SIGNALING SYSTEM ADAPTED FOR DEEP SEA TELEPHONE CABLES

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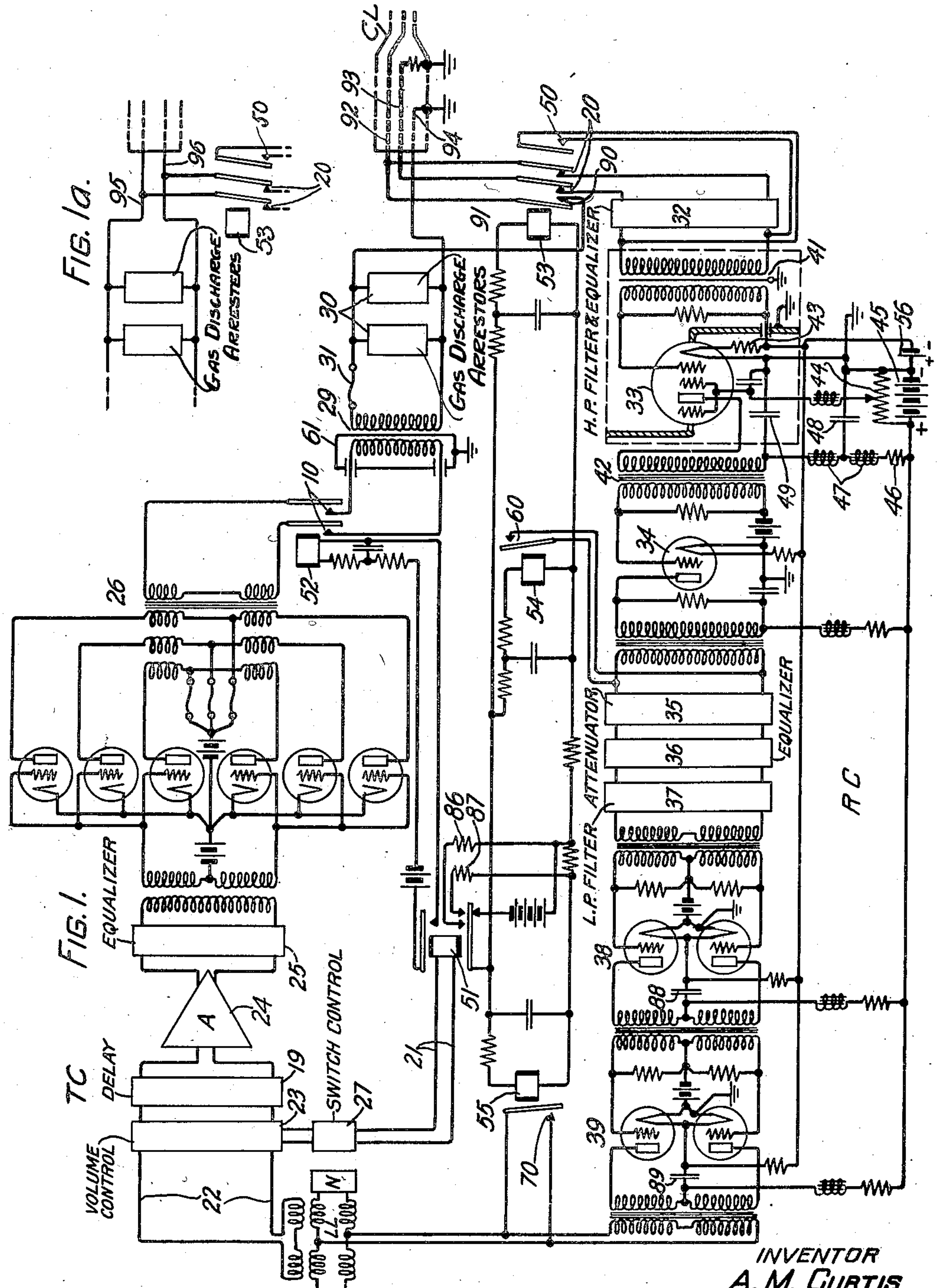

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Dec. 11, 1934. A. M. CURTIS 1,984,058

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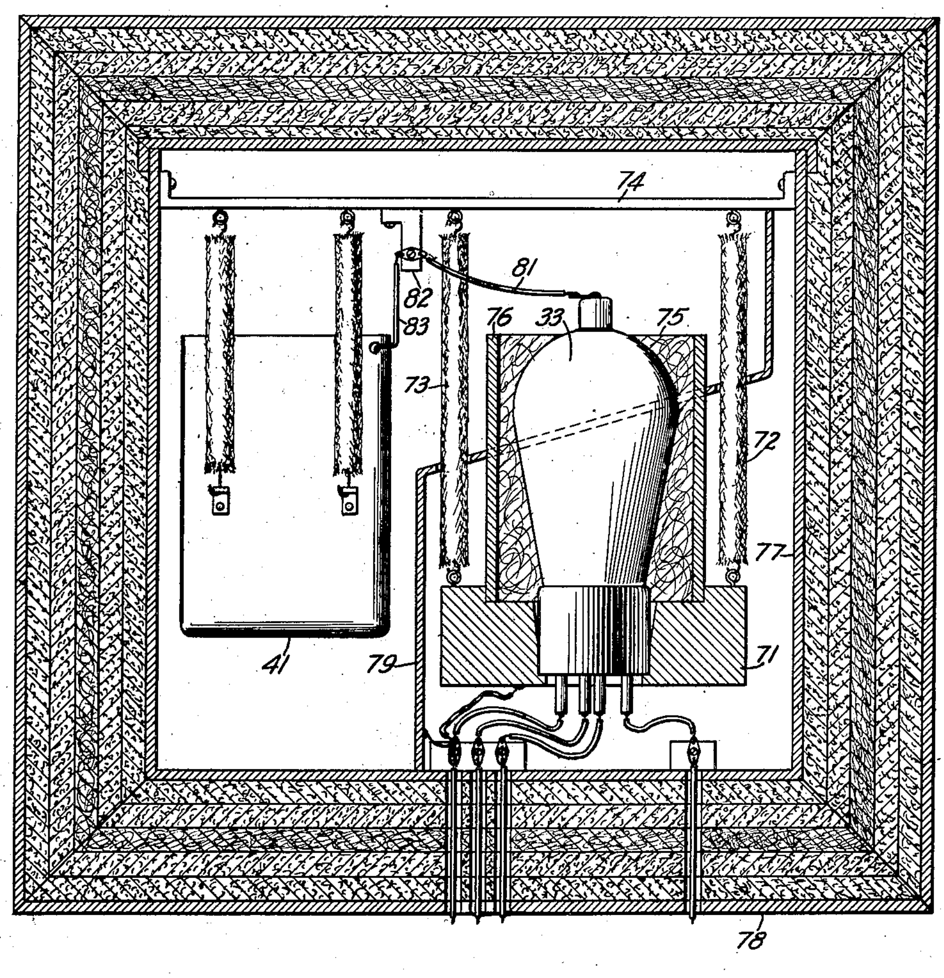
FIG. 2



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SIGNALING SYSTEM ADOPTED FOR DEEP SEA TELEPHONE CABLES

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The present invention relates to electrical wave transmission and particularly to long distance transmission requiring amplification, although in certain aspects the invention relates to wave amplification for any purpose.

An object of the invention is to effect high gain in an amplifier while keeping the tube noise and other disturbances at a negligibly low level.

A related object is to provide an improved terminal circuit for a wave transmission system of high attenuation and large distortion such as a deep sea telephone cable.

One feature of the invention comprises a transmitting circuit for supplying to the cable or other transmission line speech or signal energy at the requisite power level with minimum danger of excessive voltages on the cable due to any abnormal condition in the circuit.

Another feature comprises a receiving circuit capable of furnishing the requisite high gain and a large signal-to-noise ratio. The receiving circuit of the invention also compensates wholly or in part for the distortion produced in the cable or other transmission line.

To aid in reducing disturbances in the highly amplified received waves the invention includes as one feature a tube and transformer mounting especially constructed to protect the most sensitive portions of the amplifier from mechanical or acoustic vibrations and from electrostatic and electromagnetic fields.

The invention will be described as applied to a deep sea telephone cable which may consist, for example, of a single span continuously loaded preferably with a nickel iron alloy of special composition, heat treatment and manner of application as described, for example, in U. S. patents to G. W. Elmen 1,715,541, of June 4, 1929 and O. E. Buckley 1,586,874 of June 1, 1926. Such a cable may be assumed for purposes of illustration to have a maximum attenuation of the order of 140 db. or more and a total variation in attenuation with frequency between limits of the essential speech frequency range of the order of 80 db.

Reference will now be made to the attached drawings for a more complete understanding of the various features and objects of the invention.

In the drawings, Fig. 1 is a schematic diagram of a two-way terminal circuit for a single core deep sea telephone cable in accordance with the invention; Fig. 1*a* shows a manner of terminating a twin-core cable, and Fig. 2 shows a preferred construction for protecting the amplifier apparatus from mechanical, electrical and acoustical vibrations.

Referring first to Fig. 1 the transmitting circuit TC and receiving circuit RC are arranged for two-way transmission between the land line LL and the cable CL. Preferably only one of the circuits RC or TC is effectively connected to the cable at the same time. Any suitable switching apparatus for alternately connecting and disconnecting or disabling these circuits may be used. For the sake of illustration in the drawings it is assumed that the receiving circuit RC is normally connected to the cable and in condition to receive waves from the cable and transmit them into the land line and that the transmitting circuit TC is inoperative except when speech waves are impressed upon it from the land line. Switching or circuit disabling points are indicated at 10 for circuit TC and at 20, 50, 60 and 70 for the circuit RC. In brief, it may be considered that speech waves present in the circuit TC operate through the control means 27 to establish the circuit connections at the points 10, and 90 and to close contacts 50, 60 and 70 in sequence, and to open contacts 20, as will be more fully described hereinafter. A further example of a control system is disclosed in the application of R. C. Mathes and A. W. Horton, Jr., Serial No. 412,612, filed December 9, 1929 now Patent No. 1,844,422, patented February 9, 1933 to which reference may be made for a type of switch control that may be utilized.

Speech waves received over the land line LL pass into the circuit TC through the line 22, through volume control 23, delay device 19, amplifier 24, equalizer 25, power amplifier 26, and into the cable CL for transmission thereover. A portion of the energy of these waves acts through the switching control 27, 21 to close the contacts 10, and 90 and to open contacts 20 and close contacts 50, 60 and 70 thereby disabling the receiving circuit RC and connecting the amplifier 26 to the cable CL. The circuit remains in the transmitting condition as long as speech waves continue to be received from the land line, causing the transmitter circuit TC to be operated and the receiving circuit RC to be inoperative.

The volume control 23 equalizes for weak and strong inputs resulting either from different talkers, different lengths of land line or other causes and insures that the volume impressed on the amplifier 24 remains substantially at the same level under different service conditions. This volume control may be of any suitable type such, for example, as a vacuum tube circuit in which the operating point on the tube characteristic is varied in accordance with the level of the incoming waves so as to vary the degree of amplification in the tube in such a way to maintain the output level substantially constant.

The switch control 27 includes an amplifier-rectifier circuit for deriving from the speech energy a current for operating relay 51, to effect the circuit changes which have been indicated above.

The delay device 19 may be electrical, mechanical or acoustical and of any type capable of delaying speech until the switching relays are fully operated.

The amplifier 24 may be of any suitable type giving the requisite gain.

The equalizer 25 may be of the constant resistance network type as disclosed in the patent to Zobel 1,603,305 dated October 19, 1926 and more fully described in the article by Zobel published in the Bell System Technical Journal for July 1928 at pages 438 to 534 inclusive. Any other suitable type of equalizer may be used, the purpose being to discriminate against the low frequencies in the speech and in favor of the high frequencies so as to compensate for the unequal attenuation by the cable, to avoid overloading the transmitting amplifier by the transmission of an unnecessary amount of the lower speech frequencies and to avoid overloading the magnetic material of the cable.

The amplifier 26 comprises two banks of power tubes in push-pull relationship capable of raising the speech energy to a level of the order of 30 to 50 db. for transmission into the cable. An amplifier of this power capacity ordinarily employs a relatively large plate voltage, for example, of the order of 750 volts. Peak voltages of this order or greater might also be developed if the amplifier started to oscillate or if transients were otherwise developed in the system. In order to protect the cable from high voltages arising in the transmitting circuit TC special precautions are taken. These comprise the specially designed output transformer 29, the protective shunts 30, and the fuse 31.

The transformer 29 is provided with a grounded shield 61 between the primary and secondary windings, this shield being made of heavy gauge copper and capable of withstanding excessively high potentials without rupturing. The primary and secondary windings are suitably protected from possible conductive connection through the core or leads or in any other manner and the transformer is built to withstand excessively high voltages.

Assuming the safe voltage limit for the cable to be of the order of 100 volts, protective shunts 30 in the form of gas discharge arresters are provided to prevent the voltage applied to the cable from rising above this limit. Assuming for example, that the maximum signaling voltages applied to the cable are of the order of 75 volts, these protective shunts are arranged to break down at a voltage slightly in excess of 75 volts and below 100 volts. The fuse 31 is proportioned to carry the maximum signaling current but to break down on the discharge current of the shunts 30 so that in case of an excessive voltage causing the break down of the protectors the fuse 31 blows and the input circuit to the cable is effectively isolated from the transmitting circuit TC.

In Fig. 1 it is assumed that the cable CL has a single core 92 and that it is equipped with a relatively long, continuously loaded and properly terminated sea earth 93 for receiving and a short non-loaded sea earth 94 for transmitting. It is preferred not to use the long loaded sea earth for sending since the effective sending voltage would then be only half the available terminal voltage. A local ground could be used in sending except for liability of applying to the cable sizable voltages that might be set up in such a ground from interfering sources. A non-loaded sea earth of a few miles in length effectively avoids such difficulty.

Referring now to the receiving circuit RC, speech waves received from the cable terminal 92, 93 pass through the high pass filter and equalizer 32, through amplifier stages 33 and 34, attentuator 35, equalizer 36, low pass filter 37, amplifier stages 38 and 39 and thence into the land line LL.

The filter and equalizer 32 serve to prevent transmission to the amplifier of the relatively low frequency earth currents from the cable and the undesired low frequency components of speech and noise. The equalizer included with the filter at this point may also aid in correcting for the distortion of the speech waves in the system.

The amplifier stage 33 comprises a screen grid tube, the input of which is connected to the filter and equalizer 32 through a specially designed shielded input transformer 41.

The use of a screen grid tube at this point together with the specially constructed input transformer 41 and output transformer 42 and the shielding and protection against mechanical vibrations, as will now be described, constitute important features of the present invention.

The circuit RC is designed to provide a very high gain, for example, of the order of 150 db. Where such high gain has been attempted in the past with the use of three element vacuum tubes great difficulties have been encountered from the noise developed in the tubes and from tendency of the circuit to produce oscillations. It has been found in accordance with this invention that the requisite high gain can be obtained by a smaller number of amplifier stages with greatly reduced liability of oscillation and with very marked reduction in noise level when the initial stage comprises a screen grid tube as will be described. A screen grid tube of known type and practical design when compared with a typical three element or single grid tube possesses a markedly smaller input capacity, a much larger output impedance and a much larger amplification constant. Consequently with proper design of input and output circuits such a tube may be made to give the same gain as several stages in tandem utilizing typical three element tubes. At the same time the noise arising in the single screen grid stage of amplification is much smaller than would be obtained with several three element tubes connected in tandem to give the same gain. The high gain obtained is contributed to by the high voltage ratio obtainable in the input transformer 41 on account of the low input capacity. Applicant has obtained in practice a gain of the order of 70 db. in a single stage and a ratio of the signal out of the plate circuit of the screen grid tube to tube noise of the order of 5 to 30 times as large as would be obtained by the use of ordinary tubes and transformers. Moreover the use of a single stage of amplification where a plurality of stages have been necessary in the prior art makes the problem of shielding and protection from vibration very much less difficult since the amount of apparatus to be protected is considerably less. Provision is made for shielding and protecting stage 33 against mechanical vibrations. These provisions will be described more fully later on in connection with Fig. 2.

Transformer 41 preferably has a turns ratio of from 50 to 100 and the windings are so designed as to possess minimum capacity and permit a high voltage ratio while at the same time keeping the frequency at which the transformer and its associated apparatus resonates well above the desired transmission band of the amplifier. This transformer, preferably though not necessarily, possesses a core of nickel iron alloy of the type disclosed in Elmen Patent No. 1,620,878 dated March 15, 1927. A negative grid bias may be obtained from a C battery but as shown is obtained from filament drop through resistance 43. The screen grid is polarized from the potentiometer 44 in shunt of the plate battery 45. For this, a voltage of the order of 20 to 30 volts is suitable with the type of tube used by applicant. An inductance-capacity network is provided as shown in the circuit of the screen grid to prevent variable potentials present in the battery from being applied to the screen grid.

The output transformer 42 preferably possesses a core of nickel iron cobalt alloy such as disclosed in Elmen Patents 1,715,541, 1,715,646, and 1,715,647 all dated June 4, 1929. The core has an air gap to guard against accidental magnetization. The space current to the screen grid tube is supplied through the primary of transformer 42 through a network comprising resistance 46, inductance 47 and condensers 48 and 49. This network is suitably designed to protect the core from magnetization due to excessive currents through the primary winding. The primary to secondary turns ratio of transformer 42 may be unity. The distributed capacity and leakage reactance are kept as low as possible.

By effecting the large gain as described in the initial stage 33 of the circuit RC amplifier stages 38 and 39 of ordinary design are suitable for the later stages.

The output of amplifier 34 is connected to variable attenuator 35 and thence to equalizer 36 (which may be of the same general type as equalizer 25) which provides additional correction for the variable attenuation and phase as required by the characteristics of the transmitting amplifier, cable, receiving input equalizer, and receiving amplifier itself. Low pass filter 37 which may have a cut off frequency of the order of 3000 cycles per second prevents transmission through the later stages 38 and 39 of high frequency static, tube and resistance noise which may be present in the circuit. Thus elements 35, 36 and 37 prevent placing an unnecessary load on the amplifier stages 33 and 39. Battery 45 supplies plate voltage to all of the amplifier stages 33, 34, 38 and 39, and battery 56 supplies filament heating current to all of these stages.

High resistance shunts across the transformer windings are shown at various points in the amplifier stages 33, 34, 38 and 39. These resistances aid in reducing regeneration and resonance effects in the transformers but may be omitted where not necessary. Condensers 88 and 89 may be omitted where not necessary.

In addition to the equalization provided by networks 32 and 36 the coupling transformers throughout the receiver circuit RC are designed to discriminate against the lower speech frequencies and in favor of the higher speech frequencies and thus aid in compensating for the unequal attenuation elsewhere in the system. This may be done by designing these transformers to match their attached impedance at the higher portion only of the frequency range. This renders their transmission more efficient at the higher frequencies than at the lower frequencies.

Individual ground connections have been shown at various points of the receiving circuit RC. It is preferred in practice to employ a ground plate of good conducting material and to make all of the conductive connections to this plate.

Reference was made hereinbefore to the operation of the switching control means in sequence. It is necessary in a system such as the present one where high gain is developed in both sides of a two way circuit, to insure that the loop formed by the circuits TC and RC at the same station is not effectively closed. No balance is provided between these two branches where they connect to the cable and in any event it is difficult to maintain a sufficiently perfect balance either for a cable or for the land line LL to prevent singing around the loop circuit if balance alone were relied on.

The means for securing the proper protection against singing and also against the transmission to the talking parties of switching impulses or other disturbances will now be described. When no speech is being received from the land line relay 51 is deenergized. This relay at its upper armature opens the energizing circuit for relay 52, the armature contacts of which remain open and thus hold the circuit TC disconnected from the cable.

Relay 51 at its lower armature under these conditions closes energizing circuits for relays 53, 54 and 55. Relay 53 being thus energized, maintains the receiving input circuit from the cable closed at the two contacts 20, and maintains contacts 50 and 90 open. Relay 54 being thus energized maintains contact 60 open and relay 55 similarly maintains contact 70 open. The receiving circuit is thus in condition for receiving from the cable.

When speech is received from the land line LL, relay 51 energizes, closing its upper armature contact and opening its lower contact and at the same time closing the upper two contacts of its lower armature. The opening of the lower contact deenergizes relays 53, 54 and 55. The resistances and capacities illustrated in connection with the windings of these three relays are proportioned in a manner well known in the art to act in combination with the upper contacts on the lower armature of relay 51 to time the operation of the relays such that relay 55 releases first, relay 54 releases a brief interval thereafter and relay 53 releases at a still later time. For example the resistances and capacities permanently associated with the relays cause them to energize with a proper amount of delay while resistance 86 permits relay 55 to release quickly by rapid discharge of its condenser, and resistance 87 exerts control in similar manner over relays 53 and 54. Relay 55 in releasing closes a shunt across the output terminals of the circuit RC and protects the subscriber on the line LL from receiving a pulse of energy which might otherwise be transmitted when the circuit RC is disconnected from the cable. Relay 54 also establishes a shunt across the receiving path adjacent the attenuator 35 and affords further protection. Relay 53 in deenergizing closes contacts 50 and 90 and opens contacts 20. Contact 50 in closing establishes a shunt across the primary of the input transformer 41 and contacts 20 in opening disconnect the receiver input circuit from the cable. Earth currents, reflected energy, or other energy present in the cable circuit is thus prevented from sending down the receiver branch into the line LL a switching impulse. Contact 90 in closing connects cable conductor 92 to the transmitting circuit in series with contacts 10.

The closure of the upper contact of relay 51 energizes relay 52 closing contacts 10 and connecting power amplifier 26 to the cable. The resistances and condenser associated with the winding of relay 52 are adjusted so that relay 52 does not operate until slightly after the release of relay 53 so that circuits TC and RC are not both connected to the cable at any instant of time.

The time delay produced by the delay device 19 is sufficient to hold back the initial portion of the speech until the system is rendered in condition for transmitting.

When the speech on the land line LL ceases, relay 51 deenergizes and the timing of relay 52 is such that this relay releases before relays 53, 54 or 55 energize. Relay 52 in releasing disconnects the power amplifier 26 from the cable. Relay 53 energizes slightly before relay 54 and relay 54 energizes slightly before relay 55. Relay 53 in energizing first closes contacts 20 and at a slightly later instant opens contacts 50 and 90. This difference in time of actuation of the contacts may be effected by adjustment of the relay armatures and their retracting springs. There is thus a brief interval in which contacts 20, 50, 60 and 70 are closed. During this brief interval, reflection currents or other energy received from the cable are dissipated in the three shunts existing across the receiving circuit RC. After a brief interval, contact 50 opens, removing the shunt across the input of amplifier 33. Contacts 60 and 70 open in sequence shortly thereafter and protect the subscriber on the line LL from receiving discharge voltage or other energy from the cable since the receiving circuit RC is ineffective to transmit into the line LL until such energy has been largely dissipated.

For simplicity of disclosure, electromagnetic relays have been shown at 52, 53, 54 and 55. It is within the invention, however, to employ other circuit establishing and disabling means. For example, instead of severing the circuits at these different points, the vacuum tubes in the circuits TC and RC, or some of them, could have applied to them a large negative grid potential to block transmission through the circuits. One way of accomplishing this is disclosed for example, in an article by C. A. Beers and G. T. Evans, published in the Institute of Post Office Electrical Engineers (London), vol. 20, pages 65 to 72 inclusive, issued April 1927.

In Fig. 1*a* it is assumed that a twin core cable is used. The two conductors of the cable are shown at 95, 96. In this case armature 91 of Fig. 1 with its contact 90 may be omitted and the receiver input connected across conductors 95 and 96 in series with relay contacts 20. In Fig. 1 contact 90 protects the receiver from voltages that may be present in the sea earth connection 94.

Fig. 2 will now be referred to for a disclosure of apparatus in accordance with this invention for protecting the amplifier stage 33 from electrical, mechanical or acoustical vibrations.

The screen grid tube 33 is supported in a massive ring 71 of lead which in turn is suspended by suitably damped springs 72 and 73 from the supporting plate 74, preferably three or four supporting springs being used. The tube 33 is surrounded by felt shown at 75, which is in turn surrounded by a lead or other heavy metal sheath 76. The large mass of elements 71 and 76 together with the damped spring suspensions 72 and 73 prevent the transmission to the tube 33 of high frequency mechanical vibrations. The felt 75 effectively shields the tube from acoustical waves. This assembly together with input transformer 41 which is similarly suspended from supporting member 74 is enclosed within an iron box 77. This in turn is enclosed within an outer iron box 78 and the space between the two is filled with suitable damping material such as layers of cellotex and felt or similar material. These iron cases 77 and 78 afford effective protection against electromagnetic and electrostatic disturbances. A copper shield 79 within the box 77 electrically shields the input circuits of stage 33 from the output circuits. The input leads are shown at the base of the tube 33 and may be provided with external connections in any suitable manner. The output lead 81 extending to the transformer 41 is a short flexible lead connecting to a mechanically fixed terminal 82 from which another short flexible lead 83 extends to the transformer. The transformer 41 itself is contained within a box composed preferably of nickel iron alloy which effectively shields the transformer from magnetic disturbances.

The receiving circuit RC was found to have a tube noise level only about one sixth the resistance noise when the input transformer was connected to a resistance equivalent to the terminal resistance of a deep sea telephone cable, in a specific instance, 200 ohms.

What is claimed is:

1. In a receiver circuit for a path of high attenuation, such as a submarine cable, in which the signal energy is close to the resistance noise energy level, an amplifier having in its initial stage a screen grid discharge tube for producing higher amplification in the signal than would be possible in one stage employing the three-element type of tube, an input transformer for such tube, and means for holding the noise generated in said initial stage substantially to a minimum, comprising means for shielding said stage from electrical and mechanical vibrations, including a damped mechanical mounting for said tube and said transformer.

2. In a terminal transmitting circuit for a deep sea cable, a power amplifier for supplying amplified signal energy to said cable including a source of high voltage direct current, means comprising a shielded transformer for conductively isolating said amplifier from said cable whereby said high voltage direct current is prevented from reaching said cable and means for protecting said cable from excessive transient voltages comprising shunt discharge devices responsive to substantially instantaneous voltages in excess of the peak speech amplitude voltage to be transmitted.

3. In a receiving circuit for a deep sea cable, a band pass filter connected to the cable for suppressing all frequencies below the lowest signal frequency which is to be received, a high gain amplifier stage following said filter, and a low pass filter connected to the output of said stage and feeding into a further amplifier stage, said low pass filter passing the signal frequencies but preventing impressing on the subsequent stage the

noise and other components of frequencies higher than the signal frequencies to be received.

4. In a receiving amplifier for a line of high attenuation, an amplifier the initial stage of which comprises a high gain tube and means for shielding said stage from electrical and mechanical vibrations comprising a completely closed box of magnetic material enclosing said stage, an input transformer also enclosed in said box, said tube and said transformer each being resiliently supported within said box, a massive member fixedly associated with the tube, and a casing of magnetic material enclosing said transformer.

5. A structure according to claim 4 including a conductive shield wihin said box, connected to ground and interposed between the input and output circuits connected to said amplifier.

6. A receiver for a transmission line comprising a multi-stage amplifier comprising in its initial stage a screen grid tube to give high initial gain, a high ratio input transformer for said screen grid tube and means for shielding said tube and transformer from electrical and mechanical vibrations, the degree of shielding being of an order such that, the amplifier noise is below the resistance noise of the line.

7. A receiver for a deep sea telephone cable, comprising a multi-stage amplifier comprising in its initial stage a screen grid tube to give high initial gain, a high ratio input transformer for said screen grid tube and means for shielding said tube and transformer from electrical and mechanical vibrations, the degree of shielding being of an order such that, the amplifier noise is lower than the noise due to the thermal agitation within the cable.

8. In a submarine telephone cable system having sending and receiving circuits, a sending sea earth and a receiving sea earth, and means including voice controlled circuits for operatively associating the sending circuit with the cable and the sending sea earth while disassociating the receiving circuit from the cable, and for operatively associating the receiving circuit with the cable and the receiving sea earth while disassociating the sending circuit from the cable.

9. In a submarine telephone cable system having sending and receiving circuits at one terminal thereof, a long, loaded and properly terminated sea earth for receiving purposes, another earth connection, means normally associating the receiving circuit with said first sea earth and cable for purposes of receiving, and means responsive to speech currents present in said sending circuit for operatively isolating the receiving circuit from the cable and operatively associating said sending circuit with the cable and said other earth connection.

10. In a submarine telephone cable system, a long, loaded sea earth, a short non-loaded sea earth, connections to each and to the cable core, a transmitting circuit and a receiving circuit at one terminal of the cable, and means including voice operated relays for connecting the receiving circuit between the cable core and the long loaded sea earth to receive from the cable and for connecting the transmitting circuit between the cable and the short sea earth to transmit into the cable.

11. A system according to claim 10 in which said means opens the transmitting circuit when the receiving circuit is connected to the cable.

12. A system according to claim 10 in which said means disconnects the receiving circuit from the cable and short-circuits the receiving circuit when the transmitting circuit is connected to the cable.

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