Dec. 18, 1962 E. HOPNER ETAL 3,069,506

CONSONANT RESPONSE IN NARROW BAND TRANSMISSION

Filed Sept. 4, 1957

4 Sheets-Sheet 1

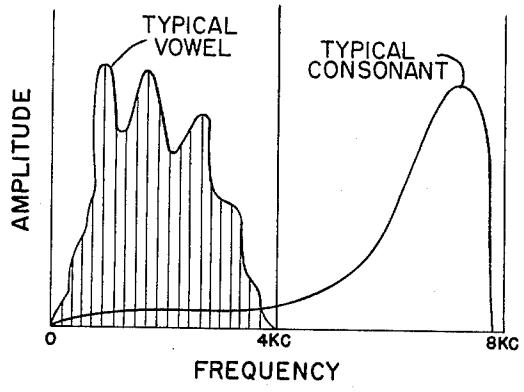


FIG. 1.

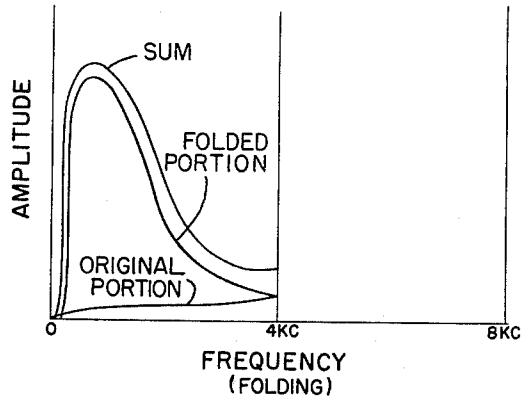


FIG. 2.

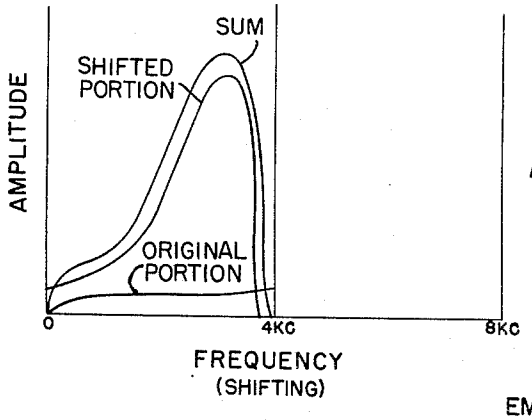


FIG. 3.

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4 Sheets-Sheet 2

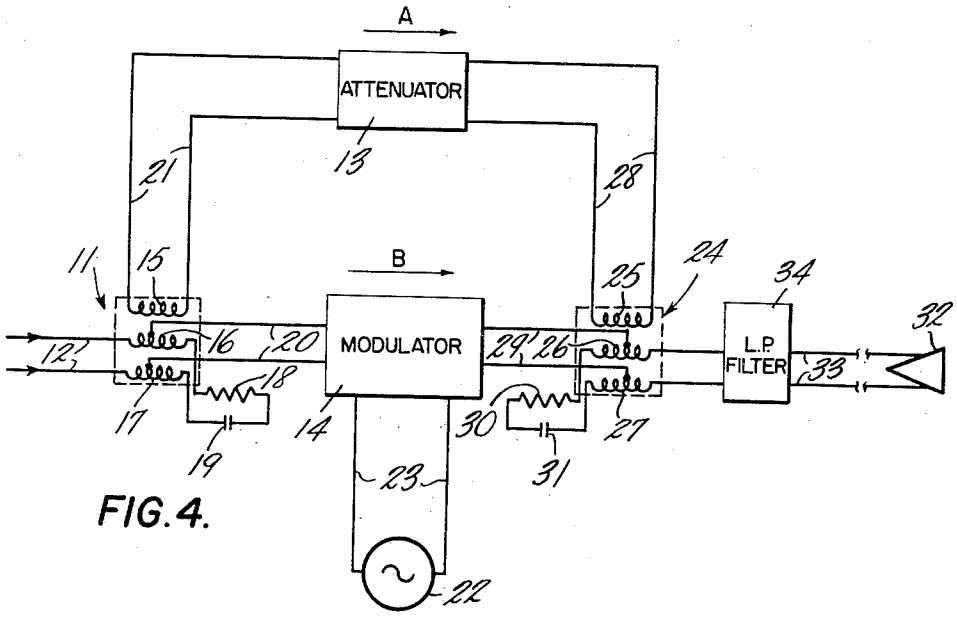


FIG. 4.

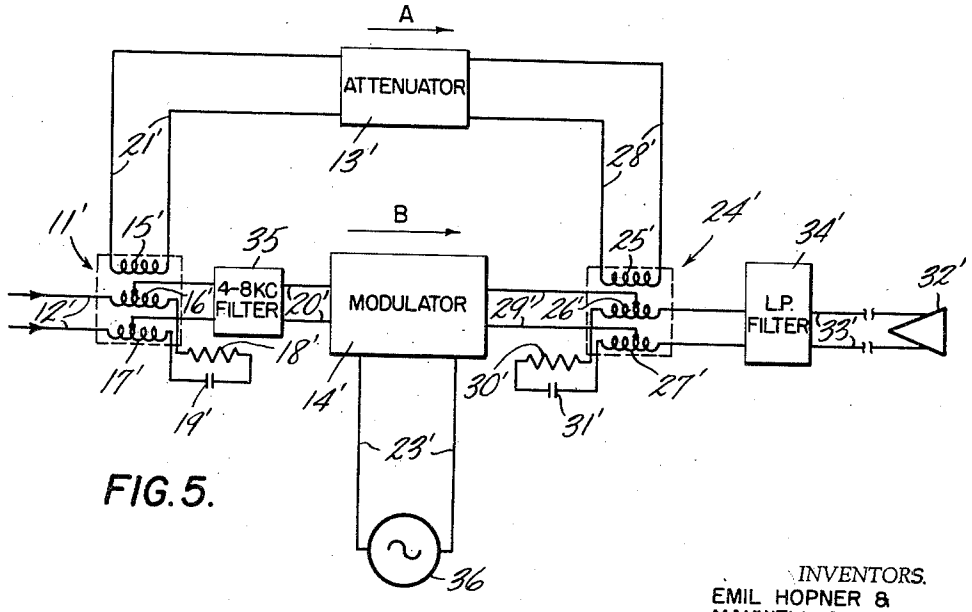


FIG. 5.

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CONSONANT RESPONSE IN NARROW BAND TRANSMISSION

Filed Sept. 4, 1957 4 Sheets-Sheet 3

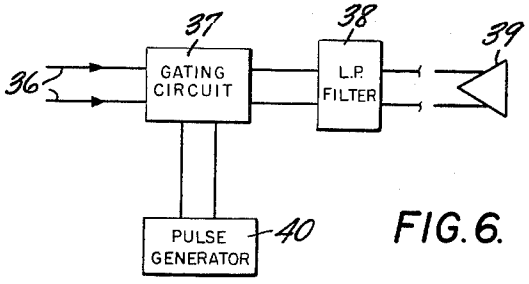


FIG. 6.

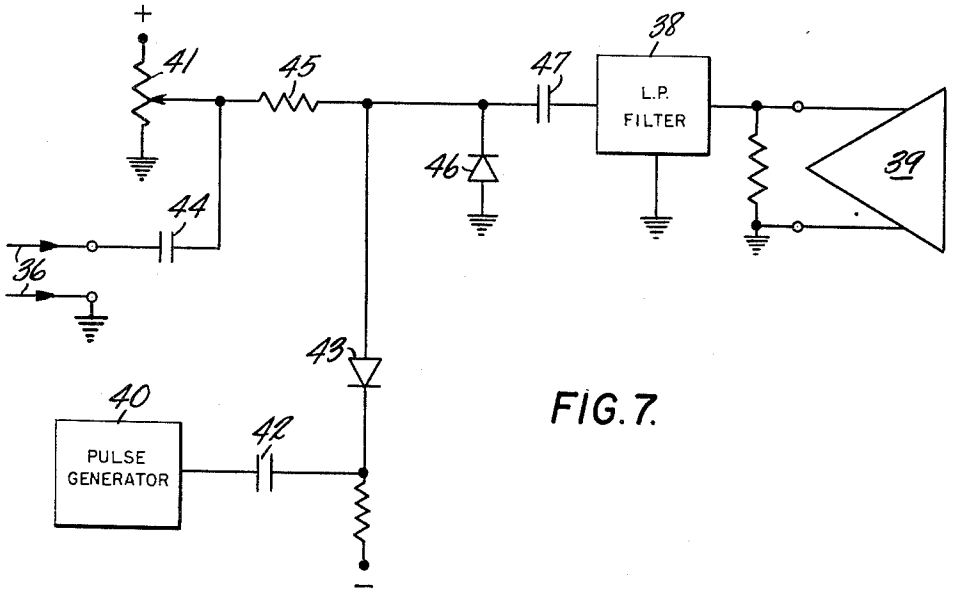


FIG. 7.

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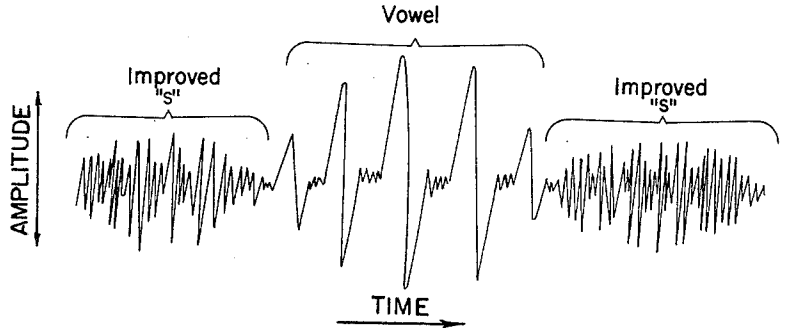


FIG. 8.

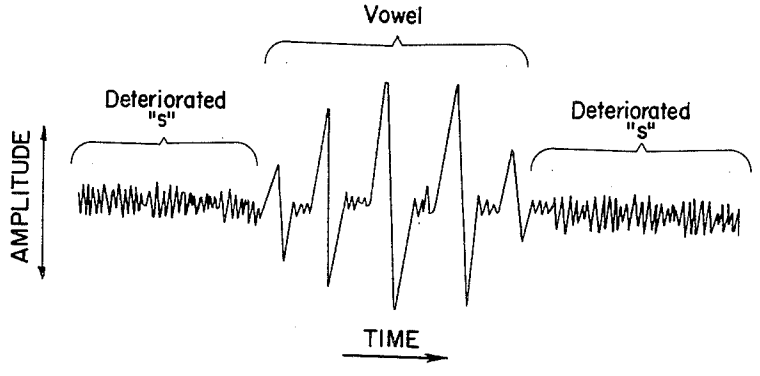


FIG. 9.

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3,069,506

CONSONANT RESPONSE IN NARROW BAND TRANSMISSION

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Filed Sept. 4, 1957, Ser. No. 681,989
10 Claims. (Cl. 179—15.55)

This invention relates to narrow band audio transmission and, more particularly, to a new and improved method and means for providing better consonant reproduction in transmission systems wherein the transmitted signals are restricted to a narrow frequency range.

In electrical systems designed primarily for transmission of speech signals, it is common practice to restrict the range of the transmitted frequencies to a narrow band, for example, 300 to 3400 cycles per second. As a consequence of this frequency restriction, the reproduced speech is impaired in tonal quality, resulting in considerably reduced understandability (articulation) of many consonants. Analysis of the frequency spectrum of the sounds comprising speech has shown that most consonant sounds include important tonal components in the four to eight kilocycle frequency range, whereas the vowel sounds are generally restricted to the frequency range below four kilocycles.

Various systems have been devised for improving the consonant response of such narrow band equipment, but these depend for their operation on the selection of speech elements according to differences in amplitude or in time duration. Also, these systems require reconstruction of the signal in its original form at the receiver.

It is an object of this invention, accordingly, to provide a new and improved method and means for transmitting speech signals through a narrow band system with reduced impairment of tonal quality.

Another object of the invention is to provide a novel method and means for obtaining improved consonant response in the transmission of speech signals over a narrow band independent of the relative amplitudes or time durations of the signal elements.

A further object of the invention is to provide a new and improved method and means for obtaining better consonant response in narrow band transmission systems wherein it is unnecessary to reconstruct the received signal in its original form.

These and other objects of the invention are accomplished by combining the high and low frequency components of the audio speech signal by shifting or folding the frequency spectrum. More particularly, a portion of the speech signal is applied to a sum-and-difference type modulator to produce a low frequency signal embodying the high frequency speech components. This signal is combined with the original audio signal for transmission through a low frequency narrow band system. The reproduced signal has been found to have substantially improved consonant distinguishability compared with ordinary signals transmitted through a narrow band system.

Further objects and advantages of the invention will be apparent to those skilled in the art from a reading of the following description taken in conjunction with the accompanying drawings, in which:

FIG. 1 is a graphical representation illustrating the relation between frequency and relative amplitude for typical vowel and consonant sounds;

FIG. 2 is a graphical representation showing the effect of combining the high frequency components of a speech signal with the low frequency components by folding the frequency spectrum;

FIG. 3 shows the effect of combining the high and low frequency components by shifting the frequency spectrum;

FIG. 4 is a circuit diagram showing a typical embodiment of the invention adapted to combine the high and low frequency components of a speech signal by folding the spectrum;

FIG. 5 is a circuit diagram showing another embodiment of the invention whereby the frequency spectrum is shifted to combine the high and low components;

FIG. 6 illustrates diagrammatically a modification of the invention shown in FIG. 4, whereby the frequency spectrum is folded to combine the high and low frequency spectra by means of a pulse sampling technique;

FIG. 7 illustrates a typical circuit for carrying out the invention according to the embodiment shown in FIG. 6;

FIG. 8 shows the amplitude-time function after transmission through a low-pass line of a syllable consisting of a typical vowel preceded and followed by the consonant "*s*" wherein the frequency band has been folded according to the invention; and

FIG. 9 shows how the consonant "*s*" information is deteriorated in going through a low-pass line limited in frequency to about 3.5 kilocycles in the absence of a folding or shifting operation.

In FIG. 1 the frequency distribution of a typical consonant sound is shown to extend from one hundred cycles to eight kilocycles per second, with the greater amplitudes being in the four to eight kilocycle range. As there illustrated, the spectrum of a typical vowel sound is restricted approximately to the range between one hundred cycles and four kilocycles.

Folding of the spectrum according to the invention, in the manner hereinafter described, produces a constant sum signal restricted to the zero to four kilocycle range, containing signal information originally included between zero and eight kilocycles. This is illustrated in FIG. 2, in which the typical vowel curve has been left out for convenience.

When the frequency spectrum is shifted according to the invention, the consonant sum signal illustrated in FIG. 3 is obtained, the sum frequencies again being restricted to the zero to four kilocycle range.

It will be observed that the consonant sum curves shown in FIGS. 2 and 4 are composed of signal amplitudes representing the information originally contained in both the zero to four and the four to eight kilocycle ranges. Thus the resultant signal, as reproduced at the receiver, is responsive to the amplitude variations in the original signal occurring over the entire range from zero to eight kilocycles, although transmitted through a zero to four kilocycle system.

Typical circuits adapted to fold the frequency spectrum in the manner described above are illustrated in FIGS. 4 and 6. The embodiment of the invention shown in FIG. 4 comprises a hybrid coil 11 effective to cause an input signal from two conductors 12 to be transmitted over two parallel circuit paths A and B to an attenuator 13 and a sum-and-difference type modulator 14, respectively.

Three coil elements 15, 16 and 17 comprise the hybrid coil 11, the elements 16 and 17 being connected at one end to the input conductors 12 and shunted at the other end by a series resistor 18 and capacitor 19. Center taps on these two coil elements lead to the sum-and-difference modulator 14 through two conductors 20, the other coil 15 being connected to the attenuator 13 through two more conductors 21. In order to provide suitable input impedance, the resistor 18 may, for example, have six hundred ohms resistance and the capacitor 19 two micro-farads capacitance.

The modulator 14 is of the conventional type which produces two output signals representing the sum and the difference between the frequencies of two input signals applied to it. For example, a balanced modulator may be

utilized. An eight kilocycle generator 22, connected to the modulator 14 through two conductors 23, supplies a beat frequency signal to be mixed with the signal from the input conductors 20.

The attenuator 13 is likewise of conventional design, comprising, for example, a series-parallel resistance combination which is adapted to attenuate the signal in the A path to the same extent as does the modulator 14.

A second hybrid coil 24, having three coil elements 25, 26 and 27, recombines the signals in the A and B paths, the coil element 25 being connected to the attenuator 13 by two conductors 28, while two more conductors 29 lead from the modulator 14 to center taps on the coils 26 and 27. These two coils are shunted at one end by a series resistor 30 and capacitor 31, the output signal from the other ends of the coils 26 and 27 being carried to a transducer such as a loudspeaker 32 through two conductors 33.

In order to restrict the range of the transmitted signal to the desired low frequencies, a zero to four kilocycle low-pass filter 34 is inserted in the output line 33. This filter may be one of the usual type such as described, for example, in the United States patent to Campbell No. 1,227,113.

In operation, an electrical audio signal, having a frequency range from zero to eight kilocycles is divided by the coil 11 into two similar signals which are applied to the paths A and B, respectively. By mixing the B path signal with the eight kilocycle signal from the generator 22, the modulator 14 produces an eight to sixteen kilocycle signal and a zero to eight kilocycle signal, each having the same relative spectral distribution as the input signal, the second of the two being inverted with respect to frequency.

Thus the four to eight kilocycle portion of the original signal appears as a four to zero kilocycle signal at the coil 24, where it is combined with the attenuated zero to eight kilocycle signal from the A path. The eight to sixteen and eight to four kilocycle portions of the modulator output are eliminated by the low-pass filter 34 along with the four to eight kilocycle component from the A path. Therefore, the output conductors 33 carry a signal represented by the "sum" curve of FIG. 2 and the "typical vowel" curve of FIG. 1 reduced in amplitude.

In order to transfer the four to eight kilocycle information to the zero to four kilocycle range by shifting the frequency spectrum, a circuit such as the one shown in FIG. 5 may be utilized. This circuit is similar in all respects to that of FIG. 4, except that a filter 35 is inserted in the B path and a four kilocycle generator 36 replaces the eight kilocycle generator. The elements of the circuit which are similar to those shown in FIG. 4 are indicated by primed reference numerals in FIG. 5.

The filter 35 is a band pass filter having a range from four to eight kilocycles and may be of the type described in the United States patent to Campbell No. 1,227,113, if desired.

In operation, the filter 35 restricts the signal in the B path to a four to eight kilocycle range, the A path signal range being zero to eight kilocycles as before. When the four to eight kilocycle signal and the four kilocycle signal from the generator 36 are mixed by the modulator 14', an eight to twelve kilocycle sum signal and a zero to four kilocycle difference signal results, each having the same relative spectral distribution as the original four to eight kilocycle signal.

The modulator output and the signal from the A path are combined by the hybrid coil 24', the components above four kilocycles being filtered out by the low-pass filter 34'. This leaves the zero to four kilocycle components from the A path and the original four to eight kilocycle components, now shifted down to the zero to four kilocycle range, from the B path. These components of the typical consonant sound and their sum, illustrated in FIG. 3, represent the signal appearing at the speaker 32' along with the typical vowel curve shown in FIG. 1.

Another embodiment of the invention, illustrated diagrammatically in FIG. 6, employs a pulse sampling technique and is similar to that shown in FIG. 4 in that the high and low frequency components of the speech signal are combined by folding the frequency spectrum. The system shown in the block diagram of FIG. 6 comprises a pair of speech input conductors 36 connected through a gating circuit 37 which acts as a modulator and a low-pass filter 38 to an output device such as a speaker 39, a pulse generator 40 controlling the operation of the gating circuit 37.

During the pulse time the gating circuit 37 opens to allow samples of the speech signal to reach the low-pass filter 38. Pulses from the generator 40 are applied to the gating circuit 37 at a fixed frequency close to the upper limit of the speech frequency band, which is in the neighborhood of eight kilocycles per second. As a result, speech signal components in the four to eight kilocycle band are, in effect, modulated by the fundamental component of the eight kilocycle pulse signal, producing a zero to four kilocycle signal and a twelve to sixteen kilocycle signal, each having the same relative spectral distribution as the four to eight kilocycle portion of the speech input signal, the former of the two being inverted with respect to frequency. As in the previously described embodiments, the low-pass filter 38 prevents all signals except those in the zero to four kilocycle range from being transmitted to the speaker device 39.

In the more detailed illustration of the circuit in FIG. 7, whereby the spectrum is folded in the manner described above with respect to FIG. 6, signals received on the input conductors 36 are positively biased by a potentiometer 41. Positive pulses from the pulse generator 40 are applied through a coupling capacitor 42 to the cathode of a diode 43, which is also resistively coupled to a negative voltage source.

Meanwhile, the speech signals are carried through a coupling capacitor 44 and a series resistor 45 to the anode of the diode 43 and to the cathode of another diode 46, which has a grounded anode, the potentiometer 41 being set so that the signal reaching the diode 46 never becomes negative with respect to ground in the presence of a positive pulse from the pulse generator 40. During the interval between pulses both the diodes 43 and 46 conduct and no signals reach the filter 38, but when a positive pulse holds the anode of the diode 43 positive, the diode 44 ceases to conduct since its cathode becomes positive with respect to ground. This permits the speech signals to reach the low-pass filter through a coupling capacitor 47. The output of the speaker device 39 thus contains speech waves of improved quality for standard telephone line transmission.

The improvement in consonant response attained by the practice of the invention is exemplified by the typical signal patterns shown in FIGS. 8 and 9 wherein the high frequency components of the consonant "*s*" have been attenuated by transmission through a low-pass transmission line or filter. In FIG. 8, it will be seen that the improved "*s*" signal exhibits the essential characteristics of the original speech, having frequency components which maintain a relatively high amplitude as a result of a shifting or folding operation. In the absence of such shifting or folding, an "*s*" signal is deteriorated, in the manner shown in FIG. 9, by low-pass transmission, the important high frequency components being substantially eliminated.

It will be apparent from the above description that the invention provides a novel method and means for improving the distinguishability of speech transmitted over a narrow band system, independently of differences in amplitude or time duration of the speech elements, and without requiring reconstruction of the original signal.

Although the invention has been described with reference to particular embodiments, many variations and modifications of these will be apparent to those skilled in the art. Accordingly, the invention is not intended to be

limited in scope except as defined in the accompanying claims.

We claim:

1. Apparatus for modifying electrical audio signals having a selected frequency range for transmission through a narrow frequency range electrical system having a frequency range narrower than the selected range to improve the intelligibility of the reproduced signal comprising means for dividing an original electrical audio signal into first and second components, the frequency range of the second component signal including the narrow frequency range, means for transferring information contained in the first component signal from a frequency range outside the narrow band to the frequency range of the narrow band, means for combining the two component signals into a single signal having a corresponding narrow frequency range narrower than the selected range for transmission through the narrow range system, and a single electrical transmission line having a frequency range narrower than the selected range connected to the combining means to receive the single signal.

2. Apparatus for modifying electrical audio signals having a selected frequency range for transmisison through a low frequency narrow band system having a frequency range narrrower than the selected range to improve the intelligibility of the reproduced signal comprising means for dividing an original electrical audio signal into first and second component signals, the frequency range of the second component signal including the narrow frequency range, means for transferring information contained in the first component signal from a frequency range outside the narrow band range to the frequency range of the narrow band system by folding the frequency spectrum means for combining the two component signals into a single signal having a corresponding narrow frequency range narrower than the selected range for transmission through the low frequency narrow band system, and a single electrical transmission line having a frequency range narrower than the selected range connected to the combining means to receive the single signal.

3. Apparatus for modifying electrical audio signals having a selected frequency range for transmission through a low frequency narrow band electrical system having a frequency range narrower than the selected range to improve the intelligibility of the reproduced signal comprising means for dividing an original electrical signal into first and second component signals, the frequency range of the second component signal including the narrow frequency range, means for transferring information contained in the first component signal from a frequency range outside the narrow band range to the frequency range of the narrow band system by shifting the frequency spectrum, means for combining the two component signals into a single signal having a corresponding narrow frequency range narrower than the selected range for transmission through the low frequency narrow band system, and a single electrical transmission line having a frequency range narrower than the selected range connected to the combining means to receive the single signal.

4. Apparatus for improving the consonant response of electrical audio signals having a selected frequency range transmitted through a narrow band electrical system having a frequency range narrower than the selected range comprising means for dividing an electrical audio signal into first and second component signals, the frequency range of the first component signal including that of the narrow band system, generator means for producing a signal having a substantially fixed frequency, means for mixing the second component signal with the fixed frequency signal to produce sum-and-difference signals one of which has a frequency range corresponding to that of the narrow band system, means for attenuating the first component signal, coil means for combining the attenuated signal with the mixed signals to produce a single signal having a corresponding narrow frequency range narrower than the selected range, and a single electrical transmission line having a frequency range narrower than the selected range connected to the coil means for receiving the single signal.

5. Apparatus for improving the consonant response of electrical audio signals having a selected frequency range transmitted through a low frequency narrow band electrical system having a frequency range narrower than the selected range comprising means for dividing an electrical audio signal into first and second component signals of different audio frequency range, the frequency range of the first component signal including that of the narrow band system, generator means for producing a signal having a substantially fixed frequency at least as high as the upper limit of said narrow band, means for mixing the second component signal with the fixed frequency signal to produce a difference signal within the frequency range of the narrow band system, means for combining the first component signal and the difference signal to produce a single signal having a corresponding narrow frequency range narrower than the selected range for transmission through the narrow band system, and a single electrical transmission line having a frequency range narrower than the selected range connected to the combining means to receive the single signal.

6. Apparatus for improving the consonant response of electrical audio signals having a selected frequency range transmitted through a low frequency narrow band electrical system having a frequency range narrower than the selected range comprising a hybrid coil for dividing an electrical audio signal into first and second audio component signals, the first component signal including the frequency range of the narrow band system, a signal generator for producing a signal having a substantially fixed frequency higher than the upper limit of said narrow band by an amount approximately equal to the width thereof, a modulator for mixing the fixed frequency signal with the second component signal to produce a difference signal within the frequency range of the narrow band system, means for combining the first component signal with the difference signal to produce a single signal having a corresponding narrow frequency range narrower than the selected range for transmission through the narrow band system, and a single electrical transmission line having a frequency range narrower than the selected range connected to the combining means to receive the single signal.

7. Apparatus for improving the consonant response of electrical audio signals having a selected frequency range transmitted through a low frequency narrow band electrical system having a frequency range narrower than the selected range comprising means for dividing an original electrical audio signal into first and second component audio signals, the second component signal including the frequency range of the narrow band system, means restricting the first component signal to a higher frequency band substantially equal in band width and adjacent to said low frequency narrow band, generator means producing a signal having a substantially fixed frequency approximately equal to the upper limit of said low frequency narrow band, modulator means for mixing the restricted signal with the fixed frequency to produce a difference signal within the frequency range of the narrow band system, means for combining the difference signal with the second component signal to produce a single signal having a corresponding narrow frequency range narrower than the selected range for transmission through the narrow band system, and a single electrical transmission line having a frequency range narrower than the selected range connected to the combining means to receive the single signal.

8. Apparatus for modifying electrical audio signals having a selected frequency range for transmission through a narrow band electrical system having a frequency range narrower than the selected range to improve the intelligi-

bility of the reproduced signals comprising input means for receiving electrical audio signals having frequency components outside the frequency range of the narrow band system for transmission through the system, first channel means connected to the input means to carry a first portion of an audio signal applied to the input means, second channel means connected to the input means to carry a second portion of an audio signal applied to the input means, signal generating means producing a signal having a substantially fixed frequency, mixing means in one of the channel means connected to the signal generating means for mixing the signal from the signal generating means with the portion of the audio signal carried by the corresponding channel means to transfer information contained therein from a frequency range outside the narrow band frequency range to a frequency range within the narrow band frequency range, combining means connected to the first and second channel means to receive signals therefrom and produce a single signal having a corresponding narrow frequency range narrower than the selected range for transmission through the narrow band system, and a single electrical transmission line having a frequency range narrower than the selected range connected to the combining means to receive the single signal.

9. Apparatus according to claim 8 wherein the mixing means comprises a gating circuit responsive to pulse signals from the signal generating means to alternately transmit and block transmission of audio signals in the corresponding channel means at the frequency of the signal generating means.

10. Apparatus for modifying audio signals for transmission through a narrow band system to improve the intelligibility of the reproduced signals comprising input means for receiving audio signals having frequency components outside the frequency range of the narrow band system for transmission through the system, first channel means connected to the input means to carry a first portion of an audio signal applied to the input means, second channel means connected to the input means to carry a second portion of an audio signal applied to the input means, signal generating means producing pulse signals at a substantially fixed frequency which is outside the frequency range of the narrow band, mixing means in one of the channel means connected to the signal generating means for mixing the signal from the signal generating means with the portion of the audio signal carried by the corresponding channel means to transfer information contained therein from a frequency range outside the narrow band frequency range to a frequency range within the narrow band frequency range, and combining means connected to the first and second channel means to receive signals therefrom for transmission through the narrow band system.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,069,506 December 18, 1962

Emil Hopner et al.

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 2, line 43, for "4" read -- 3 --; column 8, under list of references cited, add the following:

2,686,831 Dome-------Aug. 17, 1954

Signed and sealed this 2nd day of April 1963.

(SEAL)
Attest:
ESTON G. JOHNSON

Attesting Officer

DAVID L. LADD
Commissioner of Patents