

Dec. 29, 1936.

A. NYMAN

2,066,048

TELEVISION SYSTEM

Filed Sept. 24, 1931

8 Sheets-Sheet 1

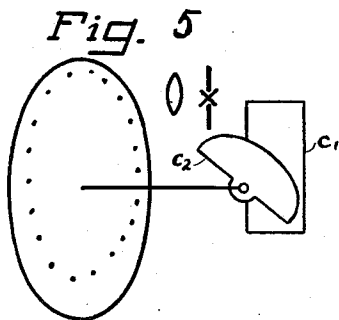
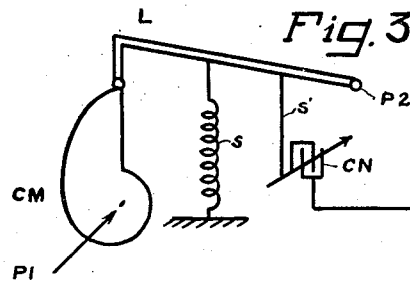
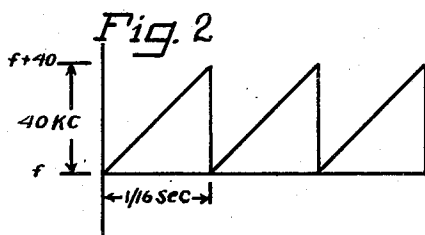
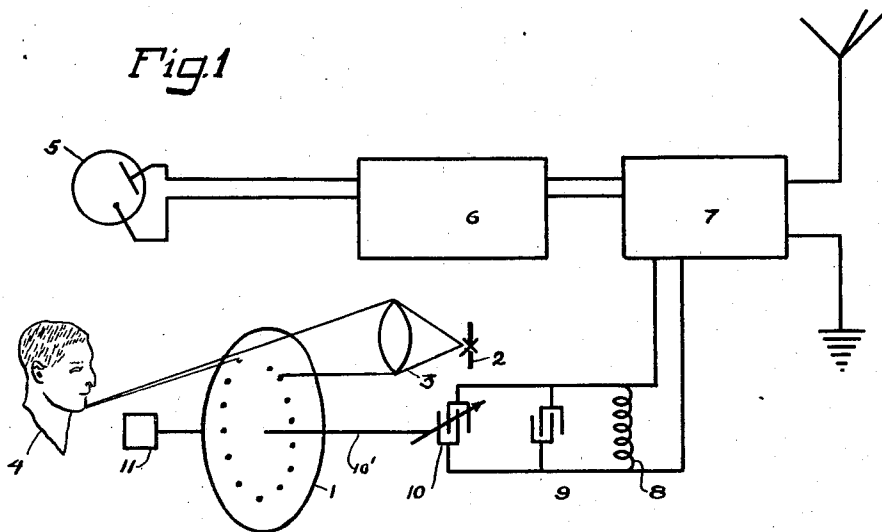
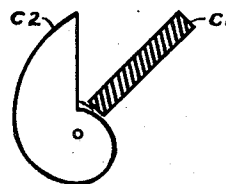


Fig. 4



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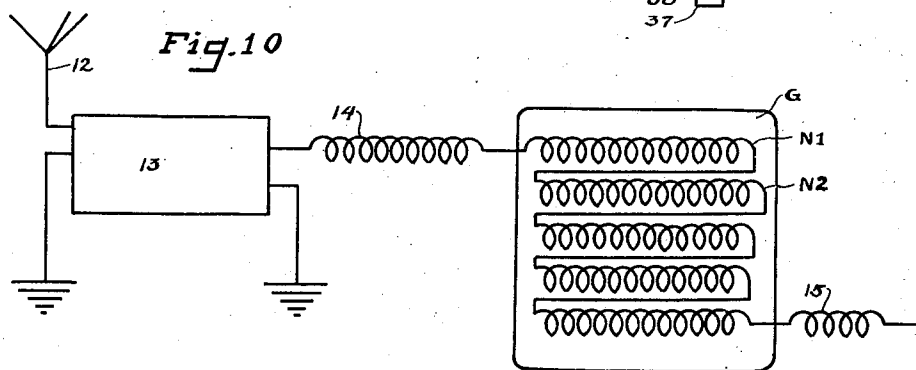
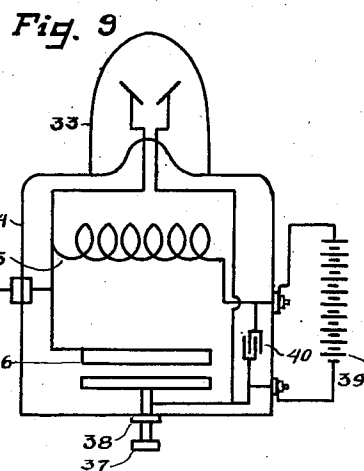
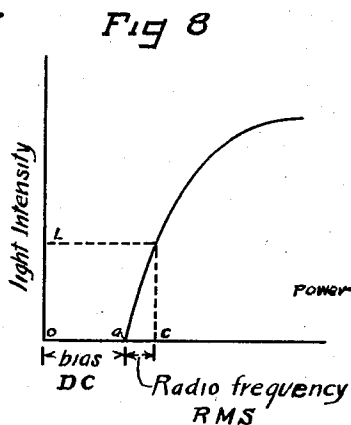
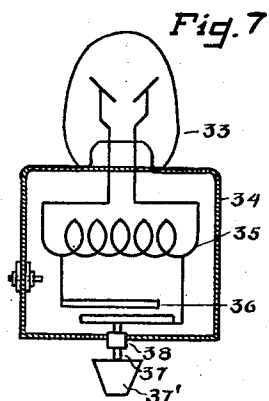
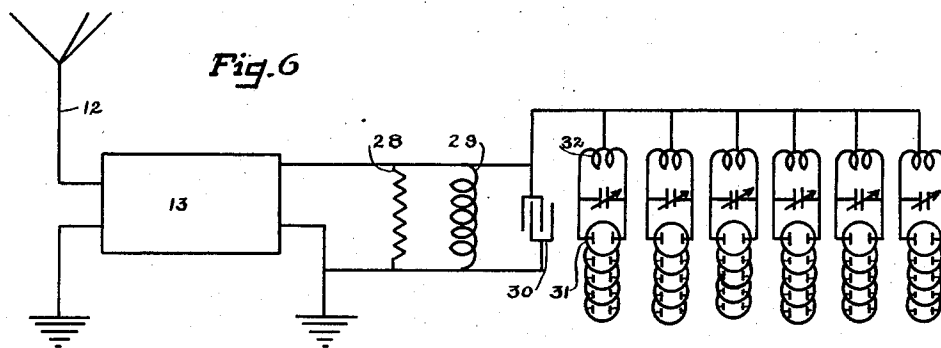
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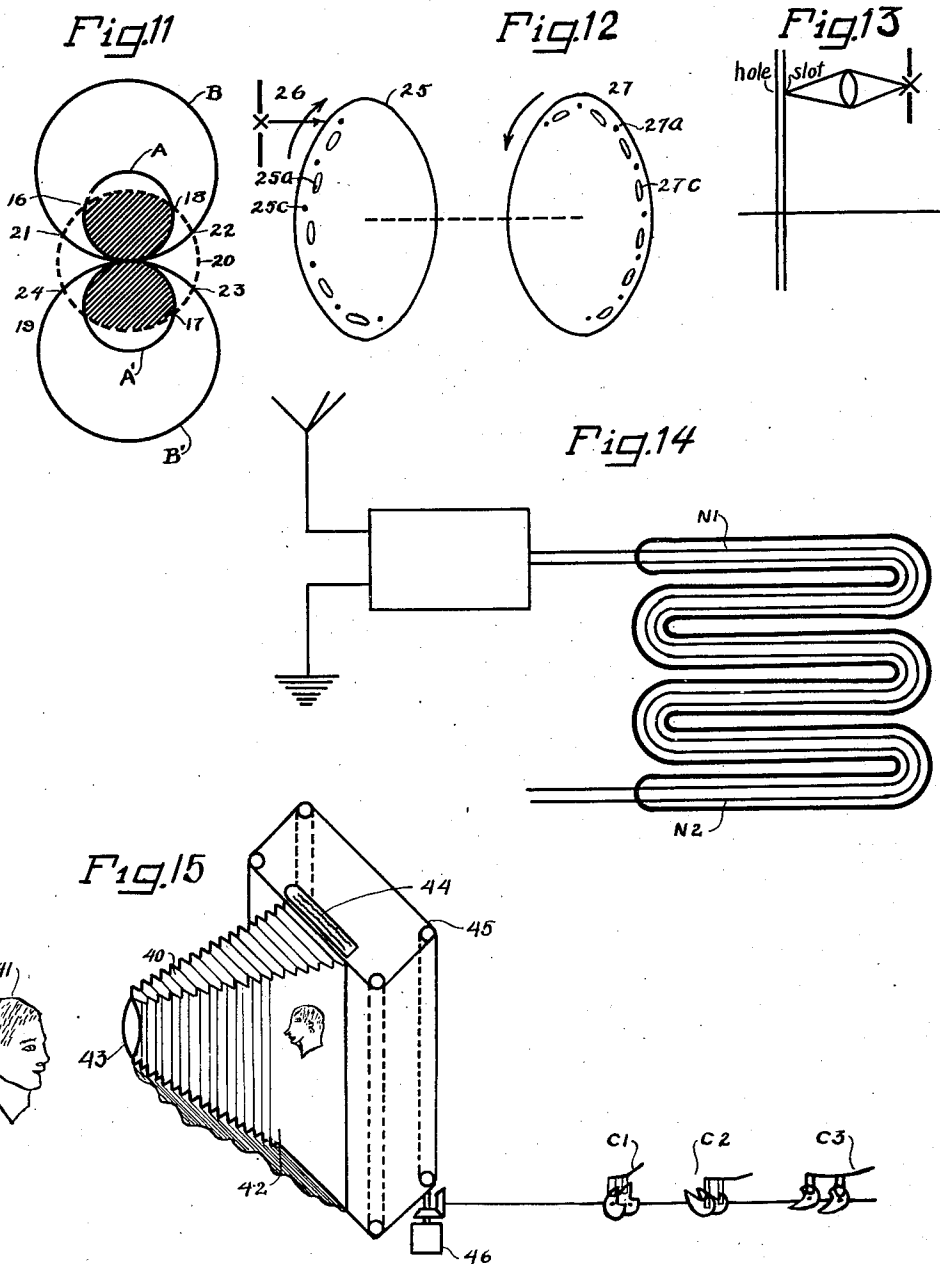
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8 Sheets-Sheet 3



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Fig.16

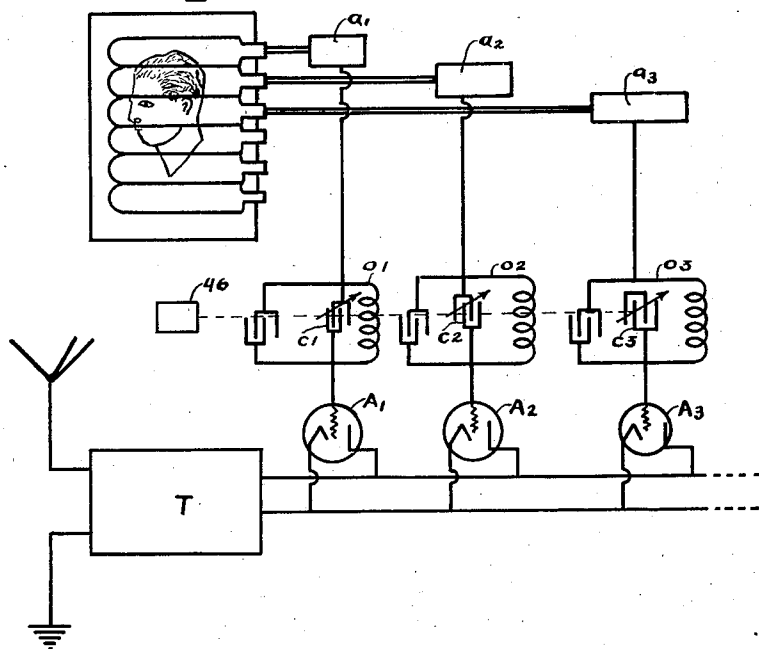


Fig.17

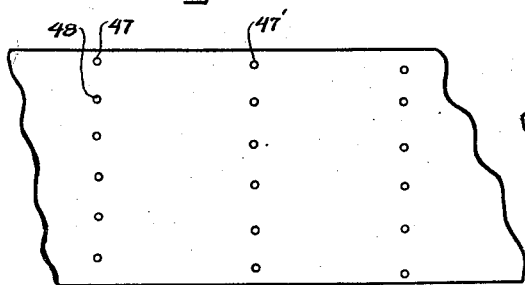
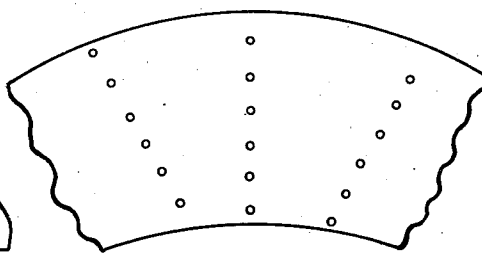


Fig.18



* 49

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Fig. 19

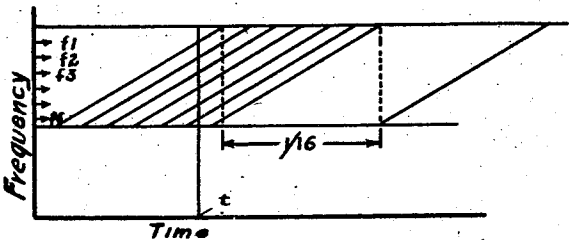
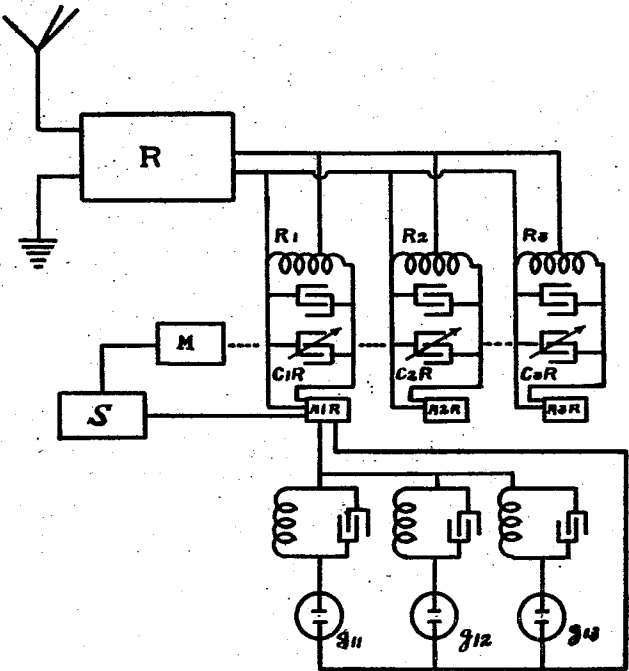


Fig. 20



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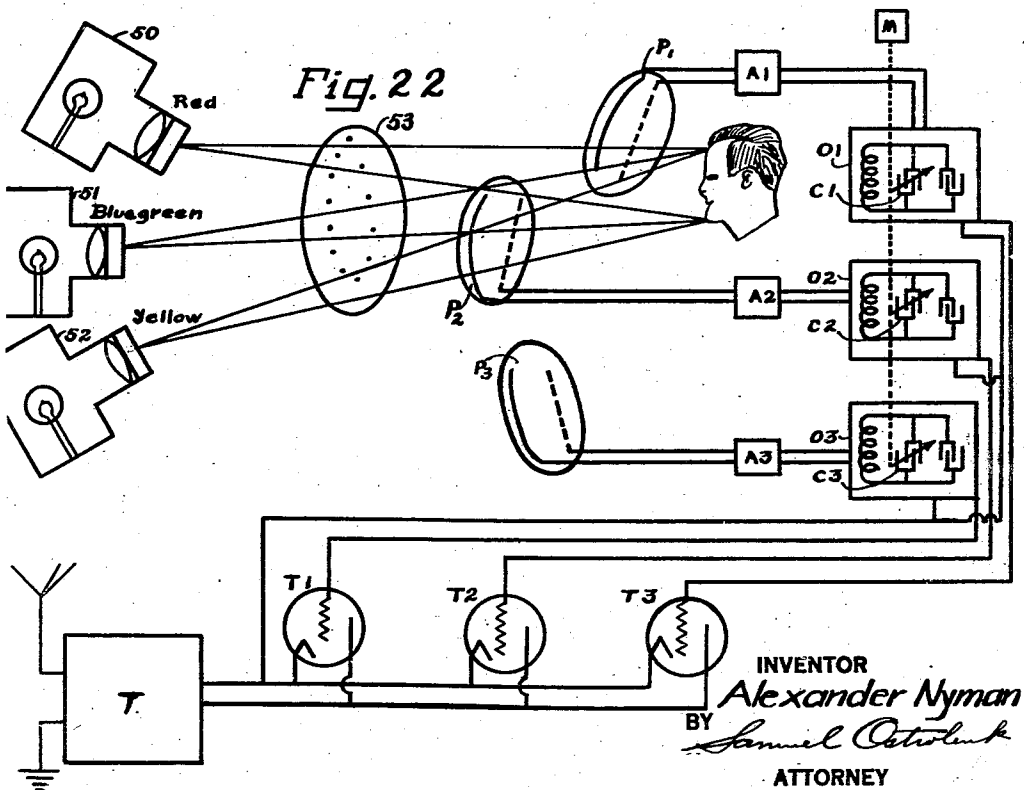
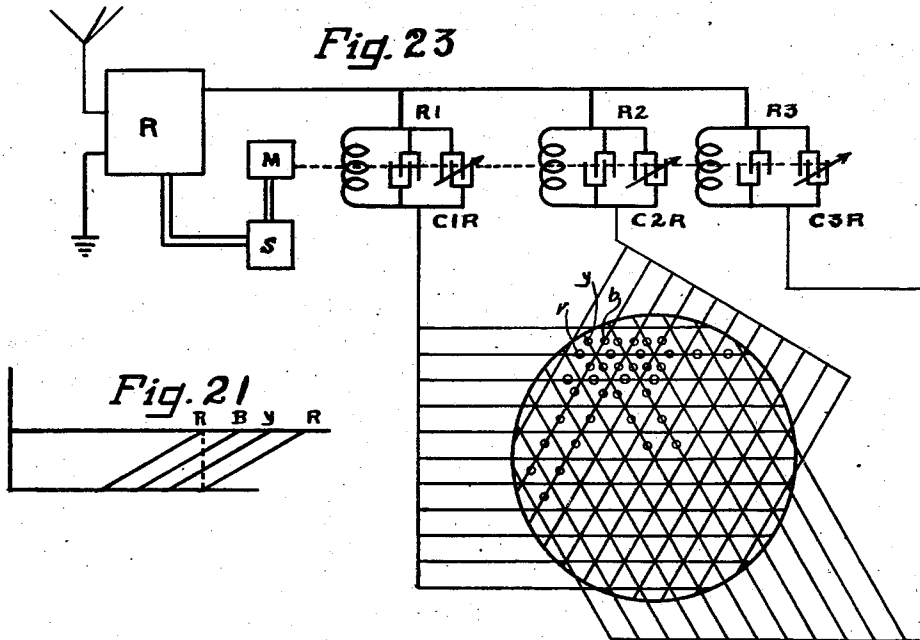
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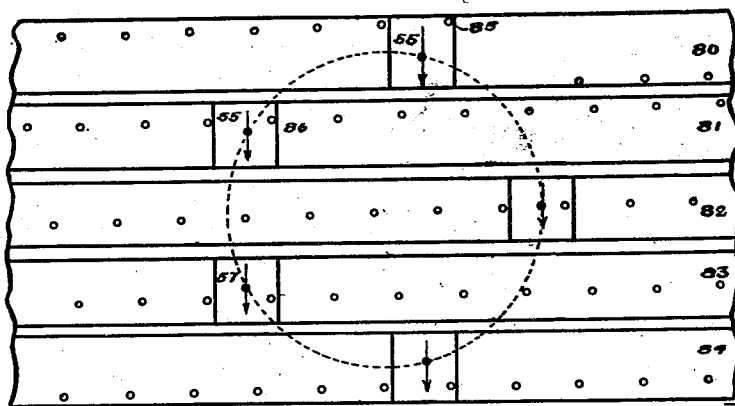


Fig. 25

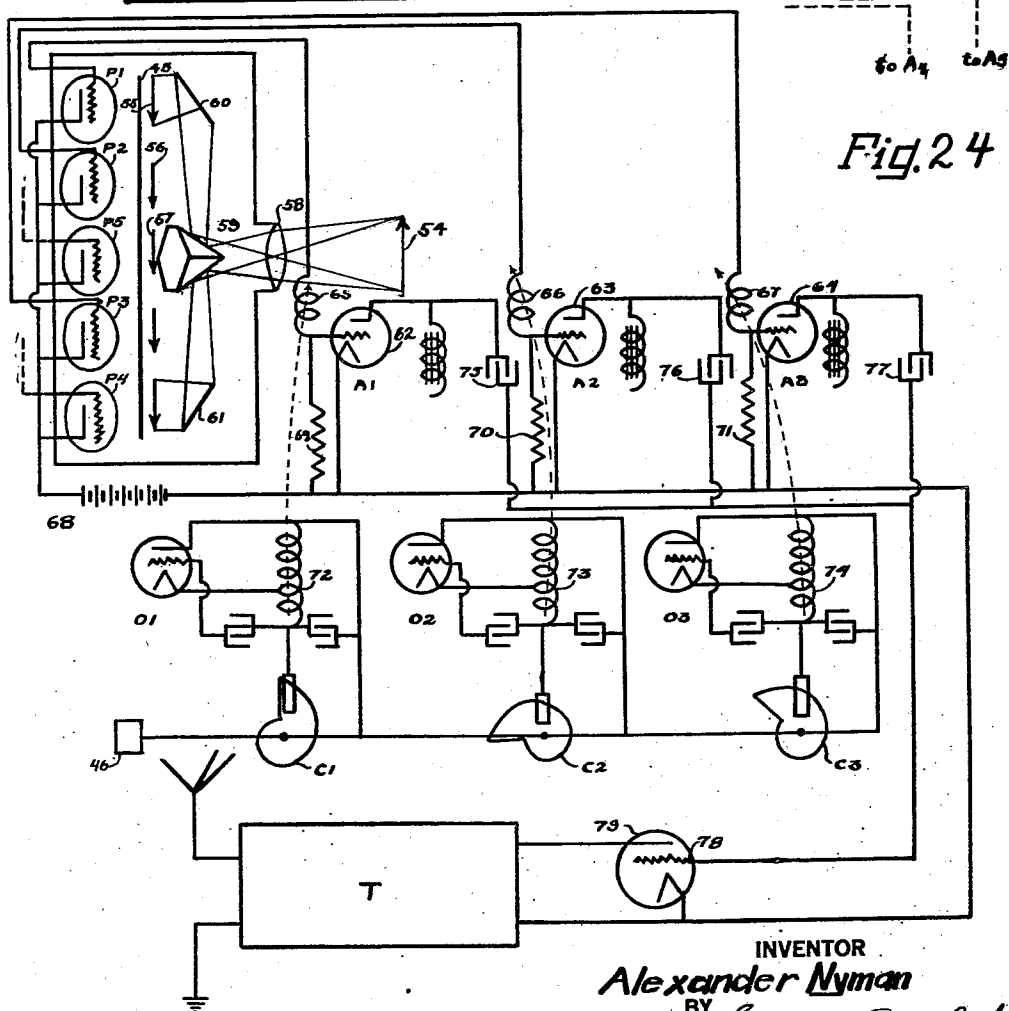


Fig. 24

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UNITED STATES PATENT OFFICE

2,066,048

TELEVISION SYSTEM

Alexander Nyman, Dobbs Ferry, N. Y., assignor,
by mesne assignments, to Radio Corporation
of America, a corporation of Delaware

Application September 24, 1931, Serial No. 564,778.

10 Claims. (Cl. 178—6)

My invention relates to a novel apparatus for and method of signalling system, and more particularly to a picture transmission system adaptable for television; that is, capable of reproducing
5 images at such a rate that a continuous moving image is obtained.

Heretofore, television systems have, in general, utilized a single frequency channel on which are superimposed modulations corresponding to the
10 light intensity of successive series of image elements to be transmitted. For television, the complete scanning of the image must be accomplished within about one-fifteenth of a second. To obtain a clear image, such as a face, at least
15 2,500 points on the image must be scanned. Accordingly, even where the least amount of detail will suffice, the transmitting channel is modulated at a frequency of at least 2,500 times 15 or 37,500.

Such a high modulating frequency is generally
20 expressed in terms of a wide side band range; that is, it is found that on account of the high frequency of modulation, the resulting side band frequencies cover a range of from 40 to 50 kilocycles and often much more.

The present broadcasting stations are each assigned to a frequency range covering only ten kilocycles; that is to say, each station is assigned a carrier wave which is separated ten kilocycles from the next succeeding assigned carrier wave.
25 Accordingly, a single television station operating with side bands of at least forty kilocycles would require at least four different broadcasting channels. In view of the limited channels available, however, and the wide demand for these, there is
30 little likelihood that many television stations will be granted so wide and numerous broadcasting channels for their broadcasting purposes.

Accordingly, an object of my invention is to provide means for reducing the frequency band
35 necessary in a television system.

A further object of my invention is to provide means for transmitting more elements of a television image over a single television channel.

A further difficulty of the wide frequency band of forty kilocycles necessary for television heretofore has been the tuning of the receiving system. Radio receiving circuits include receiving circuits which are relatively sharply tuned to a particular carrier frequency of the system.
45 Those picture signals therefore, which are near the end of the end of the forty kilocycle bands are necessarily distorted due to the fact that the receiver circuit is tuned to receive signals which
50 are twenty kilocycles away. Heretofore, an at-

tempt has been made to avoid this condition by assigning very short waves to the television systems. As will be evident, in the short wave range the forty or fifty kilocycles side bands represent a relatively small percentage of the high frequency carrier as compared to the percentage
5 difference where the carrier frequency is lower. This arrangement, however, has the disadvantage that television broadcasting is thereby confined to a range of frequencies subject to strong fading
10 and consequently to considerable distortion.

Accordingly, a further object of my invention is to provide means for eliminating distortion of the television signals.

A further object of my invention is to provide
15 means for reducing the modulating range of the carrier.

Still a further object of my invention is to substitute a variable operating frequency over a full assigned frequency range of stations instead
20 of modulating the single carrier in accordance with the picture signals to be transmitted.

A further problem in television is the synchronization of the transmitting and receiving sending elements. As will be evident, at the extremely high speed of signalling necessary for
25 television, it becomes increasingly difficult to prevent slight changes in the speed of operation of either the receiving or transmitting sending elements and results in distortion of the received
30 signals.

Accordingly, a still further object of my invention is to provide a television system which will operate without requiring any synchronization.
35

According to my invention, I propose to continually change the operating or carrier frequency over the full range of 40 or 50 kilocycles during each transmission period of the image; that is, in the case of television during $\frac{1}{10}$ or $\frac{1}{15}$ of a second. This change is continuous, as the scanning of the image progresses, in such a way that each element of the image as it is being scanned
40 will be transmitted at a definite or individual frequency different from all other points. It is evident, therefore, that at the receiving end it will only be necessary to tune in separately for each received point to its own particular frequency to secure perfect registration without any
45 special means for synchronization.

Moreover, both at the transmitting and receiving end, much sharper tuning will be possible since the amplitude modulation at each frequency will not change as rapidly as with the past
55

system, but only at the rate at which the transmitted object changes its configuration.

A further object of my system is, therefore, to provide a definite operating frequency for each point of an image transmitted.

Still a further object of my invention is to provide means for varying the frequency over the assigned frequency range during the scanning period.

Another object of my invention is to provide receiving means in which each point of the received image has its own definite tuned frequency.

Still another object is to utilize individual glow discharge tubes with individual tuning elements at each point of the receiving screens and to provide the necessary voltage bias, and also the frequency adjusting means.

Still a further object of my invention is to provide a novel signalling system in which code combination of signalling systems may be transmitted without requiring synchronization of transmitting and receiving apparatus.

Still a further object of my invention is to provide a novel code system for signalling systems.

In one embodiment of my system, I sub-divide the transmitted image into a number of sections. To each section I assign a varying frequency channel. Thus, a number of picture points can be transmitted simultaneously, each of said frequency channels passing through the full range of the assigned frequencies, but at staggered periods of time. By this arrangement, I sub-divide the scanned image into sections, the corresponding points of each section being scanned simultaneously.

Accordingly, a further object of my invention is to provide means for varying the frequencies in each of the above channels simultaneously, but in staggered relation.

Still a further object of my invention is to provide a receiving system with several frequency channels, each of them going through the same frequency variations as the sending channels.

Still another object of my invention is to synchronize these variable frequency channels with the sending channels.

A further object of my invention is to provide a novel type of band or disc scanner which scans several points of an image simultaneously.

A further object of my invention is to provide a receiving screen with several sections simultaneously operated.

In the drawings, Figure 1 is a diagrammatic illustration of the general arrangement of a transmitting system, in accordance with my invention.

Figure 2 is a diagrammatic representation of the variation of frequency with time in my system.

Figure 3 shows an arrangement of variable condenser by means of which I can accomplish the desired variation of frequency.

Figure 4 is a modification of such a variable condenser.

Figure 5 is an arrangement in which double scanning is carried out during each revolution and a suitable condenser arrangement is provided for varying the frequency back and forth during this double period.

Figure 6 represents the preferred arrangement of a receiving system.

Figure 7 shows an element of the receiving screen with an individual adjustable tuned circuit.

Figure 8 shows how a glow discharge tube may

be biased in order to give proper illuminating values, in accordance with the signals transmitted.

Figure 9 is a diagram of connections to accomplish this biasing.

Figure 10 is a modification of a receiving system where the points of the received screens are tuned to the transmitted frequencies by virtue of standing waves in a wave coil.

Figure 11 represents diagrammatically the duration of time and the voltages where illumination will take place.

Figure 12 is an alternative arrangement of scanning in which individual lines are scanned in opposite directions.

Figure 13 represents the same arrangement from the side, illustrating the double scanning disc and the path of light therethrough.

Figure 14 represents a receiving screen consisting of lecher wires in a glow discharge tube arranged to operate with the transmission scanner as in Figures 12 and 13.

Figure 15 represents a modification of my transmitting system, in which a number of frequency channels are transmitted simultaneously.

Figure 16 represents the same system, but illustrates the connections of the photoelectric cells with the transmitting circuits.

Figure 17 represents in detail the scanning band suitable for this system.

Figure 18 is an alternative arrangement which shows a scanning disc suitable for this system.

Figure 19 represents the frequency and time relation of the different channels in this modified system.

Figure 20 represents the receiving arrangement to be utilized with this modified system.

Figure 21 is a chart illustrating a three channel system suitable for transmission of colored images.

Figure 22 is a circuit diagram of the transmitter for a three channel system for colored images.

Figure 23 is a circuit diagram of the receiver for a three channel system for colored images.

Figure 24 is a multi-channel system for simultaneous scanning of full image on each channel.

Figure 25 is a diagrammatic illustration of the arrangement of scanning bands in a system such as shown in Figure 24.

Figure 25A to 29B are curves showing the shape of picture currents, resultant modulated waves, and the curves derived from the sharply tuned receiving systems.

Referring now to Figure 1, I show a scanning disc 1 which, by means of the spiral arrangement of holes, moves a beam from the source of light 2 through lens 3 to scan an image or subject 4 in the usual manner. The varying intensities of the light shades reflected from the subject 4 are impinged upon the photoelectric cell 5 in the usual manner.

Photoelectric cell 5 translates these varying intensities of light rays into electrical impulses which are amplified at 6 and transmitted by transmitter or radio sending apparatus 7.

Sending apparatus 7 is connected to a tuning circuit consisting of an inductance 8, condenser 9, and a small variable condenser 10. The rotating plates of variable condenser 10 are connected to the shaft 10' on which scanning disc 1 is mounted for rotation. The shaft 10' is driven by motor 11. In this manner, the capacity of condenser is varied in timed relation with the picture scanning by disc 1. As the ca-

capacity of condenser 10 is changed, the wave length of the transmitter 7 is changed correspondingly, since condenser 10 forms part of the tuning circuit of the transmitting circuit 7.

As the scanning disc 1 rotates, each of the perforated openings in the disc 1 scans a predetermined portion of the subject or image 4 and for each complete rotation of the disc 1, the image 4 will be completely scanned. A beam of light from the source 2, as it is moved over the image 4 by the disc 1, is reflected and impinged on the photoelectric cell 5 in any well known manner. The current flow from the photoelectric cell 5 is accordingly varied in accordance with the light reflected from various points of the image 4.

Figure 2 shows diagrammatically the curves of frequency obtained, as a result of which, a frequency variation ranging from a value of f kilocycles to a value of $f+40$ kilocycles over a period of $\frac{1}{16}$ of a second is obtained. This variation is shown as a straight line giving the same separation of frequencies for all consecutive points. By suitably changing the design of the frequency varying means any other type of frequency variation may be secured.

Figure 3 shows one possible arrangement of a variable condenser to accomplish the necessary result. In this case, a cam CM rotating around the pivot P1 is driven by motor 11. A lever L is provided with a follower which rides on the cam CM by action of the spring S. Lever L is pivoted at P2 and is connected by an arm S' to the variable plates of a variable condenser CN. As the cam CM rotates, lever L varies the capacity of condenser CN through a cycle which is repeated for each revolution.

Figure 4 shows an alternative arrangement, wherein a fixed condenser plate C1 cooperates with a rotating condenser plate C2 in such a way that the overlapping areas between these two plates will vary as the rotation proceeds. It is evident that in Figure 3 or in Figure 4, the shape of the cam or of the rotating condenser plates can be designed to give any desired variation of frequency in the oscillating circuit.

In Figure 5 I have shown an alternative arrangement of scanning where the series of scanning points is repeated twice during the revolution in opposite sense and in that case a variable condenser of usual type may be utilized.

I have shown in Figure 6 a receiving circuit with an antenna 12, an amplifier 13, and a broadly resonant circuit consisting of resistance 28, inductance 29, and condenser 30, which supplies its energy to a bank of sharply resonant circuits 32, each one of which is connected to its own glow discharge element of any well construction. Each one of these sharply tuned circuits 32 is tuned to a predetermined frequency corresponding to the frequency which is transmitted when the scanning disc 1 of Figure 1 illuminates a corresponding point on the transmitting image. Thus, the glow lamp 31 connected to the tuned circuit 32 will glow only at the instant when the corresponding element on the transmitted image is being transmitted at this particular frequency.

Since each tuned circuit 32 corresponds to one definite point on the picture to be transmitted and one definite frequency, this circuit will respond only when that particular point is being scanned and when that definite frequency is being transmitted; that is, once during every tenth or sixteenth of a second.

Inasmuch as the amount of energy which can be applied to such a circuit may be considerable and as a glow discharge of small size absorbs only little energy, it is possible to extend the period of illumination of each glow discharge tube to be a considerable portion of the scanning period, as explained hereinafter in connection with Figures 25 to 29. This assists the persistency of vision and also gives a larger average intensity of illumination as compared with the present systems where each point of the receiving screen is illuminated only during an extremely small fraction of a second equal to the scanning interval for any one point.

In Figure 7, I have illustrated a possible arrangement of the sharply tuned circuit 32 in combination with the glow discharge element. It consists of a glow discharge tube 33 and a casing 34, preferably of metal, in which is located a small inductance coil 35 and an adjustable condenser 36. The bottom plate of this condenser is shown to be supported on an adjustable screw stem 37 in a nut 38. Stem 37 extends to the outside of the casing 34 and is connected to any suitable member, such as a knob 37', for rotating the stem.

In Figure 8 I have shown a curve showing the voltage oa to which each of the glow discharge tubes should be biased so as to be just near the ignition point. By normally biasing the tube just near the ignition point, any additional voltage ac applied to the glow discharge tube will result in emission of light L which will be proportional over a certain range to the voltage applied.

In Figure 9 I have shown one way in which such a bias may be applied by means of a battery 39 shunted by a condenser 40. The remaining elements of this figure are like those shown in Figure 7. Although a battery bias is shown in this figure, a bias may be obtained by means of the unmodulated portion of the carrier wave.

The biasing arrangement of the tube permits the glow discharge to respond to minute values of transmitted signal. Of course, it is evident that such a biasing may be obtained by other means than a direct current battery; such, for example, as some other local supply of direct or alternating voltage, or it may be the unmodulated carrier of the transmitted signal. As illustrated in Figure 6, individual tubes for each tuned circuit may be provided, or alternatively individual electrodes in a common tube may be used. In either case, these electrodes or tubes will be arranged to illuminate a screen of suitable size in a manner to correspond to the transmitted points; that is, the circuit connected to each of the tubes is tuned to the frequency of the point on the transmitted image having the same relative location.

Figure 10 shows a receiving arrangement with an antenna 12, a receiving set 13, and a wave coil screen 14, which comprises a section indicated by G which may be located within an attenuated gaseous atmosphere so that the voltage nodes on the wave coil will produce luminous sections. Each nodal point, such as N-1 or N-2 is individual to a predetermined frequency and may therefore correspond to each position of the image to be transmitted. It is evident that in this case, as in the case of Figure 6, no synchronizing elements are necessary.

I have shown in Figure 11 diagrammatically by means of vectorial curve A-A', the voltage relations during each cycle at any one of the nodal points. The circle 20 indicates the ignition values.

of the glow discharge. It will be seen that the ignition will occur at intersecting points 16 and 17, while the extinction will occur at points 18 and 19. Since, in this case, the duration of the illumination at each nodal point will depend to a large extent on the magnitude of the operating voltage, it will be necessary to operate the device with a definite minimum or bias voltage; that is, for the ignition voltage as represented by circle 20, the area above the circle 20 which is not shaded will represent the amount of illumination at the receiver which can be secured for such a voltage and its duration is from 16 to 18 and 17 to 19. It is evident, of course, that if the operating voltage is increased, as illustrated by the circles B—B', the illumination is proportional to the area above the circle 20 and it will be considerably increased approximately in proportion to the square of the value of voltage, thus giving a brighter recorded point. The minimum or bias voltage may be in this case the unmodulated portion of the carrier wave.

Figure 14 shows an alternative arrangement in which the wave coil is replaced by straight wires in a zigzag tube, in which case short waves may be employed to produce the nodes and the scanning discs must be arranged as in Figures 12 and 13; that is, it is necessary to have two scanning discs rotating in opposite directions which will scan the image in successively opposite directions. Thus, when the scanning disc 25 of Figure 12 has a hole 25a opposite the source of light 26, the scanning disc 27 will have a slot 27a. Therefore, the scanning will be clockwise, while at the next instant the disc 25 will have a slot 25c opposite the source of light, while the disc 27 will have a hole 27c and the scanning will be in the opposite direction.

The system employing wave coils or parallel wires has the advantage of simplicity, but the disadvantage that the nodal points are not sufficiently sharp and the adjacent areas close to the brilliant spots will be correspondingly affected. This disadvantage is not found in the system of Figure 6.

It is important to realize that the operation of the system cannot be explained in the usual terms, such as frequency or amplitude modulation with application of the mathematical conclusions based on frequency analysis, side band response and similar considerations commonly used in analyzing the sending and receiving circuit conditions for radio frequency telephone transmission or television transmission on a radio carrier wave where the ordinary type of amplitude modulation is used.

To illustrate this clearly, consider a television system in accordance with my invention wherein the frequency is changed during the cycle of $\frac{1}{25}$ second between the limits of 1,020,000 and 980,000 cycles, which will correspond to the usual television broadcasting range of 40 kilocycles. Assuming that the system is designed for 2,500 scanning points, in accordance with my system, each scanning point will be distinguished by a resonant circuit with a frequency separated by 16 cycles from the adjacent scanning points. On the other hand, with 2,500 scanning points in $\frac{1}{25}$ second the scanning points will succeed each other at time intervals of $\frac{1}{40,000}$ second. Thus, taking an average frequency of 1,000,000 cycles, we would have the scanning points following each other at intervals of 25 cycles of the 1,000,000 carrier.

Consider two extreme types of pictures illus-

trated by Figures 25A and 25B respectively. 25A shows a magnification of a picture in which light and dark spots follow each other at intervals of one scanning point. 25B shows a single light scanning spot on a black line being scanned.

I have shown in Figure 26A the corresponding modulated carrier wave with pulses of oscillations following each other at approximately 50-cycle intervals and corresponding to the light scanned points. The corresponding pulses have at their maximum points the operating frequencies of 1,000,032, 1,000,000 and 999,968, corresponding to the interval of two light spots with a black scanned spot in between.

I have shown in Figure 27A a resonant curve of one particular receiving device on the same scale as 25A with regard to the carrier frequencies. The curve a'—a—b—b' represents the envelope of the modulated carrier of 26A. At this point, the distinction between the ordinary carrier wave modulated at 40,000 cycles and the carrier wave with a frequency varying in accordance with my invention and modulated in amplitude at the same time, will become apparent. Thus, if the carrier frequency remains constant, the response to this carrier will be in accordance with curve C; that is, constant during the whole period, and the envelope of received signals would be in accordance with Figure 28A, the oscillations building up during each pulse and dying out to a certain extent in between these pulses.

This explanation is evidently independent of any theory of side bands but merely shows that an amplitude modulated carrier on a resonant circuit will result in a response modulated in amplitude but at a constant frequency. Of course, the degree of modulation in the receiving circuit will depend on the inherent damping of the responsive system. Thus, if this inherent damping is extremely low, the modulation will be of small amplitude and may have to be amplified by some special means.

This corresponds in effect to the system known at the present time as the Stenode system, where the responsive circuit is arranged to have extremely sharp tuning characteristics, in fact, tuning characteristics which do not include any of the side bands. The above explanation will show why such a system will nevertheless reproduce the modulations.

Referring again to the system in accordance with my invention, I have shown at D the response characteristics of the receiving circuit of the individual scanning point of 1,000,000 cycles, as illustrated for example in Figures 7 and 9. It is evident now that during the time that the modulated carrier with the envelope a'—a is entering into this circuit, the response is incomplete, since the average frequency is 1,000,032 and would have an average value of d_1 . This would result in a pulse in the receiving circuit corresponding to Figure 29A (the section marked e' to e). During the next pulse marked a—b on Figure 27A, this pulse, being at the resonant frequency of 1,000,000 cycles on the average, will have a response amplitude of d_2 and result in a pulse in the receiving circuit illustrated by the section e—f of Figure 29A. Moreover, this oscillation will not die out at point f immediately but with a slight damping of the resonating system will continue with a slow decrement, possibly for the full length of $\frac{1}{25}$ second until the next pulse of 1,000,000 cycles will be applied. Following this comes the pulse illustrated as b—b' on Figure 27A and corresponding to the average frequency

of 999,968. It will also have a low response amplitude such as d_3 and will result in a slight hump, as illustrated at $f-f'$ on the high amplitude oscillation commenced during the period $e-f$, as illustrated in Figure 29A.

It is also evident that if the 1,000,000 cycle pulse during the period $a-b$ is of a low amplitude, then the response oscillation $e-f$ is also relatively small. On the other hand, the amplitude of the preceding and succeeding pulse $A'-a$ and $b-b'$ will have small effect.

I have illustrated in Figure 26B the high frequency oscillation corresponding to a light spot on a dark line of Fig. 25B and in Figure 27B the response characteristic D of the receiving system and the envelope of the single pulse $a-b$.

Figure 29B illustrates the pulse in the receiving circuit built up by $a-b$. Its average amplitude, as can readily be seen, will be practically the same as the pulse built up in Figure 29A. Thus, it is evident that the illumination of the points ahead and behind the point under investigation has practically no effect on the response of the receiving system tuned to the 1,000,000 cycles and the same applies, of course, throughout the receiving screen consisting of a number of individual elements similar to the one shown in Figure 6.

In the above described system, each point is given only a very short instant for transmission and, therefore, the receiving circuit must be extremely sharply tuned. In another embodiment of my invention, a number of variable frequencies are transmitted simultaneously, each one of these frequencies passing through the complete frequency range but being at any instant of a different value from any of the others. It, therefore, becomes equivalent to a number of frequency channels transmitted simultaneously, each one of said channels passing through the full range of frequencies. This is illustrated diagrammatically in Figure 19 where six frequency ranges are shown to vary through the full cycle in $\frac{1}{6}$ th of a second, (but the beginning of each cycle; that is, the instant of say, minimum frequency, is different for each channel). At any instant t there will be six operating frequencies as shown $f_1, f_2 \dots f_6$.

Figure 15 illustrates one possible arrangement for transmitting apparatus utilizing this multiple channel in which the picture is divided into as many sections as there are frequency channels, each frequency channel covering only its sections. I have shown in this figure, bellows 40 with one side cut away to make visible a projection of the object to be transmitted 41 on a transparent or translucent screen 42, by means of a lens 43 similar to a photographic apparatus. Back of the screen 42 there are located a series of horizontal photoelectric cells 44, each one extending the full length of the screen. In front of the photoelectric cells, I have placed a scanning band 45 which is shown in detail in Figure 17 and which may be arranged with as many sets of scanning holes 47, 48, and so forth, as there are simultaneous transmitting channels. As shown in Figure 17, there are six of such sets, corresponding to six photoelectric cells and six simultaneous channels.

These holes, 47, 47' for any one channel follow each other but slightly displaced as the band rotates with a distance between them equal to the width of the image transmitted. Consecutive sets may begin the scanning of each section at staggered time intervals to coincide with, say, the minimum value of the channel frequency of

the corresponding channel. The scanning band may be continuous, as illustrated in Figure 15, propelled by motor 46, the same motor also driving a set of variable condensers C1, C2, C3, and so forth, arranged in different and consecutive phase relation of its plates, so that each one of these condensers passes through its maximum capacity at different instants.

Figure 16 illustrates the manner in which the photoelectric cells may be connected to a transmitting equipment. I have shown a separate amplifier A1, A2, A3 and so forth, for each one of the photoelectric cells, each cell being individual to a predetermined section of the picture. The output of each of these amplifiers is connected to modulate its own oscillator, not shown in detail but which may be of any known type, for instance, vacuum tube oscillators, comprising control oscillatory circuit O1, O2, O3 including the above mentioned variable condensers C1, C2, C3 driven by motor 46. These control circuits influence through further amplifiers A1, A2, A3, the transmitter set, all of these latter amplifiers being connected in parallel to the transmitter T. I have now shown in detail how the control circuits O1, O2, and so forth, control the transmitter set as this is well known in the art.

Figure 18 shows an alternative arrangement of the usual type of scanning disc with a centre at 49 but with a multiplicity of set of holes to give them multiple scanning. Each set of holes begins at a different radius and follows a separate spiral. The first holes of each set are preferably in a staggered circumferential position corresponding to the minimum frequency so that each section can be easily checked with regard to relation of frequency to the position of any one point scanned.

Figure 20 illustrates the arrangement of a receiving circuit, suitable for this type of transmission. It is seen in this case that a broadly tuned receiver R supplies received energy in parallel to a number of variably tuned receiving circuits R1, R2, R3, and so forth, each one of which includes variable condensers C1R, C2R, C3R, and so forth, arranged in exactly the same phase relation as C1, C2, and C3 (Figure 16) and operated by a motor M which is synchronous with motor 46. The synchronization may be effected by any well-known means, for instance, by a synchronizing device S which is connected to one of the variably tuned circuits R-1 and will operate dependent on the extreme frequencies which are transmitted over this particular receiving circuit. Such synchronizing devices are well known in the art, but any other type may also be used.

The tuned receiving circuits are connected to additional amplifiers A1R, A2R, A3R. Each of said amplifiers is then connected to a bank of lamps with sharply tuned circuits, which are identical to those illustrated in Figures 7, 8, and 9. Each bank, however, will include only as many elements as there are picture elements transmitted through its own corresponding channel. Thus, for photoelectric cell 44 operating through amplifier A1, oscillating control C1, the frequency channel F1, variable receiving circuit R1, amplifier A1R, there will be a set of glow discharge lamps G11, G12, G13, each one tuned to its own particular frequency and arranged to correspond to as many horizontal lines as can be scanned by one photoelectric cell 44. It will be seen now that although a number of

frequency bands are transmitted simultaneously each one of the variable receivers R-1, R-2, R-3 will tune only to its own variable channel and, therefore, the bank of lamps which is connected to this variable receiver will be illuminated only in correspondence to the picture elements which are transmitted by this one channel. Thus, the sharpness of tuning of the individual receiving lamps can be broadened by a multiple equal to the number of channels utilized, or else with the same sharpness of tuning the number of scanning points is multiplied by the number of channels used.

While I have shown in Figures 15 to 20 a method of picture transmission utilizing a number of frequency channels simultaneously, each one scanning a certain section of the picture, it is also possible to arrange so that each one of the frequency channels scans the whole of the picture. I have illustrated such methods of picture transmission in Figures 21 to 25. Such a multiple channel transmission may be utilized, for instance, for transmitting color images.

I have shown in Figure 21 three frequency channels, identified by three primary colors, such as red, blue-green and yellow. These three channels cover the full frequency range and are staggered with respect to the points of minimum frequency, so that at any one instant three frequencies at relatively wide intervals from each other are transmitted.

I have shown in Figure 22 one way of utilizing these three frequency channels for transmitting a colored image. Three projection lights 50, 51, and 52 are directed towards three separated locations on the scanning disc 33, which is of the usual type. The illuminated sections may, for instance, be separated by angles of 120°, so that the scanning of each color covers the transmitted object by lines in different directions and in different location relative to the edge of the object. In order to create the color distinction, I supply the three lights 50, 51, and 52 with color filters, for example, of red, blue-green, and yellow. I have also supplied three photoelectric cells P1, P2, and P3, respectively, responsive to red rays, blue-green rays, and yellow rays. These may be photoelectric cells, specially arranged by the proper choice of photoelectric material to be responsive to such rays, as is known in the present-day art, or else they may be photoelectric cells responsive to white light but provided with special color filters to make them responsive to the respective colors. The rays from the three sources of illumination 50, 51, and 52 are directed towards the object to be transmitted, and as the scanning disc 53 rotates, it explores simultaneously in three colors the object to be transmitted.

It will be evident, that if the scanning lines for, say, a red light will be horizontal, those for blue-green will be at 120° to the first lines, and the scanning lines, due to yellow light, again at 120° to the blue-green. Each one of the photoelectric cells picks up the impulses of its corresponding light from the illuminated object and each one is supplied with separate amplifiers such as A1, A2, and A3. The amplifiers are respectively connected to oscillators O1, O2, and O3 illustrated diagrammatically, with variable condensers C1, C2, and C3 controlling the frequency of the oscillations and staggered 120° in exactly the same manner as those of Figure 15 were staggered 60°. These three condensers are operated from a common controlling motor M which also drives the scanning disc 53.

Thus, three transmitting channels are established at staggered frequencies, as illustrated in Figure 21, each one of these channels covering the whole of the picture but transmitting light corresponding to one color only. The output of the oscillators is directed to three amplifying tubes T1, T2, and T3 and the output of these tubes through further amplification to the transmitter T, is radiated through an antenna or communicated over lines.

Figure 23 illustrates a receiving circuit which consists, as before, of a broadly tuned receiving set R connected to three variable tuning elements R1, R2, and R3 controlled by condensers C1R, C2R, and C3R, which are staggered in the same way as the condensers C1, C2, and C3 and are driven by a motor M synchronized by suitable synchronizing devices S, controlled from the receiving set R. Each one of the controlled responsive circuits R1, is connected to sets of lights similar to those of Figures 7 or 9, but provided either with a gas giving a definite color of light or by colored glass which emits the respective colors.

Thus, the circuit R1 may be connected to a series of red lamps, the circuit R2 to a series of blue-green lights, and the circuit R3 to a series of yellow lights. These lights are interspaced, as illustrated in the diagram, where the letter *r* indicates the red lights, arranged in horizontal lines; *b* the blue-green lights, arranged in lines at an angle of 120°; and *y* the yellow lights, arranged in lines at 120° to blue-green and sufficiently closely spaced so that at the distance from which the image is observed, the individual lights cannot be distinguished but only their common effect. The individual circuits of lights of each color are tuned to the frequency at which the corresponding point of the object is transmitted with that particular color. It is evident that in any one instant three lights of three different colors may be illuminated at widely different portions of the screen but since the full screen is covered by the scanning process in 1/25 second, the retention of stimulus by the eye or persistency of vision during this period of time will give the effect of a composite picture in natural colors.

I have shown in Figure 24 an arrangement in which multiple channels are utilized for scanning an object with one color and each channel covers the whole picture. To distinguish between the channels at the sending end, I have shown an optical means for producing a multiple image of the object to be scanned. Thus, the object 54 is made to form images 55, 56, 57 and others (that is, 5 altogether), by means of a photographic lens 58 and a mirror 59 in the shape of a pentagonal prism, the faces of which reflect the part of the light which strikes them towards one of the five radial directions towards flat mirrors such as 60 and 61, and hence to form the images 55, 56, and 57 spaced in the plane of a scanning band 45' similar to that of Figure 15 and at, for instance, five separate locations, as illustrated in Figure 25.

Opposite each one of these images, there are located photoelectric cells such as P1, P2, P3, P4, and P5 so that each of these photoelectric cells scans only its own image, but by virtue of the location of this image relative to the scanning band, each photoelectric cell at any instant scans a different portion of the object. For instance, in the present case with five images, the scanning band is divided into five sections, 60, 70, 75

81, 82, 83, and 84, corresponding in location to the five photoelectric cells P1, P2, P3, P4, and P5 and the images which they scan. Taking, for instance, section 80, the scanning holes in this section covering the whole of the image begin on the top at the definite instant indicated as 85. The next image 86, which is located opposite the photoelectric cell P2 and opposite the band 81, is scanned by a set of holes in such a way that the scanning begins at the top of the image at an instant of time which is ahead of 85 by one-fifth of the total scanning interval, so that the hole 86 shown is already advanced by one-fifth of the total number of scanning holes. In the same manner, the scanning holes for each of the other groups 82, 83, and 84, are arranged to start the scanning of each image at intervals of time spaced by one-fifth of the total scanning interval.

The photoelectric cells are connected to modulating amplifiers A1, A2, and A3, which are shown in detail in this diagram as consisting of vacuum tubes 62, 63, and 64, with the grid circuits connected respectively to photoelectric cells P1, P2, and P3 through coupling coils 65, 66, and 67. The photoelectric cells are supplied with voltage from a battery 68. The return circuit is completed through grid leaks 69, 70, and 71. The coupling coils are shown to be influenced by individual oscillators O1, O2, and O3 controlled by variable condensers C1, C2, and C3 similar to those in the arrangement of Figure 15, except that they are staggered 72° and driven by a motor 46. The oscillator which may be of any type and is shown to be merely a feed-back vacuum tube oscillator, has the coils 72, 73, and 74 coupled respectively to coils 65, 66, and 67 of the amplifiers. The output of the amplifiers is connected through condensers 75, 76, and 77 to the controlling grid 78 of a further amplifier 79. Each one of the output circuits will carry its definite frequency channel staggered from the other frequency channels and each one modulated in accordance with the picture signals derived from one of the five images.

While I have illustrated only three of the amplifiers, oscillators and variable condensers, it will be evident that the remaining two can be connected in the identical manner and that the number of channels need not necessarily be five, but may be any convenient number. Thus, for six channels, I would utilize a prism to form six images with six corresponding photoelectric cells and six equally spaced scanning positions separated by, say 60°. Also, I may use an even number of channels so that each half of this number scans one group of two stereoscopic images from two separate lenses, located at suitable stereoscopic distance from each other.

The output of the amplifier tube 79 is connected to the transmitter T and hence radiated or connected to a line. Since in this transmitting circuit each frequency at any instant will define exactly the position of the transmitting point, I may utilize the simple receiving screen such, for instance, as is illustrated in Figure 6. Thus, although the transmitting arrangement will be relatively complicated, which will not detract from its practicability since an expensive installation need be made only at the central broadcasting location, yet the receiving arrangement is quite simple and could be applied to a number of receiving points. Moreover, this receiving arrangement need not have any special synchroniz-

ing means as the frequency of each signal at any instant accurately defines its point.

The reduction of scanning speed for the same number of transmitting points results of course in a modulation of light at a lower speed; that is, a narrower side band of amplitude modulation. The side band will have a narrower range in proportion to the number of simultaneous channels used. Thus, for example, assuming an ordinary scanning method requiring a side band range of 40 kilocycles on each side of the carrier as is usual in television transmission, multiplying the channels by five will narrow this side band range to 8 kilocycles to which, of course, has to be added the range of frequency modulation. If this latter is assumed to be also 8 kilocycles, the total band width will be 24 kilocycles as against 80 kilocycles with the ordinary system.

While I have illustrated the principle of generating successive carrier currents of different frequencies by means of a continuously rotating condenser at the transmitting station and a plurality of tubes and circuits at the receiving station individual one for each of the generated carrier currents as applied to a television system, it will be obvious that this principle of code transmission may be applied to any other form of signalling system in which code combination of impulse conditions are utilized.

Thus, for example, in telegraph systems, particularly in wireless telegraphy, the same principle may be applied, as well as in supervisory control systems, stock quotation systems, and railway signalling, and other forms of signalling systems; and I accordingly wish it understood that the illustrations herewith shown are merely shown for purposes of illustration and I do not wish to confine this invention to the particular illustrations thereof as shown.

While I have shown in the above disclosure various modifications of the general principle of transmitting pictures with the amplitude defining the intensity of the light and the frequency defining the location of the point, it will be evident to those skilled in the art that various other modifications in circuits illustrated may easily be developed and I do not wish to limit the invention to the particular circuit and arrangement, except as defined in the appended claims.

I claim:

1. The method of transmitting pictures by means of electric current comprising subdividing the object to be transmitted into sections, scanning all of said sections simultaneously, transmitting electric signals by means of separate frequencies for each section simultaneously amplitude modulated in accordance with the optical characteristics of successive elementary areas of the respective sections and cyclically variable in frequency and in overlapping staggered phase relationship with regard to the cyclically variable scanning frequency of the other sections, controlling the progress of scanning in accordance with the frequency variation, and receiving said signals on separate sections individually responsive to only one of said variable frequencies.

2. A system of picture transmission comprising means for scanning several sections of an object to be transmitted simultaneously, means for producing several scanning frequencies, means for varying cyclically each of said frequencies simultaneously but in overlapping staggered phase relation over a definite frequency range in regard to the cyclic variation, means for controlling the

scanning in accordance with the frequency variation, and means for modulating the amplitude of each of said frequencies in accordance with the light intensity of the points scanned in each of the corresponding sections.

3. A system of picture transmission comprising means for scanning several sections of an object to be transmitted simultaneously, means for producing several scanning frequencies, means for varying cyclically each of said frequencies simultaneously but in overlapping staggered phase relation over a definite frequency range in regard to the cyclic variation, said means comprising sets of variable reactors, corresponding sets of tuned circuits in which said reactors are included, and common means for varying said reactor simultaneously but in staggered phase relation, means for controlling the scanning in accordance with the frequency variation, and means for modulating the amplitude of each of said frequencies in accordance with the light intensity of points scanned in each of the corresponding sections.

4. The method of picture transmission by means of sending currents of several frequencies, comprising the steps of simultaneously scanning several sections of the object to be transmitted, producing a plurality of sending currents, varying cyclically each of the produced sending currents within the same predetermined frequency range in staggered overlapping time phase relation in regard to the cyclic variation for a given scanning period, and controlling the progress of scanning of the object to be transmitted in accordance with the frequency variation.

5. A method of picture transmission comprising simultaneously scanning several sections of an object to be transmitted, producing a number of alternating currents of different frequencies cyclically varying between the same predetermined limits, and in staggered overlapping time phase relation over a given scanning period in regard to the cyclic variation, controlling the progress of scanning of the object being transmitted in accordance with the frequency variation, and varying the amplitude of said currents in accordance with the degree of brightness of the respective picture areas being scanned.

6. A method of picture transmission by means of electric current comprising simultaneously sending a plurality of alternating currents of different frequencies each representative of a different section on the object being transmitted,

cyclically varying the frequency of said currents between predetermined limits and in staggered overlapping time phase relation in regard to the cyclic variation, and controlling the progress of the respective section of the object being transmitted in accordance with the frequency variation.

7. A method of picture transmission by means of electric currents comprising simultaneously sending a plurality of alternating currents each being representative of a different area of the picture to be transmitted, cyclically varying the frequency of said currents between the same predetermined limits and in staggered overlapping time phase relation in regard to the cyclic variation within the scanning period of the object being transmitted, and varying the amplitude of said currents in accordance with the degree of brightness of the respective areas of the object being scanned.

8. A method of picture transmission by means of electric current comprising simultaneously sending a plurality of alternating currents each being representative of a different area of the picture to be transmitted, cyclically varying the frequency of each of said currents between predetermined limits and in staggered overlapping time phase relation in regard to the cyclic variation, controlling the progress of scanning of a separate section of the object being transmitted in accordance with the frequency variation, and varying the amplitude of said currents in accordance with the degree of brightness of the respective areas of the object being scanned.

9. A scanning device comprising two scanning disks, each of said disks being provided with alternate slots and holes arranged along a single spiral trace, the pitch of which is opposite to that of the trace upon the other of said disks, means for rotating the disks at the same speed and in opposite directions whereby successive lines of the object are scanned in opposite directions alternately by said scanning disks.

10. A scanning device comprising two coaxial scanning disks, each of said disks being provided with alternate slots and holes arranged along a single spiral path, the pitch of which is opposite to that of the trace upon the other of said disks, means for rotating the disks in opposite directions whereby successive lines of the object are scanned in opposite directions alternately by said disks.

ALEXANDER NYMAN.