Oct. 4, 1966 I. SPONGA 3,277,245
APPLIANCE FOR RECORDING AND/OR TRANSDUCING ELECTRIC AND/OR
ACOUSTIC OSCILLATIONS OF VARIOUS FREQUENCIES
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Fig. 1

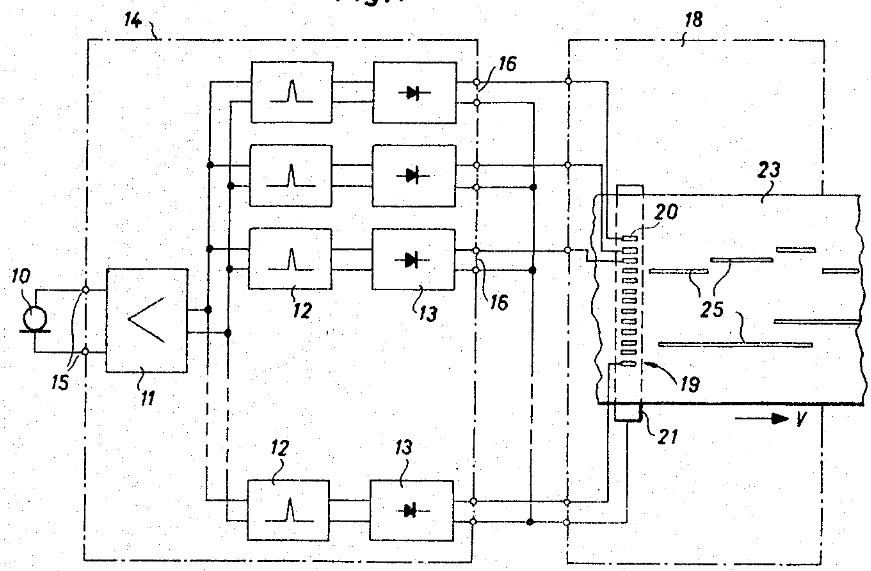

Fig. 2

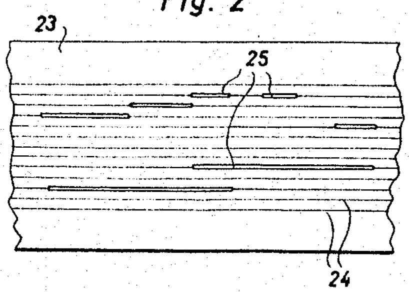

Fig. 4

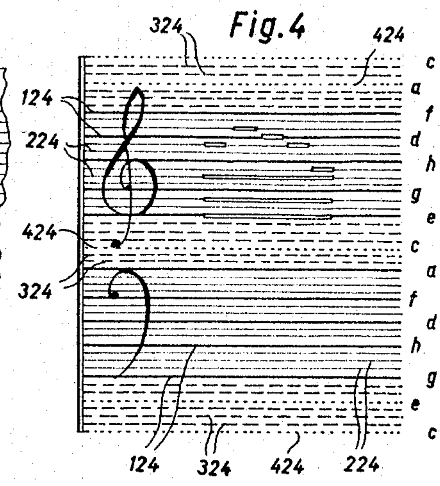

Fig. 3

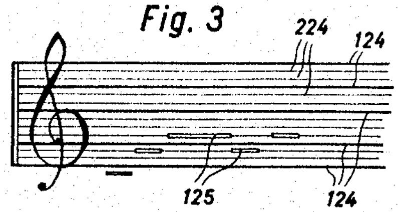

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Fig. 5

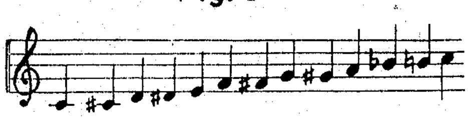

Fig. 7

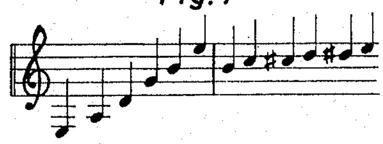

Fig. 6

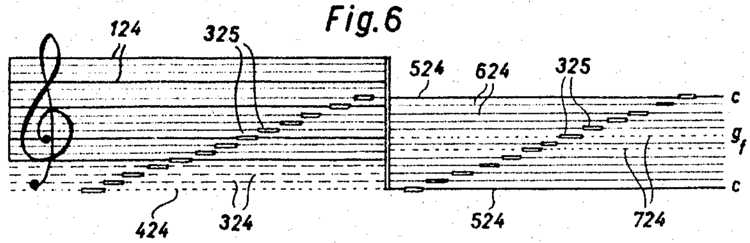

Fig. 8

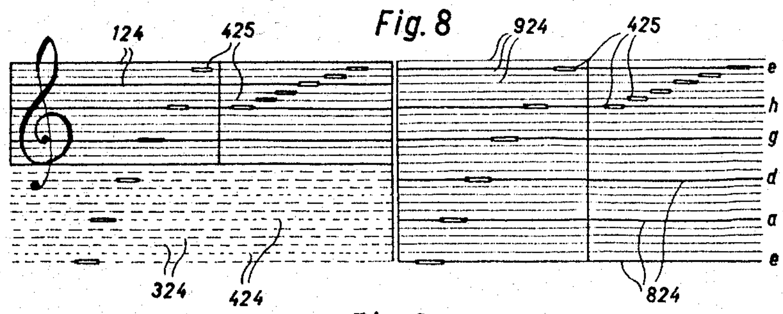

Fig. 9

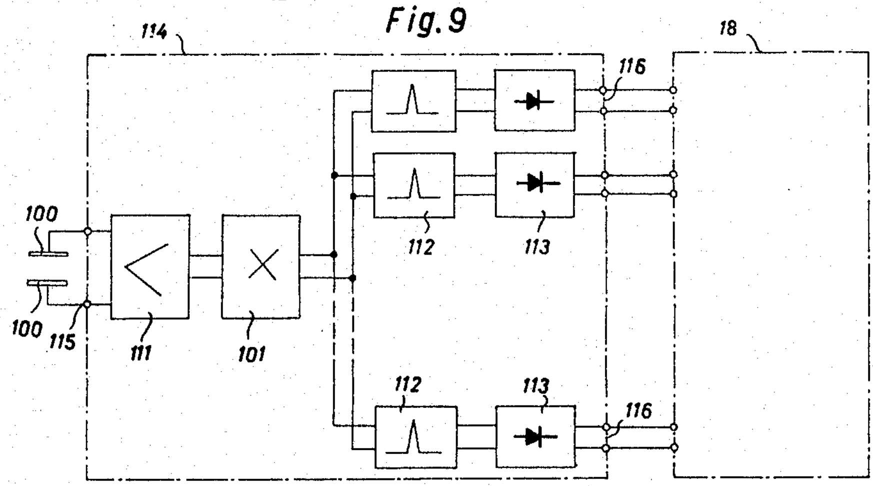

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Fig. 10

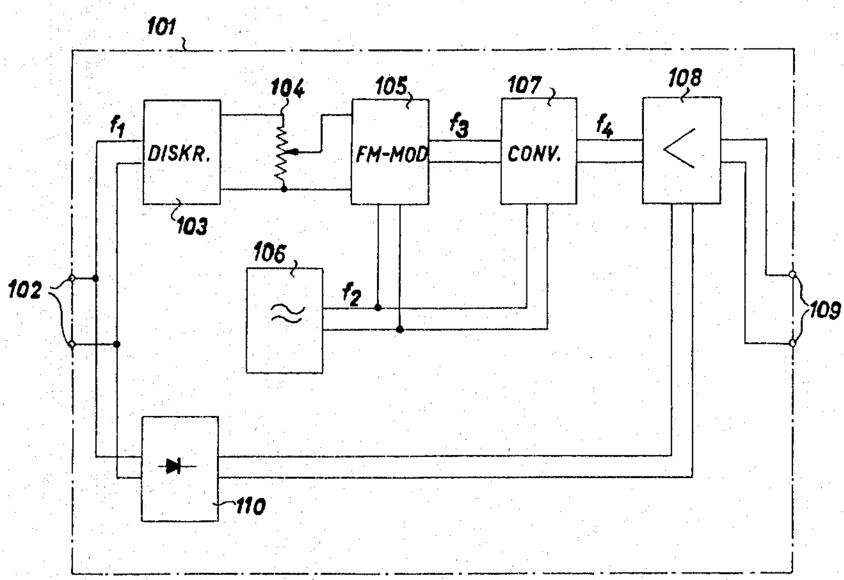
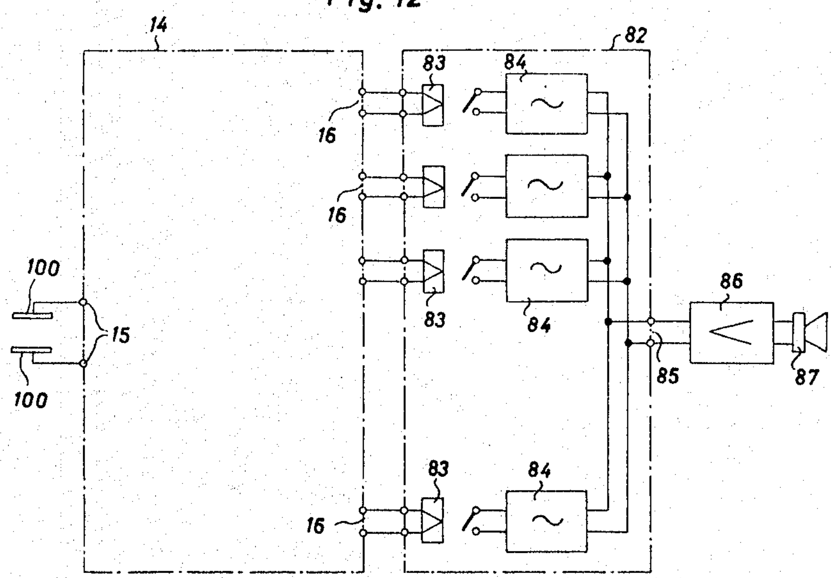


Fig. 12



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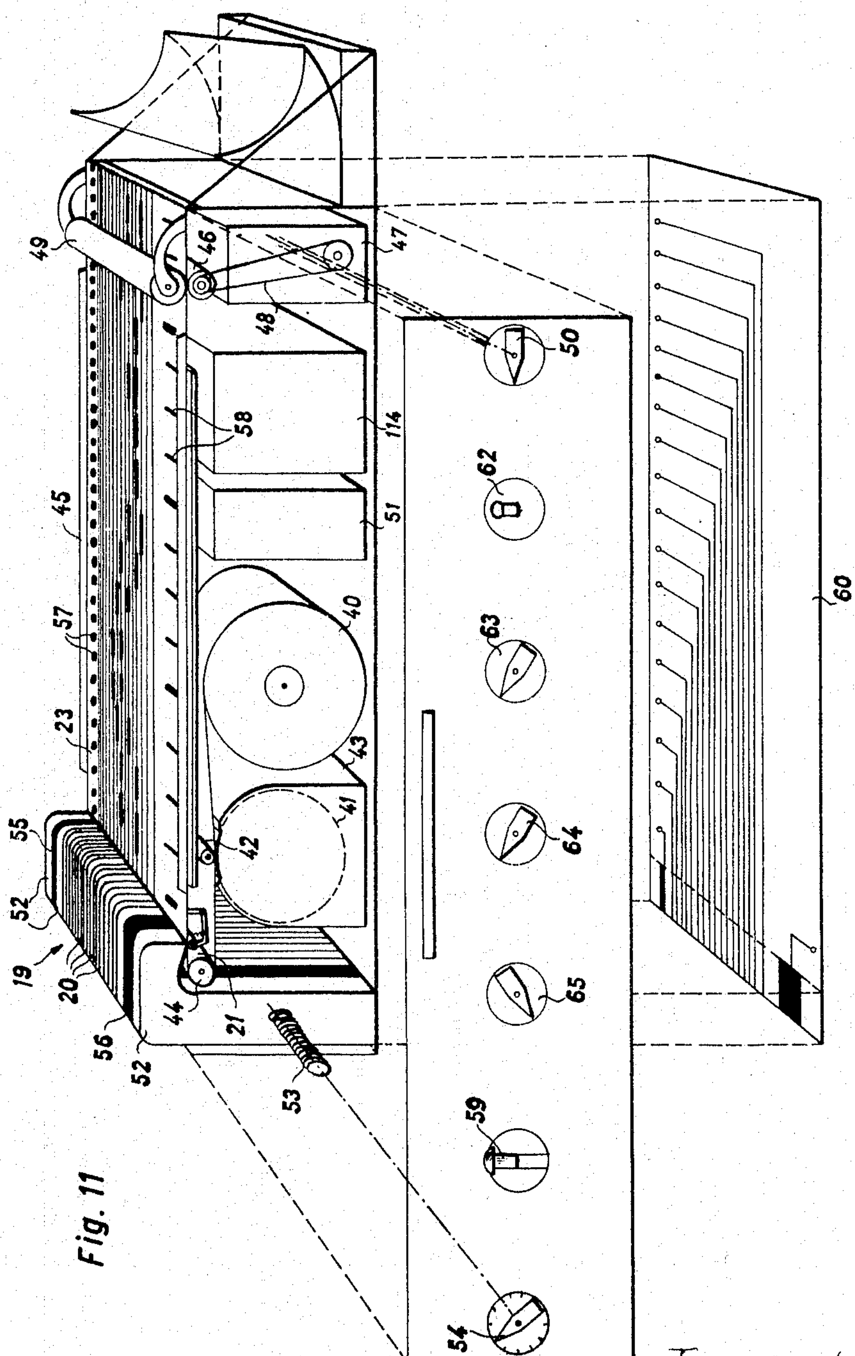

Fig. 11

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APPLIANCE FOR RECORDING AND/OR TRANSDUCING ELECTRIC AND/OR ACOUSTIC OSCILLATIONS OF VARIOUS FREQUENCIES

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Claims priority, application Switzerland, Aug. 8, 1961, 9,327/61
7 Claims. (Cl. 179—100.2)

This invention relates to a system of transcribing music more particularly the present invention relates to an appliance for recording and/or transducing electric oscillations or acoustic oscillations converted into electric oscillations of various frequencies.

The leading feature of the invention is that a set of electric wave filters are tuned to a series of passing frequencies, which follow each other in the ratio of $1:\sqrt[12]{2}$ the inputs of all filters being connected to a common input amplifier and the output of each filter to its own transducer which is activated by the specific electric oscillation passing through the associated filter thus initiating a certain process to be described hereunder.

Other features of the invention will follow from the claims, the specification and the accompanying drawings. In the following pages, by way of example only, several embodiments of the invention are described in greater detail with reference to the drawing.

FIG. 1 is a purely diagrammatic representation of the first embodiment of the invention designed for the automatic recording of the spectrum of electric oscillations varying in time;

FIG. 2 shows a sample of the associated recording strip with some recordings;

FIG. 3 shows another recording strip with a different line pattern and some recordings of oscillations within the acoustic range;

FIG. 4 shows a similar recording strip with an extended frequency range;

FIG. 5 represents a scale of semitones in conventional notation;

FIG. 6 shows the same scale of semitones as transcribed by the appliance in FIG. 1 on two recording strips with different line patterns;

FIG. 7 shows a sequence of tones in conventional notation;

FIG. 8 shows the same sequence of tones as transcribed by the appliance in FIG. 1 on two recording strips with different line patterns;

FIG. 9 shows a modification of the appliance in FIG. 1, which is designed to record the frequency spectra of brain currents;

FIG. 10 shows a detail of the appliance in FIG. 9;

FIG. 11 is a schematic perspective view of a concrete embodiment of the appliance in FIG. 9;

FIG. 12 is a diagram of an appliance designed to transduce electric oscillations, e.g. those produced by brain currents, into oscillations of different but proportional frequencies, e.g. audio-frequencies.

In the appliance shown in FIG. 1, a microphone **10** is connected to an input amplifier **11**, which in turn is connected to a set of electric wave filters **12**, as shown in the diagram. The inputs of the filters **12** are connected to the output of the amplifier **11**. Each of the filters **12** has a different passing frequency. Taken together the passing frequencies form an ascending series following with the ratio of $1:\sqrt[12]{2}$. If the passing frequencies are set within the acoustic range of man, the pitch of each of the audio-frequencies passing through the filters **12** differs by a semitone from the pitch of the preceding and the following frequency. The output of each filter **12** is connected to an associated rectifier circuit **13**, and each of these circuits may be provided with an additional amplifier if necessary. Elements **11** to **13** form a structural unit **14**, equipped with one pair of input terminals **15** connected to the microphone **10** and several pairs of output terminals **16** in connection with the rectifier circuits **13**.

The output terminals **16** are connected to a recording unit **18** with several recorders **19**, which act as transducers and operate in conjunction with a common recording strip **23**. By means of mechanical devices which are not shown in the diagram, the recording strip **23** can be moved forward at uniform speed in the direction indicated by the arrow V. Each of the recorders **19** has an upper electrode **20**, while the lower electrode **21** is common to all recorders. These electrodes **20** and **21** are in connection with the terminals **16**. The recording strip **23** passes between the electrodes **20** and **21** and is in contact with those parts of the upper electrodes that serve as recorder heads. The contact surface between the recorder heads and the recording strip is relatively small. All the recorder heads are arranged in parallel and spaced at equal distances in a straight line at right angles to the longitudinal and feed direction of the strip **23**. A concrete embodiment of the recording unit will be described later with reference to FIG. 11.

The recording strip **23** may for instance consist of paper prepared with chemicals which change colour when subjected to the action of electric current, so that discolorations are produced wherever current passes between an electrode **20** and the lower electrode **21**, the intensity of electric current or the voltage applied being reflected by the intensity of the discoloration. In a modified form the the recording medium could be metal-coated paper or plastic film, with the thin metal coating being burned away where electric current passes through.

The appliance described works as follows: When the microphone **10** is exposed to sound waves of different frequencies, it produces electric oscillations, which are amplified by the input amplifier **11** and then fed to the filters **12**. In accordance with its specific frequency each oscillation is passed by the appropriate filter **12** and then transmitted to the associated rectifier circuit **13**, where a direct current voltage is produced, the magnitude of which is proportional to the intensity of the oscillation passing through its filter **12**. The voltage is applied between the appropriate electrode or electrodes **20** and the counter-electrode **21** separated by the running recording strip **23**, which is marked by the passage of the electric current. Since the strip **23** moves at uniform speed, e.g. 1 cm. per second, in the direction indicated by the arrow V, the oscillation passed by the filter is recorded as a line. The position of this line indicates the frequency or pitch of the oscillation recorded, its length the duration of the tone, and the intensity of its colour the volume of the tone.

It is advisable to use a horizontally lined recording strip **23**, as shown in FIG. 2, with equidistant auxiliary lines **24**, each of which corresponds to one of the recorder heads of the electrodes **20**. The auxiliary lines **24** can also be marked with the corresponding frequencies, if so required. FIG. 2 also shows some recordings **25**.

It should be noted that in the procedure outlined above generally only the fundamental oscillations of the tones are recorded, while their overtones (upper partials) are too low in amplitude to produce an effect. However, the appliance described can also be used to analyse the frequencies of a single tone or noise, if so desired, by amplifying the overtones to the required sound level and, if necessary, filtering out the fundamental oscillation of the tone to be analyzed.

If—as it was assumed so far—the oscillations recorded are within the acoustic range of man and thus correspond to musical tones, it will be preferable in some cases to make use of the arrangement shown in FIG. 3, where those auxiliary lines which correspond to the conventional staves **124** are set off, for instance by making them thicker than the other auxiliaries **224**. The recordings **125** as set within the auxiliary lines **124** ("stave lines") and **224** ("intermediate lines") will then produce a notation not unlike the conventional notation, which can be read and interpreted by musicians as easily as the conventional notation, if not more so. The intermediate lines **224** clearly indicate the pitch of the recordings or notes situated between the stave lines **124**. Since each tone has its assigned location on one of the stave lines **124** or intermediate lines **224**, the new notation is quite unambiguous, and no key signatures are necessary to raise or lower the recorded pitch. The lenth of each tone is clearly shown by the length of its recording **125**. No auxiliary symbols are needed to indicate rests, which are evident from the recording. To transpose a composition from one key (say D major) to another key, all that has to be done is to raise or lower the auxiliary lines **124** and **224** in relation to the recordings **125**, which need not be altered in any way. This is a considerable simplification and improvement over the conventional notation.

Since the filters **12** and the recorders **19**, which are coupled with them, are quite independent of each other, the appliance can also be used to record polyphonic music with any amount of voices. For this purpose the strip should be lined as shown in FIG. 4 and the number of filters **12** and recorders **19** increased accordingly. The line pattern in FIG. 4 clearly brings out the relationship between bass clef and treble clef. It is no longer a problem to "bridge the gap" when changing over from one system to the other, since the classical staves represented by the stave lines **124**, the intermediate lines **224** and the supplementary lines **324** and **424** all form part of one integrated system, so that clefs could actually be dispensed with; the only reason they are retained is to give musicians their accustomed bearing.

Furthermore the appliance opens up completely new perspectives in the transcription of music, by making it possible to record tones in quite different notation systems, e.g. systems that are specially adapted to specific musical instruments. Instead of setting off the lines corresponding to the staves of the conventional five-stave notation, other lines can be brought out, which are specially suited to the instrument in question. Illustrations are given in FIGS. 5 to 8.

FIG. 5 represents the scale of semitones within one octave as transcribed in conventional notation; FIG. 6 shows the same scale in two recordings produced by the appliance in FIG. 1. The line pattern in the left half of FIG. 6 is the same as the one in FIG. 3 or 4, with the lines corresponding to the conventional staves **124** printed thicker than the others. In the right half of FIG. 6 the same recordings **325** are set in a different pattern of lines **524**, **624** and **724**, which corresponds to the arrangement of the keys of a piano covering an octave. To guide the eye, lines **524** corresponding to notes C are printed thicker than the others, and lines **724**, representing notes G and F, are dotted. This notation is therefore particularly suited to the requirements of pianists, singers and beginners, since "bearings" are the same for every octave.

With the appliance shown in FIG. 1, the tone sequence as transcribed in conventional notation in FIG. 7 can be recorded as illustrated in FIG. 8. In the left half of FIG. 8 the recordings **425** are set in a system of lines **124**, **324** and **424**, with the conventional stave lines **124** clearly set off from the rest. In contrast, the right half of FIG. 8 illustrates a line pattern specially adapted to a six-chord guitar. All lines **824** corresponding to the pitches of the untouched chords are thicker than the other lines **924**. This notation is so simple that even a beginner will have no trouble in finding the recorded notes on his instrument.

Since the recordings produced by the appliance are independent of the line pattern used on the recording strip it is possible to transcribe any recording at will into any line pattern, so that the notation which is best suited to any particular instrument can easily be obtained. Alternatively, the tones can also be recorded on a blank strip, on which a transparent film with the pattern required can be superimposed for reading or playing the recorded tones.

The appliance which is the subject of the present invention is not necessarily confined to recording oscillations within the audio-frequency range, since the filters **12** and the amplifier **11** can also be designed for electric oscillations in the ultrasonic or infrasonic range, the ratio of the passing frequencies being the same, i.e. $1:12\sqrt{2}$. However, to meet the difficulty of building filters sufficiently selective for the infrasonic range, another embodiment is proposed in FIGS. 9 and 10.

The appliance shown in FIG. 9 differs from the appliance in FIG. 1 mainly in having a pair of electrodes **100** instead of the microphone **10** and a differently designed unit **114** instead of the unit **14**, which has been described above. By means of the connecting terminals **115** the two electrodes **100** are joined to the input of an amplifier **111**, which is specially designed for the transmission of electric oscillations in the infrasonic range, e.g. from 1 to 32 cycles. However, the amplifier should preferably be capable of transmitting oscillations in the audio-frequency range (e.g. up to 20 kilocycles) as well. The output of the amplifier **111** is connected to a frequency changer **101**, which will be described in detail with reference to FIG. 10. The output of the frequency changer **101** is connected to the inputs of a series of filters **112** of the same design as the filters **12** in FIG. 1, the passing frequencies of which are in the audio-frequency range and follow each other in the ratio of $1:\sqrt[12]{2}$. The output of each filter **112** is connected to its own rectifier circuit **113**, and the outputs of all these rectifier circuits **113** are joined by means of terminals **116** to a recording unit **18** like the one shown in FIG. 1.

The frequency changer **101** may be designed as shown in FIG. 10. A pair of input terminals **102** is connected to a frequency discriminator **103**, which produces a D.C. voltage proportional to the frequency f_1 of the incoming electric oscillations. By means of a controllable voltage divider **104** the D.C. voltage is transferred to a frequency modulator **105** with linear frequency deviation. A high-frequency oscillator **106** produces an A.C. voltage of frequency f_2 (e.g. 100 kilocycles) which is supplied to the frequency modulator **105** as well. The modulated high-frequency voltage which then arises at the output of the frequency modulator **105** has the actual frequency f_3 and is fed to a converter **107**. The degree of frequency modulation of said output voltage of the modulator **105** can be varied by adjusting the controls of the voltage divider **104**. In the converter **107** a constant high-frequency voltage of frequency f_2 supplied by the oscillator **106** is heterodyned with the frequency modulated voltage of frequency f_3, thus producing a voltage of frequency f_4, which is equivalent to the difference between f_3 and f_2 and lies within the acoustic range. Frequency f_4 is higher than frequency f_1 by a constant factor, the quantity of which can be regulated by means of the voltage divider **104**. Through a variable-gain amplifier **108** the voltage of frequency f_4 is transferred to the pair of output terminals **109** of the unit **101**. Through the input terminals **102** the A.C. voltage of infrasonic frequency is also fed into a rectifier circuit **110** producing a D.C. voltage which is proportional to the amplitude of the A.C. voltage and automatically controls the volume of amplification in the amplifier **108**. As a result, any changes in the amplitude of the A.C. voltage at the input terminals **102** are exactly reproduced in the A.C. voltage at the output terminals **109**, so that the dynamic response is maintained.

The appliance shown in FIGS. 9 and 10 may, for instance, work in the following way:

The electrodes **100** are fixed to the subject's head in the usual way, in order to scan his brain currents. In some cases it may be preferable to use more than one pair of electrodes and connect them to the terminals **115**. Brain currents are alternating currents with a low frequency f_1 ranging between 10 and 30 cycles. The voltage scanned by the electrodes **100** is amplified in the amplifier **111** and fed into the unit **101**, where it is "processed" as described above. As has already been mentioned with reference to FIG. 10 the A.C. voltage is generated at the output of the unit **101** is completely analogous to the input voltage, but has a frequency f_4 which is, for instance, a hundred times higher, that is 1000 to 3000 cycles in the case considered here. The multiplication factor is determined by adjusting the voltage divider **104**. The electric oscillations are then separated according to their frequencies by the filters **112** and rectified by the circuits **113**; the D.C. voltages obtained are then conducted to the recorder heads in the recording unit **18**. By means of the appliance described brain currents can thus be recorded in terms of their frequency and duration, in more or less the same manner as has already been described for the recording of music. The result is a frequency spectrum of the alternating currents of the brain.

Such a recording will give physicians and psychologists a profound insight into a person's character, his state of mind, his emotions, his personal rhythm, etc. Analyses of this kind may also provide valuable information with respect to the problem which persons are suited to each other.

While recording the alternating currents of the brain, one may at the same time record the electric potentials produced by muscular tension of selected muscles, cardiac currents and/or the rate of respiration, preferably on the same recording medium and with or without the aid of already existing devices. In this way one can obtain a complete "personal score."

FIG. 11 shows a structural embodiment of the appliance described. The recording strip **23** winds off a delivery roll **40** and then runs between a conditioning roller **41** and an auxiliary roller **42**. The conditioning roller **41** is encased in a container **43**, which holds a reagent that changes colour when subjected to the action of electric current. Subsequently the recording strip **23** runs over a deflecting roller **44** and a guiding table **45** to a drive roller **46**, which is driven by the power provided by a motor and gear box **47**, e.g. by way of a belt drive **48**. The drive roller **46** is associated with an auxiliary roller **49**, and the recording strip **23** passes between these two rollers **46** and **49**. The advance rate of the recording strip can be adjusted within certain limits by means of a knob **50**.

The delivery roll **40** and the container **43** with its rollers **41** and **42** are situated underneath the guiding table **45** and so are the structural unit **114** (shown in detail in FIG. 9) and an electric power supply unit **51**.

The recorder electrodes **20** are metal laminae embedded between layers of insulating material **52** thus forming a laminated unit which can be moved sideways (i.e. at right angles to the recording strip **23**) by means of a lead screw **53** and a knob **54** to position the recording heads in relation to the printed lines on the recording strip **23** and to transpose musical recordings into any key or tonality desired. The lower electrode **21** is a roller which presses the recording strip against the recorder electrodes **20** by means of a spring (not shown).

In addition to the electrodes that record the oscillation spectrum, the laminated unit described in the preceding paragraph contains two more such laminar electrodes **55** and **56**, which also operate in conjunction with the common roller electrode **21**. Electrode **55** serves for an automatic time marking **57** by means of pulses, which may for instance follow at the rate of one per second. The other electrode **56** makes it possible to record beat markings **58** by tapping a lever **59** by hand. The system is so designed that the voltage applied to the electrode **56** with relation to the lower electrode **21** depends on the pressure exerted on the lever **59**, which makes it possible to stress some of the beat markings more than the others.

The electric connections of the electrode plates **20, 55** and **56** are preferably designed as a printed circuit on a sheet of insulating material **60**, which may be connected with the laminated unit by means of screws not shown on the drawing.

The knobs **50** and **54**, which have already been mentioned, as well as the lever **59** are arranged on a front panel **61**, which also includes a switch **62** to turn the apparatus on or off, a knob **63** to control the volume of amplification in the amplifier **111** (cf. FIG. 9) and a knob **64** to control the multiplication factor by adjusting the voltage divider **104** (FIG. 10). Finally there is a multistage selector switch **65** to adapt the appliance for different purposes. In one position of the switch **65** the appliance works as described with reference to FIGS. 9 and 10, i.e. it can be used to record the frequency spectrum of brain currents. In a second position of the switch **65** the appliance works as described in connection with FIG. 1: the frequency changer **101** is by-passed, and the output of the amplifier **111** (FIG. 9) is directly connected to the inputs of the filters **112**. This is the position for recording music. In a third position of the switch **65** the gain of amplifier **111** is increased to such an extent that not only the fundamental oscillation of a tone but also its overtones (upper partials) can be recorded, thus making it possible to analyse the timbre of individual tones.

The embodiment of the invention shown in FIG. 12 is also provided with a pair of electrodes **100**, which is connected to a structural unit **14**, as described under FIG. 1, with the difference that the filters will pass fresuencies between 1 and 32 cycles. The recording unit **18** is replaced by another unit **82**, which contains as many relays **83** as there are filters **12** in the structural unit **14**. Each of the exciting circuits of the relays **83** is connected to one of the pairs of terminals **16** of unit **14**. The relays **83** act as transducers which initiate predetermined processes, i.e. starting or stopping electric sound frequency oscillators **84**, each of which is associated to one of the relays **83** and thus to one of the filters **12**. The frequencies of the sound waves which can be produced by the oscillators **84** are chosen in proportional relationship to the passing frequencies of the filters **12**; consequently the frequencies of the sound frequency oscillators **84** also form a series with a progressive ratio of $1:\sqrt[12]{2}$. Thus each of the frequencies of the oscillators **84** differs from the frequency of the preceding oscillator by a semitone pitch. The outputs of all oscillators **84** are connected to a common pair of terminals **85**, which in turn is connected to a loudspeaker **87** by way of an amplifier **86**. Alternatively a pair of earphones can be connected to the terminals **85** instead of the amplifier and loudspeaker.

The appliance shown in FIG. 12 works as follows: The alternating currents of the brain are scanned by the electrodes **100** and then selected by the filters **12** in unit **14**. Whenever an electric oscillation passes through one of the filters it energizes the associated relay **83**, which in turn switches on the corresponding sound frequency oscillator **84**, which then produces its specific sound oscillation as long as oscillations pass through the associated filter **12**. Consequently each alternating brain current gives rise to another current of acoustic frequency, which is made audible by means of the loudspeaker **87**. Since the frequencies of brain currents are constantly varying the audible tones changes in the same proportion, thus producing a kind of "music," which could be termed "brain music." Thus unit **82** is basically an electric or electronic organ, which is automatically played by the subject's brain currents.

This "brain music" can be expanded into a kind of "integral organic music" by making the action currents of the sympathetic and vegetative nervous system (e.g. muscular action currents, electrocardiogram) audible as well.

The appliance according to FIG. 12 opens up a wide range of new approaches to psychoanalysis and psychotherapy; in particular, it will be possible to literally confront a patient with his own ego, by letting him hear his own "organic music." The wider the split in the patient's personality the more dramatic results can be expected from this new therapy. In psychotics this treatment may produce emotional "chain reactions" which could have a similar effect on the patient as the currently used shock therapy. In neurotics the effect will probably be less striking and mainly of a cathartic nature and if the treatment is repeated in several sessions it should be equivalent to a condensed meditation training which progressively leads to self-recognition, self-awareness and self-integration.

The appliance shown in FIG. 12 can also be adapted to produce vibrations other than sound waves or to generate electric or magnetic fields, to which the subject whose brain-currents produce these vibrations can be exposed.

Finally it should be noted that the recordings illustrated in FIGS. 2, 3, 4, 6 and 8 are ideally suited to be read by machine scanning with photo-electric transducers. A device designed for this purpose could for instance comprise unit **82**, amplifier **86** and loudspeaker **87** in FIG. 12. In that case the exciting circuits of the relays **83** are not connected to unit **14**, but each is joined through its own amplifier to an associated photo-electric transducer, which scans the recording strip along its appropriate auxiliary line and responds whenever it detects a recording within its range. By moving the recording strip at right angles to its feed direction in relation to the scanning transducers, the recorded "music" can be played in any desired key.

.A slightly modified embodiment of the applicance shown in FIGS. 9 and 10 can also be used to make "brain music" directly audible. To this end the output of the frequency changer **101** is connected, either directly or by way of an additional power amplifier to a pair of earphones or to a loudspeaker, which makes the sound frequencies corresponding to the electric oscillations of the brain currents audible to the human ear. At the same time the brain currents can be transcribed by the recording unit **18**.

What I claim is:

1. A system for transcribing music, comprising an electro-responsive recording strip, means for moving said recording strip lengthwise at a given rate including means for adjusting the recording strip at right angles to the said lengthwise movement, a plurality of electrical recorder heads arranged adjacent said recording strip for co-operation therewithin, said recorder heads being arranged in a line extending perpendicular to the lengthwise direction of said recording strip, a plurality of electric-wave filters tuned to a series of passing frequencies which follow each other in the ratio of $1{:}\sqrt[12]{2}$ whereby each filter passes a musical tone one semitone apart from its adjacent filters, the outputs of said filters each being

connected with one of said recorder heads, the input of said filters being connected to the output of a common amplifier, and means for feeding the input of said amplifier with electrical signals corresponding to the music tones to be musically transcribed, said recording strip having thereon a plurality of reference lines running parallel to the longitudinal direction of the strip, said reference lines representing a scale of semitones and each of the reference lines corresponding to one of the recorder heads and being alined therewith.

2. A system according to claim **1** wherein the recorders are combined into a laminated structural unit, with as many electrically conductive laminae as there are filters, the laminae being arranged in parallel and insulated from each other, each lamina having a portion which acts as a recorder head, said recording strip being sensitive to the passage of electric current and passing between the recorder head portions of the laminae and a counter-electrode extending over the entire width of the unit.

3. A system according to claim **1**, wherein the recorders are combined into a laminated structural unit, with as many electrically conductive laminae as there is filters, the laminae being arranged in parallel and insulated from each other, each lamina having a portion which acts as a recorder head, said recording strip being sensitive to the passage of electric current and passing between the recorder head portions of the laminae and a counter-electrode extending over the entire width of the unit, the counter-electrode being a rotating movable roller which presses the recording strip against the recorder head portions of the laminae.

4. A system according to claim **1**, wherein the recorders are combined into a laminated structural unit, with as many electrically conductive laminae as there are filters, the laminae being arranged in parallel and insulated from each other, each lamina having a portion which acts as a recorder head, said recording strip being sensitive to the passage of electric current and passing between the recorder head portions of the laminae and a counter-electrode extending over the entire width of the unit, the laminated structural unit being adjustable, so that it can be moved up and down at right angles to the recording strip.

5. A system according to claim **1**, in which an additional recorder head is provided for recording time markings on the recording strip, said additional recorder head being in line with the other recorder heads.

6. A system according to claim **1**, in which an additional recorder head is provided for recording beat markings on the recording strip, said additional recorder head being in line with the other recorder heads.

7. A system according to claim **1**, wherein the input amplifier is connected to a microphone.

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