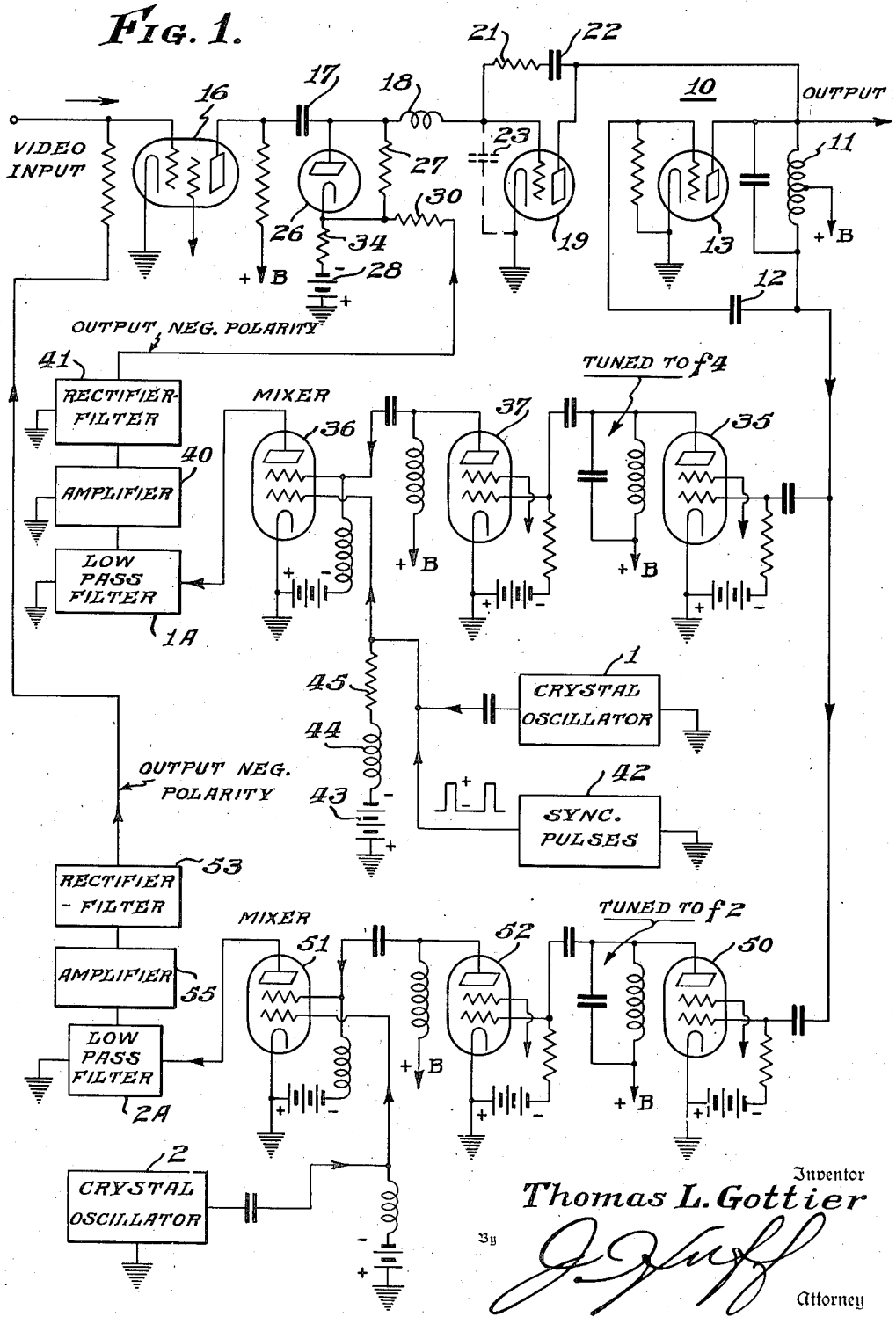
Dec. 22, 1942. T. L. GOTTIER 2,305,864

TELEVISION SYSTEM

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FIG. 1.



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FIG. 2.

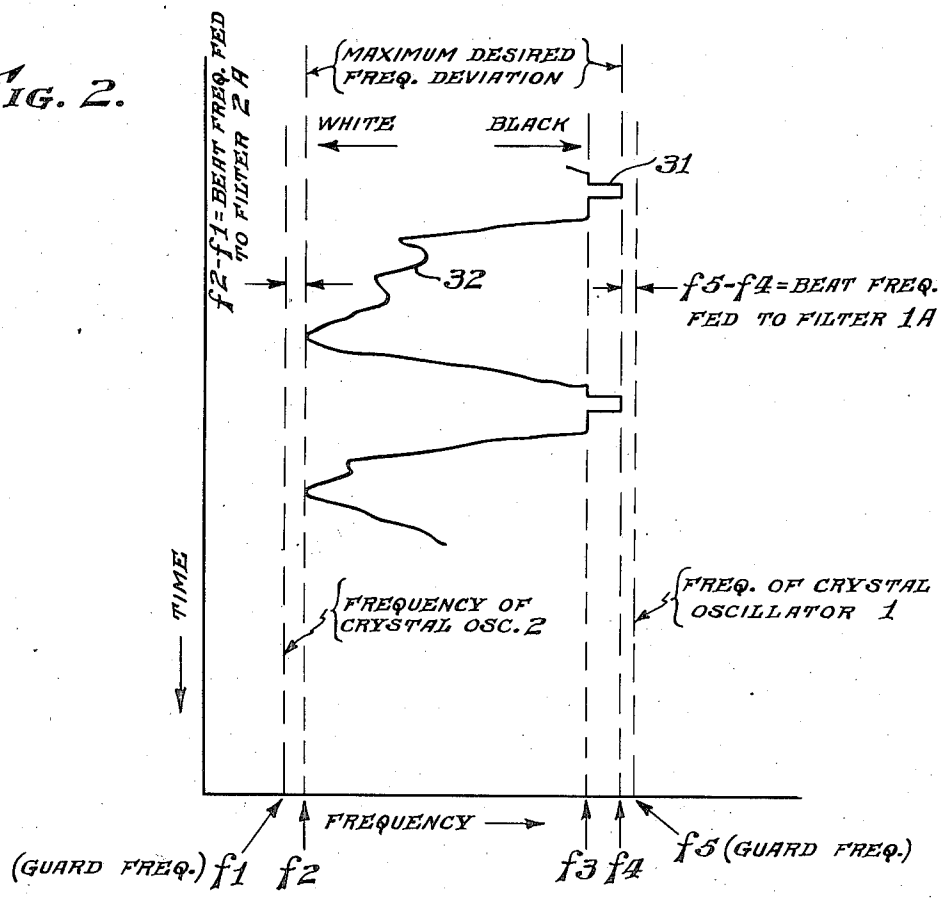


FIG. 3.

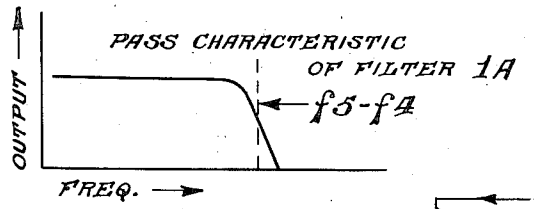


FIG. 4.

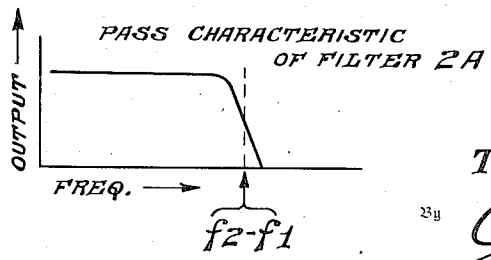
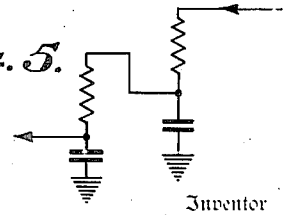


FIG. 5.



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2,305,864

TELEVISION SYSTEM

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Application December 31, 1940, Serial No. 372,470

14 Claims. (Cl. 178—7.2)

My invention relates to the art of frequency modulation, particularly as applied to television or other picture transmission systems.

In television systems employing amplitude modulation, it has been the usual practice to so modulate a carrier wave that the synchronizing pulses of the modulating signal modulate the carrier wave either to a predetermined maximum amplitude or to a predetermined minimum amplitude such as zero carrier, the two ways of modulating being referred to as negative and positive modulation, respectively. The modulating signal referred to is a mixture of synchronizing pulses and picture signal, the said pulses being in the direction of "black" in the picture.

An object of the present invention is to provide an improved frequency modulation system for a television or picture transmitter which retains the above-mentioned feature of having the synchronizing pulses always go to a predetermined modulation level. This predetermined level in a frequency modulation system is, of course, a predetermined frequency.

A further object of the invention is to provide an improved frequency modulation system for a television or picture transmitter in which the picture signals in the white direction, or at least certain frequency components thereof, cannot exceed a predetermined modulation level.

A further object of my invention is to provide an improved method of and means for holding the frequency deviation or frequency swing of a frequency-modulated carrier wave within predetermined frequency limits.

A still further object of the invention is to limit that frequency deviation of a frequency-modulated carrier wave which is produced by certain frequency components, such as low frequency components, of the modulating signal.

In one preferred embodiment of the invention, the peaks of the synchronizing pulses are held at the desired predetermined level or frequency by utilizing a stable oscillator, such as a crystal oscillator, to provide voltage at a guard frequency and by beating this voltage with the output of the carrier wave oscillator. The resulting beat frequency voltage is fed to a frequency discriminating network such as a low pass filter having a cut-off frequency close to the beat frequency. If the beat frequency changes, the filter output changes, and this change is utilized to shift the carrier wave oscillator frequency back to a value where the peaks of the synchronizing pulses swing the oscillator to the desired predetermined frequency.

If desired, the frequency swing of the carrier wave oscillator may be prevented from swinging beyond a fixed frequency limit in the direction of white in the picture by employing a method similar to that just described but differing in that the controlling voltage supplied from the discriminator network is applied to an amplifier in the modulating signal channel. In the example under consideration, it is so applied to a video amplifier that any increase in the amplitude of the low frequency components of the picture signal in the white direction which swings the oscillator beyond the frequency limit will lower the gain of this amplifier.

The invention will be better understood from the following description taken in connection with the accompanying drawings in which

Figure 1 is a circuit diagram of a portion of a television transmitter embodying my invention,

Figure 2 is a diagram which is referred to in explaining the operation of the invention,

Figures 3 and 4 are curves showing the pass characteristics of certain filters shown in Figure 1, and

Figure 5 shows one form of frequency discriminator that may be used to replace the low pass filters of Figure 1.

Referring to Figure 1, there is shown a television transmitter comprising a carrier wave oscillator 10 which may be of a well-known type having a tuned circuit 11, one end of which is coupled to the grid of the oscillator tube 13 by a condenser 12.

The output of oscillator 10 is frequency-modulated by the video or television signal input which is amplified by a video amplifier 16 and applied through a blocking condenser 17 and an inductance coil 18 to the grid of a reactance tube 19.

The function of the reactance tube 19 is to vary the effective reactance across the oscillator-tuned circuit 11 in accordance with the voltage amplitude variations on the grid of the reactance tube. Thus, a frequency-modulated carrier is obtained. In the particular example shown, the tube 19 is connected across the tuned circuit 11 by a connection from the plate of tube 19 to the plate of oscillator tube 13 and by a connection from the cathode of tube 19 to ground. A resistor 21 connected between the grid and plate of tube 19 through a blocking condenser 22 functions, together with the grid-cathode capacity indicated at 23, to provide the necessary out-of-phase component for the reactance tube operation.

A diode 26 is provided to reinsert the direct current component of the video signal. The D. C.

reinsertion circuit operation is well known and may be explained briefly as follows: The synchronizing pulses are of positive polarity at the plate of diode 26 and will cause a flow of diode current whenever they drive the diode plate positive with respect to its cathode. This puts a charge on coupling condenser 17. At the end of a pulse the condenser 17 loses a small part of its charge through a path which includes a high impedance resistor 27 whereby the D. C. voltage across condenser 17 may always have a value determined by the peaks of the synchronizing pulses as measured from the A. C. axis of the signal.

The battery 28 applies a negative bias to the control grid of tube 19 so that the synchronizing pulses plus the radio frequency voltage never drive the grid of tube 19 positive with respect to its cathode.

Inductance coil 18 is provided to separate the electrode capacities of tubes 19 and 26 for the purpose of holding up the high frequency response. Coil 18 also functions to prevent the oscillator from feeding back radio frequency energy.

Referring now to my method and circuit for holding the peaks of synchronizing pulses at a fixed frequency, a stable oscillator, such as a crystal oscillator 1, is provided which produces a voltage at a frequency slightly beyond the said fixed frequency representing peaks of synchronizing pulses.

Referring to Figure 2, the frequency of oscillator 1 is represented as $f5$ and may be referred to as a guard frequency. The frequency at which the peaks of synchronizing pulses are to be held is represented as $f4$. The synchronizing pulses and the picture signal which comprise the modulating video signal are indicated at 31 and 32, respectively.

The output of oscillator 1 is fed to the grid of a mixer tube 36. Also, signal from the carrier wave oscillator 10 is fed to another grid of mixer tube 36 through amplifier tubes 35 and 37. Amplifier 35 may have its plate circuit tuned to the frequency $f4$ representing peaks of synchronizing pulses. The voltages at frequencies $f4$ and $f5$ beat in the mixer tube 36 to produce a voltage at the difference frequency $f5—f4$ which is supplied to a frequency discriminating circuit such as a low pass filter 1A.

The filter 1A may have the characteristic shown in Fig. 3, the beat frequency $f5—f4$ being located slightly beyond the filter cut-off frequency, as indicated in Fig. 3, when the peaks of pulses 31 are at the correct frequency $f4$. If the beat frequency changes, the voltage output of filter 1A changes. This output is amplified in an amplifier 40 and supplied to a rectifier-filter unit 41. By rectifying and filtering the amplified output in the unit 41, there is obtained a biasing voltage which is supplied to the grid of reactance tube 19 through a low impedance resistor 30 and through resistor 27 and coil 18, this biasing voltage changing in accordance with any change in the filter output. In the example shown, the rectifier 41 supplies a negative bias. A low impedance resistor 34 connected between the diode 26 and battery 28 provides the necessary impedance between ground and the point at which it is applied. If the frequency representing the peaks of pulses 31 (Fig. 2) increases to a frequency higher than $f4$, there is a decrease in the beat frequency fed to filter 1A with the result that there is an increase in the negative bias on the reactance tube 19 which lowers the frequency of oscillator 10, bringing it back to the desired value $f4$ during the said peaks.

Preferably, the above-described circuit is operated in one of two ways to insure that the frequency which beats with the guard frequency $f5$ is the one representing the peaks of pulses 31. One way is to key the mixer tube 36 by means of positive pulses supplied from a suitable source 42 so that a beat frequency is produced in the mixer only during the occurrence of the synchronizing pulses 31. When operated in this way the mixer 36 is biased to cut-off in the absence of keying pulses by means of a biasing source 43. An inductance coil 44 and a resistor 45 are provided merely to provide impedance in the grid circuit of the mixer tube so that voltages from units 1 and 42 will appear on the control grid of the mixer tube 36.

Obviously the keying pulses preferably should occur during and only during the occurrence of the synchronizing pulses 31. For this reason it may be desirable to make the keying pulses narrower than the pulses 31.

When the circuit is operated with keying pulses, the amplifier tube 37 may be biased to operate as a class A amplifier or it may be biased to pass only the larger amplitude frequency components. Also, the amplifier 35 may be untuned if preferred.

The second way of operating the circuit is to omit the keying pulses, lower the negative bias from source 43 so that the mixer 36 will at all times mix any signals applied to its grids, and, finally, to bias tube 37 so that only the frequency components of high amplitude will pass through it and mix with the crystal oscillator output. The bias on tube 37 usually should be sufficient to bias the tube beyond cut-off.

For the case where it is desired to hold the peaks of pulses 31 at $f4$ and not merely to keep them from exceeding $f4$, the bias on the reactance tube 19 should be such that, if the deviation control circuit were made ineffective, these peaks would deviate the carrier frequency to a frequency slightly higher than $f4$. With this adjustment the control circuit is effective to prevent a frequency deviation in either direction.

It may be desirable to provide a guard frequency such as the frequency $f1$ indicated in Fig. 2 to prevent the picture signal in the white direction from shifting the oscillator frequency too far on the low frequency side. Assume, for example, that it is desired to prevent the frequency deviation of the carrier wave oscillator 10 from going beyond $f2$. This is accomplished by means of a circuit similar to the control circuit previously described and includes a stable oscillator such as a crystal oscillator 2 feeding into a mixer tube 51. The frequency modulated output of oscillator 10 also feeds into the mixer tube 51 through amplifier tubes 50 and 52. The amplifier 50 preferably is tuned to the frequency $f2$. The tube 52 is biased to pass only the higher amplitude signal components.

The output of mixer tube 51 is supplied to a frequency discriminating circuit such as a low pass filter 2A having the characteristic shown in Fig. 4.

The output of filter 2A is amplified by an amplifier 55 rectified in a suitable rectifier-filter circuit 53 to produce a negative biasing voltage which is applied to the grid of the video amplifier 16.

So long as the frequency deviation of oscillator 10 does not go beyond $f2$, the lowest beat fre-

quency produced in the mixer tube 51 is equal to $f2-f1$. If the deviation goes beyond this point, the beat frequency is lower than before, more signal passes through filter 2A and there is an increase in the negative bias applied to the grid of video amplifier 16. This lowers the gain of amplifier 16 whereby the frequency swing of oscillator 10 in the direction of "white" in the picture is reduced.

It will be understood, however, that when both of the above-described control circuits are used at the same time the reduction in video amplifier gain does not cause the peaks of the synchronizing pulses 31 to go to a frequency lower than $f4$. They are always held at the modulation level $f4$ by the control bias applied to the reactance tube 19. Perhaps it should be noted with respect to the level setting of the synchronizing pulse peaks at a definite level such as frequency $f4$ that if the carrier wave oscillator had no frequency drift these peaks would always be set substantially at $f4$ by the D. C. inserter diode 26 and its associated circuit. Since some frequency drift of the oscillator 10 may be expected, the use of the control circuit embodying my invention is desirable to insure a level setting at the desired frequency.

It will also be understood from the foregoing that my invention may be applied to a frequency modulation system by employing a guard frequency on either side of the frequency deviation of the carrier wave without using a guard frequency on the other side, or by employing both guard frequencies at the same time, as illustrated.

It should be mentioned that there may be certain limitations in the effectiveness of the guard frequency $f1$ used on the white side of the picture signal. These limitations may also apply to a more or less extent to the application of one or more guard frequencies to a carrier wave which is frequency modulated by audio signals such as speech. It is well known that a frequency modulated carrier wave when analyzed is found to have sine wave components consisting of signal components at a carrier frequency and at a plurality of side band frequencies. Both the amplitude of the side band components and the width of the side bands depends upon the ratio of the absolute frequency deviation to the imposed modulating frequency, this ratio being known as the frequency modulation index. This is described in the July 1930 Proceedings of the I. R. E. in the article on Frequency modulation, by van der Pol, pages 1194 to 1205.

If the modulation index is large, the side band frequency is of large amplitude and signal at this frequency may be passed through a tube biased beyond cut-off to the exclusion of other side band components which have been produced by higher frequency modulating components. Thus, on the synchronizing pulse side of the frequency modulated carrier wave, the side band component which is produced by the fundamental component of the line frequency pulse is of large amplitude compared with the side band components produced by the picture signal itself. In one embodiment of the invention the frequency deviation is 0.75 megacycle each side of the carrier frequency and the fundamental frequency of the line pulses is 13,230 per second, giving a modulation index of about 60. Because of this, the operation is entirely satisfactory in the embodiment where the circuit is operated without keying the mixer tube.

On the "white" side of the modulated carrier there is no regularly recurring signal such as the synchronizing pulses on the "black" side. However, a picture ordinarily contains some strong low frequency components as a result of the difference in shading (i. e. dark gray, light gray, etc.) of comparatively large areas in a picture. For these components the modulation index is high enough so that the amplitude of a side band frequency component at or near the limit frequency $f2$ is greater than that of other side band components whereby the tube 52 (Fig. 1) may be biased to pass this one component to the exclusion of adjacent frequency components. Therefore, components having frequencies close enough to the frequency $f2$ to cause additional beat frequencies that might be pased by the filter 2A are prevented from passing into the mixer tube 51. It is assumed, of course, that it is one of the above-mentioned strong low frequency components that swings the carrier wave oscillator to the limit frequency $f2$.

In some cases it may be desirable to peak the high frequency components of the transmitted signal. This may be desirable for the purpose of increasing the signal-to-noise ratio in a region where a large amount of noise is present. This may be accomplished by peaking the high frequency components of the modulating signal before it is applied to the modulator tube. As a result, the high frequency components will swing the carrier wave oscillator beyond the guard frequencies since the guard frequency control circuits will not respond to the high frequency deviations. These control circuits will continue to function as previously described, however.

It will be apparent that my invention is not limited to the use of the specific circuits and apparatus previously described. For example, the low pass filters may be replaced by suitable resistor-capacitor networks having the desired frequency characteristic. Such a network is illustrated in Fig. 5.

Also, the use of an oscillator to produce a beat frequency is not essential although it is used in the preferred embodiment of the invention. By properly designing the frequency discriminator 1A, for example, voltage at the frequency $f4$ itself may be supplied thereto with frequency $f4$ located on the slope of the frequency-response curve. In this case the slope of the discriminator characteristic curve should be reversed since an increase in the deviation frequency beyond $f4$ now is an increase, rather than a decrease in the control frequency. A high pass filter will give this reversed slope.

For filter design reasons or the like, it may be desirable to lower the frequency $f4$ at a point in or preceding the control circuit, as by frequency division, in an embodiment where the stable guard frequency oscillator is not used.

I claim as my invention:

1. A picture transmitter comprising a carrier wave oscillator, means for frequency modulating said oscillator in accordance with a signal comprising picture signals and recurring synchronizing pulses whereby the peaks of said pulses are represented by a certain maximum deviation of said oscillator frequency, means for deriving a frequency control bias which changes in response to a change in the frequency representative of said peaks, and means for controlling the frequency of said oscillator in accordance with said control bias.

2. A picture transmitter comprising a carrier

wave oscillator, means for frequency modulating said oscillator in accordance with a signal comprising picture signals and recurring synchronizing pulses whereby the peaks of said pulses are represented by a certain maximum deviation of said oscillator frequency, means for deriving a frequency control bias which changes in response to a change in the frequency representative of said peaks, and means for applying said control bias to the frequency modulating means.

3. A picture transmitter comprising a carrier wave oscillator, means including a reactance tube for frequency modulating said oscillator in accordance with a signal comprising picture signals and recurring synchronizing pulses whereby the peaks of said pulses are represented by a certain maximum deviation of said oscillator frequency, and means for causing the peaks of said pulses always to swing the output of said oscillator to a predetermined frequency, means for producing a frequency control bias which changes in response to a change in the frequency representative of said peaks, and means for applying said control bias to said reactance tube.

4. A picture transmitter comprising a carrier wave oscillator, means for frequency modulating said oscillator in accordance with a signal comprising picture signals and recurring synchronizing pulses which go to a fixed voltage level whereby the peaks of said pulses are represented by a certain maximum deviation of said oscillator frequency, means for causing the peaks of said pulses always to swing the output of said oscillator to a predetermined frequency regardless of the tendency of said oscillator to drift in frequency, said last means including means for deriving a frequency control bias which changes in response to a change in the frequency representative of said peaks, and means for controlling the frequency of said oscillator in accordance with said control bias.

5. The invention according to claim 4 wherein said last means comprises means for producing a guard frequency and for beating said guard frequency with said predetermined frequency.

6. In a picture transmitter having an oscillator, the method which comprises frequency modulating said oscillator by picture signals and recurrent synchronizing pulses, deriving from the resulting frequency modulated signal a control voltage which changes in response to changes in the frequency representative of the peaks of said pulses, and utilizing said control voltage to make a predetermined frequency always representative of said peaks.

7. A frequency modulation transmitter comprising a carrier wave oscillator, means for producing a modulating signal containing periodically recurring pulses which go to a predetermined voltage level, means for varying the frequency of said oscillator in accordance with the instantaneous amplitude of said modulating signal, and means for limiting said frequency variation so that it does not exceed a certain frequency limit for the lower frequency components of said pulses, said last means comprising a frequency discriminating circuit, means for applying to said frequency discriminating circuit a voltage having a frequency which varies in accordance with any changes in the frequency representative of said pulse peaks to obtain a control voltage which varies in amplitude in accordance with changes in said last mentioned frequency, and means for so controlling the frequency of said oscillator in accordance with said control voltage that said frequency limit is not substantially exceeded.

8. A frequency modulation transmitter comprising a carrier wave oscillator, means for varying the frequency of said oscillator in accordance with the instantaneous amplitude of a modulating signal, and means for limiting said frequency variation so that it does not exceed a certain frequency limit for at least certain frequency components of said signal, said last means comprising a stable oscillator which produces a voltage at a guard frequency located just beyond said frequency limit, means for mixing the voltages having said limit frequency and said guard frequency to produce a voltage at the difference frequency, a frequency discriminating circuit to which said last voltage is applied whereby there is obtained a control voltage which varies in amplitude in accordance with changes in said beat frequency, and means for so controlling the frequency of said oscillator in accordance with said control voltage that said frequency limit for at least said components is not substantially exceeded.

9. A frequency modulation transmitter comprising a carrier wave oscillator, means including a reactance tube for varying the frequency of said oscillator in accordance with the instantaneous amplitude of a modulating signal, an amplifier through which the modulating signal is supplied to said reactance tube, and means for limiting said frequency variation so that it does not exceed a certain frequency limit for at least certain frequency components of said signal, said last means comprising a stable oscillator which produces a voltage at a guard frequency located just beyond said frequency limit, means for mixing the voltages having said limit frequency and said guard frequency to produce a voltage at the difference frequency, a frequency discriminating circuit to which said last voltage is applied whereby there is obtained a control voltage which varies in amplitude in accordance with changes in said beat frequency, and means for controlling the gain of said amplifier in accordance with said control voltage so that said frequency limit is not substantially exceeded.

10. A frequency modulation transmitter comprising a carrier wave oscillator, an amplifier for amplifying a modulating signal, means for varying the frequency of said oscillator in accordance with the instantaneous amplitude of said modulating signal, and means for limiting said frequency variation so that it does not exceed a certain frequency limit for at least certain frequency components of said signal, said last means comprising a frequency discriminating circuit, means for applying to said frequency discriminating circuit a voltage having a frequency which varies in accordance with any changes in the frequency representative of said certain frequency components to obtain a control voltage which varies in amplitude in accordance with changes in said last-mentioned frequency, and means for controlling the gain of said amplifier in accordance with said control voltage so that said frequency limit is not substantially exceeded.

11. A radio transmitter comprising a carrier wave oscillator, means for frequency modulating said oscillator in accordance with a modulating signal which includes control pulses which go to a predetermined voltage level whereby the peaks of said pulses are represented by a certain maximum deviation of said oscillator frequency,

control means including a stable oscillator for causing the peaks of said pulses always to swing the output of said oscillator to a predetermined frequency, and means for effectively connecting said control means to said oscillator during and only during the occurrence of said control pulses.

12. A radio transmitter comprising a carrier wave oscillator, means including a reactance for frequency modulating said oscillator in accordance with a signal comprising a modulating signal and recurring control pulses whereby the peaks of said pulses are represented by a certain maximum deviation of said oscillator frequency, and means for causing the peaks of said pulses always to swing the output of said oscillator to a predetermined frequency, means including a stable oscillator for producing a frequency control bias which changes in response to a change in the frequency representative of said peaks, keying means for making said stable oscillator effective for producing said bias during and only during the occurrence of said control pulses, and means for applying said control bias to said reactance tube.

13. A picture transmitter comprising a carrier wave oscillator, means for frequency modulating said oscillator in accordance with a signal comprising picture signals and recurring synchronizing pulses which go to a fixed voltage level whereby the peaks of said pulses are represented by a certain maximum deviation of said oscillator frequency, limiter means through which frequency modulated signal is passed for removing substantially all the signal except that representative of said pulses, and control means responsive to said limited signal for causing the peaks of said pulses always to swing the output of said oscillator to a predetermined frequency regardless of the tendency of said oscillator to drift in frequency.

14. A frequency modulation transmitter comprising a carrier wave oscillator, means including a reactance tube for varying the frequency of said oscillator in accordance with the instantaneous amplitude of a modulating signal, an amplifier through which the modulating signal is supplied to said reactance tube, and means for limiting said frequency variation so that it does not exceed a certain frequency limit for at least certain frequency components of said signal, said last means comprising a stable oscillator which produces a voltage at a guard frequency located just beyond said frequency limit, limiter means through which frequency modulated signal is passed for removing substantially all the signal except that representative of low frequency large amplitude components, means for mixing the voltages having said limited signal and said guard frequency signal to produce a voltage at the difference frequency, a frequency discriminating circuit to which said last voltage is applied whereby there is obtained a control voltage which varies in amplitude in accordance with changes in said beat frequency, and means for controlling the gain of said amplifier in accordance with said control voltage so that said frequency limit is not substantially exceeded.

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