Dec. 17, 1935. W. KUNZE 2,024,234

COMPENSATOR

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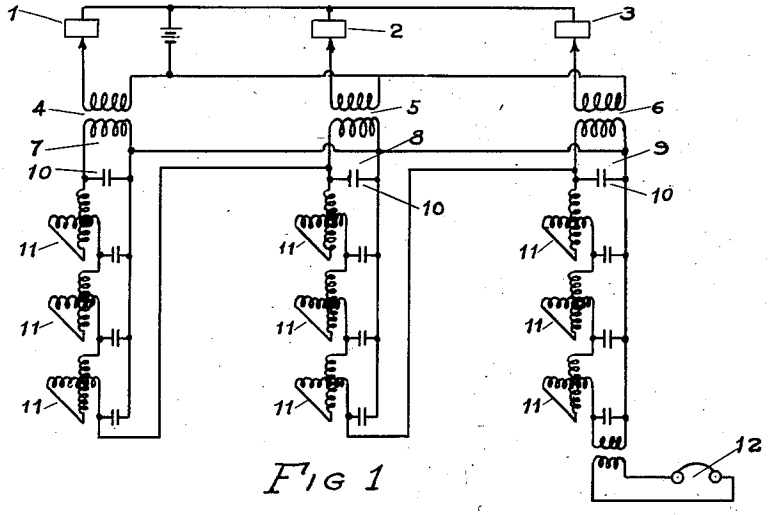


FIG 1

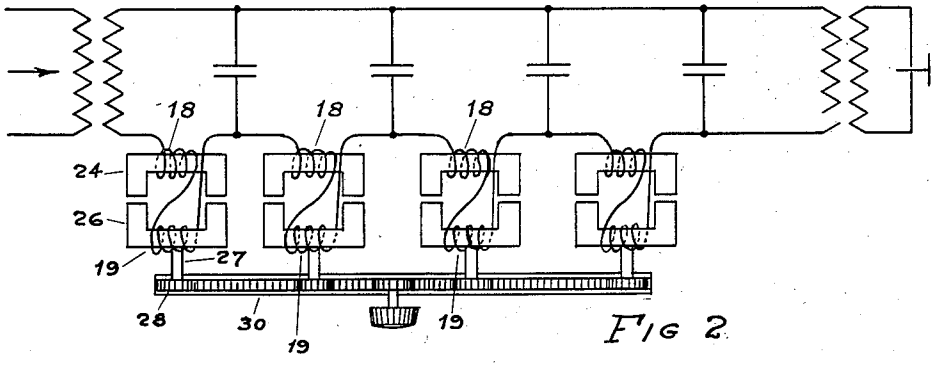


FIG 2

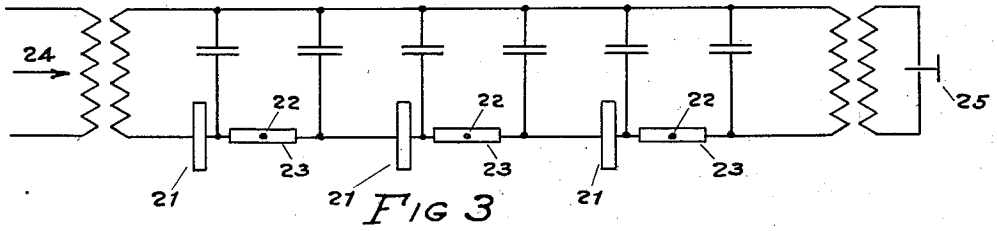


FIG 3

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COMPENSATOR

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2 Claims. (Cl. 178—44)

The present invention relates to electric compensators of the type that are used in determining the direction of a source of sound waves or in measuring small time intervals.

The type of compensator usually employed comprises an artificial line composed of sections of inductances in series and capacities in shunt. These sections are either connected together into a permanent line or are opened in such a way that as many sections of the line as is desired may be used in the operation of the device. According to the type first mentioned where the sections are permanently connected in line, there must be provided a series of contacts at the end of each section for a telephone connection or other indicating device so that the operator may choose the correct point along the line where the indicator should be placed in order to make a measurement with the apparatus. Where the line is one continuous line and the telephone or indicating device is tapped off at the desired point, it may be noted that the impulse traveling along the line still continues to pass through the other sections and that thereby all the energy put into the line is not transferred to the indicating device.

Besides this disadvantage in this system it is necessary to provide a contact for each section to connect to the indicator. It is necessary not only to keep these contacts particularly clean, but also to be certain that the switching device makes a good contact at all times in order to avoid varying resistances in the compensator circuit. Such switches and contacts have from a mechanical point of view been found very impracticable and necessitate considerable care in order to insure their proper operation.

In the type of apparatus where each section is an individual section and as many sections are connected step by step in the line as is necessary to compensate for the time interval, very complicated switching mechanism is necessary and the same difficulties of keeping the contacts clean and touching are present.

While compensators of the type above described have proved to be satisfactory and capable of use for accurate measurement, they are liable to become useless and inaccurate unless continually cared for. Further, it should be noted that in these types of compensators the measurement is made by inserting or removing a small increment of the line and not by a continuous variable compensation as would be necessary for an absolute balance.

In the present invention all electrical contacts may be progressively varied and thereby a setting obtained which is accurate to a far greater limit than the interval of retardation of one section of the ordinary compensating line. In the present invention the whole of the line may be used and dead ends of the line, therefore, avoided.

The invention will be more fully described in connection with the drawing in which Figure 1 shows schematically the operation of the system with three receivers of wave energy; Figure 2 shows some of the details for varying the retardation of the line; and Figure 3 shows a modification of the circuit shown in Figure 1.

In Figure 1 the system of which may be a sound-receiving system, the sound is picked up by the sound receivers 1, 2, and 3 and transmitted through the transformers 4, 5, and 6, respectively, to the lines 7, 8, and 9. The line 7 with its maximum compensation is capable of retarding the impulse received by the receiver 1 the time interval needed for the energy to travel in the external medium between the receivers 1 and 2 and, therefore, compensate the receivers 1 and 2 for any direction from which the energy comes, and the line 8 can similarly compensate the receivers 2 and 3. Each line may be provided with fixed capacities 10, 10, 10 and with variable inductances varied by means of the variometers 11, 11, and 11. The retardation interval of the line may thereby be varied since the time retardation per section

$$T=\sqrt{LC}$$

where L is the self-induction in series and C is the capacity in parallel for each section of the line. By varying L and keeping C constant, T will vary as the

$$\sqrt{L}$$

and consequently the total line will be varied in time retardation the equivalent of nT where n is the number of sections and T is the retardation per section. By means of the variometer, as indicated by 11 in Fig. 1, the retardation per line may be made continuously variable and a balance may be found in the phone or indicator 12 where the wave energy has the greatest intensity. At this point the sound energy arriving at the receiver 1 will have been brought into phase with wave energy arriving at the receiver 2, and both energy waves arriving at receivers 1 and 2 will be brought into phase with the energy arriving at the receiver 3, thus

providing a maximum intensity at the indicator 12.

The apparatus shown in Fig. 1 may be used binaurally by having the receiver 12 connected to one ear and providing a duplicate system, as shown in Fig. 1, independently connected to the receiver or indicator for the other ear. The variometer in each of the lines should all be similarly operated so that each section always provides the same time retardation.

It is also preferable to have all the line similarly operated so that all sections of all the lines at any instant have the same retardation. This may be done by the apparatus as shown in Fig. 2 where the inductances 18 and 19 in series in the same section of the line are wound on opposite halves of the iron cores 24 and 26. The lower core 26 may be rotated about an axis 27 by means of the spur gear 28 which is operated by the chain 30 meshing with it. All of the inductances in the line are simultaneously controlled in such a manner that the inductances of each section is similarly varied. The cores 24 and 26, as shown in Fig. 2, are provided with pole faces which when the magnetic path is shortest are opposite one another. The coils 18 and 19 may be wound to aid one another or to oppose one another. If wound to aid one another, the inductances per section and therefore the time retardation will be greatest when the poles of the pieces 24 and 26 are opposite one another. If the coils 18 and 19 are wound to oppose one another, the retardation at this point will be least. It is preferable to control all the lines which may be used in a compensating system by a single hand wheel. This may be done by having the chains 30 all driven from the same shaft geared to or mounted on the shaft on which the hand wheel is rotated.

As in other types of compensators the direction of the energy source may be calibrated directly on a scale, so that when a maximum or a binaural setting is obtained, the compensator will indicate this direction.

In the device shown in Fig. 3 the time retardation of the line may be varied by varying the mutual induction between sections. In Fig. 3 energy approaching over the line 24 in the direction of the arrow is transmitted over a line having fixed inductances 21 and inductances 23 which may all simultaneously be varied by rotation about an axis 22 in a phase similar to that shown in Fig. 2. In the position shown in Fig. 3, the inductance between sections is least. As the sections 23 are rotated, the induction may correspondingly be increased and thereby increase the time retardation of the line, in this manner delaying as desired the impulse reaching the telephone 25.

By means of the system shown in the present invention, it is possible to determine very accurately the direction of the source of sound. In the prior art where fixed retardation sections were employed, it was only possible to determine with an accuracy equal to the time retardation per section since placing the switch at the next point added or took out a section of the line, and thereby increased or decreased the time interval by just the amount of the retardation per section. In the present invention the accuracy of the setting is entirely independent of this feature since the time retardation may be continuously varied. Besides this feature, as has been noted previously above, all wiping or rolling contacts have been avoided, thus avoiding all switching mechanism which has proved to be cumbersome and difficult to place in the necessary space to allow a direct scale calibration.

While in the present invention I have indicated that the time retardation per section may be varied by varying the inductance, it should also be noted that the same principles may be employed in varying the capacity. For this purpose the shunt capacities in each section of a line may be made variable and controlled by a single shaft similarly as used in operating radio broadcast receivers.

Likewise, it is also possible to vary both inductance and capacity and this may be done in such a fashion as to maintain the surge impedance

$$\frac{L}{C}$$

of the circuit uniform at all times, and therefore prevent reflections from the ends of the line by providing a terminal impedance of a desired value. If the end of the line is terminated in an indicating apparatus, this indicating apparatus may have the desired terminal impedance to match with the impedance constantly maintained by maintaining the correct relation of inductance and capacity in the sections while varying the time retardation of the line.

By the term "artificial line" I mean a lumpy electric line (as defined by Dr. A. E. Kennelly in his book "Artificial Electric Lines", published by McGraw Hill Book Company, 1917, page 2) composed of similar sections of alternate reactors in series and condensers in shunt.

Having now described my invention I claim:

1. In a system for determining the direction of wave energy, an electric compensator including an artificial retardation line having inductance series elements and capacity shunt elements, said inductance series elements comprising at least two windings per section having cores presenting poles opposite each other, means for supporting one set of said cores and windings and means for simultaneously rotating said set from a single source to vary the retardation of the line without changing the number of sections.

2. In a system for determining the direction of wave energy, an electric compensator including an artificial retardation line having inductance series elements and capacity shunt elements, said inductance series elements comprising at least two windings per section having cores presenting poles opposite each other with coils wound thereon, means supporting one set of said cores and windings and means for simultaneously rotating the other of said sets from a single source comprising a plurality of rotatable shafts on which said cores are mounted, a plurality of similar gears supported at the end of said shaft and means for simultaneously rotating all of said gears.

WILLY KUNZE.