

April 3, 1934.

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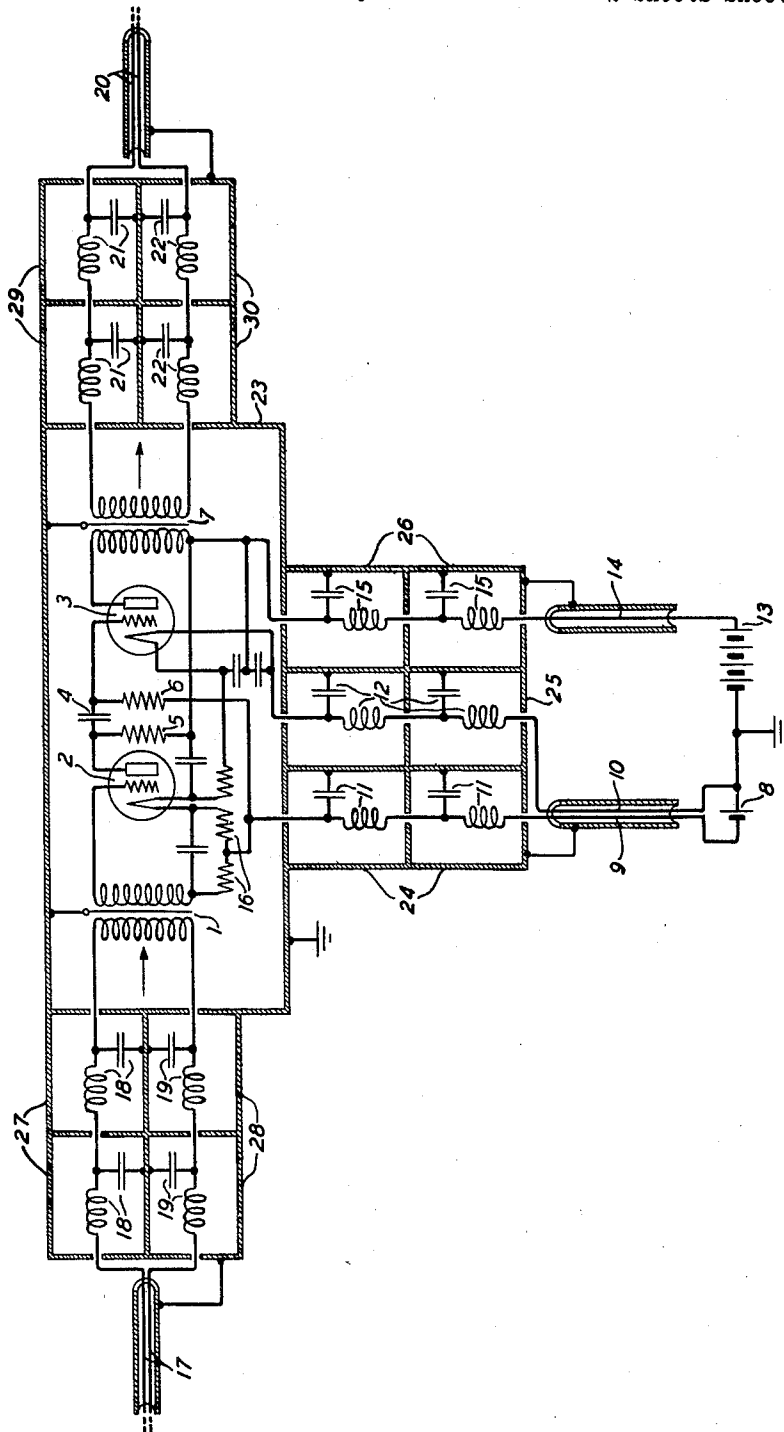
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DISTORTION REDUCTION IN SIGNALING SYSTEMS

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2 Sheets-Sheet 1

FIG. 1



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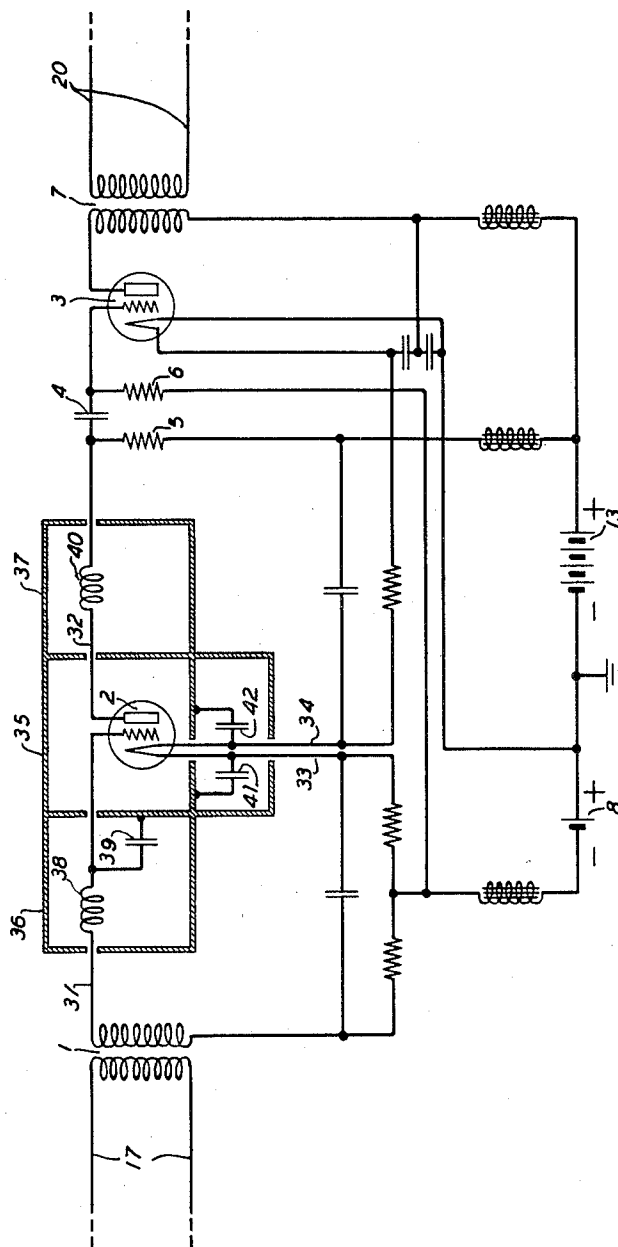
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FIG. 2



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DISTORTION REDUCTION IN SIGNALING SYSTEMS

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3 Claims. (Cl. 178—44)

The invention relates to signal transmission circuits employing as transmission elements therein electric space discharge devices, for example, electric space discharge amplifying devices, and particularly to means for reducing the effects of noise in said circuits.

An object of the invention is to improve the operation of a signal transmission circuit employing electric space discharge devices, and subject to interfering noise waves.

The invention is particularly directed to the suppression of so-called "click" disturbances in systems for electrically broadcasting speech and music programs over a transmission medium such as a telephone circuit. The term "click" refers to the interfering sound that is manifested in the output circuit of a telephone repeater when the current in a relay circuit which is in the vicinity of the repeater wiring is interrupted by a relay, switch or other means. It is the type of sound that is heard through a radio loud speaker when a light switch is turned off. "Click" disturbances are much more marked when the circuit in which the contacts of the relay or switch make or break includes inductance.

It has been found that "click" disturbances are due partly to direct audio frequencies from the disturbing source and partly to modulation in the vacuum tubes of the amplifier of a broad band of high frequencies which also originate in the source of the disturbance. Potentials which may be quite large are generated in the relay circuit for all frequencies. The coupling between the repeater circuit and the relay circuit permits these waves to be induced in the repeater circuit. The audio noises are probably transferred by magnetic as well as capacitive and common impedance couplings while the high frequencies are induced almost entirely through condenser action. Because the first stage vacuum tube commonly used in telephone repeaters is an efficient modulator of short wave frequencies, these higher frequencies combine therein to produce audio noise. This amplified noise is further amplified in the other stages of the repeater and is passed along with the wanted signals or program as noise within the band of frequencies being transmitted.

Noise interference tests, which have been carried out under the supervision of the applicant in connection with the voice frequency amplifiers used in high quality systems for broadcasting speech or music programs over telephone circuits, have shown that the radio waves of rather short wave length apparently cause noise

which is from 70 to 100 decibels louder than the noise due to direct audio frequency interference. The predominance of the noise at these extremely high frequencies is due to the fact that they are propagated with great facility along the cables and other materials, jumping from one part to the other through very small capacities which would ordinarily stop waves in the audio and even carrier frequency range.

Heretofore, low pass filters have been inserted in the battery supply leads to amplifiers, these filters being designed to pass direct current from the batteries to the electrodes of the amplifying tubes while attenuating the higher frequencies caused by battery fluctuations and the like. It has been found that these low pass filters as ordinarily designed are not effective to suppress a broad band of very high frequencies such as would be caused by relay operation as above pointed out.

In accordance with one embodiment of the present invention, disturbing noise produced in signal transmission systems in the above described manner, is substantially suppressed by inserting in each of the leads entering or leaving the amplifier and in each of the battery supply leads to the electrodes of the vacuum tubes therein, a filter designed to suppress a broad band of high frequencies. These filters, which are preferably electromagnetically shielded from other portions of the circuit to increase the protection against noise may comprise a series of filters connected in tandem and having graded cut-offs, each operating to suppress a different portion of the interfering waves.

In a modification of the invention, the suppression filters may be located in each of the four leads to the first stage of the amplifier only instead of in all the leads leading into and out of the amplifier; this modification while decreasing the protection against noise, somewhat, has advantages from the standpoint of economy of apparatus and space.

The invention will be better understood from the following detailed description thereof when read in connection with the accompanying drawings, Figs. 1 and 2 of which show diagrammatically different modifications of the invention applied to a multi-stage voice frequency vacuum tube amplifier such as is used in program broadcasting systems.

Fig. 1 shows the invention applied to a voice frequency amplifier such as has been used at a repeating point in a high quality cable system for broadcasting speech and music over long distances. As shown schematically, the amplifier

comprises an input transformer 1, two 3-electrode amplifying vacuum tubes 2 and 3 connected in tandem through a network comprising series condenser 4 and shunt resistances 5 and 6, and an output transformer 7.

Heating current is supplied to the filaments of tubes 2 and 3 in series from the grounded direct current battery 8 through the shielded supply leads 9 and 10, and the low pass filters 11 and 12. A common battery 13 supplies space currents for amplifying tubes 2 and 3, its negative terminal being connected to ground and its positive terminal being connected through shielded supply lead 14, low pass filter 15, and thence through coupling resistance 5 and the primary winding of the output transformer 7, respectively to the plates of the two tubes. Suitable negative potentials for the grids of tubes 2 and 3, respectively, are obtained by connecting these grids to suitable points on the resistances 16 in the filament heating circuit for the tubes.

The cable (not shown) carrying the incoming voice currents to be amplified, is connected to the input transformer 1 of the amplifier through the shielded input leads 17 and low pass filters 18 and 19. The output transformer 7 of the amplifier is connected to the outgoing section of cable through the shielded output leads 20 and the low pass filters 21 and 22.

The portion of the amplifier comprising input transformer 1, tubes 2 and 3 and output transformer 7 is completely enclosed in a box or case 23 of copper or other conductive material, which may or may not be connected to ground.

The band pass filters 11, 12, 15, 18, 19, 21 and 22 are shielded from each other and from other transmission apparatus in the amplifier circuit by enclosing boxes 24 to 30, respectively, of conductive material similar to that in the box 23. To obtain still further shielding, the various sections of the filters may be separated from each other by conductive partitions suitably attached to the boxes enclosing the filters, and containing apertures through which extend the wires joining the filter sections. The shields surrounding the battery supply leads 9, 10 and 14, and the shields surrounding the input and output leads 17 and 20, respectively, are conductively connected as indicated to the shields surrounding the adjacent filter sections.

The filters 11, 12, 15, 18, 19, 21 and 22 may be of as simple or as complex construction as is required to obtain the required suppression of a band of high frequencies such as would be produced by relay operation in the same or adjacent circuits. The fundamental purpose of these filters is to prevent the high frequencies, which as pure high frequencies can cause no trouble, from reaching the amplifying tubes 2 or 3 or other parts of the amplifier which can modulate them together to form interfering frequencies in the audible range.

As indicated in Fig. 1, each section of the band pass filters 11, 12 and 15 in the respective battery supply leads, may comprise an inductance element in series therewith and a shunt condenser having one terminal connected to a terminal of the inductance element and its other terminal connected to the enclosing shield. Similarly, each section of the filters 18 and 19 in each of the voice input leads 17 may comprise an inductance element in series therewith and a shunt condenser having one terminal connected to a terminal of the inductance element and its other terminal connected to the conductive shield enclos-

ing the filter section. Similarly, each section of the band pass filters 21 and 22 in each of the voice output leads 20 may comprise an inductance element connected in series therewith and a shunt condenser having one terminal connected to one terminal of the inductance element and its other terminal connected to the conductive shield enclosing the filter section.

The reactive elements in each filter section are given such values that the section greatly attenuates a portion of the interfering high frequency band impressed thereon while transmitting with little or no attenuation frequencies in the wanted signal band or the direct currents from the supply batteries. Each filter may contain any number of sections depending on the degree of suppression desired, but designed so that the filter as a whole reduces the amplitude level of all of the interfering high frequencies to such a value that they will not produce objectionable audio noise when modulated by the amplifier tubes or the other portions of the amplifier circuits.

The shielded filters in the circuits of Fig. 1 operate to suppress a wide band of interfering high frequencies in the following manner:

Any high frequency (short radio wave) has a tendency to flow along the external surface of a conductor and not in its center. A longitudinal radio wave which normally would travel along the battery leads, through the general mass of apparatus inside the amplifier, in an indiscriminate manner, and out along the input leads, for example, will be diverted from the battery wires and wire shield to the amplifier shield in place of going through the mass of apparatus inside the amplifier. The diverted currents will then flow over the surface of the amplifier shield, without entering inside where the tubes are located, and leave by way of the filters in the input leads to flow along the input wires and wire shields or by way of the output filters, wires and shields or by way of both. In a similar manner the high frequency interfering waves which are picked up by the output leads 20 will be diverted from these leads and their shields to the amplifier shield, flowing over the surface of this shield and leaving by way of the filters in the input leads or battery supply leads to flow along the input or battery supply wires and the wire shields therefor. Similarly, high frequency interfering energy flowing toward the amplifier by way of the input leads would be effectively excluded from the amplifier and tubes by means of the filters, the filter shields, the amplifier shields and the wire shields.

From the above explanation it is apparent that the input leads, the amplifier shields and the output leads of the amplifier, for example, might be made part of a radio antenna and yet no radio potential differences could be impressed upon any part of the tubes 2 and 3.

If the high frequency interfering waves were not longitudinal, like those received in a radio antenna, but are such as to flow down one wire and back on another as in a transmission line, these waves would also be suppressed by the filters and prevented from reaching the tubes of the amplifier in the manner which has been described.

Another way of looking at the operation of an amplifier, designed in accordance with the invention as shown in Fig. 1, is to regard the shield about the amplifier as isolating a volume of space within which no changes of potential can take place except by wires which enter. The filters inserted in these wires shunt all external poten-

tial variations (of high radio frequencies) to the amplifier shield so that no high frequency variations can enter along the wires.

It is apparent that the larger the number of sections used in the filters in the battery supply leads and the input and the output leads of the amplifier, the greater the noise suppression which may be obtained. However, experiments have indicated that the use of suitably designed two section filters and shields, such as shown in Fig. 1, in the various amplifier leads will ordinarily reduce the noise caused by relay operation to an unobjectionable amount. In the case of the particular amplifier and system with which the invention was tried out, sufficient protection was obtained by using in the first section in each filter a 0.1 millihenry inductance and a 0.01 microfarad capacity. The second filter section in the input and output leads was omitted while that in the plate battery lead 14 comprised an inductance of 3 henrys and a capacity of 20 microfarads. The filter in the ungrounded filament battery lead 9 comprised an inductance of 0.14 henrys and no condenser; while no second section was used in the grounded filament lead 10. Such a series of filter sections will suppress noise incoming over the battery leads both in the audio range and in the very high radio frequency range.

As the use of suppression filters in all of the leads entering a repeater shown in Fig. 1 may involve considerable expense and also rewiring if the repeater has already been installed, the arrangement of Fig. 2 was designed for use in systems in which the noise requirements are not as severe as in a system in which the scheme of Fig. 1 would be used.

Fig. 2 shows a two-stage resistance coupled voice frequency amplifier similar to that shown in the circuit of Fig. 1 but in which the suppression filters are inserted only in the four leads of one stage of the amplifier instead of in all the leads entering or leaving the amplifier. In this modification, the filter structure is not so complex and the shielding is not so thorough as in the case of the circuit of Fig. 1. The result is that less protection is obtained, but it will be sufficient for many systems.

Suppression filters are inserted in the four leads to the first stage tube 2 of the amplifier, namely, in the lead 31 connecting the grid of tube 2 to the secondary winding of the input transformer 1, in the lead 32 connecting the plate of tube 2 to the condenser 4 and resistance 5 in the interstage coupling network and in the two leads 33 and 34 connecting the filament of tube 2, respectively, to the positive and negative terminals of the filament heating battery. The amplifier tube 2 is shielded from the other portions of the circuit by the enclosing box 35 of copper or other conductive metal having apertures therein through which the grid, plate and filament leads extend. The suppression filters in the grid and plate leads, respectively, are shielded from each other and from the vacuum tube 2 by enclosing boxes 36 and 37 of copper or other conductive metal. The boxes 35, 36 and 37 preferably comprise a composite structure with partitions therein separating the various elements from each other as illustrated in Fig. 2.

In one of the simplest forms of the invention, the filter in the grid wire may comprise only one series inductance coil 38 and a shunt condenser having one terminal connected to the terminal of the inductance coil 38 nearest the grid of tube 2 and the other connected to the enclosing shield-

ing structure; the filter in the plate wire may comprise only one series inductance coil 40 and no condenser; and the filters in the two filament wires 33 and 34 may comprise only one shunt condenser 41, 42, per wire, connected between the filament wire and the shielding structure.

The completeness of shielding and filtering can be varied from that which will give maximum protection as illustrated in the circuit of Fig. 1 to that which will give protection which is sufficient for most practical cases as illustrated in Fig. 2, or to give even less protection where that would be sufficient, for example, by dispensing with one or more of the filters, filter elements or shielding boxes shown in Fig. 2.

In the circuit of Fig. 2 only the inductance coils and condensers 38 to 42 inclusive are utilized for obtaining high frequency protection. All the other inductance coils and condensers shown in the circuit of Fig. 2 are a part of the audio circuit of the amplifier and function at audio frequencies either to give the amplifier the proper transmission characteristics or to protect it from interfering electrical noises in the audio frequency range in well known manner. As indicated, the second vacuum tube stage 3 of the amplifier, the input transformer 1, the output transformer 7, the incoming voice leads 17, the outgoing voice leads 20, and the supply leads to the batteries 8 and 13 need not be shielded in the modification of the invention shown in Fig. 2, although the shielding of one or more of them in the manner illustrated in Fig. 1 might be desirable in some cases. It is to be understood that the invention is not limited to the particular structures of the suppression filters and the particular values specified for them, or to the particular kind of shielding illustrated and described, which were given by way of an example only as applicable to a particular type of amplifier circuit and system, but that any other types of shields and filters, and other values of the elements thereof which will give the desired suppression of the high frequency interference may be used depending on the degree of protection desired and the characteristics of the circuits to which the invention is applied.

Other modifications which may be made in the circuits illustrated and described which are within the scope and spirit of the invention as defined in the appended claims will occur to persons skilled in the art.

What is claimed is:

1. In an electrical system for transmission of signal waves representing speech and music over a signal transmission line including means for amplifying said signal waves comprising one or more space discharge devices having input and output electrodes and sources of energizing potential connected to said electrodes, means for eliminating substantially distortion in said system due to interfering waves of a wide band of frequencies including frequencies high in comparison with those of said signal waves, comprising a filter network in each of the circuits connecting said amplifying means to said line, and said electrodes to said sources, each designed to suppress a wide band of high frequencies including the higher frequencies of said interfering waves, and means for electromagnetically shielding said filters from each other and said space discharge devices, and said filters and space discharge devices from other portions of the system.

2. In an electrical speech and music transmission system subject to interfering waves of a wide range of frequencies including radio frequencies,

- and including a repeater comprising two or more tandem connected vacuum tube amplifying devices having input and output circuits, input and output electrodes and sources of energizing potential connected to each of said electrodes, means for reducing distortion in said system due to said interfering waves, comprising one or more filters in both the input and output circuits of the first vacuum tube stage of said repeater and between each electrode in said first vacuum tube stage and its source of energizing potential, said filters being designed to offer high attenuation to a wide band of radio frequencies, and means for electromagnetically shielding said filters from each other and said first vacuum tube stage, and said filters and said first vacuum tube stage from other portions of the system.
3. In a signal transmission system subject to interfering waves of high frequencies including radio frequencies and comprising an amplifier consisting of one or more electric discharge devices for repeating voice frequency signals between an incoming and an outgoing circuit, said devices having input and output electrodes and power sources for energizing said electrodes, means for eliminating substantially the production of audio noise in said system by modulation of the interfering waves of said high frequencies in said amplifier, said means comprising a filter network connected between said incoming circuit and said amplifier, a second filter network connected between said outgoing circuit and said amplifier, other filter networks connected respectively between each electrode of said devices and its energizing source, each of said filter networks being designed to suppress a broad band of high frequencies including said radio frequencies, and means for electromagnetically shielding said filter networks and said devices from each other and other portions of said system.
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