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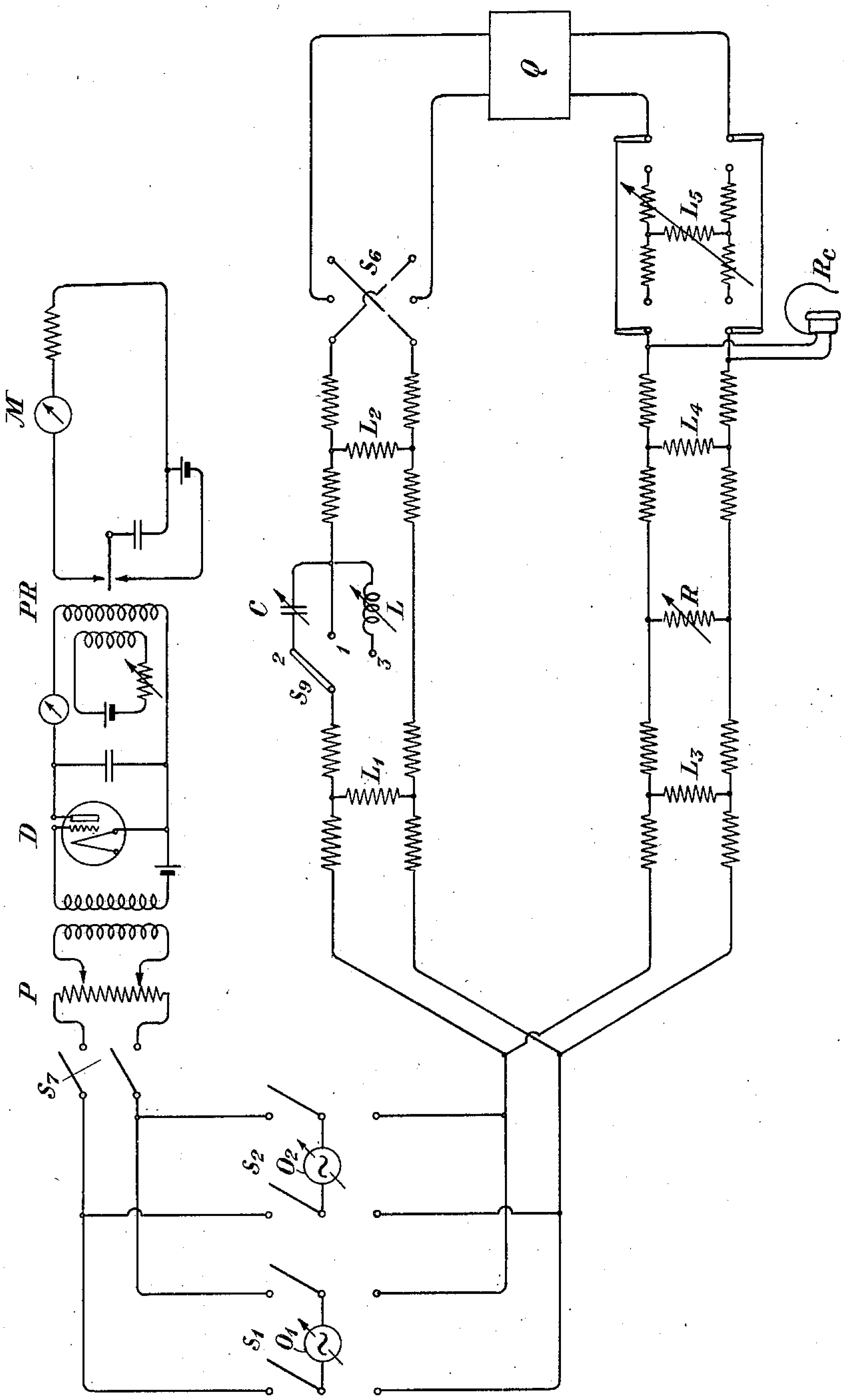

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MEASURING TRANSMISSION DELAY.

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An object of our invention is to provide a new and improved method and suitable apparatus for measuring delays in transmission lines and other transducers. Another object of our invention is to provide for a wide range of cases, including delays of several periods and delays of only a small fraction of a single period. In one form in which our invention may be embodied, two oscillators are employed and the frequency is varied from one to the other corresponding to an easily determined change in the phase shift through the transducer under investigation. The difference of frequency between the two oscillators may be determined by the beat method and from these data the delay through the transducer may be computed. In the accompanying drawing we have illustrated one example of practice according to our invention but it will be understood that the invention is defined in the appended claims and that the following specification relates to this particular embodiment thereof.

Referring to the drawing, this is a diagram showing circuits and associated apparatus by which our invention may be practiced.

Two oscillators O_1 and O_2 are provided, each adjustable as to frequency. Either or both of them may be connected through two parallel paths to the receiver R_c. Also, either or both oscillators may be connected through certain elements of apparatus to the polar relay PR. If the transducer Q gives a gain instead of a loss, then enough loss is interposed at L_5 to make the overall effect a loss. Further details of structure will be pointed out in connection with the following description of the procedure to measure the delay through the transducer Q.

Switch S_1 is closed down and switch S_9 is closed on the point 1. Current from the oscillator O_1 will reach the receiver R_c over two parallel paths, and in general there will be a tone heard in the receiver corresponding to the frequency of the oscillator O_1. The frequency of the oscillator O_1 is now varied slowly and the resistance R is adjusted until the tone in the receiver R_c disappears. It may help to reach this condition to reverse switch S_6. Call this frequency f_1. The disappearance of the tone in the receiver means that at this frequency the currents arriving at the receiver R_c over the two parallel paths are in opposite phase, that is, the delay over one path differs from the delay over the other path by 180 degrees or an odd multiple of 180 degrees.

Now reverse the switch S_6 and a loud tone will be heard in the receiver R_c. Then throw the switch S_2 down to connect both oscillators O_1 and O_2 alike in the circuits leading to the receiver R_c. The beats between the two frequencies for these two oscillators will be heard in the receiver R_c and the oscillator O_2 should then be adjusted in frequency to no beat, thus giving assurance that it has the same frequency as O_1. Now disconnect oscillator O_1 and throw S_6.

Assume first that the transducer Q has a delay of several periods, as may readily be the case for a loaded cable circuit, for example. The frequency of the oscillator O_2 will be gradually increased and presently a frequency f_2 will be reached at which the tone disappears from the receiver R_c. This will mean that the frequency has been changed from f_1 to f_2 over a range that changes the delay through the transducer Q by a half-period or 180 degrees.

The formula for this delay is

$$T=d\beta/d\omega$$

where T is the delay in seconds of time, β is the phase shift which is π in the present instance, and ω is 2π times the frequency. The frequency increment is f_2-f_1.

Throwing the switches S_1 and S_2 up and closing the switch S_7 causes currents of these two frequencies to be transmitted through the potentiometer P, and their electromotive forces are superposed in the detector D. Accordingly, the armature of the polar relay PR in the detector output circuit vibrates to the beat frequency and by means of a suitable calibration curve, the reading of the integral current through the meter M gives the beat frequency, which is the value of $f_2 - f_1$.

Substituting in the foregoing formula

$$T = \pi / [2\pi (f_2 - f_1)]$$

and this reduces to

$$1/[2(f_2 - f_1)]$$

But if the delay through the transducer Q is not as large as several times a half-period, then the change of a half-period between the two frequencies will be too great a change to get a precise value at a particular mean frequency, and in such a case we pursue a somewhat different method.

After having proceeded as before to the point of adjusting the frequency of the oscillator O_1 to the condition of zero tone in the receiver R_c with the switch S_9 on the point 1, the switch S_9 is shifted to one of the other points, 2 or 3, so as to interpose a small adjustable reactance such as that due to coil L or condenser C. As in the first case, designate the first frequency adjustment for oscillator O_1 as f_1, and also as in that case readjust it to another frequency f^2 at which there is again a null effect, this time with the said small reactance in series. The artificial lines L_1 and L_2 are made up of resistances and are of considerable equivalent length and each is of 600 ohms value looking into it from between them. Accordingly, the intermediate circuits through the reactance C or L and the two artificial lines L_1 and L_2 has an impedance value of 2 times 600 ohms plus the reactance value referred to. In short, the impedance of this circuit expressed numerically is $1200 + i2\pi f L$, assuming that the switch S_9 is on the point 3. It follows at once that by shifting the switch S_9 from the point 1 to the point 3, there has been introduced a phase shift.

$$\Delta\beta = \tan^{-1}(2\pi f L / 1200).$$

We know the frequency increment, and accordingly

$$\Delta\omega = 2\pi (f_2 - f_1)$$

is known and the value for T can be determined from the formula already given. The frequency difference $f_2 - f_1$ may be determined by the beat method as already described for the earlier case considered in this specification.

We claim:

1. The method of measuring the delay in transmission through a given transducer, which consists in transmitting from an adjustable oscillator to a balanced receiver over two paths, one through said transducer and the other past it, interposing a small reactance in one path to vary the delay therethrough, adjusting the frequency of the oscillator to restore the balance on the receiver, and from the known magnitude of the reactance and the change of frequency computing the delay.

2. The method of measuring the delay in transmission through a given transducer, which consists in changing the frequency to annul the delay due to a small increment of reactance in the circuit of the transducer, and from the data of these changes computing the delay.

3. In combination, an oscillator, a receiver connected therewith by two paths, one comprising a transducer whose delay is to be measured, a reactance and a switch by means of which it may be cut in or out of one of the paths, and means to adjust the frequency of said oscillator.

4. In combination, an oscillator, a receiver connected therewith by two paths, one comprising a transducer whose delay is to be measured, a reactance and a switch by means of which it may be cut in or out of one of the paths, means to adjust the frequency of said oscillator, and artificial lines connected in on both sides of said reactance.

5. The method of measuring the delay of transmission through a given transducer at a certain frequency, which consists in receiving the input and output currents in a common receiver and adjusting the frequency to zero tone, then causing a delay in one path by a small known angular magnitude, and adjusting the frequency again to get zero tone and computing the delay from the data of these changes.

6. In combination, an oscillator adjustable for frequency, a receiver connected therewith by two paths, one comprising a transducer whose delay is to be measured, means to reverse the current in one path if the said delay is large and make a smaller phase shift in one path if the said delay is small, and means to determine the frequency difference between two adjustments of the oscillator.

In testimony whereof, we have signed our names to this specification this 27th day of August 1925.

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