

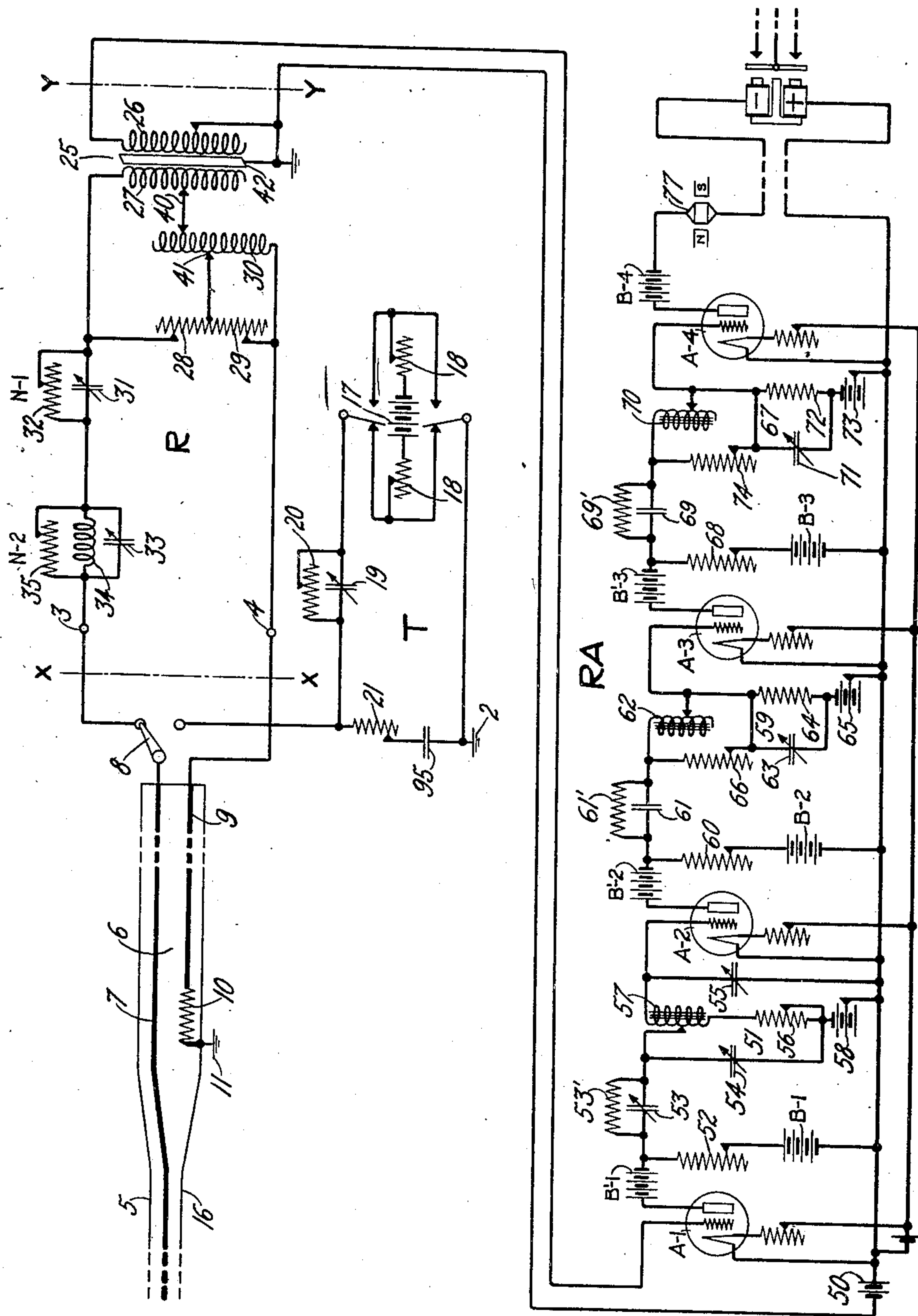
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ELECTRIC CURRENT TRANSMISSION

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ELECTRIC-CURRENT TRANSMISSION.

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This invention relates to electric current transmission, especially in systems for receiving signals from circuits such as submarine telegraph cables or the like, and aims to amplify electric currents or electromotive forces, as, for example, weak signals arriving from transoceanic submarine telegraph cables, in such manner that the amplified signals will be free from undue disturbance and will have the desired shape, and especially so that they will be free from excessive zero wander. The invention is described hereinafter with especial reference to its application in cable telegraphy, but is capable of other applications.

It is also an object of the invention, as applied to circuits or cables arranged for transmission in opposite directions alternately, to reduce the time lost in switching the circuit or cable and the amplifier from the condition in which they should be while signals are being sent over the circuit or cable from the end at which the amplifier is located to the condition in which they should be while signals are being received from the circuit or cable by the amplifier.

In a well known type of space discharge amplifier circuit the coupling from the plate circuit of one stage to the grid circuit of the next stage is by means of a resistance and a condenser, the resistance being connected in the plate circuit of the one stage, and the drop of voltage across the resistance being applied between the filament and the grid of the next stage through a circuit including a condenser. The condenser is connected between the plate of one tube and the grid of the next tube in order to prevent the high voltage applied to the plate from being communicated to the grid. It has been customary to consider that this coupling condenser has infinite resistance, but it has been found that although the leakage resistance is so high that the operation of the amplifier is not appreciably influenced where it is used for amplifying speech or radio signals, this is not the case where the amplifier is used for the reception of low frequency telegraph signals, as, for instance, signals received from a submarine cable. This is because the dielectric of the condenser, polarized by the plate battery voltage of the amplifier may decrease its leakage resistance very rapidly with a small increase in volt-

age, unless the polarizing voltage is low. The leakage resistance of the coupling condensers between the stages of a multi-stage amplifier makes it possible for direct voltage to be transmitted through the amplifier, and the non-linear characteristic of the leakage resistance causes a certain amount of rectification of an alternating current input as the latter varies the condenser voltage. Consequently, if the direct voltage impressed upon a coupling condenser from the space current source of the amplifier stage ahead of the condenser is high, impressing a signal upon the amplifier input produces a rectified signal component which passes through the amplifier and, in the case of a receiving amplifier for a submarine telegraph cable, appears as a cumulative shift of the normal signal zero in all stages. Under some conditions this shift of the zero may amount to 25% of the signal amplitude and has interfered seriously with the operation of the system. Moreover, the variation of the leakage resistance of a coupling condenser may cause variations in the transmission efficiency of the amplifier for extremely low frequencies, especially if the condenser and the grid leak resistance for the space discharge device of the second of the stages connected by the resistance-condenser-resistance coupling are large in order that for such frequencies the value of the transmission efficiency of the amplifier may be considerable.

In a specific aspect of a form of the invention herein chosen for illustration, an electric space discharge amplifier is provided having an interstage coupling of the resistance-condenser-resistance type, with a third resistance connected across the coupling condenser, and with the space current source of the first stage so arranged that the polarizing voltage which it causes to be applied to the coupling condenser may be given zero value or any desired positive or negative value, within limits. By giving this polarizing voltage a proper value and properly proportioning the magnitude of the resistance which shunts the condenser, with reference to the magnitude of the grid leak resistance connected across the input circuit of the second stage, the transmission efficiency of the amplifier for very low frequencies may be made considerable and con-

stant and given any desired value relative to the value of the transmission efficiency for higher frequencies, and at the same time the signal rectification mentioned above as tending to produce shift of the normal signal zero may be reduced or avoided. This is accomplished without making the amplifier unduly sensitive to variations in the voltage of the plate current batteries.

Moreover, in accordance with the invention the transmission efficiency of the amplifier for very low frequencies may thus be made sufficient to give the desired signal shape (or the desired ratio between the amplitude of the low frequency components of the signals and the amplitude of the high frequency components of the signals) at the output side of the amplifier, with the amplitude of the very low frequency components of the signal at the input side of the amplifier much smaller than would be necessary were an interstage network of the plain resistance-capacity type used.

This arrangement is of particular advantage in cases where a cable is operated in opposite directions alternately and where the networks between the cable and the amplifier contain condensers or inductances arranged so that the time taken for a direct current to arrive at a steady condition in the networks is a matter of several seconds. On switching from sending to receiving under these circumstances, the earth currents always present in submarine cables prevent reception for a few seconds by causing a surge through the amplifier, this surge persisting until the earth currents have arrived at a steady value. The duration of this surge consequently determines the minimum time which must be lost on switching from sending to receiving. As the time during which the surge interferes with reception of signals is proportional to the magnitude of the surge, and this magnitude is in turn proportional to the final value to which the earth current is permitted to rise, it is important to reduce this final value by making the receiving system present a high direct current resistance to the cable. This can be done properly only if the amplifier itself transmits effectively the extremely low frequency components of the signal.

Other objects, aspects and features of the invention will be apparent from the following description taken in connection with the drawing, the single figure of which is a circuit diagram of a system embodying a form of the invention.

In the drawing a single core submarine cable 5 is terminated in a twin core section of submarine cable 6. One core 7 of the twin core section 6 is connected at one end to the single core cable 5 and at the other end to the switch 8 by means of which it can be connected in its upper position to ter-

minal 3 of the signaling receiving apparatus R facing line X—X from the right and in its lower position to the transmitting apparatus T. It should be understood that this switch 8 is merely for the purpose of indicating that the cable is to be switched from the transmitter to the amplifier and that in actual practice the switching mechanism might be much more complicated than indicated. The other core 9 of the twin core section 6 is connected through a resistance 10 to a conductor in contact with the sea water, thus forming a so-called "sea-earth." In the particular arrangement shown, the resistance is connected to the cable armor wires at point 11 and a conventional ground connection symbol is used to indicate that the armor wires are grounded. The core 9, together with the network 10 grounded at the point 11, constitutes a cable balancing return circuit, which reduces interfering disturbances local to the shore end of the cable. The shore end of core 9 is connected to terminal 4 of the receiving apparatus R.

Each of the cores 7 and 9 comprises a copper conductor 14 provided with a wrapping (not shown) of a nickel-iron alloy of the general type described and claimed in a patent to G. W. Elmen, 1,586,887, issued June 1, 1926. The cores are surrounded by insulation and armor wires indicated generally at 16.

This invention is, however, applicable to ordinary unloaded cables used with or without a balancing sea-earth cable.

The transmitting equipment T comprises a positive and negative impulse transmitter 17, series resistance 18, of the order of 10 to 50 ohms, and condenser 19 of capacity of the order of 20 to 100 microfarads with shunting resistance 20 of the order of 5,000 to 100,000 ohms. With switch 8 in its lower position one terminal of the terminating equipment is connected to the core 7, while the other terminal is grounded at a beach earth 2 or through a short length of a low resistance conductor forming an extra sea-earth. A comparatively low resistance 21 of the order of 50 to 200 ohms is connected between the terminals of the transmitting equipment, that is, between the core 7 and earth 2, and a very large condenser 95 of capacity of the order of several hundred microfarads is inserted in series with sending shunt resistance 21, this capacity being so large that it has little influence on the action of the shunt resistance at any of the frequencies of the signal components except the extremely low frequencies. This feature is claimed in a patent to A. M. Curtis, 1,624,396, April 12, 1927.

The immediate purpose of the shunt resistance 21 is to prevent the variation of cable impedance with frequency from having and material effect on the circuit con-

sisting of sending battery 17, battery resistance 18, shunted condenser 19, and cable and shunt resistance 21. The effect of resistance 21 is to cause the application to the cable of the voltage wave form produced by charging the condenser 19 through a practically constant resistance. When, as previously was the practice, the resistance 21 is omitted, the voltage applied to the cable is modified by the changing impedance of the latter in a direction to react unfavorably against the effect of the series condensers. The efficiency of the sending condenser network may be judged by the effect it has in lowering the applied voltages at the lower frequencies, which should be discriminated against, since the principal difficulty in correcting the distortion of the loaded cable for signaling speeds above 30 cycles per second lies in sufficiently reducing the relatively enormous amount of signaling components of the lower frequencies with respect to those of higher frequencies. The function of condenser 95 will be pointed out hereinafter.

A similar transmitting equipment (not shown) is provided at the distant end of the cable for transmitting to the receiving apparatus R.

The twin core section 6 is connected to receiving equipment comprising the circuit illustrated between line X—X and Y—Y, which is claimed in Patent 1,624,396 referred to above. This circuit includes a shielded transformer 25, the secondary winding 26 of which is connected to the input circuit of a receiving amplifier RA. The primary winding 27 is connected to coupling resistance 28 by means of an auto-transformer 30. Resistance 28 is variable to a value of the order of 10,000 ohms. Resistance 29 is variable up to a value of the order of 100,000 ohms. Connected in series with the core 7 is a variable receiving condenser 31 of a value of the order of 0.1 to 10 microfarads shunted by a variable resistance 32 of a value of the order of 10,000 to 2,000,000 ohms forming network N¹. This network is used to control the amplitude and phase of the low frequency components of the signaling current.

An anti-resonant network N² consisting of a variable condenser 33 of 0.1 to 2 microfarads, inductance 34 of 50 to 200 henrys and a shunt resistance 35 of 1000 to 20,000 ohms, is also connected in series with the core 7 and network N¹. This network N² is tuned to a frequency below the signaling frequency for which the rest of the system is adjusted and is used to reduce the amplitude of this and adjacent components of the signaling current, and at the same time maintain a high impedance termination for the cable at these frequencies. The adjustment of the resistance 35 is customarily low

enough to insure that this network is highly damped, and does not superpose an oscillation on the signal. Resistance 35 is also useful in adjusting the very low frequency components of the signal, that is, those below the range in which condenser 33 and the inductance of coil 34 are effective.

Auto-transformer 30 is variably connected to the input winding 27 of transformer 25 by way of conductor 40. The point 41 of the primary winding is connected to the junction point of resistance 28 and 29. The secondary winding 26 of transformer 25 is surrounded by shield 42 which is connected to the locally grounded terminal of winding 26.

The auto-transformer 30 may be a coil of about 50 henrys inductance wound on a core of iron dust rings. These rings have a permeability of approximately 55 and are described in an article by Messrs. Speed and Elmen, entitled "Magnetic properties of compressed powdered iron," published in the Journal of the American Institute of Electrical Engineers, vol. 40, July 1921, page 596. Resistance 29 is preferably of a high value so that its effect on the circuit is small; but at adjustments which might allow the received signal to produce troublesome oscillations, this resistance is used to increase the damping of the circuit and so reduce its tendency to oscillate. The purpose of this auto-transformer is to increase the definition of the signal by partially suppressing a certain band of frequencies somewhat lower than the signaling frequency which, without this suppression, would cause the received wave to overshoot and distort signals beyond legibility. This is also the purpose of the series anti-resonant circuit N², but while the latter is adjusted to be effective at approximately one-third of the signaling frequency, the auto-transformer is usually adjusted to be effective at about two-thirds of the signal frequency. This is accomplished by the proper adjustment of the resistance 28 with relation to the primary inductance and primary to secondary turns ratio of auto-transformer 30. Transformer 30 is connected so that the induced secondary voltage opposes the voltage drop across resistance 28, but the adjustment is such that this opposing voltage is negligible except for the band of frequencies which it is desired to suppress.

A suitable design for transformer 25 is described in a patent to A. M. Curtis, 1,586,972, June 1, 1926. The core is of the shell transformer type and is made up of strips of nickel-iron alloy. The winding is arranged to have very small distributed capacity. Both the primary and secondary windings are made up of pancake sections. By far the larger part of the winding space is occupied by the primary coil, sufficient

space being occupied by the secondary coil to give a reasonable primary to secondary turns ratio when the smallest wire available is used for the secondary winding. The use of a high resistance secondary coil is permissible on account of the fact that the secondary coil works into practically an infinite impedance. Measurements on an actual transformer at a value of current of the order of that encountered in submarine signaling, show that its primary inductance is 6300 henrys and its direct current resistance is about 0.28 ohm per henry. With the primary closed on its normal impedance, the leakage inductance measured from the secondary terminals is of the order of 50 henrys. The ratio of primary reactance to primary resistance is not less than 40 from four to twenty cycles per second. The capacity between the primary sections adjacent to the secondary shield and the secondary shield is of the order of 500 micro-microfarads.

The apparatus thus far described in detail herein is the same as apparatus included in the disclosure in Patent 1,624,396, mentioned above.

The receiving amplifier RA comprises four stages of electron discharge amplifiers with suitable coupling circuits and signal shaping networks. The first stage amplifier A^1 is provided with a negative grid battery 50 of, for example, several volts. The filaments of all the amplifiers are connected together and if desired may be earthed as shown, and are heated by current from a battery under the control of rheostats, as shown.

Space current for amplifier A^1 is supplied from batteries B^1 and B'^1 through a resistance 52, batteries B^1 and B'^1 tending to send current in the same direction through the resistance 52. Space current for amplifier A^2 is supplied from batteries B^2 and B'^2 through a resistance 60, batteries B^2 and B'^2 tending to send current in the same direction through resistance 60. Space current for amplifier A^3 is supplied from batteries B^3 and B'^3 through resistance 68, batteries B^3 and B'^3 tending to send current in the same direction through resistance 68.

The space current circuit of amplifier A^1 is coupled to the shaping network 51 by means of a coupling condenser 53 and a resistance 53' shunted across the condenser. The shaping network 51 consists of a primary variable condenser 54 secondary variable condenser 55, adjustable resistance 56 and inductance coil 57.

A type of coil which is suitable for auto-transformer 57 has a core consisting of permalloy strips built up in the manner of a shell type transformer core in which a small air-gap is included in the magnetic circuit at one end of the central leg. The winding consists of pancake sections, for example,

each 0.35 inch thick and containing 8300 turns of No. 40 single silk-covered copper wire. A coil of this type is described in patent to A. M. Curtis, 1,586,970, June 1, 1926.

The upper terminal of coil 57 is connected to the grid of amplifier A^2 . A grid polarizing battery 58 is provided for amplifier A^2 . The action of the system as regards the maintenance of the steady potentials of the grids of amplifier A^2 and the succeeding amplifiers is described hereinafter.

The shaping network 51 is not primarily a resonant network but comprises an auto-transformer with an abnormally high primary resistance. This resistance (considering it as including resistance 56) is so high in relation to the primary reactance at all of the higher frequency components of the signal that the current in the primary circuit is practically in phase with the voltage across it. However, the turns ratio of the transformer is so large that the secondary induced voltage for the higher frequency components of the signal adds considerably to the voltage transmitted conductively to the secondary terminals by the drop in potential across the primary resistance. The resulting characteristic of this network is that voltages of the lower frequencies, applied to this network, are transmitted to the secondary terminals unchanged, while the higher frequencies have their voltage increased substantially. The time interval between a signal component of a certain frequency at the secondary terminals of the auto-transformer, (considered as including resistance 56) and a signal component of another frequency, is substantially the same as the time interval between these signal components at the primary terminals over the greater part of the range of frequencies for which the auto-transformer is effective in increasing the voltage, or, looked at from the point of view of changes in phase angles rather than intervals expressed directly in time units, the components of the signal voltage appearing at the secondary terminals are retarded in phase relatively to the same components of the signal at the primary terminals by angles which are approximately proportional to the frequencies of the components. Under these circumstances, the retardation of the components does not change the shape of the signal, but merely retards it bodily in time; but as the amplification is greater for the higher frequencies than for the lower, the variation of the attenuation of the cable with frequency is partly compensated for. The primary condenser 54 and the secondary condenser 55 are used with caution principally for the purpose of reducing the effect of interference higher in frequency than any of the essential components of the signal.

The space current circuit of amplifier A^2

is coupled to shaping network 59 by means of a coupling condenser 61 and a resistance 61' shunted across the condenser. Shaping network 59 consists of inductance coil 62 shunted by resistance 66, both connected in series with condenser 63. The input circuit of amplifier A^3 is connected across the resistance 64 which may have a resistance of from 100,000 ohms to 2 megohms, depending on other constants of the circuit, and which is connected in shunt to condenser 63. A battery 65 which may be of any suitable polarity and voltage is provided, to assist in maintaining the proper steady grid potential on the grid of amplifier A^3 .

The space current circuit of amplifier A^3 is coupled to network 67 by means of a coupling condenser 69 and a resistance 69' shunted across the condenser. The shaping network 67 consists of an inductance coil 70, a condenser 71, and a resistance 74. The coil 70 and resistance 74 are in parallel with each other and, in series with the condenser 69 and its resistance shunt 69', are connected from the junction of resistance 68 with battery A^3 to the grid of amplifier A^4 . The condenser 71 is connected across a grid leak resistance 72 for amplifier A^4 and thus forms a shunt from the grid of that tube to the ground, through a grid polarizing battery 73 of any desired potential and polarity.

Space current for amplifier A^4 is supplied by battery B^4 of the order of 250 volts. Amplifier A^4 might consist of several vacuum tubes connected in parallel. For simplicity one only is shown. The output circuit of amplifier A^4 including battery B^4 extends through a receiving device 75 which is shown as a relay for operating a siphon recorder or other signal receiving apparatus, not shown. A second receiving device 77 which may be a siphon recorder, as shown, may be connected in series to the output circuit of the amplifier for monitoring purposes.

Elements 62, 63 and 66 may be adjusted so as to consist of a resistance and capacity in series or inductance and capacity in series or a shunt inductance in series with a capacity, the capacity being shunted by the grid leak resistance 64, and the voltage which is impressed upon the input circuit of the succeeding amplifier being that across the condenser 63 and grid leak resistance 64 in all cases. Each of the adjustments discriminates against interfering components having frequencies higher than those essential to signaling.

The coupling between amplifier A^1 and the signal shaping network 51 to which it couples that tube is substantially of the resistance-condenser-resistance type, except that the coupling condenser 53 is shunted by the resistance 53' and the coupling resistance 52 is connected between the space current

sources for amplifier A^1 ; and similarly the coupling between amplifier A^2 and the signal shaping network 59, and the coupling between amplifier A^3 and network 67 are substantially of the resistance-condenser-resistance type, except that in each case the coupling condenser is shunted by a resistance and in each case one of the resistances of the coupling is connected between two space current sources. It has been customary to consider that coupling condensers such as 53, 61 and 69 have infinite resistance. Although it is not strictly true that they have, their resistance is high enough so that their effect on the signal would be negligible if the resistance were constant. The resistance is not constant, however, as the leakage through the dielectric is a function of the voltage applied, and if this voltage exceeds a relatively low amount the leakage resistance may decrease very rapidly with a small increase in voltage.

The leakage of the condensers makes it possible to transmit a direct voltage through the amplifier and due to the non-linear characteristic of the leakage resistance the latter may in part rectify an alternating wave impressed thereupon. Consequently, if the direct voltage on the condensers is high, it is found that impressing a signal upon the amplifier input produces a rectified signal component which passes through the amplifier and appears as a cumulative shift of the normal signal zero in all stages. Under some conditions in cable receiving amplifiers this has amounted to as much as 25% of the peak amplitude of the signal in the last stage and has interfered seriously with the operation of relays such as 75.

As will now be explained, the interstage coupling network between amplifiers A^1 and A^2 , or that between amplifiers A^2 and A^3 , or that between amplifiers A^3 and A^4 , substantially eliminates the rectification or reduces it to as small a value as desired by reducing the coupling condenser polarizing voltage to a sufficiently small value, and at the same time by shunting the condenser by a definite leak makes the transmission of extremely low frequencies through the coupling network definite instead of variable in amount, and large enough to assist in shaping signals. As pointed out above, the space current battery for each amplifier A^1 , A^2 and A^3 is divided into two parts, one of which should be insulated from earth. Considering, for example, the coupling between amplifiers A^3 and A^4 , if B^3 and B'^3 be proportioned so that the voltage drop in resistance 68 due to the normal current through that resistance when no signals are being received is equal and opposite to the voltage of B^3 , then the normal voltage across condenser 69 caused by the plate voltage will be zero. By varying the value of resistance 68 or the

voltage of batteries B^3 and B'^3 , the steady voltage across battery B^3 and resistance 68 can be made to assume any desired positive or negative value, within limits. In the absence of the battery 73 the steady potential of the grid of amplifier A^4 would be determined substantially by the direct current flowing through the path consisting of resistance 69', inductance 70 and resistance 74 in parallel, and resistance 72, due to the difference between the voltage of battery B^3 and the voltage drop in resistance 68, and therefore would be approximately equal to the steady voltage applied to this path from battery B^3 and resistance 68 multiplied by the ratio of the value of resistance 72 to the combined resistance value of 72, plus 69', plus 70 and 74 in parallel, provided the steady voltage across condenser 69 were maintained sufficiently small to substantially avoid rectification of signals due to change of the inherent leakage resistance of condenser 69 with change of the voltage across the condenser. This value which the steady potential of the grid of amplifier A^4 would have may be modified as desired by the addition of the battery 73. Thus, by properly proportioning the value of resistance 68 and the voltages of batteries B^3 and B'^3 and the values of the resistances of 69', 70, 74 and 72 and the voltage of battery 73, the steady voltage across the coupling condenser 69, the steady potential on the grid of amplifier A^4 , and the ratio of the resistance 69' to that of the combined resistance value of 69', plus 72, plus 70 and 74 in parallel, can be adjusted to any desired values, within limits. Consequently the transmission efficiency of the coupling for extremely low frequencies, for which the impedance of condenser 69 is high, can be made considerable and constant and given any desired value relative to the transmission efficiency for higher frequencies. At the same time the signal rectification mentioned above as tending to produce shift of the normal signal zero can be avoided, and the tendency of the amplifier battery voltage variations to cause shift of the normal signal zero can be curbed. When the condenser is shunted by a resistance 69', which is several times as large as resistance 72, yet low compared to the leakage resistance of the condenser, it becomes possible to pass through the amplifier a definite and sufficient amount of extremely low frequencies without being compelled to use a very large coupling condenser and grid leak resistance 72, which exaggerate the effect of condenser leakage. Moreover, the transmission efficiency of the coupling for extremely low frequencies can be sufficiently great to permit of the shunt 32 around the receiving condenser 31 being high enough so that the final value of the earth current

which builds up in the primary winding 27 of transformer 25 when the switch 8 disconnects the cable 5 from the sending apparatus and connects the cable to the receiving apparatus is small and consequently the time taken for the earth current to reach a substantially steady state is considerably reduced. It is of advantage to have the surge caused by this building up of the current which flows from the cable to earth when the receiving apparatus is switched into connection with the cable, as small as possible, since then the period during which the surge causes an objectionable shift of the normal zero of the amplifier and prevents signals from being received is proportionally reduced. The reason why the use of the resistance 69' enables the resistance 32 to be increased is that these resistances, by shunting low frequencies around the condensers 69 and 31, tend to increase the transmission efficiency of the receiving apparatus for those frequencies, and therefore, for a given signal shape, or in other words for a given ratio between the transmission efficiency of the receiving apparatus for very low frequencies and its efficiency for high frequencies, the lower the resistance 69' the higher may be the resistance 32 providing other things remain unchanged. As will be explained hereinafter, the employment of the condenser 95 in the sending apparatus T also enables the resistance 32 to be increased, with further tendency toward reduction of the period, following the switching of the receiver into connection with the cable, during which the reception of signals must await the building up, to a substantially steady state, of the earth current which flows from the cable through the primary winding of transformer 25 to earth at 11.

The space current source for the amplifier A^2 is divided into batteries B^2 and B'^2 , so that the polarizing voltage which that source causes to be applied to the coupling condenser 61 can be given any desired value. The elements B^2 , B'^2 , 60, 61, 61', 64 and 65 are related to each other, and function, in substantially the manner described for the elements B^3 , B'^3 , 68, 69, 69', 72 and 73, to which they correspond, respectively.

Likewise, the elements B^1 , B'^1 , 52, 53, 53', 56 and 58 are related to each other, and function, in substantially the manner described for the elements B^3 , B'^3 , 68, 69, 69', 72 and 73, to which they correspond, respectively.

Such sets of elements, although they have been described in connection with interstage signal shaping networks of the type disclosed in Patent 1,624,396, mentioned above, may be employed for coupling repeaters, without such signal shaping elements or networks. For instance, in accordance with

the invention, two vacuum tubes may be coupled as are the tubes A³ and A⁴ in the drawing, but with elements 70, 71 and 74 omitted.

5 As hereinbefore explained, the low resistance shunt 21 is important in high speed working, since it greatly increases the effectiveness of the usual sending condenser, but it has the disadvantage of shunting to earth
10 the larger part of the extremely low frequency components of the transmitted signal, thereby requiring that the series condenser 31 at the receiving end of the cable be shunted by a relatively low resistance,
15 although not so low as would be necessary in the absence of resistances 53', 61' and 69'. Such a low resistance at the receiving terminal is objectionable, since it permits a rather strong earth current to flow through the
20 shaping network which is located between the cable and the amplifier. As mentioned above the establishment of this earth current during switching from sending to receiving produces a heavy surge through the amplifier and momentarily displaces the zero of
25 the signal. The insertion of the large condenser 95 materially reduces the strength of earth current and switching surges by permitting the use of a much higher resistance shunt on the receiving condenser.
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The invention is not limited to the specific arrangement and values hereinbefore given, but is capable of embodiment with considerable modification within the scope of the
35 invention as defined by the appended claims.

What is claimed is:

1. In combination, a circuit comprising a resistance and means for producing potential variations across said resistance, a
40 vacuum tube having input electrodes, and a connection for conductively impressing said variations on said electrodes, said connection comprising a series arm including a condenser and a resistance shunted thereabout and a conductive shunt arm having
45 one of its ends connected to said series arm at a point between said condenser and said electrodes, said shunt arm including resistance.

2. In combination, a condenser and means for supplying electromotive force variations to said condenser, said means comprising an electrical path including a source of said
55 variations, said path including also another source of electromotive force, and said means including also means connecting said condenser to points on said path at substantially equal potentials with respect to the frequency of said other source, said points being
60 so located on said path that said sources are in serial relationship to each other and to said condenser.

3. In combination, an electrical path including sources of electromotive forces differing in frequency, a circuit connected

across said path and including a condenser, said sources being in serial relationship to each other and to said circuit, the magnitude of the voltage of one of said sources being such that if said voltage were applied to
70 said condenser said other source would cause substantial variations in the leakage resistance of said condenser, and said circuit being connected to said path at points on said
75 path the potential difference between which is, for the frequency of said one source, sufficiently small to avoid said substantial variation in said leakage resistance of said condenser.

4. In combination, a condenser having a
80 resistance connected thereacross, and means for applying electromotive force variations to said condenser and said resistance, said means comprising an electrical path including a source of said variations, said path including also a source of electromotive force of zero frequency, and said means including
85 also means connecting said condenser to points on said path at substantially equal potentials with respect to zero frequency, said source of said variations having a substantial impedance at zero frequency.
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5. A space discharge amplifier for amplifying waves of frequencies less than 1000 cycles per second including two stages with
95 a resistance-condenser coupling therebetween and with a space current source for the first of said two stages so arranged that the polarizing voltage impressed upon the coupling condenser from said source is substantially less than the voltage of said source.
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6. An amplifier according to claim 5, in which said first stage has a space current circuit including a space current source and a resistance affording a substantial voltage
105 drop due to the space current, and in which connection is provided to the coupling condenser and the cathode of the second of said two stages from across said resistance and a portion of said source furnishing a voltage
110 of sign opposite to said voltage drop in said resistance and of a value in the neighborhood of the value of said voltage drop in said resistance.

7. In combination, a signaling path having large distributed resistance and capacity, and a network for receiving signals from said path, said network comprising a space discharge amplifier including two stages with a resistance-condenser coupling therebetween and with a space current source for the first of said two stages so arranged that the coupling condenser polarizing voltage from said source is substantially less than the voltage of said source, and with means comprising a resistance in shunt to the coupling condenser for making the very low frequency transmission through the coupling definite in amount and sufficient to assist in shaping the signals.
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8. The combination set forth in claim 7, in which said means includes a conductive shunt across the input circuit of the second of said two stages of said amplifier, said latter shunt including a resistance, and the value of said resistance shunting said coupling condenser being high compared to the value of the resistance of said shunt across the input of said second stage, whereby the direct current voltage drop applied to said input circuit of said second stage from said latter shunt is small compared to the direct current voltage drop in said resistance shunted across said condenser.

9. In combination, a submarine cable, a multistage amplifier having an input circuit for receiving signals from said cable, and means conductively connecting said cable to earth through said input circuit, said last means including means for reducing earth current discharging from said cable upon connection of said cable to said input circuit, each stage of said amplifier comprising an anode, a cathode and an element for controlling the impedance between said anode and said cathode, and said amplifier comprising a resistance-capacity interstage coupling, with a resistance shunting the coupling capacity and rendering the coupling between the anode of one stage and the impedance control element of the succeeding stage conductive, and with a conductive connection,

including resistance from the junction of said capacity and said control element of said succeeding stage to said cathode of said succeeding stage.

10. A signaling circuit, means for transmitting signals to said circuit, means comprising a multistage amplifier for receiving signals from said circuit, means for alternately conditioning said receiving means for receiving signals from said circuit and conditioning said transmitting means for transmitting signals to said circuit, said circuit transmitting a surge through said amplifier upon operation of said last mentioned means to condition said receiving means for receiving signals from said circuit, means for decreasing the time during which said surge interferes with the reception of signals, said last mentioned means attenuating signal components of certain frequencies sufficiently to produce frequency distortion in the signals, and coupling means between stages of said amplifier, said coupling means comprising means compensating for said distorting effect, said compensating means comprising a condenser shunted by a resistance low in comparison to the leakage resistance of the condenser.

In witness whereof, I hereunto subscribe my name this 26 day of March, A. D., 1926.

AUSTEN M. CURTIS.