

March 10, 1936.

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2,033,242

MECHANICAL REPEATER CIRCUITS

Filed Oct. 12, 1933

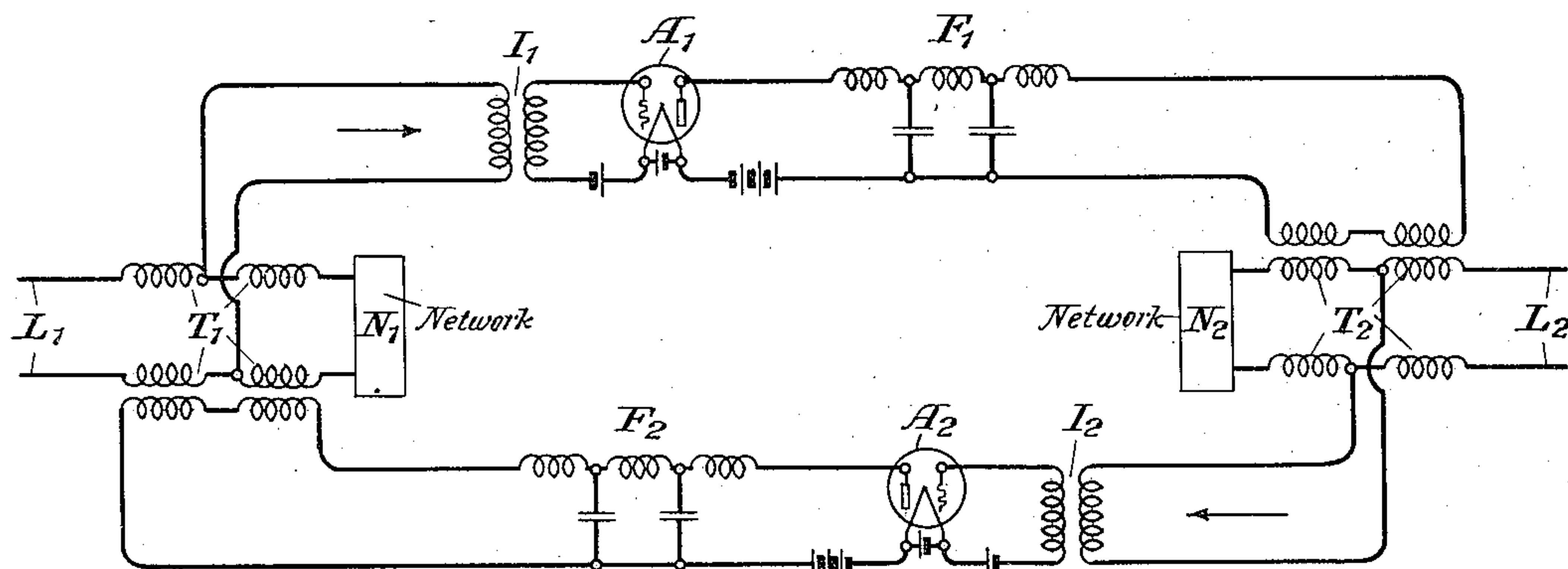


Fig. 1

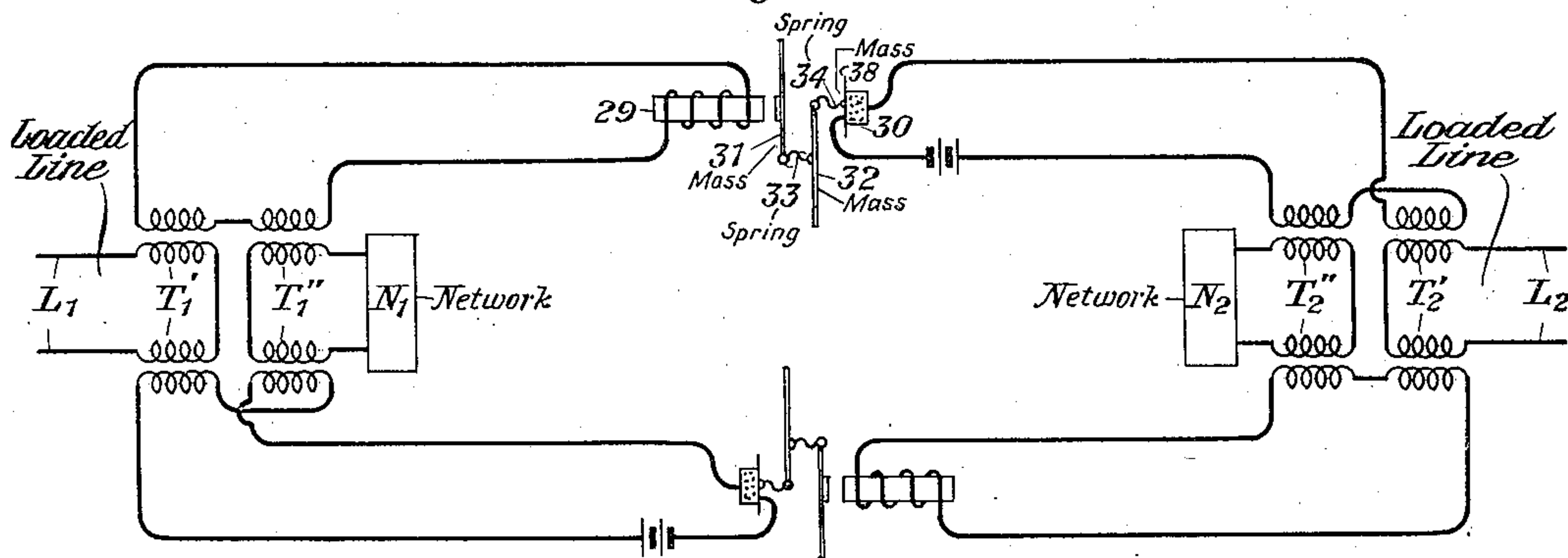


Fig. 2

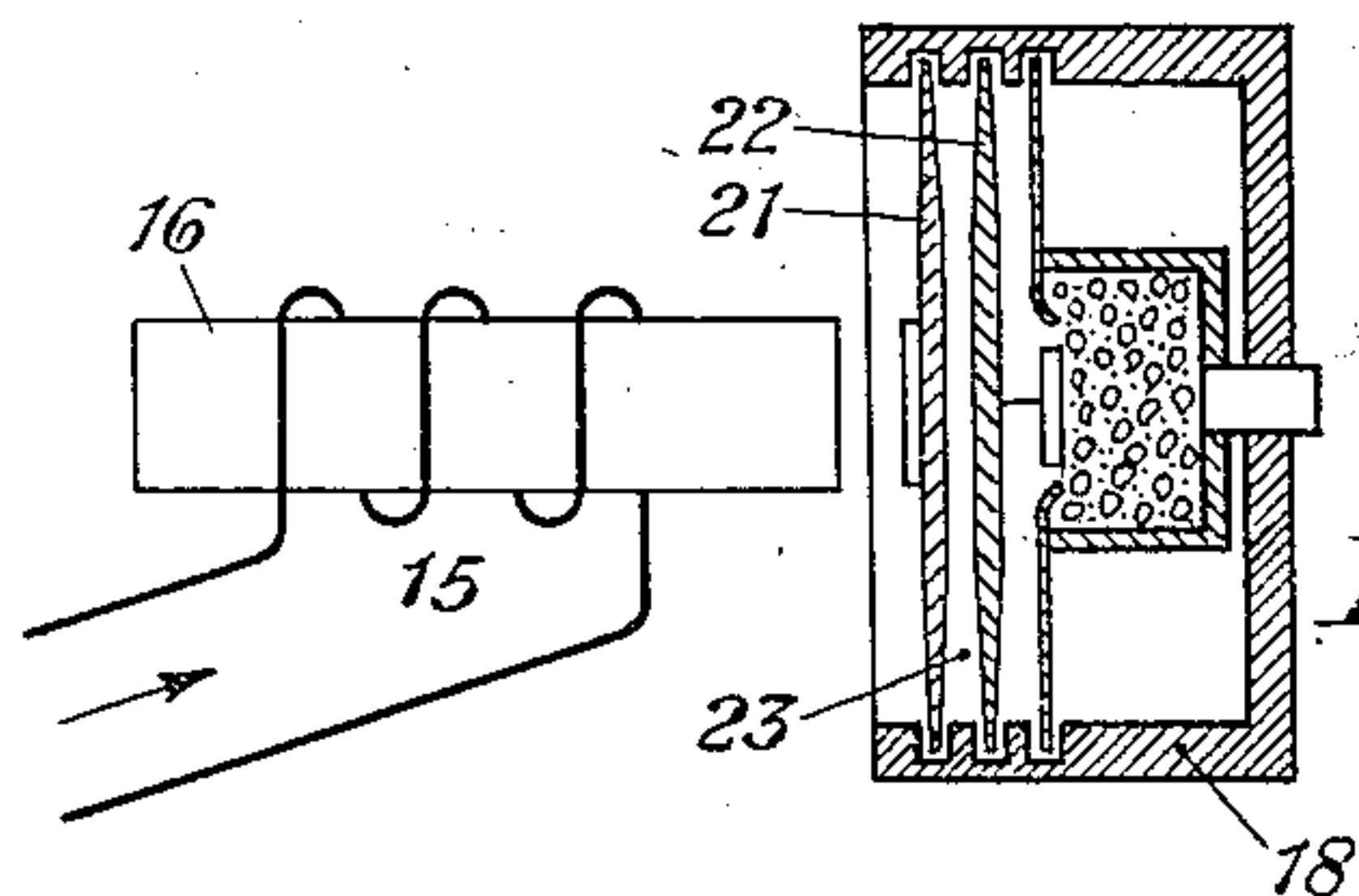


Fig. 3

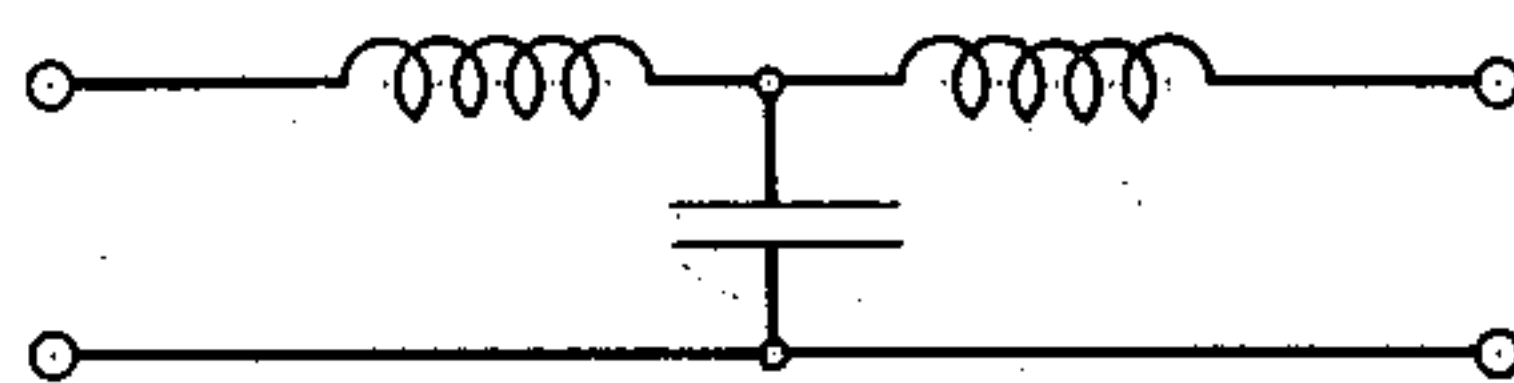


Fig. 3a

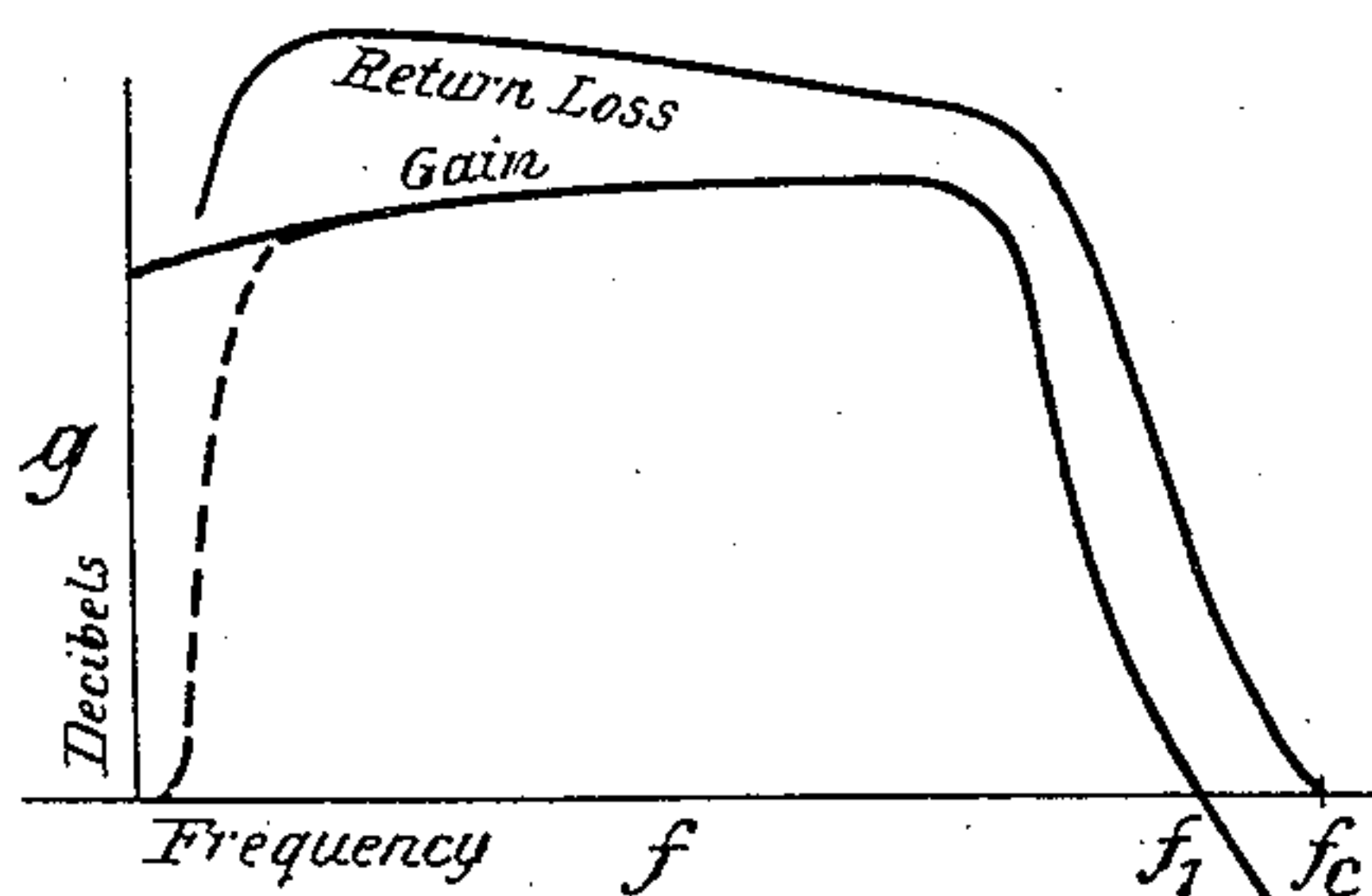


Fig. 4

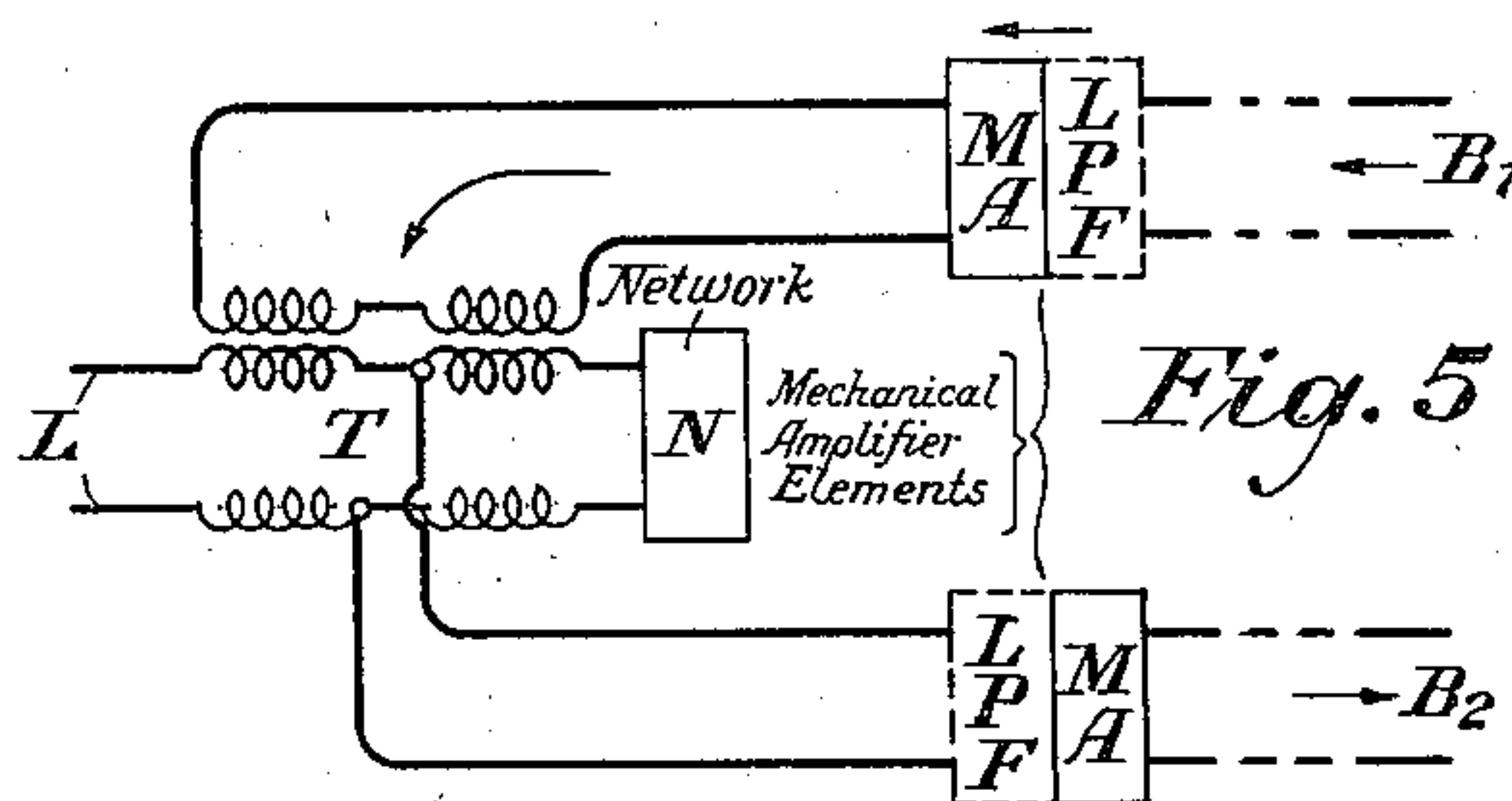


Fig. 5

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2,033,242

MECHANICAL REPEATER CIRCUITS

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Application October 12, 1933, Serial No. 693,354

10 Claims. (Cl. 179—170)

This invention relates to mechanical repeater circuits, and more particularly to circuits of this type requiring electrical filters or their equivalent for the purpose of restricting the frequency band to be transmitted. The invention consists broadly in so designing the mechanical amplifying element or elements of the repeater as to incorporate the filter characteristic in the mechanical structure, and assembling the elements into a repeater circuit without separate electrical filters.

The invention will be better understood by reference to the following specification and the accompanying drawing, in which Figure 1 shows the ordinary form of 22-type repeater circuit, with vacuum tube amplifying elements and electrical filters. Fig. 2 shows schematically the analogous circuit representing one embodiment of my invention, in which the amplifying elements are mechanical and incorporate the filter characteristics in the elements. Fig. 3 shows diagrammatically the mechanical construction of a form of amplifier of this type, and Fig. 3a the electrical filter analogue of this form. Fig. 4 shows graphically certain characteristics relating to the invention. Fig. 5 shows a circuit illustrating a second embodiment of my invention.

The repeater shown in Fig. 1 is of the well-known 22-type, comprising hybrid coils T_1 and T_2 , balancing networks N_1 and N_2 , input transformers I_1 and I_2 , vacuum tube amplifiers A_1 and A_2 , and electrical filters F_1 and F_2 , all connected in the usual way. Speech currents arriving over line L_1 are amplified in the upper branch of the circuit, as indicated by the arrow, and sent out on line L_2 ; and similarly speech currents arriving over line L_2 are amplified in the lower branch, and sent out over line L_1 . The use of low-pass filters, as indicated by F_1 and F_2 , is common practice in the art, especially where the repeaters are connected to loaded cable circuits. Such filters, when properly designed, transmit with small and nearly uniform loss all frequencies up to the neighborhood of a certain critical point called the cutoff frequency, determined by the relation between the inductances and capacities, and cause a large attenuation to frequencies in excess of this critical value. The reason for incorporating such filters in a repeater circuit lies in the fact that for most types of line the impedance characteristic becomes increasingly irregular at the higher frequencies, making it increasingly difficult to obtain a satisfactory balance with any simple type of network. This is especially true of a loaded circuit, which as is well known pos-

sesses a cutoff frequency of its own. In the neighborhood of this cutoff frequency the impedance characteristic of such a line changes very rapidly with frequency, and a satisfactory balance cannot be obtained.

The measure of the degree of impedance balance between a line and the corresponding network is known as the return loss, and is ordinarily expressed in decibels, the same unit in which are expressed transmission losses and repeater gains. A typical curve of return loss with frequency for a loaded circuit is indicated by the upper line in Fig. 4 of the drawing. It will be seen that the return loss falls off rapidly at frequencies approaching the cutoff point of the line, f_c . To avoid danger of singing, the repeater gain-frequency characteristic, indicated by the lower line in Fig. 4, must be kept below the return loss curve, the minimum vertical distance between the curves being the margin against singing. The magnitude of this margin is a measure of the stability of the circuit. In order to obtain a gain characteristic of the shape indicated in Fig. 4, low-pass electrical filters are ordinarily used, as shown in Fig. 1. The decrease in gain at low frequencies, indicated by the dotted portion of the curve, usually results from the inefficiency of the transformers at these frequencies.

Under certain conditions, particularly when it is necessary to install a repeater at some isolated point, the cost of a vacuum tube repeater and associated power equipment may be comparatively high, and a substantial saving may be effected by the use of a mechanical repeater, the power requirements of which are relatively simple. A further economy can be made if the electrical filters can be eliminated. This I propose to do as indicated in Fig. 2. The mechanical amplifier unit consists essentially of a receiver element 29, a carbon transmitter element 30, and a coupling arrangement between them which constitutes the filter element. This coupling arrangement is indicated schematically in the drawing as an assembly of masses and springs, so disposed and proportioned as to comprise a mechanical transmission system with a filter characteristic.

The design of such mechanical transmission systems has been described at length in various publications. For example, as applied to phonographs it is covered in considerable detail in an article entitled "High Quality Recording and Reproducing of Music and Speech", by J. P. Maxfield and H. C. Harrison, published in the Bell System Technical Journal for July 1926, and in

U. S. Patent No. 1,730,425, issued to H. C. Harrison, October 8, 1929. Briefly stated, it depends upon the analogy between masses and elasticities in a mechanical vibratory system, and inductances and capacities, respectively, in an electrical system. In Fig. 2, the three masses comprising the armature 31, the intermediate bar 32, and the diaphragm 33, correspond to the three inductance elements in the electrical filters F_1 and F_2 , while the elastic coupling members 33 and 34 correspond to the two shunt condensers. By giving stiffness to the supporting members 33 and 34, the system could be given the characteristics of a band pass filter if desired, since the elasticities of these members would correspond to series condensers, not shown in the filters F_1 and F_2 .

It should be pointed out that in general the purpose of the mechanical filter construction, as used in phonographs and other acoustical devices, is to obtain a uniform transmission-frequency characteristic over the widest possible frequency range. To this end the cutoff point of the system is usually made as high as is consistent with the dimensions required and the materials available. In this invention I propose not only to take advantage of the substantially uniform transmission characteristic of the mechanical filter within its band, to provide good quality of speech, but also to set the cutoff frequency at a predetermined point, lower than the line cutoff, for the entirely distinct purpose of preventing repeater singing without the need of supplementary electrical filters.

A somewhat different form of amplifier unit, which might be preferable under certain conditions, is indicated in Fig. 3. In this form the coupling comprises only a single filter section instead of two: the electrical analogue is shown in Fig. 3a. Two diaphragms 21 and 22 are provided, constituting mass elements, diaphragm 22 being connected directly to the front electrode of the carbon button. The elastic coupling between the diaphragms is provided by the very narrow air space 23. It would be possible, of course, to modify this construction in various ways to give various filter characteristics. Thus a second low pass section could be added, as indicated in Fig. 2, by using an elastic coupling between diaphragm 22 and the front electrode, or by providing a third diaphragm, or by other means. Series stiffness could be introduced in the clamping of the diaphragms, and other modifications could be made.

The amplifier element thus acquires the necessary form of gain-frequency curve, as indicated in Fig. 4 of the drawing. The full line represents the low pass characteristic, without series elasticity, the gain falling to zero at frequency f_1 , substantially below the cutoff frequency of the line, designated by f_c . The dotted line indicates the modification that would be made by the series stiffness elements, giving a band pass characteristic that might be advantageous under some conditions.

Returning for the moment to Fig. 2 of the drawing, it will be noted that there is a certain difference between this circuit and that of Fig. 1, apart from the amplifier and filter elements. The hybrid coils T_1 and T_2 have been replaced by the pairs of coils T'_1 , T''_1 and T'_2 , T''_2 , respectively, and the input coils I_1 and I_2 have been omitted. It is well known in the art that electrically a pair of similar coils such as T'_1 , T''_1 may be made equivalent to a hybrid coil such

as T_1 , and under some conditions may be advantageously substituted for it. This is not ordinarily done in a vacuum tube type of repeater, since individual input coils are required on account of the high input impedance of a vacuum tube. This condition does not exist with the mechanical amplifier, the input and output impedances of which can be given any reasonable values. The hybrid set, such as T'_1 , T''_1 , may therefore be used instead of the hybrid coil, such as T_1 , if desired. There may under some conditions be an advantage in the use of a single type of coil in a repeater, rather than two types as required by the circuit of Fig. 1. Either arrangement can, of course, be used with the mechanical amplifier elements.

Fig. 5 of the drawing shows the application of the invention to a four-wire terminating set. Such a set, as is well known, is used to make connection between an ordinary two-wire line and a portion of the circuit which it is desired to operate on a four-wire basis. In the drawing, L designates the two-wire line, and B_1 , B_2 the four-wire circuit. T is a hybrid coil, for which may be substituted a hybrid set as discussed above, and N is a balancing network corresponding to the line L. Mechanical amplifier elements with inherent low pass filter characteristics are provided as indicated. Speech currents arriving over line L are amplified and transmitted over line B_2 ; speech currents in the opposite direction arrive over line B_1 and are amplified and transmitted to the two-wire line L as indicated by the arrows. Lines B_1 and B_2 may be led to a subscriber's premises, in which case the transmitter of the subscriber set would be connected to line B_1 , and the receiver to line B_2 . More commonly, the lines B_1 and B_2 will be connected at a considerable distance to a second four-wire terminating set, the reverse of that shown in Fig. 5, thus providing a section of four-wire line between two two-wire lines. If the two-wire lines are loaded, filters will be required as in the 22-type repeater, to avoid the possibility of singing around the four-wire circuit. The ordinary four-wire terminal includes two vacuum tube amplifiers and two electrical filters; I propose to replace these by mechanical amplifiers with inherent low pass filter characteristics, as already described.

Various modifications and additional applications of my invention will be apparent to those skilled in the art, but the invention is to be understood as being defined by the following claims.

What is claimed is:

1. In a two-wire signaling system including a two-wire line and a four-wire section inserted in said two-wire line and associated therewith by means of hybrid sets, a mechanical amplifier in each side of said four-wire section, and mechanical means forming a part of each of said amplifiers for restricting the gain of the amplifier to such a frequency range that no singing occurs from lack of balance against said two-wire line, said mechanical means comprising an inertia mass and a spring.

2. In a telephone repeater for use with loaded lines, a pair of hybrid sets connected to the lines, a network corresponding to each line and simulating the impedance of that line over a certain range of frequencies, and a mechanical amplifier for each direction of transmission, each amplifier comprising a receiver element, a carbon transmitter element, and a coupling element between said receiver element and said transmitter element, the parts of said coupling element

being proportioned to provide a substantially uniform gain characteristic over the frequency range within which said networks simulate the impedances of the respective lines but to reduce the gain outside said range substantially to zero.

3. In a signaling system, a transmission line with low pass filter characteristics and a mechanical repeater associated therewith, said repeater including as a part thereof means for limiting the gain of said amplifier to a certain frequency range, with a cutoff frequency substantially lower than that of said line.

4. In a signaling system, a transmission line, a 22-type repeater circuit inserted therein, and a mechanical amplifier in each branch of said repeater circuit, said amplifier including means forming a part thereof for limiting the gain of the amplifier to a certain frequency range with a cut-off frequency substantially lower than that of said line.

5. In a signaling system, a loaded transmission line having a certain cutoff frequency, a four-wire terminating set associated therewith including a network designed to simulate the impedance of said line, and a mechanical amplifying device in each branch of said terminating set, each of said amplifying devices comprising a receiver element, a carbon transmitter element, and a coupling element between said receiver element and said transmitter element, the parts of said coupling element being so proportioned as to provide a substantially uniform gain characteristic over the frequency range within which said network simulates the impedance of the line but to reduce the gain outside that range substantially to zero.

6. A mechanical amplifier for use with a loaded signal transmission line, comprising a receiver element, a carbon transmitter element, and a coupling element between said receiver element and said transmitter element, the parts of said coupling element being so proportioned as to limit the gain of the repeater to a frequency range below that transmitted by the line whereby disturbances due to irregularities near its cut-off point are avoided.

7. In a telephone system, a loaded transmission line, a mechanical repeater for use with the line comprising a mechanical amplifying element and a vibratory mechanical system having an upper cutoff below that of the line.

8. In a telephone repeater associated with a

loaded transmission line and involving a return loss against said line comparatively high over a certain range of transmission frequencies and becoming progressively lower as the transmission frequency approaches the cutoff point of said line, a mechanical amplifying means forming a part of said repeater and characterized in that its gain frequency characteristic is substantially flat over a considerable portion of the range of frequencies transmitted by the line and maintains a minimum margin between the return loss and the gain of the repeater as the transmission frequency increases.

9. In a two-way transmission system including a loaded two-wire line and a two-way repeater inserted in said line and associated therewith by means of hybrid sets and networks designed to simulate the impedance of said line over a certain range of frequencies transmitted by the line, whereby the return loss will be large over said certain frequency range and progressively smaller as the transmission frequency rises above the upper limit of said range, mechanical amplifying means in each branch of said repeater and mechanical means forming a part of said amplifying means for maintaining a minimum margin between the return loss and the gain of said amplifying means as the transmission frequency increases.

10. In a two-way transmission system including a loaded two-wire line, means at a point in the line for deriving separate paths for the two directions of transmission, said means including hybrid sets and networks designed to simulate the impedance of the line over a certain range of frequencies, with an increasingly great deviation from such simulation as the transmission frequency approaches the cutoff frequency of the line, whereby the return loss will be large over said certain frequency range and progressively smaller as the transmission frequency rises above the upper limit of said range, and a mechanical amplifier in each of said paths, each of said amplifiers comprising a receiver element, a transmitter element, and a coupling element between said receiver element and said transmitter element, the parts of said coupling element being so proportioned as to maintain a minimum margin between the associated return loss and the gain of the amplifier as the transmission frequency increases.

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