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METHOD AND APPARATUS FOR CONTROLLING FEEDBACK

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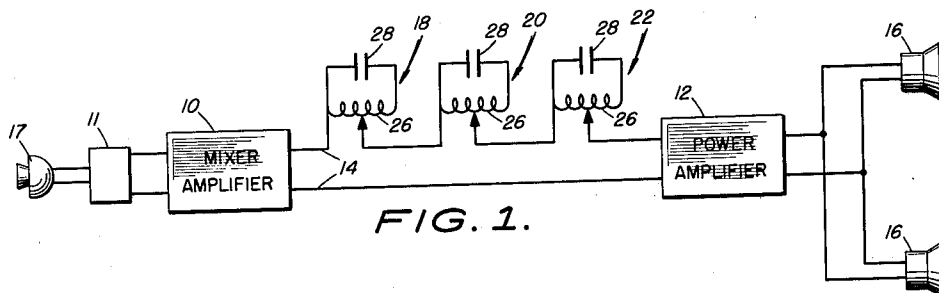


FIG. 1.

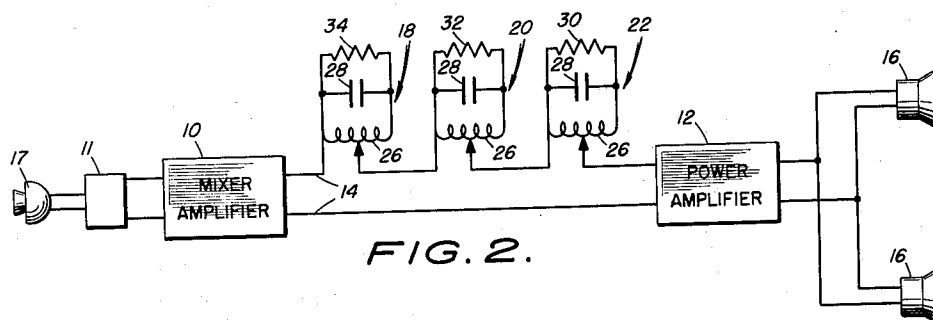


FIG. 2.

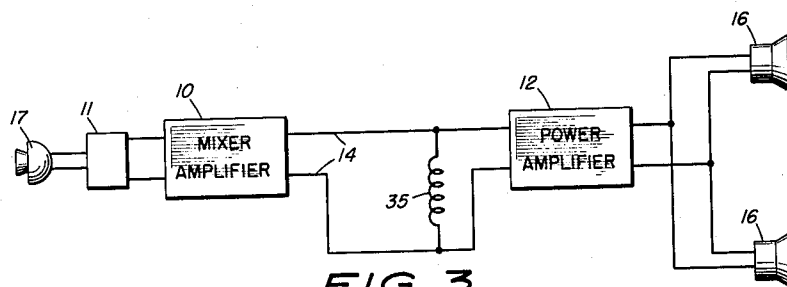


FIG. 3.

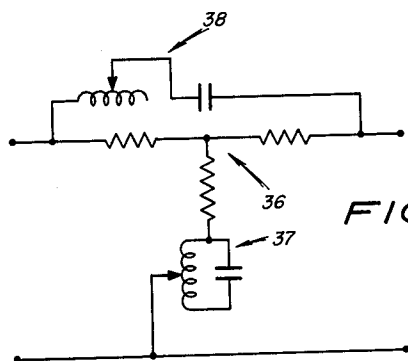


FIG. 4.

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1

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METHOD AND APPARATUS FOR CONTROLLING FEEDBACK

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9 Claims. (Cl. 179-1)

The present invention relates generally to stabilized sound reenforcing systems. More particularly it relates to an improved method and apparatus for controlling feedback, for reducing the effects of room "ringing," and for increasing the naturalness of reenforced sound.

It has long been common practice to "equalize" sound reenforcing systems and other systems employing electronic amplification. Such broad-band equalization is intended to produce the required frequency response of the system, for whatever purpose the system is to serve. It is well known, however, that even when a sound reenforcing system has undergone the usual broad-band equalization, it often suffers from excessive feedback produced by the acoustical coupling between the sound system itself and the room or other space in which it is located. When feedback of this type occurs at such a low level of system gain that the resulting sound delivered to the room is insufficient, it is commonly said that there is too much acoustical feedback.

In the past, standard operating procedures for reducing acoustical feedback have included various broad-band equalization steps and other equivalent measures. Such measures have comprised, but have not been limited to, roll-off of the bass response, roll-off of the treble response, various broad-band reductions in gain somewhere between the bass and the treble regions, highly directional loudspeakers and highly directional microphones.

After an extensive study it was determined that feedback in sound systems is essentially a narrow band rather than a broad band problem. That is, when a sound system feeds back, and when a room "rings," both occur at single frequencies, or groups of single frequencies. These single frequencies or groups of frequencies are audible and can be readily measured and demonstrated. They may occur at any point within the total response spectrum of the sound system and its containing room. Accordingly, the principal object of the present invention is to eliminate feedback in sound reenforcing systems by a method which, basically, comprises determining the frequency and/or groups of frequencies at which feedback takes place, and introducing an anti-resonant circuit, or anti-resonant circuits, tuned to the feedback frequency or groups of frequencies.

Another object of the invention resides in the provision of a method for controlling feedback or room "ringing" which may be used with minimum insertion losses.

As a further object, the invention provides means for controlling feedback in a sound reenforcing system, which means comprises one or more properly adjusted filter circuits connected to the input of the power amplifier of the system.

Further objects of the invention will become evident from a reading of the following description.

In the drawings:

FIG. 1 is a circuit diagram showing the basic embodiment of the invention.

FIG. 2 is a circuit diagram similar to FIG. 1 but show-

2

ing resistors shunted across the anti-resonant filter units to control bandwidth.

FIG. 3 is a schematic showing the toroid coil employed connected across the amplifier input.

FIG. 4 is a circuit schematic illustrating a modification that may be used for obtaining bass boost or treble boost.

The method and apparatus constituting the present invention are intended for use with a sound reenforcing system including a power amplifier and loudspeakers, a driver or mixer amplifier, and a low impedance link circuit connecting the driver or mixer amplifier to the power amplifier. Considered briefly, feedback in such a system may be suppressed, according to the invention, by:

(1) Accurately measuring the frequency of a particular feedback oscillation mode when it is in the steady state;

(2) Observing carefully the manner in which such mode comes into its oscillatory state, and how it leaves said oscillatory state when the gain of the amplifier in the system is reduced slightly;

(3) Connecting a high-Q toroidal inductor, capable of covering the entire range of frequencies subject to feedback oscillation, in the low impedance link circuit between the driver and the power amplifier;

(4) Tuning the coil for maximum Q, by a suitable capacitor connected in parallel therewith, said coil being provided with taps to permit the introduction of the desired depth of narrow notch into the link circuit;

(5) Adjusting the connection to the proper tap on the toroidal coil for the minimum insertion loss required to eliminate the feedback oscillation mode, after tuning the entire coil to said oscillation mode, measured according to step (1) above;

(6) Observing, as to coexisting modes of oscillation, which is controlling, and eliminating it first; and

(7) Repeating steps (1) through (6) above, to eliminate additional oscillation modes until the desired system gain before feedback is attained.

Referring to the drawings, and first to FIG. 1 thereof, a line or mixed amplifier is shown at 10, a preamplifier at 11, and a power amplifier at 12. A link circuit 14 connects the amplifiers 10 and 12, and should have an impedance of between 75 ohms and 600 ohms. Conventional loudspeakers 16 are connected to the output of the power amplifier 12, and a plurality of microphones, one of which is shown at 17, is connected to the preamplifier 11. In the showing of FIG. 1 it is assumed, by way of example, that the problem of feedback elimination is simple in that only three oscillation modes need be suppressed. Ordinarily many more must be eliminated. In the example shown three filter network sections 18, 20, and 22 are connected in series in the link circuit 14, each said section comprising a coil 26 and a tuning capacitor 28 in parallel with the coil. In practice it has been found that the inductance of the coil should be 160 millihenries; a satisfactory coil consisted of a 1000 turn winding, with No. 22 wire, and with taps at 30 turns, 100 turns, 200 turns, and 400 turns. A suitable switch (not shown) may be used for selecting the proper coil tap, as will be described hereinafter. The value of each of the capacitors was sufficient to tune its associated coil throughout its entire frequency range.

With the apparatus described thus far and following the method outlined hereinbelow, it has been possible to provide a sound reenforcing system which will be free from feedback and that will be stable.

The amplifiers 10 and 12, the link circuit 14 (minus the filter network sections 18, 20, and 22), and the loudspeakers 16 constitute components of a conventional sound reinforcing system, but one that is ordinarily not free from feedback. In carrying the method of the present invention into effect, however, it is assumed that the system is operating normally, with reasonable freedom from circuit noise and parasitic oscillation. It is also assumed that the system is installed at its permanent location, such as in an auditorium. After installation the "finishing out" process is effected, as with all sound systems, this process involving first the injection of a test signal into any of the microphones 17. The test signal may consist of critical bands of white noise or the like. Next, with the use of a suitable sound level meter and such filter networks associated with it as may be desirable, the acoustical response of the system, as driven by the test signal, is measured in the seating area of the auditorium, this measurement, commonly called the "house response," is plotted in db versus frequency (logarithmic scale). Then with standard broad-band filter networks, the "house response" is flattened as much as feasible. Usually it is desirable to provide an essentially flat response down to the bottom of the base capability of the system. No bass roll-off is necessary, unless desired for some other reason. For optimum audience satisfaction, it has been found that the treble response around 8 to 12 kilocycles should be allowed to roll off slightly, perhaps 8 to 12 db down at 12 kilocycles versus one kilocycle. Although not necessary for the "finishing out" process or feedback control, it has been found that this treble roll-off provides better audience acceptability, in view of the imperfect nature of some voices and various noises associated with program material.

After the "finishing out" process has been completed, as above described, the system is ready for application of the feedback suppressing technique, now to be described.

With the microphone (or microphones) 17 in operation, the gain of the system is raised until feedback takes place. The gain is adjusted until a steady state of oscillation is reached. If the system oscillation takes place at a single frequency, this frequency should be measured accurately by beating it against a known frequency, such as that produced by a calibrated local oscillator.

If more than one frequency of oscillation is present at the same time, the way in which the two or more come into being and how they die out when the gain is reduced should be noted. If one of these multiple frequencies manifests itself first and is more persistent than the others, its frequency should be measured and steps for its elimination taken first. If one of the multiple frequencies, although not the first one to show up, seems to dominate, its frequency should be measured and steps for its elimination taken first. If "hunting" takes place among several oscillation frequencies concurrently present, with first one and then another becoming most prominent, the higher frequency oscillation should be measured and eliminated first. If two of the oscillation frequencies produce audible beats of not more than 10 to 15 cycles beat frequency, the geometrical mean of the two is taken to be the measured frequency of oscillation.

Let it be assumed, at this point in the description, that a certain frequency of feedback oscillation has been measured, by the procedure outlined above, and that one of the filter network sections shown in FIG. 1, say the section 18, is to be used to control this feedback oscillation frequency. First the entire coil 26 is tuned to the measured frequency of feedback oscillation, by the capacitor 28 connected thereacross. This tuning must be done accurately, since the resonance curve is very sharp and the requirement is critical. The notch provided by the toroidal coil 26 and capacitor 28 combination is introduced into the link circuit 14 by adjusting the coil connections so as barely to stop oscillation at the measured frequency. The notch

should be at minimum depth at this point in the process, although it may be necessary to deepen it later.

After the measured frequency of oscillation has been removed as above outlined, the system gain is raised until the next frequency of feedback oscillation is elicited. This oscillation frequency may be removed in the same way as was the first, but with the filter network 20. The system gain may again be raised until a third feedback oscillation frequency appears. This third feedback frequency may be removed by the third network section 22, in the manner described for the removal of the first and second feedback oscillations.

It should be understood that the system gain will tend to rise as the procedure progresses, but that not every filter section introduced will cause the gain to rise. Frequently it is necessary to remove minor or "precursor" oscillation modes which stand in the way of uncovering a major mode of oscillation. The elimination of some modes will permit substantial increases in overall system gain; the elimination of other such modes will not result in gain, but must be effected.

As previously stated, it is usual for there to be many feedback oscillation frequency modes to be eliminated, by the procedure above described, and a circuit showing but three filter network sections was illustrated only for simplicity. In one practical application involving a large auditorium, thirty six filter network sections were required to eliminate feedback. In spite of the relatively large number of networks required, the system was stable and reproducible.

In a system with multiple oscillation modes, it was found that as more and more were measured and eliminated, by the procedure above described, there was a tendency for several modes to coexist. These were measured and eliminated in the manner previously described.

To introduce the filter notch into the link circuit 14, the parallel combination of coil 26 and capacitor 28, with proper tap connections to the coil, is connected in series with the high side of the link circuit, as shown in FIG. 1. With this connection, at the frequency to which the network has been tuned, the tendency is to open the link circuit, not to short it. As each additional section of the network is completed, it is connected in series with the preceding section, as shown in FIG. 1, so that the complete feedback suppression network consists of a series-wired string of sections. The sections may be conveniently mounted on a chassis and the chassis placed in the amplifier rack, or elsewhere.

If a room tends to "ring" at one or more discrete frequencies, as is commonly the case even in large rooms, the procedure above described will remove the room ring by reducing the gain of the sound system at the ringing frequency. The sound system may or may not be oscillatory at the frequency or frequencies of room ring. The room itself will continue to ring if excited, but when the source of sound is feeding into the microphone, the sound system will not excite the room overly at that frequency. The required adjustment is rather delicate, but is quite practical and stable. Frequently, even when there is little if any acoustical feedback, the elimination of room ring through the procedure described, for material going through the sound system, is quite worthwhile.

If the sound system is in a reverberant room, in which speech is heard with difficulty, it is frequently possible to use the procedure described hereinabove to reduce the sound system gain at that series of room frequencies which produce the most reverberation. The net effect of using the described method in such cases is to increase the effective ratio of direct sound to reverberant sound in the room and therefore to improve intelligibility of speech. The method may be practiced without sacrificing the reverberant nature of the room for music.

The net effect accomplished by the method of the present invention is to provide a complete sound system

5

that, in the presence of feedback and room acoustics, is flatter than is normally the case. In consequence, system feedback is more nearly independent of position of microphone relative to loudspeaker than is frequently the case.

It often occurs, during listening tests of a sound system completed as described hereinabove, that the reenforced speech or music does not sound as natural to the listener as is desired. The procedure described herein above provides a method of altering the system response as may be desired to improve the naturalness of the resulting sound. If, for example, one narrow frequency band is too pronounced for satisfactory naturalness, the filter section for that band, say the section 22 in FIG. 1, can be tuned to reduce the gain. Band width, and thus notch insertion loss, can be conveniently controlled by adjusting the taps of the coil 26 of the section, or by shunting the section with a resistor, say one having a value of 1000 ohms, or by utilizing both of these measures. Such a shunting resistor is shown in FIG. 2 at 30. If a somewhat wider band, say that controlled by the anti-resonant filter section 20, requires attenuation, then a different tap on the coil of said section is used to introduce the attenuation, and a lower value resistor is used to provide the required broadening. Such a resistor, having a value of say 800 ohms, is shown at 32 in FIG. 2. A still wider rejection band may be introduced by using two or more of the tapped coils, say the coils of all of the filter sections shown in FIG. 1, each tuned to the proper frequency in the rejection band and each shunted by a resistor of proper value. For example, the coil 26 of filter section 18 could be shunted by resistor 34 (FIG. 2) having a value of 600 ohms.

If bass roll-off is desired, it may be effected by using the procedure described above for narrow band filtering, with the addition, however, of the proper shunting resistor. Alternatively, as shown in FIG. 3, a coil 35 may be connected across the link circuit 14 instead of in series with it, and no shunt capacitor is used.

If it is desired to insert a T-pad into the link circuit 14 for bass boost, or treble boost, the desired tuning elements in either the series or shunt arms of the T-pad, or other pad, may use a tapped toroidal coil similar to the one above described, with proper capacitors. Thus, as shown in FIG. 4, a treble boost T-pad may consist of the proper resistive pad 36 with an anti-resonant toroid coil and capacitor 37 in the shunt arm and a series-resonant toroid coil and capacitor 38 across the top of the T, i.e., in parallel with the series connected resistors of the pad 36. Such toroidal coil-capacitor combinations may be used for other desired response curves or pads.

What is claimed is:

1. An apparatus for controlling feedback in a sound reenforcing system having a power amplifier, an amplifier, and a link circuit connecting said amplifiers, comprising:

a coil connected in series in said link circuit between said amplifiers,
and a capacitor connected in shunt with said coil, said capacitor tuning said coil to a frequency of oscillation producing feedback for eliminating said feedback,
the inductance of said coil being adjustable to provide minimum insertion loss at the frequency required to eliminate the feedback.

2. In combination with a sound reenforcing system having acoustically coupled sound pick-up and reproduction devices, an amplifier, a power amplifier, and a link circuit connecting the amplifier to the power amplifier;

means for controlling feedback resulting from coupling between said pick-up and reproduction devices,

said means comprising a coil connected in series in said link circuit,

6

a capacitor connected in shunt with said coil, said coil and capacitor constituting an anti-resonant filter,

said filter being tuned to the frequency of oscillation causing said feedback, and means for adjusting the inductance value of the coil in the link circuit, whereby the gain of the system without feedback may be set at optimum value.

3. A method for eliminating feedback in a sound reenforcing system, comprising:

(a) the step of measuring a frequency of oscillation that produces feedback,

(b) the step of tuning the system to such frequency of oscillation causing feedback for eliminating feedback at that frequency of oscillation,

(c) the step of then tuning the system to any chosen frequency of a group of frequencies causing feedback for eliminating feedback at that frequency,

(d) the step of tuning the system to eliminate each of the remaining feedback frequencies of such group of frequencies, and

(e) the step of adjusting the system for optimum gain as each feedback frequency is eliminated.

4. In combination with a sound reenforcing system having sound pick-up and reproducing devices, and amplifying means connected between said devices and including a link circuit, means for controlling feedback in the system, comprising:

(a) an anti-resonant filter connected in series in said link circuit and tuned to a frequency of oscillation producing feedback, said tuned filter eliminating feedback at such feedback producing frequency, said tuned filter having an inductance coil provided with taps between its ends, said coil being connected in the link circuit by said taps, the variation of the impedance ratio between the entire coil and that portion between the taps providing minimum insertion loss at the feedback producing frequency without changing the tuning or frequency breadth of the system, and

(b) pad means for improving the treble and bass response of the system.

5. A method of suppressing feedback in a sound reenforcing system having acoustically coupled input and output devices, amplifiers connected between the devices, and a link circuit connected between the amplifiers, comprising the steps of

(a) raising the gain of the amplifiers until feedback ensues,

(b) adjusting the gain until a steady state of oscillation is reached,

(c) measuring the frequency of the oscillation,

(d) filtering the link circuit to stop said oscillation,

(e) increasing the gain of the amplifiers until other frequencies of oscillation are elicited,

(f) repeating steps (a) through (d) hereinabove for suppressing each of the said other frequencies of oscillation one by one, and

(g) readjusting the system for maximum gain without feedback as said frequencies of oscillation are suppressed.

6. The method recited in claim 5, including the additional step of broadening the response of the system to improve the naturalness thereof.

7. In a sound reenforcing system having pick-up and reproduction devices, an amplifier, a power amplifier, and a link circuit connecting the amplifiers, means for controlling feedback produced by oscillation of the system at multiple frequencies, comprising:

a plurality of notch filters connected in series in said link circuit,

each of said filters being tuned to a feedback producing frequency for eliminating feedback at the frequency to which it is tuned,

7

and means for adjusting the filters for minimum insertion loss without feedback whereby optimum system gain may be obtained.

8. A sound reenforcing system as recited in claim 7, wherein each of said filters comprises a coil, and a capacitor connected in shunt with the coil.

9. A sound reenforcing system as recited in claim 7, wherein each of said filters includes a coil, a capacitor connected in shunt with the coil, and tap means for varying the inductance of the coil.

8

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