July 16, 1946. R. K. POTTER 2,403,997

REPRESENTATION OF COMPLEX WAVES

Filed April 14, 1942 2 Sheets-Sheet 1

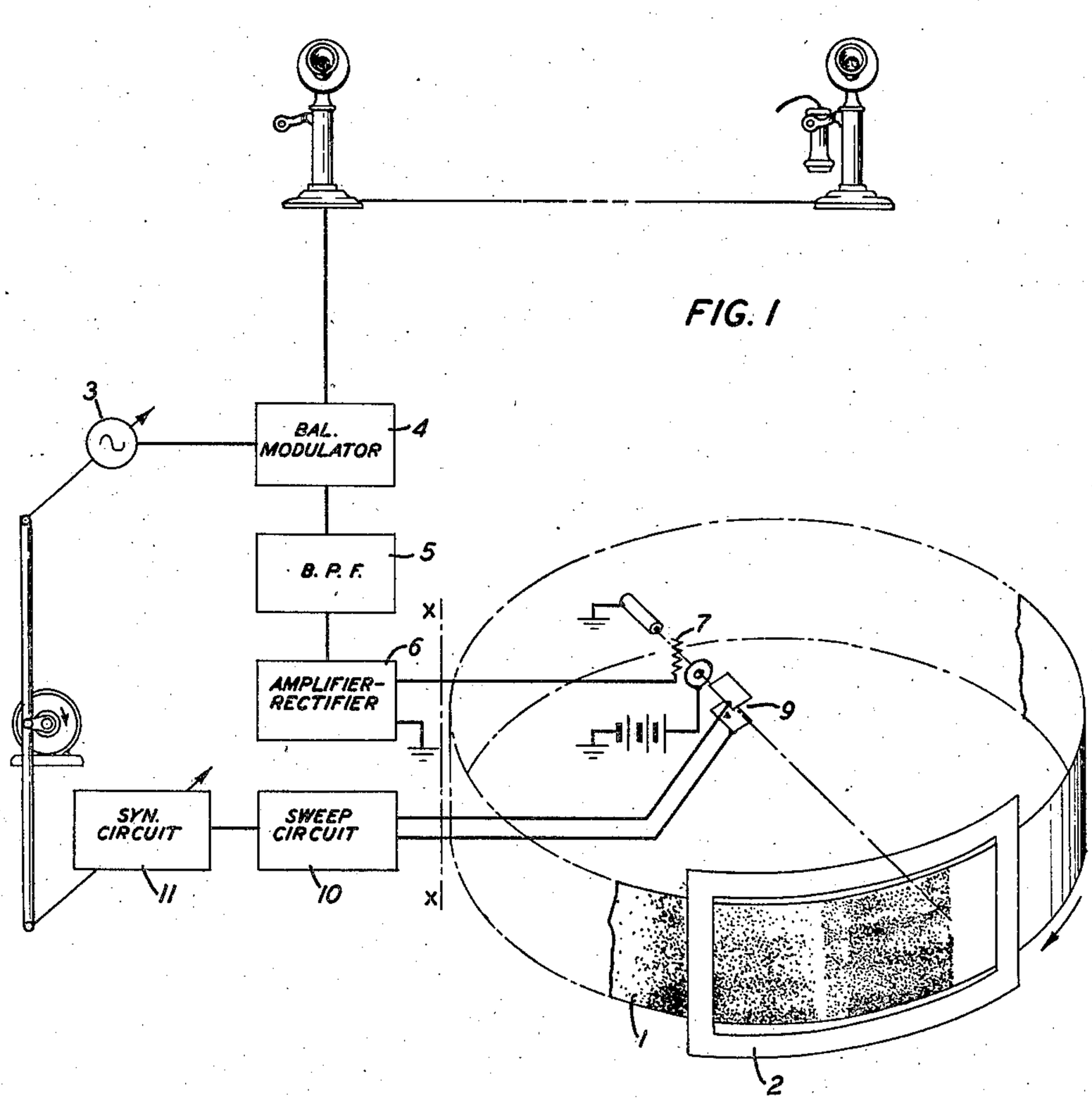
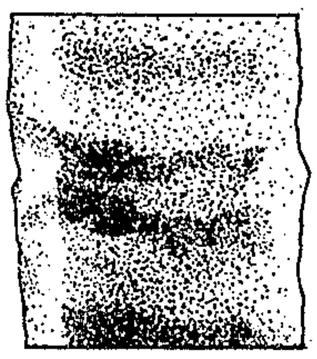


FIG. 1

FIG. 2



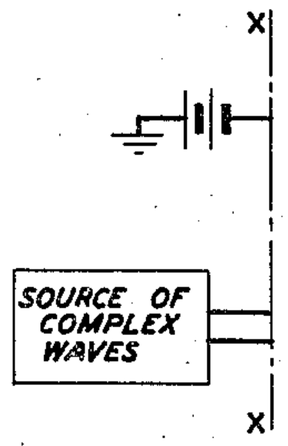


FIG. 6

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REPRESENTATION OF COMPLEX WAVES

Filed April 14, 1942 2 Sheets-Sheet 2

FIG. 4

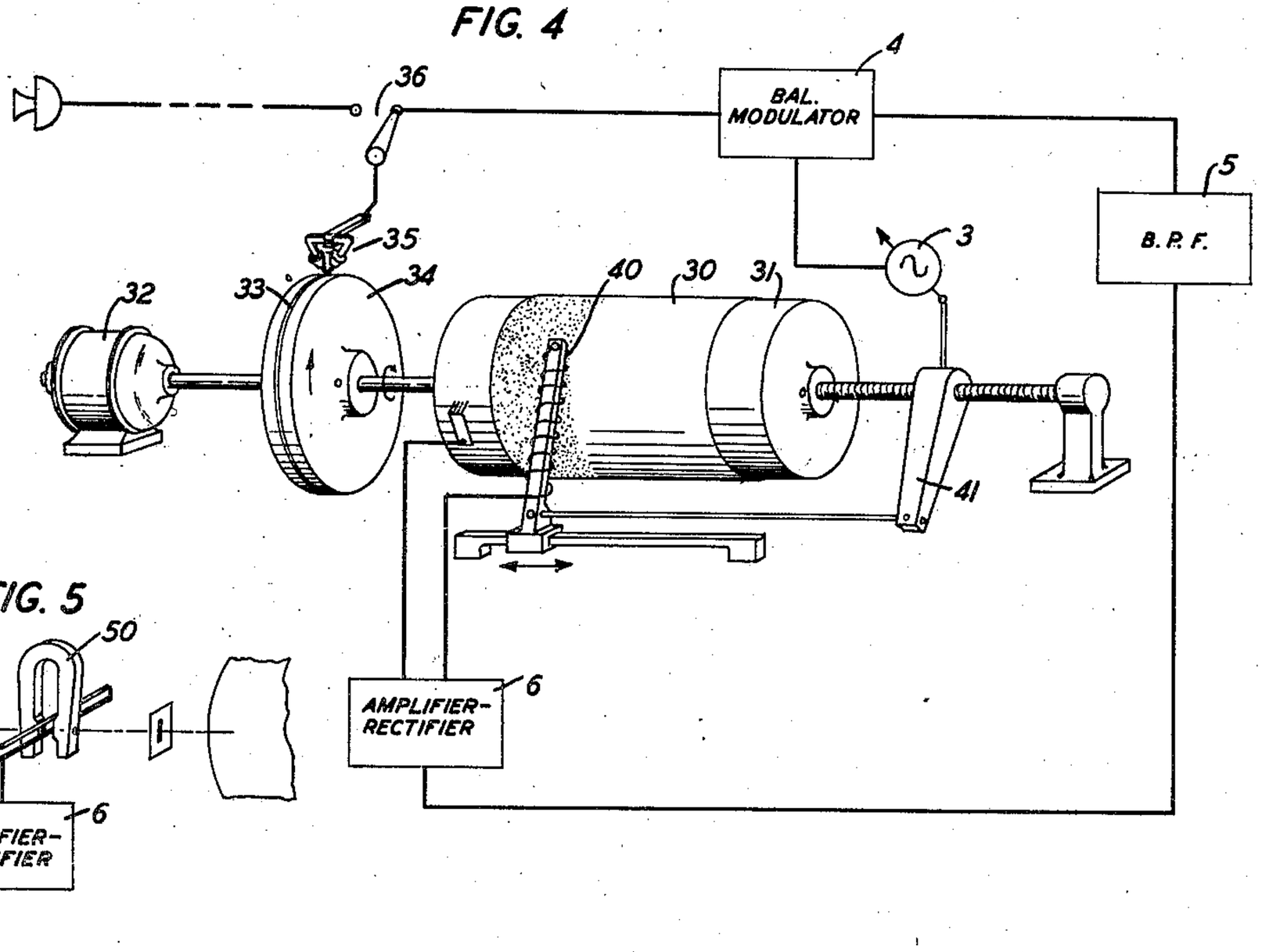


FIG. 5

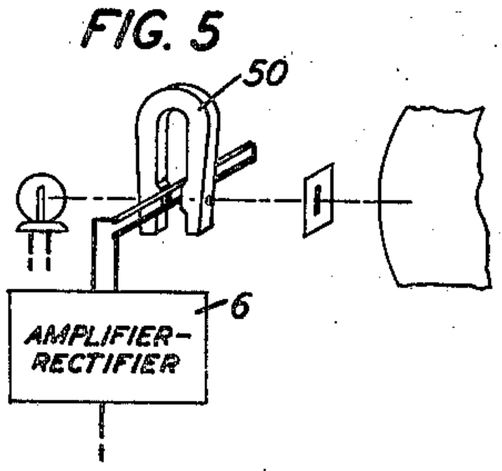
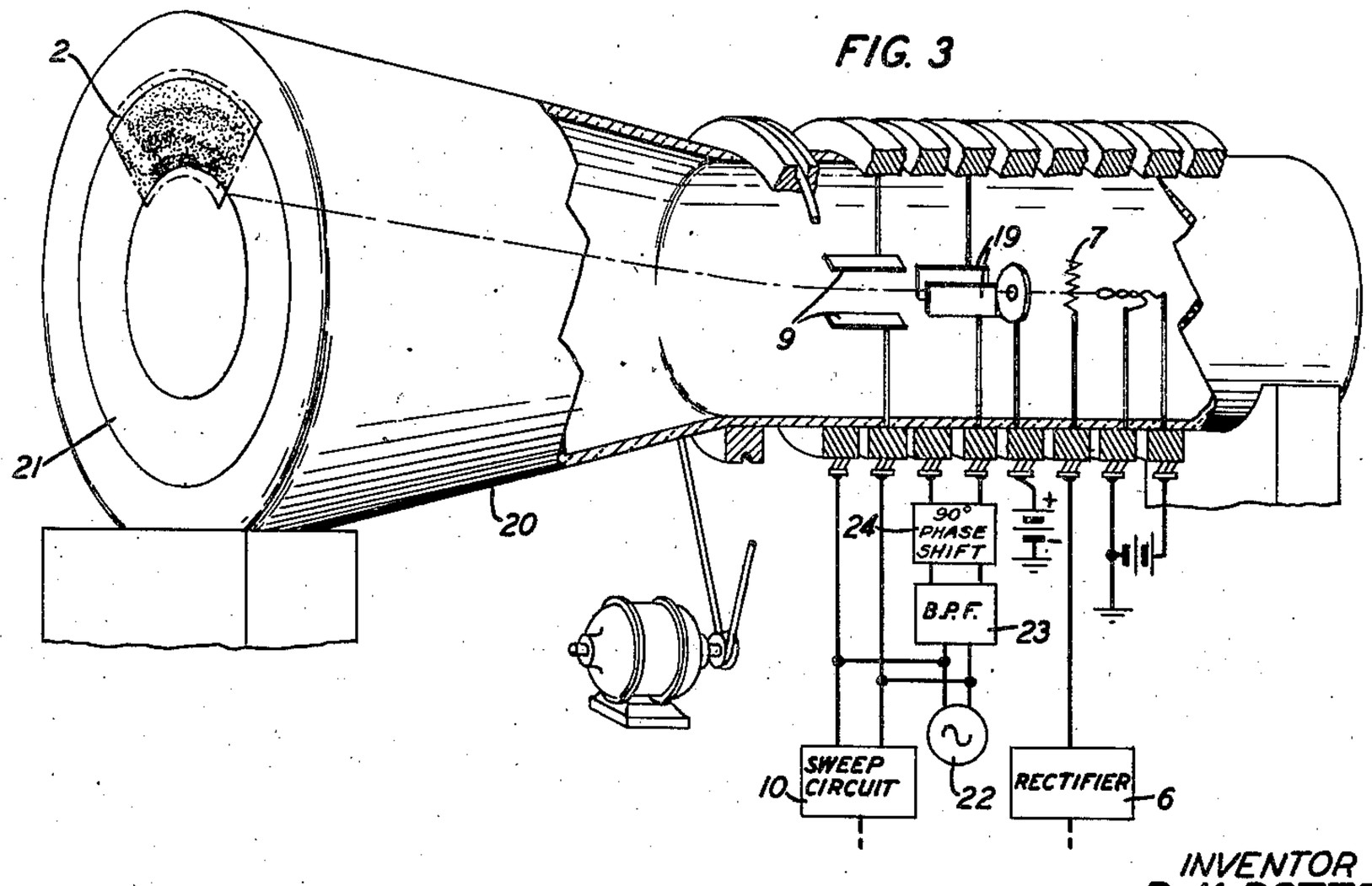


FIG. 3



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REPRESENTATION OF COMPLEX WAVES

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Application April 14, 1942, Serial No. 438,878

44 Claims. (Cl. 179—1)

1

This invention relates to the analysis, synthesis and visual representation of complex waves and more particularly, although in its broader aspects not exclusively, to the visual representation of speech waves and the like.

An object of the invention is to provide methods and means for representing complex waves in such visual form that the composition of the waves and the interrelation of the basic parameters thereof are simply and clearly revealed.

Another object is to provide methods and means for producing from signal waves, and more particularly from speech waves, a contemporaneous visual representation thereof of such character as to reveal readily the message content.

A further and related object is to produce from complex waves a contemporaneous visual representation thereof in which the passage of time is represented by uninterrupted movement.

Another and principal object of the present invention is to enable the practice of what may be called deaf telephony whereby the deaf may receive, in lieu of or in addition to the usual audible reproduction of telephone signals, a contemporaneous visual representation thereof that is susceptible of being read or interpreted in whole or in part.

Still another object of the invention is to facilitate speech education of the deaf.

In accordance with a feature of the present invention complex waves are visually represented as an integrated picture or pattern revealing the time variation in the distribution, over the frequency range occupied by the waves, of the intensity or power content. In accordance with another feature the passage of time is represented in the visual pattern along, or otherwise associated with, one coordinate, and the frequency-intensity composition at substantially any instant is represented along, or otherwise associated with, another coordinate. More particularly, time and frequency are associated with respective coordinates, thereby being represented by distance or displacement, and the intensity at any frequency and at any instant is represented by a variable, visually distinguishable attribute or parameter of the pattern other than displacement from the two coordinates whereby virtually a third dimension is obtained. In the embodiments of the invention hereinafter to be described the last-mentioned parameter is intensity, e. g., brightness or density or blackness, whereby the pattern takes on the general appearance of a half-tone picture, although it will become evident that there are

2

various other attributes, such as color for example, that are also adaptable to the purposes in view.

In accordance with another feature of the invention complex waves are contemporaneously, visually represented on a sensitized record surface, such as the luminescent screen of a cathode ray oscilloscope, and the representation is moved relative to the observer to represent the passage of time. More particularly, for example, the representation is caused to appear on a record surface having some persistence, in a viewing area that is stationary relative to the observer, the record surface being moved so that the representation appears to move continuously across the viewing area, whereby the observer may for a brief period visually correlate and compare any portion with preceding and succeeding portions.

In accordance with still another feature of the invention, complex waves to be graphically represented are stored in their original form as, for example, on a magnetic tape or phonograph record, and the stored waves are then reproduced repeatedly while on each repetition an elemental portion of the graphic representation is recorded in fine detail until the complete representation is built up.

The nature of the present invention and its various features, objects and advantages will appear more fully from a consideration of the specific embodiments illustrated in the accompanying drawings and hereinafter to be described. Although the invention will be described largely in terms of its application to deaf telephony and the like, it is to be noted that the means and method disclosed are adaptable to other uses, such as that disclosed in my application, Serial No. 438,879, filed of even date herewith, and that the scope of the invention is to be ascertained from the appended claims.

In the drawings:

Fig. 1 illustrates a system for deaf telephony in accordance with the invention;

Fig. 2 illustrates a typical visual representation obtained with the Fig. 1 system;

Fig. 3 illustrates a modification of the system shown in Fig. 1;

Fig. 4 shows a combination for recording complex waves in graphic or pattern form;

Fig. 5 illustrates an alternative detail thereof; and

Fig. 6 illustrates another embodiment of the invention.

Referring more particularly now to Fig. 1, a

voice frequency telephone system is represented schematically by a pair of telephone subscribers' stations and an interconnecting transmission line. Associated with one of the subscribers' stations is an apparatus in accordance with the invention adapted to produce contemporaneously with the transmitted speech signals a visual representation of the speech waves whereby the subscriber at that station can visually receive or read the incoming message. For those whose sense of hearing is seriously impaired but not quite lacking, the visual receiver may be used to supplement the ordinary telephone receiver so that reception is partly oral and partly visual; and in any case the visual apparatus may be so connected to the telephone system, if desired, that it is operated by both outgoing and incoming signals.

The specific visual apparatus illustrated in Fig. 1 comprises in general outline a cathode ray oscilloscope, a frequency analyzer of the heterodyne type having a narrow pass-band of continuously variable mean frequency, and associated apparatus for concurrently controlling the deflection and intensity of the cathode ray. The oscilloscope is illustrated diagrammatically as comprising an electron gun with associated control electrodes and a sensitized cylindrical screen **1** upon which the cathode ray impinges to leave a luminescent trace. The cylindrical screen is adapted for continuous rotation about its axis and the electron gun may be disposed within the screen to direct the cathode ray more or less along a diameter. Suitable structures are disclosed in considerable detail in my application Serial No. 422,194 and in that of J. B. Johnson Serial No. 422,192, both filed December 9, 1941, and the disclosures of those applications are to be deemed incorporated herein. The cathode ray is focused to a point so that it produces a luminous spot on the screen, the spot is controllably displaced across the screen at right angles to the direction of movement thereof, and the intensity of the ray is simultaneously varied to control the brightness of the spot, all in a manner and for a purpose to be described.

The oscilloscope screen has a certain degree of retentivity, that is to say, the luminous spot formed by the cathode ray persists after the ray is displaced or extinguished, and it is desirable to have the persistency or retentivity such that the spot does not substantially fade before the movement of the screen causes it to disappear from the viewing area, the latter being represented within the rectangle **2** in Fig. 1. On the other hand, however, the retentivity should be low enough that the luminescence fades substantially completely before rotation of the screen again brings it into the viewing area. Alternatively, however, the screen may have higher retentivityy and some means such as a source of infra-red waves may be used to erase the image on the screen after the image has passed the viewing area, as disclosed in the application of J. B. Johnson, supra.

The speech signals from the telephone system in Fig. 1 and beating or carrier waves from an oscillator **3** are applied to a balanced modulator **4** of the carrier suppression type and the side-bands that are produced are applied to a filter **5** of the narrow band-pass type. The narrow band of waves passed by filter **5** is applied to an amplifier-rectifier **6** the unidirectional output voltage of which is in turn applied to control grid **7** of the cathode ray tube which regulates the intensity of the cathode ray. The frequency of beating oscillator **3** is continuously and repeatedly varied over a predetermined range as by means of a motor, and in such relation to the frequency position of the band passed by filter **5** that as the frequency of the oscillator is varied from one extreme to the other, one of the side-bands produced by the modulator is swept completely across the pass-band of filter **5**. In an illustrative case the pass-band of the filter may have a mean value of about 10,000 cycles per second and a band width of 20 cycles, and the beating oscillator a frequency range of from 10,100 to 14,000 cycles. In the same case, the oscillator frequency may be varied from one extreme value to another at the rate of about 60 times per second, for example. Thus, the speech signal is scanned many times a second by the frequency analyzer and during each scanning the brightness of the spot is varied in proportion to, or otherwise in correlation with, the wave power found in each successive frequency band.

Deflection of the cathode ray in a plane at right angles to the direction of movement of the oscilloscope screen is effected by means of a pair of deflecting plates **9** and a sweep circuit **10**. The latter is synchronized with the variations in the frequency of the beating oscillator **3** by a mechanically operated pulse generator or any other suitable synchronizing circuit **11**, of which many examples are to be found in the television art, so that the voltage applied to the deflecting plates **9** is continuously increased or decreased as the frequency of the oscillator is changed from one extreme value to the other. The individual components of the Fig. 1 system are for the most part well known in the art and it will be understood that the diagrammatic showing here made is purely illustrative.

If, as indicated in Fig. 1, the oscilloscope screen moves from right to left relative to the observer the spot is made to appear at the right-hand edge of the viewing area. The sweep circuit causes the spot to move rapidly and repeatedly across the viewing area adjacent the right-hand edge thereof, the movement being, for example, either repeatedly from bottom to top if the sweep circuit produces the usual saw-toothed wave or alternately in each direction if the sweep voltage wave is of triangular form. The control grid circuit may be so biased if desired that in the absence of signals the spot is almost extinguished. Upon application of signals to the system the brightness of the spot is variably increased more or less in proportion to the intensity of the waves transmitted by the frequency scanning elements whereby the amplitude-frequency characteristic during each increment of time, i. e., during each scanning period, is recorded as a vertical band on the screen. The movement of the screen allows the vertical bands corresponding to successive increments of time to be recorded side by side, and in view of the retentivity of the screen a visible two-dimensional pattern is therefore produced. The rate of movement of the screen is adjusted in relation to the length of the viewing area and the definition in the pattern to suit the observer. In the illustrative case hereinbefore described the rate may be about an inch per second, for example, which allows several words to be represented in the viewing area at one time.

Theoretically, greater definition along the frequency coordinate can be secured by making the pass-band of filter **5** narrower, and improved definition along the other or time coordinate ac-

companies an increase in the scanning frequency. It is characteristic of band-pass filters now available, however, that the narrower the pass-band the greater the tendency of the filter to lengthen pulses applied to the input and generally to distort the amplitude-time relations in the transmitted waves, and the distortion is greater the more rapid the changes in amplitude. In practice, therefore, increased definition along either coordinate entails a sacrifice in definition along the other coordinate. Although in the specific example hereinbefore described the compromise made is such that the definition along both coordinates is substantially the same, this is not an essential condition, and in some applications of the present invention the two may be quite different.

In Fig. 2, applicant has endeavored to depict the visual representation of a single word as it might appear on the oscilloscope screen. Passage of time and the movement of the screen are represented along the horizontal axis, frequency is represented along the vertical or transverse axis, and the wave intensity at any frequency and instant of time is represented by the brightness or blackness of the pattern at the intersection of the corresponding coordinates. The pattern shown happens to be the one characteristic of the word "two." Every distinct spoken word or syllable has its own characteristic "sound pattern."

Study of many patterns reveals certain fundamental characteristics that are directly related to fundamental characteristics of speech. Regions of resonance associated with the vocal cavities, for example, appear as bright bands at different frequency levels in the patterns, or as dark bands as the pattern is depicted in Fig. 2. There are in general three predominant resonances. The resonances vary as the mouth shape, tongue position, etc., are changed, thereby producing a weaving of the bands. The resonances are most clearly distinguishable in the vocal sounds; they appear indistinctly in some of the unvoiced sounds, but are practically absent in the majority of "hiss" sounds. The latter produce a characteristic mottled appearance in the pattern suggesting a lack of harmonic relation among the components. Explosive sounds have the characteristic of click sounds in that the sudden energy is spread through the audible spectrum.

The apparatus and method herein described enable the three dimensions or parameters of speech waves that are most significant with respect to the communication of intelligence to be effectively displayed, simultaneously and in a manner providing direct and continuous correlation of the three. Two of the parameters, frequency and time, are, so to speak, spread out along dimensional coordinates or otherwise translated into terms of distance or displacement, while the third, intensity, is directly represented by brightness or other visually perceptible attribute of points in the surface to which the coordinates apply. This is in sharp contrast to the ordinary oscillographic showing of a complex wave in which the spot is displaced from the time axis in proportion to the instantaneous amplitude of the wave. In the latter case only two parameters of the wave are shown directly, both being translated into terms of displacement, and in the case of speech waves, moreover, the visual representation is ill adapted, or practically not at all, to reveal the message content of the waves. In the latter case also the record is discontinuous

whereas in accordance with applicant's invention the visual representation flows continuously across the viewing area. This feature is especially valuable for the practice of deaf telephony inasmuch as successive word patterns are collated at all times.

Whereas in Fig. 1 the screen of the oscilloscope is movable relative to the electron gun and control electrodes, Fig. 3 shows an arrangement in accordance with the invention in which all of the parts of the oscilloscope tube proper are fixed relative to each other.

In this embodiment the cathode ray is projected axially through an elongated oscilloscope tube to impinge on a disc-like or annular screen **21** at the end thereof. The oscilloscope tube is arranged for rotation on its longitudinal axis, and slip rings and brushes are utilized to connect the various electrodes to the external apparatus. Two sets of deflecting plates **9** and **19** are included whereby the ray may be deflected from the axis in planes orthogonal to each other. A low frequency oscillator **22** is connected directly to the one set of deflecting plates **9**, and through a 90-degree phase shifter **24** to the other set of deflecting plates **10**. It is well known that under these circumstances the cathode ray will produce a circular trace on the screen, the angular velocity of the spot being fixed by the frequency of the oscillator **22** and the radius of the circular trace being determined by the intensity of the oscillations applied to the plates. The angular velocity of the spot and the velocity of rotation of the oscilloscope structure are made equal and opposite to each other, whereby the spot appears to an observer to be stationary although it is actually moving relative to the screen. The position of the spot may therefore be so adjusted that in the absence of signals it appears at say the lower right-hand corner of the stationary semi-annular viewing area **2** represented by the dotted enclosure in Fig. 3.

The sweep circuit **10** of Fig. 1 is connected to the deflecting plates **9** and the latter are so oriented that the spot moves radially along the right-hand radial edge of the viewing area. A filter **23** may be interposed in the leads to deflecting plates **9** to preclude application of the sweep voltage to them. At the same time the output of amplifier-rectifier **6** of Fig. 1 is applied to the control electrode **7**. The net result is that the spot repeatedly sweeps along the radial edge of the viewing area in synchronism with the changes in the frequency of the beating oscillator **3**, while the brightness of the spot fluctuates in accordance with the time variations of wave power in the different frequency bands of the speech waves. It will be understood then that the word patterns are generated at the right-hand edge of the viewing area and appear to move slowly across it at a rate fixed by the rate of rotation of the oscilloscope. Except for its curvature the pattern obtained in Fig. 3 is essentially as illustrated in Fig. 2, for example.

For the practice of deaf telephony, speech education of the deaf, and the like, it may be desirable to record typical patterns in permanent form. The combination illustrated in Fig. 4 is adapted for this purpose and others as will presently appear.

Referring to Fig. 4, the permanent record is built up on an electrosensitive cylindrical chart **30** which is mounted on a metal-faced drum **31** rotated by a motor **32** or other suitable means. The speech currents to be represented are first

stored or recorded so that they may be reproduced repeatedly, and for this purpose a phonographic or magnetic tape recorder-reproducer is utilized. The latter is shown as comprising an endless tape **33** of magnetic material mounted on the periphery of a disc **34** that rotates with the drum **31**, and an associated magnetic recorder and pick-up device **35**. On throwing a switch **36** to the left the device **35** is connected to the source of speech signals and the signals are recorded on the magnetic tape.

On throwing switch **36** to the right the device **35** acts as a pick-up and the stored speech currents are repeatedly reproduced, once on each complete rotation of disc and drum, and applied to the input of balanced modulator **4**. The latter may be of the same type as that disclosed with reference to Fig. 1 and it is similarly supplied with beating oscillations from a variable frequency oscillator **3**. The output of the modulator **4** is applied as in the Fig. 1 system to a narrow band-pass filter **5** which leads to an amplifier-rectifier **6**, and the output of the latter is applied to a recording stylus **40**. Again as in Fig. 1 the voltage output of the rectifier **6** is at any instant a measure of the wave intensity in some speech frequency band.

Whereas in the Fig. 1 system the entire speech frequency range is scanned once during each increment of time, in Fig. 4, there is little or substantially no change in the frequency passed by the analyzer during a given repetition of the recorded signal. The frequency is progressively changed on repetition of the stored signals, however, so that referring to Fig. 2, the pattern is built up one horizontal band at a time instead of by vertical bands. The mechanism is as follows: An electrorecording stylus comprising a needle-like electrode **40** is mounted over the chart and arranged to be movable parallel to the axis of rotation. It is connected to a bar **41** which rides on a threaded portion of the rotating drum shaft whereby during each complete rotation of the shaft, or in other words on each repetition of the signal, the stylus is advanced slightly. The frequency control of beating oscillator **3** is also controlled by or otherwise correlated with the movement of the stylus so that during each repetition of the signal the oscillation frequency is changed by a small amount that is equal to or at least comparable with the band width of filter **5**. On each rotation of the drum, therefore, the stylus records the time variations in wave amplitude for substantially one narrow frequency band represented in the stored signals, and rotation continues until all of the component frequency bands have been covered.

The electrosensitive chart may comprise, for example, a titanium oxide-carbon recording paper (such as the "Teledeltos Grade H" facsimile paper of the Western Union Telegraph Company). This has, as the name suggests, a thin layer of titanium oxide on the recording face and a carbon backing. The output voltage of amplifier-rectifier **6** is applied between the metallic face of the chart drum **31** and the needle-like electrode **40**, the point of which is slightly spaced from the face of the chart. The voltage thus applied causes the portion of the chart that is directly under the electrode **40** to turn dark or blacken immediately, and the density or degree of blackness is more or less proportional to the applied voltage. In this manner variations in wave intensity are translated via the stylus into corresponding variations in density or blackness in the half-tone word pattern much as such variations are translated via an electronic stylus in Figs. 1 and 3 into corresponding variations in brightness.

In lieu of the electrosensitive chart **30** a photosensitive one may be used in conjunction with an optical recording stylus. As illustrated in Fig. 5, for example, a pencil of light may be directed to the photosensitive surface and the intensity of the light varied by a light valve **50** controlled in accordance with the voltage output of rectifier **6**. Ordinarily in this case the word patterns do not appear immediately but only on chemical development.

In the recording apparatus of Figs. 4 and 5, the pass-band of filter **5** may be made much narrower than it is in Figs. 1 and 3, for the same amount of distortion. Definition along both coordinates can be correspondingly improved.

Amplitude compression of the control voltage derived from the narrow band filter **5** is to be recommended for, inasmuch as both the oscilloscope and the recording paper have definite limits on the range of control voltages they can effectively translate into distinguishable variations in brightness or blackness, amplitude compression enables effective reproduction of intensity variations having a greater percentage range. The compression may be obtained, for example, in the amplifier section of amplifier-rectifier **6**. When speech waves are involved it may be found that even with amplitude compression the high frequency, low energy components do not register on screen or paper as effectively as components lying in the lower frequency range where most of the speech energy is concentrated. In such cases frequency discrimination in favor of the higher frequencies may be incorporated at an appropriate point in the circuit, and modulator **4** may be equalized for this purpose.

The present invention provides a new tool for educating the deaf to speak or to improve their speech. Apparatus of the kind shown in Figs. 1 and 3, for example, is adapted to give the student a definite picture of the sounds he utters which may be compared with the like word patterns produced by the instructor and used as a basis for judging the effect of changes in utterance. Alternatively the student may use as a model word pattern records of the kind produced by the Fig. 4 apparatus.

Fig. 6 illustrates an application of the invention to ordinary oscillographic work in which, in sharp contrast with the usual system employing a sweep circuit for introducing the time factor, the line trace of the applied waves is continuous, that is, uninterrupted with respect to the time dimension. As shown, the source of waves may be connected directly across the deflecting plates **9** of the Fig. 1 oscilloscope whereby a continuous trace of instantaneous wave amplitude versus time is obtained on the screen. The control electrode **7** is held at a fixed biasing potential and the rate of movement of the screen is adjusted to give whatever time scale is most convenient for the purpose at hand. The waves or other electrical effects to be represented may be of substantially any character, as for example, cardiac waves, telegraph code signals, speech waves, etc.

What is claimed is:

1. The method of pictorially representing speech-bearing waves in the form of a half-tone pattern on a record surface which comprises assigning to said surface dimensional coordinates

representative of time and frequency respectively, and impressing at substantially each point on said surface a visual record the intensity of which is graded according to the intensity which the speech wave component represented by the frequency coordinate of the point has at the instant of time represented by the time coordinate of the point.

2. In a system comprising a sensitized surface and means for variably marking said surface substantially point by point, the method of visually representing the inter-relation of the following three parameters of a complex wave: frequency, wave intensity at a particular frequency, and time, which method comprises effectively displacing the marking means across said surface progressively in one direction and simultaneously and repeatedly in another direction crosswise of said one direction, the two coordinates of each position of said marking means being respectively representative of the values of two of said parameters, and varying the mark made at such positions according to the respective associated value of the third parameter.

3. The method which comprises receiving speech-bearing waves, translating the said waves contemporaneously with their reception into a transient visual representation in the form of a pattern portraying the varying frequency composition of said waves, the dimensional coordinates of said representation having the significance of a frequency axis and a time axis, respectively, and the character of the representation at each coordinate position being correlated with the effective intensity of a particular frequency component at a particular time indicated by the coordinates of each such position.

4. The method of deaf telephony which comprises receiving speech-bearing waves, continually subjecting the received waves to frequency analysis, and translating the analyzed waves, substantially simultaneously with their reception, into a half-tone pattern having dimensional coordinates respectively corresponding with frequency and the passage of time, the said pattern differing in tone from one part thereof to another in correlation with differences in the wave power that appears in the analyzed waves at the respective frequencies and times indicated by the coordinate positions of such parts.

5. The method of depicting speech-bearing waves in a predetermined viewing area which comprises receiving the said speech-bearing waves, assigning successive laterally adjacent bands extending in one coordinate direction across said area to respective progressively different speech frequency bands, and continually generating in each of said adjacent bands, substantially simultaneously with the reception of said waves, a transient visual representation that varies along the length of each of said bands in correlation with the varying average wave power appearing in the frequency band respective thereto.

6. The method defined in claim 5 in which the said representation is generated at points in said adjacent bands that are fixed relative to said viewing area and in which the representation is advanced uninterruptedly in another coordinate direction to maintain the representations last generated within the viewing area.

7. The method which comprises receiving waves having a multiplicity of energy components of variable effective intensity, continually analyzing

the received waves to determine the relative frequencies and effective intensities of the several components present at any time, generating from the analyzed waves, substantially contemporaneously with their reception, a visual representation thereof in a predetermined stationary viewing area, successive positions in one direction across said viewing area respectively corresponding to successive different frequencies and the character of the representation being varied in the said direction across the area to depict differences in the effective intensities of the said components, and advancing the said representation across the said viewing area continuously in a direction crosswise of the first-mentioned direction to maintain in view the representation of the wave portions last received.

8. The method which comprises receiving variable complex waves, continually deriving from the received waves separate effects each dependent on the amount of wave energy in a predetermined frequency band within the frequency range of said complex waves, and continuously generating, contemporaneously with the reception of said waves and under the control of the said derived effects, a visual representation of the said waves in which one of the dimensional coordinates of the representation has the significance of a frequency axis.

9. In a system for the creation of a visual representation of complex waves, means providing a sensitized surface on which the visual representation is to be formed, stylus means for producing at any point on said surface a visible impression of controllable intensity, means operative on said stylus means for moving the point of impression progressively in one direction across said surface and repeatedly in a crosswise direction from one predetermined limit to another, successive positions in one of said directions being individual to respectively different frequencies within a predetermined frequency band including said complex waves and successive positions in the other of said directions being individual to respectively different instants of time, and means for continually varying the intensity of the impression made by said stylus means during the aforesaid movement comprising means for deriving from said complex waves and applying to said stylus means a control effect representative of the wave intensity at the frequency and instant corresponding to each successive position of the point of impression.

10. In combination with a sensitized surface and stylus means relatively movable over said surface for impressing a visual representation thereon, means for causing said stylus means systematically to traverse the entire said surface with simultaneous progressive movement in a first direction and continually repeated excursive movement in a second direction transverse to the first direction, means for selectively receiving the different frequency components of a complex wave, and means for regulating the intensity of the impression made by said stylus means at each point on said surface according to the intensity of a selected frequency component the frequency of which is correlated with the displacement of said point along one of said directions of movement.

11. A device for forming a picture representative of the composition of speech-bearing waves comprising frequency scanning means for selecting in succession the various frequency components of said waves, means providing a sensitized

surface on which the picture is to be formed, stylus marking means relatively movable across said surface along a predetermined course covering substantially every point in a predetermined area on said surface, means for coordinating the relative movement of the said marking means along said course and the successive selection of the various frequency components whereby each point along said course is identified with a particular frequency component, and means for varying the character of the mark made by said marking means under the control of the selected components.

12. The method of depicting complex waves which comprises recording the frequency-intensity composition of said waves at substantially a given instant as a line differing in brightness along its length, each point along said line being individual to a particular frequency component and the brightness at each said point being correlated with the intensity of the frequency component individual thereto, and similarly recording the frequency-intensity composition at successive instants of time as laterally contiguous lines, with the points individual to the same frequency components being in registry with each other.

13. In a system comprising a record surface and a recording stylus, the method of depicting on said surface the time variations in the frequency-intensity composition of a complex wave which comprises displacing said stylus relative to said surface progressively in one direction as a function of time and repeatedly across said one direction through successive positions that are preassigned to respective different frequency components of the complex wave, and during each repeated displacement varying a visually distinguishable attribute of the recording to mark at each successive position the intensity of the respectively corresponding frequency component.

14. In combination with a source of complex waves, frequency discriminatory means for deriving from each frequency component of the said waves a measure of its intensity, an oscilloscope including a luminescent screen and means for producing a luminous spot of controllable position on said screen, means for displacing said spot in one direction across said screen to successive positions that are preassigned to respective different frequency components, means including said first-mentioned means for fixing the brightness of said spot at each instant according to the intensity of the frequency component that is respective to the position occupied by the spot at that instant, and means for establishing relative movement between said spot and said screen in another direction.

15. In combination, frequency selective wave translating means for cyclically scanning a predetermined frequency range, an oscilloscope comprising a luminescent record surface and electronic stylus means for producing a luminous spot of controllable position on said record surface, means for moving the spot on said surface along a multiplicity of laterally adjacent paths in succession, means for synchronizing the movement of the spot with the aforesaid cyclical scanning, and means for varying the brightness of the spot under the control of the wave output of said translating means.

16. In combination, means for receiving waves lying within a predetermined frequency range, frequency analyzer means for scanning said frequency range many times per second, an oscilloscope comprising a luminescent record surface, means for directing an exciting beam against said surface to produce a luminous spot thereon and means for controlling the position of the spot on said surface, means tending to move said spot progressively and repeatedly around a closed path on said record surface including means for rotating at least the record surface of said oscilloscope, means for simultaneously moving said spot crosswise of said path many times per second in synchronism with the said scanning of the frequency range, and means for varying an attribute of said spot under the control of said frequency analyzer means.

17. In combination, means for receiving electric waves lying within a predetermined frequency range, frequency selective wave translating means connected thereto having a narrow band-pass characteristic, means for effectively sweeping the pass band of said selective means periodically across the said frequency range, a cathode ray oscilloscope comprising a luminescent screen, means for deflecting the cathode ray in one direction from one predetermined limit to another periodically in synchronism with the periodic sweeping of the pass band of the said wave translating means, means for simultaneously displacing the cathode ray relative to said screen in another direction and at a relatively gradual rate, and means for modulating said cathode ray under the control of the output of said wave translating means.

18. A combination in accordance with claim 17 in which said means for displacing the cathode ray in the said other direction includes means for moving at least the said luminescent screen of the oscilloscope continuously in a single directional sense whereby the luminous record made by the cathode ray appears to an observer to flow uninterruptedly in the said directional sense.

19. In combination with a source of complex waves, an electric discharge device comprising a luminescent screen and means for projecting a beam discharge against said screen, means for continuously moving said beam relative to said screen along a predetermined path, means for simultaneously, cyclically moving said beam crosswise of said path, means for deriving from said complex waves a control effect that varies in the course of each of successive crosswise movements of the beam as the wave energy varies across the frequency range from one to another of progressively different frequency bands occupied by said waves, means for variably controlling the intensity of said beam in accordance with said derived control effect, and synchronizing means connecting said means for cyclically moving the beam and said means for deriving the control effect.

20. In combination with a source of complex waves, an electric discharge device comprising a luminescent screen and means for projecting a beam discharge against said screen, means for continuously moving said beam relative to said screen along a predetermined path, means for simultaneously, cyclically moving said beam crosswise of said path, means for deriving from said complex waves a control effect that varies in the course of each of successive crosswise movements of the beam as the wave energy varies across the frequency range from one to another of progressively different frequency bands occupied by said waves, means for variably controlling the intensity of said beam in accordance with said derived control effect, and synchronizing

means connecting said means for cyclically moving the beam and said means for deriving the control effect, said means for deriving a control effect from said complex waves comprising frequency analyzer means for cyclically scanning said complex waves.

21. In combination, wave receiving means including frequency band selecting means for cyclically scanning a predetermined frequency range, an oscilloscope comprising a luminescent screen and electric discharge means for generating a luminous spot on said screen, means for moving said spot cyclically across said screen in synchronism with the aforesaid cyclical scanning, means establishing progressive relative movement of said spot to represent the passage of time, and means controlling a parameter of said spot in accordance with a parameter of the output of said scanning means.

22. The method of forming a graphic representation of speech bearing waves which comprises storing said waves, deriving from the stored waves individual measures of the manner in which wave intensity varies with time in respectively corresponding component frequency bands thereof, and graphically recording the aforesaid manner of variation in substantially contiguous parallel lines individual to the said component bands, including the method step of varying a visually distinguishable attribute of the recording in each of said lines in correlation with the time variation in the respectively corresponding measure.

23. In a system comprising a record surface and recording stylus, the method of deriving a graphic representation of complex waves which comprises storing said waves, repeatedly reproducing the stored waves, imparting to said stylus two components of motion relative to said record surface, one being progressive movement in a predetermined path across said surface and the other being movement cyclically across said path synchronized with the repetitions of the stored waves, and varying the intensity of the recording in accordance with the time variations in the intensity of successively different frequency components of said waves.

24. A complex wave pattern recorder comprising means for storing in reproducible form the complex waves to be recorded, means for repeatedly reproducing the stored waves, a record surface, stylus marking means in marking relation to said surface, means for moving said stylus marking means relative to and across said surface along a multiplicity of laterally adjacent paths in succession at a rate such that each path is traversed once while the stored waves are reproduced once, means for selecting a frequency component from the reproduced waves, means for progressively changing the selected component while the stored waves are being repeatedly reproduced, and means for varying the mark made by said stylus under the control of the selected component.

25. A speech pattern recorder comprising a record surface on which the pattern is to appear, stylus means disposed in printing relation to said surface, means for establishing relative movement between said stylus means and said record surface such that said stylus means traverses a multiplicity of laterally adjacent bands on said surface, the last-mentioned bands being respectively individual to the several component narrow frequency bands in the speech waves to be recorded, means for deriving from the said speech

waves respective measures of the intensity variation in the several frequency bands, and means operative on said stylus means for varying the intensity of the print along each of said last-mentioned bands under the control of the respectively corresponding derived measure.

26. A recorder comprising a record surface, printing stylus means for printing on said surface, means for receiving complex waves to be visually represented on said surface, means for selecting the different frequency components of the received waves, means for relatively moving the said stylus means over the said surface along a predetermined course covering a multiplicity of substantially contiguous bands that are respectively individual to the several frequency components, and means controlled by said selecting means for regulating the intensity of the print made by said stylus means at any point on the surface according to the intensity of the selected frequency component corresponding to the particular band that passes through that point.

27. A speech pattern recorder comprising a record surface, a recording stylus in operative relation thereto, means for progressively moving said stylus relative to said surface along a fixed path such as to cover substantially all points of a predetermined area on said surface, said area comprising a multiplicity of collateral bands each of which is respective to a particular speech frequency and each point along every said band being respective to a particular instant of time, and means under the control of applied speech waves for automatically adjusting the intensity of the recording made by said stylus at each point along its path according to the intensity which the speech frequency respective to the band in which the point lies has at the instant of time corresponding to the position of said point in the band.

28. A system for the production of a visual representation of complex waves comprising a recording of the said waves, means for cyclically reproducing the waves from said recording, a record surface on which the visual representation is to be produced, stylus means in marking relation to said surface, means for effecting movement of said stylus means relative to said surface along a predetermined course covering substantially every point of a predetermined area on said surface, said movement comprising a steady progression in one direction across said area with cyclically repeated excursions crosswise of said direction, means for synchronizing said cyclically repeated excursions and the cyclical reproduction of said waves, and means for varying the mark made by said stylus means during successive excursions under the control of successively different frequency components in the said waves.

29. The method of forming an image graphically representing speech-bearing waves which includes the steps of storing said speech-bearing waves in reproducible form, repeatedly reproducing the stored waves, selecting progressively different component frequency bands from the reproduced waves during respectively corresponding successive reproductions of the said waves, and during each reproduction registering the variations in energy content appearing in the respective selected band along a preassigned strip-like portion of a surface on which the image is to be formed, said strip-like portions being side by side and each being respective to a particular one of the said frequency bands.

30. In combination, means for storing complex waves in reproducible form, means for repeatedly reproducing the stored waves, filter means adapted to select a component frequency band from the reproduced waves, means for shifting the frequency band that is selected by said filter means at any time continuously across the frequency range while the stored waves are repeatedly reproduced, and means responsive to the wave effects selected successively by said filter means for visually representing the composition of said waves.

31. A speech wave record comprising a record surface and a visual representation of the varying frequency composition of a speech wave recorded thereon, each elemental area of the representation being respective to a predetermined speech frequency band and a predetermined time interval, and the density of the recording in each such elemental area being graduated according to the amount of wave energy that appears in the frequency band respective to the area during the time interval respective to the area.

32. A record surface having a pattern representative of a sound wave recorded thereon, every successive point in one coordinate direction across the surface being substantially respective to a predetermined different frequency in the frequency range occupied by the recorded sound waves, and successive points in another coordinate direction across the surface being respective to successive instants of time.

33. A record surface having a helf-tone pattern representative of a complex wave recorded thereon, one dimensional coordinate of the surface constituting a time axis and another dimensional coordinate of the surface constituting a substantially continuously scaled frequency axis, and the intensity of the recording at each point on said surface being graded according to the effective intensity of the particular frequency component at the particular instant of time corresponding to the coordinates of the point.

34. A record surface having a complex wave recorded thereon in the form of a pattern in which the intensity of the recording varies from point to point substantially continuously in both coordinate directions across said surface, the intensity of the recording at different points across the pattern in one coordinate direction being substantially continuously graded according to the wave power content at respectively corresponding predetermined different frequencies in the frequency band occupied by said complex wave.

35. A sound wave record in which the recording is in the form of a half-tone pattern that comprises a multiplicity of laterally contiguous bands respectively individual to predetermined different frequency bands which together embrace substantially every frequency in the range of frequencies occupied by the recorded sound wave, the recording varying along each of said contiguous bands to represent the varying wave power content in the corresponding frequency band.

36. A record surface having a sound wave recorded thereon in the form of a pattern in which laterally adjacent bands are individual to successive increments of time and in which the recording varies continuously from point to point along each of said bands as the wave power content varies from frequency to frequency in the recorded sound wave.

37. A record surface that bears a recording of a wave of variable frequency composition, the recording being in the form of a pattern and all of the various frequency components of said wave being represented by respective laterally contiguous band-like regions in the said pattern, and the character of the recording in each of said band-like regions varying along the length thereof in correlation with the time variations in the effective intensity of the respectively corresponding frequency component.

38. A record that bears a visual representation of speech waves in the form of a pattern depicting substantially the varying manner in which the wave power is distributed across the frequency range occupied by said waves, successive positions crosswise of said pattern representing the progressively different frequencies constituting said range, successive positions lengthwise of said pattern representing successive instants of time, and a visually distinguishable attribute of the representation being graded, both crosswise and lengthwise of the pattern, to indicate at each of such positions the relative wave power at the time and frequency appertaining thereto.

39. A record having a surface with a visual representation of speech-bearing waves thereon, the dimensional coordinates of said surface having substantially the significance of frequency and time respectively and each elemental area of said representation being substantially respective to a predetermined speech frequency band and particular time, an attribute of the representation being graded across said surface to depict for each area the relative power content that appears in the frequency band respective to that area at the time respective to that area.

40. A record that bears a visual representation of speech waves in the form of a pattern depicting substantially the varying manner in which wave power is distributed in the frequency range occupied by said waves, one of the dimensional coordinates of said record constituting a time axis and another dimensional coordinate of said record constituting a frequency axis, the representation varying from one region to another across said record in accordance with the relative variations in the wave power that is present at the frequencies and times indicated by the coordinate positions of said regions.

41. A spectrographic record of speech-hearing waves in which the dimensional coordinates of the record substantially constitute wave frequency and time axes, respectively, whereby each elemental area of the record represents a particular frequency band and particular time, the character of the recording differing visibly from any one such area to another as the effective wave intensity in the particular frequency band at the particular time represented by the one such area differs from the effective wave intensity in the particular frequency band at the particular time represented by the other such area.

42. A record having a surface that carries a spectrographic representation of speech-bearing waves, said surface comprising a multiplicity of laterally adjacent, longitudinally extending regions each respective to a different frequency band, all of said frequency bands together embracing the frequency range occupied by said waves, the character of the representation varying visibly along the length of each such region in correlation with variations in the effective wave intensity in the frequency band respective thereto.

43. A record having a surface that carries a spectrographic representation of speech-bearing

waves, said surface comprising a multiplicity of laterally adjacent, longitudinally extending regions in each of which the character of the representation varies visibly along the length of the region in correlation with variations in the effective intensity of the speech wave components appearing in a preassigned frequency band, the representations in the several regions that pertain to the same time interval being substantially in alignment crosswise of the record.

44. A record bearing a visual representation of speech waves in which the transverse dimension of the record has the significance of a frequency

axis and the longitudinal dimension has the significance of a time axis, said representation being characterized in part by distinctly defined areas respectively corresponding to the principal resonances associated with the vowel sounds in said speech waves, the relative positions of said areas transversely of the record differing according to the differing frequencies of resonance, and the relative position and extent of each such area longitudinally of the record corresponding to the relative time of appearance and duration of the respective corresponding resonance.

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