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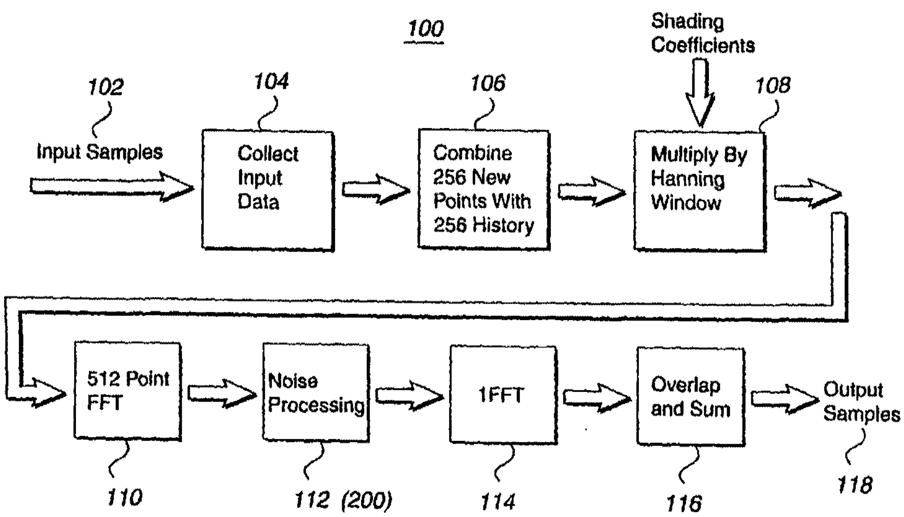

Spectral Subtraction System

(57) Abstract

A system for cancelling and reducing an audio signal noise arising from electrical or electromagnetic noise sources such as AC to DC power converter used by computers. The system receives a digital audio signal (102) sampled at a frequency which is at least twice the bandwidth of the audio signal. The input samples are stored in a temporary buffer of 256 points (104). when the buffer is full, the new 256 points are combined in a combiner (106) with the previous 256 points to provide 512 input points which are multiplied by multiplier (108) with a shading window with the length of 512 points. The shaded results are converted to the frequency domain through an FFT processor (110). The FFT output is processed in a noise processor (112) which includes the noise magnitude estimation for each frequency bin, the substraction that estimates the noise free complex value for each frequency bin and the residual noise reduction process.

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SYSTEM, METHOD AND APPARATUS FOR CANCELING NOISE

RELATED APPLICATIONS INCORPORATED BY REFERENCE.

This application claims priority from U.S. Patent Application Serial Nos. 09/252,874 filed February 18, 1999 and 09/385,996 filed August 30, 1999 and reference is made to U.S. Patent Application Serial No. 60/126,567 filed March 26, 1999, all of which are herein incorporated by reference.

The following applications and patent(s) are cited and hereby herein incorporated by reference: U.S. Patent Application Serial No. 09/252,874 filed February 18, 1999, U.S. Patent Application Serial No. 09/130,923 filed August 6, 1998, U.S. Patent Application Serial No. 09/055,709 filed April 7, 1998, U.S. Patent Application Serial No. 09/059,503 filed April 13, 1998, U.S. Patent Application Serial No. 08/840.159 filed April 14, 1997, U.S. Patent Application Serial No. 09/130,923 filed August 6, 1998, U.S. Patent Application Serial No. 08/672,899 now issued U.S. Patent No. 5,825,898 issued October 20, 1998; and U.S. Patent Application Serial No. 09/089,710 filed June 3, 1998, U.S. Patent No. 5,825.897 issued October 20, 1998, U.S. Patent No. 5,732,143 issued March 24, 1998, U.S. Patent No. 5,673,325 issued September 30, 1997, U.S. Patent No. 5,381,473 issued January 10, 1995, U.S. Patent Application Serial No. 08/833,384 filed April 4, 1997. And, all documents cited herein are incorporated herein by reference, as are documents cited or referenced in documents cited herein.

FIELD OF THE INVENTION.

The present invention relates to noise cancellation and reduction and, more specifically, to noise cancellation and reduction using spectral subtraction.

BACKGROUND OF THE INVENTION.

Ambient noise added to speech degrades the performance of speech processing algorithms. Such processing algorithms may include dictation, voice activation, voice compression and other systems. In such systems, it is desired to reduce the noise and improve the signal to noise ratio (S/N ratio) without effecting the speech and its characteristics.

Near field noise canceling microphones provide a satisfactory solution but require that the microphone in the proximity of the voice source (e.g., mouth). In many cases, this is achieved by mounting the microphone on a boom of a headset many cases, this is achieved by mounting the microphone on a boom of a headset which situates the microphone at the end of a boom proximate the mouth of the wearer. However, the headset has proven to be either uncomfortable to wear or too restricting for operation in, for example, an automobile.

Microphone array technology in general, and adaptive beamforming arrays in particular, handle severe directional noises in the most efficient way. These systems map the noise field and create nulls towards the noise sources. The number of nulls is limited by the number of microphone elements and processing power. Such arrays have the benefit of hands-free operation without the necessity of a headset.

However, when the noise sources are diffused, the performance of the adaptive system will be reduced to the performance of a regular delay and sum microphone array, which is not always satisfactory. This is the case where the environment is quite reverberant, such as when the noises are strongly reflected from the walls of a room and reach the array from an infinite number of directions. Such is also the case in a car environment for some of the noises radiated from the car chassis.

OBJECTS AND SUMMARY OF THE INVENTION

The spectral subtraction technique provides a solution to further reduce the noise by estimating the noise magnitude spectrum of the polluted signal. The technique estimates the magnitude spectral level of the noise by measuring it during non-speech time intervals detected by a voice switch, and then subtracting the noise magnitude spectrum from the signal. This method, described in detail in *Suppression of Acoustic Noise in Speech Using Spectral Subtraction, (Steven F Boll, IEEE ASSP-27 NO.2 April, 1979),* achieves good results for stationary diffused noises that are not correlated with the speech signal. The spectral subtraction method, however, creates artifacts, sometimes described as musical noise, that may reduce the performance of the speech algorithm (such as vocoders or voice activation) if the spectral subtraction is uncontrolled. In addition, the spectral subtraction method assumes erroneously that the voice switch accurately detects the presence of speech and locates the non-speech time intervals. This assumption is reasonable for off-line systems but difficult to achieve or obtain in real time systems.

More particularly, the noise magnitude spectrum is estimated by performing an FFT of 256 points of the non-speech time intervals and computing the energy of each frequency bin. The FFT is performed after the time domain signal is multiplied by a shading window (Hanning or other) with an overlap of 50%. The energy of each frequency bin is averaged with neighboring FFT time frames. The number of frames is not determined but depends on the stability of the noise. For a stationary noise, it is preferred that many frames are averaged to obtain better noise estimation. For a non-stationary noise, a long averaging may be harmful. Problematically, there is no means to know a-priori whether the noise is stationary or non-stationary.

Assuming the noise magnitude spectrum estimation is calculated, the input signal is multiplied by a shading window (Hanning or other), an FFT is performed (256 points or other) with an overlap of 50% and the magnitude of each bin is averaged over 2-3 FFT frames. The noise magnitude spectrum is then subtracted from the signal magnitude. If the result is negative, the value is replaced by a zero (Half Wave Rectification). It is recommended, however, to further reduce the residual noise present during non-speech intervals by replacing low values with a minimum value (or zero) or by attenuating the residual noise by 3OdB. The resulting output is the noise free magnitude spectrum.

The spectral complex data is reconstructed by applying the phase information of the relevant bin of the signal's FFT with the noise free magnitude. An IFFT process is then performed on the complex data to obtain the noise free time domain data. The time domain results are overlapped and summed with the previous frame's results to compensate for the overlap process of the FFT.

There are several problems associated with the system described. First, the system assumes that there is a prior knowledge of the speech and non-speech time intervals. A voice switch is not practical to detect those periods. Theoretically, a voice switch detects the presence of the speech by measuring the energy level and comparing it to a threshold. If the threshold is too high, there is a risk that some voice time intervals might be regarded as a non-speech time interval and the system will regard voice information as noise. The result is voice distortion, especially in poor signal to noise ratio cases. If, on the other hand, the threshold is too low, there is a risk that the non-speech intervals will be too short especially in poor

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