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P. MERTZ

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COMMUNICATION SYSTEM

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FIG. 1

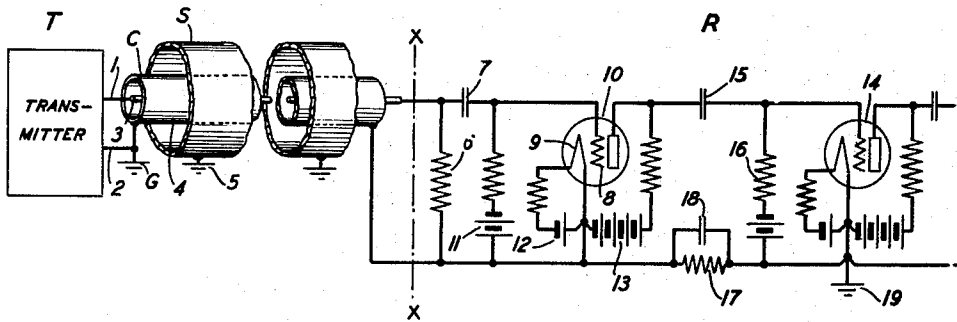


FIG. 2

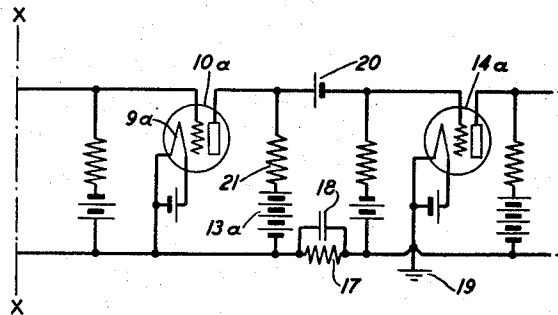
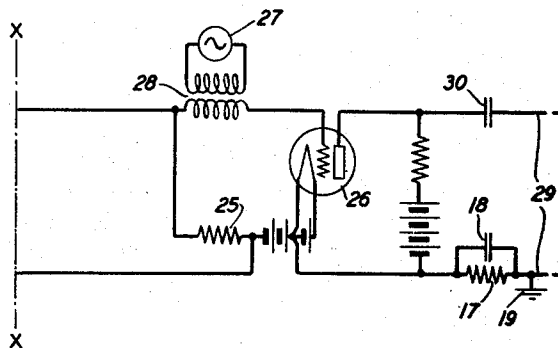


FIG. 3



INVENTOR
P. MERTZ
BY *J. H. Meville*
ATTORNEY

UNITED STATES PATENT OFFICE

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COMMUNICATION SYSTEM

Pierre Mertz, Bellerose, N. Y., assignor to Bell Telephone Laboratories, Incorporated, New York, N. Y., a corporation of New York

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2 Claims. (Cl. 178—69)

The present invention relates to communications systems and more particularly to methods of and means for reducing interference in signal transmission systems.

As disclosed in Hitchcock Patent 1,507,178, September 2, 1924, the effect of interfering energy, which may be introduced into a signal transmission circuit between stations by virtue of the association of a part of the path with an extraneous voltage source, is reduced by causing the signal waves to be amplified to a relatively high energy level before it is supplied to the section of the line which is contiguous to the extraneous source, for example, a power line which parallels a portion of the path.

U. S. Patent 1,931,829, October 24, 1933, to Poulsen et al. discloses an arrangement for effecting a similar result. In this case, the signal producer is coupled by a step-down transformer to a low impedance circuit which extends through the zone in which the interfering currents may be picked up and, at the other end of this zone, a step-up transformer is used to couple the low impedance circuit to a high impedance circuit.

According to the first system, the energy of the signal is boosted to such a high level, before entering the zone where interference may occur, that the intensity of the interfering currents picked up in this zone is insignificant compared with the signal intensity, while in the second system, the same result is effected by spanning the interference zone with a path which has an extremely low pick-up for interfering currents.

The present invention provides a third method of and means for effecting a similar result and in order to disclose its principles, the invention will be hereinafter described in detail, by way of example, as applied to the transmission of television image currents over a coaxial conductor system to which it especially applies, since, in these systems, the inner conductor is shielded against the introduction of energy supplied by extraneous sources by the outer conductor, whereas the latter is grounded and hence is connected in series with ground return, consequently sources included in the return path will cause interfering or noise current to flow through the outer conductor and to be introduced into the transmission path. However, this invention provides means which operates to discriminate against current flowing in the outer conductor without materially affecting the signals which are supplied to both conductors. This invention, therefore, serves to minimize the effect of the

extraneously supplied energy and hence to materially increase the ratio of signal-to-noise.

As is well known, a coaxial conductor system provides a transmission path over which energy comprising current variations extending over a wide frequency range, for example, from zero frequency to one or more million cycles per second, as is the case in present day television image currents, may be readily transmitted.

However, when signal currents having variations extending over the frequency range under consideration are transmitted over a coaxial conductive system, having the respective terminals of the outer conductor connected to ground, either by ground connections applied to its terminals or because its terminals are connected to grounded elements of the transmitting and receiving apparatus units included in the signal system, the low frequency portion of the signal range occupies an unfavorable position with respect to interfering or noise currents, i. e., currents caused by voltage sources external to the signal transmission path. By virtue of the ground connections, the outer conductor of the coaxial system is included in a series circuit comprising a ground return path, whereas the inner conductor is not so connected, consequently the conductor system is unbalanced with respect to ground, and external voltage sources, included in the return path, operate to cause currents of the frequencies of these sources to flow through the outer conductor.

At the high frequency end of the signal range, the outer conductor is an effective shield, and hence it operates to prevent the introduction of high frequency currents into the signal path. At the low frequency end of the range, however, the efficiency of the outer conductor as a shielding means is relatively low, and, as a result, low frequency currents circulating through the outer conductor will cause energy of this frequency to be introduced into the signal path.

Because of these conditions, the conductor system tends to readily pick up low frequency noise currents, and this pick-up is particularly marked when both ends of the outer conductor are grounded locally.

However, it is not always necessary to ground both ends of the coaxial conductor locally and, where it is possible to operate with ground at one end only, the ratio of signal-to-noise may be materially improved. At the receiver end of the signal system, grounding is most necessary in the power stages of the apparatus supplied with the incoming energy, i. e., where the intensity of the

signals is so great and the impedance of the circuit upon which the incoming energy is impressed is so high that the noise voltage introduced by the ground connection is not important.

In order to overcome the disadvantageous effect of the noise currents, it is proposed, as will hereinafter appear, to increase the impedance of the series circuit including the outer or coaxial conductor and the ground return for extraneously produced low frequency current variations. This is effected by connecting the output terminal of the outer conductor, i. e., the terminal connected to a receiving apparatus whether at a terminal or repeater station, to ground through an impedance which is high compared with the resistance of the series circuit, but is low compared with the impedance of the circuits to which this terminal of the coaxial system is connected. It is also proposed, at the receiving station, to supply the combined signal and interfering energy to a circuit which operates to differentiate in favor of the signal to the detriment of the currents caused by the interfering sources associated with the transmission path.

In other words, this invention contemplates the combined use of attenuation and the characteristics of the circuits supplied with the combined signal and interfering energy to discriminate in favor of the signal, whereby the ratio of signal-to-noise is materially increased.

An object of the invention is to minimize the effects of interfering energy, picked up by a path over which signals are transmitted, by increasing the impedance of the path for this energy without materially increasing the impedance of the path for the transmitted signals.

Another object is to minimize the effect of interfering energy picked up by a transmission path by supplying the combined signal and interfering energy to means which discriminates in favor of the signal energy.

A detail description of the invention follows and is illustrated in the attached drawing, in which:

Fig. 1 shows a diagrammatic circuit including the invention;

Fig. 2 illustrates a receiving apparatus which may replace that shown at the right of section line X—X in Fig. 1; and

Fig. 3 illustrates the application of the invention to a carrier system.

Referring now to Fig. 1, the station T is connected to a remote station R by means of a coaxial conductor system C enclosed in a grounded sheath S.

Station T may comprise a studio in which a television transmitter is used to scan a field of view or subject, that may be a motion picture film, to produce an image current, and station R may be a distributing point, whence the image current is supplied over a line in its normal frequency range, or as modulations of a carrier wave to be transmitted over a line or a radio link, to remote television subscribers' stations, either alone or in association with accompanying sound currents; or it may be any station at which the television image current is produced in its natural frequency range, for example, a broadcast receiving station, whence the image current is distributed to a series of subscribers.

As shown in Fig. 1, the station T may include an apparatus adapted to produce an image current, which extends continuously over a frequency range from a million or more cycles per second to a few cycles per second and to supply

this current to a coaxial conductor C enclosed in but insulated from a grounded sheath S.

The output circuit of the apparatus at station T is connected by lead 1 to the inner central conductor 3 and by a lead 2 to the outer tubular conductor 4, which may be connected to ground at G, and the sheath S is grounded at 5. The ground G may be directly connected to the conductor 4, or it may be applied to an element of the transmitting apparatus, for example, to the cathode of a vacuum tube power amplifier used to raise the image current to the desired energy level for transmission.

The remote terminal of the coaxial has its inner and outer conductors connected in the well-known manner, i. e., by a coupling resistance 6 and condenser 7 to the grid 8 and cathode 9, respectively, of the tube 10 included in the first stage of a plural stage amplifier, herein shown, by way of example, as comprising a series of cascade connected three-electrode thermionic tubes. Biasing potential is applied to the grid 3 by a source 11, its cathode is supplied with heating current from the source 12 and space current is supplied to the tube by source 13.

The output circuit of the first amplifier is connected to the input electrodes of a second amplifier 14 by a coupling comprising a series condenser 15 and a shunt resistance 16, and the cathode of the first tube is connected to that of the second tube over a path including a resistance 17, which may be shunted by condenser 18. The cathode of the second tube is connected directly to ground at 19.

It is assumed that the coaxial conductor system extends through a region in which voltage sources, external to the signal system and effective through the ground connections G and 19, cause currents to be set up in the series circuit comprising the outer conductor 4, ground connections G and 19 and ground return. As pointed out above, the outer conductor operates to effectively shield the signal path against high frequency currents flowing through the outer conductor, but for current in the low frequency portion of the spectrum, the efficiency of the latter conductor as a shielding means is relatively low, consequently low frequency currents circulating in this conductor will be introduced into the signal transmission path and seriously interfere with efficient transmission of signals.

The signal path is protected against the introduction of noise currents flowing through the sheath, because the latter is effective as a shielding means at the high frequency end of the range, and the insulation, between the sheath and the coaxial conductor, operates to isolate the latter at the low frequency end of the range.

The resistance 17 and shunting condenser 18 are included in the circuit comprising the outer conductor 4, ground 19, ground return and ground G. Resistance 17, therefore, constitutes an impedance in series with the external voltage sources and hence serves to attenuate these voltages and thereby reduce the amplitude of the interfering or noise currents flowing through the conductor 4. In order to effect the desired result, the value of resistance 17 should be large enough, compared with the resistance of the outer coaxial, to provide noise isolation, but its value, compared with the impedances of the tube circuits, should be such that it does not materially attenuate the signal voltages. It has been found that resistances of 100 ohms and 1000 ohms, respectively, when included as described

above in an amplifier circuit which had an impedance of the order of several thousand ohms and which was associated with a coaxial conductor system a few miles long, the characteristic impedance of which is of the order of 75 ohms, served to reduce the ultimate noise current, due to 60 cycle current induced in the coaxial system by extraneous sources, by approximately 37 and 58 decibels, respectively. The direct current resistance of the outer conductor of a coaxial system is only a few ohms.

The amplifier 10 and its power supply source may be insulated from ground, and condenser 18 may represent the capacity to ground of this amplifier and its power supply, or it may be a condenser which is introduced to dominate this capacity and thereby provide a fixed value of capacity in the ground connection for the first amplifying device.

The value of the capacity 18 should be so chosen that it has substantially no effect upon the operation of the circuit at low frequencies, for example, in the range of commercial voltages. Although the capacity will tend to annul the effect of the resistance 17 at the high frequency end of the signal range, the shielding effect of the outer conductor 4 will be sufficient in this range to prevent the introduction of noise currents into the signal path.

As an alternative the effect of low frequency noise currents may be minimized by omitting the resistance 17 and relying solely upon the condenser 18. In this case, the condenser 18 should be of such value that it presents the same impedance to the flow of the low frequency noise currents as the resistance 17. In other words, its capacity should be such that its impedance in the range of the noise voltages should be equal to that of resistance 17.

The arrangements described above apply to the case where the signal current to be transmitted does not include a direct current component. However, if the transmitting apparatus is of the type which supplies the coaxial conductor with a signal current having a direct current component, the receiving apparatus shown in Fig. 2 should be used in place of that shown in Fig. 1.

According to Fig. 2, the inner and outer conductors 3 and 4 of the coaxial system are respectively connected to the grid and cathode of a three-electrode direct current amplifier 10a having its anode or plate connected to the grid of a second amplifier 14a by a lead including a source of direct current potential 20, and its cathode connected to ground 19 by a lead including the resistance 17, which may or may not be shunted by a condenser 18.

Source 13a applies direct current operating potential to the plate of the tube included in amplifier 10a, and the source 20 applies a voltage corresponding to that developed across the coupling condenser 15 of Fig. 1. The positive terminal of source 20 is connected through the plate resistance 21 to the positive terminal of source 13a. The purpose and function of source 20 is similar to that of the blocking condenser in that it permits the amplified signal voltage to be impressed on the amplifier 14a, while preventing the positive potential supplied by source 13a from being impressed upon the grid of the tube included in amplifier 14a.

Aside from the fact that the apparatus of Fig. 2 serves to amplify a signal current including a direct current component this apparatus operates in the same manner as that shown in Fig. 1.

Fig. 3 illustrates a receiving station R which may be substituted for that shown to the right of section line X—X of Fig. 1.

As shown in Fig. 3, the coaxial conductor system is connected across a resistance 25 included in the cathode lead of a modulator 26, which is also supplied with carrier current from a carrier source 27, via the transformer 28. Resistance 25 being situated in the modulator circuit as shown, i. e., with one terminal connected to the cathode, is operated at approximately ground potential.

When signal currents are received, a signal potential is developed across the resistance 25 and is impressed upon the input electrodes along with the carrier current supplied by the source 27, and the impressed signal and carrier are combined in the modulator to produce a signal modulated carrier current, which is supplied to a transmission circuit 29. This circuit, which includes a blocking condenser 30, may be connected to a wire line or a radio transmitter.

The cathode of modulator 26 is connected to ground 19 by a lead including a resistance 17 shunted by a condenser 18, and this combination (17—18) operates, in the manner described in connection with Fig. 1, to minimize the effect of low frequency noise currents picked up by the coaxial system. The apparatus shown in Fig. 3 will operate to produce a modulated carrier wave having components corresponding to the variations of signal current, whether the signal current does or does not include a direct current component. In case no direct current component is present in the received signal current, the resistance 17 may be replaced by a condenser 18 of the proper value, as set forth in the description of Fig. 1.

From the preceding description, it will be apparent that the present invention is applicable to any system comprising stations connected by a transmission path over which signals or useful energy is transmitted, the transmission path having the terminals of one of its conductors included in a series circuit supplied with voltages from sources external to the system, which voltages cause interfering or noise currents to flow through the grounded conductor and thereby cause interfering energy to be introduced into the transmission path.

It will also be evident that the invention contemplates the use of an attenuator of such value that its impedance to the flow of the noise currents is high compared with the resistance of the conductor through which these currents circulate, but is low compared with the impedance of the circuits of the receiving apparatus to which the combined useful and interfering energy is supplied. As a result, the energy level of the noise currents and hence the corresponding noise voltages, applied to input circuits of the apparatus supplied with the incoming energy, is materially reduced. Consequently, the energy level of the noise currents produced in the output circuit of this apparatus is of small amplitude compared with that of the useful energy.

The noise suppression means, being included in the output circuit of the receiving apparatus, will serve to introduce noise voltage into this circuit that may be somewhat higher than that which would have been introduced into the input circuit of the receiving apparatus if the suppression means herein disclosed had not been used, but the voltage of the signal produced in the output circuit is increased by the energy amplification of the amplifier 10 or 10a, and also by the

impedance step-up due to the high impedance of the output or plate circuit of the amplifier with respect to the cable impedance, or by the frequency selective characteristics of modulator 26. The net result is, therefore, that the ratio of the signal-to-noise is materially increased.

While the invention has been herein described as applied to a system in which an image current of wide frequency range is transmitted over a coaxial conductor system and specific values for the attenuator and length of the conductor have been set forth, by way of example, in order to disclose its principles; it will be apparent that the invention provides means for minimizing the effect of currents, introduced into one conductor of a line, which may interfere with the efficient transmission of useful energy over the line. Consequently it may be applied to any system in which these undesired conditions are found to exist, whether the energy to be transmitted is representative of a single signal or a series of simultaneously transmitted signals respectively representing different messages, one or more of which may be subject to interference. The values of the attenuator and the length of the conductor herein given apply to a particular case. However, in the limiting case, the value of the former and the length of conductor with which it may be used, will depend upon the possibility of providing an attenuating element or network which is of high impedance compared with the outer conductor and of low impedance compared with the circuits of the receiving apparatus. Such being the case, the value of the resistance or condenser and the length of the conductor may be materially different from those given above.

In certain examples described above, the receiving apparatus has been described as comprising a multistage amplifier including three-electrode vacuum tubes with the suppression means connected between the first and second stages. However, any well-known type of distortionless amplifier may be used and in case vacuum tube amplifiers are used, the tubes may include more than three electrodes.

Instead of a resistance and/or condenser, the attenuating or suppressing means may comprise networks designed to effect the same result, and a noise suppressing means may be included in the circuits of two or more of the initial stages of an amplifier, whereby each of these stages may be caused to discriminate in favor of the signal.

Again, any other well-known type of modulating device may be substituted for the three-electrode vacuum tube device herein disclosed.

It is, of course, necessary that the substitute amplifiers and modulator be designed to operate successfully with a signal having current variations extending from a high frequency down to a frequency of the same order as the frequency of the interfering current, and, in certain cases, to zero frequency.

What is claimed is:

1. A transmission system comprising a line having a plurality of conductors over which useful energy is transmitted, means for supplying signals to said line, said line passing through a region in which interfering energy in the same frequency range as at least a part of the signal is introduced into said line via one of its conductors, a terminal apparatus supplied with combined signal and interfering energy received from said line, said terminal apparatus comprising a plurality of cascade-connected electron amplifiers, each amplifier including a vacuum tube enclosing a cathode, an anode and a grid, the line conductors being connected to the grid and cathode of one of said tubes, said conductor through which interfering energy is introduced into the line being connected to the cathode of said one tube, energizing sources for the respective electrodes of said one tube, each source having one terminal thereof directly connected to the cathode of said one tube, and means for minimizing the effect of said interfering energy, comprising attenuating means included in a lead connecting the cathode of said one tube, the associated terminals of said energizing sources and said one conductor to the ground connection for the cathode of the tube included in the succeeding amplifier.

2. A transmission system comprising a line having a plurality of conductors over which useful energy is transmitted, means for supplying signals to said line, said line passing through a region in which interfering energy in the same frequency range as at least a part of the signal is introduced into said line via one of its conductors, a terminal apparatus supplied with combined signal and interfering energy received from said line, said terminal apparatus comprising a plurality of cascade-connected electron amplifiers, each amplifier including a vacuum tube enclosing a cathode, an anode and a grid, the line conductors being connected to the grid and cathode of one of said tubes, said conductor through which interfering energy is introduced into the line being connected to the cathode of said one tube, energizing sources for the respective electrodes of said one tube, each source having one terminal thereof directly connected to the cathode of said one tube, and means for minimizing the effect of said interfering energy, comprising means which attenuates current components of low frequency, shunted by a by-pass means which is of high impedance for the current components to be attenuated but of low impedance for current components of high frequency, said attenuating and by-pass means being included in a lead connecting the cathode of said one tube, the associated terminals of said energizing sources and said one conductor to the ground connection for the cathode of the tube included in the succeeding amplifier whereby said one amplifier is caused to amplify the signal while the energy level of the interfering energy is reduced.

PIERRE MERTZ.