Oct. 10, 1961 E. F. HEMBROOKE 3,004,104

IDENTIFICATION OF SOUND AND LIKE SIGNALS

Filed April 29, 1954

Fig. 1.

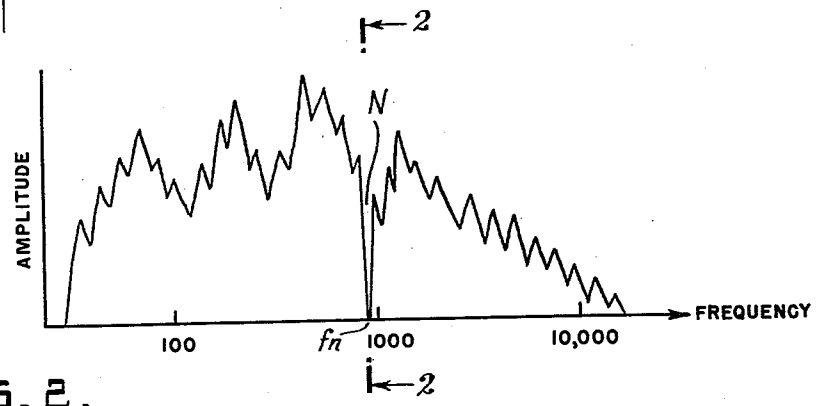


Fig. 2.

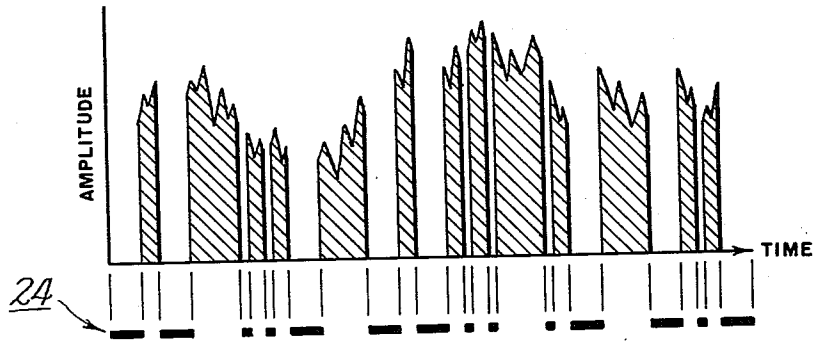


Fig. 3.

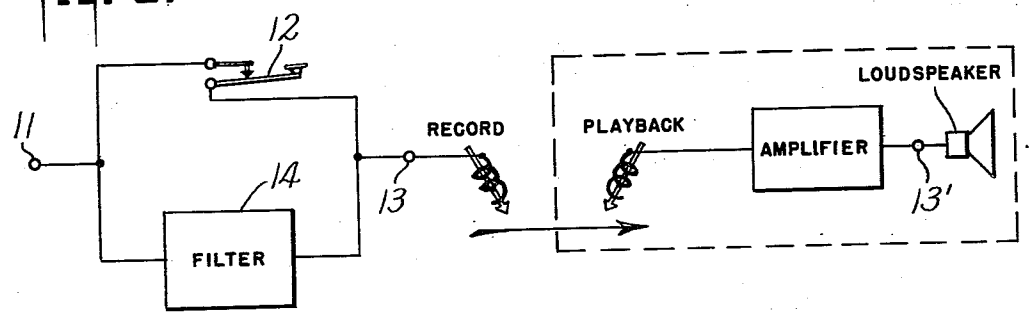
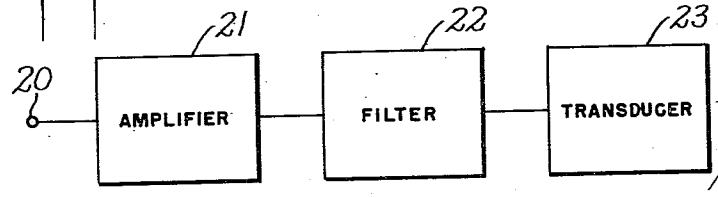


Fig. 4.



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IDENTIFICATION OF SOUND AND LIKE SIGNALS

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This invention relates to a method and apparatus for the identification of sound and like signals and particularly it relates to the identification of such signals when they are reproduced.

An object of this invention is to provide for the positive but unobtrusive identification of signals by impressing upon them a characteristic code.

Other objects will become apparent or will be pointed out hereinafter.

A particular advantage of the invention is that it provides for the identification of recorded music or other audio signals by coded signals which are not evident to a listener but which nonetheless can easily be detected and which are such an integral part of the audio signals that they are difficult if not impossible to obliterate.

The unauthorized recording and rebroadcasting of musical performances, for example, has been difficult to prevent because of the inability to detect positively whether the rebroadcast is an exact reproduction of the original or a different performance. The present invention makes possible the positive identification of the origin of a musical presentation and thereby constitutes an effective means of preventing such piracy, i.e. it may be likened to a watermark in paper.

The invention may be used for the identification of any kind of signal, whether audio, or other, comprising a number of different frequency components, although for purposes of illustration it is shown and described herein as applied to the identification of audio signals.

It is well known that a complex audio signal, such as music or speech, is composed of a number of frequency components extending over a wide range of frequencies. In accordance with the present invention such a signal is identified by suppressing a selected frequency, or narrow band of frequencies, within the frequency spectrum of the signal at timed intervals according to a predetermined code. Because of the insensitivity of the ear in detecting the absence of a particular frequency or narrow band of frequencies in a sound signal, the identifying code will be imperceptible to the listener.

The suppression of a selected frequency or narrow band of frequencies is accomplished, in a specific embodiment of the invention, by converting the signal into a complex electrical voltage and then passing this voltage through a very narrow band-reject electrical filter which passes all but a very narrow range of frequencies in the complex voltage.

In the accompanying drawings:

FIGURE 1 is a graph of the spectrum of frequencies in a typical sound signal at an instant of time when a predetermined narrow range of frequencies is being suppressed;

FIGURE 2 is a graph of the amplitude of the sound signals in said predetermined narrow range of frequencies, plotted versus time to portray an illustrative coding sequence;

FIGURE 3 is an electric circuit, in block form, for impressing an identifying code on a signal in accordance with one embodiment of this invention;

FIGURE 4 is an electric circuit, in block form, for detecting the identifying code.

In FIGURE 1 the horizontal scale represents the frequencies of the various components in a typical sound signal while the vertical scale represenst the amplitude of these various components at a particular instant of time. The audible frequency range of the sound signal, as indicated in this figure, extends approximately from 20 cycles per second to 20,000 cycles per second.

The amplitudes of frequency components of the signal over a very narrow range of frequency, for example, 10 cycles per second, at some place in the frequency spectrum are attenuated, in accordance with the invention, in order to identify the signal. The attenuation of these particular frequency components leaves a notch in the frequency curve as indicated by notch N in FIGURE 1. The center frequency f_n of this range of attenuation is advantageously placed in that part of the frequency band, for example, in the vicinity of 1000 cycles per second, that can be accommodated in even the cheapest reproducing systems since the permanence as an identifying mark of the attenuated harmonic components when so placed is greater than if frequency f_n were placed at one edge of the signal frequency range. If it were placed at one edge, for example, at approximately 20,000 cycles per second, the identifying effect could be entirely eliminated simply by filtering out all of the very high frequencies of the sound signal. Moreover, in this regard, the frequency f_n should be placed at a frequency which is generally present in the signal to be identified. This frequency will of course depend upon the signal, but for music approximately 1000 cycles per second has been found to be satisfactory.

As shown in FIGURE 2, the identifying "mark" is discontinuous and eliminates the selected frequency components of the signal only at certain intervals of time, according to a predetermined, coded pattern.

FIGURE 3 shows a specific illustrative embodiment of a coding apparatus according to the invention comprising an electric circuit for impressing upon the signal to be "marked" a code of the type illustrated in FIGURE 2. The audio signal voltage, comprising a number of frequency components extending over a wide range of frequency, is applied at input terminal **11**. This voltage is switched by means of an encoding switch **12** either directly from terminal **11** to terminal **13** or through a band-reject filter **14** to terminal **13**, depending upon whether the switch **12** is open or closed. The switch **12** is opened and closed in sequence according to a predetermined coding pattern, for example, the name of the orchestra or the trademark of the recording company may be spelled out in International Code, or any other suitably identifiable sequence of pulses may be utilized as a proprietary code. The encoding switch may be actuated mechanically, as by means of a coding cam, so that the coding equipment is fully automatic and may be employed continuously at very slight expense. The band-reject filter **14** preferably has a very high "Q"—that is, it is sharply tuned to reject only the frequency components within an extremely narrow range on either side of its resonant frequency, f_n, so that the absence of the rejected frequency components will be imperceptible to the listener. This necessitates, of course, that the reduction in the total power of the audio signal due to the deletion of said selected frequency components be less than approximately 3 decibels.

The output voltage from terminal **13** may be broadcast concurrently or it may be recorded and reproduced at a later time, as illustrated in FIGURE 3, by means of a playback head, amplifier and speaker.

The code impressed on the signal by switch **12** will serve to identify thereafter the origin of the audio signal so "marked."

FIGURE 4 shows a specific illustrative embodiment

of an apparatus for detecting the identifying code in the audio signal. This apparatus includes an input terminal **20** to which may be applied an audio signal voltage similar to that obtained at terminal **13** or terminal **13'** in FIGURE 3. This voltage is amplified by means of an amplifier **21** and fed through a band pass filter **22**, which has a transmission characteristic such that it will pass only frequency components within the same narrow range of frequency which the band-reject filter **14** will reject, as previously described. In other words, the transmission characteristics of the band-pass filter **22** are substantially opposite to those of the band-reject filter **14**. The output of the band-pass filter **22** is connected to a suitable transducer **23**, such as a recording meter, oscilloscope, or the like. As the voltage applied to terminal **20** passes through the filter **22**, all frequency components of the signal lying outside the pass band are eliminated and only those within this band are passed. Since these frequencies were alternately suppressed and passed by the encoding circuit illustrated in FIGURE 3, the voltage applied to the transducer **23** will be intermittent. If transducer **23** is a recording meter containing a rectifier which converts these audio frequency alternating current voltages to direct current voltages, it can plot a graph of their amplitude versus time. Thus, a graph of the type illustrated in FIGURE 2 is plotted, in which the coding pattern, as indicated at **24** in FIGURE 2, is readily apparent. Alternatively, transducer **23** may be a loudspeaker to convert the identifying code into sound.

The foregoing is intended in illustration and not in limitation. Changes or modifications in the embodiments illustrated will occur to those skilled in the art and these changes or modifications may be made without departing from the spirit or scope of the invention as set forth.

I claim:

1. In combination, an input terminal, means for supplying to said terminal an electric signal corresponding to an original signal and having a plurality of frequency components each having a respective frequency and amplitude, an output terminal, encoding means for impressing a distinctive code on said electric signal for identifying the origin of said original signal, said encoding means including a narrow-band-reject filter adapted to attenuate said components of said electric signal within a very narrow frequency range, and also including a switch for connecting and for disconnecting said filter between said terminals in a predetermined time sequence to form said distinctive code.

2. A system of reproducing a continuous sound such as a musical selection and of permanently but unobtrusively identifying its origin comprising: means for continuously generating an electric signal corresponding to said sound and having frequency components extending substantially over the audio range of frequencies, means for variably attenuating in accordance with an identifying code frequency components of said signal lying within a very narrow band of frequency within said audio range, and means for then utilizing said identified electric signal whereby either said sound substantially in original form without the audible presence of said code or said code alone can be reproduced.

3. The system as in claim 2 wherein said means for utilizing includes means for eliminating all frequency components of said electric signal except those remaining in said narrow band.

4. The system as in claim 2 wherein said narrow band of frequency has a width of only a few cycles per second, and is near the center of said band.

5. A method of unobtrusively identifying a sound signal such as a musical selection, said method comprising the steps of taking a sound signal having frequency components within the audio range, and attenuating the components in a very narrow frequency band within said range in accordance with an identifying pattern so that said signal will be permanently marked with an easily detectable pattern but a person hearing said marked signal will be unaware of audible change in it.

6. The method as in claim 5 wherein said narrow frequency band has a width of the order of ten cycles per second and lies in said audio range near a frequency of one thousand cycles per second.

References Cited in the file of this patent

UNITED STATES PATENTS

1,724,938	Jammer	Aug. 20, 1929
2,116,172	Hyneman et al.	May 3, 1938
2,335,335	Zenner	Nov. 30, 1943
2,352,918	Smith	July 4, 1944
2,376,275	Rhoads	May 14, 1945
2,398,755	Shepherd	Apr. 16, 1946
2,406,034	Phelps	Aug. 20, 1946
2,474,191	Reid et al.	June 21, 1949
2,503,701	Baughman	Apr. 11, 1950
2,580,973	Sueur	Jan. 1, 1952
2,636,936	Goldsmith	Apr. 28, 1953