

PATENT SPECIFICATION

(11) 1 576 442

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- (21) Application No. 18694/77 (22) Filed 4 May 1977
 (31) Convention Application No. 51/055059
 (32) Filed 14 May 1976 in
 (33) Japan (JP)
 (44) Complete Specification published 8 Oct. 1980
 (51) INT CL³ H04N 9/04
 (52) Index at acceptance

H4F CB D1B1 D1D1 D1K1 D27C1 D27S D53D D54 D81P
 D83B

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(54) SOLID STATE COLOUR CAMERAS

(71) We, SONY CORPORATION, a corporation organised and existing under the laws of Japan, of 7-35 Kitashinagawa-6, Shinagawa-ku, Tokyo, Japan, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to solid state colour cameras and more particularly to solid state colour cameras using a solid state image sensing means from which a colour video signal of the quasi-NTSC system is obtained.

In the art, when a charge coupled device (CCD) is used as a solid state image sensor, the CCD is usually constructed as shown in Figure 1 of the accompanying drawings. The solid state image sensor 10 shown is of the frame (or field) transfer type. An image sensing array 1A on which an image is projected comprises a plurality of image sensing cells 2 (serving as picture elements) arranged in rows and columns, and is associated with a temporary storage array 1B which is substantially the same as the image sensing array 1B in construction except that it is optically shielded and stores carriers corresponding to the image on the image sensing array 1A and transferred from the image sensing array 1A to the positions corresponding to those of the image sensing array 1A, and a horizontal shift register 1C which reads out the information carriers of one horizontal scanning period (1H) from the storage array 1B and supplies the information to an output terminal 3. Channel stoppers 4 extending in the carrier transfer direction.

Figure 2 is a diagram of a few of the image sensing cells 2 of the image sensing array 1A on an enlarged scale. The image sensing cells 2 are aligned in the horizontal and vertical scanning directions parallel with one another, and τ_h is the pitch of the image sensing cells 2 in the horizontal direction. The arrangement in Figure 2 corresponds to an interlaced system. Thus, the image sensing cells 2 shown by solid lines in Figure 2 are used in odd fields, while the image sensing cells 2 shown by dotted lines are used in even fields.

A CCD with an arrangement of image sensing cells as shown in Figure 2 is conventionally called a parallel-aligned CCD. A CCD in which the arrangement of image sensing cells is, for example, in checker-board pattern can be also used as a solid state image sensor.

Figure 3 shows a part of one example of a checker-pattern CCD. Areas of each image sensing cell 2 are optically shielded over $\tau_h/2$, that is, one half the pitch, as shown by the hatched portions in Figure 3 and the optically shielded areas are arranged alternately so as to make the output signals of adjacent lines have opposite phases.

Figure 4 is a diagram of a view of the image sensing cells 2 on an enlarged scale.

Before describing a solid state camera using such a CCD, a problem which arises when using such a CCD in a solid state camera will now be described.

Since the input light information corresponding to the image of an object is converted to electric signals by being sampled at every image sensing cell, the signal S_o picked up includes a sideband component (ac component) S_m in addition to a base-band component or modulated component (dc component) S_{dc} which will become a luminance signal, as shown in Figure 5. This means that a part of the side-

band component S_m overlaps a high-band portion of the modulated component S_{dc} and causes so-called 'folded error' S_{dh} . This causes deterioration of the quality of the reproduced picture.

It is, however, possible to eliminate the folded error by suitably selecting the band-width of the modulated component S_{dc} and the fundamental transfer frequency (sampling frequency) $f_c (=1/\tau_H)$, but this generally means that the band-width of the modulated component S_{dc} must be selected to be narrow. If the band-width of the modulated component S_{dc} is selected, for example, to be about 3.5 MHz, as is usual, the number N_H of image sensing cells in the horizontal scanning direction must be increased, because the transfer frequency f_c becomes high as the band-width of the modulated component S_{dc} is widened. Thus the above methods are not suitable in practice.

A previously proposed solid state camera which is free from the above problem will now be described. In such a camera, as indicated in Figure 6, three CCDs 10A, 10B and 10C are used, and are relatively displaced by $\tau_H/3$ from one another with respect to projected images. Thus, if the side-band components derived from the CCDs 10A, 10B and 10C are taken as S_{ma} , S_{mb} and S_{mc} respectively, and the time relation on reading out signals from the CCDs 10A, 10B and 10C is selected to have a phase difference of 120° , the phase difference between the adjacent side-band components S_{ma} , S_{mb} and S_{mc} becomes 120° as shown in Figure 7. Thus, as shown in Figure 8, if output signals S_{oa} , S_{ob} and S_{oc} from the CCDs 10A, 10B and 10C which satisfy the above time relation are supplied to an adding circuit 5, the adding circuit 5 produces a signal S_T in which the side-band components S_{ma} , S_{mb} and S_{mc} are cancelled and hence there is no folded error. The solid state camera shown in Figure 8 is disclosed in U.S. Patent No. 3,975,760, so a detailed description thereof will not be given. But, in Figure 8, an object 6 is imaged by an optical system 7 onto a spectroscopic system 8 which includes, for example, half-mirrors 8a and 8b, and mirrors 8c and 8d. Optical colour filters 12R, 12G and 12B are located in front of the CCDs 10A, 10B and 10C respectively, a matrix (decoder) circuit 9 is supplied with the signal S_T from the adding circuit 5, and an encoder 11 is supplied with the output signal from the matrix circuit 9 and produces a colour (video) signal satisfying the NTSC system at an output terminal 11a.

By using a plurality of CCDs, the number N_H of image sensing cells of each CCD can be decreased.

In order to obtain a desired colour signal of the NTSC system at the output terminal 11a of the camera of Figure 8, it is conventional to supply the composite signal S_T from the adding circuit 5 to the decoder 9 and to carry out the conversion processing of the signal.

In order that the signal S_T be satisfactory as a colour (video) signal S_{NTSC} of the NTSC system (this system will hereinafter be called the direct NTSC system) the following conditions (I) and (II) at least must be satisfied:

(I)

$$S_{NTSC} = S_T + S_C \quad (1)$$

$$S_T = 0.30 E_R + 0.59 E_G + 0.11 E_B \quad (2)$$

$$S_C = \frac{R-Y}{1.14} \cos 2\pi \cdot f_s \cdot t + \frac{B-Y}{2.03} \sin 2\pi \cdot f_s \cdot t \quad (3)$$

(II)

$$f_s = \frac{4.55}{2} f_H \quad (4)$$

$$f_H = \frac{525}{2} f_V \quad (5)$$

where:

E_R , E_G and E_B are the R (red), G (green) and B (blue) colour signals

f_s is the frequency of the colour sub-carrier

f_H is the horizontal scanning frequency

f_V is the vertical scanning frequency.

The condition (I) can be satisfied by suitably selecting, for example, the spectroscopic system and demodulating system, and the condition (II) can be satisfied by selecting, for example, the frequency f_c of the transfer signal S_c , which will be fed to the horizontal shift register 1C of the CCD 10, equal to the frequency $f_s (= 3.57945 \text{ MHz})$ of the colour sub-carrier of the NTSC standard.

That is, since the input light information corresponding to the image of the object is converted to the electric signals by being sampled at every image sensing cell, the chrominance component in the picked-up output signal S_r from the CCDs 10A, 10B and 10C is obtained as a carrier chrominance signal. More over, if the transfer frequency f_c is selected to be equal to the colour sub-carrier frequency f_s , the carrier frequency of the carrier chrominance signal becomes the transfer frequency of colour sub-carrier frequency to satisfy the above conditions (I) and (II). As a result, even if the encoder 11 is not used, the colour video signal of the NTSC system can be obtained.

There is, however, a problem with such a camera, and this is a flicker phenomenon in the reproduced picture, and this flicker phenomenon will now be described in the case of a parallel-aligned CCD. Figure 9A shows the spatial arrangement of the image sensing cells 2 in the image sensing array of a CCD, and Figures 9B and 9C show the disposition of the reproduced picture elements within a reproduced picture.

The number N_H of image sensing cells in the horizontal scanning direction in one horizontal scanning period T_H is expressed as follows:

$$N_H = f_s \cdot T_H \quad (6)$$

Therefore, the displacement of the arrangement of the reproduced picture elements from the spatial arrangement of the image sensing cells of a CCD can be obtained from equations (6) and (4).

If an odd field at an odd frame is taken as a reference of first consideration, the number of the last image sensing cell in N lines is given as follows:

$$N \cdot N_H = N \cdot f_s \cdot T_H \quad (7)$$

Since:

$$f_H = \frac{1}{T_H} \quad (8)$$

equation (7) can be expressed as follows, using also equation (4):

$$\begin{aligned} N \cdot N_H &= \frac{455}{2} \cdot f_H \cdot T_H \cdot N \\ &= \frac{455}{2} N \end{aligned} \quad (9)$$

Thus, if N is an odd number, or since for the first line of this field $N=1$, equation (9) can be rewritten as follows:

$$\begin{aligned} N_H &= \frac{455}{2} \\ &= \text{an integer} + 1/2 \end{aligned} \quad (10)$$

In general, if the order of reading out which corresponds to television scanning is taken into consideration, the last image sensing cell $N \cdot N_H$ and the first image sensing cell $(N \cdot N_H + 1)$ in the following $(N+1)$ line are τ_H apart from each other, as are the other image sensing cells. Therefore, the fraction $1/2$ in equation (10) means that the first cell in the next (second) line is displaced from the reference time of the horizontal scanning period T_H by $\tau_H/2$. That is, positions of the reproduced picture elements between the N and $(N+1)$ lines are relatively displaced by $\tau_H/2$.

Accordingly, at an odd field in an odd frame, a displacement of $\tau_H/2$ of reproduced picture elements appears between the N line (odd line) and N+1 line (even line) as shown in Figure 9B by the solid line.

Next, an even field in an odd frame is considered. In this case, since 264th line becomes the first line, the number of image sensing cells between the lines 263 and 264 can be calculated, similarly to equation (9), as follows:

$$\begin{aligned} 263 \cdot N_H &= 263 \times \frac{455}{2} \cdot f_H \cdot T_H \\ &= \frac{1}{2} \times 263 \times 455 \\ &= \text{an integer} + 1/2 \end{aligned} \quad (10')$$

Thus, the reproduced picture elements are displaced by $\tau_H/2$.

Accordingly, in the case of even fields, unlike odd field, the reproduced picture elements of only the odd lines are displaced, which is shown in Figure 9B by dotted lines.

In the case of an even frame, the reproduced picture elements opposite to those of the odd frame are displaced in the respective fields, which is shown in Figure 9C. That is, in an even frame the reproduced cells on the odd lines of the odd field are displaced, while the reproduced cells on the even lines of the even field are displaced.

As may be apparent from comparison of Figures 9B and 9C, the displacement occurs between the odd and even frames, and there is a period of two frames.

When a checker-pattern CCD is used, a similar phenomenon occurs. In this case, however, the displacement of the reproduced picture elements occurs in only one field in either of the odd and even frames, as shown in Figures 10A, 10B and 10C.

According to the present invention there is provided a solid state colour camera comprising:

an image sensing device having a two-dimensional array of image sensing cells extending in both horizontal and vertical directions;

filter means for providing three primary colour separated images on said image sensing device;

means for reading out an image signal as to satisfy an interlaced signal reading system of a standard television signal, said image signal comprising a luminance signal and a carrier modulated chrominance signal;

means for supplying a carrier signal to said reading-out means, said carrier signal being selected to differ by a small predetermined amount from a standard colour sub-carrier frequency or a half thereof; and

means for selecting vertical and horizontal frequencies of a read-out image signal.

The invention will now be described by way of example with reference to the accompanying drawings throughout which like references designate like elements, and in which:

Figure 1 is a schematic diagram showing one example of a solid state image sensor;

Figure 2 is a part of Figure 1 on an enlarged scale, showing a pattern of imaging sensing cells of the sensor of Figure 1;

Figure 3 is a schematic diagram showing a part of another example of a solid state image sensor;

Figure 4 is a part of Figure 3 on an enlarged scale, showing a pattern of image sensing cells of the sensor of Figure 3;

Figure 5 is a frequency spectrum diagram of an output signal from the image sensor;

Figure 6 is a schematic diagram showing a spatial arrangement of a plurality of solid state image sensors;

Figure 7 is a phasor diagram showing the phase relation of side-band components;

Figure 8 is a systematic diagram showing an example of a previously proposed solid state camera system;

Figures 9A, 9B and 9C and 10A, 10B and 10C are diagrams used for explaining the image sensing displacement of the camera of Figure 8;

Figures 11A, 11B, 12A and 12B are diagrams used for explaining the invention;

Figure 13 shows a pattern of image sensing cells of a CCD which can be employed in embodiments of the invention;

Figure 14 is a block diagram of an embodiment of solid state colour camera according to the invention;

Figures 15 and 16 are waveform diagrams for explaining the operation of the camera of Figure 14; and

Figures 17A and 17B are schematic diagrams showing a CCD which can be used in embodiments of the invention.

In the embodiments, at least the phase of the colour sub-carrier frequency f_s expressed by equation (4) is repeated at the frame period, and accordingly the colour sub-carrier frequency (sub-carrier) f_s , which is used as the transfer frequency f_c , is determined by the following equation (11):

$$f_s = \left(\frac{455}{2} \pm \frac{2I+1}{2 \times 525} \right) F_H \quad (11)$$

where:

$$I=0, 1, 2, \dots$$

$$F_H = f_H$$

$$F_H = \frac{525}{2} f_v \quad (12)$$

or

$$F_H = f'_H \neq f_H; \quad f'_H = \frac{525}{2} f'_v; \quad F_v \neq f_v \quad (13)$$

where F_H and F_v represent the horizontal and vertical synchronizing signals used in the embodiments, and f_H and f_v represent the horizontal and vertical synchronizing signals used in the standard system.

In the case that F_H is the same as the horizontal scanning frequency f_H , as in equation (12), the sub-carrier f_s differs from the prior art somewhat. In such a case, however, the term I in equation (11) is so selected that the frequency of a shifted sub-carrier f_s is within a synchronized capture range of the automatic phase control (APC) circuit of a television receiver, or preferably within a broadcasting standard. In general, even if the frequency of the shifted sub-carrier f_s differs within a range of about 10 Hz to 200 Hz from the normal value, the synchronization is not disturbed.

In the case of equation (13), the respective values are selected within at least the synchronized capture range. In general, there will be no problem even when f_H is shifted by about ± 200 Hz and f_v by about $\pm$ several Hz.

The following description is for the case of equation (11), and consideration is given to whether it is an integral multiple of 525 or not; namely, the following cases:

$$A. \quad 2I+1 \neq 525M$$

$$B. \quad 2I+1 = 525M$$

where M is an integer.

Firstly, in the case of A, in order to facilitate the explanation, the following condition is assumed:

$$2I+1=1$$

$$f_s = \left(\frac{455}{2} + \frac{1}{2 \times 525} \right) f_H \quad (14)$$

Thus, the following equation (15) is established on the even field in an odd frame:

$$\begin{aligned}
 263 \cdot N_H &= 263 \times \left(\frac{455}{2} + \frac{1}{2 \times 525} \right) f_H \cdot T_H \\
 &= \frac{263 \times 455}{2} + \frac{263}{2 \times 525} \\
 &= \left(m + \frac{1}{2} \right) + \frac{1}{4} \\
 &= m + \frac{3}{4}
 \end{aligned} \tag{15}$$

where:

$$\begin{aligned}
 \frac{263 \times 455}{2} &= m + \frac{1}{2} \quad (m \text{ being an integer}) \\
 \frac{263}{2 \times 525} &= \frac{1}{4}
 \end{aligned}$$

From equation (15) it will be apparent that the reproduced picture elements are displaced by $\tau_H/4$ in the even field.

Although not described, in the odd field only the reproduced picture elements on the even line are displaced by $\tau_H/2$ similar to the prior art, so that the arrangement of reproduced picture elements becomes as shown in Figure 11B.

The reproduced picture elements on the even line of an even field is expressed by the following equation (16) if $N=264$:

$$\begin{aligned}
 264 \cdot N_H &= 264 \times \left(\frac{455}{2} + \frac{1}{2 \times 525} \right) \\
 &= m + \frac{1}{4} \quad (m \text{ being an integer})
 \end{aligned} \tag{16}$$

Thus, on the even line the reproduced picture elements are displaced by $3 \tau_H/4$ as shown in Figure 11B.

Next, an even frame will be considered; since the reproduced picture elements are expressed by the following equation (17), the reproduced picture elements are not displaced on the first line:

$$\begin{aligned}
 525 \cdot N_H &= 525 \left(\frac{455}{2} + \frac{1}{2 \times 525} \right) \\
 &= \left(m + \frac{1}{2} \right) + \frac{1}{2} \\
 &= m + 1 \quad (m \text{ being an integer})
 \end{aligned} \tag{17}$$

Also, the reproduced picture elements on the next line are expressed by the following equation (18), so that on the next line the reproduced picture elements are displaced by $\tau_H/2$.

$$\begin{aligned}
 526 \cdot N_H &= 526 \left(\frac{455}{2} + \frac{1}{2 \times 525} \right) \\
 &= m + \frac{1}{2}
 \end{aligned} \tag{18}$$

In an even field, the reproduced picture elements on the first line are given by the following equation (19):

$$\begin{aligned}
 (525+263)N_H &= \frac{788 \times 455}{2} + \frac{788}{2 \times 525} \\
 &= m + \frac{3}{4}
 \end{aligned} \tag{19}$$

so that the reproduced picture elements are displaced by $\tau_H/4$ on the first line.

The reproduced picture elements on the next line are given by the following equation (20):

$$\begin{aligned}
 (525+264)N_H &= \frac{789 \times 455}{2} + \frac{789}{2 \times 525} \\
 &= \left(m + \frac{1}{2}\right) + \frac{3}{4}
 \end{aligned} \tag{20}$$

so that the reproduced picture elements are displaced by $3\tau_H/4$.

Thus, the reproduced picture elements are displaced in the even frames the same as in the odd frames, so no displacement of reproduced picture elements occurs between the fields, and the displacement of reproduced picture elements between the frames can be eliminated.

Where the checker-pattern CCD is used, since the image sensing cells are shifted by $\tau_H/2$ between the adjacent lines as shown in Figure 12A, the reproduced picture elements are not displaced on odd fields but the reproduced picture elements are only displaced on the even fields as shown in Figure 12B. Therefore, it will be easily understood that if a checker-pattern CCD is employed, the reproduced picture elements are displaced less as compared a CCD with a parallel-aligned pattern and hence a reproduced picture becomes more stable.

If the spatial arrangement of image sensing cells is selected to be the same as the arrangement of reproduced picture elements and accordingly a CCD, which has the image sensing cell arrangement shown in Figure 13 (this type of CCD will hereinafter be called a modified checker-pattern CCD), is used, the displacement of reproduced picture elements becomes zero. When the modified checker-pattern CCD is formed in practice, a diode array or the like is most preferred.

As described above, if the term $(2I+1)$ of equation (11) is selected to satisfy the above condition A, it will be apparent that the required effect can be achieved.

Next, the above condition (I) will be described briefly.

In the spectroscopic system, in order to satisfy the following conditions (a) and (b):

- (a) the ratio of the levels of the R, G and B signals forming the luminance signal in the NTSC system satisfies equation (2), and
- (b) the side-band components become the colour difference signal of equation (3)

the levels of output signals from the respective CCDs 10A, 10B and 10C must be equal to one another, so that the spectroscopic characteristics of the colour filters 12R, 12G and 12B must be selected to satisfy the above conditions.

If colour filters transmitting light of a single colour as shown in Figure 8 are used, the above conditions cannot be satisfied. Thus, colour filters having the following spectroscopic characteristics are required.

Firstly, the relation between the output signals S_{oa} , S_{ob} and S_{oc} of the CCDs 10A, 10B, 10C, and signals R, G, B is expressed as follows:

$$\begin{pmatrix} S_{oa} \\ S_{ob} \\ S_{oc} \end{pmatrix} = \begin{pmatrix} r_1 & g_1 & b_1 \\ r_2 & g_2 & b_2 \\ r_3 & g_3 & b_3 \end{pmatrix} \begin{pmatrix} R \\ G \\ B \end{pmatrix} \quad \dots (21)$$

5 In the above equation (21), in order to satisfy the above conditions (a) and (b), although a detailed explanation will not be given, it is sufficient that the constants of r_1 to b_3 are selected, for example, as follows: 5

$$\begin{pmatrix} r_1 & g_1 & b_1 \\ r_2 & g_2 & b_2 \\ r_3 & g_3 & b_3 \end{pmatrix} = \begin{pmatrix} 0.2028 & 0.1305 & 0.0000 \\ 0.0423 & 0.2911 & 0.0000 \\ 0.0549 & 0.1684 & 0.1100 \end{pmatrix} \quad \dots (22)$$

From equation (22), the levels E_R , E_G , E_B of the output signals R, G, B become as follows:

$$\left. \begin{aligned} E_R &= (r_1 + r_2 + r_3)R = 0.3000 \\ E_G &= (g_1 + g_2 + g_3)G = 0.5900 \\ E_B &= (b_1 + b_2 + b_3)B = 0.1100 \end{aligned} \right\} \quad \dots (23) \quad 10$$

Thereby, the condition (a) is satisfied. Moreover, since the output signals S_{oa} , S_{ob} and S_{oc} from the respective CCDs 10A, 10B and 10C are expressed by the following equation (24):

$$\left. \begin{aligned} S_{oa} &= r_1 R + g_1 G = 0.3333 \\ S_{ob} &= r_2 R + g_2 G = 0.3334 \\ S_{oc} &= r_3 R + g_3 G + b_3 B = 0.3333 \end{aligned} \right\} \quad \dots (24)$$

15 where $R=G=B=1$, the above condition (b) is also satisfied. Accordingly, the filtering characteristics of the colour filters 12R, 12G, 12B which are disposed in front of the CCDs 10A, 10B and 10C are determined to satisfy equation (22).

20 A solid state colour camera 30 which satisfies the above conditions (I) and (II) will be described with reference to Figure 14. The respective horizontal shift registers of three CCDs 10A, 10B and 10C of the camera 30 are supplied with the 20

transfer signal S_c obtained from a synchronizing board 31. In this case, as described previously, the frequency f_s of the transfer signal S_c is selected as follows:

$$f_s = f_c = \left(\frac{455}{2} + \frac{1}{2 \times 525} \right) f_H$$

$$= 3.579560 \text{ MHz} \quad (25)$$

It may easily be understood from the above description that the CCDs 10B and 10C are supplied with transfer signals S_{c2} and S_{c3} (Figure 15) which are shifted in phase by $2\pi/3$ and $4\pi/3$ from the transfer signal S_c (S_{c1} hereinafter) supplied to the CCD 10A by phase shifters 32 and 33. Thus, the output signals S_{oa} , S_{ob} and S_{oc} are alternately and successively derived from the respective CCDs 10A, 10B and 10C with time delays, and then fed through sampling hold circuits 34A, 34B and 34C to an adding circuit 35 to be added or composed as a composite signal S_r .

The composite signal S_r is supplied to a low-pass filter 36 to be limited within a desired band (about 4.5 MHz), and thereafter to a composite circuit 37 which is supplied with various synchronizing signals so as to produce a well known composite colour video signal S_{NTSC} . That is, a blanking pulse signal BLK, synchronizing signals VD and HD, and burst signals BURST obtained from the synchronizing board 31 are supplied to the composite circuit 37.

The phase of the burst signal BURST is selected as follows. When demodulating the carrier chrominance signal at a receiver, the demodulating axes are the R-Y axis and B-Y axis, but it is necessary that the colour signal demodulated with these demodulating axes satisfies the condition of the NTSC system, or equation (3). To this end, R-Y and B-Y axes are selected as shown in Figure 16. An angle θ shown in Figure 16 can be determined, for example, as follows:

$$\theta = 12.4^\circ \quad (26a)$$

The demodulated output signal (colour signal) S_d in the case of equation (26a) is expressed by the following equation (26b):

$$S_d = 0.245A \left\{ \frac{R-Y}{1.14} \cos 2\pi \cdot f_s \cdot t + \frac{B-Y}{2.03} \sin 2\pi \cdot f_s \cdot t \right\}$$

. . . (26b)

In equation (26b), A represents the output gain ratio of the side-band component S_m to the modulated component S_{dc} so that, as the demodulated output signal S_d of the NTSC system, only the factor 0.245 A is different. However, the factor 0.245 A can be made coincident with that of the NTSC system by utilizing the operation of the automatic colour control (ACC) circuit of the receiver.

If the phase of the burst signal is selected to satisfy equation (26a) as shown in Figure 16, the colour difference signal can be demodulated. To this end, as shown in Figure 14, there are provided a level adjusting circuit 40 connected to the output side of the synchronizing board 31 and a phase adjusting circuit 39 connected between the level adjusting circuit 40 and the composite circuit 37.

If the optical characteristics and transfer signal are selected as described above, a solid state colour camera of the direct NTSC system can be made, and also a reproduced picture from the video signal therefrom is free from flicker.

The above description is given only for the case of $(2I+1=525 \text{ M})$, but it is of course possible in the case of $(2I+1=525 \text{ M})$ or the above condition B, that the phase of the transfer frequency f_c is repeated at every frame. Although the detailed explanation will be omitted, if in the following equation (27):

$$f_s = \left(\frac{455}{2} \pm \frac{M}{2} \right) F_H \quad (27)$$

M is an even number, a fraction (1/2) appears in the term of F_H . Thus, M must be an odd integer. Therefore $M=2M'+1$, M' being an arbitrary integer.

Therefore, equation (27) is rewritten as follows:

$$f_s = \left(\frac{455}{2} \pm \frac{2M'+1}{2} \right) F_H$$

$$\therefore f_s = \left(m + \frac{1}{2} \right) \pm \left(M' + \frac{1}{2} \right) F_H$$

$$= M'' F_H \quad (28)$$

where M'' is an integer.

In this case, F_H must be different from f_H and the tolerance range of the former is determined as follows:

$$F_H = f_H \pm \Delta f_H$$

$$\Delta f_H = 200 \text{ Hz} \quad (29)$$

Further, the transfer frequency f_c is selected, for example, to be within several tens of the Hz of f_s above or below.

Since $M=1$, $M''=228$ (or 227). Therefore, in this case, if F_H is selected as 15.69975 Hz (15.7689 Hz), the purpose can be achieved without changing the frequency f_s . In other cases, the respective values can be selected suitably.

With equation (28), regardless of whether M'' is even or odd, it can be satisfied, and hence there is no displacement of the reproduced picture elements. Therefore, it will be apparent that a CCD of parallel-aligned type is preferred.

The foregoing description is given for the case that the carrier frequency of a colour difference signal is the repeating frequency of $f_c = f_s$. It is, however, possible that even if, for example, the transfer frequency f_c is selected as $f_s/2$ and the frequency where the second high harmonic ($=f_s$) is obtained is selected as the carrier frequency to produce the colour difference signal, the purpose can be achieved.

In this case, however, since the transfer frequency f_c is itself in the band of the luminance component, it is necessary to eliminate the fundamental side-band components produced about the frequency f_c . Therefore, in the case where the above system is employed, the signal processing system must cancel the above side-band component by utilizing the vertical correlation.

As described above, if $f_c = f_s/2$ is used, the frequency f_c is expressed as follows:

$$f_c = \frac{1}{2} M'' F_H \quad (30)$$

Thus, if M'' is odd, it is sufficient that the circuit is formed so as to reverse the phase of the transfer frequency f_c at every frame. In this case, the displacement of reproduced picture elements becomes as shown in Figure 11B, so that the checker-pattern CCD is preferred.

As another example of the case that M'' is odd, it is possible that equation (30) is modified as equation (11).

When $M''=2M''' + 1$ (M''' is an integer), the following equation (31) is obtained:

$$f_c = \frac{1}{2} f_s = \left(\frac{2M''' + 1}{2} \pm \frac{1}{2 \times 525} \right) F_H \quad (31)$$

With this system, the reproduced picture elements are displaced as shown in Figure 11B, so that a CCD of modified checker-pattern is preferred, but a CCD of a checker-pattern can be used without any trouble.

In case of M'' being even, although the detailed explanation will be omitted, it is sufficient to employ the transfer signal the phase of which is reversed at every 1 H and every frame, and a CCD similar to that of the above example can be used.

As described above, the frequency of the transfer signal is selected to be very near the colour sub-carrier frequency, so that various defects of the direct NTSC system inherent to the prior art can be avoided. Accordingly, signal processing circuits such as an encoder can be omitted to simplify the circuit construction, but the deterioration of picture quality is avoided.

The above description is given for the case where three CCDs are used to form the solid state colour camera, but it is not essential to use three. for example, one CCD may be used.

Figure 17A shows the case where a single CCD is used. In this case, the R, G and B colour signals are provided by a single CCD, so that three image sensing cells S_1 , S_2 and S_3 make a unit as shown in Figure 17A. Figure 17A is the case of a checker-pattern CCD. When the CCD is formed to satisfy the above conditions, the arrangement of the reproduced picture elements becomes as shown in Figure 17B.

WHAT WE CLAIM IS:—

1. A solid state colour camera, comprising:
 - an image sensing device having a two-dimensional array of image sensing cells extending in both horizontal and vertical directions;
 - filter means for providing three primary colour separated images on said image sensing device;
 - means for reading out an image signal as to satisfy an interlaced signal reading system of a standard television signal, said image signal comprising a luminance signal and a carrier modulated chrominance signal;
 - means for supplying a carrier signal to said reading-out means, said carrier signal being selected to differ by a small predetermined amount from a standard colour sub-carrier frequency or a half thereof; and
 - means for selecting vertical and horizontal frequencies of a read-out image signal.

2. A camera according to Claim 1 wherein said carrier signal is selected to satisfy the following equation:

$$f_s = \left(\frac{455}{2} \pm \frac{2I+1}{2 \times 525} \right) \times F_H$$

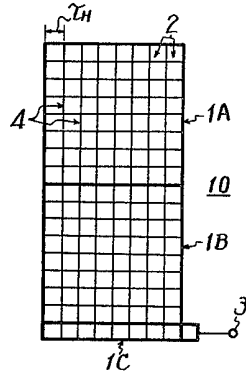
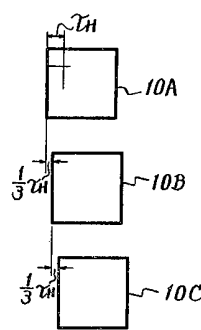
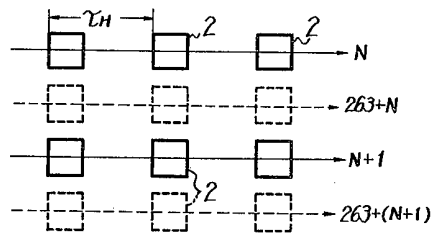
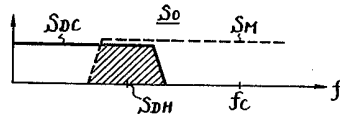
where I is 0, 1, 2, ..., f_s is selected as said carrier signal, and F_H is selected as a horizontal frequency.

3. A camera according to Claim 2 wherein said image sensing device includes three CCD imaging chips, said filter means of three primary colours are respectively disposed in the light path of each of said CCD imaging devices, and outputs of said CCD imaging chips are mixed to derive said image signal.

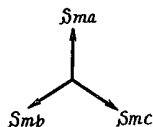
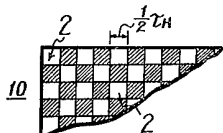
4. A camera according to Claim 3 wherein light transmitting characteristics of each of said filter means are determined for said luminance signal to satisfy colour ratios of a luminance component of a standard composite colour television signal.

5. A solid state colour camera substantially as hereinbefore described with reference to Figure 14 of the accompanying drawings.

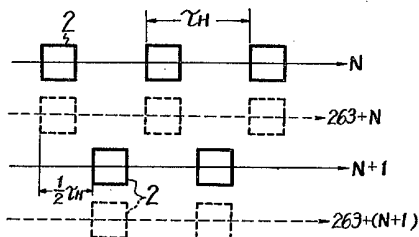
For the Applicants
D. YOUNG & CO.,
Chartered Patent Agents,
9 & 10 Staple Inn,
London WC1V 7RD.

FIG. 1**FIG. 6****FIG. 2****FIG. 5**

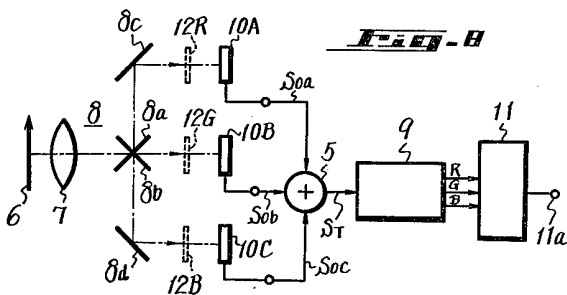
IFM.7



FD-4



FD-8

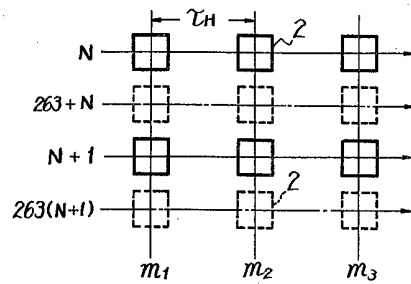
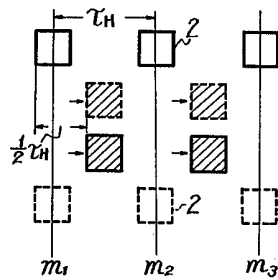
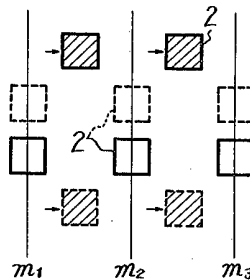


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Fig. 9A**Fig. 9B****Fig. 9C**

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Fig. 10A

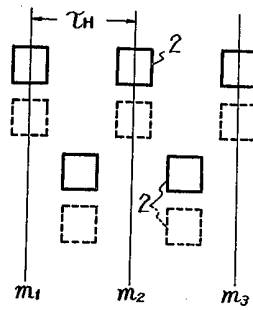


Fig. 10B

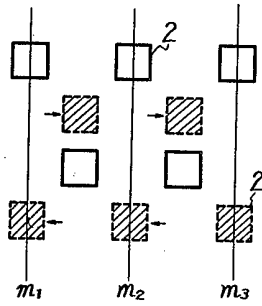


Fig. 10C

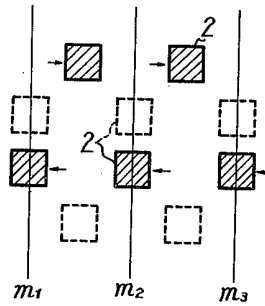
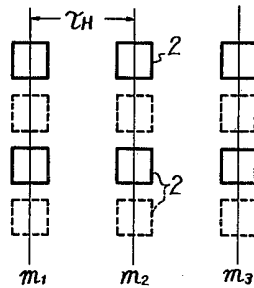
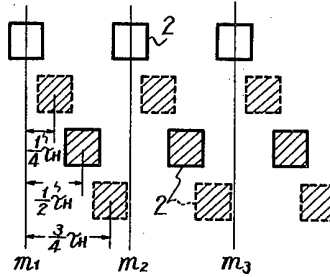


FIG. 11A**FIG. 11B**

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FIG. 12A

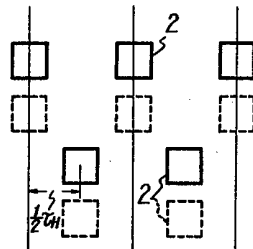


FIG. 12B

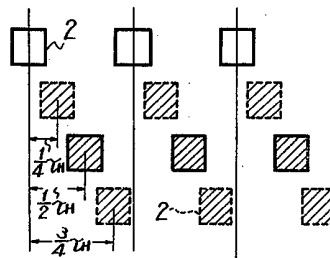
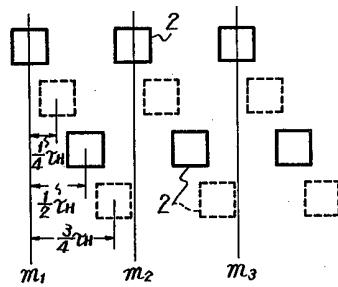


FIG. 13



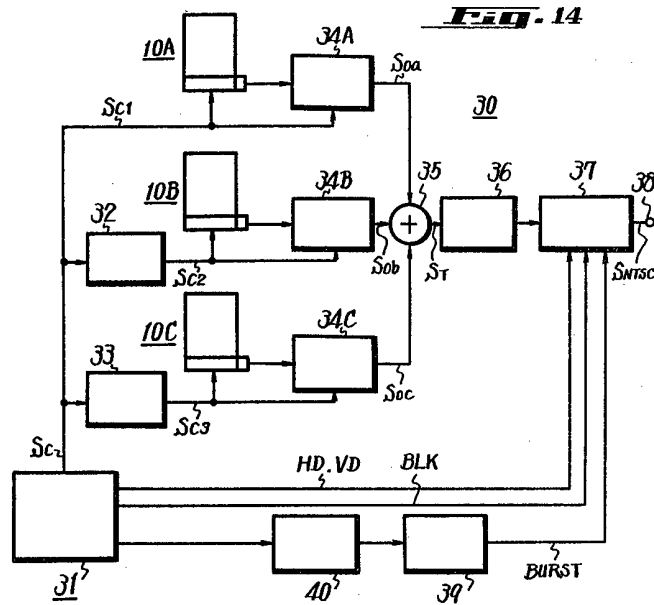
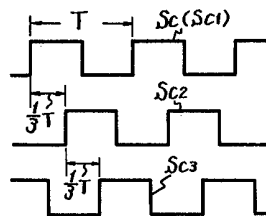
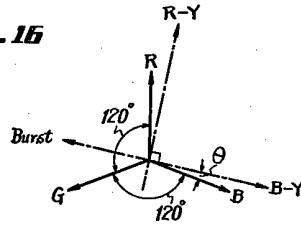
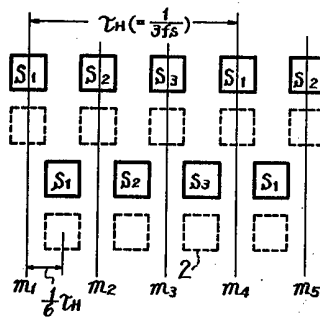
**Fig. 15A****Fig. 15B****Fig. 15C**

FIG. 16**FIG. 17A****FIG. 17B**