FOUR CHANNEL STEREOPHONIC BROADCASTING SYSTEM

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Filed: Nov. 9, 1971
Appl. No.: 196,932

Foreign Application Priority Data
Nov. 9, 1970 Japan............................. 45/98513

U.S. Cl. 179/15 BT
Int. Cl. H04h 5/00
Field of Search 179/1 GQ, 15 BT

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ABSTRACT

A broadcasting system wherein a left front, a right front, a left rear, and a right rear signal are transmitted on a single radio frequency channel with no significant increase in bandwidth. It should be compatible, that is, it should give satisfactory monophonic and two channel stereophonic reception on receivers presently in use by the public.

7 Claims, 2 Drawing Figures
FIG. 2

Diagram showing a block diagram of a stereo decoder system with connections labeled 21 to 28.
FOUR CHANNEL STEREOPHONIC BROADCASTING SYSTEM

BACKGROUND OF THE INVENTION

1. Field of the Invention
The invention relates to systems for the transmission of multiplex signals and particularly to systems for the transmission of four channel stereophonic signals by means of frequency modulation broadcasting, and to transmitters and receivers for use in such systems.

2. Description of the Prior Art
The FM multiplex stereophonic broadcasting system, which has been adopted in Japan and is called the pilot tone system, transmits a left (or L) channel signal and a right (or R) channel signal on a single radio frequency channel and converts the signals with a receiver into L and R signals to achieve two channel stereophonic reproduction. On the other hand, there have been recently developed magnetic tapes and record discs having recorded thereon left front and right front signals in addition to left rear and right rear signals; consequently, a system for four channel stereophonic broadcasting is now demanded.

The main factors which are desirable in such a four channel system can be summarized as follows: it should be compatible, that is, it should give satisfactory monophonic and two channel stereophonic reception on receivers presently in use by the public; it should give quality equal to present systems in frequency characteristic, distortion factor, signal-to-noise ratio and other characteristics; and it should be capable of transmission of a composite signal on about 100 KHz or less with no significant increase in bandwidth.

SUMMARY OF THE INVENTION
It is one object of the present invention to provide a novel and improved four channel stereophonic broadcasting system which is compatible with the present FM broadcasting system.

It is another object of the present invention to provide a four channel stereophonic broadcasting system which is equal in quality to the present system in frequency characteristic, distortion factor, signal-to-noise ratio and other characteristics.

It is a further object of the present invention to provide a four channel stereophonic broadcasting system in which a composite signal can be transmitted on about 100 KHz or less with no significant increase in bandwidth.

BRIEF DESCRIPTION OF THE DRAWING
FIG. 1 is an electrical block diagram of a preferred embodiment of a transmitter in accordance with the invention, and also graphical representation of frequency relationships of signals used in carrying out the invention.

FIG. 2 is an electrical block diagram of a preferred embodiment of a receiver in accordance with the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT
The system of the invention will now be described with reference to the drawings. In FIG. 1, a signal source 11 produces a signal representing a left front (or LF) channel, a signal representing a right front (or RF) channel, a signal representing a left rear (or LR) channel and a signal representing a right rear (or RR) channel. As indicated schematically in FIG. 1, these signals are added or subtracted to obtain an (LF + LR) signal, an (RF + RR) signal, an (LF - LR) signal and an (RF - RR) signal. Further, these signals are added or subtracted to obtain an (LF + LR) + (RF + RR) signal (hereinafter being called only "A" signal for simplicity), an (LF + LR) - (RF + RR) signal ("B" signal), an (LF - LR) + (RF - RR) signal ("C" signal) and an (LF - LR) - (RF - RR) signal ("D" signal). The "A" signal is position as a main channel signal corresponding to the main signal (L + R) of the present FM multiplex broadcasting system. The "B" signal, after being converted into a carrier suppressed AM signal wherein the frequency of the carrier is 38 KHz or a doubled 19 KHz pilot signal, is positioned as a first subchannel signal corresponding to the subsignal (L - R) sin out of the present FM multiplex broadcasting system.

The "C" signal and the "D" signal are converted in the same manner, that is, the "C" signal is positioned as a main channel signal (30 Hz - 9 KHz) corresponding to the "A" signal, and the "D" signal is positioned as a subchannel signal (10 KHz - 28 KHz) corresponding to the "B" signal after being converted into a carrier suppressed AM signal wherein the frequency of the carrier is 19 KHz which is the same as that of the pilot signal. The "C" signal and the "D" signal which are positioned in a frequency spectrum are positioned as a second sub-channel (57.5 KHz - 113.5 KHz) higher than the first sub-channel (23 KHz - 53 KHz) after being frequency modulated in 85.5 KHz ± 10 KHz. As is well known only one sideband of the 85.5 KHz carrier need be transmitted.

By the above converting process, the "A", "B", "C" and "D" signals are converted and positioned as shown in the lower part of FIG. 1, further modulated into a frequency modulated signal by the frequency being used in a present FM stereo broadcasting system at present, and then transmitted.

Now, the receiving system of this invention will be described with reference to FIG. 2. A receiving antenna 21, an FM tuner 22 and a stereo decoder 23 are shown in a dotted line 24 and are the same as those in FM stereo receivers presently in use by the public. Therefore, the (LF + LR) signal and the (RF + RR) signal are led out from the output terminals of the stereo decoder 23.

One part of the output power of the FM tuner 22 is fed into an FM demodulator 25 for the second subchannel and is further frequency demodulated to produce an output signal containing the "C" signal and the "D" signal. The output signal of the FM demodulator 25 is fed into a stereo decoder 26 for the second sub-channel to be converted into the (LF - LR) signal and the (RF - RR) signal by the pilot signal which is supplied from the stereo decoder 23 and then the two converted signals are led out from output terminals of the decoder 26.

The (LF + LR) signal and the (LF - LR) signal are fed into a matrix circuit 27 and are added and subtracted to produce the LF signal and the LR signal on the two output terminals of the matrix circuit 27. The (RF + RR) signal and the (RF - RR) signal are fed into a matrix circuit 28 and are added and subtracted to produce the RF signal and the RR signal on the two output terminals of the matrix circuit 28.
The received signal may be discriminated whether it is a monaural signal or a stereophonic signal by using the pilot signal being led out from the FM tuner 22, as in a prior art receiver. Furthermore, the received signal may be discriminated whether it is a two channel stereophonic signal or a four channel stereophonic signal by using the 19 KHz pilot signal being led out from the FM demodulator 25. Therefore, an automatic switching operation may be easily obtained so as to compose a reproduction circuit corresponding to either a monoaural, two channel stereophonic or four channel stereophonic signal.

The present invention has many improvements, as described hereinabove. First, compatibility can be obtained, that is, the invention gives satisfactory monaural or two channel stereophonic reception on receivers presently in use by the public. In other words, if a monaural receiver receives the four channel stereophonic signal of the present invention, the mixed signal (LF + LR + RF + RR) can be reproduced; and, if a two channel stereophonic receiver receives the four channel signal, the left signal (LF + LR) and the right signal (RF + RR) are reproduced.

On the other hand, if the receiver of the invention receives a monaural signal, the monaural signal is reproduced by the front left and right and the rear left and right speakers; and, if the receiver of the invention receives a two channel stereophonic signal, the left signal of the stereophonic signal is reproduced by the front and rear speakers of the left side, and the right signal is reproduced by the front and rear speakers of the right side. In these cases, it is, of course, unnatural that the same signal is heard from both front and rear speakers; however, it is easy to cut off the rear signals so as to eliminate the unnatural sound by using the pilot signal, the second sub-carrier of other suitable signals.

Second, the four signals, that is, the front and the rear signals of the left side and those of the right side are equal to each other in their qualities, and it is easy to get more than 30 db in channel separation between each channel.

Third, if the modulation degree of the main channel and the first sub-channel is set at less than 40 percent, and that of the pilot signal and the second sub-channel is set at less than 10 percent, the system of the invention is capable of transmission on a present signal radio-frequency channel with no interference between neighboring radio-frequency channels.

While the invention has been particularly shown and described with reference to preferred embodiments thereof, it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the spirit and scope of the invention.

I claim:

1. A four channel stereophonic composite signal broadcasting system comprising a transmitter and at least one receiver, said transmitter comprising:
   a. sources of left front (LF), right front (RF), left rear (LR) and right rear (RR) stereophonically related audio frequency signals,
   b. means for adding the audio frequency signals together to obtain first intermediate signals including an (LF + LR) signal and an (RF + RR) signal,
   c. means for subtracting said audio frequency signals one from the other to obtain second intermediate signals including an (LF - LR) signal and an (RF - RR) signal,
   d. means for adding said first and second intermediate signals to obtain an [(LF + LR) + (RF + RR)] or an "A" signal and an [(LF - LR) + (RF - RR)] or an "C" signal,
   e. means for subtracting said first and second intermediate signals one from the other to obtain an [(LF + LR) - (RF + RR)] or a "B" signal and an [(LF - LR) - (RF - RR)] or a "D" signal,
   f. means for suppressed carrier amplitude modulating the B signal on a carrier of 38 KHz producing a bandwidth of 23 KHz-5 KHz,
   g. means for suppressed carrier amplitude modulating the D signal on a carrier of 19 KHz producing a bandwidth of 10 KHz-28 KHz,
   h. means for combining the C signal and the modulated D signal to produce a first composite signal in which the C signal occupies a bandwidth of 30 KHz-9 KHz and the modulated D signal occupies a bandwidth of 10 KHz-28 KHz,
   i. means producing a pilot signal at 19 KHz,
   j. means for frequency modulating said first composite signal on a carrier of 85.5 KHz ± 10 KHz producing a bandwidth of 57.5 KHz-113.5 KHz,
   k. means for combining said A signal, said pilot signal, said modulated B signal, and said frequency modulated first composite signal to produce a second composite signal in which said A signal occupies the bandwidth 30 KHz-15 KHz, said modulated B signal occupies the bandwidth 23 KHz-53 KHz, and said modulated first composite signal occupies the bandwidth 57.5 KHz-113.5 KHz,
   l. means for frequency modulating said second composite signal, and
   m. means for broadcasting said frequency modulated second composite signal.

2. A broadcasting system as defined in claim 1 wherein said one receiver comprises:
   a. a first FM demodulator circuit for demodulating the received FM second composite signal,
   b. a first stereo decoder for obtaining an (LF + LR) signal and an (RF + RR) signal by using the output signal of said first FM demodulator circuit and a pilot signal,
   c. a second FM demodulator circuit for further demodulating the signal coming from the first FM demodulator circuit,
   d. a second stereo decoder for obtaining an (LF - LR) signal and an (RF - RR) signal by using the output signal of the second FM demodulator circuit and the pilot signal, and
   e. matrix circuit means for combining said (LF + LR), (RF + RR), (LF - LR) and (RF - RR) signals to obtain LF, LR, RF and RR signals.

3. A four channel stereophonic composite signal broadcasting system including a transmitter comprising:
   a. sources of left front (LF), right front (RF), left rear (LR) and right rear (RR) stereophonically related audio frequency signals,
   b. means for adding the audio frequency signals together to obtain first intermediate signals including an (LF + LR) signal and an (RF + RR) signal,
   c. means for subtracting said audio frequency signals one from the other to obtain second intermediate
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5 signals including an \((LF - LR)\) signal and an \((RF - RR)\) signal, d. means for adding said first and second intermediate signals to obtain an \([LF + LR]) + (RF + RR)\) or \("A"\) signal and an \([LF - LR] + (RF - RR)\) or \("C"\) signal, e. means for subtracting said first and second intermediate signals one from the other to obtain an \([LF + LR]) - (RF + RR)\) or \("B"\) signal and an \([LF - LR] - (RF - RR)\) or \("D"\) signal, f. means for suppressed carrier amplitude modulating the \(B\) signal on a carrier of 38 KHz producing a bandwidth of 23KHz–53KHz, g. means for suppressed carrier amplitude modulating the \(D\) signal on a carrier of 19KHz producing a bandwidth of 10KHz–28KHz, h. means for combining the \(C\) signal and the modulated \(D\) signal to produce a first composite signal in which the \(C\) signal occupies a bandwidth of 30Hz–9KHz and the modulated \(D\) signal occupies a bandwidth of 10KHz–28KHz, i. means for producing a pilot signal at 19KHz, j. means for frequency modulating said first composite signal on a carrier of 85.5KHz±10KHz producing a bandwidth of 57.5KHz–113.5KHz, k. means for combining said \(A\) signal, said pilot signal, said modulated \(B\) signal, and said frequency modulated first composite signal to produce a second composite signal in which said \(A\) signal occupies the bandwidth 30Hz–15KHz, said modulated \(B\) signal occupies the bandwidth 23KHz–53KHz, and said modulated first composite signal occupies the bandwidth 57.5KHz–113.5KHz, l. means for frequency modulating said second composite signal, and m. means for broadcasting said frequency modulated second composite signal. 4. A receiver for receiving the broadcast frequency modulated signal formed in accordance with claim 3, 40 said receiver comprising a. a first FM demodulator circuit for demodulating the received FM second composite signal, b. a first stereo decoder for obtaining an \((LF + LR)\) signal and an \((RF + RR)\) signal by using the output signal of said first FM demodulator circuit and the pilot signal, c. a second FM demodulator circuit for further demodulating the signal coming from the first FM demodulator circuit, d. a second stereo decoder for obtaining an \((LF - LR)\) signal and an \((RF - RR)\) signal by using the output signal of the second FM demodulator circuit and the pilot signal, and e. matrix circuit means for combining said \((LF + LR)\), \((RF + RR)\), \((LF - LR)\) and \((RF - RR)\) signals to obtain LF, LR, RF and RR signals. 5. A method of broadcasting a four channel stereophonic composite signal comprising the steps of a. generating left front (LF), right front (RF), left rear (LR) and right rear (RR) stereophonically related audio frequency signals, b. adding the audio frequency signals together to obtain first intermediate signals including an \((LF + LR)\) signal and an \((RF + RR)\) signal, c. subtracting said audio frequency signals one from the other to obtain second intermediate signals in- cluding an \((LF - LR)\) signal and an \((RF - RR)\) signal, d. adding said first and second intermediate signals to obtain an \([LF + LR] + (RF + RR)\) or \("A"\) signal and an \([LF - LR] + (RF - RR)\) or \("C"\) signal, e. subtracting said first and second intermediate signals one from the other to obtain an \([LF + LR] - (RF + RR)\) or \("B"\) signal and an \([LF - LR] - (RF - RR)\) or \("D"\) signal, f. suppressed carrier amplitude modulating the \(B\) signal on a carrier of 38KHz producing a bandwidth of 23KHz–53KHz, g. suppressed carrier amplitude modulating the \(D\) signal on a carrier of 19KHz producing a bandwidth of 10KHz–28KHz, h. combining the \(C\) signal and the modulated \(D\) signal to produce a first composite signal in which the \(C\) signal occupies a bandwidth of 30Hz–9KHz and the modulated \(D\) signal occupies a bandwidth of 10KHz–28KHz, i. producing a pilot signal at 19KHz, j. frequency modulating said first composite signal on a carrier of 85.5KHz±10KHz producing a bandwidth of 57.5KHz–113.5KHz, k. combining said \(A\) signal, said pilot signal, said modulated \(B\) signal, and said frequency modulated first composite signal to produce a second composite signal in which said \(A\) signal occupies the bandwidth 30Hz–15KHz, said modulated \(B\) signal occupies the bandwidth 23KHz–53KHz, and said modulated first composite signal occupies the bandwidth 57.5KHz–113.5KHz, l. frequency modulating said second composite signal, and m. broadcasting said frequency modulated second composite signal. 6. A method as defined in claim 5, further comprising receiving the broadcast FM composite signal by: a. frequency-demodulating the received FM second composite signal to obtain a first output signal, b. decoding the first output signal with the pilot signal to obtain an \((LF + LR)\) signal and an \((RF + RR)\) signal, c. further demodulating the first output signal to produce a second output signal, d. decoding the second output signal with the pilot signal to obtain an \((LF - LR)\) signal and an \((RF - RR)\) signal, and e. combining said \((LF + LR)\), \((RF + RR)\), \((LF - LR)\) and \((RF - RR)\) signals to reproduce the LF, LR, RF and RR signals. 7. A method of receiving the broadcast FM composite signal formed in accordance with the method of claim 5 and comprising: a. frequency-demodulating the received FM second composite signal to obtain a first output signal, b. decoding the first output signal with the pilot signal to obtain an \((LF + LR)\) signal and an \((RF + RR)\) signal, c. further demodulating the first output signal to produce a second output signal, d. decoding the second output signal with the pilot signal to obtain an \((LF - LR)\) signal and an \((RF - RR)\) signal, and e. combining said \((LF + LR)\), \((RF + RR)\), \((LF - LR)\) and \((RF - RR)\) signals to reproduce the LF, LR, RF and RR signals.