

Oct. 31, 1944.

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2,361,523

CROSS-TALK IMPROVEMENT

Filed June 24, 1942

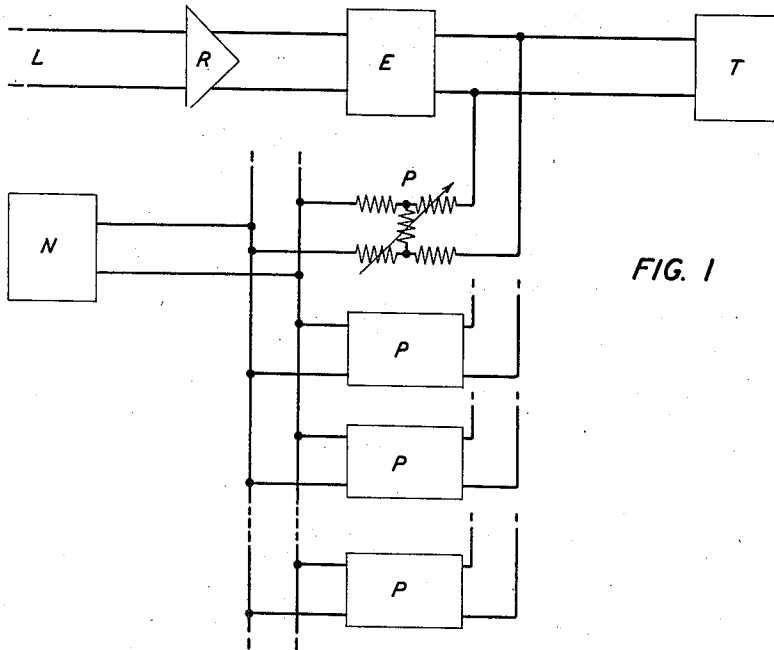


FIG. 1

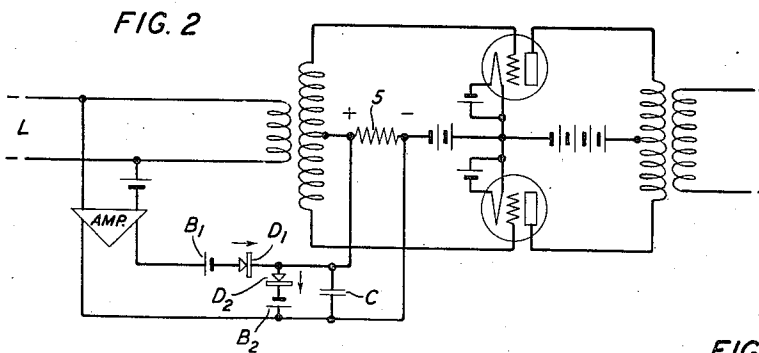


FIG. 2

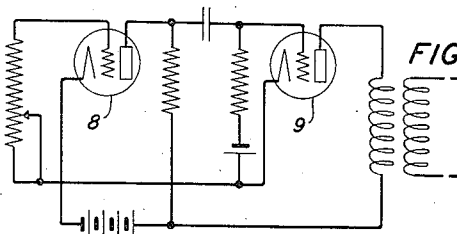


FIG. 4

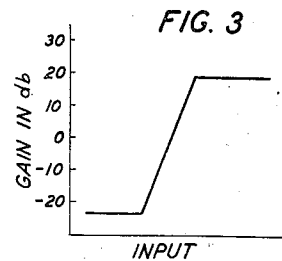


FIG. 3

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2,361,523

CROSS-TALK IMPROVEMENT

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Application June 24, 1942, Serial No. 448,278

9 Claims. (Cl. 179-78)

This invention relates to a method and means for improving the conditions due to cross-talk in communication systems, such as voice frequency toll circuits, carrier frequency systems, loud-speaker telephone sets, or other circuits.

A principal object of the present invention is to reduce the intelligibility of cross-talk in telephone transmission systems.

In accordance with the invention provision is made at a receiving station in a telephone transmission system for expanding the received signals and the commingled cross-talk and normal circuit noise, or otherwise reducing the cross-talk and circuit noise levels with respect to the signal level, and thereafter introducing artificially produced noise in such amount that the cross-talk is rendered unintelligible.

In the development over the past years of telephone circuits of the kind referred to above it has been possible to reduce the noise level by various expedients and now in many high quality transmission lines, especially in cable circuits and in coaxial lines, the noise level is well below that formerly considered satisfactory. The same is true of cross-talk. On the other hand, as use has been made of higher and higher frequencies and of larger groups of channels closely associated electrically, the difficulties of meeting the usual cross-talk requirements have increased. Furthermore, as the noise level has been lowered it has become evident that cross-talk, which formerly was scarcely noticed, becomes troublesome.

Some of the newer types of communication systems, such as the carrier systems, have been designed to operate satisfactorily over very long distances during hot weather when noise conditions are adverse. Consequently, during the winter months the carrier channels are relatively quiet except for transient types of noise, such as modulation noise and occasional static. During the quieter periods low volume cross-talk is much more noticeable and also more intelligible than it would be in the presence of a higher volume of noise. It becomes evident that if a minimum steady noise of reasonable value were maintained on each channel the cross-talk coupling limits could be relaxed, the amount of relaxation being dependent on the type and magnitude of noise selected. Thus, assuming a minimum total noise of 23 decibels above reference circuit noise at the -9 decibel level we estimate that the permissible root-mean-square cross-talk coupling between so-called type K channels could be increased by about 3 decibels

for a line of 4,000 miles. This 3-decibel increase—corresponding to a doubling of the power—is very valuable when difficulty is experienced in meeting engineering requirements.

5 As a part of our disclosure, then, we propose to introduce such a steady noise on the various channels involved to permit some relaxation in the cross-talk coupling requirement.

The masking effect of a noise is dependent 10 on the nature of the noise. In particular, we would state that "thermal noise"—noise due to chaotic thermal agitation in resistance elements—is one of the least objectionable types of noise, is easily produced, and is particularly 15 effective in masking cross-talk. Thus, laboratory tests indicate that 23 decibels of thermal noise is as effective in masking cross-talk as about 32 decibels of ordinary open wire line noise. On the other hand, judgment tests have shown that 20 thermal noise is no more interfering to direct transmission than an equal amount of line noise. In other words, 23 decibels of thermal noise is no more interfering than 23 decibels of open wire noise even though its masking effect on cross- 25 talk is appreciably greater. The effect of noise on the transmission in a communication line can conveniently be expressed in terms of transmission impairment. Thus, the transmission impairment due to 23 decibels of noise is about 0.2 30 decibel which is approximately 0.6 decibel less than that for 29 decibels of noise, the present limiting value. This amount of impairment would hardly be noticeable to the subscriber nor would the noise itself be objectionable from the 35 annoyance standpoint. Of course, any artificial noise impressed on a circuit increases the total noise on that circuit. For example, during periods when the normal noise on a channel is 29 decibels an added noise of 23 decibels would 40 increase the total noise to about 30 decibels and increase the noise transmission impairment from 0.8 decibel to 1.0 decibel. However, this increase in noise transmission impairment of 0.2 decibel represents the approximate maximum increase 45 due to the addition of 23 decibels of artificial noise regardless of the amount of normal noise on the circuit.

It has been suggested heretofore that a limited range expander be used as a means for reducing 50 noise and cross-talk on message circuits. By a limited range expander is meant a device which, within limits, will have a variable gain, the gain being the greater as the volume of the signal becomes greater. Since, in all partial systems, 55 both the cross-talk and the noise levels are

quite low, it becomes evident that putting the message with this disturbance through an expander amplifies the signal components more than the others and that the ratio of cross-talk to signal and noise to signal are both reduced, although the ratio of cross-talk to noise remains substantially the same. The amount of improvement by this expedient is limited by the distortion caused by the expanding device since the amount of distortion increases as the range of expansion is increased. If, in fact, an expander were to be used primarily for cross-talk reduction, it would be necessary that the amount of expansion be considerably greater than it now appears practicable to provide. This is particularly true for the case of loud-speaking telephone sets which, for transmission reasons, require a high gain (60 to 70 decibels) for satisfactory operation. One method by which the effective cross-talk expansion can be increased is through the introduction of artificial noise in the output of the expander. This we find can be done without the degradation to transmission characteristic that is incidental to use of a limited range expander of a wide range, and it can be done with little additional degradation due to the added noise.

The cross-talk improvement of an expander alone, referred to above, is due to the reduction in volume of the cross-talk, which makes it less intelligible. Since the noise and cross-talk are each expanded by substantially the same amount, no change in the cross-talk to noise ratio is effected by the expansion process. When the circuit noise is high, expansion improves the noise condition but such improvement is not necessary for cross-talk reasons because, in general, it is the cross-talk appearing during periods of low circuit noise which is most likely to be intelligible. When the noise is low, expansion improves the cross-talk condition, but is not necessary so far as noise is concerned. It is obvious, then, that a moderate level of noise may be introduced at the expander output and the noise performance will still be satisfactory and the intelligibility of the cross-talk will be materially reduced because of the decrease in cross-talk to noise ratio. Instead, then, of increasing the range of the expander to further reduce the cross-talk we may take advantage of the fact that the expander in use has reduced the noise level so that one may add some noise and still keep within the requirements; but the added noise will materially assist in masking the cross-talk.

The particular values of expansion and of introduced noise will depend upon the system to which our invention is applied. As an illustration, however, reference may be made to a loud-speaker set in which it was found that a combination of 12 decibels of expansion followed by the introduction of 5 decibels of thermal noise gives about the amount of cross-talk improvement to make the loud-speaker set equivalent to a good commercial telephone set with respect to overhearing of cross-talk. Our experiments show the interesting fact that about 30 decibels of expansion alone or about 15 decibels of thermal noise alone would be required to give the same cross-talk improvement. Neither of these conditions is feasible, the first because of distortion inherent in the expander and the second because the magnitude of noise required is too high for satisfactory loud-speaker performance.

We find that one of the reasons that the com-

bination of noise and expansion is so effective in cross-talk improvement is because of the type of noise specified. Thus, our experiments have shown that the cross-talk masking effect of thermal noise is approximately 8 decibels greater than that of an equal amount of open wire line noise. This means that 5 decibels of added thermal noise will provide as much cross-talk masking as 13 decibels of line noise without increasing the actual noise any more than it would be increased by the addition of 5 decibels of line noise.

The invention will be better understood by reference to the accompanying drawing, in which:

Fig. 1 shows in block diagram a circuit embodying the invention;

Fig. 2 is a simple expander circuit suitable for application in the circuit of Fig. 1;

Fig. 3 is a diagram showing the general characteristics of such an expander; and

Fig. 4 is a typical noise generator of a type suitable for carrying out our invention.

Referring to Fig. 1, there is shown an incoming line L which may pass through a repeater R and then to an expander E and on to apparatus T. This apparatus T may be terminating equipment such as a telephone set or a loud-speaker set, or may be the connections to a continuing line for transmission to more remote points. There may also be included in T any amplifiers, equalizers and similar equipment appropriate to a communication line.

Bridged across the output of the expander E is the output from a noise source N, the connection containing an adjustable attenuating pad P introducing a considerable amount of loss, such as 50 decibels. The chief purpose of this pad is to prevent loss of the signal on the line L down through the noise source or other associated circuits.

The expander E is of the type commonly called a limited range expander. A simplified circuit for such an expander is shown in Fig. 2 in which line L feeds through a balanced amplifier whose gain is controlled by the bias voltage across resistance 5. A branch circuit from line L in front of the expander goes through an amplifier in the output of which is the rectifier D₁ passing current in the direction of the arrow. The detector circuit is so biased by the voltage of battery B₁ that no current passes through the detector until the signal on the line L exceeds a certain value. By means of a condenser C and the resistance 5 a bias in the direction to increase the gain of the balanced amplifier is produced, the gain increasing as the amplitude of the signal increases. When this signal has reached a certain higher value, the detector D₂ subject to the biasing voltage of battery B₂ will then introduce loss so that the biasing voltage across resistance 5 remains substantially constant for further increase in signal intensity.

Another form which an expander may take on is such as that shown in the patent to Norman 2,063,334, December 8, 1936. The essential characteristics of an ideal limited range expander is illustrated by Fig. 3, which shows that the gain of the amplifier within the expander E is zero at some intermediate volume of input. For volumes less than this the expander introduces a loss, whereas for greater volume of input there is positive gain. All this holds between specified limits, the circuit being so designed that if the volume of input is less than a specified

amount the gain is substantially constant and if it exceeds a certain higher specified amount the gain becomes substantially constant at a higher value.

The noise generator indicated by N may take on a variety of forms. We have found that the characteristic noise known as thermal noise is particularly suitable for carrying out our invention. Such noise may be generated by a variety of circuits, one of which is shown in Fig. 4. This comprises two tandem amplifiers 8, 9 with resistance coupling, there being a high resistance connected in the grid circuit of the first tube.

Such a noise generator as described above is capable of supplying a much larger volume of noise than is necessary for the line shown in detail in Fig. 1. Also, in general, there will be a large number of signal channels on different lines closely associated or a large number of channels on a single line. It is the cross-talk between these different channels against which this invention provides protection. But just as the one circuit shown in some detail requires the expander and the introduction of noise, so each of the other channels would usually require such equipment. In view of the excess noise power which the generator N can provide, this generator may be arranged to supply the necessary noise to a plurality of lines or channels, as indicated in Fig. 1. There must, of course, be a suitable pad or loss device P inserted in the path going to each channel. These pads serve not only to keep signal power from going down to the noise generator, but to keep cross-talk from the one channel to another through the noise circuits to a negligible amount.

While preference has been indicated for that type of noise characterized as thermal noise, it is to be understood that variations from this are not only permissible but in some cases are desirable. It is to be observed, for example, that the major portion of the energy of a speech wave lies in the neighborhood of 1,000 cycles, whereas the amount of energy in the neighborhood of 3,000 cycles is relatively small. Obviously, then, the bulk of the energy in cross-talk also lies in the neighborhood of 1,000 cycles and the necessity for masking may be somewhat greater for this portion of the speech spectrum than for others. Furthermore, the energy components lying in the vicinity of 1,000 cycles contribute relatively more to the intelligibility of transmitted speech than do the components at materially lower or higher frequencies. Consequently, we find it desirable in some cases so to shape the energy distribution of the noise curve as to give somewhat more noise volume in the general neighborhood of 1,000 cycles, or any other selected portion of the voice spectrum, than elsewhere. In this manner we find that the total amount of noise power necessary to mask the cross-talk is reduced somewhat further, with a consequent reduction in annoyance due to the noise.

While in Fig. 1 the repeater R and expander E are shown as separate units, it is to be understood that these may be consolidated into one unit so that the expander E provides the necessary amplification as well as the desired expansion.

What is claimed is:

1. In a telephone transmission circuit carrying signals subject to cross-talk, at the receiving

station an expander for raising the level of the signals relative to the cross-talk, a source of thermal noise at the output of the expander for masking the cross-talk and an electroacoustical transducer connected in the circuit beyond the point where the noise is introduced to receive the resultant output.

2. In a telephone transmission circuit carrying signals subject to cross-talk, at the receiving station means for decreasing the cross-talk to signal ratio and the noise to signal ratio and means for producing and introducing noise on the circuit to decrease the cross-talk to noise ratio.

3. The combination of claim 2 characterized by this that the introduced noise shall be sufficient to effectively mask the cross-talk.

4. The combination of claim 2 characterized by the fact that the noise produced for introduction shall be thermal agitation noise.

5. The combination of claim 2 characterized by this that the noise level of the introduced noise shall exceed the cross-talk level by approximately 3 decibels.

6. In a telephone transmission circuit carrying signals subject to cross-talk and noise, means at the receiving station for lowering the cross-talk to signal ratio and the noise to signal ratio, and means thereafter for introducing noise, the amount so introduced being such that the total noise level is still below a specified upper limit of noise level.

7. In a telephone transmission circuit carrying signals subject to cross-talk and noise, means at the receiving station for lowering the cross-talk to signal ratio and the noise to signal ratio, means thereafter for introducing noise, the amount so introduced being such that the noise to signal ratio after the introduction of the noise is not appreciably larger than before the expansion.

8. The combination of claim 7 characterized by this that the first-named means is a limited range expander and that the second-named means comprises a source of thermal noise.

9. In a system for the reception and reproduction of telephone signals that are accompanied by cross-talk and also by noise which may vary in intensity between an upper value sufficient to mask the reproduced cross-talk and a lower value such that said reproduced cross-talk tends to become intelligible, the method which comprises receiving and concurrently expanding the said signals, cross-talk and noise to reduce the ratio of noise level to signal level and to reduce also the ratio of cross-talk level to signal level although not enough for the cross-talk to be masked by the received noise during periods when the intensity of the received noise is at its said lower value, and introducing artificial noise into the expanded signals, cross-talk and noise in fixed amount sufficient to mask the cross-talk during periods when the intensity of the received noise is at its said lower value, whereby the total noise is at substantially all times sufficient to mask the cross-talk and yet not materially greater than is the received noise alone when the intensity of said received noise is at its said upper value.

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