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ELECTRIC WAVE SYSTEM

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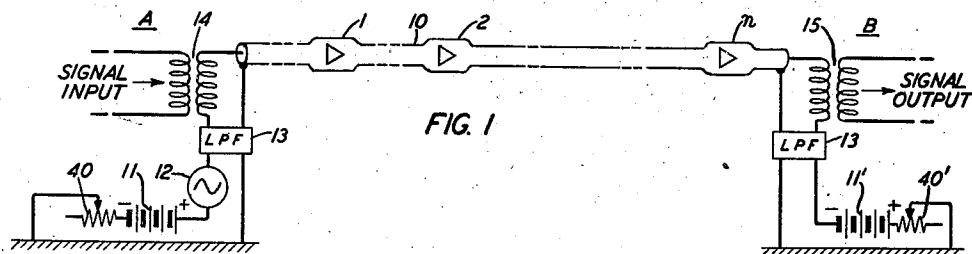


FIG. 2

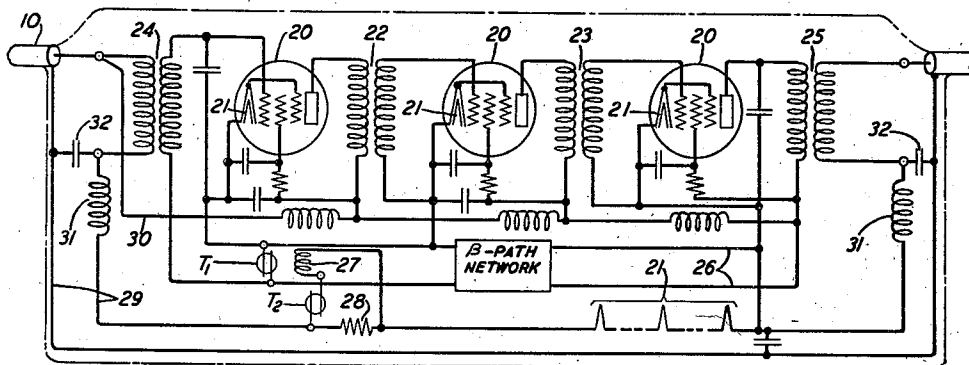
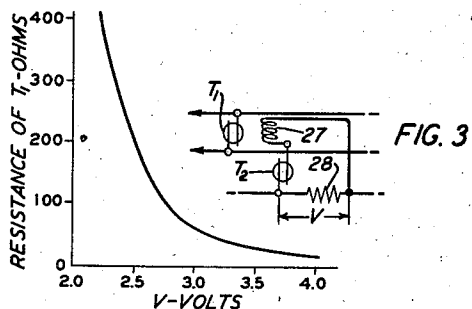
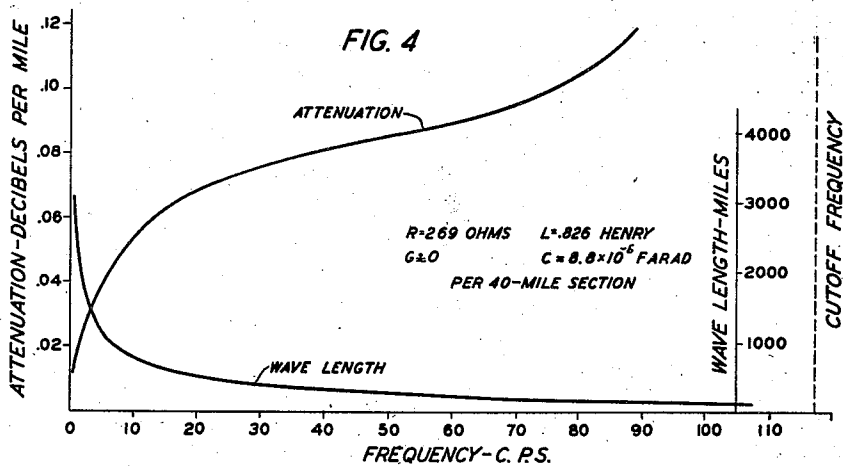


FIG. 4



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ELECTRIC WAVE SYSTEM

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The invention relates to electric wave systems, and, more particularly, to a transmission system including a submarine cable having one or more repeaters or amplifiers inserted therein at spaced intervals between its ends.

An object of the invention is to improve submarine signal systems.

Another object is to enable regulation of the gain of an amplifier in a submarine cable in a simple and efficient manner.

A further object is to enable selective regulation of the gain of a plurality of amplifiers inserted in a submarine cable at spaced intervals between the shore ends thereof.

In accordance with this invention there are still other objects are realized in a transmission system comprising a transmission line, specifically, a submarine cable, having a plurality of amplifiers inserted therein at spaced intervals between the ends thereof, the signal current to be amplified and the energizing current for the electronic devices in the amplifier being transmitted over the line from one end thereof. Each amplifier includes a stabilizing negative feedback connection incorporating a temperature-dependent resistance element or thermistor, variation in the resistance of which is adapted to vary the gain-reducing effect of the feedback connection. The temperature and, therefore, the resistance of the thermistor, is dependent on the magnitude of the energizing current supplied over the line, the energizing current normally being of a substantially fixed or constant value. The gains of all of the amplifiers may be simultaneously adjusted by a change in the magnitude of the energizing current, or the gains of some or all of the amplifiers may be changed to the same or different degrees by superposing on the substantially constant energizing current a low frequency control current which may be an electric wave of sinusoidal or of the square topped type. The low frequency current may be of the order of a fraction of a cycle per second or of the order of a few cycles per second, and may have a wave-length equal to or approximating the length of the transmission line.

A more complete understanding of the invention will be obtained from the detailed description that follows, taken in conjunction with the appended drawing, wherein:

Fig. 1 represents a submarine cable or transmission system for signal transmission in one direction between two widely separated points;

of a repeater or amplifying station included in the cable of Fig. 1 at spaced intervals;

Fig. 3 shows the volts-resistance characteristic curve for a thermistor circuit included in the amplifier of Fig. 2 for gain control purposes; and

Fig. 4 shows the attenuation and wave-length versus frequency characteristics of a submarine cable over a portion of the low frequency range.

With reference in particular to Fig. 1, there is shown a submarine cable 10, connecting two land points A, B, for transmission of signal currents in one direction, for example, from point A to point B. This cable may be of the general type disclosed in O. E. Buckley-O. B. Jacobs Patent No. 2,020,297 of November 12, 1935, in that it encloses a plurality of carrier frequency signal repeaters or amplifiers 1, 2 . . . n at spaced intervals; power supply for the amplifying devices at the amplifiers being furnished over the cable from suitable sources 11, 11', for example, batteries, at the ends of the cable. In accordance with a feature of the invention, a source 12 of very low frequency alternating current may be connected in the power supply path at one end of the cable. The source 12 may comprise a suitable alternating current generator; or it might comprise a variable resistance caused to increase and decrease cyclically between pre-assigned limits at a desired frequency, whereby the current supplied to the cable from the power supply contains a low frequency component. A low pass filter 13 may be inserted between the cable and the sources 11, 11' to confine the signal currents to the cable and the input and output transformers 14, 15 at the ends of the cable.

Fig. 2 is illustrative of the repeaters or amplifiers 1, 2 . . . n enclosed at spaced intervals in the cable 10. Each amplifier may comprise a plurality of electronic devices, specifically, vacuum tubes 20, connected in tandem and comprising an indirectly heated cathode, an input grid, a screen grid, a suppressor grid and an anode. The heater filaments for the tubes are indicated by the numeral 21. The interstage networks 22, 23 may be transformers, the initial electronic device being connected with the cable through an input transformer 24 and the final stage with the cable through output transformer 25. The amplifier circuit may be of the type that includes a stabilizing negative feedback connection or path 26 of the general type proposed in H. S. Black Patent No. 2,102,671 of December 21, 1937. A temperature-dependent variable resistance or thermistor T_1 is connected

across the feedback path, and may comprise a bead of a material or substance having a high positive or negative temperature coefficient of resistance, for example, uranium oxide, which has a high negative temperature coefficient of resistance. The thermistor T_1 , as explained in greater detail hereinafter, is provided for amplifier gain control purposes, and is adapted to be heated indirectly by a heater coil 27 connected in series with a second thermistor T_2 across a resistor 28. The resistor 28 is connected in series with the heater filaments 21 in the power supply connection or loop 29 around the amplifier. Anode and screen grid potentials for the electronic devices are provided over the cable and connection 30 in the amplifier, the necessary difference of potential between anode and cathode being obtained by connecting the latter to the point of lowest relative potential in the amplifier, and the anode to the point of highest relative potential. The anode and screen potentials therefor are provided by the potential drop across the heaters 21 and incidental resistances in the power supply loop at the amplifier, the direction of power supply current flow being assumed from left to right in Fig. 2. Low-pass filters comprising coils 31 and condensers 32 segregate the signal currents channel and the power supply loop 29.

The arrangement described permits of remote control, that is, from one end of the transmission system, of the gains of amplifiers enclosed in a submarine cable. The cable with its self-contained amplifiers would, of course, be laid with the expectation of not doing any maintenance on the amplifiers except in the event of a disabling fault requiring a major repair.

Automatic or manual gain control arrangements are usually included in transmission systems intended for use either in the open air or buried in the earth because of the effect of temperature variations on the attenuation characteristic of the transmission line embodied in the system. This problem does not exist with submarine transmission systems, particularly in the case of a cable on a ocean bottom, since the temperature thereat is substantially invariable. For one or more of the following reasons, it may be desirable, however, to be able to control from the shore terminals the gain of the amplifiers embodied in a system such as has been described with reference to Figs. 1 and 2: The amplifier gain will decrease slowly with time because of ageing of the electronic devices. Unavoidable small errors in design calculations for the system may make initial gain adjustment necessary. In testing the submarine cable after it has been laid and particularly in trying to locate an amplifier that has developed a fault, a method and means of changing the amplifier gain would be useful. Because of noise conditions resulting from unanticipated disturbances or originating in noise sources of a temporary character, it may be desired to change the gains of some of the amplifiers by an amount different from that of the others.

In accordance with one feature of the invention the gains of all of the amplifiers may be changed simultaneously by changing in a small amount the magnitude of the direct current supplied over the cable from the sources 11, 11'. This change in the magnitude of the direct current may be effected by adjustment of the variable resistances 40, 40'. The change in the direct current could be too small to have any adverse effect upon the

operation of the electronic devices, but yet be sufficient to cause a change in the resistance of the thermistor T_1 , the temperature of which is controlled by the potential drop in the resistor 28. Variation in the potential drop across the resistor 28 causes a variation in the heating effect of the series-connected heater coil and the thermistor T_2 on the thermistor T_1 . The thermistor T_2 , it will be noted, is directly heated, and introduces a booster or amplifier effect with respect to the heating current flowing in the heater coil. Although the thermistor T_1 is shown connected in shunt in the feedback path of the amplifier, it could be connected in the series path of the feedback connection; the shunt arrangement is preferable, however, because failure of the thermistor T_1 because of ageing or burning out merely changes the gain of the amplifier by a small amount, whereas, if the thermistor were connected in the series path of the feedback connection, the amplifier would be disabled. Variation in the temperature and, therefore, in the resistance of the thermistor T_1 varies the amount of loss in the feedback connection and, consequently, causes a change in the over-all gain of the amplifier. Fig. 3 shows a characteristic curve for a typical thermistor circuit such as is included in the amplifier of Fig. 2. Along the horizontal axis is plotted voltage across the series-connected heater coil 27 and thermistor T_2 , and along the vertical axis is plotted the resistance of the thermistor T_1 . If the direct current supplied over the cable were .25 ampere, and the resistance of the resistor were 10 ohms, 2.5 volts would normally be impressed on the thermistor circuit, under these conditions the thermistor T_1 would have a resistance of 200 ohms. If the beta circuit impedance were of the order of, say, 250 ohms pure resistance, the 200 ohms thermistor would then introduce a loss of 4.2 decibels in the feedback path. A change as small as ± 2 per cent in the direct current would cause a change of voltage across the resistor 28 of from 2.55 to 2.45 volts and this in turn would cause a change in the resistance of the thermistor T_1 from 170 to 230 ohms. Such changes in the resistance of the thermistor T_1 would vary the loss in the beta circuit from 4.8 decibels to 3.8 decibels. Since, in feedback amplifiers as generally designed, the change in gain obtained is substantially equal to the change in the loss in the beta circuit, the gain of the amplifier would be changed over a range of one decibel. If it is assumed that the amplifiers are spaced forty miles apart and that the cable is 2,000 miles long, this would provide a total range of gain control of the order of 50 decibels.

Changes of a fixed amount in the magnitude of the direct current supplied from the ends of the cable would produce equal changes in gain in all of the amplifiers in the cable. In accordance with another feature of the invention, the gain of some amplifiers may be changed to a different extent than that of others in the cable. This may be done by superimposing a slowly varying alternating current on the normal steady supply current, for example, by means of the device 12. Since the variable component of the total current would be attenuated and the steady component would not, the effective value of the total current would decrease along the cable. As a result, the gains of the amplifiers nearest the control terminal would be affected more than would those at more distant points. By sending the variable component of current from one end or the other of the cable, the amplifiers at either end could

be so controlled. In order to exercise an inverse type of selective control, that is, one in which the gains of the amplifiers in the central portion of the cable would be changed more than those near the ends of the cable, the thermistor circuit of the amplifiers should be of varying sensitivity, with the more sensitive ones in the amplifiers near the middle of the cable, so that a given change or variation in the power supply current produces more change in gain in the amplifiers near the middle of the cable than in those near the end. Any mode of gain variation along the cable between this condition and the condition where all the gain changes are alike may be obtained by superimposing an appropriate magnitude of slowly varying alternating current at the end of the cable to compensate for the lesser sensitivity of the thermistor circuits in the amplifiers nearest the ends of the cable.

To obtain an appreciable change in the effective value of the total current sent through the power supply loop of the amplifiers may require an alternating current of appreciable magnitude. If the normal or steady value of the power supply current is I_0 , and the maximum amplitude of the sinusoidal current is I_1 , the effective total current is

$$I = \sqrt{I_0^2 + \frac{1}{2} I_1^2} \quad (1)$$

or

$$\frac{I}{I_0} = \sqrt{1 + \frac{1}{2} \left(\frac{I_1}{I_0} \right)^2} \quad (2)$$

This indicates that if the superimposed sinusoidal current has an amplitude of one-tenth that of the steady current, the effective value of their combination would be of the order of one per cent greater than the steady current. To obtain a 2 per cent increase in the total effective current requires that the amplitude of the varying current be made about 28 per cent that of the steady current. The desired result, however, could be obtained with smaller peak current fluctuations by using a square topped wave instead of a sinusoidal wave. Such a square-topped wave could be generated, of course, by means of a simple commutator arrangement. For a superimposed square-topped wave of amplitude I_2 , the formula for the effective value of the total current would be

$$\frac{I}{I_0} = \sqrt{1 + \left(\frac{I_2}{I_0} \right)^2} \quad (3)$$

To obtain a 2 per cent increase in effective current would then require that I_2 be only 20 per cent of I_0 .

Fig. 4 shows an attenuation vs. frequency and a wave-length vs. frequency characteristic curve for the power supply channel of a submarine cable of the type disclosed herein and having the constants indicated in the figure. The power channel is essentially a heavily "loaded" circuit with a low cut-off frequency, the "loads" being the filter coils at each amplifier. It will be noted that the attenuation is substantial, and increases very rapidly with increase in frequency. By way of example, it will be observed from the attenuation-frequency curve that for a current varying at the rate of say one cycle per second, the attenuation is of the order of .0185 decibel per mile, or .185 decibels for a thousand miles, which is about half the length of a transatlantic cable. The effect on the amplifier gains of superimposing a one cycle per second current on the

normal steady current, would be felt only close to the end of the cable. For a superimposed current varying at the rate of one cycle in four seconds, the loss would be of the order of about 9 decibels for about a thousand miles.

If the amplitude of a superimposed sinusoidal current at the sending end were a fraction δ of the normal steady current, the total current would increase by the factor

$$\frac{I}{I_0} = \sqrt{1 + \delta^2} \approx 1 + \frac{\delta^2}{4} \quad (4)$$

At the middle of the cable the total current would then be increased by the factor

$$\frac{I}{I_0} = \sqrt{1 + \frac{(.355\delta)^2}{2}} \approx 1 + \frac{.126\delta^2}{4} \quad (5)$$

If all of the thermistor circuits at the amplifiers were alike, the changes in gains of the amplifiers at the middle of the cable would be about one-eighth of those at the control end of the cable. Conversely, to obtain approximately uniform gain changes under these conditions would require that the thermistors at the middle of the cable be eight times as sensitive relatively.

The use of superimposed slowly varying alternating current for selective gain control would not cause the amplifier gains to go up and down appreciably with the variation because of the stabilizing effect of feedback. In addition, the modulation envelope produced at successive amplifiers would be out of phase and the "ripple" would tend to average out. The thermistor T_1 at each amplifier should be proportioned so as to have sufficient lag in heat transfer so that its resistance does not follow the slow variation in the power supply current.

Although this invention has been disclosed with reference to certain specific embodiments, it will be understood that it is not limited thereto, but that its scope is evidenced by the appended claims.

What is claimed is:

1. A signaling system comprising a transmission line over which a substantially constant current is supplied from an end of the line to a power consuming device in said line, and means for superimposing on said current an alternating current of wave-length of the order of that of the length of the line for regulating said device.

2. A signaling system comprising a submarine cable over which a substantially constant current is supplied from an end of the cable to a power consuming amplifying device in said cable between the shore ends thereof, and means for superimposing on said current an alternating current of wave-length of the order of that of the length of the cable for regulating the gain of said amplifying device.

3. In a transmission system comprising a transmission line and an amplifier inserted in the line between the ends thereof and in which both the signal current to be amplified and the energizing potential and current for the amplifier are supplied to the amplifier over the line, means to superimpose on said energizing current a low frequency alternating current and means in said amplifier to vary the gain of the amplifier, said means being responsive to said low frequency alternating current.

4. In a transmission system comprising a submarine cable and an amplifier inserted in the cable between the shore ends thereof and in which both the signal current to be amplified and the energizing potential and current for the amplifier

are supplied to the amplifier over the cable, means to superimpose on said energizing current a low frequency alternating current and means in said amplifier to vary the gain of the amplifier, said means being responsive to said low frequency alternating current.

5. A signaling system comprising a transmission line over which a substantially constant current is supplied from one end of the line to a power consuming amplifying device in said line, and means for introducing a low frequency component in said current for regulating the gain of said device.

6. A signaling system comprising a transmission line over which a substantially constant current is supplied from one end of the line to a plurality of power consuming amplifying devices inserted at spaced intervals in said line between the ends thereof, and means for introducing a low frequency component in said current for selectively regulating the gains of said devices.

7. A signaling system comprising a submarine cable over which a substantially constant current is supplied from one end of the cable to a power consuming amplifying device inserted in said cable between the shore ends thereof, and means for introducing a low frequency component in said current for regulating the gain of said device.

8. A signaling system comprising a submarine cable over which a substantially constant current is supplied from one shore end of the cable to a plurality of power consuming amplifying devices inserted in said cable at spaced intervals between the shore ends thereof, and means for introducing a low frequency component in said current for selectively regulating the gain of said devices.

9. A signaling system comprising a transmission line, a plurality of signal current amplifiers inserted therein at spaced intervals between the ends thereof, a gain reducing feedback connection in each amplifier, a thermistor in the feedback connection for varying the gain reducing effect of the feedback connection, each amplifier having a signal current path therethrough and a power supply path therearound, means at one end of the line for supplying a substantially constant current over said line and through the power supply path at each amplifier to provide the required energizing potential and current to each amplifier and its thermistor; and means to introduce a low frequency component in said power supply current to selectively regulate the temperature of the thermistors.

10. A signaling system comprising a submarine cable, a plurality of signal current amplifiers inserted in the cable at spaced intervals between the shore ends thereof, a gain reducing feedback connection in each amplifier including a thermistor for varying the gain reducing effect of the feedback connection, each amplifier having a signal current path through the amplifier and a power supply path around the amplifier, means at a shore end of the cable to supply a substantially constant current over said cable and through the power supply path at each amplifier to furnish the required energizing potential and current to each amplifier and thermistor, and means to introduce a low frequency component in said power supply current to selectively regulate the temperature of each thermistor.

11. A signaling system comprising a transmission line, and an amplifier in said line adapted to receive the signal current to be amplified and

amplifier energizing current over said line from one end thereof, said energizing current comprising a direct current component and a subaudible low frequency component.

12. A signaling system comprising a transmission line, a signal current amplifier inserted therein between the ends of the line, a gain reducing feedback connection in said amplifier, a thermistor in the feedback connection for varying the gain reducing effect of the feedback connection, said amplifier having a signal current path therethrough and a power supply path therearound, means at one end of the line for supplying a substantially constant current over said line through the power supply path at the amplifier to provide the required energizing potential and current to the amplifier and its thermistor, and means to introduce a low frequency component in said power supply current to regulate the temperature of the thermistor.

13. The system of claim 12 in which the power supply path around the amplifier includes means for indirectly heating the thermistor, said heating means including a second thermistor.

14. A signaling system comprising a transmission line over which a substantially constant current is supplied from one end of the line to a power consuming device in said line, said power consuming device including a thermistor, means for transmitting periodically varying current over said line and means for causing said periodically varying current to regulate said device through variation of the temperature of said thermistor.

15. A signaling system comprising a transmission line over which a substantially constant current is supplied from an end of the line to a power consuming amplifying device in said line, said amplifying device including a gain regulating circuit containing a thermistor, means for transmitting periodically varying current over said line and means for causing said periodically varying current to regulate said gain circuit through variation of the temperature of said thermistor.

16. A transmission system comprising a transmission line and an amplifier inserted in the line between the ends thereof and in which both a signal current to be amplified and the energizing potential and current for the amplifier are supplied to the amplifier over the line, means to superimpose a low frequency alternating current on said energizing current and a thermistor in said amplifier to vary the gain of the amplifier, said thermistor being responsive to said low frequency alternating current.

17. In a transmission system comprising a submarine cable and an amplifier inserted in the cable between the shore ends thereof and in which both the signal current to be amplified and the energizing potential and current for the amplifier are supplied to the amplifier over the cable, means to superimpose a low frequency alternating current on said energizing current and a thermistor in said amplifier for varying the gain of the amplifier, said thermistor being responsive to said low frequency alternating current.

18. A signaling system comprising a submarine cable over which a substantially constant current is supplied from one shore end of the cable to a plurality of power consuming amplifying devices inserted in said cable at spaced intervals between the shore ends thereof, a thermistor in each of said amplifying devices, and means for introducing a low frequency component in said current for selectively regulating the gains of said devices

through variation in the temperatures of said thermistors.

19. In a transmission system comprising a power consuming device at a distance from the source of power supply for said device, the method that comprises transmitting a primary substantially constant current from said supply to said device to energize the latter and introducing a low frequency alternating current component in said primary current for regulating the power level of said device.

20. In a transmission system comprising a power consuming device at a distance from the source of power supply for said device, the method that comprises transmitting a direct current from said supply to said device to energize the latter and introducing a sinusoidal component in said primary current for regulating the power level of said device.

21. In a transmission system comprising a power consuming device at a distance from the source of power supply for said device, the method that comprises transmitting a direct current from said source to said device to energize the latter and introducing a square-topped wave component in said direct current for regulating the power level of said device.

22. The method of claim 19 in which said alternating current component is of subaudible frequency.

23. The method of claim 20 in which said sinusoidal component is of subaudible frequency.

24. The method of claim 21 in which said square-topped wave component is of subaudible frequency.

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