Dec. 27, 1927.

1,654,123

R. V. L. HARTLEY

FREQUENCY SELECTIVE TRANSMISSION SYSTEM

Filed Sept. 30, 1924 4 Sheets-Sheet 1

FIG. 1a.

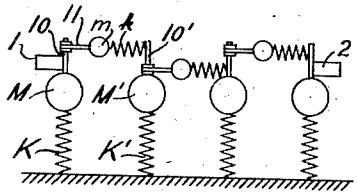


FIG. 1b.

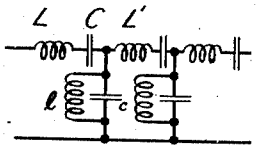


FIG. 2a.

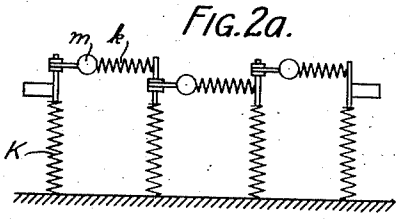


FIG. 2b.

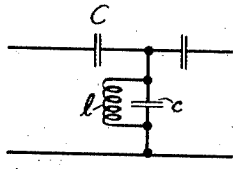


FIG. 3a.

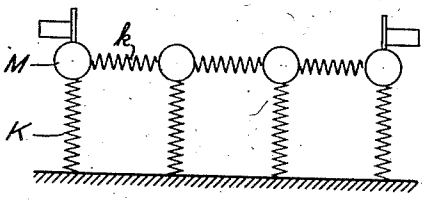


FIG. 3b.

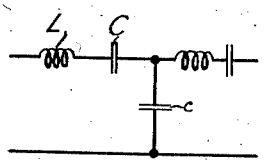


FIG. 4a.

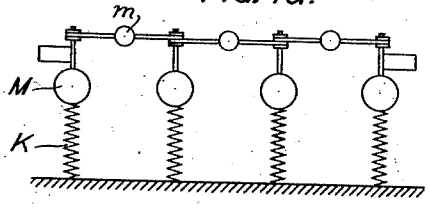


FIG. 4b.

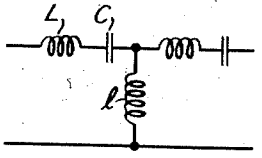


FIG. 5a.

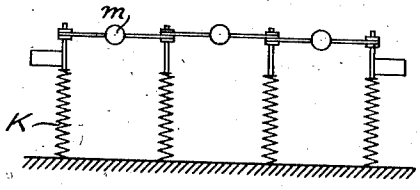
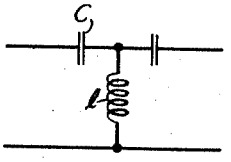


FIG. 5b.



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Dec. 27, 1927. 1,654,123

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FREQUENCY SELECTIVE TRANSMISSION SYSTEM

Filed Sept. 30, 1924 4 Sheets-Sheet 2

FIG. 6a.

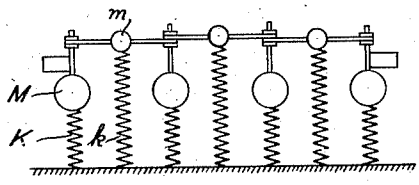


FIG. 6b.

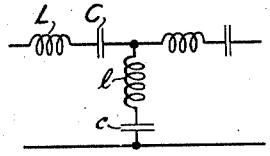


FIG. 7a.

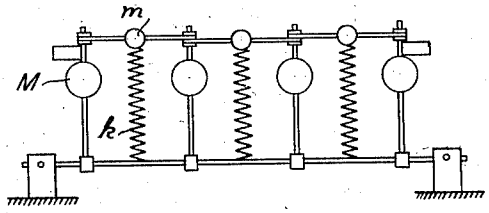


FIG. 7b.

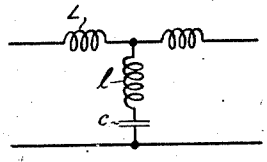


FIG. 8a

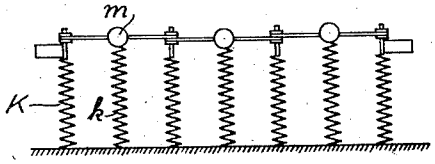


FIG. 8b.

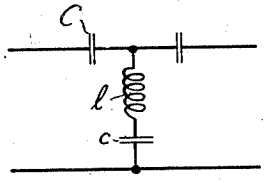
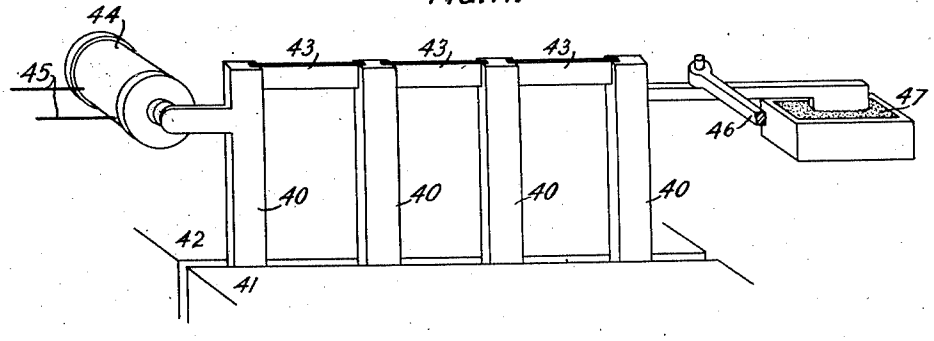


FIG. 11.



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Dec. 27, 1927. 1,654,123

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FREQUENCY SELECTIVE TRANSMISSION SYSTEM

Filed Sept. 30, 1924 4 Sheets-Sheet 3

FIG. 9.

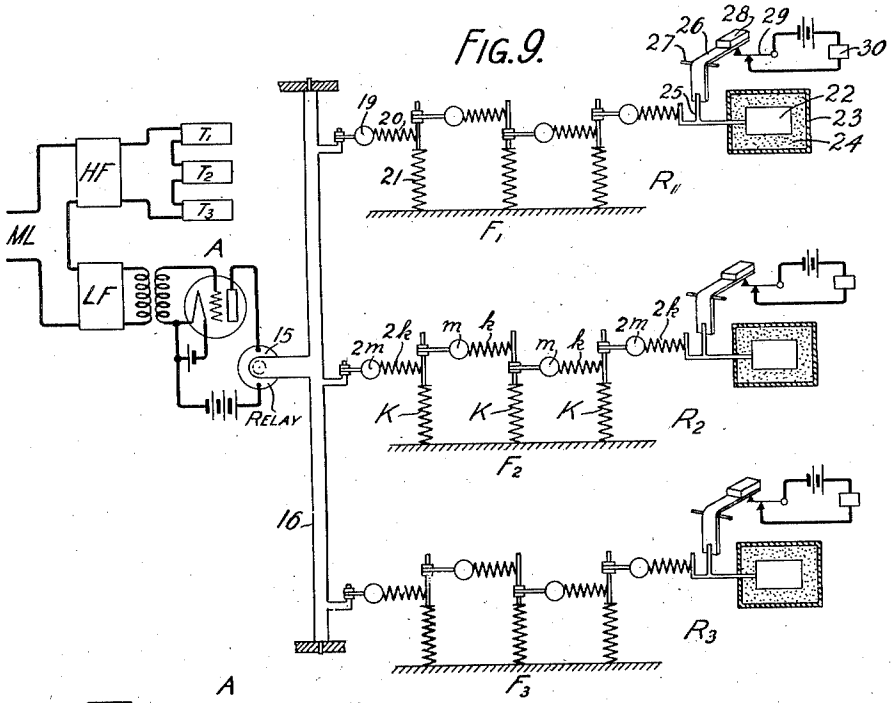
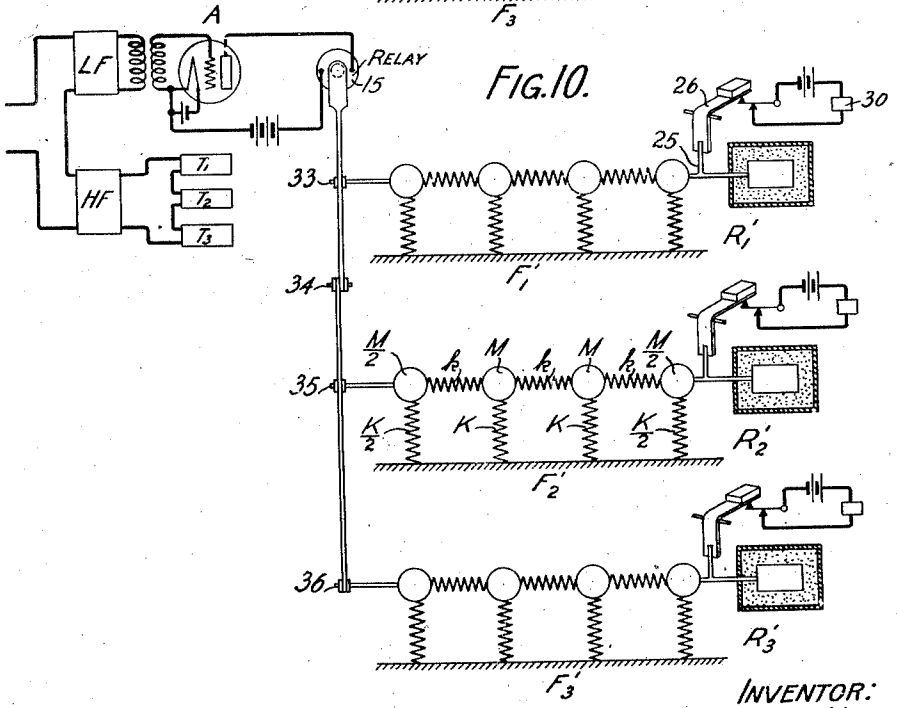


FIG. 10.



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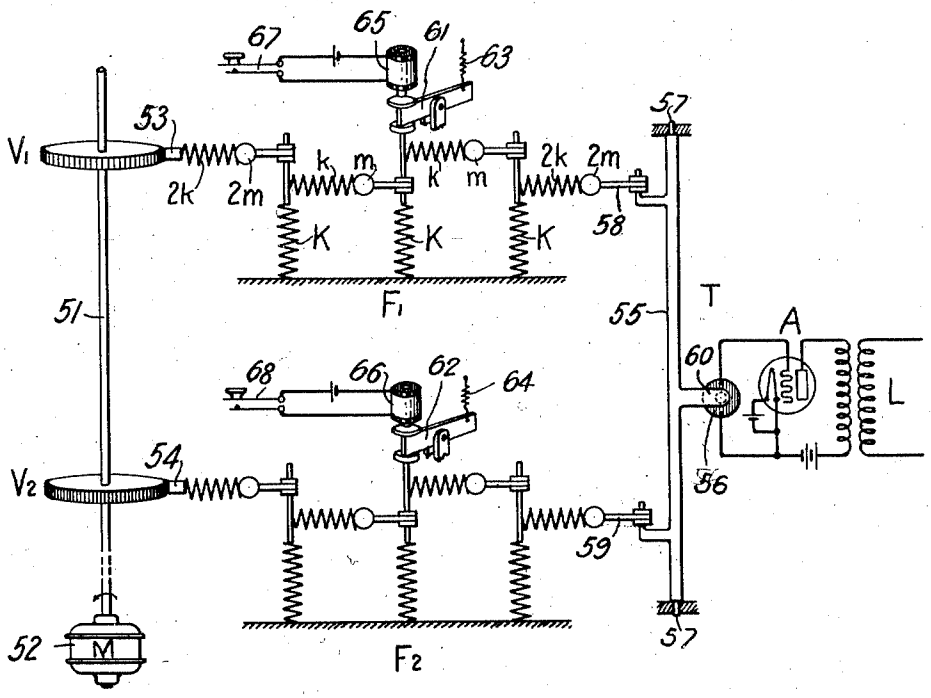
Dec. 27, 1927. 1,654,123

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FREQUENCY SELECTIVE TRANSMISSION SYSTEM

Filed Sept. 30, 1924 4 Sheets-Sheet 4

FIG. 12.



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by E. W. Adams Atty.

Patented Dec. 27, 1927. 1,654,123

UNITED STATES PATENT OFFICE.

RALPH V. L. HARTLEY, OF SOUTH ORANGE, NEW JERSEY, ASSIGNOR TO WESTERN ELECTRIC COMPANY, INCORPORATED, OF NEW YORK, N. Y., A CORPORATION OF NEW YORK.

FREQUENCY SELECTIVE TRANSMISSION SYSTEM.

Application filed September 30, 1924. Serial No. 740,724.

The present invention relates to selective wave transmission such as the transmission and selection of waves of particular frequencies for desired purposes.

The present invention further relates to vibrating systems and particularly to the generation, translation and control of mechanical vibrations.

It is a particular object of the invention to effect desired frequency selections by means partly or wholly mechanical.

A further object of the invention is to provide for any desired band width of frequency selection by complex mechanical structures.

A further object of the invention is to provide a system of the type indicated which will be simple in construction and efficient in operation.

It is a special object of this invention to provide for selecting mechanical vibrations by mechanical wave filters and for converting the vibrations into electrical variations.

A further object is to provide a signal transmitting system capable of selecting mechanical vibrations of different frequencies representing different signals and converting them into electrical variations for transmission to a distance.

Electrical filters generally comprise a reiterative series of sections which may be uniform throughout the entire filter network but which in practice are generally made up of different types to suit the particular filter requirements. Various types of electrical filters and the theory and design formulæ for them are disclosed in the following publications; U. S. patent to Campbell No. 1,227,113, May 22, 1917 and an article by Otto J. Zobel in the Bell System Technical Journal for January 1923 Vol. II, No. 1, pages 1 to 46.

The ideal electrical filter would have lumped inductances and capacities free from resistance. Similarly the ideal mechanical filter would have rigid masses and massless springs connected by massless connections and moving without friction. In practice these conditions can never, of course, be realized, but in the design of any filter an approach to these conditions may be made.

A field in which the mechanical filter may be used to particular advantage is in carrier wave signaling. The limitations as to the number of channels in such systems are determined by the character of the selective means available. What is desired is a filter which introduces a uniform loss for frequencies within the range of a particular channel and a very large loss for frequencies outside that range. It is known that a mechanical vibrator has a very much smaller damping and energy dissipation than the best electrical circuit of practical construction. The entire resonance curve of a tuning fork of one thousand cycle frequency, for example, was found to lie in a frequency interval of the order of one cycle. This type of selective element realizes the desired condition of low damping within the resonance-frequency interval and very high loss for a frequency only one or two cycles distant. The fact that the resonance interval is so extremely narrow, however, makes a vibrator of this character practically useless for signal transmission since the frequency components representing the signal are cut off.

According to the invention, a number of mechanical vibrators are combined with appropriate coupling elements to form a filter in which the low damping which is characteristic of this type of vibrator is secured over a considerable frequency range and in which very large losses will be introduced for frequencies only slightly outside the range of free transmission.

According to a particular embodiment of the invention to be described more fully hereinafter, a plurality of mechanical vibrators of different respective frequency are connected through suitable mechanical filters to a common translating device which serves to convert all of the mechanical vibrations selectively transmitted to it into electrical variations for transmission. A novel type of modulating arrangement is provided whereby the mechanical vibrations are con-

trolled in accordance with signals to be sent.

A more complete understanding of the invention may be had from the following detailed description in connection with the accompanying drawing; in which Figs. 1^a to 8^a inclusive, show types of mechanical filters corresponding to the electrical filters shown schematically in the respective Figs. 1^b to 8^b inclusive;

Figs. 9, 10 and 12 show in schematic form the application of mechanical filters to carrier signaling systems in accordance with the invention; and

Fig. 11 shows a physical embodiment of one form of mechanical filter.

Referring now to the figures illustrative of the different types of filter, Fig. 1^b represents the general case of electrical filter of the transmission type as distinguished from the suppression type. That is, each section is comprised of series inductance L and capacity C in series with each other and shunt inductance l and capacity c in parallel with each other. When both series and both shunt elements are present in each section the filter transmits two distinct bands of frequencies and greatly attenuates currents of all frequencies except those included in the two bands. The two bands are coalescent or confluent if $LC=lc$, and by omitting one of the series elements from each section or one of the shunt elements, or both a series and a shunt element, the filter may be transformed into one of the types shown in the other Figures 2^b to 5^b inclusive, and may be made to have only a single transmission band having two finite frequency limits or having as one limiting frequency either zero or infinity. Each of these filters is of the transmission type as distinguished from the suppression type which will be defined hereinafter. All this is disclosed in Campbell Patent 1,227,113 to which reference has been made.

In Fig. 1^a showing the mechanical analogue of the electrical filter of Fig. 1^b, the mass M corresponds to the inductance L, the spring K corresponds to the reciprocal of the capacity C, and the coupling elements m and k correspond to the elements l and c. Vibrations to be transmitted are applied at 1 and the output is taken off from 2. Corresponding to current flow through L, the mass M takes up motion from the impressed vibrations, but continued movement of M in one direction is prevented by spring K which stores energy similarly to the accumulation of a charge on condenser C.

In each of the "a" figures no attempt is made to represent the appearance which the corresponding filter might present in actual practice, for the reason that it is desired to adopt a convention for the figures that will facilitate comparison with the electrical type by emphasizing the positions of the quantities. For instance in Fig. 1^a, the elements M, K, may represent a single member which possesses appreciable mass and elasticity such as a tuning fork or single reed. The fork or reed may have either evenly distributed mass or may be weighted so that its mass is partly or principally concentrated at a point along its length. The property of elasticity is indicated by the zig-zag line. The spring or reed is firmly secured at its lower end and the vibrations applied at 1 are in the direction perpendicular to the plane of the drawing.

Secured to the top of the reed or spring is a pin 10 which passes through a hole in the rod 11 so that rod 11 is free to rotate about pin 10. Suitable collars may be provided on pin 10 to maintain the rod 11 at the desired level. The hole in rod 11 may be elongated to permit pin 10 to move to and fro in a vertical plane perpendicular to the paper and still permit rod 11 to move about pin 10′ as a pivot without elongating or compressing spring k.

Secured to rod 11 is the coupling mass m (coupling mass shown by a small sphere in each instance). Mass m is connected to pin 10′ by the coupling spring k which preferably has its end fixed rigidly to pin 10′.

The ideal case will be approached by concentrating, as far as possible, all of the mass in the spheres and by having the pin 10, rod 11, and springs k and K as light (massless) as possible.

Just as elements M, K may be embodied as a tuning fork or reed, the elements 11, m, k, may be embodied in a reed having one end fixed to pin 10′ and the other end mounted in any suitable manner to allow endwise slipping relative to pin 10 and bending about pin 10′, and this reed may have a weight located at a point along its length or may have distributed mass.

In any case where the mass is concentrated it will be obvious to provide a weight which is slidable along the rod or reed.

When sudden movements occur in M, the mass m tends to remain stationary and the rod 11 in being moved by pin 10 exerts a moment about m as a center distorting k. The mass m is capable of a translatory motion without having to rotate. This effect may be secured by rotatably mounting m on a vertical pin (not shown) secured to rod 11 or the equivalent reed. A motion is thus communicated to pin 10′ and to mass M′. As k becomes distorted m is constrained to move. With these explanations of the interaction between the elements, the complete operation will follow clearly from that given in connection with Fig. 1^a.

From the conventions employed in all of the figures, it will be apparent how each of the other types is constructed and operates.

Figs. 6^b to 8^b show typical forms of sup-

pression filters, and Figs. 6^a to 8^a the mechanical analogues. A suppression type of filter is one in which either or both the following conditions are met: (1) the series impedance of a section is equivalent at all frequencies to that of a capacity element and an inductance element in parallel; (2) the shunt impedance of a section is equivalent at all frequencies to that of a capacity element and an inductance element in series. It is an outstanding property of this type of filter that its attenuation may be made very high at a frequency just outside of the range of free transmission, and the cut-off of the filter therefore be made extremely sharp.

The design data for any of the types of filter that have been given may readily be obtained by use of the formulæ given in the Campbell patent above referred to or in the article by Zobel.

As an example, suppose that from convenience or other considerations it is desired to build a band pass filter of the type shown in Fig. 3^a and that this filter is to have free transmission for all frequencies between 900 and 1000 cycles per second, and high attenuation for all other frequencies and that the mechanical resistance within the transmission band is to be 30 dynes/cm./sec., that is, such that an alternating sinusoidal force of 30 dynes is required to maintain sinusoidal motion of the moving element with maximum velocity of 1 cm. per second.

Referring to Fig. 3^b and to page 42 of the Zobel article it is seen that the type of filter chosen for the example is that corresponding to Zobel's type VI_1. The design formulæ for the electrical and for the mechanical types are then as follows, remembering that stiffness is the reciprocal of capacity:

Electrical	Mechanical
$L_1 = \frac{R}{\pi (f_2 - f_1)}$	$M = \frac{R}{\pi (f_2 - f_1)}$
$C_1 = \frac{f_2 - f_1}{4\pi f_1^2 R}$	$K = \frac{4\pi f_1^2 R}{f_2 - f_1}$
$C'_2 = \frac{1}{\pi (f_1 + f_2) R}$	$k = \pi (f_1 + f_2) R$

where $f_1 = 900$, $f_2 = 1000$, and $R = 30$, as assumed. Substituting these numerical values, M is found to be 0.95 gram, K is found to be 30.5×10^5 dynes per cm., and k is 17.9×10^4 dynes per cm. The actual design of a spring to have a required stiffness is well known in the art. See for example Mechanical Engineers' Handbook by L. S. Marks.

The quantity M is expressed in the above example as simply mass. This is on the assumption that most of the mass is concentrated at the point indicated in the drawing and that the amplitude of vibration is small compared with the distance of the mass from the center of rotation. If the vibrations are such that the mass has appreciable angular displacement, M would need to be expressed in terms of moment of inertia. If this were the case the stiffness of k and K would need to be expressed as moments of force per unit angular displacement.

The structure shown in Fig. 11 illustrates by way of example only, the appearance which the filter of Fig. 3^a may have in actual practice. The reeds 40 may be steel bars or the like firmly clamped at their lower ends between bed pieces 41 and 42. Instead of single reeds, tuning forks, diaphragms or other vibratory members may be used. Secured to the reeds 40 at a suitable point along their length, preferably at their free ends, are the coupling springs 43. By reference to Fig. 3^a it is seen that these coupling springs are "massless", and hence are as light as possible, consistent with their required stiffness. Reeds 40, however, have "mass" and are indicated as comparatively heavy. The mass may be distributed as in the case illustrated, or may be lumped in the form of a weight (not shown) secured to the reed.

In operation the end reed 40 is set into vibration in any suitable manner, such as by the driving magnet 44 connected in any suitable circuit 45 carrying variation currents and the vibrations are transmitted through the coupling springs 43 to the successive reeds 40. The vibrations to which the structure is selective are passed with uniform small attenuation to the output element 46 while vibrations of all other frequencies are damped out. The filter is shown terminating in a mechanical resistance 47 the nature of which will be described more fully in connection with Figs. 9 and 10.

Reference will now be made to the applications, shown in Figs. 9 and 10 of the mechanical filter to typical signaling systems.

In Fig. 9, the main carrier line ML terminates in three carrier telegraph transmitters T_1, T_2 and T_3, and in three carrier telegraph receivers R_1, R_2 and R_3. The transmitters may be of any suitable type for sending waves of respective frequencies and keys or relays for controlling the respective waves in accordance with messages to be sent. The frequencies employed by these transmitters are assumed to lie in a higher range than the frequencies employed by the otherwise similar transmitters at the distant terminal for actuating the receivers R_1, R_2 and R_3. Accordingly the oppositely directed transmissions may be separated at the terminal stations by means of high pass filters and low pass filters of the type shown in Campbell's patent above cited or in the Zobel article cited. HF designates the high pass grouping filter and LF the low pass grouping filter.

The receiving filter LF feeds into an amplifier A which may comprise any number of

stages but is shown for simplicity as comprising only a single tube of the well known audion type. The amplified received waves representing all three messages actuate electromagnetic relay 15 causing its armature 16 to vibrate about the centers 17 and 18. These armature vibrations are applied to the three mechanical filters F_1, F_2 and F_3 which serve to filter out and transmit selectively to the respective receivers R_1, R_2 and R_3 the particular vibrations representing the individual messages.

Each of these filters will be recognized as being of the type shown in Fig. 2^a, this being a band pass filter adapted for series connection with other filters, that is, its input end section may be connected in series with the input end section of another or other filters of the same type. To be suited to this manner of connection a filter should have an impedance between its input terminals of the same order as the impedance of the load to which it is connected for those frequencies which it is to transmit selectively and this impedance must be high compared with the impedance which it has for other frequencies. These filters are terminated mid-shunt in order to give them the proper terminal impedance.

That the filters F_1, F_2 and F_3 are series connected to the armature 16 may be seen from considering the corresponding electrical filter of Fig. 2^b. If this filter is assumed to have a mid-shunt termination it will have as its terminal element a shunt connected parallel-inductance-capacity of $2l$ and $\frac{c}{2}$.

One indication of the "series" connection is that the input end sections of all the filters have the same motion, corresponding to the series current through the end sections of electrical filters so connected.

In the case of filters F_1, F_2 and F_3, vibrations of the frequency at which the mid-shunt elements 19 and 20, for example, resonate produce motion of large amplitude in these elements. Vibration of other frequencies results either in displacing the mass 19 or distorting the spring 20 or in both of these effects but does not produce as great movement in the end of spring 20 attached to spring 21 as do the currents of resonant frequency. This discriminating action is, of course, carried out by all of the other elements of each filter in such manner as to select the particular band of frequencies employed by the respective channel.

The output member of each filter is connected to a relay contact and a damping device. The latter may consist of a vane 22 arranged within an enclosure 23 so that as the vane moves it compresses dust or granular material 24 of proper density and elasticity to offer substantially a non-reactive impedance to the movement.

The pin 25 in vibrating taps against the downwardly extending arm of the lever 26 which is pivoted at 27 and carries a weight 28 for restoring the lever and closing the contact 29. This contact is normally closed, holding energized the sounder or other receiver 30.

The lever 26 and its cooperating elements will be recognized as the analogue of a detector and relay. The rapid tapping by the pin 25 raises weight 28 to open contact 29, and due to the inertia of the lever and weight, the contact is not again closed until the tapping ceases, that is, until the termination of the wave representing the dot or dash impulse.

The damping device 22, 23, 24 aids in giving the filter the desired "resistance" termination.

The system of Fig. 10 is similar to that of Fig. 9 except that the filters F_1', F_2' and F_3' are of the type shown in Fig. 3^a, this type of band filter being adapted for parallel connection, that is, its input terminals may be connected in parallel with the input terminals of another or other filters. A requirement of filters for parallel connection is that each should have an impedance of the same order as the impedance of the load for currents of the frequencies which the filter is to transmit and this impedance must be low compared with the impedance which it has for currents of other frequencies. These filters in Fig. 10 are preferably terminated-mid-series.

Received currents energize relay 15 as in the case of Fig. 9 and cause actuation of its armature. This armature is secured to a lever system the fulcrums of which are at 33, 34, 35 and 36. Attraction of the armature (motion toward the back of the paper) tends to move pin 33 backward in the drawing, pin 34 forward, pin 35 forward, pin 36 backward. It is evident that the motion absorbed by any filter is proportional in some inverse manner to the motion absorbed by the others. For example, if at any instant only the particular vibrations to which F_1' is selective are being received, pin 33 will take up the motion on account of the low impedance of filter F_1' to vibrations of these frequencies, while pins 34, 35 and 36 will remain practically stationary on account of the high impedance offered to these vibrations by filters F_2' and F_3'. If only vibrations are received to which filters F_2' and F_3' are selective, pin 33 remains practically stationary and pins 35 and 36 take up the motion, the link between 35 and 36 oscillating about an imaginary fulcrum somewhere along its length between pins 35 and 36.

The "detecting" and receiving elements may be identical with those of Fig. 9.

Fig. 12 of the drawing illustrates two carrier telegraph transmitting channels which

are similar in all respects except as to the carrier frequency employed. It will be obvious to provide any desired number of additional channels by duplicating those shown except that the carrier frequencies of the various channels should all be different for obvious reasons.

The two channels illustrated in the drawing comprise the mechanical vibrators V_1 and V_2, the corresponding mechanical filters F_1 and F_2 and the translator, generally indicated at T, for converting the mechanical vibrations into electrical variations for transmission over any desired circuit L which may be the usual multiplex telegraph line. An amplifier A including any desired number or arrangement of vacuum tubes may be included as desired.

The vibrators V_1 and V_2 are shown in the form of notched discs secured to the shaft 51 which is driven from the motor 52. The carrier frequency for each channel is determined by the speed of rotation of the shaft 51 and by the number of notches in the discs so that by providing different numbers of notches on the different discs, different carrier frequencies are secured. Cooperating with the notches in the discs are the elements 53 and 54 which are set into vibration by the rotation of the discs somewhat after the manner of a pawl riding freely over a ratchet wheel. The elements 53 and 54 serve to apply to the filters F_1 and F_2 the mechanical vibrations produced by the vibrators V_1 and V_2.

The filters F_1 and F_2 are of the type indicated in Figs. 2^a and 9. The constants of the filter F_1 may, in manner hereinbefore described, be proportioned so that this filter transmits vibrations of the frequency generated at V_1 and also transmits a sufficiently wide band of frequencies on either or both sides of the carrier frequency to enable signaling to be carried out at the desired speed. The filter F_2 will have its constants differently proportioned from those of the filter F_1 so as not to transmit vibrations of the same frequencies as those transmitted by the filter F_1 but to transmit selectively the vibrations generated at V_2 and such other frequencies as are necessary in order to transmit the signals on the corresponding channel.

The translating means T includes the bar 55 and the electromagnet 56. The bar 55 is adapted to be given rotational vibrations about the axis 57, 57 by the output elements 58 and 59 of the respective filters F_1 and F_2. The bar 55, therefore, partakes of vibrations of all of the frequencies selectively transmitted by the filters associated with it. In vibrating, the bar 55 causes the armature 60 of the electromagnet 56 to vibrate near the pole of the magnet and to set up corresponding E. M. F.'s in the magnet winding. The winding should have a permanent magnet core or some other means for establishing a normal field. The E. M. F.'s generated in the winding 56 are applied to the input of the amplifier A and the amplified waves are impressed on the line L.

The filters F_1 and F_2 are illustrated as having their terminal sections connected to the bar 55 in series, as is indicated by the fact that the output end sections of both filters have the same motion corresponding to the current through the end sections of electrical filters so connected. In order to better adapt the terminal impedance of the filters for this type of connection, they are shown terminated mid-shunt, that is, the terminal coupling mass and elasticity each have double the values of those of the intermediate sections of the filters. If desired, the filters may be connected with their terminal sections in parallel with each other and in common to the translating device, in which case the filters should be terminated mid-series instead of mid-shunt. A more convenient filter for this form of connection is that of the type shown in Fig. 3^a and the manner in which the end sections would be associated with the translating device is, in general, similar to that employed in Fig. 10. As pointed out above, the internal impedance of the filters should, in either type of connection, be of the same order of magnitude as the impedance of the load into which they work.

With the arrangements as thus far described, when the motor 52 is set into vibration at the proper constant speed, vibrations of respectively different frequency are transmitted from the vibrators V_1 and V_2 continuously through the filters F_1 and F_2 to the bar 55. In order to control these vibrations in accordance with telegraph signals to be transmitted, stop members 61 and 62 are provided for acting upon an element of the respective filter. These stop members are normally biased by the springs 63 and 64 so that they bear upon the central series element of the filter with sufficient pressure to arrest the motion of this element. So long as either stop member 61 or 62 is solely under the influence of the biasing springs therefor, the central element of the corresponding filter is held stationary and no vibrations are transmitted by it from the central element on through the filter to the bar 55. The transmission of the vibrations in each channel may, therefore, be controlled by alternately removing the corresponding stop member from contact with the filter element or allowing it to bear upon the filter element. The means for controlling the stop members is illustrated in the drawing as an electromagnet 65 or 66 included in a local circuit with key 67 or 68. Upon depressing key 67, for example, the magnet 65 becomes energized, raising the stop member 61 from

engagement with the filter element and permitting the vibrations to be freely transmitted through filter F_1 to the bar 55. When key 67 is raised and electromagnet 65 de-energized, stop member 61 is brought to bear upon the filter element, causing it to stop vibrating and the corresponding vibrations are cut off from the bar 55. Stop member 62 may be similarly controlled by electromagnet 66 and key 68 to control the transmission of vibrations through filter F_2.

What is claimed is:

1. In combination, a source of mechanical vibrations, means for translating said mechanical vibrations into electrical variations, means to control the application of the mechanical vibrations to the translating means in accordance with signals, and a mechanical frequency selective device interposed between said source and the translating means for freely transmitting to the translating means vibrations within predetermined frequency limits only.

2. A signal transmitter comprising a plurality of mechanical vibrators of respectively different frequency, a mechanical filter associated with each vibrator to receive from it and to transmit selectively vibrations of its particular frequency, and a common means arranged to receive the vibrations transmitted by all of said filters and to translate the vibrations into electrical variations.

3. In combination, a mechanical vibrator, a device arranged for actuation by vibrations from said vibrator, a mechanical frequency-selective device interposed between the vibrator and the first-mentioned device, and means for acting on the selective device to control application of vibrations to the first-mentioned device.

4. In a transmitting system, a continuously operating vibrator, a mechanical wave filter having an input section arranged to be actuated by said vibrator, and means acting on the wave filter for controlling transmission through it of mechanical vibrations.

5. In a carrier transmitting system, a mechanical element capable of vibration, a plurality of vibrators of different frequencies for imparting vibrations to said element, and means for translating the vibrations of said element into electrical variations.

6. In a carrier transmitting system, a plurality of mechanical vibrators, means to translate the vibrations into electrical waves for transmission, and means for restricting the vibrations that are translated to a frequency band of predetermined frequency level and width.

7. In a carrier transmitting system, a plurality of mechanical vibrators, means to translate the vibrations into electrical waves for transmission, means for restricting the vibrations that are translated to a frequency band of predetermined frequency level and width, and means for controlling said vibrations in accordance with signals.

8. In combination a mechanical wave filter and means for controlling the transmission characteristic of said filter to modulate the vibrations transmitted through the filter in accordance with signals.

9. A plurality of mechanical wave filters for transmitting vibrations of distinct frequency ranges, unitary means actuated in common by the vibrations transmitted by all of said filters, and means individual to each filter for controlling the application of vibrations to said unitary means.

10. In a carrier telegraph system, means to generate mechanical vibrations, means to modulate the vibrations in accordance with a telegraph message, a mechanical filter to select the vibrations, and means to translate the modulated and selected vibrations into electrical waves.

11. A wave transmission system comprising means for continuously generating mechanical vibrations, means for controlling said vibrations in accordance with signals, and means for converting the resultant vibrations into electrical waves.

12. A signal transmission system comprising means for generating continuous mechanical vibrations of a definite frequency, means for converting said vibrations into electrical variations, means selective of vibrations of said frequency for applying said vibrations to said converting means, and means for controlling the applied vibrations in accordance with signals.

13. A communication system including a continuous source of mechanical vibrations, means for converting said vibrations into electrical variations and means for selecting said vibrations and applying them periodically in accordance with signals to said converting means.

14. In a carrier telegraph system means for constantly generating mechanical vibrations, means to modulate said vibrations in accordance with telegraph messages, means for selecting said vibrations, means to translate said selected modulated vibrations into electrical waves and means for transmitting the electrical waves to a distant point.

15. A multiplex communication system comprising sources of continuous mechanical vibrations each of said sources being adapted to generate vibrations at a different frequency, means for converting said mechanical vibrations into electrical waves, mechanical filters associated with each of said sources, said filters being selective of the respective frequencies of said sources, means for controlling the selected mechanical vibrations in accordance with signals and means for applying the resultant vibrations to said converting means.

16. A mechanical wave filter comprising a series of elongated vibratable members securely mounted at one end and free to vibrate at the other end, coupling members associated with the free ends of the vibratable members for communicating vibrations from one vibratable member to the next, the members of one kind possessing considerable mass, and the members of the other kind being capable of considerable distortion and when distorted of forcibly tending to restore to undistorted condition, the structure as a whole transmitting with substantially uniform attenuation vibrations comprising a band of frequencies and highly attenuating and approximately extinguishing vibrations of neighboring frequencies lying outside of said range.

17. A mechanical wave filter comprising a plurality of tuned reeds secured at one end to a rigid support and free to vibrate independently, and coupling members associated with the free ends of the reeds for communicating vibrations from one reed to the next in the series, said coupling members offering mechanical impedance to vibrations dependent in amount upon the frequency of the vibrations, said reeds and coupling members cooperating to transmit from the first through the system and to produce in the last reed of the series vibrations comprising a broader band of frequencies than is comprised in the range of free vibration of any reed of itself.

18. A mechanical wave filter comprising a series of reeds mounted for independent vibration and yielding means coupling the free ends of said reeds to each other.

19. A mechanical wave filter comprising a series of reeds mounted to leave free ends capable of independent vibration, yielding members coupling the free ends of said reeds to each other, means to impress vibrations upon the first reed of the series, and a signaling element actuated by another reed of the series.

20. A selective system comprising a plurality of mechanical filters each composed of a series of vibratable members, and coupling members for communicating vibrations from one vibratable member to another in the series, the elements of said filters being differently proportioned in the respective filters to determine a different range of frequencies for freely transmitted vibrations for each filter, a common means for applying to all of the filters vibrations of frequencies within their selective transmission ranges and an individual vibration-responsive device operatively associated with an output element of each filter.

21. A selective system according to claim 20, said mechanical filters being terminated adjacent said common means in fractional-section termination.

22. A selective system for mechanical vibrational energy comprising a plurality of multi-section mechanical wave filters each selective to vibrations of a different range of frequencies, a common vibrationally-operating device connected to all of said filters in series so that the element of each filter connected to said device has the same motion in the case of all the filters, the element connected to said device offering in the case of each filter high mechanical impedance to vibrations of the frequencies to which the respective filter is selective, and offering lower mechanical impedance to vibrations of other frequencies.

23. A selective system according to claim 22, each filter of which is connected to said common device by a fractional-shunt section giving the filter a terminal impedance of the same order of magnitude as the impedance of said device.

24. A selective system for mechanical vibrational energy comprising a plurality of multi-section mechanical wave filters each selective to vibrations of a different range of frequencies, a common vibrationally-operating device connected to said filters in parallel, said device being connected to an element of each filter so as to divide the vibrational motion among the said elements, depending upon the frequency of the vibrations, the element connected to said device offering in the case of each filter high mechanical impedance to vibrations of all frequencies outside the range to which the respective filter is selective and offering lower mechanical impedance to vibrations of frequencies within the selective range of the respective filter.

25. A selective system according to claim 24, each filter of which is connected to said common device by a fractional-series section giving the filter a terminal impedance of the same order of magnitude as the impedance of said device.

In witness whereof, I hereunto subscribe my name this 23 day of September, A. D. 1924.

RALPH V. L. HARTLEY.