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R. A. HEISING
NOISE SUPPRESSION CIRCUIT

1,968,450

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FIG. 1

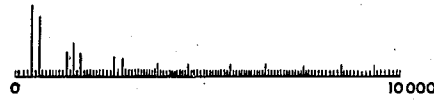


FIG. 2

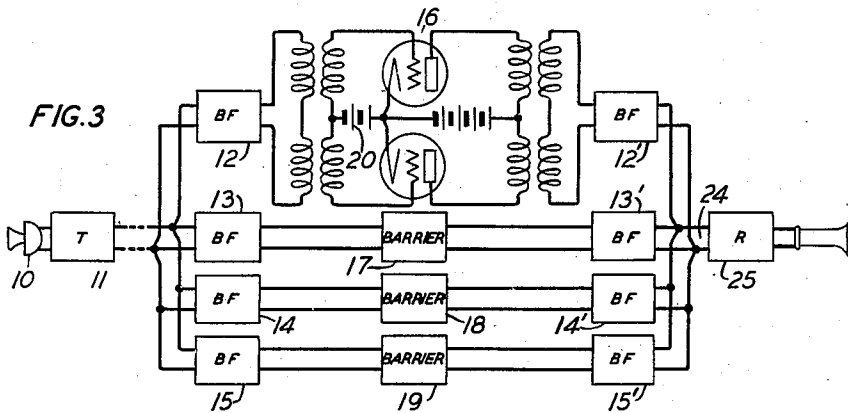
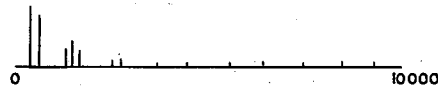


FIG. 4

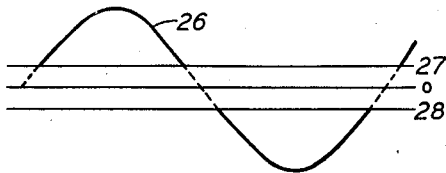


FIG. 5

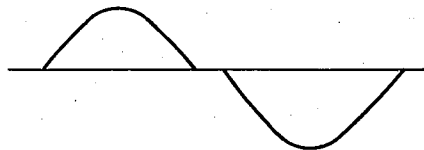
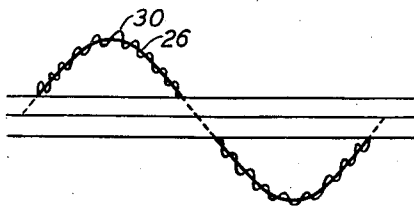


FIG. 6



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NOISE SUPPRESSION CIRCUIT

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Application December 29, 1932, Serial No. 649,315

3 Claims. (Cl. 179—78)

This invention relates to the transmission of waves for signaling or similar purposes and relates more especially to the reduction of interference or noise effects in wave transmission systems.

A general object of the invention is to secure an overall discrimination against the interference energy and in favor of the signal.

In the case of speech and some other forms of signal waves, such as music, which are ordinarily spoken of as comprising a band of frequencies, it is an observed fact that the signal does not at all times contain components of all frequencies within the band. At some instants the signal may have principal components at only a few frequencies with perhaps less important frequencies also scattered in the band. At another instant the signal may comprise other frequency components but components which likewise do not fill up the whole band. Interference or noise, on the other hand, is often either of a random character as regards frequency distribution or, as in the case of resistance noise and tube noise, may be substantially uniformly distributed over the frequency band.

A receiver connected to respond to the energy coming in over the entire frequency band will in such a case often receive a sum total of noise energy greater than the signal energy whereas the actual signal components at the instant of time under consideration may have energies greater than that of noise of the same frequencies.

In accordance with the present invention, the receiver does not have impressed upon it at all times the energy coming in over the entire signal band, but is controlled by the signal that is being received at any instant so that the signal and only something less than the total noise energy distributed over the entire band are impressed on the receiver. In particular, selective circuits are employed to prevent noise from being impressed on the receiver in portions of the frequency band not at the moment occupied by important signal components. In this way the signal to noise ratio is increased.

A system of this general character is disclosed and claimed in an application of F. B. Llewellyn Serial No. 649,316 filed of even date. The present application discloses and claims a modification of the system disclosed in that application.

A more complete description of the invention and its various features and objects will be given in connection with the accompanying drawing in which:

Figs. 1 and 2 are graph diagrams showing fre-

quency distribution of speech and noise components such as may be encountered in typical cases to which the invention may be applied;

Fig. 3 shows in schematic form a circuit for carrying out the present invention; and

Figs. 4, 5 and 6 show curves illustrating operational characteristics of the circuit of Fig. 3.

As stated above, observation shows that in ordinary speech only a few frequencies are actually present at any one instant and a particular sound may be reproduced at a receiving point if only those particular frequencies are present at the instant under consideration. Noise, on the other hand, may be considered in typical cases to be of a random nature more or less continuously distributed over the entire frequency band in which case the noise energy present in the receiver is proportional to the total frequency band which is received. Consequently, an improvement in the signal-to-noise ratio may be obtained if the output of the receiving system is arranged to pass only those frequencies which are actually employed in transmitting the speech components at the particular time at which they occur.

Fig. 1 represents an imaginary instantaneous frequency spectrum as well as the noise distribution over a band comprising frequencies from zero to ten thousand cycles. The individual amplitudes of the relatively few frequencies occurring at each instant in speech will be larger in a typical case than the amplitudes in the noise. This fact permits the use of an amplitude discriminating device such as will prevent the noise from getting through while allowing the speech energy of larger amplitudes than the noise to pass readily.

Fig. 2 represents the same frequency spectrum as Fig. 1 except that the noise energy has been eliminated and each of the speech components has been reduced in amplitude by an equivalent amount. This reduction in amplitude of the speech components, being disproportionate to their amplitudes, may introduce a form of distortion, but such distortion may be less harmful than the noise.

It might at first be thought that the frequency amplitude distribution of the speech components shown in Figs. 1 and 2 is not in accord with the usual speech energy spectrum which shows an enormous disproportion between energies in the low and high frequencies. It should be borne in mind that such a speech energy spectrum represents the energy in the various frequencies integrated as to time and does not give a true picture of the instantaneous amplitude-frequency

distribution of speech components. The low frequencies in the voice where the integrated energy is very large occur almost continuously during speech and do not contribute much to the intelligibility but serve to produce the timbre or character. From about 500 cycles to 2000 cycles or higher there is a region in which the various frequencies are quite variable in their occurrence depending upon the particular speech sounds that are being spoken. It is these variable components which carry the intelligibility. While the average energy in the various speech components in the range of 500 to 2000 cycles is small, these frequency components may individually have quite large amplitudes. They are much larger than might be expected from the averaged speech energy spectrum above referred to. Moreover, in the case of any one sound the number of these frequency components which occur simultaneously is sufficiently small so that even when the energy content of speech and that of uniformly distributed noise are the same, the amplitudes of the individual speech components may be much greater than the amplitude of the noise.

These various factors are taken advantage of by the invention as illustrated in Fig. 3, for example, to suppress the noise while permitting the speech components to get through to the receiver. A source of speech waves, music waves or any other waves to be transmitted is shown in the form of a microphone at 10. This leads to any suitable or desired transmission apparatus 11 which may include amplifiers, for example. The output of transmission apparatus 11 leads to a number of filters 12, 13, 14, 15, only four of which have been indicated for purposes of illustration, for sub-dividing the total signal band into a number of sub-bands.

Associated with the output side of each filter, such as 12, is a barrier circuit 16 comprising preferably a pair of push-pull vacuum tubes having their grids biased slightly beyond the cut-off point by the grid battery 20 although a single vacuum tube may be employed. The barrier circuits 17, 18 and 19 may be entirely similar to 16. The output of each barrier circuit is connected to another filter 12', 13', 14' or 15' as the case may be, each of which may be identical with the corresponding filter on the input side. The output sides of all of the last-mentioned filters are connected in common to the outgoing circuit 24 which may lead to a receiver of any suitable type indicated at 25.

It is assumed that noise energy is present in the system coming in either through microphone 10 or in the transmitting apparatus 11 or elsewhere in the system and that it is impressed together with the speech waves on each of the filters 12 to 15, inclusive. The noise energy passing through any one filter, such as 12, is insufficient, however, to overcome the bias from battery 20, so that the barrier circuit remains in non-transmitting condition when exposed only to the influence of the noise through any one of the sub-dividing filters. When one or more signal components passes through a sub-dividing filter such as 12, however, it will, if it has sufficient amplitude, overcome the bias of battery 20 and be transmitted in part through the barrier circuit 16 and through the filter 12' into the outgoing circuit 24. The various frequency components present in speech at any one time, therefore, are transmitted through the various filters whose pass ranges include these respective components, and thence through the corresponding barrier circuits and output filters

into line 24 and receiver 25. Since, for any one particular sound not all of the filters contain in their pass ranges any important signal components, no energy will be transmitted through the corresponding barrier circuits, and hence the amount of noise reaching the receiver is reduced.

The action of the barrier circuit is illustrated in Figs. 4 and 5. The sine wave curve 26 may represent a signal component which is to be transmitted. The zero line in this figure represents the normal grid potential due to the bias and the horizontal lines 27 and 28 represent for the respective tubes of the push-pull circuit the grid potential (ordinates) that must be reached by an input wave before the barrier circuit is rendered capable of transmitting. In the case assumed, the noise that is to be suppressed would have an amplitude lying between the zero line and either of the lines 27 and 28 but not exceeding them. In other words, the dotted portion of the curve 26 will not be transmitted but only the full line portion extending beyond the limiting lines 27 and 28. The shape of the wave actually transmitted may be assumed to be something of the character of that shown in Fig. 5.

This type of curve represents a distorted wave. The distortion due to this type of wave is primarily composed of odd harmonics so that if the circuit is arranged on the output side of each barrier circuit to suppress the harmonics of the components being transmitted, the distortion produced by the action of the barrier circuit is reduced or eliminated. This may be done by sub-dividing the speech band into sub-bands of such narrow extent that the frequency ratio of the harmonics to be suppressed to the fundamental is greater than the ratio of the extreme frequencies transmitted by the filter. If the two tubes in the barrier circuit are not sufficiently balanced or if only one tube is employed in the barrier circuit some even harmonics will be produced. These may be eliminated if the sub-bands are made narrower than a 2 to 1 ratio of extreme frequencies so that the second harmonic of the lower frequency cannot get through. Since the odd harmonic distortion above referred to would also fall outside the limits of such a band, both of these types of distortion would be suppressed.

A third form of distortion or interference which may come in is illustrated in Fig. 6 where a relatively high frequency noise curve 30 is shown superposed on the signal curve 26. The noise 30 if present alone in the circuit would not get through the barrier circuit but in the presence of the high amplitude wave 26 some of the noise is raised above the cut-off line of the barrier circuit and is permitted to be transmitted along with the signals. This source of disturbance comes in only in the case where the noise frequencies are relatively high compared to the signal frequencies. By employing a sufficiently narrow range in each of the sub-dividing filters, therefore, this source of noise is also eliminated. The noise on the output side of each filter will, of course, have frequencies in the same range as the desired signal frequencies. Such noise in the presence of a signal component might beat with the signal and tend to produce sum and difference frequencies. However, if the bands are less than 2 to 1 in frequency ratio as has previously been mentioned, they will eliminate both the sum and the difference frequencies.

The greater the number of bands into which the speech band is divided, the less will be the chance that some one of the different distortions

that have been mentioned above will come in and the greater will be the amount of noise reduction. A band width ratio of 2 to 1 or less is desirable from the standpoint of suppressing these distortions. The band may be still narrower than this, however, and the minimum band width is determined by the time delay in the filters designed to pass very narrow bands.

The invention is not to be construed as limited to the specific forms that have been shown since it is capable of wide variation in practice and is therefore to be limited only by the scope of the appended claims.

What is claimed is:

1. The method of transmitting a band of waves and reducing noise energy comprising sub-dividing the waves into narrow bands, normally blocking transmission of any of the bands not containing signal components, selectively and under control of signal energy permitting bands containing signal components to be transmitted, and selecting from the transmitted waves the signal components and attenuating components of frequencies different from the signal frequencies.

2. In a system for transmitting signal waves

of a band of frequencies and reducing noise, a source of signal and noise waves, filters for subdividing the waves from said source into sub-bands of frequencies in separate paths, a barrier circuit in each path for passing waves only in excess of a predetermined minimum amplitude, whereby low energy noise components are suppressed while large amplitude signal components are transmitted, and means connected to the output of each barrier circuit for reducing the distortion produced in the waves transmitted by said barrier circuits.

3. In a transmission system for waves of a band of frequencies, a plurality of narrow band filters for sub-dividing the transmitted waves, a second plurality of filters similar to the first with the similar filters connected in pairs, the filters of each pair in tandem, a barrier circuit connected between the filters of each pair, and an outgoing circuit connected to the output sides of the second plurality of filters in common, said barrier circuits each being biased against transmission of low amplitude waves but readily transmitting waves of relatively high amplitude.

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