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VOICED SOUND FUNDAMENTAL FREQUENCY DETECTOR

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VOICED SOUND FUNDAMENTAL FREQUENCY DETECTOR

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ABSTRACT OF THE DISCLOSURE

Means are provided to determine the fundamental frequency of a complicated wave by passing waves through a filter that passes waves of frequencies higher than the fundamental frequency, amplitude detecting the passed wave and applying the detected wave to a frequency meter. If the wave is an unvoiced speech wave, the indication by the frequency meter may be incorrect. Means are also provided to indicate that the wave is, or is not a voiced wave.

This invention relates to apparatus for determining the fundamental frequency of a wave having many components such as a speech wave.

In transmitting speech over a transmission line, it may be convenient to separate the speech into its frequency components and to transmit signals representing these components, the speech being reconstituted at a receiver in response to the receipt of these signals. The reconstituted speech should be as natural sounding as is conveniently possible. It may, therefore, be important to transmit a signal to the receiver which is an indication of the fundamental frequency of the transmitted speech whereby the fundamental frequency component of the transmitted speech may be added to the received speech in the receiver.

Speech waves can be very complicated, including many frequency components in addition to a fundamental frequency, and in fact the amplitude of the fundamental frequency can be very small or the fundamental frequency can be entirely missing. The ear recognizes and apparently itself supplies the fundamental frequency of the speech wave applied thereto, whereby the speech sounds natural to the ear. However, if the speech wave is broken down into its frequency components and signals representing the components are transmitted and the speech is reconstituted from the signals by a receiver, the speech may sound very unnatural or may even be unintelligible if the fundamental frequency is not provided.

One way to determine the fundamental frequency of a speech wave is to apply it to a low pass filter which will remove all or most of the harmonics of the speech wave and will substantially leave only the fundamental wave. The wave passing through the low pass filter is then applied to a frequency meter which determines the frequency of the speech wave. However, the amplitude of fundamental components of the speech wave may be so small, or the noise present in the speech at or near the fundamental frequency may be so great, or both, that the reading of the frequency meter may be unreliable.

It is an object of this invention to provide improved apparatus for determining the fundamental frequency component in a complicated wave such as a speech wave.

It is a further object of this invention to provide an apparatus for determining the fundamental frequency of a complicated wave in which the wave of fundamental frequency is of very small amplitude.

A further object of this invention is to provide an apparatus for determining the fundamental frequency of a complicated wave in which so much noise is present in the range of frequencies of the fundamental frequency that determination of the frequency thereof is difficult by prior art devices.

This invention is based on the discovery that the higher frequency components of a speech wave are amplitude modulated by the fundamental frequency. In accordance with this invention, the speech whose fundamental frequency is to be determined is applied to a pass filter for passing frequency components of the speech that are higher than the fundamental frequency and in a range where the noise components are not of great amplitude.

The waves passed by the pass filter are peak detected and the envelope of the peak detector is applied to a frequency meter which indicates the fundamental frequency of the speech wave.

It has been found that unvoiced portions of a speech wave, which themselves have no fundamental frequency, may manifest themselves by low frequency modulations of the high frequency components of the unvoiced speech wave. Therefore, when determining the fundamental frequency of a speech wave, an indication should be provided as to whether a portion of the speech being analyzed for its fundamental frequency is not unvoiced so as to prevent an improper indication. For purposes of this discussion and as understood in the art, the term voiced sound refers to those speech sounds originated by the vocal cords and the term unvoiced sound refers to those speech sounds produced in some manner other than by vocal cords.

The novel features of the invention, both as to its organization and method of operation, as well as additional objects and advantages thereof, will be understood more readily from the following description when read in conjunction with the accompanying drawings in which:

The single figure is a block diagram of one embodiment of this invention.

A speech wave of which the fundamental frequency is to be determined can be recorded on a magnetic tape or other record medium (not shown) and reproduced from the tape by a reproducer 10 as an electrical wave appearing at the output thereof. The reproduced electrical wave can be applied to a monitor 12, permitting an operator to monitor the operation. The electrical wave output of the tape reproducer 10 is applied to a high pass filter 14 which passes all frequency components of the electrical wave above about 775 cycles per second (c.p.s.). If desired, the output of the high pass filter 14 can next be applied to a low pass filter 16 which passes all waves having a frequency less than about 2,650 c.p.s., although the low pass filter 16 is not necessary since the wave passing the high pass filter 14 contains information as to the frequency of the fundamental wave. The two filters 14 and 16 act as a band pass which passes a band of frequencies from 775 c.p.s. to 2,650 c.p.s., and if desired a band pass filter (not shown) passing this band of frequencies can be substituted for the filters 14 and 16. The frequencies of the waves passed by the high pass filter 14, with or without the low pass filter 16, are much higher than the fundamental frequency of the recorded speech wave, which fundamental frequency may be below 160 c.p.s., and this band is so chosen as to exclude noise waves as much as possible. Since all the components of the speech wave below 775 c.p.s. are eliminated by the filters 14 and 16, the fundamental wave as such does not appear at the output of the filters 14 and 16 and all the noise components of the speech wave that are coincident with or near the fundamental frequency of the speech wave are eliminated from the wave appearing at the output of the filter 16.

The wave appearing at the output of the filter 16 is amplified by being applied to an amplifier 18. The amplified wave is then peak detected by a diode detector 20, and the peak detected wave, which includes the
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fundamental frequency as well as higher frequency waves, is applied to the two low pass filters 22 and 24 in tandem. The low pass filter 22 can have a cut-off of about 318 c.p.s. and the low pass filter 24 can have a cut-off of about 160 c.p.s. whereby the low pass filters 22, 24 together form a band of frequencies of speech below 160 c.p.s., whereby the fundamental frequency of the wave applied thereto in the range of 160 c.p.s. or less appears across the load resistor 26 at the output of the filter 24. Only one low pass filter may be used, or, if no fundamental frequency is found at the range below 160 c.p.s., the low pass filter 24 may be by-passed and the wave below 318 c.p.s. which is passed by the filter 22 can be applied to the load resistor 26. The output wave appearing across the resistor 26 is applied to a frequency meter 28. The frequency meter 28 can be one arranged to give a reading of the desired fundamental frequency, in addition, the wave appearing across the resistor 26 can be applied in parallel to the frequency meter 28 and to a rectifier for a pen recorder 30. The output of the frequency meter 28 and of the rectifier 30 are shown as being applied to a recording device 32, which records the frequency track of a record 34 of the wave applied to the load resistor 26. The device 32 records on another track of the record 34 the frequency of the modulation of the higher frequency components of the speech wave which, as noted above, comprises the fundamental frequency of the speech wave. Power supply for the speech recorder is provided by a suitable power supply means 36.

As noted above, analysis of an unvoiced wave can present a false indication of a fundamental frequency. Therefore, the wave to be analyzed is shown as being applied to an unvoiced sound indicator 38, whose output is applied to the recording device 32 to provide a track 40. When the track 40 is on one side of an intermediate axis 42, the track indicates unvoiced sounds, and when the track 40 is on the other side of the axis 42, the track indicates voiced sounds. The indicator 38 can be of a conventional construction known in the art, and, for example, includes a band pass filter passing waves (of about 50-400 c.p.s.) that normally include the fundamental frequency (if any) of the speech being tested and an indicator of the presence or absence of a wave in this band. An indication of an absence of a wave in this band is an indication that the portion of speech being analyzed is unvoiced. Therefore, the frequency trace indication recorded by the recording device during periods shown to be the voiced portion of the speech indicates the fundamental frequency of the speech wave. The frequency trace occurring during unvoiced portions of the speech wave can be an incorrect indication of a fundamental frequency. If desired, the unvoiced indicator 38 can be operated in a manner to disable the recording device 32, so that the recorder device 38 gives no frequency indication during periods of unvoiced speech.

Although only a single apparatus for determining the fundamental frequency of a complicated wave such as a speech wave has been shown and described, it will be apparent to those skilled in the art that variations are possible within the spirit of the present invention. For example, the speech to be analyzed for a fundamental frequency can be spoken directly into a microphone, whose output is coupled, either directly or after amplification to the band pass filter constituted by the filters 14 and 16, in which case the tape recorder and monitor 10 and 12 are not necessary. Hence, it should be understood that the foregoing description of the invention is to be considered as illustrative only.

What is claimed is:

1. Means for determining the fundamental frequency of a wave which includes a plurality of components of various frequencies which are higher than said fundamental frequency and in which said higher frequency components are amplitude modulated by said fundamental frequency comprising means to pass only frequency components of said wave which are higher than said fundamental frequency, means to apply said wave to said passing means, means for peak detecting said passed frequency components whereby said detected components include a wave of said fundamental frequency, and means for indicating the frequency of said detected frequency components to determine said fundamental frequency wave.

2. Means for determining the fundamental frequency of a wave which includes a plurality of components of various frequencies which are higher than said fundamental frequency and in which said higher frequency components are amplitude modulated by said fundamental frequency, said wave also including high frequency components which are amplitude modulated by a frequency other than said fundamental frequency comprising means to pass only frequency components of said wave which are higher than said fundamental frequency, means for applying said waves to said passing means, means for peak detecting said passed frequency components whereby said detected components include a wave of said fundamental frequency and may also include a wave of other than said fundamental frequency, means for indicating the frequency of said detected wave, and means for indicating the occurrence of high frequency components amplitude modulated by other than said fundamental frequency, whereby said fundamental frequency can be determined.

3. Means for determining the fundamental frequency of a wave which includes a plurality of components of various frequencies which are higher than said fundamental frequency comprising high pass filter means for passing only waves which are higher in frequency than said fundamental frequency, means for applying said speech wave to said filter means, peak detector means for detecting said passed waves whereby said detected waves includes a wave of said fundamental frequency, low pass filter means for passing components of said detected waves including said fundamental frequency wave, and frequency measuring means responsive to said components passed by said low pass filter means for determining the frequency of said fundamental frequency wave.

4. Means for determining the fundamental frequency of a voiced portion of a speech wave which includes a plurality of components of various frequencies which are higher than said fundamental frequency comprising an indicator responsive to said speech wave for indicating at a given time whether said speech is voiced or unvoiced, and filter means for passing only waves which are higher in frequency than said fundamental frequency, means for applying a speech wave including both voiced and unvoiced sounds to said filter means, peak detector means for detecting said passed waves whereby said detected waves may include a wave of said fundamental frequency, low pass filter means for passing components of said detected waves including said fundamental frequency wave if present in said speech wave, and frequency indicating means responsive to said components passed by said low pass filter means and operated by said indicator for determining the frequency of said fundamental frequency wave only.
5. A system for determining the fundamental frequency of a complex wave comprising, means for detecting the amplitude modulation of those frequency components in said complex wave that are higher in frequency than the range of said fundamental frequency, and means responsive to the output of said detecting means to indicate said fundamental frequency.