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Ishigaki et al.

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[54] **SYSTEM FOR A MULTICHANNEL RECORD DISC WITH CROSSTALK COMPENSATION PROVIDED DURING RECORDING**

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[51] **Int. Cl.**.......................... **G11b 3/00;** G11b 3/74

[58] **Field of Search**...179/1 TD, 100.2 K, 100.2 MD, 179/100.4 ST, 100.4 C, 1 GQ, 1 ST, 1 R, 1 BT; 360/65, 66, 124

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Primary Examiner—Bernard Konick
Assistant Examiner—David K. Moore

[57] **ABSTRACT**

A cutting and recording system for multichannel discs has means for applying beforehand crosstalk compensation correction components to the recording signals. This compensation cancels a crosstalk component produced between left and right channels during the recording of multiplexed signals on a disc. This crosstalk correction signal is obtained from an angular modulated wave signal of the left channel system and applied to an angular modulated wave signal of the right channel system. A similar crosstalk correction signal, obtained from the angular modulating means of the right channel system, is applied to the angular modulated wave signal of the left channel system.

4 Claims, 4 Drawing Figures

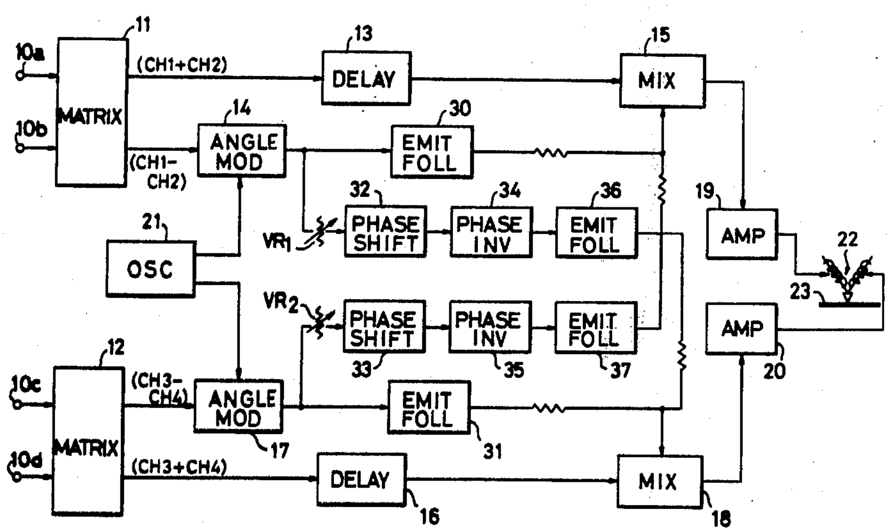


FIG. 1 PRIOR ART

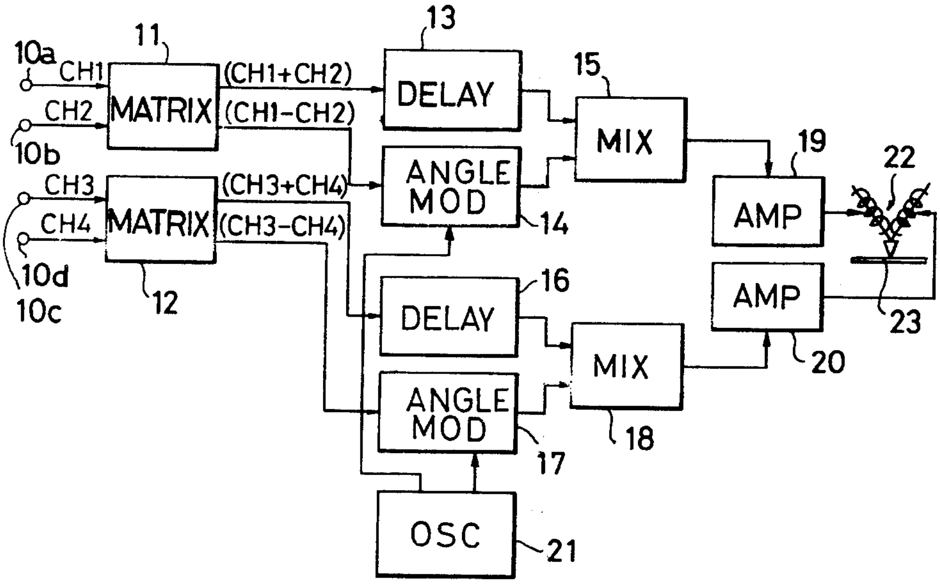


FIG. 4

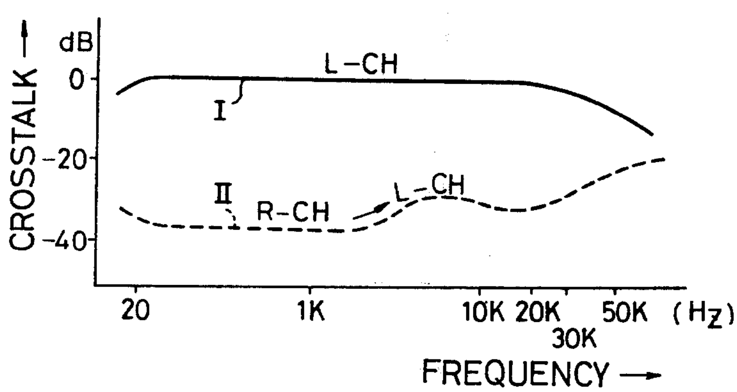
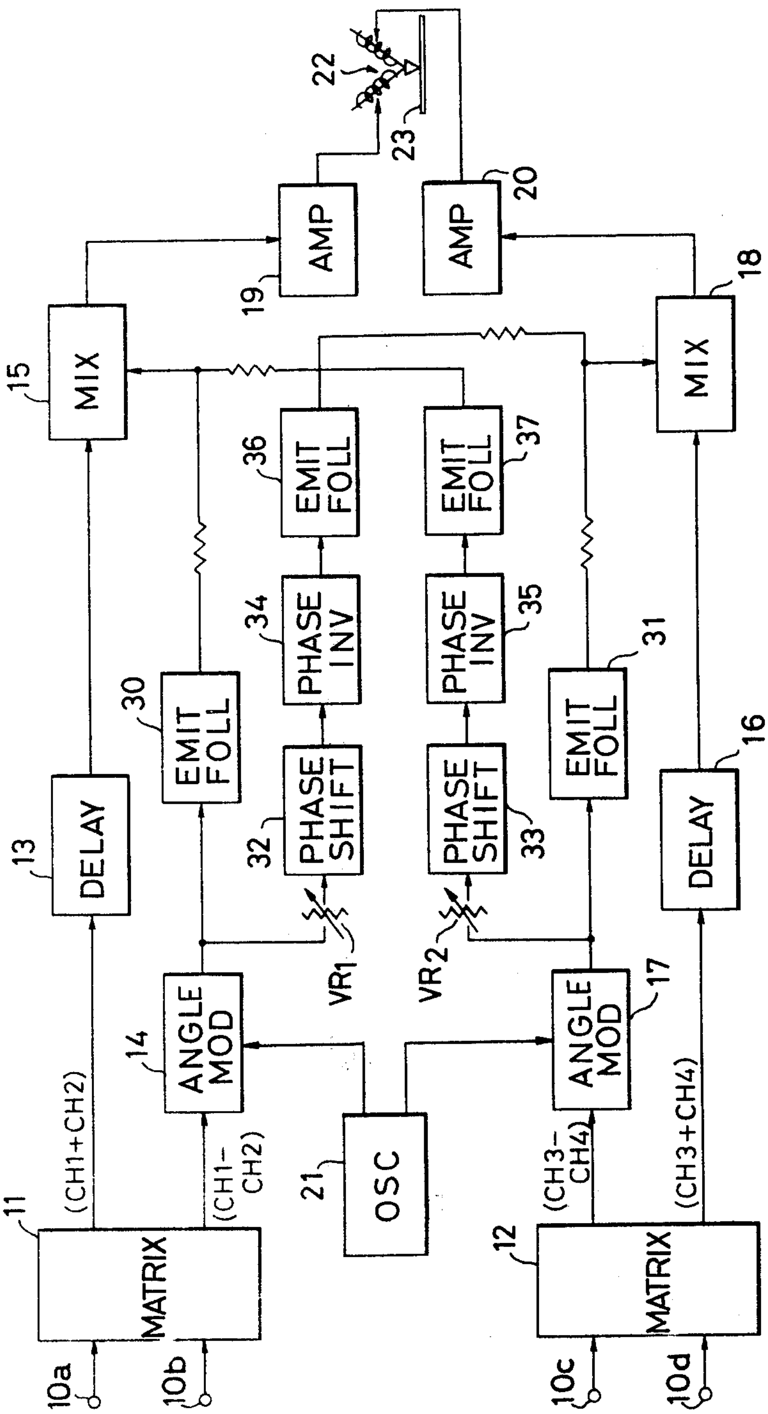


FIG. 2


MATRIX
MATRIX
DELAY
DELAY
ANGLE MOD
ANGLE MOD
EMIT FOLL
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EMIT FOLL
PHASE SHIFT
PHASE SHIFT
PHASE INV
PHASE INV
MIX
MIX
AMP
AMP
OSC
(CH1+CH2)
(CH1–CH2)
(CH3–CH4)
(CH3+CH4)
VR1
VR2
10a
10b
10c
10d
11
12
13
14
15
16
17
18
19
20
21
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23
30
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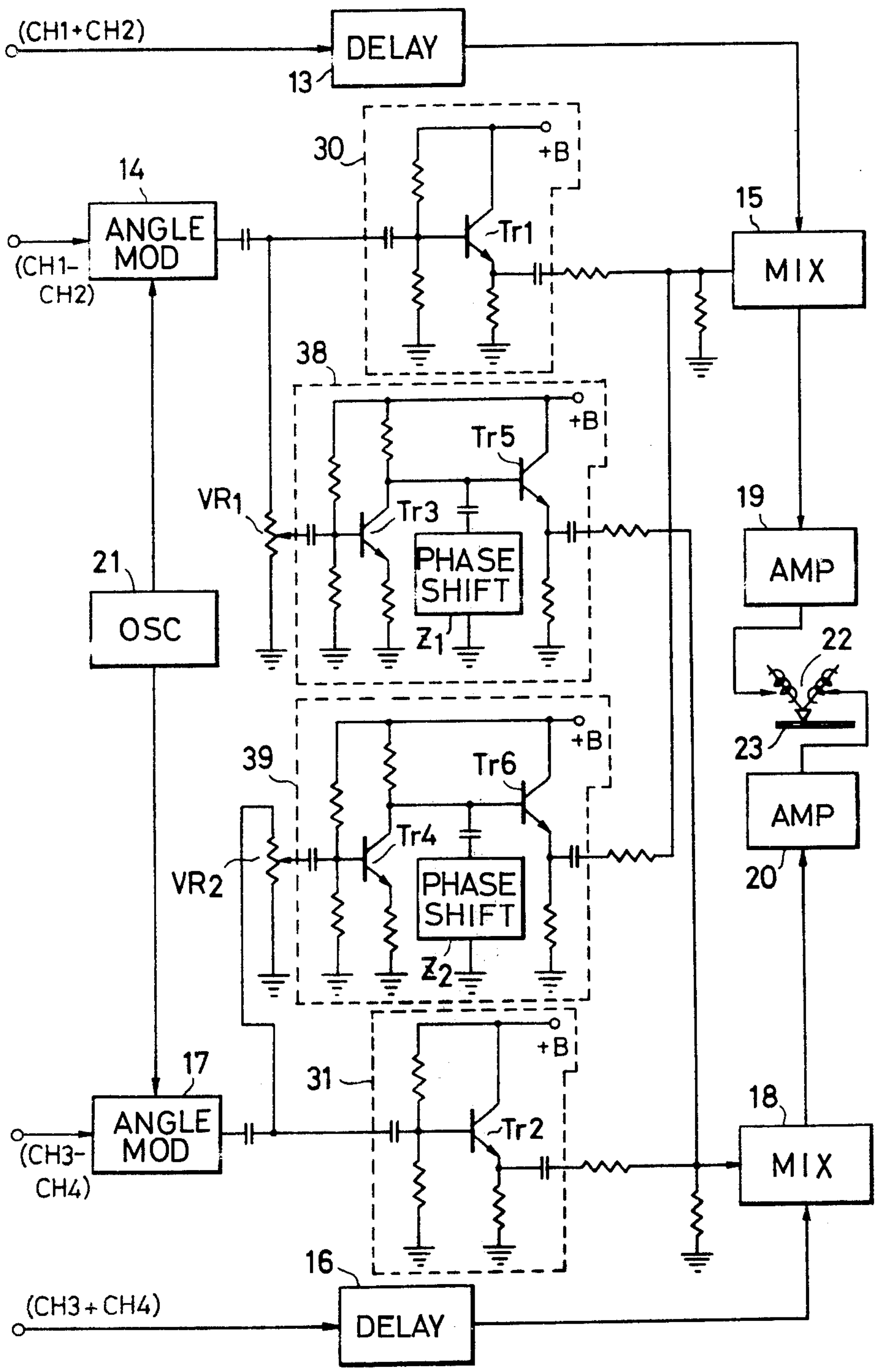
FIG. 3


(CH1+CH2)
DELAY
13
30
+B
14
ANGLE MOD
Tr1
15
MIX
(CH1-CH2)
38
+B
Tr5
VR1
Tr3
19
AMP
21
PHASE SHIFT
OSC
Z1
22
39
+B
23
Tr6
AMP
Tr4
VR2
PHASE SHIFT
20
Z2
+B
17
31
ANGLE MOD
Tr2
18
MIX
(CH3-CH4)
16
(CH3+CH4)
DELAY

SYSTEM FOR A MULTICHANNEL RECORD DISC WITH CROSSTALK COMPENSATION PROVIDED DURING RECORDING

BACKGROUND OF THE INVENTION

This invention relates generally to a cutting and recording system for a multichannel record disc, and more particularly, to a system for cutting a multichannel record disc, wherein a component for nullifying or canceling crosstalk is added to the signal to eliminate crosstalk occurring at the time of recording.

In general, we have previously proposed a compatible-discrete, 4-channel (CD-4) system, which has already been reduced to practice. The direct wave of the sum signal of two channels out of four channel signals and an angular modulation wave of the difference signal of the two channels are multiplexed at the time of recording. The resulting signal is recorded on one of the wall surfaces of the sound groove. With respect to the other two channels, multiplexing is carried out in the same way. The resulting signal is recorded on the other wall surface of the sound groove.

In this recording system, there is a crosstalk of angular modulated waves, between the left and right channels. Crosstalk is produced by the process wherein the electrical signal applied to the cutting stylus or cutter is converted into a mechanical vibration, as described hereinafter in detail. When crosstalk occurs in this manner, it appears as distortion during playback or reproduction, and the reproduced tone quality deteriorates.

SUMMARY OF THE INVENTION

Accordingly, the present invention contemplates adding to the recording signal a component for nullifying the above mentioned crosstalk component. The recording of multichannel signals on a disc follows without the occurrence of crosstalk.

It is a prime object of the invention to provide a new and useful multichannel disc cutting and recording system in which crosstalk is prevented at the time of the recording of multichannel signals on a disc.

Another object of the invention is to provide a multichannel disc recording system wherein an opposite crosstalk component, of opposite phase and equal quantity relative to the crosstalk component, is introduced beforehand into the recording signal. Recording is carried out with the net result that crosstalk is prevented from occurring.

Still another object of the invention is to provide a multichannel disc recording system wherein, by merely adjusting components such as a variable resistor and a phaseshifting circuit in accordance with the crosstalk characteristic of the recording cutter, it is possible through the electrical circuit system to eliminate the crosstalk component in the electric signal-mechanical vibration transducer of the cutter.

Other objects and further features of the invention will be apparent from the following detailed description when read in conjunction with the accompanying drawing, throughout which like parts are designated by like reference numerals and characters.

BRIEF DESCRIPTION OF THE DRAWING

In the drawing:

FIG. **1** is a block diagram showing the essential organization of one example of a four-channel disc recording system of a general type, known heretofore;

FIG. **2** is a block diagram showing the essential organization of one embodiment of a four-channel disc recording system according to the invention;

FIG. **3** is a circuit diagram showing one embodiment of a specific electrical circuit of the essential parts of the system shown by block diagram in FIG. **2**; and

FIG. **4** is a graph indicating one example of crosstalk characteristics of a cutter head.

DETAILED DESCRIPTION

As conducive to a full understanding of this invention, a known cutting and recording system and problems associated therewith will first be briefly described with reference to FIG. **1**.

First and second channel signals **CH1** and **CH2** and third and fourth channel signals **CH3** and **CH4** are introduced through input terminals **10***a* and **10***b* and input terminals **10***c* 10*d*, respectively, as indicated in FIG. **1**. These signals are respectively supplied to matrix circuits **11** and **12** and there rendered into sum signals and difference signals. The output sum signals (CH1 + CH2) and (CH3 + CH4) of the matrix circuits **11** and **12** are respectively passed through delay circuits **13** and **16** for matching their phase with angular modulation difference signals, described hereinafter. Then, they are supplied to mixing circuits **15** and **18**.

On the other hand, the output difference signals (CH1 − CH2) and (CH3 − CH4) of the matrix circuits **11** and **12** are respectively supplied to angular modulation circuits **14** and **17**. There, a carrier wave from a single master oscillator **21** is angular modulated. The output angular modulated difference signals of the angular modulation circuits **14** and **17** are supplied to the above mentioned mixing circuits **15** and **18** and there mixed and multiplexed with the above mentioned direct-wave sum signals.

The output multiplexed signals of the mixing circuits **15** and **18** are amplified by amplifiers **19** and **20**. Then, they are applied to the coils of the channel L and the channel R of a cutter **22**. This cutter **22** is driven accordingly, whereby the recording signals are recorded on a disc **23** by the cutting stylus of the cutter respectively on the left and right walls of the recording groove according to the 45-45 system.

In a recording system of this known character, however, crosstalk of the angular modulation wave is produced between the channels L and R, as a result of the process of converting of an electrical signal applied to the cutter **22** into a mechanical vibration. More specifically, while a crosstalk due to a direct-wave sum signal of relatively low frequency presents almost no problem. However, in the case of an angular modulated difference signal of relatively high frequency, the quantity of crosstalk becomes large at the range of high frequency because of the structural mechanical accuracy of the cutter **22** and of the signal wavelength at which cutting is carried out. When crosstalk exists in this manner, at the time of cutting, distortion is produced in the reproduced sound during playback of the multichannel disc thus recorded.

The above mentioned crosstalk and distortion will now be considered more fully. With respect to the angular modulated signals, the angular modulated signal relating to the difference signal (**CH1** − **CH2**) will be denoted by L. The modulated signal relating to the difference signal (CH3 − CH4) will be denoted by R. Then, L and R can be expressed by the following equations.

$$\left.\begin{aligned} L &= \cos\,[\omega ct + f(t)] \\ R &= \cos\,[\omega ct + g(t)] \end{aligned}\right\} \quad (1)$$

where: ωc is the angular frequency of the carrier wave, and $f(t)$ and $g(t)$ are respectively phase angles representable as functions of the difference signal component.

Then, by representing the crosstalk by $Ke^{j\varphi}$, the signal component leaking into the channel L can be represented by the following Equation (2).

$$R \times Ke^{j\varphi} = K.\cos\,[\omega ct + g(t) + \varphi] \quad (2)$$

Accordingly, the signal L' of the channel L containing the crosstalk becomes

$$\begin{aligned} L' &= \cos\,[\omega ct + f(t)] + K{\cdot}\cos\,[\omega ct + g(t) + \varphi] \\ &= \sqrt{1 + K^2 + 2K{\cdot}\cos\,[f(t) - g(t) - \varphi]} \\ &= x \cos\left\{\omega ct - \tan^{-1} \frac{\sin[f(t)] + K{\cdot}\sin[g(t) + \varphi]}{\cos[f(t)] + K{\cdot}\cos[g(t) + \varphi]}\right\} \end{aligned} \quad (3)$$

The demodulated signal, denoted by D(t) is determined from the following equation.

$$D(t) = -\frac{f'(t) + K^2 g'(t) + K[f'(t) + g'(t)]\cos[f(t) - g(t) - \varphi]}{1 + K^2 + 2K{\cdot}\cos[f(t) - g(t) - \varphi]} \quad (4)$$

If the value of K in this Eq. (4) is sufficiently small,

$$D(t) \approx -\left\{f'(t) + K[f'(t) + g'(t)]\cos[f(t) - g(t) - \varphi]\right\} \quad (5)$$

From the above Eq. (5), the component relating to the crosstalk and distortion becomes

$$-K[f'(t) + g'(t)]\cos\,[f(t) - g(t) - \varphi] \quad (6)$$

As for the component of crosstalk and distortion in the channel R, it may be similarly expressed as follows.

$$-K[f'(t) + g(t)]\cos\,[g(t) - f(t) - \varphi] \quad (7)$$

Consequently, in a conventional recording system, as described above, the crosstalk expressed by the above equation gives rise to distortion, and high fidelity is impaired.

The above described difficulties accompanying the conventional recording system have been overcome by the present invention, one embodiment of which is illustrated by the block diagram in FIG. 2. In FIG. 2, blocks which are the same as or equivalent to those in FIG. 1 are designated by like reference numerals, and detailed description thereof will not be repeated.

The angular modulated difference signals derived as output from the angular modulation circuits **14** and **17** and expressed by the above Eq. (1) are supplied by way of emitter follower circuits **30** and **31** to mixing circuits **15** and **18**. There, they are mixed with direct-wave sum signals transmitted from the matrix circuits **11** and **12** by way of delay circuits **13** and **16**. The output multiplexed signals of the mixing circuits **15** and **18** are amplified by amplifiers **19** and **20** and then recorded by a cutter **22** on a disc **23**.

As is apparent from the above Eq. (3), only the angular modulated wave from within each signal applied to the cutter **22** can expressed by the following equations.

For the channel L,

$$L' = \cos[\omega ct + f(t)] + K.\cos[\omega ct + g(t) + \phi] \quad (8)$$

For the channel R,

$$R' = \cos[\omega ct + g(t)] + K.\cos[\omega ct + f(t) + \phi] \quad (9)$$

The crosstalk component in the channel L, from the channel R, is

$$K.\cos[\omega ct + g(t) + \phi] \quad (10)$$

The crosstalk component in the channel R, from the channel L, is

$$K.\cos[\omega ct + f(t) + \phi] \quad (11)$$

Then, in order to cancel or nullify these crosstalk components in accordance with the system of the present invention, the block system is organized as described below.

The essential parts of the block system according to the invention as illustrated in FIG. 2 will now be described. The output angular modulated difference signals of the angular modulation circuits **14** and **17** are supplied to the emitter follower circuits **30** and **31**, as mentioned above. At the same time, these difference signals are also supplied by way of variable resistors VR1 and VR2 to phase-shifting circuits **32** and **33**. These angular modulated difference signals are multiplied K times by the variable resistors VR1 and VR2, thereby being adjusted for the crosstalk correction quantity, and are then shifted in phase by the phase-shifting circuits **32** and **33**.

The output signals of the phase-shifting circuits **32** and **33** are phase inverted by phase-inversion circuits **34** and **35** and then supplied to emitter follower circuits **36** and **37**. Consequently, the output of the emitter follower circuit **36** becomes

$$-K.\cos\,[\omega ct + f(t) + \phi] \quad (12)$$

while the output of the emitter follower circuit **37** becomes

$$-K.\cos\,[\omega ct + g(t) + \phi] \quad (13)$$

The output signal of the emitter follower circuit **36** is supplied to the mixer **18** together with the angular modulated wave produced as output of the angular modulator **17**, passed via emitter follower circuit **31**. The output signal of the emitter follower circuit **37** is supplied to the mixer **15** together with the angular modulated wave produced as output of the angular modulator **14**, passed via emitter follower circuit **30**. Therefore, the angular modulated waves produced as outputs L'_o and R'_o of the mixing circuits **15** and **18** can be expressed respectively as follows.

$$\begin{aligned} L'_o &= \cos[\omega ct + f(t)] + K.\cos[\omega ct + g(t) + \phi] - K.\cos[\omega ct + g(t) + \phi] \\ &= \cos[\omega ct + f(t)] \end{aligned} \quad (14)$$

$$\begin{aligned} R'_o &= \cos[\omega ct + g(t)] + K.\cos[\omega ct + f(t) + \phi] - K.\cos[\omega ct + f(t) + \phi] \\ &= \cos[\omega ct + g(t)] \end{aligned} \quad (15)$$

As is apparent from the above Eqs. (14) and (15), the crosstalk components are completely nullified.

It is to be observed that the foregoing equations are satisfied when: the quantity of crosstalk due to the cutter is equal to the signal quantity K passed through the variable resistors VR1 and VR2; when the phase characteristic of the crosstalk is equal to those of the phase-shifting circuits **32** and **33**; and when the phases of the carrier waves applied from the master oscillator **21** to the angular modulators **14** and **17** are equal.

The essential parts of the block system indicated in FIG. 2 can be reduced to a practical form, as illustrated by one embodiment of a specific electrical circuit in FIG. 3. The circuit **38** enclosed by an intermittent line is a circuit including the phase-shifting circuit **32** (FIG. 2), the phase-inversion circuit **34**, and the emitter follower circuit **36**. Similarly, the circuit **39** includes the circuits **33** (FIG. 2), **35**, and **37**. The transistors Tr1 and Tr2 are connected in an emitter follower configuration. The circuits including these transistors and enclosed by intermittent lines correspond to the aforementioned emitter follower circuits **30** and **31**. In the circuits **38** and **39**, the circuits including transistors Tr3 and Tr4 correspond to the phase-inversion circuits **34** and **35**. Circuits Z1 and Z2 are connected in series with transistors Tr3 and Tr4 and ground (earth) correspond to the phase-shifting circuits **32** and **33**. The circuits including emitter follower transistors Tr5 and Tr6 correspond to the emitter follower circuits **36** and **37**.

One example of the crosstalk frequency characteristics of the cutter **22** is graphically represented in FIG. **4**, in which the curve I represents the frequency characteristic of a signal of the channel L. The curve II represents the frequency characteristic of a crosstalk component leaking from the channel R into the channel L. In general, the quantity of the shift of the phase of the crosstalk of the cutter head differs with frequency band used. For example, when the band of the angular modulated wave is from 20 KHz to 45 KHz, and the phase thereof at the time is in an advanced phase state, one measure is to cause the phase-shifting circuits Z1 and Z2 to have an advanced phase characteristics. For example, equalizer circuits of characteristics equal to the frequency characteristics of the crosstalk components are used for the phase-shifting circuits Z1 and Z2.

The above described system, according to the present invention, has the following advantageous features.

1. By adjusting the variable resistors and phase-shifting circuits in accordance with the crosstalk characteristic of the cutter used, the crosstalk quantity can be reduced to zero or to a minute value very close to zero, whereby distortion due to crosstalk can be eliminated, and recording of high fidelity can be achieved.

2. The crosstalk of the cutter is nullified with an electric circuit system. Therefore, even if there are deviations due to the cutter in the above mentioned crosstalk characteristic, it is possible to correct this deviation in a simple manner. Accordingly, there is no necessity of selecting the cutter to be used on this point, which is an economical feature.

3. By using a circuit for nullifying crosstalk, it is possible to use a higher frequency band, than heretofore, for the angular modulated wave band. Accordingly, the cutting operation at the time of recording of a multichannel disc can be carried out at a higher rate than heretofore. Therefore, the disc can be cut in a smoother manner, the signal to noise ratio being improved. At the same time, the productivity of the operation is increased.

Modifications will readily occur to those who are skilled in the art. Therefore, the appended claims are to be construed to include all equivalents falling within the scope and the spirit of the invention.

What we claim is:

1. A multichannel disc system for recording first and second channels on a left groove wall and third and fourth channels on a right groove wall of a phonograph record, said system comprising:

a. first matrix means for forming a first sum signal and a first difference signal responsive to said first and second channel signals;

b. second matrix means for forming a second sum signal and a second difference signal responsive to said third and fourth channel signals;

c. first modulating means for angularly modulating a carrier wave responsive to the first difference signal to produce a first angular modulated wave;

d. second modulating means for angularly modulating the carrier wave responsive to the second difference signal to produce a second angular modulated wave;

e. first attenuating means for attenuating the first angular modulated wave;

f. first phase-shifting means for shifting the phase of the output signal of said first attenuating means;

g. first phase-inverting means for inverting the phase of the output signal of said first phase-shifting means;

said first attenuating means having an attenuating quantity for making the amplitude of the output signal of said first phase-inverting means equal to the amplitude of a first crosstalk component leaking from the left channel into the right channel; said first phase-shifting means having a phase-shifting quantity for causing the phase angle of the output signal of said first phase-inverting means to cancel the phase angle of the first crosstalk component;

h. second attenuating means for attenuating the second angular modulated wave;

i. second phase-shifting means for shifting the phase of the output signal of said second attenuating means;

j. second phase-inverting means for inverting the phase of the output signal of said second phase-shifting means;

said second attenuating means having an attenuating quantity for making the amplitude of the output signal of said second phase-inverting means equal to the amplitude of a second crosstalk component leaking from the right channel into the left channel; said second phase-shifting means having a phase-shifting quantity for causing the phase angle of the output signal of said second phase-inverting means to cancel the phase angle of the second crosstalk component;

k. first mixing means for mixing and multiplexing the first direct-wave sum signal, the first angular modulated wave and the output signal of said second phase-inverting means;

l. second mixing means for mixing and multiplexing the second direct-wave sum signal, the second angular modulated wave and the output signal of said first phase-inverting means; and

m. recording means for recording the output signal of said first and second mixing means on the left and right channel sides, for simultaneously recording the output signal of said first mixing means on the left wall of a groove of a record disc and the output signal of said second mixing means on the right wall of the groove.

2. A multichannel disc recording system as claimed in claim 1 in which said first phase-shifting means comprises an equalizer circuit means having a characteristic equal to the frequency characteristic of the first crosstalk component, and said second phase-shifting means comprises an equalizer circuit means having a characteristic equal to the frequency characteristic of the second crosstalk component.

3. A multichannel disc recording system for recording first and second channels on a left groove wall and third and fourth channels on a right groove wall of a phonograph record, said system comprising:

a. first matrix means for forming a first sum signal and a first difference signal responsive to said first and second channel signals;
b. second matrix means for forming a second sum signal and a second difference signal responsive to said third and fourth channel signals;
c. first modulating means for angularly modulating a carrier wave responsive to the first difference signal to produce a first angular modulated wave;
d. second modulating means for angularly modulating the carrier wave responsive to the second difference signal to produce a second angular modulated wave;
e. first attenuating means for attenuating the first angular modulated wave;
first phase-inverting means for inverting the phase of the output signal of said first attenuating means;
g. first phase-shifting means for shifting the phase of the output signal of said first phase-inverting means;

said first attenuating means having an attenuating quantity for setting the amplitude of the output signal of said first phase-shifting means equal to a first crosstalk component leaking from the left channel into the right channel; said first phase-shifting means having a phase-shifting quantity for causing the phase angle of the output signal of said first phase-shifting means to cancel the phase angle of the first crosstalk component;

h. second attenuating means for attenuating the second angular modulated wave;
i. second phase-inverting means for inverting the phase of the output signal of said second attenuating means;
j. second phase-shifting means for shifting the phase of the output signal of said second phase-inverting means;

said second attenuating means having an attenuating quantity for setting the amplitude of the output signal of said second phase-shifting means equal to the amplitude of a second crosstalk component leaking from the right channel into the left channel; said second phase-shifting means having a phase-shifting quantity for causing the phase angle of the output signal of said second phase-shifting means to cancel the phase angle of the second crosstalk component;

k. first mixing means for mixing and multiplexing the first direct-wave sum signal, the first angular modulated wave and the output signal of said second phase-shifting means;
l. second mixing means for mixing and multiplexing the second direct-wave sum signal, the second angular modulated wave and the output signal of said first phase-shifting means; and
m. recording means for recording the output signal of said first and second mixing means on the left and right channel sides, for simultaneously recording the output signal of said first mixing means on the left wall of a groove of a record disc and the output signal of said second mixing means on the right wall of the groove.

4. A multichannel disc recording system as claimed in claim 3 in which said first phase-shifting means comprises an equalizer circuit means having a chracteristic equal to the frequency characteristic of the first crosstalk component, and said second phase-shifting means comprises an equalizer circuit means having a characteristic equal to the frequency characteristic of the second crosstalk component.

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