Dec. 21, 1965 N. W. PARKER 3,225,143

MULTIPLEX STEREOPHONIC RECEIVING SYSTEM

Original Filed June 14, 1961 2 Sheets-Sheet 1

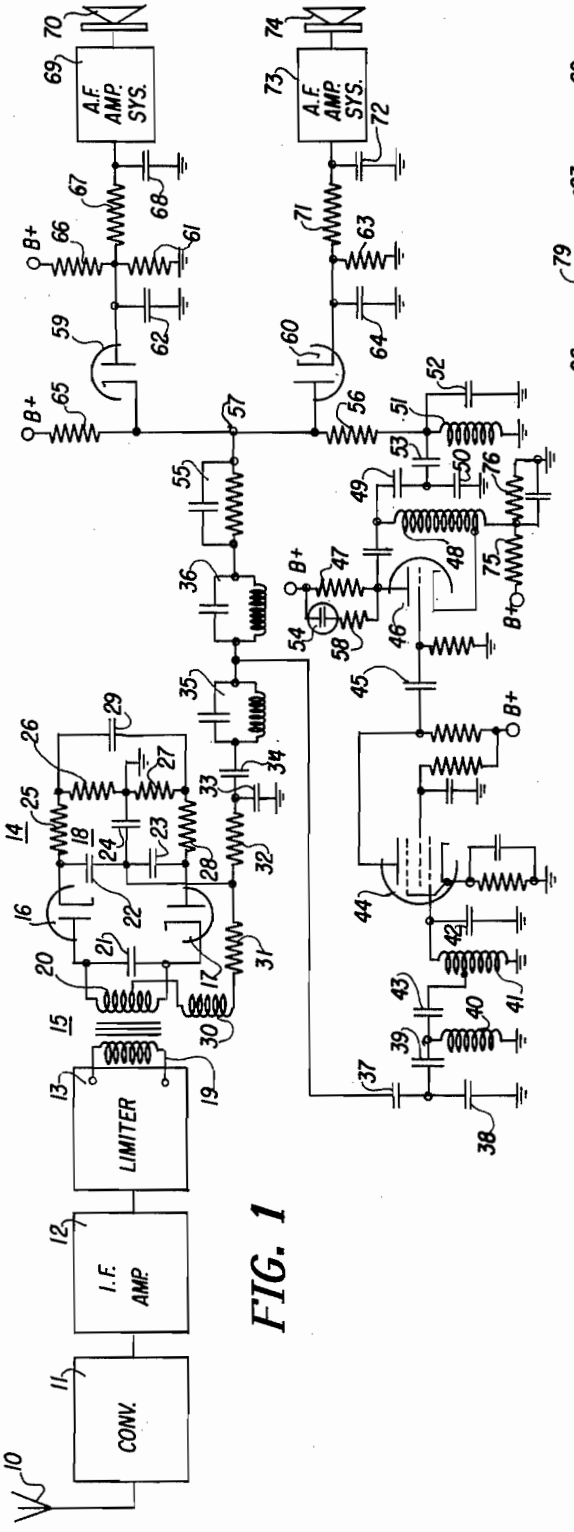


FIG. 1

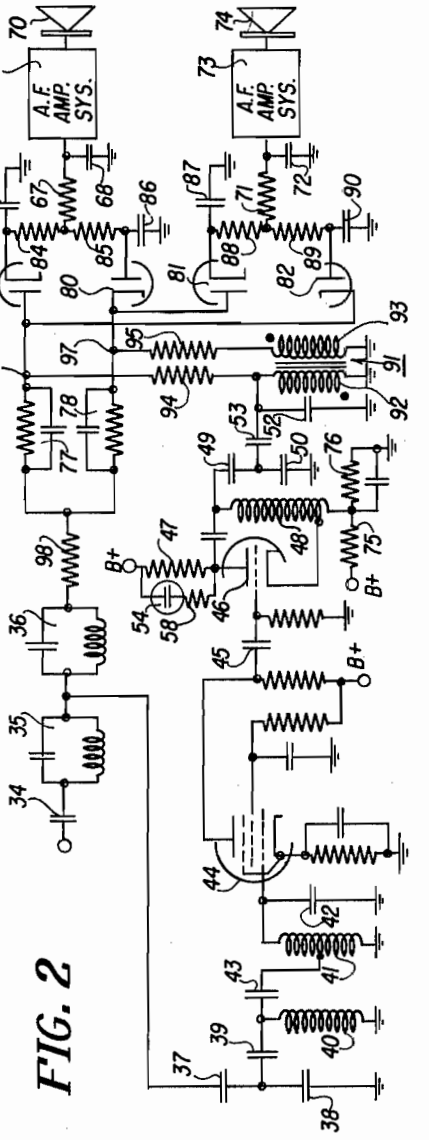


FIG. 2

INVENTOR.
Norman W. Parker
BY Mueller & Aichele
Attys.

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MULTIPLEX STEREOPHONIC RECEIVING SYSTEM

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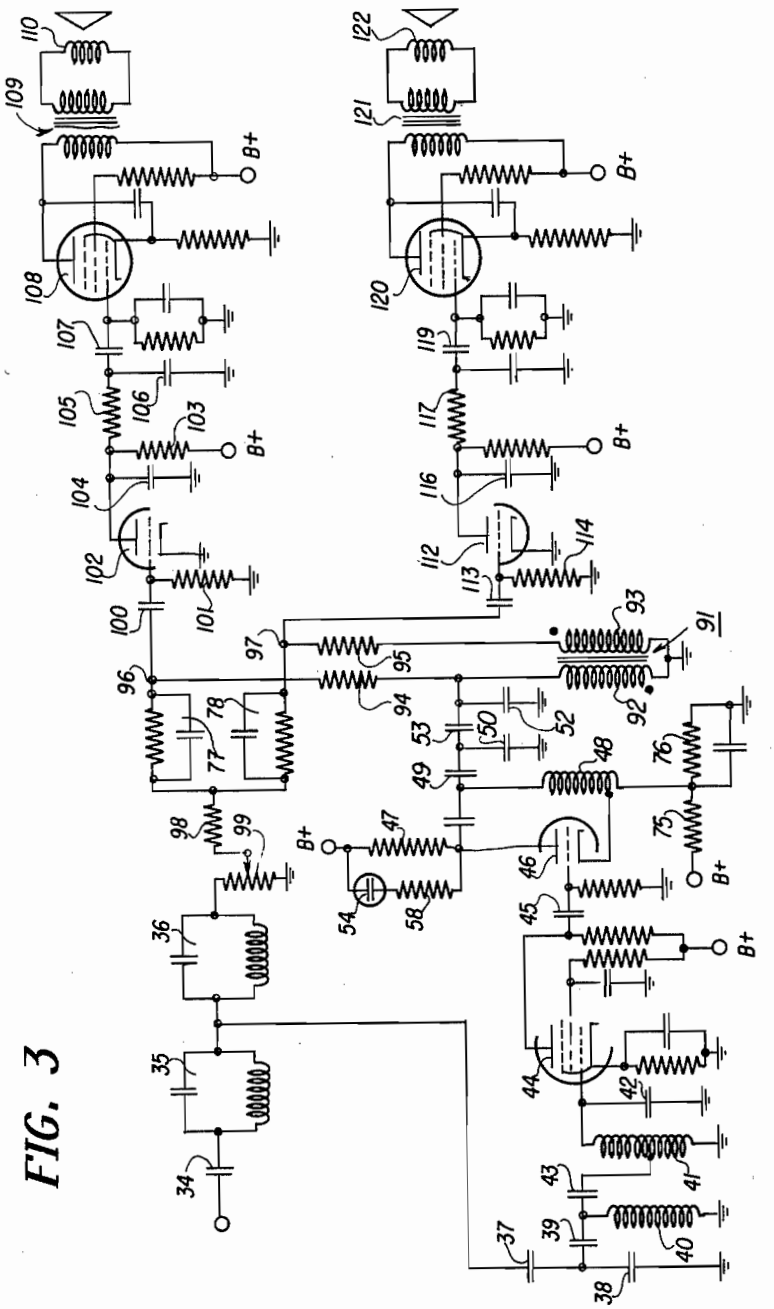


FIG. 3

INVENTOR.
Norman W. Parker
BY Mueller & Aichele
Attys.

United States Patent Office 3,225,143
Patented Dec. 21, 1965

3,225,143

MULTIPLEX STEREOPHONIC RECEIVING SYSTEM

Norman W. Parker, Wheaton, Ill., assignor to Motorola, Inc., Chicago, Ill., a corporation of Illinois

Continuation of application Ser. No. 117,191, June 14, 1961. This application Nov. 30, 1962, Ser. No. 242,049
4 Claims. (Cl. 179—15)

This invention relates generally to carrier wave receivers, and more particularly to a receiver for producing stereophonic sound from a received carrier wave frequency modulated by a composite signal including the sum stereo signals from two channels and the difference stereo signals modulated as a suppressed carrier wave.

This application is a continuation of my application Serial No. 117,191, filed June 14, 1961, and assigned to the assignee of the present application.

Various systems for producing stereophonic sound by radio transmission have been proposed. A multiplex system has recently been standardized wherein a composite signal is provided by the sum of the stereo signals from right and left channels, a suppressed carrier wave amplitude modulated by the difference between the stereo signals in the right and left channels, and a pilot tone signal at half the frequency of the suppressed carrier wave. This composite signal is frequency modulated on a carrier wave in the usual way. In the receiver it is necessary to reinsert the carrier to demodulate the multiplex suppressed carrier wave to obtain the difference signal and then to combine the sum and difference signals to provide the individual right and left stereo signals.

The receiver circuitry required to reproduce the received wave has been relatively complex inasmuch as the carrier generated in the receiver must be synchronized with the pilot carrier to provide the demodulating oscillations, and then a circuit for demodulating the difference modulated wave is required, and a matrix for combining the difference signals obtained with the sum signals. Also the receiver must be suitable for use with monaural signals and it is therefore necessary to disable the carrier oscillator and to pass the monaural signals to the audio amplifiers of both channels, so that it is reproduced thereby.

It is therefore an object of the present invention to provide a simple and improved frequency modulation receiver for reproducing multiplex stereo signals and monaural signals.

A further object is to provide a frequency modulation receiver including a demodulation circuit for a suppressed carrier multiplex signal which directly combines the modulated difference stereo signal, the demodulating wave and the sum stereo signal to produce right and left stereo signals.

Another object of the invention is to provide a frequency modulation receiver for receiving monaural signals and multiplex stereo signals wherein the circuit for demodulating the multiplex signals is disabled in the absence of a pilot tone signal and the monaural signal is translated thereby and applied to the two stereo channels of the receiver and reproduced thereby.

A feature of the invention is the provision of a stereo multiplex receiver including first and second circuits each including a rectifier to which the directly modulated sum signal and the suppressed carrier modulated difference signal are applied, and a carrier reinsertion circuit which selects the pilot tone signal and produces a wave at the frequency of the suppressed carrier wave and applies the same to the two rectifiers and each demodulates one phase of the suppressed carrier modulated difference signal. The difference signals are combined with the sum signals in the rectifier circuits to produce the right channel stereo signal in one circuit, the left channel stereo signal in the other circuit, and the two stereo signals are amplified and reproduced to provide stereophonic sound reproduction.

A further feature of the invention is the provision of a multiplex stereo reproducing system as described in the preceding paragraph wherein the rectifiers are biased to be continuously conducting in the absence of the supplied carrier wave so that monaural signals are passed by both branches and applied to both reproducers, and the system is automatically conditioned to reproduce monaural signals in the absence of a pilot tone signal. When a multiplex stereo signal is received the pilot tone causes the carrier wave to be applied to the rectifiers so that the rectifiers derive the envelope of the modulated wave which is the stereo difference signal.

Another feature of the invention is the provision of a stereo multiplex receiver including two separate branches for deriving the right and left stereo signals, each of which includes a pair of rectifiers connected with opposite polarities and with the reinserted carrier wave being applied thereto with opposite phases so that the carrier wave is balanced out in each branch circuit.

Still another feature of the invention is the provision of a stereo multiplex receiver including a detector circuit for deriving stereo signals having two branches, each of which includes a triode tube which derives and amplifies the signals of one channel, so that the stereo signals are at high level and can be directly applied to power amplifiers which drive the loudspeakers of the stereo channels.

The invention is illustrated in the accompanying drawings wherein:

FIG. 1 is a schematic diagram of a frequency modulation stereo receiver with the frequency modulation detector and the stereo signal detecting circuits shown in detail;

FIG. 2 illustrates an alternate embodiment of the stereo detector circuit which includes a pair of diodes connected in a balanced manner for deriving the signal for each channel; and

FIG. 3 is a further embodiment of the stereo detector circuit in which triode rectifier tubes are used.

In accordance with the invention, a radio receiver is provided to derive first and second stereophonic sound signals from a received multiplex frequency modulated carrier wave having modulation components including a first signal component formed by the sum of the right and left stereo sound signals, a second signal component formed by the difference of the right and left stereo signals provided as an amplitude modulated suppressed carrier wave, and a third signal component formed by a pilot tone signal at one half the carrier frequency of the suppressed carrier wave. The composite signal including the sum stereo signal, the difference modulated wave and the pilot tone signal is detected in a frequency modulation detector circuit. The sum signal and the suppressed carrier modulated difference signal are fed to a pair of detector or rectifier branch circuits. The pilot tone is selected and amplified and either doubled in frequency, or used to synchronize an oscillator having a natural frequency at twice the pilot tone frequency. The wave at the carrier frequency of the suppressed carrier amplitude modulated wave is coupled to the two detector or rectifier branch circuits. The applied wave supplies the carrier to the suppressed carrier wave so that a normal amplitude modulated wave is produced, and the rectifiers detect the envelope of this wave. The rectifiers may be connected with opposite polarities, or the oscillations may be applied in opposite phases so that each rectifier detects one phase of the modulated wave. The demodulated difference signals at the two rectifiers are therefore 180° out of phase and when combined with the sum

signals, the right stereo signals will be added and the left stereo signals will be cancelled in one channel, and the left stereo signals will be added and the right stereo signals will be cancelled in the other channel. The separate right and left stereo signal components are then separately reproduced in audio amplifier and speaker systems. A single diode, or pair of diodes connected in a balanced manner, can be used in each detector branch circuit, or triode tubes can be used to provide high level detector outputs.

As the rectifiers are biased so they conduct continuously, for monaural operation when no demodulating wave is applied thereto, both channels will reproduce the monaural audio intelligence applied from the FM detector circuit. As there is no pilot tone during monaural operation, a doubler for producing the demodulating wave will have no output, and when an oscillator is used, it is biased so that it is not conducting in the absence of the pilot tone.

In the receiver of FIG. 1, the frequency modulated carrier wave containing the sum signal of the right and left stereo channels, their difference signal amplitude modulated on a suppressed carrier wave, and a pilot tone of one-half of the suppressed carrier frequency is received by antenna **10**. The selected wave is converted to intermediate frequency in converter **11**. The intermediate frequency wave is amplified and limited in IF amplifier **12** and limiter **13** respectively. The limited wave is applied to the FM detector **14** through transformer **15**.

The composite signal containing the stereo sum signal, the difference stereo signal modulated on a suppressed carrier wave, and the pilot tone are detected in frequency modulation detector **14**. The secondary winding **20** of transformer **15** is connected between the plate of diode **16** and the cathode of diode **17**. A capacitor **21** is connected in shunt with winding **20** forming a discriminator circuit at the selected frequency. Winding **30** of transformer **15** is connected to the center tap of winding **20** and through resistor **31** to the network **18** to provide a signal having a reference phase to the diodes **16** and **17**. The detected signals are developed across network **18**, consisting of capacitors **22** and **23** connected in series between the cathode of diode **16** and the plate of diode **17** and shunted by resistors **25**, **26**, **27** and **28** in series. A large capacitor **29** is bridged across resistors **26** and **27**. The junction of resistors **26** and **27** is connected to ground. The detected audio intelligence is derived across capacitor **24** and applied to the filter section including resistor **32** and capacitor **33**.

The detected signal which includes the directly modulated sum signal and the difference signal provided as a suppressed carrier amplitude modulated wave, together with the pilot tone, are applied through coupling capacitor **34** to trap **35**. This trap is provided to remove higher frequency subcarriers which may be applied to the frequency modulated wave for additional communication channels. At the output of trap **35** is a second trap **36** to further attenuate the higher frequency subcarriers and apply the sum signal and the difference modulated subcarrier wave to the stereo signal deriving circuit. Also connected to the output of trap **35** is a filter for the **19** kilocycle pilot tone.

The pilot tone filter includes coupling capacitor **37**, a first filter section including capacitors **38** and **39** and coil **40**, and a second filter section including coil **41** and capacitor **42**, to which signals are applied from the first filter section through coupling capacitor **43**. The pilot tone selecting filter therefore is a double tuned circuit which selects the pilot tone and excludes adjacent frequencies. The pilot tone frequency is amplified in pentode tube **44**, and the amplified signal is applied through coupling condenser **45** to the regenerative amplifier **46**. This amplifier has a tank circuit formed by coil **48** and capacitors **49** and **50** which is tuned to 38 kilocycles (double the pilot tone frequency), to provide a wave for demodulating the suppressed carrier modulated wave. To provide further filtering of the 38 kilocycle wave, and exclusion of the 19 kilocycle tone, an additional filter section is provided including coil **51** and capacitor **52**, which is coupled to the tank circuit through coupling capacitor **53**. The tank circuit and the additional filter section form a double tuned circuit to provide a 38 kilocycle demodulating wave which is substantially free of other frequency components. This demodulating wave is applied through resistor **56** to terminal **57**.

The sum signal and the difference modulated subcarrier wave at the output of trap **36** are applied through resistor capacitor network **55** to terminal **57**, where the 38 kilocycle carrier is combined so that the carrier wave is added to the suppressed carrier wave. This produces a normal double side band amplitude modulated wave, the envelope of which may be detected. This composite signal is applied to diode rectifiers **59** and **60** which are connected with opposite polarities. Resistor **61** shunted by capacitor **62** forms the load for the rectifier **59** and resistor **63** shunted by capacitor **64** forms the load for rectifier **60**. Resistor **65** connected to B+ provides a positive potential on the anode of rectifier **60** and resistor **66**, also connected to B+, provides a greater positive potential on the anode of rectifier **59** than that on its cathode. Accordingly, the two diodes **59** and **60** are both biased to be conducting.

In the rectifier **59**, the envelope of the subcarrier modulated wave of one polarity is detected and this appears across load resistor **61** together with the sum signal which is conducted through the diode. Accordingly, across resistor **61** there appears the sum signal L+R and the difference signal L—R. The right or R signals are opposite and balanced out, and the left signal alone is applied through de-emphasis network including resistor **67** and capacitor **68** to the left channel audio amplifier **69** and loudspeaker **70**. The diode **60** is connected with opposite polarity so that the opposite polarity of the envelope of the subcarrier wave is derived therein. Accordingly, across resistor **63** will be developed the L+R sum signal and the minus (L—R) difference signal. The left or L signals therefore oppose and are balanced out across resistor **63**, and the right signal alone is applied through the de-emphasis net work including resistor **71** and capacitor **72** to the right channel audio amplifier **73** and loudspeaker **74**.

The circuit which has been described is also suitable for reception of monaural transmissions, this being applied directly as frequency modulation of the main carrier wave. For monaural transmission there is no subcarrier wave and no pilot tone. Inasmuch as the diodes **59** and **60** are biased to be continuously conducting, the monaural signal will be applied through both diodes and will appear at both loudspeakers **70** and **74**. It is desired to eliminate the 38 kilocycle demodulating wave and this is accomplished by biasing the regenerative amplifier to be nonconducting in the absence of the pilot tone. A voltage divider formed by resistors **75** and **76** applies a positive potential to the bottom terminal of coil **48**, which is in turn applied to the cathode of tube **46**. Accordingly, the tube **46** is biased to be nonconducting and will produce no output in the absence of a pilot tone. Therefore during monaural transmissions, no tone is applied to the circuit including rectifiers **59** and **60**. When the pilot tone is present and is amplified by pentode tube **44**, the signal applied to the oscillator is of sufficient amplitude to cause the same to oscillate and provide the wave required to demodulate the suppressed carrier wave.

An indicator may be provided to show when a stereo transmission is being received. This is shown in FIG. 1, and is provided by a neon bulb **54**, connected in series with resistor **58** across resistor **47**. Resistor **47** develops a voltage thereacross when the amplifier **46** conducts and this voltage causes the neon bulb **54** to glow. Accordingly, when the 19 kilocycle tone is received, and this overcomes the bias on amplifier **46** so that it conducts, the

neon bulb **54** will glow to show that a stereo transmission is being received.

Referring to FIG. 2, a partial schematic is shown to be taken in conjunction with FIG. 1. Components with the same function are given the same reference numerals. As described in FIG. 1, the composite signal containing the stereo sum signal, the difference stereo signal modulated on a suppressed subcarrier wave, and the pilot tone are applied from detector **14** to network **35** through capacitor **34**. The sum signal and the difference modulated subcarrier wave are applied from the output of filter **35** to the audio detector circuit through filter network **36** and resistor **98**. The pilot tone signal is applied to the input of tone amplifier **44** through the pilot tone filter network consisting of components **37–43**. The pilot tone frequency is amplified in pentode tube **44**, the output of which is applied through capacitor **45** to the input of tube **46** operating as a regenerative doubler amplifier to provide the 38 kilocycle carrier signal. Regenerative amplifier **46** includes transformer **91** connected to its output with windings **92** and **93** connected in reverse polarity.

The sum signal and the difference modulated subcarrier wave are applied through resistor-capacitor networks **77** and **78** to terminals **96** and **97** respectively. The carrier frequency from amplifier **46** is also applied to these terminals through series resistors **94** and **95**, and is added to the suppressed subcarrier for producing the normal double side-band amplitude modulated wave. The carrier wave signal applied to terminal **96** is reversed in phase with respect to the carrier wave signal applied to terminal **97** due to the 180° phase shift effected in winding **93** of transformer **91**. The envelope of the suppressed subcarrier is detected and combined with the sum signal in the manner previously described to obtain the individual right and left stereo signal components for reproduction in separate loudspeaker systems.

Each stereo detector channel includes a pair of diodes connected in push-pull. The left channel includes diodes **79** and **80** and the right channel includes diodes **81** and **82**. The diodes of each channel are connected in opposite polarity; the plate of diode **79** being connected to the cathode of diode **82**, and the cathode of diode **80** being connected to the plate of diode **81**. The signals are applied to the right and left stereo detector channels in parallel.

For the derivation of the left stereo signal component, diode **79** rectifies the envelope having one polarity of the modulated subcarrier wave at terminal **96** and diode **80** rectifies the envelope having a reverse polarity of the modulated subcarrier wave at terminal **97**. By connecting diodes **79** and **80** in reverse polarity relation, the detected envelopes will be added when combined at the common junction between load resistors **84** and **85** and the subcarrier wave components will be balanced out. This greatly reduces the distortion that may occur in the detection process. Similar to the manner described in FIG. 1, the sum signal L+R and the difference signal L—R are combined in the detector channel such that the right stereo signals are cancelled and the left stereo signals alone are applied through de-emphasis network including resistor **67** and capacitor **68** to the left channel audio amplifier **69** and loudspeaker **70**.

A similar action takes place in the right stereo channel. Diodes **81** and **82** are connected in reverse polarity with respect to diodes **79** and **80** wherein the left stereo signals are cancelled at the junction of load resistors **88** and **89**, with the right stereo signals alone being applied through de-emphasis network including resistor **71** and capacitor **72** to the right channel audio amplifier **73** and loudspeaker **74**.

In FIG. 3 there is shown a further embodiment of the invention. This circuit corresponds to the circuit of FIG. 2 up to the terminals **96** and **97** except for the addition of a volume control potentiometer **99** between the filter network **36** and the resistor **98**. The signals at point **96** are applied through coupling capacitor **100** and across resistor **101** to a triode detector **102**. Operating potential is applied to the triode from B+ through resistor **103**, and the carrier frequency is bypassed by capacitor **104**. The triode amplifies as well as detects the signal to provide a high level output signal which may be applied directly to a power amplifier. The detected difference signal L—R is combined with the sum signal L+R so that the output across the load resistor **103** constitutes the L or left channel signal of the stereo system. This is applied through the de-emphasis network including resistor **105** and capacitor **106**, and through coupling capacitor **107**, to pentode power amplifier **108**. The output from the amplifier **108** is applied through transformer **109** to loudspeaker **110**.

The signal from point **97** is similarly fed to a triode detector **112** through coupling capacitor **113**. The grid of the triode **112** is returned to ground through resistor **114**. Inasmuch as the subcarrier wave is applied to point **97** from winding **93**, it is of opposite phase to that applied to the triode **102**. This is effective to reverse the difference signal L—R so that the output of the triode developed across the load resistor **115** is the R or right channel signal. The subcarrier frequency is bypassed by capacitor **116**. The right channel signal is passed through de-emphasis network including resistor **117** and capacitor **118**, and through coupling capacitor **119**, to the power amplifier **120**. This is a pentode power amplifier of known design to produce an output sufficient for driving a loudspeaker. The output is applied through transformer **121** to loudspeaker **122**.

The system of FIG. 3 provides an inexpensive circuit for stereo reproduction. By using triode detector tubes, high level outputs are provided which are sufficient for driving pentode power amplifiers which in turn drive the speakers. The circuits of FIGS. 1 and 2 which provide low level outputs may be used in systems which have stereo amplifiers suitable for use with low level inputs such as provided by stereo tape pickups. In such case the stereo amplifiers present will operate from low level inputs, and there is no advantage in having a high level detector output. However, in cases where the amplifiers are not required for other purposes, the amplifiers can be simplified by use of the circuit of FIG. 3.

The circuits described have been found to be highly effective in providing reproduction of frequency modulation stereo radio broadcast transmissions. The circuits are automatically operative for either stereo or monaural broadcast reception whichever may be required at any time. It is apparent that the invention may be practiced by extremely simple circuits, or that more complex circuits may be provided for particular applications, with each of the circuits disclosed providing effective operation.

I claim:

1. A multiplex stereophonic receiver for deriving a right stereo signal and a left stereo signal from a received signal which includes a sum signal composed of the sum of the right and left stereo signals, a difference signal composed of a suppressed carrier wave amplitude modulated by the difference between the right and left stereo signals, and a pilot tone signal having a frequency for reconstituting the suppressed carrier wave, said receiver including in combination, circuit means for deriving the sum signal and the difference signal with a demodulating wave of suppressed carrier frequency controlled by the pilot tone signal, a demodulating circuit to develop the right and left signals including first and second detector circuits connected to said circuit means, said detector circuits each having a diode connected with polarities to conduct on opposite phases of the demodulating wave, the sum and difference signals being translated in said demodulating circuit and said demodulating wave having an amplitude and phase so that a right stereo signal component is developed by conduction and nonconduction of said first de-

tector circuit and a left stereo signal component is developed by conduction and nonconduction of said second detector circuit, direct current supply means to forward bias said diodes with a potential such that said diodes are conductive in the absence of the demodulating wave for conducting monaural signals therethrough from said circuit means, and first and second output circuits coupled to said first and second detector means respectively for translating the right and left stereo signals therefrom.

2. A multiplex stereophonic receiver for deriving a right stereo signal and a left stereo signal from a received signal which includes a sum signal composed of the sum of the right and left stereo signals, a difference signal composed of a suppressed carrier wave amplitude modulated by the difference between the right and left stereo signals, and a pilot tone signal having a frequency and phase for reconstituting the suppressed carrier wave, said receiver including in combination, circuit means for deriving the sum signal and the difference signal with a demodulating wave of suppressed carrier frequency which is controlled in phase and frequency by the pilot tone signal, first and second envelope rectifying means coupled to said circuit means, said rectifying means each having one diode connected with polarities so that each one conducts on an opposite phase of the demodulating wave, the sum and difference signals being translated in each of said envelope rectifying means and the demodulated wave having an amplitude and phase so that only the right stereo signal is developed by conduction and non-conduction of said first diode and only the left stereo signal is developed by conduction and nonconduction of said second diode, and first and second output circuits coupled to said first and second rectifying means respectively for translating the right and left stereo signals therefrom.

3. Signal translation apparatus for deriving a right stereo signal and a left stereo signal from a composite of signals which includes a sum signal formed by the sum of the right and left stereo signals, a difference signal formed by a suppressed carrier wave amplitude modulated by the difference between the right and left stereo signals, and a pilot tone signal having a frequency one-half that of the suppressed carrier wave, said apparatus including in combination, first means for deriving the sum signal and the difference signal, second means for deriving the pilot tone signal means coupled to said second means for producing oscillations at the frequency of the suppressed carrier wave in response to and phase locked with the pilot tone signal, a detector circuit including first and second branches, each of said branches including a non-linear rectifying device and an associated detector load circuit to form an envelope detector circuit in each of said branches, means coupled to said first means and to said oscillation producing means and to said detector circuit for applying the sum signal and the difference signal and the oscillations to said branches of said detector circuit, the oscillations being applied to said rectifying devices of each branch with a phase and amplitude such that said first and second branches conduct on opposite phases of the oscillations so that envelope detection takes place and right stereo signals are developed in said first branch of said detector circuit and left stereo signals are developed in said second branch of said detector circuit, and an output circuit means including first and second portions respectively coupled to said detector load circuit for translating the right and left stereo signals.

4. Signal translation apparatus for deriving a right stereo signal and a left stereo signal from a composite of signals which includes a sum signal formed by the sum of the right and left stereo signals, a difference signal formed by a suppressed carrier wave amplitude modulated by the difference between the right and left stereo signals, and a pilot tone signal having a frequency one-half that of the suppressed carrier wave, said apparatus including in combination, first means for deriving the sum signal and the difference signal, second means for deriving the pilot tone signal, means coupled to said second means for producing oscillations at the frequency of the suppressed carrier wave in response to and phase locked with the pilot tone signal, a detector circuit including first and second branches, each of said branches including a multielectrode rectifying device and an associated detector input circuit to form an envelope detector circuit in each of said branches, each rectifying device having a pair of input electrodes connected to one of said input circuits and further having an output electrode for deriving an amplified form of a detected signal, means coupled to said first means and to said oscillation producing means and to said detector input circuits for applying the sum signal and the difference signal and the oscillations to said branches of said detector circuit, the oscillations being applied to said rectifying devices of each branch with a phase and amplitude such that said first and second branches conduct on opposite phases of the oscillations and envelope detection takes place with only right stereo signals developed in said first branch of said detector circuit and only left stereo signals developed in said second branch of said detector circuit, and an output circuit means including first and second portions respectively coupled to said output electrodes of said rectifying devices for translating amplified forms of the right and left stereo signals.

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DAVID G. REDINBAUGH, *Primary Examiner.*