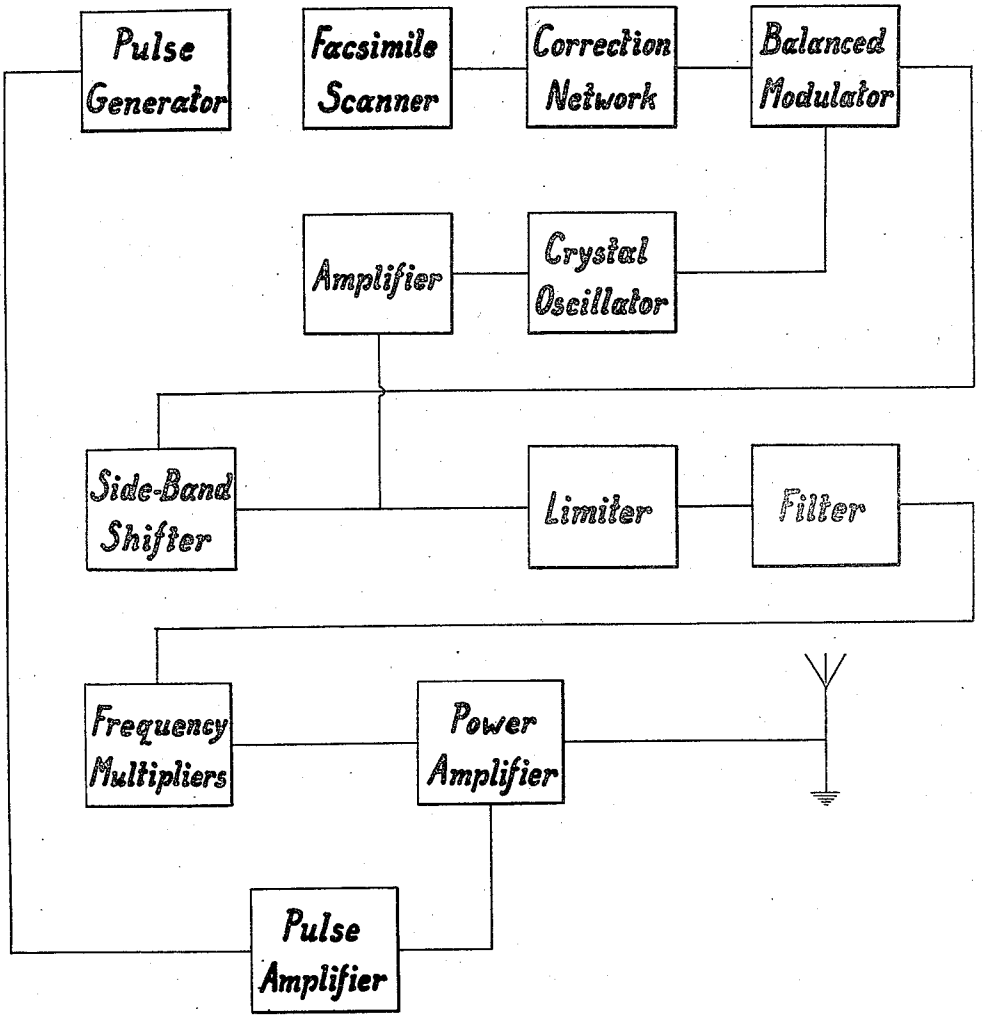
July 21, 1942. W. G. H. FINCH 2,290,229

FREQUENCY MODULATION FACSIMILE TRANSMISSION

Filed April 5, 1940 5 Sheets-Sheet 1

Fig. 1



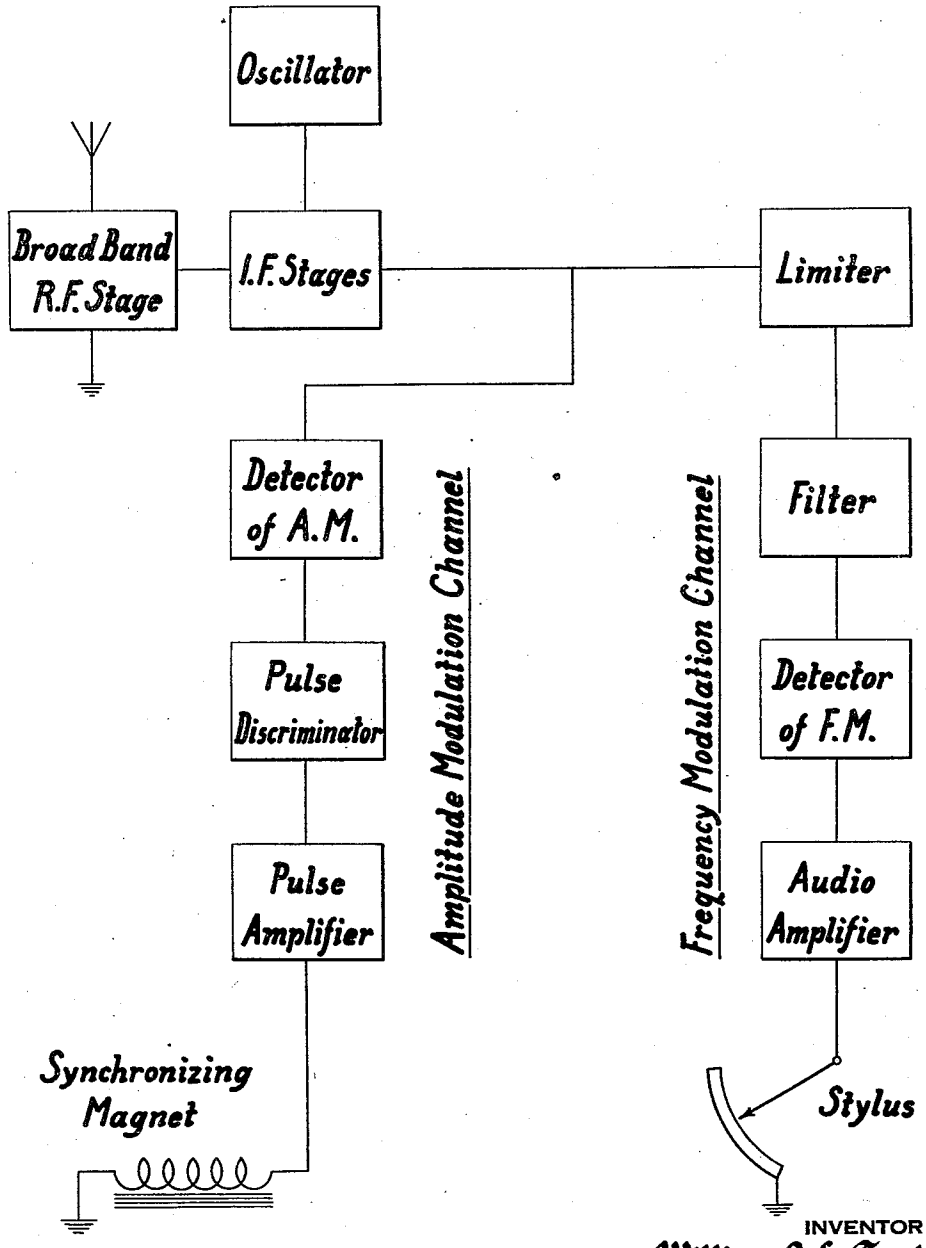
INVENTOR
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July 21, 1942. W. G. H. FINCH 2,290,229

FREQUENCY MODULATION FACSIMILE TRANSMISSION

Filed April 5, 1940 5 Sheets-Sheet 2

Fig. 2



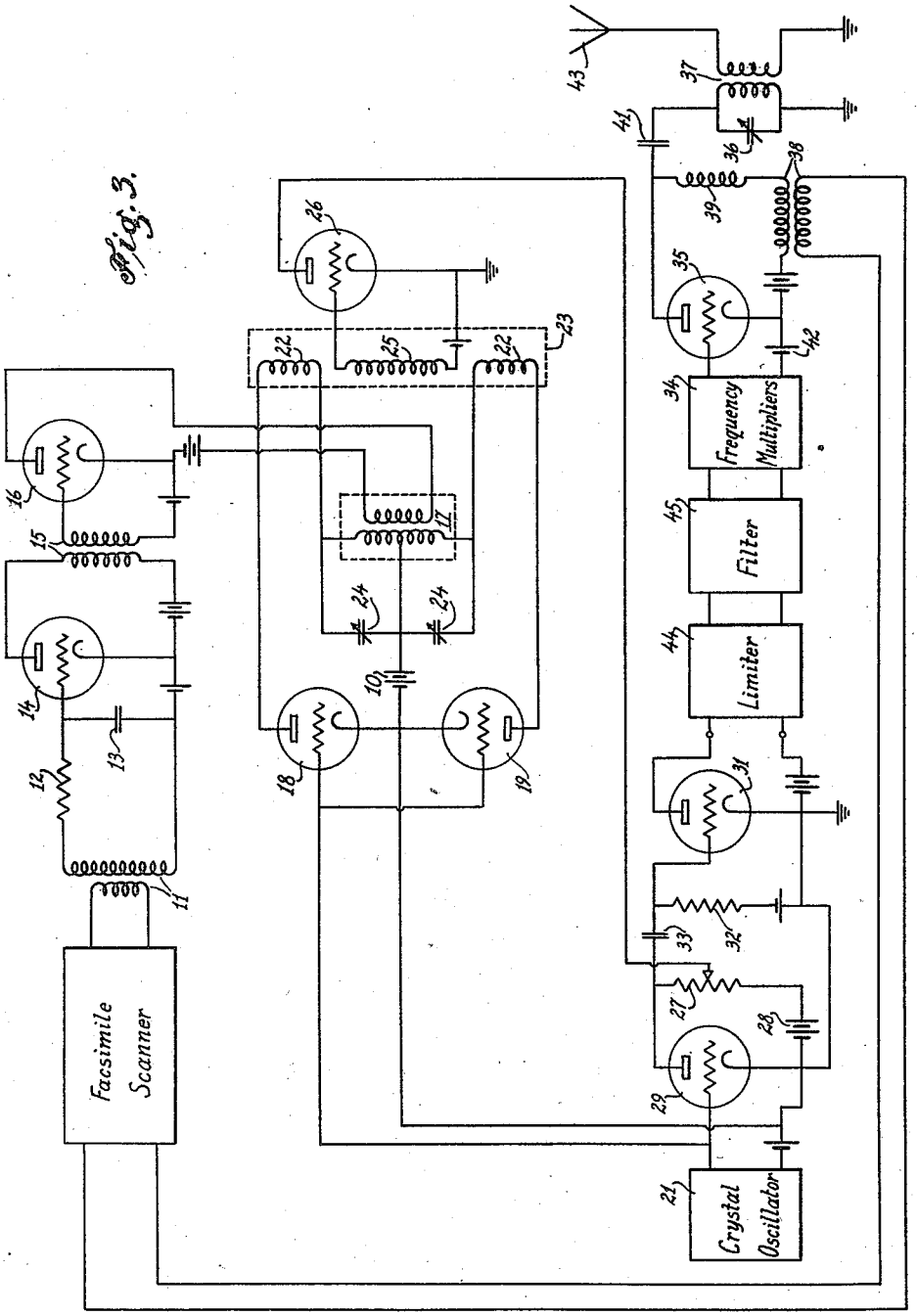
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FREQUENCY MODULATION FACSIMILE TRANSMISSION

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Fig. 3.



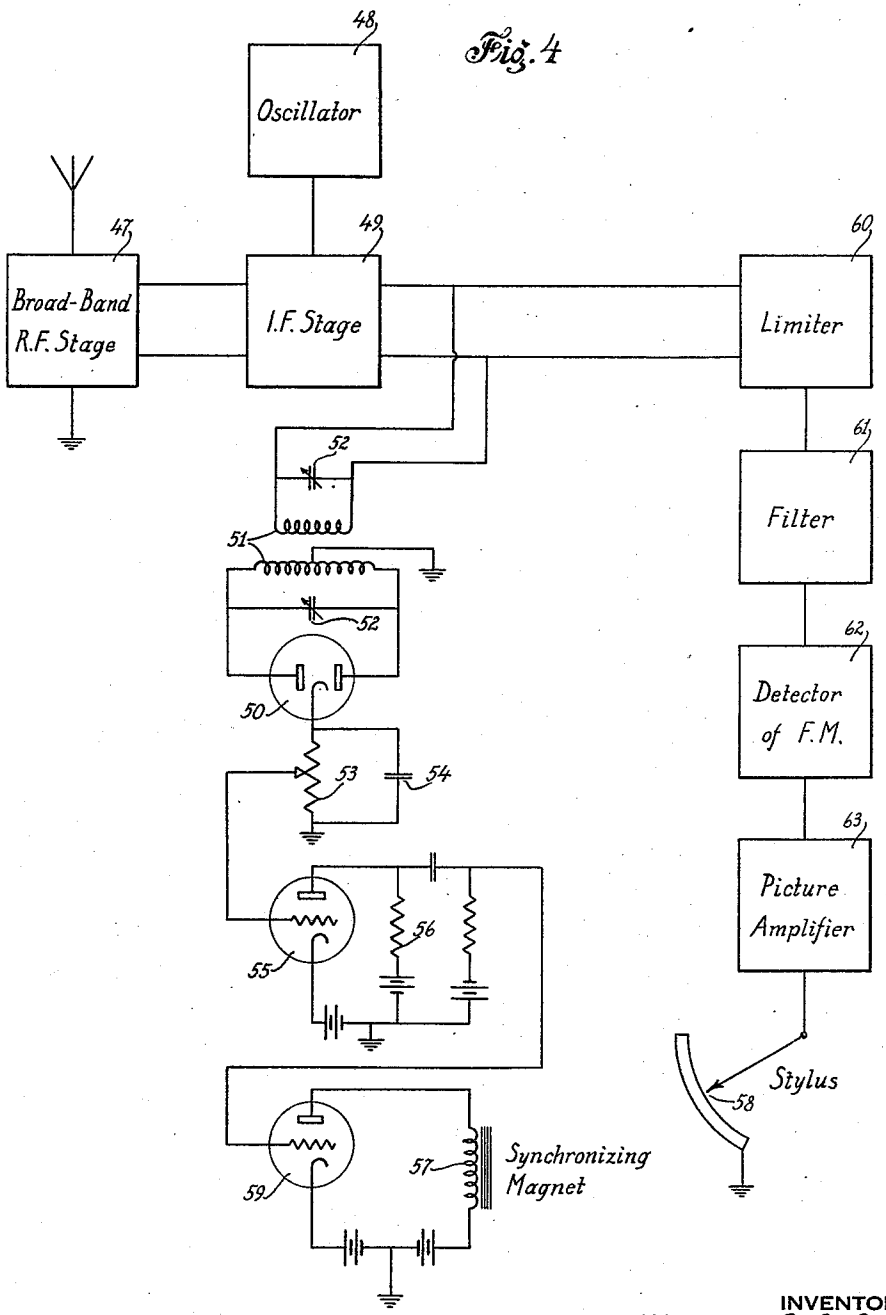
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FREQUENCY MODULATION FACSIMILE TRANSMISSION

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Fig. 4



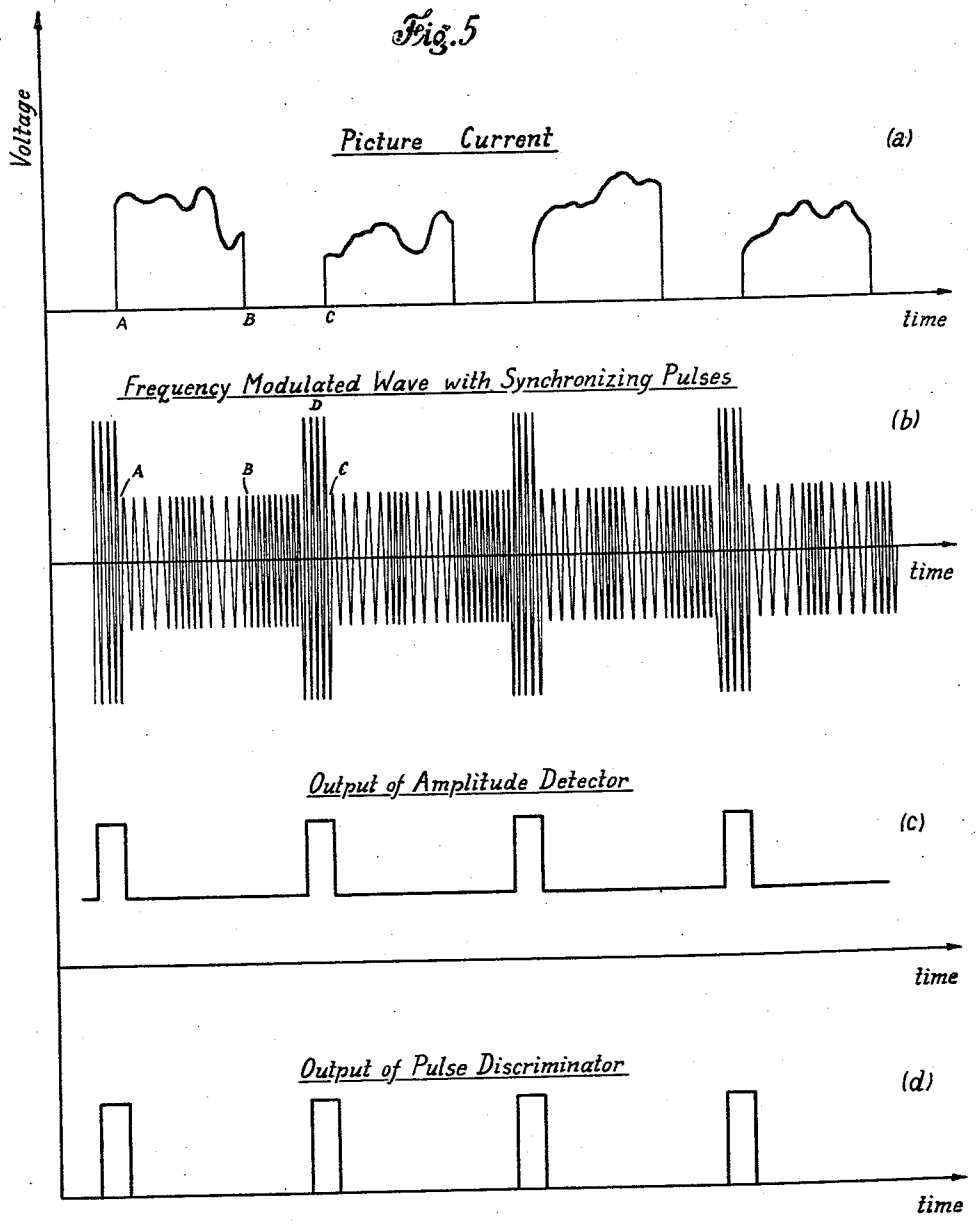
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FREQUENCY MODULATION FACSIMILE TRANSMISSION

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Fig. 5



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Patented July 21, 1942 2,290,229

UNITED STATES PATENT OFFICE

2,290,229

FREQUENCY MODULATION FACSIMILE TRANSMISSION

William G. H. Finch, Newtown, Conn.

Application April 5, 1940, Serial No. 328,137

3 Claims. (Cl. 178—6.6)

My invention relates in general to the field of facsimile transmission and reception but more specifically concerns the application of frequency modulation transmission methods to picture transmission.

Frequency modulation offers several distinct advantages over the more common amplitude modulation methods when transmitting intelligence in the form of speech or pictures. The most notable advantage obtained in the transmission of speech by broad band frequency modulation is the low noise level and the minimizing of general disturbances, such as man-made or natural static. This may briefly be explained by the fact that both man-made or static noises generally are of a nature which affect the amplitude of the signals, but cannot produce fluctuations of frequency.

When applied to picture transmission, frequency modulation offers additional advantages, not only in the reduction of the faults, streaks, and spots due to interference and noise, but in improvements in the transmission channels and simplification of the problem of synchronization.

The quality of a received frequency modulation signal is dependent upon the maximum frequency deviation or band width. For a given signal the quality at the receiver will increase rapidly as the band width is extended, and for high fidelity transmission, broad band modulation is utilized, the frequency deviation sometimes being as great as 100 kilocycles.

Low band frequency modulation may be employed with band widths not exceeding that of the picture signal itself. Although the reduction of faults will not be the maximum attainable, such a system would be justified by the economy and the saving of space in the frequency spectrum.

Since the common facsimile image is transmitted with a band width of a few thousand cycles, I contemplate as one form of my invention to employ the ordinary "broadcast" frequencies with a 10 kilocycle band width for picture transmission by frequency modulation.

The superposition of intelligence such as a picture signal upon the carrier wave in a frequency modulation transmitter is accomplished by low level modulation of the oscillator after which the modulated wave is successively amplified up to the power amplifier. This is alternative to high level modulation in which the picture signal is first amplified to relatively high power level and then superimposed on the carrier. The high picture level required for high level modulation results in considerable distortion of the high frequency components of the wave because of the broad band of frequencies which must necessarily be amplified. With low level modulation of the carrier, the band width becomes relatively small, and a more linear amplification characteristic is obtained. I accordingly contemplate low level picture modulation in my system.

In facsimile transmission systems, it is necessary to periodically transmit a synchronizing pulse in order to maintain synchronism between the scanning mechanisms at the transmitter and receiver. The most practical method heretofore employed involves an arrangement for switching the receiver when the receiver scanning mechanism has reached a predetermined point for receiving a synchronizing signal in a special synchronizing circuit which by-passes the picture receiving circuit. The moving part of the receiver is operated start-stop i. e. it is caused to rotate just enough faster than the transmitter as to insure its return to the starting point just ahead of the transmitter. The receiver then stops and awaits a synchronizing pulse which the transmitter sends out as soon at it reaches the starting position. On receipt of the synchronizing pulse the receiver starts into movement again, in synchronism with the transmitter.

This has some disadvantages. Foremost it is based on deliberately driving the receiver slightly out of synchronism with the transmitter. Moreover, it materially reduces speed limits and operation determined by the speed with which the receiver can be stopped and started again without mechanical strains.

Frequency modulation, when applied to facsimile transmission, offers several new possibilities insofar as synchronization is concerned. Synchronizing signals may be transmitted on the frequency modulated carrier by means of a distinct frequency component removed from the picture band by some ten or twenty per cent. At the receiver, a high selectivity filter is paralleled with the input to separate the synchronizing signal from the picture for the purpose of applying it to the synchronizing means, which may be a magnet controlled friction clutch or the like.

In television, where two types of synchronizing pulses are required, one for scanning and one for framing, two distinct frequencies associated with two sharply tuned circuits to accomplish separation, effect proper synchronization.

The objection to this synchronizing method is that the maximum band width allowable can not be gainfully applied to the picture to secure

a faithful reproduction; but must be reduced by the aforementioned ten or twenty per cent in order to transmit the synchronizing signal.

I have discovered that I may employ the full width of this signalling channel for simultaneous transmission of picture and synchronizing pulses which may be applied to facsimile transmission and to television transmissions. More broadly, I have discovered that I may secure the benefits of two channel transmission over what has heretofore been regarded as a single channel by employing a composite system of frequency modulation and amplitude modulation.

Moreover in accordance with my invention I can transmit by radio a synchronizing signal which can be used for driving synchronous motive transmitter and receiver equipment for maintaining synchronism instead of a start-stop system.

In the conventional system for picture transmission, the receiver employs a switch operated by a cam on the scanning unit, which is timed to interrupt the current to the receiver stylus and complete the circuit to the synchronizing means for the duration of the synchronizing pulse. Such switching is undesirable because of constant wear and other electrical problems but is a necessary precaution in the amplitude modulation system to prevent the synchronizing pulse from recording as a black streak along the edge of a picture. Also, if amplitude pulses are used for synchronization in a facsimile recorder using the discoloration of dry paper to produce the image, a large current pulse passing through a point in the paper constitutes a fire hazard.

In accordance with my invention the synchronizing signals are transmitted by variations in the amplitude of the carrier. Inasmuch as the amplitude of the frequency modulated picture signal is constant and the frequency of the amplitude modulation synchronizing signal is constant discrimination between the picture and the synchronizing pulse at the receiver is made upon an amplitude basis in accordance with the novel circuit I have devised and I may therefore eliminate the switch and its operations.

Such discrimination is effected by my novel circuit arrangement for discriminating between the frequency modulated signals and the amplitude modulated signals, in which the frequency detector in the frequency modulated circuit operates only in response to variations in frequency, to produce corresponding variations in amplitude in its output and will therefore pass through only the frequency modulated signals which are of constant amplitude but vary in frequency, and in which the amplitude detector in the amplitude modulated circuit operates only in response to variations in amplitude to produce corresponding variations in amplitude in its output and will therefore pass through only the amplitude modulated synchronizing signals.

I thus employ two circuits, through one of which I pass the frequency modulated signals and through the other the amplitude modulated signals.

Thus, the synchronizing circuit and the picture circuit may be in parallel without any switching means between them. There can be no interference between the two signals mentioned because a frequency modulation receiver responds only to the rate of change of frequency deviation and the amplitude modulating frequency and its associated side bands are constant.

The combination of the frequency modulation and amplitude modulation of a single carrier may be carried one step further in which the picture signal may be employed to modulate the frequency of the carrier, as in the foregoing, while a constant frequency continuously modulates the amplitude of the carrier. This constant frequency may be employed to effect synchronization between the transmitting and receiving ends of a facsimile system avoiding the necessity of the start-stop system with its inherent mechanical limitations. If the amplitude modulating signal is controlled at the transmitter, it may be employed to maintain synchronism between devices at both transmitter and receiver by the expedient of locking an oscillating circuit at the receiver into synchronism with the original source of alternating currents. These two currents of identical frequency may then be employed to drive their respective facsimile systems in synchronism with each other.

Another application of my novel combined amplitude and frequency modulation scheme would be in television systems in which I transmit two distinct amplitude variations each of constant frequency on the frequency modulated carrier, which after detection at the receiver operate both the scanning and framing means, namely, the cathode ray tube deflecting plate oscillators. Such a system eliminates the need for the synchronizing pulses of an amplitude nature transmitted upon the amplitude modulated carrier, which pulses are quite often a source of interference due to the relatively high frequency at which they occur.

It is therefore an object of my invention to provide for a novel method of transmitting images by frequency modulation.

Another object of my invention is to combine frequency and amplitude modulation in one transmitter and employ a single carrier.

Still another object of my invention is to provide means for the transmission of synchronizing pulses by amplitude variations on a carrier which is frequency modulated in accordance with the picture signals.

A further object of my invention is to provide means for a system of transmitting television signals by frequency modulation along with synchronizing signals of an amplitude nature, which cannot be a source of interference.

Still a further object of my invention is to provide a novel synchronizing means.

These objects and others will become evident from the following specification taken in conjunction with the accompanying drawings in which:

Figure 1 is a block diagram of a frequency modulation transmitter coupled with a facsimile scanning unit.

Figure 2 is a block diagram illustrating one embodiment of a receiver designed to receive and to discriminate between amplitude and frequency modulation signals.

Figure 3 is a schematic wiring diagram of the transmitter of Figure 1.

Figure 4 is a schematic diagram of the receiver indicating the various circuit details.

Figure 5 is a diagram illustrating the wave form of the current in successive stages of the facsimile system.

Referring now more particularly to Figures 1 and 3 there is shown one possible embodiment of a frequency modulation transmitter coupled to a facsimile scanner. Figure 1 illustrates gen-

erally the various scanning and frequency modulation circuits grouped into a block diagram.

The facsimile scanner may be of any well known form as the oscillating arm, the endless chain type or optical form similar to those disclosed in my patents Nos. 2,047,863 and 2,136,789. The other components of the transmitter concern themselves chiefly with the conventional frequency modulation circuits and my novel system for coupling the synchronizing pulse generator thereto.

For purposes of illustrating my invention, I have herein described and illustrated the frequency modulation system disclosed in Patent No. 1,941,068, although it will be understood that I am not limited to this type of frequency modulation transmitter or receiver and may use any other practical form.

Tracing through the block diagram of Figure 1 the facsimile scanner converts the light fluctuations impinging upon the photoelectric cell into corresponding amplitude variations of current in the output circuit. These amplitude fluctuations, in the manner well known in the art as shown in the aforementioned patents, are of an alternating current nature as shown in Figure 5a and are applied to the input of the frequency modulation transmitter for producing variations in frequency varying from the carrier in accordance with amplitude fluctuations as will now be described.

Referring to Figure 3, the frequency modulator circuit includes a low frequency crystal oscillator 21 for generating the carrier wave. The natural frequency of the crystal is some submultiple of the finally radiated carrier frequency and must be multiplied in a circuit which will hereinafter be described, in order to raise the frequency to that required for transmission. The output of the crystal oscillator 21, as shown, is fed to two distinct channels, one of which is the balanced modulator, comprising the vacuum tubes 18 and 19 and their associated circuits.

The balanced modulator is an amplitude modulator which suppresses the carrier from the output circuit.

The grids of the modulator tubes 18 and 19 are driven by the oscillator 21 which supplies the carrier wave. Modulation is effected by varying the plate voltages applied to tubes 18 and 19 through the source of electromotive force 10, by means of the modulating currents that flow in the transformer 17, coupled into the plate circuits of the tubes.

The plate circuits of each of these tubes, which may be triodes or of multigrid construction, each inclues one-half of the primary winding of the output transformer 22—22.

This output circuit is made non-reactive by placing the variable condensers 24—24 in series with the transformer primaries 22—22 and in parallel with the secondary of the modulating transformer 17, and tuning the condensers to make the net reactance zero for frequencies in the order of the oscillator natural frequency.

The sections 22—22 of the output transformer primary are differentially coupled to the secondary 25 and since the voltages applied to the control grid elements of tubes 18 and 19 are in phase, the net voltage produced in the secondary 25 will be zero, for the conditions of no modulating current.

Therefore the carrier wave does not appear in the secondary 25 of the output transformer 23. When modulating current flows in the transformer 17 the plate voltage of one tube will be driven to a higher value than the other, and the plate current of one will increase while that of the other decreases proportionately. Under these conditions a voltage will be induced in the secondary 25 which will be applied to the grid of the amplifier 26.

The voltage induced in the transformer secondary 25 will be an amplitude modulated wave, from which the carrier has been excluded. Therefore, the resultant current contains only the side band frequencies generated in the modulator. Furthermore, it should be noted that since the plate circuits of the vacuum tubes 18 and 19 have been tuned to resonance, the impedance of the circuits is purely resistive. Therefore, the current in the plate circuit is in phase with the oscillator voltage applied to the control grids.

The potential drop across the inductive branch of the circuit, namely, the transformer primary 22, is 90° ahead of the current therein, and depending upon the sense of the coupling between the primary and secondary of this transformer the voltage induced in 25 will be either 90° leading or lagging in phase with respect to the oscillator voltage applied to the control grid.

The balanced modulator comprising the vacuum tubes 18 and 19, and the associated transformers 17 and 23, have therefore served to generate the side band frequencies displaced 90° in phase with respect to the oscillator voltage. In Figure 1 this is schematically represented in the block diagram by the series circuit of the balanced modulator and side band shifter.

The shifted side bands are amplified by the vacuum tube 26 which employs resistor 27 for a plate circuit load and battery 28 for a source of E. M. F.

At this point another circuit comprising the oscillator 21 and the vacuum tube amplifier 29, may be traced to the resistor 27 and the battery 28, which functions merely to amplify the current at oscillator frequency. Inasmuch as the load resistance 27 is common to both the oscillator amplifier and the side band amplifier, the voltage impressed across it will at all times be the resultant of two waves; first, the constant amplitude carrier wave and second, the side bands of the amplitude modulator, the phase displacement between the two waves being 90°. In accordance with the principles described in Patent No. 1,941,068 the resultant wave will be the frequency modulated carrier, in which the frequency deviations from the carrier are in accordance with the amplitude variations.

The frequency modulated voltage developed across resistor 27 is coupled to the amplifier circuit 31 by means of the condenser 33 and the resistor 32 and the amplified output is coupled to the current limiter 44, to smooth any amplitude fluctuations which may be present in the frequency modulated wave. The current limiter may be a saturating transformer, vacuum tube, or the like, and any harmonics generated therein are removed by the band pass filter 45.

The frequency multiplier 34 into which the output is then passed, functions to raise the frequency of the frequency modulated wave up to the desired carrier, and comprises several frequency doublers and triplers. At this stage, the frequency modulated wave is in its final form, but at a low power level. The discussion of the power amplifier will be completed in a later paragraph.

The signal or modulating current employed to drive the balanced modulator is derived from the circuit comprising the photoelectric cell in the facsimile scanner, the correction network and an amplifier. In order to produce a change in carrier frequency which is constant over all ranges of modulating frequency, it is necessary to introduce a correction network which varies the modulating voltage inversely with the signal frequency. The correction network comprises the vacuum tube **14** and the network composed of the resistor **12** and condenser **13**. The modulation input is connected into this circuit by the transformer **11** and the voltage that actuates the control grid of the tube is the voltage which is developed across the condenser **13**. In a series circuit composed of resistance and capacitance the voltage across the capacitance will vary inversely with the frequency of the voltage injected into the circuit, if the resistance is high compared to the impedance of the condenser for the frequencies of modulation.

Therefore the output of the vacuum tube **14** will have the desired characteristic and this modulating voltage is coupled to the vacuum tube amplifier **16** by means of the coupling transformer **15**. The output of the amplifier contains the primary of the modulating transformer **17**, and the modulating voltage is amplified sufficiently to drive the balanced modulator to its full capacity.

Summarizing the above, picture signals produced in the facsimile scanner are first impressed across a correction network which varies the modulating voltage inversely with the signal frequency. These signals then modulate a low frequency carrier generated by the crystal oscillator in the balanced modulator which suppresses the carrier. The output, consisting of the side bands of the amplitude modulated signals are shifted 90° and applied to the original carrier to produce frequency modulated signals of constant amplitude. Any fluctuations in amplitude are eliminated by the limiter. Any harmonics in these signals are eliminated by the band pass filter. The resulting frequency modulated picture signals are then passed through a series of multiplications and raised to the carrier frequency, then passed through a power amplifier and transmitted, as by radiation from an antenna. As will now be clear, I employ the full band width of my carrier channel for these pictures.

In accordance with my invention, I contemplate transmitting a synchronizing frequency over this same carrier channel without requiring the need of a switching operation and attendant contact trouble at the receiver.

The synchronizing signal generated in a second circuit originating at the facsimile scanner will be traced to the power amplifier through the pulse generator and pulse amplifier. This circuit comprises the usual mechanical switching arrangement or any other means for generating synchronizing pulses at the facsimile scanner, such as shown in my Patent No. 2,047,863. The synchronizing pulses may be generated by switching a direct current circuit which may comprise a series circuit of batteries, switches, and resistors as disclosed in my above referred to patent.

Switching such a circuit will generate a pulse of rectangular wave form for a predetermined interval. The pulses are amplified by conventional amplifiers if the magnitude thereof is not sufficient to drive the modulator. The amplified pulses are then supplied to the frequency modulation transmitter circuits through a transformer, or they may be coupled directly to the grid of the last stage of amplification. The synchronizing pulse will occur at a time when the picture modulating current is equal to zero and accordingly there will be no frequency modulation of the carrier wave.

The synchronizing pulse will therefore serve to vary the amplitude of the transmitted wave for a period equal to the duration of the pulse. The energy of the pulse may be supplied to the transmission circuit by the high level modulation scheme illustrated in Figure 3, wherein the synchronizing circuit is coupled through transformer **38** to the plate circuit of the power amplifier **35**.

However, the synchronizing pulse circuit may be coupled to the grid of the power tube **35** so that the power requirement will not be too great, or may be coupled to any of the preceding voltage amplifiers, if the point at which coupling is accomplished follows the current limiter **44**.

The output circuit of the power amplifier **35** comprises two parallel circuits, as illustrated in the embodiment of Figure 3, namely the pulse modulating circuit and the resonant tank circuit. The modulating circuit comprises the secondary of the modulating transformer **38** and inductance **39** which restricts the flow of radio frequency energy to the pulse generator and to the battery **42**. The tank circuit is composed of the coil **37** and the variable tuning condenser **36**, the distinction between this and tank circuits used in conventional amplitude modulation transmitters being that the coil **37** must have a relatively low Q to provide for a broad band characteristic. The condenser **41** is placed in series with the tank coil to preclude the short-circuiting of the battery **42** by the low resistance tank coil **37**.

The coil is coupled to the antenna **43** whereat the wave is radiated into space. The radiated wave is of the form indicated by Figure 5*b*, and may be analyzed in the following manner: Between points A and B on the generated wave the carrier frequency is alternately varied above and below the mean value in accordance with the fluctuations of modulating picture currents, illustrated in Figure 5*a*. At point B the scanning cycle has been completed and the frequency remains constant until point C where the next cycle begins. It is at this frequency that the synchronizing pulse occurs and that the amplitude varies as shown at D. It should be emphasized that the synchronizing pulse occurs at carrier frequency immediately after which the succeeding scanning stroke begins and proceeds to modulate the frequency. This process is repeated once for each cycle of the scanning arm.

Since the synchronizing pulse occurs at carrier frequency there is little danger of interference between this frequency and communicati·n circuits of neighboring frequencies. Therefore, the magnitude of the pulse may be considerable to facilitate discrimination at the receiver between the amplitude pulse and any fluctuations in the amplitude of the wave due to disturbances such as lightning, ignition interference and the like.

An important characteristic of the transmitting circuit described, and of all other frequency modulation transmitters, is that the signal is converted to variations in frequency, and that any constant frequency which may be superimposed thereon will not affect or interfere with the signal. Therefore the circuit employed to superimpose the synchronizing signals upon the carrier

may be modified to continuously modulate the amplitude of the carrier with a constant frequency which is some multiple of the scanning frequency. Inasmuch as the synchronizing signal comprises a single predetermined frequency of constant amplitude, the amplitude modulation will comprise two side bands of constant frequency which may, as will be described hereinafter, be selectively filtered at the receiver and employed to operate the synchronizing means. Moreover, there can be no interference between this synchronizing signal and the picture signal as long as the synchronizing frequency remains constant, as may easily be effected by the well known frequency control circuits.

This amplitude modulation may be effected by the high level circuit illustrated by Figure 3 or by low level modulation of the output of the frequency multiplier.

The facsimile scanner may be used directly to generate the synchronizing frequency or it may be generated by a crystal controlled oscillator and employed at both the transmitter and the receiver to operate the synchronizing means as will be described hereinafter.

The frequency modulation circuits herein illustrated are not limited to facsimile transmission but may be also employed in other communications systems as for high speed picture transmission of the type encountered in television. Of course, the signal frequencies of a television modulator comprise a much greater band than the facsimile signals but this simply necessitates changes in the design of the tuned circuits, which is easily performed by those skilled in the art.

When this frequency modulation circuit is employed for television the amplitude modulator shown may be again modified to apply two distinct frequencies to the carrier wave, one of which may be coupled to the scanning and the other to the framing circuit.

The receiver of course will require a channel tuned to the amplitude side band frequencies in order to discriminate between the signalling waves and the synchronizing frequency signals which are then applied to their respective saw tooth oscillators to maintain synchronism between the cathode ray tube beam and the similar beam in the television camera. At the receiver, as at the transmitter, discrimination between the different waves may be simply accomplished because the frequency modulation detector may be employed to act as a filter to the amplitude modulation. Since the frequency modulator detector responds only to the rate of change of frequency, an amplitude modulation of constant frequency will represent zero current in the output circuit. Furthermore interference between the amplitude fluctuations and the picture signal may be avoided because the current limiter connected in series with the frequency modulation detector excludes any variations in amplitude.

One possible embodiment of the receiving circuit is illustrated herein by Figures 2 and 4. The receivers illustrated are multi-channel circuits, each channel responding to a predetermined wave form.

The voltage induced in the antenna circuit will have a wave form similar to that illustrated by Figure 5*b*, if the amplitude synchronizing pulses described are employed with the facsimile transmitter. The first stage of the receiver may be a broad band radio frequency amplifier **47**, the band width being determined by the maximum frequency deviation allowable. After suitable amplification the wave may be passed to the discriminating circuits or the wave may be passed into the first detector **49** of a conventional superheterodyne receiver. Here the radio frequency signal is heterodyned to the desired intermediate frequency by means of the local oscillator **48**, and the output of this circuit is the voltage which may be passed to the selective circuits.

The receiver illustrated has two channels connected in parallel in the output circuit of the intermediate frequency amplifier **49**. These circuits comprise the frequency modulation and amplitude modulation detectors and have the synchronizing means and picture recording means connected into the corresponding circuits.

The frequency modulation detector may be of the type designed to convert the frequency variations to corresponding fluctuations in amplitude. Before reaching the actual detector, however, the incoming wave is first passed through a current limiter **60** which functions to smooth the wave and exclude any variations in amplitude as its counterpart **44** in the transmitter. The current limiter **60** may be a saturable element such as a transformer or a saturable vacuum tube device. The numerous harmonics generated in the limiting circuit may be excluded by means of the band pass filter **61** connected in series therewith.

Although the limiter serves primarily to reduce the amplitude variations encountered in atmospheric and other disturbances it also serves to block the increased amplitude synchronizing pulses.

As a result the stylus current will be zero at the time of the synchronizing pulse. The frequency modulation detector **62** illustrated schematically in the block diagram is again not limited to any particular construction but may be composed of any practical, operable circuit elements.

The output of the detector is a current varying in accordance with the photoelectric cell light variations in the transmitter. This current may be amplified by an audio amplifier **63** and supplied to the stylus **58** of the recorder if the recorder is of the dry paper type, or the picture current variations may be translated by any other of the well known facsimile means, as shown in my Patents 2,047,863 and 2,136,789.

The second channel of my novel combination of amplitude and frequency modulation detectors is a detector which may be of the type commonly employed in amplitude modulation receivers and may comprise a grid bias detector or a rectifier detector or the like. If the broad band system of modulation is employed, the tuned circuits of the amplifiers and detectors will have to be designed accordingly.

The circuit illustrated in Figure 4 is a full wave rectifier detector **50** where the incoming wave is coupled to the plates through the coupling transformer **51**, which is tuned to the proper frequency by means of the condensers **52—52**. The rectified output appearing between the cathode and ground is passed through a suitable load resistance **53** that is shunted by a condenser **54** of small capacity. The condenser functions to reduce the radio frequency potential difference appearing across the load resistance **53**. The voltage generated across the resistance **53** is therefore similar to that shown by Figure 5*c* and it may be seen that the amplitude remains substantially constant throughout the picture cycle except for the amplitude pulse of rectangular wave form employed for synchronization.

The radio frequency by-pass condenser **54** will serve to eliminate the radio frequency components of the incoming signal even though they are varying considerably as a result of the frequency modulation.

This voltage is then applied to the grid of the pulse discriminator **55**, sufficiently biased below cut-off to prevent current from flowing in **55** until the grid potential exceeds the constant amplitude of the frequency modulated wave. Therefore the potential appearing across the discriminator load resistance **56** will contain only the amplitude pulses as illustrated in Figure 5*d*.

After suitable amplification in the vacuum tube amplifier **59**, the pulses are directly connected to the synchronizing means **57** which may be in the form of a magnet operating a friction clutch or the like.

Discrimination between the frequency modulation signal and the amplitude pulse could also be effected in this circuit by suitably biasing the cathode of the rectifier **50**, that is, the cathode could be maintained at a positive potential, high enough to prevent current flow until the large amplitude synchronizing pulse occurs.

Also, it is possible to dispense with the discriminator circuit by adjusting the synchronizing means to be inoperative for values of current less than the amplitude of the frequency modulated wave and operative only for currents exceeding this, such as the synchronizing pulse.

The output of the synchronizing circuit may therefore be connected directly to the synchronizing means without the need for interposed switches or other circuit interruptors. The synchronizing current will operate the magnet once following each scanning line for a time controlled by the switching operation at the transmitter.

Therefore both the picture and the synchronizing circuits have been connected to the input circuit of the receiver without means for selecting the individual signals other than the receiver itself, and as a result the need for a switch operated by a cam on the scanning mechanism has been eliminated.

In another form of my invention I employ frequency modulation of the carrier both for the transmission of picture signals and of the synchronizing signals. In this case I eliminate the circuit from the pulse generator to the pulse amplifier and power amplifier and instead connect the pulse generator of the facsimile mechanism by means of switching mechanisms, as is now commonly well known and as is illustrated in my Patent No. 2,047,863, to the correction network. At the end of each scanning cycle a synchronous signal is then transmitted by my pulse generator through the correction network to the balanced modulator and thence on as described above for the transmission of a synchronous signal by frequency modulation.

In this case I do not employ any separate discriminating amplitude modulating channel at the receiver but instead merely pass the synchronizing signal through the frequency modulation receiver circuit where it is switched after selection as described in my above referred to patent, to maintain the receiver in synchronism with the transmitter.

In the above I have described two forms of my invention in one of which I have eliminated the need of switching equipment. In these synchronizing systems the receiver is usually rotated slightly faster than the transmitter and brought to a stop at the beginning of each scanning cycle to await the receipt of the synchronizing pulse from the transmitter which is received when the transmitter has reached the corresponding starting position of the scanning cycle. In response to this synchronizing pulse the receiver scanner then starts up for the next cycle.

This has the disadvantage, where large facsimile units are employed, of mechanically limiting the speed of operation since such speed is dependent upon the mechanical limitations in stopping and starting the receiver in each cycle.

It has long been recognized as preferable that the transmitter and receiver be rotated continuously and at synchronous speed. This is possible where the transmitter and receiver are connected to the same source of alternating currents which may then be used to drive synchronous motors at the transmitters and receivers. Such is the case, for example, where the driving power line and where the transmitter is also driven from power from the same local power line.

In broadcasting operations however it is rarely possible to have the transmitter on the same power supply with the receivers which are to be operated by the transmitters. In such cases, the transmission of alternating currents for supplying the power for driving the transmitter and receiver has been suggested, but this requires a separate synchronizing channel or as is the case of television where the same source of alternating current is employed for providing the sweep circuits of the cathode ray tubes a part of the signals channel must be devoted for this purpose which correspondingly reduces the accuracy and efficiency of transmission of the signals.

In accordance with my invention I may, without sacrificing any of the signalling channel, simultaneously transmit a synchronizing frequency for driving the transmitter and receiver continuously in synchronism with each other.

In this form, an alternating current of predetermined frequency is employed to drive the facsimile scanner at the transmitter. This alternating current is then impressed upon the frequency modulated carrier through an amplitude modulator after the picture carrier has passed through the current limiter, or the carrier frequency may be amplitude modulated by the synchronizing frequency independently of the frequency modulated wave. This wave may then be transmitted along with the frequency modulated picture wave. By this means, an amplitude modulation of the carrier by the synchronizing pulse is produced.

Dispensing with the discriminating circuit **55**, the constant frequency wave may be amplified sufficiently and may be employed to maintain synchronism between a device at the receiver and a similar unit at the transmitter.

In order that sufficient power may be provided, the synchronizing signal at the receiving end may be amplified through thyratrons which may operate in response to the synchronizing frequency to generate amplified signals at the frequency of the synchronizing signals for directly operating a motor; or the energy of the synchronizing signal may be employed to act as a trigger for controlling the synchronous motion of a tuning fork driven from a local source of power, the incoming synchronizing signal thus maintaining the tuning fork at synchronous speed. The output of the fork may be amplified to supply sufficient power to drive a motor for operating the receiver. The power method of amplifying the signal at the receiver is not a part of my invention, as any

well known means may be employed. Under these conditions of operation, the scanning mechanism at the receiver will lock into step with that of the transmitter. However, it is also necessary to determine that the phase relationship between the two scanning mechanisms is identical, that is, it is necessary for both scanning arms to start and complete their strokes simultaneously. To accomplish this "phasing operation" the friction clutch of the start-stop system may be utilized, and at the beginning of each transmission, and if necessary during the period of transmission, an amplitude pulse may be transmitted to operate the synchronizing magnet and bring both scanning devices into step.

It will thus be seen that I have provided a system in which a single carrier may be frequency modulated for the transmission of one form of communication signal and may be amplitude modulated for the transmission of another form of signal, each without interfering with the other and proper discriminating circuits at the receiving end may be employed for separating or filtering each of these signals from each other for operation of the receiver.

I claim:

1. In a frequency modulation facsimile system, scanning means for producing signals varying in amplitude in accordance with the lights and shades of a picture to be transmitted, a source of carrier current, means for frequency modulating said carrier current at constant amplitude in accordance with the amplitude variations of said picture currents, means coacting with said scanning means for generating synchronizing pulses at the termination of each picture scanning cycle, means for increasing the amplitude of said carrier in accordance with said synchronizing pulses, means for transmitting said frequency and amplitude modulated carrier, facsimile receiver means for receiving said transmitted wave comprising a frequency modulation detector in circuit with the picture recording means, and an amplitude modulation detector in circuit with the recorder synchronizing means, said frequency modulation detector being non-responsive to amplitude variations and said amplitude modulation detector being responsive only to signals of magnitude greater than said constant amplitude frequency modulated wave, said synchronizing means coating with the output signals of said amplitude modulation detector for maintaining said picture recording means in synchronism with said transmitter scanning means.

2. In a frequency modulation facsimile system, scanning means for producing signals varying in amplitude in accordance with the lights and shades of a picture to be transmitted, a source of carrier current, means for frequency modulating said carrier current at constant amplitude in accordance with the amplitude variations of said picture currents, means for generating synchronizing pulses at the termination of each picture scanning cycle, means for increasing the amplitude of said carrier in accordance with said synchronizing pulses, means for transmitting said frequency and amplitude modulated carrier, said frequency modulation detector being non-responsive to amplitude variations and said amplitude modulation detector only being responsive to signals of magnitude greater than said constant amplitude frequency modulated wave, means for periodically arresting the motion of said recording mechanism, and means in the output circuit of said amplitude modulation detector for starting said recording mechanism on receipt of said synchronizing signal.

3. In a frequency modulation facsimile system, scanning means for producing signals varying in amplitude in accordance with the lights and shades of a picture to be transmitted, a source of carrier current, means for frequency modulating said carrier current at constant amplitude in accordance with the amplitude variations of said picture currents, means for generating a constant frequency synchronizing signal and a first synchronous motor energized by said constant frequency signal for driving the transmitting scanning mechanism in synchronism with said synchronizing signal, means for continuously modulating the amplitude of said frequency modulated wave in accordance with said synchronizing signal, means for transmitting said frequency and amplitude modulated carrier, facsimile receiver means for receiving and recording said transmitted signals, including a frequency modulation detector in circuit with said recording means, an amplitude modulation detector, means for amplifying the output frequency of said amplitude modulation detector and means for operating said recording means in synchronism with said output frequency, said last mentioned means comprising a second synchronous motor energized by said amplified output frequency, said synchronous motor being similar to said first transmitting scanning synchronous motor, said synchronous motor driving said recording means.

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