Dec. 30, 1958 L. J. FOGEL 2,866,848

METHOD OF IMPROVING INTELLIGENCE UNDER RANDOM NOISE INTERFERENCE

Filed April 2, 1954

FIG. 1

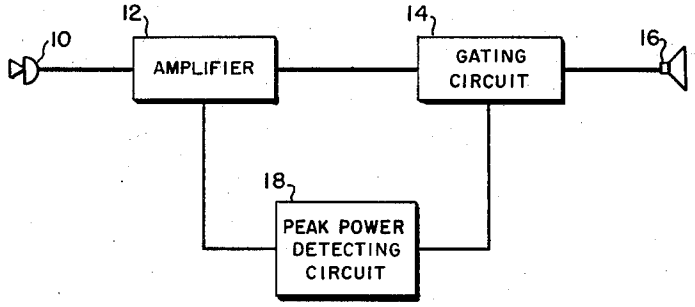


FIG. 2

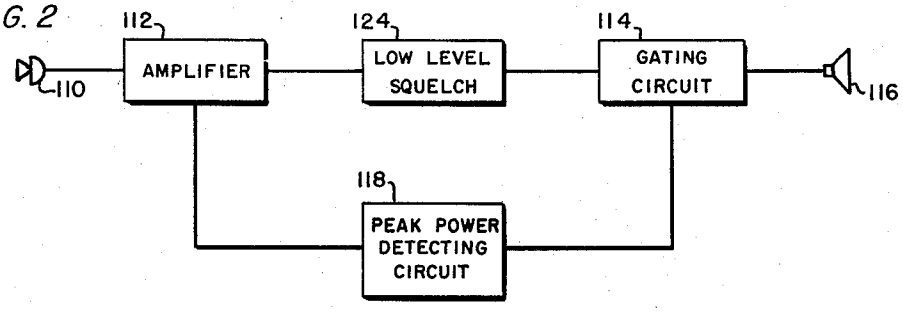
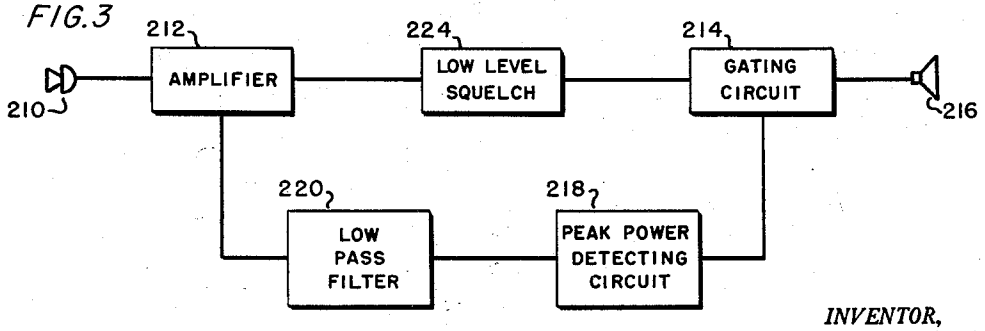


FIG. 3



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United States Patent Office 2,866,848 Patented Dec. 30, 1958

2,866,848

METHOD OF IMPROVING INTELLIGENCE UNDER RANDOM NOISE INTERFERENCE

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Application April 2, 1954, Serial No. 420,764

3 Claims. (Cl. 179—1)

(Granted under Title 35, U. S. Code (1952), sec. 266)

The invention described herein may be manufactured and used by or for the Government for governmental purposes, without the payment of any royalty thereon.

This invention relates to a method for improving the intelligibility of speech and more particularly to a method of improving the intelligibility of speech being amplified by electronic circuitry and having low signal to noise ratio.

The problems of improving the relative quality of the signal in electronic transmission of sound has been approached in many different ways. There are many systems for reducing noise and some for improving intelligibility by reducing noise, but most of them appear to lose sight of the basic premise that the improvement of intelligibility in sound transmission depends to a large extent on the transmission of consonant characteristics which provide a high degree of intelligibility as compared with vowel sounds which, contrarily, have the larger amount of sound energy.

The basic noise or scratch reducing systems, standard in audio amplifiers for many years, use a low-pass filter to reduce the high frequency noise energy but do this at the expense of the consonant energy which would improve intelligibility. Other more recent noise suppressing systems pass all the sound energy during a high level energy interval then cut off the higher frequencies or the entire signal when it falls below a certain level. These are also predominately actuated by vowel sounds and lose the value of consonant energy as far as the intelligibility of threshold signals is concerned.

These suppressing systems have also been applied to amplifiers where speech is divided into bands. Such systems include: the patent to Llewellyn 1,968,460 where each sub-band of speech energy is separately squelched, which favors the vowel sounds; the patent to Beers 1,961,329 where the high frequency is decreased when the signal is low, which again favors the vowel sounds and the patents to Hammond 2,008,825 and Doba 2,173,472 which divide the speech energy into bands with expansion and compression within each band to accentuate the stronger parts. All of these systems appear to be actuated by the vowel sounds and to accentuate them at the expense of the consonants which are more important as far as intelligibility is concerned.

The method of improving intelligibility relied on here is based on the suppression of the peaks of energy which are dominant vowel sounds so that the remainder of the signal and even some of the noise, where important consonant sounds may be partially masked, may be accentuated. This method relies on the psycho-acoustical ability of the mind to fill in short gaps in sound that are omitted from a familiar pattern of speech.

It is therefore an object of this invention to provide a means for improving the intelligibility of speech.

It is a further object of this invention to provide a means for the improvement of intelligibility of speech under high ambient noise conditions.

It is a further object of this invention to provide a means for improving the intelligibility of speech by reducing the vowel sounds and accentuating the consonant sounds wherein maximum intelligibility lies.

It is a further object of this invention to provide means for improving the intelligibility of sounds by constructing an amplifier to reduce peaks of energy which contain predominate vowel energy so that the remaining consonant energy may be accentuated.

It is a further object of this invention to provide a system for supplementing a standard noise suppressor by eliminating the peaks of energy as well as the nulls of energy.

Other and further objects of this invention will become apparent from the following specification and the drawing in which Fig. 1 represents a block diagram of a typical circuit, Fig. 2 represents an additional circuit and Fig. 3 represents a circuit for use with a standard squelching system.

Referring more particularly to Fig. 1, a system is shown including a microphone **10** energizing an amplifier **12** whose signal goes through a gating circuit **14** to a loudspeaker or other electromechanical transducer **16**. The signal in the amplifier **12** actuates a peak detecting circuit **18** which supplies a gating signal to the gating amplifier **14**. In operation, a signal is applied by the microphone to the amplifier **12** which may include vacuum tubes or other devices well known in the art. The gating circuit **14** may also include well known electronic circuitry. The peak detecting circuit **18** monitors the signal in the amplifier **12** and turns on and off the gating circuit to pass the lower component of the signal rather than the higher component to the loud speaker **16**.

It should be stressed here that the gating time duration must be limited to a very small fraction of time. This time interval must be very much smaller in practice than the time constant usually allotted to squelch circuits, since the length of time that the mind of the hearer can psycho-acoustically fill in an omitted sound without becoming conscious of an interruption is very small.

Fig. 2 shows the circuit of Fig. 1 with similar parts similarly numbered and with the addition of a low level squelching circuit **124** of a standard type for reducing or eliminating the fraction of the signal completely under the noise level. This will help reduce the more dominant noise factor as in other systems. More noise may be tolerated in this arrangement than with a standard circuit because the overall noise is ultimately decreased during the vowel interval and the fragment of noise that is passed also contains a high factor of intelligibility.

In Fig. 3 the circuit has been varied by the addition of a filter circuit **220** before the gate actuating squelch circuit **218**. The filter **220** is a low-pass filter to limit the signal peaks actually operating the gate to the lower frequencies. The other elements in the circuit are equivalent to the elements of Figs. 2 and 1 and are similarly marked.

To describe the circuits functionally, in Fig. 1, the microphone applies a signal to the amplifier, which is conventional. The microphone may also represent any source of signal, such as the output of standard radio receiver. The noise may come from the source or be introduced by the electronic circuitry in any of several ways well known in the art. The peaks of energy of the signal are detected by the peak detecting circuit which then closes the gating circuit to reduce or eliminate the peaks of energy normally applied to the loud speaker or earphone **16** and, ultimately, the ear.

Fig. 2 is a similar but is supplemented by the low level squelching circuit **124** which may be of any of the types well known in noise reducing systems.

Fig. 3 is again similar but has a low-pass filter **220** preceding the peak detecting circuit to assure that low frequency or vowel peaks and not the consonant peaks actuate the gating circuit.

The concept here is that the consonant energy is actually of prime importance in speech intelligibility whereas the vowel energy is relatively less important. The voltage peaks of both vowels and consonants may be substantially the same or the peaks of consonant voltage may be even higher than the peaks of vowel voltage, but the consonants appear as sharp transients of extremely short time duration while the vowel sounds are of considerably longer duration. Therefore, the mean energy is much higher during a vowel interval than during a consonant interval. The effect on the ear where the gain is turned up under difficult conditions would be somewhat of a saturation of the ear from vowel sound to vowel sound to make the recognition of the consonant transient peaks even less likely. This results in an overall decrease in intelligibility. In the subject invention the vowel peaks are detected and made to actuate a gating circuit so they can be reduced or eliminated in the transducer to avoid distracting the ear from its more important task of catching the consonants.

The importance of consonant energy in intelligibility is emphasized by many authorities and it is discussed and proven, for example, in the work of Licklider and Miller, beginning on page 1048 of the "Handbook of Experimental Psychology," edited by S. S. Stevens and published by John Wiley & Sons in 1951. The same article also points out that the frequencies of speech under 1000 cycles contain 80% of the power while contributing only 10% to the articulation of speech.

Relating this to applicant's device, if the peak detecting circuit is used without filtering, as in Fig. 1, it can be assumed that 80% of the actuating signal energy will be contributed by the lower frequencies and, in any case, the removal of the portion of the peak energy sections of the speech may only decrease the intelligibility by 10%. On the other hand, the elimination of the noise for a substantial portion of the reception time will increase the intelligibility considerably more than the decrease from altering the speech pattern.

The well known correlation of frequencies and vowel sounds is discussed in much detail by Fletcher in chapter 5, pages 282–286 of his volume on "Speech and Hearing," published by Van Nostrand Co., Inc. in 1929. Fletcher also shows typical electronic high and low-pass filters and shows the results of filtering on the various components of speech.

According to the teachings of these texts and others, most of the energy in speech is carried in a portion of the frequency spectrum that contributes the least to the intelligibility. This portion of the frequency spectrum is the lower portion, for the most part below 1000 cycles and, generally speaking, comprising vowel sounds.

It is obvious from the teachings of these texts that a substantial portion of the vowel sounds may be subtracted from the consonant sounds by either detecting peak energy or by frequency discrimination, or both. On the other hand, it is fairly apparent that since this invention deals with psychological acoustical phenomena it is not limited to vowel sounds alone but includes the effects of peak energy or low frequency intervals.

Use of this described system allows increase of the average signal intensity sound level and thereby increases the average power that may be delivered under conditions of signal reception close to the threshold of pain. In some ways this invention is the aural equivalent of automatic "speedwriting" reading.

As an additional feature during the cut-off period of the vowel sounds an artificial substitute tone of approximately 200 cycles per second can be added to the output to provide a mental fill-in and increase the length of time that the ear will tolerate interpretations. This is possible in practice, since the psycho-acoustical capacity of the ear and mind to identify well known words make the mind substitute the probably correct vowel sounds for the artificial substitute tone.

A further modification of this signal reception technique might be particularly applicable for extremely slow speech where the vowel sounds could be reduced only to the average level rather than completely eliminated. This would require the gating circuit to be by-passed by attenuated vowels signals.

It is also conceivable that a second channel of information, not necessarily speech, may be transmitted during the speech vowel gap time and thereby accomplish multiplexing.

Having thus described my invention, what is claimed is:

1. In a system for increasing the intelligibility of speech in the presence of noise, an amplifier having an input and two outputs, a gating circuit having an input, an output and a control connection, a peak detecting circuit for transforming alternating current energy peaks of audio frequencies into direct current switching pulses, said detecting circuit having an input for low frequency audio signals and an output for the direct current switching pulses, a low pass filter connecting the input of said detecting circuit to one of the outputs of said amplifier, the output of said detecting circuit connected to the control connection of said gating circuit, the input of said gating circuit connected to the other of the outputs of said amplifier, and an electromechanical transducer connected to the output of said gating circuit, said gating circuit being in an "on" position when no signal is being detected and in an "off" position when a peak energy signal is being detected by said detecting means.

2. In a system for increasing the intelligibility of speech in the presence of noise, an amplifier having an input and two outputs, a source of signals connected to said input, a gating circuit having an input, a control connection and an output, a low-pass filter for low frequency audio signals having an output and an input connected to one of the outputs of said amplifier, a detecting circuit for transforming alternating current energy peaks of audio frequencies into direct current pulses, said detecting circuit responsive to energy peaks above the average level, said detecting circuit having an input for audio frequency signals and an output for direct current switching pulses, the input of said detecting circuit connected to the output of said low-pass filter, the output of said detecting circuit connected to the control connections of said gating circuit, a low level squelch circuit having an input connected to the other of the outputs of said amplifier and an output connected to the input of said gating circuit for cutting off signals below a given level substantially below said average level, said gating circuit being in an "on" position when said signals are between the said average level and said given level.

3. A squelch circuit for increasing the intelligibility of speech in the presence of noise comprising a signal source, an audio frequency low pass filter coupled to said source, a transmission path coupled to said source, control means in said path controlling the transmission of signals through said path, a gating means to actuate said control means to block said path, a circuit adapted to be actuated by signal energy from said low pass filter exceeding a given level to produce a rectangular pulse, and an audio frequency low pass filter means for applying a portion of said pulse to said gating circuit to actuate it upon the signal energy exceeding said level, said gating circuit acting to block said transmission path when actuated by said pulse and to unblock said transmission path at other times when no high energy signal is actuating said circuit.

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