July 21, 1931. R. E. A. PUTNAM 1,815,657

SUBMARINE CABLE SYSTEM

Filed March 6, 1930 2 Sheets-Sheet 1

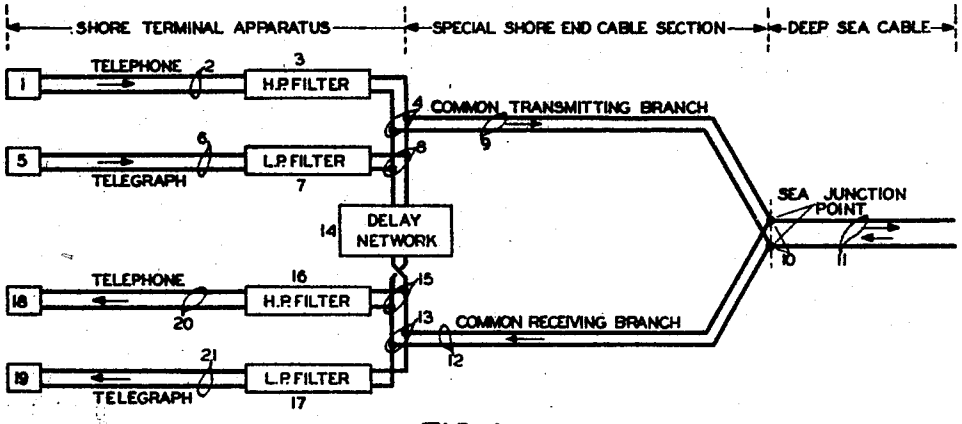

FIG. 1

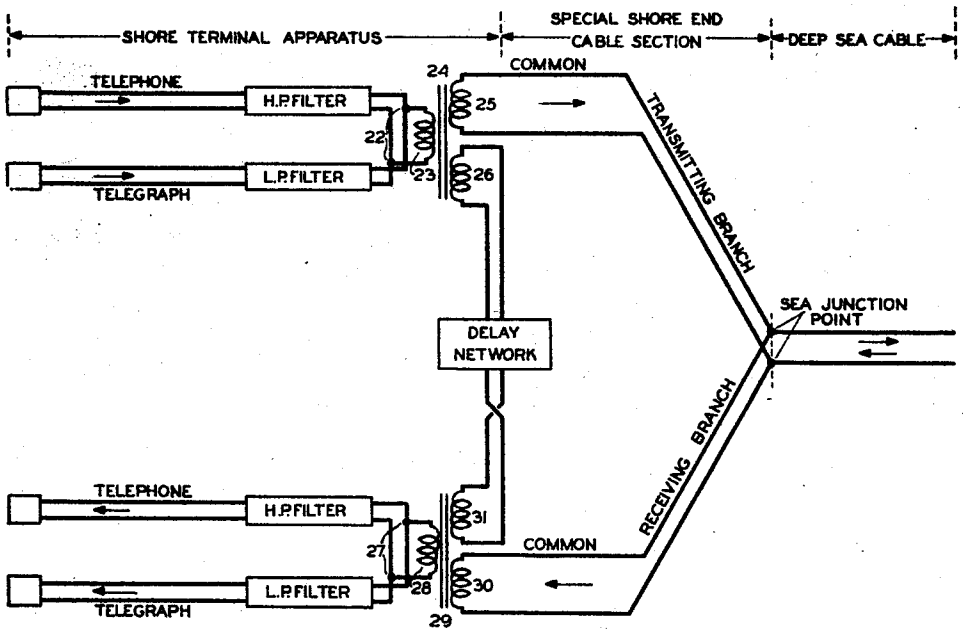

FIG. 2

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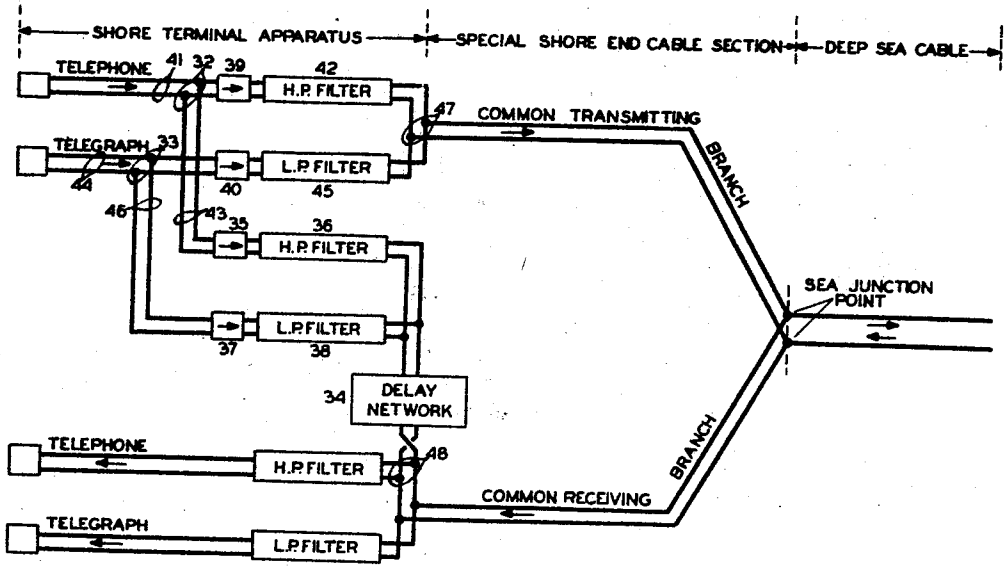

FIG. 3

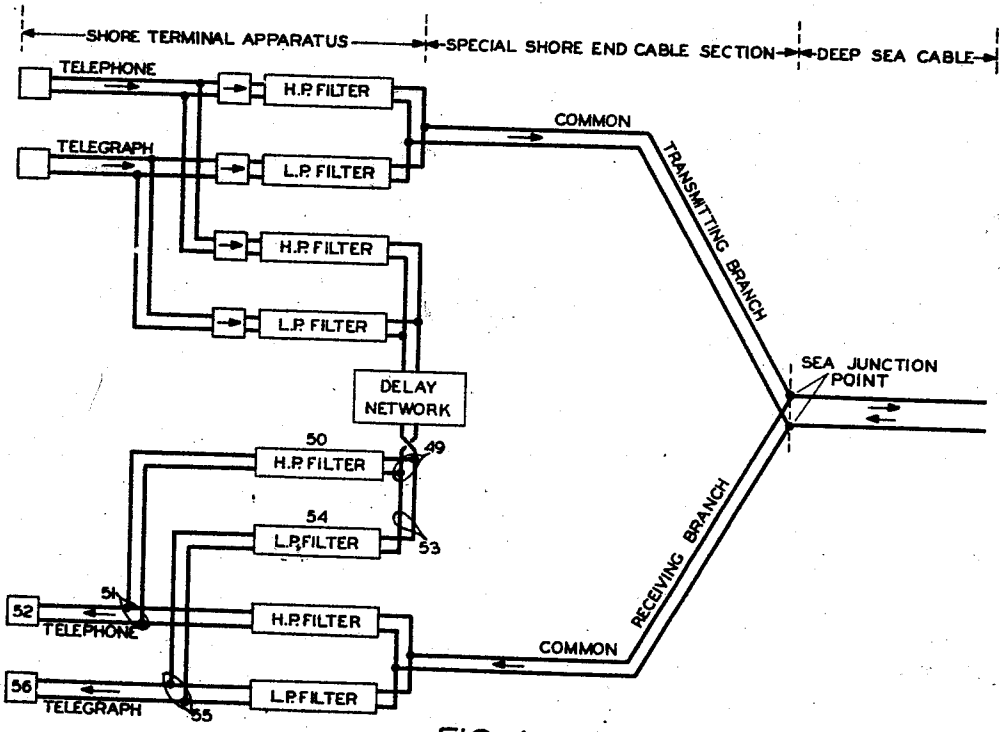

FIG. 4

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UNITED STATES PATENT OFFICE

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SUBMARINE CABLE SYSTEM

Application filed March 6, 1930. Serial No. 433,648.

This invention relates to an improvement in submarine cable telephony and telegraphy and has particular reference to the systems whereby telephone and telegraph messages are transmitted over the same cable simultaneously in both directions.

The object of this invention is the production of a submarine cable for the simultaneous transmission of telephone and telegraph signals which will substantially reduce the amount of interference to the telephone signals caused by the large D. C. telegraph currents impressed on the cable at the sending end.

Another object of this invention is the production of a cable system for the simultaneous transmission of telephone and telegraph signals which will eliminate interference caused by transmitted telephone and telegraph currents passing into their respective local receiving circuits.

Another object of this invention is the simplification of the filter equipment normally required in the usual form of cable circuit, and the consequent reduction in the amount of filter equipment necessary and in the cost of this equipment.

In accordance with the objects of the invention, special shore end sections of the cable are provided, each containing two or more special conductors which merge with the main deep sea cable at junction points remote from shore, and whose shore ends are respectively joined to the local telephone and telegraph transmitting circuits and to the local telephone and telegraph receiving circuits, and intermediate the local transmitting and receiving circuits is interposed a delay network circuit.

In the drawings, Fig. 1 represents one end of the cable and a portion of the local telephone and telegraph transmitting and receiving circuits, and a delay network circuit interposed between the local transmitting and receiving circuits.

Fig. 2 is similar to Fig. 1 but shows inductive coupling of the local transmitting and receiving circuits and their respective branches of the shore end cable section in place of the conductive coupling of Fig. 1.

Fig. 3 is similar to Fig. 1, with the exception that the delay network connections are differently arranged and one-way devices are shown in the local transmitting and delay network circuits.

Fig. 4 is similar to Fig. 3 but illustrates a modification of the connections between the delay network circuit and the local receiving circuits shown in Fig. 3.

In order to operate a loaded submarine cable designed to carry telephone frequencies economically, it is necessary that advantage be taken of the ability of the individual conductors, not only to operate in duplex, but to transmit several telegraph channels simultaneously with the telephone channels.

One of the major difficulties usually encountered in composite operation of the ordinary duplex submarine cable is the problem of maintaining a substantially perfect artificial line balance so as to prevent locally transmitted signals of either telephone or telegraph frequencies from reaching their respective associated local receiving circuits.

A second difficulty results from the tendency of the large D. C. telegraph currents at the sending end of the cable to cause partial saturation of the cable loading material and thereby introduce harmonics of the telegraph signals into the cable circuit by reason of the non-linear magnetization characteristic of the loading material. The portions of these spurious frequencies so introduced which fall within the voice frequency range are able to pass back into the local telephone channel, and may thus decrease seriously the intelligibility of any speech currents that may be received simultaneously.

To eliminate the above difficulties it is proposed to use a cable with split shore end sections merging with the main cable at a point remote from shore, one branch of each shore end section to be used as a common transmitting branch and the other as a common receiving branch, these branches to be connected with the local transmitting and receiving circuits respectively, and the local transmitting and receiving circuits to be connected by a circuit containing a delay network.

While this form of cable construction has one disadvantage in that an impedance irregularity exists in the sea junction points where the shore end sections merge with the main cable, such as to cause an appreciable transmission loss, it is believed that this factor is of small importance in comparison with the advantages to be gained by the use of this type of cable.

In Fig. 1 the invention is shown as applied to a two-way simultaneous telephone and telegraph cable system, one end of the main cable and the corresponding special shore end cable section and local circuits only, being shown, as the construction at the two ends of the cable is identical. The telephone signal current is passed from the telephone transmitting station 1 to the local telephone transmitting circuit where it is impressed on conductors 2 and passed through a high pass filter 3 to junction point 4 where the local telephone transmitting circuit merges with the common transmitting branch of the special shore end section of the cable. The telegraph signal current is passed from the telegraph station 5 to the local telegraph transmitting circuit where it is impressed on conductors 6 and passed through a low pass filter 7 and junction point 8 to junction point 4 where the local telegraph transmitting circuit merges with the common transmitting branch of the special shore end section of the cable. When the telephone signal currents reach junction point 4 and the telegraph signal currents reach junction point 8 each current is divided and approximately one-half of each current is impressed on the common transmitting branch of the shore end cable section 9 and passes to the sea junction point 10 where a portion of each signal current is passed to conductors 11 of the deep sea cable and thus to the distant receiving terminals. By reason of the impedance irregularities presented by the sea junction point 10, a portion of each transmitted current is reflected back over common receiving branch conductors 12 to junction point 13 where these conductors connect with the local telephone and telegraph receiving circuits. The component part of each signal current passed into the common transmitting branch conductors 9 from junction points 4 or 8 is passed into a delay network 14, a device well known in the art and which has a time constant and attenuation constant equal to that of the loop formed by the common transmitting branch of the shore end cable section 9, sea junction point 10 and the common receiving branch of the shore end cable section 12 so that the signal currents reaching junction point 15 after leaving the delay network 14 are identical with their component signal currents reflected back from the sea junction point 10, except that the signal currents passing through the delay network are reversed in polarity either in the delay network itself or at some other point in the delay network circuit, with the result that the two components of each signal current cancel each other and the reflected currents are thereby eliminated before they pass filters 16 or 17 and so are prevented from reaching receiving station 18 or 19 over local receiving conductors 20 or 21 respectively.

Incoming signal currents of both telephone and telegraph frequencies, arriving over main cable conductors 11, will obviously divide on reaching sea junction point 10, approximately one-half of each signal current passing over conductors 12 to junction point 13 where the signal currents of the two frequencies will be separated by filters 16 and 17 and will be passed to their respective receiving stations 18 or 19 over conductors 20 or 21 respectively. The component part of the received signal currents will pass from sea junction point 10 over conductors 9 to junction point 4 where each signal current will again be split and a portion of the current will pass into the delay network 14 and consequently into the local receiving circuits at junction point 15. By reason of the fact that the portions of the signal currents flowing through the delay network circuit will be attenuated and retarded in phase and will also be reversed in polarity, they may tend to interfere with the directly received signal components under certain conditions. If, however, the attenuation of the delay network is of the order of 20 decibels or higher, corresponding approximately to a special shore end cable section of at least 100 nautical miles in length, it is probable that any interference produced will not be objectionable. For this reason the special shore end cable section used in this system should be between 100 and 500 nautical miles in length, although under certain circumstances a shore end section of even 50 nautical miles in length might be satisfactory. The exact determination of the length of this section is, however, not made a part of this invention.

The preceding discussions and figures relate to methods wherein the cables are conductively connected to the terminal telephone and telegraph equipment. Under conditions where it is desired to protect the cable from dangerous potentials to which the terminal apparatus or associated land lines may be exposed, or alternatively to keep out of the terminal receiving apparatus certain types of interference currents which may be induced in the cable conductors, the conductive form of coupling may be replaced advantageously by inductive coupling utilizing transformers as shown in Fig. 2. While the transformers shown in Fig. 2 apply to both the telephone and telegraph signal currents it will be obvious to those skilled in the art that alternative arrangements may be readily substituted

wherein transformers are introduced only in the telephone branches, leaving the telegraph branches connected metallically where local conditions indicate that this is the more advantageous method.

With the above exception the system shown in Fig. 2 is identical in construction and operation with that set forth in Fig. 1 and therefore only so much of the system as has been modified will be described. In this system, instead of connecting the delay network circuit metallically with the local transmitting and local receiving circuits, the local telephone and telegraph transmitting circuits are extended from junction point 22 to winding 23 of transformer 24, the alternate windings 25 and 26 of which are electrically balanced and are connected to the common transmitting branch of the special shore end cable section and to the input end of the delay network circuit respectively. Likewise the local telephone and telegraph receiving circuits are extended from junction point 27 to winding 28 of a second transformer 29, the alternate windings 30 and 31 of which are electrically balanced and are connected to the common receiving branch of the special shore end cable section and to the output end of the delay network circuit respectively.

In Fig. 3 is shown a system designed for use with special shore end cable sections of shorter length than will operate advantageously with the systems previously illustrated. This system is identical in construction and operation with that shown in Fig. 1 except that certain one-way devices have been added to the circuit and the connections modified accordingly, and therefore only so much of the system as has been modified will be described.

In this figure the input side of the delay network circuit, instead of being connected to the local telephone and telegraph transmitting circuits at junction points 4 and 8 respectively, as in Fig. 1, is connected to said circuits at junction points 32 and 33 respectively. In the circuit connecting the delay network 34 with junction point 32 a one-way device 35, consisting of vacuum tube amplifiers or relays, and a high pass filter 36 have been inserted; similarly in the circuit connecting the delay network 34 with junction point 33 a one-way device 37 and a low pass filter 38 have been inserted. One-way devices of the type just described have also been inserted in the local telephone and telegraph transmitting circuits, viz. 39 and 40.

These modifications do not materially alter the operation of the system in regard to transmitted signal currents. The transmitted telephone signal currents impressed on conductors 41 divide at junction point 32, approximately one-half of the current passing through one-way device 39 and through high pass filter 42 to the common transmitting branch of the special shore end cable section, the remaining component of each signal current passing over conductors 43 through one-way device 35 and high pass filter 36 to the delay network 34. The transmitted telegraph signal currents impressed on conductors 44 divide at junction point 33, approximately one-half of the signal current passing through one-way device 40 and low pass filter 45 to the common transmitting branch of the special shore end cable section, the component part of each signal current passing over conductors 46 through one-way device 37 and low pass filter 38 to the delay network 34. The operation whereby signal currents passing through the delay network cancel such part of their respective component signal currents as are reflected from the sea junction point into the local telephone and telegraph receiving circuits has been described under Fig. 1. The operation of the system shown in Fig. 3 is materially different from that of the previously described systems in regard to the incoming signal currents. The incoming signal currents are divided at the sea junction point, approximately one-half of each signal current passing directly over the common receiving branch of the special shore end cable section to one of the receiving stations. The remaining component of the signal current passes over the common transmitting branch of the special shore end cable section to junction point 47, and through either filter 42 or 45 to one-way device 39 or 40, where the currents will be stopped and thus prevented from passing through the delay network 34 into the local receiving circuits and so interfering with the received signals. By reason of the fact that the component parts of the signal currents are so stopped before reaching the delay network there is no need for a special shore end cable section of such length that it will attenuate and delay the signals passing through the delay network to a point where there can be no interference with the directly received signals, and the special shore end cable section may, in this case, be less than 100 nautical miles in length, although the exact determination of the length of this section is not made part of this invention.

The system shown in Fig. 4 is identical in construction and operation with that illustrated in Fig. 3 except that it shows an alternative method of connecting the delay network circuit with the local telephone and telegraph receiving circuits. Only so much of the system as has been modified will be described. Under this modification the delay network circuit is not connected directly to the local telephone and telegraph receiving circuits as at point 48 of Fig. 3, but the telephone signal currents passing through the delay network circuit are passed through

junction point 49 to high pass filter 50 and from there to junction point 51 where said currents meet and cancel the locally transmitted telephone currents reflected back from the sea junction point and thus prevent such currents from reaching telephone receiving station 52. Likewise the telegraph signal currents passing through the delay network circuit are passed through conductors 53 to low pass filter 54 and from there to junction point 55 where said currents meet and cancel the locally transmitted telegraph currents reflected back from the sea junction point and thus prevent such currents from reaching telegraph receiving station 56.

What is claimed is:

1. The method of transmitting telephone and telegraph currents simultaneously in both directions over a submarine cable having special shore end sections merging with the main cable at points remote from shore and containing transmitting and receiving conductors, comprising impressing a portion of each current on the transmitting conductors and passing the component part of the current through a delay network circuit which so affects the current that on passing into the local receiving circuit it cancels the current from the local transmitter which returns by way of the sea junction point and local receiving conductors to the local receiving circuit.

2. The method of receiving telephone and telegraph currents simultaneously over a submarine cable having special shore end sections joined to the main cable at points remote from shore and containing transmitting and receiving conductors, whereby the signal currents on reaching the sea junction point at the receiving end of the cable divide, a part of each current passing over the common receiving conductors to the terminal receiving apparatus, the component part of the current passing over the common transmitting conductors from which a portion of it passes through the delay network where it is so attenuated and delayed that it offers negligible interference to the directly received signals, when it enters the local receiving circuit from the delay network circuit.

3. The method of transmitting telephone and telegraph currents simultaneously over a submarine cable having special shore end sections containing transmitting and receiving conductors merging with the main cable conductors at junction points remote from shore, comprising impressing a portion of each signal current on the transmitting conductors and passing the remaining component of each current through a delay network circuit which so controls its magnitude, phase and polarity that on passing into the local receiving circuit it cancels the current from the local transmitter which returns by way of the sea junction point and the local receiving conductors to the local receiving circuit and comprises dividing the signal currents at the sea junction point at the receiving end of the cable, one part of each current passing over the common receiving conductors to the terminal receiving apparatus, the component part of each current passing over the common transmitting conductors from which a portion of it passes through the delay network which so attenuates and delays the current that on entering the local receiving circuit it offers negligible interference to the directly received signal current.

4. The method of transmitting telephone and telegraph currents simultaneously over a single submarine cable which comprises impressing a part of each signal current at the transmitting station upon common transmitting conductors extending from said station and merging with the main cable conductors at a junction point remote from shore, and passing the component part of each signal current through a delay network circuit interposed between the local transmitting and receiving circuits, which so affects the magnitude, phase and polarity of each current that on its passage into the local receiving circuit it cancels the component current from the local transmitter which is reflected from the sea junction point to the local receiving circuit over the common receiving conductors, and comprises dividing the signal currents at the sea junction point at the receiving end of the cable, one part of each current passing directly over the common receiving conductors to the terminal receiving apparatus, the component part of each current passing over the common transmitting conductors from which a portion of it passes through the delay network which so attenuates and delays the current that on entering the receiving circuit it offers negligible interference to the directly received signal currents.

5. The method of transmitting telephone and telegraph currents simultaneously over a single submarine cable which comprises passing the transmitted currents into a transformer where a part of each signal current is impressed upon common transmitting conductors extending from said station and merging with main cable conductors at a junction point remote from shore, and passing the component part of each signal current through a delay network circuit connected to the local transmitting circuits through said transformer, and connected with the local receiving circuits through a second transformer similarly placed, said delay network circuit so affecting the magnitude, phase and polarity of each current that on its passage into the local receiving circuit it cancels the current from the local transmitter which returns by way of the sea junc-

tion point, local receiving conductors and second transformer to the local receiving circuit.

6. The method of transmitting telephone and telegraph currents simultaneously over a single submarine cable which comprises passing a part of the telephone signal current through a one-way device and a high pass filter and passing a part of the telegraph signal current through a one-way device and a low pass filter and thereafter impressing said portions of both currents upon common transmitting conductors extending from the transmitting station and merging with the main cable conductors at a junction point remote from shore, and passing the component part of the telephone current through a separate one-way device and high pass filter and passing the component part of the telegraph current through a separate one-way device and low pass filter and thereafter passing said parts of both currents through a delay network circuit interposed between the local transmitting and receiving circuits which so affects the magnitude, phase and polarity of each current that on its passage into the local receiving circuit it cancels the component current from the local transmitter which is reflected from the sea junction point to the local receiving circuit over the common receiving conductors, and comprises dividing the signal currents at the sea junction point at the receiving end of the cable, one part of each current passing directly over the common receiving conductors to the terminal receiving apparatus, the component part of each current passing over the common transmitting conductors to the transmitting circuit where it is stopped by said one-way devices inserted in the local transmitting circuit before it passes into the delay network circuit.

7. A submarine cable system comprising in combination, a local telephone transmitting circuit, a local telegraph transmitting circuit, loaded transmitting conductors, loaded receiving conductors, said transmitting and receiving conductors merging with loaded deep sea cable conductors at a sea junction point remote from shore, and a delay network circuit joining said local transmitting and receiving circuits and having a time constant and attenuation constant equal to that of the loop formed by the transmitting and receiving conductors and the sea junction point.

8. A submarine cable system, comprising in combination, a local telephone transmitting circuit, a local telegraph transmitting circuit, transmitting conductors, receiving conductors, either the transmitting or receiving conductors being loaded, and the others of said conductors unloaded, and all of said conductors merging with loaded deep sea cable conductors at a sea junction point remote from shore, and a delay network circuit joining the said local transmitting and receiving circuits, and having a time constant and attenuation constant equal to that of the loop formed by the transmitting and receiving conductors and the sea junction point.

9. A submarine cable system comprising in combination, a local telephone transmitting circuit, a local telegraph transmitting circuit, a local telephone receiving circuit, a local telegraph receiving circuit, taper loaded transmitting conductors, taper loaded receiving conductors, said transmitting and receiving conductors merging with taper loaded deep sea cable conductors at a sea junction point remote from shore, and a delay network circuit joining said local transmitting and receiving circuits and having a time constant and attenuation constant equal to that of the loop formed by the transmitting and receiving conductors and the sea junction point.

10. A submarine cable system comprising in combination, a local telephone transmitting circuit, a local telegraph transmitting circuit, loaded transmitting conductors, said local transmitting circuits being connected to said conductors through a transformer, a local telephone receiving circuit, a local telegraph receiving circuit, loaded receiving conductors, said local receiving circuits being connected to said conductors through a transformer, both of said conductor groups being merged with loaded deep sea cable conductors at a sea junction point remote from shore, a delay network circuit joining said local transmitting and receiving circuits through said transformers and having a time constant and attenuation constant equal to that of the loop formed by the transmitting and receiving conductors and the sea junction point.

11. A submarine cable system comprising in combination, a local telephone transmitting circuit, a high pass filter in said circuit, a local telegraph transmitting circuit, a low pass filter in said circuit, a local telephone receiving circuit, a high pass filter in said circuit, a local telegraph receiving circuit, a low pass filter in said circuit, loaded transmitting conductors, loaded receiving conductors, said transmitting and receiving conductors merging with loaded deep sea cable conductors at a sea junction point remote from shore, and a delay network circuit joining said local transmitting and receiving circuits and having a time constant and attenuation constant equal to that of the loop formed by the transmitting and receiving cables and the sea junction point.

12. A submarine cable system comprising in combination, a local telephone transmitting circuit, a one-way device and a high pass filter in said circuit, a local telegraph transmitting circuit, a one-way device and a low pass filter in said circuit, a local tele-

phone receiving circuit, a high pass filter in said circuit, a local telegraph receiving circuit, a low pass filter in said circuit, loaded transmitting conductors, loaded receiving conductors, said transmitting and receiving conductors merging with loaded deep sea cable conductors at a sea junction point remote from shore, a delay network circuit having a time constant and attenuation constant equal to that of the loop formed by the transmitting and receiving conductors and the sea junction point, and connected with the local telephone transmitting circuit by a circuit containing a one-way device and a high pass filter, and connected with the local telegraph transmitting circuit by a circuit containing a one-way device and a low pass filter, and connected with the local telephone and telegraph receiving circuits.

13. A submarine cable system comprising in combination, a local telephone transmitting circuit, a one-way device and a high pass filter in said circuit, a local telegraph transmitting circuit, a one-way device and a low pass filter in said circuit, a local telephone receiving circuit, a high pass filter in said circuit, a local telegraph receiving circuit, a low pass filter in said circuit, loaded transmitting conductors, loaded receiving conductors, said transmitting and receiving conductors merging with loaded deep sea cable conductors at a sea junction point remote from shore, a delay network circuit having a time constant and attenuation constant equal to that of the loop formed by the transmitting and receiving conductors and the sea junction point, and connected with the local telephone transmitting circuit by a circuit containing a one-way device and a high pass filter, and connected with the local telegraph transmitting circuit by a circuit containing a one-way device and a low pass filter, and connected with the local telephone receiving circuit by a circuit containing a high pass filter, and connected with the local telegraph receiving circuit by a circuit containing a low pass filter.

14. A submarine cable system for simultaneous two-way communication comprising in combination a cable, telephone and telegraph circuits connected to said cable, means for impressing signals upon said circuits, means for separating the components of the impressed signals, and means for returning and cancelling a portion of one component of the current so divided.

15. A submarine cable system for simultaneous two-way communication comprising in combination a cable, telephone and telegraph transmitting and receiving circuits connected to each end of said cable, means for impressing signals on said transmitting circuits, means for dividing each impressed signal into several component parts, and means whereby a portion of one of the unused signal components can be returned to the local receiving circuit and cancelled.

16. A submarine cable system for simultaneous two-way communication comprising in combination a cable, telephone and telegraph transmitting and receiving circuits connected to said cable, means for impressing signals upon said transmitting circuits, means for separating the several components of the signals so impressed, means for reflecting a portion of one of said signal components back to the local receiving circuit, and means for cancelling the signal component so reflected.

17. A submarine cable system for simultaneous two-way communication comprising in combination a cable, telephone and telegraph transmitting and receiving circuits connected to said cable, means for impressing signals upon said transmitting circuits, means for separating the components of the signals so impressed, means for delaying one of said signal components.

18. A submarine cable system for simultaneous two-way communication comprising in combination a cable, telephone and telegraph transmitting and receiving circuits connected to said cable, means for impressing signals upon said transmitting circuits, means for separating the components of the signals so impressed, and means for delaying and reversing the polarity of one of said signal components.

19. A submarine cable system for simultaneous two-way communication comprising in combination a cable, telephone and telegraph transmitting and receiving circuits connected to said cable, means for impressing signals upon said transmitting circuits, means for separating the components of the signals so impressed, means for delaying and reversing the polarity of one of said signal components, means for reflecting a portion of the remaining signal component back to the local receiving circuit and there cancelling it by means of the delayed signal component.

20. In a simultaneous two-way submarine signalling system wherein each end of the cable is divided into two branches, one for transmitting and the other for receiving, the method of preventing the signals transmitted at one end from interfering with the receiver thereat, which comprises impressing a portion of each transmitted signal directly upon the receiving branch in such magnitude, phase and polarity as to balance the signal component impressed on the receiving branch at the cable junction.

21. In a submarine cable system for simultaneous two-way telephone and telegraph communication wherein each end of the cable is divided at a point remote from shore into two branches, one for transmitting and

the other for receiving, the method of preventing the signals transmitted at one end from interfering with the receiver thereat, which comprises impressing a portion of each transmitted signal directly upon the receiving branch in such magnitude, phase and polarity as to balance the signal component impressed on the receiving branch at the sea junction point.

In witness whereof, I hereunto subscribe my name this 5th day of March, 1930.

RALPH E. A. PUTNAM.