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BROADCAST STEREO RECEIVER

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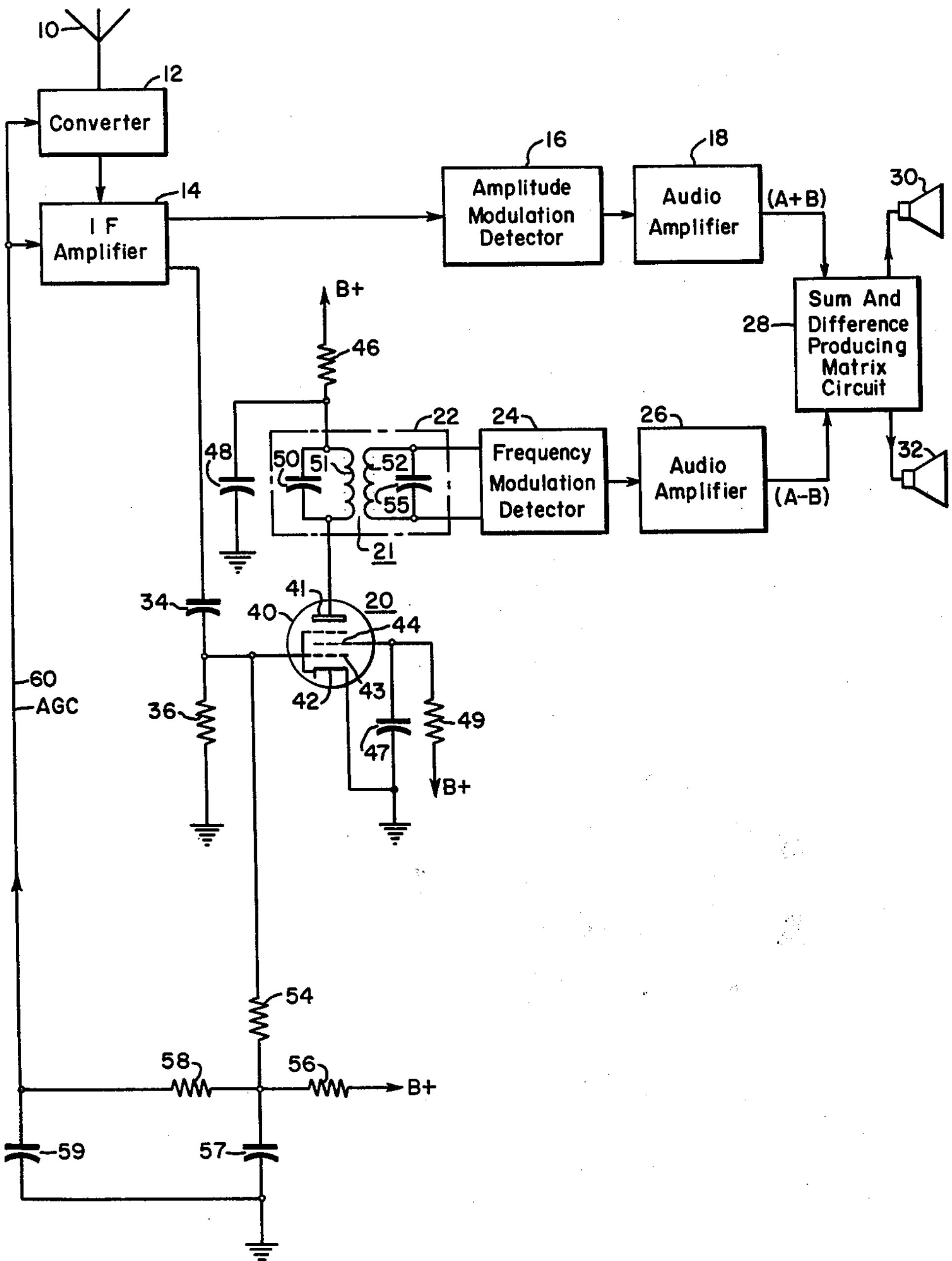

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BROADCAST STEREO RECEIVER

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The present invention relates to apparatus for reception of stereophonic radio signals and more particularly to improved apparatus for receiving signals in which a compatible monophonic component is supplied as conventional amplitude modulation and stereophonic intelligence is supplied as angle modulation of the same carrier wave.

When sound is transmitted by the ordinary system over radio channels only a single channel is normally provided for monophonic reception and audio perspective is entirely lost since the spatial displacement between the sounds received by the two ears of the listener bears no relation to the spatial displacement of the sounds at the microphone which feeds the transmitter.

Stereophonic reception has heretofore been demonstrated using two microphones, set up at locations on each side of a stage on which an orchestra is situated. Each microphone is connected by a separate radio channel to one of two loud speakers placed similarly as the microphones but in a listening chamber where the receiving apparatus is situated. By such an arrangement an auditory effect may be obtained which is substantially the same as though the orchestra or other source of sound were actually located in front of the listener rather than the sound being reproduced by the loudspeakers.

In applying stereophonic sound to radio channels there arises one very series one very serious obstacle from a practical point of view. The need for two separate channels for the transmission of a single program has heretofore prohibited commercial stereo transmission in the AM broadcast band. Such stereo transmission depends, for acceptability, upon the use of compatible apparatus which will eliminate the need of two separate radio channels. Desirable solutions to the problem permit transmission of both audio channels over the same carrier frequency, thereby using but one radio channel and reducing to a minimum the additional investment required at the transmitter as well as the additional investment required of prospective listeners.

One proposed stereophonic system using a single channel has been described in detail in "Electronics" magazine, issue of February 1941, at pages 34 to 36. That proposed system suggests transmission of the audio signal from a first microphone as amplitude modulation and that from a second microphone as angle modulation of the same carrier. Such a system has the disadvantage that a conventional receiver will reproduce the signals from the first microphone only. Thus a conventional receiver produces sound signals corresponding to those heard at one end of a stage on which the orchestra is located. A primary requisite of a genuinely compatible system is that a conventional receiver should produce balanced monophonic sound substantially corresponding to the sound effects which would be heard by a listener seated near the center of the studio in which the orchestra is located.

The receiving operations of the present invention find particular application in reception of signals transmitted in accordance with a system for compatible stereophonic transmission as described in detail in copending application Serial No. 808,038, filed April 22, 1959, by Harold E. Sweeney and Charles W. Baugh, Jr., and assigned to the same assignee as the present application. In the system of that application audio signals A and B from

spaced microphones are transmitted by adding the signals and sending the resulting sum signal $A+B$ as amplitude modulation of a broadcast band carrier signal. Simultaneously, the audio signals A and B are subtracted by an appropriate difference producing means and the difference signal $A-B$ is transmitted as frequency modulation of the same carrier wave. The transmission system there utilized enables a conventional AM receiver tuned to the transmitted signal to produce the sum signal $A+B$, which signal contains substantially equal components of the signal from each microphone and therefore will produce a balanced monophonic sound.

For use with that proposed transmission system, the aforementioned copending application proposes a special receiver having two separate signal detecting channels coupled to a common converter and IF amplifier strip. The first signal detection channel incorporates a conventional amplitude modulation detector and the second signal channel incorporates a frequency modulation detection system for reproducing the stereophonic difference signal $A-B$. The $A+B$ summation signal is produced at the output of the first signal detecting channel and the $A-B$ stereophonic difference signal is produced at the output of the second signal channel.

Those two outputs are simultaneously applied to appropriate sum producer and difference producer networks for providing separate audio signals A and B which are then coupled respectively to the separate spaced loudspeakers.

In such systems it will be appreciated that the relative amplitudes of the sum signal $A+B$ and the difference signal $A-B$, as reproduced in the receiver, should be the same as the relative amplitudes of those signals as transmitted. Difficulty has been encountered in maintaining the relative reproduction amplitudes because of the fact that the $A+B$ amplitude modulation may vary considerably with changes in received carrier wave signal strength, while the amplitude of the frequency modulation signal is of course independent of variations in the received carrier wave signal strength. It has been found that conventional automatic gain control systems of the type normally used in broadcast receivers are not adequate to maintain the desired amplitude relation between the sum signal and difference signal as reproduced by the first and second channels.

Accordingly, it is a primary object of the present invention to provide a sterephonic receiver of the type described in which a control voltage is derived from the frequency modulation channel and is used to control the average signal strength of signals applied to the amplitude demodulation channel.

It is another object of the present invention to provide a multiplex radio communication system in which a monophonic summation signal is transmitted as amplitude modulation and a stereophonic difference signal is simultaneously transmitted as frequency modulation of the single carrier wave and in which a receiver incorporating an improved gain control circuit is utilized to reproduce the sum signal and the difference signal with the relative amplitudes of the reproduced signals being maintained substantially independent of variations in the signal strength of the received carrier waves.

In transmitting systems of the type described and claimed in the above-mentioned copending application, Serial No. 808,038, it is highly desirable, in order to conserve transmitter power that the amplitude modulation of the transmitted carrier be maintained at modulation levels approaching 100%. For example, in a preferred such system, the amplitude modulation would be permitted to be as high as 95%. The transmitting stations will of course endeavor to maintain the amplitude modulation as close as possible to that limit. Such high amplitude modulation means that the frequency modulated carrier signal applied to the frequency demodulation channel will fall to very low amplitude levels during periods of high amplitude modulation and will have a very large range of amplitude variation. Accordingly, such high amplitude modulation requires that the frequency demodulation channel of the receiver should have much higher gain and much better limiting action than is conventional in frequency modulation receivers. If the usual intermediate frequency, for example 456 kilocycles, were used both in the intermediate frequency section of the receiver and in the frequency demodulation channel, the extremely high gain of the frequency demodulation channel would give rise to danger of regeneration from inadvertent feedback from the frequency demodulation channel to the intermediate frequency section. In order to prevent such regeneration, expensive arrangement and shielding of the intermediate frequency amplifier circuits and the frequency demodulation channel would be necessary.

Accordingly, it is a further object of the present invention to provide frequency multiplication of the carrier signal so that all or part of the frequency demodulation channel operates at a frequency outside the band-pass of the intermediate frequency amplifier section.

It is a different object of the present invention to avoid such regeneration by providing an amplitude limiter in the frequency demodulation channel which produces appreciable energy at frequencies corresponding to harmonics of the intermediate frequency carrier wave applied to its input, and to provide resonant circuit means coupled between the output circuit of the limiter and the input circuit of the frequency demodulation means for relatively attenuating the intermediate frequency carrier signal and accentuating the frequency modulated harmonic components produced by the limiter.

The foregoing and other objects and features of the present invention will be apparent from the following description taken with the accompanying drawing, throughout which like reference characters indicate like parts, which drawing forms a part of this application and in which:

The single figure is a schematic diagram of a receiver embodying the features of the present invention.

Referring now to the drawing, a carrier wave of the type transmitted by the system of the aforementioned copending application Serial No. 808,038, is received by antenna **10**. In accord with the teachings of that application the received wave is amplitude modulated substantially in accordance with a first signal $A+B$ and is frequency modulated in accordance with the second signal $A-B$, in which A and B are stereophonic audio frequency signals respectively representative of sound intelligence at first and second spaced locations. The wave received by an antenna **10** is applied to a radio frequency section of the receiver comprising a conventional heterodyne converter or first detector **12** which produces an intermediate frequency carrier wave having the same modulation as the received radio frequency wave. The intermediate frequency carrier wave is applied from converter **12** to a first input of an intermediate frequency amplifier **14** having first and second output circuits.

Amplitude modulated and frequency modulated intermediate carrier signals from the first output of amplifier **14** are applied to an amplitude modulation detector **16** which is coupled to the first output circuit. The detector circuit **16** may be conventional and may be any one of the usual types utilized in ordinary broadcast receivers. The detector **16** of course ignores the frequency modulation of the carrier signal and rectifies the carrier wave to produce an output voltage which varies substantially in accordance with the amplitude modulation of the received carrier wave. The demodulated sum signal $A+B$ thus produced by detector **16** is coupled to audio amplifier **18** and from the output thereof to a first input of a sum and difference producing matrix **28**.

One signal combining matrixing network of the type suitable for the block **28** is disclosed and described in detail in an article entitled "Single Push-Pull for Stereo Channels," published in Radio & Television News, issue of January 1959, at pages 48 and 49. It will be apparent to those skilled in the art that addition and subtraction of signals by means of transformer arrangements as shown in the above-mentioned article is not essential to the present invention. Other arrangements, known per se, utilizing resistance networks or phase inverters and additive amplifier circuits may also be used in the system of the present invention. The purpose and function of matrixing network **28** will be described in greater detail hereinafter.

The amplitude and frequency modulated intermediate frequency carrier signals from intermediate frequency amplifier **14** are applied by way of the second output circuit thereof, through a coupling capacitor **34** to the grid **43** of electron discharge device **40**. Discharge device **40** taken together with its associated energizing circuits constitutes an amplifier-limiter for substantially increasing the minimum peak-to-peak amplitude level of the carrier wave and at the same time stripping the carrier wave of the $A+B$ sum signal amplitude modulation. The anode **41** of discharge device **40** is connected through primary winding **51** shunted by a capacitor **50** and through a dropping resistor **46** to the positive terminal B+ of a source of energizing potential. The negative terminal of the energizing potential source may of course be connected to ground or a point of reference potential in accordance with conventional practice.

The secondary winding **52** of transformer **21** is connected to the input terminals of a frequency modulation detector **24**. Windings **51** and **52** are respectively tuned by capacitors **50** and **55** to a frequency which is a multiple of the intermediate frequency carrier signal. For example, if the intermediate frequency carrier at amplifier **14** has a center frequency of 456 kilocycles, corresponding to the usual intermediate frequency used in conventional broadcast receivers, then windings **51** and **52** are preferably tuned to resonate at 1.82 megacycles.

The cathode **42** of discharge device **40** is connected to ground and the screen grid **44** is connected to the source of B+ through a conventional dropping resistor **49** bypassed by capacitor **47**.

The output circuit of frequency modulation detector **24** is coupled to the input circuit of conventional audio amplifier **26**. The output of audio amplifier **26** is connected to a second input of the sum and difference producing matrix **28**. The sum and difference producing matrix **28** is provided with first and second output circuits which are respectively connected to first and second loudspeakers **30** and **32** which may be spaced apart in a listening area or auditorium. Sum and difference producer **28** operates in response to the $A+B$ out from audio amplifier **18** and the $A-B$ output from audio amplifier **26** to produce the algebraic sum of the two inputs and apply such algebraic sum A to loudspeaker **30**. Similarly, sum and difference producer **28** combines the two inputs subtractively to produce the algebraic difference at its second output and apply that algebraic difference B to the second loudspeaker **32**.

Since the amplitude modulation levels of the carrier wave as received by the receiver of the FIGURE approaches 95%, the peak-to-peak value of the frequency modulated carrier wave during the valley of the waveshape will be relatively small. Accordingly, it is necessary that the amplitude limiter **20** including discharge device **40** and its associated circuits should have sufficient gain so as to provide adequate frequency modulated signal input to detector **24** at the times of maximum amplitude modulation. If the 456 kilocycle intermediate frequency carrier were amplified to the extent required of the limiter **20**, there would be grave danger of regeneration due to inadvertent coupling between the frequency demodulation channel and the intermediate frequency amplifier **14**. Accordingly, the present invention provides frequency multiplication via joint action of the harmonic generating limiter **20** and the frequency selective circuit comprising the double tuned transformer windings **51** and **52**. Transformer **21** is tuned to the fourth harmonic of the intermediate frequency carrier signals so that the fourth harmonic is amplified extensively by limiter **20** and the fundamental of the intermediate frequency carrier signal and the lower harmonics are relatively attenuated by transformer winding **51**. Accordingly, the use of limiter-amplifier tube **40** connected in cascade with the fourth harmonic frequency selecting circuit **22** and frequency demodulation detector **24** enables high level amplification of the frequency modulated fourth harmonic only, thereby eliminating the possibility of regenerative feedback coupling from the output of limiter **20** to the converter **12** and/or the intermediate frequency amplifier **14**. Elimination of the possibility of regenerative feedback enables the receiver to be constructed with less care as to the layout of the circuit components and with less care as to the shielding of the various components which shielding would be necessary if the frequency demodulation channel operated at the same frequency as the intermediate frequency amplifier **14**.

The control grid **43** of limiter tube **40** is connected through resistors **54** and **56** in series to the positive terminal B+ and is connected to ground through resistor **36**. The junction point of resistors **54** and **56** is connected to ground by a bypass capacitor **57** and is connected through a filter resistor **58** to the input of an AGC line shown as conductor **60**. The junction point of resistor **58** and conductor **60** is connected to ground by a second bypass capacitor **59**. Resistors **54** and **58** and capacitors **57** and **59** comprise a low pass filter network for producing a variable direct-current control voltage at conductor **60** in response to pulses of grid current applied from control grid **43** through resistor **54**.

As stated heretofore, it is essential for proper matrixing of signal by matrix circuit **28**, that the relative signal levels of the sum signal $A+B$ at the output of audio amplifier **18**, and the difference signal $A-B$ at the output of audio amplifier **26**, should be held constant even in the presence of substantial variations in received carrier wave signal strength. More specifically, it is readily seen that speaker **30** for example will produce the stereophonic signal A only if the B component of the sum signal $A+B$ at amplifier **18** is substantially equal and opposite to the B component of the difference signal $A-B$ at audio amplifier **26**. In order to accomplish that, the ratio of the reproduced sum signal to the reproduced difference signal must be substantially equal to the ratio of the same two signals at the input to the transmitter.

In the absence of gain control, the sum signal amplitude at the detector **16** would vary as a direct function of the received carrier wave signal strength. The difference signal amplitude from detector **24** is, of course, independent of carrier signal amplitude variations. Thus it is seen that a high gain automatic gain control feedback system is required to obtain proper matrixing of the reproduced sum and difference signals in the presence of variations in received signal strength. It has been found that conventional automatic gain control circuits in which control voltage is developed at the amplitude modulation detector are not adequate for use in receivers of the type shown. Such conventional gain control loops do not provide sufficient feedback to maintain the desired relationship between the reproduced sum and difference signals.

The circuit as shown in the drawing provides improved gain control by utilizing the direct-current potential developed at the grid of limiter **40** as a source of automatic gain control potential.

The peak-to-peak level of the intermediate frequency carrier wave on the grid electrode **43** of limiter tube **40** is much greater than that which is available at detector **16**. Since tube **40** has no fixed or cathode bias, positive peaks of carrier signal applied to grid **43** will cause grid current flow in tube **40** so that a negative direct-current voltage is developed at the grid **43** resistor **36**. An incremental change in RF carrier peak-to-peak amplitude will produce a larger incremental change in the direct-current potential at grid **43** than could be produced at the detector **16**. The negative voltage at grid **43** is biased toward ground by voltage divider resistors **54** and **56** so that a negative control voltage appears across capacitor **57** which has a smaller average direct-current value but has substantially the same incremental change in response to a change in intermediate frequency carrier amplitude.

The feedback control voltage appearing across capacitor **57** is filtered and decoupled by means of filter resistor **58** and capacitor **59** and is applied by way of automatic gain control line **60** to the AGC inputs of converter **12** and intermediate frequency amplifier **14**. It will be appreciated that converter **12** and amplifier **14** preferably incorporate remote cutoff amplifier tubes of the type which are commonly used to enable gain control of amplifier circuits. The gain control voltage from conductor **60** is applied as a variable direct-current bias to the grids of such tubes.

The following table shows, by way of example, values for the components in a circuit, in accordance with the drawing which has been operated successfully. These component values are set forth by way of example only and the present invention is not limited to these values nor to any of them.

Table I

Resistor **36**	120 kilohms.
Resistor **46**	27 kilohms.
Resistor **49**	68 kilohms.
Resistor **54**	1.0 megohm.
Resistor **56**	15 megohms.
Resistor **58**	3.3 megohms.
Capacitor **34**	10 mmf.
Capacitor **47**	.003 mf.
Capacitor **48**	.003 mf.
Capacitor **57**	.01 mf.
Capacitor **59**	.05 mf.
Tube **40**	Type 6AU6.
Voltage source B+	+95 volts.

While the present invention has been shown in one embodiment only, it will be obvious to those skilled in the art that it is not so limited but is susceptible of various changes and modifications without departing from the spirit and scope thereof.

I claim as my invention:

1. Apparatus for receiving a single carrier wave amplitude modulated with a first signal $A+B$ and frequency modulated with a second signal $A-B$ wherein A and B are stereophonic signals representative of sound intelligence at first and second spaced locations, said receiver apparatus comprising an input signal path including at least one high frequency amplifying stage for translation of carrier signals having said amplitude and frequency modulations, first channel means coupled to the output of said signal path and including amplitude demodulation means responsive to the amplitude modulation of said carrier signals for reproducing said first signal $A+B$; second channel means coupled to said signal path and including in cascade connection, an amplitude limiter, carrier frequency multiplying means, and a frequency modulation detector for reproducing said second signal $A-B$, said frequency multiplying means being arranged to convert the frequency modulation carrier signals in

said second channel to a frequency outside the pass-band of said high frequency amplifying stage whereby spurious regeneration involving said second channel and said stage is prevented.

2. A stereophonic receiver responsive to a single carrier wave having amplitude modulation and frequency modulation respectively representative of a sum signal $A+B$ and a difference signal $A-B$, wherein A and B are coherent stereophonic signals respectively representative of sound intelligence at first and second spaced locations, said receiver comprising an input signal path including at least one high frequency stage and an intermediate frequency bandpass filter having a predetermined bandwidth; first and second channels respectively including amplitude demodulation means and frequency demodulation means for responding to carrier signals translated by said signal path to reproduce said sum signal $A+B$ and said difference signal $A-B$ respectively; said second channel further including an amplitude limiter and frequency multiplier means coupled between said signal path and said frequency demodulation means, said amplitude limiter being adapted to generate a frequency modulated harmonic of the intermediate frequency carrier signals translated by said signal path, and said frequency multiplier means comprising a resonant circuit for attenuating said intermediate frequency carrier signals and relatively accentuating said harmonic whereby the frequency modulated harmonic signals applied to said frequency demodulation means are of a frequency outside the bandpass of said intermediate frequency bandpass filter so that spurious regeneration involving said high frequency stage and said second channel is prevented.

3. A stereophonic receiver responsive to a single carrier wave having amplitude modulation and frequency modulation respectively representative of a sum signal $A+B$ and a difference signal $A-B$, wherein A and B are coherent stereophonic signals respectively representative of

sound intelligence at first and second spaced locations, said receiver comprising an input signal path including heterodyne converter means for producing an intermediate frequency carrier having said amplitude and frequency modulations, and an intermediate frequency stage coupled to said converter means and having a frequency selective bandwidth corresponding to that of a normal amplitude-modulation receiver not substantially exceeding 10 kilocycles; first channel means coupled to the output of said intermediate frequency stage and including an amplitude detector for reproducing said sum signal $A+B$; second channel means including an amplitude limiter, a frequency multiplier and a frequency modulation detector coupled in cascade to the output of said intermediate frequency stage for reproducing said second signal $A-B$, said frequency multiplier being operative to relatively attenuate carrier signals having frequencies within said intermediate frequency bandwidth whereby inadvertent coupling between said second channel and said input signal path is prevented from causing spurious regeneration therein.

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