Colour Television Systems

THE SEARCH FOR A EUROPEAN STANDARD

THE European Broadcasting Union is currently investigating the three selected systems of colour television—N.T.S.C., SECAM and PAL—with the object of advising the C.C.I.R. on its choice of a system for use in Europe, and thereby avoiding the haphazard jumble of types that seems to be the result of every invention from railways to valve bases. Demonstrations of three systems and associated equipment were given to the *ad hoc* committee of the E.B.U. during July, and the O.I.R.T., which is the Eastern European equivalent of the E.B.U. sent observers, so that it seems possible that the whole of Europe may be covered by a single standard.

It is some time since the subject was aired in *Wireless World,* and to keep our readers up to date with developments, we are giving a short description of each system, with comparisons of performance in several aspects.

N.T.S.C.

The American system was the earliest one in regular public use, apart from an even earlier mechanical type, also American, and was developed in co-operation with the National Television System Committee (hence the name). Like the other two, the system is compatible, which means that pictures transmitted in colour can be received on a black and white set with only a small deterioration in quality.

Ignoring, for the moment, a recent camera development, the video signal is obtained from three camera tubes, each with its colour filter, providing a signal corresponding to the three additive primary colours, red, blue and green. (Yellow is a subtractive primary, provided, for instance, by yellow paint, which absorbs and subtracts from white ambient light all colours but yellow.) After the camera outputs have been operated upon to cancel the effect of the non-linear light output/grid voltage law of a cathode-ray tube (gamma correction), a proportion of all three is applied to a resistive adding matrix in which they are combined to provide brightness, or "luminance" information, which can be displayed on an ordinary monochrome receiver. The red and blue signals, or rather the differences between these and luminance, are now used to modulate a subcarrier which, on a 625-line system, is 4.43Mc/s. The two signals are separated in phase by 90°, and as the subcarrier is amplitude modulated, they can be regarded as a vector, whose length determines the *amount* of red or blue, or the "saturation," and whose phase angle with respect to a transmitted reference signal denotes hue, i.e., whether the picture is red, blue, or a mixture of both.

It is conveniently found that the eye does not respond to colour pictures in quite the same way as it does to black and white ones. If a b. and w. scene is fuzzy (bad high-frequency response in a receiver, for instance) the result is objectionable. This is not so with colour, as can be illustrated by the "colouring-book" analogy. Children are not very skilful at keeping crayon or paint within the printed line, and the coloured areas tend to have ragged edges. These are not very noticeable, however, as the printed line, corresponding to television luminance or brightness information, defines the coloured areas precisely, and the ragged edges are not noticed. This effect enables the bandwidth of colour information to be considerably reduced and in fact, the wider bandwidth signal occupies only 1.5Mc/s. The vector components actually used do not correspond exactly to red and blue, but are offset slightly to place the narrow-band axis in the region where the eye is unable to distinguish changes in small areas of colour. This axis is consequently in the green/magenta part of the spectrum and is called the "Q" axis. The wider bandwidth signal is then in the orange/cyan sector and is called the "I" axis.

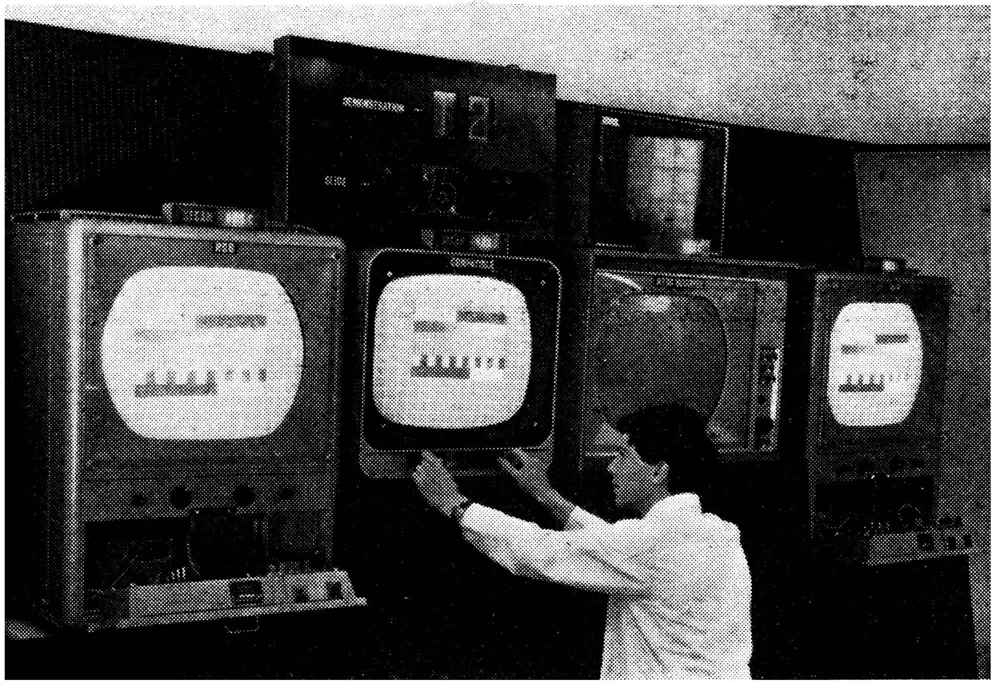
At the receiver, the red and blue information is derived by two synchronous phase detectors, fed by sine waves at subcarrier frequency 90° apart. The phases of these reference signals are kept correct by the transmission of a burst of subcarrier frequency on the back porch of the video signal. The phases of the colour burst and the reference oscillator are compared and, if any difference exists, correction made. The green information is obtained by combining the red and blue information with luminance in a resistive matrix at the receiver.

The three colour signals are now applied to the three grids of an R.C.A. shadow-mask tube, or to three tubes with colour filters projecting through an optical system on to a screen.

SECAM

The next system to appear was developed in France by the Compagnie Française de Télévision, and was originally known as the Henri de France system, after its inventor. It differs in two major respects from N.T.S.C. in that the red and blue information is transmitted on alternate lines, and in the fact that the subcarrier is frequency modulated.

It has been mentioned that the bandwidth of colour information can be reduced, which means that the horizontal definition of a colour picture will be limited. If the normal number of lines of colour are transmitted, the vertical definition will be greater than the horizontal, which does not make for a satisfactory balance. Moreover, it is found that the colour information in one line does not often differ appreciably from that in the preceding line. In SECAM, advantage is taken of these facts to transmit each colour, red and blue, on alternate lines.



Colour monitors being set up by an engineer of ABC Television, prior to a demonstration for E.B.U. delegates.

A delay line stores each line of colour information for one line period and it is then displayed, along with the new information of the other colour, in the next line. An electronic switch routes each line into the delay line in turn, so that two sets of colour information are always displayed, even though one really belongs to the preceding line. The result is about half the vertical colour definition obtained in an N.T.S.C. receiver.

As only one set of colour information is transmitted on any one line, frequency-modulation of the subcarrier is possible. This has the advantage that differential fading and phase errors which occur in the transmission path and in the input circuits of the receiver itself have virtually no effect on the colour rendering. A frequency-modulated carrier is not affected by these factors as long as there is sufficient signal to cross the threshold of the limiter in the frequency-discriminator which is used as a subcarrier detector. To make the channel switch operate in phase with the switch at the transmitter, lines transmitted during the vertical flyback have on their back porches a burst of subcarrier, which is alternately positively or negatively frequency modulated, corresponding to blue or red respectively. Pulses derived from this modulation trigger the switch in the correct phase.

PAL

The third system to be considered is the West German PAL (Phase Alternation Line) which was developed by Walter Bruch at Telefunken. It combines the advantages of SECAM with a basic similarity to N.T.S.C., and relies to a larger extent than other systems on the eye's insensitivity to small areas of colour.

As the name implies, the phase of one of the vectors, I as it happens, is reversed on alternate lines in both transmitter and receiver. If, therefore, the phase of the subcarrier is changed by a few degrees during transmission, and in the input circuits of the receiver, this error will appear to be of opposite sign on the succeeding line. If the error is less than about $\pm 7^\circ$, the eye sees the average, or correct, colour rather than two slightly incorrect lines. This is the system known as "Volks PAL" and is the one shown to the E.B.U.

A slightly more expensive variety, known as "de luxe PAL," uses a delay line to help the eye to average out colour errors. The delay line is used in the same way as in SECAM, so that four colour signals are available on each line, I and Q from one line, delayed by one line interval, and I and Q of the succeeding line, the two sets having phase errors of opposite sign, which are thus cancelled.

Rather better vertical definition than in SECAM is claimed, and it is pointed out that N.T.S.C., Volks PAL and de luxe PAL receivers are so similar that modifications to receivers and transcoding between systems are quite simple. An incidental point in PAL's favour is the fact that although the colour subcarrier is a vestigial sideband transmission, the reversal of phase effectively re-establishes the missing sideband, with a corresponding improvement in performance when differential fading is a problem. It also means that the change in characteristics of i.f. valves and drift in tuners is not quite so serious.

It is extremely difficult, and probably unfair, to make a judgment on the three systems in the absence of about 90% of the evidence considered by the E.B.U. We will try, however, to put together the facts we have, and make some guesses at the rest.

Cost

Probably the first question that springs to mind is "How much?" It is justifiable to neglect the cost of transmitters and studio operations, and confine ourselves to home receivers. Most manufacturers are reticent in the extreme about prices, but the figure most often mentioned is 2.5—3 times the cost of a monochrome set. N.T.S.C. is the cheapest, PAL next (if no delay line) and SECAM third. The cost of the delay line determines the difference between the three, as otherwise they are all virtually identical in complication. Lines made by Corning International sell for 50 dollars at present, with the prospect of a substantial decrease for quantity use. The cost of the shadow-mask tube and its associated components, together with a stabilized power and e.h.t. supply is such that the cost of the delay line is insignificant.

Operation

Recovering from the shock of the probable cost, the next question is likely to be concerned with the "usability" of the receiver. We have all heard grim stories from the U.S.A. about resident service technicians "in every home" and wonder if things have improved in eight or nine years. It seems to be a fact that the N.T.S.C. system is still subject to phase distortions and differential fading affecting the hue, and a knob is invariably provided for correct setting. One can imagine the havoc that could be created by compulsive knob-twiddlers with a control which allows much variation in colour. The receivers shown at last year's Radio Show were all N.T.S.C. types, and as we said then, the variations of flesh colour ranged from a sickly pallor to rude, almost indecent, health. SECAM and PAL receivers have no colour controls at all; SECAM has its f.m. subcarrier, and PAL cancels phase distortions, giving the same colour signal as that as the transmitter.

From the studio point of view, N.T.S.C. has had the longest run, and techniques are well worked out. It was originally difficult to handle a SECAM signal in such operations as "wiping", fading and other effects due to the fact that an f.m. subcarrier is hard to fade. ABC Television have now evolved a method of doing this, so that SECAM compares with N.T.S.C. in this respect. PAL is similar to N.T.S.C.

Compatibility

The high cost of colour receivers makes it fairly certain that they will be "status symbols" for some years. For the man whose contempt for the Jones' is exceeded only by his overdraft, black and white receivers will suffice, and he will not want too much patterning on his screen from colour transmissions.

For reasons of economy in bandwidth, the colour subcarrier in all three systems is inside the vision frequency band. It is found that the energy of the luminance signal is mainly grouped about multiples of the line frequency, and if the subcarrier is fixed at odd multiples of half this frequency, interference will be a minimum. In practice, the subcarrier is a fairly high frequency, and the subcarrier breakthrough is not usually objectionable. It takes the form of brightness modulation of the picture and has been described as "boiling porridge." In N.T.S.C. and PAL, when the colours are not saturated, which is most of the time, the subcarrier is small and interference negligible. Worst patterns occur in heavily-saturated areas of the picture. It is possible to arrange a notch filter in the luminance channel with its trough on the chrominance subcarrier, which leaves the high end of the luminance response untouched. Rapid transitions of colour, however, produce sidebands outside the range of the notch filter and patterning is again seen. In SECAM the f.m. subcarrier is of small but constant amplitude, and although this gives less breakthrough than the other two on an average picture, two further operations can be performed. The phase of the subcarrier is controlled at the start of each line, so that the dot structure is stable. A shift of half a cycle of the subcarrier is then introduced between frames, which tends to interlace the pattern, and further phase-shifts at intervals of a few lines to break up the vertical pattern to reduce the effect of breakthrough still further.

Colour Rendering

In demonstrations we have seen recently, no difference could be detected between receivers that could be put down to differences in transmission systems. Whether this would be true under any but laboratory conditions is open to question.

Definition

The bandwidth of the colour information is limited, as has been seen. In SECAM, the vertical definition is also reduced. Due to the fact that two consecutive lines carry the same information almost-horizontal edges in the picture tend to jitter somewhat. The effect is not bad and only occurs rarely. PAL and N.T.S.C. have better vertical resolution than that in the horizontal direction. Definition on colour generally is noticeably poorer than on monochrome, as the lack of colour bandwidth does have some effect.

Recording

It is necessary, in order to maintain correct hue, to keep the phase of the N.T.S.C. carrier within $\pm 5°$, and it can be shown that the operations of recording and playback must be carried out at a tape speed which does not vary by more than $\pm 0.015\%$, or about ten times the constancy of speed needed for monochrome signals. SECAM, on the other hand, is less affected by phase errors, and as long as the tape speed, and therefore subcarrier frequency, is held within $\pm 0.4\%$, the colour rendering is correct.

Noise

No difference could be detected on the receivers we have seen when various types of noise were superimposed on the signal. No effect on colour rendering was observed, and the only remark we have to offer is that ignition noise on the 625-line, negatively-modulated signal was much less obtrusive than on 405-line positive modulation.

Conclusions

N.T.S.C. has been in regular use for about eight years. It is often said that this, in some indeterminate way, confers an advantage on it. It is difficult to see why age is any qualification for supremacy, especially as little development has taken place as a result of experience over this period. Phase errors, differential fading and difficulty with magnetic recording, are not negligible factors, and seem to us to put the system at a disadvantage.

SECAM is a simple system with much to recommend it, but also with its own peculiar disadvantages. Although free from colour errors due to a long and tortuous transmission path, the system would respond badly to a signal below limiter threshold level, which would also be the probable result of such a transmission path. If an N.T.S.C. or PAL colour signal is reduced to zero, the receiver reproduces black level. In SECAM, black level is dependent on the discriminator characteristic, which may drift. The SECAM method of colour coding gives only one colour per line from the transmitter. This rather rules out any possible future developments which could make it possible to increase colour definition, as the vertical resolution is fixed at the width of two lines.

On the available evidence, PAL appears to be the most attractive system. It is sufficiently close to N.T.S.C. to satisfy that system's enthusiasts. It transmits all colours all the time. It is less sensitive to phase and fading errors. It compares favourably in cost with SECAM. Operation by the viewer is simple. Small saturations produce less patterning, while SECAM has a constant amplitude subcarrier giving a constant pattern. PAL has better resolution than SECAM. PAL, like SECAM, is less affected than N.T.S.C. by phase distortion in magnetic recording, and has the further advantage of better vertical resolution.

Separate Luminance

In all three systems proposed, the luminance signal, which provides brightness or monochrome information, is formed by adding proportions of the red, green and blue camera outputs according to the equation $E_Y = 0.3E_R + 0.59E_G + 0.11E_B$, where E_R, E_G and E_B are the signals corresponding to the colour channels and E_Y is luminance. The receiver cathode-ray tube does not brighten in proportion to the voltage on its grid, and the luminance signal must therefore be "gamma-corrected" to take account of the (roughly) square law of the c.r.t. This entails raising the luminance signal to the power of $1/\gamma$, or 1/2.2, which gives

$$(E_Y{}^{1/\gamma}) = (0.3E_R + 0.59E_G + 0.11E_B)^{1/\gamma} \quad .. \quad (1)$$

The N.T.S.C. luminance signal, however, is given as

$$E_Y{}^{1/\gamma} = 0.3E_R{}^{1/\gamma} + 0.59E_G{}^{1/\gamma} + 0.11E_B{}^{1/\gamma} \quad .. \quad (2)$$

which is not the same as (1). The result is that the luminance is not properly reproduced, as on saturated colours it only reaches a fraction of its correct value. To make up the balance, some luminance is transmitted with the chrominance signals which are band-limited, and a loss in resolution is incurred. Furthermore, three wide-band camera tubes are needed.

Both E.M.I. and Marconi have produced cameras in which the luminance signal is kept completely separate from the chrominance information. In the E.M.I. camera, a 4½in image orthicon provides the luminance signal, three vidicons being used for the colour signals. Marconi's three vidicons are complemented by a new monochrome tube, the "Plumbicon," recently produced by Philips.

The only wide-band signal is now the 5Mc/s luminance channel, the three vidicons providing low-definition colour signals.

One small disadvantage is that, at the receiver, green is obtained by combination of luminance and red and blue signals. On a separate-luminance signal, a standard N.T.S.C. decoder would produce a slightly erroneous green signal. This could be avoided by a little extra circuitry in the receiver, but to be honest, the difference between the correct and incorrect greens is very little and seems hardly worth worrying about.

A separate-luminance camera is very much more sensitive than an ordinary RGB type, and it is found that pictures can be produced with an illumination of 100 foot-candles at an aperture of f/8. The registration of the colour camera tubes is no longer important, as they are low-definition types, and "lag" experienced in vidicon cameras, is not troublesome. With saturated colours, the correct luminance signal is presented to the receiver c.r.t. and better definition is given. The separate luminance principle is applicable to all three proposed systems.

P. R. D.

LONDON RADIO SHOWS

AS there will not be a national radio exhibition in this country this year, many of the manufacturers and some agents for overseas manufacturers are organizing independent trade shows during the normal show period. We list these below but stress that admission is limited to the trade and that some are not open at weekends. Several companies are also holding public shows in provincial towns.

In our next issue we shall be surveying some of the salient features of the new season's domestic television, radio and audio equipment.

Aerialite	Café Royal, Regent St., W.1	Aug. 27—30
Alba	Café Royal, Regent St., W.1	Aug. 28—30
Antiference	Café Royal, Regent St., W.1	Aug. 29 & Sept. 4
Belling-Lee	Café Royal, Regent St., W.1	Aug. 26—30
Ben Nevis	2 King St., St. James, W.1	Aug. 26—30
Blue Spot & Uher	Bosch Ltd 205 Gt. Portland St., W.1	Aug. 26—30
Brown Brothers	Gt. Eastern St., E.C.2	Aug. 28—Sept. 5
Bush & Murphy	Savoy Hotel, Strand, W.C.2	Aug. 26—30
Clairtone & Braun	2 Ridgmount Place, W.C.1	Sept. 2—5
Dansette	Honeypot Lane, Stanmore	Aug. 26—Sept. 6
Decca	Café Royal, Regent St., W.1	Aug. 26—Sept. 6
Defiant	C.W.S., Leman St., E.1	Aug. 26—30
Dynatron	Hilton Hotel, Park Lane, W.1	Aug. 26—30
E.M.I. Sound Products	100 Wigmore St., W.1	Aug. 26—Sept. 7
Ekco & Ferranti	41/47 Old Street, E.C.1	Aug. 26—30
Elizabethan	May Fair, Berkeley St., W.1	Aug. 27—Sept. 3
Elpico	Hotel Russell, Russell Sq., W.C.1	Aug. 26—30
Eumig	Blazy & Clement, 26 St. Cross St., E.C.1	Aug. 26—Sept. 6
Falcon	Café Royal, Regent St., W.1	Aug. 26—30
Ferguson	Thorn House, Upper St. Martin's Lane, W.C.2	Aug. 26—30
Fidelity	Hilton Hotel, Park Lane, W.1	Aug. 27—Sept. 3
G.E.C., Masteradio, McMichael & Sobell	Carlton Tower, Cadogan Place, W.1	Aug. 27—Sept. 5
Grundig	Hilton Hotel, Park Lane, W.1	Aug. 27—29
H.M.V.	Cadogan Pier, Chelsea, S.W.3	Aug. 27—29
K.B., R.G.D., Regentone, Ace & Argosy	Kensington Palace Hotel, De Vere Gdns., W.8	Aug. 26—30
Loewe-Opta, Ingelen & Perpetuum Ebner	Highgate Acoustics, 71/3 Gt. Portland St., W.1	Sept. 9—13
Lugton	Café Royal, Regent St., W.1	Aug. 27—Sept. 5
Marconiphone	Café Royal, Regent St., W.1	Aug. 27—29
Mullard	Mullard House, Torrington Place, W.C.1	Aug. 26—Sept. 6
Pam	295 Regent St., W.1	Aug. 26—Sept. 6
Perdio	Savoy Hotel, Strand, W.C.2	Aug. 29
Philips, Stella, Cossor & Peto Scott	Fairfield Halls, Croydon	Aug. 26—Sept. 4
Retra	R.T.R.A., 19 Conway St., W.1	Aug. 27—29
Revelation Silvertone	W. Wood & Son, 24 Princes St., W.1	Aug. 28—30
Schaub-Lorenz, Trio & National	Winter Trading, 95/9 Ladbroke Grove, W.11	Aug. 24—31
Telerection	Carlton Tower, Cadogan Place, W.1	Aug. 27—Sept. 5
Tellux & Sony	De Vere Hotel, W.8	Oct. 9—10
Ultra	Hilton Hotel, Park Lane, W.1	Aug. 26—30
Unitra	May Fair, Berkeley St., W.1	Aug. 27—Sept. 3
Wolsey	Mount Royal Hotel, Marble Arch, W.1	Sept. 2—5