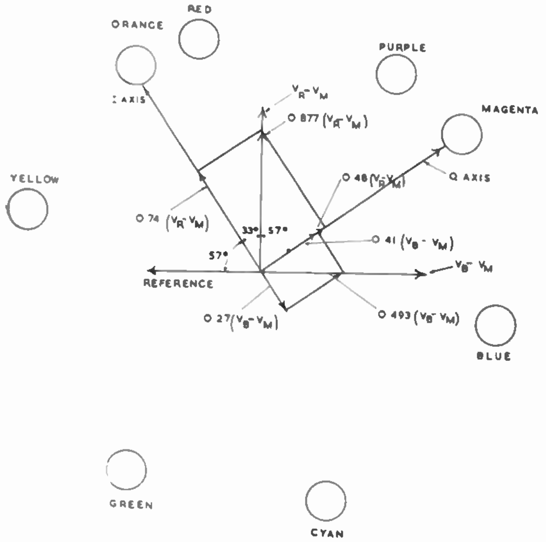


Fig. 39.—I and Q signals.

Colours corresponding to a vector at right angles (green to magenta via white) are not so important. Accordingly, instead of using the $V_R - V_M$ and $V_B - V_M$ signals to modulate the sub-carriers, colour difference signals corresponding to the above colours are used and known as the I (orange-cyan) and the Q signal (green-magenta) so that the best use is made of the available bandwidth. The combination of the luminance signal, I signal and Q signal is shown in Fig. 40.

If the chrominance signals are transmitted at the correct level with respect to the luminance signal it can be shown that when the sub-carrier is added to the luminance signal the overall voltage excursion is 1·84 times that for monochrome. To reduce this to about 33 per cent. (which only happens occasionally) the $V_R - V_M$ and $V_B - V_M$ signals are reduced to 87·7 per cent. and 49·3 per cent. respectively. A suitable correction is, of course, made at the receiver. From Fig. 39 it is seen that the equivalent I signal is:—

$$0{\cdot}74(V_R - V_M) - 0{\cdot}27(V_B - V_M) \quad \ldots\ldots(29)$$

and the equivalent Q signal is:—

$$0{\cdot}48(V_R - V_M) + 0{\cdot}41(V_B - V_M) \quad \ldots\ldots(30)$$

and substituting for the V_M signal:—

$$V_I = 0{\cdot}60V_R - 0{\cdot}28V_G - 0{\cdot}32V_B \quad \ldots\ldots(31)$$

$$V_Q = 0{\cdot}21V_R - 0{\cdot}52V_G + 0{\cdot}31V_B \quad \ldots\ldots(32)$$

3.10.4. Transmitter[114-116]

A simple block diagram of the transmitter is shown in Fig. 41. The three signals from the camera after passing through the gamma correcting amplifiers are fed to the matrix M where they are combined to give the luminance signal (see equation 6).[117-119] This signal is then fed through a filter passing frequencies to about 4·1 Mc/s and delay circuit[120] to correct for the delay time of the various filters. Similarly the I signal as given in equation (31) is obtained from a matrix and fed through a filter to eliminate frequencies above about 1·5 Mc/s. This is then fed to a balanced modulator which is supplied with a carrier at 57 deg. (or 237 deg.) to the reference (see Fig. 39). The Q signal is similarly obtained (equation 32) and passed through a filter to remove all frequencies above about 0·5 Mc/s. This is fed to the balanced modulator supplied with a carrier at 147 deg. to the reference. The three signals are then fed to the transmitter where the synchronizing pulses are added together with the reference burst of sub-carrier.

3.10.5. Receiver[121, 122]

A block diagram of a receiver is shown in Fig. 42, the r.f. and i.f. and sound sections being omitted as these are the same as for a monochrome receiver. The video signal is first fed to the luminance amplifier M through a filter

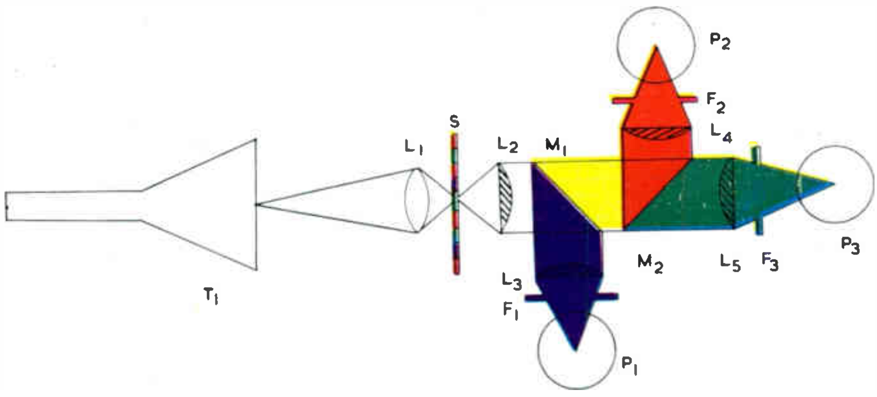


Fig. 22.—Colour slide camera.

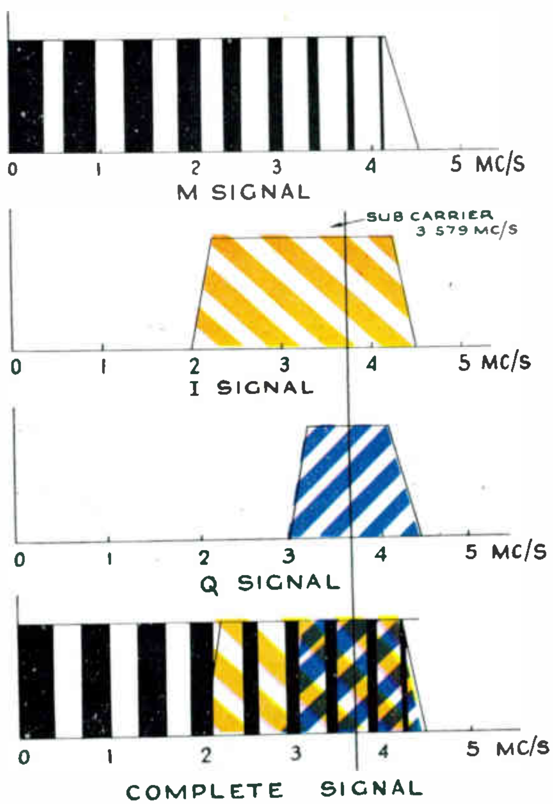


Fig. 40.—Relationship between monochrome, I and Q signals.

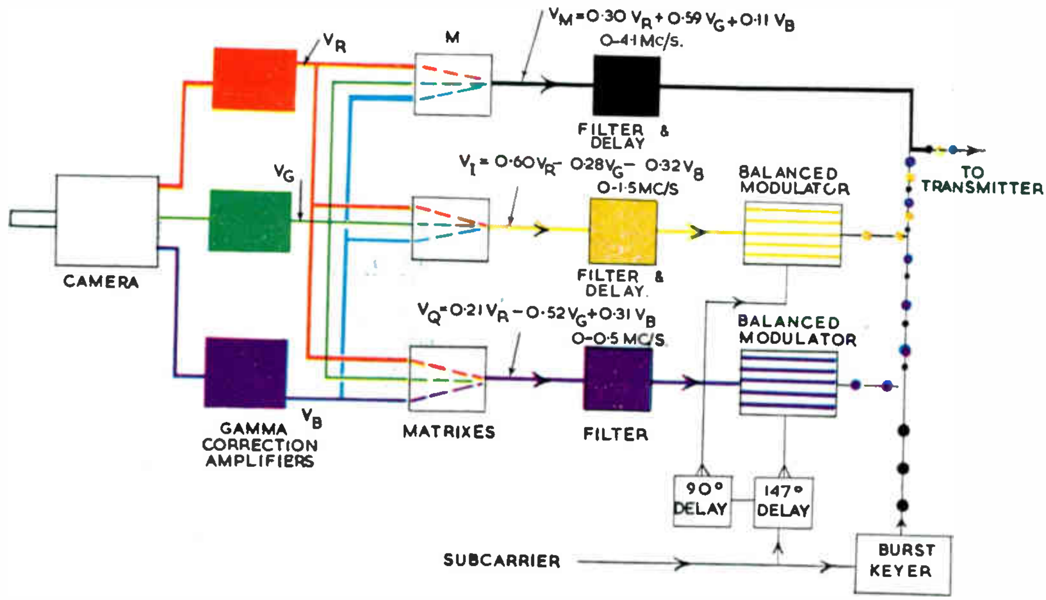


Fig. 41.—Block diagram of transmitter for N.T.S.C. system.

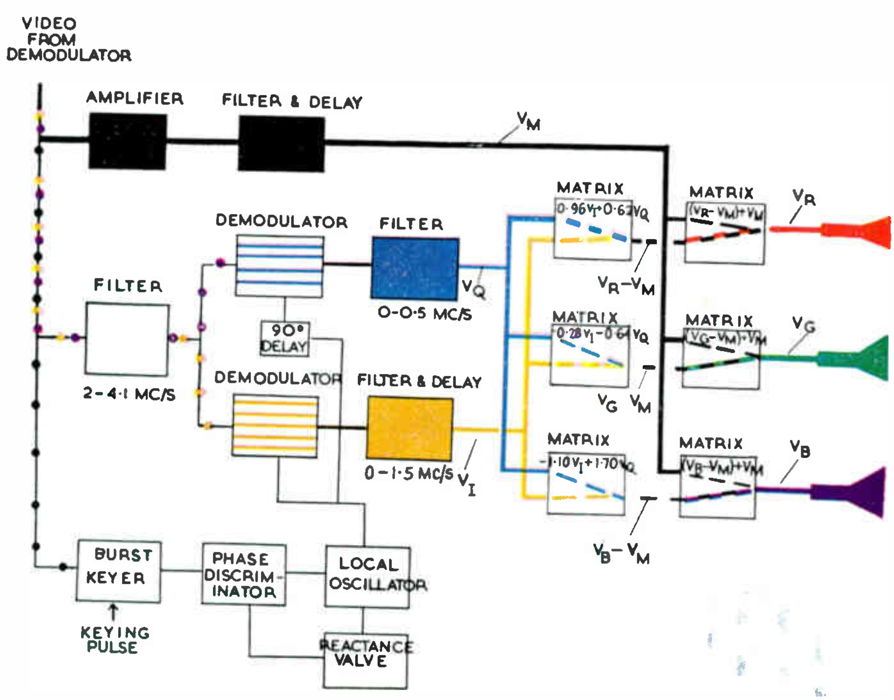


Fig. 42.—Block diagram of receiver suitable for N.T.S.C. system.

Plate VI

which tails off at high frequencies so as to reduce the effect of the chrominance sub-carrier. The video signal is also fed to the I and Q filters which allow frequencies to pass from 2 to 4·1 Mc/s, so cutting out the low frequency portion of the luminance signal. The resultant signal is then demodulated by the two synchronous detectors which are fed with sub-carrier frequencies of the correct phase from the local oscillator. Spurious signals are removed from the I and Q signals by suitable filters, the I filter cutting off above about 1·5 Mc/s and the Q filter above about 0·5 Mc/s. The resulting I and Q signals are now fed to the matrixes to obtain the $V_R - V_M$, $V_B - V_M$ and $V_G - V_M$ signals. It can be shown that:—

$$V_R - V_M = 0{\cdot}96V_I + 0{\cdot}62V_Q$$
$$V_B - V_M = -1{\cdot}10V_I + 1{\cdot}70V_Q$$
$$V_G - V_M = -0{\cdot}28V_I - 0{\cdot}64V_Q$$

The signals are then matrixed to the luminance signal V_M to obtain the colour signals V_R, V_G and V_B which are fed to the modulator electrodes of the cathode ray tubes or tricolour tube. On this diagram is also shown the burst keyer for selecting the sub-carrier burst and the local oscillator with its phase correcting section.

Modern receivers are designed so that the relationship between the various signals depends as little as possible on component values and gains of valves. A simplified system of demodulation and matrixing may be used which does not utilize the advantage of the I and Q signals.[48]

3.11. *British N.T.S.C. and its Modifications*

It is possible to scale down the N.T.S.C. system to fit in with the British television standards in approximately the ratio 405/525 or 3/4. The sub-carrier is around 2·65 Mc/s and the bandwidths of the I and Q signals are reduced to about 1 Mc/s and 0·4 Mc/s respectively. The luminance signal is, of course, limited as in monochrome transmissions to about 3 Mc/s and the only change in the synchronizing pulses is the addition of the sub-carrier burst on the back porch of the line pulses. Unfortunately when the figures are scaled down there is a tendency for greater interference from the sub-carrier because:—

(*a*) the high frequency response of normal sets at a frequency of 2·65 Mc/s is good;

(*b*) the picture frequency is lower and the cancellation by the retentivity of the eye is therefore less.

Since the line and frame frequencies are derived from the sub-carrier the system cannot be synchronized with the mains and this may cause trouble with many receivers.

Transmissions using these standards have been demonstrated by Marconi's Wireless Telegraph Co. Ltd.[123, 46, 47] and are at present being transmitted experimentally by the B.B.C.[124, 125] (See also refs. 45 and 126 for standards of British N.T.S.C.). Modifications of this are possible, such as the transmission of the luminance signal exactly as at present and the transmission of the chrominance information on a separate channel, either as a combined modulation of a single carrier or as the modulation of two separate carriers. If this is done in Band I then, for example, the luminance signal might be transmitted as at present from Holme Moss (for Northern viewers) with the chrominance signal from Holme Moss but at London frequency. There is a possibility of interference in the London area by the chrominance signal from Holme Moss but this may be less than that when the chrominance signal is transmitted in the same video band as in the N.T.S.C. system.

4. Conclusions

It is seen that colour television is considerably more complex and likely to be more costly than monochrome. Although colour television transmissions have been available in America for approximately one year they have not been taken up by either the advertisers or the public in the way that was hoped.[127] This is probably due to the high cost of receivers, which is inevitable until they can be mass produced on a large scale.

It is obvious that highly trained television servicing engineers will be required when colour programmes are available in this country, not only to service the sets, but also to adjust the set when first installed, as this is a highly skilled job.

No doubt the present tests by the B.B.C. will be looked upon with great interest by all concerned with television. The author feels that much is being missed by the lack of colour in many programmes and the public appear to be greatly interested in the subject, the author having given closed circuit colour television demonstrations to over 4,000 persons. On the other hand it is important that colour transmissions are not started until a satisfactory system is available as one would be committed to the system for a long time. It is also important to be able to manufacture satisfactory receivers at a reasonable price.

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NOTICES

OBITUARY

The Council of the Institution has learned with ;ret of the deaths of the following members, d has expressed sympathy with their relatives:

James Robinson, M.B.E., B.Sc., Ph.D. *(ember),* died on 21st October at the age of venty-two. Dr. Robinson was a graduate of ·mstrong College of the University of Durham 1907, and obtained the Ph.D. of the University Göttingen in 1909. He subsequently received e D.Sc. degree of the University of Durham. ·om 1911 until 1915, Dr. Robinson held appoint-ents as Lecturer in Mathematics at Armstrong)llege and as Lecturer in Physics at the niversities of Sheffield and London.

During the first World War, Dr. Robinson rved in the R.N.V.R. and the R.A.F., and in '19 was appointed Head of the Department of 'ireless, Photography and Instruments at the .A.F. Experimental and Development Station at ggin Hill, and subsequently at the Royal Aircraft stablishment at Farnborough. While at Farn-)rough he pioneered the use of the radio compass aircraft, and was appointed an M.B.E.

On leaving Government service in 1925, Dr. obinson undertook consultant work and was sociated with several firms in this capacity up to .e time of his death. During this period he eveloped the stenode system and the use of the iartz crystal gate for obtaining high selectivity radio receivers. He was the author of many chnical papers on a wide range of subjects cluding photo-electricity, acoustics, and applica-ons of physics to radio. His paper on "Aspects : Modulation Systems" was published in the *)urnal* of September 1942.

Dr. Robinson was elected a member of the istitution in 1942, and served as a Vice-President ·om 1942 until 1947. He was a member of the istitution's Parliamentary Committee, and presented the Institution on the Parliamentary nd Scientific Committee.

Chandurbhan Fatechand Mirchandani *(Student)* ied on 7th July, at the age of twenty-three. He 'as a graduate of the University of Baroda, 'here he obtained his B.Sc. and M.S. degrees. 1r. Mirchandani was employed as an engineer 'ith a New Delhi radio manufacturing organiza-on, and registered as a Student of the Institution 1 1953.

Norman W. V. Hayes Memorial Medal

The Council of the Institution of Radio Engineers, Australia, has announced that the Hayes Memorial Medal for 1955 is to be awarded to Mr. John Swift for his paper on "Disc-seal Circuit Techniques," which was published in three parts in the *Proceedings of the Institution of Radio Engineers, Australia.* The first two parts of the paper have been reprinted in the *Brit.I.R.E. Journal.*

Members will know that the Brit.I.R.E. and the Institute of Radio Engineers of New York adjudicate in alternate years for this award of the Australian Institution; this year it was the turn of the Brit.I.R.E. to make the recommendation.

B.B.C. Research Scholarships

The B.B.C. are presenting one or two research scholarships each year, valued at £385 per annum, to University Graduates in Electrical Engineering or Physics who obtain good Honours Degrees, giving them the opportunity to work for a higher degree at any University in the United Kingdom, not necessarily at the one where they graduated.

The scholarships are for two years in the first instance, with the possibility of extension in suitable cases. The subject for research must be in those fields of telecommunications or physics which have an application to sound or television broadcasting.

New Journal on Productivity

The first issue of a new bi-monthly journal published by the College of Industrial Science and Technology appeared this month. The journal, which is to be called *Higher Productivity,* will be devoted to work study, mechanical handling, and automation. Further information may be obtained from the College, at Charing, Ashford, Kent.

Correction

The following corrections to the paper by E. J. Frank in this issue were received too late for incorporation before going to press:—

Page 634, 3rd line of last paragraph, *for* "$t \gg \tau$," *substitute* "$t \geqq \tau$."

Page 637, last two paragraphs, for $\ll$ substitute $\leqq$ throughout.

Page 644, first column, the last formula *should read :*

$$A = 7{\cdot}2 \times 10^{-6} \left(\frac{R}{d}\right)^2 \frac{n}{k\tau} \text{ microcurie } (\textit{in vacuo}).$$

TELEVISION DEVELOPMENTS

B.B.C. Colour Television Test Transmissions

On November 5th, the B.B.C. started its third series of experimental colour television transmissions. This series, which will continue for about six months, is being transmitted on Channel I (vision—45 Mc/s; sound—41·5 Mc/s) from the new station at Crystal Palace; transmissions will take place after normal programme hours on Mondays, Wednesdays and Fridays, starting at 11.10 p.m. approximately and lasting for about 40 minutes.

Two previous series of tests were transmitted from Alexandra Palace in October 1955 and in April of this year, and the system of transmission used in the new series will be the same as used previously, namely a modified version of the American N.T.S.C. system adapted to suit the British standards of 405 lines, 25 frames per second.* The signals will therefore be compatible.

The earlier experimental transmissions were mainly concerned with problems of compatibility. The new series will have as one of its main objects the assessment of quality and acceptability of the colour pictures produced by the complete chain of colour equipment from the studio to the receiver.

The transmitted items will include "live" studio material, colour films, still pictures, and test patterns originating from the B.B.C.'s experimental colour television cameras and equipment at Alexandra Palace, from where they will be sent over G.P.O. circuits to the Crystal Palace transmitter. The transmissions will be received at a number of selected points in the service area of the Crystal Palace Station on colour receivers specially developed for the tests. They will also be received on monochrome receivers which will provide more information about compatibility.

American Colour Television

Forecasts that 1956 would see a rapid expansion in the acceptance by the American public of colour television have not proved accurate, and a New York correspondent of *The Financial Times* reports that a number of colour receiver manufacturers, who had earlier in the year anticipated a heavy demand,† have reduced their output.

* *J.Brit.I.R.E.*, **15**, pp. 576-581, November 1955.

† *J.Brit.I.R.E.*, **16**, p. (xi), April 1956.

Sales have lagged in spite of the offering by number of firms of sets retailing for less tha $500 (about £175); members of the industry fe that many potential customers still consider tl price high compared with that of a monochron receiver. A later report in *The Financial Tim* states that sales of monochrome receivers are als appreciably below expectations.

The quality of colour programmes, which ca also be received on monochrome receivers, do not seem to have impressed the public. A Chicag station has been offering 42 hours of colou programmes weekly, but there has been n particular increase in the demand for colou receivers in that city.

B.B.C. Temporary Transmitter at Sandale

By making use of temporary equipment, th B.B.C.'s new television transmitting station a Sandale, Cumberland, has been brought int operation many months earlier than woul otherwise have been possible. The site approximately 1,200 feet above sea level, an some 14 miles south west of Carlisle. Because o its lower power, the coverage of the temporar station will not be as great as that to be provide by the permanent station, but it is expected t include Carlisle, Wigton, and Maryport.

The temporary station will operate on the sam frequencies as those to be used by the permaner station so that receivers and aerials set up fo reception of the temporary station will not hav to be changed when the permanent station come into operation. The transmitter will operate i Channel IV (vision—61·76 Mc/s; sound—58·2 Mc/s), with horizontal polarization.

In the absence of any existing cable circuits t carry the sound and vision signals to th transmitting site, the sound signal will be picke up by radio direct at Sandale from the B.B.C television stations at Pontop Pike or Holme Moss while the vision signal will be received fron Pontop Pike by a Post Office receiving station a Haltwhistle, from where it will be re-transmitte to Sandale by a microwave link.

Sandale is also to be a v.h.f. sound broadcastin station, which will provide improved reception i the greater part of Cumberland and Westmorland as well as the coastal areas of south-wes Scotland. It is hoped to have both the permanen television station and the v.h.f. sound broadcastin station in operation before the end of 1957.

A WAVEFORM RECORDER EMPLOYING SAMPLING TECHNIQUES *

by

A. W. Gooder (*Associate Member*)†

SUMMARY

The instrument provides a permanent record on a pen recorder of oscilloscope traces of recurrent waveforms. The X sweep voltage from the oscilloscope is used in the recorder to determine once per sweep the time at which a 0·5 μsec pulse is to be generated. The recorder is "gated" by the pulse to produce a sample of the amplitude of the waveform, which is peak rectified, and applied to the recorder.

1. Introduction

The cathode ray oscilloscope provides the only worthwhile method for displaying recurrent waveforms in the majority of electronic devices. When, however, one requires a permanent record to be made of such waveforms the methods available are:—

(*a*) The manual copying of the oscillogram from the cathode ray tube face by tracing or by a combination of observation and taking measurements of the important points, or

(*b*) One of the photographic methods.

In the case of (*a*) this is laborious and liable to human error, and in the case of (*b*), whilst the record is accurate so far as waveform is concerned, measurements must still be made if the oscillogram is to give quantitative information. Further, since the brightness of the trace will vary over the waveform due to variations in spot speed the resultant photograph may well be under-exposed in some parts and over-exposed in others. Since one cannot be sure of a photograph until processing is complete valuable time is wasted. Finally, photography is expensive.

With these considerations in mind it was decided to investigate other methods of recording such waveforms.

2. Requirements

In the laboratories where the instrument is used the waveforms most commonly investigated are those produced by such devices as multivibrators, time-base circuits, step generators, squaring and differentiating circuits, etc. Further, these waveforms usually recur at a rate in the audio-frequency spectrum, or a little above it. In many of these circuits it is also highly desirable to be able to compare the phase relationship of waveforms.

When the system to be described was decided upon a decision had to be taken between producing an instrument of high accuracy which would be large, expensive and somewhat complicated, or sacrificing a little in accuracy (mainly in the recording of very rapid rises and falls) and having a much simpler portable unit working in conjunction with existing standard laboratory equipment.

The latter course was decided upon and finally an instrument was devised having thirteen valves, twelve of them being miniature types. It derives its power supply from a.c. mains via a small regulated power pack and requires, to complete the equipment, a recording milliameter and a double beam oscilloscope. Several oscilloscopes were found to be suitable, e.g. Cossor Models 339, 1035, 1049 and Army Oscilloscope type 13.

3. General principles

About three repetitions of the waveform to be recorded are displayed on an oscilloscope having a linear sweep and stable time-base.

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† Radar and Telecommunications Branch, Royal Military College of Science, Shrivenham, Wilts.

U.D.C. No. 621.317.75:621.374.

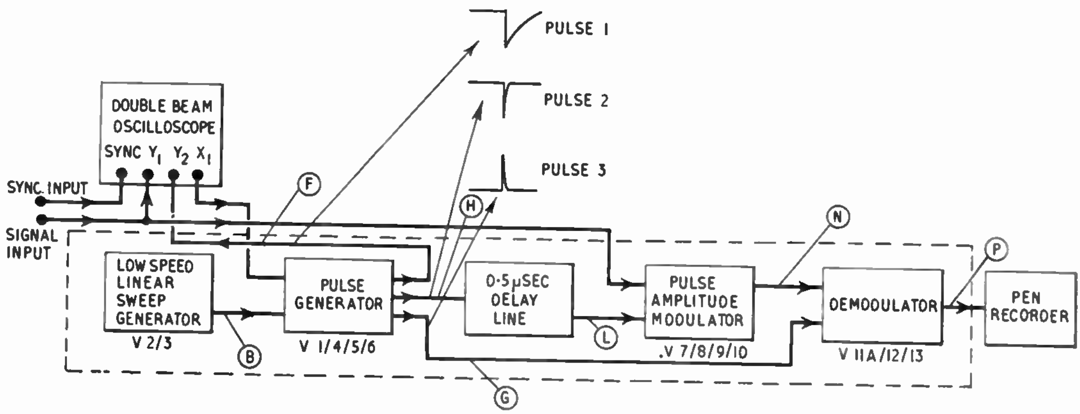

Fig. 1.—Simplified block diagram of the waveform recorder. The instrument described is within the dotted lines, the oscilloscope and pen recorder being separate instruments. The letters labelling points refer to the main circuit diagram (Fig. 2).

The "X" sweep voltage is extracted and used in the recorder to determine once per sweep the time at which a half microsecond pulse is to be generated. The waveform under examination is also fed into the recorder and "gated" by the pulse, thus producing a sample of the amplitude of the waveform. This sample is peak-rectified and so a voltage proportional to the instantaneous amplitude of the waveform is produced and applied to the recording instrument.

The point of sampling is initially set towards the origin of the trace on the cathode ray tube and the pulse moves slowly and linearly along the time-base sweep; thus the d.c. output varies slowly and with the pen-recorder motor set in action the waveform is automatically traced out. The sample can be made to travel along the trace at one of four speeds with corresponding recording times of ½, 1, 1½, and 2 minutes approximately.

4. Details of the Instrument

The equipment has been divided into seven blocks (including an oscilloscope and pen recorder, which are external units) but does not include the power supplies. A block diagram is shown in Fig. 1.

Briefly the purposes of the various units are as follows:

(*a*) *The double-beam oscilloscope:* To display the waveform being recorded, to provide a high-speed sweep to the pulse generator for the purpose of sampling, and to indicate on the other beam where sampling is taking place.

(*b*) *Low-speed linear sweep generator:* To provide a linear negative-going sweep of time period ½, 1, 1½, or 2 minutes which is used to delay progressively the sample point along the oscilloscope sweep.

(*c*) *Pulse generator:* To provide three simultaneous pulses once per repetition of the oscilloscope sweep. If the low-speed sweep generator is switched off these may be fixed (by manual control) at some point on the sweep (normally near the origin). When the low-speed sweep generator is switched on these pulses are made slowly and linearly to move along the oscilloscope sweep. Pulse 1 (an extended pulse) is returned to the oscilloscope to indicate where sampling is taking place. Pulse 2 is delayed and then used in the pulse amplitude modulator. Pulse 3 is used in the demodulator.

(*d*) 0·5 *microsec delay line:* This provides sufficient delay to enable the demodulator to be reset before the arrival of each sampling pulse (see *f*).

(*e*) *Pulse amplitude modulator:* This has two input terminals; one receives the waveform being recorded whilst the other receives pulse 2 after suffering a delay of ½ microsecond (see *f*). The output at (N) is a pulse, amplitude modulated proportionally to the instantaneous value of the waveform being recorded.

(*f*) *Demodulator:* The function of this unit is to convert the pulses at (N) into a slowly varying voltage so that its output can be followed by the pen recorder. Being of the "box car" or pulse stretching type it requires a resetting pulse just before the pulse at (N). Pulse 3 is used for this purpose and is made to occur before the pulse at (N) by delaying pulse 2 by 0·5 μsec between the pulse generator and the pulse amplitude modulator.

(*g*) *Pen Recorder:* Is used for the obvious purpose of recording the waveforms.

5. The Circuit Details (Fig. 2)

5.1. *Generating the Sampling Pulses*

The high speed negative-going sweep from the oscilloscope time-base is a.c.-coupled to grid 1 of V1 which is a cathode follower whose grid is returned to h.t.+ to prevent the valve cutting off towards the end of the sweep.

The cathode of V1 is directly coupled via a grid stopper to the grid of V4B. Thus the signal at (A) will cut off the anode current of V4B to produce a positive anode voltage step at an instant of time determined by its cathode potential which is common to V4A.

With the RESET-RUN switch in the RESET position −250 V is applied to grid 3 of V2 and its anode current is cut off. Its anode potential, and hence that of the grid of V4A, is determined by the setting of the RESET POSITION potential divider.

The positive voltage step at the anode of V4B is further amplified and twice inverted by the d.c. amplifiers V5A and V5B producing a very rapid positive step at (E).

The 100-pF and 100-kΩ coupling components differentiate the step and apply it to the grid of V6 which is a gas triode biased beyond cut off. The arrival of the pulse at its grid "fires" the triode and discharges the 0·001-μF capacitor, producing a short duration positive pulse at (G) and a similar negative one at (H). Meanwhile the anode (F) rapidly drops in potential before rising slowly as the 0·001-μF capacitor charges through the 100-kΩ anode load, V6 being cut off. From the foregoing it will be seen that output pulses are produced at (G) and (H) at constant amplitude at a point along the high-speed sweep dependent on the setting of the RESET POSITION control.

5.2. *Movement of the Sampling Pulses*

Returning to V2 it will be seen that this is a conventional linear sweep generator of the "Miller" type. So far it has been rendered inoperative by the −250 V bias applied to grid 3 and its anode potential fixed by the RESET POSITION control.

If the RESET-RUN switch is now set to the RUN position, the anode voltage will fall in a linear manner after a small initial drop. From the circuit diagram it will be seen that the time constants involved are very long, C being 8 μF and R being 10, 20, 30, or 40 MΩ according to the setting of the VELOCITY switch, with a maximum time for run-down of about 2 minutes.

Once run-down commences the diode V3 cuts off and the anode potential of V2 now sets the grid and cathode potentials of V4A. Thus the instant at which V4B cuts off is slowly and linearly delayed for each sweep of the linear high-speed time-base, and so for each successive sweep the sampling pulse is generated a little later relative to the start of the high-speed sweep and hence to the point along the waveform under examination at which the initial pulses were generated.

This process continues until V2 "bottoms." Pulses cease to be generated a little before this because the cathode potential of V4B will have been reduced so low that the waveform at (A) will no longer go sufficiently negative to cut off V4B.

Owing to the high resistance in the grid circuit of V2 care was taken to choose a VELOCITY switch with very low leakage. The associated 8-μF capacitor was chosen for its negligible internal leakage and was mounted on perspex to minimize leakage to earth.

5.3. *Production of Samples*

Concerned in this process are the waveform to be recorded, the negative pulse at (H) and valves V7, V8, V9 and V10.

The waveform to be recorded is a.c.-coupled to grid 1 of the cathode follower V7 which has its grid leak returned to the +250 V h.t. line to prevent the valve cutting off on negative parts of the cycle. The cathode load of this valve takes the form of a potential divider to enable large signals to be reduced to about 20 or 30 volts peak to peak. The slider of this control (SIG. AMP) is a.c.-coupled to grid 1 of a second cathode follower V8 which has a d.c.

level set by the 270 kΩ + 100 kΩ resistance chain across the h.t. supply. Thus at (K) we have an attenuated version of the waveform to be recorded at a pre-determined d.c. level and at low impedance. This point (K) is connected, through a 50 kΩ resistor, to the anode of V9 whose grid 1 is returned to earth (and cathode) via a low impedance path made up of the 1,000-Ω termination of the delay line shunted by the delay line and the 220-Ω between (H) and earth. Thus V9, being biased to zero, will, in the absence of a signal at its grid, present a relatively low impedance between (M) and earth and the waveform at (K) will not appear at (M), until V9 is cut off by the negative pulse from the delay line, when its anode potential rises towards the instantaneous value of the potential at (K). The function of the delay line is explained in the next paragraph. V10, being a normal cathode follower, has a series of pulses at its cathode (N) of width about 0·5 μsec and of amplitudes proportional to the successive instantaneous amplitudes of the waveform to be recorded as the slow sweep proceeds. The remaining requirement is to demodulate these pulses with a peak detector which will maintain a constant level between pulses but whose level will change according to the amplitude of each pulse as it arrives.

5.4. *Demodulation*

Demodulation is carried out by the "box car" detector, V11A, V12 and V13. The pentode V12 is d.c. biased beyond cut-off at grid 1 and in this condition provides a high impedance between (O) and earth. Thus if a positive pulse is produced at (N) which is greater than the potential at (O), V11A will conduct charging the 0·001-μF capacitor between (O) and earth and so the potential at (N) will be reproduced at (P), the cathode of the cathode follower V13. On the cessation of the pulse at (N), V11A will cut off leaving (O) and (P) at the peak value of the last sample at (N) since there is only the leakage path (which has been kept very high) to discharge the 0·001-μF capacitor. If another sample arrives at (N) which is greater in amplitude than the previous one, the potential at (P) will rise to the new value. However, if the pulse should be smaller than the previous one further circuits are called into play to allow the detector to accommodate itself to this situation. In such a case consider the behaviour due to the pulse at (G) which preceded the sample by 0·5 μsec. Thus V12 is made to conduct for 0·5 μsec before the arrival of each sample at (N) and this is sufficient partially to discharge the 0·001-μF capacitor and thus reduce the potential at (O) so that its new potential can be set whether the next sample is equal to, greater than, or, within limits, smaller than the preceding pulse.

Thus at (P) we have a slowly changing level of potential which will, in a comparatively long time, trace out the waveform of the signal to be recorded.

5.5. *Precautions in the use of the Pen Recorder*

The pen recorder used is an Elliot Bros. 0–1 mA synchronous motor pen recorder (mains driven) having a nearly linear pen movement. The paper speed used is 2 inches per minute.

From (P), the cathode of V13, a 22-kΩ resistor is connected to the positive terminal of the recorder. The purpose of this resistor is merely to reduce the sensitivity of the instrument. The negative terminal of the instrument should be returned to some suitable potential with respect to earth to give the necessary Y shift. If a potential divider across the supply is used, the variation of this control will vary the sensitivity of the instrument which is obviously undesirable. To avoid this the recorder negative terminal is taken to the cathode of the cathode follower V14, and Y SHIFT set by adjustment of the d.c. potential of grid 1 of this valve.

The inertia of the instrument and the ink drag will cause some distortion which has been substantially overcome by applying a 50-c/s signal from the heater supply to grid 1 of V14. This provides "dither" at a frequency too high to be followed by the pen but sufficient to reduce sticking to an insignificant amount.

To prevent the pen of the recorder being driven hard against the zero stop due to potential reversal at its terminals when sampling ceases at the end of a run, the METER LIMIT control has been fitted in the cathode of V14, and its slider connected to the anode of V11B. If the potential at (O) falls below that of the slider of this divider, V11B conducts preventing the potential at (O) and consequently (P) falling further. Hence the METER LIMIT control can be set so that the pen is not driven negative at the end of a run, whilst during a run the cathode of V11B remains positive, with respect to anode, and does not interfere with the process of demodulation.

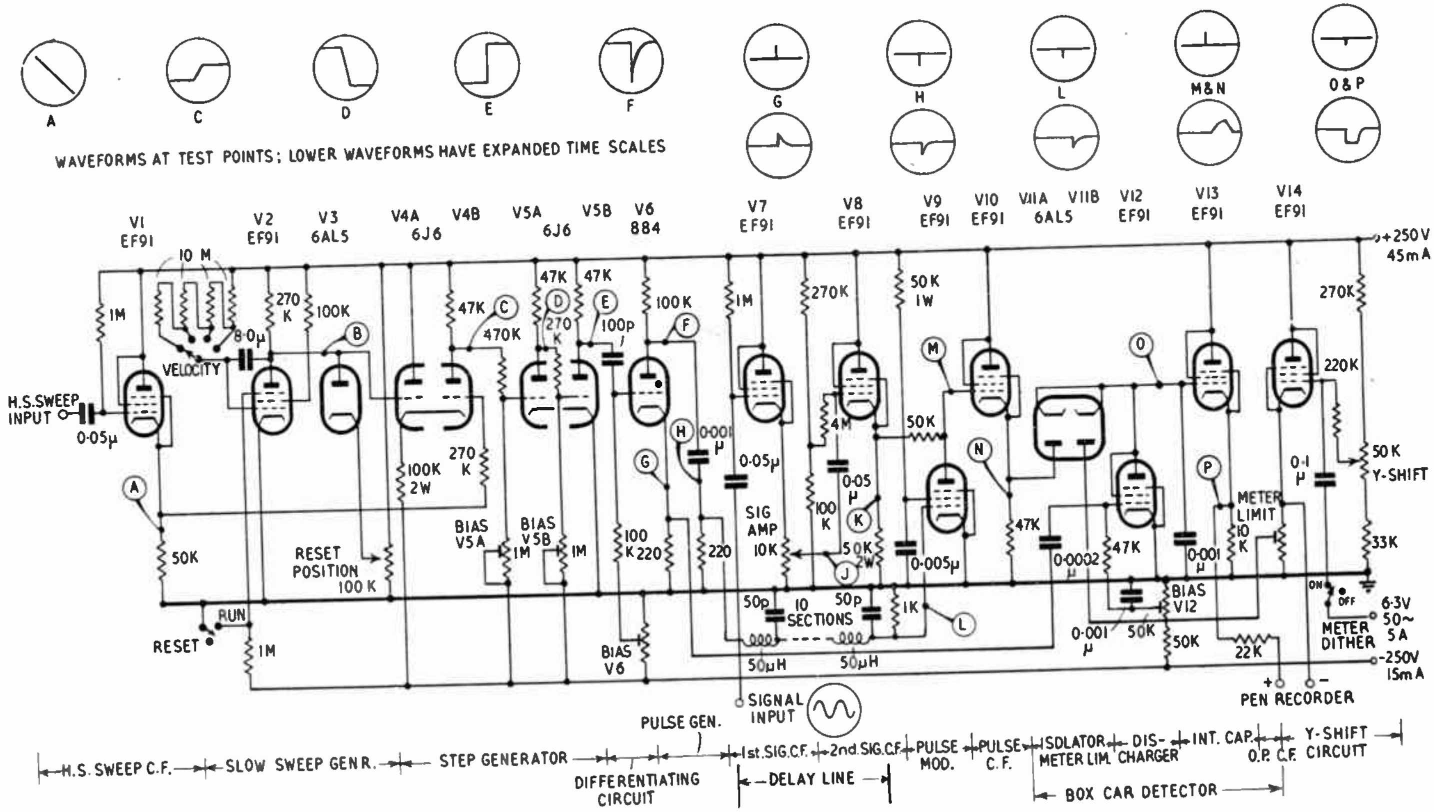

Fig. 2.—Circuit diagram of the recurrent waveform recorder.

6. Factors Governing Sample Width and Recording Time

Consider the behaviour of the recorder when set up to accept a waveform consisting of short pulses. The output from the "box car" detector circuit is always the most positive potential which occurs during that sampling time, hence it follows that narrow positive pulses will produce a corresponding rise in output level even though the duration is less than the sampling time. However, negative pulses of duration less than the sampling time will not cause a corresponding reduction in output level since during some of the sampling period the potential must be greater than the minimum for the pulse. As the sampling time is reduced relative to pulse width the pulse waveform will be more faithfully reproduced. Thus it would be advantageous to have a sampling time as short as possible. It is also obvious that if subsequent samples are widely spaced along the sweep, information will be omitted and the waveform thereby degenerated.

Hence as many samples as possible should be taken; in fact the fidelity will be improved if samples over-lap on the sweep with one or more previous samples. More generally, for a rapidly varying waveform, high fidelity will depend on the same considerations. So far as the pen recorder itself is concerned, additional degeneration may occur due to the inability of the pen to follow rapid changes, even after having been slowed down by the sampling process. To reduce this effect it is necessary to increase the recording time and to run the paper through at a suitable speed.

In the instrument described the figures adopted are: sampling time 0·5 μsec: maximum recording time 2 min.

Using these figures gives the following table:

Time-base Sweep Repetition Frequency	No. of Samples per Record for 2-minute run	Relative Time Delay between Successive Samples (μsec)
10 c/s	12×10^2	83·33
100 c/s	12×10^3	·83
1 kc/s	12×10^4	·008 3
10 kc/s	12×10^5	·000 083
100 kc/s	12×10^6	·000 000 83

From the above table it is clear that for a 10-c/s sweep there will be a gap along the trace between subsequent samples of about 83 μsec and hence it would appear that the signal would be badly degenerated. However, some 1,200 samples will be taken and waveforms normally viewed at such a sweep speed will be reasonably faithfully reproduced.

At 100 c/s the gap has been reduced to a fraction of a microsecond and at 1 Kc/s the gap has been reduced below zero (the samples overlap). Thus it will be seen that the instrument is capable of recording waveforms faithfully except those having excessively steep changes.

This information can be more readily expressed in terms of the highest frequency component present in the signal which is still apparently retained after the sampling process. Adopting the usual criterion that two samples per second are required for each cycle per second of signal bandwidth, then for the 10-c/s sweep the system cuts off at 6 kc/s, for the 100 c/s sweep at 600 kc/s etc., these figures being proportionately reduced for the lower slow sweep times.

Of course, this estimate is based on an assumed sampling pulse of zero time duration. With a pulse of 0·5 μsec it will be clear that this restriction places an upper frequency limit of the order of 2 Mc/s, which overrides the other considerations for the higher speed sweeps.

7. Practical Results

This instrument has been found to give very good and repeatable results in practice so long as certain precautions are taken not only in the design as mentioned but in the use of the instrument. Some of these are obvious but it may be useful to mention them here.

7.1. *The Oscilloscope*

This must have a linear and stable sweep and be set up to display about three repetitions of the waveform to be recorded. Care must be taken in doing this since if the time-base should "slip" during a recording the point of sampling will also slip and the record will be incorrect. However if this should occur, since the waveform can be observed on the oscilloscope and the progress of the recording also observed, it will be immediaely seen. This fault will be annoying but the oscilloscope can be quickly re-synchronized and a new record made.

7.2. *Amplitude and Y-shift and Reset Position*

Before an actual record is made it is wise to perform a "dummy run" to set the position of start of the run to a suitable point, to adjust the AMPLITUDE and Y-SHIFT controls to suitable values and to check the time base of the oscilloscope for stability over the whole run of the slow speed sweep.

7.3. *Relative Time Measurements*

When time relationships of several waveforms are to be taken it is best to synchronize the oscilloscope from a recurrent waveform which will remain constant in waveform and amplitude for all the subsequent records.

One waveform source is then connected to the oscilloscope Y plates and the input terminal of the recorder and the instruments carefully set up as before. Once set up and recording started, the RESET POSITION control must not be adjusted or time relationship will become valueless. After the dummy run the pen recorder is set to a fresh part of the paper and with the pen recorder motor stationary the RESET RUN switch set to RUN. This will give a vertical line on the paper representing an arbitrary time mark for $t=0$.

The paper of the recorder is then turned back by hand about 1 inch, the RESET/RUN switch set to RESET and the motor switched on. As the pen crosses the $t=0$ line the RESET/RUN switch is set to RUN and the record made as before.

The next record is made by connecting the instrument to the appropriate point, turning the paper back about an inch before the $t=0$ mark, and proceeding as before. This can be repeated adjusting the Y-SHIFT as required each time as often as required or until the records become too congested. Alternatively time relationships can be obtained by using a new part of the recording paper each time and inserting the $t=0$ line in each case.

It is of course essential that the VELOCITY switch position must not be changed during this type of recording.

7.4. *Recording Small Amplitude Signals*

When signals are applied directly to the input terminal their peak-to-peak voltage amplitudes may be between 10 V and 200 V. Signals smaller than 10 V peak-to-peak may be recorded by applying them to the oscilloscope amplifier and connecting the oscilloscope amplifier output to the recorder input. No provision has been made for signals greater than 200 V peak-to-peak but if records of such signals are required they must first be attenuated to a suitable value otherwise the cathode follower V7 will introduce distortion.

8. Some Practical Examples of Records (Fig. 3)

A set of three and another of six records were taken and in each case a photograph was taken of the waveform during recording: these are reproduced in Fig. 3. The oscilloscope used was Cossor type 1035 and the camera, Cossor type 1428.

8.1. *The First Set*

The sine wave (a) was generated at 1 kc/s with an amplitude of 115 V peak-to-peak. This was applied to two triode squaring stages producing the square wave (b). The third is the output of a "boot strap" ramp-function generator initiated by the square wave (c). Throughout these records the AMPLITUDE, RESET/RUN and VELOCITY controls of the recorder and the time-base controls of the oscilloscope were kept at the same setting. In addition, before each recording the paper was turned back by hand (the pen being lifted from the paper and the RESET/RUN control being at RESET). The pen recorder motor was set in motion and the RESET/RUN control set to RUN as the start line was crossed by the pen. The only adjustment made between recordings was the Y-SHIFT control of the recorder which was adjusted for convenience.

The completed record shows information of waveform, amplitude and time in each case together with phase relationships.

The photographs were taken to check the results and agreement will be seen except in the case of the square wave. The record (b) indicates an almost flat top and bottom whilst the photograph shows an apparent tendency to degeneration of the lower frequency content of the waveform within the oscilloscope.

In order to check this the waveform was applied directly to the Y plate, with the result shown in the next photograph (b′). Further checks were made using other oscilloscopes and all indicated that the top and bottom parts of the waveform were virtually horizontal.

No attempt was made to check the waveform on other oscilloscopes of the same type, so it may well be that this particular instrument had a fault. A quick examination of the manufacturer's circuit diagram did not reveal any likely

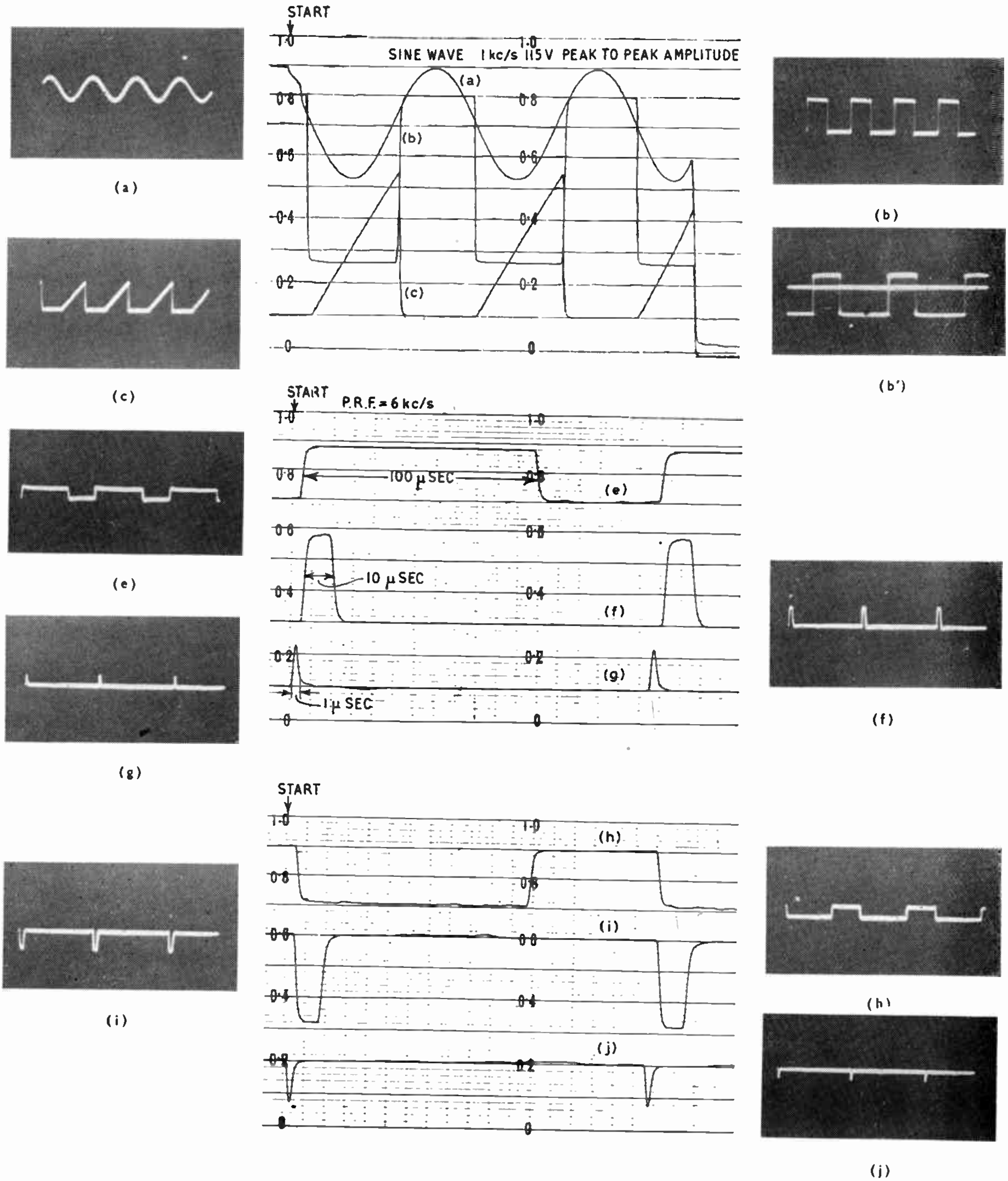

Fig. 3.—Records of waveforms taken on the Waveform Recorder together with comparative cathode-ray oscillograms.

cause such as a coupling circuit with too short a time constant.

Investigation of the oscilloscope was considered to be outside the scope of this work and so was discontinued.

8.2. *The Second Set*

These were the waveforms produced by a Dawe Pulse Generator and the procedure was as before. Again a flat top and bottom appear in the case of the square wave compared with a tendency to low-frequency distortion in the photograph (e) and (h), whilst in the case of the 1-μsec pulse far more detail is seen than in the photograph (g) and (j). This set also indicates that both positive and negative pulses are equally well recorded.

9. Use as Very Low Frequency Complex Waveform Generator

Although experiments have not yet been carried out it appears reasonable that the instrument could be readily adapted to assist in the generation of complex waveforms at a repetition frequency down to one cycle per minute.

The general procedure would be to generate the waveform at audio frequency and apply it and the high-speed sweep to the recorder as for recording. The output would then be applied to a d.c. amplifier and with the slow-speed sweep set to a suitable value the output would be a very low frequency version of the audio frequency waveform.

The final output would not be continuously repetitive as the low-speed sweep would have to be reset after each run. The maximum number of cycles per run would be determined by the number of cycles displayed on the oscilloscope. In addition, as the number of cycles displayed is increased so the final output p.r.f. will be increased.

10. Conclusions

The development described and subsequent tests have shown that such an instrument can be very useful in producing permanent records of waveforms. The basic principles are sound but great care has to be taken in the design and use of the equipment. The design problems have been dealt with but a few additional remarks from the user point of view may not be out of place.

In this connection it was found that any small changes in either the rate of run-down of the slow- or high-speed sweeps could produce error. In the case of the high-speed sweep this was largely dependent on the oscilloscope used, some being much less susceptible to mains supply voltage variations than others. In the case of the low-speed sweep, the linearity of subsequent sweeps was very much dependent on the stability of the power pack in use and stabilized mains were used for most of the work.

In the event of an improved instrument being designed the basic principles will remain but the following changes may be made:

(1) Other forms of slow sweep generation will be investigated including a mechanically driven potentiometer connected to the paper-drum shaft of the pen recorder, probably geared down and with a clutch mechanism.

(2) A highly stable power supply may be incorporated.

(3) An oscilloscope may be built in.

(4) An alternative to (3) may be to build in a high-speed sweep generator of high stability and linearity for connecting to any other oscilloscope.

(5) It is also felt that the present pen recorder is heavy and bulky and if anything can be done to build in a small light instrument it will be an advantage.

The next instrument is hoped to be in one self-contained mains-driven unit in a portable form.

11. Acknowledgments

I would like to express appreciation to my colleagues at the Royal Military College of Science, especially to Associate Professor A. Lee, M.A., for the facilities he made available, his encouragement and constructive criticism, and to Mr. A. J. Parker for assistance in the preliminary construction of the recorder. I am grateful to the War Department for permission to publish this paper.

# of current interest . . .

Inauguration of Trans-Atlantic Telephone Cable System

The world's first ocean telephone system was officially inaugurated on 25th September by a three-way conversation between Ottawa, London and New York. The cable, which cost £14M., was completed two months ahead of schedule, and was the outcome of twenty-five years of planning.

Telegraphic communication between Canada and the United Kingdom was made possible by the laying of the first trans-Atlantic cable in 1866. Voice communication between the two countries was established by radio in 1922. Development of built-in repeaters in the new cable now makes it possible to provide telephone service of great clarity and freedom from atmospheric interference at all times.

The cable carries 36 channels, of which all but one will be used for telephone purposes. The remaining channel will be split into 22 telegraph circuits each capable of working at 60 words per minute. These circuits are also available for private teleprinter connections, facsimile transmission, and broadcast relays. The new cable is not capable, however, of carrying television signals.

There are sixteen repeaters on the shallow-water and overland section, across Newfoundland and over the Cabot Strait to the United States. On the deep sea section, from Newfoundland to Scotland, where two cables are used, there are fifty-one repeaters in each direction.

Very Low Frequency Symposium

The United States National Bureau of Standards, in association with the Professional Group on Antennas and Propagation, of the Institute of Radio Engineers, is to hold a Symposium on Very Low Frequency Propagation at Boulder, Colorado, on 23rd to 25th January, 1957.

The low frequency range of the radio spectrum has been virtually ignored for many years, principally because the h.f. spectrum offered so much more transmission room. Now that the h.f. spectrum is being threatened with overcrowding, there is renewed interest in applications of the l.f. spectrum. For instance, in 1919 it was shown by experiment that l.f. communication could be made with a totally submerged submarine, whereas communication at high frequencies requires that the antenna be raised above the water.

Research with l.f. will eventually result in a more efficient utilization of the complete radio spectrum, with a standard reference frequency broadcast at l.f. serving as a master to keep stations more precisely to their assigned frequency. Experiments are being carried out with a low-frequency 60-kc/s standard signal which should be received with greater accuracy, since the propagation medium for l.f. is more stable than that for the high frequencies, which are propagated via the ionosphere. Another application is the use of l.f. standard signals to provide a stable source for accurate measurements in research laboratories. Civil aviation organizations have for some years employed l.f. navigation systems.

Research observations in the l.f. range have revealed new and interesting phenomena known as "whistlers." These are weak signals initially generated by a lightning discharge. The resulting radio wave is reflected in both directions over great distances, and can be detected after amplification of the order of 10^4 or 10^5 times. These "whistlers" penetrate the ionized layers, following the lines of force of the earth's magnetic field, and cross the hemisphere at heights of up to 25,000 miles. They may thus be used to give information on the state of the ionosphere at far greater distances from the earth than have hitherto been possible.

American Transistor Production

Some information on transistor production in the United States is given in a News Letter from the Department of Scientific and Industrial Research.

The cost of transistors remains about three times as high as that of valves, but is expected to decrease as their greater reliability and lower power consumption lead to an increase in their use. One firm, which claims to have made half of the seven million transistors now in use, expects to double its output annually, and other companies are to increase their production by an even greater proportion.

The best transistors made last year were capable of handling 25 Mc/s signals. A new type has now been developed, using the "grown-diffused junction," which is effective in amplification up to 250 Mc/s, and can generate radio frequencies up to 400 Mc/s, thus enabling transistors to be used in radar for the first time. These new high frequency transistors are costly: £12 for silicon and £7 for germanium, but the price is likely to drop. Germanium is used in all transistors except those which are to operate at high temperatures.

AN AIRBORNE COMPUTER-CONTROLLED DETECTOR FOR RADIOACTIVE ORES*

by

E. J. Frank (Graduate)†

SUMMARY

In the aerial survey of gamma-emitting radioactive materials, the use of two identical detectors, one trailed vertically below the other, allows automatic computation of the true slope of the signal-to-height curve. Thus immediate automatic correction for relative altitude variations is possible during flight. The computer incorporates a new multiplier system based on frequency pulse-width multiplication.

1. Introduction

It has been found that present methods[1-12] used in aerial survey not only involve tedious work of flight data interpretation on the ground, but also give rise to erratic conclusions for reasons inherent in these methods.

The main source of error lies in the necessity to correct the radioactivity curve for altitude variations. This is at present done by reading both the altitude and the radio-activity records on either side of apparently anomalous points and plotting a signal-to-height graph. The slope of this graph is then used to correct the measured activity values for altitude variations. In this way fairly strong and extensive sources are easily recognized, but weaker signals are lost by averaging or by not being recognized as anomalies *before* correction even starts. Also non-existent sources may seem to be found, expensive ground investigations subsequently revealing a fallacy. As the correction is made after returning to base, the existence of anomalies is usually verified by a second flight over the same area. Such a procedure evidently raises costs considerably.

The continuous operation of an aircraft and the employment of associated staff must be justified from the economic point of view, especially where the area to be surveyed is limited. On the basis of a survey of more than 300 flight hours, planned and attended by the author, using conventional methods, it was concluded that a more efficient and reliable method of survey was required.

According to the method proposed in the present work, data obtained should be more easily interpreted than in the conventional methods where accurate correction for altitude variations is very difficult or (for reasons mentioned in Sect. 2) not possible at all.

Not all of the theoretical aspects of gamma-ray detection will be discussed, but rather only those which have a direct bearing on the proposed method. Material not essential for the understanding of the principles and available in existing literature will not be treated. However since this work evolves directly from results obtained by conventional methods, these are discussed in detail and specimen results are given. Conventional methods are of interest, as many techniques developed for their use are adaptable to the proposed method as well.

2. Conventional Methods of Aerial Survey

When correction for altitude variations is carried out in order to evaluate real activities, a dependable result cannot always be expected since the slope obtained and used for correction is not necessarily valid for the portion of the graph under consideration. When flying over undulating terrain the plot of a path extending far enough before and after the apparently anomalous portion must be considered, in order to give results of any practical value. Moreover, experience shows that in general a source of

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† Department of Nuclear Physics, The Weizmann Institute of Science, Rehovoth, Israel.
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diameter, D, greater than 2,000 ft may be considered "infinite" (i.e. does not satisfy the inverse square law relationship) for the usual maximum height flown. Now, to pass over such a source (which, if present, is easily detectable), at 75 miles/hr, would take approximately 20 sec. In this time and at a convenient chart speed of 1½ in/min, a graph of not more than ½ in. length would be obtained. It is obvious that with relatively low counting rates, a path of this length is insufficient for the determination of a slope because of large statistical fluctuations (see Figs. 8-10). This is the most favourable case for an "infinite" source; thus clearly an area of scattered point sources,* possibly resulting in different individual slopes, cannot be taken as a reference for any altitude correction, because of the poor resolution obtained. It may be pointed out that there are quite valuable sources, e.g. veins of not more than 5 ft width, which in this way, when not strong enough, are lost in statistical fluctuations of the background.

Conventional methods have been used by the author with an efficiency of ~50 per cent.

3. Theory of the Proposed Method

The proposed method involves the use of an auxiliary detector below a computer mounted in the aircraft. All altitude variations are corrected automatically during the flight so that only true activities above the normal background are indicated. Advantages of this method are:

(1) accuracy, results being verifiable during flight over the suspected area;

(2) minimization of the ground staff needed for the interpretation of recorded data;

(3) avoidance of repeated return flights for the verification of records;

(4) an increased general efficiency of operation of at least 60 per cent. due to factors (1)–(3) and also due to the possibility of completing a full working-day during flight.

The method works according to the following principle (Fig. 1): the aircraft, flying at a certain optimum altitude, carries a detector "A" and a second detector "B" trails at h fee[t] vertically below the first. This arrangemen[t] which is feasible for aircraft of the "Catalina" flying-boat type (see Sect. 6), establishes tw[o] simultaneously obtained signals, from which [a] true correction slope is automatically computed. The formula giving the relationship by whic[h] the correction for altitude variations may b[e] effected is reduced to

$$A_{H0} = A_H + kH$$

where A_{H0} is the relative radioactivity of the ground below the aircraft, A_H the activity measured at height H, and k the slope.

$$k = \frac{A_{H-h} - A_H}{h}$$

where A_{H-h} is the activity measured by "B" and h is the vertical distance between "A" and "B." H is measured by a radar altimeter.

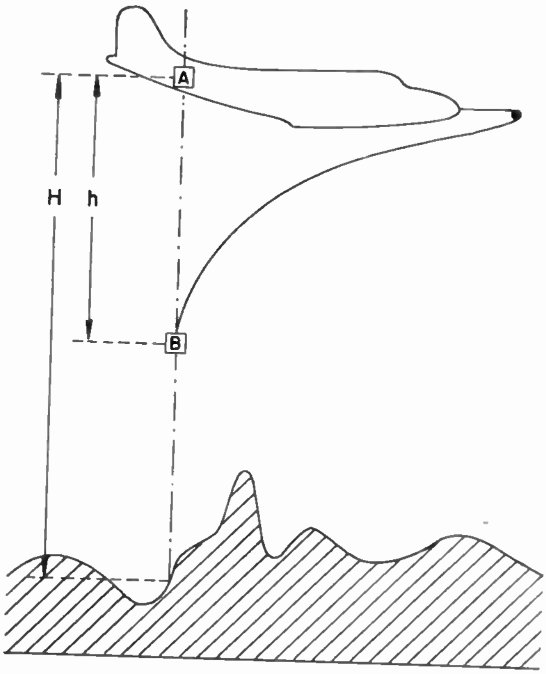

Fig. 1.—Double detector system.

With reference to Fig. 1, it is evident that the double detector system will establish a true slope at any time, as long as $t \gg \tau$, where τ is the time-constant of the integrating circuit and t is the period during which the detector remains

* A recognizable point source is here defined as one contributing a value not less than $\frac{1}{2}\sqrt{n}$, where n is the number of events recorded. It has been experimentally found that such a source will have an identifiable curve flattening effect (Fig. 8b).

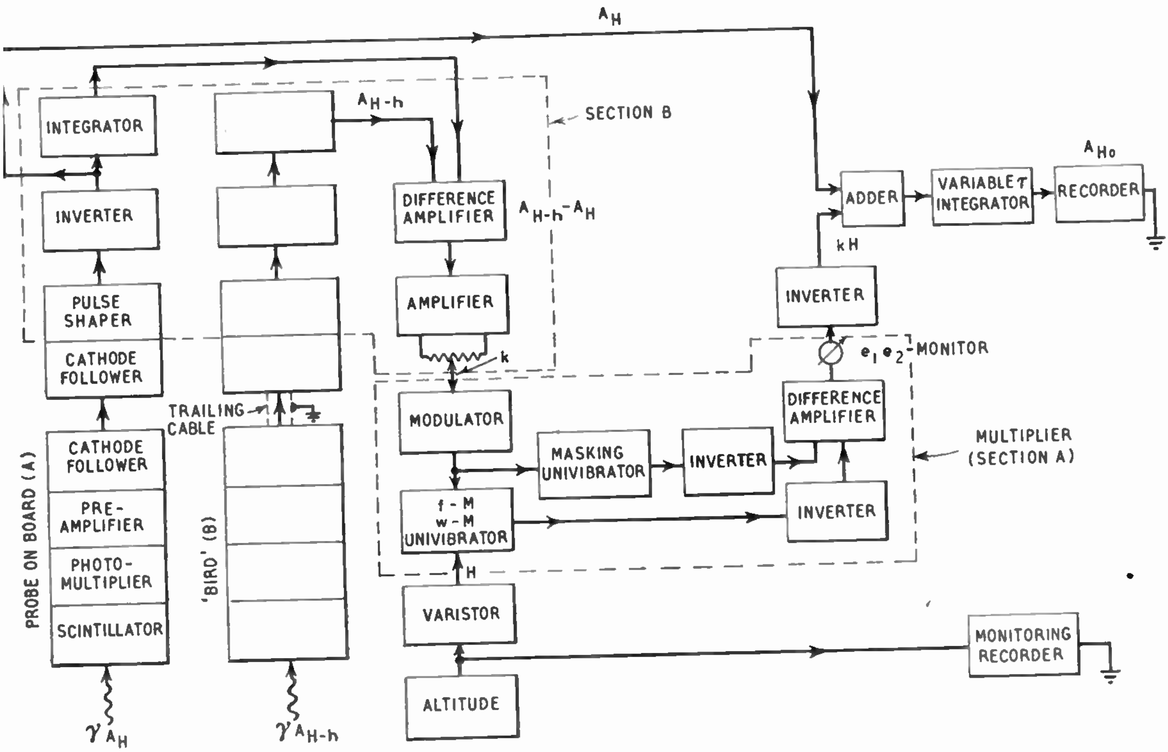

Fig. 2.—Simplified block diagram of the computer.

over the centre of a point-source. This, for a convenient value of τ of 0·8 sec, is not feasible for aircraft other than helicopters, which for reasons of expense of operation are not always practical. A_{H0} and the accuracy of the slope obtained thus depend on the minimum velocity of the aircraft, v_{min}. For a typical aircraft, $v_{min}=32$ m/sec, and hence approximately 25 m will be covered in $t=\tau=0{\cdot}8$ sec.

The smallest diameter of a homogeneously distributed source, for which a signal at a given height may still be expected to develop to its maximum value, is thus defined by v and τ (absorption in air being neglected). A signal will not develop to its maximum for sources of $D<v\tau$. It is evident that in order not to lose sources of small diameter, which may be of considerable interest, it is of vital importance to determine a correct slope at any instant without reference to even the close vicinity.

With a source of known nature and strength and a detector of known efficiency, the maximum signal may be calculated (see Appendix 1). In practice however this situation is not encountered, since neither the nature nor the strength of the source is known.

It is hoped that by using the new method quantitative interpretation of recorded data will also be possible. So far, results are qualitative only. Also it should be possible to define more clearly transitions between linear and non-linear effects, and thereby to differentiate with greater certainty between "infinite" and point sources, and to evaluate actual source shapes. By conventional methods, such transitions tend to be masked by statistical fluctuations of the background, unless suppressed by sufficiently high counting rates.

4. Description of the Computer

A simplified block diagram of the computer is shown in Fig. 2. As can be seen, the two detectors "A" and "B" are identical. In practice identity should be approached as closely as possible in order to obtain a correct slope. Each of the two units consists of a large sodium iodide (thallium-activated) crystal with a magnesia reflector coupled with silicone fluid to a 5-in photomultiplier with a mu-metal antimagnetic shield (to prevent defocusing by external magnetic fields). Pulses from the photomultiplier are fed into a preamplifier consisting of a cathode-follower, a linear amplifier-discriminator and a second cathode-follower. By these means, low source impedance is offered to the relatively long (low impedance) cables leading to a pulse shaper (univibrator) from which pulses of uniform amplitude are fed into integrating circuits (see Fig. 3).

The gain of the amplifiers is variable between 10 and 100. By grid bias, the following discriminator is adjusted to the base (lower energy level) of the thorium 232 photo-peak (Fig. 11), the source being in equilibrium. This setting must be verified by a high resolution pulse-height analyser before the computer is installed in the aircraft. The amplifier adjusted to this level will have maximum efficiency for the energy range of interest, but will ensure stable operation at a lower level still far enough from noise. Noise may interfere seriously when adjustment of the amplifier for maximur efficiency in the field is attempted by mean other than a calibrated standard source o known energy spectrum. In general, the gai of the external amplifier should be kept as lov as possible in order to minimize amplificatio of external noise. This is accomplished b operating the photomultiplier at potentials higl enough to ensure sufficient internal amplification of the pulses without impairing the signal to-noise ratio. For cylindrical NaI(Tl) crystals $1\frac{1}{2}$ in. × $1\frac{1}{2}$ in. and larger, no difficulties are encountered when adjustment to maximum efficiency is carried out as outlined above, since the photo-peak is clearly recognized and contributions from Compton scattering may be neglected. For crystals of smaller radius or length, however, the Compton peak is much more pronounced and consequently a discriminator setting much closer to noise level is necessary in order to achieve maximum efficiency for the same energy spectrum.

The computer block diagram shows the signal path as well as the mathematical operations performed in successive stages of computation.

Throughout the computer, equipment is standardized wherever possible by the use of commercially available double-triodes of the miniature type.

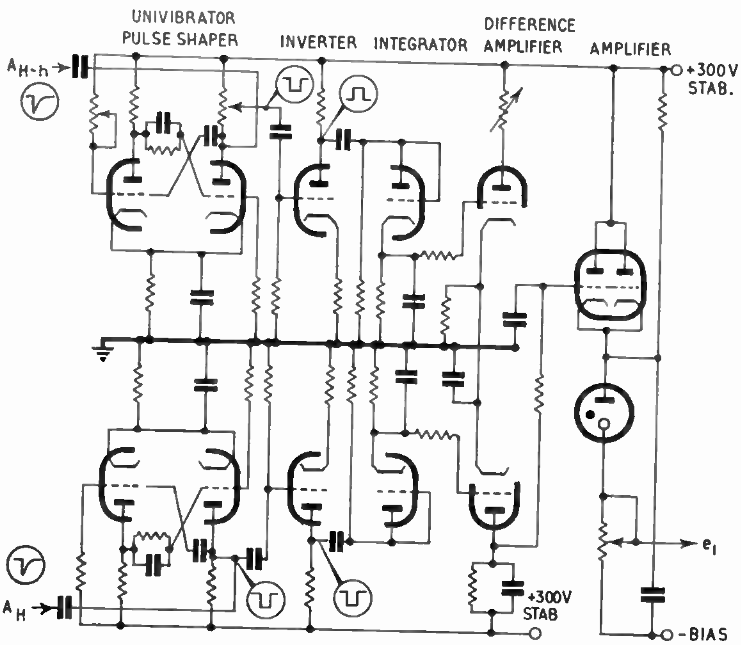

Fig. 3.—Schematic diagram of Section B. (See Fig. 2.)

4.1. *Multiplier unit* (Fig. 4)

In order to avoid the use of electronic multipliers based on linear–log conversion of information, the author has developed a linear multiplication method which is distinguished by excellent stability over long periods of time. The principle underlying the operation of the multiplier is frequency pulse-width multiplication.

Consider a square wave (Fig. 5) of constant amplitude. If

$$e_1 e_2 = \alpha I_0,$$

where α is the factor of proportionality and I_0 the d.c. value of the current,

and
$$f = F_1(e_1)$$
$$w = F_2(e_2)$$

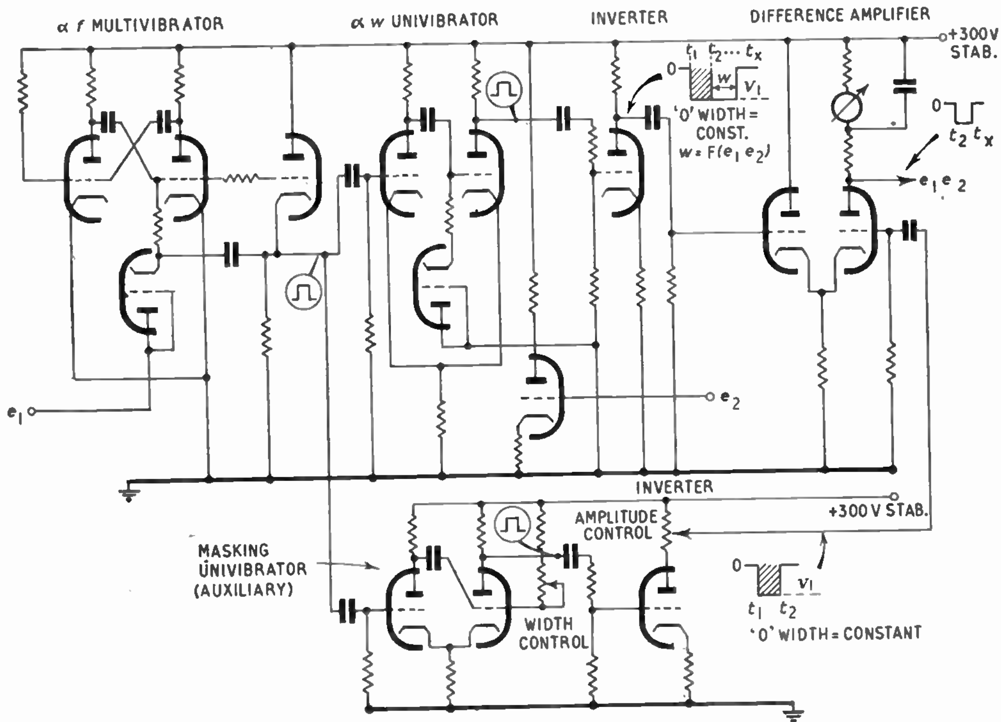

Fig. 4.—Schematic diagram of Section A. (See Fig. 2.)

where f and w are frequency and width respectively, then

$$I_0 = F_3(f, w).$$

(In the case of w=constant, the problem is reduced to simple frequency multiplication.)

Now f is supplied by a free-running multivibrator (Fig. 4), whose frequency of oscillation is controlled by e_1. The derived pulse triggers a one-shot multivibrator, from which a pulse of constant amplitude E_{st} but variable width, controlled by e_2 is obtained. In principle it is this pulse, i.e. the area under the curve, which furnishes I_0. Since, however, an ideal square wave does not exist, because of the finite rise

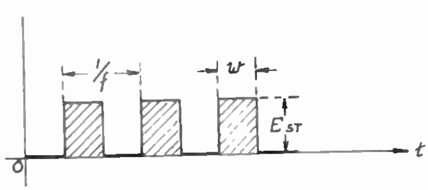

Fig. 5.—Ideal square wave.

and decay times, it follows that the pulse-width must necessarily be very much greater than these times in order that they may be neglected. On the one hand it follows that in order to provide a sufficient range for multiplication, f must now be as low as possible. For stable operation, $w_{max} < 1/f$, that is to say, the range of the function represented by f must be smaller than that represented by w.

With reference to Fig. 6, the ranges of values for k and H of practical application to airborne computation are:

$$0{\cdot}2 \ll k \ll 1 \text{ (counts/min ft}^{-1}\text{)}$$

and $$0 \ll H \ll 500 \text{ (ft)}$$

It is evident that f will represent the slope k, and w the height H.

Of course the free-running multivibrator must have some "zero-frequency" and the one-shot multivibrator some "zero-width." From the above considerations for k and H it may be shown that if

$$3 \ll f \ll 41 \text{ (pulses/sec)}$$

and $$500 \ll w \ll 25{,}000 \text{ (}\mu\text{sec)}$$

then all conditions are satisfied. Since an absolute zero *does* exist for H, the pulses from the oscillator are fed into an auxiliary one-shot multivibrator, the pulses delivered from which have exactly the "zero-width" (500 μsec). The pulses of both one-shot multivibrators are fed into a difference amplifier, the output of which is equal to αI_0. Thus the "zero-width" may be completely masked by the second one-shot multivibrator and w becomes variable from zero.

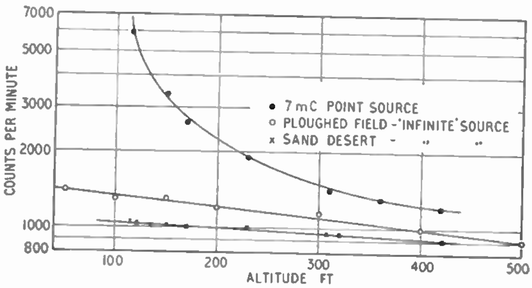

Fig. 6.—Typical slopes obtained by conventional methods.

It will be noticed that a strong point-source yielding $k>1$ will overdrive the system through overlapping and consequently the recorded result will not be in units of calibration. However, sources of such strength are not of interest from the view-point of the computer, being recognizable as anomalies in any case.

A 0–1 mA meter in the anode circuit of the difference amplifier serves as calibration monitor. Table 1 gives the setting and reading for a typical calibration.

4.2. *Computer set-up and calibration procedu*

The discriminator bias of the identic detectors "A" and "B" is set, as explained, t the base of the photopeak of Th232 (equilibrium). With the highest permissib voltage (for a good signal-to-noise ratio) on th photomultiplier, the gain is adjusted to ensu a stable bias setting at the lowest possib value. The bias of both detectors is adjuste so that they give rise to equal counting rates equal distances from the source. The use c equally spaced pulses, as obtained by puls generators, is not recommended for this pu pose. The counting rates, however, must b checked against a non-integrating device suc as a scaler and clock system for suitable period of time, in order to determine the exac resolving power of the unit and to ascertain tha coincidence losses are kept to a minimum.

The integrators following the probe assembl are then calibrated and the output voltages fe into the difference amplifier. With two Th23 sources, placed at different distances in front o the two detectors, slopes from 0·2 to 1·0 ar simulated. With $h = 100$ft, k should, within thi range of slopes, vary from 24 to 78 V (Table 1) The output voltage derived from the cathode follower in the radar altimeter (Fig. 7), i passed through a varistor network[13] an linearized for the useful range of 0–500 ft. Th residual voltage resulting from the idlin current of 1·5 mA in the cathode-follower ("0" of altitude indicator), is balanced out and the voltage change for the mentioned range should be from 0–14 V.

Table 1

Typical Calibration Chart

k →	e_1 →	f	×	H →	e_2 →	w	=	I_0
Counts/min ft^{-1}	Volts	Pulses/sec		Ft.	Volts	μsec		μA
0·2	24	3		0	0·0	0		0
1·0	78	41		0	0·0	0		0
0·2	24	3		10	0·28	500		4
1·0	78	41		10	0·28	500		20
0·2	24	3		500	14·0	25000		200
1·0	78	41		500	14·0	25000		1000

e_1 and e_2, derived from low impedance ›urces, are fed as outlined into the multiplier nd the output-meter reading of the difference mplifier checked to give $aI_0 = e_1 e_2$. The two ignals, A_H and kH, are fed into the final stage or addition and integration. The time constant n the integrating circuit is variable from 0·2 to ·8 sec and is calibrated to give a recorder ull-scale deflection for from 10,000 to 100,000 counts/min at 1 mA.

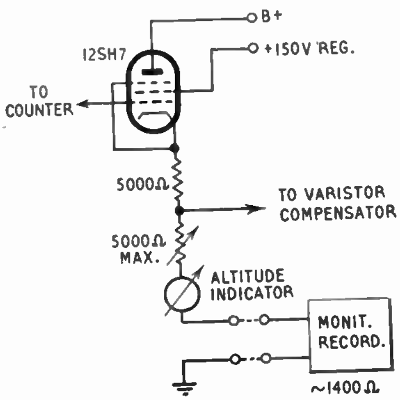

Fig. 7.—Modification of indicator amplifier of the radar altimeter.

The instrument, once calibrated by the aid of an oscilloscope with a Th232 source, may now be recalibrated in the field at any time with the same source and from the same distance without requiring further attention, provided that other critical voltages are held within permissible limits. Final calibration, however, should preferably be carried out in the same location, with "A" within the aircraft and "B" outside, in order to provide for characteristic background conditions. Should it become desirable to calibrate the scale in U_3O_8-equivalent-% (U-e-%) (see Sect. 8), instead of in counts/min, natural samples of uranium ore at equilibrium and in different concentrations may be used from a standard distance and the scale accordingly calibrated.

4.3. *Resolving Time of System*

Since the decay time of fluorescence in a NaI(Tl) crystal is about 2–3 × 10^{-7} sec (for liquid scintillators even less than that), the resolving time is not determined by the detecting element itself but by the pulse shapers following the probe assemblies. These univibrators have a maximum RC time-constant of 200 microsec. The dead time may be somewhat less and depends on the energy of the incident quanta.

5. Recorders

The strip-chart recorders are of the twin-unit, clockwork-driven type. The chart speed is variable and is operated most suitably at 1½ in./min. One recorder plots the final graph of the relative radio-activity on the ground, while the other (inserted in the cathode-follower as shown in Fig. 7) records the relative changes of altitude; the full-scale deflection of the recorder is 5 mA, but the meter is adjusted for a zero-reading of 1·5 mA. The second recorder is used as a visual check on the computer only. Both recorders have chronograph pens, and turning points during grid flights are marked by the operator. The marker system is also synchronized with a continuously-running camera viewing the ground. A push-button actuating the marker system is installed in the co-pilot's stick holder in the aircraft.

6. Trailing Detector ("Bird") (Fig. 1)

As expected, h will be dependent on the velocity of the aircraft and calculations have been made in order to determine the practical feasibility of the trailer arrangement, since a reasonable stability of h is required. Results were encouraging and calculations made for a "Catalina" Flying-boat gave the following results:

In order to trail a detector "B" at $h = 100$ ft vertically below another detector "A", the latter must be mounted in the far rear of the aircraft, while the former is lowered to the height $H-h$ by means of a winch, via a boom, extending 8 ft from the nose of the aircraft. The mutual position of the detectors will be correct if the average speed of the aircraft is 75 miles/hr, and the "bird" design conforms to the following specifications:

"Bird" body: Diameter 1 ft. (max.)
Weight 40 lb. (max.)
Length not critical

Trailing cable: Thickness ¾ in. (max.)

For $h = 100$ ft and a change in speed of 20 miles/hr, the deviation from the nominal h should not be more than 7 per cent. That is, such a change in speed should result in a 7 ft rise or fall of the "bird." The horizontal

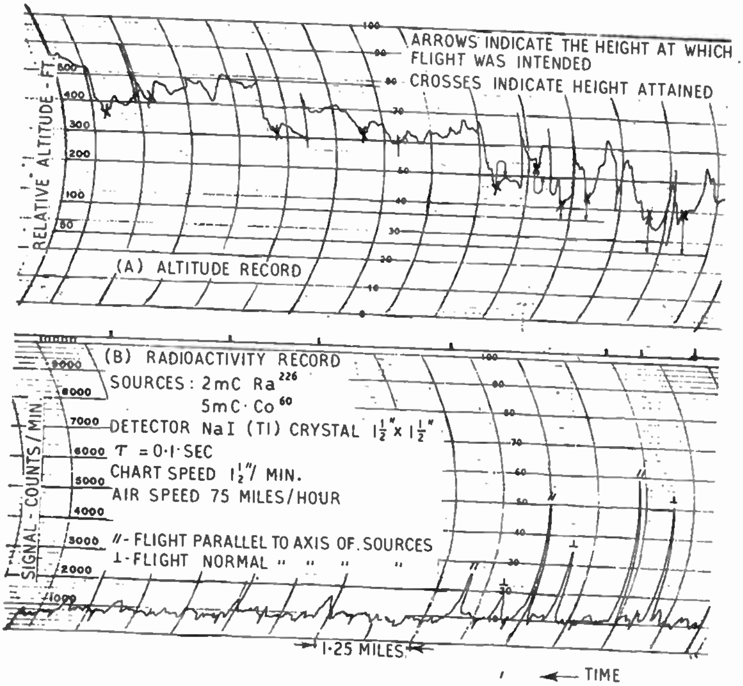

Fig. 8.—Sensitivity test chart.

resolution of the system was limited by an insufficient utilization of obtained information, rather than by a limitation through lack of sensitivity of the detecting element: since under the same conditions the source shape was distinguishable when observed in a direction normal to this axis, because of the proximity of the two sources, this was not expected. Thus a good solution at a given velocity is not only determined by the disintegration rate of the source, the effective area of the gamma-sensitive element and the optimum τ (which is, of course, dependent on the instantaneous disintegration rate), but will depend also on the damping factor of the recording instrument (i.e. equivalent parallel resistance), friction of the pen element on chart paper (varying with chart speed) and movement may be neglected. Thus any change in ground speed of the aircraft or in h lies, under normal flight and weather conditions, within allowable tolerance limits.

7. Overall Sensitivity Test

As a final sensitivity test, the aircraft is best flown at different altitudes over known sources of known strength, floating on an effectively infinite plane of water. Interfering background is thus minimized and nearly all possible source configurations may be simulated.

Using conventional methods with a 1½ in. × 1½ in. NaI(Tl) crystal* and $\tau = 0{\cdot}1$ sec, it may be seen from Fig. 8 that two sources, 5 mC of cobalt 60 and 2 mC of radium 226, placed ~15 ft. apart, were indistinguishable as two anomalies being detected as one integral amplitude when observed at 200, 100 and 50 ft in the direction of their axis. Here the object was to simulate a "point-source" of a non-homogeneously distributed nature and to observe the ability of the detector to distinguish a "shape." It was found that, in this case, the

* Type x6L6, The Harshaw Chemical Co., Cleveland 6, Ohio, U.S.A.

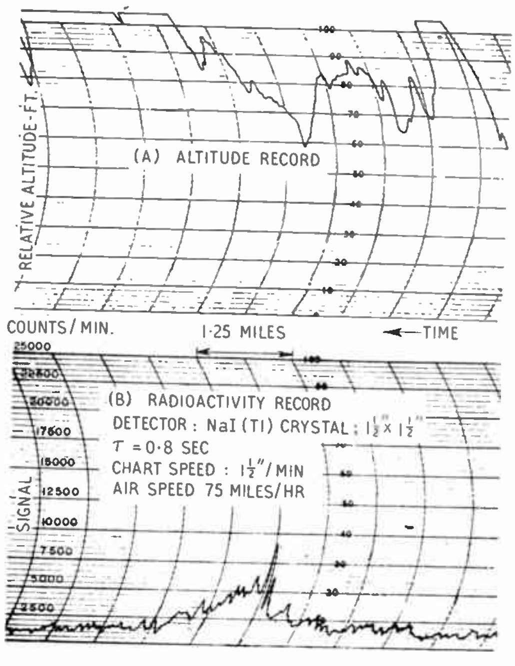

Fig. 9.—Typical "infinite" source of low activity.

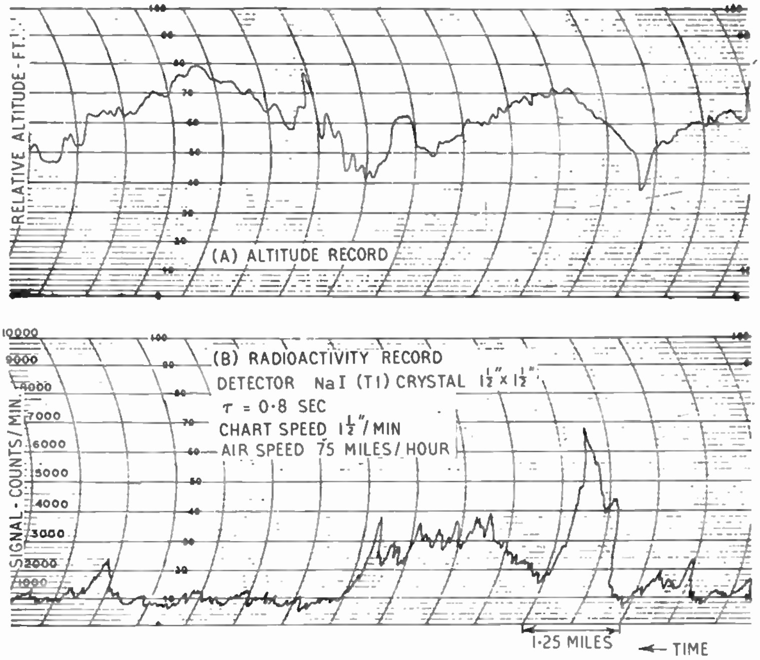

Fig. 10.—Record of typical source area of moderate activity.

the inertia of the element. The sharp amplitudes at lower altitudes are indicative of these restrictions, since the maximum of the observed signal was not recorded. In this case the two sources were placed on the plane surface of a runway, the vicinity of which was known to be an "infinite" source of normal background activity.

The change in signal, for the indicated change in altitude, also shows that for the given range of air and under normal humidity conditions, absorption of gamma-rays in the given energy spectrum is practically negligible.

Records of typical source areas are given in Figs. 9, 10.

7.1. *Unit of Measurement Determination*

The unit of measurement may be taken as the background over the sea or the background relative to a specific area which is to be surveyed. In the first case, where an inverse square law relationship is not observed, the background value is immediately obtained, no matter at what velocity recorded. In the second case, the procedure is as follows: At standard height, v is increased up to a certain optimum where, because of the finite response time of the recording equipment, the records no longer contain distinct peaks. On integration, these records give the overall background for a given area of typical geological structure. This may be used afterwards as a basis for assaying.

8. Selective Detection of Ores

Uranium 238 itself is a very poor gamma-emitter, and can be traced from the air only through its gamma-emitting decay products, the characteristic radiation of which serves as indicator. This limits the scope of actual analysis of uranium-bearing ore by sampling radiation data. The gamma-radiation as such generally is not indicative of the quantity of uranium present in any particular ore, since a proportional characteristic of the gamma-emitter only exists when the uranium is in equilibrium with its decay products. Therefore the exact uranium-content of the ore can be verified in the laboratory only. The lack of detectable gamma-radiation is in no way indicative of absence of uranium. This is true since uranium is more soluble than its daughter elements and may have been separated from them by natural physical changes, whereas the remaining elements may emit gamma-radiation not attributable to the presence of uranium.

A certain knowledge of the nature of U238 and Th232 decay schemes is most valuable for the efficient utilization of airborne detectors, since the gamma-emitters of these series are also the most abundant in nature. U235, occurring only in the ratio of approximately 1:140 to U238, may be neglected. Th232 however is much more abundant, standing in a ratio of about 1:2½ to U238 and must therefore also be taken into consideration. In Tables 2 and 3, the various gamma-emitters of the U238 and Th232 series are tabulated in the order of their formation. As can be seen from the tables, the gamma radiations of the Th232 decay scheme cover nearly the whole energy spectrum of the U238 decay scheme and therefore a simple discrimination between these two elements is not possible. However, since only when taken as a whole is the energy spectrum significant for a given element in equilibrium, it is possible to lower the efficiency of the detector for Th232 or alternatively for U238, by the following method:

With the aid of a pulse height analyser of as many channels as available (for good resolution and minimization of errors) a graph of count-rate as a function of discriminator setting is plotted for both U238 and Th232 series (in equilibrium). Since the pulse amplitudes derived from the photomultiplier are fairly proportional to the energy of the incident quanta, the abscissa may be calibrated in units of energy. This may be conveniently accomplished by using the mono-energetic line of Cs137 (0·66 MeV) and the two lines of Co60 (1·17 and 1·33 MeV).

Table 2
The Gamma-emitters of the U238 Series

Elements	Half-life		E (MeV)*
U238	$4{\cdot}51 \times 10^{9}$	years	0·05
Th234	24·1	days	0·093
Pa234	1·14	min	0·8
U234	$2{\cdot}69 \times 10^{5}$	years	0·05→0·12
Th230	$8{\cdot}22 \times 10^{4}$	years	0·068→0·23
Ra226	$1{\cdot}62 \times 10^{3}$	years	0·186
Pb214	26·8	min	0·053; 0·35; 0·24; 0·29
Bi214	19·7	min	0·61; 0·06→2·45
Po214	2×10^{-4}	sec	0·46
Pb210	22·2	years	0·047; 0·007→0·043
Po210	139	days	0·8

Table 3
The Gamma-emitters of the Th232 Series

Elements	Half-life		E (MeV)*
Th232	$1{\cdot}39 \times 10^{10}$	years	0·05
Ra228	6·7	years	0·03
Ac228	6·13	hours	0·058→0·97
Th228	1·9	years	0·084; 0·087
Ra224	3·64	days	0·24; 0·05
Pb212	10·6	hours	0·238; 0·3; 0·11→0·25
Bi212	60·5	min	0·04→2·2
Tl208	3·1	min	2·615; 0·58; 0·51; 0·23→0·86

* Where ranges are given, energies are closely spaced but discontinuous.

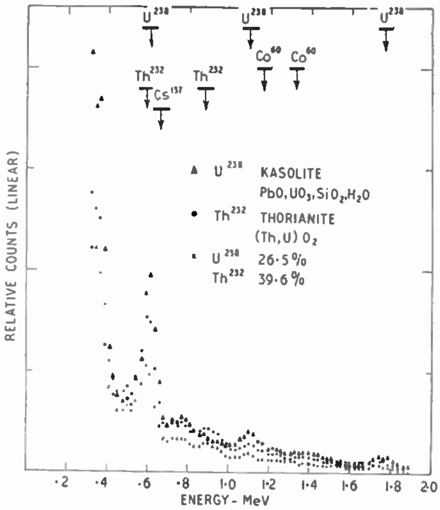

Fig. 11.—Energy spectra of uranium and thorium ores in equilibrium, from laboratory measurements.

The calibrated graphs of the two series (Fig. 11) are then compared with reference to the principal emitters of each series, and those energies which are not common to both spectra are selected. For detection of a particular peak of one or the other material, undesired energy-levels may be rejected by suitable "closed windows" (channelling). By comparing Fig. 11 with Tables 2 and 3, it is noted that U238 and Th232 are actually represented by other elements, namely, Pa234, Bi214 and Ac228, Bi212, Tl208 respectively, these being the gamma-emitters contributing most greatly.

Where the detection of all radioactive material is desired, all energies below about 0·45 MeV may readily be discriminated, in order to improve the signal-to-background ratio and to avoid the masking of small but valuable sources. After discrimination, pulses undergo integration and are injected into the computer.

It is important that the equilibrium state of the materials used be verified analytically. Erratic conclusions may be drawn from spectra obtained with purified material, some of the decay-products of which may have been removed in one way or the other. A typical example is given in Fig. 12, where Th232 in equilibrium is compared with metallic U238, apparently with far more favourable results than those obtained in Fig. 11. However, these may be misleading by suggesting that simple discrimination may be applied.

It should be noted that Ra226 sources, which are usually supplied with uranium survey instruments, for calibrating the *indicator* scale, may be used for this purpose only. Any attempt to use the spectra of these sources for a window setting (as outlined above) would not fulfil the purpose.

9. Acknowledgment

The work presented in this thesis was sponsored by, and is published by permission of the Israel Atomic Energy Commission. It was carried out at The Weizmann Institute of Science, Department of Nuclear Physics, under the supervision of Dr. I. Dostrovsky.

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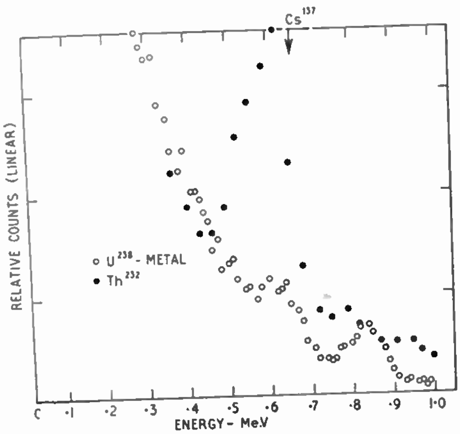

Fig. 12.—Comparison of spectra from ore, purified and in equilibrium.

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11. Appendix 1: Computation of Activity from Count Rate for a Circular Detector of Flat Exposed Surface, in vacuo

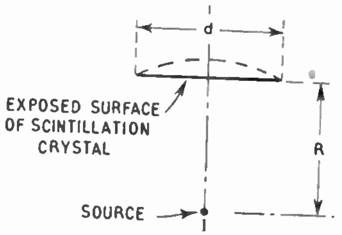

Fig. 13.—Detector point-source geometry.

Considering Fig. 13, if we neglect the difference between the spherical area (broken line) and the plane area (full line), the fraction of radiation impinging on the exposed surface is

$$\frac{\pi d^2/4}{4\pi R^2} = \frac{1}{16}\left(\frac{d}{R}\right)^2$$

The activity, A (in microcuries) may be expressed as $3{\cdot}7 \times 10^4 A$ disintegrations per second or $2{\cdot}22 \times 10^6 A$ disintegrations per minute. The number of emitted particles or quanta, the counting of which is desired, is not necessarily equal to the total number of disintegrations. Let their ratio, the efficiency of the emitter, be k; then we have $2{\cdot}22 \times 10^6 k\, A$ particles or quanta of the desired type emitted per minute by the source and the number of impacts on the exposed surface is therefore

$$2{\cdot}22 \times 10^6 k\, A \frac{1}{16}\left(\frac{d}{R}\right)^2 \quad \text{per minute,}$$

and the number of counts per minute

$$n = 1{\cdot}39 \times 10^5 \left(\frac{d}{R}\right)^2 k\, A\, \eta \text{ counts/min}$$

where η is the efficiency of the counter, defined as

$$\frac{\text{number of counts}}{\text{number of impacts on crystal surface}},$$

or

$$A = 7{\cdot}2 \times 10^{-6}\left(\frac{R}{d}\right)^2 \text{ microcurie } (\textit{in vacuo})$$

The absorption factor has not been included in this calculation since it depends on factors such as: (1) energy of particle or quantum; (2) medium to be penetrated and its thickness; and (3) temperature and pressure of the medium.

As shown in the theory another important factor enters the above formula, namely, the efficiency of the recording instrument when the detector ceases to be stationary with respect to the source. This factor further reduces the attainable counting rate (see Sect. 3).

12. Appendix 2: Technical Information and Notes

12.1. *Cosmic and other Background Radiation*

At those altitudes, for which the computer is designed (0–500 ft), the variation in cosmic radiations has been found to be negligible. Measured at sea level and far off-shore, where radiation from water or from radon in the air is nearly nil , the contribution from cosmic radiation was essentially constant and averaging 1000 counts/min for a $1\frac{1}{2}$ in. × $1\frac{1}{2}$ in. NaI (Tl) crystal. Daily checks were made to verify this reading.

Detector "A", which is situated within the aircraft, must not be shielded against any radiation (after removal of all radioactive material from the aircraft), since the trailed detector "B" can of course not be loaded with lead. Shielding one detector only, without appropriate compensation in the computer, would result in an incorrect slope being obtained from the system.

Radioactivity due to impurities in the aircraft building materials as well as in the equipment itself or originating in the end-window of the photomultiplier, is constant and may for all practical purposes be neglected.

12.2. *Interference*

Should unusual peaks be recorded, the vicinity should be checked first for strong radiation fields (e.g. transmitting stations) and especially for directed beams. The effect of these beams on the recorder meter coils may be most irritating.

12.3. *Compass (magnetic)*

Since correct grid flying depends primarily on the accuracy of the compasses (gyro and magnetic), appropriate attention must be paid to these instruments. After any major repair carried out on the aircraft or after addition or removal of instruments, the magnetic compass must be swung and if necessary corrected.

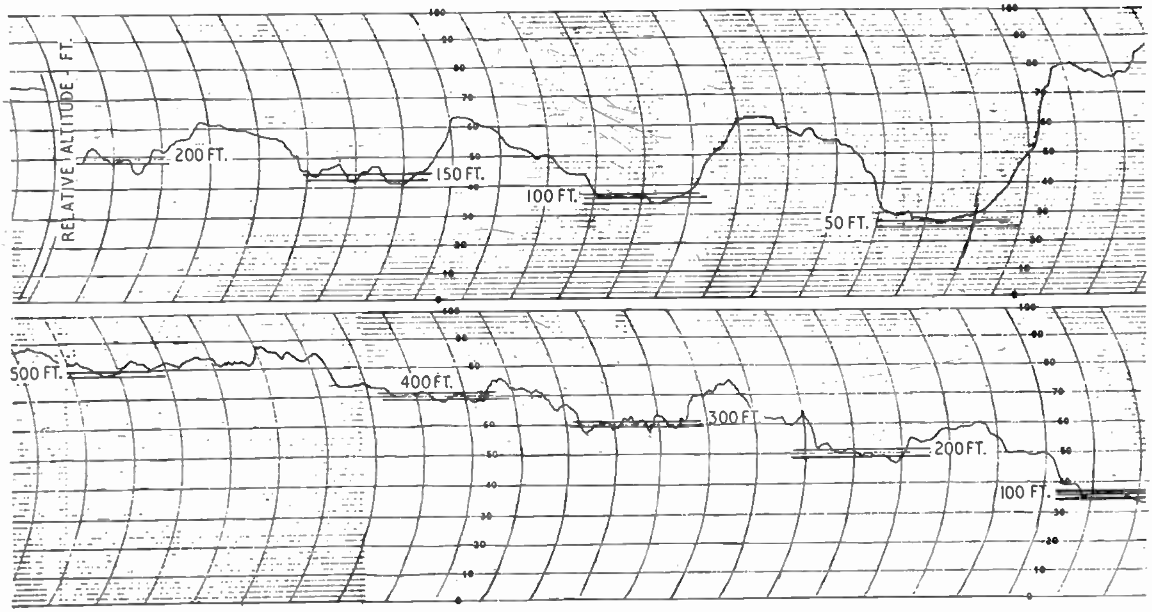

Fig. 14.—Altimeter calibration chart.

Failure to do this may result in an inability of the pilot to fly in parallel lines, since a true course is always obtained by comparison of the gyro and magnetic compass readings.

12.4. *Camera*

The camera which is synchronized with the marker system, is operated only on traverse lines and stopped at turning points. The mounting of the unit should be of the gyro type, so that viewing the ground vertically below the aircraft is possible at all times.

12.5. *Radar altimeter*

The scale in use with the altimeter is 0–800 ft. A daily routine check, before departure, should be made by flying at different altitudes over the flat surface of the runway and verifying the relative altitude indication (Fig. 14) against that obtained with the aneroid barometer (which must of course be previously normalized to the airport). Fig. 7 shows the necessary changes to be made within the radar altimeter.

12.6. *Safety Precautions*

An automatic cable cutter and an electronic cut-out device should be provided for the "bird-system," in case detector "B" should hit an obstacle.

12.7. *Weather conditions*

During periods of rain or dew, aerial survey is generally not recommended, since gamma-absorption becomes very much greater (absorption by water being about 830 times greater than by air). For the same reason, survey in the desert during sandstorms should also be avoided.

. . . Radio Engineering Overseas

A selection of abstracts from European and Commonwealth journals received in the Library of the Institution. All papers are in the language of the country of origin of the journal unless otherwise stated. The Institution regrets that translations cannot be supplied.

534.851:681.842.081.3

Mechanical phenomena in gramophone pick-ups at high audio frequencies. J. B. S. M. KERSTENS. *Philips Technical Review*, **18**, pp. 89-97, September 1956.

The stylus (sapphire, diamond), whose spherical tip rides in the groove of the record, causes elastic deformation of the groove walls. The convex wall is deformed to a greater depth than the concave wall. This causes a loss in the stylus deflection, the static tracing loss. This loss is greater the smaller the radius of curvature of the groove. At a given frequency—the cut-off frequency—this loss is equal to the recorded signal, so that the stylus tip does not vibrate at all; this loss becomes apparent even considerably below the cut-off frequency. The dynamic tracing loss is caused by the stiffness force of the pick-up exceeding the inertia force on the stylus tip; this is the case at frequencies below the free resonance frequency of the pick-up system. At higher frequencies this loss becomes negative and thus acts in opposition to the static loss. The total loss (the sum of the static and the dynamic losses) may even become negative particularly in the neighbourhood of the frequency at which resonance of the groove-wall stiffness and the effective mass at the stylus tip occurs; the resonance curve of this system is called the dynamic pick-up characteristic. A combination of the latter with the static characteristic produces the actual pick-up characteristic. According to whether the cut-off frequency lies higher or lower than the stylus-groove resonance frequency, the actual characteristic will either show a slight peak or no peak at all.

551.510.535

On the determination of electron density distribution in the ionospheric regions from h'-f records. A. K. SAHA. *Indian Journal of Physics*, **30**, pp. 464-479, September 1956.

Comparative studies have been made of the various available methods for the determination of the height distribution of electrons in the ionospheric layers. It is concluded that, for routine ionospheric work, Ratcliffe's method is the quickest and that, under restricted conditions, some of the other methods yield more accurate results. Methods which take into account the effect of earth's magnetic field have also been studied. It is, however, found that the errors due to the neglect of the magnetic field are of the same order as the limits of observational errors in height measurement. The complications involved in including the magnetic field are, therefore, not warranted. This is particularly because the inclusion of the magnetic field affects only the thickness of the layer and not its height of maximum ionization, and the MUF is mainly controlled by the latter.

621-52

Automating the engineer's task. J. KATES, *Engineering Journal of Canada*, **39**, pp. 1014-1019, August 1956.

Automation is applicable particularly to the processes of engineering analysis, and the digital electronic computer is one of the most important tools for automatically carrying out engineering tasks.

621.314.7:621.375.4

On the stabilization of the d.c. operating points of transistors. W. GUGGENBÜHL and B. SCHNEIDER. *Archiv der Elektrischen Übertragung*, **10**, pp. 361-375, September 1956.

In the first part of this paper the temperature dependence and fabrication spread of transistor d.c. parameters are dealt with. Starting from Shockley's d.c. equations for junction transistors, it is useful to choose the collector saturation current, the d.c. current amplification factor and the voltage between emitter and base as parameters for describing the transistor d.c. performance. The temperature dependence of these parameters is discussed from experimental results for germanium and silicon transistors. The fabrication spread for 50 samples of a hearing-aid transistor is presented. In the second part of the paper the design of circuits for the stabilization of d.c. operating points with ohmic resistances is discussed. Formulae are developed for the calculation of the circuit elements for a specified spread of the d.c. operating point. Some simple circuits are discussed in detail. The experimental results for some tested circuits agree with the design formulae. The final part deals with some aspects of the a.c. performance of stabilizing circuits and with the stabilization methods using temperature sensitive elements.

621.37/8:025.4

A new technique for classification and selection of documents. J. SAMAIN. *Onde Electrique*, **36**, pp. 671-675. July, 1956.

A new method of organizing documentation is described which facilitates finding, grouping and reclassifying documents for whatever the subject and point of view. The principle employed is to record each document on a photographic file together with the different characteristics and ideas which it embraces. These microfilms can be sorted at any time, by an electronic selector according to the problem presented. The term "document" is here taken in its most general sense.

621.37/8:621.43

Electronic programme control arrangement for test benches. F. D. DAYONNET, and J. ILLIEN. *Onde Electrique*, **36**, pp. 634-649, July 1956.

The first part of the paper describes an electronic arrangement which constrains a heat engine on a test bed to follow a pre-determined and variable programme of tests. The programme, depicted as a family of curves representing the variations, as a function of time, to be followed by the various parameters, is interpreted by a multiple curve reader. The second part describes a method of recording the various magnitudes on actual service automobiles. Results and applications are then given.

621.37/8:621.43

Electronic apparatus for tests and research investigations on hydro-carbons. F. KERMARREC, L. SOUKIANNIAN, J. WEISSMANN. *Onde Electrique*, **36**, pp. 650-660, July 1956.

The article describes electronic methods for classification studies of hydro-carbons on the test bench and on the road. The apparatus gives the relative intensity of pre-ignition on single cylinder engines on the test bench and indicates the speed of the engine and the advance of the ignition giving a constant degree of pre-ignition during acceleration of a vehicle on the road.

621.37/8:621.43

The use of electronic apparatus for the study of rapidly varying pressures. L. SOUKIASSIAN, *Onde Electrique*, **36**, pp. 661-670, July 1956.

This article describes a cathode ray strobe monograph developed by the Institut Français du Petrole. The apparatus is intended to reproduce indicator diagrams of internal combustion reciprocating engines. Without much modification it can be used to record all periodic phenomena. The basic element for reproducing pressure diagrams is a pick-up with a balanced diaphragm. The making and breaking of contact between the diaphragm and the associated electrode, under the influence of pressure, produce two luminous spots on the screen of a cathode ray tube. The horizontal sweep of the cathode ray tube is synchronous with the engine. Visual deflection of the spot, proportional to the balancing pressure, is produced by an electro-pneumatic circuit. The pressure-volume diaphragm can be derived by taking account of the ratio of the lengths of the crank and the connecting rod of the engine under test.

621.375.4

Neutralization of the selective transistor amplifier. G. MEYER-BROTZ. *Archiv der Elektrischen Übertragung*, **10**, pp. 391-397, September 1956.

Because of strong reaction the selective transistor amplifier requires neutralization. A number of possible neutralizing circuits exist and are applicable both for the transistor and generally. The neutralizing network can be realized with complex impedances which, in the case of the transistor, can be easily composed from frequency-dependent circuit elements over a wide frequency range. These circuits are reviewed for simplicity and dependence on frequency and operating point.

621.376.2:621.396.029.64:621.318.134

Absorption modulation of centimetre waves by means of ferroxcube. H. G. BELJERS. *Philips Technical Review*, **18**, pp. 82-86, September 1956.

An external biasing field at a given carrier frequency is allowed to vary in intensity, causing variations in losses which may be used for absorption modulation, allowing modulation up to frequencies of 1·3 Mc/s. The carrier frequency for this modulation can in principle be chosen between 2,000-12,000 Mc/s provided a type of ferroxcube is used which has a suitable saturation magnetization value. The nature of the losses is discussed; they arise through resonance phenomena under the influence of crystal anistropy fields and internal magnetic fields that can assume different values by de-magnetization. The experimentally found maximum frequency at which losses occur can also be explained theoretically.

621.385.029.6:621.396.43

Microwave tubes in a relay system. W. KLEEN. *Archiv der Elektrischen Übertragung*, **10**, pp. 415-420, October 1956.

This system uses frequency modulation in a band between 3,800 and 4,200 Mc/s and either 600 telephone channels or one television channel are transmitted. The frequency-modulation is achieved by a reflex klystron characterized by very high modulation sensitivity and low distortion. A travelling-wave tube with 9 watts saturation power is used as transmitting tube. The focusing permanent magnet has a special geometric form by which magnetic stray fields are strongly reduced. An isolator is introduced between the output of the travelling-wave tube and the antenna cable. The isolator consists of a helix embedded in a ferrite cylinder and, using the effect of gyromagnetic resonance, a forward attenuation smaller than 1 db is obtained with a backward attenuation higher than 20 db.

621.385.16

Plasma-wavelength and the low noise travelling-wave tube. J. LABUS and R. LIEBSCHER. *Archiv der Elektrischen Übertragung*, **10**, pp. 421-423, October 1956.

The calculation of the plasma-wavelength of the electron beam is usually based on the assumption that the electrons do not rotate around the axis of the beam. Even in the case where the cathode is not shielded against the magnetic focusing field, that condition can be realized with an infinite magnetic field only, if the space charge is finite. The reduction factor of the plasma-wavelength is a function of the ratio of magnetic flux along the beam; the theory is then applied to the design of the drift region of a low noise travelling-wave tube.

621.385.832.032.269.1:621.397.62

A pentode gun for television picture tubes. J. C. FRANCKEN, J. DE GIER and W. F. NIENHUIS. *Philips Technical Review*, **18**, pp. 73-81, September 1956.

The electron beam in picture tubes is required to be as narrow as possible, because deflection defocusing increases with the diameter of the beam in the deflection coils. The product of beam angle and spot size becomes smaller with increasing screen potential and current density at the cathode. If spherical aberration and space charge phenomena are taken into account, the values obtained in practice are in fairly good agreement with the theory. The pre-focusing lens should be positioned as near as practicable to the cathode. Examination of various possible forms of pre-focusing lenses has led to the development of a pentode gun. Varying the voltage on the third electrode changes the width of the beam and the size of the spot on the screen, thus enabling the optimum size of spot to be chosen to suit the line system in use. It also allows a very narrow beam to be employed with a fairly coarse line system, which means that the deflection coils can be simplified without causing excessive deflection de-focusing. Finally, the pentode gun makes it possible in principle to apply partial correction of deflection and modulation de-focusing.

621.396.67

Circular arc antennas. S. BALARAM RAO. *Indian Journal of Physics*, **30**, pp. 390-406, August 1956.

This paper deals with the general problem of a radiating element bent in the form of an arc of a circle assuming a sinusoidal current-distribution along the length of the arc. The far field in the plane of an isolated circular arc current-filament is derived. This leads to the derivation of the radiation fields of two types of symmetrical composite arc antennas in the horizontal plane. The vertical radiation patterns of the composite types of arc antennas are also derived. In the experimental section of the paper, the horizontal patterns of the composite types of antennas are verified for cases where the radius of the arc is small compared to the wavelength.

621.396.932.1

An analysis of the effects of rotary fields on visual direction finding. H. GABLER, G. GRESKY and M. WACHTLER. *Archiv der Elektrischen Übertragung*, **10**, pp. 383-391, September 1956.

A brief review of the properties of the various reflecting objects on ships is followed by an analytical investigation of the influence of elements, primarily producing rotary fields, on the indications of a visual direction finder. The results are widely analogous to the known influences of various reflecting objects on the bearing errors (theory of radio-beam deviation) and are confirmed by experimental investigations on board.

681.14

Principles of operation and production of a parallel binary adding machine. M. BATAILLE, *Onde Electrique*, **36**, pp. 742-749, August-September 1956.

A parallel binary adding machine is described with simultaneous carry-forward; the operation is asynchronous and aperiodic: the operations are initiated for all timings from manual step-by-step to the maximum operating speed. The first part gives the operating principles and the logical development of the circuits; the second part deals with standard apparatus developed for the production of this equipment, with the desire to ensure interchangeability and reliability. The "flip flops" work at 250 kc/s, and the duration of addition is 10 microsec.

681.14

A new h.f. computing method. H. J. UFFLER. *Onde Electrique*, **36**, pp. 770-779, August-September 1956.

This new computing method, based on the application of h.f. circuits, is used for the solving of algebraic problems. The major advantages claimed for the system are simplicity, flexibility, stability and accuracy. The characteristics of the h.f. computer place it in a class of its own, somewhere between the analogue and the arithmetical computers of more conventional type.

681.14

An automatic method of solving mathematical problems using an electronic arithmetical computer. L. GAUDFERNAU. *Onde Electrique*, **36**, pp. 732-741, August-September 1956.

A simple application of the classical numerical methods to electronic machines is insufficient to assure the rational operation of a computer. A functional basic plan can be used on an electronic machine, enabling it to act as a servo system, the information remaining exclusively numerical. The method does not pre-suppose a knowledge of the analytical solution. Several examples are given of applications where the performance is satisfactory even on a small machine. A comparison is made between a machine used in this manner and an analogue computer. Similar methods can be conveniently used for the solution of very complex mathematical problems.

681,14

Philosophy of automatic computers. L. BOUTHILLON. *Onde Electrique*, **36**, pp. 693-708, August-September 1956.

After a preliminary review of the definitions and main features of analogue and digital computers, the author deals with the new problems which their application sets for the science of mathematics, and explains how such computers help mathematics. The part played by computers in the development of industrial automation is then considered. Various philosophical, economic and social aspects on these new techniques are examined, also their relation to scientific research. Applications outside the field of mathematics are mentioned: "player" automats, self-reproducing machines, "brainy" machines capable of fulfilling certain functions and imitating the behaviour of animals, machines that are capable of being "trained", automatic translators, "reasoning" machines. Finally the problem is considered of artificial brains and of "thinking" machines. It is concluded that our large computers and automats do not offer anything that is fundamentally new in the problem of matter and mind relationship.

Extended summaries of the following papers from *Archiwum Elektrotechniki, Warsaw*, **5**, No. 2, 1956, are available in English:

The analysis of the super-regenerative circuit with quenching causing frequency modulation. F. WISNIEWSKI. (pp. 263-89).

On methods of microwave optics. K. BOCHENEK and J. PLEBANSKI. (pp. 293-321).

Reduction of side lobes in directional antennas. S. MANCZARSKI. (pp. 326-337).

Doppler effect in ionospheric propagation. S. BOROWSKI, S. JASINSKI, and S. MANCZARSZI. (pp. 343-351).

Prediction of solar activity. K. URBANIK and A. ZIEBA. (pp. 355-363).

Figure of merit for band-pass filters with a Tchebycheff characteristic. J. LENKOWSKI. (pp. 365-373).

Criterion for root square distortion at limited noise power. R. KULIKOWSKI and A. RYBARSKI. (pp. 379-399).

On the concept of entropy. J. SEIDLER. (pp. 401-423).