PUBLISHED
JULY 13, 1943.
BY A. P. C.

G. VALENSI
SYSTEM OF TELEVISION IN COLOURS
Filed Jan. 14, 1939

Serial No.
251,004
6 Sheets-Sheet 1

Fig. 1

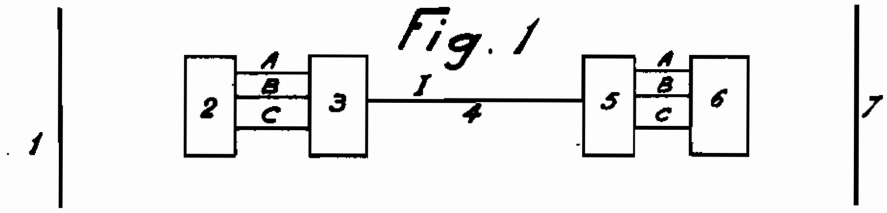


Fig. 3

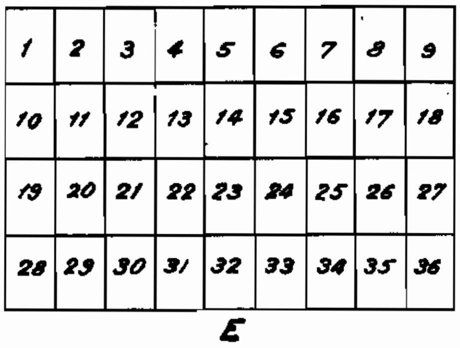
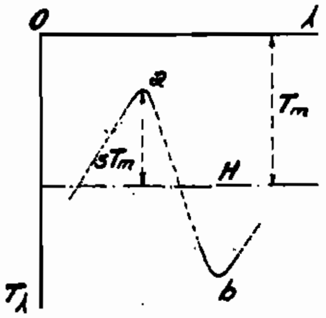


Fig. 8



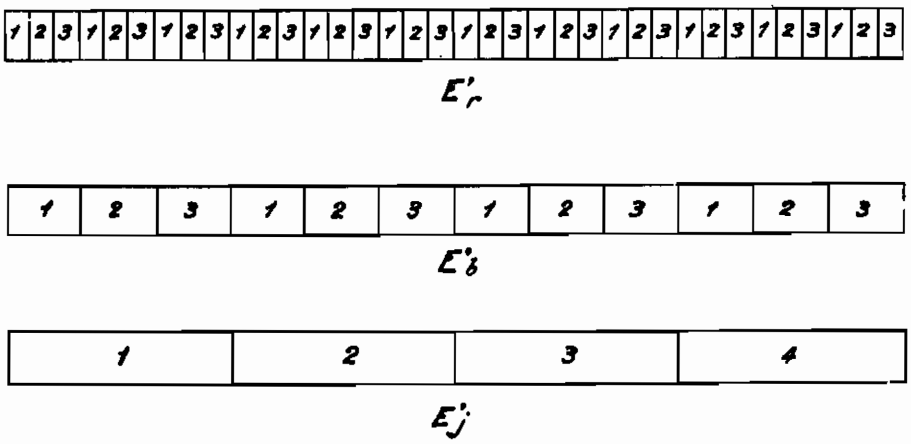


Fig. 7

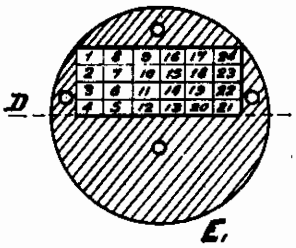


Fig. 7a

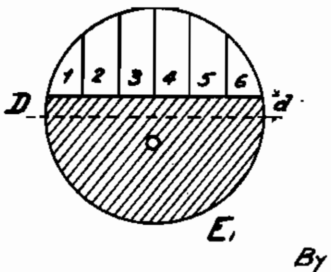


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Fig. 2

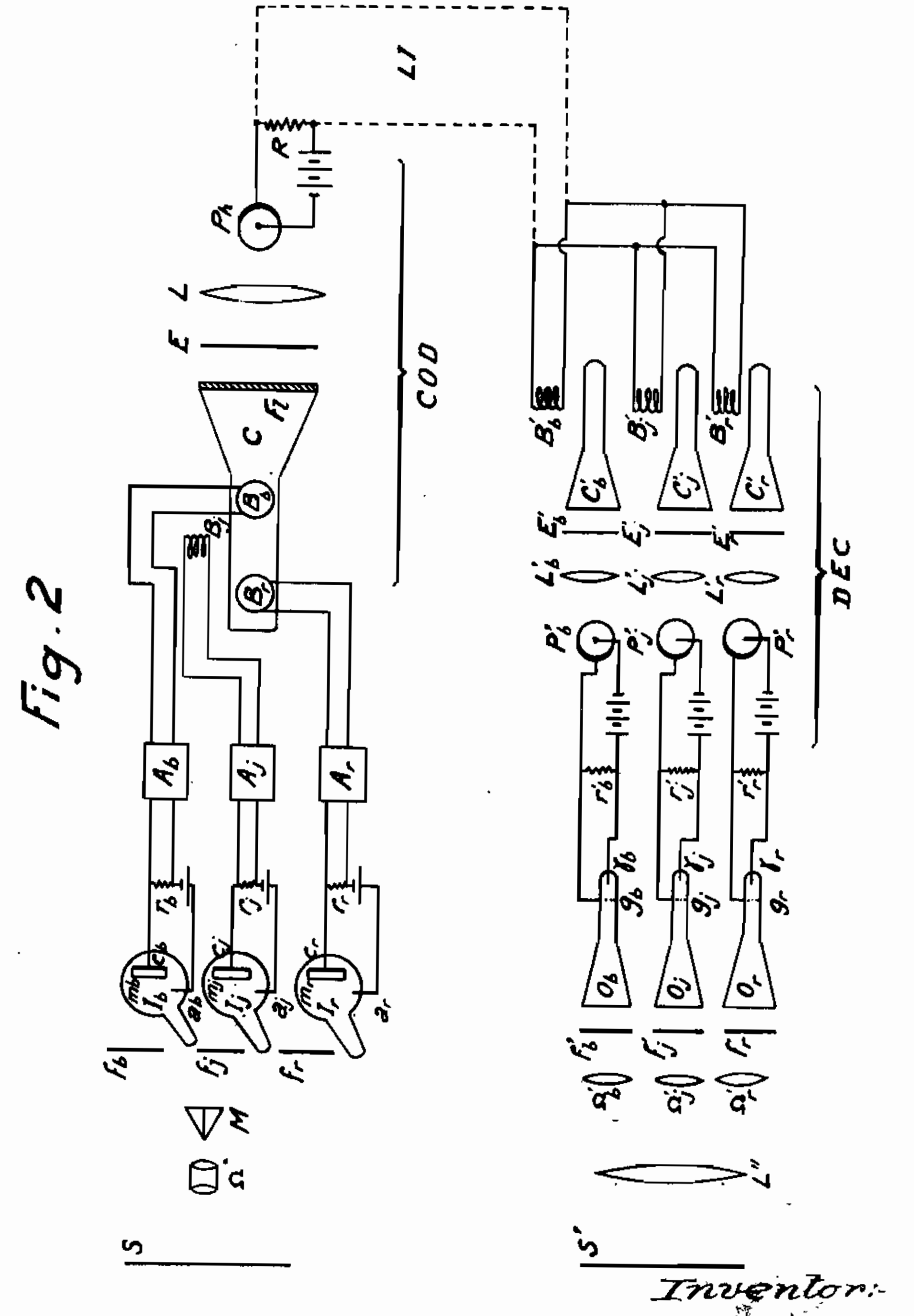

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Fig. 14a

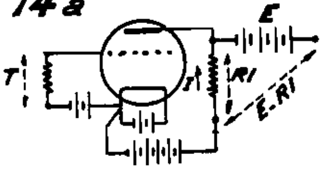


Fig. 14b

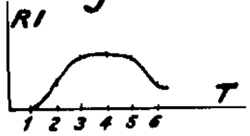


Fig. 14c

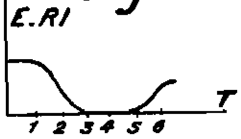


Fig. 4

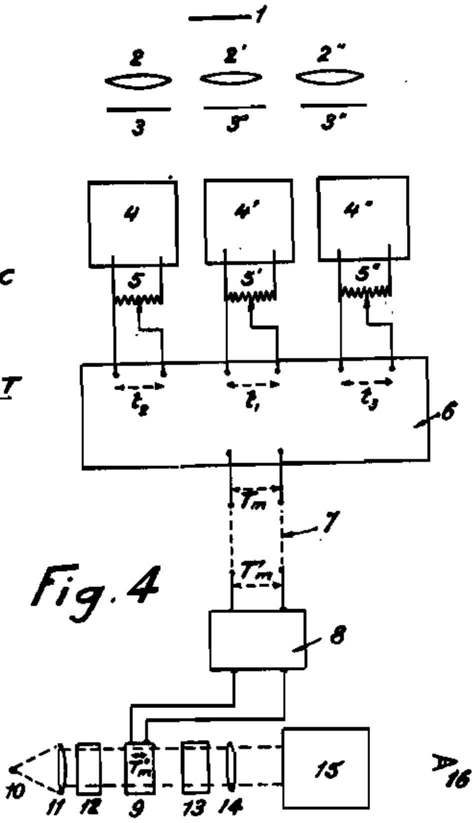


Fig. 15a

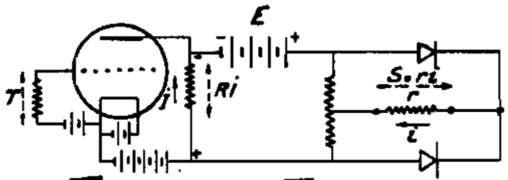


Fig. 15b

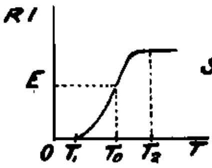


Fig. 15c

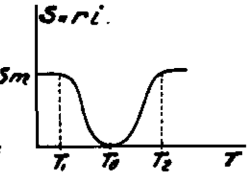


Fig. 5

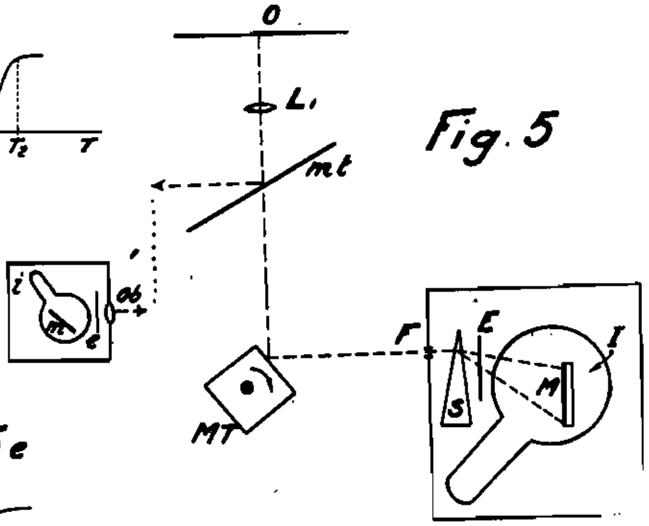


Fig. 15d

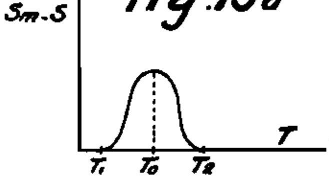
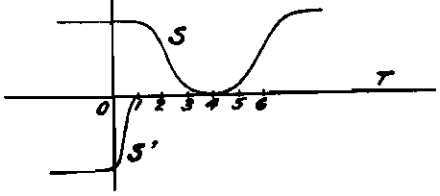


Fig. 15e



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251,004
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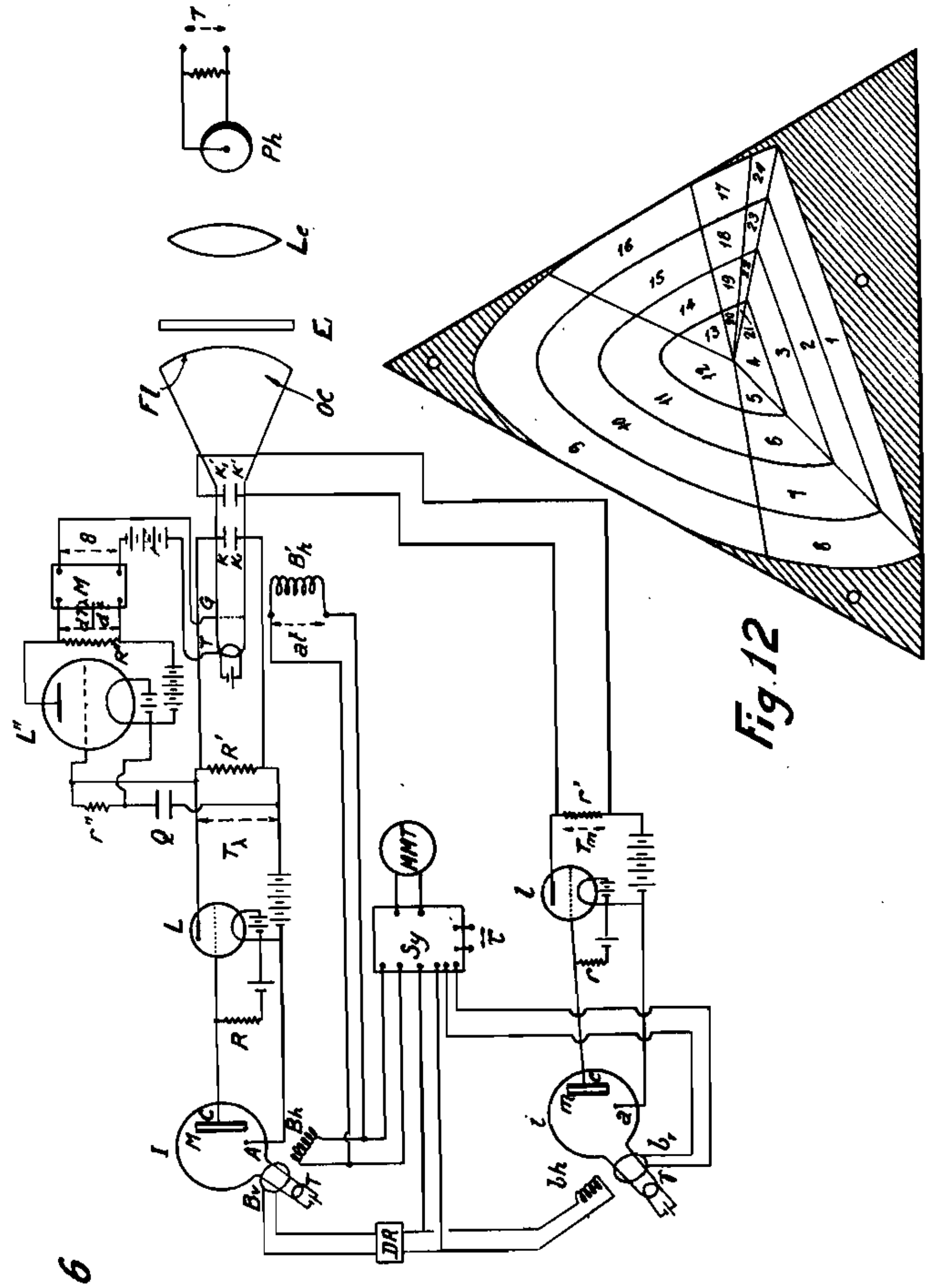

Fig. 6

Fig. 12

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PUBLISHED
JULY 13, 1943.
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SYSTEM OF TELEVISION IN COLOURS
Filed Jan. 14, 1939

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Fig. 9

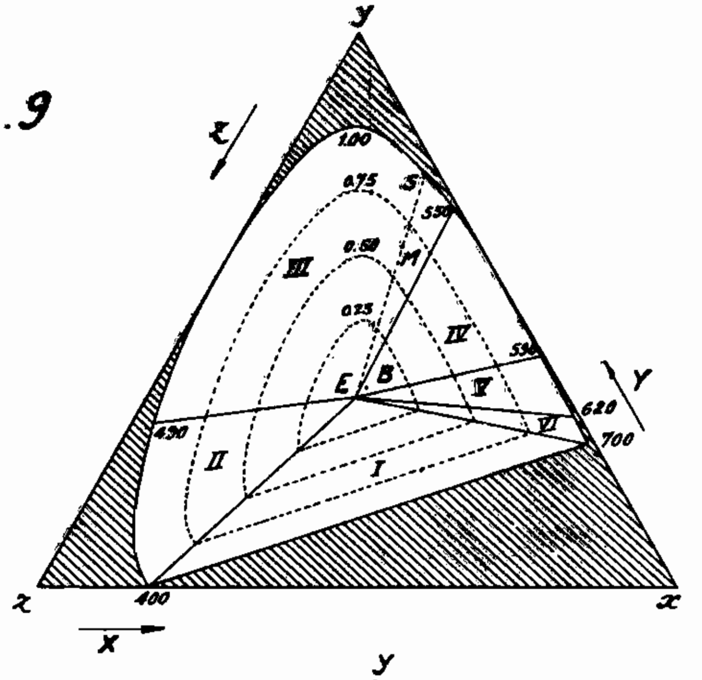
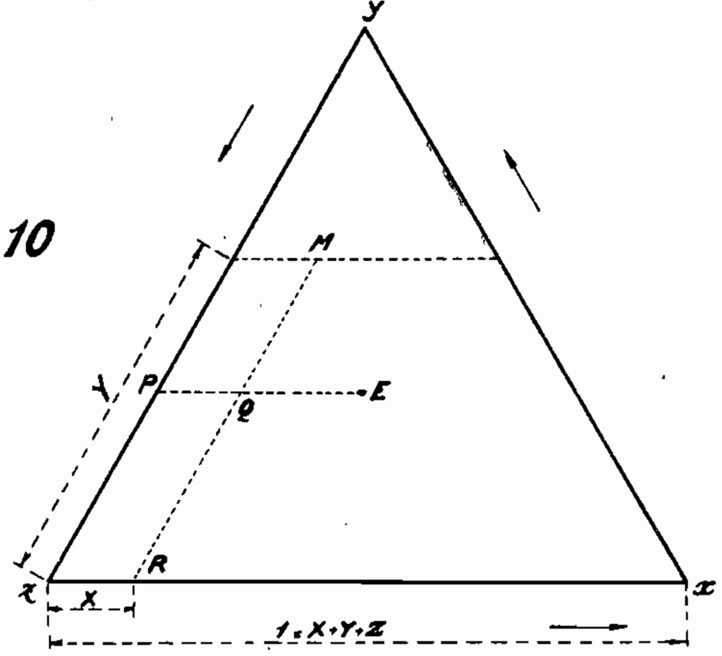


Fig. 10



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PUBLISHED
JULY 13, 1943.
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G. VALENSI
SYSTEM OF TELEVISION IN COLOURS
Filed Jan. 14, 1939

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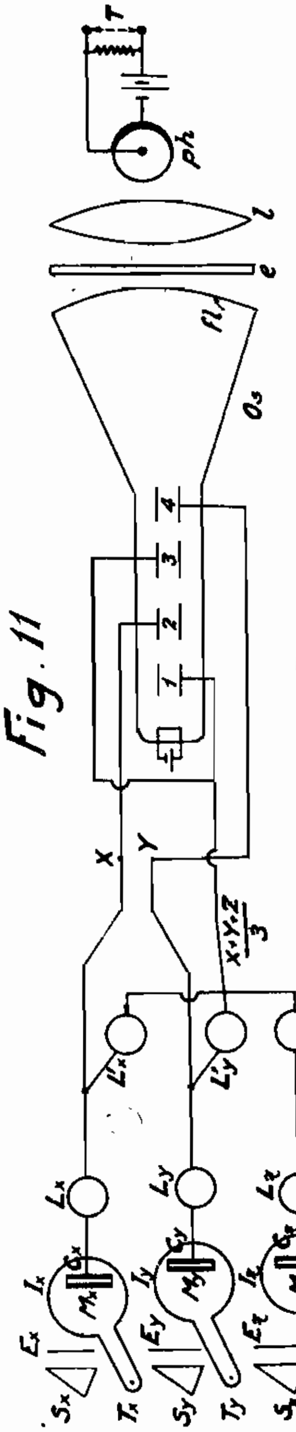

Fig. 11

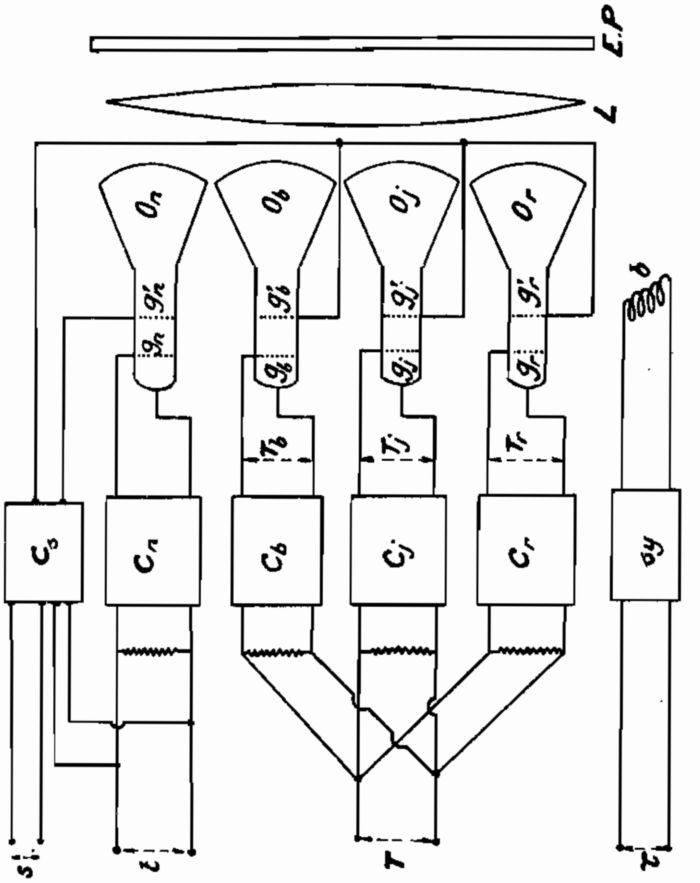

Fig. 13

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Published July 13, 1943 **Serial No. 251,004**

ALIEN PROPERTY CUSTODIAN

SYSTEM OF TELEVISION IN COLOURS

Georges Valensi, Paris, France; vested in the
Alien Property Custodian

Application filed January 14, 1939

The object of my invention is a colour television system which does not require between the transmitting and receiving television stations a metallic line or a radio-link transmitting effectively a band of frequencies much larger than the band required for an ordinary black and white television. Instead of transmitting over said line or radio link, for each point of the object to be shown at distance, three signals on three different channels (that is the three brightness values of the three basic components (say blue, red and yellow) of the colour of said point), like in the colour television systems already known, I transmit only one signal $\dot{I}$ on one channel only, said signal carrying both the brightness and the colour,—or I transmit two signals I and I′ on two channels (one signal for the brightness and one signal for the colour). My invention permits either an economy in the cost of the metallic line, or a less congestion of the other in case of a radio link. Moreover my invention permits the privacy of television transmission (or secret televisional transmissions.)

The principle of my invention is illustrated in Figure 1, where **1** is the object or scene to be shown at distance; **2** is a scanning device producing for each point of the object **1**, three elements or magnitudes A, B, C, characterising the mean brightness and the actual colour of said point; **3** is a coding device which combines the three elements A, B, C in one electric signal I (or two electric signals I and I′) transmitted to the distant station over the metallic line or radiolink **4**. There the decoding device **5** restores the characteristic elements A, B, C which act on the television receiver **6** to produce on the screen **7** a coloured luminous point having the same position, mean brightness and actual colour than the point of the object **1** scanned at that instant in the transmitting station, so that the image of object **1** is reproduced on screen **7** both in shape and in colours.

In a first embodiment of my invention, the three characteristic elements A, B, C are respectively the brightness values of the three basic components (for example, blue red and yellow) of the coloured point of the object which is scanned at the considered instant.

In a second embodiment of my invention, the three characteristic elements A, B, C are: 1°—the mean brightness of said point, that is: the signal which would be sent in an ordinary black and white television system; 2°—the position in the visible spectrum of the radiation or wavelength which should be mainly absorbed in said visible spectrum in order to reproduce the actual colour of said point, 3°—the "degree of saturation" of the actual colour of said point, that is: the proportion of white to be added to an appropriate monochromatic colour (complementary to said most absorbed radiation) in order to reproduce said actual colour of said point.

In a third embodiment of my invention based on Maxwell's triangle of colours, the three characteristic elements A; B, C are: 1°—the mean brightness of said point, as above;—2°—the "hue" or predominating monochromatic colour corresponding to said point,—3°—the "degree of saturation" of the actual colour of said point.

In the first embodiment of my invention, I transmit generally on the line or radiolink one signal $\dot{I}$ only for each point of the object to be shown at distance, said signal $\dot{I}$ combining the three elements A, B, C.

In the second and third embodiments, I may transmit on one channel a signal which is precisely proportional to element A (thus giving an image in black and white) and on another channel a signal I′ combining the elements B and C (thus adding coloured touches to said image in black and white). In such a case I need two channels on the metallic line or radiolink, but the ordinary television receivers can then be still generally used for providing black and white images, whereas, in some receivers only, an attachment for adding colours to said images is used. However in the second and third embodiments of my invention, I may also combine the three elements A B C in one signal $\dot{I}$, so that one channel only will be required on the metallic line or radiolink.

The appended drawings illustrate examples of realisation of my invention, but any other form of realisation embodying other features well known in the television art should be considered as contained in the frame of my invention.

Figure 2 illustrates the first embodiment mentioned hereabove and Figure 3 shows the coding screen E and the decoding screens E'_r E'_b E'_j.

Figure 4 illustrates an application of the second embodiment of my invention in which the modulation of the colour at the television receiving station utilizes the "chromatic polarisation" or the "dispersion of optical rotatory power for various wave lengths" associated with the Kerr effect electrically controlled, or with the electric accidental birefringence of a crystal, or with the Verdet effect magnetically controlled (magnetic optical rotation).

Figures 5 and 6 illustrate the transmitting television station in the second embodiment of my invention, in which the spectral curve of the actual colour of each point of the object to be shown at distance (curve shown in Figure 8) is automatically drawn, and in which the coding screen of Figure 7 is used. Figure 7-*a* shows another coding screen for a simplified transmitting station on the principle illustrated by Figures 5 and 6.

Figure 9 illustrates the Maxwell's triangle of colours and Figure 10 a graphic construction in said triangle, whereas Figure 11 illustrates the transmitting station in the third embodiment of my invention which is based on said Maxwell's triangle and in which the coding screen shown in Figure 12 is used.

Figure 13 illustrates a television receiving station using cathode ray oscillographs and Figures 14 *abc* and 15 *abcde* show the performance of the devices controlling said cathode ray oscillographs.

On Figure 2, S is the coloured object to be shown at distance, Ω an objective (or lens) having a rear diaphragm in the pupilla of which is located a trihedral mirror M giving three images of S (through a blue screen *fb*, a yellow screen *fj* and a red screen *fr*), said images being located respectively on the photosensitive mosaics *mb*, *mj* and *mr* of three iconoscopes *Ib*, *Ij*, *Ir*, the anodes of which are *ab*, *aj*, *ar*, and the collecting plates of which are *cb*, *cj*, *cr*. The three electric voltages obtained at a given instant across the terminals of resistances *rb*, *rj*, *rr*, are proportional to the brightness values A, B, C of the blue, yellow and red basic components of the actual colour of the point of object S being scanned at that instant.

These three characteristic elements ABC are combined in the coding device COD comprising: 1°—a cathode ray oscillograph C (with a fluorescent screen *Fl* and three deflecting coils B_b, B_j, B_r energized by elements A, B, C through three amplifiers A_b, A_j, A_r—2°— transparent coding screen E,—3°—a lens L condensing all the luminous rays produced by the luminous spot on *Fl* through E,—4°—a photoelectric cell *Ph*, giving across the terminals of its output resistance R a voltage I which constitutes the coded signal transmitetd over the metallic line of radio link LI.

At the distant television station, said signal I acts on a decoding device DEC comprising: 1°—three cathode ray oscillographs *C'b C'j C'r* with fluorescent screens and deflecting coils *B'b B'j B'r*;—2°—three transparent decoding screens *E'b E'j E'r*, located in front of said fluorescent screens; 3°—three lenses *L'b L'j L'r* condensing all the luminous rays produced by the three luminous spots of oscillogdaphs *C'b C'j C'r* through *E'b E'j E'r* respectively in three photoelectric cells *P'b P'j P'r*.

The three electric voltages obtained at the given instant across the terminals of the output resistances *r'b*, *r'j*, *r'r* of said photolecertic cells reproduce the three elements ABC of the actual colour of the point of object S being scanned at said instant in the television transmitting station; these three voltages are applied to the control grids of three cathode ray oscillograhs *Ob Oj Or* with fluorescent screens in front of which are located respectively a blue screen *f'b*, a yellow screen *f'j* and a red screen *f'r*. Three objectives or lenses *Ω'b Ω'j* and *Ω'r* associated with a collecting lens L'' superpose on the receiving screen S' the three basic images (blue, yellow and red) of object S.

For the simplicity of explanation, let us assume that the electric voltage T_r (across r_r) may have one of three values $R_1=0$ (absence of red, R_2 (mean proportion of red), R_3 (large proportion of red),—that the voltage T_b across r_b may have one of three values, $B_1=0$ (absence of blue), B_2 (mean proportion of blue), B_3 (large proportion of blue),—that the voltage T_j across r_j may have one of four values $J_1=0$ (absence of yellow), J_2 (small proportion of yellow), J_3 (mean proportion of yellow), J_4 (large proportion of yellow). Let us assume also that the combination R_3 B_3 J_4 corresponds to white whereas the combination R_1 B_1 J_1 corresponds to black. Let us assume that the gains of the amplifiers A_b A_j A_r are adjusted in such a way that the luminous spot on fluorescent screen *Fl* is just in front of the square of the transparent coding screen E (Figure 3) which has the same number as the compartment of the following coding table which contains the combination of the values of R, B, J existing at the same instant. For example when $T_r=R_2$ $T_b=B_2$ $T_j=J_4$, said luminous spot is in front of square Nr 32 of the coding screen E, corresponding to compartment Nr 32 in the following coding table).

Coding table

1 $R_1 B_1 J_1$	2 $R_2 B_1 J_1$	3 $R_3 B_1 J_1$	4 $R_1 B_2 J_1$	5 $R_2 B_2 J_1$	6 $R_3 B_2 J_1$	7 $R_1 B_3 J_1$	8 $R_2 B_3 J_1$	9 $R_3 B_3 J_1$
10 $R_1 B_1 J_2$	11 $R_2 B_1 J_2$	12 $R_3 B_1 J_2$	13 $R_1 B_2 J_2$	14 $R_2 B_2 J_2$	15 $R_3 B_2 J_2$	16 $R_1 B_3 J_2$	17 $R_2 B_3 J_2$	18 $R_3 B_3 J_2$
19 $R_1 B_1 J_3$	20 $R_2 B_1 J_3$	21 $R_3 B_1 J_3$	22 $R_1 B_2 J_3$	23 $R_2 B_2 J_3$	24 $R_3 B_2 J_3$	25 $R_1 B_3 J_3$	26 $R_2 B_3 J_3$	27 $R_3 B_3 J_3$
28 $R_1 B_1 J_4$	29 $R_2 B_1 J_4$	30 $R_3 B_1 J_4$	31 $R_1 B_2 J_4$	32 $R_2 B_2 J_4$	33 $R_3 B_2 J_4$	34 $R_1 B_3 J_4$	35 $R_2 B_3 J_4$	36 $R_3 B_3 J_4$

The transparence of the coding screen E increasing regularly from the square Nr 1 (completely opaque) to the square Nr 36 (completely transparent), the electric voltage I produced across the terminals of the output resistance R, after the photoelectric cell *Ph*, is proportional to the number of the square in front of which said luminous spot is located at a given instant. This signal I characterising the particular combination of red, yellow and blue which corresponds to the actual colour of the point of object S being scanned at that instant, is transmitted over the metallic line or radiolink LI to the receiving television station where said signal I acts simultaneously on the cathode rays of the three oscillographs *C'b C'j C'r* in the decoding device. The decoding screens E'_b E'_j E'_r (Figure 3) are opaque except along the line explored by the luminous spot of the corresponding oscillograph, where they have a certain number of more or less transparent squares: on E'_r there are 36 squares in 12 series of 3 (squares **1** completely opaque and corresponding to R_1, squares **2** half transparent and corresponding to R_2, squares **3** completely transparent and corresponding to R_3),—on *E'b* there are 12 squares in 4 series of 3 (squares **1** completely opaque and correspond to B_1, squares **2** half transparent and corresponding to B_2, squares **3** completely transparent and corresponding to B_3),—on *E'j* there are 4 squares marked **1**, **2**, **3**, **4** and the transparence of which is regularly increasing (square **1** being completely opaque and corresponding to J_1, whereas square **4** is completely transparent and corresponds to J_4).

Consequently for each value of signal I, the electric voltages across the terminals of the output resistances r'_b r'_j r'_r have the values t_b, t_j and t_1, indicated in the following decoding table:

Decoding table

Numbers proportional to the electric voltage I applied on line or radio link LI	Voltage t_r modulating the red component in the received image	Voltage t_b modulating the blue component in the received image	Voltage t_j modulating the yellow component in the received image
1	1	1	1
2	2	1	1
3	3	1	1
4	1	2	1
5	2	2	1
6	3	2	1
7	1	3	1
8	2	3	1
9	3	3	1
10	1	1	2
11	2	1	2
12	3	1	2
13	1	2	2
14	2	2	2
15	3	2	2
16	1	3	2
17	2	3	2
18	3	3	2
19	1	1	3
20	2	1	3
21	3	1	3
22	1	2	3
23	2	2	3
24	3	2	3
25	1	3	3
26	2	3	3
27	3	3	3
28	1	1	4
29	2	1	4
30	3	1	4
31	1	2	4
32	2	2	4
33	3	2	4
34	1	3	4
35	2	3	4
36	3	3	4

The perfect correspondence between the above coding table and decoding table, shows that, if the voltages t_r, t_b and t_j are applied to the grids g_r g_b g_j of the three cathode-ray oscillographs O_r O_b O_j, and if the images of the fluorescent screens of these three oscillographs through red screen f_r, blue screen f_b and yellow screen f'_j are well superposed on screen S' the image of object S will be well reproduced on S', both in shape and in colours.

Naturally, in practice, instead of having on the coding screen E and on the decoding screens E'_b E'_j E'_r (Figure 3) a finite number of squares, I utilize continuous gradations of increasing transparence (corresponding to the hereabove mentioned series 1 to 36, 1 to 3 and 1 to 4) so that I obtain a very great variety of colours in the images received on screen S'. I may also change at will the law of variation of the transparence of the various parts of the coding screen E, and use corresponding decoding screens E'_r E'_b E'_j, in order to secure the privacy of the television transmission (in black and white, or in colours).

In the coding device of Figure 2, I may also place the photoelectric cell *Ph* and the coding screen E within the cathode ray tube C, on the same mounting than the fluorescent screen *Fl*; and I may do the same in the decoding device for P'_b E'_b C'_b or P'_j E'_j C'_j or P'_r E'_r C'_r.

Instead of using photoelectric cells in these devices, I may utilize an emission of secondary electrons, and so avoid the intermediate transformation in light; in such a case the coding and decoding screens (E, E'_b, E'_j, E'_r) are mosaics of juxtaposed elements of emitting and non emitting materials, swept by the beam of cathode rays which produces a more or less intense flux of secondary electrons, said electrons being concentrated by appropriate "electron optics" on a collecting electrode connected to the output resistance (R, r'_b, r'_j or r'_r).

I may also place the whole decoding device in the same vacuum tube (instead of three separate tubes C'_b C'_j C'_r) using "cylindrical electron optics."

In Figure 4, the object to be shown at distance is represented in **1**. **4**, **4'**, **4''** are devices scanning synchronously three images (of said object **1**) obtained through lenses **2**, **2'**, **2''** and through a yellow screen **3**, a purple screen **3'** and a green screen **3''** respectively. At a given instant, electric voltages t_1, t_2, t_3, are obtained across the terminals of the output potentiometers **5' 5 5''**, which are proportional to the brightness values of the purple (t_1), yellow (t_2) and green (t_3) components of the actual colour of the point of object **1** being scanned at that instant. In this case the coding device **6** is an "electrical differential arrangement" of three electrodes vacuum tubes combining these electric voltages t_1, t_2, t_3 together and producing a voltage T_m which characterises the wave-length of the radiation which should be mainly absorbed in the visible spectrum in order to reproduce the actual colour of said point of object **1**. This voltage T_m, transmitted over the metallic line or radiolink **7** and amplified at the receiving station by amplifier **8** produces a voltage T''_m across the terminals of the Kerr cell **9**.

The electrical differential arrangement **6** is such: 1°—that T''_m has a value T''_{mo} corresponding to colour No. 7 in the following table when (t_1-t_2) and (t_1-t_3) is positive, that is to say when the purple predominates in the actual colour of said point of object 1 which corresponds to a velocity difference of relative value 0 in the second column of said table; 2°—that, when (t_1-t_2) or (t_1-t_3) is negative, T''_m differs from T''_{mo} and in fact is larger than T''_{mo} if (t_3-t_2) is positive, and is smaller than T''_{mo} if (t_3-t_2) is negative; 3°—that the difference $(T''_m-T''_{mo})$ in the latter cases increases in absolute value rapidly when t_1 is small and more slowly when t_1 is large (see the column "Relative value of velocity differences" in the following table) because the purple colour corresponding to T''_{mo} is the most sensitive colour in such optical phenomena.

Nr of the colour	Relative value of the velocity difference produced by the Kerr cell 9	Most absorbed radiation	Colour obtained after anlyser 13
1	−259	Indigo	Light yellow.
2	−233	Blue	Bright yellow.
3	−135	Blue (greenish)	Yellow (orange).
4	−60	Green (bluish)	Orange (reddish).
5	−29	Pale green	Red.
6	−14	Green (yellowish)	Dark red.
7	0	Light green	Purple.
8	+10	Yellow (greenish)	Violet.
9	+24	Bright yellow	Indigo.
10	+99	Orange	Blue.
11	+163	Orange (brownish).	Blue-(greenish).
12	+182	Red (light carmine.	Green.
13	+261	Purple	Light green.

The Kerr Cell **9** in the television receiving station acts as a "modulator of colour." Inserted between polariser **12** (Glazebrook prism or the like) and analyser **13** (Glazebrook prism crossed with **12**) on the path of the luminous rays produced by source of white light **10** between lenses **11** and **14**, said Kerr cell **9** produces a velocity difference in the luminous rays and acts like a crystal plate, the thickness of which would vary in accordance with the electric voltage T''_m applied between the electrodes of said Kerr cell **9**. So the radiation most absorbed by said cell varies in accordance with column 3 of the above table when T''_m varies in such a way that the velocity difference varies itself in accordance with column 2; consequently the colour of the corresponding point of the image seen by eye **16** through the scanning device **15** varies in accordance with column 4 of the above table.

Instead of a Kerr Cell, I may use, for the modulation of the colour, a device utilising the electric or magnetic accidental birefringence of a crystal (quartz, Rochelle salt, etc.) or the magnetically controlled dispersion of the optical rotatory power (for various wave lengths) of a substance having a great Verdet effect (flint or silicoborate of sodium, carbon disulphide, arsenic trichloride, etc.).

Instead of using a purple screen **3'**, a yellow screen **3** and a green **3''**, I may use screens of complementary colours (light green for **3'**, blue for **3** and red for **3''**), the differential electrical arrangement **6** being then adjusted to produce an electric voltage T_m indicating which is the smallest among the voltages t_1, t_2, t_3 at each instant.

Figure 5 shows the optical arrangement and Figure 6 the electrical arrangement of the second embodiment of my invention, in which the spectral curve or diagram "energy-wave length" (Figure 8) of the actual colour of each point of object O is automatically drawn on the fluorescent screen *Fl* of the cathode-ray oscillograph OC within the coding device (Figure 6). The half transparent mirror *mt* (Figure 5) associated with lens L_1 and objective *ob* forms a first image of object O on the photosensitive mosaic *m* of a first iconoscope *i*, through a coloured screen *e* which has a curve of chromatic sensitivity inverse to the curve of chromatic sensitivity of said mosaic *m*. Consequently the electric voltage obtained at the output of iconoscope *i* (Figure 6), across the terminals of the output resistance *r'* of the amplifying vacuum tube L, is proportional to the mean ordinate T_m of the spectral curve of the colour of the point P of object O being scanned at a given instant.

The half transparent mirror *mt* (Figure 5) associated with the rotating prismatic mirror MT and the spectograph S (which slot is F) produces simultaneously on the photosensitive mosaic M of a second iconoscope I, the optical spectra of the colours of the various points of one line of object O, through a coloured screen E which has a curve of chromatic sensitivity inverse to the curve of chromatic sensitivity of said mosaic M. Consequently the electric voltage obtained at the output of iconoscope I (Figure 6), across the terminals of the output resistance R' of the amplifying vacuum tube L, is proportional to the various ordinates T_λ of the spectral curve of Figure 8 successively (energy e_λ corresponding to each wave-length λ in the actual colour of the point P of object O).

A synchronising device *Sy* synchronises the motion of the electric motor MMT (Figure 6) which rotates the rotating mirror MT (Figure 5) with the deflection of the cathode ray in iconoscope *i* (by means of deflecting coils b_h for horizontal sweeping of mosaic *m* and *bv* for vertical sweeping) and with the deflection of the cathode ray in iconoscope I (by means of deflecting coils B_h for horizontal sweeping and B_v for vertical sweeping of mosaic M). The horizontal sweeping of mosaic M being very rapid, I prefer to make it by means of a current in shape of double saw-tooth (isoseceles triangle) produced by a symmetrical relaxation oscillator having a period equal to twice the duration of the scanning of one point of object O. A retardating device DR (loaded artificial line for example) introduces a delay (equal to the duration of the scanning of one point of object O) for the current producing the vertical sweeping of mosaic M referred to the current of same wave shape which produces the horizontal sweeping of mosaic *m*. Consequently during the interval of time required by the electric voltage across resistance R' (Figure 6) to take successively the various values of T_λ (corresponding to the ordinates of spectral curve of the actual colour of point P of object O), the electric voltage across resistance *r'* keeps a constant value T_m which is precisely the mean ordinate of said spectral curve corresponding to the same point P of object O.

The electric voltages T_λ and T_m are applied in opposite directions to the deflecting plates KK_1 and $K'K'_1$ producing the vertical sweeping of the fluorescent screen *Fl* of cathode ray oscillograph OC, whereas the horizontal sweeping of said screen *Fl* produced by B'_h is synchronised with the horizontal sweeping of mosaic M. Consequently the luminous spot would draw on the fluorescent screen *Fl* a curve, the ordinates of which are proportional to the difference $(T_\lambda - T_m)$ whereas the abscissae are proportional to the wave-length λ (Figure 8). But the voltage T_λ is also applied to a condenser Q in series with a resistance *r''*, which is connected to the grid of a three electrode vacuum tube L''. Across the terminals of the output resistance R'' of said tube L'', I obtain a voltage equal to dT_λ/dt (*t* being time) which is applied to a controlling device M arranged in accordance with Figure 15—*a* and having a performance characteristic of the type represented on Figure 15—*c* (curve in shape of a "bell"); consequently when dT_λ/dt differs from zero, the voltage θ at the output of said controlling device M is always positive and, by means of the control grid G, suppresses the luminous spot on fluorescent screen *Fl*. On the contrary, when

$$\frac{dT\lambda}{dt}=0$$

that is for the minima and the maxima of the spectral curve (Figure 8), the luminous spot appears in its full brightness; finally on the screen *Fl*, alone the portions of said spectral curve represented in full line on Figure 8 appear luminous (that is only around the minimum *a* and the maximum *b*).

In this form of my invention the actual colour of the point P of object O being scanned is characterised by the wave-length corresponding to point *a* (most absorbed radiation) and by the "degree of saturation *s*" which is the ratio between the distance sT_m of point *a* to the mean horizontal line H and the value T_m of the mean ordinate of the spectral curve (Figure 8). It is well known that, when the degree of saturation *s* decreases, that is to say when the proportion of white added to the monochromatic colour (corresponding to the actual colour of the considered point) increases, the minimum *a* of the spectral curve gets nearer to the mean horizontal line H. For that reason, I use in the coding device of Figure 6 the coding screen E_1 represented on Figure 7, which is completely opaque on all the hatched part marked O, and which is progressively more and more transparent from square No. 1 to square No. 24. In this case, the coding table is the following:

Electric voltage T at the output of photo electric cell Ph in the coding device	Most absorbed radiation	Colour to be reproduced in the receiving television station	Degree of saturations of said colour
0	(All wave lengths equally absorbed.)	Black	------------
1	Violet	Yellow	1,00 à 0,75
2	Violet	Yellow	0,75 à 0,50
3	Violet	Yellow	0,50 à 0,25
4	Violet	Yellow	0,25 à 0
5	Blue	Orange	0 à 0,25
6	Blue	Orange	0,25 à 0,50
7	Blue	Orange	0,50 à 0,75
8	Blue	Orange	0,75 à 1,00
9	Green	Red	1,00 à 0,75
10	Green	Red	0,75 à 0,50
11	Green	Red	0,50 à 0,25
12	Green	Red	0,25 à 0
13	Yellow	Violet	0 à 0,25
14	Yellow	Violet	0,25 à 0,50
15	Yellow	Violet	0,50 à 0,75
16	Yellow	Violet	0,75 à 1,00
17	Orange	Blue	1,00 à 0,75
18	Orange	Blue	0,75 à 0,50
19	Orange	Blue	0,50 à 0,25
20	Orange	Blue	0,25 à 0
21	Red	Green	0 à 0,25
22	Red	Green	0,25 à 0,50
23	Red	Green	0,50 à 0,75
24	Red	Green	0,75 à 1,00

The electric voltage T, obtained at the output of the photoelectric cell P*h* (Figure 6) in which are concentrated the luminous rays produced by the portion *a* only of the spectral curve (Figure 8) on the fluorescent screen *Fl* (Figure 6) through the coding screen E_1 and the lens L*e*, constitutes the signal I′ characterising the actual colour of each point P of object O, and is sent on the line or radiolink towards the receiving station.

Another voltage *t*, obtained also at the transmitting station and proportional to the mean brilliancy of said point P of object O, is sent also towards the receiving station. This voltage *t* (characterising the brightness value of point P in an ordinary black and white image) may be obtained by another iconoscope (not shown on Figures 5 and 6) in the ordinary way. But I may also obtain this voltage *t* across the terminals of resistance *r′* (Figure 6) if the screen *e*, combined with the mosaic *m* of iconoscope *i*, reproduces the curve of chromatic sensitivity of the human eye; in such a case the voltage T*m* (mean ordinate of the spectral curve "energy-wave length") is obtained, from the voltage *t*, by means of a three electrode vacuum tube inserted between *r′* and K′K′$_1$ (Figure 6), the grid of which is controlled by the voltage *at* (existing across the terminals of deflection coil B′*h*), said voltage at being modified by a controlling device such as the one of Figure 15—*a* with a performance characteristic in shape of a bell, that is to say precisely the shape of the curve of chromatic sensitivity of the human eye.

Instead of using on Figure 6 the coding screen E_1 represented on Figure 7, I may use the coding screen E_1 represented on Figure 7—*a*, where the hatched portion marked O is black and completely opaque, whereas the portions marked 1 to 6 have an increasing transparence (from 1 to 6). The opaque portion O of screen E_1 (Figure 7—*a*) covering a portion of fluorescent screen *Fl* up to a height *d* above the horizontal diameter D, if the complete spectral curve is drawn on the fluorescent screen *Fl* (omitting on Figure 6 the circuit elements marked Q, *r″*, L″, R″, M, G), only the lower part of said spectral curve (corresponding to the most absorbed band of wave-lengths) will pass luminous rays through the coding screen, and the electric voltage T obtained at the output of photoelectric cell P*h* will indicate then only the colour (and not the degree of saturation), which may be sufficient as a first approximation.

Figure 9 shows the Maxwell's triangle of colours in the form recommended by the International Illumination Commission in 1931. The position of point M, representing graphically a given colour, is defined by three "trichromatic coordinates" X, Y, Z, taken along the axis *z x*, *x y* and *y z* respectively in the direction of the arrow, with X+Y+Z=1. The center E of the triangle (located quite close to the point B representing the colour white) corresponds to a "spectrum of equal energy" (hypothetic source radiating the same energy for each wave-length).

In terms of $e_{\lambda n}$ (proportion of energy per second for wave length λ_n),

$$\bar{x}_n\bar{y}_n\bar{z}_n$$

(coefficients of distribution for stimuli of equal energy, or coordinates of the various points S on the curve representing the monochromatic colours inside the triangle of Figure 9), X, Y and Z are given by the following formulae:

$$X=\frac{\Sigma e_{\lambda n}x_n}{\Sigma e_{\lambda n}\bar{x}_n+\Sigma e_{\lambda n}\bar{y}_n+\Sigma e_{\lambda n}\bar{z}_n}$$

$$Y=\frac{\Sigma e_{\lambda n}y_n}{\Sigma e_{\lambda n}\bar{x}_n+\Sigma e_{\lambda n}\bar{y}_n+\Sigma e_{\lambda n}\bar{z}_n}$$

$$Z=\frac{\Sigma e_{\lambda n}z_n}{\Sigma e_{\lambda n}\bar{x}_n+\Sigma e_{\lambda n}\bar{y}_n+\Sigma e_{\lambda n}\bar{z}_n}$$

The area of the triangle on Figure 9 has been subdivided in six segments I, II, III, IV, V, VI corresponding respectively to violet-purple, blue, yellow, green, orange and red. Also dotted curves have been drawn, parallel to curve S, and marked respectively **0,25—0,50—0,75.**

The intersecting point S between the curve of monochromatic colours and the straight line E M (supposed in coincidence with the straight line B M) corresponds to the "hue" (or predominating wave-length in the spectrum of the actual colour represented by point M); the ratio

$$\frac{ME}{ES}$$

is equal to the "degree of saturation" of said actual colour, that is the ratio between the brightness of the hue and the total brightness in said actual colour.

The graphical construction of Figure 10 shows that the point M might be obtained in starting from the center E of the triangle: 1°—by means of a first displacement E P, in the direction of axis *z x*, equal to

$$-\frac{1}{3}=-\frac{X+Y+Z}{3}$$

followed by a second displacement P Q in the direction of said axis *z x*, equal to X.

2°—by means of a third displacement Q R, in the direction of axis *y z*, equal to

$$\frac{1}{3}=\frac{X+Y+Z}{3}$$

followed by a fourth displacement R M in the direction of said axis *y z*, equal to —Y.

Advantage is taken of this remark in the third embodiment of my invention, utilizing the transmitting television station shown schematically on Figure 11 and the transparent coding screen of Figure 12.

The iconoscopes Ix Iy Iz of Figure 11 have cathodes Tx Ty Tz in form of wires emitting electrons and the photosensitive mosaics Mx My Mz are swept vertically by rectilinear "electronic images" of said cathodes obtained by clindrical "electronic optics" not shown on the drawing.

An optical device (not shown completely on Figure 11) forms, on said mosaics Mx My Mz, through the spectographs Sx Sy Sz and the transparent screens Ex Ey Ez, the optical spectra of the actual colours of the various points of one line of the object O to be shown at distance (line being scanned at the given instant). The screen Ex has parallel vertical lines black (opaque) or gray (half transparent) or white (completely transparent): the vertical line of E_x corresponding to the vertical line of mosaic Mx allocated to wave-length λn has a transparence

$$S_n=\frac{\bar{x}_n}{\rho_n}$$

($\bar{x}_n$ being the trichromatic coordinate X for monochromatic radiation of wave length λ_n and ρ_n being the chromatic sensitivity of mosaic Mx for the wave length λ_n).

Similarly the screens Ey and Ez have vertical lines of transparences

$$\frac{\bar{y}_n}{\rho_n} \text{ and } \frac{\bar{z}_n}{\rho_n}$$

in front of the vertical lines of mosaics My and Mz allocated to wave-length λ_n ($\bar{y}_n$ and $\bar{z}_n$ having been defined hereabove and $\bar{\rho}_n$ being the sensitivity of mosaic My (or mosaic Mz) for wave-length λ_n).

Consequently the electric voltages X, Y, Z obtained at a given instant at the output of the amplifiers Lx Ly Lz, connected respectively to the collecting plates Cx Cy Cz of iconoscopes Ix Iy Iz, are proportional to

$$\Sigma e_{\lambda n}\bar{x}_n,\ \Sigma e_{\lambda n}\bar{y}_n,\ \Sigma e_{\lambda n}\bar{z}_n$$

that is to say are proportional to the trichromatic coordinates of the point M representing in Maxwell's triangle the actual colour of the particular point of the object O being scanned at that instant.

These electric voltages X, Y, Z are added together in the common output circuit of three-electrodes vacuum tubes L'x L'y L'z, in shunt with tubes Lx Ly Lz.

The electric voltages X, Y, Z and

$$\frac{X+Y+Z}{3}$$

are applied to the deflecting plates **1**, **2**, **3**, **4** of the cathode ray oscillograph *os* of the coding device, as shown on Figure 11, in order to produce the four above mentioned displacements of the luminous spot on the fluorescent screen *fl* of said oscillograph *os* (plates 1 and 2 being perpendicular to the axis *zx* of Maxwell's triangle and plates **3** and **4** being perpendicular to the axis *yz* of said triangle). Consequently at a given instant the luminous spot of oscillograph Os has in said Maxwell's triangle precisely the position M representing the actual colour of the point of object O being scanned at that instant.

The coding transparent screen *e*, located in front of the fluorescent screen *fl* is shown on Figure 12; the hatched portion marked O is black (completely opaque) and the other portions have a transparence which increases regularly from portion No. 1 to portion No. 24. In this case, the coding table is the following:

Electric voltage T obtained at the output of the coding device, after photoelectric cell ph	Hue, or predominating monochromatic colour corresponding to the actual colour of the point being scanned	Degree of saturation of said actual colour
0	Black	
1	Violet	1,00 à 0,75
2	Violet	0,75 à 0,50
3	Violet	0,50 à 0,25
4	Violet	0,25 à 0
5	Blue	0 à 0,25
6	Blue	0,25 à 0,50
7	Blue	0,50 à 0,75
8	Blue	0,75 à 1,00
9	Green	1,00 à 1,75
10	Green	0,75 à 0,50
11	Green	0,50 à 0,25
12	Green	0,25 à 0
13	Yellow	0 à 0,25
14	Yellow	0,25 à 0,50
15	Yellow	0,50 à 0,75
16	Yellow	0,75 à 1,00
17	Orange	1,00 à 0,75
18	Orange	0,75 à 0,50
19	Orange	0,50 à 0,25
20	Orange	0,25 à 0
21	Red	0 à 0,25
22	Red	0,25 à 0,50
23	Red	0,50 à 0,75
24	Red	0,75 à 1,00

The electric voltage T, obtained at the output of the coding device after the photoelectric cell *ph*, in which are concentrated the luminous rays produced by the luminous spot on the fluorescent screen *fl* through the coding screen *e*, constitutes the signal I' characterising the actual colour of each point of object O, and is sent on the metallic line or radiolink towards the television receiving station.

Another voltage *t*, obtained also at the transmitting station and proportional to the mean brilliance of each point of object O, is sent also towards the television receiving station. This voltage *t* (characterising the brightness value of a given point in an ordinary black and white image) may be obtained by another iconoscope (not shown on Figure 11) in the ordinary way. But I may also obtain this voltage *t* in adding three voltages equal to g_xX, g_yY, g_zZ produced at the output of three vacuum tubes L''_x L''_y L''_z (not shown on the drawing, but supposed connected in shunt to tubes L_x L_y L_z and tubes L'_x L'_y L'_z); the gains g_x, g_y, g_z produced by said amplifying tubes L''_x L''_y L''_z should take into account the shape of the chromatic sensitivity of the human eye, so that the sum $t=g_xX+g_yY+g_zZ$ represents the mean brightness of the point of the object, whereas X, Y and Z are energies.

I may either use two channels on the metallic line or radiolink between the transmitting and receiving television stations, in order to transmit separately the signal I' (or voltage T characterising the colour) and the signal I (or voltage *t* characterising the mean brightness)—or combine these two voltage T and *t*, before the origin of said line or radiolink, into a single coded signal, by means of a coding device such as COD of Figure 2,—a decoding device such as DEC of Figure 2 being used at the receiving station after the end of said line or radiolink. Said decoding device (DEC) would restore the electric voltages T and *t* separately at the receiving station.

Figure 13 represents a form of realization of the receiving television station corresponding either to the transmitting television station shown on Figure 6 (second embodiment of my invention) or to the transmitting television station shown on Figure 11 (third embodiment of my invention).

Let us assume that a decoding device of the type shown on Figures 2 and 3 (devices not shown on Figure 13) has discriminated the electric voltage *t* characterising the brightness value of each point of the ordinary black and white image of the object to be seen at distance,—the electric voltage T characterising the colour (either the most absorbed radiation, or the "hue"=predominating radiation),—the electric voltage *s* characterising the "degree of saturation",—and the synchronising impulses τ.

The electric voltage T (characterising the colour) is applied to the input terminals of the devices C_b, C_j, C_r which control respectively the brightness of the cathode ray oscillographs C_b, C_j, C_r (producing respectively a blue image, a yellow image and a red image), by means of the control grids, g_t, g_j and g_r respectively.

Simultaneously the electric voltage *t* (characterising the mean brightness) is applied to the input terminals of device C_n controlling the brightness of the cathode ray oscillograph O_n (producing a black and white image), by means of the control grid g_n.

The electric voltages *t* (mean brightness) and *s* (degree of saturation) are applied to the input terminals of device C_s which controls the proportion of white light and of coloured light which are mixed on the projection screen E P, in order to reproduce the appropriate "degree of saturation," this control being made by means of the auxiliary control grids g'_n, g'_b, g'_j and g'_r.

The deflections of the cathode rays in oscillographs O_r, O_b, O_j, O_r are simultaneously produced by a device *sy* (with deflecting coils *b*) which is synchronised by the synchronising impulses τ transmitted by the corresponding television transmitting station; consequently at a given instant the 4 luminous spots on the fluorescent screens of oscillographs O_n, O_b, O_j, O_r have the same geometrical position in the image (black, blue, yellow, or red); an optical system represented schematically by lens L, concentrates and superposes the luminous rays emitted by said 4 luminous spots on the same point of the projection screen EP. Oscillograph O_n draws on screen EP the shape (in black and white) of the object O to be seen at distance, whereas the oscillographs O_b, O_j, O_r add to this drawing "coloured touches," the control grids g_b g_j g_r determining the colour of said coloured touches and the auxiliary control grids $g'n$ $g'b$ $g'j$ $g'r$ determining the degree of saturation of said coloured touches.

Let us consider for example the coding table given hereabove and corresponding to the transmitting television station of Figure 6 (second embodiment of my invention). To conform to this coding table, the controlling devices C_b C_j C_r must produce at their output terminals the following electric voltages T_b T_j T_r respectively applied to the control grids g_b g_j g_r when the voltage T is applied to their input terminals.

Value of the electric voltage T received from transmitting station (modulation of colour).	0	1 to 4	5 to 8	9 to 12	13 to 16	17 to 20	21 to 24.
Most absorbed radiation	All wave lengths equally absorbed.	Violet	Blue	Green	Yellow	Orange	Red.
Voltage T_b controlling the blue component	0	0	0	0	1	2	1.
Voltage T_j controlling the yellow component	0	2	1	0	0	0	1.
Voltage T_r controlling the red component	0	0	1	2	1	0	0.
Hue, or predominating monochromatic colour corresponding to the actual colour obtained on the projection screen at the receiving station.	Black	Yellow	Orange	Red	Violet	Blue	Green.

The above table shows that, when voltage T increases regularly from 1 to 24, each voltage T_b T_j or T_r should vary according to a law represented graphically by a curve in shape of a "bell" (like Figure 14—*b* or Figure 15—*d*) or of an "inverted bell" (like Figure 14—*c* or Figure 15—*c*), the top (or the bottom) of said "bell" being conveniently located along the T axis.

Devices having such a performance characteristic are shown, as examples, on Figures 14—*a* and 15—*a*.

Figure 14—*a* represents a three-electrodes vacuum tube, the grid of which is polarised in such a way that the curve giving the output voltage RI in terms of the input voltage T has the shape shown on Figure 14—*b* (dynatron effect). By means of a battery E (Figure 14—*a*), the other shape of curve shown on Figure 14—*c* (E—RI in terms of T) may be readily obtained.

Figure 15—*a* represents a three-electrode vacuum tube having the characteristic (RI in terms of T) shown on Figure 15—*b*. At the output of said tube is connected a Wheatstone bridge, two arms of which are high resistances of equal values, whereas the two other arms are copper-oxide rectifiers. Across the terminals of the resistance *r*, in the diagonal of said Wheatstone bridge, I have a uni-directional current, the intensity *i* of which is equal to zero when $T=T_0$ and rises always when T becomes larger or smaller than T_0; the maximum S_m of the voltage $S=ri$ is obtained for $T=T_1$ or $T=T_2$; consequently the performance characteristic of such a device shown on Figure 15—*a* has either the shape of the curve of Figure 15—*c* (S in terms of T) or of the curve of Figure 15—*d* (S_m-S in terms of T).

For the devices C_b and C_r producing the voltages T_b (control of the blue component) and T_r (control of the red component), an arrangement such as Figure 14—*a* or 15—*a* with a performance characteristic such as Figure 14—*b* or Figure 15—*d* is used according to the above table; for the device C_j producing the voltage T_j (control of the yellow component), I associate a device shown on Figure 15—*a* having the performance characteristic S of Figure 15—*c* with a pentode having the performance characteristic S' of Figure 15—*e*, in order to obtain a value $T_j=o$ when $T=o$ (black colour), in accordance with the above table.

In the case of the other coding table given above and corresponding to the transmitting television station of Figure 11 (third embodiment of my invention), the controlling devices C_b C_j C_r would be arranged to respond to the "hue" [predominating radiation (or wave-length)] [and not to the "most absorbed radiation" (or wave length)], but they would also be made on the principles of Figure 14—*a* or Figure 15—*a*.

Although in the above described television stations cathode ray devices have been shown exclusively (iconoscopes for the transmission and oscillographs with fluorescent screens for the reception of television), the invention applies just as well to colour television installations using electromechanical scanning devices and any type of source of coloured light such as (1) ionic relays constituted by luminescent electrical discharge valves (gas or vapour) whose brilliance is controlled by means of a modulating electrode (2) incandescent lamps fitted with devices for modulating colour and brilliance, calling into play either chromatic polarisation with electric or magnetic double refraction (Kerr effect, accidental electrical double refraction of a piezoelectric crystal, etc.) or rotatory magnetic dispersion, or any other known electro-optical or magneto-optical phenomenon.

Finally I may use, for the coding or decoding device, a cathode ray commutator having a number of contacts (or studs) connected to different points of a scale of potentials in accordance with the signalling code adopted; the cathode rays beam, under the action of a deflecting coil (or deflecting plates) energized by the controlling current applied to the input terminals of said coding or decoding device, hits the proper stud, and consequently applies the proper electric voltage to the output terminals of said coding or decoding device.

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