Aug. 20, 1946. R. B. SHANCK 2,406,042

CARRIER TELEGRAPH SYSTEM

Filed July 22, 1942

FIG. 1

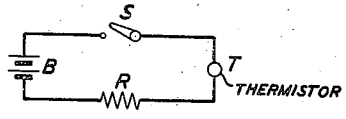


FIG. 2

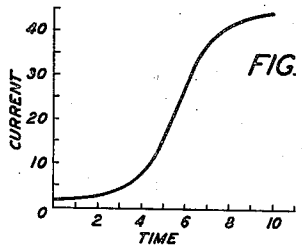


FIG. 3

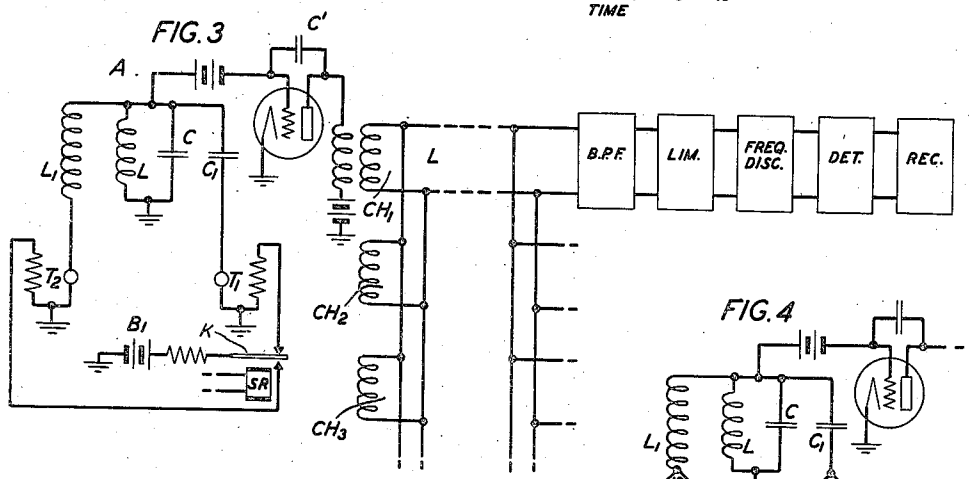


FIG. 4

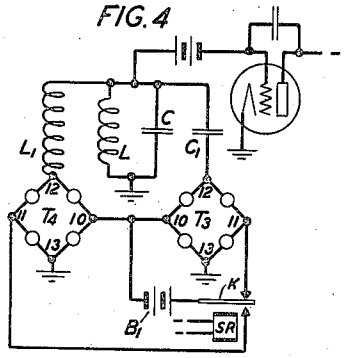


FIG. 5

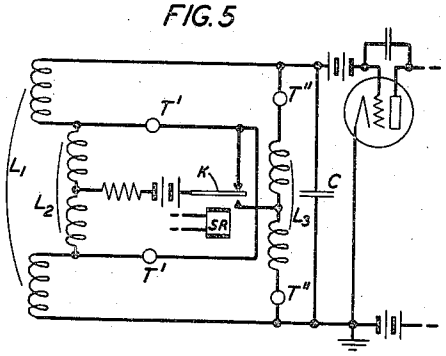
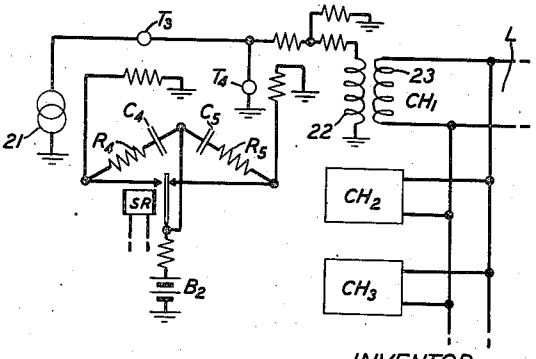


FIG. 6



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CARRIER TELEGRAPH SYSTEM

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Application July 22, 1942, Serial No. 451,905

9 Claims. (Cl. 178—66)

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This invention relates to signaling and in one form relates to carrier frequency telegraphy in which signals of different characteristics are used in the marking and spacing periods. More specifically it relates to a system in which one of the periods at least is characterized by a carrier frequency current, and in which the other period may be characterized by a current of zero frequency and zero amplitude, that is, no current. Still further it relates to a system in which two or more frequencies may be used to correspond to the different characteristics of the signal, such as the marking and spacing periods.

The invention will be described in connection with telegraph signaling but, as will be apparent to those skilled in the art, it is applicable to transmission system such as telephone signaling, telemetering, remote control, and picture transmission.

In practically all telegraph circuits, particularly those which operate simultaneously over wires or radio, it is desirable to round off the transmitted signal waves in order to avoid interference in neighboring signal channels. This is commonly done by providing either channel filters or "noise killers" or both. Furthermore, in the case of frequency modulation telegraphy it has been found that a gradual transition from one frequency to the other is of benefit from a transmission standpoint.

It is the object of the present invention to effect this rounding off by means which change the physical characteristics of one or more elements in a circuit. One specific means which I have found of particular value comprises an element commonly classed as a semiconductor, possessing the characteristic of substantial change in resistance with change in temperature. Such materials may be employed to form circuit elements by fusing or otherwise binding platinum or other conductor leads into electrical contact with a suitable quantity of the semiconductor compound. These elements are ordinarily of comparatively high resistance but as the temperature is raised, either because of an external heater or because of the heating effect of such current as is flowing through the element, the resistance falls very greatly. The device therefore takes on the nature of a switch in which the control is exercised through change in temperature. Devices of this kind have been called "thermistors" and for convenience that term will be used throughout the specification and claims as defining such a device.

The invention will be better understood by reference to the following specification and accompanying drawing in which:

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Figs. 1 and 2 illustrate the characteristics of a typical thermistor;

Fig. 3 shows a frequency modulation telegraph system including certain thermistors;

Figs. 4 and 5 show modifications of this circuit; and

Fig. 6 shows a carrier frequency telegraph system using amplitude modulation, the control of the circuit still being through thermistors.

Referring more specifically to Fig. 1, there is shown a circuit comprising a battery B, a resistance R and a thermistor T in series with each other and under control of a switch S. When the switch S is closed it finds the thermistor element offering a high resistance. The current flowing through a heating element or through the semiconductor gradually raises the temperature, and the resistance of the semiconductor element falls with a corresponding increase in current from the battery B. The manner in which the current through the circuit may increase as a function of time is shown in the curve of Fig. 2. This represents the general behavior of thermistors and it will be understood that the relationship between current and time can be adjusted to a desired form by change in the heating element or the size or the composition of the compound forming the thermistor element.

Referring more particularly to Fig. 3, there is shown a line L at one end of which is a transmitter A. This transmitter is shown as comprising a vacuum tube oscillator of the tuned grid circuit type, including a condenser C' from grid to plate and a tuned grid circuit LC. Connected in parallel with this tuned circuit is a condenser C_1 in series with a thermistor T_1. Also in parallel with the tuned circuit is an inductance L_1 in series with thermistor T_2. Associated with each thermistor is a heating element, one or the other of which is supplied with heating current from a battery B_1, dependent upon whether the key K is in marking or spacing position, the key K being itself subject to the sending relay SR.

The frequency of the transmitting oscillator is determined substantially by the resonant circuit LC when the two thermistors have high impedances. With the sending relay tongue resting on its upper contact the impedance of T_1 is reduced to a small value, effectively connecting C_1 in parallel with C so that the oscillator frequency is reduced. When the tongue leaves the upper contact, T_1 is deprived of heating current and will start to cool. When the tongue travels across to

the lower contact the impedance of T_2 will commence to diminish and inductance L_1 will be gradually effectively connected in parallel with L so as to increase the oscillator frequency. At the same time, due to the cooling of T_1, C_1 is gradually disconnected from C and this likewise serves to increase the frequency. Operation of the relay tongue, back to the upper contact results in gradual decrease of frequency in a similar manner. Thus with proper selection of the thermistor and proper proportioning of the circuit elements, the oscillator frequency can be swung to and fro between spacing and marking frequencies at constant amplitude, the change being made gradually in a time, for instance, in the order of one-third or one-half of the duration of a perfect or square dot signal element. Under these conditions it is apparent that there is obtained a frequency modulated carrier telegraph signal in which the amplitude of the wave is constant but the frequency changes gradually from that corresponding to a marking period to that corresponding to a spacing period, or the reverse.

In a frequency modulated signaling system in which there is a swing from f_1 to f_2, with a carrier of mid-frequency f_0, all at constant amplitude, the side frequencies comprise an infinite series of frequencies spaced from the carrier by an amount

$$\frac{v}{2\pi}$$

where v is the frequency of the swing. The amplitude of the successive components will depend on the way in which the change is made from the one frequency to the other and their amplitude falls off to negligible values most rapidly if the form of modulation is itself sinusoidal. For a "square top" modulation, that is, a very sudden change from one frequency to the other, the side frequencies fall off in amplitude rather slowly so that the signal occupies a relatively wide frequency band. By rounding off the corners of a square top envelope, representing the character of the modulation, the essential band width is narrowed and the extent of deleterious effects on neighboring signal channels is correspondingly reduced while still retaining the advantages inherent in frequency modulation.

With the circuit of Fig. 3 I find it possible to obtain a modulation character closely approaching a sine wave for frequency versus time, if desired. In any case, with this circuit it becomes possible either to eliminate or to simplify the sending channel filters, especially in the case of a multichannel system. In the case of the latter system the transmitters of all channels would ordinarily be connected to the line circuit in parallel, either directly or with a suitable resistance pad inserted in each channel.

Fig. 4 shows a modification of Fig. 3 in that the temperature and therefore the resistance of the thermistor is controlled by the current flowing through the thermistor, rather than by a separate heating element. The circuit is the same as that of Fig. 3 except that the thermistors T_1 and T_2 are replaced by balanced bridge thermistors T_3 and T_4, each comprising four thermistors. Thus, if the thermistors of T_3 are matched, then the points **10** and **11** are conjugate to the points **12** and **13**. Any voltage, such as that from the battery B_1, impressed on the points **10** and **11** will cause current to flow through the thermistors, thus altering the temperature, but there will be no voltage set up therefrom across

the points **12** and **13**. Similarly alternating current voltage coming through the condenser C_1 and setting up potential differences from **12** to **13** will give no potential difference between the points **10** and **11**. Thus in this array there is maintained complete separation of the direct current source and the alternating current source. The same holds for the thermistor bridge T_4. For this circuit it may be desirable that the battery B_1 shall not be connected to ground. Aside from these changes the circuit of Fig. 4 operates in the same manner as the circuit of Fig. 3. That is, when battery current flows through T_3 the resistance in the condenser branch falls to a low value, effectively connecting the condenser C_1 in circuit and when the battery is connected across T_4 the inductance L_1 is effectively connected in the circuit.

Fig. 5 shows still a further modification requiring but four thermistors whereas that of Fig. 4 requires eight.

In the circuit of Fig. 5 there are shown three inductances L_1, L_2 and L_3. When the tongue K is on spacing position the thermistors T' have their resistances lowered, placing a short circuit across L_2. At the same time the thermistors T'' are at high resistance so that the inductance L_3 is effectively disconnected. The frequency f_1 of the oscillator is then determined by the inductance L_1 and condenser C. In the transition condition the resistance of the thermistors T' rises gradually introducing the inductance L_2 whereupon the frequency of the oscillator slowly falls. On marking position the resistance of the thermistors T' will have risen to a high value and the resistance of the thermistors T'' will have fallen, placing the inductance L_3 in parallel with L_1, L_2, thus lowering the effective inductance. By choosing the appropriate magnitude for the inductance L_3 this lowered effective inductance will be such that the resultant frequency f_2 will be raised to a value higher than that corresponding to the transition value and may be adjusted so that the intermediate frequency f_0 during transmission will be substantially equal to

$$\frac{f_1+f_2}{2}$$

While Figs. 4 and 5 show two circuits in which the temperature of the thermistors is controlled by the direct current flowing through the semiconductor compound, it is apparent that many variations of this circuit may be devised and the two shown are for illustrative purposes only.

Fig. 6 shows a modification of my invention in which a wave of any suitable frequency, such as that in the voice range or in the more usual carrier range, is applied for one of the periods, such as the marking period of the telegraph signal, and no current is transmitted for the other period, this corresponding to amplitude modulation rather than frequency modulation. In Fig. 6 a source of frequency **21** is connected to the primary **22** of a transformer, the secondary **23** of which is connected to line L. A thermistor T_3 is connected in series and the thermistor T_4 is connected in shunt with the primary **22**.

A sending relay SR operates to apply battery B_2 to the heating element of T_4 when the armature is on spacing position. In this case the resistance of T_4 becomes very low and serves as a substantial short circuit to the primary **22**. At the same time the thermistor T_3 is in the con-

dition of high resistance, still further suppressing current from the source 21. When the tongue of SR moves to marking position, the resistance of T_3 is lowered and the resistance of T_4 rises so that current from the source 21 then flows through the primary 22 to impress the signal on the line L through channel 1. A plurality of other channels may also be similarly associated with the line L, channels 2 and 3 being indicated.

A spark-killing arrangement comprising condensers C_4 and C_5 and resistances R_4 and R_5 is shown connected to the tongue of the sending relay. Here again it will be observed that the transition from the marking to spacing condition is gradual which makes it possible to dispense with sending filters and other attachments characteristic of many present telegraph systems, or to use simpler types of filters.

What is claimed is:

1. A carrier telegraph transmitter adapted to impress on the line signals corresponding to marking and spacing conditions, means for changing gradually from the one condition to the other in going from marking to spacing and the reverse, the said means comprising relatively slow-acting thermistor elements and means to vary their temperatures between respective values corresponding to marking and spacing conditions.

2. In a frequency modulation carrier system, a transmitter comprising a source of a plurality of oscillation frequencies and adapted to impress on the line one frequency for marking and another frequency for spacing, means for changing gradually from one frequency to the other in going from marking to spacing and the reverse, the said means comprising a device which changes the frequency on the line from the one frequency to the other, said device comprising a slow-acting thermistor, a source of heating current therefor and means to vary the heating current in accordance with marking and spacing signals.

3. In a frequency modulation carrier telegraph system, a transmitter comprising a source of a plurality of oscillation frequencies adapted to impress on the line one frequency for marking and another frequency for spacing, said source comprising an oscillator and means for changing from one frequency to the other comprising two thermistors one of which in the marking period changes the natural frequency of the oscillator in one direction and one of which in the spacing period changes the frequency in the other direction and means for changing the resistance of each thermistor comprising means to apply a variable amount of heating current thereto.

4. The combination of claim 3 including means for changing the resistance of each thermistor comprising means to pass a direct current through each thermistor to heat the same, and means for changing the strength of the direct current in accordance with telegraphic signals.

5. The combination of claim 3, said thermistors being in circuit paths traversed by oscillatory currents, and means for changing the resistance of each thermistor comprising a circuit for causing direct current to flow in different times through the respective thermistors corresponding respectively to marking and spacing times, and means for maintaining the paths for conducting direct current through the thermistors conjugate to the paths traversed by oscillatory currents.

6. In a carrier telegraph system, a transmitter adapted to impress an oscillatory signal of one amplitude on the line during marking period and a different amplitude during the spacing period, means for changing gradually from the one amplitude to the other in going from marking to spacing and the reverse, said means comprising slow-acting thermistors and means for variably heating the thermistors.

7. In a carrier telegraph system, a transmitter adapted to impress on the line a carrier signal corresponding to marking period and no signal corresponding to spacing period, the transmitter comprising a source of carrier frequency, a thermistor in series with the source and the line, a second thermistor shunting the line, means for supplying heating current to control the resistance of the thermistors such that during marking period the series thermistor is at low resistance and the shunt thermistor is at high resistance and during spacing period the series thermistor is at high resistance and the shunt thermistor is at low resistance, the rate of change of the resistance of the thermistors being relatively low so that on the line the amplitude of the impressed frequency changes gradually from the one condition to the other.

8. In a frequency modulation carrier system, a transmitter comprising a source of a plurality of oscillation frequencies and adapted to impress on the line a different frequency for each signaling condition, and means for changing gradually from one frequency to the other in going from one signaling condition to another, the said means comprising a pair of slow-acting thermistor devices and circuits for supplying variable heating currents thereto.

9. In a carrier telegraph system, means for generating and impressing on the line oscillatory currents of carrier frequency, means to vary the amplitude of the oscillatory currents impressed on the line to indicate telegraphic signals, said latter means including a thermistor having an inherent time lag sufficient to round off the beginnings and endings of the shortest telegraphic impulse to be transmitted, and means to supply to the thermistor a heating current varying in accordance with telegraphic signals.

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