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COMPRESSED BAND TELEPHONY

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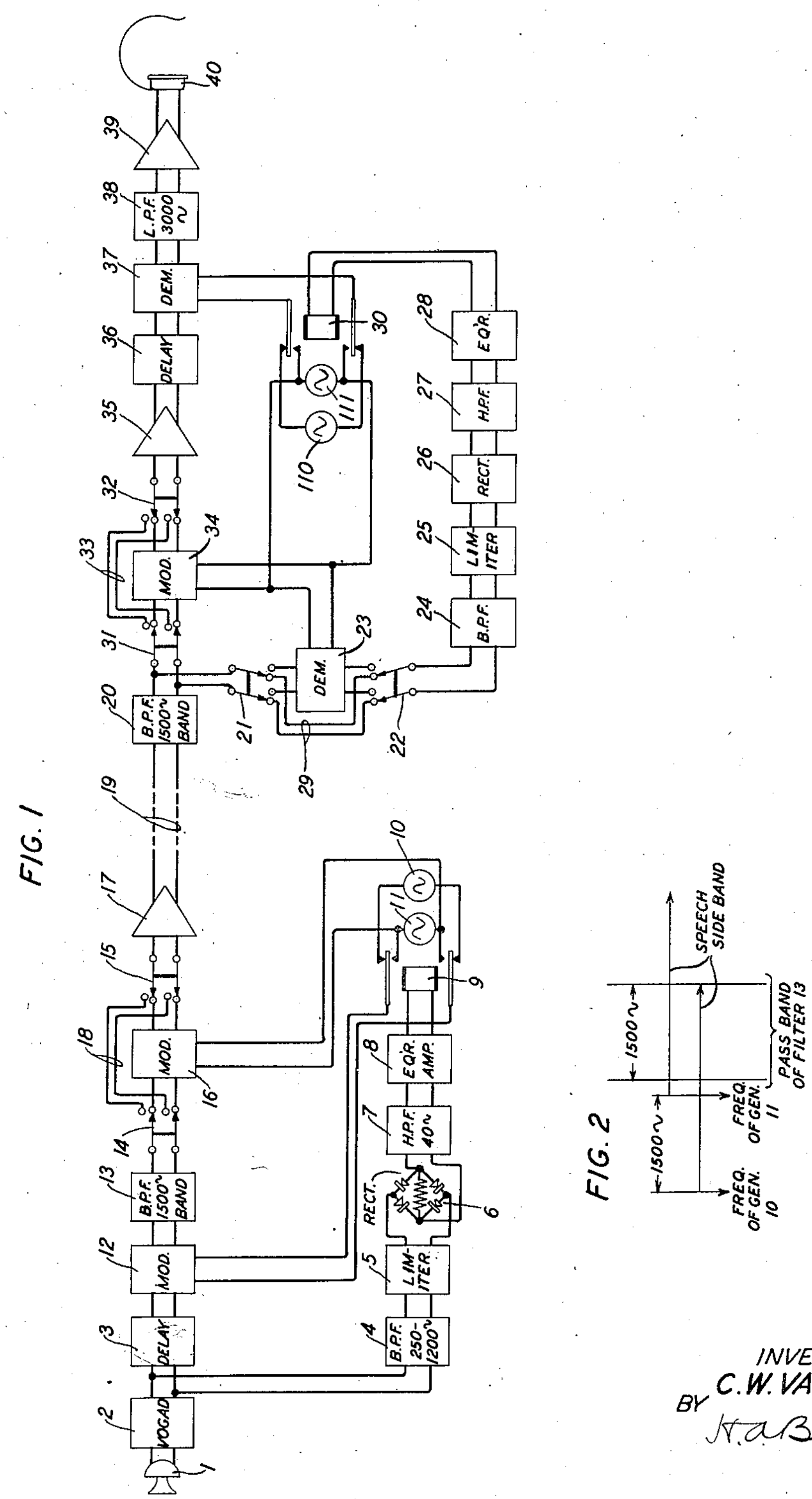

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COMPRESSED BAND TELEPHONY

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9 Claims. (Cl. 179—1)

The present invention relates to the transmission of speech or similar waves with reduced frequency range. Such transmission is useful either where the transmission channel is incapable of transmitting normal speech band width or where it is desired to conserve frequency space for any reason.

It has been proposed heretofore to conserve band width by taking advantage of the observed fact that vowel sounds and consonant sounds, or more accurately, voiced sounds and unvoiced sounds, do not occur simultaneously in speech but occur in successive time intervals; and of the further fact that unvoiced sounds as a rule average higher in the frequency scale than voiced sounds. In such proposal, a method was used for depressing the frequencies of the unvoiced sounds when they occur, so that they occupy the same frequency band as the voiced sounds. This method involved separating the two kinds of sounds and treating them differently in transmission. This required mechanism for performing switching operations at the frequency of occurrence of the two kinds of sounds, at approximately syllabic frequency.

The present invention, while also shifting the frequency of certain elemental speech components to overlap in frequency certain other components, is based upon a different principle. In accordance with the present invention the speech is subdivided or chopped at a relatively high rate and the elements that have their frequencies shifted are chosen without regard to whether they are voiced or unvoiced sounds. The high rate of chopping has two very important advantages as regards freedom from distortion. First, the principle of persistence of hearing is used, whereby the ear does not perceive the received fragments of speech separately and individually but they merge into one more or less continuous sensation analogous to the effect of persistence of vision. Second, the rate of chopping is not only high but it is chosen to be the same as, and varies with, the fundamental or vocal cord frequency of the voiced sounds, which are the high energy sounds. This has been found to eliminate the raucous, rasping type of distortion that is observed to result from chopping speech at any fixed high rate or at any high rate which is different from the fundamental frequency. Both the articulation and the naturalness are, therefore, enhanced by the method of the invention as compared with prior art methods.

The nature of the invention and its various objects will be more apparent from the following detailed description when read in connection with the accompanying drawing, in which:

Fig. 1 is a schematic circuit diagram of a complete system from transmitter to receiver embodying the invention; and

Fig. 2 is a frequency diagram to be referred to in the course of the description.

Referring to Fig. 1, the speech that is to be transmitted is assumed for illustration to lie within the frequency range of 200 to 3200 cycles per second. This speech is produced by talking into the transmitter 1. After passing through the voice-operated gain-adjusting device (vogad) 2 the speech divides into two paths, one leading to the delay device 3 and the other leading to the band-pass filter 4. The vogad may be of the type disclosed in Mitchell et al. 2,019,577, November 5, 1935, or other suitable type.

The apparatus including elements 4 to 9, inclusive, in combination, serve as a fundamental frequency extractor. It takes the vocal harmonics in the region 250 to 1200 cycles and by means of a rectifier derives the difference products which include the fundamental and harmonics thereof. The filter is shown at 4 and the rectifier at 6. The fundamental is the strongest component when using a balanced full wave rectifier of the type shown but in order to strengthen it further relative to its harmonics an equalizer 8, which may also contain amplification is used. This equalizer is a network having increasing loss, starting at 80 cycles and increasing with frequency. High-pass filter 7 with a cut-off at 40 cycles is used to attenuate syllabic pulses. The limiter 5 may be omitted, if desired, but is included for illustration for a purpose to be more fully described further on. This limiter is for the purpose of maintaining the input to the rectifier constant for all voice sounds including both voiced and unvoiced sounds.

As a result of the action of the elements 4 to 8, inclusive, a succession of pulses is produced at the fundamental or vocal cord rate in the case of voiced sounds and at a random rate in the case of unvoiced sounds and the relay 9 is constructed to vibrate its armatures in synchronism with these pulses.

The speech which passes through the delay circuit 3 enters the input side of the modulator 12 to which there is applied continuous waves from either the source 10 or the source 11 depending upon the position of the armatures of relay 9. Sources 10 and 11 have frequencies that are high compared to speech frequencies and that differ from each other by 1500 cycles. The output of modulator 12 is filtered by a band-pass filter 13 which has a band width of 1500 cycles between frequency limits suitably related to the frequencies of the generators 10 and 11 as indicated in the diagram of Fig. 2. When waves from the generator 10 are applied to modulator 12 the upper side-band is so related to the pass-band of filter 13 that the upper half of the speech range is transmitted through the filter. When waves from generator 11 are applied to modulator 12 the modulated frequency is 1500 cycles higher than in the first case and the upper side-band is raised sufficiently to permit only the lower half of the speech range to pass through filter 13. As relay 9 vibrates, therefore, the upper half and the lower half of the speech band are transmitted in rapid succession and shifted in frequency to occupy the same frequency band.

The output of the band filter 13 could be passed directly over the line 19 to the receiver in case transmission at a carrier frequency were desired. This can be accomplished in the figure by shifting the D. P. D. T. switches 14 and 15 to their alternate positions so that the transmitting path extends through conductors 18 and amplifier 17 to line 19. When the D. P. D. T. switches 14 and 15 are in the position shown, the output of band filter 13 is applied to the input of modulator 16 which is supplied with waves from source 11. As a result of this modulation, the 1500-cycle band is shifted downward to occupy the range of 200 to 1700 cycles which is transmitted through amplifier 17 to line 19.

The received waves pass through band-pass filter 20 and in part through D. P. D. T. switches 21 and 22 which in one position lead through conductors 29, and in the other position lead through demodulator 23, to the fundamental frequency extractor circuit 24 to 28. The path 29 is used if the transmission over the line is in the range 200 to 1700, while the demodulator 23 is used if the transmission over the line is at high frequency. A continuous wave from the source 111, which has the same frequency as source 11, is applied to the demodulator 23 to step the received waves in the latter case down to the level of 200 to 1700 cycles. The fundamental frequency extractor circuit 24 to 28 may be identical with that at the transmitter, the parts being indicated by the same reference characters raised by 20. As a result of the action of the fundamental frequency extractor, the relay 30 vibrates in unison with the relay 9 of the transmitter.

A portion of the speech band transmitted through filter 20 leads to the D. P. D. T. switches 31 and 32 which include either the modulator 34 or the conductors 33 in the circuit. Conductors 33 are used if transmission over the line is at high frequency, while modulator 34 is used if the band transmitted over the line is in the 200-to-1700-cycle range. Modulator 34 has applied to it continuous waves from generator 111 for the purpose of stepping the frequency of the received band from 200 to 1700 cycles up to the frequency position of the pass-band filter 13 at the transmitter. This band (which is the same for either position of a switch 32 under the above assumptions) after passing through amplifier 35 and delay circuit 36 is applied to the input side of demodulator 37 where it modulates either the wave from generator 110 or the wave from generator 111, depending upon the position of the armatures of relay 30. As a result of these modulations the received waves are alternately stepped down in frequency by different amounts, those corresponding to the upper half of the speech band being shifted 1500 cycles less in frequency than those corresponding to the lower half of the speech band. As a result the two portions are restored to the same positions as in the original speech so that they occupy a region 200 to about 3000 cycles, there being a slight loss in band width due to the switching operations. Low-pass filter 38 is, therefore, indicated as having a cut-off of 3000 cycles, although it could have a higher cut-off, if desirable. Received waves are heard in the receiver 40 which may be any suitable type of sound reproducer. As noted above, the listener does not hear all of the spectrum of the signal at one instant but hears different portions of the sound spectrum in such rapid succession as to get an impression of hearing all of the spectrum at once.

If the limiters 5 and 25 were omitted, the switching relays 9 and 30 would follow the fundamental or vocal cord frequency of the voiced sounds but would remain unoperated by unvoiced sounds because of the relatively low energy level of the latter. Both relays would, therefore, release their armatures to the rest contacts during transmission of unvoiced sounds. In this position of the armatures there is applied to the modulators 12 and 37, the lower of the two waves, i. e., the wave from generator 10 and generator 110. Reference to Fig. 2 shows that under these conditions the upper portion of the speech band is transmitted. Since most of the intelligence in the unvoiced sounds lies in the upper portion of the speech frequency band, this method of transmission would enable the major part of the unvoiced sound energy to be transmitted. However, the use of the limiters 5 and 25 is preferred, since the energy represented by the unvoiced sounds varies sufficiently rapidly to cause actuation of relays 9 and 30 in random manner, resulting in the transmission of both high and low frequencies of unvoiced sounds. A third method would comprise use of a continuous wave of arbitrary frequency for switching oscillators 10 and 11 and 110 and 111 when relays 9 and 30 are deenergized similarly to the method disclosed in Dudley application Serial No. 310,527 filed December 22, 1939.

The purpose of the delay circuits 3 and 36 is to permit the fundamental frequency extractor circuit and switching relays to have time to operate before the speech arrives at the modulator circuits.

While the switching devices have been indicated as relays, other devices, such as space discharge or varistor type of switches using no movable parts, may be used.

In a multiplex system where several channels are on one line the filter pass-bands and the carrier frequencies can be arranged such that the frequency of generator 10 for one channel is the same as the frequency of generator 11 for the channel just below. This would result in having to supply only $(n+1)$ carrier frequencies for n channels instead of $2n$ frequencies.

Instead of transmitting over a line the transmission could take place over any other suitable type of medium, such as over a radio channel.

Among the advantages secured by the method and system of the invention are:

(1) Frequency range reduction by a factor of substantially two to one without a corresponding loss of quality.

(2) Privacy on account of the difficulity of understanding the waves as transmitted with any simple type of receiver.

(3) Increased signal-to-noise ratio arising from the fact that the full load on the system may comprise at any one instant the energy of only one half of the speech spectrum, the energy sent corresponding to the high speech frequencies being equal to that corresponding to the low speech frequencies. In the usual system the average energy falls off for higher speech frequencies. In order to transmit the upper half of the band at relatively high level so as to load the system to the same extent at the lower half, the voltage of generator 10 may be higher than that of generator 11 whereby the output from modulator 12 is greater by the right factor when energized from source 10 than when energized from source 11, for the same signal input. At the receiver, a compensating change is made by making the voltage of source 110 smaller than that of source 111 by corresponding amount.

(4) The need for a separate pilot frequency or channel to synchronize switching is eliminated.

The invention is not to be construed as limited to the specific circuit arrangements or numerical values given, since these are to be taken as illustrative rather than as limiting. The scope of the invention is defined in the claims which follow.

What is claimed is:

1. The method of transmission of speech waves comprising transmitting, at certain instants of time, only the upper speech frequencies and, at other and intervening instants of time, only the lower speech frequencies, and alternating between said two frequency ranges at the fundamental vocal cord frequency of the transmitted speech.

2. The method of transmission of speech waves comprising continuously deriving from speech waves the fundamental vocal cord frequency, alternately transmitting the high frequency portion of the speech spectrum and the low frequency portion of the speech spectrum and controlling the frequency of alternation by a continuously derived fundamental vocal cord frequency.

3. In the transmission of speech with reduced frequency range, the method comprising selecting from a speech wave only the lower frequency portion and transmitting the same in alternate time intervals each of a duration equal to the fundamental voice period, selecting from said speech wave only the upper frequency portion and transmitting the same in the intervening periods each of said same duration, and shifting the frequency position, prior to transmission, of the waves selected from one of said frequency portions so that they overlap in frequency the waves selected from the other of said frequency portions.

4. In the transmission of speech with reduced frequency range, the method comprising transmitting to line in alternate exclusive times in rapid succession the energy representing the upper speech frequencies only and the energy representing the lower speech frequencies only, respectively, and controlling the length and rapidity of said times to correspond with the length and rapidity of the vocal cord fundamental period.

5. The method of conserving frequencies in the transmission of speech comprising subdividing the speech waves on a time basis at the frequency of the voice fundamental, and also on a frequency basis such that only the high frequency components are retained in alternate times and only the low frequency components are retained in the intervening times, and shifting alternate wave portions in frequency to overlie the frequency range occupied by the intervening wave portions.

6. In a system for the transmission of speech, a filter having a pass-band sufficient to cover only a portion of the speech frequency band, means to shift the frequency level of a speech band such that only the high frequency portion of the speech band is passed through said filter in alternate times and such that only the low frequency portion of the speech band is passed through said filter in intervening times, and means for changing from one of said shifting operations to the other at a rate corresponding to the voice fundamental frequency.

7. In a speech transmission system, means to define a series of time intervals of the frequency of the voice fundamental during occurrence of voiced sounds and of random frequency during occurrence of unvoiced sounds, means to transmit waves in a relatively narrow frequency range taken from only the high frequency portion of the speech band in every other time interval, and means to transmit waves in said narrow frequency range taken from only the low frequency portion of the speech band in each of the intervening time intervals.

8. In a speech transmission system, a source of speech waves, an outgoing path, a frequency translating circuit between said source and said path, said circuit having two alternate operating conditions, said circuit in one condition transmitting to said path waves representing only the upper speech frequencies and in the alternate condition transmitting to said path waves representing only the lower speech frequencies, said circuit shifting the frequency of the waves transmitted in one condition so that they occupy the same frequency band as those transmitted in the opposite condition, means to derive from the speech waves the fundamental voice frequency, and means for commutating said circuit between said two conditions in synchronism with said fundamental voice frequency.

9. A receiving system for the system defined in claim 8 comprising means to receive the waves transmitted over said path, a receiver, a receiving frequency shifting circuit between said path and said receiver, means operating in one condition of said circuit to apply to said receiver waves having the frequency of the transmitted waves of unshifted frequency, means operating in another condition of said circuit to restore the waves of shifted frequency to the original frequencies which they had before shifting, and means for commutating said receiving frequency shifting circuit between its two said conditions in synchronism with the commutations of the frequency shifting circuits at the transmitter.

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