Radio Telephone Noise Reduction by Voice Control at Receiver *

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In listening to speech transmitted over radio circuits, the noise arriving in the intervals between the signals may be annoying. There is also evidence that the intelligibility is reduced due to this noise shifting the sensitivity of the ear. Reducing the noise occurring in the intervals of no speech should therefore improve reception.

This paper gives the underlying requirements for a device to accomplish this type of noise reduction and describes the action of a typical "noise reducer." Laboratory and field tests are described which show that its use is equivalent to an improvement in signal-to-noise ratio which reaches a maximum value of about 5 db. It also reduces false operation of the voice-operated relays used on long radio telephone connections.

Introduction

IN transmitting speech over radio telephone circuits there are a number of conventional methods of increasing the signal with respect to the noise. Examples of such methods are the use of higher power, directive antennas, diversity reception and filters to narrow the received frequency band. In addition, there are other methods of a special character which reduce the effect of the noise interference with the speech transmission. One example of such a device limits the noise interference by eliminating the high peaks of noise of very short duration and depending upon the persistence of sensation of speech in the ear to bridge the gaps. Another method diminishes the noise in intervals of no speech. This is the method which will be discussed here.

Speech and Noise Considerations

Speech signals may be represented by a group or band of frequencies occupying a certain interval of time. In using the conventional method of narrowing the received frequency band, filters eliminate all noise outside the band actually required. In fact we sometimes go beyond this and remove some of the outer frequency components of

* Presented at the Pacific Coast Convention of A. I. E. E., Spokane, Washington, September 2, 1937. Published in *Elec. Engg.*, August, 1937.

speech which are weak and submerged in the noise and therefore contribute little or nothing to the intelligibility. Experiments have shown the effect on voice transmission of removing portions of the frequency range.[1] Articulation tests were used to afford a quantitative measure of the recognizability of received speech sounds. These show that the upper frequencies may be cut off down to about 3000 cycles without serious reduction in articulation. After such treatment, as the noise level increases, the weaker and less articulate sounds become more and more submerged in the noise and additional reduction in the detrimental effect of the noise is required.

In addition to the speech waves covering a frequency band they occupy intervals of time. The unoccupied intervals between the speech sounds contain noise. Reduction of the noise reaching the ear in these intervals has been found to result, under certain conditions, in an improvement in speech reception. This may possibly be explained by considering the characteristics of the ear.[1] It has been shown that noise present at the ear has the effect of shifting the threshold for hearing other sounds or has a deafening effect. That is, there is a reduction of the capacity of the ear to sense sounds in the presence of noise. For example, if a person has been listening to a noise for a certain period, his ear is made insensitive so that speech signals following are not so easily distinguished. The ear has a sensory build-up time, that is, a time needed for the noise to build up to a steady loudness. By reducing the noise in the intervals of no speech the average threshold shift seems to be diminished. Aside from this the presence of the noise tends to distract the attention from the perception of the speech. Removal of noise during the intervals of no speech tends to reduce this effect.

Requirements

In considering the elimination of the noise during these intervals it is necessary to bear in mind certain characteristics of speech.[2] Speech waves may be regarded as nonperiodic in that they start at some time, take on some finite values and then approximate zero again. In connected speech it is usually possible to approximately distinguish between sounds and to ascribe to each an initial period of growth, an intermediate period which in some cases approximates a steady state and then a final period of decay. The duration intervals of various syllabic sounds vary from about .03 to as much as .3 or .35 second. When noise is high the weaker initial and final sounds become obscured so that they contribute little to the intelligibility.

[1] See end of paper for references.

In connected speech, silent intervals occupy about one-fifth to one-third of the total time. Also there are frequent intervals when the sounds are rather weak. However, if we attempt to suppress noise during all these intervals, experience shows that the suppression becomes too obvious, and the speech is apt to sound mutilated. For this reason the function of any device to be used for reduction of noise in the intervals between speech is to operate rather quickly to remove suppression and pass the speech and approximately to sustain this condition for sufficient periods to override weaker intervals so that obvious speech distortion does not occur.

To reduce the noise in the intervals between speech it is necessary to depend for control upon either the speech itself or upon some auxiliary signal usually under the control of the speech at some point in the circuit where the signal-to-noise ratio is better. This latter condition is illustrated on a circuit where the carrier is transmitted only during speech intervals. The carrier then acts as an auxiliary signal which operates a device at the receiver to remove loss.[3, 4] The device to be discussed below utilizes the speech itself at the receiver to perform this function.

In using the speech in this way it is obvious that control can be accomplished only when the speech energy sufficiently exceeds the noise energy so that the presence of the speech is distinguishable. The device could operate abruptly as, for example, a relay which removes a fixed loss in the operated position and restores it when non-operated. Experience indicates that the use of such a device makes the suppression too obvious if it is to follow the speech sounds closely. It is desirable, then, to perform this reduction by more or less gradually removing loss as the speech increases to accentuate the difference between levels of speech sounds and levels of noise which occur in the gaps between speech.

Noise Reducer

This kind of performance has been secured in a device known as a noise reducer. A comparison of the action of the noise reducer and a relay having similar maximum loss is shown in Fig. 1. This figure shows the input-output characteristics of these devices over the voice amplitude range to which they are subjected on a radio circuit. The noise reducer may be likened to a relay with a variable loss, the loss not varying instantaneously but over a short period of time. The loss, for any short period, may be any value within the loss range and the device has, therefore, been likened to an elastic or shock absorbing relay.

The noise reducer has no loss for strong inputs, considerable loss for weak inputs and changes this loss gradually over a short interval of time. It introduces loss in the absence of speech but reduces this loss in proportion to the amplitude and duration of waves impressed upon it. The time required for the loss change is such that abruptness of noise change is absent and very short impulses of static do not effec-

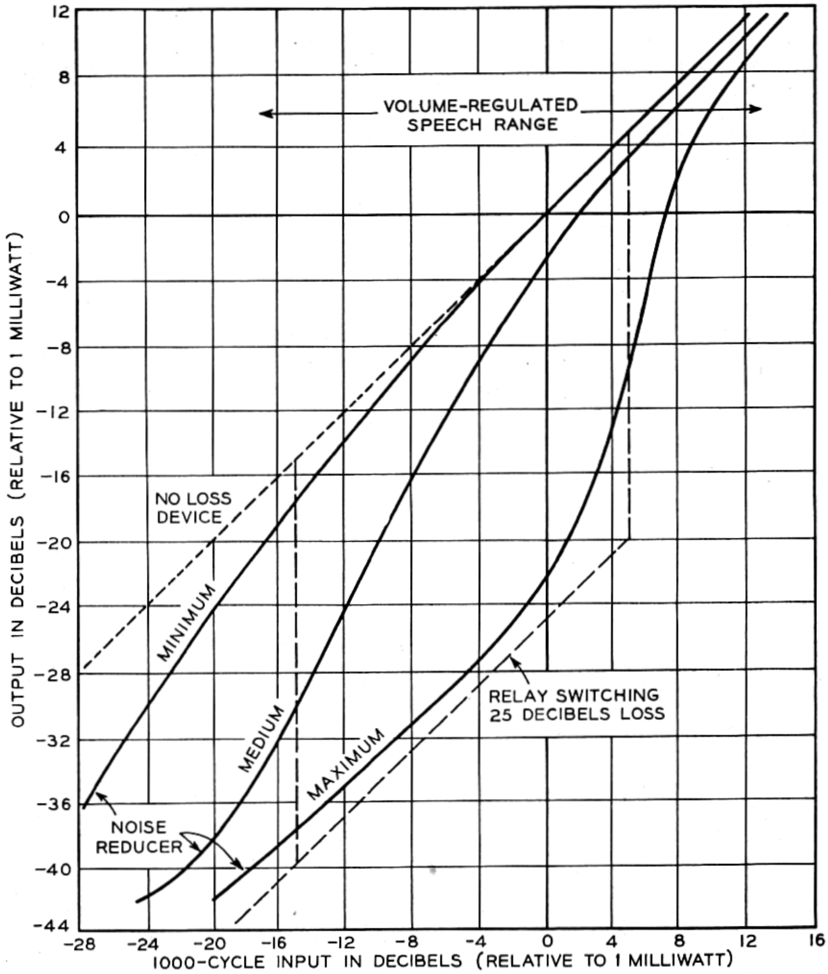

Fig. 1—Input-output comparison of noise reducer and voice-operated relay.

tively control the loss. This contrasts with a very fast limiter acting on high-peak crashes only.

The noise may control the loss if its average amplitude is strong enough. Therefore, the control is made adjustable so that the noise waves are not permitted to control for any noise condition within the range of usefulness of this device. Thus the noise in the absence of speech is always reduced and the portions of the initial and decay periods of the speech sounds which are also reduced vary with this adjustment for noise intensity. Of course, if the speech-to-noise ratio becomes too small or if other transmission conditions interfere, an improvement becomes impossible.

Circuit Arrangement

Figure 2 shows the circuit of the noise reducer in simplified schematic form.[5] Incoming waves pass from left to right through the fixed pad,

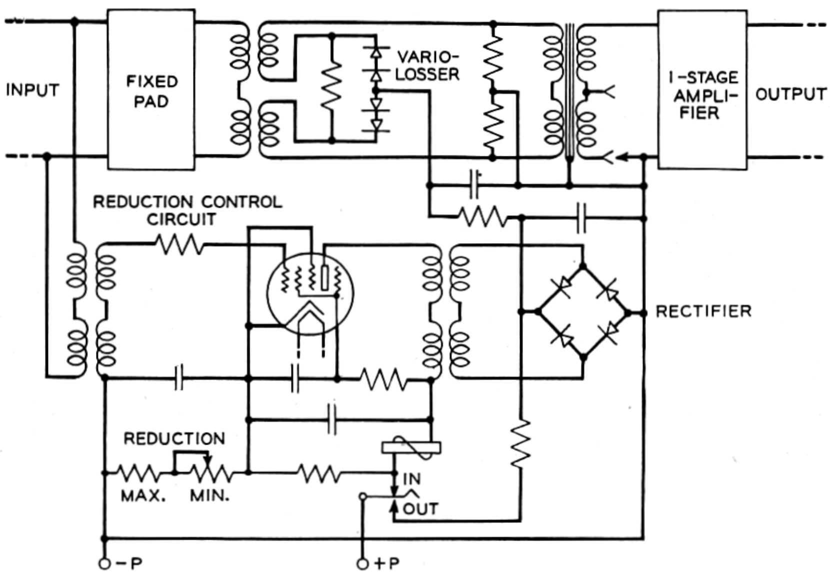

Fig. 2—Simplified schematic of noise reducer.

the vario-losser and the amplifier to the output. At the input, part of these waves pass through the reduction control branch circuit which includes a variable resistor, an amplifier and a rectifier. The direct current produced by the rectifier is applied through the condenser and resistance filter to the copper-oxide losser circuit. For current below a threshold value, no appreciable change occurs in the losser and the loss introduced is about 20 db. As input increases, rectified current reaches a value where the loss begins to change rapidly. It becomes 0 db at an input about 20 db above the point at which the loss starts to change. The design is such that the loss remains substantially constant for higher inputs.

The vario-losser makes use of the resistance variation with current of copper-oxide rectifier disks. This variable resistance shunts a fixed resistance in series with the windings of a repeating coil as shown in Fig. 2. The maximum loss is determined by the fixed resistance when small current is flowing through the disks while the varying loss is determined by the shunting copper-oxide resistance which decreases rapidly with increasing current above a threshold value until a low value is reached. The minimum loss is limited by the output of the control tube approaching a maximum and the shunting resistance becoming so small that additional decrease affects the loss inappreciably.

The variable resistor setting in the reduction control circuit determines the input amplitude at which reduction begins and therefore the point above which the loss remains substantially constant. If there is a difference in amplitude between speech and noise, the reduction

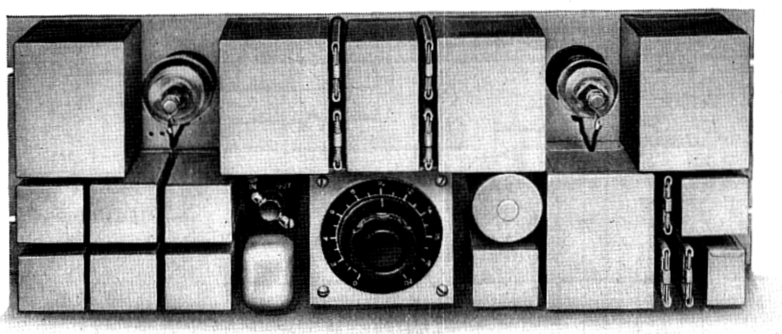

Fig. 3—noise reducer panel.

control may be so adjusted that the noise on the circuit, when no speech is present, is appreciably reduced. The action then is as follows: In the absence of speech, noise is reduced usually the maximum value of 20 db; during intervals of lower speech amplitudes the loss decreases in proportion to the increase in amplitude, and during speech of high amplitude both noise and speech are transmitted without loss. As the noise encroaches upon the range of speech amplitude, it becomes necessary to reduce greater amplitudes, thereby also further reducing the weaker parts of speech.

The noise reducer is contained on a 7¼ inch panel for relay rack mounting. Figure 3 gives a front view. The panel contains the reduction control resistor and an In-Out key which, in the Out position, gives the device a fixed loss. Both resistor and key may be duplicated external to the panel with the wiring arranged to give remote control.

CHARACTERISTICS

Figure 4 gives the 1000-cycle input-loss characteristic for three settings of the reduction control. For any setting, there is an input volume above which the loss remains constant, while for volumes below this the loss increases with decreasing input until the maximum loss is reached. The volume regulated speech range encountered on radio circuits at some point in the circuit which is 5 db above reference volume as measured on a volume indicator is indicated as extending from + 13 db to − 17 db referred to 1 milliwatt for the purpose of showing approximate corresponding speech amplitudes.

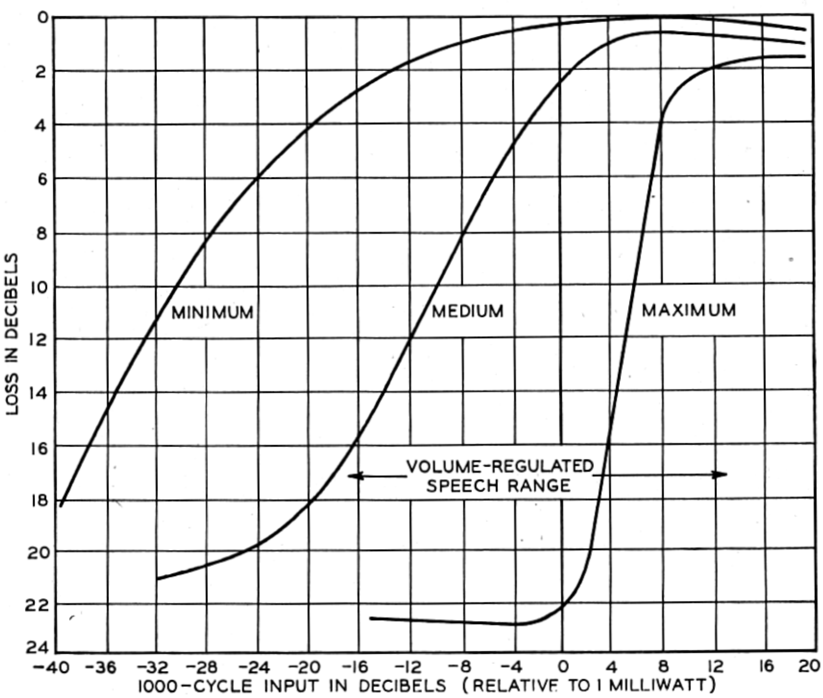

Fig. 4—Loss versus input for several settings of the reduction control.

Figure 5 shows oscillograms giving the input and output characteristics of noise for maximum reduction and of speech for maximum, medium and minimum reduction. The upper trace is the input and the lower trace the output. The middle trace is not used. It will be noted by inspecting the IN and OUT traces at the beginning and ending of the word "bark" that there is some distortion in speech for the maximum reduction condition, but very little distortion for minimum reduction. Maximum reduction would be used only in case of high noise where this distortion is less objectionable than the noise.

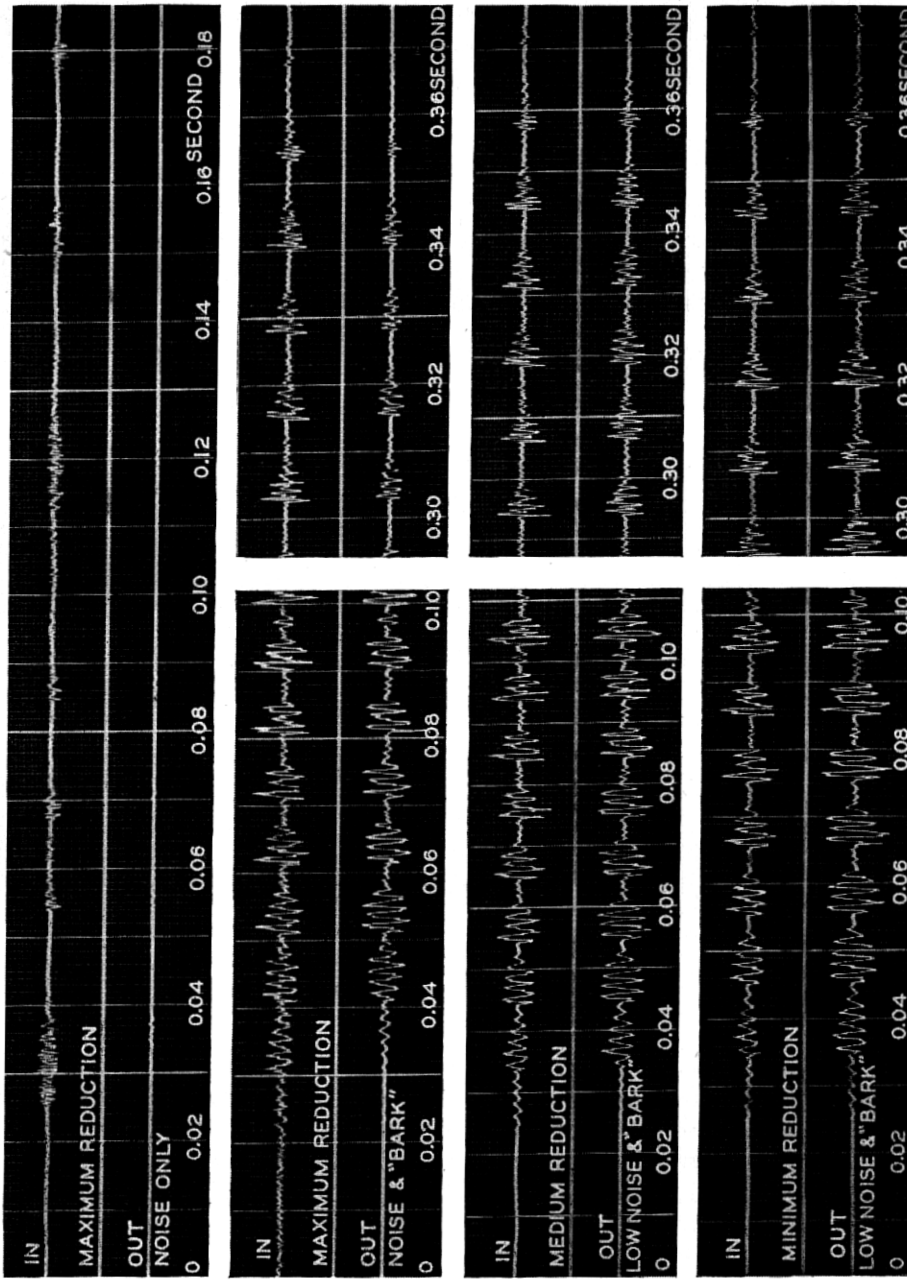

Fig. 5—Input and output for: (1) high noise with maximum reduction; (2) high noise with the beginning and ending of the word "bark"—maximum reduction; (3) low noise, the word "Bark"—medium reduction; (4) low noise, the word "bark"—minimum reduction.

Performance

Laboratory tests have been made in an attempt to evaluate the advantages to be gained by the use of the noise reducer. It was shown that, for the rather limited and controlled conditions which were tested, definite advantage can be observed in judgment tests of the effectiveness of speech transmission through noise with and without the noise reducer. This advantage is of the order of magnitude of 3 to 5 db at the border line between commercial and uncommercial conditions on the noisy circuit.

This figure is in approximate agreement with results obtained from records of performance on commercial connections. A curve is available which shows the approximate relation between percentage lost circuit time and transmission improvement for a long-range short-wave radio telephone circuit.[6] From the records of lost circuit time as affected by the noise reducer use, an improvement of 4 db is obtained from this curve.

Observations were made and records kept for twelve months of the use of the device at the land terminal of the high seas ship-to-shore circuit and for shorter periods on New York-London circuits. These observations indicate that the noise reducer most satisfactorily reduces objectionable effects where the interference consists of noise of a fairly steady character. As might be expected it is somewhat less effective on crashy static. If the noise is very low there is no improvement; as the noise increases the benefit increases up to a certain point; when the noise amplitudes begin to approach too closely the peak amplitudes of the voice waves it becomes impossible to distinguish between them without producing objectionable speech distortion and there is again no advantage. Where volume fading is present there is a tendency to accentuate the volume changes and it becomes necessary to adjust the reduction control to limit this. Otherwise this effect may offset the possible noise improvement. The operating practice is to adjust the reducer control circuit for each noise or transmission condition so that optimum reception as judged by the technical operator is obtained. The general rule is to use the minimum reduction possible.

Use of Noise Reducer with Voice Switched Circuits

On radio telephone circuits for connection to the land telephone system, control terminal equipment is used at the junction of the land lines and the two one-way radio channels (one transmitting the other receiving) necessary for two-way communication. In making this connection a widely used method is one in which the two-wire land circuit is normally connected to the receiving radio channel and is

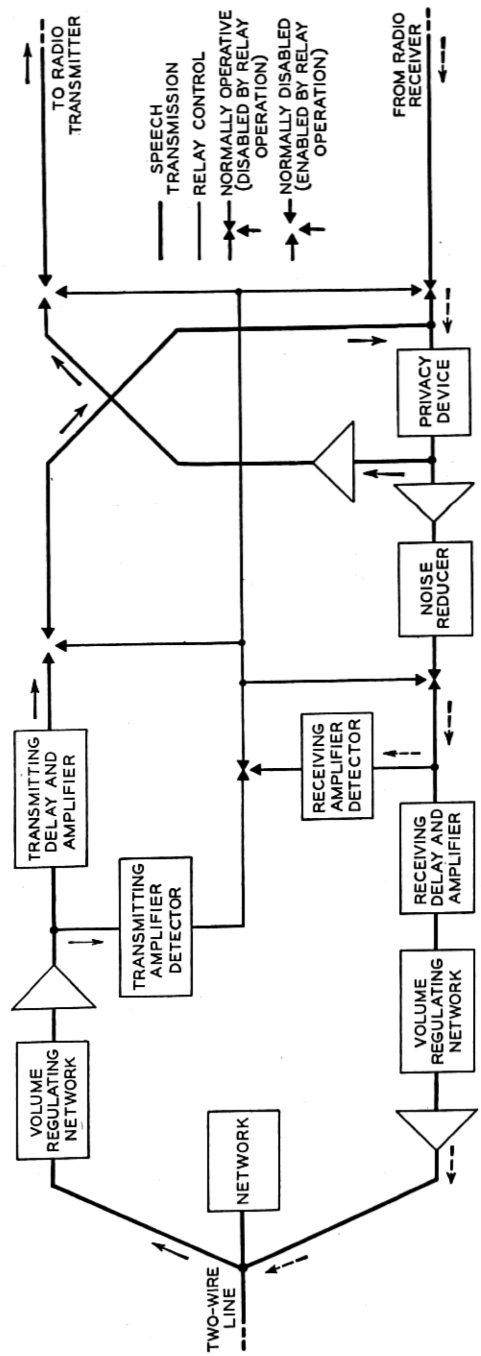

Fig. 6—Application of noise reducer to radio control terminal.

switched to the transmitting channel when the land subscriber talks. This switching is done by voice-operated relays.[7, 8] The noise reducer in addition to improving the intelligibility of the speech received protects these voice-operated relays against false operation by the received noise.

Figure 6 shows the application of the noise reducer to such a control terminal. Speech entering the terminal from the left goes through the upper branch of the circuit, with volume regulating means and privacy apparatus, to the radio transmitter. Speech received from the distant terminal enters at the lower right from the radio receiver and proceeds through the privacy apparatus, the noise reducer, receiving regulating network and amplifier to the two-wire line. Outgoing speech operates the transmitting path and disables the receiving path. Incoming speech operates the receiving amplifier detector, which disables the transmitting amplifier detector, thus preventing singing and reradiation of received waves.

Without the noise reducer the receiving relay may be operated by noise in the receiving path and such operation to an excessive extent will interfere with outgoing speech. To avoid this effect, it is customary to reduce its sensitivity so that noise may not operate it. This results in the weaker speech parts also failing to operate the receiving relay. This weak speech and noise returned to the transmitting path through the land line connection may be strong enough to operate the transmitting relays and thus cut off incoming speech. This is avoided by reducing the volume to the land line. Therefore, any device which reduces noise in the receiving path in the absence of speech effects an improvement not only in the switching operation but also in the received volume. By placing the noise reducer in the receiving path false operation is diminished and volume increases of 5 to 15 db are realized. The noise reducer is applied to the receiving side of the terminal beyond the privacy apparatus so that it does not introduce any distortion in the privacy portion of the circuit. It is placed ahead of the receiving amplifier detector, thereby reducing noise between words which might affect the operation of this relay apparatus.

Summary

The noise reducer, which is a voice controlled variolosser with limited and controllable action, has been provided for use on short-wave radio telephone circuits and has proved to be a valuable and relatively inexpensive means of securing noise reduction. Improved reception is obtained for many of the transmission conditions experienced on such circuits. This results in better intelligibility to the

subscriber, greater margin in the operation of two-way radio telephone circuits and a reduction of difficulties in the wire plant caused by connection to noisy radio circuits.

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