May 24, 1932. C. R. KEITH 1,859,565

APPARATUS FOR REDUCING CROSSTALK CURRENTS

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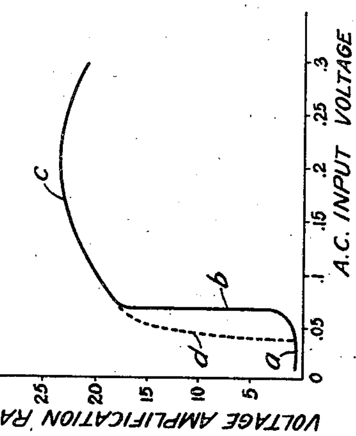

FIG. 1A

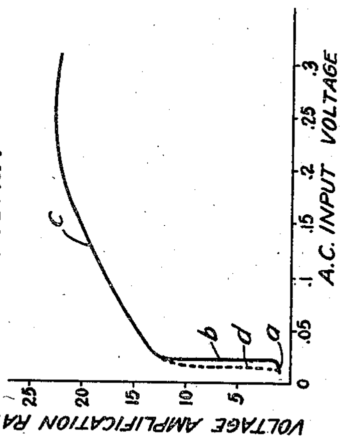

FIG. 2A

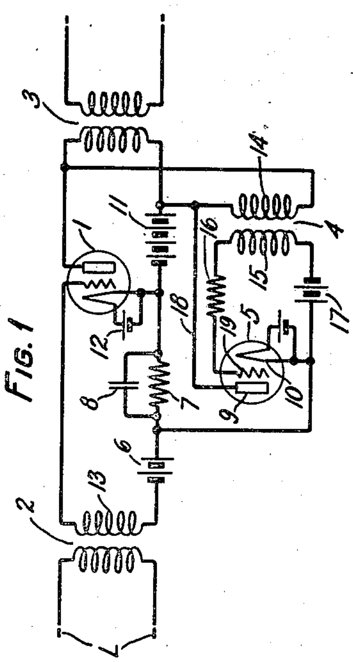
FIG. 1

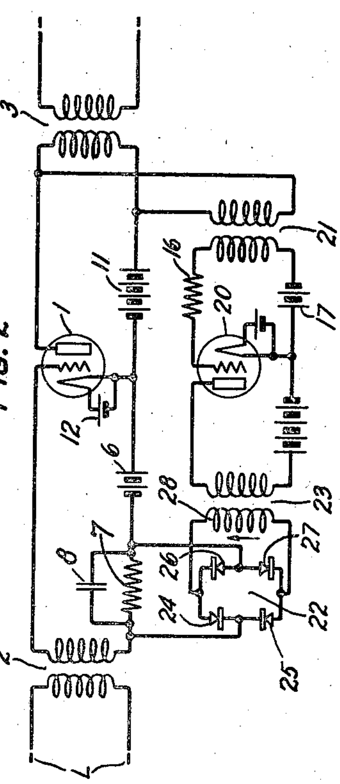
FIG. 2

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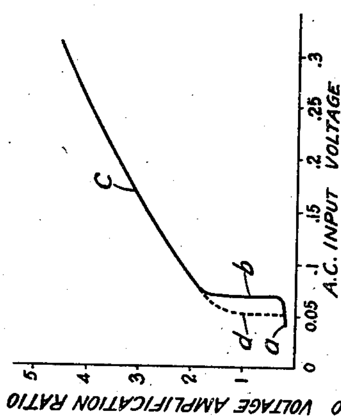


FIG. 3A

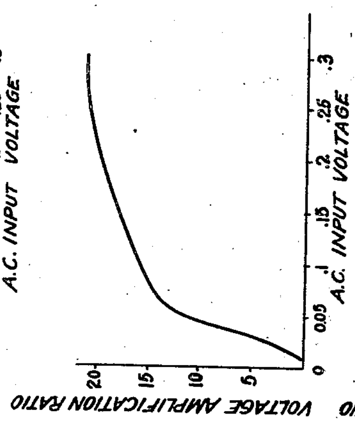


FIG. 4A

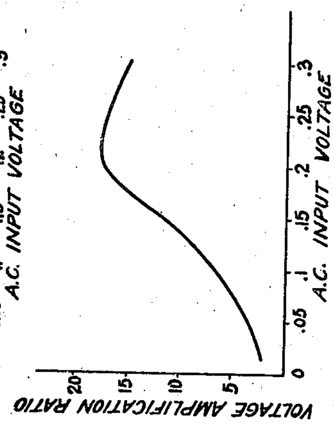


FIG. 5A

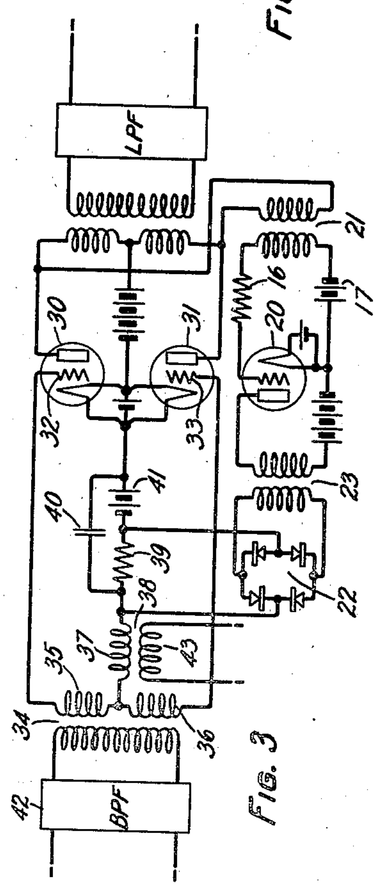


FIG. 3

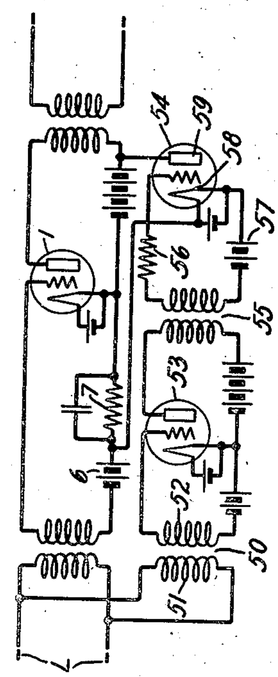

FIG. 4

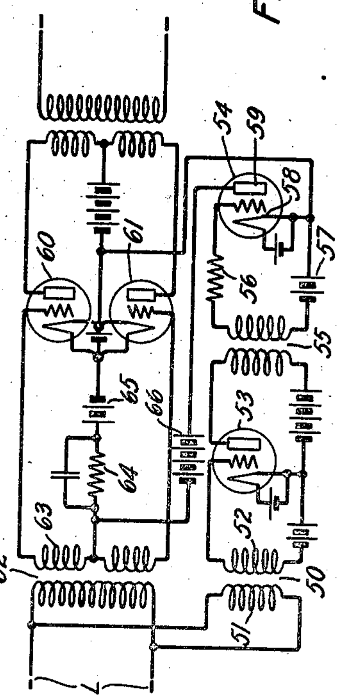

FIG. 5

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# UNITED STATES PATENT OFFICE

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## APPARATUS FOR REDUCING CROSSTALK CURRENTS

Application filed December 4, 1928. Serial No. 323,724.

This invention relates to transmission systems and particularly to circuits for discriminating between currents of different amplitudes.

It is well known that interfering sounds are more noticeable and objectionable occurring alone than when accompanied by sounds of much greater intensity, since in the latter instance they are masked out to a considerable extent. On this account noise or crosstalk currents are more objectionable during pauses in conversation than when accompanied by speech.

The maximum allowable amount of crosstalk is governed by the amount permissible during the pauses in conversation since this amount is less than that permissible during the talking periods. In other words a very much smaller amount of crosstalk will become understandable or objectionable during silent intervals than that which would be required to detrimentally affect the intelligibility of speech during talking periods.

An object of this invention is to render a circuit capable of discriminating between currents of different amplitudes.

Another object of the invention is to control the amplification of an amplifying device in accordance with signals transmitted over the line.

A further object of the invention is to vary the conductivity of a vacuum tube translating device in a manner determined by the current transmitted therethrough.

In order to accomplish these objects, a circuit is equipped with an amplifier or some other suitable arrangement of space discharge devices and means are provided for causing the transmission efficiency of the circuit to vary so that the system has considerably less gain in response to small currents than in response to signal currents.

In one aspect of the invention an amplifier is connected in a transmission line having a portion of its output current rectified and fed back through a resistance in the grid circuit of the amplifier causing a voltage drop thereacross in opposition to the normal negative grid voltage on the tube. When the current on the line is small as for instance that resulting from crosstalk during pauses in conversation, the amount of current rectified is negligible and the normally high negative voltage on its grid effectively blocks the transmission of current through the amplifier. However, during the transmission of speech the current available in the output of the amplifier for rectification and application upon the amplifier input circuit is considerably larger and is sufficient to reduce the effects of the negative grid bias on the amplifier grid electrode, so that normal amplification of the signals is permitted.

In another embodiment of the invention the gain of a demodulator system is made dependent upon the strength of signals in its output circuit which is considerably larger for normal talking currents than for small currents corresponding to crosstalk.

In several other embodiments of the invention a similar but not quite so pronounced effect is obtained by rectifying a portion of the input current before amplification by the amplifier and applying it to the grid circuit thereof through a resistance to produce a voltage in opposition to a high negative grid voltage normally impressed upon the amplifier. As in the other case the smaller crosstalk currents are prevented from being transmitted through the amplifier whereas signals of speech amplitude are amplified to a normal extent.

A better understanding of the invention may be had by reading the following description together with the accompanying drawings of which Fig. 1 shows an amplitude discriminator comprising an amplifier, the output circuit of which supplies the current for controlling the biasing voltage on the control electrode. Fig. 2 is a similar arrangement differing only in the type of rectifier circuit used. Fig. 3 illustrates the invention applied to a demodulator circuit. In Fig. 4 an amplifier similar to that of Fig. 1 is shown differing only in that current is supplied to the rectifier from the input circuit of the amplifier instead of the output circuit to obtain the grid bias. Fig. 5 is similar to Fig. 4 except that the amplifier is of the balanced or push-pull type and the fixed static grid bias is positive. Figs. 1—A to 5—A are curves illustrating respectively the operations of circuits 1 to 5.

Referring now to Fig. 1 the amplitude discriminator comprises a vacuum tube amplifier 1 connected to the line L by means of a transformer 2. The ouput of the amplifier is connected to a line or any suitable receiving apparatus through the transformer 3. The amplifier is of the three element space discharge type comprising a plate maintained at a suitable potential by means of a source of energy 11, a filament suitably energized from a source of filament current 12 and a grid connected to the filament through the secondary winding 13 of the transformer 2, the battery 6 for impressing a negative grid potential upon the grid and the resistance 7. Resistance 7 is shunted by a condenser 8, the purpose of which will be hereafter described. Shunted across the output circuit of the amplifier is the primary 14 of the transformer 4, to the secondary winding 15 of which is connected the rectifier 5 for supplying rectified current to the resistance 7, to produce therein a voltage which tends to reduce the negative bias on the grid of the amplifier 1.

The input circuit of the rectifier may be traced from the grid 19, through the resistance 16, transformer winding 15, negative grid battery 17 to the filament 10. The output circuit of the rectifier 5 may be traced from filament 10 through the resistance 7, battery 11, the lead 18 to the plate 9.

The operation of the circuit may be readily understood by reference to the curve of Fig. 1—A which shows A. C. input voltage to the amplifier as abscissa plotted against the amplification ratio of input to output voltage. Small voltages corresponding to crosstalk on the line are substantially suppressed as shown by portion *a* of the curve. This results from the fact that current which passes through the resistance 7 from the rectifier is so small as to have practically no effect upon the fixed negative grid potential produced by source 6, which, under these circumstances, is sufficiently large to prevent transmission through the tube 1. As the voltage on the wire is increased, however, a critical value *b* is reached above which a sufficient amount of current is amplified by the tube 1, rectified by tube 5, and passed through resistance 7 to produce a voltage in opposition to the voltage of battery 6. This reduces the "C" bias on the grid of amplifier tube 1 sufficiently to permit it to transmit current with a relatively high gain as shown by portion *c* of the curve in Fig. 1—A.

In passing from the region of low gain, *a*, to the region of high gain, *c*, a region of instability *b* exists due to regeneration as the optimum value of grid potential is being built up. This has no effect upon the transmission of signals, however, as the signal voltages are normally considerably greater than the voltages in the unstable region. As the voltages on the line decrease the region of instability on the curve *d* which represents a rapid decrease in the amplification ratio of the amplifier is lower than the region in which the amplification ratio rapidly increases for ascending voltages. This phenomenon is advantageous, however, since it tends to keep the transmission level of the system constant between words and sentences of the conversation.

The condenser 8 which shunts the resistance 7 acts as a filter to prevent alternating currents transmitted by the rectifier 5 from being impressed on the grid of amplifier 1. This prevents singing through the amplifier and rectifier circuits. At the same time condenser 8 provides a low impedance to unwanted frequencies in the output of rectifier 5 and so allows the rectifier to operate at maximum efficiency. The condenser also tends to keep the gain of the amplifier from varying so rapidly that the speech or signals sound choppy. In order to make the change of gain with input voltage as large as possible after the maximum crosstalk voltage has been reached, the rectifier should have its maximum gain for voltages just above this value and lower gain both for lower voltages and higher voltages. The lower gain for higher voltages is quite important since otherwise the effective "C" bias of the amplifier would decrease to zero for large input voltages resulting in a decrease of both gain and quality.

The rectifier current output may be made to rise rapidly to a maximum and then stay practically constant by means of the resistance 16 in the grid circuit of the rectifier tube. With the rectifier grid battery 17 of such a value that the initial space current of tube 5 is very small, the rectified current through resistance 7 increases with the input to rectifier 5 as long as the grid of tube 5 does not become positive with respect to the filament. However, when the input is sufficiently large for this to take place, the grid-filament impedance of tube 5 becomes so low that the voltage across it increases very little and consequently the rectified current in resistance 7 remains substantially constant. By selecting the proper grid biasing resistance 7 for the amplifier tube 1 the effective bias for maximum input voltage can be made very close to the optimum.

In an actual circuit as used by applicant, which resulted in the experimental curve in Fig. 1—A, the amplifier tube 1 and rectifier tube 5 were standard Western Electric tubes designated respectively 101—D and 102—D. The transformers were of the voice frequency type, the input transformer 2 having an impedance ratio of 600 to 100,000 ohms, the output transformer 6000 to 600 ohms and the transformer 4 connecting the rectifier with the amplifier 18,000 to 300,000 ohms.

The resistance 16 which controls the range over which the amplifier can operate without overloading was 1 megohm which together with a rectifier "C" bias of 3 volts used in this case gave the characteristic curve shown. The amplifier tube required a plate voltage of 130 volts with a fixed "C" bias of 25 volts. A 10,000 ohm resistance was used in the amplifier grid circuit while the condenser 8 had a value of 2 microfarads. With this circuit crosstalk currents having one tenth the amplitude of speech currents were reduced to approximately one hundredth of this amplitude. Thus, with the value of circuit elements given above, the normal speech voltage working into a 600 ohm resistance averages .3 volts while crosstalk up to .03 volts is suppressed.

Another embodiment of the invention is shown in Figs. 2 and 2—A. Since this is similar to Fig. 1 in many respects, corresponding elements have been given the same designation. This circuit operates in a manner similar to that shown in Fig. 1, the main difference residing in the type of rectifier which supplies current to the resistance 7 in the amplifier grid circuit. In this circuit a portion of the current from the output of the amplifier 1 is impressed upon the input of the vacuum tube amplifier 20 through the transformer 21. The amplified current from the output of the amplifier 20 is impressed through transformer 23 upon the group of rectifiers 22 which are arranged to rectify current to both polarities. Thus when current in the secondary of the transformer 23 is in the direction of the arrow, rectified current through the resistance 7 may be traced from the transformer secondary through the rectifier 24, resistance 7, rectifier 27 and back to the lower terminal of the transformer winding 28. When the current in winding 28 is in the opposite direction its path lies through the rectifier 25, resistance 7 and rectifier 26 to the upper end of the transformer winding 28. One advantage of this circuit resides in the fact that only a single source of filament heating current is required since the rectifiers of this circuit may be of the crystal or copper oxide type which require no filament battery. However, the circuit is not limited to this type of rectifier since any type of rectifier may be successfully used. In order to simplify the drawings, two filament batteries have been shown, although the manner in which a single battery may be used for both amplifiers will be at once apparent to those skilled in the art. The operation of this circuit is very similar to that of the circuit of Fig. 1 and, therefore, will not be described. The operating characteristic of this circuit is shown in Fig. 2—A which is similar in most respects to the characteristic curve of Fig. 1—A.

The circuits disclosed in the foregoing figures and described above are suitable for use in systems employing speech frequencies on the transmission line. Fig. 3 discloses a type of noise or crosstalk suppression circuit which may be used in connection with radio or carrier wave transmission.

Since the gain of a plate circuit modulator or demodulator varies with the grid bias in a manner similar to an amplifier, crosstalk reduction may also be effected in accordance with the invention in this type of circuit. A circuit accomplishing this result is shown in Fig. 3. A demodulator of well known type is shown comprising a pair of three-element vacuum tubes 30 and 31 in balanced relation, the grid electrodes of which are connected together through the branches 35 and 36 of the secondary winding of the transformer 34. The mid-point of the transformer is connected to the filaments of the tubes through the secondary winding 37 of the transformer 38, the resistance 39 and the battery 41 which are in the common branch of the demodulator input circuit. The band pass filter 42 for excluding all but the desired frequency band is connected to the primary of the transformer 34 so that a frequency equivalent to the sum or the difference between the carrier and voice frequency is differentially impressed upon the grids of the vacuum tubes while the locally supplied carrier for the well known process of demodulation is impressed upon the grids of the tubes in phase from a source connected to the transformer 38, the secondary of which is located in the common branch of the input circuit. A condenser 40 shunting the resistance 39 serves to prevent singing and provides an optimum impedance for the rectifier 22. Rectified current from the rectifier amplifier flows through the resistance 7 producing a voltage drop in opposition to the negative grid potential of battery 41. The rectified current is dependent upon the current in the demodulator output since the input of the rectifier amplifier is connected to the output of the demodulator through the transformer 21.

The rectifier amplifier is similar to the one shown in Fig. 2 and therefore will not be described in detail. The operation of the circuit with reference to the varying grid potential for the reduction of crosstalk is similar to that of the circuits of Fig. 1 and Fig. 2. The ratio of side band output voltage to signal input voltage of the circuit for various input voltages is illustrated in Fig. 3—A. The curve shows how small voltages corresponding to crosstalk are suppressed to a considerable degree whereas above a certain value, in the region of signal voltage, the gain is relatively large. The portions $a$, *b*, *c* and *d* of the curve correspond generally to the corresponding portions of the curves for an amplifier.

Fig. 4 illustrates a crosstalk reducing circuit comprising an amplifier with a variable grid bias similar to that shown in Fig. 1. However, in this circuit the current to be rectified is obtained from the input of the amplifier, instead of from the amplifier output, as in the circuits heretofore described. Referring to Fig. 4 the transformer 50 has its primary winding 51 shunting the line L and its secondary winding 52 connected to the input circuit of vacuum tube amplifier 53 which is of any well known type. The output of the amplifier is connected to the input circuit of the rectifier 54 through the transformer 55. The resistance 56 and negative grid battery 57 in the input circuit are adjusted to a value which permits maximum gain for voltages above the maximum crosstalk voltage and lower gain for voltages above and below this value. The latter is essential since should the grid impedance of the amplifier be made too small, most of the voltage drop in the amplifier input circuit would be across the transformer winding resulting in very inefficient transmission through the amplifier. The output circuit of the rectifier traced from the filament 58 through the resistance 7 is poled to reduce the grid biasing voltage 6. As in the circuits already described, small voltages corresponding to crosstalk have practically no effect on the negative grid biasing voltage which is large enough to prevent transmission through the amplifier. However, the signal voltages are considerably larger and reduce the negative grid voltage sufficiently to prevent the blocking action and permit normal transmission through the amplifier 1.

Fig. 4—A shows the operating characteristic of this circuit, as experimentally obtained. It is seen from the curve that the crosstalk is effectively discriminated against, relative to speech.

Suppression of small voltages in a variable bias amplifier may also be obtained by using an initially positive bias. A circuit of this type is shown in Fig. 5. Herein a push-pull amplifier comprising vacuum tubes 60 and 61 is connected to the line L through transformer 62. The grids of the amplifier are connected together through the upper and lower branches of the secondary winding 63 of the transformer 62. The grid circuits of the vacuum tubes are completed through the common branch which connects the midpoint of the transformer secondary winding 63 to the filaments, and comprises resistance 64 and a source of positive grid potential 65. The output of the amplifier is arranged in accordance with the well known push-pull circuit.

An amplifier rectifier similar to that in Fig. 4 is connected to the input of the push-pull amplifier. The output circuit of the rectifier may be traced from the filament 58, to the filaments of vacuum tubes 60 and 61, the source of potential 65, resistance 64, back to the plate 59 of the rectifier through the source of potential 66. In this circuit the voltage drop through the resistance 64 is poled to decrease the positive bias on the grids of the amplifiers 60 and 61 so that as the voltage in the input circuit L increases the variable grid bias is decreased. According to the theory of operation of this circuit, small voltages upon the line, have little effect on high positive grid bias which makes the grid impedance of the amplifiers very low. Under these conditions most of the voltage drop in the grid circuits is across the transformer winding and very little is impressed upon the grid to be repeated to the output circuit. However, larger voltages corresponding to speech on the line increase the amount of current rectified and reduce the positive bias on the amplifiers 60 and 61 to a point where the impedance of the transformer matches the grid impedance of the tube under which circumstances maximum transfer of energy results. The operation of this circuit is illustrated by the curve, in Fig. 5—A, which shows negligible transmission for currents of small crosstalk amplitudes and good transmission for currents corresponding to signal amplitudes.

It will be apparent that the circuits described herein are typical of many which will suggest themselves to those skilled in the art within the spirit of the invention. The invention is to be limited therefore only by the scope of the appended claims.

What is claimed is:

1. In a signal transmission system for discriminating between currents of different amplitudes, a space discharge amplifier for amplifying waves of normal signal amplitude substantially without distortion, a source of signals for supplying signal waves to said amplifier for amplification therein, said amplifier having a control electrode associated with said source, a source of biasing potential for said electrode for preventing substantial amplification of currents small in comparison with said signal currents and means for varying said biasing potential in accordance with the amplified current from said device to make it readily amplify currents of normal signal magnitude substantially without distortion.

2. The combination in a transmission system of a line for the transmission of signals, and means for the suppression of disturbing currents therein comprising an amplifier therein for amplifying substantially without distortion waves of normal signal amplitude impressed on said amplifier from said line, said amplifier being normally opaque to

currents of crosstalk amplitude but having means dependent upon the current transmitted through said amplifier for rendering the gain thereof as a distortionless amplifier high for currents of normal signal amplitude.

3. The combination in a transmission system of a line for the transmission of signals, means for the suppression of disturbing currents therein comprising an amplifier therein for amplifying substantially without distortion waves of normal signal amplitude impressed on said amplifier from said line, said amplifier being normally opaque to currents of crosstalk amplitude, and means for rectifying a portion of the energy transmitted through said amplifier and utilizing it for rendering the gain of said amplifier as a distortionless amplifier high for currents of normal signal amplitude.

4. The combination in a transmission system of a line for the transmission of signals and means for the suppression of disturbing currents therein comprising a space discharge amplifier device therein for amplifying substantially without distortion waves of normal signal amplitude impressed on said device from said line, said device having a control element, means for impressing a voltage upon said control element of value sufficient to prevent substantial amplification in said device of currents of crosstalk amplitude, and means for reducing the effect of said voltage in response to increase of the currents transmitted through said device to permit readily the amplification of currents of normal signal amplitude substantially without distortion.

5. The combination in a transmission system of a line for the transmission of signals and means for the suppression of disturbing currents therein comprising a space discharge amplifier device therein for amplifying substantially without distortion waves of normal signal amplitude impressed on said device from said line, said device having an input circuit and an output circuit, means comprising a source of potential in said input circuit for rendering said device opaque to disturbing currents small in comparison with currents of normal signal amplitude, a resistance in said input circuit, means for rectifying a portion of current from said output circuit and transmitting it through said resistance to produce a potential to oppose said other source of potential rendering said device readily capable of amplifying substantially without distortion currents of normal signal amplitude.

6. The combination in a transmission system of a line for the transmission of signals and means for the suppression of disturbing currents therein comprising a space discharge amplifier device therein for amplifying substantially without distortion waves of normal signal amplitude impressed on said device from said line, said device having an input and an output circuit, said input circuit comprising a control electrode, means comprising a rectifier connected to said output circuit for impressing a static potential upon said control element for controlling the transmission of current through said device, said static potential being dependent upon the current transmitted through said device, said potential being varied in such a manner that the gain of the device as a distortionless amplifier increases from a small value for crosstalk currents to a large value for signal currents within a very small range between crosstalk and signal voltages.

7. The combination with a transmission system of a line for the transmission of signal voltages and means for the suppression of low level disturbing waves therein comprising a space discharge translating device having an input and an output circuit, means in said input circuit for causing the translation device to discriminate between currents of different amplitudes, said means comprising a resistance, a rectifying means for supplying a potential drop across said resistance determined by the current in said transmission line and a resistance in the input circuit of said rectifier means for causing the current supplied to said first mentioned resistance to increase rapidly around the voltage region of maximum permissible disturbance but to remain practically constant for voltages above and below said voltage region.

In witness whereof, I hereunto subscribe my name this first day of December, 1928.

CLYDE R. KEITH.