PD.579

COLOUR TELEVISION EQUIPMENT

Marconi

MARCONI'S WIRELESS TELEGRAPH COMPANY LIMITED

Chelmsford, Essex, England · Telephone: Chelmsford 3221 · Telex: 1953 · Telegrams: Expanse Chelmsford Telex

INTRODUCTION

In 1936 the British Broadcasting Corporation, using the Marconi-E.M.I. system, opened the world's first public television service from Alexandra Palace in London. Further development in the post-war years has been devoted to providing a complete national television network using that same system.

FOR SOME CONSIDERABLE TIME, however, discussions have been taking place on the best system for transmitting and receiving colour television pictures. A final decision has now been made for the United States but has yet to be made for other countries. The problems involved are ultimately economic, and considerable technical ingenuity has been employed in evolving systems and equipment to overcome them.

COLOUR CAMERA MOUNTED ON STUDIO CAMERA PEDESTAL

MARCONI COLOUR TELEVISION

Marconi Colour Television Camera Channels are available both for live pick-up and for use with 16mm and 35mm film and slides. In all cases a simultaneous system is used in preference to a sequential one. For normal broadcast use the simultaneous signals are encoded to produce a compatible signal, that is one which may also be used by existing black and white receivers. For most closed circuit applications, the complexity of the encoding system may be dispensed with.

Except for the camera and the camera remote control panel housed in the operating console, the various units of the camera channel are designed to operate both with the studio and with the telecine cameras. All those units which handle the simultaneous Red, Green and Blue signals are housed in the operating console together with a Black and White Picture and Waveform monitor. The power supplies, and the encoding equipment where used, are housed in standard 19" cabinets.

The waveform generating equipment required for the production of the encoded signal is mounted in a 19" cabinet. A complete range of test equipment has been designed for use with Marconi Colour Equipment and these items are available in mobile or rack-mounting form.

The standard Colour Monitor employs a 21" three-gun shadow mask picture tube. Projection receivers capable of displaying colour pictures up to 8 x 6 feet in size can be provided where large numbers of viewers are involved. Direct view monitors employing separate picture tubes for the three primary images are also available.

All colour equipment can be supplied to operate on 405, 525 or 625 interlaced scanning lines per frame.

The Transmission System

Marconi equipment is designed to generate the American N.T.S.C. type of signal, the standards being suitably modified for operation with 405 or 625 line systems.

It is a property of the human eye that the sensation produced by practically any colour encountered in real life, can be simulated by an additive mixture of red, green and blue lights. It is the function of the colour television camera to analyze the light received from the televised scene into these three primary components. Basically, three monochromatic cameras are used to provide three independent vision signals defining the red, green and blue contents of the picture. From these signals are derived three further quantities, one being the luminance and the other two together forming the chrominance. The vision R.F. carrier is so modulated by these three quantities that the total bandwidth required does not exceed that at present used for black and white transmissions. In proportioning the available bandwidth between the luminance and the chrominance components, advantage is taken of the fact that the eye is insensitive to colour in fine detail, and furthermore, that this effect is most marked along the green-purple axis of the colour triangle and least so along the orange-cyan axis. The luminance component is allotted the same bandwidth as would be employed in a black and white system, and is transmitted as amplitude modulation of the vision R.F. carrier. This component is therefore identical to the signal used for the transmission of black and white pictures and it is this fact which enables the composite colour signal to be received on standard black and white television sets.

A colour sub-carrier is used to convey the two components of the chrominance signal and is added to the luminance component before transmission. The choice of sub-carrier frequency is governed by two requirements - that it produces a negligible interference level on standard black and white receivers and that sufficient bandwidth is available for the chrominance signal, the latter being limited in one direction by the sound carrier. There are four factors all of which tend to reduce the visibility of the interfering dot-pattern to a point where it is barely noticeable. First, the average receiver characteristic has fallen off appreciably at frequencies which still afford an adequate bandwidth for the chrominance signal. Secondly, the exact frequency is chosen so that the dots tend to cancel on alternate fields. Thirdly, the carrier is locked to the synchronising pulses, thus preventing a moving pattern. Finally, the system is designed so that the amplitude of the sub-carrier is zero in the absence of any colour information, that is for whites and greys, and approaches full amplitude only in areas of highly saturated colour such as are rarely found in an average scene.

The two chrominance components, known as the Quadrature or "Q" and the In-phase or "I" signals are carried on the colour sub-carrier as a combination of phase and amplitude modulation. In effect, the phase of the modulated sub-carrier denotes the hue of a colour while the colour saturation is denoted by the amplitude.

The available chrominance bandwidth is asymmetrical, being limited in one direction by the sound carrier, and to avoid cross-modulation between the Q and I components it is necessary to restrict one of these to the symmetrical part of the band. The fullest use of the bandwidth is made by arranging the two chrominance components so that the Q signal conveys information relating only to colours lying along the green-purple axis and the I signal to those on the orange-cyan axis. Because of the reduced sensitivity of the eye to colour detail along the green-purple axis, the narrower bandwidth can then be used for the Q signal without materially affecting the quality of the received picture.

In order that the colour receiver may recover the Q and I components as two independent quantities, a colour synchronising signal consisting of a short burst of the sub-carrier at a known reference phase, is transmitted immediately following each line synchronising pulse. The composition of the colour signal is shown in the diagrams at the end of the book.

The Colour Camera

Two basic colour cameras are available. The studio camera employs three 3" Image Orthicon tubes. The sensitivity of these tubes enables good pictures to be obtained at light levels of approximately 200 foot candles (2000 lux). A three vidicon camera is available for use where high scene illumination is no problem. Good pictures can be obtained at 1000 to 1500 foot candles (10,000 to 15,000 lux), a sensitivity which permits the camera to be used for outside shots in all except very dull weather. These light levels are also commonly found in operating theatres making the smaller vidicon camera ideal for surgical applications. The longer storage characteristic of the vidicon tube also makes this camera suitable for use in telecine applications where this feature eliminates the need for fast pull-down projectors and synchronous running.

The vidicon camera is simpler to operate and it is therefore preferable to use it wherever conditions permit, especially where facilities for technical maintenance are limited.

The two cameras employ similar optical systems typical examples of which are illustrated at the end of the text. Light enters the camera through one of four turret mounted lenses to form an image at a field lens mounted inside the turret. An optical relay system follows and the final image is formed at a distance which allows a light-splitting system of filters and mirrors to be interposed. The light division is performed by two dichroic filters mounted as a vee, green light passing straight through while blue and red are deflected to opposite sides, the light paths then being brought back into line by front silvered mirrors. Further shaping of the spectral response of each channel is performed by a combination of dichroic and conventional colour filters. Astigmatism correctors are employed to overcome the distortion introduced by the dichroic filters. Overall gain control is provided by a remotely motor-operated iris incorporated in the optical relay system.

Three pick-up tubes are used, one for each colour, and neutral density filters are inserted in the individual light paths to ensure that the tubes are operated over similar parts of their characteristics, the working range being restricted to the linear portion to ensure colour balance with change of light level. The focusing and deflexion yokes are made to close tolerances and the provision of individual as well as of common controls of height, width and centring, enables a very high degree of registration of the three component images to be obtained. Switching facilities on the viewfinder and on the monitor housed in the operating console allow the individual pictures to be superimposed for this purpose. Under normal working conditions a degree of registration equivalent to 500-line definition at the centre and 350-lines in the corners may be achieved. Individual shading controls are provided to compensate for non-uniformity of sensitivity over the scanned area of the pick-up tubes. Three amplifiers are housed in the body of the camera together with the necessary deflexion circuits.

For telecine applications the camera lens is dispensed with and the film projector is arranged to produce an image directly in the plane of the field lens. For a permanent installation, the three vidicon camera assemblies are mounted on a pedestal which houses the deflexion circuits. The longer optical path length and the small convergence angle at the dichroic filters renders the use of astigmatism correctors unnecessary with this arrangement. This economy is only made possible by reflecting at the first dichroic surface, the green image which contributes the greatest percentage of the picture detail. No optical relay system is used in this case and light control is provided by means of a variable neutral density filter wheel incorporated in the projector.

An alternative arrangement for televising film is to use the vidicon live pick-up camera. This may offer certain over-all economies in some installations.

Cameras are normally provided with a special suspension enabling them to be left in any position without the use of counterweights, springs or friction pads. The single multi-core cable is brought away from the centre of gravity of the camera in order to reduce any tendency to drag during operation. Focusing and turret controls are normally operated from the rear of the camera, the focus control being incorporated in the panning handle. Special fittings are available for surgical applications and remote control of focus and turret can be provided.

Operating Console

The operating console houses the following units:-

a) Picture and Waveform Monitor.

b) Camera Remote Control Unit.

c) Remote Control Unit.

d) Vision Signal Processing Amplifiers.

Operating controls are provided with edge illuminated scales for ease of operation in low light levels.

The first unit provides black and white picture and waveform displays and is similar to the monitor employed with black and white camera channels. Additional switching is provided so that the red, the green, and the blue pictures can be examined individually, superimposed in pairs, or all three together. The sweep speed of the waveform display is adjusted to accommodate either three lines or fields which are gated to appear sequentially in colour order, red, green and blue.

The Camera Control Unit carries all the electrical controls necessary to keep the camera in operation. A different version of this unit is used for image orthicon and vidicon cameras.

On the Remote Control Unit are housed the controls for the operation of the light control, and for the remote operation of the lens turret and for remote focusing if these facilities are provided.

The Processing Amplifiers comprise three separate signal channels, red, green and blue in the form of identical plug-in units together with the shading waveform, clamping, and blanking pulse generators. Apart from the correction of shading errors, the signals are gamma corrected to allow for the non-linearity of the receiving picture tubes, and aperture correction is applied to allow for the finite size of the scanning spot. Peak signal and background levels are also adjusted in this unit.

Where Red, Green and Blue signal distribution is possible, the outputs of the Processing Amplifier may be used directly.

Encoding Equipment

For broadcasting or transmission over long distances, the Red, Green and Blue signals are fed to the colourplexer where they are mixed to form the three transmitted components, luminance, Q and I as described above. The bandwidths of the Q and I signals are restricted by appropriate filters and compensating delay networks are inserted in the I and luminance channels to allow for the delay introduced by the narrow band Q filter. Two balanced modulators, which ensure a zero output in the absence of chrominance information, are each fed with the colour sub-carrier, the signals to the Q and I modulators being in phase quadrature. The outputs of the two modulators are added to form the complete chrominance signal which is added to the luminance and synchronising signals to form the complete colour signal. Automatic carrier balance control is provided for both modulators.

Distribution

Current designs of Marconi distributing, mixing, and transmitting equipment may be used with composite colour signals.

Waveform Generating Equipment

In order to produce a fully coded signal it is necessary to provide a sub-carrier frequency signal generator the output of which is locked to the line and field synchronising waveforms.

The colour sub-carrier generator employs a temperature controlled crystal oscillator, the frequency stability being better than three parts in a million. In multi-channel installations the sub-carrier is fed to each colourplexer via a phase-shifter by which the phases of the various signals may be adjusted for coincidence at the mixer. The sub-carrier is also fed to a counter unit which provides an output at twice line frequency used to lock the synchronising pulse generator. A Burst Gating Pulse generator is also provided. The output of this unit is mixed with the sub-carrier to provide the colour synchronising signal.

Since the requirement that the synchronising pulses be locked to the sub-carrier prevents their being locked to the supply frequency, all units used with colour equipment are designed to operate asynchronously with the mains supply.

Where it is intended to use Red, Green and Blue signal distribution, no sub-carrier generator is used and the synchronising generator may be locked to the supply frequency.

Monitors

The Marconi direct view transmission monitor employs a 21" three-gun shadow mask tube which gives a high quality picture of excellent brightness. The circuit is built on several removable units which are mounted with the picture tube in a wooden cabinet. Access to these units is provided through side covers and the entire front is hinged forward to facilitate replacement of the picture tube without otherwise disturbing the set. The monitor will accept R.F., composite vision, or simultaneous Red, Green and Blue signal inputs. Where all these facilities are not required, the monitor can be supplied without the unwanted units. A sound channel is provided.

The signal is first fed to the decoder unit when operated from a composite source, or to the R.F. receiver unit if the set is in use as an R.F. monitor. In the decoder the luminance and chrominance components are separated by means of filters, and the Q and I components are recovered from the chrominance signal in two synchronous demodulators. In effect, a local sub-carrier frequency oscillator is locked in frequency and phase to the incoming reference burst, and two outputs derived which are 90° apart in phase. These reference signals are fed one to each synchronous demodulator where they are mixed with the chrominance signal to produce the required Q and I signals. These are then mixed with the luminance component to reproduce the original Red, Green and Blue signals which are amplified and fed to the three separate guns of the picture tube. The electron beam from each gun is constrained by the shadow mask to excite only those dots of the appropriate colour on a compound screen printed with a regular pattern of red, green and blue phosphor dots. The original picture is therefore reproduced on the face of the tube.

The projection receiver is similar to the direct view monitor except that the Red, Green and Blue signals are fed to three television projection units and the three resulting images are superimposed on the viewing screen.

In the case of the direct view monitor using a set of three 12" picture tubes each with a different phosphor, the three primary images are combined by using a set of dichroic filters.

Test Equipment

The following Marconi test gear has been designed for use with colour equipment:-

a) Colour Bar Generator

b) Vectorscope

c) Grating and Dot Generator

d) Linearity Checker

e) Colour Signal Analyser

The colour bar generator is designed to simulate the Red, Green and Blue signals produced by a camera televising a test card comprised of a series of six vertical colour bars. Being electronically generated, the hue and saturation of each bar may be accurately set and the performance of the various units in the system may be assessed by inspection of the test signal at various points.

It has already been stated that the hue and saturation of any colour are defined respectively by the phase and amplitude of the colour sub-carrier. The vectorscope is designed to display the chrominance signal in vector form. The amplitude of the vector is given by the radial distance of the scanning spot from the centre of the screen of a 5" cathode ray tube, while its phase is indicated by the angular displacement from a given reference. A graticule is provided upon which are indicated the correct positions of the vectors obtained when the colour bar test signal is being transmitted. The use of the vectorscope in conjunction with the colour bar generator provides a quick and accurate check of colour equipment and at once indicates any amplitude or phase distortion of the chrominance signal. A measurement accuracy of $\pm1^\circ$ in phase and ±2% in amplitude is obtained with this instrument.

The Grating and Dot generator produces the test signals necessary for the proper adjustment of the colour monitors.

The Linearity Checker produces a stepped sawtooth test signal which may be used for checking amplitude linearity. If desired a constant amplitude sine wave can be superimposed on the stepped sawtooth enabling linearity to be measured at the sub-carrier frequency.

The Colour Signal Analyser may be used in conjunction with the Linearity Checker in order to detect phase/amplitude distortion. In effect the phase of the sub-carrier signal is measured at each luminance level and any change may be determined to an accuracy of $\pm0.1^\circ$.

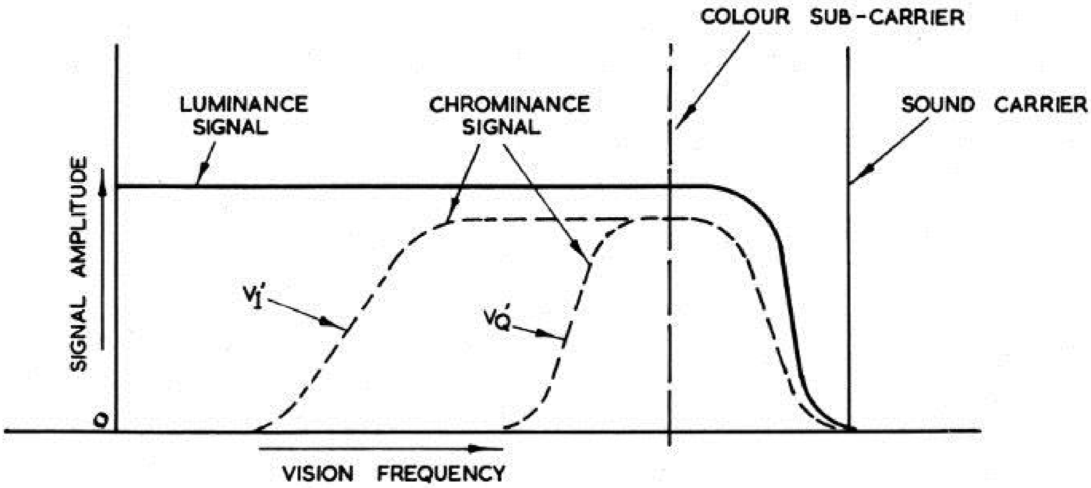
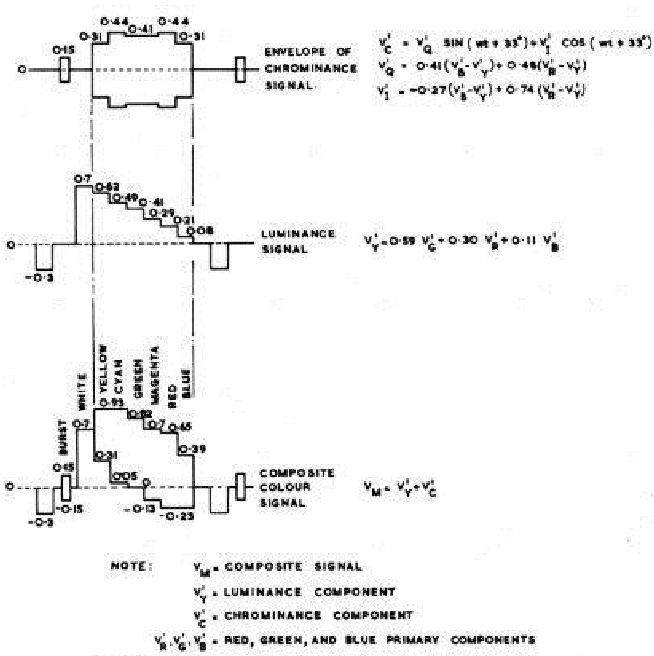
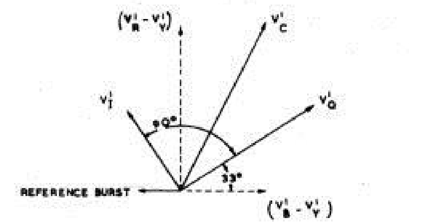


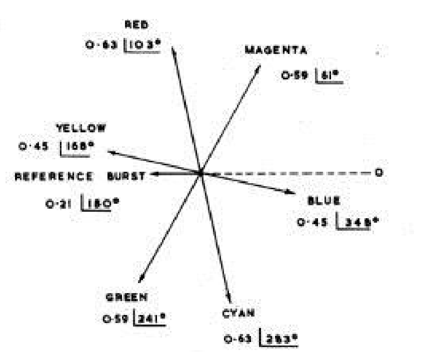
CHART SHOWING RELATIVE BAND WIDTHS OF THE LUMINANCE AND CHROMINANCE COMPONENTS



WAVEFORM DIAGRAM SHOWING COMPOSITION OF THE FULLY CODED COLOUR SIGNAL WHEN THE COLOUR BAR TEST SIGNAL IS TRANSMITTED.

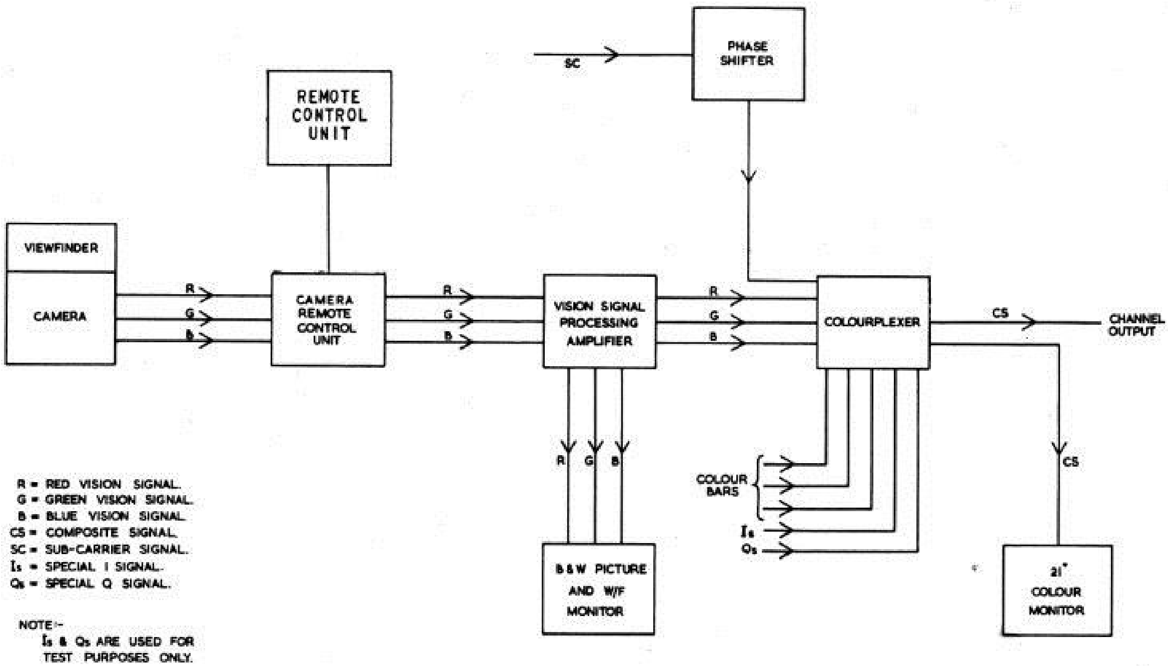


VECTOR DIAGRAM SHOWING PHASE RELATIONSHIPS BETWEEN THE VARIOUS COLOUR DIFFERENCE SIGNALS AND THE REFERENCE BURST IN THE CHROMINANCE SIGNAL.

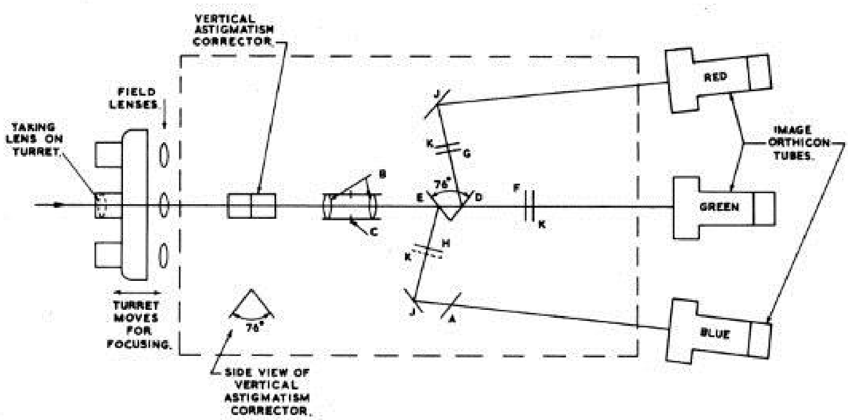


VECTOR DIAGRAM SHOWING AMPLITUDES AND PHASE ANGLES FOR THE SATURATED PRIMARY AND COMPLIMENTARY COLOURS.

THE COLOUR TELEVISION SIGNAL



COLOUR CAMERA CHANNEL
SIMPLIFIED BLOCK DIAGRAM



A–HORIZONTAL ASTIGMATISM CORRECTOR.
B–RELAY LENSES BOTH 9·375 F/4.
C–REMOTELY CONTROLLED IRIS.
D–RED REFLECTING DICHROIC.
E–BLUE REFLECTING DICHROIC.
F–GREEN TRIMMING FILTER.
G–RED TRIMMING FILTER.
H–BLUE TRIMMING FILTER.
J–FRONT SURFACE MIRROR.
K–NEUTRAL DENSITY FILTER.

COLOUR CAMERA OPTICAL SYSTEM

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