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Ishigaki et al.

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[54] **MAGNETIC RECORDING AND/OR REPRODUCING SYSTEM**

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[73] Assignee: **Sony Corporation**, Tokyo, Japan

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[22] Filed: **Dec. 28, 1976**

Related U.S. Patent Documents

Reissue of:

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Appl. No.: **542,697**
Filed: **Jan. 21, 1975**

[30] **Foreign Application Priority Data**

Jan. 21, 1974 [JP] Japan 49-9160

[51] **Int. Cl.**2 .... **H04N 5/78**

[52] **U.S. Cl.** **358/4**; 358/8

[58] **Field of Search** 358/4, 8, 11, 16; 360/33, 18

[56] **References Cited**

U.S. PATENT DOCUMENTS

3,821,787 6/1974 Kihara 358/4

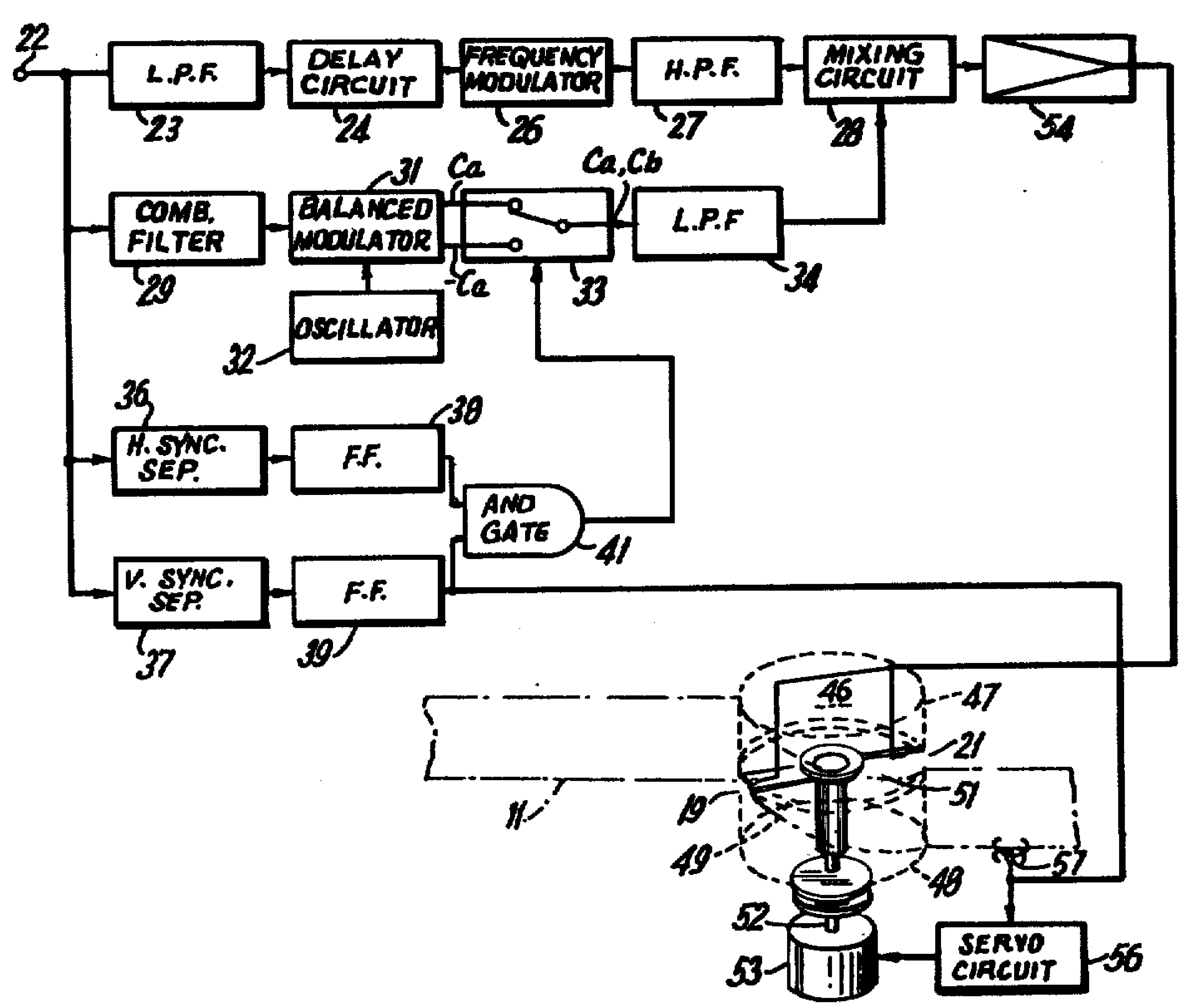
Primary Examiner—Robert L. Richardson

Attorney, Agent, or Firm—Lewis H. Eslinger; Alvin Sinderbrand

[57] **ABSTRACT**

In reducing crosstalk between the low frequency, frequency-converted chrominance portions of h-aligned video signals on adjacent tracks, the frequency converting carrier, but not the entire frequency converted portion, has its polarity inverted at the end of each line interval during the recording of alternate tracks but not during the recording of the remaining alternate tracks. This eliminates the extraneous signal that would otherwise be produced in the balanced modulator of the playback apparatus by any direct voltage offset or transient remanent of a direct voltage offset in the recorded signal.

14 Claims, 20 Drawing Figures



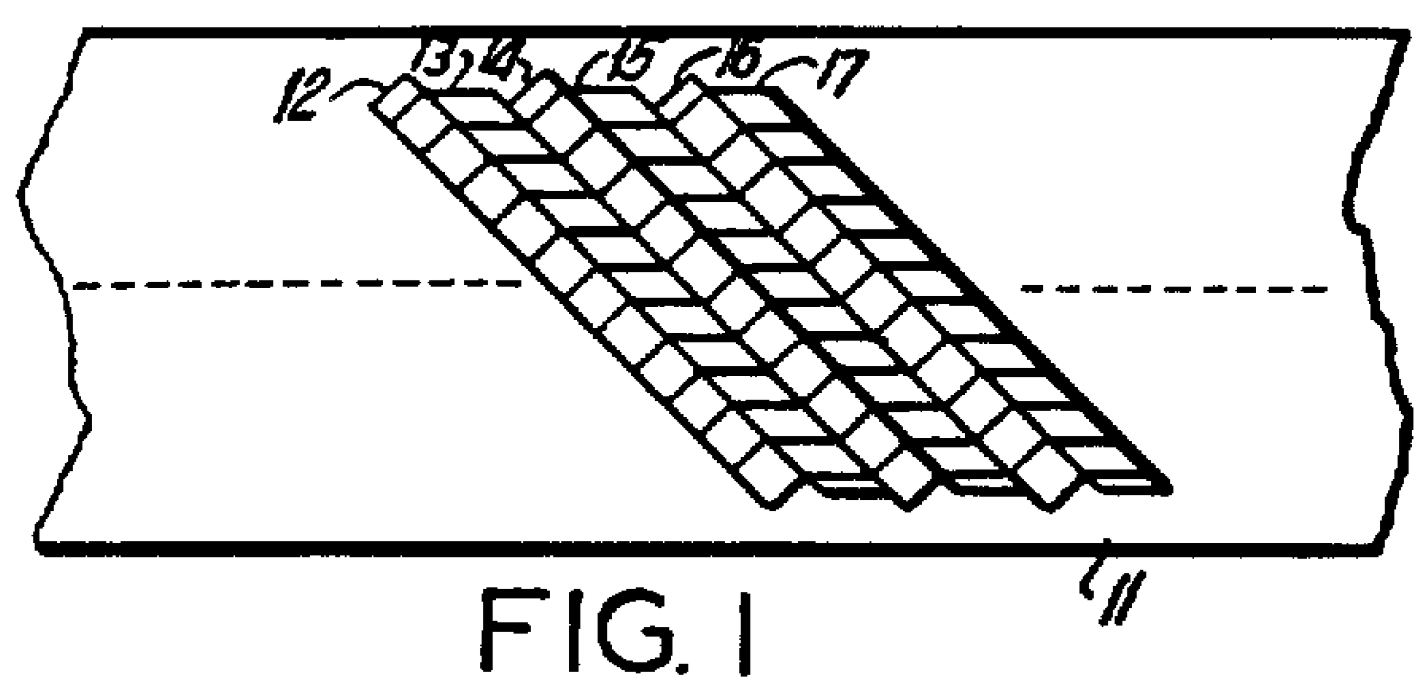


FIG. 1

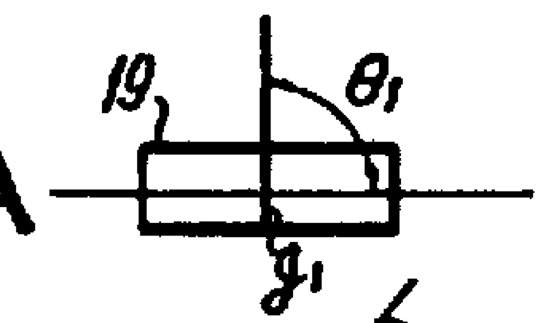


FIG. 2A

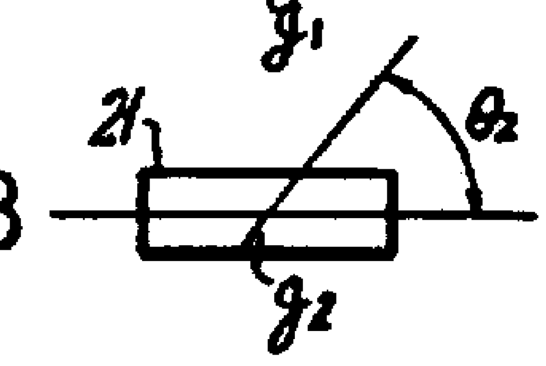


FIG. 2B

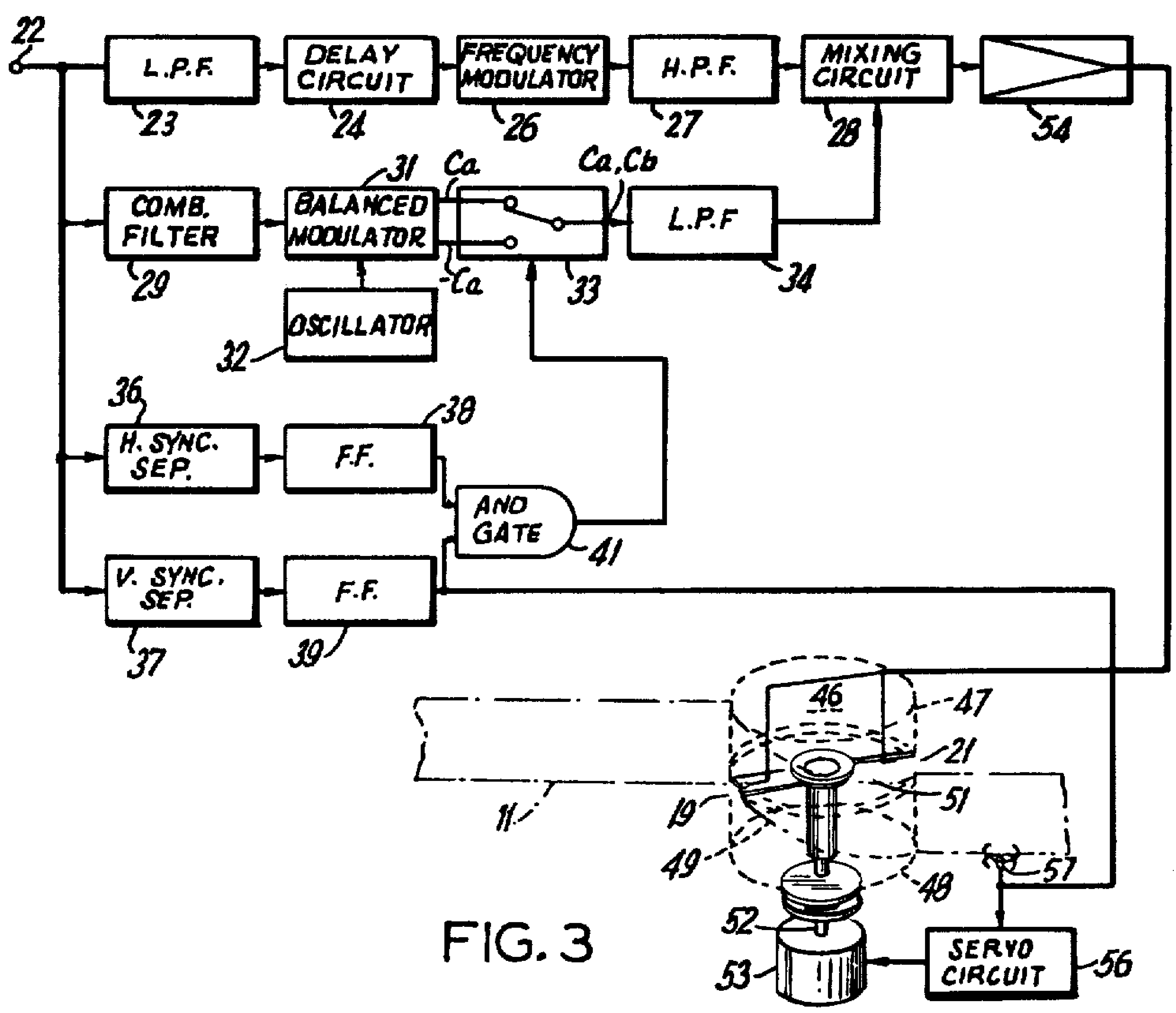


FIG. 3

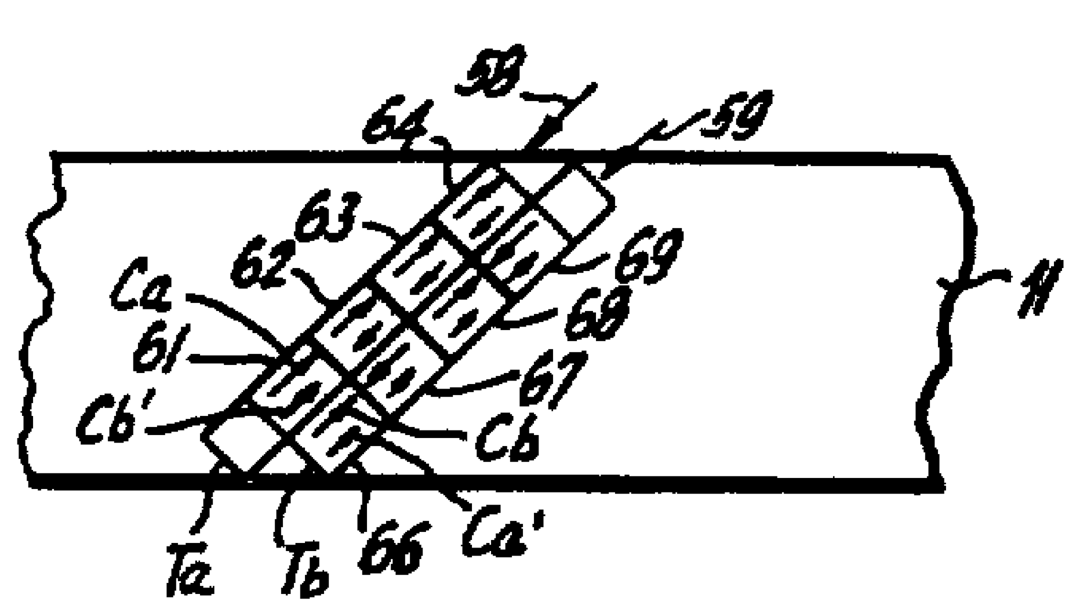


FIG. 4

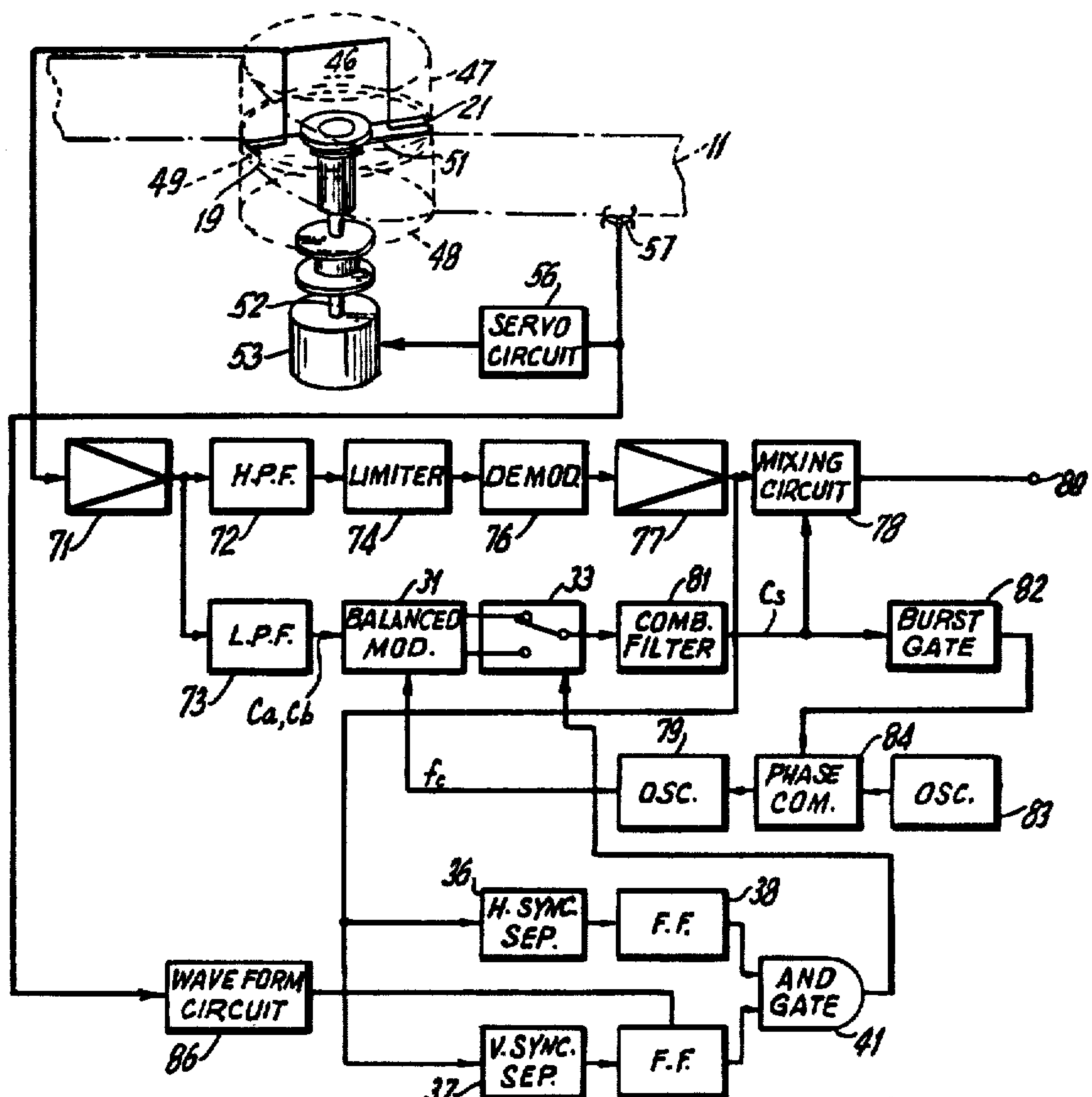


FIG. 5

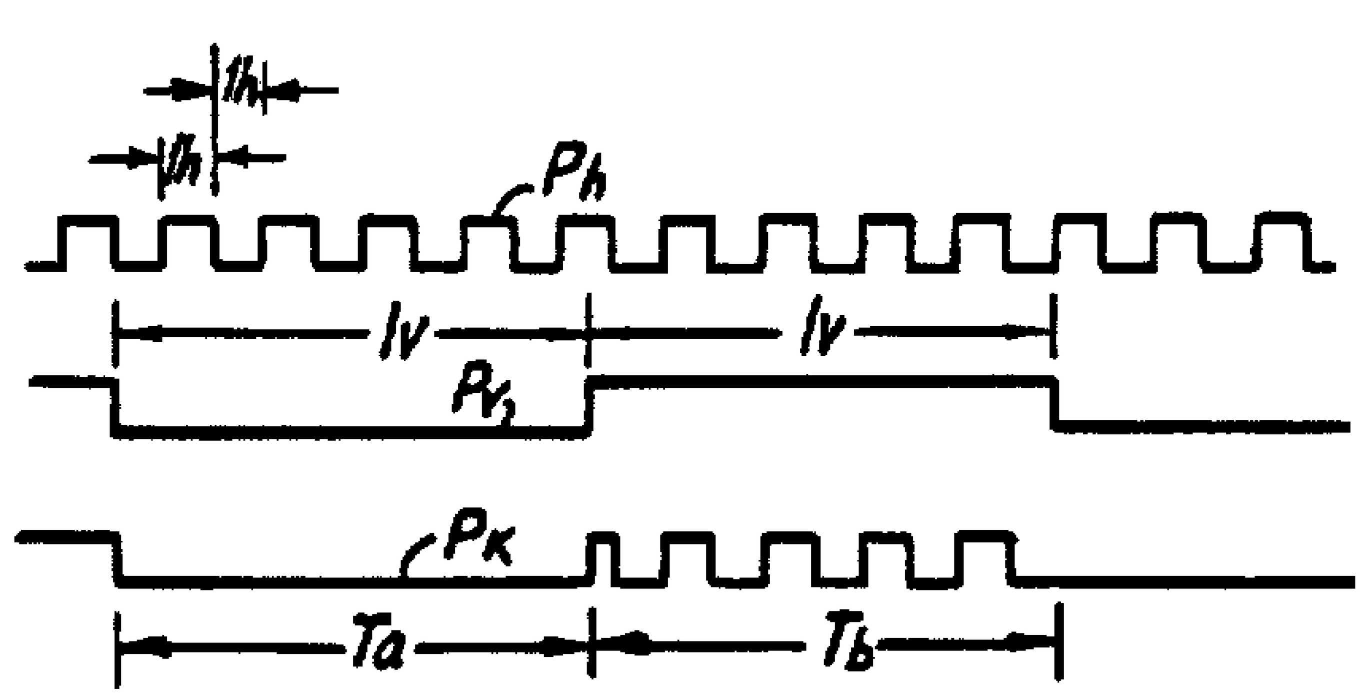
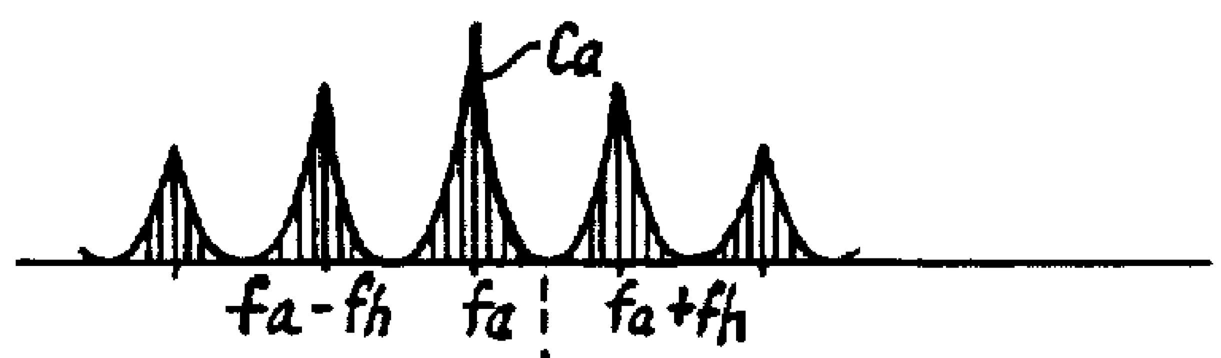


FIG.6A

FIG.6B

FIG.6C

FIG.7A


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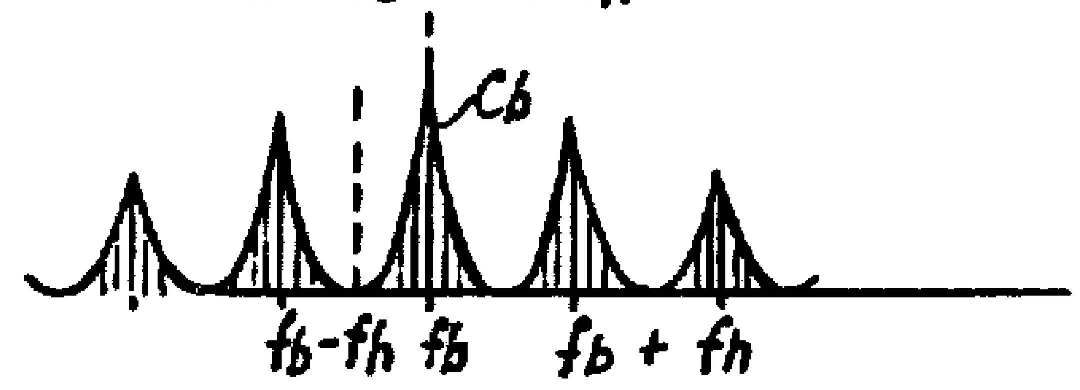

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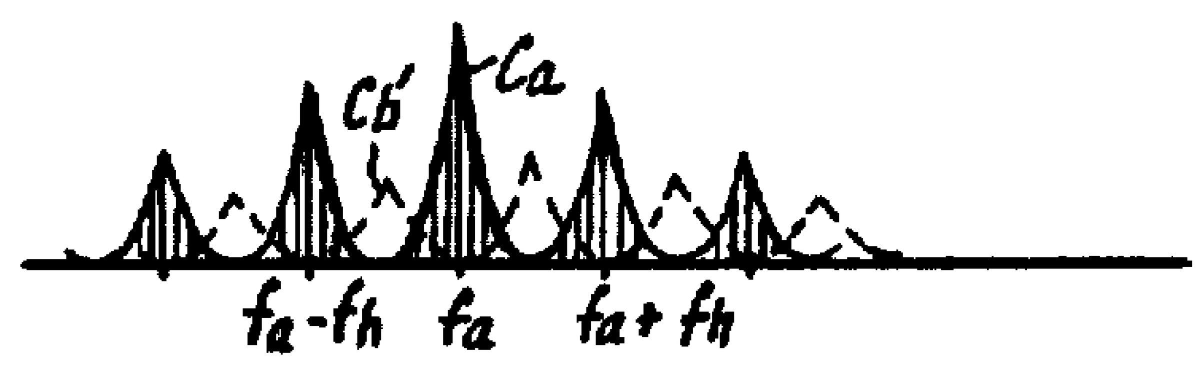

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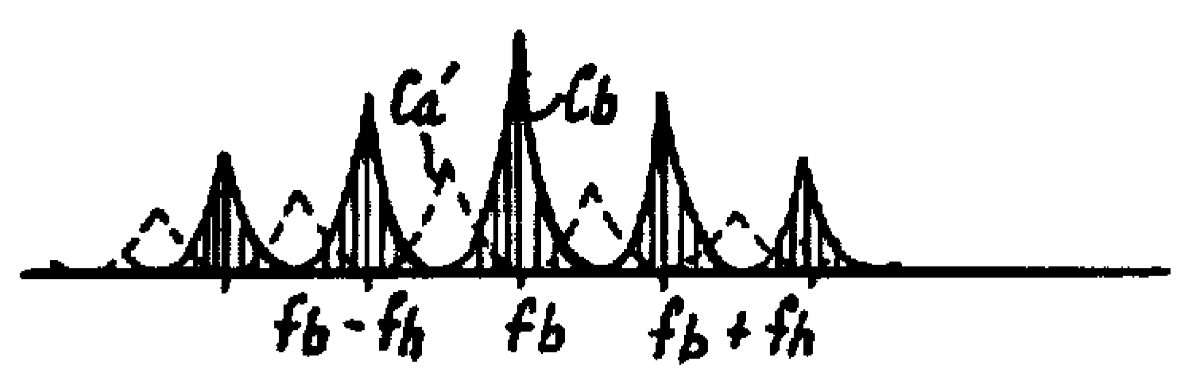

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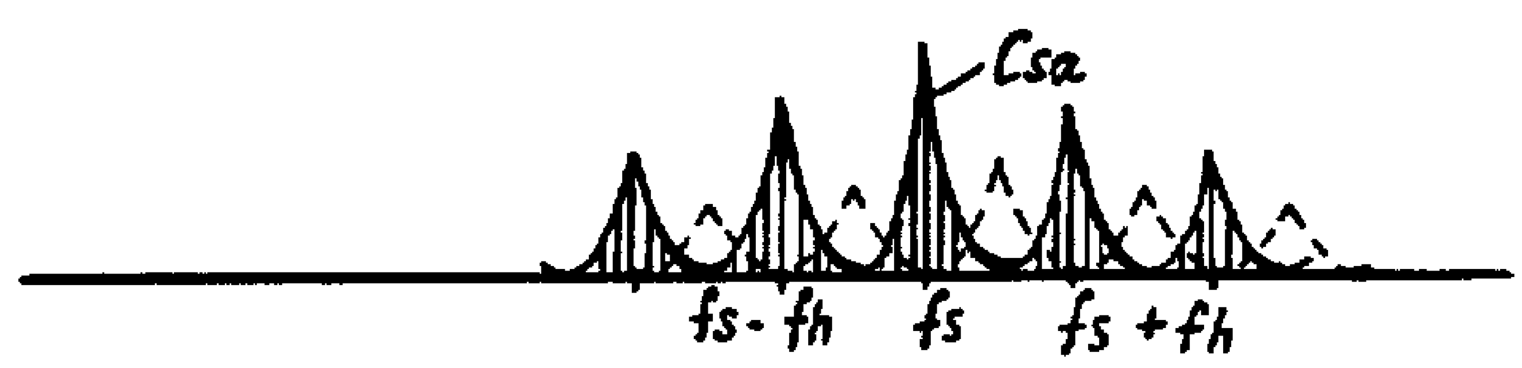

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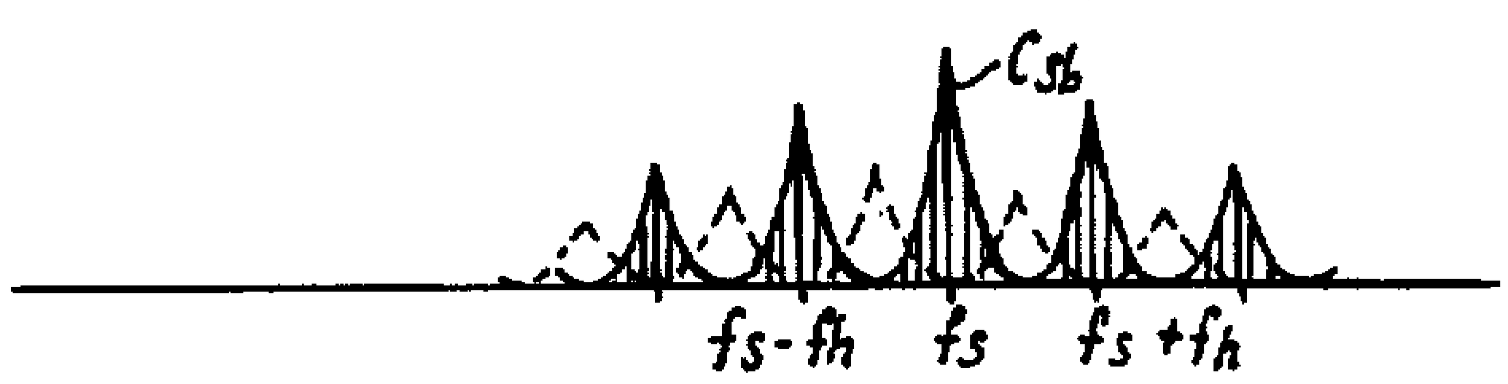


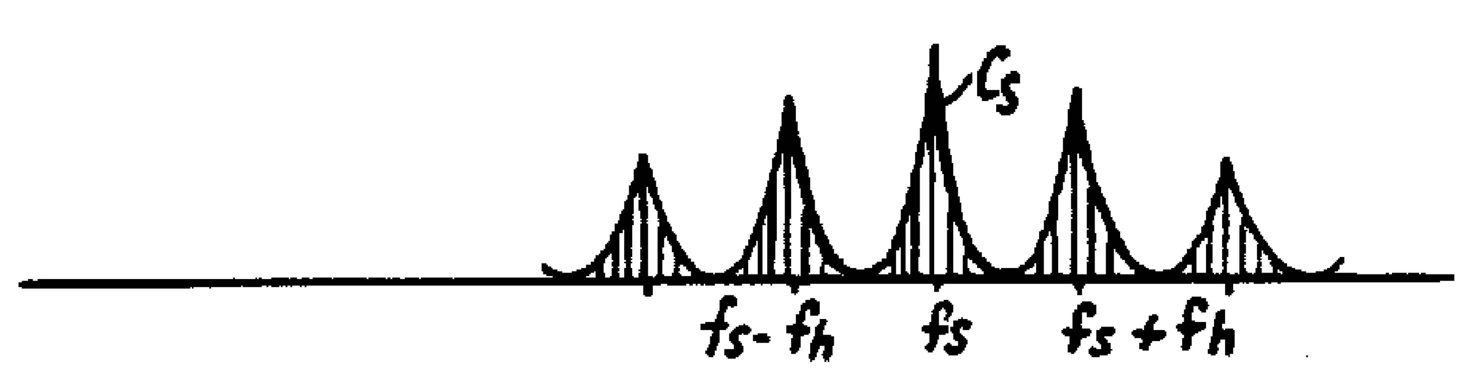
FIG.7G


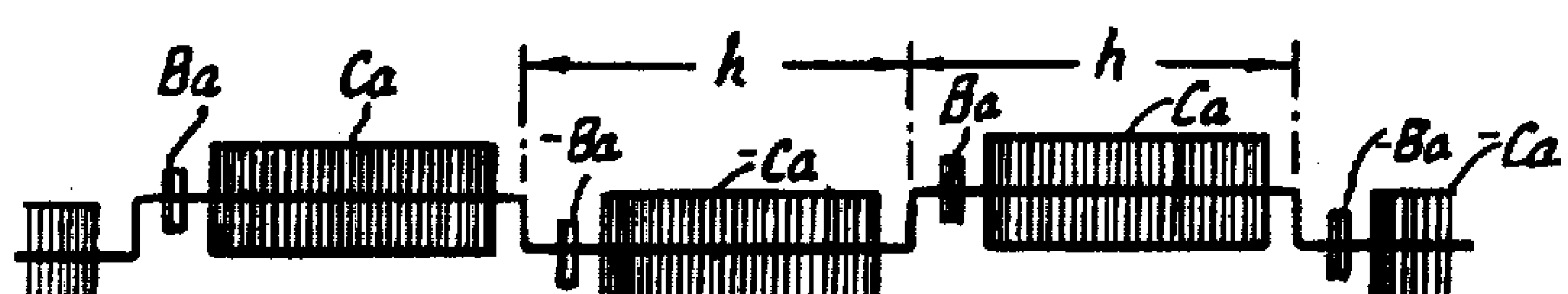
FIG.8A


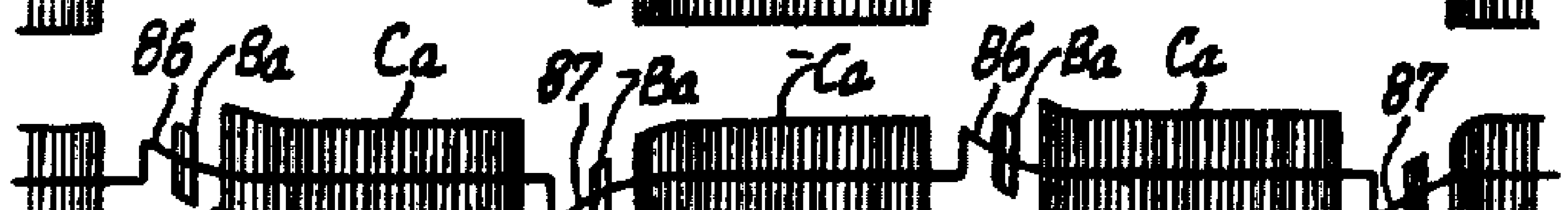
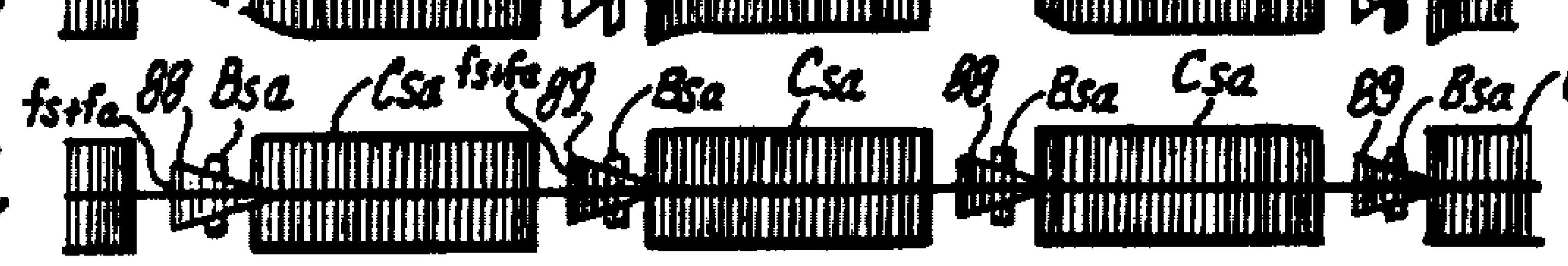
FIG.8B


FIG.8C


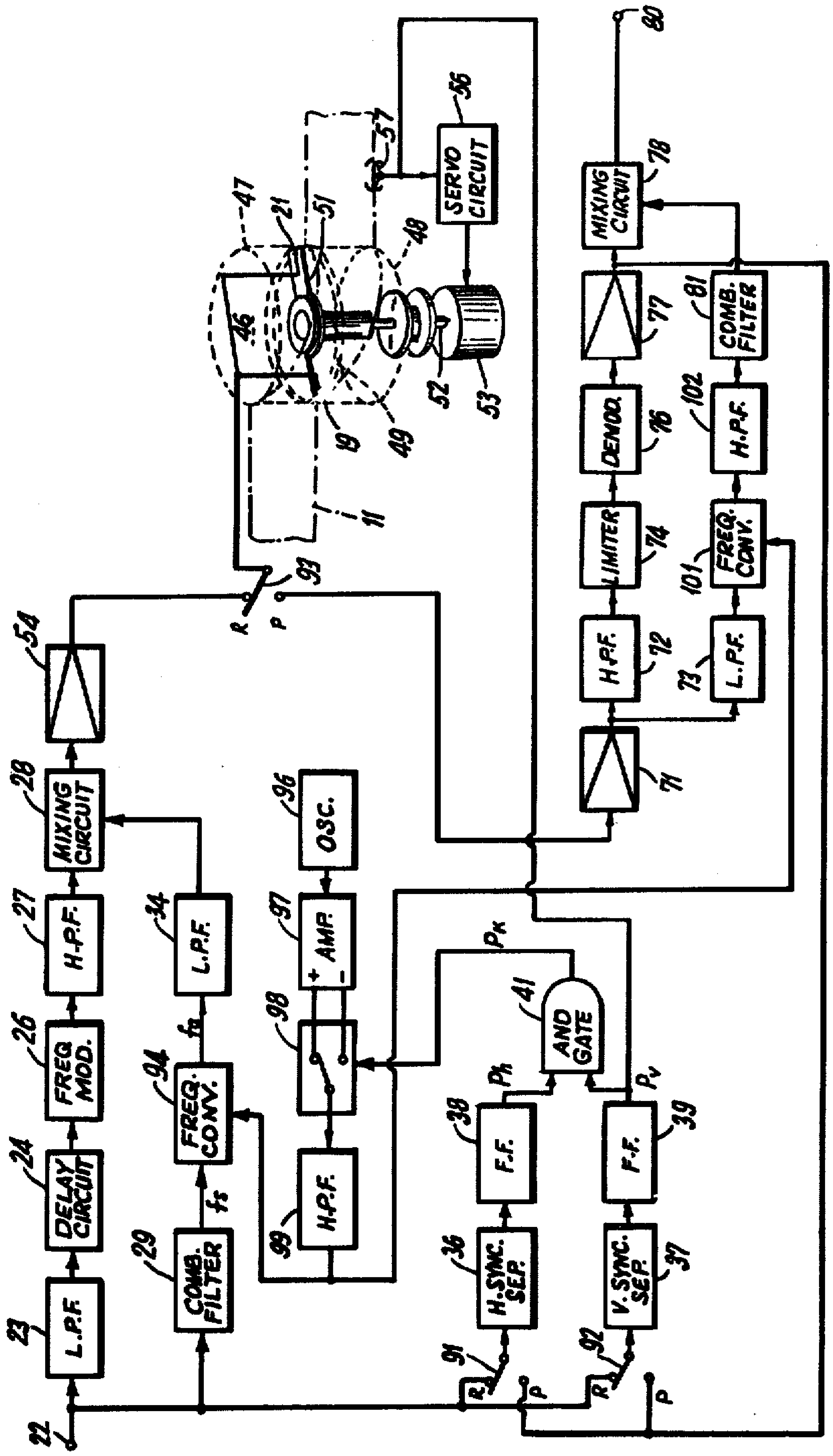

L.P.F.
DELAY CIRCUIT
FREQ MOD.
H.P.F.
MIXING CIRCUIT
COMB. FILTER
FREQ. CONV.
L.P.F.
OSC.
AMP.
H.P.F.
AND GATE
H. SYNC. SEP.
F.F.
V. SYNC. SEP.
F.F.
SERVO CIRCUIT
H.P.F.
LIMITER
DEMOD.
MIXING CIRCUIT
L.P.F.
FREQ. CONV.
H.P.F.
COMB. FILTER

FIG.9

MAGNETIC RECORDING AND/OR REPRODUCING SYSTEM

Matter enclosed in heavy brackets [ ] appears in the original patent but forms no part of this reissue specification; matter printed in italics indicates the additions made by reissue.

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to the field of magnetic recording and reproducing systems for video signals and particularly to the type of system in which there is a polarity reversal of a certain portion of the signal at the end of each line interval of certain groups of line intervals.

2. The Prior Art

This system is related to the system described in copending U.S. application Ser. No. 492,330, filed July 26, 1974, and assigned to the assignee of the present application. In that system it was proposed to reduce the crosstalk interference of the low frequency portions of the video signals recorded on adjacent tacks in h-alignment by reversing the polarity of the chrominance components at the end of each line interval of alternate tracks but not to reverse the polarity at the end of line intervals during the remaining alternate tracks. As a result, the crosstalk component picked up during playback of each line interval would have a polarity that was either the same as or opposed to the polarity of the main, or desired, chrominance component signal. The chrominance components and cross-talk signals of successive line intervals were then combined in a comb filter, which is a type of filter that includes delay means and a subtractor circuit to combine, in opposite polarity, the signal applied to the delay means with the output signal of the delay means. The length of the delay is one line interval and so the chromiance signal for each line interval is combined in opposite polarity with the chrominance signal of the succeeding line interval. During the recording of alternate tracks the chrominance components of successive line intervals are recorded in opposite polarity so that when they are combined subtractively, the alternation in polarity cancels out and the chrominance components of successive line intervals then return to the same polarity and are added. However, the cross-talk signals, when passed through this same comb filter emerge in successively opposite polarities and so are cancelled out or, at least, are reduced.

For those tracks in which the successive line intervals of the chrominance signal are not reversed in polarity, switching means are provided in the playback apparatus to select, during alternate line intervals, chrominance components of opposite polarity so that, as applied to the comb filter, they do have the required successive opposite polarity condition. Again, the crosstalk signals reproduced along the desired chrominance signals of the latter tracks are affected by the same switching and comb filter arrangement so that they are cancelled or are at least substantially minimized.

The comb filter not only provides means for combining successive line interval signals, but also has a filtering effect that results in the substantially complete attenuation of signals having integral multiples of the fundamental frequency that is delayed by one cycle in passing through the delay means. In the case of delay means having a delay of one line interval, thus fundamental frequency is the basic line repetition frequency of the system.

The effect of inverting the polarity of chrominance components during successive line intervals is to produce a frequency offset. In the simplest terms, if a sine wave signal having the frequency f_s of the chrominance signal carrier were periodically inverted at a repetition frequency f_h, which may conveniently be understood to be the basic line repetition frequency, the resultant modified signal would not have the frequency f_s any more but, by Fourier analysis, would be seen to be the combination of sinusoidal signals having frequencies $f_s+\frac{1}{2}(f_h)$ and $f_s-\frac{1}{2}(f_h)$. By choosing the frequency f_s to be $nf_h+\frac{1}{2}(f_h)$ where n is an integral number, the signal having the frequency f_s could pass through the comb filter, but the signals having the frequencies $f_s\pm\frac{1}{2}(f_h)$ would not pass through the comb filter. This provides further separation of the desired signals, which may be the f_s signal and its side bands spaced from it by mf_h, from the undesired signals, which have frequencies $f_s\pm\frac{1}{2}(f_h)$ with side bands spaced mf_h therefrom. The number m is an integer and usually is much smaller than n. The side bands of the desired signal interleave with side bands of the undesired, or crosstalk, signal and are all at frequencies to be separated from the undesired signal and its side bands by the frequency response of the comb filter as well as by the subtractive combination of successive line interval signals in the comb filter.

The circuit that achieves the desired switching of polarity of alternate line interval signals of the chrominance signal in the above-mentioned prior application may inadvertently and undesirably introduce a voltage offset. This is due to the fact that the signal of one polarity may have a certain DC axis and the signal of the other polarity may have a different axis so that when alternate line interval segments of these two signals are combined, the DC axes come through the switching operation as a square wave having a voltage magnitude equal to the difference in the DC axes. Even if the switched signal is passed through a filter to remove DC components, switching transients are still likely to remain. For example, if the filter is simply a series capacitor, the leading edge of the square wave component will pass through unattenuated and the level portion of the square wave component will decrease exponentially in each cycle. The difficulty of removing the undesired components, or transient remanents, by filtering is increased due to the fact that the chrominance components are typically converted to a frequency band of about 687 KHz, but their bandwidth is such that they extend ±500 KHz from the 687 KHz figure. Thus the filter would have to eliminate DC signals but pass all signals between approximately 187 KHz and 1,187 MHz.

It is one of the objects of the present invention to provide an improved system for eliminating the direct voltage offset in a system generally of the foregoing type.

Further objects will be apparent from the following specification together with the drawings.

SUMMARY OF THE INVENTION

According to the present invention, the entire chrominance component signal is not subjected to polarity inversion during alternate line intervals. Instead, only the carrier has its polarity inverted. The polarity is inverted during selected line intervals before being used to convert the frequency of the original chrominance component signal from the relatively high chrominance sub-carrier frequency f_s which, in the NTSC-system is about 3.58 MHz, to the relatively low frequency converted frequency of about 587 KHz.

In the playback portion of the system, which may be constructed separately from the recording portion or may be constructed as part of a combined recording and playback device, the polarity of the frequency reconverting carrier is inverted during selected line intervals to achieve the necessary reconversion of the chrominance components to their required relatively high frequency band around 3.58 MHz carrier.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a simplified representation of a short section of magnetic tape showing the arrangement of recording of several tracks divided into line intervals in h-alignment.

FIGS. **2A** and **2B** show the operative recording portion of two transducers for recording the tracks in FIG. **1**.

FIG. **3** is a block diagram of a prior art recording system in which the polarity of selected line intervals of the frequency converted chrominance signals are inverted.

FIG. **4** is a simplified representation of a short section of magnetic tape illustrating the relationship between the polarities of the desired chrominance signals and crosstalk signals as recorded by the apparatus in FIG. **3**.

FIG. **5** is a block diagram of a prior art playback system for reproducing signals recorded by the apparatus in FIG. **3**.

FIGS. **6A** to **6C** show waveforms used in the recording and playback apparatus in FIGS. **3** and **5**.

FIGS. **7A** to **7G** are a series of graphical representations of desired and undesired chrominance signals, illustating interleaving of the undesired signals with the desired signals.

FIGS. **8A** to **8C** are a series of waveform diagrams illustrating the effect of direct voltage offset of the chrominance signals.

FIG. **9** is a block diagram showing both recording and reproducing apparatus constructed according to the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The short length of tape **11** shown in FIG. **1** has six tracks **12–17** recorded on it. There tracks are shown as being recorded in abutting relationship, and the tracks are shown divided into small subsections, each of which represents the small area on which the entire video signal corresponding to one line of a complete television image is recorded. The smaller sections at the ends of the tracks represent half-line intervals for interlaced scanning.

The lines marking the ends of each of the subsections in each of the tracks **12–17** may be considered to represent the locations at which the horizontal synchronizing signals are recorded. The recording is said to be h-aligned since the horizontal signal, sometimes referred to as the h signals, are recorded in alignment with corresponding signals on adjacent tracks. This is a well-known technique for reducing the type of crosstalk that would otherwise occur between adjacent tracks if the recorded horizontal synchronizing signals were not aligned.

The lines representing the location of recording of the horizontal synchronizing signals in the tracks **12**, **14**, and **16** are represented as being perpendicular to the longitudinal direction of such tracks whereas the lines representing the location of recording of horizontal synchronizing signals in the tracks **13**, **15**, and **17** are at a different angle with respect to the longitudinal direction of those tracks. This difference in angle is produced by the air gap in the recording transducers as shown in FIGS. **2A** and **2B**. The air gap g_1 in the transducer **19** in FIG. **2A** has an angle θ_1 with respect to the line representing the direction of movement of the tape relative to the transducer **19**. The angle θ_1 is represented as a right angle and thus the tranducer **19** would be used to record the tracks **12**, **14** and **16**. The transducer **21** in FIG. **2B** has an air gap g_2 at an angle θ_2 with respect to the line representing the direction of relative movement between the tape and the transducer. The transducer **21** is the one that would be used to record the tracks **13**, **15**, and **17**. The angles θ_1 and θ_2 are known as the azimuth angles, and it is not necessary that either of them be perpendicular to the direction of relative movement between the transducer and the tape.

The recording of information at different azimuth angles reduces cross talk between adjacent tracks not only from horizontal synchronizing signals but also from other signals. In order to pick up the highest frequency components recorded on a magnetic medium it is important that the azimuth angle of the reproducing transducer correspond exactly to the azimuth angle of the transducer used to record that information. Any discrepancy in the azimuth angles of the recording and reproducing transducers reduces the highest frequency signals that could otherwise be reproduced. Deliberately choosing widely different azimuth angles in recording adjacent tracks **12–17** in FIG. **1** substantially reduces any cross-talk from high frequency, and even medium frequency, components recorded on adjacent tracks. Only the cross-talk between relatively low frequency components remains a problem.

The aforesaid prior application provided several techniques to reduce cross-talk of low frequency components between adjacent tracks, even though the tracks were recorded in abutting or even slightly overlapping relationship. FIG. **3** shows a block diagram of one type of recording apparatus described in the aforesaid prior application.

In FIG. **3** a composite video signal is applied to an input terminal **22**. From there the signal branches out into four paths one of which leads to a low pass filter **23** that passes luminance signal components upto about 2.5 MHz or so. The output of the low pass filter is applied to a delay circuit **24** that equalizes the signal delay in other parts of the branched circuit. The luminance signal output of the delay circuit **24** is connected to a frequency modulator **26** to frequency modulate a carrier signal in accordance with standard video tape recording practice. The output signal of the frequency modulator is filtered by a high pass filter **27** and applied to a mixing circuit **28**.

The composite video signal is also applied to a comb filter **29** which passes the chrominance signal components to a balanced modulator **31**. An oscillator **32** is also connected to the balanced modulator **31**. The modulator **31** has two output terminals connected to the fixed terminals of a single-pole double-throw switch, or selecting device **33** and the arm of this switch is connected to a low pass filter **34** which is connected, in turn, to the mixer **28**.

The composite video signal is also supplied from the input terminal **22** to a horizontal synchronizing, or sync, signal separator **36** and to a vertical sync signal separator **37**. The horizontal sync separator **36** is connected to a flip-flop **38** and the vertical sync separator **37** is connected to a flip-flop **39**. Both of these flip-flops are connected to an AND gate **41** the output of which is connected to control the switching, or selecting, circuit **43**. The flip-flop **39** is also connected to a servo-circuit **43** and to a control signal transducer **44** to record control signals along one edge of the tape **11**.

The tape **11** wrapped helically part of the way around a drum **46**. This drum comprises an upper portion **47** and a lower portion **48** with a slot **49** therebetween. The two transducers **19** and **21** are located at opposite ends of an arm **51** affixed to the end of a shaft **52** driven by a motor **53**. The motor is controlled by the servo-circuit **43**. An amplifier **54** connects the mixer **28** to the transducers **19** and **21**. The recording apparatus also includes a servo-circuit **56** connected to the motor **53** to control the operation of the motor and connected to the output of the flip-flop **39** to be controlled by signals therefrom. The flip-flop **39** is also connected to a fixed transducer **57** to record the output pulses of the flip-flop along one edge of the tape **11** to serve as control pulses to govern the speed of the tape during playback.

In the operation of the apparatus shown in FIG. 3, the oscillator **32** generates a signal having a fixed frequency $f_c=f_s+f_a$, and this signal combines, in the balanced modulator **31**, with the chrominance signal components that pass through the comb filter **29**. The balanced modulator **31** subtracts the frequencies of the signals supplied thereto, produces two output signals indicated as C_a and $-C_a$ which are of opposite polarity. Each of these signals has the same frequency converted carrier frequency f_a, when considered instantaneously, and they are selected alternately by the switching circuit **33** to be applied to the low pass filter **34** that eliminated undesired side bands and applies only the proper frequency converted chrominance component signal to the mixer **28**.

The operation of the switching circuit **33** to select either signal C_a or signal $-C_a$ is controlled by the AND gate **41** in response to output signals from the flip-flops **38** and **39**. The selected pattern of recording of the signals C_a and $-C_a$ is illustrated in FIG. 3 which shows a short length of the tape **11** with two adjacent tracks **58** and **59** recorded on it. The track **58** is shown with four line areas, or increments **61-64** and the track **59** is shown with four line areas, or increments, **66-69** h-aligned with the adjacent line areas **61-64** respectively, on the track **58**. Each of the line areas **61-64** and **66-69** has two arrows in it, the larger of which indicates the polarity of the frequency converted chrominance component recorded therein, and the smaller of which indicates the polarity of the cross-talk interference signal, which is the frequency converted chrominance component signal in the next adjacent line area of the adjacent track.

All of the frequency converted chrominance component signals recorded on the track **58** have a carrier of the same polarity. This may be either the polarity of the signal C_a or of the signal $-C_a$. For the sake of simplifying the explanation it will be assumed that the polarity of the larger arrows in the track **58** indicates that the signal C_a is recorded in all of the line increments **61-64**. In the track **59** the polarity of the signal is reversed in alternate line areas of increments, that is, in line areas **66** and **68**, the signal C_a is recorded and in line areas **67** and **69** the signal $-C_a$ is recorded. However, the effect of alternately switching back and forth between the signals C_a and $-C_a$ is not as simple as it seems. As will be described hereinafter, the signal in the track **59** may be considered to be a new signal C_b having frequency components offset with respect to the components of the signal C_a (or $-C_a$) to interleave therewith.

In order to record the signals C_a and $-C_a$ in the pattern set forth in FIG. 3, the simple logic circuit involving the AND gate **41** is used. FIG. **6A** shows the output signal P_h of the flip-flop **38** as being a square wave having high and low intervals, each having a duration of one line interval, or 1h. One complete cycle of the signal in FIG. **6A** thus has a fundamental frequency $\frac{1}{2}(f_h)$. The output signal of the flip-flop **39** is shown in FIG. **6B** as a square wave P_v having high and low intervals each equal to 1v, where v is a field interval.

Since the AND gate **41** can produce a high output only when both of the applied signals P_h and P_v are high the output of the AND gate as is shown in FIG. **6C**, remains low during one entire field interval T_a and goes high only during alternate line intervals of the alternate field interval T_b. This is based on the assumption that each track records one complete field interval. The pattern shown in FIG. **3** corresponds to having the arm of the switching circuit **33** apply the signal C_a to the low pass filter **34** when the output of the AND gate **41** is low and having the arm apply the signal $-C_a$ to the low pass filter **34** when the output of the AND gate **41** is high.

FIG. **5** shows a playback apparatus for reproducing video signals recorded by the apparatus of FIG. **3**. Many of the components in FIG. **5** are identical with those in FIG. **3** and such identical components are indicated by the same reference numerals as in the earlier figures and descriptions of such elements. The description of their operation will not be unnecessarily repeated.

The reproduced signals from the transducers **19** and **21**, which are also used in playing back recorded signals, are amplified in an amplifier **71** and are applied to a high pass filter **72** and a low pass filter **73**. The high pass filter **72** passes the frequency modulated signal that includes the luminance components. This signal is limited in a limiter **74** and demodulated in a demodulator **76**. The re-created luminance signal is then amplified in an amplifier **77** and applied to a mixer **78**.

The frequency converted chrominance signal separated by the low pass filter **73** is applied to the balanced modulator **31** along with a signal from an oscillator **79**. The signal from the oscillator **79** has a frequency $f_c=f_s+f_a$ and is constant during all line and field intervals. Two output terminals of the balanced modulator **31** are connected to the fixed terminals of the switching circuit **33**, and the output of the latter is applied to a comb filter **81**. The output of the comb filter is connected to the mixer **78** and to a burst gate **82**. The burst gate and the output of an oscillator **83** are connected to a phase comparison circuit **84** that is connected to the oscillator **79**. A waveform circuit **86**, which may be a rectifier, is connected to the transducer **57** to receive reproduced control signals therefrom, and its output is connected to a resetting terminal of the flip-flop **39**.

The operation of the system in FIG. **5**, insofar as the chrominance component signal is concerned, consists in applying the signal having the frequency $f_c=f_s+f_a$ from the oscillator **79** to the balanced modulator **31** to convert the frequency f_a of the signals C_a and C_b, which are applied alternatively to the balanced modulator **31** back to the original chrominance carrier frequency f_s. The two output terminals of the balanced modulator **31** provide signals of opposite polarity. One of them includes the desired signals C_{sa} and the undesired or cross-talk signal C_{sb}', while the other includes the desired signal $-C_{sa}$ and the undesired or cross-talk signal $-C_{sb}'$. The designation C_{sa} indicates that the carrier frequency of the frequency converted chrominance signal C_a has been reconverted to the original frequency f_s. The designation C_{sb}' indicates that the signal C_b, which consisted of alternate line intervals of the signals C_a and $-C_a$ has been reconverted by the same converting signal having the frequency $f_c=f_s+f_a$.

The switching circuit **33** is controlled by the AND gate **41** to produce exactly the same switching pattern as is shown in FIG. **6**C. The waveform circuit **86** assures that the operation of the flip-flop **39** in the playback unit properly relates to the operation of the flip-flop **39** in the recording system of FIG. **3**.

The output of the switching circuit **33** is applied to the comb filter **81**. It will be recalled that the comb filter includes both a direct signal and a path in which the signal is delayed by one horizontal line interval. The output of the direct path is combined in the delayed output of the other path. Thus, when the chrominance component signals of the track **58** in FIG. **4** are being reproduced, the desired reconverted chrominance component signals C_{sa} corresponding to the signals C_a indicated by the long arrows in two successive line areas **61** and **62** or **62** and **63** or **63** and **64** are combined, with the polarities of their carriers being the same, at the output of the comb filter. However, the undesired, or cross-talk, components C_{sb}' corresponding to the signals C_b' indicated by the small arrows in the line increments have carriers of opposite polarities in successive pairs of lines, and thus cancel each other when combined at the output of the comb filter **81**. As a result, the output signal of the comb filter **81** in FIG. **5** during the reproduction of the track **58** consists substantially only of the desired chrominance components C_a having the proper carrier frequency f_s. During the reproduction of the track **58**, the switching circuit **33** does not switch back and forth between its two input terminals but remains on only one terminal as indicated during the interval T_a in FIG. **6**.

During the reproduction of the track **59**, the switching circuit **33** does switch back and forth at the end of each line interval of time in accordance with the output signal of the AND gate **41** during the interval T_b as indicated by the long arrows in line areas **66–69** in FIG. **4**. The switching signal is indicated in FIG. **6**C. Thus, the comb filter **81** receives the signals C_{sb} and C_{sa}' during group of line intervals recorded along the track **59**.

Considering the signals on a line-by-line basis, since the chrominance signal components recorded in line areas **66** and **67** have opposite polarities, inversion of the signal reproduced from line area **67** causes the chrominance components signal to be combined, in phase, with the delayed chrominance component signal reproduced from line area **66** at the output of comb filter **81**. However, since the chrominance component signals are recorded in all line areas of the next adjacent track **58** with carriers of the same polarity, the reconverted cross-talk signals C_{sa}' from track **58**, which are reproduced with the chrominance component signals recorded in the successive line areas of the track **59** also have the same polarity. Therefore, the abovementioned inverting of the signal reproduced from line area **67** of track **59** causes the cross-talk signal C_a' reproduced with the signal recorded in line area **67** to be combined, with its phase or polarity reversed, with the delayed cross-talk signal reproduced with the signal recorded in line area **66**, whereby the combined cross-talk signals cancel each other at the output of comb filter **81**.

The reason why inversion of polarity of the signal C_a at the end of each line interval changes the signal frequency may be explained by considering a simplified situation in which signals C_a and $-C_a$, both of which have the carrier frequency f_a, are not modulated by chrominance components but are available at the two output terminals of the balanced modulator **31** in FIG. **3** as pure sine waves of opposite polarity. During the field interval T_b when signals C_a and $-C_a$ are selected alternately by the switching circuit **33**, the output signal of the switching circuit is no longer a single signal but is a sine wave whose polarity reverses, or whose phase shifts 180°, at a repetition rate of $\frac{1}{2}(f_h)$. When a Fourier analysis is made of such a signal over a complete cycle of the interval of two horizontal lines, it will be found that the carrier frequency f_a is no longer present, but has been replaced by first upper and lower side bands spaced by $\pm\frac{1}{2}(f_h)$ from the original carrier frequency and by additional upper and lower side bands spaced from the first mentioned side bands and from each other, in order, by f_h. Therefore, in effect, the signal-pole, doublethrow switching circuit **33** operates as a balanced modulator, and the modulating signal is the switching signal P_k in FIG. **6**C. During the interval T_b, this signal changes its level at a rate that takes two horizontal line intervals for a complete cycle and therefore has a frequency of $\frac{1}{2}(f_h)$. Being, in effect, a balanced modulator, the switching circuit **33** produces a balanced output signal without a carrier. This balanced output signal, since it interleaves with the signal C_a may be referred to as the signal C_b, and thus there is, in fact, an interleaving relationship between the carriers of the frequency converted carrier components of the signal recorded on the track **58** and that recorded on the track **59** in FIG. **4**. Such interleaving relationship provides for an interleaving relationship between the previously referred to cross-talk or interference signals C_{sb} and $-C_{sb}$ and the desired signals C_s which further improves the cancellation of the cross-talk signals.

FIGS. 7A to 7G show the interleaving frequency relationship of the chrominance signals in the circuits in FIGS. **3** and **5**. FIG. 7A shows a portion of the spectrum of the frequency converted signal C_a which comprises a central carrier frequency f_a with principal harmonics spaced from it $\pm nf_h$ and with subsidiary harmonics spaced from the carrier frequency f_a and from each of the principal harmonics by the field repetition frequency of the system. The signal C_a is generated in the balanced modulator **31** in FIG. **3** during the recording of the track **58** in FIG. **4**.

FIG. 7B shows a spectrum similar to that in FIG. 7A, except that its components are offset $\frac{1}{2}(f_h)$ with respect to the frequencies in FIG. 7A. The signal in FIG. 7B is the desired chrominance signal C_b recorded in the track **59** in FIG. **4**.

As indicated by the double arrows in each of the line interval areas in the tracks **58** and **59** in FIG. **4**, each of the desired chrominance signals is unavoidably mixed with a cross-talk signal. These cross-talk signals are illustrated in the spectra in FIGS. 7C and 7D which correspond, respectively, to the spectra in FIGS. 7A and 7B. In FIG. 7C the cross-talk signal is actually an attenuated version of the signal C_b, and is therefore designated as C_b. In FIG. 7D the cross-talk signal is an attenuated version of the signal C_a, and is therefore designated as C_a'.

FIGS. 7E and 7F show the spectra of the chrominance signals at the output of the switching circuit **33** in FIG. **5**. Although the signals C_a and C_b are converted in the balanced modulator **31** by the signal $f_c=f_s+f_a$ from the oscillator **79**, and, as converted, are designated as signals C_{sa} and C_{sb}, the fact that the arm of the switching circuit is held fixed in one position during the playback of the track **58** in FIG. **4** but is switched from one of its positions to the other at the end of each line interval during the playback of the track **59** in FIG. **4**, results in eliminating the ½(h) offset of the signal C_b. Thus, the reconverted signals C_{sa} and C_{sb}, both have the same carrier frequency f_s, which is the original chrominance sub-carrier frequency of the television system. In the spectra shown in FIGS. 7E and 7F the undesired cross-talk signals C_{sa}' and C_{sb}' spaced midway between the principal side bands of the desired signals C_{sa} and C_{sb} and can be eliminated by the comb filter **81** to yield the desired signal C_s, which is shown in FIG. 7G and is free of cross-talk components.

FIG. **8**A shows the waveform of several line intervals of the chrominance signal C_a and $-C_a$ and accompanying burst signal B_a and $-B_a$ at the output of the switching circuit **33** in FIG. **3**. There is a DC offset of alternate line interval signals due to the fact that the input terminals of the switching circuit **33** are connected to points in the circuit of the balanced modulator **31** that have different DC components. Although the DC offset is illustrated as if it were positive for the line intervals in which the signal C_a is selected and relatively negative for the remaining line intervals when the signal $-C_a$ is selected, the polarity of the offset could be reversed. Passing the signal shown in FIG. **8**A through the low pass filter **34** reduces the DC component and results in the signal shown in FIG. **8**B. However, this signal still has an initial offset **86** or **87** at the beginning of each horizontal line interval when the switching of the circuit **33** takes place. When this signal with the offsets **86** and **87** is recorded on the tape **11** and is then played back by means of the circuit shown in FIG. **5**, the carrier signal having the frequency f_c is modulated in the balanced modulator **31** not only by the relatively high frequency chrominance components $\pm B_a$ and $\pm C_a$ of the frequency converted chrominance and burst signals, but also by the DC offset components **86** and **87**. This is due to the fact that the balanced modulator **31** in FIG. **5** produces an output signal based on its carrier freqency f_c whenever the input signal from the filter **73** differs from zero. As a result, the output signals of the balanced modulator **31** in FIG. **5** as shown in FIG. **8**C not only have the frequency reconverted chrominance portions C_{sa} during the visible part of each line interval and B_{sa} during the bursts, but also have undesired signals **88** and **89** of the frequency $f_c=f_s+f_a$ and of amplitude determined by the remanent of DC offset **86** and **87** of the switching signal as recorded on the tape **11**.

FIG. **9** shows an embodiment of the present invention including both recording and playback sections. The recording section includes many components found in the recording apparatus shown in FIG. **3** and the playback section includes some components found in the playback apparatus of FIG. **5**. The description of these components and their operation will not be unnecessarily repeated.

Between the input terminal **22** and the horizontal and vertical synchronizing separators **36** and **37** are two double throw switches **91** and **92**. The arm of another double throw switch **93** is connected to the transducers **19** and **21**. The arm of each of the switches **91-93** makes contact either with a pole identified R or a pole identified P, depending upon whether the apparatus is to be used for recording or playback. In practice the arms of the three switches **91-93** would be mechanically linked together to operate as a three-pole double-throw switch.

The chrominance components of the video signal applied to the input terminal **22** to be recorded are separated out by the comb filter **19** and applied to a frequency converter **94**. This frequency converter also receives signals that originate in an oscillator **96** and are amplified in a differential amplifier **97** that has two output terminals of opposite polarity. These output terminals are connected to two fixed terminals of a switching circuit **98**, and the arm of the switching circuit is connected through a high pass filter **99** to the frequency converter **94**. The output terminal of the AND gate **41** is connected to the actuating input terminal of the switching circuit **98**.

In the playback section of the apparatus in FIG. **9**, reproduced signals amplified by the amplifier **71** and filtered by the low pass filter **73** are connected to another frequency converter **101** that also receives signals from the high pass filter **99**. The output of the frequency converter **101** is connected through a high pass filter **102** to the comb filter **81**. In the operation of the apparatus of FIG. **9** the composite video signal applied to the input terminal **22** is separated by the low pass filter **23** and the comb filter **29** into luminance and chrominance components, respectively. The luminance components are applied to a frequency modulator **26** and the resulting frequency modulated signal is applied to the mixing circuit **28**.

The chrominance components pass through the filter **29** and are applied to the frequency converter **94**, have a carrier frequency f_s, which for NTSC signals, is approximately 3.58 MHz. The oscillator **96** produces a signal having a frequency $f_c=f_s+f_a$. This signal is amplified by the amplifier **97** and positive and negative polarity versions of this signal are passed, in a predetermined sequence, through the switching circuit **98**. The resulting signal is filtered by the high pass filter **99** and applied to the carrier frequency input terminal of the frequency converter **94**.

The sequence in which positive and negative versions of the signal having the freequency f_c are passed through the switching circuit **98** is controlled by the output signal of the AND gate **41**. This signal is shown in FIG. **6**C. During the interval T_a in FIG. **6**C, the switching circuit **98** passes only one version of the signal, either the positive or the negative version. During the next interval T_b, corresponding to the next recorded track on the tape **11**, the switching circuit **98** would alternate back and forth between the positive and negative polarity signals. For the reason given previously, the resulting signal passed through the high pass filter **99** during the interval T_b in FIG. **6**C would not only reverse polarity at the end of each horiziontal line interval but would actually shift to a frequency relationship that would interleave with the basic frequency f_c generated by the oscillator **96**.

Contrary to the arrangement shown in FIG. **3** in which the entire chrominance signal is applied to the mixing circuit **28** in either positive or negative polarity, only the carrier signal is applied to the frequency converter **94** in either positive or negative polarity. It is relatively easy to eliminate any DC component of the signal of the output of the switching circuit **98** by means of the filter **99**, and there is no DC offset produced in the frequency converter **94**. However, there is still the desired reversal of polarity of the frequency converted carrier during certain intervals as determined by the switching operation depicted in FIG. **6C**, and there is also the frequency interleaving relationship between components of the frequency converted signal produced during the interval T_a in FIG. **6C** and that produced during the interval T_b. As a result, all of the advantages heretofore described with respect to the recording apparatus shown in FIG. **3** are retained, but the disadvantage of having a DC offset is eliminated.

The resulting chrominance signal is combined in a mixing circuit **28** with the frequency modulated signal that includes luminance information, and the combined signal is passed through the switch **93** to be recorded by the transducers **19** and **21** on the tape **11**.

During playback of information previously recorded on the tape **11**, the arms of the switches **91–93** are transferred to their P terminals. This permits signals picked up by the trnsducers **19** and **21** to pass through the switch **93** to the amplifier **71** and be separated into high frequency and low frequency components. The high frequency components include the luminance information in frequency modulated form, and this information is extracted by the demodulator **76** and applied through the amplifier **77** to the mixing circuit **78**.

The low frequency components that include the frequency converted chrominance signal pass through the low pass filter **73** to the frequency modulator **101**. These components have a frequency converted carrier with a basic frequency f_a. The converting carrier from the high pass filter **99** applied to the frequency converter **101** has a frequency f_c, and the output of the frequency converter **101** thus has a carrier that is returned to the original sub-carrier frequency f_s. The chrominance components grouped around the carrier at the frequency f_s are able to pass through the high pass filter **102**, and the desired components are separated from the cross-talk components by the comb filter **101** in exactly the same way that the desired components and the cross-talk components are separated in the circuit shown in FIG. **5**. Since there is no DC offset in the recorded signal, the signals **88** and **89** shown in FIG. **8C** are not produced, and the reproduced composite signal at the output terminal **80** is free of this undesired interference.

The invention has been described in specific terms but it will be understood by those skilled in the art that modifications may be made therein. One such modification would be to derive the signal P_v shown in FIG. **6B** from a transducer associated with the rotating shaft **52**. Such transducers are known, and in this instance, the use of a signal P_v derived therefrom would have the advantage of causing the intervals T_a and T_b in FIG. **6C** to correspond exactly to the rotation of the shaft **52**. Still further modifications may be made in the invention within the scope of the following claims.

What is claimed is:

1. Apparatus in which video signals are recorded in h-alignment in adjacent tracks on a recording medium, said apparatus comprising:

A. means for generating a frequency converting carrier signal in first and second versions of opposite polarity;

B. a frequency converter to receive chrominance components of said video signals; and

C. means to apply said first and second versions of said carrier signal in a predetermined sequence to said frequency converter, said sequence being such that, during alternate tracks, only one of said versions is applied and, during the remaining alternate tracks, said first and second versions are applied alternately in successive line intervals.

2. The apparatus of claim **1** in which said carrier generating means comprises:

A. an oscillator to generate said carrier signal;

B. a double-throw switching circuit comprising first and second input terminals connected to receive said first and second versions of said carrier signal, said switching circuit comprising an output terminal that can be conductively connected to said first and second input terminals alternately; and

C. a filter connecting said output terminal of said switching circuit to said frequency converter.

3. The apparatus of claim **1** comprising:

A. a low pass filter connected to said frequency converter; and

B. transducer means connected to said filter to record the frequency converted signals on said recording medium.

4. The apparatus of claim **3** comprising:

A. a second frequency converter a connected to said means to apply said carrier signal, whereby said second converter receives said first and second versions in said predetermined sequence;

B. switching means to connect said transducer means alternatively to receive frequency converted signals from said first-named frequency converter and to supply reproduced signals from said recording medium to said second frequency converter; and

C. a comb filter connected to said second frequency converter to filter interleaved cross-talk components from desired, frequency converted chrominance signals of opposite polarity.

5. The apparatus of claim **1** comprising:

A. reproducing transducer means to play back information recorded on said recording medium; and

B. a comb filter connected to said frequency converter to filter interleaved cross-talk components from desired, frequency converted chrominance signals of opposite polarity.

6. Apparatus in which video signals are recorded in adjacent tracks on a recording medium, said apparatus comprising:

A. means for generating a frequency converting carrier signal in first and second versions of opposite polarity;

B. a frequency converter to receive chrominance components of said video signals; and

C. means to apply said first and second versions of said carrier signal in a predetermined sequence to said frequency converter, said sequence being such that, during alternate tracks, only one of said versions is applied and, during remaining alternate tracks, said *first and second versions are applied alternately in successive line intervals.*

7. Apparatus for reproducing video signals that have been recorded in adjacent tracks on a recording medium with a carrier having one set of phase conditions line interval by line interval in alternate tracks and a different set of phase conditions line interval by line interval in the remaining alternate tracks, the phase conditions of carriers of the signals recorded in adjacent tracks being such as to create predetermined cross-talk relationships during reproduction, said apparatus comprising:

A. means to reproduce the signals recorded on each track and cross-talk signals from adjacent tracks;

B. means to shift the carrier frequency and phase condition of the reproduced signals for a line interval at a time; and

C. means to combine the resultant reproduced and revised signals and cross-talk signals with the reproduced and revised cross-talk signals of the next successive line interval to reduce the amplitude of said cross-talk signals.

8. The apparatus of claim 7 in which said means to combine comprises a comb filter that comprises an input terminal, an output terminal, and parallel signal paths joining said input terminal to said output terminal, one of said paths comprising delay means to delay the passage of signals therethrough by a period of time equal to one horizontal line interval.

9. Apparatus for recording video signals in adjacent tracks on a recording medium and for playing back the recorded signals, said apparatus comprising:

A. means for generating a frequency converting carrier signal in first and second versions of opposite polarity;

B. a frequency converter to receive chrominance components of said video signals;

C. means to apply said first and second versions of said carrier signal to said frequency converter in a predetermined sequence such that, during the recording of alternate ones of said tracks, only one of said versions is utilized to frequency convert said chrominance components and, during the remaining alternate tracks, said first and second versions are utilized alternately for frequency converting successive line intervals;

D. means to record and reproduce said chrominance components line interval by line interval and track by track, said reproducing means also reproducing cross-talk chrominance signals from the next adjacent track;

E. means to reconvert the frequency of the reproduced carrier in the reproduced chrominance components by means of a carrier signal having the same frequency as said frequency converting carrier signal;

F. means to control the phase of said carrier applied to said frequency reconverter to correspond to said first and second versions of opposite polarity according to a predetermined sequence; and

G. a comb filter connected to the output of said frequency reconverter to filter out cross-talk components of the frequency reconverted signal.

10. Apparatus in which video signals are recorded in adjacent tracks on a recording medium, said apparatus comprising:

A. means for generating a frequency-converting carrier signal, the phase of which changes in a predetermined manner at predetermined line intervals;

B. a frequency converter to receive chrominance components of said video signals; and

C. means to apply said carrier signal to said frequency converter, the sequence of phase changes of said carrier signal being such that, during the recording of adjacent tracks, the relative phase of the carrier of the frequency converted signal has a predetermined relationship to the phase of the carrier of the adjacent recorded signal in the next adjacent track.

11. Apparatus in which video signals are recorded in adjacent tracks on a recording medium, said apparatus comprising:

A. means for generating a carrier signal the phase of which is changed in a predetermined manner at the end of certain horizontal line intervals;

B. means for changing the frequency and phase of chrominance components of said video signals in accordance with said carrier signal and to produce a frequency converted chrominance signal; and

C. frequency converter means for changing the frequency verted chrominance signal on said recording medium with a predetermined phase relationship to minimize interference during playback of said frequency converted chrominance signals recorded in adjacent tracks.

12. Apparatus in which video signals are recorded in adjacent tracks on a recording medium, said apparatus comprising:

A. a chrominance signal source for supplying a chrominance signal having a first carrier frequency;

B. a carrier signal source for supplying a carrier signal having a second frequency higher than said first frequency, the phase of said carrier signal being changed in a predetermined manner at the end of selected line intervals for cancellation of cross-talk between signals from adjacent tracks during reproduction of the recorded signals;

C. frequency converter means for chaing the frequency of said chrominance signal to a third frequency corresponding to the difference between said first frequency and said second frequency in response to said carrier signal; and

D. recording head means for recording the frequency changed chrominance signals in adjacent tracks on said recording medium.

13. Apparatus for reproducing chrominance signal recorded in adjacent tracks on a recording medium, the recorded chrominance signals on adjacent tracks having different phase conditions, said apparatus comprising:

A. means for reproducing said recorded chrominance signals;

B. means for generating a carrier signal the phase condition of which is changed in response to the phase condition of the chrominance signal being reproduced;

C. means for frequency converting the reproduced chrominance signal in accordance with said carrier signal;

D. comb filter means; and

E. means for supplying said frequency converted chrominance signal to said comb filter means.

14. Apparatus for recording video signals in adjacent tracks on a recording medium and for reproducing said signals, said apparatus comprising:

A. a chrominance signal source for supplying a chrominance signal having a first carrier frequency;

B. a carrier signal source for supplying a frequency converting carrier having a second frequency higher than said first frequency, the phase of said frequency converting carrier signal being changed in a predetermined manner at the end of selected line intervals;

C. frequency converter means for changing the frequency of said chrominance signal to a third frequency corresponding to the difference between said first frequency and said second frequency in response to said frequency converting carrier signal as changed;

D. means for recording the frequency changed chrominance signal in adjacent tracks on said recording medium and for reproducing said recorded frequency changed chrominance signal;

E. means for generating a frequency reconverting carrier signal at said second frequency, the phase of said reconverting carrier signal being changed at the end of selected line intervals in a manner determined by said changed frequency converting carrier signal to cancel cross-talk between signals from adjacent tracks during reproducing of the recorded signals; and

F. comb filter means connected to receive the frequency reconverted chrominance signal to reduce the amplitude of undesired cross-talk signals therefrom.

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