US005550924A

United States Patent [19]

Helf et al.

[11] Patent Number: 5,550,924

[45] Date of Patent: Aug. 27, 1996

[54] **REDUCTION OF BACKGROUND NOISE FOR SPEECH ENHANCEMENT**

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[21] Appl. No.: **402,550**

[22] Filed: **Mar. 13, 1995**

Related U.S. Application Data

[63] Continuation of Ser. No. 86,707, Jul. 7, 1993, abandoned.

[51] **Int. Cl.**[6] **H04B 15/00**

[52] **U.S. Cl.** **381/94**; 381/46; 381/47; 395/2.34; 395/2.35

[58] **Field of Search** 381/94, 46, 47; 395/2.34, 2.35

[56] **References Cited**

U.S. PATENT DOCUMENTS

4,185,168	1/1980	Graupe et al. .	
4,628,529	12/1986	Borth et al. .	
4,630,304	12/1986	Borth et al. .	
4,630,305	12/1986	Borth et al. .	
4,653,102	3/1987	Hansen .	
4,658,426	4/1987	Chabries et al. .	
4,696,039	9/1987	Doddington	381/46
4,852,175	7/1989	Borth et al. .	
4,868,880	9/1989	Bennett, Jr. .	
4,912,767	3/1990	Chang .	
5,012,519	4/1991	Adlersberg et al. .	
5,133,013	7/1992	Munday .	

FOREIGN PATENT DOCUMENTS

3132221	5/1991	Japan	381/94

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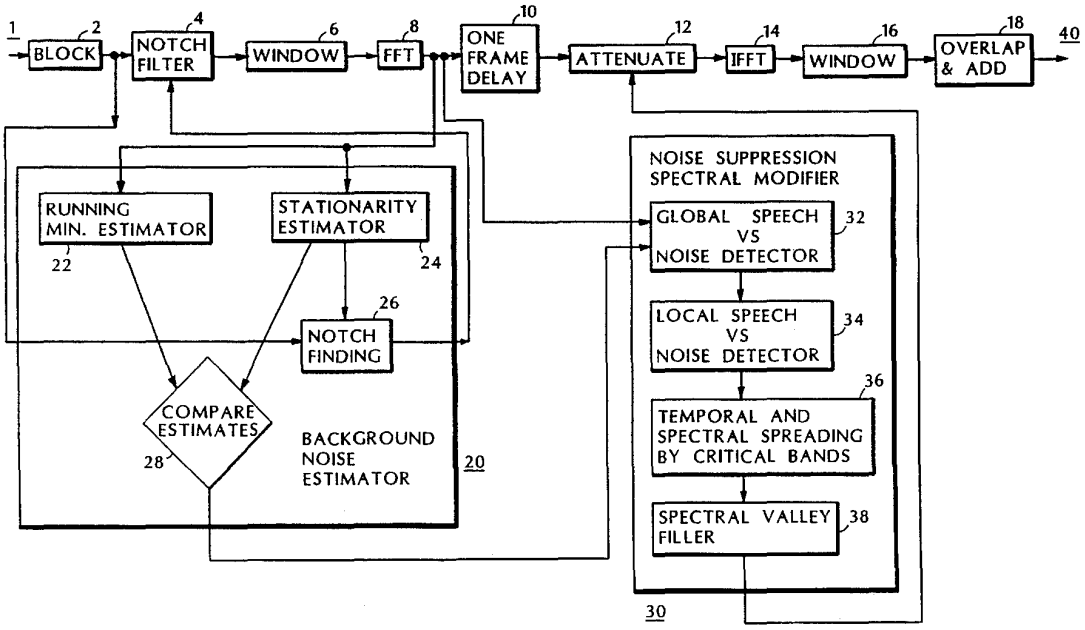
Attorney, Agent, or Firm—Fish & Richardson P.C.

[57] **ABSTRACT**

Properties of human audio perception are used to perform spectral and time masking to reduce perceived loudness of noise added to the speech signal. A signal is divided temporally into blocks which are then passed through notch filters to remove narrow frequency band components of the noise. Each block is then appended to part of the previous block in a manner which avoids block boundary discontinuities. An FFT is then performed on the resulting larger block, after which the spectral components of the signal are fed to a background noise estimator. Each frequency component of the signal is analyzed with respect to the background noise to determine, within various confidence levels, whether it is pure noise or a noise-and-signal combination. The frequency band's gain function is determined, based on the confidence levels. A spectral valley finder detects and fills in spectral valleys in the frequency component gain function, after which the function is used to modify the magnitude components of the FFT. An inverse FFT then maps the signal back from the frequency domain to the time domain to give a frame of noise-reduced signal. This signal is then multiplied by a temporal window and joined to the previous frame's signal to derive the output.

21 Claims, 3 Drawing Sheets



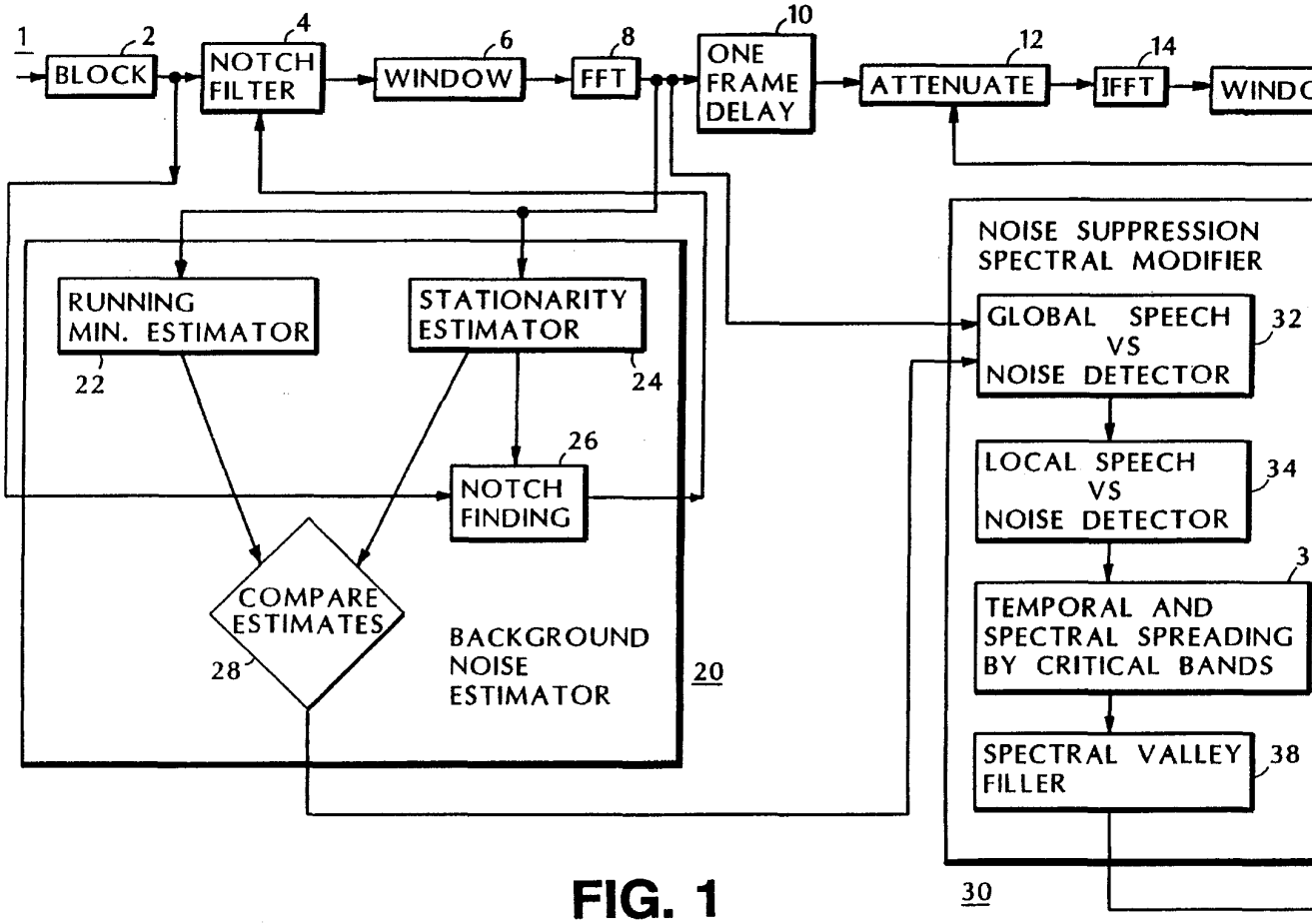


FIG. 1

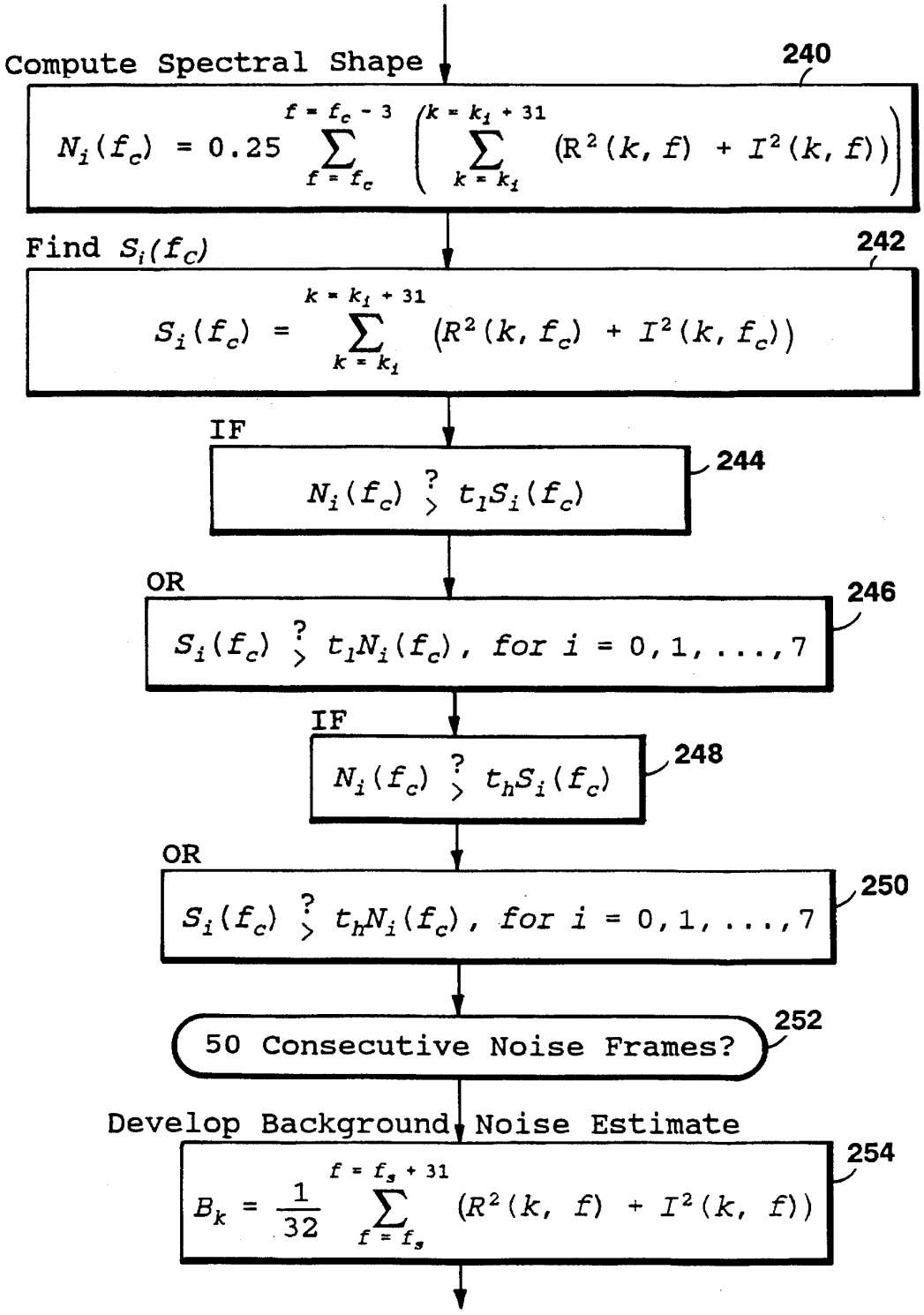


FIG. 3

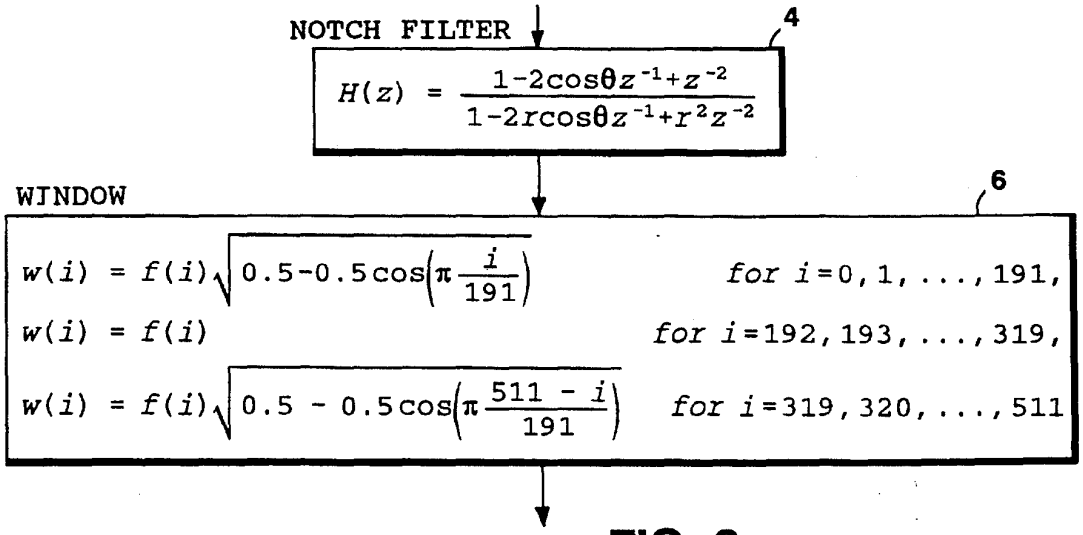


FIG. 2

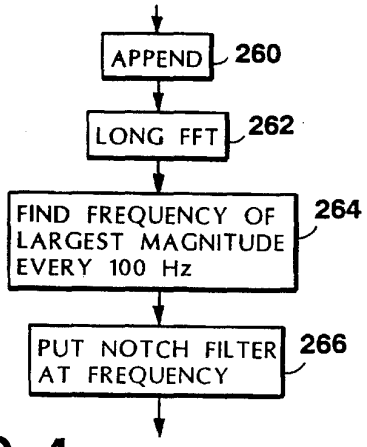


FIG. 4

REDUCTION OF BACKGROUND NOISE FOR SPEECH ENHANCEMENT

This is a continuation of application Ser. No. 08/086,707, filed Jul. 7, 1993, now abandoned.

BACKGROUND OF THE INVENTION

This invention relates to communicating voice information over a channel such as a telephone communication channel.

Microphones used in voice transmission systems typically pick up ambient or background sounds, called noise, along with the voices they are intended to pick up. In voice transmission systems in which the microphone is at some distance from the speaker(s), for example, systems used in video and audio telephone conference environments, background noises are a cause of poor audio quality since the noise is added onto the speech picked up by a microphone. By their nature and intended use, these systems must pick up sounds from all locations surrounding their microphones, and these sounds will include background noise.

Fan noise, originating from HVAC systems, computers, and other electronic equipment, is the predominant source of noise in most teleconferencing environments.

A good noise suppression technique will reduce the perception of the background noise while simultaneously not affecting the quality or intelligibility of the speech. In general it is an object of this invention to suppress any constant noise, narrowband or wideband, that is added onto the speech picked up by a single microphone. It is a further object of this invention to reduce fan noise that is added onto the speech picked up by a single microphone.

SUMMARY OF THE INVENTION

In one aspect, generally, the invention relates to a device for reducing the background noise of an input audio signal. The device features a framer for dividing the input audio signal into a plurality of frames of signals, and a notch filter bank for removing components of noise from each of the frames of signals to produce filtered frames of signals. A multiplier multiplies a combined frame of signals to produce a windowed frame of signals, wherein the combined frame of signals includes all signals in one filtered frame of signals combined with some signals in the filtered frame of signals immediately preceding in time the one filtered frame of signals. A transformer obtains frequency spectrum components from the windowed frame of signals, and a background noise estimator uses the frequency spectrum components to produce a noise estimate of an amount of noise in the frequency spectrum components. A noise suppression spectral modifier produces gain multiplicative factors based on the noise estimate and the frequency spectrum components. A delayer delays the frequency spectrum components to produce delayed frequency spectrum components. A controlled attenuator attenuates the frequency spectrum components based on the gain multiplicative factors to produce noise-reduced frequency components, and an inverse transformer converts the noise-reduced frequency components to the time domain.

In preferred embodiments, the noise suppression spectral modifier includes a global decision mechanism, a local decision mechanism, a detector, a spreading mechanism, and a spectral valley filler.

The global decision mechanism makes, for each frequency component of the frequency spectrum components, a determination as to whether that frequency component is primarily noise. The local noise decision mechanism derives, for each frequency component of the frequency spectrum components, a confidence level that the frequency component is primarily a noise component. The detector determines, based on the confidence levels, a gain multiplicative factor for each frequency component. The spreading mechanism spectrally and temporally spreads the effect of the determined gain multiplicative factors, and the spectral valley filler detects and fills in spectral valleys in the resulting frequency components.

In other aspects of the preferred embodiment, the background noise estimator also produces a noise estimate for each frequency spectrum component, and the local noise decision mechanism derives confidence levels based on: ratios between each frequency component and its corresponding noise estimate, and the determinations made by the global decision mechanism.

In another aspect, the invention further features a post-window and an overlap-and-adder mechanism. The post-window produces smoothed time-domain components for minimizing discontinuities in the noise-reduced time-domain components; and the overlap-and-adder outputs a first portion of the smoothed time-domain components in combination with a previously stored portion of smoothed time-domain components, and stores a remaining portion of the smoothed frequency components, where the remaining portion comprises the smoothed frequency components not included in the first portion.

In preferred embodiments of the device, the background noise estimator includes at least two estimators, each producing a background noise estimate, and a comparator for comparing and selecting one of the background noise estimates. One of the estimators is a running minimum estimator, and the other estimator is a stationary estimator.

In preferred embodiments, the device also includes a notch filter mechanism for determining the locations of the notches for the notch filter bank.

BRIEF DESCRIPTION OF THE DRAWING

FIG. **1** is a block diagram of a noise suppression system according to the invention; and

FIGS. **2–4** are detailed block diagrams implementing parts of the block diagram of FIG. **1**.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The simplest noise suppression apparatus, in daily use by millions of people around the world, is the so-called "squelch" circuit. A squelch circuit is standard on most Citizen Band two-way radios. It operates by simply disconnecting the system's loudspeaker when the energy of the received signal falls below a certain threshold. The value of this threshold is usually fixed using a manual control knob to a level such that the background noise never passes to the speaker when the far end is silent. The problem with this kind of circuit is that when the circuit turns on and off as the far end speaker starts and then stops, the presence and then absence of noise can be clearly heard. The noise is wideband and covers frequencies in which there is little speech energy, and thus the noise can be heard simultaneously as the person is talking. The operation of the squelch unit produces a very

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