

July 4, 1933.

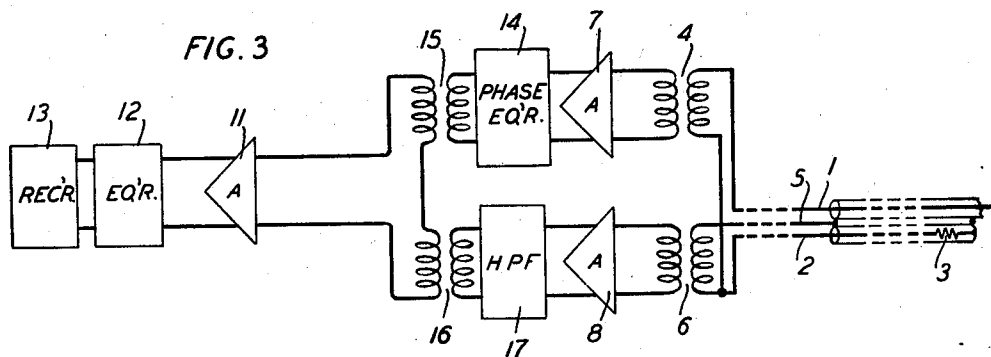
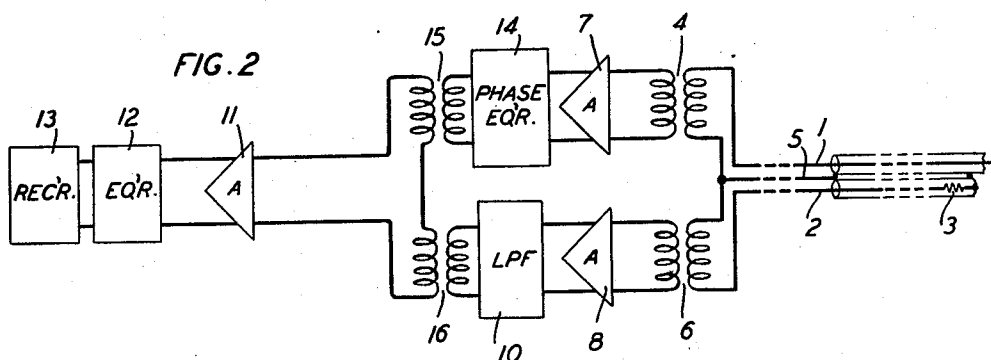
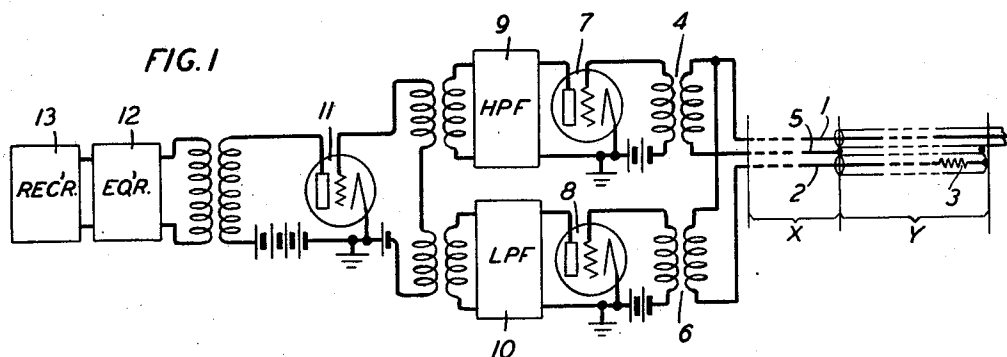
O. B. JACOBS

1,917,035

CIRCUIT FOR REDUCING INTERFERENCE

Filed Feb. 25, 1932

2 Sheets-Sheet 1



INVENTOR

O. B. JACOBS

BY

H. A. Burgess
ATTORNEY

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O. B. JACOBS

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CIRCUIT FOR REDUCING INTERFERENCE

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2 Sheets-Sheet 2

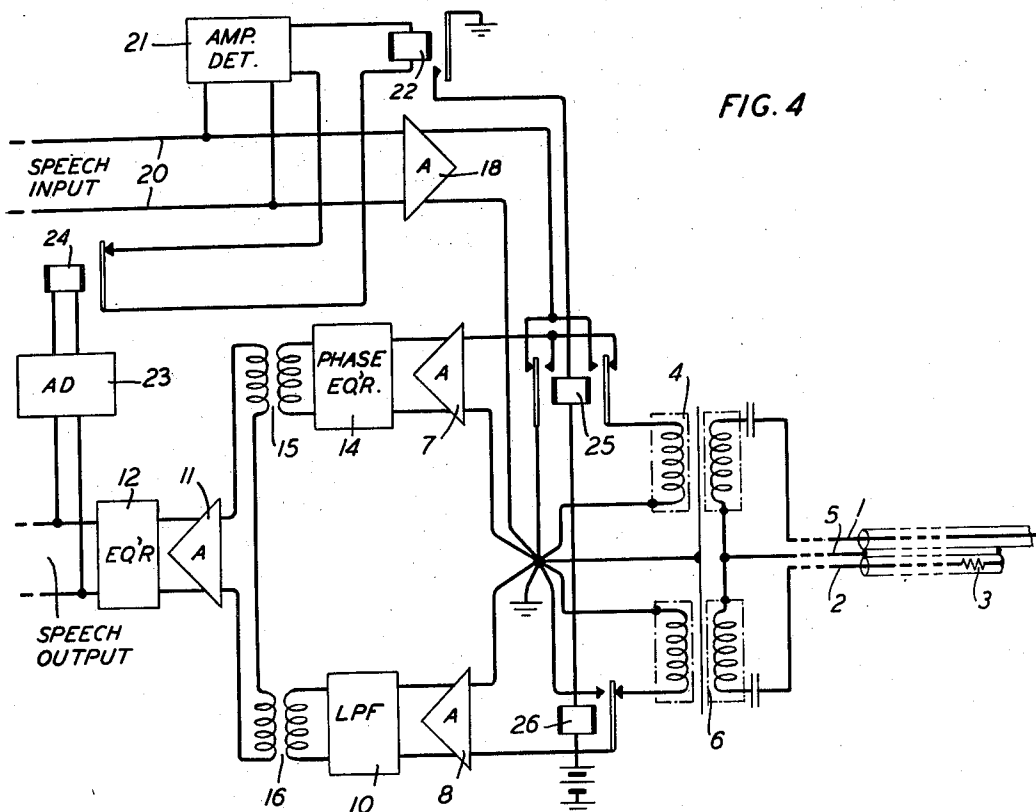


FIG. 4

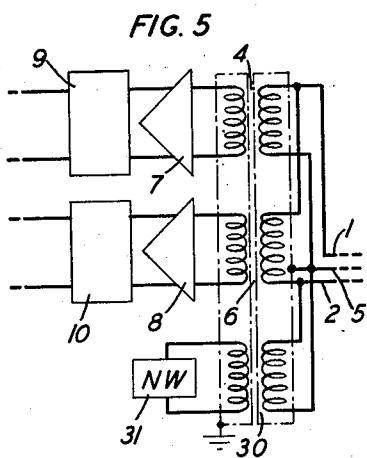


FIG. 5

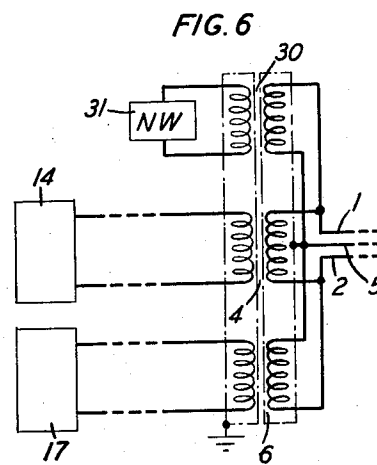


FIG. 6

INVENTOR

O.B. JACOBS

BY *H.A. Burgess*
ATTORNEY

ATTORNEY

UNITED STATES PATENT OFFICE

OLIVER B. JACOBS, OF MORRISTOWN, NEW JERSEY, ASSIGNOR TO BELL TELEPHONE LABORATORIES, INCORPORATED, OF NEW YORK, N. Y., A CORPORATION OF NEW YORK

CIRCUIT FOR REDUCING INTERFERENCE

Application filed February 25, 1932. Serial No. 595,050.

The present invention relates to the reduction of noise energy in an electrical transmission system such as a submarine cable system.

5 The present invention is concerned principally with two kinds of noise: interference and resistance noise. Interference is used in this specification to include static and noise of any other character that is picked up by
10 the system from extraneous sources. Resistance noise has its origin within the system and is due to the thermal agitation in the conductors, particularly the cable core and the balancing or neutralizing conductor.
15 Resistance noise consists of random components of about equal intensity at all frequencies at the points of origin, but on account of the higher amplification that is used in the receiving amplifier of a submarine cable system for the higher frequencies in the
20 signal range, the resistance noise in the receiver output is most pronounced in the upper portion of the signal frequency range.

Interference picked up by the cable becomes stronger towards the lower end of the signal frequency range as is explained in J. J. Gilbert Patent No. 1,678,184, patented July 24, 1928 and in the article by Gilbert "Extraneous Interference on Submarine Telegraph Cables" published in the Bell System
30 Technical Journal for July, 1926, pages 404-417.

The Gilbert patent and article referred to disclose the use of a long-loaded sea-earth
35 conductor for reducing or balancing out, to a large extent, the interference currents in the receiver. The use of a sea-earth conductor in this manner substantially doubles the internal impedance of the cable system
40 for received signals and therefore practically doubles the resistance noise. This increase in resistance noise may be of small consequence in systems employing only relatively low frequencies. At these low frequencies the disturbing effects of the interference are much
45 greater.

In a system employing a broad band of frequencies, however, as in the case of a telephone system, the effect of the interference
50 currents at the high end of the frequency

range may be negligible, but the use of a sea-earth conductor to reduce the interference effects at the low frequency end of the range will substantially double the resistance noise effects at the upper frequencies in the band. If this increase results in a material increase in the total noise on the circuit, it then constitutes a limiting factor in the operation of the system.

An object of the present invention is to permit the interference to be reduced in the low frequency range where it is most troublesome without at the same time increasing the resistance noise effects at the high frequencies due to the use of the long sea-earth connection.

The invention is applicable where the interference is weaker than the resistance noise in the part of the frequency range where the greatest amplification is used.

In carrying out this object, applicant divides the total frequency range by one or more selective circuits into different portions and applies a different type of terminal connection for the circuit transmitting the
75 respective portions of the frequency range, such as to reduce the noise of one kind or another in the frequency ranges in which it is most pronounced.

A better understanding of the invention will be had from the following detailed description taken in connection with the accompanying drawings in which:

Fig. 1 illustrates diagrammatically a submarine cable system in which the interference is balanced out in the low frequency range without materially increasing the resistance noise in the higher frequency range;

Figs. 2 and 3 show other circuits for accomplishing a similar object;

Fig. 4 discloses a two-way terminal using voice-operated switching circuits for controlling the transmitting and receiving apparatus when the receiving circuit is in accordance with Fig. 2; and

Figs. 5 and 6 show modified forms of the circuits of Figs. 1 and 3, respectively.

The main cable 1 as shown is provided with a core and a concentric return conductor. Sea-earth conductor 2 has the same construction

tion as the main cable, including a similar concentric sheath.

Signals received over the main cable pass from the core of the cable through two parallel paths. One path extends through the primary winding of transformer 4 and back through conductor 5 to the concentric return conductor of the main cable. The other path extends through the primary winding of transformer 6, sea-earth conductor 2 and balancing resistance 3 to the concentric return of the cable or cable sheath. Since the sea-earth conductor 2 terminated by resistance 3 is designed to have the same impedance as the main cable, the total impedance offered to received signals in the path comprising transformer 6 is about twice as great as that in the path comprising the primary of transformer 4 and connection 5 to the concentric return conductor. The resistance noise impressed on the receiver through the input transformer 4 is therefore only about one-half that impressed through the transformer 6. The purpose of using the sea-earth conductor 2 is, as stated, to neutralize a large part of the static interference that is picked-up by the main cable. The conductor 2 is laid adjacent the main cable so that both conductors are subject to the same interference.

The receiving conditions in the system as has been described are briefly as follows. Signals and interference from the main cable are received by the primary of transformer 4. Signals accompanied by interference from the main cable and interference of the same character but without signals from the conductor 2 are impressed upon the primary of transformer 6, with the result that the interference is reduced and substantially eliminated while the signals are not materially reduced. The resistance noise received by transformer 4 is about half of the resistance noise received by transformer 6 because of the similar reduction in the magnitude of the resistance component of the internal impedance of the cable circuit connected to the primary of transformer 4.

Currents from the respective transformers 4 and 6 are transmitted through the individual amplifiers 7 and 8. The high-pass filter 9 confines the current in the output of amplifier 7 to the higher speech frequencies, comprising for example a range a few hundred cycles wide. Low-pass filter 10 confines the current in the output of amplifier 8 to a frequency range from the lower edge of the essential speech band, up to the cut-off value of the filter 9. The outputs from the amplifiers 7 and 8, as limited in frequency by the filters 9 and 10, are impressed in common on the input circuit of amplifier 11 where they are furthered amplified and transmitted through the equalizer 12 to the receiving circuit 13 which may be of any suitable type such as a local receiver or a connection to a tele-

phone exchange for repeating the received telephone currents over other toll circuits or an ordinary subscriber's line.

The equalizer 12 corrects at least partially for the unequal attenuation of the cable for the different speech frequencies and for this reason it introduces greater attenuation to the low frequencies in the speech range than to the high frequencies. The over-all gain of the receiving circuit is thus higher for the high speech frequencies than for the low. The use of the neutralizing sea-earth conductor 2, transformer 6 and transmission path 8, 10, results in the suppression of interference throughout the low frequency range where it is most troublesome. The use of the low internal resistance connection comprising conductor 1, transformer 4 and conductor 5 in connection with the transmission path 7-9, enables the higher frequency portions of the speech waves to be received with only about half as much resistance noise as would be included if these high frequency components were received through transformer 6, that is, through the circuit comprising the sea-earth conductor 2 as a return.

Amplifiers 7 and 8 may be omitted in this and subsequent figures. If they are used, they should have high impedance input circuits. If they are omitted, the filters 9 and 10 should have high input impedance outside their transmission frequency ranges and should not materially reduce the input impedance of amplifier 11 which should be kept high in case amplifiers 7 and 8 are not used.

The concentric return shown in this and subsequent figures is not essential and may be omitted. That is, the distance represented by Y in Fig. 1 may be zero and conductor 5 may extend to the junction point of resistance 3 with the cable sheath. Conversely, the two concentric shells around conductors 1 and 2 may be used and may extend all the way to the receiving set, in which case the distance X in Fig. 1 is zero. Where the conducting sheaths around conductors 1 and 2 are used they are substantially in contact with each other.

In the circuit of Fig. 2 the low frequency interference currents are not balanced out in the transformer 6 as in the case of Fig. 1, but are balanced out in the input circuit to amplifier 11. In this case the entire speech band is transmitted through the path comprising transformer 4, amplifier 7, phase equalizer 14 and transformer 15 to the input of amplifier 11. The other path includes low-pass filter 10 which confines transmission through this path to the lower frequencies of the speech range, in which the interference currents are more troublesome than resistance noise. Transformers 15 and 16 are connected in opposed relation to the input of amplifier 11 so that the interference currents within the ring transmitted through low-

pass filter 10 are balanced out in the input circuit of this amplifier. Network 14 aids in obtaining this neutralizing action by making whatever phase change may be necessary in the currents transmitted through the amplifier 7 and transformer 15. It will be understood that the signals are not similarly balanced out since substantially no signaling energy is present in the path included between transformers 6 and 16. This is for the reason that transformer 6 is not connected to the cable core, but is connected only between the neutralizing conductor 2 and earth or the concentric return of the main cable. The resistance noise is kept low by use of the low resistance connection 1-5 as explained in the case of Fig. 1 and by the use of low-pass filter 10.

In the circuit of Fig. 3 the speech band as a whole is transmitted in the path 4-15 with suitable amplification by amplifier 7 and phase adjustment at 14 to be referred to later. The primary of transformer 4 is connected between the main cable core and the sea-earth conductor 2 in this case so that the interference is reduced or eliminated in the path 4-15. The resistance of the incoming circuit including the cable core, transformer 4 and neutralizing conductor 2 is high and for reasons already explained, the resistance noise is correspondingly high so that it might be disturbing in the final receiver 13 following the equalizer 12 which tends to emphasize the high frequency. This high frequency noise may be reduced by the circuit path 6-16. Transformer 6 is connected between the return conductor and the neutralizing conductor 2. It therefore has impressed upon it both interference and resistance noise, the former predominating in the lower frequency range and the latter in the upper frequency range. Transformer 6 receives substantially none of the signals, but the resistance noise received is the same as half of the resistance noise transmitted through transformer 4. The unbalanced interference being greatest at the low frequencies is largely eliminated by high-pass filter 17 which transmits only the range a few hundred cycles wide comprising the uppermost frequencies of the utilized speech bands. The resistance noise transmitted through this high-pass filter and confined to this relatively high frequency range is impressed on the input to amplifier 11. If an amplifier is used at 7, one must be used at 8 and must have exactly the same gain vs. frequency and phase characteristics. Thus, the high frequency resistance noise transmitted through the path 6-16 is caused to balance out, in the amplifier 11, half of the resistance noise within this same frequency range transmitted through the path 4-15. As in the circuits of the previous figures, therefore, the signaling current as finally received at

13 are accompanied by a minimum amount of both interference and resistance noise.

The circuits of Figs. 1, 2 and 3 show only arrangements for receiving signals from the cable. Ordinarily the cable would be used for two-way transmission so that provision would be made for transmitting signals into the cable as well as receiving from the cable.

Fig. 4 shows in diagrammatic form a two-way terminal circuit for a cable embodying in the receiving side the same type of noise and interference reducing arrangement that is disclosed in Fig. 2. Voice-operated switching circuits are also shown for converting the circuit from the transmitting to the receiving condition and vice versa under the control of speech.

Similarity of reference numerals will enable identification in Fig. 4 of the parts corresponding to those of Fig. 2. In this case the windings of transformers 4 and 6 which are connected to the apparatus are shown as provided with shields connected to the common ground point, while the other windings are provided with shields connected to conductor 5. The circuit is shown in its normal or receiving condition, the connections between transformers 4 and 6 and their respective amplifiers 7 and 8 being closed respectively through back contacts of relays 25 and 26 which are normally deenergized. The circuits operate in the same manner as was described in connection with Fig. 2 to receive signals from the cable and to balance the interference and reduce the resistance noise in the frequency ranges in which these are most troublesome.

Attached to the speech output circuit is an amplifier-detector 23 which causes operation of relay 24 in response to received speech. Relay 24 by its operation opens the energizing circuit of transmitting master relay 22 which insures that relays 25 and 26 remain in their normal unoperated condition during the time that speech is being received. At the cessation of the received speech relay 24 releases its armature, placing transmitting master relay 22 under the control of the amplifier-detector 21.

When speech is to be transmitted into the cable, a portion of the incoming speech in the circuit 20 is diverted into the amplifier-detector 21 and causes operation of relay 22. This relay, upon operating, causes operation of switching relays 25 and 26 which perform the following switching operations: Relay 26 upon initial movement of its armature opens the connection between transformer 6 and amplifier 8 and after completion of its armature stroke places a short circuit across the input of amplifier 8, thus effectively disabling the receiving branch including amplifier 8; relay 25 at its right-hand armature first opens the circuit between transformer 4 and amplifier 7 and at the front contact of

this armature extends the output circuit of power amplifier 18 through to the transformer 4 for transmitting into the cable; relay 25 at its left-hand armature first opens the normal short circuit existing across the output of power amplifier 18 and upon the completion of the armature stroke places a short circuit across the input of amplifier 7. The operation of relays 25 and 26 thus insures that both of the receiving paths including amplifiers 7 and 8 are disabled and that the power amplifier 18 is connected to the transformer 4 so that the amplified speech currents may be transmitted into the cable. These outgoing speech currents are applied between the cable core and the return conductor of the cable, or transmitting sea-earth. It is to be understood that the relay contacts may be arranged so that the short circuit on the transmitting path will not be released until the receiving paths are short-circuited and that these remain short-circuited until the transmitting path is again short-circuited.

For a more complete disclosure of a voice-operated switching system adapted for use in connection with the present invention, in a two-way system of the general type indicated in Fig. 4, reference may be had to United States Patent No. 1,856,654, issued May 3, 1932, to C. N. Nebel.

It will be understood that the noise compensating arrangements illustrated in Figs. 1 and 3 are adapted for use in a two-way system equally as well as the arrangement shown in Figs. 2 and 4.

An advantage of the balancing arrangements of Figs. 2 and 3 over that of Fig. 1 is that only one of the two receiving transformers need be connected to the cable core instead of both transformers as in Fig. 1.

An advantage of the arrangement shown in Fig. 1 is that the gains of amplifiers 7 and 8, if used, may vary from each other without affecting the degree to which the various types of noise are balanced out.

For simplicity of illustration, no shields have been shown for the transformers 4 and 6 of the first three figures but it will be understood that shielding is to be assumed and may be like that of Fig. 4.

Figs. 5 and 6 show how a more perfect balance can be obtained than in Figs. 1 and 3, by use of a symmetrical circuit including a third transformer 30 and network 31. In Fig. 5, network 31 simulates the impedance looking to the left from the secondary of transformer 4, so that conductors 1 and 2 are terminated symmetrically with respect to conductor 5. In Fig. 6 symmetry is obtained by making network 31 simulate the impedance into which transformer 6 works. These circuits permit a more complete neutralization of the interference currents.

Instead of effecting all of the attenuation equalization in network 12, the amplifiers 7

and 8 can be given transmission characteristics such as to result in greater amplification at higher frequencies and thus produce an equalizing effect. It is not essential that equalizer 12 be located at the point shown but it may be placed at any suitable point in the receiving circuit.

The invention is capable of various changes and modifications within the scope of the appended claims.

What is claimed is:

1. In a receiving system, a main signaling conductor exposed to interference, an auxiliary conductor exposed to similar interference, a receiver, separate receiver coupling circuits for said conductors, one including said main conductor and auxiliary conductor in series whereby the interference energy received from both conductors is balanced out in the receiver, and the other circuit of lower resistance noise, said receiver connected to both of said coupling circuits, and filter means for impressing only relatively high frequency currents from said circuit of lower resistance noise on said receiver whereby the resistance noise is kept low in the upper range of signal frequencies.

2. In a signal receiving system, a main signaling conductor exposed to interference, an auxiliary circuit having transmission properties similar to those of the main conductor and exposed to similar interference, a receiver, means for applying to said receiver interference energy from both conductors in opposed relation in the lower frequency portion of the signal range whereby the low frequency interference energy is balanced out but signals are received, and a circuit for impressing lower resistance noise and signal energy of higher frequency range from said main conductor on said receiver whereby the resistance noise is kept low in the region of high signal frequencies.

3. A circuit according to claim 2 in which phase adjusting means is included between said receiver and said main conductor for changing the phase of the currents of certain of said frequency ranges impressed on said receiver whereby the separately applied currents combine to reproduce the signal in said receiver.

4. In a signal receiving system, a main signaling conductor exposed to interference, an electrically similar auxiliary conductor similarly exposed to interference, a receiver connected to receive waves from said conductors over a plurality of paths, one such path comprising a circuit including said two conductors in series for balancing out the interference energy over only the low frequency portion of the total signal range, and another of said paths having a lower resistance noise level and comprising a connection to the signaling conductor for applying higher

frequency signal components to said receiver with a lesser amount of resistance noise than is present in the first path.

5. In a signal receiving system, a main signaling conductor exposed to interference, an electrically similar auxiliary conductor similarly exposed to interference, a signal receiver, a circuit connecting said receiver to both conductors in opposed sense whereby the interference is balanced out while the signals are retained, a connection of low resistance noise from said receiver to said auxiliary conductor comprising filter means for impressing resistance noise of high frequencies only on said receiver, and connections between said receiver and said connecting circuits whereby the resistance noise energy in said connecting circuits combine to produce a reduced resultant resistance noise in the receiver in the higher frequency portion of the signal frequency range.

6. A two-way signaling system comprising a main signaling conductor exposed to interference, an electrically similar auxiliary conductor similarly exposed to interference, a receiving system connected to receive waves from said conductors over a plurality of paths, one such path comprising a circuit including said two conductors in series for balancing out the interference energy over only the low frequency portion of the total signal range, another of said paths having a lower resistance noise level and comprising a con-

nection to the signaling conductor for applying higher frequency signal components to said receiver with a lesser amount of resistance noise than is present in the first path, a transmitting system associated with said receiving system and connected to said first mentioned path and voice operated switching means for disabling connections between said paths and said receiving system in response to speech current energy in said transmitting system.

7. A main signaling conductor exposed to interference, an auxiliary conductor exposed to practically identical interference, a local earth conductor, a receiver, a plurality of couplings between said receiver and said conductors, one coupling circuit containing a high frequency selective circuit, and supplying said receiver with a portion of the signal frequency range in which interference is weaker than the resistance noise, another of said couplings being from the main conductor and auxiliary conductor, and containing a low frequency selective circuit for supplying to said receiver a portion of the signal frequency range in which the interference currents are higher than the resistance noise, said latter coupling minimizing said interference by differential balance.

In witness whereof, I hereunto subscribe my name this 24th day of February, 1932.

OLIVER B. JACOBS.