United States Patent [19]

Fein

[11] **3,895,316**

[45] **July 15, 1975**

[54] **COMPLEX TONE MODULATION**

[75] Inventor: **Harry Fein**, New Haven, Conn.

[73] Assignee: **W-P Instruments, Inc.**, New Haven, Conn.

[22] Filed: **Aug. 29, 1973**

[21] Appl. No.: **392,430**

[52] **U.S. Cl.** ..... **332/17**; 128/2.05 P; 128/2.05 Q; 128/2.05 S; 128/2.1 B; 179/1 N; 179/1 ST; 325/138; 325/152; 332/22; 332/41; 332/44

[51] **Int. Cl.** **H03c 3/38**; A61b 5/02; A61b 5/04

[58] **Field of Search** ..... 332/44, 17, 20, 22, 23 R, 332/23 A, 41, 39, 2; 325/144, 138, 152; 179/1 N, 2 A, 1 AA, 1 ST; 128/2.05 P, 2.05 Q, 2.05 S, 2.1 B

[56] **References Cited**

UNITED STATES PATENTS

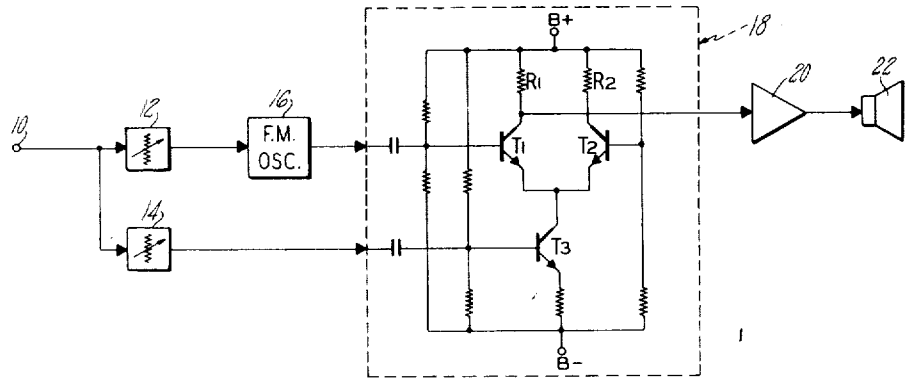
2,347,398	4/1944	Crosby	332/41 X
2,923,887	2/1960	Aiken	332/41 X
3,054,073	9/1962	Powers	332/41 X
3,486,117	12/1969	Groves et al.	332/17 X
3,562,428	2/1971	Starkey et al.	179/1 ST
3,715,474	2/1973	Calfee	332/17 X
3,778,718	12/1973	Bass et al.	332/17 X

Primary Examiner—Alfred L. Brody

[57] **ABSTRACT**

The generation of signals which vary in both frequency and amplitude in accordance with the amplitude of an information bearing input signal is disclosed. The invention thus relates to a complex tone generator wherein a monitored parameter is transduced into an electrical input signal which is employed to both frequency modulate a carrier signal in the audible frequency range and to amplitude modulate the frequency modulated carrier; the manner of amplitude modulation resulting in suppression of the unmodulated carrier.

4 Claims, 2 Drawing Figures



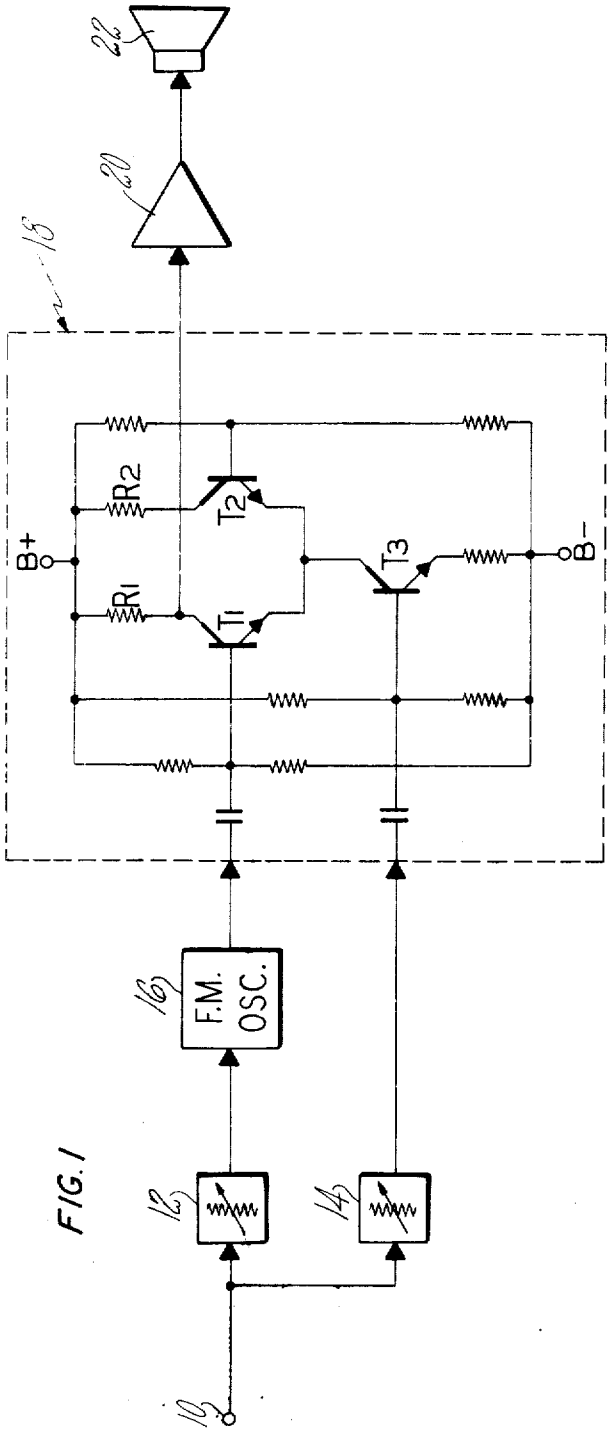


FIG. 1

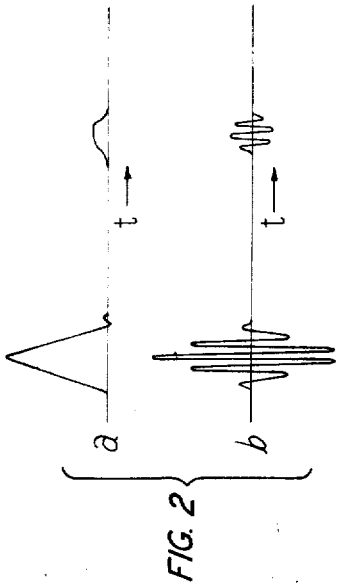


FIG. 2

COMPLEX TONE MODULATION

BACKGROUND OF THE INVENTION:

1. Field of the Invention

The present invention relates to the production of audible signals which vary in both tone and amplitude in accordance with the amplitude of an input signal commensurate with a parameter of interest. More specifically, this invention is directed to a complex tone generator. Accordingly, the general objects of the present invention are to provide novel and improved methods and apparatus of such character.

2. Description of the Prior Art

For many applications it is useful, and in some cases mandatory, to provide an audible measure of an electrical signal other than the conventionally transduced signals commensurate with speech and music. Such an audible measure is particularly useful in the case of electrical signals, commensurate with a monitored parameter, in the range of frequencies which are normally subaudible; i.e., those signals which contain frequency components from d.c. to 100Hz. Low frequency signals of this nature are, for example, provided at the output terminals of an electrocardiograph (ECG) or an electroencephalograph (EEG). An audible measure of these exemplary low frequency signals, and other similar signals, has substantial potential utility as an aid to one whose vision is normally occupied elsewhere or for the blind. Thus, by way of example, a blind physician would be able to interpret an audible electrocardiogram. Also by way of example, a surgeon whose hands and eyes are otherwise occupied can be usefully informed as to the state of a patient's heart, respiration and other organs during an operation by a device such as an audible electrocardiogram.

One method currently in use for pulsatile signals such as those which comprise an electrocardiogram encompasses the pulsing of a brief tone commensurate with the patient's heart beat. The resulting "beeping" sound, while providing an indication of the presence or absence of a heart beat, is inherently deficient in that it can not provide more subtle information about the shape of a given waveform which can be of considerable clinical importance.

SUMMARY OF THE INVENTION

The present invention overcomes the above briefly disussed and other deficiencies and disadvantages of the prior art by providing a modulation technique which permits a significant improvement in the information content of an audible monitoring signal. In accordance with the present invention a carrier signal is frequency modulated by a low frequency amplitude variable input signal. Thereafter, the resulting F.M. signal is amplitude modulated by the same modulating input signal. The form of amplitude modulation employed is suppressed carrier modulation whereby the output signal is suppressed in the absence of a modulating signal and increases from zero with the amplitude of the modulating signal. The output of the modulator is applied to an audio amplifier and audible tones will be transduced by a speaker associated with the amplifier only when a modulating input signal is present.

BRIEF DESCRIPTION OF THE DRAWING

The present invention may be better understood and its numerous objects and advantages will become apparent to those skilled in the art by reference to the accompanying drawing wherein:

FIG. **1** is an electrical circuit block diagram of a preferred embodiment of the invention; and

FIGS. **2***a* and **2***b* respectively are graphical presentations of a modulating input signal and the resultant output signal provided by the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT:

Before discussing the disclosed embodiment of FIG. **1**, some well known aspects of the physiology of hearing will be briefly discussed. It is well known that the human ear does not discriminate amplitude differences very accurately. Restated, the ear is a poor measurer of loudness. For example, on the average a steady tone must vary in loudness or intensity by ± 1.5db. for an average listener to discern the change in loudness. On the other hand the ear is an excellent discriminator of pitch (frequency). The present invention exploits the sense of hearing in a way that is particularly appropriate with the foregoing physiological principals in mind.

Since the ear is very sensitive to changes in pitch or frequency, the first step in accordance with the present invention is to frequency modulate a steady tone or carrier frequency. The carrier center frequency is chosen to lie in the band between 400Hz and 2500Hz; this frequency range being that which is the optimally heard band in human audition. The impressed modulating signal will, in the manner well known in the art, cause the carrier frequency to vary upwardly with increasing amplitude and to vary downwardly for decreasing amplitudes.

The frequency modulated signal resulting from the above described first step is amplitude modulated by the same modulating input signal. In accordance with the present invention the output of the amplitude modulator is suppressed to nearly zero in the absence of a modulating signal and increases from zero with the amplitude of the modulating signal; i.e., suppressed carrier modulation is employed and the A.M. modulator functions as a multiplier.

As a third step in accordance with the invention, the output of the suppressed carrier modulator is applied to an audio amplifier and thence to a sound transducer. Since the carrier signal is suppressed, audible tones will be heard only when a modulating input signal is applied to the system. The steps of frequency modulation and suppressed carrier amplitude modulation are performed essentially simultaneously and an audio signal having a "chirping" quality will accordingly result. The present invention enhances the discernability of the information contained in the modulating input signal in two ways. First, the invention exploits the ear's normally good pitch acuity. Secondly, by suppressing the carrier, the invention enhances the ear's ability to discriminate amplitude by providing a quiet background.

With reference now to FIG. **1**, the electrical signal to be modulated is applied at input terminal **10**. The input signal is weighted by the pair of attenuators **12** and **14**. The function of this weighting is the proportioning of the input signal which is to be F.M. modulated and the portion which is to be A.M. suppressed carrier modulated. Thus, the weighting attenuators **12** and **14** determine the "index" of modulation. The weighting attenuators **12** and **14** may be linear attenuators, such as po-

tentiometers, or may be non-linear devices, such as silicone diode chains, which non-linearly weight the input signal.

The output signal of attenuator **12** is applied as the modulating input to an F.M. oscillator **16.** The F.M. oscillator **16** may be any commercially available F.M. oscillator and in one reduction to practice of the invention oscillator **16** comprised a multivibrator, functioning as a square wave oscillator, having its output signal applied to a shaping circuit which provided an essentially pure sine wave. It will be understood that, while the output of oscillator **16** is preferably a sine wave, other waveforms could be employed.

The output of oscillator **16** is applied to a first input terminal of a multiplier, indicated generally at **18,** which functions as the A.M. suppressed carrier modulator. The weighted signal from attenuator **14** is applied as a second input to multiplier **18.**

A circuit suitable for use as the multiplier **18** has been shown schematically. To understand the operation of this circuit it must be recognized that the collector current of most junction transistors is a function of the product of the transconductance and the base input voltage; the transconductance in turn being a function of collector current. Thus, if one voltage signal of a pair of such signals is caused to vary the collector current and the second signal is applied to the transistor's base, the resulting collector current will be a function of the product of the two voltage signals. In the disclosed embodiment the signal from oscillator **16** is capacitively coupled to the base of transistor **T1** while the signal from attenuator **14** is capacitively coupled to the base of transistor **T3.** Transistor **T3** is connected as an emitter follower current source for transitors **T1** and **T2.** The output voltage, measured as the voltage drops across load resistors **R1** and **R2** respectively of transistors **T1** and **T2,** with an input signal applied to terminal **10,** will be the product of the voltages applied to multiplier **18** from oscillator **16** and attenuator **14.** Transistor **T2** serves to compensate for the effects of temperature changes on transistor **T1.** The resistors in the circuit which have not been specifically identified are, in the manner well known in the art, employed for d.c. biasing.

To summarize, the frequency modulated signal from oscillator **16** and the weighted signal from attenuator **14** are applied to multiplier **18.** Multiplier **18** generates the product of these two applied signals; the output of the multiplier being delivered as the input to audio amplifier **20.** The output of audio amplifier **20** is employed to drive a loudspeaker **22.** The product of the inputs to multiplier **18** will be zero if an input signal is absent at terminal **10,** since no signal will appear at the output of attenuator circuit **14,** and no audible sound will emerge from the loudspeaker even though oscillator **16** is continuously running.

Referring to FIG. **2***a*, the wave shape of an assumed electrocardiogram signal is depicted. The resultant modulated wave shape, as would appear at the output of multiplier **18** if the waveform of FIG. **2***a* was applied to input terminal **10,** is depicted in FIG. **2***b*. It is particularly to be noted that both the frequency and amplitude of the output signal of FIG. **2***b* increases with increasing input signal magnitude and decrease with decreasing input signal magnitude.

As should now be obvious to those skilled in the art, the present invention provides a complex output waveform which, when applied to a loudspeaker, produces an audibly distinctive signal which can be easily interpreted by trained listeners. The invention exploits the sense of hearing by varying the frequency of the carrier and by suppressing the base carrier tone so that amplitude modulation effects are enhanced. The resulting sound wave has a unique sound with subtle variations which are capable of a wide range of variation. Thus, with experience, a user may learn the "voice" of unique events.

While a preferred embodiment has been shown and described, various modifications and substitutions may be made thereto without departing from the spirit and scope of the invention. By way of example, the input signal applied to terminal **10** may be derived from any transducer such as pressure, position and temperature sensors. Accordingly, it is to be understood that the present invention has been described by way of illustration and not limitation.

What is claimed is:

1. A method for the production of audible signals which vary in both tone and magnitude in accordance with the amplitude of a monitored parameter, the amplitude of the monitored parameter varying at a sub-audible frequency, said method comprising the steps of:

transducing a monitored parameter which varies in amplitude at a sub-audible frequency into an electrical information bearing signal;

frequency modulating a carrier signal in the audible frequency range in accordance with the amplitude of the information bearing signal;

directly amplitude modulating the frequency modulated carrier signal with the information bearing signal while simultaneously suppressing the carrier signal in the absence of an information bearing signal; and

transducing the amplitude modulated signal into an audible signal.

2. The method of claim **1** wherein the step of amplitude modulating comprises:

multiplying the frequency modulated carrier signal by the information bearing input signal.

3. The method of claim **1** further comprising:

proportioning the information bearing input signal whereby a portion thereof is employed for frequency modulating the carrier signal and a portion thereof is employed for amplitude modulating the frequency modulated carrier signal.

4. The method of claim **2** further comprising:

proportioning the information bearing input signal whereby a portion thereof is employed to frequency modulate the carrier signal and a portion thereof is multiplied with the frequency modulated carrier signal.

* * * * *