Nov. 17, 1942. J. T. L. BROWN 2,302,293

CROSSTALK REDUCTION

Filed Feb. 24, 1942 2 Sheets-Sheet 1

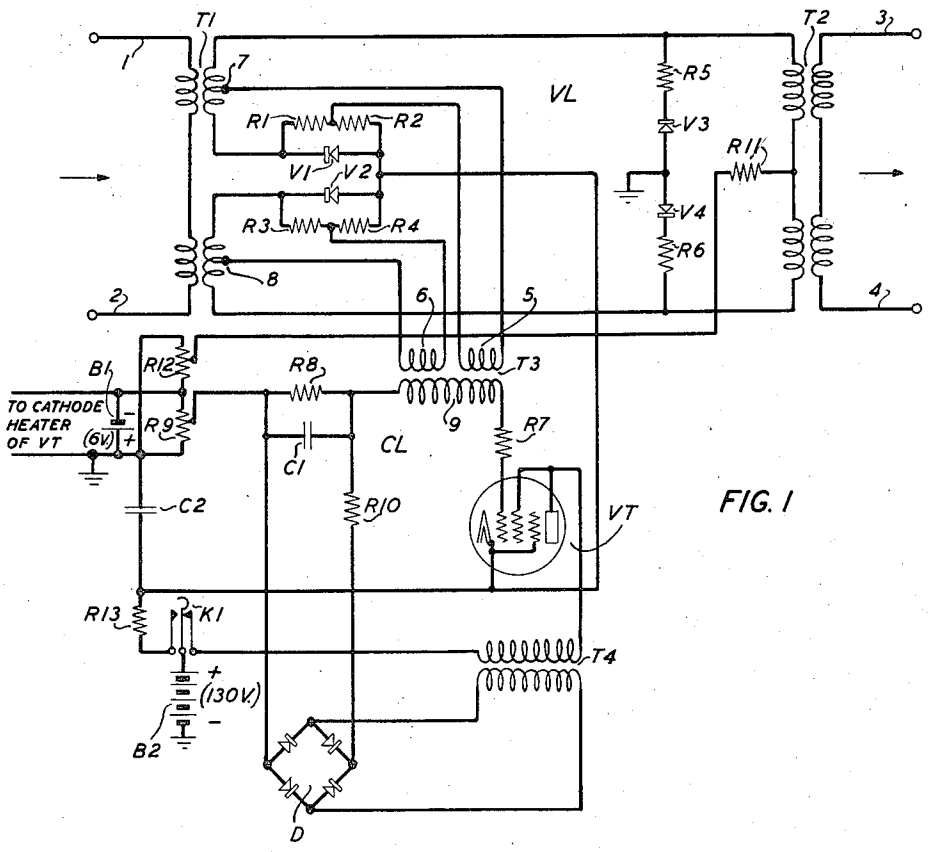

FIG. 1

INVENTOR
J.T.L. BROWN
BY
Earl C. Laughlin
ATTORNEY

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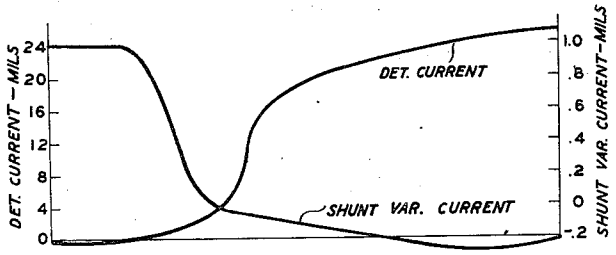

FIG. 2

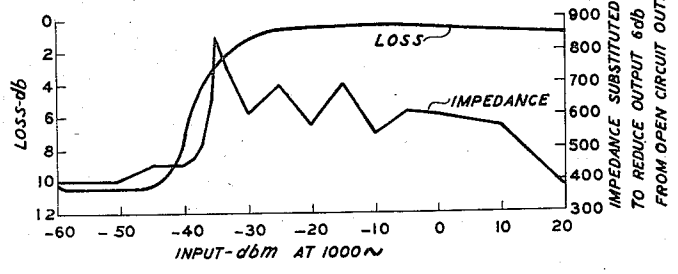

FIG. 3

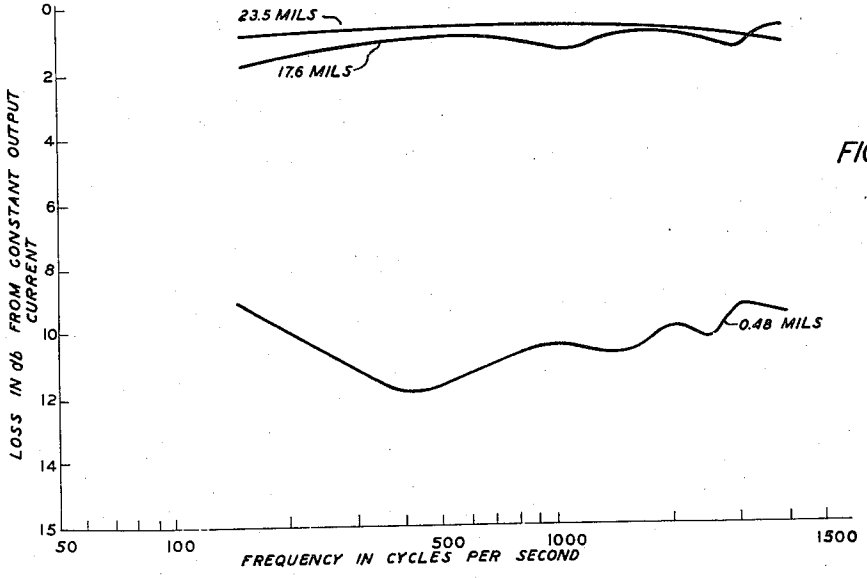

FIG. 4

INVENTOR
J.T.L. BROWN
BY
Earl C. Laughlin
ATTORNEY

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CROSSTALK REDUCTION

John T. L. Brown, Short Hills, N. J., assignor to Bell Telephone Laboratories, Incorporated, New York, N. Y., a corporation of New York

Application February 24, 1942, Serial No. 432,145

5 Claims. (Cl. 179—78)

The invention relates to a telephone transmission system and particularly to a circuit for discriminating between transmitted waves of different amplitudes in such a system.

It is known that crosstalk or other noise interference is most objectionable in telephone systems during pauses in telephone conversation for during talking intervals it is to a large extent masked by the transmitted voice signals. The maximum allowable amount of crosstalk is therefore determined by the amount permissible during the pauses in conversation.

An object of the invention is to render a telephone circuit capable of discriminating between transmitted waves of different amplitudes, for example, between crosstalk or other noise interference and speech signals.

Another object is to reduce crosstalk or other noise interference in a telephone transmission circuit, without undue distortion of the speech signals transmitted thereover.

These objects are attained in accordance with the invention by the use in the telephone circuit of a limited volume range expander comprising a variable loss network in the speech transmission circuit providing a normal loss sufficient to reduce the maximum amount of crosstalk to a negligible amount during non-speech intervals, and a voice-operated control circuit including a single tube rectified-reaction type detector for reducing the loss value of the network to a low value during talking intervals.

A feature of the invention is the use of a special connection between the speech transmission circuit and the detector input of such a circuit, providing close-coupling and thus high detector sensitivity for the lowest amplitude speech inputs, and a less efficient coupling for higher amplitude speech inputs to prevent introduction of loss and distortion in the speech circuit.

The various objects and features of the invention will be better understood from the following complete description when read in conjunction with the accompanying drawings in which:

Fig. 1 shows schematically a circuit embodying the invention; and

Figs. 2 to 4 show curves illustrating the operation of the circuit of the invention.

Fig. 1 shows a portion of a speech transmission circuit subject to crosstalk or other noise interference, having input conductors 1, 2 and output conductors 3, 4. The crosstalk reducer of the invention comprises a vario-losser VL connected in that portion of the speech transmission circuit by input transformer T1 and output transformer T2, and an associated forward-acting control circuit CL.

The vario-losser VL comprises an "L" type attenuation pad, the series arm of which includes in series between the two halves of the secondary winding of transformer T1, the equivalent oppositely poled copper-oxide varistors V1 and V2, respectively, shunted by the equal resistors R1 and R2 in series, and by the equal resistors R3 and R4 in series, and the shunt arm of which comprises the equivalent oppositely poled copper-oxide varistors V3 and V4 in series with the equal resistors R5 and R6, connected across the speech transmission circuit between the transformers T1 and T2, the mid-point of this shunt arm between the varistors V3 and V4 being connected to ground.

The control circuit CL for the vario-losser VL comprises a single tube detector of the rectified-reaction type. It includes an input transformer T3 having two equal primary windings 5 and 6 respectively connected across the intermediate voltage tap 7 on the upper half of the secondary winding of transformer T1 and a point between the resistors R1 aind R2 shunting the series varistor V1, and across an intermediate voltage tap 8 on the lower half of the secondary winding of transformer T1 and a point between the resistors R3 and R4 shunting the series varistor V2, and a secondary winding 9 in the control grid-cathode circuit of the pentode detector vacuum tube VT.

The tube VT may be a Western Electric No. 7727 tube which is particularly adapted for the required use as it has exceptionally high transconductance and its maximum plate plus screen current with zero bias and 130-volt plate battery is of the proper order of magnitude for operation of the vario-losser. Instead of using the conventional pentode arrangement in this tube, the screen grid is connected directly to the plate.

The control grid of tube VT is connected through the resistance R7, the secondary winding 9 of input transformer T3, and the parallel resistance-condenser combination R8, C1 in series to a variable tap on the potentiometer R9 (for initially adjusting the detector sensitivity) shunting the 6-volt battery B1 supplying heater current to the heater type cathode of the tube VT. The plate-cathode circuit of the tube VT includes in series the primary winding of feedback transformer T4, the righthand contacts of key K1 and the 130-volt plate battery B2.

To make the detector operate in accordance with the rectified-reaction principle, the plate-

cathode circuit of tube VT is coupled to the control grid-cathode circuit through a feedback circuit comprising feedback transformer T4, rectifier bridge D and a resistance-condenser combination R10, R8 and C1 for controlling the time constant (attack and hangover characteristics). This feedback circuit operates to rectify the alternating current output of tube VT and feed it back to the input with such polarity as to make the control grid of that tube more positive, thus increasing the detector sensitivity after it has operated in response to applied speech signals.

With no speech input to the input conductors 1, 2 of the speech transmission circuit, the amount of biasing direct current flowing through the series varistors V1 and V2 and the shunt varistors V3 and V4 of suitable value is made such that these varistors in combination with the associated resistances R1 to R6 of proper values, form a balanced 10-decibel "L" attenuation pad with an output impedance matching that of the outgoing speech transmission circuit. The circuit impedance at the vario-losser VL is normally 1500 ohms, being stepped up from the 600-ohm impedance of the incoming speech transmission circuit by input transformer T1. The initial direct current bias on the shunt varistors V3 and V4 is obtained by a connection from the mid-point of the primary winding of transformer T2 through series resistor R11 to a tap on the potentiometer R12 shunting the grounded cathode heater battery B1, which is adjusted to provide about 1 milliampere total biasing current (.5 milliampere in each varistor), making the alternating current impedance of the varistors V3 and V4 about half of the total shunt impedance. The initial direct current bias on the series varistors V1 and V2 is derived from the detector by a conductive connection from its plate-cathode circuit to a point between varistors V1 and V2 and from its cathode heater circuit through potentiometer R12 and resistor R11 to the mid-point of the primary winding of transformer T2, the total initial detector current being adjusted to about .3 milliampere. The major portion of this initial current flows through resistances R1, R2, R3 and R4, which shunt the series varistors, so that these varistors reduce the series alternating current impedance or loss in the speech transmission circuit from 2,000 ohms to about 1,600 ohms. The circuit loss for inputs to the speech transmission circuit below the operating point of the detector is therefore determined primarily by the fixed resistances R1 to R6, rather than by precise adjustment of initial detector and shunt bias current.

When the detector operates in response to the application of speech input to input transformer T3, the current from it increases to a maximum value of about 24 milliamperes. This reduces the alternating current impedance of the series varistors V1 and V2 to a negligible value. The increased detector current, flowing through resistance R11, also reverses the direct current potential on the shunt varistors V3 and V4, causing their alternating current impedance to be increased to a very high value. As a result, the circuit loss in the speech transmission circuit for full operation of the detector is reduced practically to that corresponding to the loss in the transformers T1 and T2, say about .8 decibel.

In order to obtain high detector sensitivity with respect to the speech input, a fairly efficient coupling between the detector and speech circuit is required at the lower speech inputs. At higher inputs, close coupling is undesirable because of loss and distortion introduced in the speech circuit when the detector grid draws current. Because of the high impedance ratio required in the detector input transformer T3 and design limitations on the tube VT, it is not feasible to avoid trouble from this source by a large resistance in series with the detector grid. The maximum value for the series resistance R7 should be about 250,000 ohms. The circuit has therefore been arranged so that the coupling between the speech channel and the detector input is reduced when the detector operates. The input to the detector through transformer T3 is derived effectively from two alternating current voltage sources in series. One of these is approximately half of the alternating current voltage across the series varistors V1 and V2 obtained from the taps between the resistors R1 and R2 and between R3 and R4, and has a value which ranges from about 12 decibels below the open circuit input voltage of the speech circuit at low inputs to a negligible value at high inputs. The second voltage is obtained from the taps 7 and 8 on the secondary windings of input transformer T1 and has a maximum value at high inputs corresponding to about 32 decibels below the open circuit input voltage of the speech circuit. The reduction in coupling on operation of the detector is therefore about 20 decibels. The coupling reduction is more than compensated for in the tube VT by increase in transconductance with increase in plate current. There is no discontinuity, therefore, in the increase of plate current as the detector input is increased.

The direct current connection to the vario-losser VL is in the cathode leg of the detector tube—a feature necessitated by the use of current from both the cathode and plate batteries in the vario-losser VL. The losser current from the detector is therefore the sum of the screen and plate currents of tube VT. The ratio between these two currents is practically constant in the operating range. The capacity C2 is provided primarily to reduce crosstalk between the detector circuit and the speech circuit. It also has some effect on the attack and hangover characteristics of the detector circuit, primarily controlled by the resistance-condenser combination R7, R8, C1 in the feedback circuit of the detector tube.

Key K1 is provided for effectively switching the vario-losser in and out by substituting resistance R13 in the 130-volt circuit in place of the detector tube VT when the key is operated to its left-hand contact. This control can be either local or remote, the latter to be used in the case of multiple link connections to avoid the effects of several crosstalk reducers operating in tandem.

The curves of Figs. 2 and 3 show the operating characteristics for various levels of 1,000 cycles per second tone input to the crosstalk reducer of Fig. 1, curves for loss, output impedance, detector current and current through the shunt varistors being included.

Fig. 4 shows curves of loss in the speech transmission circuit plotted against frequency provided by the crosstalk reducer of Fig. 1 for three different values of detector current. The detector current selected corresponds to full detector operation (23.5 milliamperes), a value corresponding to operation on minimum speech volumes (17.6 milliamperes), and a value corresponding to practically no operation of the detector (.48 milliampere).

Referring to the curves of Figs. 2 and 3, it will be noted that most of the change in loss occurs

between —40 dbm. (decibels referred to 1 milliwatt) and —30 dbm., the loss at —35 dbm. being within about 2 decibels of the minimum loss. The minimum loss, .8 decibel, occurs between —5 and —20 dbm. As indicated, the loss again increases for inputs above —5 dbm., because of the shunting effect resulting from overloading in the detector control grid circuit. About 8 decibels of the loss is removed with a detector current of about 3 milliamperes. At a detector current of about 10 milliamperes, the current through the shunt varistors reverses. The effect of detector current increase between 10 and 20 milliamperes is very small, so that commercial variations in tubes and other elements determining the maximum current in the losser should not be important.

Tests with the circuit of Fig. 1 indicate that crosstalk may be reduced by about 7 decibels during continuous speech transmission and 10 decibels during the longer pauses, with negligible effect on speech volume or quality.

Various modifications of the circuit which has been illustrated and described which are within the spirit and scope of the invention will occur to persons skilled in the art.

For example, the coupling between the control grid and plate of the detector tube VT may be made with a condenser in place of the transformer T4 shown. The initial bias current in the shunt varistors can be provided by fixed resistances instead of by an adjustable potentiometer as shown. The crosstalk reducer circuit described was designed for insertion in a cable carrier telephone system at the output of a demodulator-amplifier, where the lever is about +4 decibels. Some economy may be effected by combining the output transformer of the demodulator-amplifier and the speech input coil T1 of the crosstalk reducer in such a combination in a single unit. A switching loss of about 15 decibels might be desirable for some applications. It appears that this can be readily obtained by decreasing the values of the resistors R5 and R6 in the shunt arm and adding a second pair of resistance-shunted series arm varistors, forming an "H" attenuation pad.

What is claimed is:

1. In combination with a transmission circuit transmitting speech signal waves and subject to interfering noise waves of low amplitudes, such as crosstalk, a variable loss network including impedance elements having non-linear voltage-current characteristics, connected in said circuit, a rectified-reaction type detector employing a single space discharge tube, having an input circuit supplied with a portion of said waves applied to said network, and an output circuit connected to said non-linear impedance elements in such manner that the detector output current controls the alternating current impedance of said elements and thus the loss value of said network in said transmission circuit, said detector and said non-linear impedance elements being normally biased so that, in the absence of applied speech waves, said network inserts a fixed loss in said speech transmitting circuit sufficient to reduce the transmission of said noise waves of said low amplitude to a negligible amount, the output current of said detector being increased sufficiently in response to the application of speech waves to its input to reduce the attenuation of said loss network to a low value.

2. The combination of claim 1 in which the connection between said speech transmission circuit and the input circuit of said detector is such as to provide an efficient coupling therebetween for low amplitude speech inputs and a less efficient coupling therebetween for higher amplitude speech inputs.

3. The combination of claim 1 in which said variable loss network comprises a balanced "L" type attenuation pad including non-linear impedance elements shunted by linear impedance elements in the series arm and non-linear impedance elements in series with linear impedance elements in the shunt arm, the output current of said detector passing through said linear impedance elements to control the voltage applied to and thus the alternating current impedance of the associated non-linear impedance elements in accordance with the amount thereof.

4. In combination with a circuit transmitting speech signal waves and subject to interfering noise waves of low amplitudes, a variable loss network including impedance elements having a non-linear voltage current characteristic, connected in said circuit, a detector having an input circuit supplied with a portion of said waves applied to said network and an output circuit connected to said network in such manner that the alternating current impedance of said non-linear impedance elements, and thus the loss value of said network depends on the amount of detector output current, said non-linear impedance elements and said detector being normally biased so that, in the absence of speech wave transmission, said network provides a loss in said circuit of sufficient value to reduce the transmission of waves of said low amplitudes to a negligible amount, and the increase in detector output current when speech waves are applied to the input thereof causing the loss value of said network to be reduced to a low value and means for providing an efficient coupling between said speech transmission circuit and the input circuit of said detector for the lowest amplitude speech wave inputs and a less efficient coupling therebetween for higher amplitude speech wave inputs.

5. The combination of claim 4 in which said loss network includes an input transformer having two secondary windings and oppositely poled copper-oxide varistors each shunted by a linear resistance element, connected in series between said secondary windings, and said means for coupling said speech transmission circuit and the input circuit of said detector comprises a transformer therebetween having two separate primary windings, the terminals of one of which are connected across a mid-tap on the resistance element shunting one of said series varistors and an intermediate voltage tap on one of the secondary windings on said input transformer, and the terminals of the other of which are connected across a mid-point of the resistance element shunting the other of said series varistors and an intermediate voltage tap on the other secondary winding of said input transformer.

JOHN T. L. BROWN.