

May 9, 1939.

E. W. KELLOGG

2,157,178

PUBLIC ADDRESS STABILIZING SYSTEM

Filed Dec. 31, 1936

2 Sheets-Sheet 1

Fig. 1.

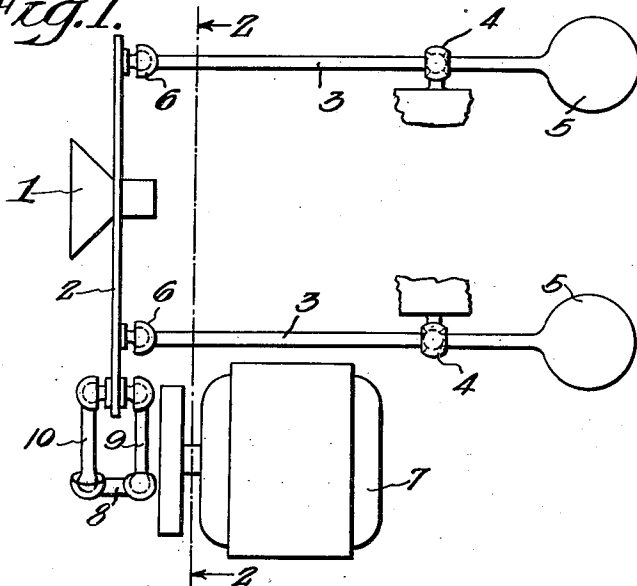


Fig. 2.

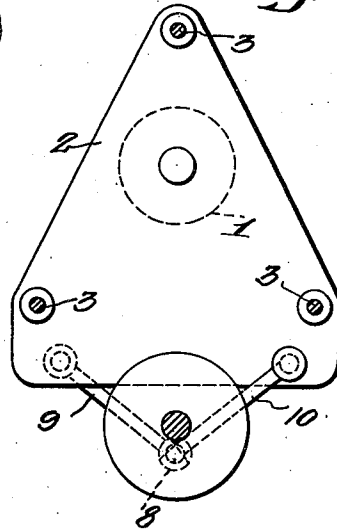


Fig. 3.

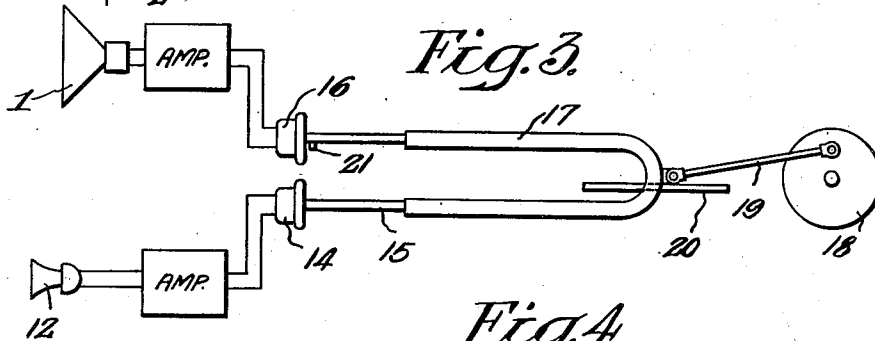


Fig. 4.

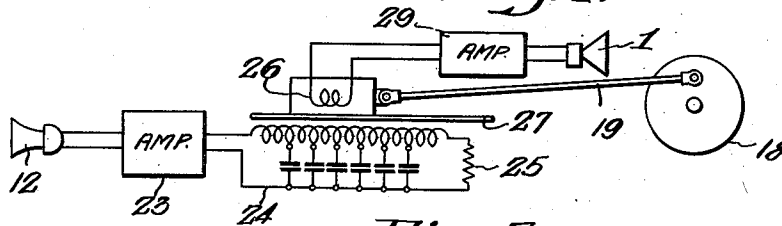
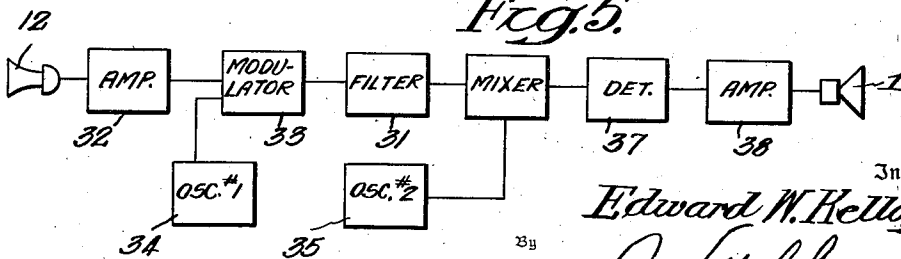


Fig. 5.



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2 Sheets-Sheet 2

Fig. 6.

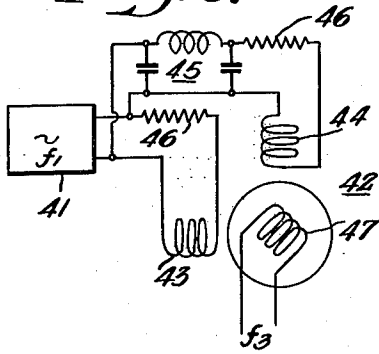


Fig. 7.

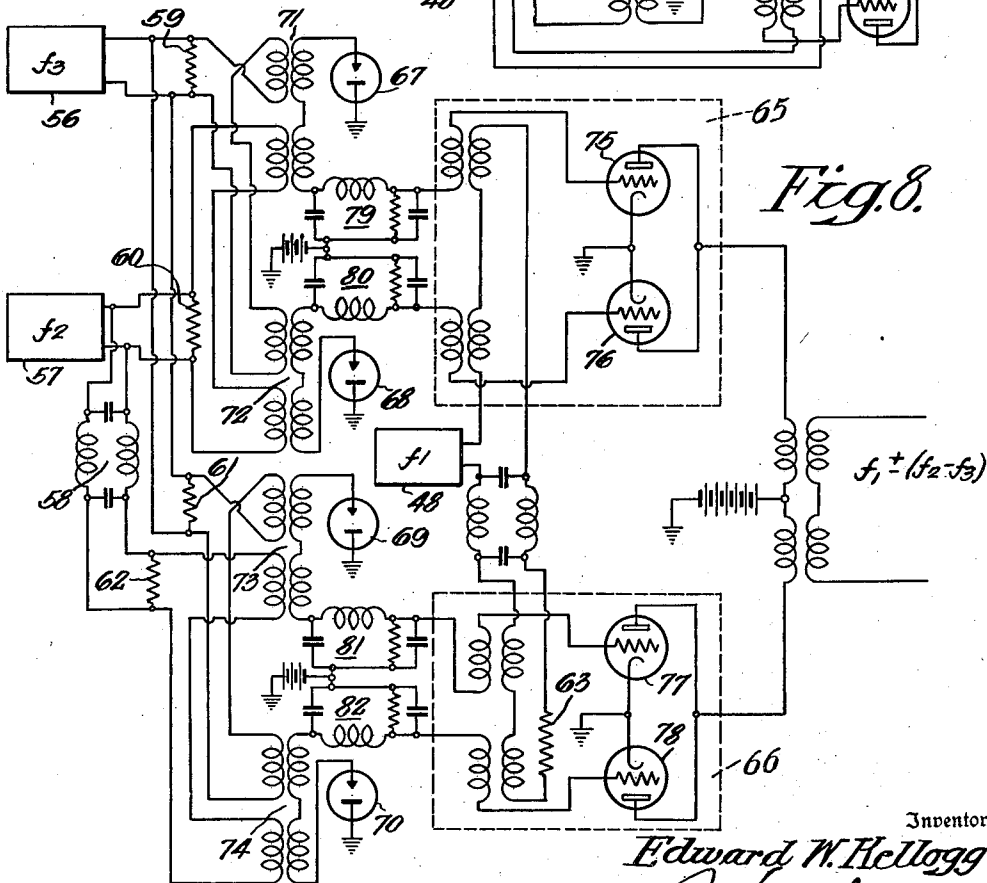
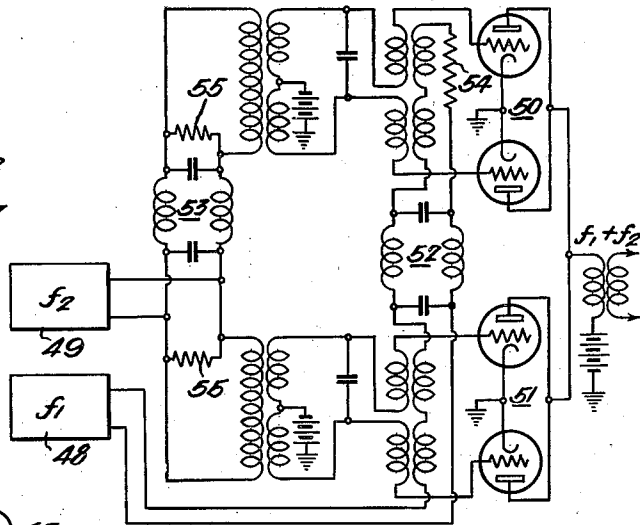


Fig. 8.

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2,157,178

PUBLIC ADDRESS STABILIZING SYSTEM

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Application December 31, 1936, Serial No. 118,441

14 Claims. (Cl. 179-1)

This invention relates to signal transmitting and receiving systems, such as are utilized for public address, sound reinforcement or like purposes, and has for its principal object the provision of an improved apparatus and method of operation whereby undesired feed-back from the loudspeaker to the microphone of such systems is avoided.

Such feed-back between acoustically coupled sound reproducing and pick-up devices, commonly results from sound which (1) is produced by the loudspeaker, (2) is picked up by the microphone and (3) produces a corresponding electrical current which is amplified and fed to the loudspeaker. If the microphone and loudspeaker are in the same room, the amount of sound amplification which can be employed is practically always limited by the feed-back point which almost always occurs at the frequency at which the overall amplification is at a maximum. This involves the complete circuit, starting with the microphone and ending with the sound received by the microphone from the loud speaker, thus including such sound reinforcement or sound losses as are imparted by the entire acoustical environment. Thus the microphone may be especially sensitive at one frequency or the loud speaker may be especially efficient at a particular frequency or the amplifier may have a peak at a certain frequency. All these factors have a part in determining the frequency at which feed-back becomes evident.

It has been found that the usefulness of a sound reinforcing system is greatly enhanced by minimizing all of the peaks in the system so that the overall characteristic is as nearly uniform with respect to frequency as possible. Further advantage has been taken of the directive properties of both microphones and loudspeakers in order that the microphone may receive a minimum of sound from the loudspeaker as compared with the sound which the loudspeaker radiates toward the hearers, and the sound which the microphone receives from the original source. It has also been proposed to provide the amplifier of a public address system with a slow acting automatic volume control of the "compressor" type for reducing the amplification when there is any prolonged sound. This would serve to stop feed-back if the sustained sounds were due to feed-back but no satisfactory arrangement has been proposed that will enable the microphone to distinguish between feed-back sounds which it is desired to amplify. In spite of what it has been possible to accomplish along these lines, the use-

fulness of public address systems is still seriously limited by feed-back.

A possible solution of the problem is the provision of means for causing the amplification to be momentarily increased in response to speech. For this purpose, a quick acting expander circuit having a limited range of volume control may be employed. Such a system is disclosed by a Leslie J. Anderson application, Serial No. 113,131, filed November 28, 1936, and assigned to the same assignee as the present application. The theory of this approach to the problem is that the high amplification condition does not last long enough to permit the building up of feed-back oscillations.

A possible solution of the problem of enabling the control system to distinguish between currents resulting from feed-back and those due to useful sound is the provision of a system including (1) means for causing the overall amplification at a certain frequency to exceed that at all other frequencies so that feed-back, if it occurs at all, will be at this frequency, and (2) means responsive to sustained currents of this frequency for reducing the gain at all frequencies to a level below that at which self-excited oscillations can be maintained. Such a system is disclosed in my application, Serial No. 113,121, filed November 28, 1936 and assigned to the same assignee as the present application.

The present invention differs from those of the aforesaid applications in that it involves the provision of means for periodically shifting the phase of the loudspeaker output with respect to the microphone. As will hereinafter appear, this periodic shift in the phase relation between the loudspeaker output and the microphone may be effected by (1) cyclically varying the length of the air path between the microphone and loudspeaker by moving the loudspeaker with respect to the microphone or vice versa, or (2) a cyclic or a continuous phase change introduced between the microphone and the loudspeaker. These solutions of the problem are based on the fact that feed-back at any given frequency is dependent on a certain phase relation between the loud speaker output and microphone input, and any phase shift upsets the process of building up oscillations.

The invention will be better understood from the following description when considered in connection with the accompanying drawings and its scope is indicated by the appended claims.

Referring to the drawings—

Figures 1 and 2 illustrate a mechanism for cyclically varying the position of a loudspeaker,

Figure 3 illustrates a mechanism for cyclically varying phase by varying the length of an air column which is introduced in the amplifying system between the microphone and loudspeaker,

Figure 4 illustrates a system including an electrical network for producing a variable delay between the loudspeaker and microphone,

Figure 5 is a block diagram of a system in which the phase shift is produced by causing a continuous drift of phase of all the frequencies throughout the audio range, and

Figures 6 to 8 are wiring diagrams of different circuits which are useful in producing the desired phase shift or frequency drift between the loudspeaker output and microphone.

Figs. 1 and 2 illustrate a possible mechanical arrangement for causing a loud speaker 1 to move in a circular path. The loudspeaker 1 is mounted on a triangular plate or frame 2 which is supported at the corners by arms 3 which are pivoted at 4 and carry counter-weights 5. The pivots are of the ball and socket type, permitting the arms to move vertically or horizontally. Ball and socket joints are also provided at 6. The loudspeaker can therefore be readily moved either horizontally or vertically but is always pointed in the same direction. Motion may be imparted to the loudspeaker by means of a motor 7, which causes rotation of a crank pin 8. Two links 9 and 10 having ball and socket or universal joints at each end transmit rotational movements of the crank pin 8 to frame 2 and thereby to the loudspeaker.

Fig. 3 illustrates a method of introducing a variable time lag between the picking up of a sound by the microphone 12 and its reproduction by the loudspeaker 1. After amplification, the output of the microphone 12 is applied to a receiver unit 14 which produces sound at one end of the air column in the tube 15, 17. The sound produced by the receiver unit 14 travels the length of this tube and is received by the transmitter 16 the output of which after amplification is applied to loudspeaker 1. The time lag between the microphone 12 and the loudspeaker 1 is proportional to the length of the air column in the tube 15. This length may be varied by constructing the tube so that it may be telescoped as in the case of an ordinary slide trombone. The U-shaped portion 17 of the tube 15 slides over the fixed straight portions and may be caused to move back and forth by means of a motor driven crank 18 and connecting rod 19, a guide 20 being provided to take the transverse thrust of the connecting rod. The sliding and actuating arrangements must be so constructed as to introduce negligible noise in comparison with the useful sound in the tube. Suitable damping must also be provided in order that standing waves may not be built up in the tube. The transmitter unit 16, if of a high efficiency electromagnetic type, can itself afford the required damping. A suitable vent 21 must also be provided so that air may enter and leave the tube. The vent 21 should be acoustically damped.

Fig. 4 shows apparatus for producing variable delay in an electrical system. The output of the microphone 22 is amplified at 23 and supplied to an artificial transmission line 24 constructed of suitably arranged series coils and shunt condensers. The waves on this line are uni-directional reflections being prevented by terminating the line with a resistance 25 of suitable value.

The voltage at various points along the line might be picked up by providing a commutator device or sliding contacts but I prefer to pick up the magnetic field which surrounds the line by means of an exploring coil 26, which is mounted on a slide 27 and moved back and forth by the motor driven crank 19. The voltage generated in the exploring coil 26 is amplified by the amplifier 29 and applied to the loudspeaker 1. The artificial line 24 is designed so that the total time required by a wave to travel the length of the line is of the order of one complete cycle of the lowest frequency for which there is any danger of feed back. At the same time if line 24 is constructed of lumped capacities and inductances, there must be at least three condensers per wave length of the highest frequency to be transmitted.

Fig. 5 shows a modification of the invention in which the change of phase is produced by causing a continuous drift of phase of all frequencies throughout the audio range. This continuous drift, rather than a reversed shift, insures better cancellation of the standing wave patterns for all frequencies. The arrangement of Fig. 5 has the further advantage that no moving mechanical parts are required. The output of microphone 12 is applied to amplifier 32, the output of which is used in the balanced modulator 33 to modulate a carrier frequency supplied by oscillator 34. The frequency of the carrier should be well above the audio range, but the design of the system is simplified if the frequency is not extremely high. A frequency of the order of 20,000 cycles is suitable. The balanced modulator is of a well-known type and results in the production of both side bands, but with the carrier frequency absent. Thus the output of balanced modulator 33 contains components of frequencies equal to 20,000 plus or minus the audio frequency. By means of the filter 31 one of the side bands is eliminated. For the purpose we may assume that the upper side band is transmitted consisting of frequencies equal to 20,000 cycles plus whatever frequency is present in the microphone output. A second oscillator 35 is tuned to a frequency differing from that of 34 by only a few cycles per second, for example, 20,002 cycles. This second carrier current is mixed with the upper side band from the filter 31. The side band combined with the new carrier frequency is applied to the detector 37, amplifier 38 and loudspeaker 1. Since we have assumed the transmission of the upper side band and a new carrier higher in frequency by 2 cycles per second than the original, the audio currents supplied to the loudspeaker will be lower in frequency than the originals by two cycles per second. Therefore, the phase relations between the loud speaker and the microphone will shift through 360° twice every second. If oscillation tends to build up, the oscillatory condition will hardly be established before the phase of the waves reaching the microphone will have shifted by 180° and tend to cancel the effects of what has preceded.

The method of producing phase shifts between the loudspeaker and microphone becomes more effective as the distance between the loudspeaker and the microphone is increased. It is thus more helpful in a large auditorium than in a small one. The reason for this is that the larger the auditorium or the greater the distance, the longer it takes to establish the system of standing waves which is usually responsible for building up the pressures at the microphone to the point at which feed back can occur.

Difficulty is sometimes encountered in operating two oscillators at very nearly the same frequency since they tend to lock into step even though the transfer of energy from one to the other may be kept to a minimum. If, in addition to avoiding actual synchronism, it is necessary to maintain the difference frequency within narrow limits, the problem is still more difficult. For example, if it is desired to operate two oscillators, one at 20,000 cycles and the other at 20,001 cycles, it is necessary that both oscillators maintain their frequency within less than one part in 20,000.

If the difference in the two frequencies is large, a sum or difference frequency can readily be obtained by modulating an oscillator and eliminating the carrier and one side band by means of a filter. Where the difference between the two desired frequencies is very small, no filter can be designed which will properly separate one side band from the carrier and other side band.

One of the possible methods of obtaining an alternating current of frequency f_2 from a frequency f_1 is to supply a polyphase stator with frequency f_1 and rotate the secondary winding at such a speed that $f_2 - f_1$ pairs of poles are passed per second. In power work, transformers for such service are sometimes called Selsyn motors or Selsyn generators. In radio frequency work, an air core coil may be employed, but the principle of operation is the same.

In Fig. 6, 41 represents an oscillator supplying current of frequency f_1 . The converter 42 has two windings 43 and 44, so disposed as to produce magnetic fields at right angles to each other. The winding 43 is supplied directly and the winding 44 through a delay circuit 45 designed to cause the current in winding 44 to lag 90° with respect to that in winding 43. Resistances 46 are included in the circuits to properly load the lines so that the delay circuit will function properly. Coil 47 is mounted on a shaft, and can be rotated so that it will alternately be in line with winding 43 and 44. The voltage induced in coil 46 has a frequency f_2 , equal to $f_1 + f_2$, if coil 47 is rotated f_2 revolutions per second in one direction, or equal to $f_1 - f_2$ if coil 47 is rotated in the opposite direction.

Fig. 7 shows an all electrical system for accomplishing the same purpose without the use of moving mechanical parts. In this arrangement 48 is an oscillator producing alternating current of frequency f_1 , which, for purpose of illustration, we shall assume to be 20,000. A second oscillator 49 produces a low frequency by which the desired source is to differ from f_1 . This is taken for illustration as 5 cycles per second, it being assumed that the desired frequency f_2 is 20,005 cycles. Two balanced modulators 50 and 51 are employed, by which the 20,000 cycle output of oscillator 48 is modulated at the rate of 5 cycles per second. The two modulators function in identical manner, except that both the high and the low frequency voltages applied to modulator 50 are in quadrature with those applied to modulator 51. The quadrature relation of the 20,000 cycle voltages is produced by means of the delay circuit 52, and that of the low frequency or modulating voltage by means of the delay circuit 53. Resistances 54 and 55 are used to load the phase shift circuits. Each balanced modulator produces a current which has an average frequency equal to f_1 but which rises to maximum, falls to zero, rises to maximum in the opposite phase and falls to zero again, with

each cycle of the modulating frequency f_2 . If a voltage which is modulated in this manner is added to another of the same frequency and amplitude, but in quadrature with the first, the rise and fall of the second voltage being also in quadrature with that of the first, the resultant voltage will have a frequency equal to that of the original frequency f_1 plus or minus the modulating frequency, depending on how the outputs of the balanced modulators are added. The relationship may be shown mathematically as follows:

The output of modulator 50 may be represented as

$$A (\cos 2\pi f_1 t) (\cos 2\pi f_2 t)$$

and that of modulator 51 as

$$A (\sin 2\pi f_1 t) (\sin 2\pi f_2 t)$$

The sum of these may be shown to be equal to

$$A \cos 2\pi (f_1 + f_2) t$$

and their difference to

$$A \cos 2\pi (f_1 - f_2) t$$

If the modulation rate is very low, as for example, 1 to 5 cycles per second, a delay circuit to produce a quadrature phase shift is difficult to obtain. Under these circumstances, resort may be had to the method of producing the low frequency voltage by means of beats between voltages of higher frequency, and rectifying the sum of the higher frequency voltages. Although some difficulty might be encountered in constructing two oscillators of high frequency, as for example 20,000 cycles or thereabouts which differ in frequency by only a few cycles per second, it is easy to build two low frequency oscillators whose frequencies differ by a very small amount. We may, for example, construct two oscillators for 20 and 21 cycles respectively, and these could be well enough stabilized to maintain the one cycle beat-rate over a long period of time. If a phase shift is produced in either of the two voltages which are beating together, a corresponding phase shift takes place in the beat. A comparatively simple delay circuit will suffice to produce a 90° phase shift in a 20 cycle current.

Fig. 8 shows a system including two oscillators 56 and 57 and four detectors 67, 68, 69, 70 in push-pull arrangement, which may be utilized to obtain two sources of one cycle voltage which differ in phase by 90°. For illustration, we may assume that oscillator 56 is supplying current of frequency $f_2 = 20$ cycles, and oscillator 57 is supplying current of frequency $f_2 = 21$ cycles per second. The output of oscillator 56 is supplied to both pairs of detectors in like phase, but the output of oscillator 57 is applied direct to one pair of detectors and through a 90° phase shift circuit 58 to the other pair of detectors. This arrangement causes the beats between the two frequencies to occur in quadrature relation in the two detector arrangements, and if the beats are in quadrature, so likewise will be the one cycle currents which result from rectification of the beating twenty and twenty-one cycle currents.

Since it would be difficult to construct a transformer to operate at 1 cycle per second, the "saw-saw" or push-pull effect required for the balanced modulators 65 and 66 of Fig. 8 is obtained by employing two rectifiers, one on each side, and the transformers 71, 72, 73 and 74, through which the 20 and 21 cycle voltages are combined for application to the rectifiers, are connected in opposite directions for the two rectifiers of a pair, so that when they are adding on one side they

are subtracting on the other. This relation is indicated in the diagram of the windings of the transformers. Thus, for example, at one instant the 20 and 21 cycle voltages applied to rectifier 67 through transformer 71 will be subtracting, while those applied to rectifier 68 through transformer 72 will be in full addition. A half cycle later the voltage applied to rectifier 67 will be the sum and that applied to 68 the difference of the 20 and 21 cycle voltages. Thus, the rectifiers will cause the grids of the balanced modulator tubes 75 and 76 to alternately swing positive and negative at one cycle per second. These tubes have non-linear characteristics, such that their amplification of the 20,000 cycle voltage supplied by oscillator 48 varies with the slowly varying, mean grid potential. The f_1 or 20,000 cycle voltage is balanced out to produce zero output when the two tubes 75 and 76 have the same grid bias, but as the balance is upset first in one direction, then in the other, at the rate of one cycle per second, there results a modulated high frequency output current as already described in connection with Fig. 7, which is equivalent to the sum of two equal side bands but without the carrier.

Circuits 79, 80, 81 and 82 serve to filter out the 20 cycle voltage so that this will not be applied to the grids of the balanced modulator tubes. Resistances are also provided in these four circuits to discharge the voltages built up by the rectifiers when the 20 cycle voltage applied across the latter decreases. The filtered outputs of the rectifiers 67, 68, 69, 70 are one cycle currents, the 20 and 21 cycle components having been removed by the filters 79, 80, 81, 82. Since, as already explained, the beats between the 20 and 21 cycle currents occur in quadrature in the upper and lower detector systems, the one cycle currents also are in quadrature. The circuits 79, 80, 81 and 82 also provide capacitors through which the 20,000 cycle current may flow in order that the voltages of these frequencies may be applied to the grids of the modulator tubes 75, 76, 77 and 78.

As in the previous cases, it is necessary, in establishing exact quadrature relations, to load the delay circuits with suitable resistances. These resistances and the values of reactance in the delay circuits should in each case be adjusted until the desired phase angle and equality of the two components is obtained. Resistances 59, 60, 61, 62, 63 are for the purpose of providing the necessary load.

The foregoing description of Fig. 8 shows how the one-cycle voltage can be obtained and applied to the grids of the balanced modulator tubes, and how these function to provide two sources of high frequency current, the one in quadrature with the other, and likewise modulated in quadrature with the other. The outputs of the two balanced modulators are added in Fig. 8 in such a manner that either the 20,001 cycle or 19,999 cycle currents are neutralized according to which frequency is desired. The method of addition of outputs of the two balanced modulators is slightly different in Figs. 7 and 8, the different arrangements being shown for the purpose of illustration. The result is the same. In order to obtain complete cancellation of the undesired component it would ordinarily be necessary to make minor balancing adjustments in the outputs of the two balanced modulators. This may be accomplished in various ways, as for example, by adjusting the plate voltages, or else grid bias of one or the other modulator.

Having obtained from the circuit shown in Fig. 6, Fig. 7 or Fig. 8 a current of frequency slightly greater or slightly less than f_1 this new source of high frequency is employed in the circuit arrangement of Fig. 5, in place of the output of oscillator 35, while the required current of frequency f_1 , supplied in Fig. 5 by oscillator 34, would be taken directly from oscillator 41 of Fig. 6, oscillator 49 of Fig. 7 or 48 of Fig. 8.

I claim as my invention:

1. The combination of acoustically coupled sound reproducing and pickup devices, an amplifier connected between said devices, and means for varying the phase relation between the sound waves at said devices whereby sustained feedback between said devices is prevented.
2. The combination of acoustically coupled sound reproducing and pickup devices, an amplifier connected between said devices, and means for cyclically varying the phase relation between the sound waves at said devices.
3. The combination of acoustically coupled sound reproducing and pickup devices, an amplifier connected between said devices, and means for periodically varying the length of the sound wave transmitting path between said devices.
4. The combination of acoustically coupled sound reproducing and pickup devices, an amplifier connected between said devices, and means for producing a phase drift of the sound waves at one of said devices with respect to the sound waves at the other of said devices.
5. The combination of acoustically coupled sound reproducing and pickup devices, an amplifier connected between said devices, and means including a delay network and an exploring coil associated with said network for changing the phase relation between the sound waves at said devices.
6. The combination of acoustically coupled sound reproducing and pickup devices, an amplifier connected between said devices, and means including a plurality of interconnected oscillation generators operated at different frequencies for varying the phase relation between the sound waves at said devices.
7. The combination of acoustically coupled sound pickup and reproducing devices, means affording a carrier wave for the audio impulses delivered by said pickup device, means for transmitting only one of the side bands as modulated by said impulses, means for superimposing on said modulated side band a second carrier wave of a frequency slightly different from that of said first carrier wave, means for detecting said impulses, and means for supplying said detected impulses to said reproducing device.
8. The method of minimizing feed-back between acoustically coupled sound pickup and reproducing devices which includes varying the phase relation between the sound waves at said devices.
9. The method of minimizing feed-back between acoustically coupled sound pickup and reproducing devices which includes cyclically varying the phase relation between the sound waves at said devices.
10. The method of minimizing feed-back between acoustically coupled sound pickup and reproducing devices which includes periodically varying the distance between said devices.
11. The method of minimizing feedback between acoustically coupled sound pickup and reproducing devices which includes periodically

varying the length of the acoustic air path of the waves between said devices.

12. The method of minimizing tendency to feed-back between acoustically coupled sound reproducing and pickup devices, which includes causing a change in frequency of all of the components of the output of the sound pickup device.

13. In a sound reinforcing system, the method of producing continuous changes of phase, consisting of modulating a high frequency current at audio frequency, eliminating the original carrier

current, supplying a new carrier current having different frequency from the original, and detecting or demodulating the resulting modulated high frequency current.

14. The combination of acoustically coupled sound reproducing and pickup devices, an amplifier connected between said devices, and means including a delay network and a reciprocating exploring coil associated with said network for changing the phase relation between the sound waves at said devices.

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