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WAVE TRANSMISSION WITH NARROWED BAND

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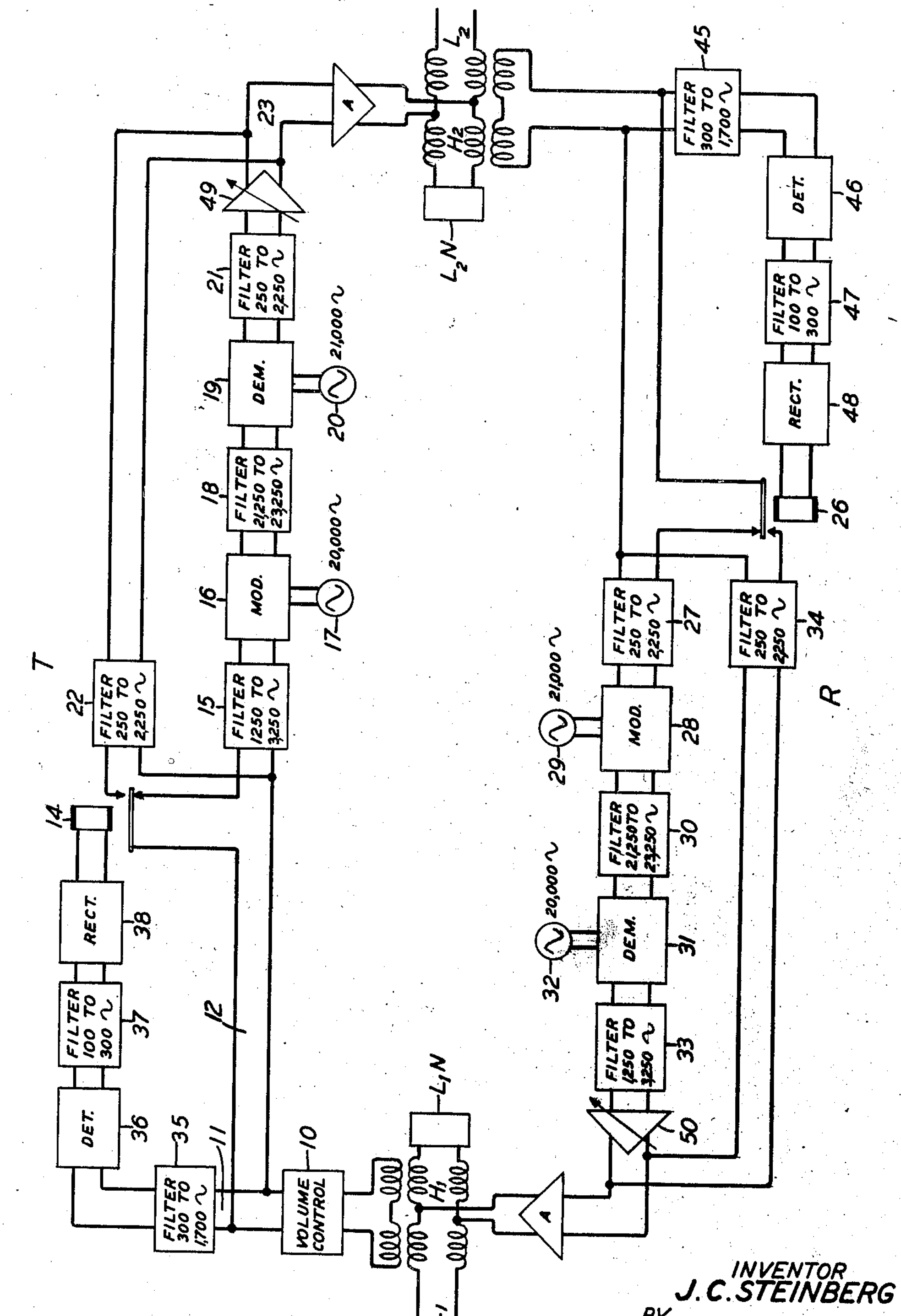

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WAVE TRANSMISSION WITH NARROWED BAND

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The present invention relates to a method and system for transmitting intelligence in which the total frequency range required is less than that embraced in the intelligence-conveying waves as produced.

The invention will be described with particular reference to speech waves, although the invention is equally applicable to other kinds of waves such as music as well as waves used to produce visual effects or the like.

The invention depends upon the existence of certain statistical characteristics in the waves, which enable their subdivision into components of different amplitude and frequency level, varying from instant to instant. The components occurring at any one small instant of that time do not fill the entire frequency range occupied by the waves occurring over a considerable time. Advantage of this fact is taken by shifting the frequency level of certain components where they exist substantially alone at any instant so that they occupy the same frequency level as (or at least overlap in frequency) the components of other frequencies existing substantially alone at some other instant of time.

In the case of speech, it has been determined that the lower portion of the total frequency range is predominantly occupied by the vowel and semi-vowel sounds. The upper portion is occupied principally by the stop and fricative consonant sounds. Moreover, both classes of sounds do not exist in speech in the same instant of time but they occur in rapid succession. This fact makes it possible to divide the one class of sounds from the other on a time basis. Also the amplitudes of the vowel and semi-vowel sounds are larger than those of the stop and fricative consonants. The two classes can, therefore, be distinguished from each other in time, in frequency range and in amplitude or energy.

In practicing the invention, filters may be used to separate the low frequency—large energy components from the high frequency—low energy components. A device responding differently to these two classes of components, switches one or other of the filters into circuit. One filter passes the components directly to the line. The other leads to a frequency-shifting circuit such as a modulator which changes the frequency level of these components so that they occupy the same range as those passed by the other filter, or at least overlap that range. Thus both classes of sounds are transmitted in a reduced band width.

At the receiver a second device differently responsive to the two classes of wave components controls connection of the line to a pair of circuits one of which leads directly to the receiver and the other to a frequency shifting circuit which effects a change opposite to that produced in these components at the transmitter.

A system of this general character is disclosed in my Patent 1,836,824, granted December 15, 1931. The present invention comprises an alternative method and means of distinguishing vowel and semi-vowel sounds from consonant sounds. The invention will be illustrated and described as embodied in a speech transmission system which is identical with that disclosed in my patent supra except for the means employed to distinguish between the two classes of speech components. The invention is, of course, capable of other embodiments and may be used, for example, merely to effect separation of the vowel and semi-vowel sounds from the consonant sounds without regard to the use for which such separation is made.

In accordance with the present invention, that characteristic of speech is made use of which is exhibited in the fact that vowel and semi-vowel sounds contain large components which are harmonics of a fundamental frequency whereas stop and fricative consonant sounds either are lacking in these harmonics or contain them only in a much smaller degree.

The wave forms of the vowels and semi-vowels show that they are characterized by certain transient and resonant variations that are impressed on a direct stream of air that has been modulated with the fundamental or vocal cord tone. This fundamental in the case of a man's voice is of the order of 125 cycles a second while in a woman's voice it is around 250 cycles. The prominent harmonics lie in the frequency range between 300 and 2000 cycles.

The wave forms of the stop and fricative consonants show that they also are characterized by transient and resonant variations which, however, are impressed on a direct stream of air which appears to be modulated with variations that arise from the frictional effects of the passage of air through the vocal cavities. In the case of the voiced stop and fricative consonants, the fundamental or vocal cord tone is also present to a small extent, but there is a noticeable absence of overtones of the fundamental in the frequency range from 300 to 2000 cycles.

The semi-vowel sounds which contain prominent harmonics in this range and thus resemble the vowels are *l, m, n, ng, r, w,* and *y*. The unvoiced stop and fricative consonants are *p, k, t, ch,* (chin) and *f, s, sh, th* (thin) respectively. The corresponding voiced consonants which, as stated, are weak in harmonics of the fundamental in the region 300 to 2000 cycles, are *b, g, d, j,* and *v, z, zh* (azure), *th* (then). These latter are thus classed with the corresponding unvoiced consonants as regards lack of prominent harmonics in the range mentioned.

In accordance with the present invention the two classes of sounds (vowels and semi-vowels as against stop and fricative consonants) are separated by detecting or rectifying speech waves in the region from about 300 cycles up to the order of 1700 to 2000 cycles and passing the resultant detected components through a filter with a pass range from about 100 to 300 cycles. The sounds that have prominent over-tones of a fundamental of either 125 cycles or 250 cycles will upon detection yield a considerable amount of such fundamental, which will pass through the filter and may be used to operate suitable switching or selecting apparatus. Sounds that are weak or lacking in these harmonics will produce little or no component in the 100 to 300 cycle range and will be of insufficient strength to operate the switching device.

The invention will now be described as embodied in a two-way telephone system shown schematically in the single figure of the accompanying drawing, which as stated is identical with Fig. 3 of my patent supra except for the switch control circuits.

The drawing shows a two-way terminal circuit for interconnecting the subscriber's line L_1 at the left with the main telephone line L_2 shown at the right.

It is assumed in this illustrative example that the maximum frequency which it is practicable to transmit over the line L_2 is about 2250 cycles. Of course, speech could be transmitted over this line employing the range from about 250 cycles to 2250 cycles and commercial quality for many purposes would be obtained. However, in case it is desired to obtain a higher quality of transmission than would be possible with the range 250 to 2250 cycles by direct transmission, the method of the present invention permitting utilization of the range 250 to 3250 cycles per second will be described showing how an increase in quality for this available total line range can be obtained.

The subscriber's line L_1 and the telephone line L_2 are each shown as provided with the usual hybrid coils H_1 and H_2 respectively, and the usual line balancing net works L_1N and L_2N respectively.

For transmitting from the line L_1 to the line L_2, there is provided a path generally indicated by T and for transmitting in the opposite direction between L_2 and L_1 there is provided a second path generally indicated by R.

In the transmitting path T beginning at the hybrid coil H_1 there is first a volume control circuit for reducing to the same level speech waves received over different length subscribers' lines or from individuals having different voice strength. This volume control may be of any suitable type, either automatic or manual, but preferably automatic, examples of this type being given in patents of R. C. Mathes No. 1,810,025 granted June 16, 1931, and D. Mitchell No. 1,853,-070 granted April 12, 1932. This volume control when used in the present system will have a relatively large time lag so that its adjustment will not be changed for instantaneous variations in speech level but so that it will regulate only the average speech level over a considerable period of time.

On the output side of the volume control 10 the circuit branches into the two portions 11 and 12.

Branch 11 leads through a filter 35, detector 36, filter 37 and rectifier 38 to the switching relay 14. Filter 35 has a pass range from about 300 to 1700 cycles, sufficient to embrace the principal harmonics of the fundamental or vocal cord frequency. Strong harmonics in this range are acted upon in detector 36 to yield an output component of fundamental frequency which is selectively passed through filter 37 and upon being rectified at 38, causes operation of relay 14. Suitable amplification (not shown) may be used in branch 11. Thus vowel and semi-vowel sounds will cause actuation of relay 14 while consonant sounds will fail to operate the relay.

Circuit 12 leads directly to filter 15, through the normally closed back contact of relay 14. This filter 15 is in the consonant branch, which branch is closed unless relay 14 is actuated by vowel sounds. Filter 15 is designed to pass currents of frequencies between 1250 cycles per second and 3250 cycles per second but to suppress currents of both lower and higher frequencies. This and the other filters throughout the system may be designed in accordance with the principles laid down in the U. S. patent to G. A. Campbell 1,227,113, patented May 22, 1917.

The output side of filter 15 is connected to modulator 16 which is preferably of the type disclosed in U. S. patent to Carson 1,343,306, dated June 15, 1920. This modulator is supplied with carrier waves from source 17, these waves having a frequency of 20,000 cycles per second. This source is preferably a vacuum tube oscillator such as is commonly used in carrier wave systems. As explained in the Carson patent, this type of modulator prevents the unmodulated carrier components from the source 17 from passing into the outgoing circuit so that only the two side bands resulting from the modulating action of the circuit appear in the final output.

The output of modulator 16 is connected through a second filter 18 which is designed to pass only the range from 21,250 to 23,250 cycles per second, this being the upper side band resulting from the modulation in circuit 16.

This side band is then demodulated in circuit 19 by means of a sustained wave of 21,000 cycle frequency generated at source 20. This demodulator 19 may be identical with the modulator circuit 16 and is of the type disclosed in the Carson patent referred to. As the result of the demodulation in circuit 19, a lower side band extending from 250 cycles to 2,250 cycles per second is produced and this passes through the filter 21, the other components of modulation being outside the transmission range of the filter and therefore suppressed.

As a result of the steps performed by the apparatus 15 to 21 inclusive, it will be seen that the consonant frequencies in the range 1,250 to 3,250 cycles per second have been stepped down in frequency to occupy the range 250 to 2,250 cycles per second.

When relay 14 attracts its armature, in response to vowel components, circuit 12 is connected to the input of filter 22 which passes the range 250 to 2,250 cycles per second directly to the outgoing circuit 23. After suitable amplification, the currents in circuit 23 are transmitted by way of hybrid coil H_2 into the outgoing line L_2.

The apparatus in the receiving side R is closely analogous to that in the transmitting branch T and the description will follow readily from that which has been given for branch T.

In the receiving branch, the elements 45, 46, 47 and 48 are analogous to elements 35, 36, 37 and 38, already described, and function in similar manner.

Consonant sounds arriving over line L_2 from the distant station contain an insufficient amount of over-tones to cause operation of relay 26. The filters 27, 30 and 33 respectively may be identical respectively with filters 21, 18 and 15. The modulators 28 and 31 may be identical with 16 and 19 as may also the sources 29 and 32 with respect to the sources 20 and 17. In fact, in practice, instead of two sources 17 and 32, one source would probably be used to supply both modulators 16 and 31, and similarly, one source would be used in place of the two sources 20 and 29 shown on the drawing. Filter 34 may be identical with filter 22.

The operation of the circuit is as follows. Speech waves coming in over the subscriber's line L_1 pass through the volume control 10 and are reduced under varying conditions of service to the same volume level. These waves pass in part into the branch 12 and in part into the branch 11. If the waves in branch 11 contain insufficient harmonic component to yield a requisite level of fundamental, relay 14 remains unactuated and branch 12 remains connected to the filter 15. As explained above, the relay 14 is adjusted so that it attracts its armature in response to vowel and semi-vowel sounds but does not attract its armature in response to consonant waves in the circuit 11. Consequently the consonant components in the subscriber's speech occupying the range from 1,250 cycles to 3,250 cycles per second pass freely through the filter 15 and into the modulator 16 where they modulate the sustained waves of 20,000 cycles from the source 17. The upper side band resulting from this modulation is passed through the filter 18 to the demodulator 19 where it is combined with the sustained wave of 21,000 cycle frequency from the source 20. The lower side band of this demodulating process lies in the range from 250 to 2,500 cycles per second and therefore passes freely through the filter 21 and through the outgoing amplifier into the hybrid coil H_2 and the outgoing line L_2. As a result of this process the consonant sounds which normally occupy the range from 1,250 to 3,250 cycles per second pass into the outgoing line L_2 in the reduced frequency range extending from 250 to 2,250 cycles per second.

Vowel sound components and semi-vowel components present in the subscriber's speech passing into the circuit 11 cause actuation of relay 14 and shift the circuit 12 from the input of filter 15 to the input of filter 22 so that these vowel sounds and semi-vowel sounds which occupy the range from 250 to 2,250 cycles per second pass directly into the outgoing branch 23 and so to line L_2.

Since normally each word of speech will comprise partly vowel or semi-vowel sounds and consonant sounds, the relay 14 will be operating continually during sustained speech and for this reason its operation should be made as fast as practicable in order not to seriously clip any portions of the words or syllables being spoken.

From the foregoing description it will be evident that the vowel and the consonant sounds transmitted to the line L_2 both occupy the same frequency range and it is necessary therefore to separate the vowel sounds from the consonant sounds in order to receive the speech in intelligible manner.

The station at the opposite end of the line L_2 may be an exact duplicate of the station shown on the drawing, so that the manner in which the speech waves are received at the distant terminal will be evident from considering that speech waves are coming in on the line L_2 to the station shown in the drawing after having been treated at the distant station in exactly the same manner as has been described above.

As already stated, consonant sounds arriving over L_2 from the distant station contain insufficient harmonics of the fundamental voice component to cause operation of relay 26. These sounds therefore pass directly into the filter 27 and from there into the modulator 28 where they are stepped up in frequency by combining with the wave of 21,000 cycle frequency from source 29. The upper side band resulting from this modulation is passed through the filter 30 and is demodulated with waves from the source 32 of 20,000 cycle frequency producing a side band extending from 1,250 to 3,250 cycles per second. This side band is transmitted to the filter 33 and into the line L_1. As a result of the modulating action just described, it is seen that the consonant sounds which were transmitted at reduced frequency level over the line L_2 are elevated to their normal frequency level before they are transmitted into the subscriber's line L_1.

Vowel and semi-vowel sound components received over the line L_2 actuate the relay 26 and connect the incoming circuit to the filter 34 instead of to the filter 27. These vowel and semi-vowel sound components occupying the range 250 to 2,250 cycles per second pass directly into the outgoing subscriber's line L_1.

It will be seen that a saving in the total frequency range of 1,000 cycles per second has been effected since the components in the range 250 to 3,250 cycles per second have been transmitted in the total range of 250 to 2,250 cycles per second over the line L_2.

In the example that has been given, an overlap of 1,000 cycles in frequency has been allowed for the vowel and semi-vowels on the one hand and consonant sounds on the other, and the frequency level of the consonant components has been stepped downward to increase the overlap with respect to the vowel sounds. It is within the invention, of course, to shift the frequency level of the vowel sound components to increase the normal overlap with respect to the consonant components.

The invention is not to be construed as limited to particular frequency values or ranges that have been given by way of example, nor to the specific circuits that have been illustrated. For example, if the line L_2 were capable of transmitting the range 250 to 2,750 cycles per second, the division might be as follows:

Vowel and semi-vowel sounds—250 to 2,750 cycles per second,

Consonant sounds—1,250 to 3,750 cycles per second.

Various other frequency limits and frequency divisions will occur to any one desiring to practice the invention in connection with a particular system or situation.

It will be noted that the present invention depends not merely upon amplitude of the speech waves but upon the presence or absence of certain frequency relations existing in some sounds and not in others. The existence or non-existence of these frequency relations is independent of absolute volume. The method of the present invention offers an advantage in distinguishing from noise currents which may lie in the vowel range and have large amplitude but do not exhibit the characteristic of having prominent components harmonically related to the speech fundamental. The method of the invention also, and in the same way distinguishes from strongly inflected or emphasized consonants, such as *sh* and *s* which may have amplitudes comparable with vowel sounds but lack the characteristic harmonically related components of vowels. Also the volume may vary to a greater extent than where relative amplitudes alone are relied upon, without interfering with the operation of the method according to this invention.

Thus, in accordance with the present invention, the unvoiced consonant sounds may be amplified to any desired level before transmission so as to enable them to over-ride noise on the line. This amplification does not interfere with separation of the vowel and consonant sounds at the receiver since, even if the consonant sounds are raised to the same amplitude as the vowels, there is not enough voicing fundamental in the consonants to cause false operation of the switching. The drawing indicates amplification in the consonant branch at 49 for producing a controllable amount of amplification before the line is reached. Amplification is shown also in the receiving consonant branch at 50, in case amplification for wave shaping purposes may be desired, although element 50 may actually need to be a loss element in some cases to restore the consonant sounds to their proper amplitude level relative to the vowels.

The element that has been described as a detector (36) may be any device that will yield a fundamental component from the harmonics present in vowel sounds, such as a vacuum tube with a non-linear input-to-output characteristic.

Instead of using an electromagnetic relay 14 to perform the switching, any other suitable means known to the art may be used that is capable of exercising the necessary circuit control.

The means and method of the invention is not limited in its use to transmission or receiving systems but may be used to effect separation of vowel components from consonant components for any purpose.

What is claimed is:

1. The method of distinguishing vowel from consonant sound comprising deriving fundamental wave components from a band of speech frequencies containing harmonics of the fundamental but none of the fundamental frequency component, and utilizing the energy of said derived fundamental to indicate vowel sounds to the exclusion of consonant sounds.

2. The method of separating vowel from consonant sounds comprising transmitting speech waves over a path normally serving as the consonant path, selecting from the speech waves a frequency band excluding speech fundamental components but including prominent harmonic components of the speech fundamental, deriving from the latter, wave energy of speech fundamental frequency, and utilizing said energy when present to cause the corresponding speech waves to traverse a different path serving as the vowel path.

3. A system for distinguishing vowel from consonant sounds comprising means to select from speech waves a frequency band excluding components of fundamental speech frequency but including harmonics of the fundamental, means to derive from such selected band a component of the speech fundamental, and means controlled by said fundamental so derived for indicating vowel sounds to the exclusion of consonants.

4. In combination, a circuit having two branches, means commutating said two branches, said means normally effectively connecting said circuit to one of said branches, means to transmit speech over said circuit, filter means to select a frequency band from said speech excluding the speech fundamental but including harmonics thereof, means to derive a component of speech fundamental from said selected band, and means controlled by said derived fundamental component for operating said commutating means to effectively disconnect said circuit from the first branch and connect it to the other branch.

5. The method of speech transmission comprising separating speech waves on the basis of the components rich in harmonics of the speech fundamental as distinguished from the components weak in such harmonics occurring in successive instants of time, and shifting the frequency level of one such group of the separated components so that they occupy the frequency level occupied by the other group, whereby both groups of components are transmitted in a band of frequencies less wide than that of the speech components as produced.

6. The method of separating vowel from consonant sounds comprising exploring speech waves to determine the presence of components rich in harmonics of the fundamental speech components as distinguished from components relatively lacking in such harmonics, and utilizing the energy of such harmonics to separate the speech components of simultaneous occurrence therewith from the speech components of a different time of occurrence.

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