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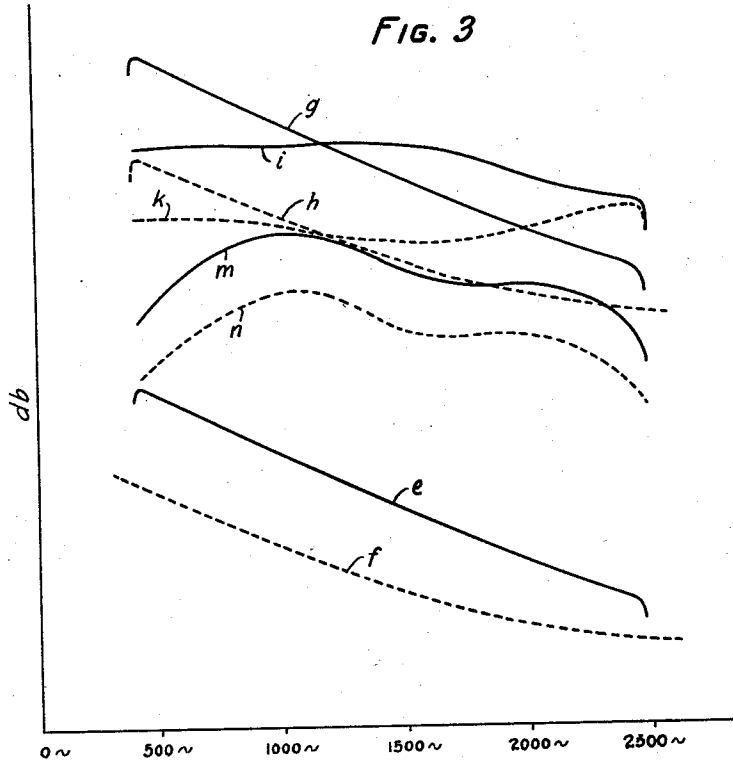
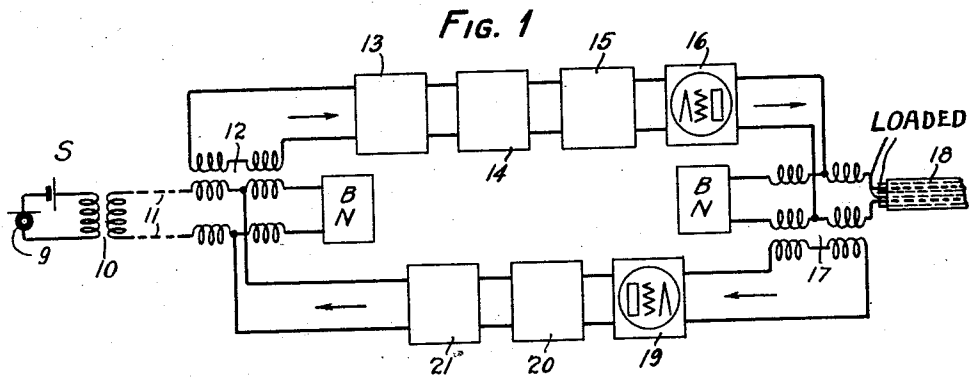
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TELEPHONE TRANSMISSION

Filed Feb. 21, 1929

2 Sheets-Sheet 1



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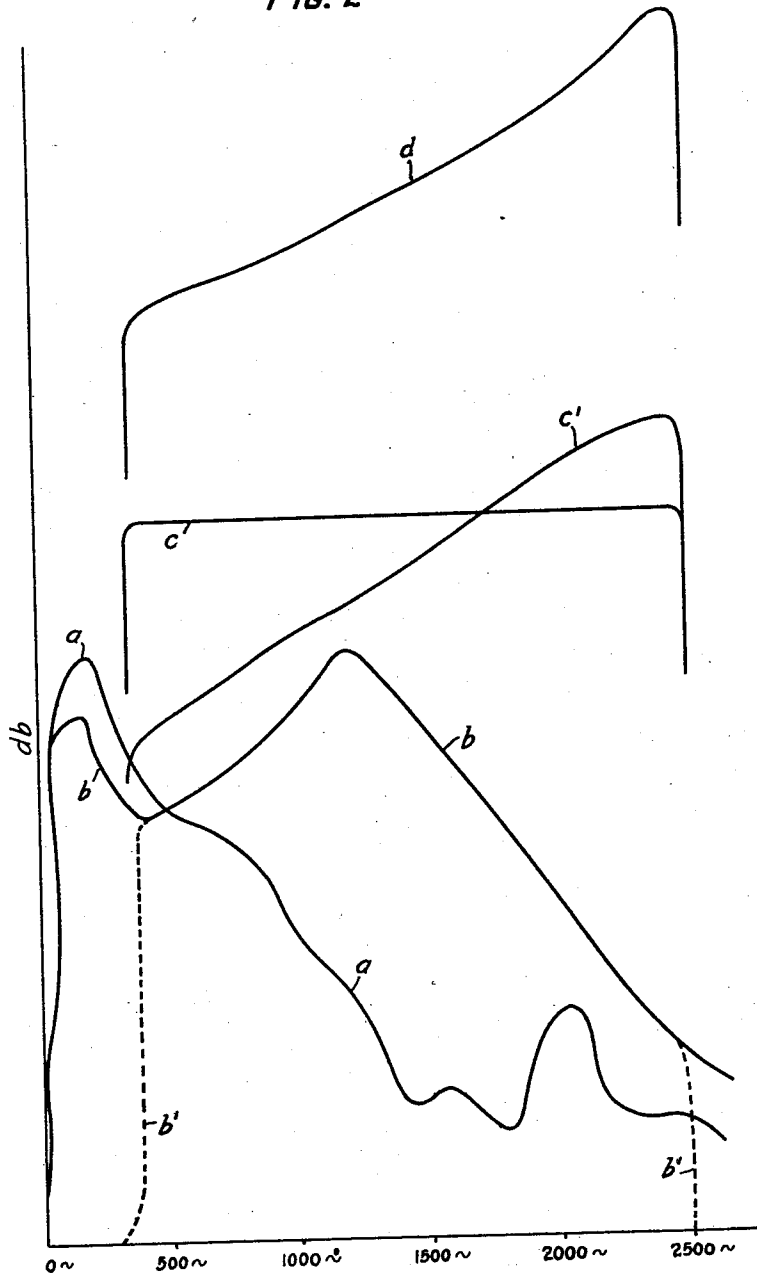
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FIG. 2



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UNITED STATES PATENT OFFICE

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TELEPHONE TRANSMISSION

Application filed February 21, 1929. Serial No. 341,623.

The present invention relates to signaling systems and particularly to the transmission of speech currents over long submarine cables.

An object of the invention is to provide for the efficient transmission and intelligible reception of speech over a submarine signaling cable where the sending current is limited by the physical characteristics of the cable, and the minimum practicable value of received current in any frequency region is established by the level of extraneous interference in that frequency region.

Another object of the invention is to utilize most efficiently a loaded submarine signaling cable of great attenuation having a variable attenuation through a wide range of the frequencies of the speech spectrum for the transmission of speech to great distances.

A further object of the invention is to provide for transmission of telephone currents over a loaded signaling conductor of great length, definite diameter, and definite physical characteristics, the length and constants of the cable being such that the transmission of commercial speech over it necessitates the application of more advanced technique than heretofore employed for telephone transmission.

In accordance with one feature of the present invention the effect of modulation on the loaded cable because of the non-linear current inductance curve of the cable makes it desirable to eliminate a wide range of the lower speech frequencies; for example, the frequencies up to 400 cycles, more or less, may be practically or wholly suppressed with no decrease or perhaps an actual gain in the intelligibility of the speech transmitted over the cable. The results of this are several-fold in that the cable is not burdened with power of the lower frequencies, which makes it possible to impress upon the cable more energy of higher frequencies which are more useful for intelligibility; in that the production of harmonics of the lower frequencies is prevented, thereby preventing the partial masking of the higher frequencies by the harmonics; and in that the production of combination tones of the frequencies below 400 cycles with those above 400 cycles is prevented. In cases where

the transmission of frequencies below 400 cycles is permissible, the band of frequencies from zero to 400 cycles may be used for simultaneous telegraphy.

In accordance with another feature of the present invention, the speech waves are pre-distorted before impression upon the cable in such a manner that the average energy of any frequency impressed upon the cable, when attenuated by the cable an amount corresponding to the cable attenuation at that frequency, is received with an amplitude above the noise level at that frequency by an amount necessary for commercial practice.

The desired results are obtained by pre-distorting the speech waves to be impressed upon the cable at the transmitting end in such a fashion that the higher frequencies in the speech band are transmitted with a greatly increased amplitude with respect to the lower frequencies. This may be accomplished by attenuating the lower frequencies to the desired level as compared with the higher frequencies and by entirely suppressing the speech frequencies below about 400 cycles and those above about 2500 cycles, because at the receiving end the amplitude of the frequencies above about 2500 cycles will be smaller (or so little greater) than the amplitude of the noise currents that they consequently cannot be efficiently received. The remaining speech frequency spectrum is then amplified to the desired sending level and the signaling waves are impressed upon the cable at the highest possible level permitted by the magnetic properties of the loading material or dielectric properties of the cable insulation.

The waves transmitted in this manner when received at the distant end and uniformly amplified will not be of sufficient intelligibility, or if intelligible, the speech will not be natural. Hence in addition to supplying a very great amplification at the receiving end, it is necessary to apply a correcting distortion or attenuation equalization, whereby the relative amplitudes of the various frequency components between about 400 cycles and 2500 cycles are made to approximate more closely those of normal speech.

Consider a cable about 2000 miles long

continuously or otherwise loaded with magnetic material and having an attenuation of 80 decibels (herein abbreviated db.) at 400 cycles and about 120 db. at 2000 cycles and
 5 having at the receiving end a normal volume and a normal distribution of noise. The problem dealt with in the present specification relates to the transmission from one end to the other and reception of speech over such
 10 a cable.

The explanation of how commercial speech may be transmitted and received over such a cable in one particular instance will be given in connection with Figs. 1 to 3, Fig. 1 being
 15 a diagrammatic representation of a four-wire circuit for connecting a land line to a cable;

Fig. 2 being graphs on a logarithmic scale of the power-frequency distribution of the signal waves at various points along the system prior to impression upon the cable and
 20 Fig. 3 being corresponding graphs at various points along the system at the receiving end of the cable.

In Fig. 1, S indicates a substation including a microphone transmitter 9 transmitting speech power through transformer 10 to land line 11 and its balancing network BN over hybrid coil arrangement 12 to band pass filter 13. The four-wire circuit with hybrid coil
 25 and network balancing the cable is a typical representation of apparatus duplicated at the distant end of the cable. For the purpose of this description we assume that the speech power impressed upon filter 13 is of practically constant volume. The following discussion will be based upon the average power
 30 distribution of various voices when the current of each voice is reduced to an equal volume. Filter 13 is adapted to suppress substantially speech waves having a frequency below about 400 and those above about 2500
 40 cycles per second. The curve *a* of Fig. 2 shows on a logarithmic scale the frequency-power distribution in the air of the sound waves impressed upon the microphone 9. Curve *b*
 45 shows the frequency-power distribution of the speech currents after transmission through the land line. Curve *b'* depicts the resultant after passing the waves through filter 13. In order to restrict the variations
 50 of the speech currents and to increase the amplitude thereof they are passed through two attenuation-equalizer-amplifiers 14 and 15 in close succession. The device 14 substantially
 55 flattens out the frequency-power distribution curve and amplifies the speech currents as shown in curve *c*. The device 15 predistorts the frequency spectrum and gives it substantially the shape shown by curve *c'*. Amplifier 16 uniformly amplifies the speech current
 60 to a level such as represented by curve *d*. Devices 14, 15 and 16 are preferably chosen so as to insert an over all gain of about 80 db. The amplified currents are then impressed
 65 upon hybrid coil 17 and from thence upon the

cable 18 at the highest level permitted by the magnetic properties of the loading material and the dielectric properties of the cable insulation.

A cable of a length of 1000-2000 nautical
 70 miles introduces a great attenuation greatly varying with frequency and distorts the transmitted speech waves in a corresponding manner. Curve *e* of Fig. 3 depicts the frequency-power distribution of the waves received at the receiving end and curve *f* illustrates the noise level over the range 400 to
 75 2500 cycles of a typical cable under average conditions. The distance between curves *e* and *f* for any particular frequency range 80 may be varied as conditions will permit or as intelligibility considerations may indicate. It is known that certain ranges of frequencies contribute more than others to speech intelligibility and these ranges may be favored.
 85 In order to render the received speech intelligible it is first passed through amplifier 19 which inserts a gain of about 50 db. and thereby raises its level from that of curve *e* to that of curve *g* and the noise level from
 90 curve *f* to curve *h*, Fig. 3. Band pass filter 20 suppresses all noise currents having frequencies below about 400 and above about 2500 cycles per second. Attenuation-equalizer-amplifier 21 shapes the curve of the received
 95 speech waves to substantially approximate the curve *i*, the curve *k* representing the correspondingly amplified and shaped noise level. The curve *m* represents the curve of the acoustic power which will finally be delivered by the receiver at the distant end and
 100 *n* the curve of the corresponding noise level.

The equalizing amplifiers 14, 15 and 21 may consist of several amplifying stages and one or several equalizing networks as may
 105 be desired. Likewise amplifiers 16 and 19 may consist of any desired number of thermionic tubes with appropriate input and output impedances and current supply sources. The equalizing networks may be designed in
 110 accordance with known principles such as set forth in U. S. patent to Zobel 1,603,305, October 19, 1926; Blackwell U. S. Patent 1,454,011, May 1, 1923; Johnson's "Transmission Circuits for Telephonic Communication" (Van Nostrand N. Y. 1925) especially
 115 Chapter XVIII; and other patents and publications.

The relative and absolute magnitudes of amplification, attenuation, and energy distribution given herein are those which may be encountered in a typical case and each case is governed by a particular set of conditions for which due allowance should be made.

What is claimed is:

1. A method of telephone transmission over a system comprising a land line and a submarine cable characterized in this that the lower frequencies of the speech currents
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received from the land line are suppressed before transmission over the cable.

2. A system for telephone transmission over a submarine telephone cable of transoceanic length, characterized in this that shaping and amplifying means are provided at the transmitting end of the cable for substantially suppressing the lower frequencies and for altering the frequency-amplitude relation of the utilized band of voice waves, said amplifying and shaping means having a combined transmission characteristic whereby the high frequencies are amplified more than the lower frequencies, and whereby after attenuation by the cable the average amplitude of the received waves is above the average received noise level at that frequency.

3. A system in accordance with claim 2 characterized by the provision of means at the receiving end restoring to a considerable extent, at least, the normal frequency-amplitude relation of the voice waves before applying them to a transmission line.

4. A system in accordance with claim 2 in which the cable is loaded with magnetic material characterized by the provision of means such as a filter at the transmitting end for suppressing a band of at least several hundred cycles of the lower frequency waves of speech.

5. A system in accordance with claim 2, in which the cable is inductively loaded, characterized by the provision of means such as a filter at the transmitting end for suppressing a band of frequencies of several hundred cycles of the higher frequency waves of speech.

6. A system in accordance with claim 2, in which the cable is inductively loaded, characterized by the provision of means such as a filter at the transmitting end for suppressing a band of at least several hundred cycles of the lower and upper frequencies waves of speech.

7. The method of transmitting speech frequency currents over a submarine cable, which comprises selectively attenuating and amplifying the currents of speech frequency, before impressing them on the cable, in such a manner that this frequency-amplitude characteristic after amplification and attenuation is the converse of the cable transmission characteristic modified in a manner converse to the amplitude-frequency distribution of the energy of normal speech.

8. A method in accordance with the immediately foregoing claim, further characterized in this, that the frequency-amplitude characteristic of the speech transmitted to the cable is further modified proportionally to the characteristic curve of the average distribution of noise energy picked up along the cable and received at the receiving end thereof.

9. Circuit arrangements for transmitting speech wave energy over a submarine cable having a certain characteristic of average noise or interfering energy with frequency at the receiver, comprising a transmitter, a land line, means for suppressing several hundred cycles of the lower frequencies of the speech spectrum, means for amplifying the upper portion of the residual frequency band at least several times as much as the lower portion with an amplification which increases toward the upper end of the upper portion, whereby the level of the received speech energy is substantially uniformly above the level of the received interfering energy.

10. A transoceanic cable telephone system comprising a source of speech waves, amplifying means and amplitude-frequency distorting means at the transmitting end, a cable, a receiver including amplifying means and amplitude-frequency distorting means, said system being characterized in this, that the amplifying and amplitude-frequency distorting means at the transmitting end impress upon the cable a maximum amplitude of energy in the frequency range about 1800 to 2500 cycles, and the amplifying and amplitude-frequency distorting means at the receiving end impress upon the receiving device a maximum amplitude of energy in the range around 1000 to 1200 cycles.

11. A speech transmission system comprising a line having a highly variable attenuation with frequency, means at the transmitting end for producing a wave derived from normal speech and of such nature that after transmission over said line the various received components within a wide band have a frequency-amplitude relation much more nearly uniform than would be the case for transmission of normal speech, and means at the receiving end for converting the received wave into a wave more nearly approximating the normal amplitude frequency relation of speech than that received.

In witness whereof we hereunto subscribe our names this 9th day of February, 1929.

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