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(54) SYSTEM FOR RECORDING AND/OR REPRODUCING FOUR CHANNEL SIGNALS ON A RECORD DISC

(71) We, NIPPON VICTOR KABU-SHIKI KAISHA, of No. 12, 3-chome, Moriya-cho, Kanagawa-ku, Yokohama-City, Kanagawa-ken, Japan, a Japanese Corporation, do hereby declare the invention for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to a system for recording four channel signals on and/or reproducing them from a record disc and, more particularly, to a system for recording four channel signals on a single groove of a record disc and/or reproducing these signals from this single groove.

In a conventional stereophonic record disc, two channel signals are recorded on the disc. In this stereo record, signals of the left and right channels are respectively recorded on two walls of a groove of the disk. This groove is called a 45—45 stereo system groove because both walls thereof are inclined at an angle of 45° with respect to a perpendicular line which passes through the deepest point of the groove. In this conventional two channel stereophonic system, there are two sound sources forming one sound plane which enables this system to have a sound source reproductivity twice as large as that of a monaural system in which there is only one sound source and no sound plane whatsoever.

However, there has recently been an increasing demand for reproducing and reviving the real atmosphere of the live performance in a reproduced sound field. It will be apparent that the degree of reality is enhanced if the number of signal sources can be increased. For this purpose, there has been proposed a magnetic tape reproducing apparatus in which sounds are reproduced from a magnetic tape having four channel signals recorded on four tracks. However, it has heretofore been considered impossible to record

four channel signals on a record disc without providing a plurality of grooves for the four channels.

This invention has made it possible to record four channel signals on a single groove of a record disc.

Even if recording of four channel signals on a single groove of a record disc is made possible, requirement for compatibility with the conventional two channel stereo record disc must be considered. More specifically, stereophonic reproduction of a two channel record disc must be possible on a four channel record disc reproducing apparatus, whereas stereophonic reproduction of a four channel record disc must be possible on a two channel record disc reproducing apparatus. Accordingly, a four channel record and a reproducing apparatus therefor which satisfy the aforementioned needs are required.

Further, in an amplitude modulation system, the signal-to-noise ratio is a problem. In a frequency modulation system, the signal-to-noise ratio can be improved over that of an amplitude modulation system. If, however, there is crosstalk between output signals from modulators having separate oscillators, a disturbing noise which did not exist originally will be produced. Therefore, a four channel record disc cannot be of practical use unless the problem of disturbing noises caused by crosstalk is satisfactorily settled.

Furthermore, in cutting and recording on an original lacquer disc, it is necessary to compress frequency bands of signals to be recorded due to limitation in operable frequency range of a cutting machine. This recording with the compressed bands must be effected without producing noises.

This invention has eliminated the barriers which obstruct realization of a four channel record and satisfies every requirement as hereinabove described. It is, therefore, a general object of the present invention to

provide a novel and useful system for recording and/or reproducing four channel signals on a record disc.

Another object of the invention is to provide a system for recording and reproducing four channel signals on a single groove of a record disc.

Yet another object of the invention is to provide a system for recording four channel signals on a record disc in such a way that substantially no disturbing noise is produced by crosstalk which may occur between each channel signal.

A further object of the invention is to provide a system for reproducing four channel signals from a record disc, which is compatible with the conventional two channel stereo record.

A still further object of the invention is to provide an angle modulation type system for recording four channel signals on a record disc, in which four channel signals can be recorded without producing noise even when the frequency bands of signals to be recorded are compressed in recording.

Other objects and features of the invention will become apparent from the description made hereinbelow with reference to the accompanying drawings, in which:

Fig. 1 is a schematic diagram showing an arrangement in which sounds from sound sources are recorded as four channel signals on a magnetic tape;

Fig. 2 is a block diagram showing one embodiment of a recording system according to the invention for cutting and recording four channel signals on a record disc;

Figs. 3A and 3B are diagrams showing frequency characteristics of the recorded and reproduced signals;

Fig. 4 is a vertical section of a groove of a record disc;

Fig. 5 is a block diagram showing one embodiment of the reproducing system according to the invention;

Fig. 6 is a diagram for illustrating a reproduced sound field;

Fig. 7 is a vector diagram showing the relationship between vectors of a groove of a record disc and an actuating axis of a pickup stylus;

Figs. 8 and 9 are vector diagrams for illustrating crosstalk;

Figs. 10A and 10B are diagrams showing signal waveforms;

Figs. 11A and 11B are diagrams showing respectively relationships between an angle θ and an angle α , and the angle θ and a vector I shown in Fig. 9;

Fig. 12 is a diagram showing the relationship between the frequency of the modulating wave and the phase deviation angle;

Figs. 13 and 14 are diagrams showing respectively examples of frequency response

characteristics of equalizers used in the recording system shown in Fig. 2;

Figs. 15 and 16 are diagrams respectively showing examples of frequency response characteristics of equalizers used in the reproducing system shown in Fig. 5;

Fig. 17 is a block diagram of a simple embodiment of a frequency modulating means which however is of no use in the recording system and is outside the scope of the claims; and

Fig. 18 is a block diagram of a preferable embodiment of the frequency modulating means in the recording system.

First, one embodiment of a recording system according to this invention will be illustrated with reference to Figs. 1 and 2.

In Fig. 1, microphones 11 and 13 for respective first and third channels are placed on the left and right close to sound sources 10. Remote from the sound sources 10, there are microphones 12 and 14 on the left and right for respective second and fourth channels. The sounds from the sound sources 10 which are collected by the microphones 11, 12, 13 and 14 are recorded as the first, second, third and fourth channel signals on four tracks of a magnetic tape in a tape recorder 15. The frequency band of each channel signal is from 30Hz up to 15KHz.

Referring to Fig. 2, the magnetic tape on which the recording has been effected is run in the tape recorder 15 at a speed of $1/S$ of the recording speed, ($S > 1$) when playing back the recorded four channel signals for groove-cutting. In the present embodiment, the running speed of the tape during this play back for example is about $1/2.7$ of the recording speed. Accordingly, frequency bandwidths of the four channel signals reproduced from the tape recorder 15 are compressed to $1/S$ ($1/2.7$ in the present embodiment) of the frequency bandwidths of the recorded signals.

The first and second channel signals Ch1 and Ch2 each having a frequency band of up to $15/S$ KHz from the tape recorder 15 are supplied to a matrix circuit 16 and the third and fourth channel signals Ch3 and Ch4 are supplied to a matrix circuit 17. In the matrix circuit 16, the first and second channel signals Ch1 and Ch2 are converted into a sum signal ($Ch1 + Ch2$) and a difference signal ($Ch1 - Ch2$). The sum signal ($Ch1 + Ch2$) is supplied through an equalizer 18 to a mixer 25. The difference signal ($Ch1 - Ch2$) is supplied through an equalizer 19 to a frequency modulator 22. At the frequency modulator 22, the difference signal ($Ch1 - Ch2$) frequency modulates a carrier signal derived from a single local oscillator 24. The frequency modulated difference signal $F(Ch1 - Ch2)$ is supplied to the mixer 25. This modulated difference signal is a signal which is frequency modulated with respect to input of

the frequency modulator 22 and is phase modulated with respect to input of the equalizer 19. Accordingly, this modulated signal will hereafter be referred to as an angle modulated difference signal, since "angle modulated" covers both "phase modulated" and "frequency modulated".

The sum signal $(Ch1+Ch2)$ supplied to the mixer 25 has a band which is shown by a broken line *a* in Fig. 3A. The angle modulated difference signal $(Ch1-Ch2)$ supplied to the mixer 25 has a band shown by a broken line *b* in Fig. 3A which is higher than the upper frequency limit of the band *a*. Accordingly, the sum signal having the band *a* and the modulated difference signal having the band *b* are multiplexed together at the mixer 25 without overlapping each other.

Similarly, the third and fourth channel signals $Ch3$ and $Ch4$ respectively having a frequency band of up to $15/S$ KHz are converted into a sum signal $(Ch3+Ch4)$ and a difference signal $(Ch3-Ch4)$ in the matrix circuit 17. The sum signal $(Ch3+Ch4)$ is supplied through an equalizer 20 to a mixer 26. The difference signal $(Ch3-Ch4)$ is supplied through an equalizer 21 to a frequency modulator 23. At the frequency modulator 23, the difference signal $(Ch3-Ch4)$ frequency modulates a carrier signal derived from the local oscillator 24, which carrier signal is the same as the one supplied to the modulator 22. This frequency modulated difference signal $F(Ch3-Ch4)$ is supplied to the mixer 26. This frequency-modulated difference signal is referred to hereafter more generally as an angle modulated difference signal. The sum signal $(Ch3+Ch4)$ supplied to the mixer 26 has a band shown by a broken line *c* in Fig. 3B. The angle modulated difference signal $F(Ch3-Ch4)$ supplied to the mixer 26 has a band shown by a broken line *d* in Fig. 3B which is higher than the upper frequency limit of the band *c*. Accordingly, the sum signal having the band *c* and the modulated difference signal having the band *d* are multiplexed together at the mixer 26 without overlapping each other. The equalizers 18 and 20 may be, for example, of a normal type having RIAA characteristic.

The multiplexed signals $\{(Ch1+Ch2)+F(Ch1-Ch2)\}$ and $\{(Ch3+Ch4)+F(Ch3-Ch4)\}$ from the mixers 25 and 26 are respectively amplified by cutting amplifiers 27 and 28. The amplified multiplexed signals are applied to a 45—45 system cutter 29. A lacquer disc 30 which is to be used as a master disc is rotated at a speed of $1/S$ of a normal rotating speed of a record disc, (for example, $1/S$ of $33\frac{1}{3}$ r.p.m.). The signals applied to the cutter 29 are recorded by a cutting stylus 31 in a single spiral groove on the lacquer disc 30.

As in a conventional two channel stereo record disc, the cutting stylus 31 cuts, as

shown in Fig. 4, a so-called 45—45 system groove 32 on the lacquer disc 30. The groove 32 has walls 33 and 34 respectively inclining at an angle of 45° with respect to a perpendicular passing through the deepest point of the groove 32. The multiplexed signal of the first and second channels $\{(Ch1+Ch2)+F(Ch1-Ch2)\}$ is recorded on the left wall 33 (corresponding to a wall where a left channel signal of the conventional two channel stereo record is recorded) of the groove 32. This signal will hereafter be referred to as an L channel multiplexed signal. Similarly, the multiplexed signal of the third and fourth channels $\{(Ch3+Ch4)+F(Ch3-Ch4)\}$ is recorded on the right wall 34 (corresponding to a wall where a right channel of the conventional two channel stereo record is recorded) of the groove 32. This signal will hereafter be referred to as an R channel multiplexed signal. Accordingly, signals of four channels are simultaneously recorded in the single groove of the lacquer disc 30.

It is to be noted that the angle modulated difference signals $F(Ch1-Ch2)$ and $F(Ch3-Ch4)$ should be maintained at a level of $1/10$, i.e., -20 dB, of the (unmodulated) sum signals $(Ch1+Ch2)$ and $(Ch3+Ch4)$.

A maximum operable frequency of the cutter 29 generally is about 17 KHz. According to this invention, each channel signal is compressed in its band as described hereinabove whereby the maximum frequency of the angle modulated difference signals $F(Ch1-Ch2)$ and $F(Ch3-Ch4)$ is limited to approximately 15 KHz. The cutter 29 is capable of recording the angle modulated signals.

As an alternative method of effecting compression of the bands one may supply the four channel signals directly from the sound sources 10 to the matrix circuits 16 and 17 and, after processes similar to those described hereinabove, record the output signals from the mixers 25 and 26 on magnetic tape by means of the tape recorder 15. In this case, the magnetic tape is run at a speed of $1/S$ of the recording speed and the reproduced multiplexed signals which are compressed in their frequency bands are recorded on the lacquer disc 30.

If, however, the difference signal is frequency modulated for the purpose of multiplexing with the sum signal before it is compressed, the maximum frequency of the frequency modulated difference signal will reach as high as 45 KHz for the frequency ranges shown in Figs. 3A and 3B. There are usually acicular crystals of magnetic material distributed at random on the magnetic surface of a magnetic tape. As a result, if, for example, an accurate sine wave is recorded on the magnetic tape, the waveform of the signal reproduced from the tape is different in each cycle and distortion is generated. Consequently, if this signal is frequency demodu-

lated, white noise is produced. It is, therefore, undesirable to effect recording and reproducing the frequency modulated signal on the magnetic tape for band compression. It follows from this that the embodiment which has been illustrated with reference to Figs. 1 and 2 is a preferable embodiment.

Fig. 5 is a block diagram showing one embodiment of a reproducing system according to the invention. A record disc 50 is formed by a conventional method using the lacquer disc 30 into which the groove has been cut and the four channel signals have been recorded as hereinabove described. The record disc 50 has a groove of the same shape as that of the lacquer disc 30. The record disc 50 is placed on a turntable of a record player and rotated at the standard speed, (for example 33 1/3 r.p.m.) which is S times as fast as the speed at which the lacquer disc 30 was cut.

A stylus 52 of a pickup cartridge 51 engages in the groove of the record disc 50 to reproduce the recorded signals. In the present embodiment, the frequency range of the pickup cartridge 51 is 20Hz to 45KHz and the stylus pressure of the cartridge is 1.5 grams. Since the record 50 is rotated at the standard speed, the frequency characteristics of the signals reproduced from the two walls of the groove of the record disc 50 are as shown by full lines in Figs. 3A and 3B. More specifically, the multiplexed signal reproduced from the left wall of the groove consists of the (unmodulated) sum signal $(Ch1+Ch2)$ shown by the full line A in Fig. 3A and the angle modulated difference signal $F(Ch1-Ch2)$ shown by the full line B in Fig. 3A. Similarly, the multiplexed signal reproduced from the right wall of the groove consists of the (unmodulated) sum signal $(Ch3+Ch4)$ shown by the full line C in Fig. 3B and the angle modulated difference signal $F(Ch3-Ch4)$ shown by the full line D in Fig. 3B. The upper frequency limit of each of the two sum signals $(Ch1+Ch2)$ and $(Ch3+Ch4)$ is approximately 15KHz. The centre carrier frequency of each of the two angle modulated difference signals $F(Ch1-Ch2)$ and $F(Ch3-Ch4)$ is 30KHz. The lower and upper limits of the frequency deviations of each of the two angle modulated difference signals are respectively 20KHz and 45KHz.

The multiplexed signal $\{(Ch1+Ch2)+F(Ch1-Ch2)\}$ reproduced from the pickup cartridge stylus 52 is supplied to a low-pass filter 53 and a band-pass filter 54. The sum signal $(Ch1+Ch2)$ filtered through the low-pass filter 53 is supplied to a matrix circuit 58 through an equalizer 57. The angle modulated difference signal $F(Ch1-Ch2)$ output from the band-pass filter 54 is demodulated by a demodulator 59. The demodulated signal $(Ch1-Ch2)$ is supplied to the matrix circuit

58 through an equalizer 60. Similarly, the reproduced multiplexed signal $\{(Ch3+Ch4)+F(Ch3-Ch4)\}$ is supplied to a low-pass filter 55 and a band-pass filter 56. The sum signal $(Ch3+Ch4)$ filtered through the low-pass filter 55 is supplied to a matrix circuit 62 through an equalizer 61. The angle modulated difference signal $F(Ch3-Ch4)$ output from the band-pass filter 56 is demodulated by a demodulator 63. This demodulated signal $(Ch3-Ch4)$ is supplied to the matrix circuit 62 through an equalizer 64.

The matrix circuit 58 effects the following matrix operation:

$$\frac{1}{2}\{(Ch1+Ch2)+(Ch1-Ch2)\}=Ch1 \quad 80$$

$$\frac{1}{2}\{(Ch1+Ch2)-(Ch1-Ch2)\}=Ch2$$

Accordingly, the first and second channel signals $Ch1$ and $Ch2$ are separately taken out of the matrix circuit 58. Similarly, the third and fourth channel signals $Ch3$ and $Ch4$ are separately taken out of the matrix circuit 62. The first to fourth channel signals $Ch1$ to $Ch4$ are respectively amplified by amplifiers 65, 66, 67 and 68 and then taken out of output terminals 69a, 70a, 71a and 72a as signals having frequency bands of 30Hz to 15KHz.

The first to fourth channel signal outputs from the terminals 69a to 72a are respectively supplied to speaker input terminals 69b, 70b, 71b and 72b shown in Fig. 6 whereby speakers 73, 74, 75 and 76 for the first to fourth channel signals reproduce the first to fourth channel signals. The speakers 73 and 74 for the first and second channels are respectively placed at the left front and the left rear of a listener 77 and the speakers 75 and 76 for the third and fourth channels are respectively placed at the right front and right rear of the listener 77.

In this case, six sound planes, i.e., planes between the speakers 73 and 75, 73 and 74, 74 and 76, 75 and 76, 73 and 76, and 75 and 74 as shown respectively by broken lines 78, 79, 80, 81, 82 and 83 are formed. Accordingly, sound source reproductivity of the system according to the invention is more realistic than the conventional two channel stereo reproducing system in which only one sound plane is formed.

If the record disc 50 constructed as hereinabove described is played back in a conventional two channel stereo record reproducing apparatus, the (relatively high frequency) angle modulated signal will of course not be rendered audible. Accordingly, the sum signal of the first and second channels will be

reproduced from a left speaker and the sum signal of the third and fourth channels from a right speaker. Conversely, if a conventional two channel stereo record disc is played back in the four channel record reproducing apparatus according to this invention, a left channel signal will be reproduced from the speakers 73 and 74 and a right channel signal from the speakers 75 and 76. Accordingly, the four channel record disc and the reproducing apparatus therefor according to this invention are completely compatible with the conventional two channel stereo record disc and the reproducing apparatus therefor.

Further, in the embodiment hereinabove described, the four channel signals are obtained by microphones placed as shown in Fig. 1 and the signals are reproduced by speakers placed as shown in Fig. 6. In the system according to this invention, however, the arrangements of the microphones and speakers are not limited to those shown in the aforementioned figures.

For example, among the microphones 11 to 14 shown in Fig. 1, the microphones 12 and 14 may be interchanged. In this case, the speakers 74 and 76 shown in Fig. 6 must of course also be interchanged. In addition, multiplexed signals recorded and reproduced in this case are, with reference to Fig. 6, a multiplexed signal of sum and difference signals of channels corresponding to the left front and right rear positions to the listener 77 and a multiplexed signal of sum and difference signals of channels corresponding to the right front and left rear positions.

Furthermore, other arrangements of the microphones 11 to 14 and the speakers 73 to 76 are possible.

In multiplexing the first and second (third and fourth) channel signals Ch1 and Ch2 (Ch3 and Ch4) and recording the multiplexed signals on one wall of the record groove, it is easily conceivable that the second (fourth) channel signal Ch2 (Ch4) only might, (but not according to the invention,) be frequency modulated and multiplexed with the first (third) channel signal Ch1 (Ch3). If, however, a four channel record disc on which recording is effected by this method were played back in the conventional two channel stereo reproducing apparatus, the second (fourth) channel signal would not be reproduced at all. Accordingly, when each channel signal has substantially different sound information, the reproduced sound would become extremely unnatural and incomplete. Therefore, there is no compatibility in such a simple system, which is excluded from the claims. In the system according to this invention, on the contrary, complete compatibility is assured by effecting matrix operation.

A second reason for effecting the aforementioned matrix operation in the system according to this invention will now be

explained. When a signal formed by multiplexing an angle modulated signal with an unmodulated signal is transmitted, signal-to-noise ratio deterioration and distortion of the demodulated carrier will generally occur which in turn will cause disturbance and noise from the unmodulated signal in the demodulated signal.

The tip radius of a play back stylus for contacting the record disc is in practice 5μ at the minimum so as not to injure the groove of the record disc. On the other hand, a half wave length of a carrier having a supraaudible frequency of 30KHz is 3.5μ measured at the innermost groove having a diameter of 120mm of a 33 1/3 r.p.m. record disc. Consequently, the amplitude of the carrier which can be reproduced by the stylus having a radius of 5μ should be below a certain value. In other words, the amount of energy of the carrier for cutting on the record disc cannot exceed a certain value. The energy of the carrier is dependent upon the frequency and amplitude of the carrier. Further, a record disc has inherent factors for generating noise due to uneven plating in the intermediate production process, the material of the record disc etc. Accordingly, the signal-to-noise ratio of the reproduced carrier becomes limited.

Further, if a high frequency component is strong in the (unmodulated) sum signal, its influence upon the carrier cannot be ignored and the carrier is disturbed to a considerable degree by the sum signal.

In the system according to this invention, noise is diminished by applying the matrix operation to the channel signals. The reason therefor will be set forth hereinbelow. Noises contained in the signals recorded on and reproduced from the left and right walls of the groove are respectively designated as L_N and R_N .

If, as described hereinabove, the signals Ch3 and Ch4 only are angle modulated and recorded and reproduced after being multiplexed with the signals Ch1 and Ch2 respectively, the reproduced channel signals Ch1' to Ch4' are represented as follows:

$$\begin{aligned} \text{Ch1}' &= \text{Ch1} \\ \text{Ch2}' &= \text{Ch2} + L_N \\ \text{Ch3}' &= \text{Ch3} \\ \text{Ch4}' &= \text{Ch4} + R_N \end{aligned}$$

On the other hand, in the system according to this invention, the difference signals (Ch1 - Ch2) and (Ch3 - Ch4) are angle modulated and are multiplexed with the sum signals (Ch1 + Ch2) and (Ch3 + Ch4). Accordingly, reproduced signals are represented by (Ch1 + Ch2), (Ch1 - Ch2 + L_N), (Ch3 + Ch4) and (Ch3 - Ch4 + R_N). Therefore, each reproduced signal Ch1' to Ch4' is represented as follows:

$$\text{Ch1}' = [(\text{Ch1} + \text{Ch2}) + (\text{Ch1} - \text{Ch2} + L_N)]/2 = \text{Ch1} + L_N/2;$$

$$\text{Ch2}' = [(\text{Ch1} + \text{Ch2}) - (\text{Ch1} - \text{Ch2} + L_N)]/2 = \text{Ch2} - L_N/2;$$

$$\text{Ch3}' = [(\text{Ch3} + \text{Ch4}) + (\text{Ch3} - \text{Ch4} + R_N)]/2 = \text{Ch3} + R_N/2;$$

$$\text{Ch4}' = [(\text{Ch3} + \text{Ch4}) - (\text{Ch3} - \text{Ch4} + R_N)]/2 = \text{Ch4} - R_N/2.$$

- 5 Accordingly, in the system according to this invention, noise in the channels (the second and fourth channels) where noise is likely to occur decreases to half compared to a system in which no matrix operation is effected.
- 10 Moreover, noise components are in opposite phase between the first and second channels whereby an auditory sensitivity to the noise becomes very low.

- 15 If the noise signal L_N is amplified K times and applied to a speaker having impedance of $R\Omega$, electric power P_1 applied to the speaker in the system in which no matrix operation is effected will be as follows:

$$P_1 = (K \cdot L_N)^2 / R = (K^2 / R) \cdot L_N^2.$$

- 20 In the system according to this invention, electric power P_2 applied to two speakers will be as follows:

$$P_2 = [(K \cdot L_N/2)^2 / R] + [(-K \cdot L_N/2)^2 / R] \\ = (1/2) (K^2 / R) \cdot L_N^2.$$

- 25 Accordingly, sound output of the noise component will be halved by effecting matrix operation as in the system according to this invention.

- 30 Furthermore, in the case where two angle modulated waves are transmitted by separate transmission systems, a beat will generally be produced between the carriers of the transmitted frequency modulated signals, if there is crosstalk between the two transmission systems. Beats will also be produced between the carrier and the side band and between the side bands. Accordingly, if there is crosstalk between the L and R channel multiplexed signals on both walls of the groove in recording and reproducing on the aforementioned four channel record groove, disturbing noises will be generated by the beats. The system according to this invention, however, is so constructed that the four channel record will be put into practical use. The detail of this construction will be described hereinbelow.

In Fig. 7, vectors $\overline{EF}$ and $\overline{FG}$ show movements of left and right channels of the cutter.

- 50 Vector $\overline{EH}$ and $\overline{HJ}$ show sensitivity axes of left and right channels of the pickup stylus. If there is a discrepancy between the cutter and the pickup stylus by an angle δ as shown in the figure, a crosstalk in the amount shown

by a crosstalk ratio C_t of the following equation will be generated:

$$C_t = 20 \log \left\{ \frac{1}{\sin \delta} \right\} \text{ (dB)}$$

where $\delta \ll 1$ radian.

It will be understood that if the angle δ is for example 0.03 radian, the crosstalk ratio C_t is about 30dB.

Further, in actual pickup operation, crosstalk will also occur due to partial deformation of the record groove or the construction of the vibration system of the pickup. Accordingly, it is difficult to confine crosstalk ratio to 20 dB or above as a whole in recording on and reproducing from the record groove of the 45—45 system.

The reason why a disturbing noise is produced in a reproduced signal due to crosstalk will now be described. This disturbing noise has a bad effect upon the reproduced sound. The bad effect is of a quite different kind from the bad effect which crosstalk occurring during recording and reproducing on a 45—45 system two channel stereo record brings with respect to the orientations of the left and right sound sources. As a cause for mutual interference between L and R channel signals, the beat between the carriers of the two channels is the greatest one. In addition to this, there are also beats which occur between the carrier of one channel and the side band of the other channel and, though small in degree, between the side bands of both channels.

For the sake of brevity in the following discussion of crosstalk, it is assumed that one of two separate L and R channel signals is a frequency modulated wave (signal) and the other is a signal having a constant frequency which is the same as the frequency of the carrier of the frequency modulated signal.

In the case where the crosstalk occurs between the separate channels, side band components of the frequency modulated difference signal included in the reproduced signal of the corresponding channel are affected by the crosstalk. As a result, disturbing noise is produced in the reproduced signal obtained by demodulating the frequency modulated wave of that channel signal. This relation will now be illustrated with reference to a vector diagram.

The frequency modulated wave of one channel is shown by vector Y and the wave having the constant frequency of the other channel is shown by vector X . Fig. 8 is a vector diagram showing the composition of the vectors X and Y caused by the crosstalk. In the diagram, the arrow in a spiral form shows that the phase angle of the carrier of the frequency modulated wave is rotated by the modulating wave. The waveform of the wave represented by the vector Y is shown in Fig. 10A and the waveform of the composite vector Z of the vectors X and Y is shown in Fig. 10B.

In Fig. 8, Z represents the composite vector of the vector X and the vector Y . The tip of vector Z which results from the crosstalk between the left and right channels moves around a circle Y_s as the vector Y is rotated. The deviation angle α between the vector X and the vector Z changes as the vector Y is rotated.

Accordingly, the variation of phase deviation in the composite wave represented by the vector Z is different from the variation of phase deviation in a pure frequency modulated wave due to presence of the deviation angle α . Consequently, harmonics of higher orders of the modulating wave are contained in the reproduced signal which is obtained after demodulation. These harmonics generate disturbing noises. The larger the phase deviation angle θ of the frequency modulated signal (the rotating angle of the vector Y), the larger the amount of disturbing noise thus generated in the reproduced signal. The above description has been made on the assumption that the vector X and the vector Y have the same carrier frequency. If these vectors have different frequencies, interference noises will be generated between the carriers and between the carrier and the side band. The level of this interference noise is much higher than the aforementioned disturbing noise. Accordingly, it is an essential condition that the separate channel signals have the same carrier frequency.

Further, in a frequency modulated wave, the index mf is shown by the relation

$$mf = \frac{\Delta f}{fm}$$

Since maximum frequency deviation Δf is a constant value independent of the modulating wave frequency fm if the level of the modulating wave is constant, the modulation index mf is varied inversely with the modulating wave frequency fm . Accordingly, the phase deviation angle of the frequency modulated wave is in inverse proportion to the frequency of the modulating wave. The inverse proportion is expressed by the straight line of -6 dB/oct as shown in Fig. 12. In the case

where the level of the modulating frequency is constant, the deviation angle will become 1/2 if the modulating frequency becomes double.

Consequently, in the case where the frequency modulated wave in each separate channel has been frequency modulated by a modulating wave having a low frequency component, the phase deviation angle θ of the frequency modulated wave becomes large whereby a great deal of disturbing noise is generated in the reproduced signal due to crosstalk between the two channel signals.

It will be understood from the above consideration of the process in which disturbing noise is generated due to crosstalk of the frequency modulated waves that in order to reduce the disturbing noise the phase deviation angle of the frequency modulated wave determined by the modulating wave must be made small. This relation will further be considered with reference to Fig. 9.

In Fig. 9, the length of vector X is designated as m , the length of vector Y as n , the length of vector Z as l , the phase deviation angle of vector Y as θ and the deviation angle of vector Z as α . Then, there is a relation

$$m/\sin \beta = n/\sin \alpha = l/\sin (\pi - \theta) \quad (1)$$

From Equation (1), Equations

$$\sin \alpha = \pm \{ \sin^2 \theta / [(m/n) + \cos \theta]^2 + \sin^2 \theta \}^{1/2} \quad (2)$$

and

$$l = \pm [(m + n \cos \theta)^2 + n^2 \sin^2 \theta]^{1/2} \quad (3)$$

are obtained.

Fig. 11A shows the relation between the phase deviation angle θ of the vector Y and the angle α of the vector Z obtained by the above Equations (2) and (3). Fig. 11B shows relation between the phase deviation angle θ of the vector Y and the length l of the vector Z . In Fig. 11A, if

$$|\theta| < \frac{\pi}{2},$$

then $\theta \sim \alpha$, i.e., the phase deviation angle θ will substantially be proportional to the deviation angle α .

As described hereinabove, within a range where the phase deviation angle θ and the deviation angle α are proportional, crosstalk which may occur between separate channel signals will not produce a higher harmonic component of the modulating wave in the reproduced signal of the other channel. Accordingly, it will not produce a disturbing noise. The above description has been made

on the assumption that the direction of the vector Y and the vector X is the same during the time when they are not modulated.

In the system according to this invention, it is intended that the same phase deviation angle θ is given to the angle modulated difference signals of separate channels so that crosstalk which may inevitably occur between separate channel signals will not produce a disturbing noise in the reproduced sound. The phase deviation angle θ satisfies the aforementioned relation $\theta \sim \alpha$ in a standard level of the modulating wave in a frequency band ranging over several hundreds to several thousands Hz which is relatively high in auditory sensitivity. This purpose of the invention is achieved by supplying carriers having the same frequency and phase to the frequency modulators 22 and 23 by means of the same local oscillator 24.

In Fig. 2, the equalizers 19 and 21 have a frequency response characteristic as shown in Fig. 13 or Fig. 14.

In the characteristic shown in Fig. 13, the output level rises at a slope of 6 dB per octave as the frequency increases. Accordingly, the frequency modulated waves which are obtained from the frequency modulators 22 and 24 through the equalizers 19 and 21 are substantially phase modulated waves. The phase deviation angle of the phase modulated wave shows a constant value independent of variations of the frequency if the level of the modulating wave is constant.

Thus, the phase deviation angle θ of the angle modulated wave which is obtained as output of the frequency modulators 22 and 24 is set at a predetermined radian (for example, approximately 0.3 to 3 rad.), when the level of the modulating wave applied to the frequency modulators 22 and 24 is a standard level. Then, the crosstalk which may occur will not finally produce a disturbing noise in the reproduced signal.

In the characteristic shown in Fig. 14 as another example of characteristic of the equalizers 19 and 21, the characteristic is flat within a low frequency range. Sounds which are usually recorded on a record disc contain few, if any, very low frequency component sounds. Even if such very low frequency components are present, their energy is very small. Further, even though the phase deviation angle of the angle modulated difference signal having a frequency corresponding to the very low sound frequency range may be large resulting in generation of the disturbing noise in the reproduced sound, the frequency component of the disturbing noise is within a range where auditory detecting ability is relatively low. Therefore, the signal-to-noise ratio in the low frequency range is improved sufficiently even if the characteristic is flat below a suitable frequency which is shown by point T in Fig. 14.

As the frequency at the point T, a frequency within the range of 100 to 2000 Hz should be selected. Experiment shows that a good result is obtained when the frequency around 800 Hz is selected.

In the reproducing system shown in Fig. 5, the equalizers 60 and 64 have a frequency response characteristic shown in Fig. 15 or Fig. 16. If the equalizers 19 and 21 have the characteristic shown in Fig. 13, the equalizers 60 and 64 have the characteristic as shown in Fig. 15 which is the reverse of the characteristic shown in Fig. 13. If the equalizers 19 and 21 have the characteristic shown in Fig. 14, the equalizers 60 and 64 have the characteristic as shown in Fig. 16 which is the reverse of the characteristic shown in Fig. 14.

As described hereinabove, in the system according to this invention, the phase deviation angle of the angle modulated difference signal obtained by angle modulation by a modulating wave at a reference level is set at a predetermined radian irrespective of the modulating wave frequency particularly in high and intermediate frequency ranges where auditory sensitivity is high. Accordingly, no disturbing noise is produced in the reproduced signal when the composite signal containing a crosstalk component is demodulated.

In the case where the level of the input modulating wave exceeds the standard level, harmonic components of higher order are developed in the reproduced signal obtained by demodulating the composite signal of the angle modulated difference signal and crosstalk component. The harmonic components of higher order in the reproduced signal obtained by demodulation are reduced to an acoustically undetectable level by the equalizers 60 and 64 which have attenuating characteristics in the high frequency range. Accordingly, even in the case where the level of the input modulating wave exceeds the standard level, no disturbing noise is produced in the reproduced signal.

The relative speed of a pickup stylus with respect to a record disc is several hundred mm/sec, and the size of dust particles which may fall into the groove of the record disc is several tens of μ . Hence, most frequency components of noise signals generated by dust particles are distributed within a high frequency range. Accordingly, signal-to-noise ratio is improved by reducing the frequency characteristic of the modulated wave in the high frequency range during reproduction of the signal.

The system according to this invention is further considered from the aspect of transmission energy. A 100%-modulation in an amplitude modulation system corresponds to the case in which the phase deviation angle of the angle modulated difference signal is set



at 1 radian in the system according to this invention. Accordingly, in the system according to this invention, the signal-to-noise ratio is improved by about 20 dB in the high frequency range and about 40 dB in the low frequency range compared with the amplitude modulation system.

In the aforementioned embodiment of the recording system, the combination of the frequency modulators 22 and 23 and the equalizers 19 and 21 is employed as modulating means. However, the modulating means is not limited to this but a modulator may be employed which has such a characteristic as to obtain an angle modulated difference signal having a constant phase deviation angle relative to an input modulating wave which is at a certain level with a range above several hundred Hz.

Fig. 17 shows an example of a frequency modulating means which is readily conceivable from the conventional prior art, but is not according to the invention. Difference signals (Ch1—Ch2) and (Ch3—Ch4) are respectively supplied from input terminals 100 and 101 to mixers 108 and 109 through reactance tubes 102 and 103, separate oscillating circuits 104 and 105 in the two channels, and buffer amplifiers 106 and 107. At the mixers 108 and 109, the difference signals are mixed with a signal from an oscillator 110. Outputs from the mixers 108 and 109 are taken out of output terminals 113 and 114 through filters 111 and 112.

It is difficult to synchronize the two oscillating circuits 104 and 105. If, for example, there is no input at the terminal 100 and there is an input at the terminal 101, the oscillating frequency of the oscillating circuit 105 deviates in accordance with the input at the terminal 101. At the same time, the oscillating frequency of the oscillating circuit 104 is also deviated by the oscillating circuit 105 notwithstanding the absence of input at the terminal 100, which produces an undesirable result. It is, therefore, very difficult to control and synchronize this system so as to obtain carriers having the same frequency and phase from the terminals 113 and 114.

In the system according to this invention, it is necessary, as described hereinabove, to have a modulator which is capable of obtaining signals of two channels having the same carrier frequency and phase, in order to prevent occurrence of distortion and disturbing noise due to crosstalk in each channel signal. Accordingly, the aforementioned modulating means which is easily conceivable from the prior art is of no practical use in the system according to this invention.

In the system according to this invention, the frequency modulating means shown in Fig. 18 is employed as a preferable embodiment. A master oscillator 120 consists of a crystal oscillator which effects stable oscilla-

tion. Output from the oscillator 120 is supplied, on the one hand, to a frequency divider 121 at which the frequency of q is divided into a frequency of q/p . A saw tooth generator 122 generates a saw tooth wave from the output of the frequency divider 121. The output of the saw tooth generator 122 is supplied as a carrier to frequency modulators 127 and 128. The frequency modulators 127 and 128 each consist of an equalizer (having a characteristic such that the response increases in the low frequency range) and a phase modulator. The difference signals (Ch1—Ch2) and (Ch3—Ch4) being input at input terminals 123 and 124 are respectively supplied to the modulators 127 and 128 after being amplified by amplifiers 125 and 126.

As modulators 127 and 128, a kind of modulator commonly known as a serrasoid modulator which is capable of effecting modulation without changing the phase of the carrier is employed. It is to be noted here that the meaning of modulation without changing the phase of the carrier is that when a carrier and a sideband which compose a frequency modulated wave are separately considered, the sideband is changed by a modulating wave and the carrier is changed only in its level. When the modulation index is large, the phase of the carrier changes by 180° , but here it should be considered that the level of the carrier has changed to negative and the phase of the carrier remains unchanged.

The output frequency modulated signals from the modulators 127 and 128 are frequency-multiplied by frequency multipliers 129 and 130 to thereby increase the degree of modulation and are thence supplied to mixing detectors 131 and 132. At the same time, the output frequency from the master oscillator 120 is supplied to the mixing detectors 131 and 132. Obtained from the mixing detectors 131 and 132 is a signal which has been frequency-converted to a frequency which is the difference between the output frequency from the oscillator 120 and the frequency of output signals from the frequency multipliers 129 and 130. This frequency-converted output signal is taken out of output terminals 135 and 136 through filters 133 and 134.

According to the frequency modulator means of the aforementioned construction, the signals which actuate the modulators 127 and 128 and the signals which are supplied to the mixing detectors 131 and 132 are all maintained at the same frequency and the same phase. Accordingly, it is possible to transmit the angle modulated difference signal without producing disturbing noises due to crosstalk even in transmission systems in which crosstalk occurs between the L and R channels.

The modulation angle obtained from the serrasoid modulators 127 and 128 is about

±1.5 radian and it is theoretically impossible to obtain a modulation angle of more than ±3 radian. Accordingly, a greater modulation angle is obtained by increasing modulation degree by means of the frequency multipliers 129 and 130.

If it is desired to obtain carriers of the output frequency modulated signals from the terminals 135 and 136 at a low frequency, the signals must be frequency-converted after being multiplied by the frequency multipliers 129 and 130. This will be understood from the fact that the frequency of the saw tooth wave at the serrasoid modulators must be selected at a frequency at least five times as high as the maximum modulating frequency in order to avoid beats which will occur between the saw tooth wave and the modulating wave if the saw tooth wave is of a low frequency.

If an oscillator in which oscillation frequency is unstable and its output has already been modulated by noises such as hum is used instead of the stable master oscillator 120 which supply the signal to the mixing detectors 131 and 132 the signal-to-noise ratio will be extremely bad. In this case, the signal-to-noise ratio will decrease in proportion to multiplication of the frequency multiplier. If, for example, the frequency is multiplied by 81, the signal-to-noise ratio will decrease by 81.

In the system according to Fig. 18, the output of the master oscillator 120 is multiplied after being frequency divided and frequency modulated. This multiplied output is frequency-converted by the output from the master oscillator 120. As a result, variation in the output of the master oscillator 120 is mostly cancelled by frequency-conversion. Accordingly, even if the output of the master oscillator 120 has a frequency-variation, there is not much variation in the frequency-converted output and hence no deterioration in the signal-to-noise ratio.

WHAT WE CLAIM IS:—

1. A system for recording four channel signals in a single groove cut on a record disc, said system comprising signal source means for supplying four separate channel signals, matrix circuit means for composing a first sum signal and a first difference signal responsive to the first and second channel signals and also a second sum signal and a second difference signal responsive to the third and fourth channel signals of the four separate channel signals, single oscillator means for generating a carrier wave having a prescribed frequency, first modulator means for modulating said carrier wave with the first difference signal, second modulator means for modulating said carrier wave with the second difference signal, the lower frequency limit of the carrier wave in the out-

put of each of said modulator means being higher than the upper frequency limit of the first and second sum signals, first mixer means for mixing and multiplexing the first sum signal with the output signal of the first modulator means, second mixer means for mixing and multiplexing the second sum signal with the output signal of the second modulator means, and means for simultaneously recording the output signal of said first mixer means on one wall of a single groove of the record disc and recording the output signal of said second mixer means on the other wall of the groove.

2. A recording system as claimed in claim 1 wherein each of said modulator means comprises means for angle-modulating said carrier with the difference signal.

3. A recording system as claimed in claim 2 wherein the output angle-modulated signal of said modulator means comprises frequency modulated signal components for predetermined frequencies of the difference signal and phase modulated signal components for other predetermined frequencies of the difference signal.

4. A recording system as defined in claim 2 wherein the phase angle deviation of the angle modulated carrier wave is between 0.3 and 3 radians at a standard level and for frequencies higher than a predetermined frequency.

5. A system for recording four channel signals on a record disc, said system comprising signal source means for supplying first, second, third and fourth channel signals, matrix circuit means for composing a first sum signal and a first difference signal responsive to the first and second channel signals and a second sum signal and a second difference signal responsive to the third and fourth channel signals, first equalizer means for receiving the first difference signal, second equalizer means for receiving the second difference signal, said first and second equalizer means having a characteristic frequency response including at least a portion having a slope of 6 dB/octave, single oscillator means for generating a carrier wave having a prescribed frequency, first modulator means for angle-modulating said carrier wave responsive to the output signal of the first equalizer means, second modulator means for angle-modulating said carrier wave responsive to the output signal of the second equalizer means, the lower frequency limit of said modulated carrier wave being higher than the upper frequency limit of each of said first and second sum signals, first mixer means for mixing and multiplexing the first sum signal with the output signal of the first modulator means, second mixer means for mixing and multiplexing the second sum signal with the output signal of the second modulator means, and means for simultaneously recording the



± 1.5 radian and it is theoretically impossible to obtain a modulation angle of more than ± 3 radian. Accordingly, a greater modulation angle is obtained by increasing modulation degree by means of the frequency multipliers 129 and 130.

If it is desired to obtain carriers of the output frequency modulated signals from the terminals 135 and 136 at a low frequency, the signals must be frequency-converted after being multiplied by the frequency multipliers 129 and 130. This will be understood from the fact that the frequency of the saw tooth wave at the serrasoid modulators must be selected at a frequency at least five times as high as the maximum modulating frequency in order to avoid beats which will occur between the saw tooth wave and the modulating wave if the saw tooth wave is of a low frequency.

If an oscillator in which oscillation frequency is unstable and its output has already been modulated by noises such as hum is used instead of the stable master oscillator 120 which supply the signal to the mixing detectors 131 and 132 the signal-to-noise ratio will be extremely bad. In this case, the signal-to-noise ratio will decrease in proportion to multiplication of the frequency multiplier. If, for example, the frequency is multiplied by 81, the signal-to-noise ratio will decrease by 81.

In the system according to Fig. 18, the output of the master oscillator 120 is multiplied after being frequency divided and frequency modulated. This multiplied output is frequency-converted by the output from the master oscillator 120. As a result, variation in the output of the master oscillator 120 is mostly cancelled by frequency-conversion. Accordingly, even if the output of the master oscillator 120 has a frequency-variation, there is not much variation in the frequency-converted output and hence no deterioration in the signal-to-noise ratio.

WHAT WE CLAIM IS:—

1. A system for recording four channel signals in a single groove cut on a record disc, said system comprising signal source means for supplying four separate channel signals, matrix circuit means for composing a first sum signal and a first difference signal responsive to the first and second channel signals and also a second sum signal and a second difference signal responsive to the third and fourth channel signals of the four separate channel signals, single oscillator means for generating a carrier wave having a prescribed frequency, first modulator means for modulating said carrier wave with the first difference signal, second modulator means for modulating said carrier wave with the second difference signal, the lower frequency limit of the carrier wave in the out-

put of each of said modulator means being higher than the upper frequency limit of the first and second sum signals, first mixer means for mixing and multiplexing the first sum signal with the output signal of the first modulator means, second mixer means for mixing and multiplexing the second sum signal with the output signal of the second modulator means, and means for simultaneously recording the output signal of said first mixer means on one wall of a single groove of the record disc and recording the output signal of said second mixer means on the other wall of the groove.

2. A recording system as claimed in claim 1 wherein each of said modulator means comprises means for angle-modulating said carrier with the difference signal.

3. A recording system as claimed in claim 2 wherein the output angle-modulated signal of said modulator means comprises frequency modulated signal components for predetermined frequencies of the difference signal and phase modulated signal components for other predetermined frequencies of the difference signal.

4. A recording system as defined in claim 2 wherein the phase angle deviation of the angle modulated carrier wave is between 0.3 and 3 radians at a standard level and for frequencies higher than a predetermined frequency.

5. A system for recording four channel signals on a record disc, said system comprising signal source means for supplying first, second, third and fourth channel signals, matrix circuit means for composing a first sum signal and a first difference signal responsive to the first and second channel signals and a second sum signal and a second difference signal responsive to the third and fourth channel signals, first equalizer means for receiving the first difference signal, second equalizer means for receiving the second difference signal, said first and second equalizer means having a characteristic frequency response including at least a portion having a slope of 6 dB/octave, single oscillator means for generating a carrier wave having a prescribed frequency, first modulator means for angle-modulating said carrier wave responsive to the output signal of the first equalizer means, second modulator means for angle-modulating said carrier wave responsive to the output signal of the second equalizer means, the lower frequency limit of said modulated carrier wave being higher than the upper frequency limit of each of said first and second sum signals, first mixer means for mixing and multiplexing the first sum signal with the output signal of the first modulator means, second mixer means for mixing and multiplexing the second sum signal with the output signal of the second modulator means, and means for simultaneously recording the

output signal of said first mixer means on one wall of a single groove of the record disc and the output signal of said second mixer means on the other wall of the groove.

5 6. A recording system as claimed in claim 5 wherein each of said equalizer means has a characteristic frequency response including at least a flat portion for frequencies lower than a predetermined frequency and a slope portion of 6 dB/octave for frequencies higher than said predetermined frequency.

10 7. A recording system as claimed in claim 5 wherein each of said equalizer means has a characteristic frequency response including at least a flat portion for frequencies lower than a predetermined frequency and an increasing slope portion of 6 dB/octave which increases in proportion to an increase of frequency higher than said predetermined frequency, and each of said modulator means is a frequency modulator.

15 8. A recording system as claimed in claim 6 or 7 wherein said predetermined frequency is a frequency within a range of 100 Hz to 2,000 Hz.

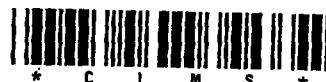
20 9. A recording system as defined in claim 6 or 7 wherein said predetermined frequency is about 800 Hz.

30 10. A system for recording four channel signals on a record disc, said system comprising a signal source means for supplying first, second, third and fourth channel signals, matrix circuit means for composing a first sum signal and a first difference signal responsive to the first and second channel signals and a second sum signal and a second difference signal responsive to the third and fourth channel signals, single oscillator means to provide an oscillator having a predetermined frequency, frequency divider means operated responsive to the oscillator signal of predetermined frequency for dividing the frequency thereof, means responsive to the output of the frequency divider means for generating a saw-tooth waveform signal, first modulator means (preferably serrasoid modulator means) for angle-modulating said saw-tooth waveform signal with the first difference signal, second modulator means (preferably serrasoid modulator means) for angle-modulating said saw-tooth waveform signal with the second difference signal, first frequency multiplier means for multiplying the frequency of the output signal of the first modulator means, second frequency multiplier means for multiplying the frequency of the output signal of the second modulator means, first mixer means responsive to the output signal of the first frequency multiplier means and the output signal of the single oscillator means for producing a signal having frequencies equal to the difference between the frequencies of the output signal of the first frequency multiplier means and the predetermined frequency if the single oscillator means,

second mixer means responsive to the output signal of the second frequency multiplier means and the output signal of the single oscillator means for producing a signal having frequencies equal to the difference between the frequencies of the output signal of the second frequency multiplier means and the predetermined frequency of the single oscillator means, whereby the carrier frequencies of the output signals of said first and second mixer means have frequencies in a recordable frequency range of the record disc, the lower frequency limit of said carrier wave being higher than the upper frequency limit of the first and second sum signals, third mixer means for mixing and multiplexing the first sum signal with the output signal of the first mixer means, fourth mixer means for mixing and multiplexing the second sum signal with the output signal of the second mixer means, and means for simultaneously recording the output signal of the third mixer means on one wall of a single groove of the record disc and the output signal of the fourth mixer means on the other wall of the groove.

11. A recording system as claimed in claim 1 wherein said signal source means comprises four microphones which are placed at predetermined distances and positions relative to a sound source for converting the sounds from said sound sources into distance and position dependent electric signals, means responsive to each electric signal generated by each of said microphones for recording said signals as the four channel signals on a magnetic tape while said tape is running at a first running speed, means for reproducing the four channel signals from said magnetic tape while said tape is running at a second running speed which is slower than said first running speed, and means for supplying the reproduced four channel signals to said matrix means.

12. A system for reproducing the four channel signals which are recorded on the record disc according to claim 1, said system comprising first separator means for separating the first sum signal and the modulated signal which is modulated with the first difference signal, said first sum signal and the modulated signal being electrical signals generated in response to the signals recorded on the one wall of the groove of the record disc, sound separator means for separating the second sum signal and the modulated signal which is modulated with the second difference signal, said second sum signal and the last-mentioned modulated signal being electrical signals generated in response to the signals recorded on the other wall of the groove of the record disc, first demodulator means for demodulating the modulated signal separated by the first separator means and thus reproducing the first difference signal,





second demodulator means for demodulating the modulated signal separated by the second separator means and thus reproducing the second difference signal, and second matrix circuit means for separately reproducing the original first and second channel signals responsive to the separated first sum signal and the reproduced first difference signal and also the original third and fourth channel signals responsive to the separated second sum signal and the reproduced second difference signal.

13. A system for reproducing the four channel signals which are recorded on the record disc according to claim 2, said system comprising first separator means for separating the first sum signal and the angle modulated signal which is modulated with the first difference signal, said first sum signal and the angle modulated signal being electrical signals generated in response to the signals recorded on the one wall of the groove of the record disc, second separator means for separating the second sum signal and the angle modulated signal which is modulated with the second difference signal, said second sum signal and the last-mentioned angle modulated signal being electrical signals generated in response to the signals recorded on the other wall of the groove of the record disc, first demodulator means for demodulating the angle modulated signal separated by the first separator means and thus reproducing the first difference signal, second demodulator means for demodulating the angle modulated signal separated by the second separator means and thus reproducing the second difference signal, and second matrix circuit means for separately reproducing the original first and second channel signals responsive to the separated first sum signal and the reproduced first difference signal and also the original third and fourth channel signals responsive to the separated second sum signal and the reproduced second difference signal.

14. A system for reproducing the four channel signals which recorded on the record disc according to claim 5, said system comprising first separator means for separating the first sum signal and the angle modulated signal which is modulated with the first difference signal, said first sum signal and the angle modulated signal being electrical signals generated in response to the signals recorded on the one wall of the groove of the record disc, second separator means for separating the second sum signal and the angle modulated signal which is modulated with the second difference signal, said second sum signal and the last-mentioned angle modulated signal being electrical signals generated in response to the signals recorded on the other wall of the groove of the record disc, first demodulator means for demodulating the angle modulated signal separated by the first

separator means and thus reproducing the first difference signal, second demodulator means for demodulating the angle modulated signal separated by the second separator means and thus reproducing the second difference signal, third equalizer means for receiving the demodulated first difference signal, fourth equalizer means for receiving the demodulated second difference signal, said third and fourth equalizer means having a characteristic frequency response including at least a slope portion of 6dB/octave, said slope portion of the characteristic of the third and fourth equalizer means having a reverse slope to the slope of the slope portion of the characteristic of the first and the second equalizer means in the recording system, and second matrix circuit means for separately reproducing the original first and second channel signals responsive to the separated first sum signal and the output signal of the third equalizer means and also the original third and fourth channel signals responsive to the separated second sum signal and the output signal of the fourth equalizer means.

15. A system for reproducing the four channel signals which are recorded on the record disc according to claim 6, said system comprising first separator means for separating the first sum signal and the angle modulated signal which is modulated with the first difference signal, said first sum signal and the angle modulated signal being electrical signals generated in response to the signals recorded on the one wall of the groove of the record disc, second separator means for separating the second sum signal and the angle modulated signal which is modulated with the second difference signal, said second sum signal and the last-mentioned angle modulated signal being electrical signals generated in response to the signals recorded on the other wall of the groove of the record disc, first demodulator means for demodulating the angle modulated signal separated by the first separator means and thus reproducing the first difference signal, second demodulator means for demodulating the angle modulated signal separated by the second separator means and thus reproducing the second difference signal, third equalizer means for receiving the demodulated first difference signal, fourth equalizer means for receiving the demodulated second difference signal, said third and fourth equalizer means having a characteristic frequency response including at least a flat portion for frequencies lower than the predetermined frequency and a slope portion of 6dB/octave for frequencies higher than said predetermined frequency, said slope portion of the characteristic of the third and fourth equalizer means having a reverse slope to the slope of the slope portion of the characteristic of the first and the second

equalizer means in the recording system, and second matrix circuit means for separately reproducing the original first and second channel signals responsive to the separated first and second channel signals responsive to the separated first sum signal and the output signal of the third equalizer means and also the original third and fourth channel signals responsive to the separated second sum signal and the output signal of the fourth equalizer means.

16. A system for reproducing the four channel signals which are recorded on the record disc according to claim 7, said system comprising first separator means for separating the first sum signal and the angle modulated signal which is modulated with the first difference signal, said first sum signal and the angle modulated signal being electrical signals generated in response to the signals recorded on the one wall of the groove of the record disc, second separator means for separating the second sum signal and the angle modulated signal which is modulated with the second difference signal, said second sum signal and the last-mentioned angle modulated signal being electrical signals generated in response to the signals recorded on the other wall of the groove of the record disc, first frequency demodulator means for demodulating the angle modulated signal separated by the first separator means and thus reproducing the first difference signal, second frequency demodulator means for demodulating the angle modulated signal separated by the second separator means and thus reproducing the second difference signal, third equalizer means for receiving the demodulated first difference signal, fourth equalizer means for receiving the demodulated second difference signal, said third and fourth equalizer means having a characteristic frequency response including at least a flat portion for frequencies lower than the predetermined frequency and a decreasing slope portion of 6dB/octave which decreases in proportion to an increase of frequency higher than said predetermined frequency in the recording system, and second matrix circuit means for separately reproducing the original first and second channel signals responsive to the separated first sum signal and the output signal of the third equalizer means and also the original third and fourth channel signals responsive to the separated second sum signal and the output signal of the fourth equalizer means.

17. A reproducing system as claimed in claim 15 or 16 wherein said predetermined frequency is a frequency within a range of 100 Hz to 2,000 Hz.

18. A reproducing system as claimed in claim 15 or 16 wherein said predetermined frequency is about 800 Hz.

19. A system for reproducing four channel

signals which are recorded on a record disc in such a manner that a first sum signal and a first angle modulated difference signal responsive to a first channel signal and a second channel signal of the four channel signals are recorded on one wall of a single groove of the record disc and a second sum signal and a second angle modulated difference signal responsive to a third channel signal and a fourth channel signal of the four channel signals are recorded on the other wall of the groove, said system comprising first separator means for separating the first sum signal and the angle modulated signal which is modulated with the first difference signal, said first sum signal and the angle modulated signal being electrical signals generated in response to the signals recorded on the one wall of the groove of the record disc, second separator means for separating the second sum signal and the angle modulated signal which is modulated with the second difference signal, said second sum signal and the last-mentioned angle modulated signal being electrical signals generated in response to the signals recorded on the other wall of the groove of the record disc, first demodulator means for demodulating the angle modulated signal separated by the first separator means and thus reproducing the first difference signal, second demodulator means for demodulating the angle modulated signal separated by the second separator means and thus reproducing the second difference signal, and matrix circuit means for separately reproducing the original first and second channel signals responsive to the separated first sum signal and the reproduced first difference signal and also the original third and fourth channel signals responsive to the separated second sum signal and the reproduced second difference signal.

20. A system for reproducing the four channel signals which are recorded on a record disc according to claim 2, said system comprising pickup means for generating first electrical signals responsive to the signals recorded on the one wall of the groove and second electrical signals responsive to the signals recorded on the other wall of the groove, first separator means for separating the generated first electrical signals into the first sum signal and the angle modulated signal which is modulated with the first difference signal, second separator means for separating the generated second electrical signals into the second sum signal and the angle modulated signal which is modulated with the second difference signal, first demodulator means for demodulating the angle modulated signal separated by the first separator means and thus reproducing the first difference signal, second demodulator means for demodulating the angle modulated signal separated by the second separator means and thus



reproducing the second difference signal, second matrix circuit means for separately reproducing the original first and second channel signals responsive to the separated first sum signal and the reproduced first difference signal and also the original third and fourth channel signals responsive to the separated second sum signal and the reproduced second difference signal, and means comprising four speakers for individually generating sound respectively responsive to the four reproduced channel signals.

21. A system for reproducing the four channel signals responsive to multiplexed signals picked up from a record disc previously recorded according to claim 2, said multiplexed signals comprising a first composite signal formed by the first sum signal and one signal which is modulated with the first difference signal and a second composite signal comprising the second sum signal and another signal which is modulated with the second difference signal; said reproducing system including first and second separator means, first demodulator means for demodulating the angle modulated signal separated by the first separator means and thus reproducing the first difference signal, and second demodulator means for demodulating the angle modulated signal separated by the second separator means and thus reproducing the second difference signal.

22. A four channel record disc having a two-wall groove according to claim 1 wherein a first multiplexed signal comprising a first combination of a sum signal of first and sec-

ond channel signals and a modulated difference signal of the first and second channel signals is recorded on one of said walls, and a second multiplexed signal comprising a second combination of a sum signal of third and fourth channel signals and a modulated difference signal of the third and fourth channel signals is recorded on the other of said walls whereby said first multiplexed signal is recorded on said one wall of the groove and said second multiplexed signal is recorded on said other wall of the groove.

23. A four channel record disc having a groove comprising one wall having recorded thereon a first complexed waveform responsive to a sum signal of first and second channel signals and a modulated difference signal of the first and second channel signals and another wall having recorded thereon a second complexed waveform responsive to a sum signal of third and fourth channel signals and a modulated difference signal of the third and fourth channel signals, the lower frequency limit of each modulated difference signal being higher than the upper frequency limit of each sum signal.

24. A system and apparatus for recording or reproducing four channel signals on a record disc substantially as described with reference to the accompanying drawings.

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