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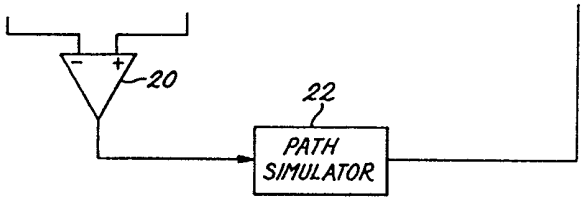
THE PATENT OFFICE
7 July 1986

the amplifier 13 passes by way of a loudspeaker 10 and a microphone 11 before reaching an addition circuit, and the error signal passes by way of means 22 simulating the loudspeaker, the microphone and the intervening path, before reaching the addition circuit, where non-linearity in the input signal to the subtractor 15 is corrected by addition of the error signal.



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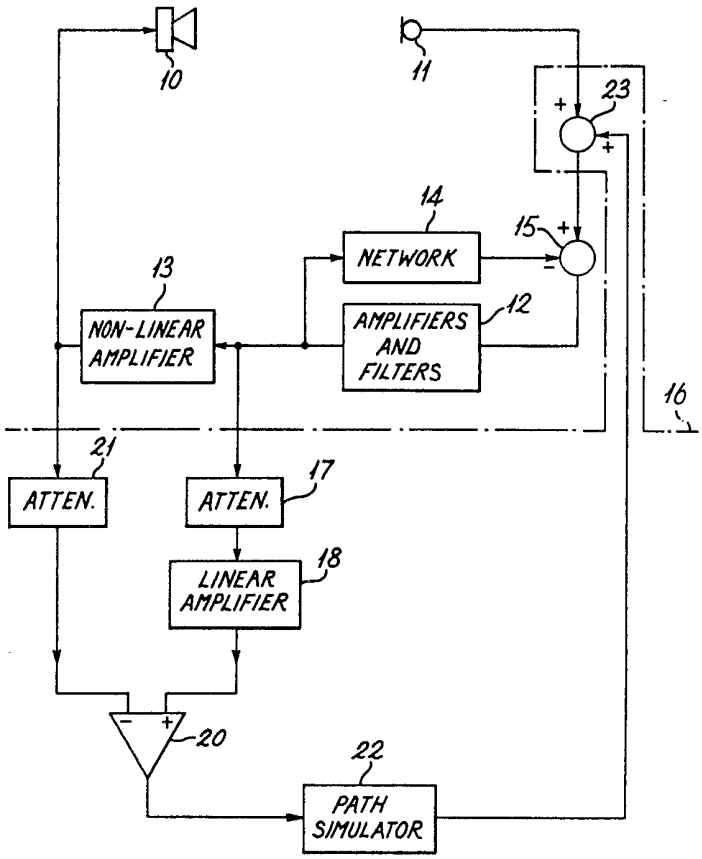
(54) Apparatus and method for providing an undistorted output signal from a non-linear device

(57) In some feedback systems, such as are used in sound cancellation systems, instability sometimes arises due to an amplifier being driven into non-linear operation. For example in the arrangement shown, stability depends on feedback via a network 14 and a subtractor 15 but instability occurs when an amplifier 13 becomes non-linear. This problem can be largely overcome by connecting a linear amplifier 18 to receive, after attenuation, the same signal as the amplifier 13. The outputs of the amplifiers after level adjustment are passed to a differential amplifier 20 which generates an error signal dependent on any non-linearity. The output of the amplifier 13 passes by way of a loudspeaker 10 and a microphone 11 before reaching an addition circuit, and the error signal passes by way of means 22 simulating the loudspeaker, the microphone and the intervening path, before reaching the addition circuit, where non-linearity in the input signal to the subtractor 15 is corrected by addition of the error signal.



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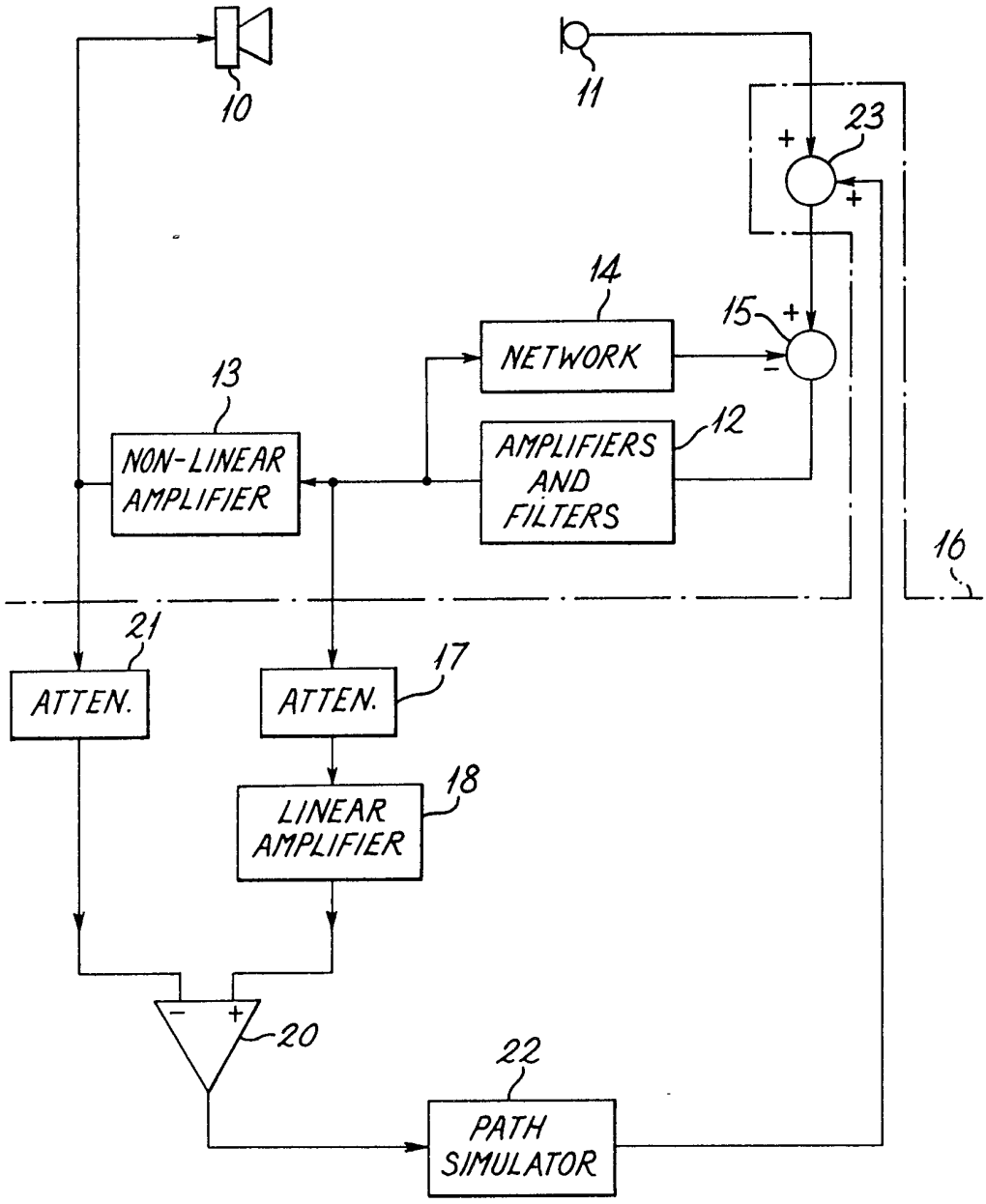
10
11
23
+
+
14
15
+
NETWORK
13
12
NON-LINEAR AMPLIFIER
AMPLIFIERS AND FILTERS
16
21
17
ATTEN.
ATTEN.
18
LINEAR AMPLIFIER
−
+
20
22
PATH SIMULATOR

SPECIFICATION

Apparatus and method for providing an undistorted output signal from a non-linear device

The present invention relates to apparatus and a method for using a non-linear device in the provision of an output signal which is linearly related to an input signal applied to the device. The invention finds application, particularly, but not exclusively where economies can be achieved by using a device which acts linearly under most conditions but in some working conditions is non-linear; the expense of a device which would function linearly under all working conditions is therefore avoided. An example of circumstances where this advantage occurs is in active sound control.

The technique of active sound control uses a sound source such as a loudspeaker to cancel unwanted sounds. In order to drive the loudspeaker a microphone is used to pick up the unwanted sounds and the output of the microphone is processed before being passed to the loudspeaker. Where in such an arrangement the microphone and the loudspeaker can interact, instability at some frequencies is likely to occur. One way in which such instability can be avoided is to provide a feedback path from the input of the loudspeaker to the input of the means for processing the microphone output, so that feedback by way of the path cancels unwanted positive feedback between the loudspeaker and the microphone. The means for processing the microphone output usually include filters and amplifiers, and under some high level conditions the amplifiers overload, providing clipped output signals. The feedback artificially provided may then no longer balance the natural unwanted positive feedback and instability may again occur.

This problem may be overcome by using more expensive amplifiers which do not clip but this means that the rating of the speakers also requires improvement to avoid damage by overload. Alternatively any overload may be detected and then the sound correction loop is switched off. Unfortunately interruption of sound cancellation at unpredictable intervals is a major disadvantage.

In this specification a non-linear device is a device which has an output signal which at least under some working conditions is non-linearly related to its input signal.

According to a first aspect of the present invention there is provided apparatus for providing an output signal, partially from a non-linear device, wherein the output signal is linearly related to an input signal applied to the said device, comprising a non-linear device, as hereinbefore defined, with input connected in parallel with a linear device, difference means for determining the difference between the output signal of the non-linear device and the linear device, and correction means employing the output signals of the non-linear device and the difference means, or respective signals representative thereof, to correct the output signal of the non-linear device or to correct a signal representative thereof.

According to a second aspect of the present invention there is provided a method of providing an output signal, partially from a non-linear device, as hereinbefore defined, wherein the output signal is linearly related to an input signal applied to the said device, comprising determining a difference signal representative of the difference between the output signal of the non-linear device and the output signal of a linear device, receiving the same input signal, and using the difference signal and the output signal of the non-linear device, or respective signals representative thereof, to correct the output signal of the non-linear device or to correct a signal representative thereof.

The invention may, for example, be usefully applied where the non-linear device is capable of providing a high power output signal compared with that provided by the linear device, the linear device making good the deficiencies of the non-linear device in some working region or over some range of parameters where, for some reason, high power is not required.

The advantage obtained is that a linear output signal, useful for example in some feedback applications, is received without using an expensive high power linear device.

Where the output of the non-linear device undergoes considerable attenuation before reaching the correction means, an attenuator may be provided at the input to the linear device to reduce the input level thereto, and the difference means may receive a signal from the non-linear device attenuated by the same amount as that provided by the said attenuator. The output of the difference means may then be connected to simulation means for providing any further attenuation required to bring the output signal of the difference means to a suitable level for application to the correction means.

An embodiment of the invention will now be described with reference to the accompanying drawing which shows a circuit diagram of part of a sound cancellation system including apparatus according to the invention.

In the Figure a loudspeaker 10 and a microphone 11 are part of a sound cancellation network which is not described in this specification but may, for example, be of the type described in UK specification 1548362, "Active Control of Soundwaves" (M.A. Swinbanks). In order to process signals from the

microphone 11 so that they are suitable for sound cancellation when applied to the loudspeaker 10, the signals from the microphone pass through amplifiers and filters 12 to a power amplifier 13 which drives loudspeaker 10.

A network 14 is provided which stabilises the loop so far described by deriving from the input signal to the amplifier 13, a signal which cancels those components of the microphone output signal which lead to instability. Such components are removed using a subtractor circuit 15 which receives the microphone output signal and the network output signal.

The apparatus so far described is still liable to instability if the amplifier 13 becomes overloaded so that its output signal is clipped but the network 14 continues to receive an undistorted input signal. Distortion only occurs when the amplifier 13 is overloaded and at other times the amplifier 13 is a linear device. Thus the amplifier 13 is primarily intended to be linear but becomes non-linear when it is overloaded.

In accordance with the invention the circuits below a chain dotted line 16 are added to overcome the overload instability.

The signal for the amplifier 13 is applied to an attenuator 17 so that, for example, while the input signal to the amplifier 13 may be ± 100 volts the input to a linear amplifier 18 is only about ± 5 volts. Clearly the amplifier 18 is much less likely to be overloaded than the amplifier 13. The two amplifiers have similar characteristics so the amplifier 18 can be regarded as simulating the amplifier 13. Such a simulator may simply be provided by a frequency characteristic shaping network comprising resistors and capacitors and an operational amplifier connected as a voltage follower.

An error signal is now formed by applying the output of the linear amplifier 18 to the non-inverting input of a differential operational amplifier 20 and by applying the output signal of the amplifier 13 by way of an attenuator 21 to the inverting input of the amplifier 20. The attenuators 17 and 21 have attenuations which, when the amplifier 13 acts as a linear amplifier, apply equal signals to the amplifier 20. Thus when there is no distortion in the amplifier 13 there is no output signal from the amplifier 20 but when distortion occurs a negative version of the error obtained by subtracting the distortion signal from the required signal appears at the output of the amplifier 20. The error signal passes by way of a path simulator 22 to an addition circuit 23 at the output of the microphone 11. The simulator 22 simulates the path between the input to the loudspeaker 10 and the output of the microphone 11 so that the addition circuit 23 receives an attenuated and phase modified version of the output signal from the amplifier 13 containing any distortion and an error signal attenuated and modified in the same way by the path simulator 22. The addition of these two signals provides an undistorted, but attenuated and phase modified, signal for the subtraction circuit 15.

Usually amplifier 13 does not introduce distortion, and under these circumstances the amplifier 20 provides no output signal and the circuit above the line 16 functions in its normal way. However when the amplifier 13 becomes overloaded a correction is applied by way of the amplifier 20 and the addition circuit 23 so that the subtraction circuit 15 and the network 14 function correctly.

Although a specific embodiment of the invention has been described it will be realised that the invention can be put into practice in many other ways. For example by reversing the input signals to the amplifier 20 and changing the circuit 23 to a subtraction circuit wherein the output of the simulator 22 is subtracted from the output of the microphone, an alternative embodiment working in a similar way is achieved.

The amplifiers and filters 12, the network 14 and the path simulator 22 may be digital circuits if analogue-to-digital converters (not shown) are inserted at the outputs of the subtraction circuit 15 and the amplifier 20, and digital-to-analogue converters (not shown) are inserted at the outputs of the amplifiers and filters 12, the network 14 and the simulator 22.

The invention may be applied to many different situations, where, for example, it is desired to use an economic amplifier and in these situations the circuits used will be different from those shown in the diagram.

CLAIMS

1. Apparatus for providing an output signal, partially from a non-linear device, wherein the output signal is linearly related to an input signal applied to the said device, comprising a non-linear device, as hereinbefore defined, with input connected in parallel with a linear device, difference means for determining the difference between the output signal of the non-linear device and the linear device, and correction means employing the output signals of the non-linear device and the difference means, or respective signals representative thereof, to correct the output signal of the non-linear device or tocorrect a signal representative thereof.

2. Apparatus according to Claim 1 wherein the non-linear device and the linear device comprise non-linear and linear amplifiers, respectively.

3. Apparatus according to Claim 2 wherein significant attenuation occurs between the output of the non-linear amplifier and the input of the correction means, and the apparatus includes first and second atten-

uators, for attenuating the input signal to the linear amplifier and to the difference means, from the non-linear amplifier, respectively.

4. Apparatus according to Claim 3 for use in a sound control system, wherein the signal path between the output of the non-linear amplifier and the correction means includes sound transmission, and the output of the difference means is coupled to an input of the correction means by way of simulation means which simulates the said sound transmission.

5. A method of providing an output signal, partially from a non-linear device, as hereinbefore defined, wherein the output signal is linearly related to an input signal applied to the said device, comprising determining a difference signal representative of the difference between the output signal of the non-linear device and the output signal of a linear device, receiving the same input signal, and using the difference signal and the output signal of the non-linear device, or respective signals representative thereof, to correct the output signal of the non-linear device or to correct a signal representative thereof.

6. A sound cancellation system including apparatus substantially as hereinbefore described with reference to the accompanying drawing.

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