

Nov. 28, 1939.

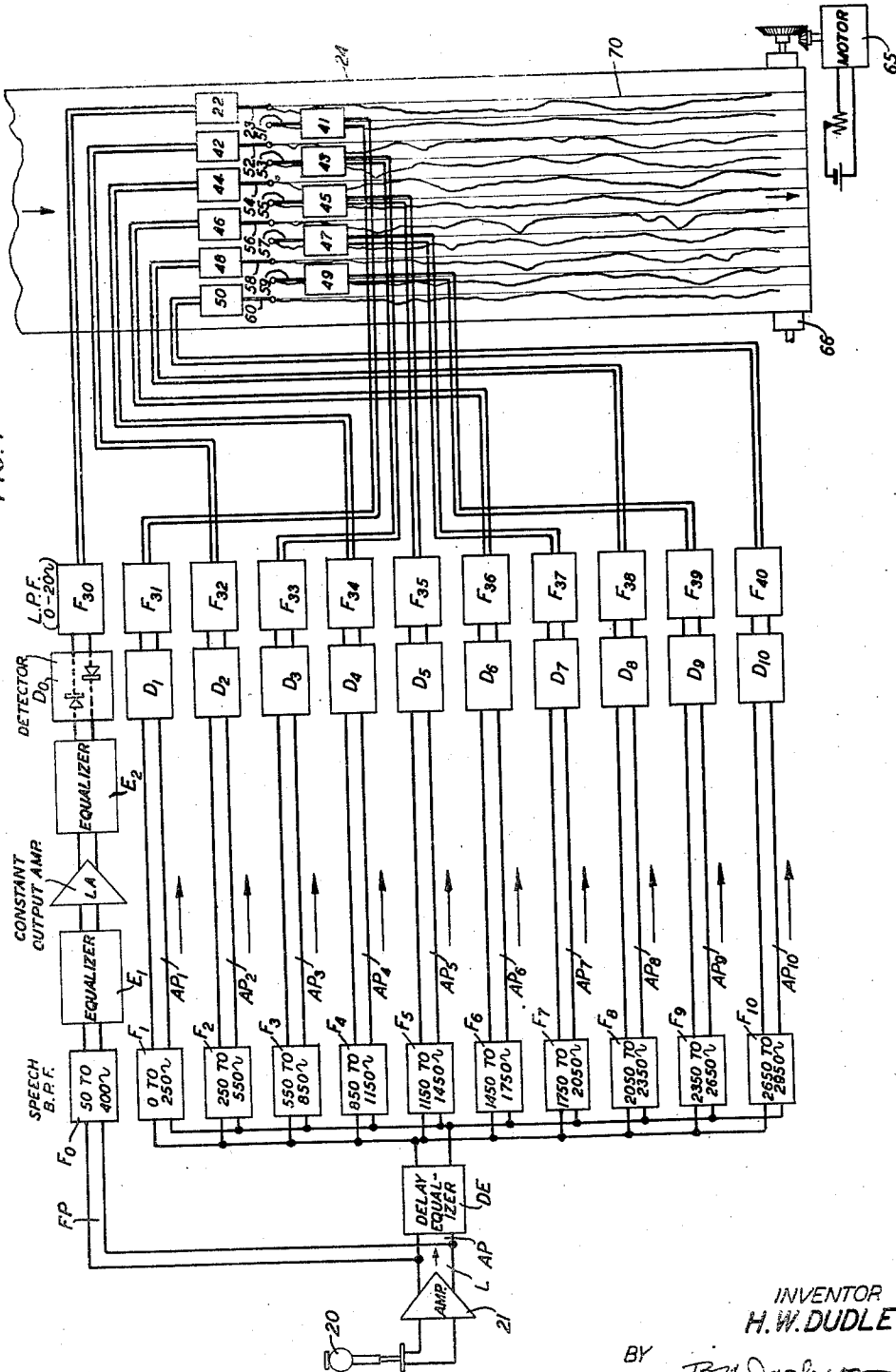
H. W. DUDLEY
SIGNALING SYSTEM

2,181,265

Filed Aug. 25, 1937

2 Sheets-Sheet 1

FIG. 1



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2 Sheets-Sheet 2

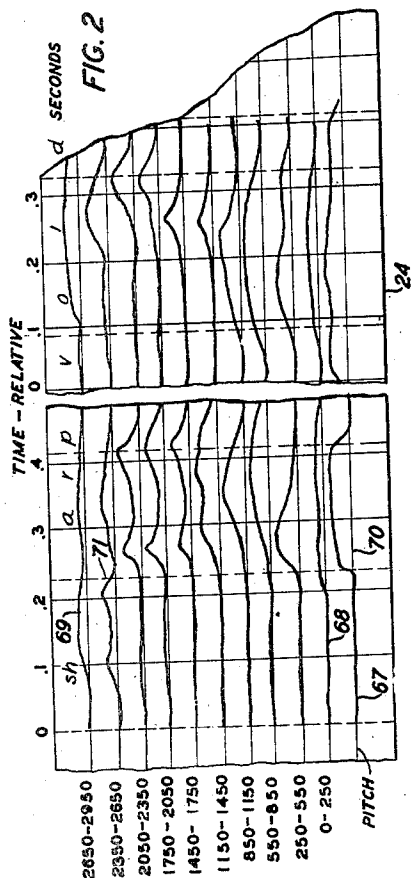
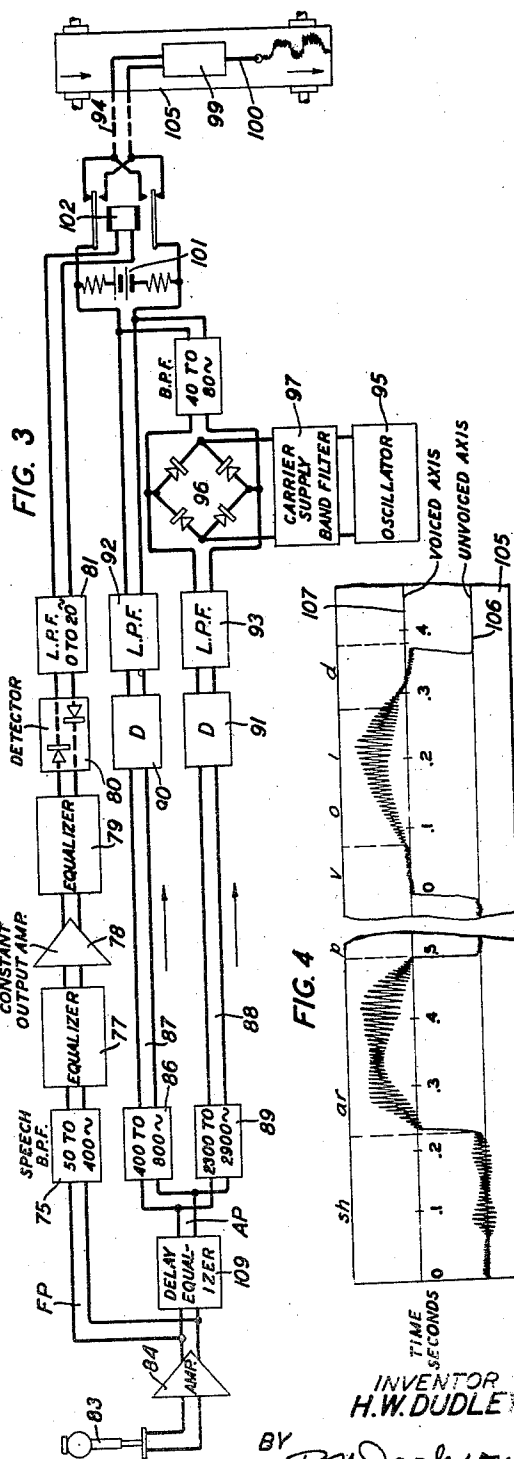
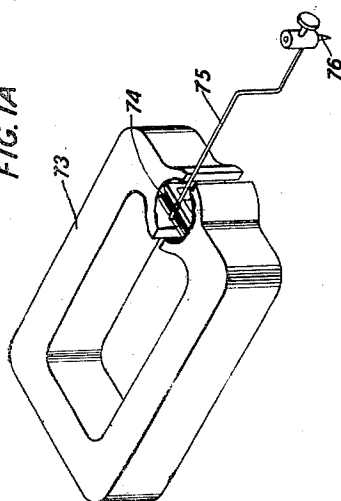


FIG. 1A



UNITED STATES PATENT OFFICE

2,181,265

SIGNALING SYSTEM

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11 Claims. (Cl. 179-100.1)

This invention relates to signaling systems and has for its main object to provide apparatus for making a visual record of a complex speech frequency message in a form capable of being readily interpreted by the eye.

In the two most common forms of speech communication the spoken word when received by the ear gives complete information, while the other, the written word, gives only partial information to the eye. This partial information conveyed to the eye by the written word insures the transmission of intelligence as far as the word content goes, but it omits all those things that enter into the voice, such as stress, intonation, duration, brogues and accents, slurring and weakening of sounds and the various other characteristics which go to make up speech. The limitations of the written word are obvious when one considers that the production of speech sounds corresponds to varying six or more elements of the vocal system, such as the lung pressure, the vocal cord tension, the position of the lips, teeth, front and rear tongue and uvula, while the written word corresponds to using a single variable to transmit the information.

In its preferred embodiment, this invention provides means for producing a visual record which gives more complete information about the nature of the message than is obtainable from the written word; more particularly to provide for the eye in a form capable of ready interpretation a record giving approximately as complete information as to the character of the message as the ear receives from the spoken word. Preferably, in accordance with this invention, the complex speech signal is not recorded directly, but is first reduced to a low frequency range (from 0 to 20 cycles, for example) without losing any of the defining characteristics of the speech message. With this frequency reduction of the message to a low frequency range the visual record may be more readily read or interpreted by the viewer than would be possible if the record covered the entire speech frequency range. The invention may, therefore, be regarded as an improved type of telegraphized speech.

The information transmitted by speech does not absolutely require all of the frequency space allotted to it by the human voice. A specific case can be worked out as to how wide a frequency band is required as a minimum, for example, by determining and taking account of the number of independent variables or parameters involved in speech production, (that is, the number of the independently movable physical elements

of the vocal system that are involved in speech production); and the rate at which these vary. Speech signals satisfy the condition for possible frequency range reduction in an outstanding manner for in one stage of speech production, namely, the muscular, there is a very simple set of controlled motions of the muscular parts making up the speech signal. Several muscular elements move to form a speech signal, but their rates of motion are the slow muscular or syllabic frequency rates. As an example, the lips move for ordinary speech at a cyclic rate not ordinarily exceeding 7 cycles per second for the fundamental or basic motion. Several other parts of the vocal system, such as the lungs, uvula, tongue, and teeth move also, but they too move at slow rates not ordinarily exceeding 7 complete cyclic changes per second.

However, there are two types of change oscillatory in nature that have motions occurring at much higher rates than 7 cycles per second, but even these two types have a basic rate of change of not over 7 cycles per second. The first motion at a higher fundamental frequency is that of the vocal cords where the fundamental frequency for men is around 125 cycles per second and for women over 200 cycles per second. This motion differs from the others mentioned in that it is a natural frequency of stretched cords. The tension of the cords is controlled voluntarily and can be changed only at slow muscular or syllabic rates. The vocal cords not only have a high fundamental frequency but they also give a wave shape which is rich in harmonics up to several thousand cycles per second. The vocal cords have a steady energy source in the lung pressure which produces air vibration at their natural frequency depending upon the tension to which they are stretched, but this tension can change only at a slow rate generally not exceeding 7 cycles per second.

The second type of high frequency energy source in speech production may, for convenience, be called a stricture. This stricture or closing with air forced through to form a hissing sound may occur between the lower lip and upper teeth as for the "f" sound or between the tongue and front part of the hard palate as for the "s" sound, or at other places for other unvoiced or breathed sounds. Such sounds have a continuous frequency spectrum with no definite fundamental frequency. It will be noted that in all such unvoiced sounds the volitional control is again applied at the low frequency muscular or

syllabic rate, generally not exceeding 7 cycles per second.

From the foregoing detailed discussion of the mechanics of speech sound production, it is seen that the various speech sounds are produced by voluntarily controlled variations in the muscular systems at slow syllabic frequency rates of 7 cycles per second or less. The important muscular elements or variables used in speech production are eight in number as follows: lung pressure; vocal cord tension and position; rear mouth resonance chamber; front mouth resonance chamber; opening from front to rear resonance chamber; mouth opening; position of uvula; position of any stricture in the sound path.

Since the important muscular variables are only eight in number, it is seen that the total frequency range required to produce sounds for the vocal systems is very limited, it being limited in fact to the number of such variables multiplied by the frequency range required to express the motion of each, which may be about 14 cycles per second if the reasonable assumption is made that the fundamental rate of change plus its first upper harmonic defines the motion reasonably well.

A simple ideal system for frequency range reduction in speech would be to analyze the speech sound to determine what the important motions are and then prescribe a narrow frequency band, say, of 20 cycles in width to define each motion, but it is difficult, if not impossible, to do it in this simple way because of the analyzing difficulties. Thus, for example, it is very difficult to determine from a speech sound just what position the tip of the tongue had in its production. However, it is reasonably simple to do this by the use of equivalent parameters. So long as the parameters are entirely independent we know mathematically that we can use any parameters we choose. Not only can they be chosen in any fashion provided they are independent, but if they are not entirely independent, more parameters can be chosen to make up for the lack of independence. Thus, as an example, the sounds can be analyzed into independent variables that are easily determined such as the power in each of several small frequency subbands within the speech range. The power in each subband is not entirely independent of that in the others, but is sufficiently so that the average power level in say eight or ten subbands of the speech range will give us a very satisfactory set of parameters for speech definition. This analysis of the power level in small frequency subbands is preferably done electrically by circuit arrangements described hereinafter.

In one specific aspect of this invention the speech message is analyzed electrically for its fundamental frequency and the average power in properly chosen subbands of frequency. In analyzing for the fundamental frequency a unidirectional current is produced whose magnitude defines the frequency of the fundamental frequency and whose magnitude varies with the syllabic rate of change in the fundamental frequency. The magnitude of the unidirectional current will also be indicative of the presence of any unvoiced sounds which, having no definite fundamental frequency, will result in a substantially zero value of the defining unidirectional current. An analyzer may also be arranged to produce separate unidirectional currents each defining the average power level in a chosen subband of the frequency range of the message.

These defining unidirectional currents in accordance with the preferred form of this invention are impressed upon separate recording devices having needles arranged to make a written record on a moving strip of paper either in the form of a scratch on the surface or in the form of an inked or pencilled line. The plurality of separate records so formed may be viewed collectively and readily interpreted after a little training. Providing there is a defining current for the average power level in, say, eight to ten subbands of the speech frequency range the visual record produced in the above manner will give to the viewer substantially as complete information as if the viewer had heard directly the spoken word. This composite record will also be much more readily interpreted and understood than if one attempted, without frequency range reduction, to make directly a single record of the complex speech wave for the entire frequency range of speech.

The present invention is therefore particularly adapted for conveying information to the deaf since the information is far more complete than could be obtained by lip reading or by the written word. Other uses, however, are contemplated such as a substitute for the existing type of telegraphy where the telegraph record comprises merely a single variable usually a series of dots and dashes according to a particular code.

Referring to the drawings:

Fig. 1 is a schematic circuit embodying one form of this invention for making an accurate visual record of a speech message;

Fig. 1A is a fragmentary view of a type of recording device which may be used in the system of Fig. 1;

Fig. 2 is illustrative of the type of record obtained for certain spoken words by the use of the apparatus of Fig. 1;

Fig. 3 is a simplified form of the invention; and

Fig. 4 is a representative record obtained by the system of Fig. 3.

Speech may be regarded as having a dual characteristic. On the one hand we have fixed parts or elements setting up oscillatory waves containing high frequency patterns. On the other hand we have varying parts or elements setting up modulatory waves of low syllabic frequency pattern. The fixed features include (a) the existence of definite frequency subbands in which the power distribution is uniform at any given instant; (b) the existence of a frequency spectrum that alternates from a continuous type of spectrum with no definite fundamental frequency to a discrete type with varying fundamental and with all the upper harmonics always present; and (c) the fact that time variations of the fundamental frequency and of the power in the frequency subbands occur only at syllabic frequency rates. The variable features include (a) the magnitude of the average power at each subband and (b) the nature of the signal spectrum as to whether it is continuous or discrete and in the latter case the frequency of the fundamental frequency and its possible variations from sound to sound.

Since there is foreknowledge as to the fixed features or characteristics of a speech signal, it is unnecessary to record information regarding them. It is sufficient merely to transmit and record information defining the variable characteristics of the signal.

The first-mentioned variable feature is the magnitude of the average power in each subband into which the speech signal is divided.

The number of subbands chosen depends upon the degree of intelligibility desired, the greater the number of subbands the greater the degree of intelligibility in the speech defining signals. As it has been previously stated it will be satisfactory for a high degree of intelligibility to divide the speech frequency band into about eight or ten subbands and provide means for indicating the syllabic rate of change of the average power in each subband. In Fig. 1 the speech signal is divided into ten subbands. The subbands may be of unequal width, since each subband may have a width depending upon its importance function in the production of speech as described, for example, in my United States Patent 2,151,091, issued March 21, 1939 on Signal transmission.

The second-mentioned variable feature of speech concerning which information should be transmitted is the nature of the speech spectrum as to whether it is a continuous spectrum without any definite fundamental frequency or whether it is a discrete spectrum and in the latter case as to what is the frequency of the fundamental frequency for each voiced sound analyzed. This information is transmitted and recorded in a simple manner by the apparatus of Fig. 1.

In the arrangement of Fig. 1 the speech or other vocal sound to be analyzed is picked up by a suitable high quality microphone 20 and amplified to a desired level by an amplifier 21 whose output is divided into a frequency pattern measuring circuit FP and an amplitude pattern measuring circuit AP. The frequency pattern measuring circuit FP takes advantage of the fact that in vowels and in other sounds having a decided fundamental frequency in the range from 80 to 320 cycles, there is a high power level, while in sounds like the sibilant consonants where the power is in the continuous spectrum rather than a discrete spectrum, the power level is much lower. When a high level discrete spectrum is received from amplifier 21 the frequency pattern measuring circuit FP sends to the recording milliammeter 22 a current of a magnitude indicating what the fundamental frequency is, but not indicating anything about the amplitude of the current of the fundamental frequency. When a low level continuous spectrum speech signal is received from amplifier 21 the output current from channel FP is substantially zero and hence no current is applied to the recording device 22.

Referring more particularly to the details of the circuit FP a band-pass filter F_0 selects the band from 50 to 400 cycles of the voiced signal so as to be sure to include the fundamental frequency, if any. The output of this band-pass filter F_0 is sent through an attenuation network E_1 of a type often termed an equalizer which has a loss increasing with frequency for the purpose of insuring that the fundamental frequency comes out at a higher level than any of its upper harmonics that may be present. For practical purposes this purifies the fundamental tone. Next the output from this equalizer E_1 is fed to a constant output amplifier LA so that from this amplifier there is obtained essentially a single frequency, the fundamental frequency of the speech signal at a constant power level regardless of what the frequency is.

This fundamental frequency may be from about 50 cycles to 400 cycles. Next we pass this power through an equalizer E_2 which has a characteristic reverse to that of network E_1 in that the output from equalizer E_2 increases as the frequency increases. This output is sent through a

copper-oxide detector D_0 which gives essentially a direct current bias which fluctuates as the fundamental frequency of speech fluctuates, that is, at a syllabic frequency. The detector output is then sent through a low-pass filter F_{30} cutting off at 20 cycles so that the unwanted higher frequency products are eliminated. This output is now used as a biasing current applied to the winding of the recording milliammeter 22 whereby its recording needle 23 is moved from its zero position an amount proportional to the defining current from filter F_{30} . That is, the departure from its normal axis of the trace made by needle 23 on the moving paper strip 24 will be proportional to the frequency of the fundamental frequency so that the fundamental frequency will be accurately indicated on the record sheet for each speech component. For a voice with a high pitch the trace made by needle 23 will depart widely from its zero axis, while for a voice with a low pitch the trace will be closer its zero axis and the position of the trace will vary with any syllabic variations in the pitch of the voice.

However, when the frequency pattern circuit FP receives a speech signal having a continuous spectrum such as when a sibilant consonant sound is impressed on the microphone 20 the entire frequency spectrum is at a low level with no frequency emphasized over the others. Hence, for such sound there will be substantially no energy output from low-pass filter F_{30} and hence milliammeter needle 23 will remain substantially on its zero axis.

There remains to be described the apparatus for analyzing the speaker's energy in the different frequency subbands of the speech frequency range in order to determine the amplitude pattern characteristic of each speech signal. The amplitude pattern measuring circuit AP of Fig. 1 is essentially a circuit for measuring how much power there is in the speech signal in chosen small frequency bands and for transmitting this information by proportional currents to a plurality of recording devices, one for each subband. The amplitude pattern circuit AP at the output of amplifier 21 is divided by suitable band-pass filters F_1 to F_{10} into ten frequency subbands. As shown on the drawings, channel AP_1 receives the speech frequencies in the band from zero to 250 cycles; channel AP_2 receives the speech frequencies in the band from 250 to 550 cycles; channel AP_3 receives the speech frequencies in the band from 550 to 850 cycles; channel AP_4 receives the speech frequencies in the band from 850 to 1150 cycles; channel AP_5 receives the speech frequencies in the band from 1150 to 1450 cycles; channel AP_6 receives the speech frequencies in the band from 1450 to 1750 cycles; channel AP_7 receives the speech frequencies in the band from 1750 to 2050 cycles; channel AP_8 receives the speech frequencies in the band from 2050 to 2350 cycles; channel AP_9 receives the speech frequencies in the band from 2350 to 2650 cycles; and channel AP_{10} receives the speech frequencies in the band from 2650 to 2950 cycles. These bands have been chosen for the purpose of illustration. Obviously, other bands may be found preferable for particular circuits and may be so used without departing from the principles involved.

Considering the channel AP_1 , for example, the output from the zero to 250 cycles band-pass filter F_1 is fed to detector D_1 which may be, for instance, of the copper-oxide type. The syllabic frequencies in the output from the detector D_1 are passed through a 20 cycle low-pass filter F_{11}

and used to energize a recording milliammeter 41 so that the amplitude of the vibrations of needle 51 of device 41 defines the average amount of power of each speech component in the frequency band from zero to 250 cycles and the amplitude of the needle vibrations will increase or diminish at a syllabic rate in response to the syllabic variations of the power level in the designated subband.

Channels AP₂ to AP₁₀ are similar to channel AP₁ just described except for the frequency range analyzed by each channel. The defining currents from channel AP₂ are recorded by needle 52 of milliammeter 42; the defining currents from channel AP₃ are recorded by needle 53 of milliammeter 43; the defining currents from channel AP₄ are recorded by needle 54 of milliammeter 44; the defining currents from channel AP₅ are recorded by needle 55 of milliammeter 45; the defining currents from channel AP₆ are recorded by needle 56 of milliammeter 46; the defining currents from channel AP₇ are recorded by needle 57 of milliammeter 47; the defining currents from channel AP₈ are recorded by needle 58 of milliammeter 48; the defining currents from channel AP₉ are recorded by needle 59 of milliammeter 49; and the defining currents from channel AP₁₀ are recorded by needle 60 of milliammeter 50. Filters F₁ to F₁₀ are alike except as to the frequency band passed, as indicated on the drawings. Detectors D₀ to D₁₀ may be all alike and filters F₃₀ to F₄₀ are all alike in that they suppress all frequencies above 20 cycles.

The apparatus of Fig. 1, therefore, utilizes one milliammeter 22 to record the frequency variations of the fundamental frequency of the speech message and utilizes ten milliammeters 41 to 50 to record the average power level in the ten subbands of frequency into which the speech frequency band is divided by the band-pass filters F₁ to F₁₀. The eleven milliammeters are preferably so constructed and mounted that their traces on the moving strip 24 are arranged compactly but without any overlapping. The paper strip 24 may be moved at a constant speed past the line of recording needles by any suitable mechanism such as an electric motor 65 geared to a cylinder 66 around which the paper is rolled after the record is made.

The character of the defining patterns set up by the eleven milliammeters is shown in Fig. 2 for two typical words "sharp" and "void". The lowest trace 67 is that of the pitch or fundamental frequency of the tone as recorded by milliammeter 22. The next trace 68 gives a measure of the average energy level in the lowest subband, zero to 250 cycles, as recorded by milliammeter 41. Proceeding upwardly on the paper strip 24 the succeeding traces are for progressively higher subbands as indicated at the left of the figure, trace 69, for example, giving a measure of the average energy level in the highest subband, 2650 to 2950 cycles. Since the pitch record 67 for the distance from zero to 2 second measured along an arbitrary time scale lies substantially along the zero axis 70 for the milliammeter 22 it will be obvious that the recorded sound during this time interval is an unvoiced sound without any definite fundamental. For the same time interval the ten traces above the pitch trace show substantially zero power level for the lower bands but with definite power levels in their upper bands particularly in the 2350 to 2650 cycle band and the 2650 to 2950 cycle band indicating definitely an unvoiced

sound. The collective picture made by the traces for the ten subbands is that given by only one sound, namely, the sound "sh". As the "a" sound is recorded beginning about the vertical line 71, the pitch record 77 indicates a voiced sound with a definite fundamental of a frequency proportional to the distance between the trace 67 and its zero axis 70 while the energy level of the sound is prominent in the lower subbands as well as in the upper subbands. The composite traces just to the right of line 71 give an accurate picture of the power level distribution for the sound "a" as in "sharp" and will be readily interpreted as representing that sound by one trained in observing such records. The record of the remainder of the spoken word "sharp" is shown still farther to the right in Fig. 2.

Another portion of the strip 24 in Fig. 2 shows the defining traces for the spoken word "void" as recorded by the eleven milliammeters of the apparatus of Fig. 1. Distinctive differences will be noted between the traces for the word "sharp" and the traces for the word "void".

The milliammeters employed as elements 22 and 41 to 50 of Fig. 1 may be, for example, of the type disclosed in Fig. 1A which is of the moving coil type. The magnet structure 73 has opposed pole-pieces substantially surrounding a small coil 74 mounted for rotation in any suitable manner, not shown, in response to currents applied to the coil from any one of the eleven channels of Fig. 1. The frame which supports coil 74 has a lightweight extension or wire 75 which, at its outer end, supports a holder for a recording needle 76. As previously stated, needle 76 may be arranged either to make a written record in the form of a scratch on the surface or in the form of an inked or penciled line.

It will be apparent from the above that the apparatus of Fig. 1 produces a type of visual symbolic speech involving the principle of analyzing the speech to get down to parameters defining the low-frequency syllabic muscular motions referred to previously as those that modulate the sound wave from the vocal cords. To restore this record to complete speech requires a corresponding process of synthesis. This synthesis, of course, is mental, if indeed, to one trained in this art the record does not become symbolic in nature itself so that one thinks in terms of speech symbols rather than in terms of speech sounds. It is to be emphasized that the system of telegraphized speech proposed by this invention is inherently phonetic in nature. In recording the speech sounds from a talker with the system of Fig. 1 it is only the phonetic sounds which he produces that are recorded and not the artificial printed symbols that are ordinarily employed. The printed word and the ordinary telegraph code use artificial speech symbols and the mind is ordinarily trained to learn a different speech language for the eye from that for the ear. When one listens to speech it is of course phonetic speech that he hears. Also the eye in lip reading is using a crude form of phonetic speech. In that respect, the telegraphized speech of this invention corresponds to lip reading rather than the earlier forms of visual symbolic speech. It should be noted that symbolic phonetic speech as given by this invention is an advantage and not a handicap because it tells the story of the speech as spoken, including the emotional content as well as the intelligence content.

Fig. 3 shows a speech recording circuit somewhat like that of Fig. 1 but greatly simplified.

The simplification results from the use of only three of the eleven channels of Fig. 1 and as a result the speech defining signals of Fig. 3 may be readily transmitted over a telegraph line by any simple mechanism and recorded at a remote station connected to the line.

As in Fig. 1 the speech to be analyzed and recorded is picked up by a microphone 83 and amplified by amplifier 84 the output of which leads to a frequency pattern measuring circuit FP and an amplitude pattern measuring circuit AP. The frequency pattern channel FP of Fig. 3 is employed to differentiate between a voice and an unvoiced sound, while the two channels of the amplitude pattern circuit 87 and 88 are employed to define the average power level in two selected subbands of the speech frequency range. The frequency pattern circuit FP is identical with the circuit FP of Fig. 1 and comprises in tandem a band-pass filter 75 passing the band between 50 and 400 cycles; an equalizer 77, a constant output amplifier 78, an equalizer 79, a detector 80 and a low-pass filter 81 passing the band between zero and 20 cycles. As explained in connection with the channel FP of Fig. 1 there will be a substantial output current from filter 81 for a voiced sound but a substantially zero output for an unvoiced sound.

In the amplitude pattern circuit AP of Fig. 3 only two channels are employed, one channel 87 containing a band-pass filter 86 passing a band between 400 and 800 cycles of the speech frequency message from amplifier 84 while the other channel 88 comprises a band-pass filter 89 passing the band between 2300 and 2900 cycles. These two channels have detectors 90 and 91 similar to detector 80 and also have low-pass filters 92, 93 similar to low-pass filter 81 in that they pass only the band between zero and 20 cycles.

The unidirectional current constituting the output of filter 92 which defines the average power level in the speech frequency subband from 400 to 800 cycles for each component of the speech message is impressed directly upon a line 94, such as a telegraph line, and therefore constitutes the main telegraph signal sent over the line. The higher band channel output from filter 93 is used to control the amount of a carrier frequency such as 60 cycles which is transmitted over the line. Oscillator 95 may be a source of 60 cycle current which is connected to a suitable modulator 96 through a filter 97 which passes only 60 cycle current. The zero to 20 cycle current from filter 93 which defines the speech characteristics in the 2300 to 2900 cycle band is also impressed upon modulator 96 whereby the 60 cycle carrier is modulated by the zero to 20 cycle band from channel 88. The output from modulator 96 passes through a 40 to 80 cycle band-pass filter 98 so that both side-bands as well as the carrier are impressed on line 94 along with the low-frequency signal from channel 87.

At the remote station a recording milliammeter 99 is connected directly to line 94 and milliammeter 99 is preferably of a type that responds efficiently to a frequency of 80 cycles or higher. It follows that indicating needle 100 will vibrate at the 60 cycle rate with the height of its vibrations varying with the control current from channel 88 while at each instant the middle point of each swing will vary from the normal axis for the needle an amount controlled by the low-frequency current from channel 87. As in Fig. 1 the indicating needle 100 is adapted to form a trace on a

moving strip of paper 105, the character of the trace being illustrated more clearly in Fig. 4.

Line 94 also has a biasing battery 101 which is impressed on the recording milliammeter 99 with a polarity determined by the presence or absence of the fundamental frequency measuring current from the pitch channel FP and therefore with one polarity for a voiced sound and with the opposite polarity for an unvoiced sound. This differentiation is accomplished by having the output from filter 81 connected to a relay 102 whose contacts in an obvious manner constitute a reversing switch for battery 101. With an unvoiced sound there is substantially zero output from filter 81 and hence relay 102 will remain unoperated and positive battery is connected to the upper wire of line 94. This will produce a direct current which biases milliammeter 99, for example, so that for an unvoiced sound the needle 100 in the absence of any control current from channels 87 and 88 would trace a straight line 106 of Fig. 4 which line will be termed the unvoiced axis. However, if the speech sound to be recorded is a voiced sound there will be a substantial output current from filter 81 to operate relay 102 and change the battery connections so that now positive battery is connected to lower wire of line 94. This will cause needle 100 in the absence of any control current from channels 87 and 88 to trace a straight line 107 which will be termed the voiced axis.

The traced record of Fig. 4 is for the words "sharp" and "void" as in Fig. 2. The first portion of the traces for the sound "sh" is along axis 106 showing that it is an unvoiced sound and the fact that the trace is on both sides of axis 106 shows very little energy content in the 400 to 800 cycle band as compared with the energy content in the 2300 to 2900 cycle band. The voiced sound "ar" causes relay 102 to reverse the battery connections and cause the trace to lie adjacent the voiced axis 107 and it will be noted on the arbitrary time scale shown on Fig. 4 from about .23 second to .5 second the median line for the 60 cycle trace lies entirely on one side of the axis 107 at a distance controlled by the energy defining currents from channel 87. The character of the trace for the spoken word "void" will be obvious from the above description, for example, for the sound "v" the record for a short interval is along the unvoiced axis and then jumps to the voiced axis but in each instance the high frequency vibrations of the trace are of very low amplitude indicating small energy output from both channels 87 and 88.

The composite trace produced by the indicating needle 100 is of a sufficiently defining nature to enable one, after a little training, to interpret accurately the speech message recorded thereby. The system of Fig. 3 may be termed a form of direct speech telegraphy since, at the sending end, the sounds of a talker are directly converted into defining currents which pass over line 94 where they are received and recorded on the message strip 105. It is, of course, obvious that if desired the person at the receiving station may convert the message record on strip 105 into the more conventional symbols of the printed word.

The frequency subbands chosen for the two channels 87 and 88 of Fig. 3 may be varied widely from the frequencies indicated on the drawings while still obtaining a satisfactory and accurate record of the speech. It will be apparent that if desired the three channels of the analyzing system of Fig. 3 may have their defining currents

impressed separately on different milliammeters in the same manner as in the system of Fig. 1.

It is also to be understood that the defining currents from the eleven channels of the system of Fig. 1 may, if desired, be transmitted over a line or other communication channel to a distant receiving station where the recording milliammeters 22 and 41 to 50 are located, although more complicated apparatus will obviously be required to enable the eleven control currents to be transmitted simultaneously.

Since the frequency pattern circuit FP of Fig. 1 and Fig. 3 tends to have more inherent delay than the associated amplitude pattern branches it will generally be advisable to introduce a certain amount of delay in common to all the amplitude pattern circuits to compensate for this difference. Thus in Fig. 1 an electric delay equalizer DE is connected in channel AP so as to be common to all channels AP₁ to AP₁₀, while in Fig. 3 a delay equalizer 109 is common to channels 87 and 88.

The above circuits for forming telegraphized speech symbols which can readily be read by the eye to give an automatic speech telegraph circuit are merely representative of the invention since it will be evident to those skilled in the art that many modifications may be made without departing from the spirit of the invention as defined in the appended claims. For example, if desired, the recording milliammeters employed may be of the logarithmic type rather than the linear type.

What is claimed is:

1. A recording system for a message represented by a complex electrical wave of a wide band of audible frequencies, said system comprising means for selecting a number of substantially independent characteristics of said wave, means for producing a plurality of low frequency currents each having a fundamental frequency of less than ten cycles per second and each defining one of the characteristics of said wave, and means controlled by said low frequency currents for producing a visual record from which the word content of said message may be interpreted by the eye.

2. A recording system for a message represented by a wide band of audible frequencies, said system comprising means for dividing said message into a plurality of frequency subbands each of a limited frequency range, separate means for deriving from each subband a low frequency wave of a fundamental frequency of less than ten cycles per second, which wave defines the average energy level in the subband, and means for producing a separate visual record of each of said defining waves for enabling the eye to interpret the word content of said message by the inspection of said records.

3. A recording system for a speech message represented by a complex electrical wave of a wide band of audible frequencies, said system comprising means for dividing said wave into a plurality of frequency subbands, separate means for demodulating each subband, and means controlled by the demodulated currents for producing a visual record from which the word content of said message may be interpreted by the eye.

4. A recording system for a message represented by a complex electrical wave of a wide band of audible frequencies, said system comprising means for selecting a number of substantially independent characteristics of said wave, means for producing a plurality of low frequency cur-

rents each having a fundamental frequency of less than ten cycles per second, and each defining one of the characteristics of said wave, analyzing means for producing from said wave a low frequency wave of a fundamental frequency of less than ten cycles per second whose amplitude defines variations in the frequency of the fundamental frequency of said complex wave, and means for producing a visual record of said low frequency currents and said low frequency wave for enabling the eye to interpret the word content of said message by the inspection of said record.

5. A recording system for a message represented by a complex electrical wave of a wide band of audible frequencies, said system comprising means for dividing said wave into a plurality of frequency subbands, separate means for demodulating each subband, analyzing means for producing from said wave a low frequency wave of a fundamental frequency of less than ten cycles per second whose amplitude defines variations in the frequency of the fundamental frequency of said complex wave, and means for producing a visual record of said demodulated currents and said low frequency wave for enabling the eye to interpret the word content of said message by the inspection of said record.

6. A speech recording system comprising means for converting speech into a complex electrical wave containing a wide band of frequencies of importance in speech, means for dividing said wave into a plurality of frequency subbands, separate means for transforming each of said subbands into a narrow band of frequencies whose upper frequency limit lies well below the average fundamental frequency of speech with the amplitude of each narrow frequency band defining the average energy level in the subband from which it is derived, and means controlled by the amplitude variations of said narrow frequency bands for producing a visual record from which the word content of the recorded speech may be interpreted by the eye.

7. A speech recording system comprising means for converting speech into a complex electrical wave containing a wide band of frequencies of importance in speech, means for dividing said wave into a plurality of frequency subbands, separate means for transforming each of said subbands into a narrow band of frequencies whose upper frequency limit lies well below the average fundamental frequency of speech with the amplitude of each narrow frequency band defining the average energy level in the subband from which it is derived, means for producing a visual record of the amplitude variations of said narrow frequency bands, and means for producing as a part of said visual record an indication distinguishing voiced portions of said wave from unvoiced portions of said wave, said indication for voiced portions of said complex wave being wholly independent of the amplitude of the fundamental frequency.

8. A recording system for a message represented by a complex electrical wave of a wide band of audible frequencies, said system comprising means for deriving said wave into a plurality of frequency subbands, a separate rectifier for each of said subbands, an output circuit for each rectifier, a separate filter in each output circuit for suppressing frequencies in excess of about twenty cycles per second, and means controlled by the filtered currents from each rectifier for producing a visual record from which the

word content of said message may be interpreted by the eye.

9. A transmission system comprising means for converting speech into a complex electrical wave containing the frequencies of importance in speech, filter means for dividing said wave into a plurality of frequency subbands each of a limited frequency range, a rectifier for each of said subbands, a recording instrument simultaneously responsive to the output of said rectifiers and additional means for controlling said instrument to distinguish between voiced portions and unvoiced portions of said wave.

10. In a transmission system, means for converting speech into a complex electrical wave containing frequencies of importance in speech, filter means for dividing said wave into a plurality of frequency subbands each of a limited frequency range, a rectifier for each of said subbands, a limited frequency line connected to the output of one of said rectifiers, a source of carrier frequency, means for impressing on said line said carrier frequency modulated by the low frequency output of another of said rectifiers, a source of direct current, means for connecting said direct current source to said line with one polarity for the voiced portions of said wave and

the opposite polarity for the unvoiced portions of said wave, and a receiving station connected to said line comprising a recording device for producing a visual record of the combined currents received from said line.

11. In a transmission system, a telephone transmitter for converting speech into a complex electrical wave, a line connected to said transmitter, a plurality of channels connected to said line, each channel comprising a filter for passing to its respective channel only a limited band of speech frequencies, each filter passing a different frequency band, a rectifier in each channel, a movable message tape, a plurality of recording devices for simultaneously making separate visual records on said tape on adjacent portions of said tape, each of a plurality of said devices being responsive to the output of one of said rectifiers, means for producing a low frequency current the amplitude of which defines the frequency of the fundamental frequency of the voiced portions of the converted speech signal while producing a substantially zero current for the unvoiced portions of the speech signal, a separate one of said receiving devices being responsive to the defining current of said last-mentioned means.

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