

A METHOD FOR DETECTING AND REMOVING HOWLING

Field of Invention

This invention relates to a method of detecting and removing howling from an audio system. It relates particularly but not exclusively to a method which involves converting an analogue signal originating from a microphone into a digital signal and undertaking the following processing within a digital signal processor before conversion back into an analogue signal - (i) analysing the digital input signal to detect the presence of howling and where howling is detected (ii) processing the digital input signal to form a synthesized signal (iii) passing the synthesized signal into an adaptive howling canceller (iv) measuring the digital output signal from the adaptive howling canceller and accordingly modifying processing within the adaptive howling canceller.

Background to the Invention

Audio amplification systems consisting of a microphone and loudspeaker are commonly used for a wide variety of applications such as public addresses and musical concerts. It is common for karaoke kiosks, lecture theatres and seminar rooms to be equipped with these types of microphone loudspeaker systems. As such, there is a need for an affordable and effective means of preventing and removing unwanted noise whenever it occurs.

It is common for the noise from the loudspeaker to be picked up by the microphone. This results in what is known as "howling". Howling occurs when the overall system amplification exceeds a particular threshold; the exact threshold is dependent on the system and the characteristics of the room. Positive feedback of an audio signal in the system may result in the generation of a high energy noise which can be irritating to listeners, and it is this noise which is known as "howling".

A conventional howling removal or feedback elimination system is made up of couples of either analogue or digital filters which are connected in series. These filters have an adjustable gain which typically must be manually adjusted to selectively block out a certain band of spectra in the input signal. A common type of filter used for feedback elimination or reduction is a graphic equalizer or a parametric equalizer. A graphic equalizer enables adjustment of the relative levels of an audio signal across the frequency spectrum, typically in one-third octave increments. Feedback can be eliminated by finding the slider nearest to the frequency of the undesired feedback, and lowering the level of that slider. However, this means that all audio signals which have frequencies in the corresponding one-third octave will have their levels attenuated, and this can impair the quality of the audio production. A parametric equalizer can be used to create a more precise "notch" in the audio signal frequency spectrum, because a parametric equalizer typically enables the user to specify a frequency and a bandwidth for a reduction or increase in the level of the audio signal. However, the feedback elimination process is still somewhat imprecise.

There are several disadvantages to these howling reduction filters. The exact calibration needed depends on the system. As such, the successful reduction of howling is dependent on the skill of the manual operator and the settings chosen.

Another major disadvantage with filters such as these is that they tend to indiscriminately remove a particular band of frequency. This can result in the removal of more than just the howling. This can result in a degradation of the signal even when howling does not occur. This is a particular problem where a large range of the spectrum is filtered resulting in a significant degradation of the signal. Another problem with filtering out howling over a wide spectrum is that typically additional hardware in the form of filters must be added to increase the frequency range which can be filtered.

Where the howling frequency falls between the filter frequencies there is a further disadvantage that the howling may not be removed effectively.

The object of the present invention is to overcome, address or alleviate one or more of the disadvantages of the prior art.

Summary of the Invention

According to the present invention there is provided a method of detecting and removing howling from an audio system, including the following steps –

- (a) converting an analogue input audio signal into a digital input signal;
- (b) analysing the digital input signal to detect characteristics thereof;
- (c) applying a processing algorithm to the digital input signal to determine the presence of howling;
- (d) using an adaptive predictor to produce a narrowband waveform noise reference signal;
- (e) passing the digital input signal and the noise reference signal into an adaptive howling canceller, wherein the signals are processed using a Finite Impulse Response filter to filter howling from the input digital signal in order to produce an output digital signal;
- (f) analysing the output digital signal and modifying processing of the adaptive howling canceller in response to characteristics of the analysed output digital signal; and
- (g) converting the digital output signal into an analogue audio signal.

The step of analysing the digital input signal may be accomplished in any suitable manner. It is preferred that the step of analysing includes buffering the signal in a fixed-length array.

Any suitable characteristics of the digital input signal may be detected in the step of analysing the digital input signal. It is preferred that the characteristics detected in the step of analysing the digital input signal include pitch, energy and gain.

The processing algorithm applied to the digital input signal may be any suitable algorithm. In a preferred arrangement, the processing algorithm consists of or includes a fast Fourier transform.

The presence of howling may be detected according to any suitable technique. According to one suitable technique, a howling flag is turned on if there is a constant narrowband signal of a particular pitch and at least a predetermined energy level which continues for at least a predetermined period of time.

According to a preferred arrangement, the processing in the adaptive howling canceller is modified by modifying the filter co-efficient of the Finite Impulse Response filter in response to characteristics of the analysed output digital signal.

Brief Description of the Drawings

The invention will hereinafter be described in greater detail by reference to the attached drawings, which show an example of the prior art and illustrate an example form of the invention. It is to be understood that the particularity of the drawing does not supersede the generality of the preceding description of the invention. In the drawings :

Figure 1 is a drawing of the physical components present in the howling removal system used in the prior art.

Figure 2 is a block diagram illustrating the hardware components of the present invention.

Figure 3 is a schematic diagram illustrating the processing of the input signal according to one embodiment of the invention.

Figure 4 is a flowchart illustrating the algorithms involved in processing of a signal according to an embodiment of the invention.

Figure 5 is a flowchart illustrating the algorithms involved in processing of a signal according to an embodiment of the invention.

Figure 6 is a flowchart illustrating processing in one aspect of the adaptive howling canceller.

Detailed Description

The hardware components for conventional howling removal system of the prior art is illustrated in Figure 1. The signal from the microphone is filtered by arranging a number of filters in series between the microphone and the loudspeaker. Typically, each filter is adjusted manually in an attempt to block out the frequency spectrum which results in the howling.

The hardware components of the present invention are illustrated in Figure 2. The components consist of a converter from analogue to digital, digital signal processor and digital to analogue converter. The signal from the microphone is converted from analogue to digital in the analogue-digital converter. The signal is then processed to remove howling in the digital signal processor and then converted from digital to analogue to be fed to the loudspeaker.

The analogue signal from the microphone is digitised with a 16-bit analogue-digital converter with a 16 kHz sampling frequency. The digitised signal is then buffered and stored in an array of fixed length. The stored signal is then processed to estimate its pitch, preferably using the Gold-Rabiner method. The stored signal is also used to compute the energy and gain of the signal.

The presence of howling is then estimated by processing this computed information and utilising a Fast Fourier Transform algorithm. Howling is identified by a rather constant narrowband pitch within the signal. This pitch is typically at a very high energy

continuing for a period of time longer than 100 ms. When these howling characteristics are detected in the signal a howling flag is turned on.

Where the adaptive predictor is turned on the input signal is used to produce a narrowband sinusoidal waveform. When the howling flag is activated the sinusoidal waveform is fed into the adaptive predictor. The adaptive predictor uses the waveform as a noise reference signal and accordingly filters out the howling from the input signal.

A normalised least square algorithm based on the input signal energy is used to cancel out the howling in the adaptive predictor. The filter taps length and convergence factor are based on the input signal energy. The structure used in the adaptive howling canceller is illustrated in Figure 3. This shows the passage of the input speech signal through adaptive filters and adaptive algorithms which eliminate howling, through to the output speech signal.

The convergence of algorithm within the adaptive howling canceller is modified by monitoring the signal after the howling removal process. This acts as a means for controlling the adaptive filter and accelerating the convergence used. The coefficients of the algorithm in the adaptive filter are trained by monitoring the output of the adaptive filter. This ensures that these coefficients are at their optimum value for fast and efficient removal of howling. The adaptive howling canceller is trained by using the last 160 digitised signals. This modification of the coefficients minimises the large initial howling signal sent to the loudspeaker.

An overall flowchart of the method is illustrated in Figure 4. The data buffers are initialised together with the digital signal processor (DSP), analogue to digital converters (ADC) and digital to analogue converters (DAC) and timers. The input signal is then accepted ready to perform the method of the present invention.

Further flowcharts of aspects of the method of the present invention are illustrated in Figure 5 & 6. In the flowchart of Figure 5, data from one frame is read. From this, pitch

is computed., and then the signal energy for the frame is computed. Measurements from numerous frames are compared to determine pitch recurrence, and thence to detect howling. Where howling is detected the adaptive predictor is activated to generate a reference signal, and the adaptive filter receives the generated waveform and uses this to cancel out or minimise the howling. In Figure 5, the inventive method is referred to by the name "SPHERES".

Figure 6 shows an interrupt service routine for the howling cancellation operation. Firstly, operating mode is checked. Mode 0 applies where howling is present, in which case the adaptive howling frequency predictor and adaptive howling canceller are activated. Mode 1 applies where no howling is present, in which case the input signal is looped back to the output digital-to-analogue converter.

It is to be understood that various alterations, additions and/or modifications may be made to the parts previously described without departing from the ambit of the invention.

Claims

1. A method of detecting and removing howling from an audio system, including the following steps-

- (a) converting an analogue input audio signal into a digital input signal;
- (b) analysing the digital input signal to detect characteristics thereof;
- (c) applying a processing algorithm to the digital input signal to determine the presence of howling;
- (d) using an adaptive predictor to produce a narrowband waveform noise reference signal;
- (e) passing the digital input signal and the noise reference signal into an adaptive howling canceller, wherein the signals are processed using a Finite Impulse Response filter to filter howling from the input digital signal in order to produce an output digital signal;
- (f) analysing the output digital signal and modifying processing of the adaptive howling canceller in response to characteristics of the analysed output digital signal; and
- (g) converting the digital output signal into an analogue audio signal.

2. A method according to claim 1 wherein the step of analysing the digital input signal includes buffering the signal in a fixed-length array whereby the buffer size is 160 samples with sampling frequency of 16KHz.

3. A method according to claim 1 or claim 2 wherein the characteristics detected in the step of analysing the digital input signal include pitch, energy and gain, using a processing algorithm consists of or includes a fast Fourier transform, and further using Gold Rabiner method where the pitch's signal detected.

4. A method according to any one of claims 1 to 3 whereby detection of howling using a constant narrowband signal of a particular pitch and using a total single energy

consisting of 160 samples of digitized signal without partitioning the sub-bands for comparison, for at least a predetermined period of time.

5. A method according to any one of claims 1 to 4 wherein the processing in the adaptive howling canceller is modified by modifying the filter co-efficient of the Finite Impulse Response filter using Normalized Least Mean Square (NLMS) algorithm, in response to characteristics of the analysed output digital signal.