Feb. 10, 1948. C. W. CARNAHAN 2,435,736

FREQUENCY MODULATED PICTURE RECEIVER

Filed Feb. 13, 1941 3 Sheets-Sheet 1

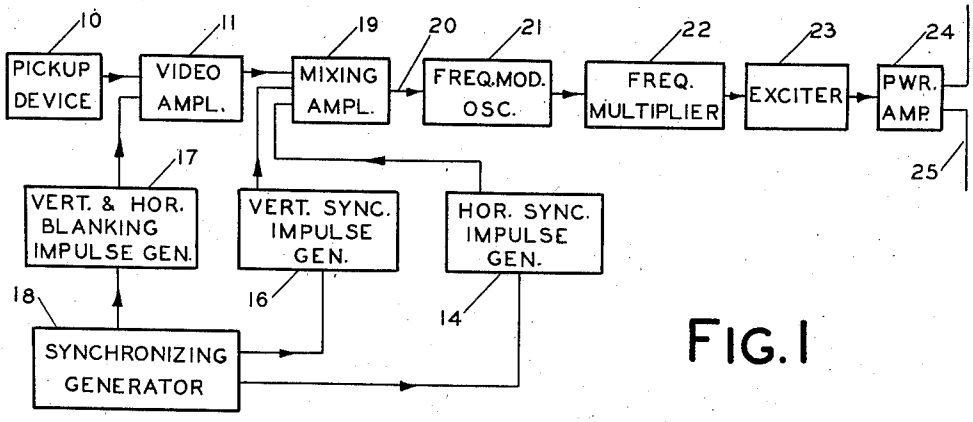


FIG. 1

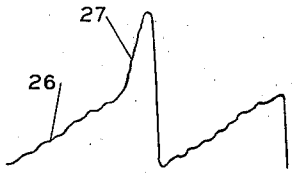


FIG. 2

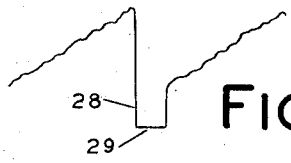


FIG. 3



FIG. 4

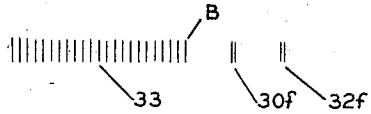


FIG. 6

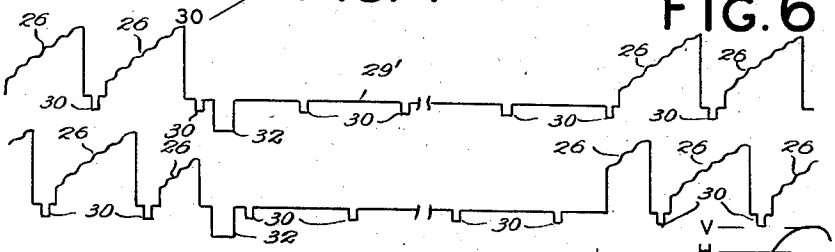


FIG. 5

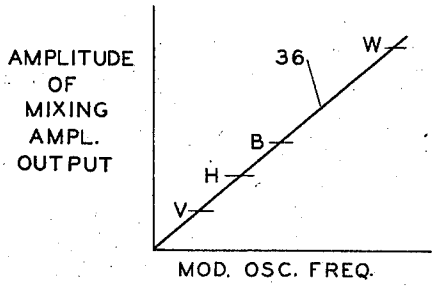


FIG. 7

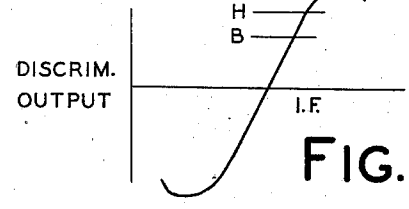


FIG. 9

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FREQUENCY MODULATED PICTURE RECEIVER

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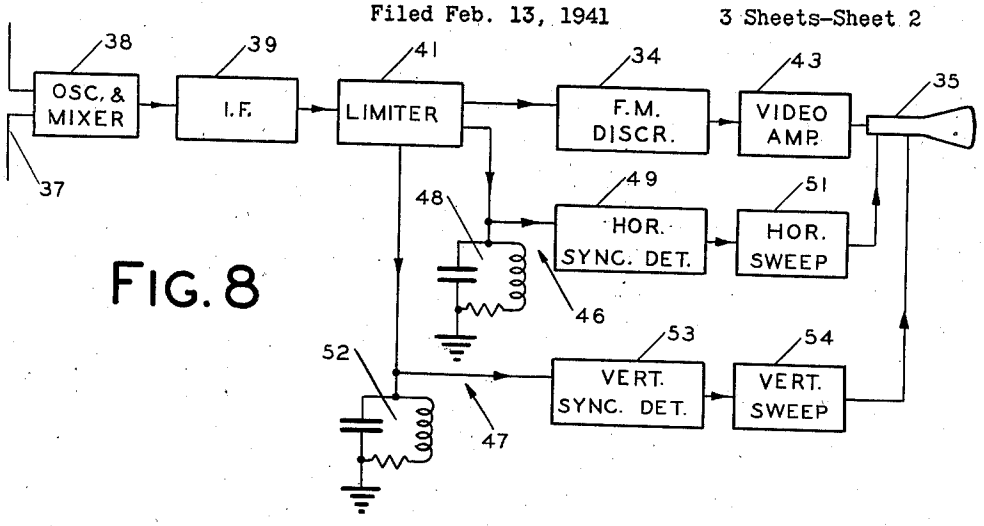


FIG. 8

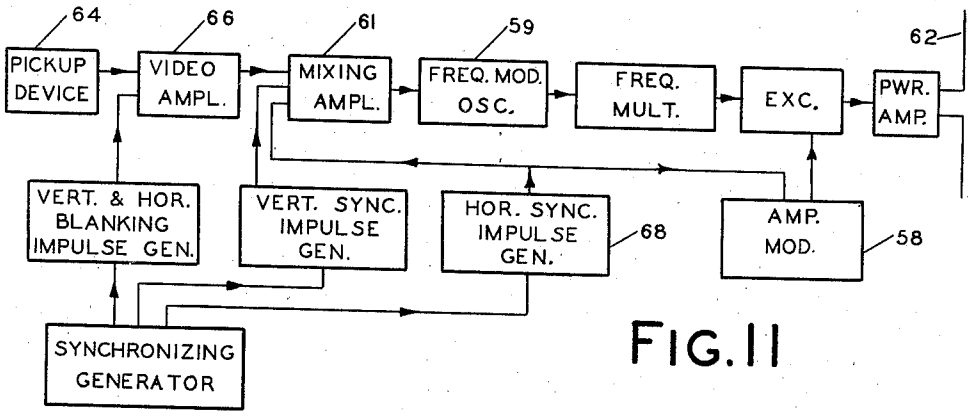


FIG. 11

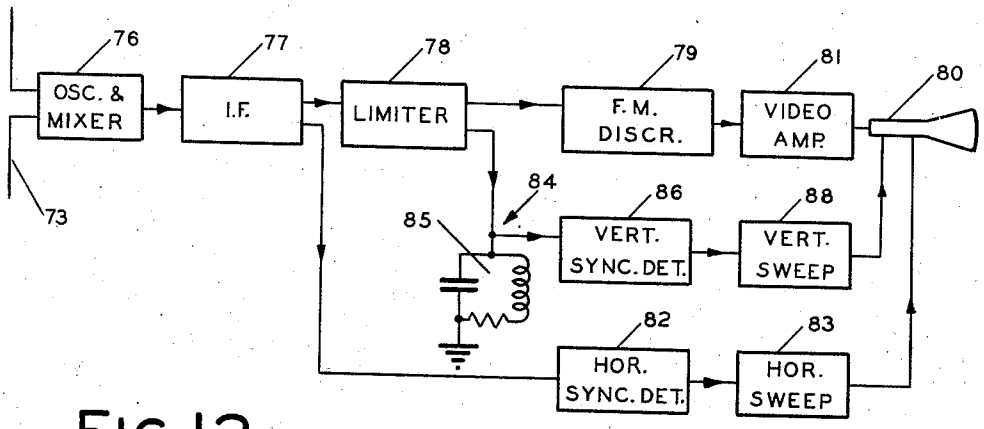


FIG. 12

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FREQUENCY MODULATED PICTURE RECEIVER

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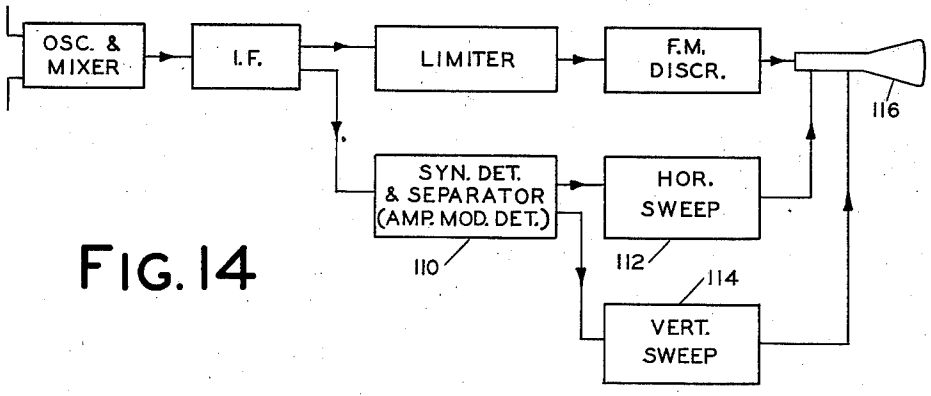


FIG. 14

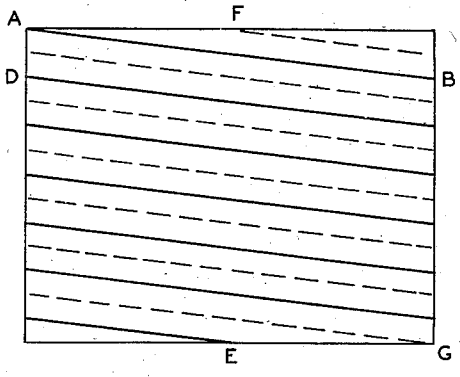


FIG. 10

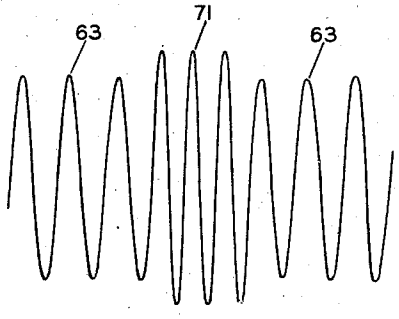


FIG. 13

FIG. 15

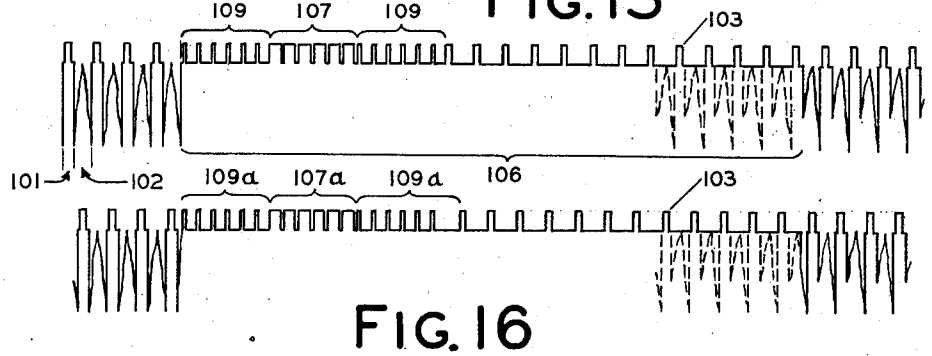


FIG. 16

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UNITED STATES PATENT OFFICE

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FREQUENCY MODULATED PICTURE RECEIVER

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Application February 13, 1941, Serial No. 378,715

4 Claims. (Cl. 178—7.3)

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This invention relates to television systems for transmitting and receiving television pictures by means of signal carrier waves and particularly relates to a new type of signal carrier waves which render improved operation and make possible the use of simplified apparatus.

In the past it has been general practice in the art to transmit picture signals by way of signal carrier waves whose amplitudes are modulated in accordance with the picture signals to be transmitted. However, amplitude modulation of a carrier wave of appreciable intensity, such as required for transmitting stations with power ratings in the order of 10 kilowatts, is accompanied with extreme difficulties. In order to obtain reasonable efficiency, it is conventional transmitter practice to employ non-linear amplifiers, so-called class C amplifiers, for power amplification of the carrier waves. Since no non-linear amplification of the carrier wave may occur after modulation thereof, it is necessary to modulate the carrier wave at a high power level. Such a modulation requires considerable modulating power, and since the modulating picture signals extend over a frequency band ranging from 60 cycles to about 4 megacycles, it is extremely difficult to obtain modulating signals of sufficient power without encountering serious signal distortion. For this reason it has been proposed to effect carrier wave modulation at a low power level. In that case the power amplifiers for increasing the power of the modulated carrier waves must have linear frequency response over a frequency band of about 4 megacycles, which is difficult to obtain and inherently makes for very low efficiency of the transmitter.

It is an object of the present invention, therefore, to provide a television transmitting system and a receiving system for cooperation therewith, which overcomes the above defects of conventional apparatus by employing frequency modulation of carrier waves in accordance with the picture signals to be transmitted.

The advantages of such frequency modulation systems will become evident from the following comparison. Modulation can be effected at a low power level of the signal carrier wave, therefore requiring no appreciable modulating power. The final power amplifier of a transmitter according to the present invention, can be operated for highest power output, that is, so-called class C operation, at the maximum plate dissipation of the amplifier tubes, since no attention need be paid to linearity in the frequency modulation amplifiers. This should result in approximately

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four times the average power output of a conventional grid modulated amplitude modulation amplifier stage and considerably greater efficiency. Hence, a transmitter according to the present invention, can produce approximately four times the average power of a conventional transmitter using substantially the same complement of tubes. A receiving antenna located at a certain distance from the transmitter according to the present invention, therefore, receives four times the average power than from a conventional transmitter at the same distance. Hence, the average carrier wave voltage amplitude at the receiver is doubled, and so is the signal to noise ratio, which considerably enhances the quality of the reproduced television picture.

In order to synchronize the operation of transmitter and receiver, it is necessary to transmit synchronizing signals in addition to the picture signals. It is conventional to transmit both types of signals by way of the same carrier waves. It will become evident from the following that considerable advantages are also obtained if the frequency of the signal carrier waves is also modulated by the synchronizing signals.

In order to appreciate the objects and advantages of the present invention, it is necessary to refer to the typical signals ordinarily employed in television at the present time and for this purpose reference is now made to Figs. 15 and 16 which graphically depict such typical signals and to Fig. 10 which shows diagrammatically in full lines and in dotted lines typical successive scanning patterns for interlaced scanning.

In the usual television system employed at the present time, a single amplitude modulated carrier is transmitted, having an envelope of the general form shown in Figs. 15 and 16. In these figures the video signals are 102. The blanking pulses between successive video signals are indicated at 101 and during these blanking pulses occur the horizontal synchronizing pulses 103. It is preferred to maintain the synchronizing pulses 103 at all times, that is, during the video transmission and also during the vertical return blanking period.

The vertical return occurs during a blanking pulse 106, equivalent in length to several scanning lines. The vertical synchronizing pulse 107 or 107a occurs during the long blanking pulse 106 and serves to initiate the return of the beam or other scanning instrumentality to the top of the frame for scanning the next field.

In order to initiate successive scannings, at different positions for interlace scanning, the verti-

cal impulses 107 and 107*a* have a successively different time relation to the horizontal synchronizing impulses in successive vertical returns. Thus, if, as shown in Fig. 10, the field has two interlaced scanning patterns, then if one vertical impulse occurs at an integral number of lines after a horizontal impulse, then the next vertical impulse will occur an integral number plus one-half lines after a horizontal impulse.

In order to prevent the pulses 103 from exercising a differential effect upon the vertical return initiated by the pulse 107 or 107*a*, it is customary to substitute a series of pulses 109 or 109*a* for the synchronizing pulses 103 immediately before the pulse 107 or 107*a*. These pulses 109 or 109*a* occur at double the frequency of the pulses 103. That is, the pulses 109 or 109*a* occur every half line for several lines and consequently the effect upon the vertical return timing of the slightly different form of the envelope before the pulse 107 or pulse 107*a*, respectively, is absolutely negligible. The pulses 109 and 109*a* are called the equalizing pulses and they will hereinafter be referred to by this term.

Alternate pulses 109 will serve the purpose of the horizontal return pulses 103 so that the horizontal return system will be maintained throughout the whole scanning operation. The other alternate pulses 109 will have no effect on the horizontal return system, since such system is only capable of being triggered by a pulse 109 or a pulse 103 at substantially line frequency.

One of the objects of the present invention is to provide an improved transmission system.

A further object of the present invention is to provide an improved transmission system in which it is unnecessary to provide a signal with equalizing impulses.

A further object of the present invention is to provide an improved transmission system in which the vertical return pulses are inherently unaffected by horizontal return pulses nothwithstanding different time relations between them.

A further object of the invention is to provide a transmission system in which the wave forms necessary for complete control of the receiver are simpler and more easily produced than has heretofore been the case.

A further object of the invention is to provide a television system which does not require the generation of large amounts of power at video frequencies for modulation.

Still another object of the present invention is to synchronize the elements of a television system by varying a characteristic, other than the amplitude, of a transmitted wave.

Still another object of the present invention is to provide a novel television system of the odd-line interlaced scanning type in which the receiver will lock into synchronism and provide satisfactory interlacing without employing equalizing impulses.

A still further object of the present invention is to greatly simplify synchronizing apparatus at the transmitter.

A still further object is to eliminate the necessity for supplying additional signals or impulses at the transmitter to equalize the effect of the horizontal synchronizing signals or impulses on alternate vertical synchronizing signals or impulses in an interlaced transmission system.

A still further object of the present invention is to provide a method of utilizing received signals which is novel in the art.

A still further object of the invention is to

facilitate derivation and application of the synchronizing components of a received picture or television signal.

The invention will readily be understood from the following description of preferred embodiments thereof taken in conjunction with the accompanying drawings in which:

Figure 1 is a diagrammatic showing of television transmitting equipment embodying the invention in a preferred form.

Figure 2 shows the wave form of an assumed picture signal as originated in an ordinary picture transmitting tube during horizontal or line scanning.

Figure 3 shows the signal of Figure 2 with the blanking impulse added.

Figure 4 shows the signal of Figure 3 with the horizontal synchronizing signal or impulse added.

Figure 5 shows the complete signal to be transmitted on a carrier from a television transmitter embodying the present invention.

Figure 6 is a chart showing the intermediate frequency variations for video, horizontal and vertical signals.

Figure 7 is a curve plotted to show video signals and horizontal and vertical synchronizing impulses.

Figure 8 shows in schematic form a complete television receiver for use in a television system embodying the invention in its preferred form.

Figure 9 is a characteristic curve of a wave detecting device with the operating points marked thereon.

Figure 10 represents one frame of a television image.

Figure 11 is a diagrammatic showing of a modified television transmitter.

Figure 12 shows in schematic form a modified television receiver.

Figure 13 shows the wave form of a modulated signal radiated by the transmitter of Figure 11.

Figure 14 shows a still further modification of a receiver in schematic form.

Figures 15 and 16 indicate the wave form of a composite signal which the receiver of Figure 14 is designed to translate into a visual reproduction.

Referring particularly to Figures 1 and 8 of the drawings, there is illustrated schematically a complete television system embodying various features of the invention, the transmitting apparatus being illustrated in Figure 1, and the receiving apparatus being illustrated in Figure 8. The arrowheads indicate the directions of flow of energy between the various units. Referring to Figure 1, the transmitting apparatus includes a video signal generator or pickup device 10 which supplies the video or picture signal to a video signal amplifier 11. The pickup device 10 may be a cathode ray tube having a screen provided on the surface thereof with a mosaic of photo-sensitized elements in the usual manner. The horizontal synchronizing signal, the vertical synchronizing signal and the corresponding blanking signals are obtained from a horizontal synchronizing impulse generator 14, a vertical synchronizing impulse generator 16, and a vertical and horizontal blanking impulse generator 17. These impulse generators are controlled by a master synchronizing signal generator 18. The several signals including the amplified video signal are combined in the composite signal amplifier 19 to obtain a composite signal which, in addition to the customary video and synchronizing signals, may also include, if desired, intel-

ligence by which background control may be obtained at the receiver.

The composite signal from the mixing amplifier 19 is supplied to a transmission line 20 capable of transmitting the necessary frequency band width. This transmission line extends from the pickup point, usually a studio, to the broadcast transmitter. The output of the transmission line 20 is, or may be, further amplified, if desired, and applied to a frequency modulator-oscillator 21 which provides a carrier in the usual manner to be phase or frequency modulated by the composite signal received from the transmission line. The output of the modulator-oscillator 21 is supplied to a frequency multiplier 22, which magnifies the phase angle change so as to produce the desired frequency deviation of the carrier from its nominal or rest frequency value. The frequency modulated carrier produced in the frequency multiplier 22 is fed to an exciter, or driving stage 23, which drives the radio frequency power amplifier 24. The output from this latter amplifier is transmitted to a radiating system indicated generally by the reference character 25. The output of the frequency multiplier 22 may be used, if desired, to energize a monitor system at the transmitting station. The monitor system may comprise a television receiver similar to that shown in Figure 8 of the drawings.

Figures 2 to 5 of the drawings show the wave form of the signal at each point of the system for an assumed horizontal scanning line, which increases in brightness from left to right as viewed by the pickup device 10 when it is focused on the field of view. In Figure 2 the output of the pickup device is shown as an increasing potential 26 and is reproduced at higher potentials in a shorter time as the scanning means, which may be an electron beam, retraces the field of view from right to left. This retrace signal 27 is undesirable and, therefore, it is removed or blotted out as indicated at 28 by an impulse from the blanking impulse generator 17, as shown by Figure 3 of the drawings.

The blanking out of the signal during the retrace period may be accomplished by any one of a number of ways known to the art. One such method is to mix the signal of Figure 2 with a large impulse occurring during the retrace period, having an amplitude in the black direction appreciably greater than the maximum signal from the pickup device during the retrace. This combined signal is then fed to an amplifying stage the grid of which is so biased that all of the signal variation during the retrace period lies below the cut off of the amplifier.

The signal level 29 obtained when the blanking impulse is applied may be selected to correspond to the darkest portion or portions of the picture, which is referred to as the black level. Numerous ways of obtaining the black value are known to the art and any of these may be employed. The pedestal level may be adjusted at the transmitter to any point for economical use of the available modulating range. It is preferably as close as possible to the maximum picture signal peaks.

Figure 4 of the drawings shows the addition of the horizontal synchronizing impulses 30, the amplitude of which in the black direction is greater than the value of the potential for the black level 29 of the picture, and which, therefore, do not affect the picture reproduced at the receiver. The horizontal synchronizing impulses 30 cause the scanning means to traverse the field

of view from right to left in preparation for the derivation of signal 26 from the next following scanning line. The series of signals shown by Figure 4 are repeated until the total area of the field has been scanned once in alternate lines.

Figure 5 of the drawings shows the signal wave form for a complete double scanning of the field. Following present conventional practice, this drawing represents 441 lines, each complete scanning involving 441 horizontal pulses 30. Figure 5 does not disclose the signal which occurs during the main part of the picture scanning, but it will be understood that such full disclosure would merely embody the multiplication of the left-hand and right-hand parts of the figure. The principal purpose of this figure is to show in a comparative relation the form of the signal at two successive vertical return periods.

The upper part of Figure 5 begins with the signals 26 representing scanning lines on the frame separated by blanking signals 29 and horizontal return signals 30.

When the last line is scanned, a prolonged blanking signal 29' occurs for the vertical return. During this blanking signal 29', the horizontal return pulses 30 occur at regular rate. It will be understood that the blanking signal 29' causes the signal trace to assume the black level indicated by the reference character 29 and to maintain this level in the absence of additional pulses throughout a period which would be occupied by the transmission of several horizontal pulses 30. As stated before, the horizontal synchronization pulses 30 are continued at their regular intervals to maintain synchronism of the horizontal oscillator which might otherwise fall out of step during the period of time when the vertical retrace to the top of the field of view is effected.

In order to return the scanning beam to the starting position on the frame for scanning the next successive field, a vertical synchronizing pulse 32 is fed to the mixing amplifier 19 from the vertical synchronizing pulse generator 16. This vertical synchronizing pulse 32 is preferably less than one half of a line in duration. The horizontal synchronizing pulses 30 are of values beyond the black level 29 of the picture. The vertical synchronizing pulse 32 is still further beyond the level 29, that is, it is greater in magnitude than the pulses 30, as clearly shown in Fig. 5. The difference in magnitude between the pulses 30 and 32 provides a basis for separation of these pulses at the receiver in a novel manner. The effect of the pulse 32 causes energization of the vertical control plates or coils of the reproducer at the proper time with respect to the horizontal synchronization pulses 30 which cause energization of the horizontal control plates or coils of the reproducer, so that the horizontal scanning of the second field will be initiated to provide correct line relationship for interlace.

The pulse 32 is applied at regular intervals. Thus, for pictures in which the scanning occurs sixty times a second, the pulse 32 is supplied each sixtieth of a second. The two portions of Fig. 5 are related so that the form shown below represents the condition of the signal one-sixtieth of a second after the signal has the form shown in the upper portion of the figure. In other words, if any point on the upper portion is taken, that point shows the condition of the signal at a particular time. Then the point on the lower portion of the figure immediately below

that point shows the condition of the signal one-sixtieth of a second after that time.

Consequently, the two pulses 32 are in vertical alignment. However, in the two portions of the figure, owing to the odd number of lines in a complete double scanning, the pulses 30 are displaced relatively half a line in the two portions of the figure. Therefore, each of the pulses 32 in the two portions of the figure and in the corresponding vertical return periods has a different relation to the horizontal pulses 30. Owing, however, to my improved method of transmission, the horizontal pulses 30 have no effect upon the result of the vertical pulses 32 and consequently I am able to avoid the necessity of the complex system heretofore necessary for the introduction of equalizing pulses.

It is to be noted that the video signal is supplied to the frequency modulated oscillator at a point of the transmitter where the power level is still low. Consequently, it is not necessary to build up the video signal to a degree of power of the same order as the output signal as has heretofore been the case with amplitude modulated television transmitters.

The frequency excursions of the transmitter carrier resulting from the amplitude values of the synchronization impulses are shown in the form of a curve 36 on Figure 7, in which the abscissae are values of modulated oscillator frequencies and the ordinates are the amplitudes of the mixing amplifier output. Point B on the curve represents the minimum visual effect and corresponds to the signal level 29 and 29' on Figures 3, 4 and 5 of the drawings. Point W represents the maximum frequency excursion which corresponds to the maximum brightness obtainable in the usual types of reproducer. This will represent maximum brilliance of the fluorescent screen or coating in the electron ray reproducing tube 35. Points H and V represent the frequency excursions caused by the horizontal and vertical synchronizing impulses 30 and 32 respectively.

Referring to Figure 8 of the drawings, the receiver may comprise an antenna system 37, an oscillator and mixer stage 38, and an intermediate frequency amplifying system 39, following conventional superheterodyne practice. The amplitude variations of the composite intermediate frequency signals are removed in the limiter stage 41 in the manner usual in phase or frequency modulated receiving systems. The limiter 41 may be of any conventional type such, for example, as the type disclosed in "Frequency modulation," by Rider, on page 53, or the type disclosed in the copending application of the present inventor, C. Wesley Carnahan, Serial No. 371,606, filed December 26, 1940, now Patent No. 2,323,880, dated July 6, 1943.

The composite signal as it comes from the limiter 41 consists of the carrier varying in frequency in accordance with the video signal and also the set of two synchronization signals. The entire composite signal is supplied to the previously mentioned video demodulator or frequency detector 34 which converts frequency variations of the carrier into amplitude variations which are substantially the counterpart of those appearing in the composite amplifier 19 in Figure 1 of the drawings. The output of the frequency detector 34 may be supplied to a video signal amplifier 43 which increases the level of the amplitude variations of the composite signal before it is applied to the reproducing device 35 shown conventionally as a picture receiving tube. The picture tube is provided with the usual horizontal and vertical deflecting coils or plates. The horizontal and vertical deflecting coils or plates are energized by current or voltage waves of sawtooth form, as conventional.

Referring to Figure 9, a desirable characteristic curve of a discriminator is shown, suitable for use as the discriminator in the receiver of Figure 8. A point B on this curve may be selected as the black value corresponding to the black value 29 of Figures 3 to 5 so that amplitude responses having this value will produce substantially no visible luminescence on the fluorescent screen of the picture tube 35. The synchronizing impulses which attain amplitude levels having values H and V indicated on the curve of Figure 7 have no effect on the reproduced picture, as they have values which are blacker than black.

The intermediate frequency signal, derived in the oscillator mixer stage of a typical picture receiver from the wave radiated from the antenna system 25, is represented by the frequency band diagram of Figure 6, which shows the total band width through which the frequency of the intermediate frequency signal varies during the transmission of the video and synchronizing signals. The frequency variation, or modulation, of the intermediate frequency signal as the picture is scanned is confined to the frequency range 33. It will be noted that frequency excursions beyond the frequency value B will have no effect on the appearance of the picture, and, therefore, the frequency spectrum beyond the point B is available for controlling receiver functions. The horizontal synchronization impulses 30 for controlling the horizontal scanning oscillator are translated into frequency variations in the narrow band labeled 30*f* on Figure 6 of the drawings, these variations being displaced in frequency from the video band 33 so as to provide ready separation therefrom on a frequency discrimination basis in a manner to be explained in connection with the operation of the receiver. The vertical synchronizing impulses 32 are translated into frequency variations and occupy a narrow frequency band 32*f* which is removed in frequency value from the video signal band 33 and the narrow band 30*f* occupied by horizontal impulses. This displacement in frequency of the horizontal and vertical components of the frequency modulated intermediate signal is obtained by reason of the larger amplitude of the horizontal and vertical components as supplied by the respective signal generators. The separation and utilization of the set of synchronization signals is done on a frequency discrimination basis and the total composite signal demodulated by the discriminator 34 is used to excite the picture tube 35 of the receiver (Figure 8), the effects of the set of synchronizing signals being eliminated by biasing the tube in the usual manner to produce no visual response when signals are impressed on the tube which are outside of the amplitude range corresponding to a black area of the original subject matter at the transmitter.

Intermediate frequency excursions produced by frequency modulation of the transmitter carrier with the horizontal and vertical synchronizing impulses are supplied from the limiter 41 to the horizontal and vertical impulse separating systems 46 and 47. The separating system 46 comprises a circuit 48, which is tuned to the intermediate frequency value attained when the horizontal synchronizing signal is applied, and an

amplitude demodulator or detector 49. The tuned circuit 48 acts as a filter in the well-known manner for frequencies other than the intermediate frequency value corresponding to the frequency produced by the horizontal synchronizing impulse. The horizontal synchronizing impulse is obtained by demodulation in the amplitude detector 49 and is applied to control the horizontal sweep generator 51, which supplies the horizontal deflecting coils or plates of the picture tube 35 with waves having a wave form to cause horizontal scanning at uniform velocity.

The separating system 47 comprises a circuit 52, which is tuned to the frequency value attained when the carrier is modulated with the vertical synchronizing impulse. The tuned circuit 52 causes the intermediate frequency signal produced by the vertical synchronizing signal to be applied to the amplitude detector 53. The vertical synchronizing impulses obtained from the detector 53 are utilized to control the vertical sweep generator 54, which supplies the vertical deflecting coils or deflecting plates of the picture tube 35 with undulations of a wave form to accomplish scanning in the manner set forth above.

A brief description of the operation of the entire system just described will now be given. Since the invention is especially applicable to a television system in which the entire frame, or field of view, is scanned in alternate lines, a system which is known as interlaced scanning, the following description of the operation of the system will deal with interlaced scanning.

In the conventional television system employing interlaced scanning, one necessary relation between the several synchronizing signals used to actuate the deflecting means for the scanner is that the ratio between the relatively high frequency of one synchronizing signal and the relatively low frequency of the other synchronizing signal must be an integer plus a fraction such as one-half, one-third, one-fourth or the like. While the invention is not limited to interlaced scanning, it provides means for readily and clearly separating synchronizing impulses having the relationship named by simple means. For a clearer understanding of the interlaced scanning process and the co-relation between the vertical and horizontal synchronizing signals reference may be had to Figure 10 of the drawings. The first field is scanned beginning with point A at or adjacent to the upper left hand corner of the total field of view, the first horizontal solid line sloping diagonally downward to the right, tracing a resultant of the horizontal and vertical scanning oscillator outputs. At B the video signal is blanked and the beam or other scanning means is returned to the point D. The wave form of the vertical oscillator decreases from its maximum value at such a rate that the second solid scanning line is displaced a distance of two lines on the frame. The first field ends at a point E at or adjacent to the center of the lower edge of the frame from which point it is returned to the point F. From F, it follows the dash line path to the point G, thereby producing the interlaced pattern. If the scanning beam moves substantially horizontally, the horizontal scanning frequency will be considerably higher than the vertical scanning frequency. For good definition, simple interlaced scanning may be employed in which two fields or interlaced sets of lines constitute a frame. There may be 441 lines to a frame and 30 frames per second. This requires,

for interlaced scanning, a vertical scanning wave of 60 pulses per second and a horizontal scanning wave of 13,230 pulses per second. For purposes of illustration the invention will be described with respect to a 441 line system. It will be understood, however, that the invention is not limited to the particular values given above, but is applicable to other systems in which the entire area of the field of view is scanned once in substantially contacting lines.

The pick-up device 10 is provided in the usual manner with horizontal deflecting means, such as deflecting plates or coils and vertical deflection means, such as vertical deflecting plates or coils, for the scanning ray. These deflecting means are excited from the synchronizing generator 18. The horizontal deflecting means are excited by an undulating voltage, or current, having what is usually known as a sawtooth wave form. By reason of this special wave form, the scanning beam will be deflected at a uniform speed from one side of the field of view to the other. As the scanning wave attains its maximum value and decreases quickly to zero, the scanning beam will return to its starting point on the field of view. This return of the scanning beam, as pointed out above, generates a signal in the pick-up device at a somewhat higher voltage because of the increased speed of scanning, but this retrace signal is blotted out in the video amplifier 11 by an impulse from the blanking impulse generator 17.

As the scanning beam sweeps back and forth under control of the horizontal impulse generator 14, it is displaced at a uniform rate by another undulating current or voltage which is applied to the vertical deflecting coils, or plates, which are in space quadrature with the horizontal deflecting coils, or plates. The horizontal and vertical control impulses from the impulse generators 14 and 16 are mixed with the video signal in the amplifier 19 to form a composite wave, which is used in the modulator 21 to vary the phase or frequency of the carrier by phase or frequency modulation. The instantaneous frequency of the carrier is multiplied in the frequency multiplier 22 and is radiated from the antenna system 25 after further amplification in the usual manner.

The foregoing description in connection with Figure 8 of the drawings contains a description of the operation of the receiver which need not be repeated here. It was pointed out therein that the signal fed to the frequency detector 34 is applied to the picture tube 35 but only the signals derived from the frequency band 33 in Figure 6 are effective to operate the picture tube since frequencies lying outside of this band produce demodulated signals of an amplitude which is too great, as explained above, to effect the picture tube, since it is rendered insensitive to signals having amplitudes beyond the picture signal range.

The elimination of the necessity for including equalizing impulses at twice the horizontal line frequency is an important feature of the invention and will be explained more in detail at this point. The equalizing impulses at twice the line frequency are added in known picture transmission systems in the region of the vertical synchronizing impulses to reduce the inequality of the phase relationship between horizontal and vertical synchronizing impulses for alternate scanning fields when separation of the horizontal

and vertical impulses is accomplished by wave form discrimination methods. The vertical synchronizing impulses for odd and even fields occur at different times with respect to the last horizontal pulse preceding the vertical pulse. Equalizing pulses are utilized to correct for dissymmetry of the horizontal synchronizing impulses with respect to the vertical synchronizing impulses. When the conventional methods of synchronizing signal separation are used, the horizontal impulses do produce a transient response of the separating circuit, thus affecting the time of occurrence of the point of the vertical synchronizing wave to which the vertical synchronizer oscillator control responds. In the absence of equalizing pulses, the effect is not uniform for odd and even fields. To eliminate this lack of uniformity, it is necessary in prior art systems to substitute for horizontal pulses immediately before the vertical pulse, a series of equalizing pulses of twice the frequency of the horizontal pulses, alternate equalizing pulses coinciding in time with the horizontal synchronizing pulses. There is, therefore, an impulse which is equivalent in value to the equalizing pulse always occurring at the same time interval before a vertical pulse. The end result of this process in known picture systems is a complex synchronization signal which, because of the variety of interlocking circuits required to produce it, adds greatly to the complexity of the transmitter equipment. A complete separation of vertical and horizontal synchronizing signals on a waveform basis is impossible without the inclusion of equalizing impulses at the transmitter in known television systems.

The system of Figures 1 to 9, which embodies the present inventions, eliminates the necessity for adding equalization impulses, since complete separation of both signals is obtained on an amplitude and frequency basis and it is not necessary to compensate for residual vertical signals in the horizontal signal separation and utilization circuits. Hence perfect synchronization can be obtained by transmitting two series of simple signals only, namely, a series of line synchronizing signals occurring at regular intervals of line scanning frequency only, and a series of field synchronizing signals occurring at regular intervals of field scanning frequency only. Nor is it necessary to separate the picture signals from the synchronizing signals before the former are applied to the picture reproducing tube **35**.

In Figure 6, assuming **32***f* as thirteen and one-half megacycles at the edge of the intermediate frequency band separated from **30***f* by approximately one-half megacycle. then with a circuit Q of 100 for the resonant circuits **48** and **52**, the ratio of unwanted to wanted signal is about .93 to 7 or 13 per cent in these circuits. This figure is arrived at by assuming a typical case and assigning arbitrary values to the chart of Figure 6. Assuming that the total frequency band in the intermediate frequency amplifier **39** extends from 8 megacycles to 14 megacycles and that the sound accompaniment utilizes a necessary band at 8.25 megacycles, the vertical synchronizing signal may lie at 5 25 megacycles above this value or at 13.5 megacycles. The horizontal synchronizing signal may be selected to lie at one-half megacycle below this or at 13.0 megacycles. The ratio of the response of the tuned circuit **52** at 13.0 megacycles to the response at 13.5 megacycles is the voltage across the inductance at 13.0 megacycles divided by the voltage across the inductance at 13.5 megacycles which is equal to

$$\frac{1}{Q\left(1-\frac{1}{V^2}\right)}$$

The above written formula is to be found in Terman's text, "Radio Engineering."

In this formula, Q is the reactance to resistance ratio of the circuit **52** of Fig. 8 and is assigned a numerical value of 100 in the case assumed for the purpose of illustration. V is the ratio of the frequency of the horizontal to the frequency of the vertical synchronizing pulses, and in the assumed case has a numerical value of .965. When the numerical values given are substituted in the formula written above the numerical result is 0.13. This means that 13 per cent of the total signal applied to the detector **53** is an undesired portion of the horizontal synchronizing pulse which is not removed by the tuned circuit **52**. This is likewise true for the circuit **48** and the dectector **49**. The unwanted signals appearing in the outputs of the detectors **49** and **53** may be readily removed by biasing these detectors so that thirteen per cent of the amplitude of the applied signals are not detected.

Equalizing pulses, as explained above, are used in prior art television systems to eliminate the effect of the transient response which follows cessation of a horizontal synchronizing pulse preceding a vertical synchronizing pulse, this transient response having a different effect on the wave form of the vertical impulse for odd and even lines. In the system of the present invention, the transient response following cessation of a horizontal pulse is so small as to be negligible for reasons now to be demonstrated.

The building up of sinusoidal currents in resonant circuits has been treated by a number of writers. One such treatment for the single mesh R, L, C circuit is found in Guillemin, "Communication Networks," vol. 1, pp. 118–120. There it is shown that when a sinusoidal voltage is suddenly impressed on a resonant circuit containing resistance R, inductance L, and capacity C, the envelope of the sinusoidal current flowing in the circuit builds up in accordance with the quantity

$$1-\exp\left(-\frac{Rt}{2L}\right)$$

Denoting the resonant frequency of the circuit by f_r, and remembering that

$$Q=\frac{R}{2\pi f_r L}$$

the damping factor

$$\frac{Rt}{2L}$$

may be written as

$$\frac{\pi f_r Rt}{2\pi f_r L}=\frac{\pi f_r t}{Q}$$

and the envelope factor for the building up period becomes

$$1-\exp\left(-\frac{\pi f_r t}{Q}\right)$$

In the present case the building up of the response to a suddenly applied sinusoidal synchronizing pulse is not pertinent, but rather the rate of subsidence of the response when the sinusoidal synchronizing signal is removed. In this

case, the envelope of the response decreases in accordance with the quantity

$$\exp\left(-\frac{\pi f_r t}{Q}\right)$$

where t is now measured from the end of the synchronizing impulse.

Substituting in this expression, the frequency at resonance, which is 13.5 megacycles, and the time, which is the reciprocal of twice the horizontal scanning impulse frequency of the time interval corresponding to one-half of a line, the result is 10^{-7} which is so small compared with unity as to have a negligible effect on the succeeding vertical impulse. If a biased detector is used, so that 13% amplitude of the horizontal impulses is not detected, a clean separation of the vertical pulse is accomplished without the necessity of equalizing pulses. The vertical synchronizing signal may then be of short time duration as shown on Figure 5 of the drawings. Because of its short duration, it need not be of the serrated type to insure continued horizontal synchronism. It is seen, therefore, that perfect synchronization can be obtained with the system according to the present invention without the use of equalizing pulses and serrated frame synchronizing pulses of complicated waveform.

Figure 12 of the drawings discloses a modified receiver for reproducing visual representations of pictures or objects from signals transmitted by a transmitter modified as shown in Figure 11 of the drawings. Referring to Figure 11, it will be seen that the transmitter disclosed thereby is similar to the transmitter of Figure 1 with the addition of an amplitude modulator **58** which amplitude modulates the carrier after it has been frequency modulated in the frequency modulated oscillator **59** by the output of the mixing amplifier which consists of the composite television signal including picture or video signal components and synchronizing signal components. The frequency modulation process has already been described in connection with Figure 1 of the drawings and need not be repeated here. Figure 13 of the drawings discloses the general nature of the wave radiated from the antenna system **62** without showing the frequency variations to any particular scale. The portion **63** of the wave carrying the intelligence or video signal is of substantially constant amplitude but varies in frequency in accordance with the amplitude variations of the video signal from the pick-up device **64**. Upon occurrence of blanking in the video amplifier **66**, the carrier resumes and maintains its unmodulated frequency until the vertical and horizontal synchronizing impulses are applied to the mixing amplifier **61**. The horizontal and vertical pulses are preferably of the form shown in Figure 5 of the drawings whereby the frequency excursion of the carrier for the horizontal and vertical impulses is made to differ by some frequency value, for example 0.5 m. c., so that the signals may be received and translated into visual representations by a receiver embodying features described in connection with Figure 8 of the drawings. Horizontal synchronizing impulses from the horizontal synchronizing impulse generator **68**, in addition to being supplied to the mixing amplifier **61**, are also supplied to the amplitude modulator **58** mentioned above. The modulator **58** serves to amplitude modulate the carrier in accordance with the horizontal synchronization signals as indicated by reference character **71**. The

percentage of modulation is not critical and need be only sufficient to enable detection by an amplitude demodulator or detector of the usual type. As its effect is to be eliminated by a limiter in the receiver the percentage modulation should not be so great as to necessitate excessive limiting.

Figure 12 of the drawings discloses a modified form of receiver embodying features of the invention which enable it to receive signals from the transmitter disclosed in Figure 11 of the drawings. Referring to this figure, **73** is an antenna system which feeds oscillator-mixer stage **76**. The oscillator-mixer stage generates an intermediate frequency which is amplified in the intermediate frequency amplifier **77**. The amplitude variations of the composite intermediate frequency signals including the position **71** are removed in the limiter stage **78** in the manner usual in phase or frequency modulated receiving systems. The limiter **78** may, like the limiter **41** of Figure 8, be of any conventional type. The frequency modulation discriminator or wave detector **79** converts the frequency variations of the carrier to amplitude variations suitable for operating the picture tube **80**. A video signal amplifier **81** may be used if desirable or necessary to amplify the video signals. The vertical and horizontal synchronization pulses which are present in the output of the wave detector **79** do not affect the picture tube for reasons pointed above in connection with Figure 8 of the drawings.

The output of the intermediate frequency amplifier **77** is fed to the amplitude demodulator or detector **82** of the usual type which provides horizontal pulses from the envelope of the portion **71** of the carrier for controlling the horizontal scanning signal generator **82**. The generator **83** functions in the same manner as the generator **51** in Figure 8 of the drawings.

Pulses for controlling the vertical scanning signal generator are derived from the frequency modulated carrier by a separating system **84** which is similar in all respects to the system **47** of Figure 8 and comprises a circuit **85**, which is tuned to the frequency of the portion **63** of the carrier. The tuned circuit **85** causes the carrier frequency produced by the vertical synchronizing impulse to be applied to the amplitude detector **86**. The output of the detector **86** is applied to the vertical scanning wave generator **88** which corresponds in function to the wave generator **54** of Figure 12 of the drawings. There is no interference from the horizontal signal in the vertical impulse detector, as it has been completely removed by the limiter **78**.

Signals radiated by the transmitter of Figure 11 may be received by a receiver embodying the features of the receiver of Figure 8 of the drawings when the frequencies representing the horizontal and vertical pulses in the intermediate frequency amplifier differ in frequency. The circuits of the separating systems **46** and **47** may be tuned to these frequencies and thereby complete separation is obtained in the manner described in connection with Figure 8 of the drawings. The amplitude difference between the horizontal and vertical pulses is completely removed by the limiter **41**.

My invention also contemplates a modification in which the video signals are transmitted as frequency modulated signals and in which both synchronizing signals are transmitted as amplitude modulations of the carrier. In operating in

this way, it is advantageous to provide horizontal and vertical synchronizing pulses of the same magnitude or amplitude and to depend upon differentiating between vertical and horizontal pulses by difference in wave form. To do this successfully, it is advantageous to employ a wave form of the same general type as is normally employed with amplitude frequency television systems. This wave form is shown in Figs. 15 and 16 and includes the equalizing pulses 109 and 109a.

Figure 14 of the drawings discloses a modified form of receiver for receiving a carrier wave whose frequency is modulated in accordance with picture signals and whose amplitude is modulated in accordance with synchronizing signals. In contrast with the systems described above, the synchronizing signals must include equalizing pulses since discrimination therebetween must now be effected on a wave-form basis. The transmitter which radiates signals suitable for reception by the receiver of Figure 14 may be similar to the transmitter of Figure 11 with the addition, however, of a means to amplitude modulate the carrier in accordance with the vertical synchronizing pulses. Since it is undesirable to frequency-modulate the carrier during the synchronizing pulses, the connections between the horizontal synchronizing pulse generator and the mixing amplifier and between the vertical synchronizing pulse generator and the mixing amplifier, are preferably omitted.

Figures 15 and 16 show the present standard television signal. A brief description of the standard signal which modulates the amplitude of the carrier the portions thereof representing synchronizing and equalizing pulses will be given in the following paragraphs. The blanking pulses 101 occur between the video signals 102 which correspond to the video signals 26 of Figure 2 of the drawings. The horizontal synchronizing impulses 103 occur during the blanking periods. Figure 16 shows the composite signal which is derived when scanning of an even field of view is completed. A blanking pulse 106 occurs equivalent in length to several scanning lines 102. The vertical synchronizing pulse 107 occurs during the long blanking pulse and serves to return the beam or other scanning instrumentality to the top of the frame or field of view in preparation for scanning of the next field. It will be noted from Figure 16 that the next vertical scanning pulse 107a is displaced one-half line with respect to the preceding horizontal pulse and, therefore, equalizing pulses 109 and 109a are substituted for the horizontal pulses in Figures 15 and 16 respectively. The equalizing impulses occur at double the frequency of the horizontal synchronizing pulses and alternate equalizing impulses coincide in time with the horizontal impulses. It will be seen from an inspection of Figures 15 and 16 that a horizontal synchronizing impulse or an equalizing impulse always occurs at the same time interval before the beginning of a vertical synchronizing impulse. The vertical synchronizing impulses therefore are always of the same wave form in the integrating circuit of the synchronization detector and separator 110 shown on Figure 14 of the drawings. This piece of apparatus 110 is of the same type used in known television systems and includes a demodulator or detector, a differentiation circuit and an integrating circuit. The last named circuits serve the purpose of separating the horizontal from the vertical synchronizing impulses on the basis of wave form. The impulses derived from the separating circuits are applied to the horizontal sweep generator 112 and the vertical sweep generator 114 respectively. These sweep generators 112 and 114 function in the usual manner to supply currents or voltages to the deflecting coils or plates of the picture tube 116 suitable for controlling the scanning beam of the picture tube 116.

The signal from the intermediate frequency amplifier, which includes frequency variations representing the video signal is passed to the limiter which effectively removes the amplitude changes representing the horizontal and vertical synchronizing impulses. The output of the limiter which contains only frequency variations is demodulated in the discriminator and is applied to control the scanning beam of the picture tube 116 or other scanning instrumentality for reproducing the picture.

While the invention has been described and explained in detail in connection with several illustrative embodiments thereof, it is to be understood that the invention may be embodied in other forms and, therefore, the invention is not limited except as indicated by the terms and scope of the appended claims.

From the foregoing, it will be seen that there has been provided a new system of transmitting picture signals by way of a frequency-modulated signal carrier wave and it has been shown that such transmission has considerable advantages over the conventional transmission of amplitude modulated waves. It has also been shown that the same signal carrier wave can also be frequency-modulated by synchronizing signals, whereby perfect synchronization can be obtained by means of signals which are much simpler than those required for satisfactory synchronization when conventional carrier amplitude modulation is used. Finally, there have been provided systems in which the frequency of the signal carrier wave is modulated in accordance with the picture signals while either its frequency or amplitude, or both, are modulated in accordance with the line or field synchronizing signals or both.

I claim:

1. In a television receiver adapted to receive a signal carrier wave having its frequency modulated within a predetermined range in accordance with video signals and having its frequency shifted to two different frequencies outside said range in accordance with line and field synchronizing signals, in combination, means for receiving said signal carrier wave, frequency discriminating means for deriving video signals from said carrier wave, picture reproducing means controlled by said video signals, a first frequency discriminating circuit substantially responsive only to a carrier frequency outside of said range characteristic of line synchronizing signals, a second frequency discriminating circuit substantially responsive to a carrier frequency outside of said range characteristic of said field synchronizing signals, said first and second circuits having applied thereto video signal components and synchronizing signal components, means for deriving line synchronizing signals from said first circuit, means for deriving field synchronizing signals from said second circuit, and means for controlling said picture reproducing means in

accordance with said line and field synchronizing signals.

2. In a television receiver adapted to receive a signal carrier wave having its frequency modulated within a predetermined range in accordance with video signals and having its frequency shifted to two different frequencies outside said range in accordance with line and field synchronizing signals, in combination, means for receiving said carrier wave, means for converting said wave into a second frequency-modulated carrier wave of intermediate frequency, frequency discriminating means for deriving video signals from said second carrier wave, picture reproducing means controlled by said video signals, a first frequency discriminating circuit substantially responsive only to the frequency of said second carrier wave characteristic of line synchronizing signals, a second frequency discriminating circuit substantially responsive only to the frequency of said second carrier wave characteristic of field synchronizing signals, means for applying said second carrier wave including video signal components and synchronizing signal components to said first and said second circuits, separate demodulating means coupled to said first and said second circuits for separately deriving therefrom line and field synchronizing signals, and means for controlling said picture reproducing means in accordance with said synchronizing signals.

3. In a television receiver adapted to receive a signal carrier wave frequency modulated in accordance with video signals, having frequency components within a predetermined range of frequencies, and having its frequencies shifted to two different frequencies outside said range in accordance with line and field synchronizing signals, in combination, means for receiving said signal carrier wave, frequency discriminating means for deriving video signals from said frequency modulated carrier wave, picture reproducing means controlled by said video signals, a first frequency discriminating circuit substantially responsive only to a carrier frequency characteristic of line synchronizing signals, a second frequency discriminating circuit substantially responsive to a carrier frequency characteristic of said field synchronizing signals, means for applying video signal components and synchronizing signal components to said first and second circuits, demodulating means for deriving line synchronizing signals from said first circuit, demodulating means for deriving field synchronizing signals from said second circuit, and means for controlling said picture reproducing means in accordance with said line and field synchronizing signals.

4. In a television receiver for the reception of a signal modulated carrier wave having its frequency modulated within a predetermined range in accordance with picture signals and having its

frequency shifted to two different frequencies outside said range in accordance with line and field synchronizing signals, the combination of a tuner for receiving such carrier wave, a limiter for limiting said received carrier wave to a predetermined amplitude, a frequency discriminator for deriving picture signals from said limited carrier wave, a picture reproducer controlled by said derived picture signals, a first frequency discriminating circuit substantially responsive only to a carrier frequency outside of said range characteristic of line synchronizing signals, a second frequency discriminating circuit substantially responsive only to a carrier frequency outside of said range characteristic of said field synchronizing signal, connections between said limiter and said first and second circuits for impressing thereon said limited carrier waves, and line and field sweep devices connected respectively with said first and second circuits and associated with said picture reproducer for controlling said picture reproducer in accordance with said line and field synchronizing signal.

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REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
2,212,968	Finch	Aug. 27, 1940
2,086,833	Walton	July 13, 1937
2,186,898	D'Humy	Jan. 9, 1940
1,941,068	Armstrong	Dec. 26, 1933
2,075,071	Usselmab	Mar. 30, 1937
2,254,435	Loughren	Sept. 2, 1941
2,296,919	Goldstine	Sept. 29, 1942
2,342,943	Kell	Feb. 29, 1944
1,548,895	Mertz	Aug. 11, 1925
2,290,229	Finch	July 21, 1942
2,289,157	Whitaker	July 7, 1942
2,326,740	Artzt	Aug. 17, 1943
2,290,517	Wilson	July 21, 1942
2,084,700	Ogloblinsky	June 22, 1937
2,293,233	Wheeler	Aug. 18, 1942

FOREIGN PATENTS

Number	Country	Date
433,295	Great Britain	Aug. 6, 1935

OTHER REFERENCES

"Radio Facsimile by Sub-Carrier Frequency Modulation," by R. E. Mathes and J. N. Whitaker. R. C. A. Review, October, 1939.

"The Service Range of Frequency Modulation," by M. G. Crosby, R. C. A. Review, January, 1940.

"Electronics" for February 1940, pages 26 and 30–32, article by C. W. Carnahan entitled "Frequency Modulation." Magazine published by McGraw-Hill Publishing Co., New York, N. Y.

R. C. A. Review, July 1940, vol. 5, No. 1 (pages 31 to 50).