

July 21, 1942.

R. R. HAUGH

2,290,823

DOUBLE CARRIER FACSIMILE

Filed June 12, 1940

3 Sheets-Sheet 1

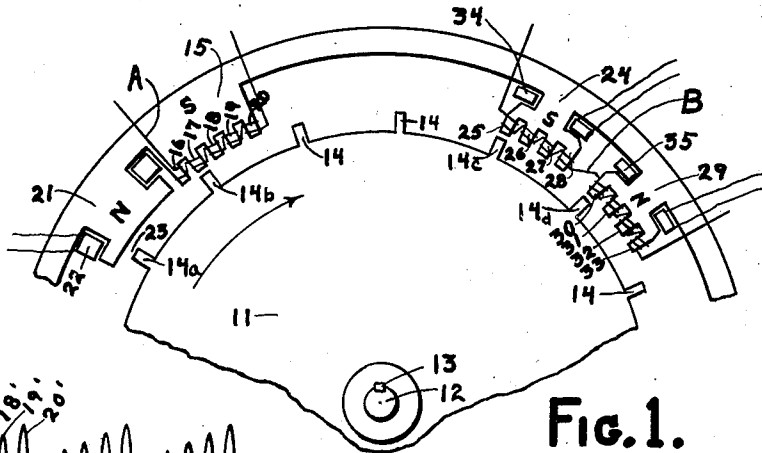


FIG. 1.

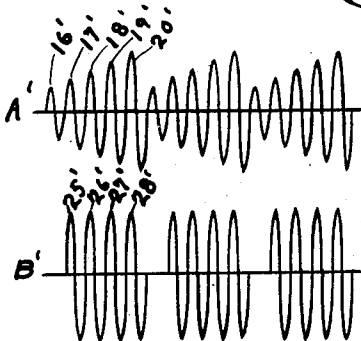


FIG. 2.

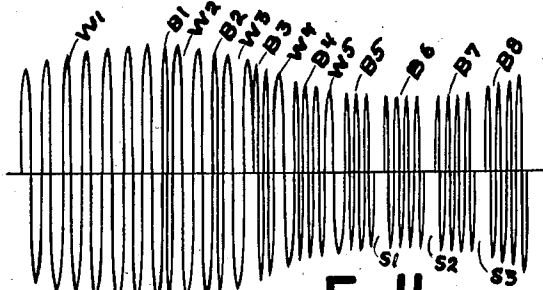


FIG. 4.

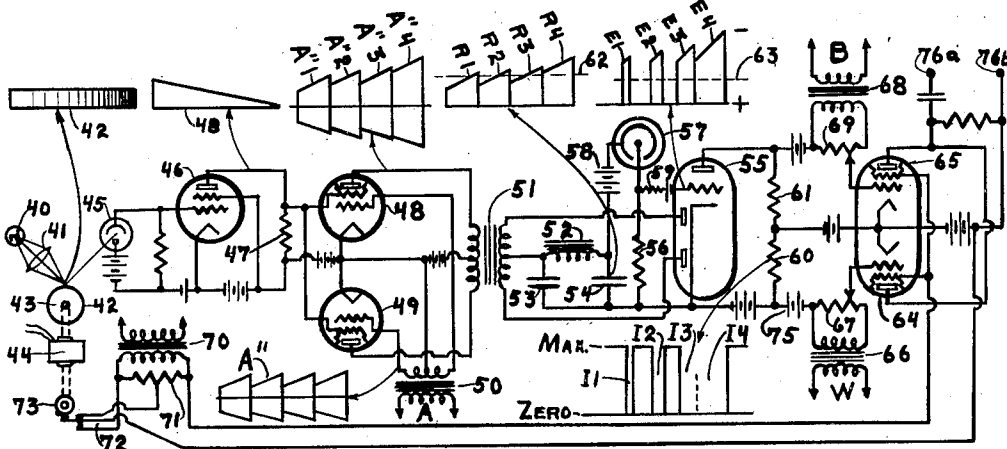


FIG. 3.

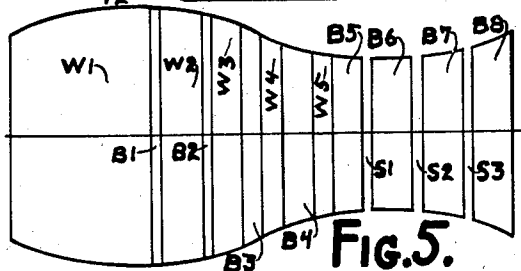


FIG. 5.

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3 Sheets-Sheet 2

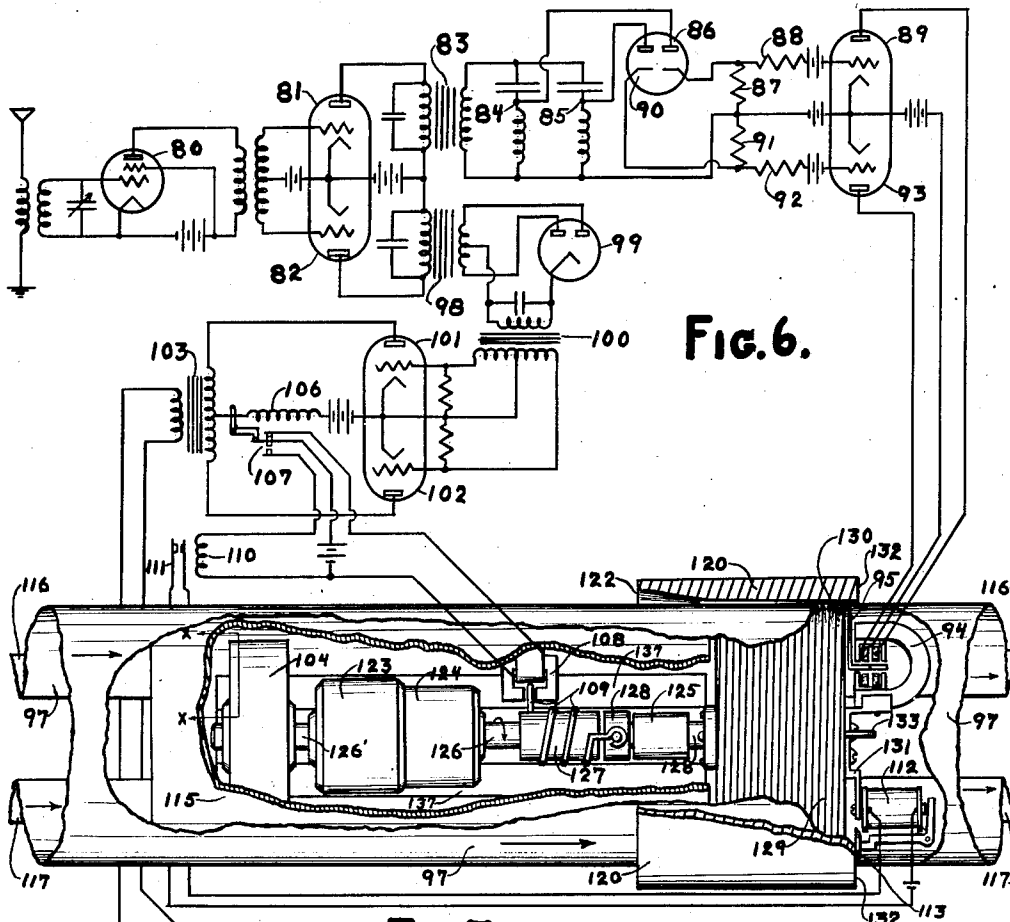


FIG. 6.

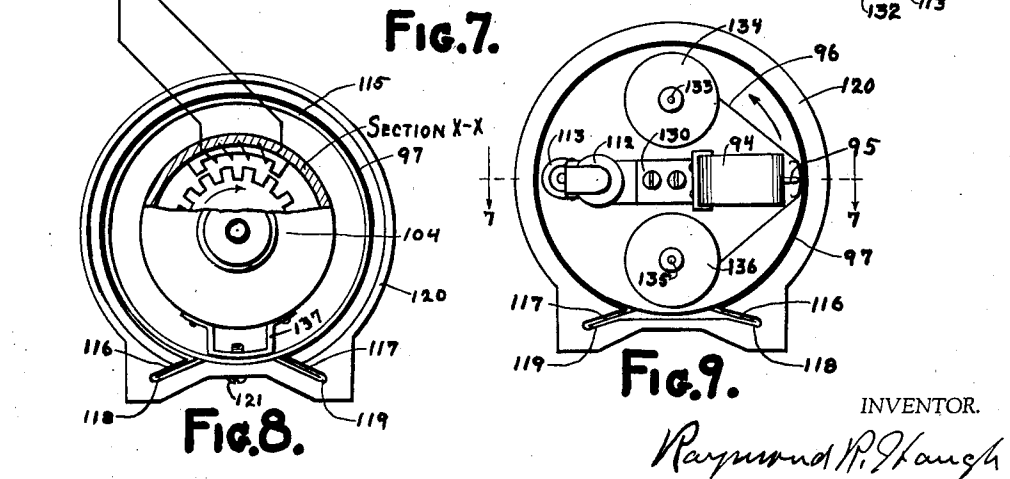


FIG. 7.

Fig.9.

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3 Sheets-Sheet 3

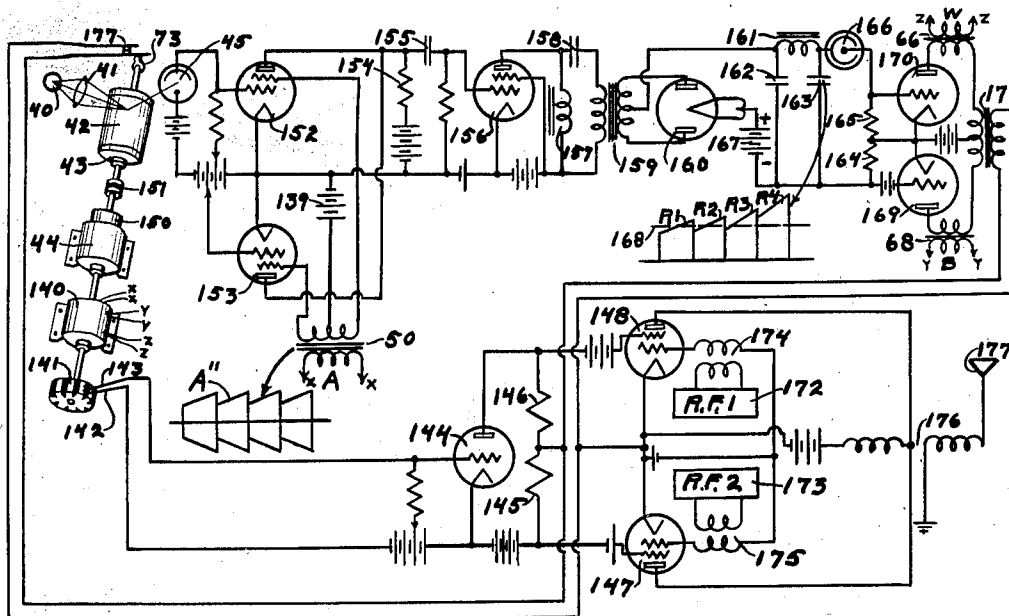


FIG.10.

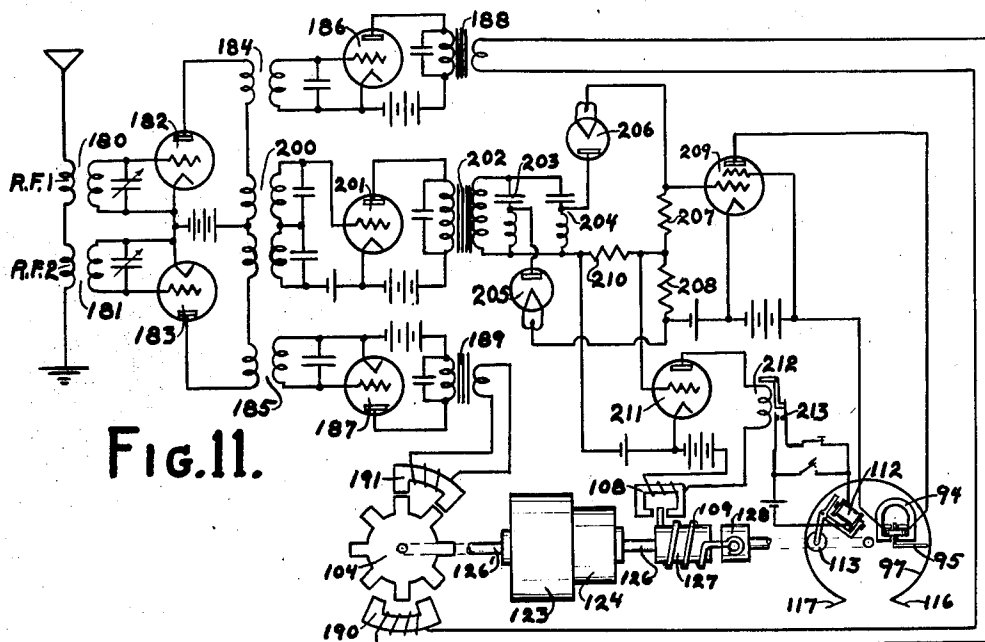


FIG.11.

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2,290,823

DOUBLE CARRIER FACSIMILE

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Application June 12, 1940, Serial No. 340,067

9 Claims. (Cl. 178—6)

This invention relates to a method of and means for transmission of shaded pictures and reception of the images over a signalling channel and particularly to refinements in the methods thereof.

It is the object of my invention to provide and improve the method of transmitting shaded pictures and improved apparatus for carrying out the method which is simple and efficient, low in cost and requiring no adjustments at the recorder.

Another object of my invention is to provide means for balancing the curve characteristics of a facsimile transmitting system.

Another object of my invention is to increase the speed for transmitting pictures.

Another object of my invention is to definitely control the duration of the signal impulses according to the shading of the scanned picture elements.

Another object of my invention is to transmit both the synchronizing and the picture signals simultaneously in such a way that they will not interfere with each other.

Another object of my invention is to provide for transmitting a picture or other image in such a way that the reception will not be unfavorably effected by static.

These objects are achieved in part by employing a simple electric generator with four separate stator windings. One of said windings produces a "control wave train" consisting of a series of increasing wave train groups, these successive wave train groups are used to divide the scanned picture into a series of picture elements. Each wave train is used as a unit for accurately measuring the shading intensity of the picture element being scanned by a photoelectric cell over a very wide range of shades and also for controlling the duration of the black and white picture carriers. The length of these two carriers of different frequency represents the shading intensity of the picture element being scanned. These two carriers are used to operate or key the receiving recorder to the frequency of the wave train groups. Another winding of the said generator produces one of the above carrier waves which carry the black picture signals, consisting of a series of wave trains of constant amplitude but skipping a cycle at regular intervals. This carrier wave will be called the "black keying carrier." The "control wave train" and the "black keying carrier" are in synchronism. Another winding of said generator produces the other carrier wave which is of constant amplitude but of

different frequency than the "black keying carrier." The function of this carrier is to carry the white picture signals. These two picture carrier waves have constant amplitudes and approximately the same signal strength. The said generator also produces a "synchronizing signal" which is of much lower frequency than any of the other three frequencies.

My invention contemplates the transmitting of three generated frequencies plus the change in duration of time that two of the frequencies are transmitted which represents the shading of the picture elements. The duration of the "black keying carrier" depends on the blackness of the picture element being scanned and the "white carrier" wave filling in the rest of the time. If the section of the picture being scanned is pure black, the "black keying carrier" is so arranged that it produces its own keying frequency by dropping a cycle at regular intervals.

In the transmission of pictures by radio it is desirable that all the energy capable of being radiated from a given transmitting station be employed, because the recorded picture depends in a large measure on the ratio of the signal energy level to the static interference energy level at the receiver. In my system the reduction of this interference is accomplished in two ways. First, by transmitting continuously with either one or the other of the two said carriers of different frequency which correspond to the shading of the picture element being scanned. (At the present time facsimile pictures are being broadcast by sending out a carrier wave for the black picture signal and no carrier wave for the white portion or vice versa. This reduces the transmitted energy level.) Second, in receiving the black and white carriers are filtered out by separate filters, rectified, and amplified and then connected to a signal amplifier so that one signal would oppose the other if they were both on at the same time, and if the signals had the same strength they would cancel out, but the two carriers are never on at the same time. When static goes through the receiver it will go through the two filters and rectifiers with the same amount of energy in each circuit and will balance out because the output of the filters and rectifiers oppose each other in the signal amplifier. This will be explained in more detail later.

There have been quite a number of different methods invented for synchronizing and framing pictures in facsimile transmission. One method sends only a framing impulse each time the picture is being scanned and this impulse releases

a clutch which allows the motor to move the recorder through one cycle or line and then waits for another impulse to come along for the next line or cycle. This system has the disadvantage that its releasing time varies with friction and signal strength and the inertia of the moving parts tends to prevent the absolute synchronism of the recorded picture elements from line to line. Another disadvantage of this system is that the synchronizing impulses have to be very much stronger than the picture signal. Another facsimile system depends on the local power circuit for holding the recorder in synchronism with the transmitter after the picture has been framed. This system works fairly well on the same power circuit but does not work well when the transmitter gets its synchronization from one power system and the recorder gets its synchronization from a different power system. Some facsimile systems use involved complicated electrical vibrators depending in most cases upon the impulse synchronizing signals sent by the transmitter to control the vibrator.

My present invention depends simply upon transmitting a continuous synchronizing frequency which controls a synchronous alternator which is driven by a local motor at the recorder in step at all times. This is accomplished by using this synchronizing signal to continuously modulate the black and white picture signal carriers about 25%. The framing signal at the end of each line is attained by modulating the white and black carriers 50% with the synchronizing signal for a very short time, which allows the framing clutch to release if the picture is framed and if not, it frames it. When the pictures are being changed at the transmitting station the synchronizing signal modulations are again changed 50% for fifteen seconds or more. This operates a delay relay at the receiving recorder which is set for this time delay and operates a paper cut-off. It can be seen that the same synchronizing frequency is used to keep the motor and recorder in step, frame the picture, and to cut off the paper.

The operation of the framing clutch is unique in the fact that it does not function except when the recorder is out of frame and then it brings the recorder into frame in one revolution. The framing clutch is always energized, except when the framing signal is being transmitted at which time the clutch releases and if the picture is in frame it will pass the clutch spring before the framing clutch is energized again. In this system once the picture has been automatically framed the continuous synchronizing signal, which controls the speed of the driving motor and the recorder, also holds the recorder in frame indefinitely.

Certain other objects and advantages will be apparent and the invention will be more readily understood by referring to the following specifications and the accompanying drawings.

Fig. 1 shows a diagram of a fragmentary section of an alternating current generator with two special stator windings.

Fig. 2 curve A' shows the increasing wave train groups generated by the winding A of the generator. These wave train groups are called the "control wave train." Curve B' shows the constant amplitude carrier wave which drops a cycle at regular intervals. This voltage is generated by winding B of the generator and is called the "black keying carrier."

Fig. 3 shows schematically the diagram of the

amplifier circuit and the wave forms in various parts of the circuit.

Fig. 4 illustrates graphically the output carrier waves corresponding to the picture elements being scanned for one cycle of the "synchronizing frequency."

Fig. 5 shows a schematic diagram of Fig. 4 showing more definitely the time that the white and black signals are operating.

Fig. 6 is a schematic diagram of the receiving amplifying circuit showing its connection to the recorder as shown in Fig. 7 and Fig. 8.

Fig. 7 shows a cutaway top view of the paper and the facsimile recorder with the typewriter ribbon and its operating mechanism removed.

Fig. 8 is the left end view of the facsimile recorder showing schematically a cutaway section of the speed control alternator.

Fig. 9 is the right end view of the facsimile recorder showing electrical recorder, paper cut-off and typewriter ribbon.

Fig. 10 is a schematic diagram of a modified form of a facsimile circuit showing the wave forms in different parts of the circuit.

Fig. 11 is a schematic diagram of a modified form of a facsimile receiver showing how it is connected to the recorder.

Referring to Fig. 1 the laminated iron rotor 11 is secured to shaft 12 by key 13. On the circumference of rotor 11 are small poles 14 equally spaced. On the face of the main pole 15 are stator poles 16, 17, 18, 19, and 20 on which are wound coils with the same numbers which are connected in series and will be called winding A. On the main pole 21 is field coil 22 which is used to magnetize the poles, making the pole 21 north and the pole 15 south. Field coil 22 is connected to a source of direct current not shown. The air gap 23 under the pole 21 changes from a wide gap to a very narrow gap as the pole piece 14a moves across the pole face, thus changing the reluctance of the entire magnetic circuit. As the pole piece 14b passes under the stator poles 16, 17, 18, 19, 20, and due to the changing of the air gap 23 at the same time, it will produce an increasing voltage in each of the succeeding coils. The five voltages generated in winding A are the results of the separate voltages generated in the stator coils 16, 17, 18, 19, and 20 as shown by curve A' in Fig. 2. These increasing voltages 16', 17', 18', 19' and 20' correspond to the voltages generated in stator winding A in Fig. 1. These voltages represent one group in the "control wave train."

On the face of the main pole 24 are small stator poles 25, 26, 27, and 28 on which are wound coils of the same numbers. These coils are connected in series. On the face of pole 29 are small stator poles 30, 31, 32, and 33 on which are wound coils of the same numbers and these coils are connected in series. Coils 30, 31, 32, and 33 are wound in the opposite direction of coils 25, 26, 27, and 28. These two sets of stator coils are connected in series and will be called winding B. Main poles 24 and 29 are excited by coils 34 and 35 which are connected to a direct current not shown. These exciting coils make pole 24 south and pole 29 north.

As the pole pieces 14c and 14d sweep under coils 25 and 30 the two voltages generated will add, and similarly voltages generated in coils 26, 27, and 28 will add to the voltages generated in coils 31, 32, and 33 respectively. The stator poles that should come after stator poles 28 and 33 are left out so that the voltage generated in winding

B will look like curve B' in Fig. 2. There will be four complete cycles of constant voltage generated and then one cycle will be dropped in this carrier wave.

The voltages generated in windings A and B in Fig. 1 are in phase with each other as shown by the curves A' and B' in Fig. 2, which illustrates graphically the waves as they occur in their respective windings in Fig. 1. The cycle that is dropped in curve B' corresponds to the lowest voltage cycle in curve A'. The voltage increase in curve A' for each wave train shown is linear but for balancing the curve characteristics of some other part of the amplifier or receiver circuits the expanding voltage may be made to vary as a convex or concave curve by changing the air gap 23 in Fig. 1 or changing the number of turns on the stator poles 16, 17, 18, 19, or 20.

By way of illustration it will be assumed that the frequency of the voltage generated in winding A in Fig. 1 is 10,000 cycles and that there are 5 cycles in each expanding wave train. A 5 cycle group will represent a single picture element. Therefore there are 2,000 wave trains per second generated in winding A. Winding B will also generate a 10,000 cycle carrier wave. In this carrier 4 cycles will be a constant voltage and the fifth cycle will be dropped. Therefore there will be 2,000 wave trains per second of 4 cycles each synchronized with the 2,000 expanding wave trains produced in winding A. On the same shaft of this generator but not shown is a winding producing a 5,000 cycle constant voltage carrier wave. Also on the same shaft of this generator but not shown is a winding producing a 200 cycle synchronizing frequency.

The first 10,000 cycle winding produces 2,000 wave trains with 5 expanding cycles in each train or group which is called the "control wave train." The second 10,000 cycle winding produces a 2,000 cycle keying frequency of 4 cycles each with one cycle missing which is called the "black keying carrier." The third 5,000 cycle winding produces a carrier of constant amplitude which is called the "white carrier" wave. The fourth 200 cycle winding produces a carrier which is called the "synchronizing frequency."

Referring to Fig. 3 the light from the exciter lamp 40 is focused by lens 41 on the picture 42 which is wrapped around the rotating drum 43 which is driven by a 200 cycle synchronous motor 44 which is connected to the 200 cycle synchronous winding of the generator. The intensity of the reflected light corresponding to the shading of picture 42 on drum 43 operates the photoelectric cell 45 and the amplifier tube 46 in such a manner that the current flowing through the plate resistance 47 has the characteristic shown by curve 48, for the white and black shading intensity of picture 42. The negative side of resistance 47 is connected directly to the two screen grids of the vacuum tubes 48 and 49 and the positive side is connected to their cathodes. The primary winding of transformer 50 is connected to generator winding A shown in Fig. 1 which produces the "control wave train" which consists of a series of expanding wave trains A' shown in Fig. 2. The secondary of transformer 50 is connected to the controlled grids of tubes 48 and 49 in a pushpull arrangement. The plates of these tubes are connected in pushpull to the output transformer 51. The change in voltage across resistance 47 due to the shading of picture 42 is impressed on the screen grids of tubes 48 and 49 and is used to modulate "control wave train"

voltage from transformer 50 which is impressed on the control grids. This voltage is shown by the schematic wave form A''. This screen grid method of modulation is described in detail in Patent #1,966,065. When the white portion of picture 42 is being scanned the current in the plate circuit of tube 46 and through the resistance 47 puts a negative bias on the screen grids of tubes 48 and 49 so that the output voltage will be low and is represented by the wave form A''1 which is a schematic drawing of a group voltage curve A' shown in Fig. 2. As the current in tube 46 decreases due to the dark shading of picture 42 the negative screen grid bias voltage across resistance 47 becomes less and the output of tubes 48 and 49 becomes gradually greater as shown by the increasing of wave forms A''2, A''3, and A''4.

The center tap of the secondary of transformer 51 is connected to a filter, consisting of choke 52 and condensers 53 and 54, which are connected to the cathode of the double diode triode tube 55. The outside wires of the secondary of transformer 51 are connected to the diodes of tube 55. The resistance 56, the discharge tube 57 and the voltage 58 are connected in series across condenser 54. The grid of tube 55 is connected through a potential and a high resistance 59 to resistance 56 and the anode of tube 57. The resistances 60 and 61 are connected in the plate circuit of tube 55. The rectified voltages across resistance 56 due to the change in transformer 51 secondary voltage caused by the scanning of picture 42 are shown by wave forms R1, R2, R3, and R4. The cutoff regulating voltage 58 is so adjusted that when the voltages get above the values indicated by dotted line 62 the tube 57 will conduct and a current will flow through resistance 56 which places a large negative voltage on the grid of tube 55 cutting the plate current through resistances 60 and 61 to zero. The value of these negative voltages on the grid of tube 55 is indicated by curves E1, E2, E3, and E4. The dotted line 63 indicates the negative voltage that is required to bring tube 55 to its cutoff point. When the voltages drop slightly below the value indicated by dotted line 62, the tube 57 will cease to carry a current and the negative voltage across resistance 56 will disappear and the plate current of tube 55 will go back to its normal value indicating that a lighter portion of picture 42 is being scanned. When a darker portion of picture 42 is being scanned the output voltage of transformer 51 will be greater and the rectified voltage will begin to rise above dotted line 62 and the more it rises the longer the time tube 57 will discharge through resistance 56 and hold the plate current of tube 55 to zero indicated by I1, I2, I3, and I4.

The resistances 60 and 61 are connected to the control grids of tubes 64 and 65 respectively. The common resistance point is connected to the cathodes of these tubes. The primary of transformer 66 is connected to the generator winding that produces the 5,000 cycle "white carrier" wave. The secondary output of transformer 66 is connected through a variable resistance 67 in the grid circuit of the tube 64. The primary of transformer 68 is connected to the generator winding B in Fig. 1 that produces the "black keying carrier" of 10,000 cycles. The secondary output of transformer 68 is connected through a variable resistance 69 in the grid circuit to tube 65. The primary of transformer 70 is connected to the generator winding that produces the 200 cycle "synchronizing frequency." Across the

secondary of transformer 70 is connected a resistance 71 which by means of a single pole double throw switch 72 the resistance 71 is entirely or in part connected in series with the screen grids of the tubes 64 and 65 and the plate potential. The cam switch 72 is operated by cam 73 which rotates with the scanning drum 43 and once each revolution this cam 73 through cam switch 72 sends a framing signal by connecting the full output voltage of transformer 70 to the screen grids of tubes 64 and 65 thus modulating the carrier wave from the controlled grids about 50%. The rest of the time the switch 72 connects only a small part of the total voltage across resistance 71 to the screen grids of tubes 64 and 65. This only modulates the carrier waves from tubes 64 and 65 about 25%. This modulation is used to keep the recorder in synchronism with the transmitter. The effect of this 25% synchronizing modulating voltage on the two carrier frequencies from tubes 64 and 65 is shown in Fig. 4.

When a white portion of picture 42 is being scanned the plate current in tube 55 is set at a predetermined high value so that the current flowing through the resistance 60 places a positive potential on a control grid of tube 64 making it operate at maximum efficiency passing the "white carrier wave" of 5,000 cycles from transformer 66. As this carrier goes through tube 64 it is modulated by the 200 cycle synchronizing voltage placed on the screen grids by transformer 70 about 25%. The same plate current from tube 55 also flows through resistance 61 biasing the tube 65 so far below the cutoff point that the carrier wave from transformer 66 cannot get through the tube 65.

When a black portion of picture 42 is being scanned the plate current in tube 55 is reduced to zero. The positive potential due to a current flowing through resistance 60 is reduced to zero and the battery voltage 75 biases the tube 64 so far below the cutoff point that the carrier wave from transformer 66 cannot get through the tube 64. The negative bias due to the current flowing through the resistance 61 is reduced to zero allowing a more positive potential to develop on the control grid of tube 65 making it operate at maximum efficiency, and passing the "black keying carrier" of 10,000 cycles from transformer 68. As this carrier goes through the tube 65 it is modulated by the 200 cycle synchronous voltage placed on the screen grid by transformer 70 about 25%. Therefore across the output terminals 75a and 75b will be either the "white carrier" or the "black keying carrier" and both being modulated by the 200 cycle synchronizing signal.

Fig. 4 shows one cycle of the modulating 200 cycle synchronizing signal. The "white carrier" 5,000 cycle wave is shown by carriers W1, W2, W3, W4, and W5.

The number of cycles in each group indicates the length of time that the white signal is being transmitted. The "black keying carrier" 10,000 cycle wave is shown by carriers B1, B2, B3, B4, B5, B6, B7, and B8. The 200 cycle synchronizing signal modulates both the 5,000 and 10,000 carriers the same amount.

As the gas discharged tube 57 is either conducting or non-conducting, the plate current of tube 55 will be either on or off so that either tube 64 will be on and 65 off or tube 65 will be on and tube 64 off, so that either the white or black carriers will be on continuously, and both in turn will be modulated by the 200 cycle synchronous signal. It will be noted when a con-

tinuous black section is being scanned the tube 65 will continuously amplify the "black keying carrier" which contains four complete cycles and then drops one cycle. These dropped cycles are shown as S1, S2, and S3 in Fig. 4. The object of dropping a cycle on a continuous black signal is to produce and transmit a keying impulse to operate the receiving recorder instead of producing a keying impulse in the receiver amplifier. Fig. 5 shows a schematic diagram of Fig. 4 showing the length of time that the white and black signals are on, and when no carrier is transmitted.

Fig. 6 shows a schematic diagram of the radio receiver and amplifier for receiving the double carrier wave picture signals which are modulated by a synchronizing signal. The radio facsimile carrier wave is received and amplified by tube 80 and then detected by tubes 81 and 82. The audio output of tube 81 is connected by transformer 83 to the two filter circuits 84 and 85, each consisting of an inductance and a capacity connected in series. The filter circuit 84 which is tuned to the 10,000 cycle "black keying carrier" is connected by rectifier 86 to the resistance 87 so that the positive end of the resistance 87 is connected through a high resistance 88 to the grid of tube 89. The filter circuit 85 which is tuned to the 5,000 cycle "white carrier" is connected by rectifier 90 to resistance 91 so that the positive end of resistance 91 is connected through the high resistance 92 to the grid of the tube 93. The output of the tubes 89 and 93 is connected in pushpull arrangement to a standard electro-magnetic speaker unit 94 in Fig. 7 which operates the recording stylus 95.

When a "black keying carrier" of 10,000 cycles is being transmitted there will be voltage generated in filter circuit 84 which will be rectified by rectifier 86 and will cause a drop in voltage across resistance 87 which will put a positive bias on the grid of tube 89. The resistance 88 is used to keep the grid current down when it goes positive. A heavy plate current due to this positive grid voltage will result, which will cause the recording stylus 95 in Fig. 9 to move forward against the typewriter ribbon 96 and mark the inside of the circular paper cylinder segment 97.

When the "black keying carrier" of 10,000 cycles is being transmitted continuously due to the scanning of a black section of a picture, the dropping of a cycle in this carrier causes the grid voltage to become negative again and reduces the plate current to normal value, allowing the stylus 95 to move back from paper 97 reducing the pressure on the typewriter ribbon 96 and the paper 97. Thus a 2,000 cycle keying frequency is impressed on the recording stylus 95 when a continuous black signal is being transmitted.

When the "white carrier" of 5,000 cycles is being transmitted continuously due to the scanning of a white section of the picture there will be a voltage generated in filter circuit 85 which will be rectified by tube 90 and will cause a drop in voltage across resistance 91 which will put a positive bias on the grid 93. The resistance 92 in the grid circuit of tube 93 is for the purpose of keeping the grid current down when the grid goes positive. A heavy plate current due to the positive grid bias will result, which will cause the recording stylus 95 to move away from the typewriter ribbon 96 and the paper 97. As long as this "white carrier" is on the recording stylus 95 will be drawn away from paper 97.

For sending shaded pictures the white and black carriers will alternate at the rate of 2,000 times a second due to the fact that the "control wave train" is operated at that frequency. The length of time that either carrier is transmitted depends on the shading of the picture being scanned. The darker the picture being scanned the longer the time that the "black keying carrier" 10,000 cycle wave is transmitted, and the lighter the picture being scanned the longer the 5,000 cycle "white carrier" is transmitted. The sum of the time that any white and black carriers are transmitted equals the time to scan one picture element or .0005 of a second.

The voltage across the resistances 87 and 91 and the grids of the tubes 89 and 93 are of such values that the plate currents will have reached their maximum value for about 70% modulation of the carrier current, so that the modulation due to the synchronizing signal of 25% will not effect the plate currents of the recording tubes 89 and 93. When either carrier is reduced to zero the battery bias in the grid of the tubes 89 and 93 reduces the respective plate currents to zero.

When static impulses are received, amplified, and rectified by this amplifying system the voltage impulses across the two filter circuits 84 and 85 will be the same because static impulses are equally distributed over a wide range of frequencies. Thus the same voltage will be impressed across the grids of tubes 89 and 93 simultaneously and due to the push pull arrangement in the magnetic recorder 94 the plate currents will balance each other and the effect of static on the recording will be zero.

The two carrier waves which are modulated by a 200 cycle synchronizing signal are all rectified out from the radio carrier by tube 82 and transformer 98. By the use of the rectifier tube 99 and the 200 cycle tuned transformer 100 the 10,000 and 5,000 carriers are filtered out, leaving only the envelope of the 200 cycle synchronizing signal to go through the transformer 100. This 200 cycle signal is impressed on the tubes 101 and 102 which are in pushpull. The 200 cycle amplified output of these tubes is connected by transformer 103 to control the speed of the synchronous alternator 104 in Fig. 8.

In this system of transmitting and receiving pictures with two carrier waves, the received energy level of the two carrier waves varies with the synchronizing signal. To compensate for this loss in energy level in the receiver when the synchronizing signal depresses the two carrier waves, it is possible to add an extra secondary winding on the transformer 100 in Fig. 6 and feed this voltage back in the right phase to the grid of the detector tube 81 so as to increase its amplification when the two carrier waves are being depressed. This smooths out the synchronizing modulation depression and increases the operating energy level of the recorder. Another way to overcome this energy loss is shown in Fig. 10 and Fig. 11 and will be described later.

In the common plate circuit of tubes 101 and 102 is relay 106 so adjusted that the ordinary 25% modulated 200 cycle synchronous signal will not operate it. A framing signal is sent once each revolution by the cam 73 operating the switch 72 in Fig. 3 which increases the 200 cycle modulating synchronizing signal for framing to about 50%. The increasing of modulation of the 200 cycle signal will increase the plate currents of tubes 101 and 102 and the relay 106 will oper-

ate single pole double throw switch 107 cutting the current off the framing clutch magnet 108 and allowing the clutch spring 109 to pass between the pole pieces.

When the cam switch 72 returns to normal the relay 106 will become deenergized enough to close switch 107 so as to energize framing clutch magnet 108 so that if the picture was not framed correctly the framing clutch magnet 108 will hold the clutch spring 109 until the next framing signal, thus framing the recorded picture.

When the paper 42 is being changed on drum 43 in Fig. 3 the cam 73 holds switch 72 in its downward position allowing the full 200 cycle synchronizing signal to modulate the 5,000 cycle "white carrier" which is then on about 50%. This 50% modulated carrier will operate relay 106 and the switch 107, opening the circuit to the framing clutch magnet 108 and also putting a potential on the delay relay 110 which has to be on 15 seconds before it operates and closes the contact 111 completing the circuit for the paper cutoff magnet 112 which operates the circular cutoff wheel 113 which cuts the paper 97 against the circular end 132 of recording casting 120. The ordinary framing signals which are on for about one tenth of a second have no effect on the delay relay 110 and the paper cutoff magnet 112.

Fig. 7 shows how the continuous sheet of paper 97 is wrapped around the cylinder 115, the two edges of this paper are folded back 116 and 117 and are slipped into the slots 118 and 119 respectively which are in the base of the round recording casting 120. The round cylinder tube 115 is placed in the round hole 122 in casting 120 so that they are coaxial and with enough clearance between them for the paper 97 to be pulled through by the threads 130 on drum 129. Cylinder 115 is fastened to the base of recording casting 120 by means of screw 121 in Fig. 8. The alternator 104, the motor 123, the gear reducer 124, and the bearing 125 are all fastened in the cylinder 115 to the recorder casting base between the slotted openings 118 and 119 so that they are coaxial with the cylinder 115 and the casting opening 122 by means of the frame 137 and screw 121.

The motor 123 drives the alternator 104 by means of shaft 126' and also drives the gear reducer 124 which turns the shaft 126 on which is mounted clutch cylinder 127. Around clutch cylinder 127 is wound a square steel wire spring 109, one end of which passes between the pole pieces of the clutch magnet 108 and the other end is secured to shaft 128 which turns in bearing 125. The shaft 126 and the clutch cylinder 127 turns in the direction of the arrow, the steel spring wire 109 will be held when the clutch magnet 108 is energized, the spring 109 will tend to unwind allowing it to slip on the cylinder 127 thus stopping the rotation of shaft 128. When the clutch magnet 108 is deenergized the spring 109 will tighten around the cylinder 127 and turn the shaft 128 at the same speed. The large threaded drum 129 is fastened to the shaft 128 and turns inside of the recording casting 120 with just enough clearance to allow the paper 97 to pass between them. The paper slides from the cylinder 115 onto the threads 130 on the surface of the rotating drum 129. The bent paper edges 116 and 117 in slots 118 and 119 respectively hold the continuous paper sheet 97 tight against the thread 130 on the rotating drum 129, and as the drum 129 rotates the paper

will be pulled from left to right by thread 130 and kept from rotating and held in a straight line by parallel slots 118 and 119.

On the right end of the threaded drum 129 is mounted a bracket 131 which holds the electromagnetic recorder 94 so that the recording stylus 95 moves around the inside of the end surface 132 of the recording casting 129, also mounted on this bracket is the cutoff magnet 112 so mounted that when the circular cutoff wheel 113 is forced outward and bears against the end surface 132 of the recording casting 129 it will cut the paper as the drum 129 revolves except the portions 116 and 117.

Fig. 9 shows that the stylus 95 can move against or away from the typewriter ribbon 96 and the paper 97 as it rotates around the inside of the recording casting 129 depending upon the frequency of the keying signals. When the stylus 95 passes between the slot openings 119 and 118, and the spring wire 109 is passing the framing clutch magnet 108 is the time when the picture is framed. In Fig. 7 the recorder 94 and the paper cutter 112 were moved 90 degrees out of phase with the framing device 108 to show a side view of both pieces of equipment. Also in Fig. 7 the typewriter ribbon 96 and the typewriter spools 124 and 125 were removed from the bearing posts 133 and 135 for the same reason.

By utilizing the variations in the length of two different carriers to represent the shading of the picture, the response of the receiver and the recorder is independent of the amplitude of the signals. By maintaining the gain of the receiving amplifier at a constant and predetermined level, the effect of the change in amplitude, due to the modulated synchronizing signal upon the recording, is eliminated.

Another embodiment of my invention is shown in Fig. 10 and Fig. 11. In this second case the shading of a picture element is transmitted by changing the duration of two audio carriers of different frequency but of the same amplitude and the synchronizing signal is sent by alternately transmitting two radio carriers of different frequency but of the same amplitude.

The motor 44 drives the generator 140 which produces in its different windings the "control wave train" in winding xx, the "black keying carrier" in winding yy, and the "white carrier" in winding zz. These windings are connected to the primaries of the transformers 50, 60 and 66 respectively. The motor also drives a commutator 141 with shorting and insulating bars. The shorting bars connect the brushes 142 and 143 together for the purpose of changing the grid potential of tube 144 from a positive to a high negative value. When the grid is near its positive value the current through the plate resistances 145 and 146 is very high. Resistance 145 puts a positive potential on the screen grid of tube 147 bringing it to its best operating point. At the same time resistance 146 is putting a negative potential on the screen grid of tube 148 making it inoperative. When the commutator 141 shorts the brushes 142 and 143 together, it places a high negative potential on the grid of tube 144 and the plate current drops to zero. The positive potential that was on the screen grid of tube 147 is reduced so that it is inoperative, while the negative voltage that was on the screen grid of tube 148 is removed and the screen grid becomes positive due to the battery in the screen grid circuit. Thus tube 148 becomes operative and tube 147 becomes inoperative when the

brushes 142 and 143 are shorted by commutator 141. When the brushes 142 and 143 are not shorted the tube 147 becomes operative and tube 148 becomes inoperative. The purpose of alternately placing one and then the other tube in operating condition is to transmit a synchronizing signal by alternately transmitting two radio carriers of different frequency but of the same amplitude. The length of time that either radio carrier is transmitted depends upon the length of time that the brushes 142 and 143 are shorted or not shorted. The frequency of this synchronizing signal depends on the number of segments and the speed of the commutator 141.

The motor 44 drives the scanning drum 43 by means of the reducing gear 150 and through clutch 151. This rotating drum 43 carries the picture 42 which is being scanned by the beam of light from lamp 40 which is reflected from the picture 42 into the photoelectric cell 45. The output of the photoelectric cell 45 controls the balanced modulator consisting of the screen grid tubes 152 and 153 connected in a bridge circuit. The plates of tubes 152 and 153 are connected together and have a common plate resistor 154. The "control wave train" voltages are applied to the screen grids of tube 152 and 153 by the center tap transformer 50. The center tap is connected to the common cathode circuit of the two tubes by battery 139. The control grids of the tubes 152 and 153 are entirely independent of each other, one being controlled by a fixed bias while the other depends on the photoelectric cell 45 output for control. When the two tubes are adjusted to the same bias the alternating current output will be balanced to zero in the common plate resistor 154. This adjustment is made with full light from a white reflecting surface of picture 42 shining into photoelectric cell 45. Any decrease in the light to the photoelectric cell 45 due to shaded or black picture elements will unbalance the bridge and the "control wave train" will appear in the output resistor 154 in proportion to the blackness of the picture being scanned or the unbalancing of the bridge circuit. In this system the "control wave train" supplies the 10,000 cycle carrier current and also the 2,000 cycle keying frequency at the same time.

The condenser 155 connects the output of tube 152 to the amplifying tube 156 which amplifies the carrier current and the keying frequency and filters out all the direct modulating frequencies by choke 157 and condenser 158. The output of tube 156 is fed by transformer 159 to the rectifier tube 160, through the filter consisting of choke 61 and condensers 162 and 163. Connected in series across condenser 163 are resistances 164 and 165 and gas tube 166. In series with the rectifier tube 160 is a bucking biasing battery 167 which is used to reduce the background noise to zero and is also used to control the threshold voltage where the gas tube 166 begins to conduct a current. This voltage is shown by dotted line 168 and any time the voltages are above this line as illustrated by peak voltages R1, R2, R3 and R4 the gas tube 166 will conduct causing a current to flow through resistances 164 and 165, putting a high positive bias on the grid of the tube 169 and a negative bias on tube 170. This will make tube 169 operative and tube 170 inoperative. This happens when a black shaded picture element is being scanned and the balanced modulator tubes 152 and 153 are thrown out of balance allowing the "control wave train" from transformer 50 to go through and operate the

amplifying tube 158, the rectifier tube 160, raising the voltage above the line 168 and operating the gas tube 166 and putting a positive bias on tube 169 causing it to operate and pass the "black keying carrier" from transformer 68 which is connected in the plate circuit of tube 169 and at the same time putting a negative bias on tube 170 stopping all current in its plate circuit.

When a white portion is being scanned the tubes 152 and 153 are in balance and the "control wave train" is suppressed and there will be no voltages above the line 168 and the gas tube 166 will not conduct so there will be no current through resistances 164 and 165. The positive potential on the grid of tube 169 due to the current that was flowing through resistance 164 will disappear and the grid will become negative due to the biasing battery in the grid circuit. This will bring the plate current to zero. The negative potential that was on the grid of tube 170 due to the current that was flowing through resistance 165 will disappear and the grid will become positive making the tube 170 operative and passing the "white carrier" wave from transformer 66 which is connected in the plate circuit of tube 170.

The carrier wave from transformer 66 or the carrier wave from transformer 68 will be impressed on the primary winding of transformer 171. The secondary of transformer 171 is connected in the common screen grid return circuit of tubes 147 and 148. The commutator 141 alternately makes tubes 147 and 148 operative or inoperative by changing the current flowing through the resistances 145 and 146, thus the tubes 147 and 148 will be alternately modulated by the black and white carrier waves from transformer 171. When tube 148 is operating the carrier waves from transformer 171 which are impressed on the screen grid of tube 148 will modulate the radio frequency carrier (R. F. 1) from oscillator 172, which is inductively coupled to the control grid circuit of tube 148 by radio frequency transformer 174. When tube 147 is operating the carrier waves from transformer 171 which are impressed on the screen grid of tube 147 will modulate the radio frequency (R. F. 2) from oscillator 173, which is inductively coupled to the control grid circuit of tube 147 by radio frequency transformer 175. The two alternated modulated radio carrier waves of the same amplitude are connected to the antenna 177 by radio transformer 176 whose primary is connected in the common plate circuit of the two radio frequency modulating tubes 147 and 148.

In this second modified system it can be seen that the two picture carrier waves are alternately transmitted at constant amplitude as in the first case, but in this instance they alternately modulate two radio carrier waves, while in the first case they only modulate one radio carrier wave. In this second modified system the synchronizing signal is transmitted by alternately transmitting two different radio frequency carriers of constant amplitude, instead of amplitude modulation of the radio frequency carrier for synchronizing as in the first case. In this second modified system the framing cutoff signals are transmitted by shorting the secondary of transformer 171 by rotating cam 73 closing shorting switch 177. The shorting of the secondary 171 stops the modulation of the alternately transmitted radio carriers from oscillator 172 and 173. The framing and cutoff signals are sent as unmodulated

radio frequency carrier waves from oscillators 172 and 173.

The receiver and recorder for the above pictures and synchronizing signals are shown in Fig. 11. The grid circuit 180 of the radio frequency amplifier tube 182 is tuned to the radio frequency carrier from oscillator 172 in Fig. 10. The output of tube 182 is connected by radio frequency transformer 184 to the detector tube 186. The output of tube 186 is connected to the stator winding 190 of the alternator 104 by transformer 183, which is tuned to the frequency of the commutator segments of commutator 141 in Fig. 10. The grid circuit 181 of the radio frequency amplifier tube 183 is tuned to the radio frequency carrier from oscillator 173 in Fig. 10. The output tube 183 is connected by radio frequency transformer 185 to the detector tube 187. The output of tube 187 is connected to the stator winding 191 of the alternator 104 by the transformer 189 which is tuned to the frequency of the commutator segments of the commutator 141 in Fig. 10. The commutator 141 by means of tubes 144, 147 and 148 alternately impresses radio frequency carrier (R. F. 1) and radio frequency (R. F. 2) on the antenna 177. These two alternated transmitted radio carriers are picked up by the receiver as described and alternately applied to the synchronous alternator 104 to keep the motor 123 and the recording stylus 95 in step with the scanning of picture 42 in Fig. 10.

The two radio frequencies from amplifying tubes 182 and 183 are connected by radio transformer 200 and are combined in detector tube 201. The transformer 202 connects the output of tube 201 to filters 203 and 204, each filter consisting of an inductance and a capacity connected in series. The detector tube 201 rectifies out the two radio carrier waves leaving the two picture carriers to go through transformer 202 and each carrier is separated out by filters 203 and 204.

The "black keying carrier" 10,000 cycle voltages are filtered out by filter 204 and are applied to the grid of amplifying tube 209, by the use of rectifier 206 and the resistance 207 which is connected in the grid circuit of tube 209. The "white carrier" 5,000 cycle voltages are filtered out by filter 203 and are applied to the grid of tube 209 by the use of rectifier tube 205 and the resistance 208 which is connected in the grid circuit of tube 209. The rectified current flowing through resistance 207 due to a "black keying carrier" places a positive bias on the grid of tube 209 causing a heavy current to flow in the plate circuit and causing the recorder 94 to move the recording stylus 95 against the paper 97. The rectified current flowing through resistance 208 due to a "white carrier" places a negative bias on the grid of tube 209 causing the plate current to drop allowing the stylus 95 to be pulled away from the paper 97 by means of a spring not shown. When there is no current in resistances 207 and 208 the tube 209 is so biased that the stylus 95 will be pulled away from the paper 97 by means of said spring.

The shading of each scanned picture element controls the duration of time that the two picture carriers of different frequencies are on. These two picture carriers of constant amplitude continually modulate the two radio carriers of different frequencies that are alternately transmitted at constant amplitude. One of these radio carriers represents one alternation of a synchronizing signal and the other radio car-

rier represents the other alternation of the synchronizing signal.

The common point of resistances 237 and 238 is connected by resistance 210 to the common return of filters 233 and 234. The resistance 210 is connected in the grid circuit of tube 211 so that any rectified current from filters 233 or 234 will place a positive bias on the grid of tube 211. This current will cause the delay relay 212 to keep the switch points 213 open and the framing clutch 188 energized. When a framing signal of one tenth of a second is being sent the cam 73 in Fig. 10 closes the switch 177 which shorts the secondary of transformer 171 cutting off the picture carrier signals from modulating the two alternately transmitted radio carriers so that the radio carrier waves go on the air without being modulated. If the radio carrier waves are not modulated there will be no voltage across the tuned filters 233 and 234 and there will be no current through resistance 210 and this will allow the grid of tube 211 to become negative and the plate current through the framing clutch 188 to drop thus deenergizing it and allowing the spring clutch 189 to pass the pole pieces of the framing clutch 188. The delay relay 212 is so adjusted that it is not effected by this short drop of plate current.

When a picture is being changed the cam 73 is so set that the switch 177 is closed and the action as described above takes place only this time if the switch is held closed for 15 seconds or more the delay relay 212 will deenergize and will allow the switch points 213 to come together and this will send a battery current through the cutoff magnet 112 causing the cutoff wheel 113 to move out and cut the paper 97 as described in connection with Fig. 7.

When static impulses are received they will be rectified and filtered by the tuned filters 233 and 234. These two filtered signals will be approximately the same strength and because they are applied to the resistances 237 and 238 in the grid circuit of tube 239 at the same time, they will balance each other out because they oppose each other with equal strength.

By utilizing the variations in the length of the two different audio carriers of different frequency to carry the shading of the picture elements the response of the receiver and the recording is independent of the amplitude of the signals. By alternately transmitting two radio carriers of different frequency modulated by the above picture signals it is possible to transmit at constant amplitude the carrier wave which contains the white and black picture signals as well as the synchronizing signal so that fading and static will have little or no effect on the recording and the synchronizing of the picture.

In these drawings only two disclosures of my invention have been shown but certain portions can be changed without destroying the spirit of this invention. For example, the white and black audio carriers in the first case may be changed to radio frequency carriers. The second method can be changed by using two audio frequency picture carriers of constant amplitude with varying durations to modulate a radio frequency. The two side bands of this radio frequency are separated out, amplified and alternately transmitted. These transmitted side band frequencies will carry the synchronizing frequency as well as the two picture carriers. The receiving system of this method will be described in a later patent.

I claim:

1. A system for transmitting facsimile picture signals, means for generating a series of expanding wave trains, means for generating a carrier of constant amplitude for carrying the white picture signals, means for generating a carrier of constant amplitude but different frequency for carrying black picture signals, means to use said expanding wave trains to divide a picture into series of picture elements, an amplifier to control the amplitude of the said expanding wave trains by the tone value of the said picture element being scanned, said amplifier transmitting one of said carriers of constant amplitude when the amplitude of the said expanding wave train is greater than a predetermined level, said amplifier transmitting the other said carrier of constant amplitude when the amplitude of the said expanding wave train is less than said level.

2. A system according to claim 1, in which the said two carriers of constant amplitude are modulated by a synchronizing signal.

3. A facsimile system of sending pictures and synchronizing signals, comprising transmitting three carrier waves, means to divide all picture elements into two time periods, the first said period is occupied by a constant amplitude white carrier picture signal, and second said period is occupied by a constant amplitude dark carrier picture signal of different frequency, said means measuring the duration of time that either said carriers are transmitted dependent on the shading of each said picture element and means to modulate the said constant amplitude picture carriers by a synchronizing carrier frequency.

4. A system according to claim 3 in which a change in the percent of the said modulation of the said synchronizing carrier transmits a framing signal and a longer change in the said modulation of the said synchronizing carrier transmits a cutoff signal.

5. In an image transmitting system, means for generating three carrier waves, first said carrier consisting of a series of expanding wave train groups, means to control the amplitude of each said expanding wave train by the shading of a picture being scanned, means for transmitting the second and third carriers alternately at double the frequency of the number of said groups and means for controlling the transmitting time of said second and third carriers in accordance with a predetermined level of the said expanding wave train.

6. A picture signaling system including means to generate a series of expanding wave train groups, means to produce electrical variations in accordance with the tone value of the picture elements being scanned, and means to control the amplitude of the said expanding wave trains by the said electrical variations, and means to transmit a carrier when the amplitude of said expanding wave train exceeds a predetermined level, and means to transmit a different carrier when the amplitude of the said expanding wave train is below said level.

7. In a facsimile receiver and recorder adapted to operate by incoming picture signals composed of two different wave trains alternately transmitted, the duration of one of said wave trains corresponding to the white tone value of a picture element being scanned, and the duration of the other said wave corresponding to the dark tone value of the said picture element, and the amplitude of the said two transmitted wave trains modulated by a synchronizing frequency,

said receiver separating out the two said wave trains, means to rotate an electromagnetic recording stylus radially inside a lengthwise moving paper cylinder, said stylus axial movement actuated by said wave trains and means for directing the axial movement of said stylus point against a marking surface onto said paper cylinder, and means for separating out said synchronizing frequency to control the speed of rotation of said recording stylus.

8. In a facsimile recorder of picture signals means to rotate an electromagnetic operated recorder stylus concentric with and inside a paper cylinder said paper moving lengthwise, inside and adjacent to a metal ring surface, and means to direct the point of said stylus against a paper marking means as said stylus and said

marking means rotate inside said paper cylinder and said ring surface, said marking means coming in contact with said paper cylinder when said electromagnetic operated stylus is actuated by a picture signal.

9. A method of transmitting facsimile picture elements and a synchronizing signal, consisting of generating two different carriers of constant amplitude, alternately transmitting both said carriers at a constant frequency, controlling the percent of time that either said carrier is transmitted by the tone value of a picture element, modulating the amplitude of said controlled carriers to transmit a synchronizing signal.

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