TREATMENT OF SPEECH WAVES FOR TRANSMISSION OR RECORDING

Filed Dec. 22, 1939 3 Sheets-Sheet 1

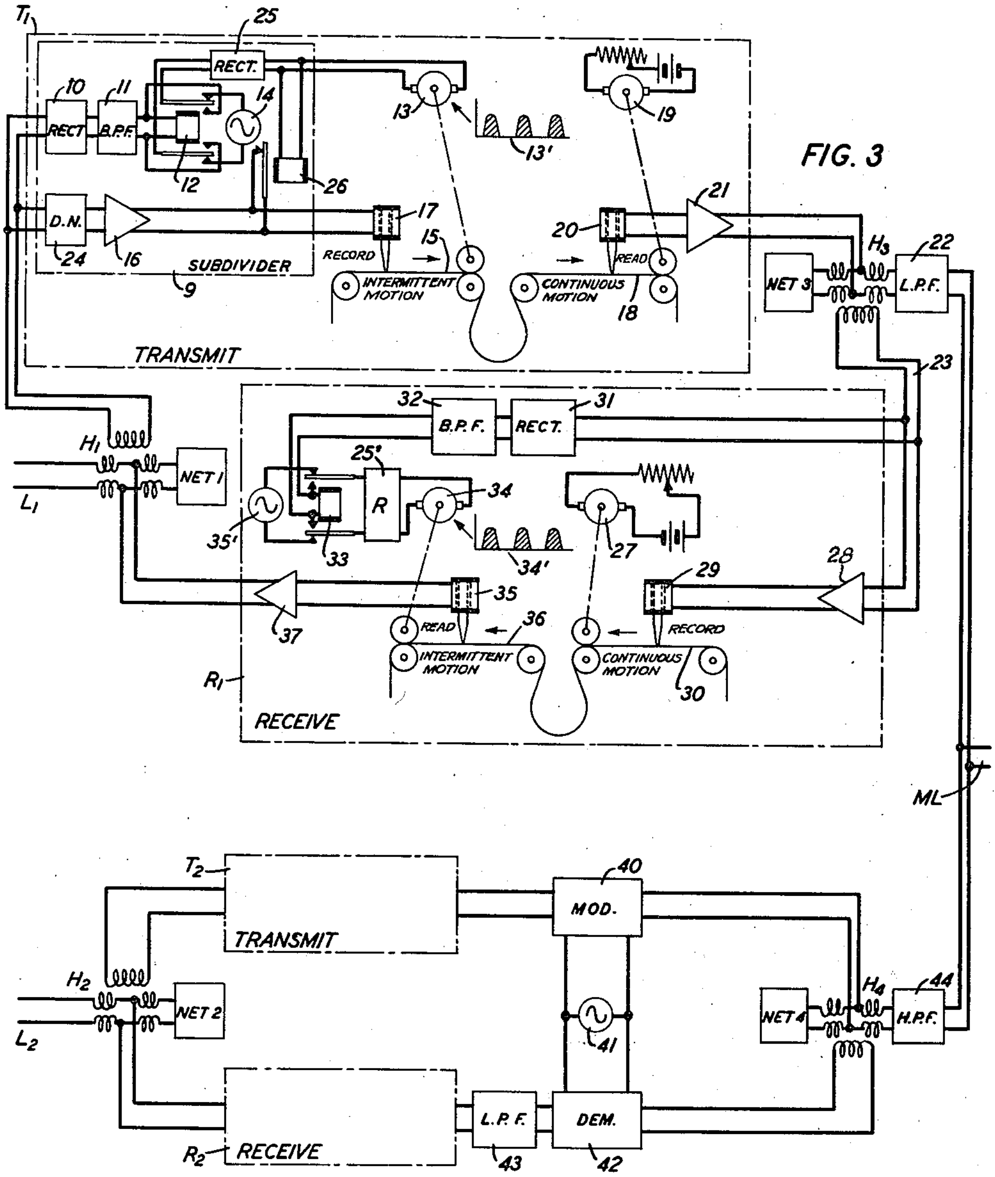

FIG. 3

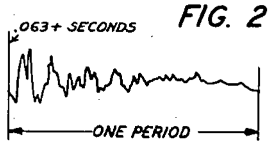

FIG. 2

FIG. 1

INVENTOR
H. W. DUDLEY
BY H. A. Burgess
ATTORNEY

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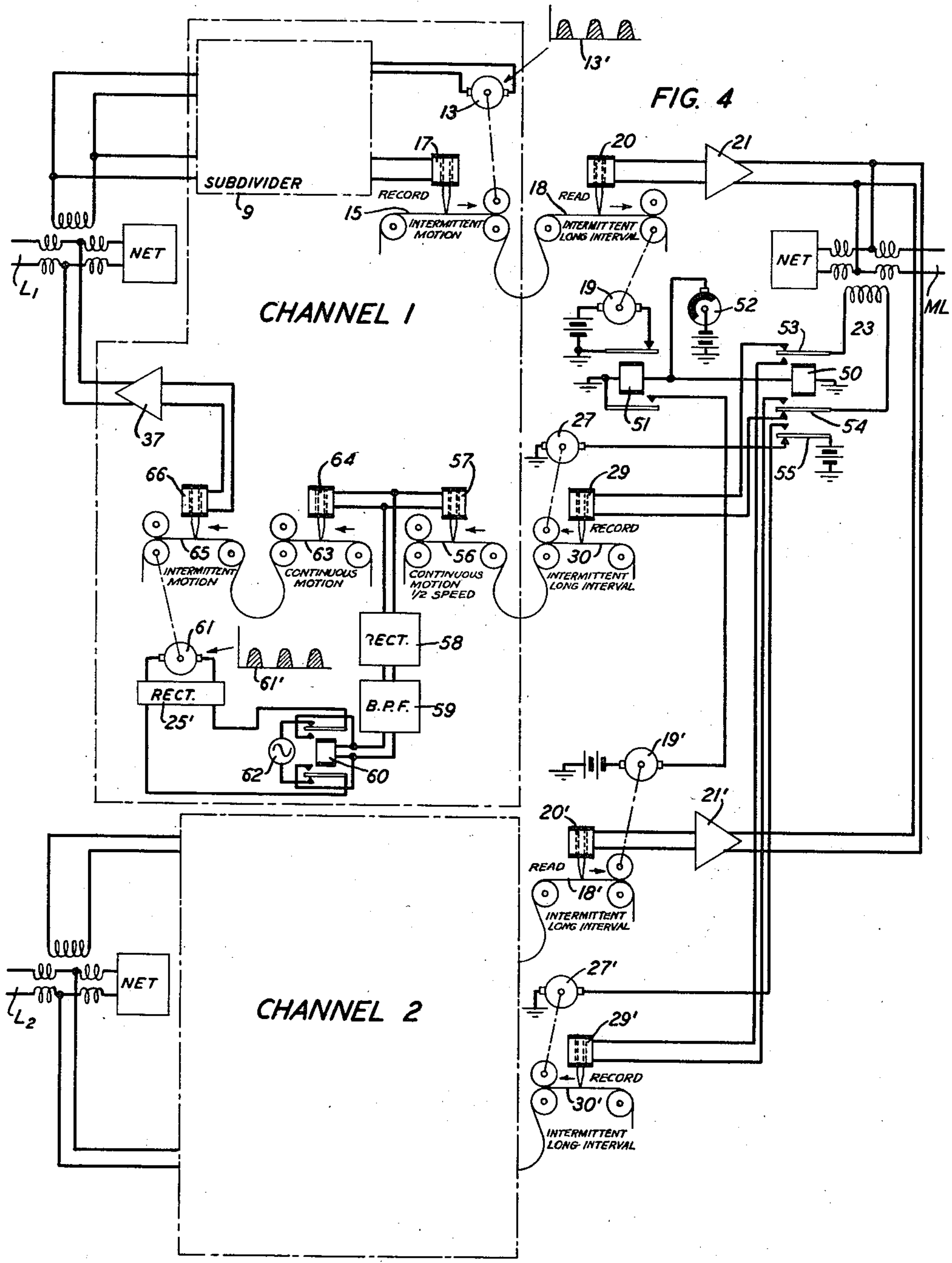
FIG. 4



INVENTOR
H. W. DUDLEY
BY H. A. Burgess
ATTORNEY

TREATMENT OF SPEECH WAVES FOR TRANSMISSION OR RECORDING

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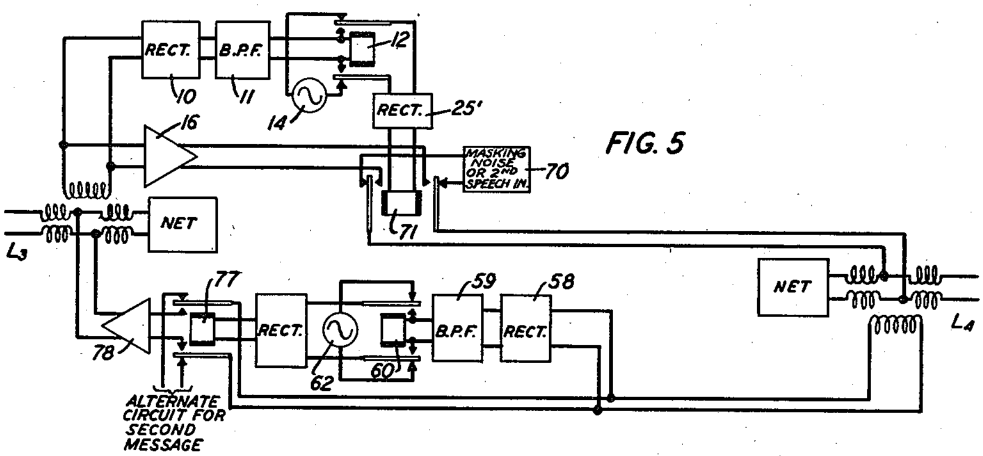


FIG. 5

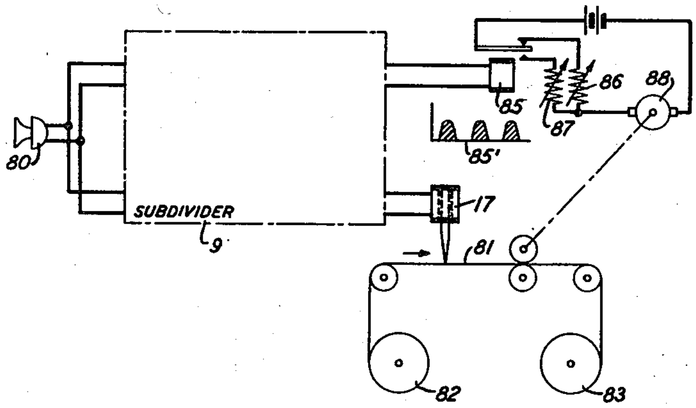


FIG. 6

FIG. 7

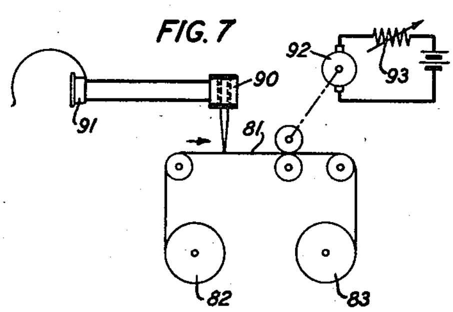
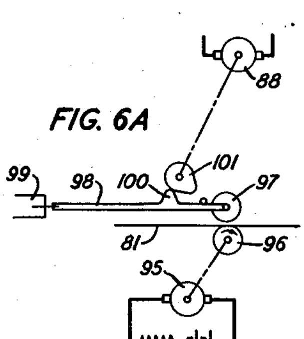


FIG. 6A



INVENTOR
H. W. DUDLEY
BY H. A. Burgess
ATTORNEY

UNITED STATES PATENT OFFICE

2,286,072

TREATMENT OF SPEECH WAVES FOR TRANSMISSION OR RECORDING

Homer W. Dudley, Garden City, N. Y., assignor to Bell Telephone Laboratories, Incorporated, New York, N. Y., a corporation of New York

Application December 22, 1939, Serial No. 310,527

18 Claims. (Cl. 179—1)

The present invention relates to transmission of speech or other message waves in which the waves are chopped and only certain fragments are transmitted.

A general object of the invention is to improve the quality or intelligibility of the reproduced message in the case of this type of transmission.

The various more specific objects as well as the nature of the invention itself will be made clear in the detailed description to follow in connection with the drawings in which:

Figs. 1 and 2 are typical wave forms to be referred to;

Fig. 3 is a schematic circuit diagram of one terminal of a multiplex system according to the invention;

Fig. 4 is a similar diagram of a terminal of an alternative type of multiplex system according to the invention;

Fig. 5 is a similar diagram of one terminal of a two-way privacy system embodying the invention; and

Figs. 6, 6A and 7 show circuits for recording and reproducing dictated material, according to the invention.

Various proposals have been made in the past for subdividing or chopping speech waves on a time basis, discarding certain of the subdivided fragments, such as every other one, and transmitting only the intervening fragments. Various rates of chopping have been proposed from a few per second up to several hundred or more per second. The present applicant in his United States Patent 2,115,803, May 3, 1938, disclosed a system in which the rate of chopping is the same as the fundamental or vocal cord frequency in the case of the voiced sounds and is of the same order of magnitude in the case of unvoiced sounds. The rate of chopping is placed under the control of the voice waves so that the rate is definitely related to and varies with the fundamental voice frequency. The reason for this is given in the patent and is found in the nature of speech itself as illustrated in typical sound wave patterns shown by way of example in Figs. 1 and 2.

Figs. 1 and 2 are respectively taken from plate No. 160 and plate No. 41 of an article, "The Sounds of Speech," by Irving B. Crandall, in the Bell System Technical Journal, vol. IV, page 586, 1925.

Fig. 1 shows the sound "s" in part. This is made by placing the tip of the tongue against the hard palate just back of the upper front teeth and then forcing air through the stricture at this point. The outcoming air forms eddies or whirling currents at this point, giving rise to the sound. As these eddies are random in amplitude, frequency of occurrence, and location, they do not give any pattern repeating itself periodically. Instead they give a fluctuating current that remains essentially the same over long periods of time. This can be seen from the figure.

Fig. 2 shows one period of the voiced sound "a" as in "father" beginning at time .064 second on Crandall's plate No. 41. The fundamental frequency is about 100 cycles per second. It is seen that at the beginning of the period there are strong amplitudes and sharp variations, while at the end there are weak amplitudes and less sharp variations. It may be considered that the period starts with a puff of air which traverses an acoustical resonant system with the energy damping out and trailing off near the end of the period.

In the method and system of transmission disclosed in the patent it is proposed to delete alternate segments of fundamental period length or duration and to supply these again at a receiving point by repetition. The present invention is based upon a different principle which can be made apparent from a consideration of the voice sound traces shown in Figs. 1 and 2. Upon examining one period of the voiced "a" sound, one notices that the amplitude swings at the middle of the sound have dropped to a small fraction of what they were at the beginning of the sound. For example, the amplitude at the middle point of the fundamental period in the case of a vowel may be only about one-tenth what it was initially. This means that the energy is only one one-hundredth as great, and so in comparison is negligible. This is particularly true since the ear cannot adjust its sensitivity over so small a period of time. Moreover, the component frequencies upon analysis are seen to exhibit heavy damping factors. This is to be expected from the manner, indicated above, in which the sound is produced, starting with a puff of energy which sets up vibrations in the resonant system that are rapidly damped to low amplitude before the next puff of energy occurs.

According to the present invention in its preferred form, the waves are chopped in such a way as to retain the large energy part of the voiced sound and to delete the low energy portion. For unvoiced sounds, illustrated in Fig. 1, corresponding segments are retained and suppressed in each period of fundamental length chosen somewhat arbitrarily to be about the length of the voiced periods. This means that the rate of interruption has to be related to the fundamental frequency of the voice since otherwise the dividing line between retained and suppressed segments would not fall between the high energy and low energy portions of each fundamental period of the voiced waves. In actual speech the vocal cord rate or fundamental frequency is continually varying. It is this that gives inflection, emphasis and shades of meaning by varying intonations. A fixed rate of interruption of any arbitrary value would not make the points of interruption coincide with particular points in the fundamental period. The distortion resulting from cutting the speech in this manner will be small in view of the low-energy level of the portion eliminated. It is also important that the cutting be done at the fundamental frequency rate. If this is not done, the cutting frequency and the vocal cord frequency beat together to produce raucous sounds that are highly unpleasant to the ear. It is found in practice that a large amount of the energy in the fundamental period can be cut out without offending the ear provided the rate of cutting is tuned to the vocal cord rate.

The fundamental frequency of the sound pictured in Fig. 2 is about 100 cycles per second. Crandall found a mean value of 125 cycles per second fundamental frequency for male speakers used in his experiments and a mean value of 244 cycles per second fundamental frequency for the female speakers or approximately twice as high as that of the male speakers. He and others find that in pronouncing a vowel sound the speaker varies the fundamental pitch several per cent from the average, for example, 25 per cent or even more.

Since most of the energy in speech is contained in the voiced sounds, suppression of only the low energy portions of each fundamental period wave of the voiced sounds and a corresponding fraction of the unvoiced sounds will make but very little difference in the total energy transmitted, even though this results in reducing the energy of the unvoiced sounds by half or two thirds, these sounds having such small energy content. The saving in time is, therefore, made without much loss in energy transmitted. Applicant has found that the loss in intelligibility from suppressing the low energy half of each fundamental length wave may be very small, since the ear response is due almost entirely to the high energy portion of the fundamental length wave, the effect of the low energy portion being a blank so far as the ear response is concerned. This fact makes the time interval represented by the low energy portion available for other uses as will be described.

The invention is not limited to any definite fraction as the fraction of the fundamental length period that is to be suppressed. This may be one half, two thirds or three fourths or any suitable or permissible value depending upon the conditions obtaining in any particular case. If sufficient intelligibility is obtainable to meet the requirements of any given case by interrupting for three fourths of the fundamental period, as many as four speech messages can be sent in the time and frequency limits occupied by a single speech message in ordinary telephony. If two thirds of the fundamental period wave can be suppressed in a given case, three speech messages can be sent within these same time and frequency limits. For simplicity of illustration and description, it will be assumed in the present detailed disclosure that one half of each fundamental length wave is suppressed and that a second message or wave is transmitted in the time intervals thus saved. By extension, however, it will be obvious how additional speech messages can be sent when the longer interruptions referred to are used.

Referring to Fig. 3, there are shown at the left two ordinary telephone lines L_1 and L_2 arranged for simultaneous transmission to or reception from the multiplex line ML shown at the right. This is made possible by the fact that each of the message waves on lines L_1 and L_2 is interrupted for one half the time in transmission through the equipment shown in this figure, and the time thus saved is utilized for a second message thus permitting the duplex transmission.

Considering the equipment associated with line L_1, this line is terminated in the usual hybrid coil H_1 and balancing network N_1. The transmitter is shown enclosed in the broken line T_1. The transmitting branch from the hybrid coil H_1 leads to the subdivider circuit shown in dotted line enclosure 9, including rectifier 10 and band-pass filter 11 of gradual cut-off which together serve to derive the fundamental or vocal cord frequency from the speech received over the line L_1 when voiced sounds are present. Relay 12 in the subdivider circuit is energized by the first of a succession of impulses of fundamental frequency from filter 11 and remains energized as long as the fundamental impulses continue to be received. Relay 12 closes a circuit through its front contacts and through rectifier 25 to the motor 13 which is driven with an intermittent motion (indicated by the impulse diagram 13') by the rectified impulses from the output of filter 11, the motor either not running at all or else running at a uniform speed. This motor 13 drives the magnetic tape 15 with an intermittent motion toward the right. For simplicity the motor is indicated as starting and stopping at the fundamental rate. Obviously the motor may run continuously and may drive the tape through a clutch intermittently operated, one form being shown in my patent above referred to. When there is an interruption in the receipt of voiced sounds the output of filter 11 ceases and relay 12 releases and connects a source 14 to the rectifier 25 and motor 13 to continue driving the motor intermittently at a rate which corresponds to a mean fundamental frequency for voiced sounds. This is in order that the unvoiced sounds may also be interrupted one half of the time.

The speech waves themselves pass through the delay network 24 of the subdivider circuit and amplifier 16 to the recording magnet 17, the core of which is near or in contact with the tape 15. During movement of tape 15 underneath the core of magnet 17 a magnetic record is produced of the received sound waves. When the tape is stationary the recorder is ineffective, relay 26 at its back contact shunting the recording magnet 17 between times of movement of the tape.

It is seen from the above description that the record made on tape 15 is a continuous record composed of segments of speech waves one half a fundamental period in length and lying adjacent one another with the intervening portions of the received waves dropped out.

The tape passes on to the right and the portion 18 of the tape is given a constant motion by motor 19 driven from a suitable battery with suitable speed control. This speed can be set at a fixed value which is one half the speed of movement of the tape at position 15 when the latter is moving. Reading magnet 20 picks up the recorded speech and reduces the frequency range by a factor of 2. These reproduced waves are transmitted through amplifier 21 to hybrid H_3 and then through low-pass filter 22 to the line ML. Filter 22 has a cut-off frequency in the middle of the normal speech range, for example, about 1,500 cycles so as to accommodate the waves from recorder 20. Hybrid coil H_3 is balanced by the usual network N_3.

The manner in which the waves so transmitted are received at the distant terminal may be seen from considering the receiver contained in the dot-dashed rectangle R_1. The received speech from receiving branch 23 is sent through amplifier 28 to the winding of recording magnet 29 so that a record is made on the tape 30 corresponding to the record sent from a tape corresponding to tape 18 at the distant terminal.

Some of the received speech is rectified at 31 and filtered at 32 to derive the fundamental frequency. It is observed that since the transmitting tape 18 moves at half speed, a high energy portion of the recorded wave representing a voiced sound passes under the reading magnet once in each fundamental cycle. Accordingly, the fundamental frequency is readily derived in the receiver by rectifying and filtering at 31 and 32 and the relay 33 is operated in the same manner as relay 12 at the sending end. The fundamental frequency impulses rectified at 25′ drive motor 34 at an intermittent fundamental rate (as indicated by the diagram 34′), thus causing the tape portion 36 to move toward the left intermittently in short jumps. The speed of movement of the tape portion 36 when it is in motion is twice the speed of the tape portion 30. The waves picked up in the coil 35, therefore, have their frequency range increased by a factor of 2 with respect to the frequency range of the waves in recorder 29. These waves in reading magnet 35 consist of segments of half fundamental period duration spaced apart by intervals, of the same length, of no current. These waves are sent to amplifier 37 through hybrid coil H_1 to the line L_1. When there are no voiced waves being received, relay 33 drops back and connects generator 35′ to the rectifier 25′ and motor 34. Generator 35′ runs synchronously with the generator corresponding to the generator 14 at the opposite terminal. The tape portion 36 is therefore driven ahead intermittently in jumps to enable reproduction of unvoiced sounds recorded thereon.

As noted above, the operation of the terminal apparatus for line L_1 transmits and receives one speech message over the line ML in one half the frequency range required by the methods of ordinary telephony.

The remaining half of this frequency range is used by the terminal apparatus of the line L_2 for transmitting and receiving a second speech message. For this purpose the transmitter T_2, indicated by broken line rectangle, may be the same as transmitter T_1 and the receiver R_2, indicated by broken line rectangle, may be the same as receiver R_1.

Waves from line L_2 transmitted through transmitter T_2 pass into modulator 40 which may be of the usual type used in carrier telephony. This modulator is also supplied with a "carrier wave" from source 41 of proper value to modulate with the output of T_2 and raise each of the frequencies by a fixed amount, for example, approximately 1,500 cycles, or to give a reverse side-band, so that they occupy the upper half of the ordinary commercial telephone speech band. These waves are then transmitted through the high-pass filter 44 to the line ML.

Waves from the distant terminal produced in similar manner and occupying the same frequency range are received through the high-pass filter 44 and sent into the demodulator 42 where they modulate with the continuous wave from source 41 and are stepped down in frequency to the frequency level at which they were produced by the transmitter at the distant station corresponding to transmitter T_2. These waves then pass through the low-pass filter 43 and into the receiver R_2 where they are translated into segments of speech waves each of half fundamental duration as in the case of receiver R_1 and are sent into the line L_2.

In the system that has just been described, the saving in time resulting from discarding one half of each wave portion of fundamental length is converted into a saving in frequency by reducing the frequency range by a factor of 2 and the frequency range thus saved is used for the transmission of a second message. It is also possible to utilize the time saved by discarding a portion of the speech segment of fundamental length for transmitting a second message in the time interval not used by the first message. One way in which this may be accomplished is shown in Fig. 4 which will now be described.

In Fig. 4, lines L_1 and L_2 are arranged for two-way repeating with the main line ML for securing the transmission over the latter line of two speech messages within the frequency and time limits required by a single speech message when transmitted by ordinary telephony. Referring first to the apparatus of channel 1 associated with line L_1, the speech is recorded on the magnetic tape 15 in the same manner as described in connection with Fig. 3, the corresponding apparatus elements being designated by the same reference characters as in Fig. 3. The waves picked up from the portion 18 of the tape by the reading magnet 20 are in this case, however, transmitted to line without any frequency reduction. For this purpose the tape is driven by motor 19 for a certain length of time as determined by interrupter 52 and the speed of motion of the tape portion 18 past the reading magnet is the same as the speed of movement of tape portion 15 during the times when the tape portion 15 is moved. The continuously rotating interrupter 52 controls the energization of two relays 50 and 51 each of which is energized half the time and deenergized half the time. The period of the interrupter 52 is such as to allow a considerable number of recorded half segments of speech of fundamental duration to be transmitted from the tape 18 without interruption. When the brush of the interrupter 52 is on its insulating segment relays 50 and 51 are deenergized. Relay 51 closes the driving circuit for the motor 19 to move the tape 18. Relay 50 at the back contacts of its armatures 53 and 54 connects the receiving branch 23 of the main line to the terminals of the recording magnet 29 and at the back contact of its armature 55 it closes the driving circuit for the motor 27 to move the tape 30. This places the tape 30 in condition to receive speech waves from the distant terminal of the line ML. Thus, during this half of the cycle of interrupter 52, tape 18 transmits its recorded material to the line ML and tape 30 records material received from the line ML.

Following through the operation of the receiving side of the channel, the portion of the receiving tape shown at 56 is being continuously driven by a motor (not shown) which is operating at all times to move the tape portion 56 one half as fast as the tape portion 30 moves during its time of movement. The waves picked off from tape portion 56 by the reading magnet 57 are seen therefore to be of the same general character as the waves that are received in the receiving branch 23 of Fig. 3. The rectifier 58 and filter 59 operate in the same way as rectifier 31 and filter 32 of Fig. 3 to derive the fundamental frequency which is then used to drive the motor 61 by an intermittent motion (as indicated by the impulses shown at 61') when the relay 60 is energized. When there is no voiced component from which to derive the fundamental frequency, relay 60 is deenergized and connects local generator 62 to the rectifier 25' and motor 61 to drive the latter intermittently at an average fundamental rate. A portion of the waves picked up by reading magnet 57 is impressed on recorder 64 which records on the continuously running tape portion 63 speech segments of the type of those recorded on tape portion 15 in the transmitting circuit. In other words, the record made on tape portion 63 consists of speech segments of one half the fundamental length with no blank spaces between. These recorded speech segments are read by the reading magnet 66 from tape portion 65 moving intermittently in such a way as to transmit each recorded segment to the line L_1 with intervening silent intervals corresponding to the wave portions deleted at the transmitter.

During the half period of interrupter 52 when the brush is on the conducting segment relays 50 and 51 are energized. Relay 51 opens the driving circuit of motor 19 causing the tape portion 18 to stop and allowing the tape portion 15 to supply slack tape preparatory to a subsequent movement of the tape portion 18. Relay 51 at its lower armature closes the driving circuit for motor 19' which starts movement of tape 18', permitting the sending of stored speech segments from reading magnet 20' through amplifier 21' to the main line ML. Relay 50 at the back contacts of its armatures 53 and 54 has now broken the circuit leading from receiving branch 23 to the recording magnet 29 and at the front contacts of its armatures 53 and 54 has connected branch 23 to the terminals of recording magnet 29'. Relay 50 by its armature 55 has opened the driving circuit for motor 27 and has closed the driving circuit for motor 27'. The operation of sending from and receiving by channel 2 is the same as that above described for channel 1, the corresponding apparatus elements being designated by the same reference characters primed in the case of channel 2. It will be understood that the apparatus inside the broken rectangle labeled channel 2 is identically the same as the apparatus inside the broken line enclosure designated channel 1.

It will be understood that the interrupter 52 must be run in synchronism with the corresponding interrupter at the distant station and that the tapes 18 and 30 and 18' and 30' run at the same speeds as the corresponding tapes at the distant station and that the other tape portions move at corresponding speeds. The correct phase adjustment of the interrupters for any particular installation may be determined by trial. The period of the interrupter 52 may be as long as desired but for purposes of two-way talking it should not be long enough to interfere with the carrying on of ordinary conversation including replies which one talker makes to the other. Since a single speech segment recorded on the tape 15, for example, is of the order of one two-hundredths of a second or less, it is seen that one half period of the interrupter 52 may be long enough to permit continuous transmission and reception of a large number of these recorded speech segments.

Referring now to Fig. 5, provision is made for two-way transmission between line L_3 and a corresponding line at a distant terminal of line L_4 with privacy. This is accomplished by using a masking noise to fill in the idle times corresponding to the segments of speech of fundamental length that are dropped out. Speech waves received from the line L_3 are analyzed for their fundamental frequency as in the previous figures by rectifier 10 and filter 11. Relay 12 is energized when voiced waves are received and deenergized in the absence of voiced waves. Relay 71 is vibrated under control of the fundamental speech frequency when relay 12 is energized and under control of generator 14 when relay 12 is deenergized. Relay 71 connects alternately noise source 70 and the output of amplifier 16 directly to the transmitting side of line L_4.

The manner in which these waves are received at the distant station may be seen from considering waves received from the line L_4 at the station shown. The received waves are analyzed for the fundamental period of the speech by rectifier 58 and filter 59 as in the previous figure and the relay 77 is caused to vibrate its armatures under control of the fundamental frequency when it is present and under control of local generator 62 when the fundamental frequency is not present as determined by the relay 60. It is seen that with a proper control of the timing of the armatures of relay 77 the receiving branch of line L_4 may be connected to the receiving amplifier 78 at those particular instants of time when the desired speech segments are being received but disconnected from the amplifier 78 during the times when fragments of the masking noise are being received. In this way the speech segments are separated from the noise segments and are transmitted to the line L_3. Obviously the local generators 14 and 62 should run in synchronism with and in proper phase relation relative to the corresponding generators at the distant end of the line. The effect of listening on the line L_4 is that of hearing the masking noise from the source 70 without hearing the speech from the line L_3, since the higher amplitude masking noise overpowers the desired speech sounds.

As an alternative a second conversation may be substituted for the masking noise where privacy for this second conversation is not required. In such case the back contacts of the armatures of relay 77 would be connected to a second receiving branch for receiving the second, non-private speech.

Referring back to Fig. 4 it is interesting to observe the frequency and word rate involved in transmission with that circuit. Since lines L_1 and L_2 both transmit intelligence over multiplex line ML, but the transmission takes place from lines L_1 and L_2 one at a time, it is evident that during the time of transmission from either line, say L_1, the rate of transmission of information over line ML is twice the rate on line L_1 for the particular information considered. This means that the word rate is doubled. As was pointed out, however, the frequency range is not increased over that used on line L_1. Fig. 4, therefore, exhibits a method of increasing the word rate, as by a factor of 2, without changing the frequency range. This is done by eliminating a part of each fundamental speech fragment, such as half, and transmitting the retained portions in continuous succession. In Fig. 4 this involves moving tape **18** continuously past reading magnet **20** at the rate of movement of tape **15** during its times of movement.

Figs. 6, 6A and 7 illustrate how use may be made of this principle in recording and reproducing speech. In Fig. 6 speech spoken into transmitter **80** is first recorded on a tape **81** driven intermittently just as in the case of tape **15** of Fig. 3 or 4. The speech waves pass into subdivider circuit **9** and the retained fragments are recorded at **17**. In this figure the motor **88** is arranged to have its speed readily adjusted to suit different conditions and is therefore shown as driven from a battery under control of relay **85** which is caused to vibrate its armature at the fundamental frequency as indicated by the impulse diagram **85'**. If variable resistance **86** is infinitely large, the motor is started and stopped as in Fig. 3 or 4 to drive the tape **81** forward in jumps. The speed of rotation of the motor is controlled by resistor **87**. The tape is wound from reel **82** to reel **83** and a record is prepared of a speech, dictation or other spoken material.

The tape is then rewound on spool **82** and is afterward run past the reading magnet **90**, Fig. 7, which is connected to telephones **91** or to a loud-speaker or other output device. The motion of tape **81** in the reproducing process is continuous and the speed is controlled by adjusting variable resistance **93** in the circuit of motor **92**. If the speed is the same as that used in recording during the times of movement of the recording tape, and if no spaces are left between the recorded segments on the record tape, the word rate is doubled, but the intelligibility is substantially unaffected because the frequency energy distribution or spectrum, on which intelligibility depends, remains unchanged. The fundamental frequency, of course, is also doubled in this particular case and this has the effect of shifting the register, an effect similar to that produced when a man talks in a false upper register simulating a woman's voice. This does not materially alter the intelligibility however. It is thus possible to "play back" the recorded material at a greatly increased talking rate, if desired, without sacrifice of intelligibility. This would not be possible with ordinary recording such as is used in dictating machines and gramophones, for an increase in record speed above normal for reproducing purposes quickly destroys the intelligibility since it alters the frequency energy distribution or spectrum.

The apparatus shown in Figs. 6 and 7 enables various ratios to be obtained between spoken word rate and the rate of reproduction. It has already been pointed out that if half of each fundamental period is dropped out and half retained, the word rate can be doubled without altering the spectrum distribution. If instead of directly connecting motor **88** to the driving rollers as in Fig. 6, a clutch is used operated by a cam as is done in Fig. 4 of my prior Patent 2,115,803 referred to, the cam may be so shaped as to cause movement of the recording tape in smaller jumps than correspond to one half the fundamental speech period, resulting in dropping out more than half the fundamental length segment of the voice wave and retaining less than half. Fig. 6A shows how such a cam may be used in a simple modification of the apparatus of Fig. 6. Motor **95** drives roller **96** at a constant speed but wire **81** is not moved until idler **97** is depressed to engage the wire **81** between roller **96** and idler **97**. Idler **97** is carried on a lever **98** flexibly mounted on bed-piece **99**. Cam **101** driven from motor **88** engages cam **100** and depresses the lever for a time which can be predetermined by the contour of the cam **101**.

If the fraction of the fundamental length speech fragment that is recorded is one third, the word rate can be multipled by three without changing the sound spectrum upon reproduction. Any other multiplication ratio can be obtained, such as 2.5, 3.1, 1.01, etc., by making the desired ratio the same as the ratio of the fundamental length speech segment to the fractional part of such segment that is retained, the remainder of each segment being deleted.

A decrease in word rate can be obtained by the apparatus shown in Figs. 6 and 7 by adjusting resistors **86**, **87** and **93** as now to be described. If motor **88** is allowed to drive the tape **81** forward in the non-recording times, that is, when relay **26** in the subdivider circuit is shunting out the recorder **17** (see Fig. 3), blank spaces will exist on the record tape **81** between the segments of recorded material. Let it be supposed that resistors **86** and **87** are given such values that when relay **85** is energized tape **81** is driven at one rate and when the relay is deenergized the tape is driven at some faster rate. The record then consists of segments of waves of, say, half fundamental length separated by blanks of greater length. If the blanks were also half fundamental length, there would be no change in either word rate or frequency distribution when the record is played back at the recording speed. But if the blanks are longer than the half fundamental length (in this case) there will be a decrease in word rate upon reproducing the sounds but no change in frequency distribution assuming the record is moved at the recording speed. This is seen from the fact that if the sound "ah" were spoken into transmitter **80** with a duration of one-third second, and if the record of this sound consisted of half periods of fundamental length separated by blank spaces of fundamental length, it would require 50 per cent longer time to reproduce this sound from the record with the speed of movement which the recording tape had in the recording intervals. In other words, the word rate is decreased in the ratio of 3/2, without altering the frequency distribution. As a general rule, if the speed of the tape in the non-recording intervals, in order to make blank spaces in the record, is M times faster than the speed during the recording times, the word rate upon reproducing the sounds to retain the same frequency distribution is reduced in the ratio

$$\frac{M+1}{2}$$

The invention is not to be construed as limited to the specific features disclosed, these being given as illustrative embodiments. The scope is defined by the claims which follow.

What is claimed is:

1. The method comprising subdividing speech waves on a time basis at the fundamental vocal cord frequency, dropping out a fractional part only of each subdivided wave portion of fundamental length, and transmitting only the retained parts of such subdivided wave portions.

2. The method comprising subdividing speech waves on a time basis at the fundamental vocal cord frequency, dropping out a fractional part only of each subdivided wave portion of fundamental length, thus leaving idle intervals between the retained parts of successive subdivided wave portions, and filling in said idle intervals with fragments of a second wave.

3. The method comprising recording on a suitable record medium a part only of each fundamental period wave segment of a speech wave and reproducing the recorded waves from said record with the time relation between the successive reproduced parts different from the time relation existing between such parts in the recording process.

4. The method of speech transmission comprising subdividing speech waves on a time basis such that each speech period corresponding to the fundamental speech frequency is divided into two portions, suppressing the low energy portion of each such period and transmitting only the remaining portion.

5. The method of speech transmission to increase the use of given transmission facility comprising chopping speech on a time basis so as to divide each speech period of fundamental length into two parts, eliminating part of each such fundamental length speech period, storing the retained portions in continuity with one another and transmitting said stored portions with said continuity.

6. The method of transmitting speech with reduced frequency range comprising chopping the speech on a time basis so as to divide each speech period of fundamental length into two parts, eliminating part of each such fundamental length speech period and increasing the transmission time of the remaining parts to use the time normally occupied by the eliminated part.

7. The method of treating speech waves comprising subdividing said waves at the fundamental vocal cord vibration rate such that the voiced sounds exhibit in the case of each subdivision a high amplitude portion rapidly damped to much smaller amplitudes and selectively utilizing for sound effects only the relatively high amplitude portion of the waves in each such subdivision in the case of voiced sounds and a corresponding portion of the waves in each such subdivision of the unvoiced sounds.

8. The method of transmitting speech with an altered word rate but with the same frequency range comprising subdividing the speech waves on a time basis at the fundamental vocal cord frequency into fragments of fundamental period duration, recording only a fractional part of each such fragment in succession with a certain space relation on the record existing between the parts so recorded, and reproducing the recorded parts with the reproduction rate the same as the recording rate in the case of each recorded fractional wave part but with the time relation between the reproduced parts different from the time relation occurring between the same parts in the recording process, the difference in said time relations being determined by said space relation on the record.

9. In a communication system, means to subdivide each of a plurality of speech waves into fragments at the fundamental vocal cord frequency of the respective speech wave, means to transmit a part only of each such wave fragment including only the high energy portion of the fragment in the case of the voiced sounds, thereby leaving between the transmitted fragments certain time intervals unused for purposes of transmission in the case of each wave, such unused time intervals corresponding to the portions of the wave fragments not transmitted, and means for utilizing such certain time intervals resulting from the transmission of one of said speech waves for the transmission of another of said speech waves.

10. In a communication system, means to subdivide each of a plurality of speech waves into fragments at the fundamental vocal cord frequency of the respective speech wave, means to transmit a part only of each such wave fragment, including means to transmit said parts of said wave fragments at reduced rate, thereby reducing the frequency range required for transmission, and means for utilizing the frequency range made available by thus reducing the frequency range required for the transmission of one of said speech waves, for transmitting another of said speech waves.

11. The method of altering the word rate of speech while retaining the intelligibility, said speech exhibiting in the case of the voiced sounds wave portions recurring at the fundamental vocal cord frequency each with a high amplitude part and a part of much lower amplitude, which method comprises recording only the high amplitude part of each such recurrent wave portion and a corresponding part only of the unvoiced waves, leaving unrecorded the low amplitude part of each recurrent wave portion in the case of voiced sounds and a corresponding part of the unvoiced sounds, using one rate of record travel during the recording periods and an arbitrarily different rate, including zero, during the non-recording periods whereby the space relations existing on the record between recorded and unrecorded wave parts is different from the time relations existing between the corresponding parts of the sound waves as spoken, and reproducing the speech from said record moving continuously at substantially its rate of movement during the recording intervals.

12. A method according to claim 11 including moving the record faster during the non-recording intervals than during the recording intervals whereby upon reproducing from the record the word rate is decreased.

13. A method according to claim 11 including stopping the movement of the record in each non-recording interval whereby upon reproducing from the record the word rate is increased.

14. In combination, a source of speech waves, means to subdivide said waves on a time basis at the fundamental vocal cord rate into wave fragments of fundamental period length, a path for the transmission of such waves, means to transmit to said path a portion only of each such wave fragment, and translating means connected to said path.

15. A combination according to claim 14 including a second source of waves of speech frequency range, and means for transmitting to

said path portions of waves from said second source in the intervals between transmission of said wave fragments from said first-mentioned source.

16. A privacy system for telephony comprising means to chop speech-representing waves at their fundamental frequency, a path for the transmission of said waves, means for transmitting to said path only a portion of each segment of the waves resulting from such chopping process, a source of confusion waves, and means to transmit bits of said confusion waves to said path in the intervals between said transmitted wave portions.

17. A receiving system for the privacy system defined in claim 16 including means to receive from said path said portions of speech-representing waves and the intervening confusion waves, a telephone receiving instrument, a switch for connecting said path to said instrument and disconnecting it therefrom intermittently at the rate of chopping employed in transmitting and in such phase as to direct the portions of the speech-representing waves into said instrument and exclude said confusion waves therefrom.

18. A privacy system according to claim 16 in which said confusion waves comprise intelligence-bearing waves, receiving means, and means at a receiving location on said path for intermittently switching said path into operative relation with said receiving means in timed relation with the chopping of said speech-representing waves and in such phase as to actuate said receiving means substantially exclusively with said confusing waves.

HOMER W. DUDLEY.