BBC

ENGINEERING DIVISION

MONOGRAPH

NUMBER 18: **MAY 1958**

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by

W. N. SPROSON, M.A.
(Research Department, BBC Engineering Division)

S. N. WATSON, A.M.I.E.E.
(Designs Department, BBC Engineering Division)

M. CAMPBELL, B.Sc.(Econ.)
(Engineering Information Department, BBC Engineering Division)

BRITISH BROADCASTING CORPORATION

PRICE FIVE SHILLINGS

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It will be appreciated that these tests involved a high degree of co-operation between a large team of engineers in the specialist and operational departments of the BBC's Engineering Division.

BRITISH BROADCASTING CORPORATION

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SUMMARY

The monograph outlines the technical considerations involved in an adaptation of the American N.T.S.C. colour television system to the 405-line standard used in the United Kingdom.

Having provisionally decided on an adapted set of standards, the BBC, with the co-operation of some British manufacturers, developed equipment for generating a composite colour picture signal conforming to these standards, and a number of colour picture display devices.

An extensive series of field trials was carried out, in which colour performance, compatibility, and reverse compatibility were all assessed, and the trials included viewing tests under both laboratory and domestic conditions.

The statistical analysis of the results of these trials is given, and it is concluded that the system as tested is technically capable of providing a satisfactory compatible colour television service in the band 41–68 Mc/s. The shortcomings which were most noticeable are not inherent in the system and should be materially reduced as certain items of equipment are improved.

1. Introduction

1.1 *Historical Summary*

The BBC has been carrying out research and development on colour television since the resumption of the television service after the war. In the early post-war years an experimental sequential system with mechanical colour separation was developed, and a considerable amount of research was carried out on the fundamentals of trichromatic colorimetry as applied to television.(1) (2)

By 1953, the consensus of opinion was that no public colour television service could be contemplated unless it were compatible, i.e. the transmissions were of a form which would enable existing monochrome receivers to produce black-and-white pictures without any modification. It seemed unlikely that compatibility would be achieved with any system which was not effectively simultaneous, and the first report of the Television Advisory Committee(3) pointed out that the impossibility of increasing the channel spacing in Band I (41–68 Mc/s) would necessitate a fully compatible system if colour transmissions were made in this band. Towards the end of 1953 the BBC Research Department undertook to develop and examine the properties of an adaptation of the American N.T.S.C. fully compatible simultaneous colour television system to the British 405-line standard.

A comprehensive series of experiments was made, the results of which are given below. No decision has yet been made on the introduction of colour television in the United Kingdom, and in the meantime experiments are being continued with the collaboration of the radio industry in order to obtain as much information as possible on the technique of television broadcasting in colour.

1.2 *Equipment and Field Trials*

Having settled the main standards on which a modified N.T.S.C. system would operate, it was necessary to devise and construct a number of items of equipment and to arrange a series of field trials.

These trials should include tests under domestic reception conditions, with receivers in the hands of both skilled and lay viewers. In addition to providing the material for a statistical analysis of the colour performance, the compatibility of the system should be investigated by means of reception tests with standard monochrome receivers picking up the colour transmissions, and the reverse compatibility of the colour receivers should also be taken into account by appraisals of monochrome transmissions as received on colour receivers. Since it is unlikely that any colour television service would be able to transmit colour programmes exclusively during the first few years of its existence, and owners of expensive colour receivers could scarcely be expected to tolerate mediocre performance on black-and-white programmes, this last consideration has more practical significance than might at first be thought. It was, of course, desirable that the field trials should lay stress on those features of the 405-line N.T.S.C. system which differed in principle rather than in mere numerical values from the original N.T.S.C. specification. Examples of these were the British use of positive instead of negative picture modulation and the use of amplitude-modulated instead of frequency-modulated sound.

Preliminary trials were carried out with equipment produced by the BBC Research Department, and as additional equipment became available more extensive field trials, including assessments of live pictures viewed under domestic conditions, were arranged.

The basic items of equipment produced for the preliminary trials included:

(*a*) A flying-spot film and slide scanner, as a source of colour picture signals. For reasons which will be discussed later, it was expedient at that time to design this scanner to use 16-mm film.

(*b*) Circuitry for generating the composite colour signal, including the coding matrix, subcarrier generator, suppressed-carrier modulators, reference burst generator, and combining circuits.

(*c*) Prototypes of a projection and a direct-viewing receiver.

(*d*) As a standard of comparison, a high-quality laboratory picture monitor, capable of displaying an accurately registered picture in which each of the three colour components had a resolution corresponding to the full monochrome video bandwidth.

(*e*) A set of laboratory-type decoding equipment, capable of reconstituting the R, G, and B video signals with greater accuracy and stability than could be expected from the circuitry in a domestic receiver.

Besides the above-mentioned receivers produced by the BBC itself, a commercial firm developed a prototype direct-viewing receiver, with co-operation from the BBC.

When this equipment had been set in operation, it was possible to carry out the first test, which was on a closed circuit basis.

The second test was made possible when a low-power television transmitter had been modified, at the research laboratories, to make it capable of handling the composite colour signal. This transmitter used a channel well separated from any of those used for television broadcasting in or near the London area, so that it could be used, in conjunction with a receiver installed in a mobile laboratory, for local field trials during normal television hours. The 5-kW standby transmitter at Alexandra Palace was used for the compatibility trials.

At a later date in the BBC colour experiments, modifications were carried out to the Crystal Palace high-power television transmitter (which serves the London area and the south-east of England) to enable it to handle the composite colour signal. In addition, one of the studios at Alexandra Palace was equipped as an experimental colour studio, with two three-tube image orthicon colour cameras manufactured by Marconi's Wireless Telegraph Company.

A colour film and slide scanner, similar to the original equipment produced by Research Department, was also installed at Alexandra Palace together with a further set of coding equipment. Accordingly it became possible, on 5 November 1956, to begin a third test in which the experimental colour signals contained material from films, slides, and 'live' cameras, and were radiated from a high-power transmitter after the close of the normal programmes. By April 1957, a 35-mm flying-spot colour film scanner had been made ready for service at Alexandra Palace, and contributions from it were included in the experimental transmissions. The BBC Designs Department was in charge of the engineering origination of the transmissions from Alexandra Palace, while the Planning and Installation Department carried out the work on the Alexandra Palace and Crystal Palace transmitters.

The fourth test was a monochrome control experiment to find what gradings would be achieved by the picture on a monochrome receiver, working on normal monochrome transmissions, if it were subjected to tests similar to those which had been applied to the colour transmissions.

A further series of high-power colour test transmissions was carried out between October 1957 and April 1958.

At the time of writing, the analysis of the questionnaires relating to this series of tests is proceeding.

2. Adaptation of the Signal Specification

2.1 *Fundamental Considerations*

In developing a 405-line adaptation of the N.T.S.C. system, it was initially assumed that the fundamental electronic and physiological factors,[(4)] on which the original system relies, would apply in similar fashion to other television systems with somewhat different scanning standards. This assumption was reinforced by the fact that the horizontal resolutions of the British 405-line and the American 525-line systems are almost exactly equal. It therefore seemed reasonable to begin by scaling the bandwidths of the chrominance signals to give the same fractions of the monochrome (luminance) bandwidth as in the original specification. This gave approximately 1·0 Mc/s for the E_I' signal and 340 kc/s for the E_Q' signal.

2.2 *Choice of Subcarrier Frequency*

The subcarrier frequency must, of course, be lower than the video frequency limit by an amount which is just sufficient to allow double-sideband modulation of the subcarrier by the E_Q' signal without exceeding the video band, and it must at the same time be an odd multiple of half the line frequency.

Beside providing a subcarrier frequency corresponding to the 'standard' E_Q' bandwidth, the original coding equipment offered two other subcarrier frequencies for use with E_Q' bandwidths above and below the standard value. The precise subcarrier frequency for the 340 kc/s bandwidth was 2·6578125 Mc/s. Other frequencies of 2·8096875 Mc/s and 2·5059375 Mc/s were intended for use with E_Q' bandwidths of 220 kc/s and 460 kc/s respectively.

2.3 *Coding Parameters*

The original N.T.S.C. system specifies linear relationships by which the luminance signal (E_Y') and the two chrominance signals (E_I' and E_Q') are derived from the gamma-corrected colour separation signals (E_R', E_G', and E_B'). These relationships, and also the 33° phase-shift between the colour-difference and chrominance axes, should apply to the adapted system without modification. All the foregoing relationships are based on the fundamental physiological factors around which the original N.T.S.C. system was built, and should not be directly affected by changes in the scanning standards. It is true that the ratio of the peak-white and synchronizing-pulse amplitudes also enters into the determination of the E_Y', E_I', and E_Q' signals, but this ratio is not greatly different in the British and American monochrome signal specifications.

Although the original N.T.S.C. system might, as has been suggested, be expected to work on different standards with few alterations other than those resulting from the changed scanning parameters, the coding and decoding equipment of any experimental adaptation would gain in versatility if it included provision for alternative matrix transformations and subcarrier phase-shift angles. It will be seen from the description of the equipment in Section 3 that this was, in fact, done.

2.4 *Effect of Band-sharing*

There was, however, another aspect of the adaptation which required very careful watching, and this was the highly intricate interlocking arrangement by which the luminance and chrominance signals are enabled to share a common video band without causing excessive mutual interference between the luminance, chrominance, and sound signals, and without impairing the compatibility. This interlocking might conceivably be affected by, for example, the British use of amplitude-modulated instead of frequency-modulated sound. The difference between the British standard of twenty-five frames per second and the American standard of thirty frames per second might also be significant, since the cancellation of interfering dot-patterns, which is a basic principle of the system, takes place over a cycle of two complete frames. This means that the cancellation occurs fifteen times per second in the original system and twelve and a half times per second in the adapted system. The cancellation is, in any event, impaired by the non-linearity of the brightness variation in the viewing tube,[4] and reduced persistence of vision at the lower rate might cause a noticeable deterioration in the cancellation.

A feature of the adaptation which might—in theory at any rate—cause a difference in the results is due to the use of positive instead of negative picture modulation. The entire chrominance signal is transmitted as a single side-band with the carrier suppressed. This results in the relative amplitudes of the chrominance and luminance signals being distorted in the detection process. In the original N.T.S.C. system, which includes negative picture modulation, this distortion produces increased saturation of the colour picture, and reduced panchromaticity of the picture received on a monochrome receiver. In the British adaptation, which includes positive picture modulation, the distortion produces reduced saturation of the colour picture, and increased panchromaticity of the monochrome picture. The gamma correction process causes reduced panchromaticity of the monochrome picture in both versions of the N.T.S.C. system,[4] and in the case of the British adaptation this last effect is offset by the effect previously mentioned, with beneficial results.

2.5 *Picture Display*

Any display device incorporating a single viewing tube must perforce use a tube of the shadow-mask type, since no alternative has yet become generally available. The 405-line picture has, theoretically, almost the same horizontal resolution as the 525-line picture, and a somewhat lower vertical resolution. Thus, any interference effects, due to the finite number of holes in the shadow mask, should be somewhat less significant on the 405-line system.

2.6 *Asynchronous Working*

In the N.T.S.C. system, the subcarrier frequency bears an exact relationship to the line-scanning frequency, and this in turn bears an exact relationship to the field frequency, as in the monochrome system. If the field frequency is synchronized with the mains supply frequency, the subcarrier frequency must vary in the same ratio as the mains supply frequency. When the equipment for the BBC colour trials was being developed, the degree of variation in the mains frequency known to occur at that time was taken into consideration. It was thought that synchronous working would make it difficult to devise a subcarrier locking circuit capable of 'pulling-in' to the received reference burst over a sufficiently wide range of frequencies, and asynchronous working, with a crystal-controlled subcarrier oscillator, was adopted for the time being.

Asynchronous working is also used in the American colour transmissions. In the U.S.A., this mode of working is much more frequently employed in normal monochrome transmissions than it is in Britain. The British field trials should therefore include an assessment of any possible effect on compatibility caused by this relatively unfamiliar practice.

Other arrangements have been proposed which would make it possible to preserve synchronous working without causing difficulty in locking the regenerated subcarrier to the burst in the receiver. In one of these systems,[5] a stable subcarrier frequency is used, and one of the divider chains at the transmitter (either the subcarrier-to-line or the line-to-field divider) is made to vary its ratio instantaneously, in such a way as to keep the field frequency locked to the mains over a period of time, without allowing the instantaneous value of the field frequency to differ from the mains by more than a negligible amount. The different division ratios are chosen in such a way as to maintain the essential characteristics of the system, such as line interlace or dot cancellation.

Another and more recent proposal[6] for synchronous working takes advantage of the fact that the difference between the sound and vision carrier frequencies is maintained in an exact ratio—normally 4:3—to the subcarrier frequency in order to minimize the form of interference referred to on page 10, para. 3.7. This difference frequency is derived at the receiver by mixing, and is then applied to a discriminator, either directly or after further mixing with the local subcarrier oscillator frequency.

The output of the discriminator controls a reactance modulator which, in turn, controls the frequency of the subcarrier oscillator and brings it sufficiently close to the burst frequency to enable a phase detector to come into operation. The output of the phase detector, which is also fed to the reactance modulator, brings the local oscillator and the burst into exact synchronization.

A further arrangement,[6] which does not demand a highly stable discriminator circuit, derives a frequency equal to four thirds of the local subcarrier oscillator frequency by multiplication and division of that frequency, and then compares this derived frequency with the vision/sound difference frequency by means of a frequency difference detector. The output of this frequency difference detector, and also the output of a phase detector similar to that used in the previous arrangement, are both fed to a reactance modulator which controls the local subcarrier oscillator.

It has not yet been possible to put any of these proposals into operation, but the results of the compatibility trials have shown that some form of synchronous working is desirable.

3. Brief Description of the Equipment

3.1 *Colour Film and Slide Scanner*

This flying-spot scanner was the original source of colour picture signals for the trials. When the flying-spot system is used there is, of course, no registration problem, since the colour separation is carried out after the flying light spot has scanned the film or slide image.

In this case, the colour separation is performed by a system of dichroic mirrors, and the three colour components

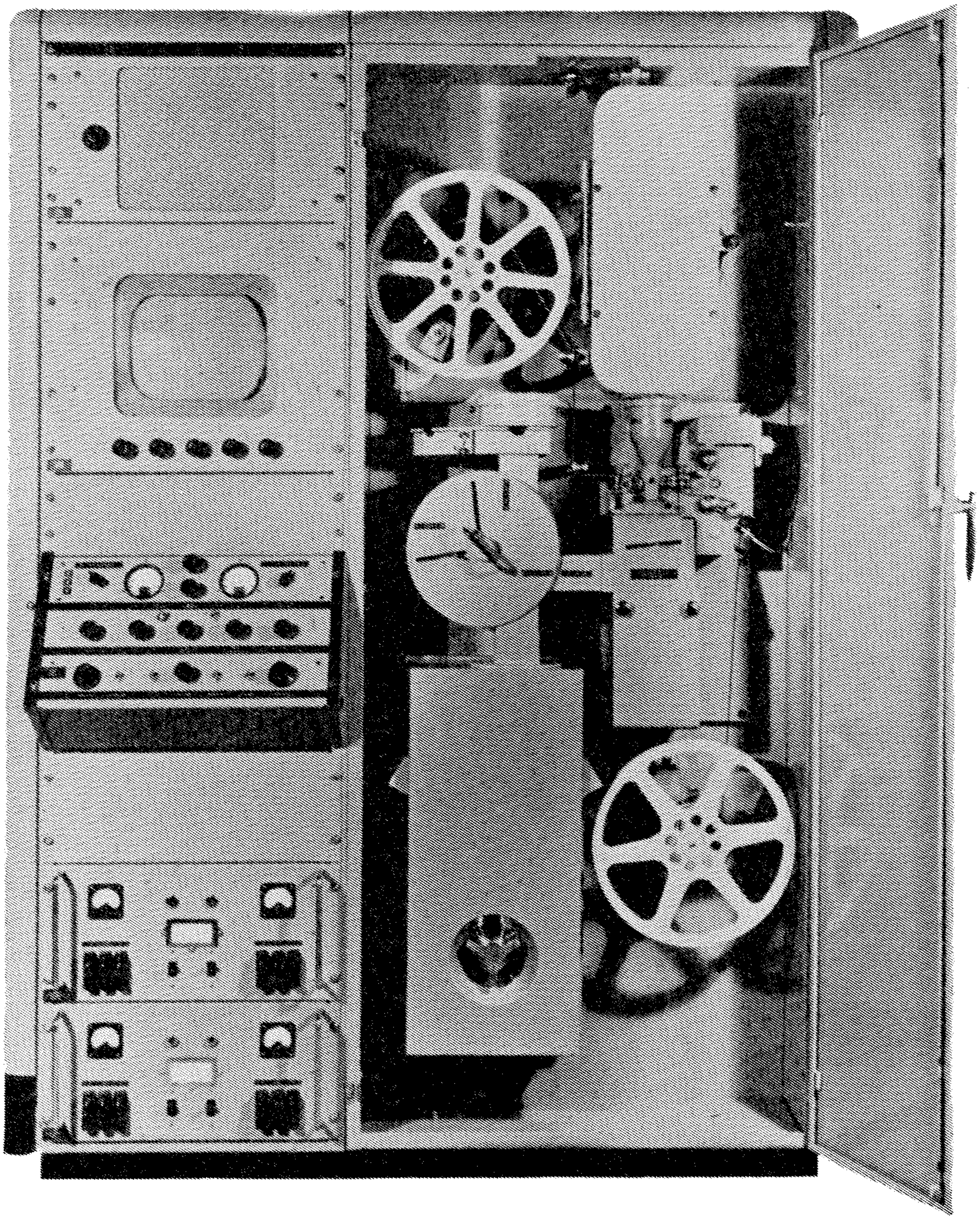


Fig. 1 — Colour film and slide scanner

are passed to three photomultipliers. The dichroic mirrors and photomultipliers are contained in a hinged box, which can be swung into alternative positions in order to deal with either films or slides. A three-position turret contains the appropriate optical systems for dealing with film, 8·3-cm × 8·3-cm slides, or 5·1-cm × 5·1-cm slides.

There was insufficient time to develop a high-quality continuous motion film scanner, so that a standard intermittent film transit mechanism had to be used. At that time some standard 16-mm mechanisms gave a 40° pulldown angle, but no 35-mm mechanisms with this pulldown angle were available. The frame blanking period of fourteen lines corresponds to a pulldown angle of 12·5°, but no satisfactory mechanism of either gauge could then be obtained with a pulldown angle of this order. It was therefore decided to design the scanner for 16-mm film and accept the known limitations of this gauge, together with the fact that the 40° pulldown would cause a loss of some thirty-one active lines at the top and bottom of the picture. The colour performance of the scanner was, however, of a very high order. This equipment is illustrated in Fig. 1.

3.2 *Triple Video Channel*

This equipment was used in conjunction with the colour film and slide scanner. It contains three similar units, each of which receives one of the three colour signals emerging from the scanner, and performs all the corrections and modifications necessary to provide standard colour separation signals suitable for coding. The signal processing includes:

(*a*) Correction for the scanning tube afterglow, by means of a series of RC circuits with progressively increasing time-constants.

(*b*) Correction for the effective scanning aperture, by subtracting from the signal an appropriate fraction of its second derivative with respect to time.(7)

(*c*) Modification of the contrast law to the standard gamma of 0·4.

(*d*) Black-level stabilization by the use of a pulsed feedback system incorporating integrators in the feedback circuit.(8) (9)

3.3 *The Coding Equipment*

This equipment was designed to be as flexible as possible. Four different matrix transformations were brought into use by switching. As mentioned in Section 2, three different bandwidths of the E_Q' signal were made available, together with three crystal-controlled subcarrier frequencies corresponding to these bandwidths. Provision was also made for running the subcarrier oscillator from an LC circuit, in order to make it possible to test the proposed arrangements for mains-locking the system.(5) (6)

The subcarrier oscillator was followed by a variable phase-shifter with a full 360° range. Apart from its serious experimental uses, this facility made it possible to display a colour picture in which the hues were correctly represented, and then to vary all the hues simultaneously around the entire colour 'triangle', while maintaining their original angular differences. It has been pointed out that rapid rotation of the phase-shift control would produce what was probably the world's most expensive black-and-white picture.

A new type of suppressed-carrier modulator, developed by the BBC, was used for the chrominance modulators. These were based on a rectifier-ring arrangement, and gave a better suppression of unwanted carrier than other types of balanced modulator which had previously been used for this purpose.

Comprehensive switching of the signal routing was provided, in order to allow instantaneous comparisons between the colour picture obtained from direct, R, G, and B links, and that resulting from different forms of coding and decoding process.

3.4 *The Laboratory Decoding Equipment*

Like the coding equipment, this was designed for maximum flexibility. Various matrices were available, giving the inverse transformations to those provided in the coder. A d.c. quadricorrelator circuit was used for locking the regenerated subcarrier to the burst signal. A variable attenuator, following the chrominance demodulator, permitted the use of different chrominance-to-luminance ratios.

3.5 *Receivers and Display Devices*

3.5.1 *Projection-type Receiver*

In order to obtain experience of a relatively inexpensive receiver built entirely from components which were readily obtainable in Britain, a receiver was constructed around three 57-mm projection tubes and their associated Schmidt optical units. When the receiver was developed, dichroic mirrors were not readily available in the U.K., and the combining of the light output of the three tubes was done by a crossed pair of titanium dioxide semi-reflecting mirrors.

Results were not very satisfactory, partly owing to the low optical efficiency of the system, and partly owing to the waste light which passed through the mirrors and caused desaturation of the colours displayed. A pair of crossed dichroic mirrors was later obtained, but the improvement resulting from their use was disappointingly small.

3.5.2 21-*in. Direct-viewing Receiver*

In 1955 a prototype of a 21-in. (53-cm) direct-viewing receiver was completed. This was based on an existing picture monitor using the R.C.A. tricolour Kinescope, Type 21/AXP/22A. The decoding circuits of this receiver were a compromise between circuits utilizing the full transmitted information in both the E_I' and E_Q' signals, and other simpler circuits which restricted the E_I' signal to the same bandwidth as the E_Q' signal. The latter type of circuit had the compensating advantage of being less costly, but full information on this type was not available to the BBC at the time when its 21-in. receiver was being developed and in any event it would have given slightly inferior colour pictures. The circuit used did not attempt to compensate the portion of the E_I' signal which is transmitted in single-sideband fashion, i.e. the portion in the range 400–1,000 kc/s, and therefore allowed a 6-dB drop to occur in this range of frequencies. Earlier compensating circuits had provoked difficulties due to lack of phase equalization. Time did not permit the development of an effective phase-equalization network, and the compensating circuit was therefore omitted altogether. A photograph of this receiver is shown in Fig. 2.

Eight of these receivers have now been produced. They have given a satisfactory and reasonably reliable performance and, in conjunction with a commercial prototype receiver, they have enabled the field trials described in the next section to be carried out, together with a further series of field trials recently completed. They can no longer be considered fully up to date, however, as they do not incorporate the latest circuit simplifications and refinements which have appeared in the U.S.A.

3.5.3 *Three-tube Direct-viewing Laboratory Monitor—'Trinoscope'*

It was desirable to have a high-quality laboratory monitor in which each of the three colour-separation images individually equalled the quality obtainable from the highest grade of black-and-white monitor. Registration would have to be almost impeccable. Such a monitor was produced by the Research Department using three specially constructed 17-in. (43-cm) rectangular cathode-ray tubes. The tubes were held in their correct relative positions by a framework of great stability and simultaneous viewing of the three tubes was contrived by an arrangement of titanium dioxide semi-reflecting mirrors.

Extreme measures were taken in both the electronic and mechanical design to ensure accurate registration. This monitor has proved a very valuable piece of test equipment. It is quite unsuitable for domestic use, although a similar, smaller, device was once seriously proposed for domestic viewing in the U.S.A., before the invention of the tri-colour tube. Fig. 3 shows a photograph of this monitor, and the light-alloy cradle in which the viewing tubes are mounted.

3.6 *Low-power Transmitter*

3.6.1 *Purpose of Transmitter*

In order to carry out some local field trials during normal television transmission hours, a 500-W vision transmitter and its associated 125-W sound transmitter were installed at the BBC's Research Department at Kingswood Warren, Surrey. These transmitters worked in the British Channel 5 (Vision, 66·75 Mc/s; Sound, 63·25 Mc/s) instead of Channel 1 (Vision, 45·0 Mc/s; Sound, 41·5 Mc/s) which serves the London Area.

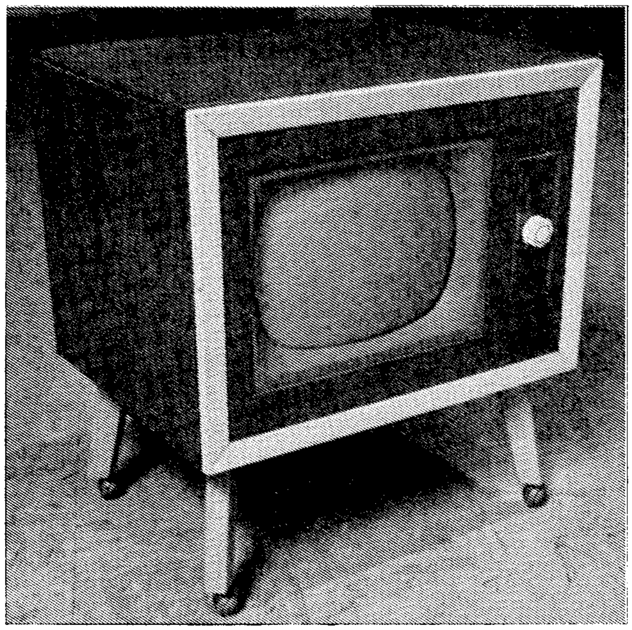


Fig. 2—Direct-viewing colour receiver developed by the BBC

3.6.2 *Correction Required*

In order to meet the requirements of the composite colour signal, it was necessary to correct the linearity, frequency response, and group delay characteristics of the vision transmitter.

3.7 *Carrier-frequency Drive Equipment*

When receiving colour signals, a spurious signal may be generated by interference between the sound and chrominance signals at the receiver vision detector. An interference pattern may be seen if the resultant beat, which has a frequency of some 840 kc/s, has sufficient amplitude. The visibility of pattern may be reduced substantially if the frequency of the beat bears an odd integer relationship with half the line-scanning frequency: this condition will be satisfied if the frequency difference between the sound and vision carriers is an integer multiple of the line-scanning frequency. A simple and convenient arrangement may be obtained if this frequency difference bears a four-thirds relationship to the colour subcarrier frequency. In both the vision transmitter and its associated sound transmitter, the carrier frequency is normally obtained by multiplying the drive frequency by nine. By changing the frequency multiplying factor to eight, the problem of locking the frequency difference between the sound and vision carriers was simplified considerably.

The additional equipment necessary is illustrated in Fig. 4. In this apparatus the reference burst contained within the N.T.S.C.-type composite signal is used to lock a subcarrier frequency (2·6578125 Mc/s) oscillator in a d.c. quadricorrelator.[10] Continuous subcarrier is then fed to a frequency divider having an output frequency of 443 kc/s, one-sixth that of the subcarrier; this in turn provides an input to a balanced modulator contained within

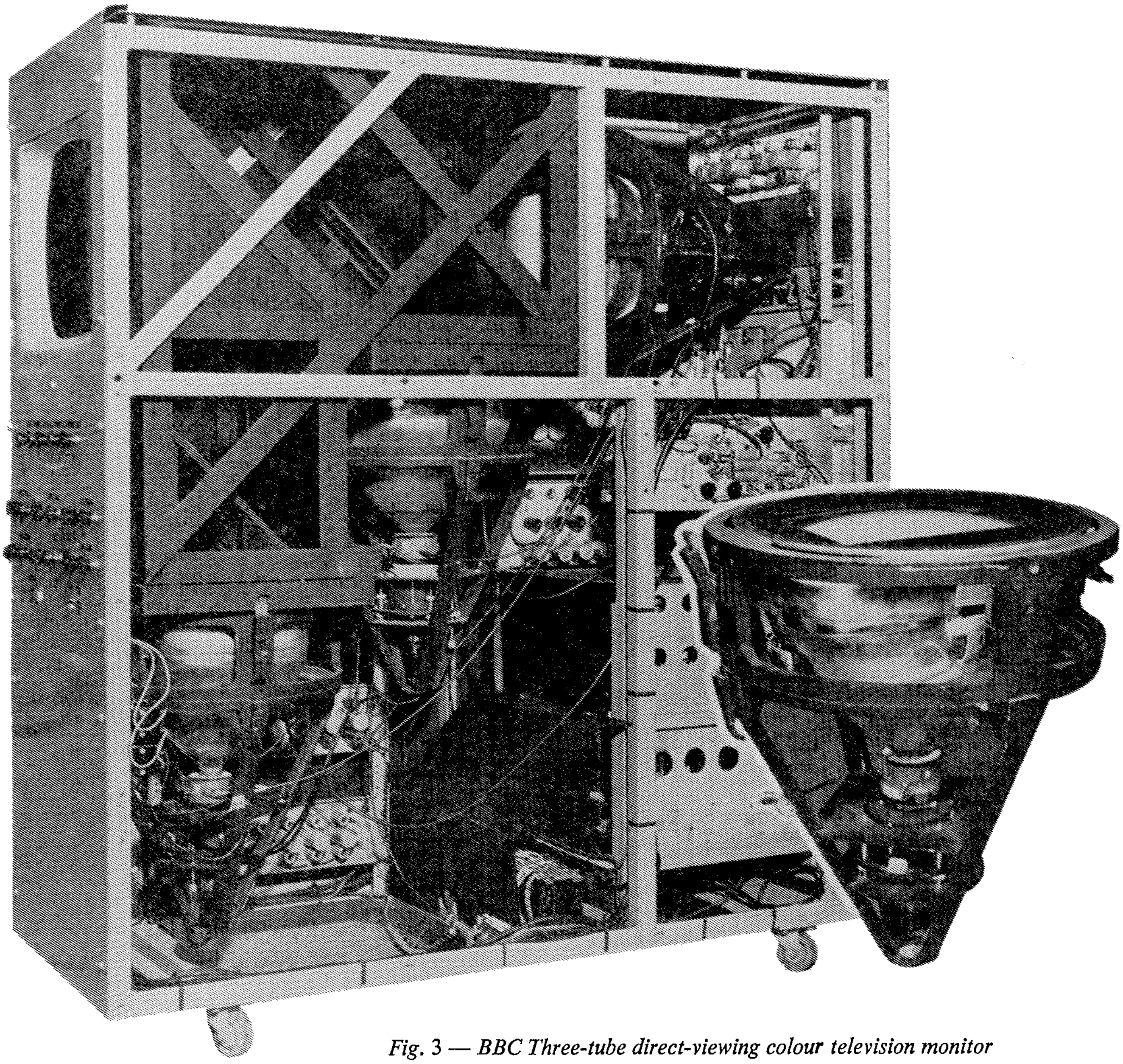


Fig. 3 — BBC Three-tube direct-viewing colour television monitor

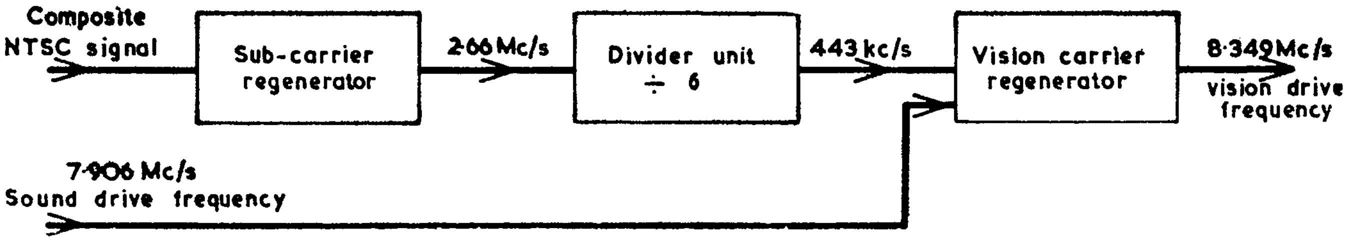


Fig. 4 — Intercarrier locking equipment

the vision carrier regenerator. The second input to this modulator is obtained from the drive circuits of the sound transmitter (with a frequency one-eighth that of the sound carrier) and, by means of a suitable bandpass filter, an output is derived which, having a frequency one-eighth that of the vision carrier, is suitable as input to the frequency multiplying stages of the vision transmitter.

3.8 *Adaptation of Crystal Palace Transmitter*

Some of the field trials, including the series just completed, have been radiated from the Crystal Palace high-power transmitter.

For this purpose, some minor modifications were carried out to the transmitter. A unit was provided which maintained the vision carrier at a value which exceeded the sound carrier by precisely four-thirds of the subcarrier frequency, for the same reason mentioned in the description of the low-power transmitter.

It was also necessary to modify the black-level stabilization circuits of the vision transmitter to allow the insertion of the subcarrier reference burst in the post-synchronizing suppression period.

3.9 *Colour Cameras*

The two cameras in the Colour Studio at Alexandra Palace each use three English Electric type P.809 3-in. (7·5-cm) image orthicon tubes. Colour separation is by dichroic mirrors.

These cameras can give excellent pictures under certain conditions of lighting, but in some respects their performance leaves considerable room for improvement. The inherent resolution of the 3-in. tube is about 12 dB worse than the 4½-in. (11·4-cm) tubes now coming into general use for British monochrome broadcasting, and the signal-to-noise ratio is also considerably poorer than it is in the larger tube. The present small tubes can give reasonably good pictures from an evenly, brightly illuminated scene of the type which is usually encountered in light entertainment. In other types of production, such as drama, however, this need for even illumination makes it difficult to light in such a way as to convey any mood. Lighting for dramatic effect produces high contrast range, and areas of low mean brightness. The high level and irregular shape of the shading signals produced by the small camera tube make it particularly difficult to match the three tubes in such areas. It is considered that all these difficulties would be greatly reduced if the 4½-in. tubes were used, and this could be done without any increase in the already large size of the camera.

3.10 *35-mm Film Scanner*

This scanner was made ready for service at the Alexandra Palace in April 1957. It uses the twin-lens flying-spot system with continuously moving film, which has been the preferred BBC system for monochrome telecine work for a number of years. Unlike the intermittent traction mechanism used as a temporary expedient in the Research Department 16-mm scanner, the twin-lens flying-spot system makes it possible to transmit all the active lines in the picture signal.

As with the 16-mm scanner, the colour separation is carried out after the light has passed through the film image, so that there is no registration problem. Given good film stock, this scanner produces colour picture signals of very high quality in all respects.

4. Performance Tests of Colour Receivers and Assessment of the Results

4.1 *Summary*

This section gives the results of field trials of the N.T.S.C. colour television system adapted to 405 lines, which were conducted in order to assess the colour performance of the system. Preparatory tests took place at the BBC research laboratories at Kingswood, Surrey, and its environs, but for the major part of the trials signals radiated from the Crystal Palace transmitter were used, the programme being received over a wide area in the London region. Comprehensive data are given concerning all technical aspects of the colour picture and also the reverse compatible pictures. In addition a 'control' experiment was undertaken in which the existing monochrome service was similarly assessed for the purpose of comparison.

The results show that this particular system of colour television is capable of providing a satisfactory colour service in the frequency bands at present in use but it is, nevertheless, desirable that certain features associated with the camera and display should be improved.

4.2 *Scope and Purpose of the Tests*

The field trials described in this section took place between 25 September 1956 and 17 May 1957, and were designed to assess critically the quality of the colour television picture which can be received in the home under ordinary viewing conditions. Demonstrations to C.C.I.R. Study Group XI and others given in May 1956 and the following months showed that very good colour television pictures can be produced under laboratory conditions, but it still remained to be shown whether results of good quality could be obtained outside the close control of a research laboratory. It should be emphasized that the tests described relate solely to the 405-line version of the N.T.S.C. colour television system.

In addition to those tests which were concerned with the quality of the colour picture, a control experiment was performed in June 1957, in which the picture quality of current black-and-white television was critically examined. In all, four tests were carried out and the principal features of these are given in Table 1.

Test No. 1 is not, strictly speaking, a field trial, because the receiving site was in the same building as the transmitting equipment and the connection between the two was a length of coaxial cable. Nevertheless, it served to give results which should be typical of high field-strength

TABLE I
DESCRIPTION OF THE TESTS

Test No.	*Picture Sources*	*Location of Picture Source*	*Location of Transmitter*	*Vision Channel*	*Location of Receivers*	*Types of Receiver*	*No. of Observers*
1	16-mm film and slide scanner	Kingswood	Closed circuit	1	Kingswood	BBC and commercial	60
2	16-mm film and slide scanner	Kingswood	Kingswood	5	25 sites near to Kingswood	BBC	3 per site
3, Part 1	16-mm film and slide scanner	Alexandra Palace	Crystal Palace	1	Homes	Various	144
3, Part 2	16-mm film and slide scanner 35-mm film scanner 2 colour cameras	Alexandra Palace	Crystal Palace	1	Homes	Various	267
4	4½-in. image orthicon cameras (monochrome)	Various O.B. sites in London area	Crystal Palace	1	Kingswood	Commercial	79

areas where ignition interference, multipath effects, and noise due to low field strength (receiver noise) are completely absent. The picture-originating equipment was a 16-mm cinematograph-picture film and slide scanner.

Test No. 2 used one of the two receivers which had been used in Test 1, and employed the 500-W transmitter, located at Kingswood Warren, operating in Channel 5 and suitably modified to give adequate performance with the type of video signal characteristic of the adapted N.T.S.C. system. The receiver was installed in a mobile laboratory, and with this twenty-five sites near to Kingswood were investigated. The range of field strengths was from 2·5 mV/m to 70μV/m. The twenty-five sites chosen included some typical of high field-strength conditions as well as a number of places where the field was low. A few sites exhibited strong multipath interference. The attempt was made to choose sites covering the complete range of receiving conditions likely to be encountered if this system of colour television were adopted for a nation-wide service.

Test No. 3 used the Channel 1 transmitter—which then had an e.r.p. of 55kW for peak white—located at Crystal Palace. The picture-originating equipment was located at Alexandra Palace. It consisted of a combined 16-mm film and slide scanner similar to the one at Kingswood, a 35-mm film scanner, and two colour cameras each using three image orthicon camera tubes. The 35-mm film scanner was not available at the beginning of the tests and was used for the first time on 17 April 1957.

Test transmissions took place after the termination of the normal television service on Monday, Wednesday, and Friday evenings.

The transmissions in this test fell into two classes. Part 1 of test No. 3 was radiated on Monday evenings and used high-quality colour transparencies and 16-mm cinematograph pictures as material. The interest in the programme content of the transmissions was intentionally of a small order so that observers were able to concentrate on the technical features of the pictures. Part 2 of the test was radiated on Wednesday and Friday evenings and consisted largely of pictures from the experimental colour studio at Alexandra Palace with, in addition, a short film on each occasion and a still picture from one of the colour transparencies of the 'Technical' transmission. The programme content was changed at approximately fortnightly intervals. Every effort was made to make the programme interesting; a wide range of subjects was covered including drama, ballet, variety, a mannequin parade, and a demonstration of cookery.

4.3 *The Analysis of the 'Technical' Transmissions*

Part 1 of Test No. 3 is further subdivided into two parts, namely the tests taking place up to and including 25 March 1957 (Part 1(a)) and those taking place on and after 1 April 1957 (Part 1(b)). This division is made because the material of the tests, both the slides and film, was completely changed on 1 April. At about that time it was felt that improved results might be obtained if more attention were paid to the colour rendering of the film used. It is well known that colour film loses much in the duplicating process, and so the BBC Research Department made a direct Kodachrome 16-mm colour film of miscellaneous subjects, which was thereafter used in place of the commercial duplicate of a travel film which had been used hitherto. A new set of slides was also chosen.

An opportunity was also taken to make one or two improvements to the ease of operation and stability of one of the types of colour receiver used in the tests.

During the period 5 November 1956 to 25 March 1957, 112 completed questionnaires were received and for the period 1 April to 13 May the number was thirty-two.

4.4 *The Analysis of the 'Programme' Transmissions*

The 265 questionnaires to be analysed cover the period from 4 January to 17 May 1957. The questionnaires returned during the period from 5 November to 14 December 1956 have been excluded. The results obtained during this period were analysed at an early date and showed a rather unfavourable reaction by observers to some important aspects of the colour pictures, not only for camera pictures but also for films and, to a lesser degree, for the still pictures. It was shown that there were a number of temporary factors, of a nature rather inevitable at the beginning of a new and complex technique, which might have affected the results. The improved results obtained in the present analysis, which covers the period when most of the temporary adverse factors had been removed by positive action, appear to justify the exclusion of the earlier results on the grounds that they were concerned with a 'teething' period with its inevitable difficulties.

The analysis will also show the degree of improvement in the observers' assessment as a result of the changes of the film gauge from 16 mm to 35 mm on 17 April.

Test No. 4 was the monochrome 'control' experiment in which the questionnaire reproduced in Appendix VII was completed by seventy-nine observers who had viewed several monochrome outside broadcasts on a high-quality 21-in. receiver.

4.5 *The Questionnaire and the System of Grading*

The questionnaire for Tests 1, 2, 3 Part 1(a), and 3 Part 1(b) is reproduced in Appendix I and was designed to test all technical aspects of the colour picture and also the reverse-compatible black-and-white picture. The questionnaire for Test 3 Part 2, the 'programme' tests, is a slightly simplified version of the previous questionnaire and is reproduced as Appendix II. The questions on the reverse-compatible picture have been deleted, as the 'programme' tests were concerned exclusively with colour pictures.

The grading system permits the allocation of a score from 1 to 6 for each individual effect, as shown in the scales below. Interfering effects are assessed on scale 1 and positive qualities are assessed on scale 2.

TABLE 2

Scale 1	*Score*	*Scale* 2	*Score*
imperceptible	1	excellent	1
just perceptible	2	good	2
definitely perceptible but not disturbing	3	fairly good	3
somewhat objectionable	4	rather poor	4
definitely objectionable	5	poor	5
unusable	6	very poor or absent	6

In both scales a low number indicates a favourable reaction and a high number an unfavourable reaction.

It is desirable at this point to define certain descriptive terms. The phrase 'acceptable' will be used when not more than 10 per cent of the observers use grades 4, 5, and 6 to describe a particular effect, and this usually corresponds to a mean grading in excess of 2·5. 'Favourable' is applied to a mean grading of between 1·5 and 2·5. A mean grading of less than 1·5 will be regarded as 'very favourable'.

TABLE 3

Mean Grading	*Suggested Interpretation*
1·0 to 1·5	Very favourable
1·5 to 2·5	Favourable
2·5 to 3·5	*Acceptable* when detailed inspection of results shows not more than 10 per cent in grades 4, 5, and 6 *Unacceptable* when detailed inspection of results shows more than 10 per cent in grades 4, 5, and 6
3·5 to 6	Unusable

4.6 *Detailed Description and Assessment of the Tests*

4.6.1 *Test 1—Colour Performance on Closed Circuit*

(*a*) *Description of the Test*

Test 1 was a closed-circuit laboratory appraisal using thirty observers for each of two colour television receivers, one made by the BBC Research Department and the other by a radio manufacturer. The picture material consisted of one technical test slide (viz., a neutral step wedge), three colour transparencies, and a portion of the 16-mm South African travel film. The colour transparencies were Ektachrome originals of size 3 in. × 2¼ in. (75 mm × 57 mm) of good colour fidelity and good definition. The 16-mm film was a commercial duplicate of rather poor colour fidelity and of the low standard of definition often associated with 16-mm film. The reason for choosing it was that it was considered typical of the usual standard of 16-mm colour film; better film is certainly available but it was thought preferable to test the system with an average rather than a good colour film. The subsequent analysis of the 'programme' transmissions in Test 3 showed, however, that this assumption was incorrect, and that the poor colour rendering of this film was producing a substantially lower grading in the tests in which it featured.

(*b*) *Results of the Test*

The mean gradings for the various characteristics are shown in Table 4, which also includes miniature histograms. Full details of the percentages of observations in each grade are given in Appendix III.

Characteristics A to M relate to the colour pictures and characteristics N to U to the reverse-compatible black-and-white picture.

(*c*) *Results for Colour Pictures*

It will be seen that the overall assessments (M) of colour pictures are 'favourable' in every case except that of 16-mm films reproduced on the BBC receiver. This last category just fails to reach the 'acceptable' criterion. It must be remembered that the poor quality 16-mm film was in use at this time, and it is highly probable that this category would have achieved an 'acceptable' grading if a better film had been used.

	CHARACTERISTIC	MEAN GRADINGS AND HISTOGRAMS			
		BBC Receiver		Commercial Receiver	
		16 mm film	Slides	16 mm film	Slides
COLOUR PICTURE	A Visibility of crawling dots	1·7	1·9	1·7	1·3
	B Colour synchronizing difficulties	1·0	1·0	1·0	1·0
	C Colour trailing due to movement	1·6	—	1·5	—
	D Noise	2·7	1·7	1·8	1·2
	E Multiple image effects	1·0	1·0	1·0	1·0
	F Misregistration	2·4	2·4	2·4	2·2
	G Cross-colour	1·5	1·6	1·3	1·4
	H Fidelity of colour reproduction	3·1	2·6	2·8	2·3
	I Achromaticity of the grey scale	—	3·4	—	3·1
	J Picture sharpness	2·3	2·2	2·3	2·4
	K Picture brightness	2·0	1·7	2·1	1·9
	L Contrast range	—	2·7	—	2·7
	M Overall assessment	2·6	2·4	2·4	2·2
REVERSE-COMPATIBLE PICTURE	N Colour trailing due to movement	1·4	—	1·3	—
	O Noise	1·9	1·5	1·3	1·3
	P Multiple image effects	1·0	1·0	1·0	1·0
	Q Misregistration	2·1	1·9	2·4	2·7
	R Achromaticity of the picture	2·2	2·2	2·4	2·6
	S Picture sharpness	2·1	2·2	2·3	2·7
	T Contrast range	—	2·4	—	2·5
	U Overall assessment	2·1	2·2	2·5	2·8

TABLE 4

Results of Test No. 1

The film receives an 'unacceptable' grading for 'fidelity of colour reproduction' (H) on both receivers.

(d) Results for the Reverse-compatible Picture

Table 4 also shows that the reverse-compatible picture was graded favourably on the BBC receiver for both slides and film.

The commercial receiver rates a lower overall assessment (U) on both slides and film, with an 'unacceptable' rating for slides. These ratings contrast with the overall assessments on colour pictures, in which the commercial receiver achieves higher ratings than the BBC receiver.

Comparison of Characteristics Common to the Colour Picture and the Reverse-compatible Picture

Eight of the characteristics are common to the colour picture and the reverse-compatible black-and-white picture, and it is of interest to examine the difference between the mean gradings for cinematograph pictures and slides. This has been summarized in Table 5 for both receivers.

TABLE 5

TEST 1

Characteristics Compared	*Difference of Mean Gradings*			
	BBC Receiver		*Commercial Receiver*	
	Film	*Slides*	*Film*	*Slides*
C–N Colour trailing due to movement	0·2	—	0·2	—
D–O Noise	0·9	0·2	0·5	−0·1
E–P Multiple image effects	0·0	0·0	0·0	0·0
F–Q Misregistration	0·3	0·5	0·0	−0·5
I–R Achromaticity of the picture	—	1·2	—	0·5
J–S Picture sharpness	0·2	0·0	−0·1	−0·3
L–T Contrast range	—	0·3	—	0·2
M–U Overall assessment	0·5	0·2	−0·1	−0·6

A positive difference means that the reverse-compatible picture is better than the colour picture since a low score means a favourable reaction.

The largest change is in the achromaticity of the reproduction of a monochrome step-wedge (I–R), where the BBC receiver was improved by 1·2 units and the commercial receiver by 0·5 units when the colour circuits were switched off. This would imply incorrect alignment of the red, green, and blue signals making up the neutral scale at either the transmitter or receiver. It must be admitted that one of the most difficult tasks to accomplish is the attainment of a really good neutral scale on a colour receiver.

'Noise' (D–O) changes appreciably for cinematograph pictures although not for slides. This is due to the fact that 16-mm cinematograph picture film gives rise to a higher level of noise than do slides, and the presence of the chrominance signal causes the visibility of the noise to be increased.

With the BBC receiver reactions to a black-and-white picture were better than to a colour picture, but the reverse is true for the commercial receiver.

Other comparable features were not significantly changed, as between the colour picture and the reverse-compatible one.

4.6.2 *Test 2—Colour Performance at Different Field Strengths*

(a) Description of the Test

This test made use of the 500-W transmitter installed at Kingswood Warren and operating in Channel 5, which was chosen so that the tests could be made during normal television service hours. The BBC receiver used in Test 1 was installed in a mobile laboratory. Twenty-five sites in the vicinity of Kingswood, Surrey, were chosen, and twenty-two of the twenty-five sites were within a radius of five miles (8 km) from the transmitter. A team of three observers recorded their observations at each site, the programme for the test transmissions being identical with that used in Test 1. The same picture-originating equipment was being used and also the same slides and film.

The results of the test can be analysed in two ways:

1. Mean gradings for each individual site for each characteristic averaged for the twenty-five sites.
2. The gradings for each individual site for each characteristic analysed in terms of the measured field strengths.

Both methods will be used but when using method (1) it should be borne in mind that the proportion of sites which have low field strengths (i.e. less than 200μV/m) is much greater than that for a typical service area. Hence, the mean gradings are likely to be less favourable (i.e. numerically greater) than those for Test 1 or Test 3.

(b) Results Expressed as Mean Gradings for the Twenty-five Sites

Table 6 gives the mean gradings and histograms for the twenty-five sites taken as a whole. Detailed information on the percentage of observations in each grade will be found in Appendix IV.

(c) Results for Colour Pictures

Considering the results for the static slides first, we see from Table 6 that the mean gradings vary from 1·4 to 3·0. The only characteristic which is in the 'very favourable' class is 'colour synchronizing difficulties' (B). 'Visibility of crawling dots' (A), 'multiple image effects' (E), 'misregistration' (F), 'cross-colour' (G), 'picture sharpness' (J), 'picture brightness' (K), and 'contrast range' (L) are all in the 'favourable' class. 'Noise' (D), 'fidelity of colour reproduction' (H), 'achromaticity of the grey scale' (I), and 'overall assessment' (M) have mean gradings in the 'unacceptable' class.

In the assessment of cinematograph pictures, Table 6 shows that the mean grading for 'colour synchronizing difficulties' (B) is the only characteristic in the 'very favourable' class. In the 'favourable' class we find 'visibility of crawling dots' (A), 'colour trailing due to movement' (C), 'multiple image effects' (E), 'misregistration' (F), 'cross-colour' (G), and 'picture brightness' (K). 'Picture sharpness' (J) has a mean grading in the 'acceptable' class: 'fidelity of colour reproduction' (H) and 'overall assessment' (M) are in the 'unacceptable' class. 'Noise' (D) is in the 'unusable' class with a mean grading of 3·6.

The fact that the 'overall assessments' for both film and slides have been graded as 'unacceptable' indicates the shortcomings of this method of analysis which places too much weight upon results from sites of low field strength. Nevertheless, it has been included because Tests 1 and 3 are analysed in this way.

(d) Results for the Reverse-compatible Picture

Table 6 shows that the range of mean gradings for slides when viewing the reverse-compatible picture is 1·9 to 2·6. 'Noise' (O) is the only characteristic with a mean grading in the 'unacceptable' class: all the remaining characteristics are in the 'favourable' class, including the 'overall assessment'.

For cinematograph pictures, the range of mean gradings varies from 1·6 to 2·8 and the following characteristics have mean gradings in the 'favourable' class: 'colour trailing due to movement' (N), 'multiple image effects' (P), and 'achromaticity of the picture' (R). 'Misregistration' (Q) and 'picture sharpness' (S) are judged to be 'acceptable'.

In the 'unacceptable' class of mean gradings we have 'noise' (O) and 'overall assessment' (U).

(e) Comparison of Characteristics Common to the Colour Picture and the Reverse-compatible Picture

Table 7 lists the eight characteristics common to both colour and reverse-compatible pictures, and gives the differences in mean grading.

One of the features which the mobile laboratory tests were designed to investigate was that of 'multiple image effects' (E–P) and it is of interest to note that the difference between the results for colour and for reverse-compatible reception is negligible. This situation is also found to be true if the data for the individual sites are examined (Para. (i)).

Most of the other common characteristics are also found to give rise to small differences in mean grading. The exceptions are 'achromaticity of the picture' (applicable only to the step-wedge in the case of the colour pictures) (I–R), 'noise' (D–O)

TABLE 6

Results of Test No. 2

	CHARACTERISTIC	MEAN GRADINGS AND HISTOGRAMS	
		16 mm film	Slides
COLOUR PICTURE	A Visibility of crawling dots	1·9	2·2
	B Colour synchronizing difficulties	1·0	1·4
	C Colour trailing due to movement	1·9	—
	D Noise	3·6	3·0
	E Multiple image effects	2·0	1·9
	F Misregistration	2·5	2·3
	G Cross-colour	2·2	2·2
	H Fidelity of colour reproduction	3·5	2·9
	I Achromaticity of the grey scale	—	3·0
	J Picture sharpness	2·9	2·5
	K Picture brightness	2·1	1·9
	L Contrast range	—	2·3
	M Overall assessment	3·4	2·9
REVERSE-COMPATIBLE PICTURE	N Colour trailing due to movement	1·6	—
	O Noise	2·8	2·6
	P Multiple image effects	1·9	1·9
	Q Misregistration	2·6	2·2
	R Achromaticity of the picture	2·1	1·9
	S Picture sharpness	2·7	2·4
	T Contrast range	—	2·1
	U Overall assessment	2·8	2·5

TABLE 7
TEST 2

Characteristics Compared	*Differences of Mean Gradings*	
	Film	*Slides*
C–N Colour trailing due to movement	0·3	—
D–O Noise	0·8	0·4
E–P Multiple image effects	0·1	0·0
F–Q Misregistration	−0·1	0·1
I–R Achromaticity of the picture	—	1·1
J–S Picture sharpness	0·2	0·1
L–T Contrast range	—	0·2
M–U Overall assessment	0·6	0·4

A positive difference means that the reverse-compatible picture is better than the colour picture.

and 'overall assessment' (M–U). These were also the characteristics giving significant differences in Test 1 (see Table 5, BBC receiver). For these three characteristics the reverse-compatible picture gives a better result than the colour picture.

Results Analysed as a Function of the Field Strength of the Individual Sites

In addition to setting up the apparatus and observing the programme of slides and film on the colour receiver, the field strength of the radiation from the low-power transmitter was measured at each of the twenty-five sites. As previously stated, the values ranged from 2·5 mV/m to 70 μV/m. The gradings for each characteristic given by the three observers were averaged for each site and hence data are available from which the mean grading for any characteristic can be plotted against the logarithm of the field strength. In Figure 5 the overall assessment (M) for colour slides is plotted in this way, and it is seen that, although there is considerable scattering, and two of the sites give anomalous results, the graph exhibits a recognizable trend.

(*f*) *'Overall Assessment of the Colour Picture'* (*M*)

Slides. As field strengths increase above 150 μV/m there is little correlation between the mean grading and the field strength. The few readings below 150 μV/m appear to indicate that the gradings deteriorate sharply at field strengths below this level.

Films. There is a slight significant correlation between the assessment and the field strength, but the grading never reaches the 'favourable' class, probably owing to the poor quality of the test film in use at the time.

(*g*) *'Fidelity of Colour Reproduction'* (*H*)

Slides and Films. Apart from the usual spread of readings, the mean grading does not seem to vary significantly with field strength in either case. This is to be expected, since the representation of hues should not alter as long as the subcarrier remains locked.

(*h*) *'Noise' in the Colour Picture* (*D*)

Slides. The gradings clearly show a deterioration with decreasing field strength, and the rate of deterioration increases more sharply as field strength diminishes.

Films. The general form of the result is similar to the case of slides for field strengths below 0·5 mV/m, but above this value the noise due to the film 'predominates' and prevents any further improvement in the grading.

(*i*) *'Multiple Image Effects'* (*E*)

There was no significant correlation between field strength and the observance of multipath effects. This need not necessarily be generally true and may be due simply to the particular sites chosen. It is perhaps significant, however, that where multipath effects were noted, the gradings in every case were within half a grade of the corresponding grade (P) for multipath effects observed in the reverse-compatible picture at the same site.

(*j*) *'Overall Assessment of the Reverse-compatible Picture'* (*U*)

Slides. As with the overall assessment of slides reproduced in the colour picture, there is evidence of a very slight improvement in grading as field strengths rise above

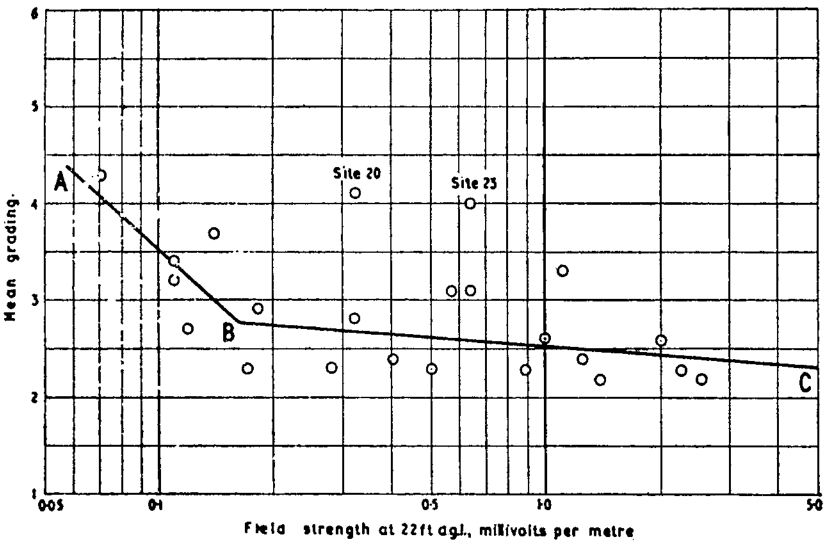


Fig. 5—Colour slides: 'Overall Assessment' (M) plotted as a function of field strength

150 μV/m, and a much sharper deterioration of grading as field strengths fall below this figure.

Films. There is a progressive change in grading throughout the whole range of field strengths, with no evidence of a change of slope at 150 μV/m.

(*k*) *'Noise' in the Reverse-compatible Picture* (*O*)

Slides. The general form of the result is similar to the corresponding result (D) for the colour picture.

Film. The result shows a more or less constant mean grading of 2·3 for field strengths above 400 μV/m. Below this field strength the locus of the curve is similar to that for slides.

4.6.3 *Test 3—Colour Performance in Domestic Reception Conditions*

Detailed results of Test 3, Parts 1(a) and 1(b) (the 'Technical' transmissions) are given in Appendix V, and detailed results of Test 3, Part 2 (the 'Programme' transmissions) are given in Appendix VII.

(*a*) *Overall Assessment* (*Characteristic M*)

TABLE 8

	'Technical' Transmissions				*'Programme' Transmissions*			
	16-mm Film		*Slides*		*Slide*	*16-mm Film*	*35-mm Film*	*Camera*
	Part 1a	*Part 1b*	*Part 1a*	*Part 1b*				
Mean Grading	2·98	2·12	2·5	2·26	1·9	2·4	1·8	2·5

'Technical' Results

Film. For Part 1(a) the mean grading of 2·98 is 'unacceptable', since 25 per cent of observers used grade 4, 5, or 6.

For Part 1(b) the mean grading of 2·12 is 'favourable'. 6 per cent of observers used grade 4 and none used grades 5 or 6.

The use of the new film (which was original Kodachrome as compared with the commercial duplicate of the old film) has improved the mean grading by almost a whole grade. It seems evident, therefore, that the unfavourable reaction in Part 1(a) of the tests was very largely due to the poor quality of the film used.

Slides. The mean gradings for slides of 2·5 for Part 1(a) and of 2·26 for Part 1(b) are both 'acceptable': the percentages of observers using grades 4, 5, and 6 were respectively 10 per cent and 4 per cent for Parts 1(a) and 1(b).

The slight improvement of one quarter of a grade may be due to better knowledge of how to operate the colour receivers rather than to the change of slides. In this case both the old and the new slides were large Ektachrome transparencies of good quality.

'Programme' Results

The mean grading of 1·9 for the slide is 'favourable'; 1 per cent of observers used grade 4; one observer only (out of 275) used grade 5; none used grade 6.

The mean grading of 2·4 for 16-mm cinematograph pictures is 'favourable'. 5 per cent of observers used grade 4; 2 per cent grade 5; and none grade 6.

The mean grading of 1·8 for 35-mm cinematograph pictures is approaching 'very favourable' and is better than the slide; no observer used grade 4, 5, or 6.

The mean grading of 2·5 for the camera is not in the 'favourable' category. 10 per cent of the observers used grade 4; one observer only, grade 5; none used grade 6. On this basis, the camera pictures can be said to be only just outside the 'favourable' category and within the 'acceptable' category.

(*b*) *Colour Rendering* (*Characteristic H*)

TABLE 9

	'Technical' Transmissions				*'Programme' Transmissions*			
	16-mm Film		*Slides*		*Slide*	*16-mm Film*	*35-mm Film*	*Camera*
	Part 1a	*Part 1b*	*Part 1a*	*Part 1b*				
Mean Grading	3·13	2·2	2·6	2·3	2·0	2·8	1·9	2·5

This feature of a colour picture is obviously of great importance and a statistical analysis based on correlation also proves this point.

'Technical' Results

Film. For Part 1(a), the mean grading of 3·13 is 'unacceptable', since 32 per cent of observers used grades 4, 5, and 6.

For Part 1(b), the mean grading of 2·2 is 'favourable': 3 per cent (i.e. only one) of observers used grade 4, 5, or 6.

Thus, it may be seen that an improvement in colour rendering of the film itself is reflected in an improvement in the scoring.

Slides. For Part 1(a), the mean grading of 2·6 is 'unacceptable', since 15 per cent of observers used grade 4, 5, or 6.

For Part 1(b), the mean grading of 2·3 is 'favourable'; 7 per cent of observers used grade 4, 5, or 6.

It is to be noticed that the colour rendering of the film in Part 1(b) has obtained a slightly better rating than that of the slides. The superior interest value of moving rather than static pictures may account for this.

'Programme' Results

The mean grading of 2·0 for the slide is 'favourable'. 2 per cent of observers used grade 4; 2 per cent grade 5, and none used grade 6.

The mean grading of 2·8 for 16-mm film is 'unacceptable', since 9 per cent of observers used grade 4, 4 per cent used grade 5, none used grade 6.

The mean grading of 1·9 for 35-mm cinematograph pictures shows a marked improvement over 16-mm, particularly as only 2 per cent of observers used grade 4 and none used grade 5 or 6.

The difference in the assessments for 35-mm and 16-mm films is due entirely to the better quality of the 35-mm film itself.

The mean grading of 2·5 for camera is on the margin of 'favourable', but since 12 per cent of observers used grade 4, and 2 per cent used grade 5, this characteristic of the camera pictures is 'unacceptable'.

(c) Misregistration (Characteristic F)

This feature, and the two others which follow, will be discussed only in relation to the 'programme' transmissions, since they appear to be of much importance only in respect of camera pictures.

TABLE 10

	Slide	*16-mm Cinematograph Pictures*	*35-mm Cinematograph Pictures*	*Camera*
Mean Grading	1·9	1·9	1·7	2·6

The mean grading of 1·9 for the slide is 'favourable'. Only 3 per cent of observers used grade 4, none used grade 5 or 6.

The mean grading of 1·9 for 16-mm cinematograph pictures is also 'favourable'. The percentage of observers using grades 4, 5, and 6 is negligible.

The mean grading of 1·7 for 35-mm cinematograph pictures is approaching 'very favourable'; no observers used grade 4, 5, or 6. The fact that 35-mm film was graded higher than either the slide or the 16-mm on misregistration shows that the assessment of observers is to some degree influenced by either the better all-round picture quality or by the programme interest of the particular film.

The mean grading of 2·6 for the camera is 'unacceptable', since 15 per cent of observers used grade 4 and 2 per cent grade 5. The question of camera misregistration will be referred to later.

(d) Picture Sharpness (Characteristic J)

TABLE 11

	Slide	*16-mm Cinematograph Pictures*	*35-mm Cinematograph Pictures*	*Camera*
Mean Grading	2·0	2·5	1·9	2·5

The mean grading of 2·0 for the slide is 'favourable'. One per cent of observers used grade 4; none used grade 5 or 6.

The mean grading of 1·9 for 35-mm cinematograph pictures is also 'favourable', and no observers used grade 4, 5, or 6. The slight improvement shown by the 35-mm cinematograph pictures in comparison with the slide again shows the influence of the interest in the programme material on observers' judgement, since the 35-mm film is not quite as sharp at the transmitting end as are the slides.

The mean grading of 2·5 for 16-mm cinematograph pictures is 'acceptable', since 7 per cent of observers used grade 4 and none used grade 5 or 6.

The mean grading of 2·5 for the camera is 'acceptable', since 8 per cent of observers used grade 4, 2 per cent grade 5, and none used grade 6.

(e) Noise (Characteristic D)

TABLE 12

	Slide	*16-mm Cinematograph Pictures*	*35-mm Cinematograph Pictures*	*Camera*
Mean Grading	1·4	1·5	1·4	1·8

The mean grading of 1·4 for the slide is 'very favourable'. No observers used grade 4, 5, or 6.

The mean grading of 1·5 for 16-mm cinematograph pictures is 'very favourable'. Only 3 per cent of observers used grade 4; none used grade 5 or 6.

The mean grading of 1·4 for 35-mm cinematograph pictures is also 'very favourable'; 1 per cent of observers used grade 4 and none used grade 5 or 6.

The mean grading of 1·8 for camera pictures is 'favourable', but nevertheless 12 per cent of observers used grade 4, 1 per cent grade 5, and none grade 6. The high mean grading results from the fact that a large percentage of observers placed their score in grade 1. This is a characteristic to which individual observers appeared to have markedly different reactions.

(f) Other Features of the Colour Picture

Complete results for the mean gradings and for the percentage of observers using grades 4, 5, and 6 are given in Appendices V and VII. Some of the features which have not already been mentioned will be briefly discussed.

The 'Technical' Transmissions

Statistical analysis has shown that brightness, sharpness, and misregistration are the features (in addition to colour rendering) which affect the overall assessments quoted by the observers. None of the other features correlates significantly with the overall assessment, and further, the mean gradings of almost all of them are in the 'very favourable' category. An exception to this is the achromaticity of the grey scale (I) which has a grading of 2·97 in Part 1(a) and 2·41 in Part 1(b). This change must be attributed to improved instrumentation both as regards the transmitter and receiver. Neither dot crawl nor cross-colour is a feature causing any significant deterioration of the colour pictures. These are two features which are characteristic of the N.T.S.C. system (but not necessarily of other colour systems) which might have caused deterioration of picture quality, but they have now been proved to have very little effect on the overall assessment.

With reference to the three features quoted above (brightness, sharpness, and misregistration), the mean gradings are in the 'favourable' category, which means that although improvement in them is desirable, they do not (even at the present state of the art) cause much degradation and each feature can be regarded as 'favourable'. It is of interest to note that brightness and misregistration are features for which the display tube is responsible and not the particular system of colour television.

The 'Programme' Transmissions

The mean gradings of the features of the colour pictures, other than the five discussed above, all fall below with two exceptions.

The first of these is the visibility of crawling dots (Characteristic A), in the case of the slide which has a mean grading of 2·2. The very marked improvement to mean gradings of 1·2 and 1·3 for the film and camera pictures shows that this feature is unlikely to be troublesome when the transmitted picture is moving and has programme interest. The other exception is in the mean gradings of the contrast range (Characteristic L), of the slide, film, and camera pictures which are all just over 2·0. The relatively slight deficiency in contrast range is almost certainly due to the failure, in this respect, of the display tube in the receiver. The number of observers using grades 4, 5, and 6 for any features of the pictures discussed in this paragraph was nowhere greater than 10 per cent of the total observers. The results in this respect are summarized in Appendix VII.

(g) Consideration of the Deficiencies of the Camera Picture

Although the camera pictures have an overall assessment which is 'acceptable' it is clear that certain features of these pictures are quite severely criticized. A brief discussion of these features follows.

(h) Noise (Characteristic D)

Although the mean grading (1·8) of the noise associated with camera pictures is 'favourable', 13 per cent of observers placed their score in grades 4, 5, and 6. This is counter-balanced by a large number of observers (57 per cent) placing their comment in grade 1. An examination of the results shows that observers assessed the camera pictures as being particularly noisy on two occasions, viz. 29 March and 10 May. If these two occasions are excluded, about 8 per cent of observers placed their comments in grades 4, 5, and 6 on all other occasions.

There is no doubt that the N.T.S.C. system sometimes worsens the appearance of pictures which are 'noisy' at the picture source. The magnitude of this effect has not been assessed but the results for film and slide, and for the majority of the camera pictures, show that it is not a fundamental difficulty. Moreover, camera tubes can be expected to improve in this respect.

(i) Misregistration (Characteristic F)

This feature of the camera pictures aroused the most unfavourable criticism of all, giving a mean grading of 2·6, with 15 per cent of observers placing their comments in grades 4, 5, and 6. This problem is not one which is associated with the N.T.S.C. system but would apply to any colour system using the cameras and display devices at present available. The cause of this criticism is not, of course, exclusively the studio camera. The mean gradings of 1·9 and 1·8 respectively for the slide and film show that the receiver makes a significant contribution since no registration problem exists at the transmitting end in the case of these pictures. This is the familiar case of two similar distortions adding together to give an unacceptable answer. It can be expected that improvements in both the camera and receiver will take place as the state of the art advances.

(j) Colour Rendering (Characteristic H)

The mean grading of 2·5 and a total of 14 per cent of observers using grades 4 and 5 make this feature of the camera pictures 'unacceptable'. An examination of the results on individual dates shows that there is a marked fluctuation in both the mean grading and in the number of observers using grades 4 and 5. On two occasions, 27 March and 3 April, 40 per cent of observers used grades 4 and 5; this percentage was not approached on any other occasion on which a sufficient number of valid forms were returned to make the assessment significant.

This is undoubtedly a difficult characteristic for observers to assess without being influenced by other factors. In any colour assessment where direct comparison between the original and the reproduction is not possible, an observer's opinion of fidelity of colour reproduction must be, to some extent, merely a guess and be strongly influenced by what he thinks the scene should look like. Although this is a perfectly valid criticism of the colour picture from the individual observer's point of view, he may well be criticizing the work of the producer and set designer rather than the technical performance of the colour system. It may be significant that the same programme was radiated on both occasions referred to above and consisted of a cookery demonstration in a modern highly-coloured kitchen which many people might consider to be quite unrealistic.

It is unlikely that the N.T.S.C. system played any significant part in affecting the fidelity of the colour rendering.

(k) Picture Sharpness (Characteristic J)

Observers consider that the sharpness of the camera pictures is 'acceptable'. The N.T.S.C. system introduces a small loss of sharpness. As the results for film and slides show, the remedy lies in improving the sharpness of the original camera picture.

(l) Comparison of Performance of 35-*mm and* 16-*mm Film*

The effect on the mean gradings of the change from 16-mm to 35-mm film is summarized in Table 13 for the more important characteristics. Between 4 January and 5 April 16-mm film was radiated on fourteen occasions; 140 questionnaires containing valid answers were used in the assessment. Between 17 April and 17 May, 35-mm film was radiated on seven occasions; ninety questionnaires containing valid answers were used in the assessment.

It can be seen that the 35-mm film has achieved the highest rating of any of the pictures and is considered to be better in all respects than the slide. An insignificant percentage of observers placed their replies to any of the questions in grades 4, 5, and 6. The improvement as compared with 16-mm is most striking. This improvement is wholly due to the better quality of the 35-mm film, *per se*, which was Eastmancolour stock on all occasions. The failings noted by observers in the 16-mm pictures are just those which are always associated with duplicate prints derived from reversal originals.

TABLE 13

Characteristic	*Mean Grading*	
	16-mm Film	*35-mm Film*
D Noise	1·5	1·4
F Misregistration	1·9	1·7
H Fidelity of colour reproduction	2·8	1·9
J Picture sharpness	2·5	1·8
M Overall assessment	2·4	1·8

(m) The Reverse-compatible Picture

TABLE 14

	Cinematograph Pictures		*Slides*	
	Part 1(*a*)	*Part* 1(*b*)	*Part* 1(*a*)	*Part* 1(*b*)
Mean Grading	2·59	2·30	2·50	2·18

(n) Overall Assessment (Characteristic U)

It is desirable that a colour television receiver shall produce satisfactory black-and-white pictures and information on this aspect was obtained in the field trials.

For cinematograph pictures the overall assessment in Part 1(a) was a grading of 2·59 improving to a figure of 2·30 for Part 1(b). The detailed results show that 9 per cent approximately of the observers used grades 4, 5, and 6 in Part 1(a), so that the overall assessment can be described as 'acceptable'. In Part 1(b), 7 per cent of the observers used grades 4, 5, and 6 to describe the overall assessment of the cinematograph picture.

The situation for the slides is also favourable: mean gradings are 2·50 for Part 1(a) and 2·18 for Part 1(b). The detailed results show that 10 per cent approximately used grades 4, 5, and 6 in Part 1(a) and no one used grade 4, 5, or 6 in Part 1(b). Thus, the general reaction to the slides has changed from one which was not quite 'acceptable' to one which is 'favourable'.

(o) Detailed Features of the Reverse-compatible Picture

Statistical analysis has shown that sharpness, achromaticity, and misregistration are the features which affect the judgement of the reverse-compatible picture. The mean gradings for these are all in the 'favourable' class. A criticism that will be of interest is on the subject of contrast range; this was found to be insufficient (i.e. grades 4, 5, and 6) by 16 per cent of the observers in Part 1(a) and 5 per cent in Part 1(b). Nevertheless, the overall reactions are favourable as described above.

(p) Comments on Test 3

The series of experimental colour programmes radiated in the earlier part of 1957 has shown that acceptable colour pictures can be received in the home with the N.T.S.C. system adapted to 405-line scanning standards. Such failings as have been revealed are associated almost exclusively with deficiencies in the present-day camera and receiver. There is no reason to think that these deficiencies would not be reduced by the natural outcome of technical development. The excellent results obtained with 35-mm film are a pointer to the standard which should be achievable from the studio cameras in due course.

4.6.4 *Test 4—Monochrome Control Experiment*

(a) Description of Test

During the period November 1956 to May 1957 the adapted N.T.S.C. colour television system had been subjected to a very searching and detailed examination. It appeared to be relevant to inquire what rating would be obtained if the present-day monochrome television service were subjected to the same kind of critical test. Accordingly, a new questionnaire was designed to see what assessment would be made of the pictures transmitted in the normal BBC television service and received on a high-quality 21-in. commercial receiver. The questionnaire (Appendix VIII) of necessity differs from the colour questionnaire, but it sets out to examine in full detail the known technical imperfections of monochrome television. The programmes chosen for this test were sporting events televised on 20, 21, 24, and 25 June 1957. The test was conducted at Kingswood Warren (as was Test 1) and the observers were allowed half an hour of normal programme in which to work through the questionnaire and give their assessments. A total of seventy-nine observers was used, more than half of whom were non-technical observers; most of the technical observers were not directly connected with work in television.

The conditions of viewing naturally have an effect on

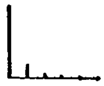
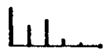
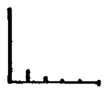
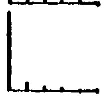
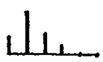
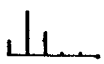
CHARACTERISTIC	MEAN GRADINGS AND HISTOGRAMS Camera Pictures	
A Visibility of scanning lines	2·6	
B Line strobing	1·9	
C Visibility of moirė patterns	1·7	
D Trailing due to movement	1·7	
E Streaking	1·6	
F Transparency effect	1·2	
G Break-up of diagonal lines	2·0	
H Geometrical distortion	2·0	
I Noise	2·6	
J Flicker	2·0	
K Synchronizing troubles	1·2	
L Redistribution effects	2·4	
M Microphony	1·2	
N Sharpness	2·1	
O Brightness	1·8	
P Contrast range	2·2	
Q Tonal gradation	2·2	
R Overall assessment of pictures	2·2	

TABLE 15

Results of Test No. 4

the assessments: for this test, the ambient lighting produced about $\frac{1}{2}$ ft-L at the tube screen and peak-white on the television picture was about 20 ft-L. Observers were seated at distances of four times, six times, and eight times the picture height. Some of those sitting at the nearest distance complained that it was too close for comfortable viewing, so that this distance was not used after the first two days.

These tests refer to only one of several types of television camera tube now in use in the BBC. The type used for all these outside broadcasts was the $4\frac{1}{2}$-in. image orthicon (Mark III) camera channel.

(*b*) *Results of the Test*

Table 15 gives the mean gradings and histograms for the various characteristics. Full details of the percentages of observations in each grade are given in Appendix IX.

The mean gradings will be seen from Table 15 to vary from 1·2 to 2·6. Three characteristics are in the 'very favourable' class, viz., 'transparency effect'* (F), 'synchronizing troubles' (K), and 'microphony' (M). Thirteen characteristics are in the 'favourable' class, viz., 'line strobing' (B), 'visibility of moiré patterns' (C), 'trailing due to movement' (D), 'streaking' (E), 'break-up of diagonal lines' (G), 'geometrical distortion' (H), 'flicker' (J), 'redistribution effects' (L), 'sharpness' (N), 'brightness' (O), 'contrast range' (P), 'tonal gradation' (Q), and 'overall assessment' (R). 'Visibility of scanning lines' (A) is 'acceptable' and 'noise' (I) is 'unacceptable' with 14 per cent of the observations in grades 4, 5, and 6.

The transmissions on 21, 22, 24, and 25 June were not all of the same standard. Thus, the mean grading for the 'overall assessment' (R) for the Ascot programme on 20 June was 1·6 for the observers seated at six times picture height. The day was bright and sunny and the pictures were undoubtedly of very good quality. On 24 June, however, the pictures from Wimbledon were noticeably below the normal standard, mainly because the weather was very dull. On that occasion, the mean grading for the 'overall assessment' (R) was 3·0 with 15 per cent of the observations in grade 4 (viewing distance again at six times picture height). In making any comparisons between the results in Table 15 and those relating to camera pictures from a studio, it should be remembered that Table 15 gives the average results for four outside broadcasts, where lighting conditions were not under the control of the producer.

5. Tests of Compatibility and Assessment of the Results

5.1 *Introduction*

Three series of field trials have been undertaken to test the compatibility aspect of the adapted N.T.S.C. colour television system. The low-power transmitter of 5-kW e.r.p. situated at Alexandra Palace was used in all these trials. The picture source was the combined film and slide scanner. This scanner will accommodate two sizes of slide, but for all the present tests the 3-in. × $2\frac{1}{4}$-in. (76-mm × 57-mm) size of slide was exclusively used because of the better signal-to-noise ratio of the picture thus produced. The tests involving cinematograph pictures were made with a 16-mm Kodachrome print for Series II and III. Series I used the 16-mm test film produced by the Society of Motion Picture and Television Engineers. Any attempt at a final assessment of the compatibility of the adapted N.T.S.C. system on the basis of the cinematograph picture results must take into consideration the limited signal-to-noise ratio of the picture produced from this source and other features where the quality is inferior to that which can be obtained from a 35-mm cinematograph picture or a live pick-up device.†

5.2 *Series I Field Trials* (*Engineer Observers*)

This set of tests took place between 10 October and 18 November 1955, and approximately 500 completed questionnaires were received. Each test consisted of the showing of eleven colour slides, one black-and-white caption, and two showings of the S.M.P.T.E. test film, one with the chrominance signal present and the other without the chrominance signal. During the first ten slides the chrominance signal was switched on and off every fifteen seconds. The observers were asked to assess:

(*a*) 'buzz' on sound
(*b*) dot pattern
(*c*) tonal gradation
(*d*) synchronizing difficulties
(*e*) vertical bars due to colour 'burst'

One particular slide was used to find whether the 800 kc/s beat pattern between the sound carrier and the chrominance signal was visible. The sound carrier was switched on and off every fifteen seconds for this test. The black-and-white caption was used as a chrominance 'burst' test card.

The effects (*a*) to (*e*) were also assessed during the cinematograph film with the chrominance signal on, whilst the change in tonal gradation was assessed when the film was repeated without the chrominance signal.

Series I tests were intended to give a fairly quick appraisal of the acceptability of the compatible black-and-white picture and for this reason only three descriptions of each effect were permitted. These were 'negligible', 'tolerable', and 'intolerable'.

The percentage of observers using the classification 'intolerable' was considered to be rather high and the query naturally arose as to whether some observers had given proper thought to, or even understood, the question when giving an answer in the 'intolerable' category. Some further checks on this matter raised considerable doubts

* This effect relates principally to photoconductive tubes and is most noticeable when a dark object moves in front of a bright background: under these conditions the dark object fails to obscure the background and hence appears transparent to some extent.

† The signal-to-noise ratio of the scanner for 16-mm film is −25 to −26 dB, and for 3-in. × $2\frac{1}{4}$-in. slides it is −34 to −35 dB r.m.s. noise to d.a.p. signal.

about a significant proportion of the 'intolerable' classifications. It was therefore decided to run a further set of tests.

Three specific results which emerged from the Series I tests were:

1. There is no marked preference for the tonal gradation with or without the chrominance signal.
2. The number of genuine cases of the presence of the 800 kc/s beat pattern between the sound carrier and the chrominance signal is very small and the effect can be regarded as virtually non-existent.
3. The troubles due to asynchronous working are serious and must be dealt with as a separate problem.[5] [6]

On the subject of the technique of subjective testing, the decision was taken that any future tests should use a more detailed set of gradings to describe the effects—these will be described in the Series II tests.

The analysis of the completed questionnaires showed that approximately 20 per cent of the viewers found one or more features of one or more of the pictures 'intolerable'. The results for 485 questionnaires together with a subdivision of the effects causing the 'intolerable' classification are given in Table 16.

TABLE 16

	Number	*Per cent*
Questionnaires in which all answers were 'negligible'	157	32·4
Questionnaires in which one or more answers were 'tolerable'	228	47·0
Questionnaires in which one or more answers were 'intolerable'	100	20·6
Analysis of the 100 'intolerables'		
Buzz on sound	14	3·0
Visibility of dot pattern	49	10·0
Synchronizing troubles	9	1·9
Visibility of 'burst'	7	1·4
800 kc/s beat pattern	6	1·2
Asynchronous working	29	6·0

5.3 *Series II Field Trials (Engineer Observers)*

The grading used in these trials was the same as that used for interfering effects in the colour performance trials, and 624 completed questionnaires were received.

The material for the test consisted of five colour slides, one black-and-white caption, and a showing of a 16-mm reversal positive colour film (South African travel film—'Durban Diary'). The slides were all moderately to highly saturated (unlike the Series I test where both saturated and desaturated slides were used). No questions were asked about either tonal gradation or the 800 kc/s beat pattern as the Series I tests had shown these questions to be unnecessary. The question on asynchronous working was also omitted because there is little doubt that one or other of the proposed schemes for overcoming its effects will have to be used.

(*a*) *Results for Cinematograph Pictures*

TABLE 17

PERCENTAGE OF OBSERVERS

Grade	*All Effects*		*Individual Effects*		
	Least Favourable Grading	*Buzz*	*Dots*	*Synch. Troubles*	*Chrominance Burst*
1	52·5	90·4	67·1	93·2	86·7
2	26·5	7·2	18·5	3·5	9·9
3	14·9	1·6	10·6	1·6	2·9
4	4·8	0·8	2·7	1·4	0·5
5	1·3	0	1·1	0·3	0
6	0	0	0	0	0

100 per cent = 624 observers

The column 'least favourable grading' is based on the lowest grade used by each individual observer, irrespective of the effect to which he ascribed this grade. It is clear that the dots due to the presence of the chrominance signal are the most serious feature, since they are placed in grade 4, 5, or 6 by 3·8 per cent of the observers, which is more than half of the 6·1 per cent of observers who used these gradings for any of the effects. The gradings on visibility of dots become progressively less favourable with increasing picture size, if subdivided on this basis. The correlation coefficient between visibility of dots and picture height is 0·278.

There is an even closer correlation coefficient of 0·347 between visibility of dots and observed resolution of the 2·5 Mc/s bar on the Test Card, and a correlation of 0·168 between 2·5 Mc/s resolution and picture height. The 5 per cent significance level for the number of questionnaires analysed is reached by a correlation coefficient of 0·088: the 1 per cent level requires a coefficient of 0·116. These correlations show that the increased visibility of dot patterns is linked with the better resolution of the larger (and newer) sets. This raises the point as to whether it would be desirable to include a notch filter in the design of future 21-in. (53-cm) monochrome receivers.

(*b*) *Results for Static Slides (Average Gradings)*

The results for the colour slides are judged on average* gradings. Since all the slides were of moderate to high

* Average grade for a given effect is the sum of the gradings divided by the number of slides.

Maximum grade for a given effect is the most unfavourable grading quoted for that effect.

saturation, the average values should give a good indication of the observer reactions to this kind of slide. Each questionnaire was dealt with individually and the average score for each effect (viz. 'buzz', dots, synchronizing troubles, and vertical lines due to 'burst' on flyback) was written on the questionnaire. The 624 questionnaires were then analysed in a similar manner to that described for the cinematograph picture results. Table 18 gives the results numerically.

TABLE 18

RESULTS FOR SLIDES: AVERAGE GRADINGS

PERCENTAGE OF OBSERVERS

Grade	*All Effects*		*Individual Effects*		
	Least Favourable Average Grading	*Buzz*	*Dots*	*Synch. Troubles*	*Chrominance Burst*
1	53·6	80·8	68·4	96·4	96·3
2	28·0	11·0	21·4	2·6	3·2
3	13·6	6·6	7·4	0·3	0·3
4	3·0	0·8	2·2	0·2	0
5	1·8	0·8	0·6	0·5	0·2
6	0	0	0	0	0

(*c*) *Results for Static Slides* (*Maximum Gradings*)

If the gradings given to the slides are analysed on the maximum grading given to any particular effect (maximum maximorum), a new set of results is obtained as shown in Table 19.

TABLE 19

RESULTS FOR SLIDES: MAXIMUM GRADINGS

PERCENTAGE OF OBSERVERS

Grade	*All Effects*		*Individual Effects*		
	Least Favourable Maximum Grading	*Buzz*	*Dots*	*Synch. Troubles*	*Chrominance Burst*
1	32·6	77·6	54·8	93·9	75·2
2	31·2	12·6	23·7	3·7	15·0
3	23·2	7·7	13·8	1·1	7·2
4	8·2	0·8	5·4	0·5	1·8
5	4·2	1·3	2·1	0·3	0·8
6	0·6	0	0·2	0·5	0

(*d*) *Slides and Cinematograph Picture* (*Maximum Grading*)

This set of results is exactly analogous to the elementary analysis that was performed on the Series I tests and it is of interest to know whether there is any similarity in the results of the two sets of tests. Table 20 is constructed in a similar manner to Table 16, although it is not to be inferred that the word 'intolerable' is equivalent to the use of all categories higher than and including No. 4.

TABLE 20

	Number	*Per cent*
Questionnaires using grade 1 only	187	29·9
Questionnaires using grades 1 and 2 or 1, 2, and 3	345	55·4
Questionnaire using grades above 3 to describe at least one effect	92	14·7
Analysis of the 92 Questionnaires		
Buzz on sound	15	2·4
Visibility of dot pattern	54	8·6
Synchronizing troubles	15	2·4
Visibility of 'burst'	15	2·4

Despite the fact that no claim is made as to the equivalence of one set of gradings in terms of the others, the percentages in Table 20 are not unlike those in Table 16. The similarity would have been greater if asynchronous running troubles had been reported in the Series II tests. These alone accounted for 6 per cent of the 'intolerables' in Series I tests. Thus the results of Series I and II are in good general agreement if the category 'intolerable' for Series I is treated as the sum of grades 4, 5, and 6, i.e. those grades describing some measure of objection to the interference. It would appear that there is no substantial disagreement between the two series of trials but the second series had the virtue of being more easy to subject to analysis, both from the point of view of layout of the questionnaire and the number of gradings which could be used in describing the effects.

5.4 *Tests using the General Public as Observers*

General Description

The Series I and II tests described above have the limitation of using one class of observer exclusively, viz. physicists or engineers. It could be that the reactions of this one class of observer are unduly critical, or, to say the least, that the reactions are not typical of the general public. To overcome this difficulty, the assistance of the BBC Audience Research Department was obtained to design and send out questionnaires to about 1,200 members of the viewing panel in the London area. The questionnaires and tests were specifically designed for the general public and differed materially from the tests used with the scientific staff. Each interference effect was explained and illustrated and then the observers were asked to state whether version A or version B (one of which contained the chrominance signal) of a particular slide showed the effect and, if so, to assess its magnitude or annoyance. Five slides were used for the 'buzz' interference effect, a further five slides for the dot pattern effect, and three slides for the vertical bars due to chrominance 'burst'. The order of showing the picture containing the chrominance signal was random, i.e. it was equally likely for the A or B version to be the one containing the chrominance signal. The purpose of this was to check whether the observer had properly understood the particular kind of interference about which the question was asked. It will be observed that, after the static slides, a 16-mm cinematograph film was shown and a general assessment was requested. The film was divided into two parts, one of which included the chrominance signal; the other part did not include the chrominance signal. Any change of grading between the first and second parts of the film must be due to the removal of the chrominance signal—provided that the general interest value in the two parts is not appreciably different.

This test for the general public was also done by a small group of engineers numbering 113. This provides a direct answer to the question 'are engineers more critical than the general public?' The results for these tests will be quoted for a sample of 424 general public and 113 engineers. 61·3 per cent of the public and 64·5 per cent of the engineers rate the film with and without chrominance in the same grading. The balance of those assessments giving a higher or lower grading, on the removal of the chrominance signal, is slightly in favour of the presence of chrominance in the case of the general public, and slightly against it in the case of the engineers.

Neither the engineers nor the general public appear to have strong opinions on the merits of the signal with or without the chrominance information, and this could be taken as a favourable reaction towards the compatibility of the adapted N.T.S.C. colour television system.

Results on cinematograph pictures for the general public and the engineer sub-group are shown in Tables 21 and 22 respectively:

TABLE 21

RESULTS FOR CINEMATOGRAPH PICTURES (GENERAL PUBLIC)

(424 OBSERVERS)

	Change in Assessment on removing Chrominance Signal No. of grades change							
	−3	−2	−1	0	+1	+2	+3	*Ungraded*
Number of Questionnaires	2	9	90	256	58	3	0	6
Percentages	0·5	2·1	21·5	61·3	13·9	0·7	0	

A positive change indicates preference for absence of chrominance signal.

TABLE 22

RESULTS FOR CINEMATOGRAPH PICTURES

(113 ENGINEERS)

	Change in Assessment on removing Chrominance Signal No. of grades change							
	−3	−2	−1	0	+1	+2	+3	*Ungraded*
Number of Questionnaires	0	4	9	69	23	2	0	6
Percentages	0	3·7	8·4	64·5	21·5	1·9	0	

A positive change indicates preference for absence of chrominance signal.

Results for Slides

In contrast to the Series II engineers' test, it is not possible in this case to make a comparison between the average gradings for slides and the grading of the cinematograph picture because only a general assessment was required of the latter. The results for the slides are given in numerical form in Table 23 for the general public, and Table 24 for the engineers. It should be noted that some questionnaires have been labelled 'unreliable'. This comment applies for a given effect to any questionnaire with more than one mistake in placing the A's or B's. The percentages do not include the 'unreliable' answers.

TABLE 23

RESULTS FOR SLIDES (GENERAL PUBLIC)

(424 OBSERVERS)

Grade	*All Effects*				*Individual Effects*					
	Least Favourable Average Grade		*Buzz*		*Dots*		*Chrominance Burst*		*Synch. Troubles*	
	Number	*Per cent*	*Number*	*Per cent*	*Number*	*Per cent*	*Number*	*Per cent*	*Number*	*Per cent*
1	331	78·0	382	94·8	349	86·2	378	93·1	369	
2	67	15·8	17	4·2	35	8·6	26	6·4	23	
3	21	5·0	4	1·0	16	3·9	2	0·5		
4	5	1·2	0	0	5	1·2	0	0		
Unreliable	0		21		19		18		32	

TABLE 24

RESULTS FOR SLIDES (AVERAGE GRADINGS)

(113 ENGINEERS)

Grade	*All Effects*				*Individual Effects*					
	Least Favourable Average Grade		*Buzz*		*Dots*		*Chrominance Burst*		*Synch. Troubles*	
	Number	*Per cent*	*Number*	*Per cent*	*Number*	*Per cent*	*Number*	*Per cent*	*Number*	*Per cent*
1	72	63·8	108	97·3	76	69·0	105	95·5	96	95
2	28	24·8	2	1·8	23	21·0	4	3·6	5	5
3	10	8·8	0	0	9	8·2	1	0·9		
4	3	2·6	1	0·9	2	1·8	0	0		
Unreliable	0		2		3		3		12	

The 'unreliable' questionnaires are those which had more than *one* mistake in placing 'A' or 'B' for a specific effect. The thirty-two listed under synch. troubles did not mark the appropriate part of the questionnaire.

It will be seen that 1·0 per cent of the observers (general public) place the 'buzz' in grades 3 and 4. Note that there are only four grades for the general public test:

Grade 1=imperceptible

Grade 2=slightly louder ('buzz') not annoying (dots and 'burst')

Grade 3=moderately louder ('buzz') moderately annoying (dots and 'burst')

Grade 4=very much louder ('buzz') very annoying (dots and 'burst')

Synchronizing troubles are allotted only two grades and are either absent or present (1=absent 2=present). The 'unreliable' questionnaires are those which had more than *one* mistake in placing 'A' or 'B' for a specific effect. The twelve listed under synch. troubles did not mark the appropriate part of the questionnaire.

It will be seen from comparison of Tables 23 and 24 that the engineer sub-group uses a higher percentage of the two lower grades, particularly in the assessment of dots. This is partly because a higher proportion of the engineer-observers used 21-in. (53-cm) receivers.

Although information on the picture height was requested, the figures given by the general public were unreliable. It would appear that many quoted the picture tube diagonal, so that no reliable statistics on picture heights can be offered for the general public.

The figures from the engineer sample, however, confirm the results of the other trials in showing a higher percentage of unfavourable gradings for dot visibility as picture size increases. This reinforces the doubts as to whether the adapted N.T.S.C. system can be regarded as fully compatible unless a notch filter is included in the larger receivers.

6. Conclusions

Although the results obtained from the earlier tests described in this monograph were not entirely conclusive because of imperfections in the design and operation of the equipment, the later tests have shown that the most noticeable defects were not inherent in the system itself. As a result of these later tests the BBC has formed the opinion that the system described is capable of giving acceptable results in terms of compatibility, reverse compatibility, and the quality of the colour picture.

The field trials described in this monograph extended over a total period of seventeen months and involved the analysis of over 1,000 completed questionnaires. For the purposes of the trials some forty transmissions were made from the standby transmitter at Alexandra Palace, forty-five from the Kingswood experimental transmitter, and fifty-five scheduled transmissions from the Crystal Palace high-power transmitter. These figures do not include the 1957–8 trials recently completed.

The Colour Picture

The field trials of the performance of the systems in terms of pictures in colour involved the completion of over 500 questionnaires over a period of six months. Analysis of the results has shown that the colour pictures produced by the N.T.S.C. system as adapted to 405 lines, with the picture sources and display tubes that are at present available, are satisfactory. The detailed results show that although the colour pictures were barely acceptable at the beginning of the tests (i.e. November and December 1956) the later results, in all cases except one, show 'favourable' mean gradings with only small percentages of observations in grades 4, 5, and 6. The one exception relates to 'misregistration' arising from the colour camera where the result is 'unacceptable'. Those features that are specifically related to the method of coding adopted in the N.T.S.C. system show mean gradings which are at the worst 'favourable' and in many cases are 'very favourable', and certain features of the display tube could with advantage be improved (e.g. 'picture sharpness', 'registration', 'picture brightness') and the problem of registration with the three-tube colour camera requires attention: but the BBC considers that the technical performance of the system is adequate for the launching of a colour-television service in the frequency bands at present in use.

A survey of the results of the 'programme' tests radiated from the Crystal Palace transmitter shows that:

98 per cent of the observers regarded the slide as satisfactory*

93 per cent of the observers regarded 16-mm film as satisfactory

100 per cent of the observers regarded 35-mm film as satisfactory

89 per cent of the observers regarded the camera picture as satisfactory.

The Reverse-compatible Picture

Although of secondary importance, it is nevertheless a very desirable property of a colour television receiver to be able to produce satisfactory reverse-compatible pictures. Whilst the standard of monochrome pictures produced by a colour receiver is (with present-day colour displays) somewhat lower than that of a receiver designed for black-and-white transmissions, the detailed results show that the reverse-compatible picture is generally satisfactory. The results of Test 3, Part 1 (the 'scientific' test radiated from the Crystal Palace transmitter) show that:

91 per cent of the observers regarded the slides as satisfactory

91 per cent of the observers regarded the 16-mm films as satisfactory.

The Compatible Picture

If the average gradings are taken as being most truly representative of the standard of reception of colour transmissions on monochrome receivers, then the following conclusions can be drawn:

1. The only likely cause of difficulty with the adapted N.T.S.C. colour television system is the dot interference pattern caused by the chrominance signal. Other effects are present to a much less extent and can almost be ignored.
2. With the present distribution of sizes of receiver tube, approximately 94 per cent of technical observers find the pictures completely acceptable, 98 per cent are prepared to accept them with some reservations and 2 per cent find one effect or other not acceptable. This state of affairs is favourable towards the introduction of this colour system.
3. For 21-in. receivers exclusively, the figures are 87 per cent completely acceptable, 93 per cent acceptable with reservations, and 7 per cent unacceptable. This implies that as more people acquire 21-in. and larger receivers, the acceptability of the compatible picture may become more questionable.
4. If the larger receivers are not to become an obstacle to the introduction of this type of colour system, a notch filter is essential.
5. The general public appear to have a slight preference for cinematograph pictures which include the chrominance signal, as compared with those transmitted in monochrome.
6. Asynchronous working may give rise to certain difficulties and means may have to be found either of overcoming them or of running colour transmissions locked to the mains supply frequency.
7. As studio cameras were not available at the time of the compatibility trials, it is desirable that further tests should be made with monochrome receivers on live camera features, in order to provide information on the possible effects of misregistration on the compatible picture.

Overall Conclusion

These conclusions show that promising results have been obtained from this extended series of tests, but further experimental work will be done to resolve the outstanding problems connected with the display devices and some of the picture-signal sources.

* The interpretation of 'satisfactory' is that the rating is in grade 1, 2, or 3.

7. References

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APPENDIX I

EXPERIMENTAL COLOUR PROGRAMME QUESTIONNAIRE

Name ....

Address ....

....

Make of set ....

Model No. ....

Picture width in inches (measured) — Under 12" / 12"–16" / Over 16"
(state exact width but place in appropriate square)

Viewing distance (feet) ....

Line visibility at this viewing distance (use score of scale 1 below)

Quality of interlace (use score of scale 2 below)

Lighting conditions (tick here): dark / soft lighting / normal room lighting

Approx. distance from transmitter (miles) ....

Date of viewing ....

Fill in this part while the colour signal is present (indicated by star in top right hand corner)

	Characteristic	Scale to be used	Slide Number 1	2	3	4	Film Moving Pictures	Any Comments
A	Visibility of crawling dots	1						
B	Colour synchronizing difficulties	1						
C	Colour trailing due to movement	1						
D	Noise	1						
E	Multiple image effects	1						
F	Misregistration (presence of colour fringes)	1						
G	Cross-colour	1						
H	Fidelity of colour reproduction	2						
I	Achromaticity of the grey scale	2						
J	Picture sharpness	2						
K	Picture brightness	2						
L	Contrast range	2						
M	Overall assessment of colour picture (including all the above effects)	2						

Fill in this part when there is NO colour signal

	Characteristic	Scale to be used	Slide Number 1	2	3	4	Film Moving Pictures	Any Comments
N	Colour trailing due to movement	1						
O	Noise	1						
P	Multiple image effects	1						
Q	Misregistration (presence of colour fringes)	1						
R	Achromaticity of the picture	2						
S	Picture sharpness	2						
T	Contrast Range	2						
U	Overall assessment of the black and white picture (including all the above effects)	2						

Please keep to your stated viewing distance (except for observing resolution of Test Card "C")

Black and White Resolution of Test Card "C"

2 Mc/s	2·5 Mc/s	3·0 Mc/s

(Score 1-6 see scale 2 below; 1 = excellent, 6 = very poor etc.)

Time taken to line up the set hours......

Was the set readjusted during the transmission (tick here): Yes / No

If so, state how many times.....

Scale 1	Score
imperceptible	1
just perceptible	2
definitely perceptible but not disturbing	3
somewhat objectionable	4
definitely objectionable	5
unusable	6

Scale 2	Score
excellent	1
good	2
fairly good	3
rather poor	4
poor	5
very poor or absent	6

APPENDIX II

EXPERIMENTAL COLOUR PROGRAMME QUESTIONNAIRE

Name ....
Address ....
....
Make of set ....
Model No. ....

Picture width in inches (measured) — Under 12" | 12"-16" | Over 16"
(state exact width but place in appropriate square)
Viewing distance (feet).............................
Line visibility at this viewing distance ☐
(use score of scale 1 below)
Quality of interlace ☐
(use score of scale 2 below)

Lighting conditions (tick here): dark ☐ / soft lighting ☐ / normal room lighting ☐

Approx. distance from transmitter (miles) ....
Date of viewing ....

Characteristic	Scale to be used	Slide	Film Moving Pictures	Camera Pictures	Any Comments
A Visibility of crawling dots	1				
B Colour synchronizing difficulties	1				
C Colour trailing due to movement	1				
D Noise	1				
E Multiple image effects	1				
F Misregistration (presence of colour fringes)	1				
G Cross-colour	1				
H Fidelity of colour reproduction	2				
J Picture sharpness	2				
K Picture brightness	2				
L Contrast range	2				
M Overall assessment of colour picture (including all the above effects)	2				
Did you think that colour added interest to the programme?					
Any other comments.					

Black and White Resolution of Test Card "C"

2 Mc/s	2·5 Mc/s	3·0 Mc/s

(Score 1-6 see scale 2 below 1 = excellent 6 = very poor etc.)

Time taken to line up the set hours....

Was the set readjusted during the transmission (tick here): Yes ☐ No ☐

If so, state how many times.....

Scale 1	Score
imperceptible	1
just perceptible	2
definitely perceptible but not disturbing	3
somewhat objectionable	4
definitely objectionable	5
unusable	6

Scale 2	Score
excellent	1
good	2
fairly good	3
rather poor	4
poor	5
very poor or absent	6

Please keep to your stated viewing distance (except for observing resolution of Test Card "C")

Please return the completed questionnaire to Head of Designs Department.

APPENDIX III

DETAILED RESULTS OF TEST 1

	CHARACTERISTIC	PERCENTAGE OF OBSERVERS IN EACH GRADE FOR EACH CHARACTERISTIC																							
		BBC Receiver												Commercial Receiver											
		16 mm film						Slides						16 mm film						Slides					
		Grade						Grade						Grade						Grade					
		1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
COLOUR PICTURE	A Visibility of crawling dots	64	14	11	7	4	0	59	13	17	3	8	0	59	14	24	3	0	0	79	15	6	0	0	0
	B Colour synchronising difficulties																								
	C Colour trailing due to movement	61	26	9	4	0	0	/	/	/	/	/	/	59	33	8	0	0	0	/	/	/	/	/	/
	D Noise	14	24	40	19	3	0	49	33	16	2	0	0	50	21	25	4	0	0	87	9	0	4	0	0
	E Multiple image effects																								
	F Misregistration	19	38	24	19	0	0	23	39	19	17	2	0	21	31	34	14	0	0	26	35	34	5	0	0
	G Cross-colour	62	25	13	0	0	0	61	20	16	3	0	0	72	21	7	0	0	0	73	17	3	6	1	0
	H Fidelity of colour reproduction	8	27	31	15	19	0	9	46	27	17	1	0	11	32	32	18	7	0	15	49	30	6	0	0
	I Achromaticity of the grey scale	/	/	/	/	/	/	0	28	32	16	24	0	/	/	/	/	/	/	0	38	23	35	0	4
	J Picture sharpness	14	50	25	11	0	0	14	62	17	6	1	0	13	50	37	0	0	0	9	50	30	10	1	0
	K Picture brightness	29	46	18	7	0	0	39	49	11	1	0	0	30	40	23	7	0	0	29	53	18	0	0	0
	L Contrast range	/	/	/	/	/	/	15	22	48	11	4	0	/	/	/	/	/	/	7	41	34	11	7	0
	M Overall assessment	8	35	42	15	0	0	4	57	35	4	0	0	11	45	35	11	0	0	7	66	26	1	0	0
REVERSE-COMPATIBLE PICTURE	N Colour trailing due to movement	71	25	0	4	0	0	/	/	/	/	/	/	74	26	0	0	0	0	/	/	/	/	/	/
	O Noise	32	50	18	0	0	0	66	22	6	5	1	0	73	24	3	0	0	0	77	19	1	3	0	0
	P Multiple image effects																								
	Q Misregistration	39	25	25	11	0	0	33	48	14	4	1	0	23	30	34	13	0	0	9	36	33	20	2	0
	R Achromaticity of the picture	26	37	30	7	0	0	25	37	29	6	3	0	10	52	24	14	0	0	12	34	37	16	1	0
	S Picture sharpness	24	45	31	0	0	0	15	55	23	7	0	0	7	62	28	3	0	0	2	38	45	14	1	0
	T Contrast range	/	/	/	/	/	/	18	39	32	11	0	0	/	/	/	/	/	/	15	44	26	8	7	0
	U Overall assessment	18	53	25	4	0	0	13	64	14	9	0	0	3	53	37	7	0	0	2	31	53	13	1	0

The figures for slides are the averages for Slides 2,3 & 4 except for characteristics I,L & T where the results are for Slide 1 only. No distribution is given for B,E & P because these effects were non-existent for Test 1. A nominal grading of 1·0 has been inserted in Table 3 for these characteristics.

APPENDIX IV

DETAILED RESULTS OF TEST 2

	CHARACTERISTIC	PERCENTAGE OF OBSERVERS IN EACH GRADE FOR EACH CHARACTERISTIC											
		16 mm film						Slides					
		Grade 1	2	3	4	5	6	Grade 1	2	3	4	5	6
COLOUR PICTURE	A Visibility of crawling dots	27	60	12	1	0	0	21	44	27	8	0	0
	B Colour synchronising difficulties	99	1	0	0	0	0	91	2	0	0	0	7
	C Colour trailing due to movement	31	49	20	0	0	0						
	D Noise	0	13	36	29	21	1	6	35	26	18	15	0
	E Multiple image effects	37	36	16	10	1	0	38	38	20	4	0	0
	F Misregistration	6	46	41	7	0	0	7	62	30	1	0	0
	G Cross-colour	17	47	33	3	0	0	23	40	31	6	0	0
	H Fidelity of colour reproduction	0	3	54	33	10	0	1	43	29	23	3	1
	I Achromaticity of the grey scale							5	26	38	27	4	0
	J Picture sharpness	0	21	70	9	0	0	1	53	41	5	0	0
	K Picture brightness	14	62	23	1	0	0	25	64	9	2	0	0
	L Contrast range							9	63	19	6	3	0
	M Overall assessment	0	12	56	17	14	1	0	37	43	15	4	1
REVERSE-COMPATIBLE PICTURE	N Colour trailing due to movement	55	29	16	0	0	0						
	O Noise	1	47	29	13	10	0	9	47	28	8	8	0
	P Multiple image effects	42	36	14	8	0	0	39	40	16	5	0	0
	Q Misregistration	5	42	43	10	0	0	12	59	26	3	0	0
	R Achromaticity of the picture	21	53	21	5	0	0	24	60	15	1	0	0
	S Picture sharpness	1	36	56	7	0	0	4	60	32	4	0	0
	T Contrast range							17	67	10	3	3	0
	U Overall assessment	0	37	47	11	5	0	1	62	28	8	1	0

The figures for slides are the averages for Slides 2, 3 & 4 except for characteristics I, L & T where the results are for Slide 1 only.

APPENDIX V

DETAILED RESULTS OF TEST 3, PARTS 1(a) AND 1(b)

	CHARACTERISTIC	PERCENTAGE OF OBSERVERS IN EACH GRADE FOR EACH CHARACTERISTIC																							
		Part 1 (a)												Part 1 (b)											
		16 mm film						Slides						16 mm film						Slides					
		Grade 1	2	3	4	5	6	Grade 1	2	3	4	5	6	Grade 1	2	3	4	5	6	Grade 1	2	3	4	5	6
COLOUR PICTURE	A Visibility of crawling dots	70	21	5	2	0	2	54	24	13	8	1	0	94	6	0	0	0	0	67	33	0	0	0	0
	B Colour synchronising difficulties	91	6	1	2	0	0	81	9	4	3	1	2	97	3	0	0	0	0	87	13	0	0	0	0
	C Colour trailing due to movement	71	19	9	0	1	0	/	/	/	/	/	/	84	10	6	0	0	0	/	/	/	/	/	/
	D Noise	28	16	27	23	6	0	76	18	6	0	0	0	84	10	6	0	0	0	77	23	0	0	0	0
	E Multiple image effects	85	11	4	0	0	0	85	11	3	1	0	0	87	13	0	0	0	0	87	10	3	0	0	0
	F Misregistration	41	44	11	4	0	0	38	40	18	3	1	0	34	50	13	3	0	0	30	60	10	0	0	0
	G Cross-colour	69	16	11	4	0	0	59	20	12	8	1	0	75	25	0	0	0	0	74	23	3	0	0	0
	H Fidelity of colour reproduction	7	16	45	25	6	1	10	42	33	12	3	0	13	56	28	3	0	0	7	63	23	7	0	0
	I Achromaticity of the grey scale	/	/	/	/	/	/	7	24	38	28	3	0	/	/	/	/	/	/	14	38	43	5	0	0
	J Picture sharpness	11	40	40	8	0	1	12	44	36	7	0	1	16	53	28	3	0	0	7	73	17	3	0	0
	K Picture brightness	15	53	26	6	0	0	20	52	24	4	0	0	15	72	10	3	0	0	23	64	13	0	0	0
	L Contrast range	/	/	/	/	/	/	8	39	35	13	5	0	/	/	/	/	/	/	4	78	11	7	0	0
	M Overall assessment	6	16	52	21	5	0	8	40	42	7	2	1	16	62	16	6	0	0	3	70	23	3	0	0
REVERSE-COMPATIBLE PICTURE	N Colour trailing due to movement	73	20	6	1	0	0	/	/	/	/	/	/	80	10	0	7	3	0	/	/	/	/	/	/
	O Noise	52	31	14	2	1	0	82	13	4	1	0	0	94	3	3	0	0	0	93	7	0	0	0	0
	P Multiple image effects	85	12	3	0	0	0	84	12	3	1	0	0	83	17	0	0	0	0	90	7	3	0	0	0
	Q Misregistration	36	40	22	2	0	0	36	41	19	3	1	0	27	47	23	3	0	0	30	50	20	0	0	0
	R Achromaticity of the picture	27	43	21	8	1	0	21	45	23	8	3	0	27	53	20	0	0	0	17	70	10	3	0	0
	S Picture sharpness	12	48	33	5	2	0	13	47	29	10	1	0	27	40	33	0	0	0	10	70	20	0	0	0
	T Contrast range	/	/	/	/	/	/	11	40	33	12	4	0	/	/	/	/	/	/	14	36	45	5	0	0
	U Overall assessment	9	35	46	8	2	0	8	43	38	7	4	0	13	50	30	7	0	0	3	74	20	3	0	0

The figures for slides are the average for Slide 2, 3 & 4 except for characteristics I, L & T where the results are for Slide 1 only.

APPENDIX VI

Application of Statistical Analysis to Results on Reverse-Compatible Pictures in Test 3, Parts 1(a) and 1(b)

The application of statistical analysis to the results for slides in Test 3, Part 1(a), gives rise to the equation:

$$U=0\cdot38\,O+0\cdot36Q+0\cdot48R+0\cdot49S-0\cdot87 \quad \ldots\ldots(9)$$

where U=grading of 'overall assessment'
O=grading of 'noise'
Q=grading of 'misregistration'
R=grading of 'achromaticity'
S=grading of 'sharpness'

This equation gives values of U calculated from the individual characteristics, which correlate with the experimental values with a correlation coefficient of 0·77. The variables in order of importance are, 'sharpness' (S), 'achromaticity' (R), 'noise' (O), and 'misregistration' (Q). These agree with known defects of the reverse-compatible picture, with the exception of 'noise', the presence of which in equation (9) seems to be somewhat anomalous.

The equation for slides in Part 1(b) is:

$$U=0\cdot62R+0\cdot72S-0\cdot55 \quad \ldots\ldots(10)$$

This equation gives a correlation coefficient of 0·79 when the calculated values of U are compared with the observed values. The equation for Part 1(b) is simpler than the corresponding one for Part 1(a) (equation (9)) and it will be observed that the two remaining variables ('sharpness' and 'achromaticity') are the two most important variables in Part 1(a).

The equations for motion pictures for Parts 1(a) and 1(b) are given in equations (11) and (12) respectively.

$$U=0\cdot24R+0\cdot71S+0\cdot53 \quad \ldots\ldots(11)$$

$$U=0\cdot12N+0\cdot45R+0\cdot38S+0\cdot5 \quad \ldots\ldots(12)$$

The correlation coefficient between observed and calculated values of U for equation (11) is 0·79 and for equation (12) is 0·74. 'Sharpness' (S) and 'achromaticity' (R) feature in both equations, although in reversed order of importance; there is the added variable, 'colour trailing due to movement' (N), in equation (12), which slightly influences the results.

The relative importance of the various coefficients in equations (9) to (12) has been evaluated by normalizing the coefficients of each equation and the results are given in Table 25.

TABLE 25

TEST 3, PARTS 1(a) AND 1(b)

Characteristic	*Relative Importance*			
	Motion Picture		*Slides*	
	Part 1(*a*)	*Part* 1(*b*)	*Part* 1(*a*)	*Part* 1(*b*)
O Noise	—	—	22%	—
Q Misregistration	—	—	21%	—
R Achromaticity	25%	47%	28%	46%
S Sharpness	75%	40%	29%	54%
N Colour trailing	—	13%	—	—

APPENDIX VII

DETAILED RESULTS OF TEST 3, PART 2

CHARACTERISTIC	PERCENTAGE OF OBSERVERS IN EACH GRADE FOR EACH CHARACTERISTIC PART 2																	
	Film (16 & 35 mm)						Camera Pictures						Slides					
	Grade						Grade						Grade					
	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
A Visibility of crawling dots	83	13	4	0	0	0	81	12	6	1	0	0	40	18	33	6	2	0
B Colour synchronising difficulties	93	5	2	0	0	0	91	6	2	1	0	0	93	4	3	0	0	0
C Colour trailing due to movement	76	18	5	1	0	0	59	29	10	2	0	0	/	/	/	/	/	/
D Noise	67	24	7	2	0	0	58	13	16	12	1	0	63	30	7	0	0	0
E Multiple image effects	86	11	3	0	0	0	75	15	7	3	0	0	88	10	2	0	0	0
F Misregistration	39	42	16	3	0	0	22	27	34	15	2	0	32	51	14	3	0	0
G Cross-colour	86	13	1	0	0	0	85	12	2	1	0	0	69	20	7	3	1	0
H Fidelity of colour reproduction	22	42	27	6	3	0	13	41	32	12	2	0	26	57	13	2	2	0
J Picture sharpness	24	45	27	4	0	0	12	37	42	8	1	0	25	51	22	2	0	0
K Picture brightness	31	52	16	1	0	0	29	50	17	4	0	0	31	58	10	1	0	0
L Contrast range	21	49	25	4	1	0	16	40	38	5	1	0	22	52	25	1	0	0
M Overall assessment	22	47	27	3	1	0	9	43	37	10	1	0	21	65	12	1	1	0

	16 mm film						35 mm film					
D Noise	62	27	8	3	0	0	76	19	4	1	0	0
F Misregistration	39	39	17	4	1	0	43	42	15	0	0	0
H Fidelity of colour reproduction	16	35	36	9	4	0	30	53	15	2	0	0
J Picture sharpness	20	40	33	6	1	0	34	50	16	0	0	0
M Overall assessment	14	44	35	5	2	0	33	52	15	0	0	0

APPENDIX VIII

QUESTIONNAIRE USED IN TEST 4 (MONOCHROME CONTROL EXPERIMENT)

MONOCHROME TELEVISION APPRAISAL

Programme ....

Time ....

Date ....

Name ....

Make of set ....

Width of picture (inches) ....

Viewing distance (feet) ....

Approx. distance from transmitter ....

Lighting conditions (tick here):

Lighting conditions	tick here
dark	
soft lighting	
normal lighting	

Characteristic	Scale to be used	Score	Any Comments
A Visibility of scanning lines	1		
B Line strobing	1		
C Visibility of moiré patterns	1		
D Trailing due to movement	1		
E Streaking	1		
F Transparency effect	1		
G Break-up of diagonal lines	1		
H Geometrical distortion	1		
I Noise	1		
J Flicker	1		
K Synchronizing troubles	1		
L Redistribution effects	1		
M Microphony	1		
N Sharpness	2		
O Brightness	2		
P Contrast range	2		
Q Tonal gradation	2		
R Overall assessment of pictures (including all the above effects)	2		

Scale 1	Score
imperceptible	1
just perceptible	2
definitely perceptible but not disturbing	3
somewhat objectionable	4
definitely objectionable	5
unusable	6

Scale 2	Score
excellent	1
good	2
fairly good	3
rather poor	4
poor	5
very poor or absent	6

APPENDIX IX

DETAILED RESULTS OF TEST 4

CHARACTERISTIC	PERCENTAGE OF OBSERVERS IN EACH GRADE FOR EACH CHARACTERISTIC					
	Grade 1	2	3	4	5	6
A Visibility of scanning lines	10	27	56	6	0	0
B Line strobing	41	37	18	3	1	0
C Visibility of moire patterns	61	17	17	5	0	0
D Trailing due to movement	54	29	13	4	0	0
E Streaking	61	24	12	3	0	0
F Transparency effect	82	12	5	1	0	0
G Break-up of diagonal lines	40	29	22	9	0	0
H Geometrical distortion	42	22	28	7	1	0
I Noise	12	34	40	14	0	0
J Flicker	45	25	17	11	2	0
K Synchronising troubles	83	11	3	1	1	0
L Redistribution effects	26	25	38	9	2	0
M Microphony	89	6	4	1	0	0
N Sharpness	19	55	19	7	0	0
O Brightness	38	49	11	2	0	0
P Contrast range	20	48	25	7	0	0
Q Tonal gradation	18	51	27	2	2	0
R Overall assessment	11	57	28	4	0	0