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H. W. DUDLEY

2,115,803

SIGNALING SYSTEM

Filed Oct. 30, 1935

3 Sheets-Sheet 1

FIG. 1



FIG. 2



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

May 3, 1938.

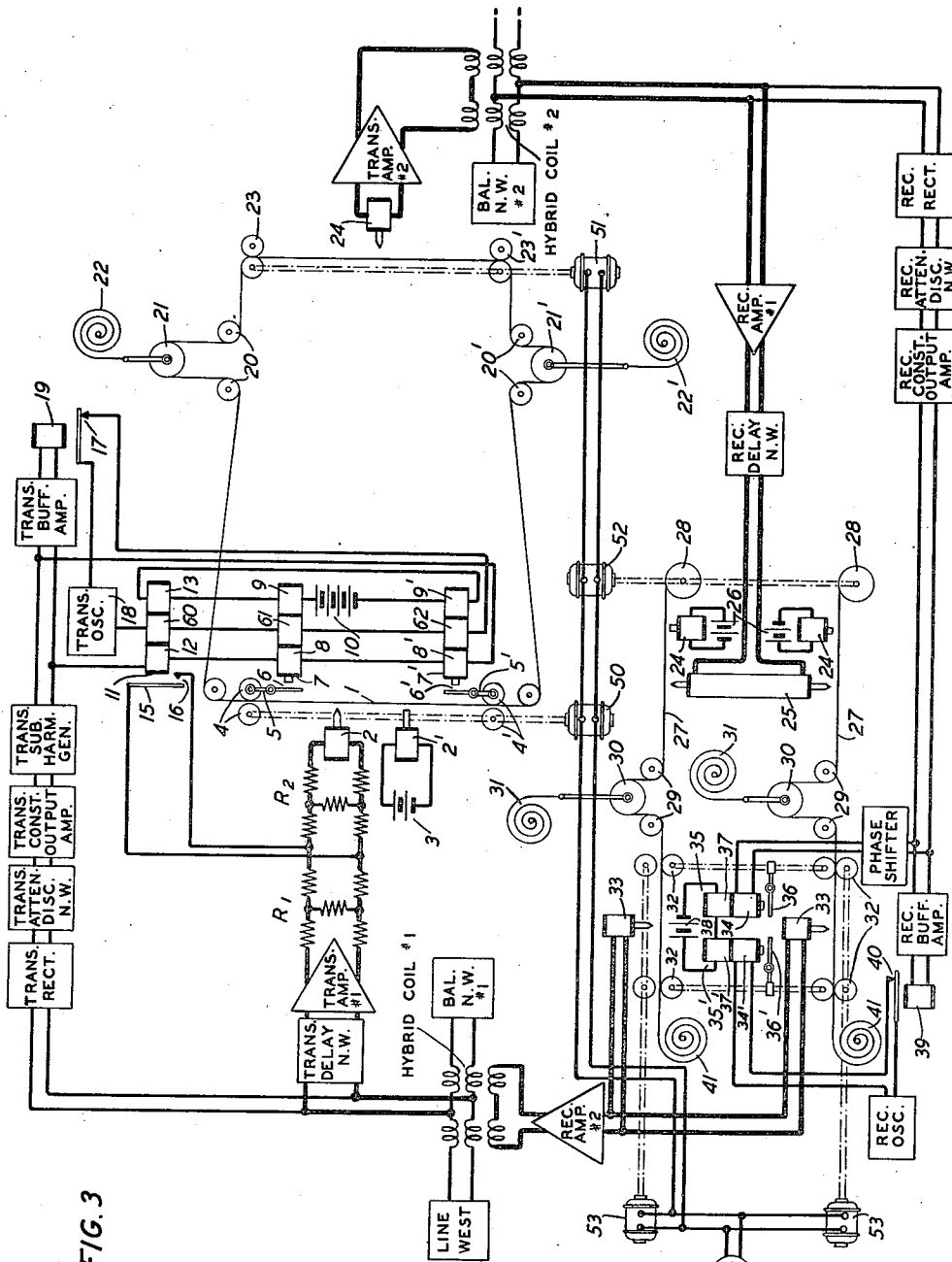
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INVENTOR
H.W. DUDLEY
BY *H.A. Burgess*
ATTORNEY

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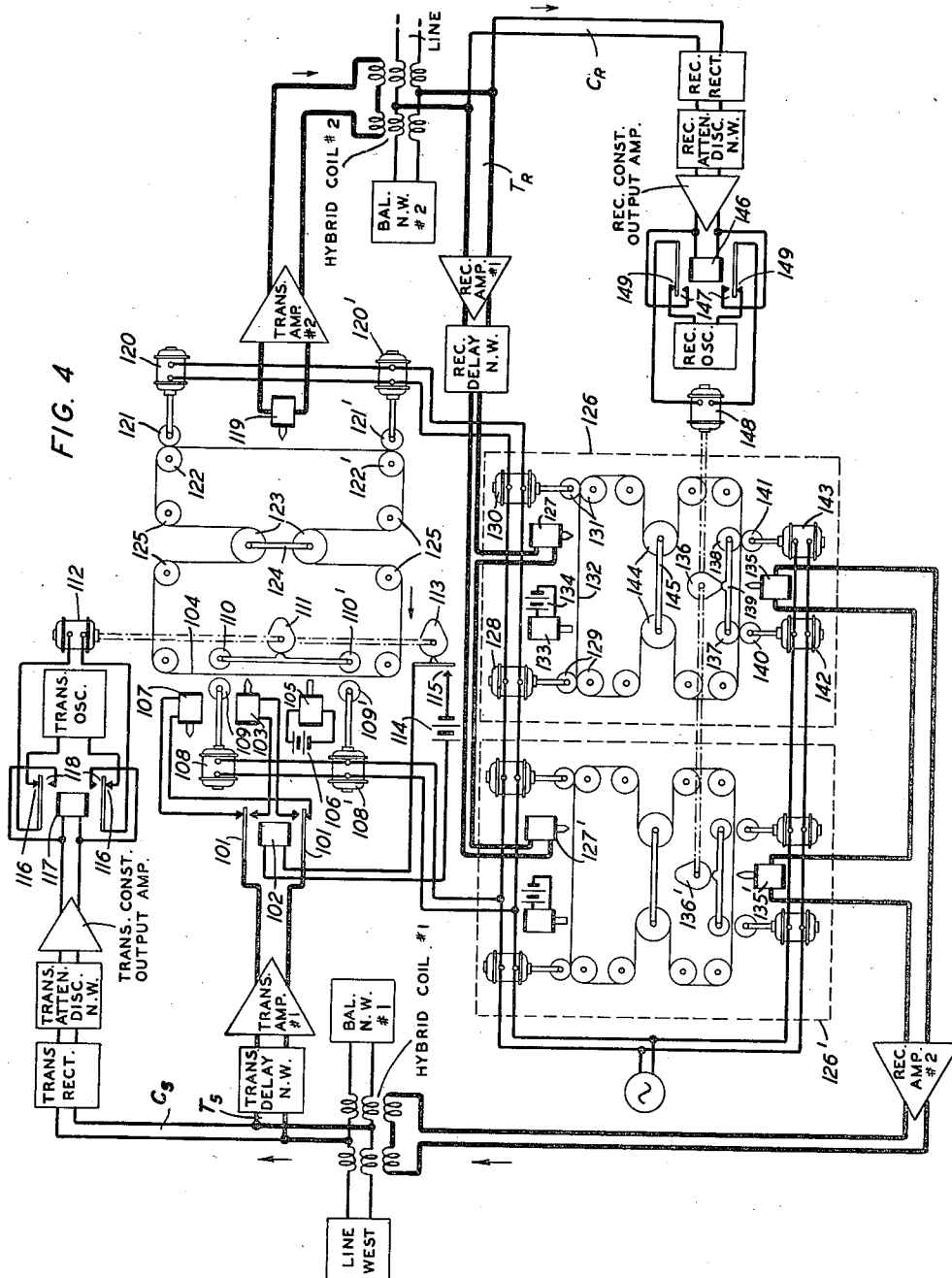
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3 Sheets-Sheet 3



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

UNITED STATES PATENT OFFICE

2,115,803

SIGNALING SYSTEM

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

Application October 30, 1935, Serial No. 47,394

19 Claims. (Cl. 179-1.5)

This invention relates to communication systems and more particularly to those systems in which the original signaling wave is not transmitted directly but a modification more suitable for meeting the requirements set by the transmitting medium is transmitted and used to reconstruct the original signal at the receiving end.

One object of this invention is to reduce the frequency band required for transmitting a message without changing the total time required thus making it possible to transmit messages over a transmission medium that would not otherwise pass the signaling frequency band. An application is to long submarine telephone cables where the higher frequencies cannot be transmitted because of excessive attenuation.

Another object is to reduce the time required to transmit messages.

Another object is to permit an increased number of channels in a given frequency band. Radio circuits and long land lines are examples for an application of this kind.

Another object is to improve the signal-to-noise ratio without increasing the sending level. A possible application of this is to long distance radio communication where the transmitting power required for a good signal-to-noise ratio becomes excessive.

Other objects will be apparent from the description to be given of the apparatus.

The method proposed for obtaining a reduction of the frequency range required for transmitting speech signals is based on the fact that the rates at which changes take place in the speech signal are limited. For the present purpose the changes with time of a speech signal may be divided into two types, which will be termed the oscillatory and the modulatory types. The oscillatory type is the only type found in sustained sounds. For such sounds the voice is essentially an acoustic oscillator with a distinguishing wave form for each sustainable sound. The oscillatory motion is either that due to the vibrations of the vocal cords if the sound is voiced or that due to the eddying motions set up in air passing through a very restricted opening such as lip to lip, upper teeth to tongue, or even between the non-vibrating vocal cords for whispering in the case of the unvoiced sounds. The voiced sound produces a wave form that is repeated over and over identically at the fundamental rate of vibration of the vocal cords. The unvoiced sound being due to eddying currents of air is not repeated rhythmically so that there is no repeated pattern of wave form, as for the

voiced sound; however, the energy-frequency characteristic is a fixed feature unchanging between intervals of time such as .01 second corresponding to intervals of time of the same order as the fundamental intervals of the vocal cords. Instead of transmitting a sustained sound directly, then, it could be transmitted as satisfactorily by transmitting a properly chosen small segment of it and then repeating this transmitted segment over and over to get the complete signal. This small segment would be a fundamental period when it exists, as in voiced sounds, and a time interval of the same order when there is no fundamental period present, as in unvoiced sounds.

The next type of change of signal amplitude with time that must be taken into account is that produced volitionally. Physically, this corresponds to a modulating or shaping of the sustained oscillatory wave and will, therefore, be referred to as a modulatory characteristic. A sustained sound is very limited as to the amount of intelligence it can contain. To communicate a maximum of intelligence requires that a multiplicity of sounds be formed as rapidly as possible. The different sounds are produced by the muscles of the vocal system shaping it into certain positions. These positions cannot be assumed in indefinitely short times, but between successive positions sufficient time must elapse for portions of flesh and bone to be moved by muscular effort. The rapidity with which such motion can take place depends on the inertia of the masses to be moved and the elastic forces available in the muscles for moving them. These factors set a limitation of 5 to 10 c. p. s. for producing sound orally. At such rates of talking, the vocal system is in a continual state of change at a rate limited only by the vocal muscular system of the talker. This rate of 5 to 10 cycles per second is much lower than the average fundamental frequency of the vocal cords which is about 100 to 150 cycles per second. The effect of these muscular changes is to put a relatively sluggish rate of change in the pattern that would be formed if the sound were sustained. Because of this slow rate of change, successive periods of voiced sounds and successive .01 second intervals of unvoiced sounds differ very little. In fact, fair resemblance can often be found between periods separated by five intervening periods.

In this invention it is proposed to take advantage of this inherent close resemblance between adjacent periods of speech and to transmit only a part of them, replacing the missing periods

by copies of the transmitted ones. These periods will be cut out in synchronism with the vocal cord vibrations when the cords are energized and at a mean frequency when they are not. This leads to a saving in time occupied by the signal. The saving in time is next converted to a saving in frequency range by stretching out the transmitted segment of speech to occupy the time interval formerly occupied by it and by the succeeding rejected time intervals.

While the method has been described in terms of speech signals, it is obvious that it applies equally well for any complex signal having a sluggish rate of change superimposed on a rapid rate of change of signal strength or from the point of view of frequency any signal having a set of low frequencies modulating a set of high frequencies. A musical note is of this type in which the high frequencies are the fundamental and upper harmonics of a resonant system formed from a stretched string, vibrating reed or air tube or chamber and the low frequency set are the rates of energizing such resonant circuits as, for example, the hand striking a piano key.

An important feature of the circuit is that portions of the signal on a time basis are chosen and intervening portions rejected, each rejected portion being essentially an integral number of repetitions of the retained portions in the case of voiced sounds and being an integral number of approximate energy-frequency copies of the retained portions in the case of unvoiced sounds.

Another feature of the invention is the modification of the retained portions of the signal so that they occupy not only their original time interval but also the time interval of the succeeding rejected portions.

Another feature of the circuit is the reduction at the receiving end of the time interval of a transmitted portion of signal to the normal value this portion of signal had before modification at the transmitting end.

Another feature of the circuit is the repetition of the transmitted portions of the signal so as to restore the signal to essentially its original form at the receiving end.

Other features of the invention will be understood from the detailed description which follows.

The attached figures will assist in understanding the working of this invention.

Figs. 1 and 2 show typical sections of a speech signal; and

Figs. 3 and 4 give two forms of the circuit for carrying out the principles of the invention.

Figs. 1 and 2 are parts of Plate No. 160 from an article, "The Sounds of Speech" by Irving B. Crandall in the Bell System Technical Journal, Vol. IV, page 586, 1925. The time scale gives the time from the beginning of pronouncing the sound "sa."

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 three periods of the voiced sound "a". The changes from period to period are seen to be very slight. The fundamental frequency

is about 110 cycles per second. It is seen that at the beginning of each 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. The end of the period where the signal form is well damped out makes an ideal point for cutting the period. Such points are marked on the figure.

Fig. 3 shows a circuit for carrying out the processes of this invention. This will be described in detail. In the figure is shown a single terminal at one end of a line transmitting a limited frequency band. At the other end there would be a similar terminal.

A message originating in line West is passed through hybrid coil #1. Due to the balance between line West and the balancing network #1, this energy divides part going to the lower side where it is dissipated in receiving amplifier #2, and part going upward where some of it goes through the main transmission circuit shown by heavy lines and the rest to a control circuit. That in the main transmission path circuit is first passed through the transmitting delay network to give the same delay in the main transmission as occurs in the control circuit, then through transmitting amplifier #1 to adjust the level, and then through two loss pads R1 and R2 with a shorting switch in between. Next, it is recorded on a telegraphone tape 1, by means of a recording magnet 2, the telegraphone wire having been wiped clean of its original record by the wiping magnet 2' energized by battery 3. The telegraphone wire is pulled by roller pins 4 and 4' driven by synchronous motor 50 when springs 5 and 5' respectively close the normal springs between the rollers and the tape as the magnet armatures 6 and 6' are attracted to the electromagnetic cores of relays 7 and 7' by energizing currents through the windings 8 and 8'. These electromagnets also have biasing windings 9 and 9' energized by a battery 10 so that when alternating current is applied to windings 8 and 8', the armatures are pulled in for one-half of the period only, such as the positive, and are released during the other half such as the negative. Polarized relays may well be used for these biased relays particularly if the adjustment proves troublesome. A relay 11 containing a core carrying control winding 12 and biasing winding 13 is arranged to operate in exact phase with the roller controlling electromagnets. For this relay 11 the core attracts armature 15 closing the contacts 16 and thus shorting the main transmitting circuit so that no energy is transmitted to the recording magnet 2 during the half period when this relay is energized. This is done between resistance pads R1 and R2 to prevent any stored energy coming out later as delayed transmission.

A third set of windings on the aforementioned electromagnets and relay is arranged to be operated from oscillator 18 which generates an average fundamental frequency of the signal. This operation takes place only when contacts at 17 are closed. This occurs when relay 19 is not energized which is the time when no energy is being fed to the main relay and roller controlling electromagnets. This then acts as a provision to give a mean frequency alternation of recording and rejecting small time intervals of

signal, when no signal fundamental frequency is energizing the relay and electromagnets.

The energy for controlling the relays and electro-magnets is that mentioned previously taken off the main transmitting circuit between the hybrid coil and the delay network. This first goes through a transmitting rectifier which may be merely some small copper-oxide elements or any suitable rectifier or detector, and which insures that a beat frequency, equal to the fundamental frequency of the signal is set up. Considering for a moment the case of speech signals, in vowels and other speech sounds having a decided fundamental frequency in the range 80 to 320 cycles there is a high power level relative to that in sounds like the sibilant consonants where the power is in a continuous spectrum rather than a discrete one; however, the fundamental in a sound with a high level discrete spectrum may be 80 cycles or so and therefore inefficiently transmitted over a telephone line such as the line west. Notwithstanding such attenuation of a low frequency fundamental of a signal, if two of the consecutive harmonics of the fundamental, as for example those of two and three times the fundamental frequency, arrive at the rectifier in considerable amplitude, their beat frequency component of fundamental frequency will be present in fair amount in the rectifier output. The fundamental in the rectifier output goes through a transmitting attenuation discrimination network which gives more attenuation to the higher frequencies. This network may be any suitable attenuating network (or so-called equalizer) having its loss increasing with frequency so as to insure that the fundamental frequency comes out at a high power level compared to any upper harmonics that may be present. For practical purposes this purifies the fundamental tone. This fundamental then goes through a transmitting constant output amplifier, such for example as that shown in C. H. Fetter Patent No. 1,565,555, December 15, 1925, so that the output does not depend on the amplitude of the input. Thus, during the times when fundamental is present in the signal, this output at any instant is practically a single frequency current, the fundamental of the signal, (which in the case of a speech signal might have a frequency from about 80 to 320 cycles per second), at a constant power level regardless of its frequency value. This output is then used to control a subharmonic generator which gives out a frequency equal to one-half, one-third, one-fourth, or other unit fractional part of a fundamental frequency applied. The subharmonic generator may be of any suitable type, as for example that shown in W. P. Mason Patent No. 1,946,223, February 6, 1934, or that described by Van der Pol and Van der Mark in their letter on Frequency Demultiplication Nature, September 10, 1927, pages 363-364 (or in their Patent No. 1,927,425, September 19, 1933). The output of the subharmonic generator feeds two branches. One contains the windings 12, 8 and 8'. The other is fed through a transmitting buffer amplifier to relay 19 which is of the quick operate slow release type with a hangover of .01 second. The rectifier, network with variable attenuation-frequency characteristic, and constant output level amplifier form a circuit (claimed in my copending application Serial No. 47,393, filed of even date herewith, for Signal transmission) which, during the times when fundamental is

present in the signal, selects the fundamental frequency and delivers the fundamental current to the subharmonic generator at constant amplitude; and this circuit and the subharmonic generator, in connection with the relay 19 and the transmitting oscillator, insures that during the times when there is a fundamental frequency in the signal the chopping of periods from the signal is synchronized with this fundamental frequency and during times when there is no fundamental frequency to control the chopping rate, the chopping will be done at an average rate, set by the frequency of the transmitting oscillator.

It will be noted from the preceding description that the telegraphone wire 1 goes with a jerky or discontinuous motion running along at a certain velocity V half the time and not running at all the other half of the time. It is necessary that there be uniform transmission and not a signal for a short time and then a blank space for an equal length of time. Accordingly, two sets of pulleys 20, 21 and 20', 21' are provided to take up the slack in the telegraphone wire. Pulleys 20 and 20' rotate about a fixed axis, whereas pulleys 21 and 21' are held by a wire around a revolving drum 22 or 22' with a constant force.

The pulleys 23 and 23' driven by a synchronous motor 51 rotate at a constant velocity $V/2$ whenever pulleys 4 are rotating at a velocity V half the time and zero the other half of the time. The message coming off the recording magnet 24 is transmitted through transmitting amplifier #2 to hybrid coil #2 which divides it up between balancing network #2 and a line of limited transmitting ability such as a limited frequency range of transmission due to high loss with increasing frequency.

It will be noticed that this signal, as compared to the original signal received from the line A, has retained only one-half, one-third, one-fourth, or other unit fractional part of the signal from line West, but has, however, spread this out so as to occupy the time that formerly was occupied by the rejected portions as well as by the retained portions. This signal is transmitted through the medium which is limited in its transmitting ability by such factors as attenuation and noise. It is then received at the distant end and used to reproduce the original signal. The circuit by which this is done is the same as that shown in Fig. 3 for a return message coming in.

In this case the signal in its modified form comes into hybrid coil #2 on the right and is split between the output circuit of transmitting amplifier #2 and the receiving circuit which is shown in the lower part of the figure. This latter circuit is divided into two parts, one for a receiving control circuit and one for the transmission of the signal message proper shown by the heavier lines. In the main transmission branch the received signal goes through receiving amplifier #1 and then through a receiving delay network to equalize the delay with that in the control circuit and then to recording magnet 25 placed just after the wiping magnet 24 energized from batteries 26. The message is recorded on two telegraphone ribbon tapes 27 which are unwound from drums 28 at a uniform speed by motor 52. Each of the tapes has the same signal recorded on it. As the next step is to pick up a portion of signal from one tape and next the same portion from the other tape, an interrupted motion is provided to take up the slack of the tape consisting of fixed rollers 29 and sliding pulleys

30 which are free to move up and down under a constant tension from the spring wound drums 31. Each tape then goes between two pairs of rollers 32 to a drum 41 on which it is wound under constant tension. Alternately each reproducing magnet 33 picks off the signal from tape 27 between the pairs of rollers 32 and transmits it to the receiving amplifier where the paths join. The outer rollers of 32 are driven by the synchronous motors 53 at a constant velocity. The inner rollers for both tapes are mounted on the same platform which for half of the time is in an upper position so that the upper tape 27 is grasped and fed through with the lower tape at rest and for the other half of the time is in a lower position with the lower tape being grasped and fed through while the upper tape is at rest.

The other circuit branch after hybrid coil #2 goes through a receiving rectifier, a receiving attenuation discrimination network and a receiving constant output amplifier to a branching point. At this point, the current is of constant amplitude and has the frequency of the signal fundamental if the signal is of discrete spectrum type and a frequency that wanders around in a random way when the signal is of the continuous spectrum type. If there is a fundamental frequency the receiving oscillator circuit is kept open at contact 40 by relay 39 operating on energy from the receiving buffer amplifier. Also, in this case, there is another path containing a phase shifter to get the optimum synchronization between the sending and chopping and the receiving and restoring of signals, and next a relay winding 34 of relay 35 for lifting armature 36. A biasing current to insure that the operation of the relay is on a half time basis is provided in winding 37 energized from battery 38. This relay may preferably be of the polarized type, the two armature positions corresponding to the two polarities. The relay adjustment is such as to make for quick switching. There is also a substitute to the circuit provided so that if, for any reason, this circuit fails to operate periodically an automatic operation of the chopping circuit is provided. This is obtained from a receiving oscillator that comes on the circuit through contacts 40 of relay 39 whenever relay 39 releases. This is a quick operate slow release relay which will operate in synchronism with relay 35 but will hang over much longer. When this relay 39 is operated, the indicated oscillator does not feed energy out. However, if insufficient energy is obtained to keep this relay operated, it releases and closes the circuit so that the oscillator feeds energy through winding 34' to the magnetic core of relay 35' which attracts armature 36'. A biasing winding 37' similar to 37 is also provided.

The energy from the two reproducing magnets 33 is fed to receiving amplifier #2 and through this to a hybrid coil #1 after which it is divided between line West and balancing network #1.

The synchronous motors 50 and 51 at the sending end must be in synchronism to prevent the tape being bunched up or stretched out unduly. The same holds for the receiving end motors 52 and 53. To insure this synchronism, all these motors are shown as being run from a common alternating current supply.

The circuit of Fig. 3 is satisfactory for cutting alternate periods of speech so that half is retained and half rejected. For the more general case of retaining one-third, one-fourth, etc., a circuit of the type shown in Fig. 4 is preferred.

For the sake of simplicity, it is shown as a halving circuit the extension required for obtaining other unit fractional parts being obvious.

The operation of this circuit will be followed through in detail. In transmitting, energy arising in line West reaches the hybrid coil where it divides between the output of the receiving amplifier and the transmitting branch shown above hybrid coil #1. The latter energy again divides between the main transmission branch Ts at the sending end shown by heavy lines and a sending control circuit Cs. In the main transmission branch Ts the energy goes through a transmitting delay network and transmitting amplifier #1 to the swingers 101 of relay 102. When this relay is operated, the swingers are at the inner position passing energy to the magnetic recorder 103 to be recorded on the telephone tape 104 after the tape has been cleared of previous messages by wiping magnet 105 energized from battery 106. When relay 102 is not operated, the energy from transmitting amplifier #1 is fed to the dummy recording magnet 107 so that the amplifier faces a constant load. The tape 104 is at rest half the time and running half the time from energy derived from synchronous motors 108 and 108' turning rollers 109 and 109'. The tape moves when the rollers 110 and 110' driven from cam 111 by synchronous motor 112 are pushed in by the outer part of the cam to hold the tape 104 against the rollers 109 and 109'. This motor 112 also drives cam 113 in synchronism with cam 111 so that when cam 111 causes the tape to move, cam 113 causes the signal to be recorded by operating relay 102 from battery 114 through the closure of contact 115. The energy for running the synchronous motor 112 is obtained from the transmitting oscillator through contacts 116 when relay 117 is not operated. When relay 117 is operated, the energy for both motor 112 and relay 117 is obtained from the aforementioned branch control path Cs through a transmitting rectifier, a transmitting attenuation discrimination network that favors the lower frequencies and therefore the fundamental of the signal if there is any and then through a transmitting constant output amplifier. This arrangement insures that when there is a fundamental frequency in the signal the chopping of periods from the signal is synchronized with this fundamental whereas if there is nothing approaching a fundamental frequency to control the chopping rate it will be done at an average rate by a locally supplied frequency from the transmitting oscillator.

The modified message is picked off the tape by the reproducing magnet 119 placed between synchronous motors 120 and 120' driving at a uniform velocity rollers 121 and 121' which press the tape 104 against the idling rollers 122 and 122'. The peripheral velocity of rollers 121 and 121' is half that of rollers 109 and 109' so that the tape at the reproducing point travels at a uniform speed equal to the average speed at the recording point considering it is there moving at double this uniform speed half the time and at zero speed the other half. Due to this different rate of travel at the recording and reproducing sides of the tape it is necessary to provide a take-up for storing the tape temporarily and then feeding it out. This is done by means of the pair of pulleys 123 fixed relative to each other by bar 124 with the tape supported by the four fixed rollers 125. With the pulleys 123 in a given position cam 111 operates and tape is fed out

clockwise between rollers 109 and 110 at the fast speed. Half of this travel will be taken up by the downward motion of the tape at the recording magnet 119. The other half will be taken up by the pulleys 123 being displaced to a lower position. A moment later cam 111 releases the tape between rollers 109 and 110 and between 109' and 110'. Now the tape at reproducing magnet 119 continues its uniform downward motion until it has used up the travel stored in the upper portion of tape between pulleys 125 due to the displacement of pulleys 123. The portion of tape between the lower pair of the pulleys 125 increases as the upper portion decreases and vice versa since the total tape within the four pulleys 125 must remain the same.

The signal picked up by the reproducing magnet 119 is sent through transmitting amplifier #2 to get the proper sending level and is then passed to the hybrid coil #2 and then divided between balancing network #2 and the line to the right. This line then transmits the lower half of the original signal frequency range. If it has a limited frequency range available elsewhere than at the lower speech frequencies then obviously a carrier system may be employed to translate the modified signal to such frequency range.

The signal transmitted down the line is received at the distant end and converted back to the original form by a receiving circuit for this purpose. As this is the same as the one supplied in the circuit of Fig. 4 for receiving and modifying incoming signals, the details of this will be gone through.

The incoming signal of halved frequency range comes to hybrid coil #2 and there divides between the output of transmitting amplifier #2 and the receiving circuit composed of a main transmission branch T_r and a control branch C_r . In the branch T_r the signal passes through receiving amplifier #1 where the level versus frequency is adjusted to the desired characteristic, then through a receiving delay network which gives the same delay for this circuit branch T_r as for the control branch C_r . The signal is then applied to a multiplicity of devices for taking the received portions of signal and reducing their time interval to that at the sending end, enough such devices being used that the signal portions repeated in the succession of them gives back each original transmitted portion or segment of signal plus a copy of such segment for each omitted segment occupying an equal time interval. In this case, the signal had alternate segments removed so two such devices, identical in detail, are required as shown in boxes 126 and 126'.

The signal from the receiving delay network is fed into recording magnets 127 and 127'. The path through box 126 will be traced alone as that through 126' is identical. Motor 128 through rollers 129 and motor 130 through rollers 131 move the telegraphone tape 132 at a uniform velocity V_r past the wiping magnet 133 energized by battery 134 and then past the point where the message is recorded on the tape by recording magnet 127. The message is picked up, segment at a time, by reproducing magnet 135 when cam 136 presses rollers 137 and 138 connected by bar 139 against the tape 132 pressing it in turn against rollers 140 and 141 driven by synchronous motors 142 and 143 respectively. Cam 136 engages half the time and during this half of the time, the tape 132 moves past magnet 135 at a double velocity $2V_r$. During the other half of

the time, the tape is stationary so that its average velocity past the reproducing magnet 135 is the same as its uniform velocity past the recording magnet 127. This requires a take-up device for holding the tape from the recording side during the time the reproducing side is not having the tape fed in and for feeding the tape out twice as fast as received when the reproducing side is taking tape. This device consists of two pulleys 144 held together by bar 145. The slack in the tape on one side is compensated for by the extra tape needed on the other side since the total tape always remains the same.

From reproducing magnet 135' there is obtained a copy of the message from reproducing magnet 135. The cam 136', however, is 180 degrees out of phase with cam 136 and closes on the tape for half the time with the result that a signal segment is picked up from reproducing magnet 135, then a copy of it from reproducing magnet 135', then a new signal segment from 135, and so on. This reconstructed signal of paired segments passes through receiving amplifier #2 and hybrid coil #1 after which it divides, part going to balancing network #1 and part to line West its ultimate destination.

The operation of cams 136 and 136' is timed by means of the control circuit C_r . Energy for this circuit comes from hybrid coil #2 through the receiving rectifier, the receiving attenuation discrimination network which picks out the lowest frequency, the fundamental of the signal and then through the receiving constant output amplifier wherefrom it energizes relay 146, closing contacts 147 through which it passes to the synchronous motor 148 which drives the cams 136 and 136' in synchronism with the fundamental frequency of the voice. Whenever relay 146 does not operate, an average frequency from the receiving oscillator is substituted for the fundamental frequency. This is automatically done through spring contacts 149 of relay 147 which are closed until the control circuit energizes relay 147. The angular position of the cams on the shaft is adjusted for optimum synchronization with the fundamental frequency.

Four synchronous motors 108, 108', 120, 120' at the sending end, and eight at the receiving end,—the four, 128, 130, 142 and 143 in box 26, and the corresponding four in box 26' have been shown for driving the telegraphone tapes. It is necessary that the motors at the transmitting end run synchronously so that there is no undue piling up or stretching of the telegraphone tape. In the same way the receiving end motors should run synchronously. To get this synchronism these motors have all been chosen of the synchronous type and running off of the same alternating current supply. These motors all run continuously at uniform speed. The two other synchronous motors 112 and 148 run at variable speed following the voice fundamental over a range of about two octaves. These two cannot be of the heavy sluggish type but must be light and sensitive to slight changes in the applied frequency.

The specific systems shown and described are illustrative of the invention and many modifications of them may be made within the scope of the invention. Thus, various other types of switching apparatus can be used without departing from the principle of the invention. Again, one skilled in the art can readily apply means for having the transmitted signal segment occupy a lesser time interval than the sum of the time

intervals originally required for it and for the immediately succeeding eliminated segments.

What is claimed is:

1. The method of operating on a message wave that a times has a functional frequency, with recurrence of substantially the same pattern in the wave at the fundamental frequency, which comprises eliminating certain wave portions respectively corresponding to periods of the fundamental frequency and retaining other wave portions respectively corresponding to periods of the fundamental frequency, and replacing said eliminated portions by reproductions of said retained portions.

2. The method of transmitting a signal in a frequency range less than that normally required which comprises eliminating parts on a time basis that are substantially copies of other parts that are retained, transmitting each retained part at a rate such that it occupies a time interval greater than it originally did but not greater than the original time interval required for the transmitted part plus that for the immediately succeeding eliminated part and, in receiving, reducing the time interval occupied by the transmitted parts to their original values and substituting for the intervening unoccupied time intervals copies of the transmitted parts to replace the eliminated parts.

3. The method of transmitting a signal according to claim 2 wherein the signal changes gradually from period to period.

4. The method of transmitting a signal according to claim 2 wherein the signal transmitted is a speech signal and changes gradually from period to period with the period that of the vocal cords.

5. The method of transmitting a signal according to claim 2 wherein the signal to be transmitted contains no fundamental frequency but has an energy-frequency pattern that changes gradually so that the change is small between successive time intervals of the order of a hundredth of a second.

6. The method of transmitting a signal as in claim 2 wherein the signal is in part energy of a discrete spectrum type changing gradually and in part energy of a continuous spectrum type also changing gradually.

7. A communication system comprising, at the sending end, means for eliminating portions of the signal and means for insuring that the eliminated portions are substantially copies of retained portions, and at the receiving end, means for substituting copies of the transmitted portions of signal for the eliminated portions.

8. A communication system comprising means at the sending end for eliminating portions of the signal that are substantially copies of retained portions and means at the receiving end for substituting copies of the transmitted portions of signal for the eliminated portions, wherein the signal to be transmitted has during some intervals of time a form characterized by a pattern that repeats itself periodically with the wave shape changing gradually from period to period and has during other intervals of time a form characterized by the absence of any regular periodicity but the presence of a power versus frequency characteristic that changes gradually between successive small time intervals such as a hundredth of a second.

9. A communication system comprising means at the sending end for eliminating portions of the signal that are substantially copies of retained portions, further means at the sending

end for spreading out the retained portions so that they substantially occupy the time formerly taken for the retained portions together with the succeeding eliminated portions and means at the receiving end for restoring the transmitted portions to their normal time intervals and further means for replacing the eliminated portions with copies of the transmitted portions.

10. A communication system comprising means at the sending end for determining the fundamental frequency of the signal, further means for methodically eliminating time intervals from the signal in synchronism with their fundamental frequency, still other means for spreading the retained portions of signals over time intervals formerly occupied by the retained portion of signal and the succeeding eliminated portion of signal, and at the receiving end means for determining the fundamental frequency of the received signal, further means for restoring the received portions of signal to the lengths of time intervals they originally occupied, still other means for substituting copies of these restored portions of signal to take the place of the portions of signal eliminated at the transmitting end.

11. A communication system comprising means at the transmitting end for deriving the fundamental frequency of the signal when it is essentially periodic in nature, means for substituting an artificial frequency corresponding to a mean length of period of the signal when it is not periodic in nature, further means for retaining one period or artificially equivalent period so determined and for eliminating an integral number of succeeding periods or artificial periods, still further means for making a retained signal portion occupy the time interval formerly occupied by it together with the time intervals occupied by the immediately succeeding eliminated time intervals, and at the receiving end means for determining the periodic frequency and the artificial equivalent thereof, means for restoring the transmitted signals to their normal time intervals, and further means for substituting for the eliminated signal portions copies of the restored transmitted signal portions.

12. A communication system comprising at the transmitting end means for deriving the fundamental frequency of the signal, an oscillator as a source of substitute frequency when no fundamental frequency is found, a magnetic tape for recording the signal, signal-controlled switching devices actuated in synchronism with the fundamental frequency and the substituted frequency to cause one true or artificial period to be recorded and an integral number of the following ones to be eliminated, said switching devices interrupting the flow of energy to the tape and the motion of the tape during a non-recording period, means for continuously reproducing this modified signal from the tape and at the receiving end means for switching in synchronism with the transmitting end switching aforesaid, magnetic tapes for recording the received modified signal a sufficient number of times to compensate for the eliminated portions of signal and reproducing means for picking up a transmitted signal portion off these tapes in rotation before the next later transmitted signal is picked up.

13. The combination with means for cutting out all but a unit fractional part of a signal, of means responsive to the signal for causing the first-mentioned means to operate in synchronism

with the fundamental period of the signal when such period is present and with an artificially chosen equivalent for such fundamental period when the fundamental period is not present.

- 5 14. The method of operating on a single signal from which periods of the signal have been eliminated and chosen small periods respectively of substantially the same wave form as eliminated periods have been retained which com-
10 prises extending the time interval of said chosen small periods within the signal relatively to the signal duration by any chosen factor so that they occupy time intervals of the signal that were formerly occupied by said periods of substantially
15 the same wave form, respectively, which have been eliminated from the signal.

- 15 15. In a system for operating on a signal having groups of fundamental periods with the adjoining fundamental periods in each group having substantially the same wave form, means for
20 eliminating from each of said groups all but an integral number of its fundamental periods and also eliminating from the signal, in intervals when fundamental periods are lacking in the signal, chosen periods whose intervals are equal to
25 fundamental intervals, and means for causing the retained parts of the signal to occupy substantially the entire time interval of the signal.

- 30 16. The method which comprises adjusting the time intervals in a signal occupied by fundamental periods so that each of said periods remains in its original time interval in the signal but occupies only an aliquot part of the interval,

said fundamental periods originally being, respectively, in groups of several successive fundamental periods that, in the same group, have substantially the same wave form.

17. The method of operating on received fundamental signal periods that in the original signal were separated by intervening periods that have been eliminated and that were respectively of substantially the same wave forms as the fundamental periods immediately preceding them, which comprises repeatedly reproducing each of
10 said received fundamental signal periods in succession so as to fill in the time intervals corresponding to those occupied in the original signal by said intervening periods.
15

18. The method of reconstructing a signal consisting of fundamental periods from selected ones of said fundamental periods which comprises repeatedly reproducing each of said selected fundamental periods, in succession an integral number of times, each selected fundamental period
20 adjoining, in the original signal, a fundamental period of substantially the same wave form.

19. The method of operating on a message wave that at times has a fundamental frequency, which comprises eliminating fundamental periods
25 of the wave that respectively have substantially the same wave form as retained fundamental periods, and replacing the eliminated periods by reproductions of their respectively corresponding
30 retained periods.

HOMER W. DUDLEY.