June 20, 1939. P. G. EDWARDS 2,163,195

MECHANICAL RELAY

Filed Oct. 8, 1936

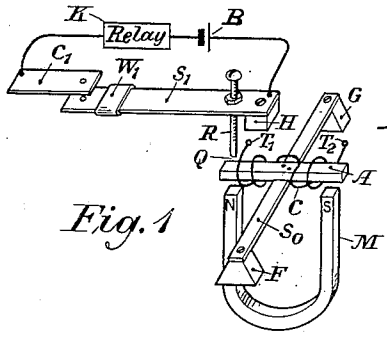


Fig. 1

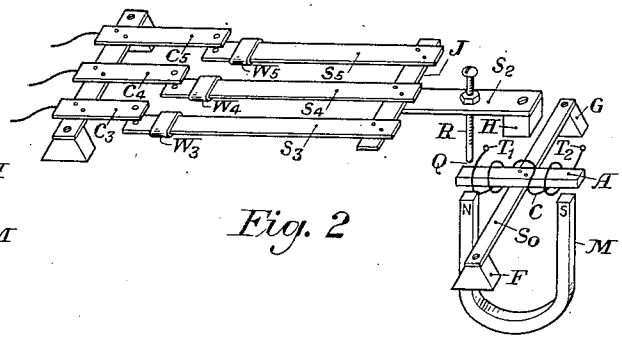


Fig. 2

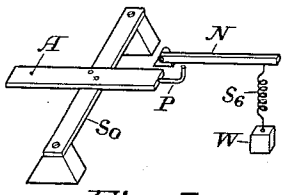


Fig. 3

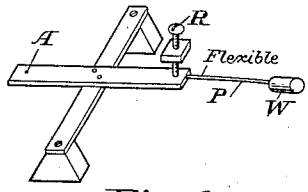


Fig. 4

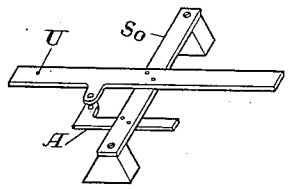


Fig. 5

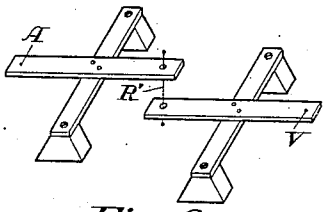


Fig. 6

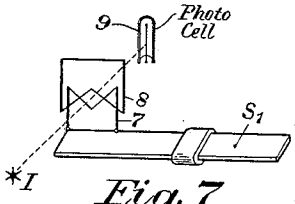


Fig. 7

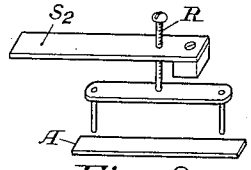


Fig. 8

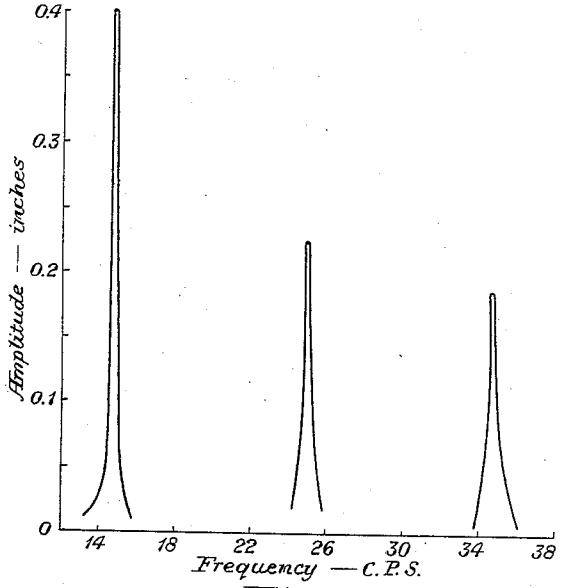


Fig. 9

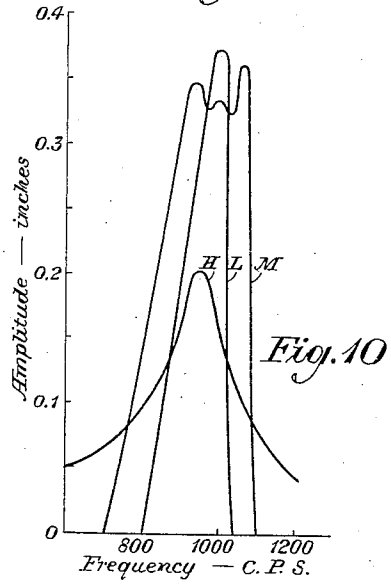


Fig. 10

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MECHANICAL RELAY

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Application October 8, 1936, Serial No. 104,738

22 Claims. (Cl. 178—48)

This invention relates to selective relays, and more particularly to those relays employing means for frequency discrimination. Still more particularly it relates to that class of relays in which a current, or currents of a plurality of frequencies are identified and caused to close and operate related circuits. It relates also to a type of relay in which a double or higher frequency selectivity is employed.

In accordance with the embodiment of the invention, a relay system is arranged to be acted upon by a carrier signal modulated by one or more currents of relatively low frequency, either singly or collectively, and the relay as a result performs a number of functions such as tuning at the carrier frequency, demodulation of the received currents, and tuning at the modulation frequency or frequencies. Moreover, it may then cause closure of one or more contacts, each controlled by one of the modulation frequencies.

The invention will be better understood by reference to the following specification and the accompanying drawing in which Figure 1 shows one form which my invention may take; Fig. 2 shows an amplification of the device of Fig. 1 adapted for multiplex signaling; Figs. 3 to 6 show various modifications of a portion of the device of Fig. 1; Figs. 7 and 8 show modifications of certain details of the previous figures; and Figs. 9 and 10 give curves showing the frequency response characteristics of a device such as that of the device of Fig. 2 under different circumstances.

Referring more specifically to Fig. 1, there is shown an element A possessing inertia and mounted rigidly on a spring member S_0, which latter is mounted on suitable supports F and G. The member A with its spring possesses a natural period of vibration which is determined by its weight and relative dimensions and the resiliency of the spring S_0 upon which it is mounted, preferably symmetrically. The member A, which is magnetic, is so mounted that its two ends are adjacent to the poles of a permanent magnet M. Around the member A is a coil C physically free from the member A but so adjusted that current passing through the coil will magnetize the member A.

Mounted on a support H is a second spring member S_1 supplied with a weight W_1. Adjacent to the free end of this spring is a contact member C_1 which leads to a circuit to be controlled, such for example, as the relay K which is included in circuit with battery B, the relay being preferably a slow release relay. Also associated with the spring member S_1 at a suitable point is a projection such as a screw member R, adjusted to be in contact or near contact with one portion of the element A.

The member A and its spring S_0 are preferably so adjusted as to mass and stiffness as to have a natural frequency in tune with a carrier frequency wave to be impressed upon the coil C. The spring S_1 with its weight is tuned to a low frequency which may be a modulating frequency used in connection with the carrier frequency. When a modulated carrier is impressed upon the winding C, A is set into vibration at the carrier frequency, building up and dying away in amplitude at the frequency of the modulation. For instance, assume that the armature A is resonant at 1000 cycles per second (C. P. S.) and that the spring S_1 with its weight has a natural frequency of 15 C. P. S., this frequency being selected at some remote point for modulating the carrier frequency. If the carrier frequency of 1000, modulated at a frequency of 15 C. P. S., is impressed upon the terminals T_1 and T_2 of the coil C, then the armature A is set into vibration at a frequency of 1000 C. P. S., the amplitude of vibration building up and dying away fifteen times per second. At an amplitude more than zero and less than the maximum, the end of the armature is arranged to strike the screw R at Q. Under these circumstances the spring S_1, resonant at 15 C. P. S., will respond under the repeated impacts, which are unidirectional in character, and will be set into vibration at a frequency of 15 C. P. S. For any other modulation frequency the response of S_1 will be negligibly small.

From the above description it is apparent that the device of Fig. 1 is adapted, first, to be selectively responsive to a carrier frequency and then to be selectively responsive to a lower modulation frequency, thus being extremely sensitive to a signal of a certain form, possessing in fact a double selectivity on a frequency basis. It will be apparent that it acts as a demodulating device for a carrier frequency and does this because of the non-linear characteristic of the mechanical system. Also it will be apparent that the relay circuit K acts effectively as a rectifier for the vibrations of the spring S_1.

Fig. 2 shows a modification of my device which is capable of being selectively responsive to a plurality of modulation frequencies. In this modification the high frequency portion of the device may be the same as that of Fig. 1. The projec-

tion member R is, however, secured to a spring member S_2, which is preferably quite stiff. Rigidly secured to the free end of S_2 is a cross-bar J, to which is secured one or more spring members S_3, S_4, S_5, usually of different lengths and each supplied with a movable weight W_3, W_4 and W_5. Adjacent to the free ends of these springs are contact members C_3, C_4 and C_5 which lead to circuits to be controlled in the manner described in connection with Fig. 1. The springs S_3, S_4 and S_5, with associated weights, may have any desired low-frequency tuning. For example, they might be tuned, respectively, to 15, 25 and 35 C. P. S. In general I prefer to make the spring S_2 stiff compared to the subsidiary springs so that only a small amount of coupling occurs between the various low frequency systems. Under these circumstances S_3 will respond with relatively high amplitude if the carrier is modulated with a frequency of 15 C. P. S., and if S_4 and S_5 are tuned to relatively low frequencies, coupling between the low frequency members will not be enough to force the adjacent systems into vibration. In other words, the action of each of the spring and weight systems is independent of the other provided harmonic relations are avoided.

Not only may the carrier be modulated with different low frequencies at different times, thus causing one or another of the low frequency springs to respond, but the carrier may be modulated with more than one frequency at one time and the corresponding springs will be caused to respond simultaneously, but only those springs having a frequency corresponding to a modulation frequency.

Various other schemes of detection may be employed. Thus in Fig. 3 there is shown a fairly stiff member N supported rigidly at one end and from the other end of which there is suspended a coiled spring S_6 and a weight W. From the element A there projects a member P which will periodically make contact with the member N, thus setting the weight W into oscillations if the natural frequency of the spring S_6 and weight W is that of the modulation frequency.

Still another form of the device is shown in Fig. 4, in which a flexible rod, attached to the member A carries a weight W, this flexible rod with the weight W having a natural frequency corresponding to the modulation frequency. A stop R is also provided with which contact will be made when A reaches sufficient amplitude and the resulting disturbance will set the weight W into oscillations when proper frequency relationships are maintained.

In Fig. 5 both the high frequency element A and the low frequency element U are mounted on the spring S_0. Projections from A and U coming close together permit contact when the element A is set in vibration. Thus again periodic unidirectional impulses are given to the member U, yielding results similar to those described in connection with the other figures.

Fig. 6 shows still a further modification in which the high frequency member A is coupled to the low frequency member V by a rigid link or chain link R'. No motion is imparted to the low frequency member unless and until the amplitude of the member A rises above a certain minimum so as to operate on the low frequency member through the link.

One specific form of controlling the subsidiary circuits has been shown in connection with Figs. 1 and 2. Obviously many variations on this may be used. For example, instead of physical contact, it would be feasible to control the circuits through a light beam from a source I operating on a photoelectric cell 9, as shown in Fig. 7, in which the spring member S_1 carries a projection 7, which will then vibrate in front of a complementary member 8 to admit more or less light to a photoelectric cell 9. The form of aperture produced by the complementary elements 7 and 8 may take on a wide variety of forms.

Numerous other modifications of this invention will occur to those skilled in the art. For example, in the device of Fig. 1 as well as the other figures, it would be possible to so arrange the system that an impulse would be given to the projection R by both ends of the member A as it oscillates. Such an arrangement is shown in Fig. 8 where R is shown as bifurcated and having a projection adjacent to each end of the member A.

As an illustration of the effectiveness of this mechanical demodulating device, reference may be made to the experimental curves shown in Fig. 9 in which the amplitude of the different low frequency members of the device of Fig. 2 is shown as a function of the modulating frequency brought in by the carrier. In this particular case the member A and its spring were tuned to 1000 C. P. S. and the system was then excited by a carrier frequency of 1000 C. P. S., which carrier was modulated with a low frequency varying from 12 to 38. Low frequency members, three in number, were tuned approximately to 15, 25 and 35 C. P. S. It will be observed that the resonance curves are exceedingly sharp and of sufficient amplitude to effectively operate the subsidiary controlled circuits. In case the tuning is too sharp it can, of course, be made broader by the introduction of damping in any desired manner, such as light vanes on the vibrating elements.

The particular response curve for any one low frequency member will depend on the positioning of the member R. This is shown in Fig. 10 in which the curve L is the response of the 15-cycle member when the contact with the projection R is very light. It will be observed that sharp resonance is present. For close coupling the curve H is obtained and it will be observed that the amplitude is smaller and the resonance less sharp. For the intermediate setting a curve is secured, as shown by M, and it will be observed that it possesses the characteristic of a band pass filter, and this property, which can be readily attained by an adjustment of the member R, is to be looked upon as an important characteristic of my device.

While it has been stated quite explicity in the specification that the element A with its spring shall be tuned to the carrier frequency of the signaling wave, it is to be understood that this is the preferred construction. It should be noted, however, that this is not necessary and that any carrier frequency may be used so long as it is of sufficient amplitude to give the necessary vibratory motion of the element A. In this event, of course, it will be recognized that for a given power input the response of the element A will not be so large and that there will also be the loss of selectivity which goes with having the element A tuned to the carrier frequency. It will also be noted that while in the description thus far given, double selectivity only on a frequency basis has been described, it is possible to have a higher order of selectivity by using a carrier wave which is modulated with an intermediate frequency which itself is modulated with some low frequency. In this event it would be

desirable to have three stages of mechanical tuning, the first stage being in connection with an element tuned to carrier frequency, the second stage being a mechanical element tuned to the intermediate frequency, and the third stage corresponding to an element tuned to the low modulation frequency, which last element would control any suitable mechanism or circuit. In this case double selectivity on a frequency basis is obtained. A similar result would be obtained with the structure of Fig. 1 if the relay K is mechanically tuned to some low frequency.

While the invention has been described particularly in terms of demodulation of a carrier wave, the reverse process may be accomplished with the same apparatus, namely, a modulation of a carrier frequency. Thus if in Fig. 1 the spring member S_1 is vibrated mechanically or electrically at its natural frequency of say 15 C. P. S. and if at the same time the element A is vibrated mechanically or electrically at its natural frequency, then the periodic contact between the elements S_1 and A will introduce modifications in the amplitude of vibration of the element A at a frequency corresponding to the modulation frequency, and there will appear in the coil C a modulated carrier wave. In this invention then I contemplate either the process of demodulation of a modulated carrier wave by mechanical means or the production of a modulated carrier wave by mechanical means.

What is claimed is:

1. In a device for demodulating a modulated carrier wave, a mechanical element having a vibratory frequency substantially equal to that of the carrier frequency and selectively responsive to the carrier frequency, and a second mechanical element mechanically coupled to the first-mentioned element and having a vibratory frequency substantially equal to a predetermined modulating component of the wave to be demodulated and selectively responsive to said modulation component.

2. In a device for demodulating a modulated carrier wave, a mechanical element having a vibratory frequency equal to that of the carrier wave and selectively responsive to the carrier wave, and a second mechanical element having a vibratory frequency equal to a predetermined modulating component superimposed upon the carrier wave and selectively responsive to said modulating component, the two mechanical elements being non-linearly coupled during vibration.

3. In a device for demodulating a modulated carrier wave, a first mechanical element having a vibratory frequency substantially equal to that of the carrier wave and selectively responsive to the carrier wave, and a second mechanical element having a vibratory frequency substantially equal to a predetermined modulating component superimposed upon the carrier wave and selectively responsive to said modulating component only when the first mechanical element is in vibration.

4. In a device for demodulating a modulated carrier wave comprising a first mechanical element having a vibratory frequency substantially equal to a harmonic of the carrier wave and selectively responsive to energy of the carrier wave, a second mechanical element having a vibratory frequency substantially equal to a harmonic of a predetermined modulating frequency super-imposed upon the carrier wave and selectively responsive to energy of the modulating component, means for vibrating the second mechanical element only during the vibration of the first mechanical element, and signaling apparatus controlled by the second mechanical element.

5. In a device for demodulating a modulated carrier wave comprising a first mechanical element having a vibrating frequency substantially equal to a harmonic of the carrier wave and selectively responsive to energy of the carrier wave, a second mechanical element controlled by the first mechanical element, said second mechanical element having a vibratory frequency substantially equal to a harmonic of the wave of a predetermined frequency superimposed upon the carrier wave and selectively responsive to the energy of the superimposed modulation frequency, signaling apparatus controlled by the second mechanical element, and means whereby the vibration of the second mechanical element is translated into electrical currents of the modulation frequency.

6. In a device for the demodulation of a modulated signal wave by mechanical means comprising a unitary structure including two mechanical elements mechanically coupled to each other, said two elements having mechanical resonance at a high frequency and at a low frequency respectively corresponding to two predetermined components of the modulated signal wave, said elements being responsive only to said two respective components of the modulated signal wave.

7. In a device for the demodulation of a modulated carrier signal wave by mechanical means comprising a unitary structure including two mechanical elements mechanically coupled to each other, said two mechanical elements possessing mechanical resonance at a high frequency and at a low frequency which are substantially equal to harmonics of two predetermined components of the signal wave respectively, said two mechanical elements being non-linearly coupled to each other.

8. In a device for the demodulation of a modulated signal wave by mechanical means comprising a unitary structure having a plurality of mechanical elements possessing mechanical resonance at predetermined frequencies corresponding to harmonic components of the signal wave, respectively, one of said mechanical elements being selectively responsive to the energy of the carrier wave and the other elements being selectively responsive subsequently only to the energy of respective modulation components superimposed upon the carrier wave.

9. In a device for the demodulation of a modulated signal wave by mechanical means comprising a unitary structure, the signal wave including a carrier wave and modulation frequencies simultaneously superposed thereon, said structure possessing a member resonant at a high frequency and a plurality of members simultaneously resonant each at a different low frequency, the high frequency being the frequency of the carrier wave and the low frequencies being modulation frequencies thereof which are simultaneously superposed on the carrier wave.

10. In a device for demodulating a modulated carrier wave and capable of double selectivity of said modulation wave, the modulated carrier wave including a carier wave and modulation frequencies simultaneously superposed thereon, a mechanically vibrating element selectively re-

sponsive to the carrier frequency, a second member coupled to the first and carrying a plurality of vibrating elements selectively responsive simultaneously to different modulation frequencies of the carrier wave, and signaling apparatus controlled by the vibrating elements of modulation frequencies.

11. A signaling system comprising a source which transmits a carrier current upon which is simultaneously superposed any one of a plurality of different low frequency currents, a mechanical vibrating element having a natural frequency of vibration equal to that of the carrier current, a plurality of mechanically vibrating rods each of which has a natural frequency equal to one of the modulating frequencies, a common frame to which all of the mechanically vibrating rods are attached so that each may vibrate independently of theothers, means for coupling said source to the mechanically vibrating element so as to set it in vibration at the frequency of the carrier current, means for imparting the vibration of the first named mechanical element to said common frame, and a plurality of slow release relays each controlled by one of the mechanically vibrating rods.

12. A relay for demodulating a carrier current upon which is superposed any one or more of a plurality of different low frequency currents comprising a mechanical vibrating element having a natural frequency of vibration equal to that of the carrier current, a plurality of rods having different vibratory frequencies each of which corresponds to one of the frequencies used in the modulation of the carrier current, a frame to which one end of each of said rods is permanently fastened so that the other end of each rod may be freely vibratory, means for imparting the mechanical vibrations of the vibrating element to the frame, and a plurality of contacts each intermittently closed by the free end of one of said mechanically vibrating rods when in vibration.

13. A multi-frequency relay comprising a plurality of steel bars, a frame to which one end of each of said bars is permanently fastened so that the other end may be freely vibrated, means for adjusting the vibratory frequency of each of said bars to a different predetermined low frequency, a steel rod which is capable of vibrating at a higher frequency of predetermined value, a coil of wire wound about said rod so as to vibrate said rod when current is transmitted through said coil of appropriate frequency, a U-shaped magnet having two pole pieces which are adjacent to the opposite ends of said rod, and a link permanently fastened to said frame and spaced by a predetermined distance from one of the free ends of said rod so that the vibration of the rod may impart an intermittent motion to said link.

14. The combination of a first bar of iron having a high natural frequency of vibration, a second bar of iron having a low natural frequency of vibration, a source transmitting current of said high frequency upon which is simultaneously superposed current of said low frequency, means responsive to said current for vibrating said first bar of iron at its predetermined frequency, the bars of iron being mechanically coupled to each other so that the vibration of the first bar of iron will vibrate the second bar of iron at its predetermined frequency.

15. The combination of a first bar of iron, means for supporting said first bar of iron at its center so that its ends may freely vibrate at a high predetermined frequency, a second bar of iron, means including a link spaced between one end of the first bar of iron and one end of the said second bar of iron so that the vibration of the first bar of iron will vibrate the free end of the second bar of iron at a low predetermined frequency, a source transmitting currents of the high frequency upon which is simultaneously superposed current of the low frequency, and a coil of wire wound about the first bar of iron, the terminals of said coil being connected to said source.

16. A device for demodulating the current of a first high frequency upon which is simultaneously superposed the current of a second low frequency comprising two iron bars which have different frequencies of vibration and which are mechanically coupled to each other non-linearly, one of said bars having a frequency of vibration equal to said first high frequency and the other a frequency vibration equal to said second low frequency, means for vibrating the first bar of iron, and a circuit controlled by the second bar of iron.

17. A multi-frequency relay comprising a first bar of material, means for supporting said first bar of material at its midpont so that both ends of the bar may freely vibrate, a second bar of material, a link permanently fastened to one end of the second bar of material so that the other end of said second bar of material may freely vibrate, said link being interposed between both bars of material so that an air space will exist between said link and one end of the first bar of material, means for transmitting current of a first frequency which is equal to the mechanical vibrating frequency of the first bar of material, said current having simultaneously superposed thereon a second current having a frequency equal to the frequency of vibration of the second bar of material, and means responsive to said current for initially vibrating the first bar of material and causing the vibration of the free end of the second bar of material.

18. The combination of a coil through which flow currents of a plurality of different frequencies and a plurality of mechanically vibratory members operated in tandem in response to currents flowing through said coil which have frequencies equal respectively to the vibratory frequencies of said members.

19. The combination of a plurality of vibratory members mechanically coupled to each other and having different frequencies of vibration, means for initiating the operation of said members in tandem, and means for maintaining all of said members in simultaneously vibration after they have been initially set into operation.

20. The combination of two vibratory elements having different natural periods, an electromagnetic device through which flow two currents having predetermined frequencies harmonically related to the frequencies of said vibratory elements, one of said elements being adjacent to said electromagnetic device and responding to one of said two currents of the appropriately related harmonic frequency, and means responsive to the vibration of the latter element to vibrate the other element only whenever current of said other appropriately related harmonic frequency is simultaneously flowing through said electromagnetic device.

21. The combination of an electromagnetic device through which flow currents of a plurality of different frequencies, a first vibratory member,

means for selectively vibrating said first member in response to one of the currents flowing in said device which has a predetermined frequency harmonically related to its own vibratory frequency, a second vibratory member and means for selectively vibrating said second member in response to the vibration of the first vibratory member whenever current is simultaneously flowing through said device which has a predetermined frequency harmonically related to its own vibratory frequency.

22. An electromagnetic apparatus through which simultaneously flow a carrier current and a modulating current of a predetermined frequency superposed on the carrier current, and two mechanically coupled vibratory members having different frequencies of vibration which are equal to the frequencies of said carrier current and said modulating current respectively and which are simultaneously vibrated only by said two currents.

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