Dec. 3, 1946. J. L. FINCH 2,411,853

PHOTO RADIO SIGNALING BY FREQUENCY MODULATION

Filed July 24, 1941 3 Sheets-Sheet 1

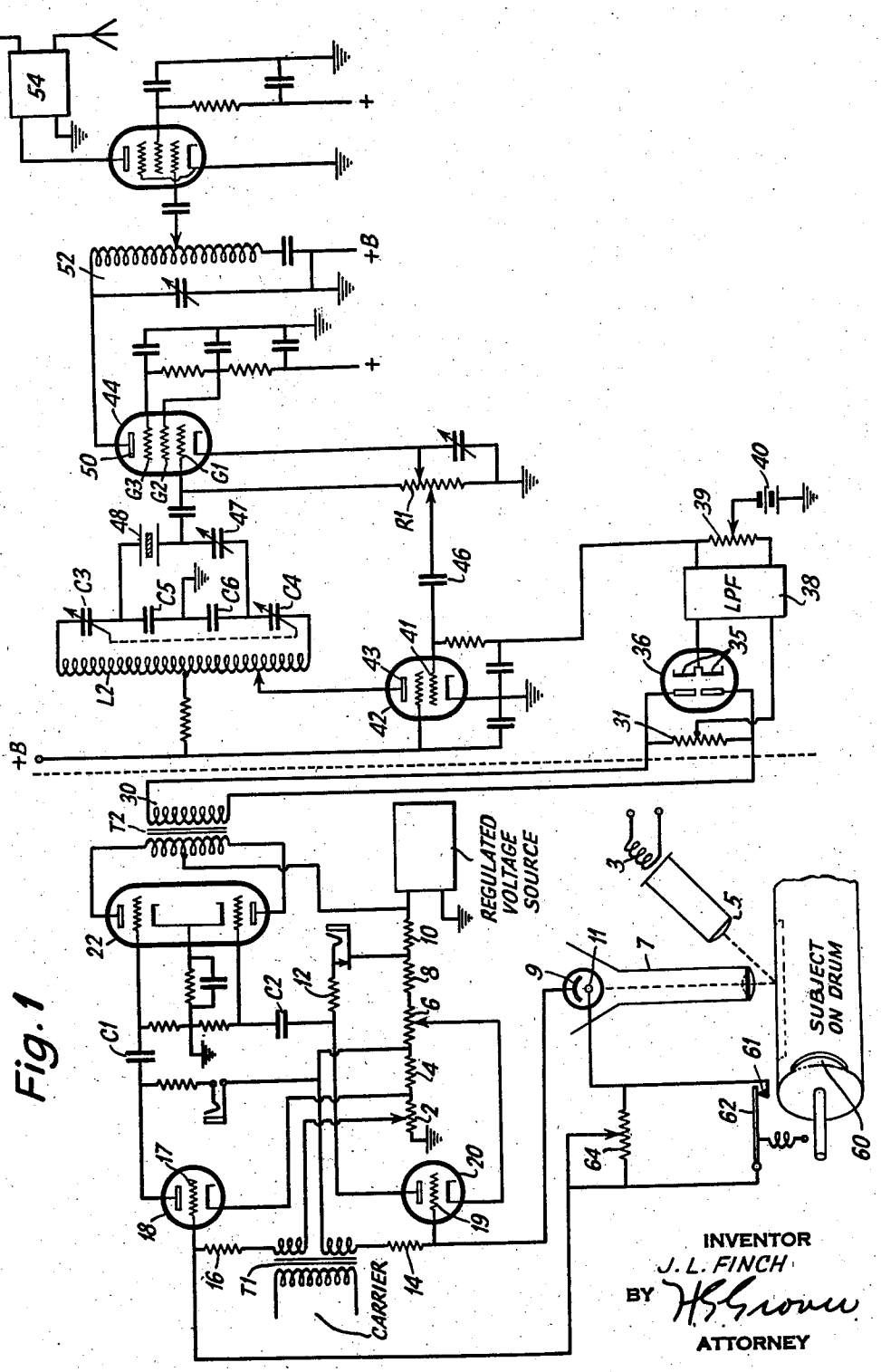


Fig. 1

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Fig. 1a

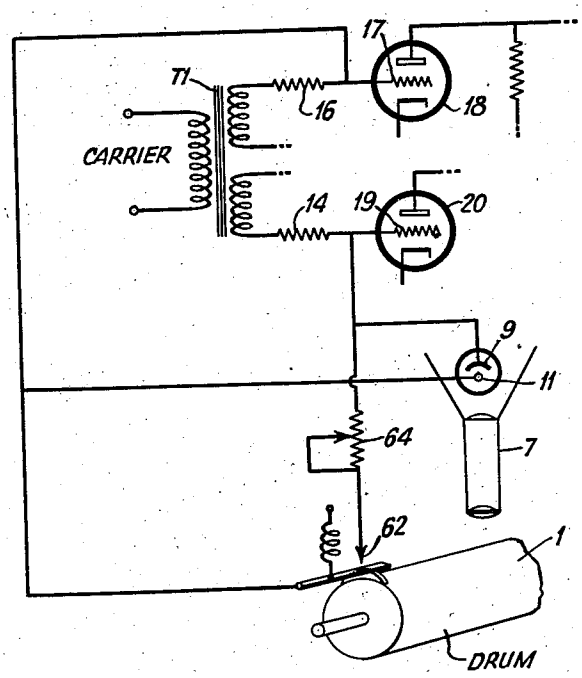
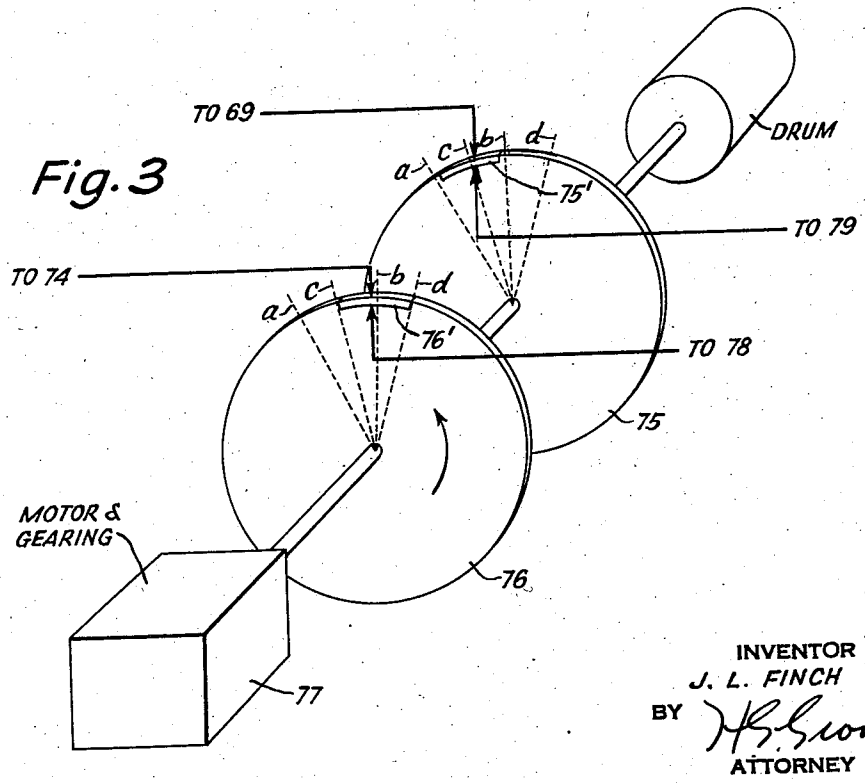


Fig. 3



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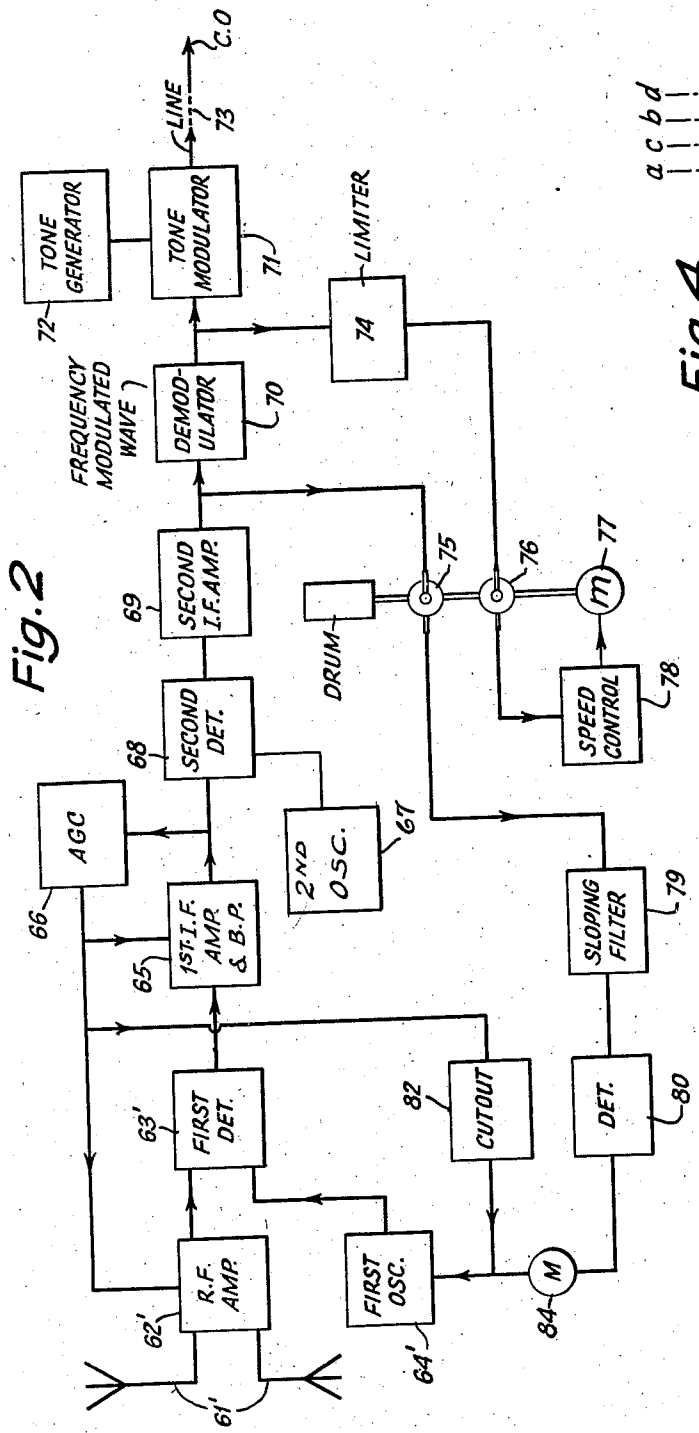


Fig. 2

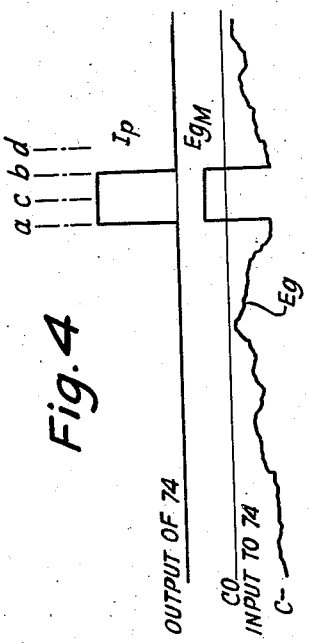


Fig. 4

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UNITED STATES PATENT OFFICE

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PHOTO RADIO SIGNALING BY FREQUENCY MODULATION

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Application July 24, 1941, Serial No. 403,821

11 Claims. (Cl. 178—6)

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This application discloses a new and improved method of and means for transmission and reception of photo radio subject matter by modulating the frequency of a carrier wave in direct proportion to the density or shading of the photo radio subject matter being scanned, transmitting the same and receiving the same.

In known systems of photo radio transmission of the type described above any variation in the frequency adjustment of the transmitter circuits may result in an error in the received photo radio matter. Should the receiver adjustment drift, then the picture may appear darker or lighter on the average than the original. Similarly, if the transmitter frequency drifts a like error results. It is conceivable that circuits of high accuracy could be arranged for use both at the transmitting end and receiving end of the circuit so that these errors could be made negligible. This, of course, involves considerable expense. My invention relates to a new and improved means for eliminating this change in contrast or shade or density in the transmitted picture during transmission without necessitating the use of circuits of such high accuracy that the circuits per se eliminate this error.

In its broadest aspect my invention involves the use of a definite time interval during the transmission for the transmission of a definite frequency used at the receiver to adjust the tune thereof to prevent changes in the picture or subject weight. In a preferred modification my system makes use of a portion of the margin of the photo radio subject matter and transmits then a definite frequency for receiver control purposes. This transmission may take place as stated above at the picture or subject margin and is applicable to all scanning systems known today, such as, for example, those wherein the drum rotates at a fairly high speed and the scanning element passes along the drum axis once per picture or the systems wherein the drum rotates at a lower speed and the scanning element passes back and forth along the drum axis a large number of times per rotation of the drum. In the former case the margin at which a definite frequency is transmitted falls along the axis of the drum. In the second type of scanner means is provided for sending the definite frequency at one or both ends of excursions of the scanning element along the axis of the drum, or vice versa. At the receiving end the said definite frequency received during this margin interval is used for automatically correcting the receiver adjustment to follow any frequency variation at the transmitter or receiver.

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I propose to transmit during this period a selected frequency corresponding to some definite picture shade, preferably black or white or some definite frequency which would be called super-black or super-white.

In describing my invention in detail reference will be made to the attached drawings wherein Figure 1 illustrates somewhat diagrammatically the essential elements of a transmitter arranged in accordance with my invention; Figure 2 illustrates a receiver arranged in accordance with my invention to receive the transmission from the transmitter of Figure 1 and to be controlled by the said definite frequency transmitted at the picture or subject margin; Figure 1*a* illustrates a modification of a portion of the transmitter of Figure 1; Figure 3 illustrates the motor, commutators, etc., of Figure 2 and is used in describing the manner in which synchronism is obtained; while Figure 4 is a curve illustrating the input and output of the limiter 74 of Figure 2.

Referring to Figure 1, the circuits and means at the left of the dotted line comprises a scanner of a well-known type including a drum 1 on which a picture or subject to be scanned is mounted. A light 3 cooperates with a diaphragm condensing lens etc. 5, which produces light that is concentrated and reflected from the subject or image to a lens and photo tube arrangement 7. The photo tube has a sensitive electrode 9 and an anode electrode 11 connected in a circuit across the grid electrodes of a pair of amplifier tubes 18 and 20, the grid electrodes of which are also excited by carrier waves to be modulated impressed on the primary winding of a transformer T1. The photo tube controls the current through resistances 14 and 16 and consequently the bias on tubes 18 and 20. The cathodes and grids of tubes 18 and 20 are connected to points along the potentiometer resistance as shown. The cam 60 on the drum, and contacts 61 and 62 actuated therefrom and described more in detail later, controls a circuit including resistance 64 in series with electrodes 9 and 11. For the present assume this contact is closed and resistance 64 is shorted. The modulator is of the nature of an unbalanced modulator wherein the carrier tone is applied in push-push and the bias potential as controlled by scanning is applied to the grids 17 and 19 in push-pull. The modulated carrier is supplied from the output electrodes of tubes 18 and 20 to the control grids of a double triode amplifier 22 and thence to the primary winding of a transformer T2. The arrangement including the tubes 18 and 20 is similar in many respects to what is known as an un-

balanced modulator, the grids 17 and 19 being excited in phase by potentials impressed on the secondary windings of transformer T1 connected push-push, and in push-pull relation by potentials which vary and are impressed on the grids 17 and 19 due to the action of the photo tube electrodes 9 and 11, the current through which is in turn controlled by the weight of the subject or picture on the drum. This system and its operation is well known in the art, and it is believed that additional description thereof at this point is unnecessary. A similar arrangement has been shown on pafe 85 of volume 1, "Radio Facsimile," RCA Institutes Technical Press.

The amplitude modulated carrier is supplied by secondary winding 30 of transformer T2 to the full wave rectifier 36. The rectifier 36 and apparatus to the right of the dotted line in Figure 1 comprises the essential elements of a frequency modulator such as disclosed in Usselman United States application Serial No. 338,838, filed June 5, 1940, U. S. Patent 2,298,437, dated October 13, 1942. The full wave rectifier 36 has its cathodes 35 connected together as shown and to one terminal of a low pass filter 38. The other terminal of this filter is connected to a point on a resistance 31 in shunt to the secondary winding 30 of transformer T2. The low pass filter has a pair of output terminals connected together by way of a resistance 39, a point on which is connected to ground by way of a source of biasing potential 40.

The potential at the upper terminal of the resistances 39 results from rectification of the carrier modulated in amplitude in accordance with the scanned subject, and therefore the potential at the end of 39 corresponds to the picture density shade or contrast. This potential is supplied to the grid 41 of a modulator tube 42 used to modulate the frequency of the oscillations generated in the oscillator 44, as will now be described more in detail.

The oscillator 44 is of the electron coupled type having a plurality of grids G1, G2 and G3, of which G1 and G2 form an oscillation generating circuit wherein G2 serves as the anode. The grid G1 is connected as shown to a crystal 48, and by way of 48 and C5 to ground. The grid G1 is also connected by way of a variable condenser 47 and condenser C6 to ground. The grid G1 is also connected to ground by way of a resistance R1. A point on this resistance R1 is connected by a coupling condenser 46 to the grid 41 of tube 42. The anode 43 of tube 42 is connected to a point on the inductance L2, which forms a tank circuit connected with the anode 43 and including reactances C3, C4, C5 and C6.

As pointed out in more detail in the said Usselman application, a first or original voltage of the generated frequency appears on the grid G1. A second voltage in phase quadrature therewith is provided and applied to the grid G1. The amplitude of this second voltage is varied in accordance with the modulating potentials to thereby relatively vary the amplitude of the phase quadrature voltages on the grid G1 and as a consequence vary the frequency of oscillation of the oscillator 44. This second phase quadrature voltage is obtained by connecting the grid 41 by way of coupling condenser 46 to a point on resistance R. This radio frequency excitation of grid 41 is amplified in tube 42, supplied by way of its anode 43 to tank circuit L2, C3, C4, etc., and thence by way of crystal 48 to the grid G1. By slightly detuning the circuit L2, C3, C4 in one direction or

the other from resonance at the generated frequency the voltage supplied to G1 may be made to advance or retard substantially 90 degrees with respect to the generated voltage originally assumed to be on G1. The biasing voltage on grid 41 is varied in accordance with the modulating potentials. As this bias voltage is increased, the voltage fed back to G1 by way of anode 43 tuned circuit L2, C3, C4, etc., is decreased, and vice versa. This voltage fed back to G1 tends to change the frequency of oscillator 44 as otherwise determined by crystal 48. The amount of this change, or frequency modulation is proportional to the amount of voltage thus fed back.

The frequency modulated oscillations are impressed on the anode 50 of tube 44 by way of the electron coupling in the tube and appear in tank circuit 52. The voltages may then be amplified, multiplied and limited as desired in apparatus 54 and transmitted.

In accordance with applicant's novel system an additional definite frequency is transmitted for correcting and synchronizing purposes at the receiver. In a preferred modification this is accomplished by means of a cam 60 on the drum 1 which cooperates with contacts 61 and 62 to include in the circuit across the grids 17 and 19 of tubes 18 and 20 an additional resistance 64 or as much thereof as desired. The modulating voltage on the tubes is thus held at a value corresponding to a super-black picture shade and is such as to modulate the amplitude of the carrier supplied to T1 an additional amount for a short time interval at the picture margins. The system is adjusted so that this amplitude modulation represents super-black but the circuit may be modified so that the bias represents super-white. The additional modulation is outside the range covered by the picture in either direction. This additional amplitude modulation acts through the translating means 22, T2, 30, 36, etc., to shift the frequency of the oscillator 44 a definite amount, this frequency to which the oscillator is deviated being outside the range wherein modulation in accordance with the scanned subject takes place.

At the receiver I propose an arrangement of circuits the equivalent of that shown in block diagram in the accompanying figure. In this figure 61' is any suitable receiving antenna; 62' is the radio frequency amplifier; 63' is the first detector; 64' is the first oscillator; 65 is the first intermediate frequency amplifier and band pass filter; 66 is the automatic gain control; 67 is the second oscillator; 68 is the second detector; 69 the second IF amplifier; 70 is the demodulator suitable for converting frequency modulation to amplitude modulation; 71 is a tone modulator; 72 is a tone source and 73 is a control line or control channel leading from the receiver to the remote central office; 74 is a direct current limiting device for cutting out all levels other than those corresponding to the margin; 75, 76, 77 is an assembly including the recording drum, two commutators and a motor, respectively, and 78 is a device for controlling the speed of the motor, the drum, and the commutators; 79 is a filter suitable for detecting changes in the frequency passed thereby (which may be audible) during the interval corresponding to the picture margin; 80 is a detector which adapts the output of 79 to control the first oscillator 64' through a suitable control device 84; 82 is a cutout device operated by the gain control 66 for preventing

further control of 64 by 81 under certain conditions.

In the operation of this invention the circuits and apparatus other than those at the receiver will perform as described above. The receiver will perform as follows: the frequency modulated received signal is heterodyned to a first intermediate frequency and passed through a band pass filter 65 in the well known manner. The automatic gain control 66 is so arranged that the output of the intermediate frequency amplifier 65 is held essentially constant notwithstanding variations in the input signal due to selective fading, noise, interference or any other source of amplitude modulation. It may be desirable to augment the devices I have shown by straight limiting circuits for maintaining constant amplitude out of the IF amplifier 65.

The second oscillator 67 and the second detector 68 heterodyne the signal down to some suitable second intermediate frequency. This intermediate frequency is frequency modulated in accordance with the original signal. Frequency demodulator 70 converts this current of varying frequency to a direct current which is amplitude modulated in proportion to the frequency modulation of the incoming signal. The value of this direct current corresponding to the margins of the picture are assumed to be either higher or lower than the said current corresponding to the remainder of the picture. Limiter 74 is such that only these extremes will be passed. Potential limiter 74 is connected through commutator 76 to speed control 78. This commutator revolves at a speed corresponding to the speed of the drum 1 of the photo radio scanner and is normally held in synchronism with it. When the phase of commutator 76 is correct it connects limiter 74 to the motor speed control means 78 during the portion of the time corresponding to the margin. Should the motor 77 and commutator 76 tend to lag then the resulting effects will readjust the speed control 78 so as to hold the motor 77 in step and in proper phase relation.

Commutator 75 also makes connections only during the interval corresponding to the margin. If the output of audio frequency amplifier 69 has the correct frequency during the margin interval then this frequency will be impressed on sloping filter 79 and through detector 80 and device 84 will control the first oscillator frequency so as to hold it at its present value. The filter 79 and detector 80 form a frequency modulation demodulation means. Now should the transmitter frequency increase the second intermediate frequency will, it is assumed, also increase. Thus the frequency of the input to filter 79 increases and the output of the sloping filter in 79 changes to change the detector output. The characteristics of 79, 80 and control or modulator M are such that it will now tend to change the frequency of oscillator 64' to correct the frequency.

The bias applied to the limiter in 74 is shown diagrammatically in Figure 4. The bias resulting from scanning the picture is represented at *Eg* and is not sufficient to cause the limiter 74 to supply output current until 62 (Fig. 1) is opened. Then the bias increases as indicated at *Egm*. The output *Ip* is supplied from 74 and fed through commutator 76 to the speed control means 78 which holds the motor 77 in step to synchronize the receiver and transmitter.

The manner in which the synchronizing effect is obtained will now be described. Assume that

the transmitter and receiver are in synchronism. Contact 62 is opened by cam 60 during the time *a* to *b* in Figures 3 and 4. The margin of the subject starts at *a* but no current can flow through 76 from 74 to 78 until the commutator 76 reaches *c*. The current flow stops at *b* because 62 has been closed by the spring. The amount of current flowing under these conditions is just sufficient to hold 77 at the correct speed.

Now assume the motor 77 tends to lag. The time *c* to *b* becomes shorter and current flows through 76 for a shorter time. This operates through the speed control device 78 to increase the motor speed by decreasing a drag or brake on the motor. In this manner the definite frequency sent out on margins synchronizes the system.

The commutator 75 closes a circuit from 69 to 79 and the definite frequency sent out on the margins acts through a narrow filter in 79 having a sloping characteristic to feed detector 80 and control the tuning means 84 to reset the receiver tuning each time the switch 62 is closed to thereby correct the picture density. If the system is in synchronism or nearly so the circuit through segment 75' (Fig. 3) is completed at the proper time. The section 75' is made slightly shorter than the time *a* to *b* to prevent incorrect correction of the receiver tuning.

It will be necessary at the start of a transmission to line up this system manually. After it is lined up it should stay in step. Should the signal fade to an abnormally low value then cutoff 82 actuated by the fast automatic gain control potentials from 66 will cause 84 to be disconnected from 64' so that 64' will continue to oscillate at the same frequency. When the signal rises to its normal value again 82 will again allow 84 to control the frequency of 64'.

The output of the demodulator 70 is used to modulate the tone source 72 through tone modulator 71. This modulated tone may be used to actuate a recorder at the receiving station or the recorder may be located at the remote central office for recording the photo radio subject or it may be recorded at both points. Any other known means can be used for using the output of the demodulator 70 to control the recorder at the central office.

When a bias corresponding to super-white is used at the scanner and a definite frequency corresponding to super-white is transmitted the circuit at the scanner is modified as indicated in Figure 1*a* to connect the resistance 64 in shunt to the photo tube electrodes 9 and 10 to impress modulating voltages on the grids corresponding to super-white at the subject margin.

The limiter in 74 may comprise an electron discharge amplifier biased so that only potentials which exceed the highest potential produced by the scanning process overcome the same to an extent such that the tube in 74 can pass curernt as indicated at IP in Figure 4. In other words, the tube in unit 74 is so biased that only potentials produced by the closing of contacts 61 and 62 are passed thereby. If the receiver circuits are such that the bias for limiter 74 is not of the proper phase the said limiter will include the proper number of direct current amplifier stages to provide a current pulse output for either modification, that is, when the definite frequency represents super-black or super-white.

A cut-out device 82 may comprise a magnetic clutch, a winding of which is connected with the

automatic gain control circuit **66** as described in my United States application Serial No. 390,228, filed April 25, 1941.

The control means in unit **78** may be of any suitable type. For example, this may comprise a drag, pressure on which is increased when the motor **77** is running too fast and is reduced as the speed of motor **77** approaches synchronism with the scanning drum. Control means of this type are well known in the prior art and will not be described in detail here.

The oscillator control or modulator means M shown at **84** may comprise a motor for driving a variable reactance in the oscillator circuit, the motor in turn being controlled as to direction of rotation and extent of rotation by the output of the wave variation detector in unit **80**. A preferred embodiment for use here has been disclosed in my United States application Serial No. 390,228, filed April 25, 1941. In some cases it may be preferable to use a modulator or control means of the reactance tube type, the reactance of which supplements the reactance of the oscillator in unit **64'** and is variable in a manner corresponding to variations in the output of the detector **80**. Such a reactance control means has been disclosed in Crosby United States applications Serial No. 136.578, filed April 13, 1937, U. S. Patent #2.279,659, dated April 14, 1942, and Serial No. 209.919, filed May 25, 1938, U. S. Patent #2.250.095, dated July 22, 1941.

Modifications have been suggested from time to time in the above description. Many other obvious modifications will occur to anyone skilled in the art. For example, in some cases it may be desirable to duplicate the system shown to obtain the benefits of diversity reception. This diversity reception can be of the space diversity type, the angle of arrival diversity type, the polarization of received signal diversity type, etc.

I claim:

1. The method of signaling by photo radio transmission which includes the following steps, modulating the frequency of a radio frequency carrier through a given range in accordance with current derived by scanning a subject, modulating the frequency of the said carrier current beyond said given range periodically, sending the carrier so modulated to a receiving point, and at the receiving point amplifying voltages characteristic of the said carrier while controlling the frequency of the voltages being amplified in accordance with said frequency modulation beyond said given range.

2. The method of signaling by photo radio transmission which includes the following steps, modulating the frequency of a radio frequency carrier in accordance with current derived by scanning a subject, additionally modulating the frequency of said carrier periodically to an extent sufficient to swing it outside the range of modulation by said current derived by scanning, sending said carrier so modulated to a receiver including a recorder and at the receiver using said additional modulation for tuning the receiver and synchronizing the recorder.

3. The method of signaling by modulation of a radio frequency carrier through a selected range in accordance with variations in the scanned subject shade which includes the following steps, modulating said carrier an arbitrary amount beyond said selected range during the time corresponding to the subject margin, sending said carrier so modulated, heterodyning the same to a lower frequency and controlling the heterodyning frequency in accordance with said modulation beyond said selected range.

4. The method of signaling by proportionally frequency modulating a radio frequency carrier through a selected range in accordance with variations in subject shade which includes the steps of modulating the frequency of said carrier beyond said selected range an arbitrary amount during the time corresponding to the subject margin, translating said modulated carrier at a receiving point for demodulation purposes, and controlling the frequency of the translated carrier at the receiving point in accordance with said modulation beyond said selected range.

5. The method of signaling by modulation of a radio frequency carrier in accordance with variations in subject shade which includes the steps of producing potentials characteristic of subject shade, modulating a sub-carrier in accordance with said produced potentials, additionally modulating said sub-carrier an arbitrary amount during the time corresponding to the subject margin, frequency modulating said radio frequency carrier in accordance with the modulations on said sub-carrier, translating said modulated radio frequency carrier, heterodyning the same to a lower frequency, and controlling the heterodyning frequency in accordance with the frequency modulations on said radio frequency carrier produced by said additional modulation of said sub-carrier.

6. In a photo radio transmission system, means for proportionally frequency modulating a radio frequency carrier in accordance with shade variations of a scanned subject, means for additionally frequency modulating said carrier an arbitrary amount during a margin of said scanned subject, means for transmitting the carrier so modulated, a receiver for the carrier so modulated and means for tuning the receiver in accordance with the arbitrary modulations of the transmitted carrier.

7. In a photo radio transmission system, means for proportionally modulating the frequency of a carrier in accordance with shade variations of a scanned subject, means for additionally modulating the frequency of said carrier an arbitrary amount during a margin of said scanned subject, a tunable receiver and recording means excited by said carrier so modulated and means at said receiver for utilizing said additional modulation to tune the said receiver and synchronize the recording means.

8. The method of signaling by photo radio transmission which includes the steps of modulating a radio frequency carrier through a given modulation range in accordance with current derived by scanning a subject, modulating the said radio frequency carrier beyond said given modulation range periodically, sending the carrier so modulated to a receiving point and at the receiving point amplifying voltages characteristic of the said carrier while controlling the frequency of the voltages being amplified in accordance with said modulation of said radio frequency carrier beyond said given range.

9. In means for signaling by modulation of a radio frequency carrier through a selected modulation range in accordance with variations in the scanned subject shade, apparatus for modulating said carrier an arbitrary amount beyond said selected modulation range during a time in the modulation cycle corresponding to the subject margin, apparatus coupled to said first apparatus for sending said carrier so modulated, a receiver for receiving said carrier, circuits coupled to said

receiver producing currents characteristic of the carrier so modulated from which the subject may be recreated, a control circuit coupled to said last named circuits for controlling the frequency of the produced currents in accordance with said modulation beyond said selected modulation range and other circuits coupled to said control circuit for inhibiting operation of said control circuit in the presence of a weak carrier.

10. Means for receiving wave energy modulated through a given range in accordance with signals and in another range in accordance with a control potential, circuits for producing currents characteristic of the modulation on said wave energy, a de-modulator coupled to said last mentioned circuits, a utilization circuit coupled with said de-modulator, a circuit coupled with said de-modulator for deriving potentials characteristic of the modulation of said wave energy through said other range by the control potentials, and a control circuit coupling said last named circuits

to said first named circuits for controlling the tuning thereof.

11. Means for receiving wave energy modulated through a given range in accordance with signals and in another range in accordance with a control potential, circuits excited by said wave energy for producing currents characteristic of the modulation on said wave energy, a de-modulator coupled to said last mentioned circuits, a utilization circuit coupled with said de-modulator, a circuit coupled with said de-modulator for deriving potentials characteristic of the modulation of said wave energy through said other range by the control potentials, a control circuit coupling said last named circuits to said first named circuits for controlling the tuning thereof, and means actuated by said wave energy for preventing said control circuit from changing the tuning of said first named circuits when the wave energy intensity falls below a usable value.

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