March 29, 1932. C. H. FETTER 1,851,092

TRANSMISSION DELAY CIRCUITS

Original Filed June 21, 1927

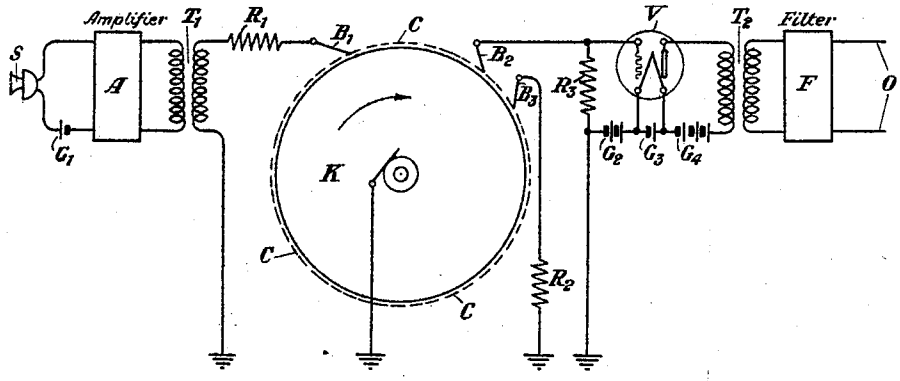

Fig. 1

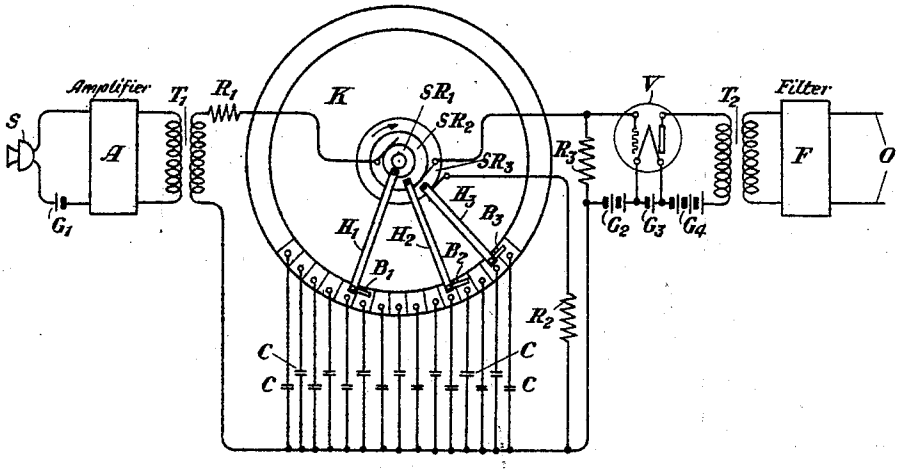

Fig. 2

INVENTOR
C. H. Fetter

BY

ATTORNEY

Patented Mar. 29, 1932 1,851,092

UNITED STATES PATENT OFFICE

CHARLES H. FETTER, OF MILLBURN, NEW JERSEY, ASSIGNOR TO AMERICAN TELEPHONE AND TELEGRAPH COMPANY, A CORPORATION OF NEW YORK

TRANSMISSION DELAY CIRCUITS

Original application filed June 21, 1927, Serial No. 200,420. Divided and this application filed February 8, 1928. Serial No. 252,831.

This invention relates to delay circuits, and particularly to arrangements of a mechanical nature for introducing delay in the transmission of signals, such as voice frequency signals which may be transmitted over telephone circuits.

This is a division of applicant's copending application, Serial No. 200,420, filed June 21, 1927.

In accordance with this invention there is provided a commutator having a plurality of segments to each one of which a condenser is connected or associated in a suitable circuit arrangement, so that all of said condensers may progressively receive an electrical charge from an electrical source, such as a voice frequency signaling source, or an input circuit, and so that said condensers may subsequently surrender their electrical charges in the same progression to a translating or amplifying device, or an output circuit, employed in the transmission of signals to a distant point. Thus, in this invention, time delay will be introduced in the impression of the charges of a plurality of condensers upon a device or output circuit employed in transmission to a distant point.

One way to introduce time delay in accordance with the principles of the invention is to associate with a commutator a number of brushes of a type to be subsequently described, one of which is connected to the electrical source or input circuit, and another one of which is connected to the translating or amplifying device or output circuit. To carry out the invention with such apparatus it is necessary either to rotate the commutator about its axis and to thereby progressively charge the condensers associated with the segments of the commutator, or to maintain the commutator stationary in position and to rotate the brushes about it. The brush connected to the input circuit transmits electrical charges to the condensers in progression as a result of the relative rotation of the commutator with respect to that brush, or vice versa, while the brush connected to the output circuit transmits, in the same progression, the electrical charges impressed upon these condensers. A third brush may, if desired, be provided to short-circuit the various condensers after each charge and discharge, thereby preparing these condensers to again receive a similar charge and to subsequently surrender it, and so on.

It becomes apparent that it is one of the objects of this invention to introduce time delay in electrical circuits by charging a plurality of condensers in progression and by discharging these condensers thereafter in the same progression after a predetermined interval of time has elapsed.

It is another object of this invention to introduce time delay of a definite value by suitably spacing brushes associated with the commutator, and further, to change the interval of delay, as desired, by changing the distance between these brushes.

This invention, as well as its further objects and features, will be better understood from the detailed description hereinafter following, when read in connection with the accompanying drawings, in which Figure 1 represents one circuit arrangement embodying the invention, in which a rotatable disk or commutator and stationary brushes are provided, and Fig. 2 represents another embodiment of the invention, in which the disk or commutator is stationary and the brushes rotatable with respect to the disk or commutator.

Referring to Fig. 1 of the drawings, there is shown a microphone S in series relationship with a battery G_1, so that speech variations may be translated into corresponding electrical variations. These electrical variations are then impressed upon an amplifier A of any well-known type, preferably of a vacuum tube type, amplifier A amplifying the electrical variations corresponding to the speech impinging upon the microphone S. The amplifier currents are then transmitted through a transformer T_1 to a brush B_1, which is connected to ground through a resistance R_1 and the secondary winding of transformer T_1. The brush B_1 is associated with a commutator or rotatable disk K having a plurality of segments, each of which acts like a condenser in its capacity to ground. Some of these condensers are desig-

nated by the reference character C. Two other brushes, B_2 and B_3, are similarly associated with the commutator K. As the commutator K revolves about its axis its segments, which act like condensers, make contact with brushes B_1, B_2 and B_3 in the order stated. As each condenser makes contact with brush B_1 a charge is impressed thereon corresponding to a variation in the signals originating in the microphone S. This condenser subsequently makes contact with brush B_2, which receives the charge and transmits it to an output circuit, as will be described more fully hereinafter. The third brush B_3 short-circuits each of the condensers through a resistance R_2 as each condenser passes brush B_3.

The electrical charges which are surrendered to the brush B_2 as a result of the rotation of the commutator K cause variations in the potential impressed across a resistance R_3. Accordingly, corresponding potential variations are effected between the grid and filament of a three-electrode vacuum tube V, which may be employed in this invention to act as an amplifier. The resistance R_3 is in series with a battery G_2 between the grid and filament of vacuum tube V, and these elements provide the bias necessary for the proper operation of vacuum tube V as an amplifier. The filament of the vacuum tube V is heated to an electron emitting temperature by the flow of current from a battery G_3. The potential variations between the grid and filament of the vacuum tube V produce corresponding variations in the current flowing between the plate and filament of that vacuum tube, the circuit interconnecting the plate and filament including the primary winding of a transformer T_2 and a battery G_4. These amplified current variations are then transmitted through the transformer T_2 to an electrical wave filter F which may be of any well-known type, preferably of the type described in the patent to G. A. Campbell, No. 1,227,113, dated May 22, 1917. The electrical wave filter F preferably freely transmits currents of frequencies below a definite limit, while substantially suppressing currents of frequencies above that definite limit. Currents of frequencies above the definite limit may be considered distortions, such as harmonics of the signaling currents, and are clearly undesirable. The output of the electrical wave filter F is then transmitted to an output circuit O, which may terminate at a distant point.

Fig. 2 shows another embodiment of the invention in which the commutator K is maintained in a stationary position. Each of the segments of the commutator is connected to a separate condenser C. These condensers are preferably of the same capacity and have one terminal in common. Slip-rings SR_1, SR_2 and SR_3 rotate about a common axis and obviously at the same speed. These slip-rings carry brush-holders H_1, H_2 and H_3, respectively, in rotation about the common axis. Brush-holders H_1, H_2 and H_3 hold brushes B_1, B_2 and B_3, respectively. Brush B_1 causes the condensers C to be progressively charged and brush B_2 causes these condensers to be discharged in the same progression. The brush B_3 is employed to short-circuit these condensers in the same progression through a resistance R_2. The apparatus of Fig. 2 is otherwise similar in all respects to the corresponding apparatus in Fig. 1 and its description, therefore, need not be repeated.

The operation of the apparatus of Fig. 2 will now be briefly described, it being understood that the general principles of the operation may be applied equally well to the apparatus of Fig. 1. The output of the amplifier A is transmitted through transformer T_1 and through a resistance R_1, slip-ring SR_1 and brush-holder H_1 to brush B_1. Since brush-holder H_1 is pinned or otherwise permanently fastened to the slip-ring SR_1, brush B_1 will rotate about the common axis at the same speed and progressively make contact with the various condensers C. The entire potential transmitted by the amplifier A through transformer T_1 is not impressed upon each condenser C because of the presence of the resistance R_1. Resistance R_1 decreases each voltage by a definite amount, though these decreased voltages correspond in every respect to the voltages transmitted by the amplifier A. Condensers C retain the charges impressed upon them by brush B_1 until brush B_2 makes contact with them. Brush B_2 is held by brush-holder H_2, which is pinned or otherwise fastened to slip-ring SR_2. Brush B_2 rotates at the same speed as brush B_1 and about the same axis though having an angular displacement with respect to brush B_1, the angular displacement determining the time delay to be effected by the apparatus. Brush B_2 picks up the charges of the various condensers in the same progression in which they were charged and impresses corresponding voltages across the terminals of the resistance R_3 and between the grid and filament of the vacuum tube V. Brush B_3 follows brush B_2, brush B_3 being held by brush-holder H_3, which is similarly pinned or otherwise fastened to the slip-ring SR_3. Brush B_3 short-circuits each condenser through the resistance R_2, thereby placing each condenser in proper condition to receive an electrical charge and thereafter to surrender it. It will be obvious that the resistance R_2 is of a suitable magnitude to thereby prevent the circuits associated with the vacuum tube V from sustaining oscillations. If each condenser were short-circuited without series resistance the tendency for the produc-

tion of sustained oscillations would obviously be very great.

In order to show how the delay device of this invention may be constructed, assume, for illustration, a commutator two feet in diameter having commutator segments about one-sixteenth of an inch in width, separated by very small distances. Such a commutator would, accordingly, have approximately 1,200 segments in its circumference. If it be assumed that the commutator is stationary and that the brushes rotate ten revolutions per second, i. e., 600 revolutions per minute, then each brush would in effect pass 12,000 condensers in a second. In fact, each condenser would be passed by each brush ten times per second. With such a commutator and with such a brush speed, it will be apparent that frequencies below 6,000 cycles, approximately, would be transmitted, although those frequencies near the 6,000 cycle limit would be somewhat distorted. Yet satisfactory transmission could be conveniently attained over a band of 4,000 or 5,000 cycles. The higher frequencies which become distorted and still other frequencies introduced by the rotation of the brushes about the commutatator could be easily removed by an electrical wave filter, particularly a low pass filter, which may be connected as shown in the drawings. If, in a particular arrangement, a set of brushes rotates about a commutator ten times per second, it is obvious that it is possible to attain a maximum delay in transmission of one-tenth of a second. If the arrangement made fifteen revolutions per second the maximum delay attainable would be one-fifteenth of a second, etc. If it becomes desirable to obtain delays which are greater than the maximum, then two or more of these arrangements might be connected in tandem, or, on the other hand, a greater number of segments might be provided on each commutator, as by making these segments narrower or by increasing the diameter of the commutator. Obviously, by changing the brush speed the maximum delay attainable may be correspondingly changed within practical limits. In general, the interval of time delay is decreased as the brush speed is increased, and vice versa.

Each voltage transmitted by the amplifier A to each of the condensers passes through the resistance R_1. If it be assumed that there exist the ideal conditions of no leakage and no inductance, then the voltage impressed across each condenser will be

$$e = E\left\{1 - \epsilon^{-\frac{t}{R_1 C}}\right\}$$

in which E is the voltage output of the amplifier A, R_1 is the magnitude of the resistance in series with the secondary winding of the transformer T_1, C is the capacity of each condenser and t is the time during which brush B_1 makes contact with each condenser. In the example given heretofore, for illustrative purposes, the time t would, at a maximum, be one twelve-thousandth of a second. The impression of such a voltage across each condenser brings about its charge at an uneven rate, the rate of charge being very great at first and much slower thereafter. Yet between definite limits the charge on each condenser is almost directly proportional to the voltage impressed thereon. It is necessary to operate between these limits to prevent amplitude distortion. If it be assumed that $e = 0.1\,E$, then

$$RC = 790 \times 10^{-6}$$

The values of R and C may then be tabulated as follows:

R	C (microfarads)
790	1
7,900	.1
79,000	.01
790,000	.001
7,900,000	.0001
79,000,000	.00001

The values of R and C may be chosen with particular regard to the type of structure employed and the convenient and practical values of its constants. As has already been stated, after each condenser becomes charged through contact with brush B_1, the voltage across each condenser is then impressed upon the grid circuit of the vacuum tube V through contact with brush B_2. Thus, the grid circuit of vacuum tube V will receive a fixed percentage of the output of amplifier A, thereby minimizing the possiblity of amplitude distortion.

By suitably choosing convenient values for the constants of the type of structure employed, the time delay may be made substantially independent of frequency, amplitude or other characteristic of the electrical circuit within practical limits. The principles underlying this invention may, for example, be applied to a radio secrecy system in which a band of frequencies corresponding to voice frequency signals is sub-divided into a plurality of sub-bands, the sub-bands being interchanged in the frequency spectrum to render the unauthorized reception of the signals practically impossible. In such a system it may be desirable to introduce time delay in the transmission of one or more of the sub-bands at the transmitting station. The remaining sub-bands may be subjected to delay at the receiving station for similar time intervals.

The particular values stated hereinabove are given merely for illustrative purposes and in practice other values may be chosen within the scope of the invention.

While this invention has been pointed out in certain particular arrangements merely for

the purpose of illustration, it is to be distinctly understood that the general principles of this invention may be applied to other and widely varied organizations without departing from the spirit of the invention or the scope of the appended claims.

What is claimed is:

1. The method of delaying the transmission of electrical waves representing speech, which comprises progressively converting the electrical waves of varying amplitude into a plurality of electrical charges which vary as do the amplitude variations of said waves, maintaining each of these electrical charges undisturbed for a predetermined period of time after the beginning of said conversion, and progressively reconverting the electrical charges into the corresponding electrical waves representing speech.

2. The method of delaying the transmission of electrical signaling waves of varying amplitudes representing speech, which consists in producing a plurality of electrical charges which vary by magnitudes corresponding to the amplitudes of said electrical signaling waves and arranged in progression, and reconverting all of said electrical charges into the corresponding electrical signaling waves a predetermined interval of time thereafter.

3. In a system including a plurality of similar surfaces all adjacent to one another and opposite to another larger surface, the method of delaying the transmission of signaling currents of varying amplitudes representing speech, which consists in progressively charging said similar surfaces to potentials with respect to said larger surface corresponding to the continuous variations in amplitude of the signaling currents, retaining the charges on said surfaces a predetermined interval of time and in the same relative magnitudes, and discharging all of said surfaces in the same progression to reproduce the signaling currents having the proper amplitude variations.

4. In a delay system, a plurality of similar electrical condensers, a source of signaling current of varying amplitude representing speech, a first moving element which progressively charges said electrical condensers in accordance with the variations in amplitude of the signaling current, an output circuit, a second moving element which discharges said electrical condensers in the same progression and successively impresses these charges on the output circuit, and a third moving element which progressively short-circuits said condensers after they have been discharged and after their charges have been impressed on the output circuit.

5. In a delay system, the combination of a plurality of similar electrical condensers, a source of signaling current of varying amplitude representing voice frequency signals, an output circuit, and three moving elements, one of which progressively charges said electrical condensers in accordance with the amplitude variations of the signaling current, another of which progressively discharges said electrical condensers and impresses these electrical charges on the output circuit, and the last of which thereafter short-circuits said electrical condensers.

6. The method of delaying the transmission of electrical waves of varying voltages representing voice frequency signals with apparatus including a plurality of similar electrical condensers, which consists in progressively charging all of said electrical condensers corresponding to the voltage variations of the electrical waves, and reconverting said electrical charges into the corresponding electrical waves of varying voltage a predetermined interval of time after the beginning of said transmission.

7. A transmission delay system comprising a commutator having a plurality of segments, a plurality of condensers, one condenser being connected to each segment, means for progressively charging all of said condensers in accordance with the variations of speech signaling waves, and means for reconverting the charges of all of said condensers in the same progression into the corresponding variations of speech signaling waves a predetermined interval of time after said charges have been impressed upon said condensers.

8. A wave transmission system comprising a plurality of condensers, three brushes which rotate at the same speed about a common axis and which are separated from each other by predetermined distances along a circumference of said axis, a source of speech signals, means associated with one of said brushes for progressively charging said condensers in accordance with said signals, means associated with another of said brushes for progressively discharging said condensers in order to reproduce said signals, and means associated with the third of said brushes for progressively short-circuiting said condensers.

In testimony whereof, I have signed my name to this specification this 6th day of February, 1928.

CHARLES H. FETTER.