

July 7, 1936.

H. F. WILDER

2,046,984

INTERPOLATING CIRCUIT

Filed April 5, 1934

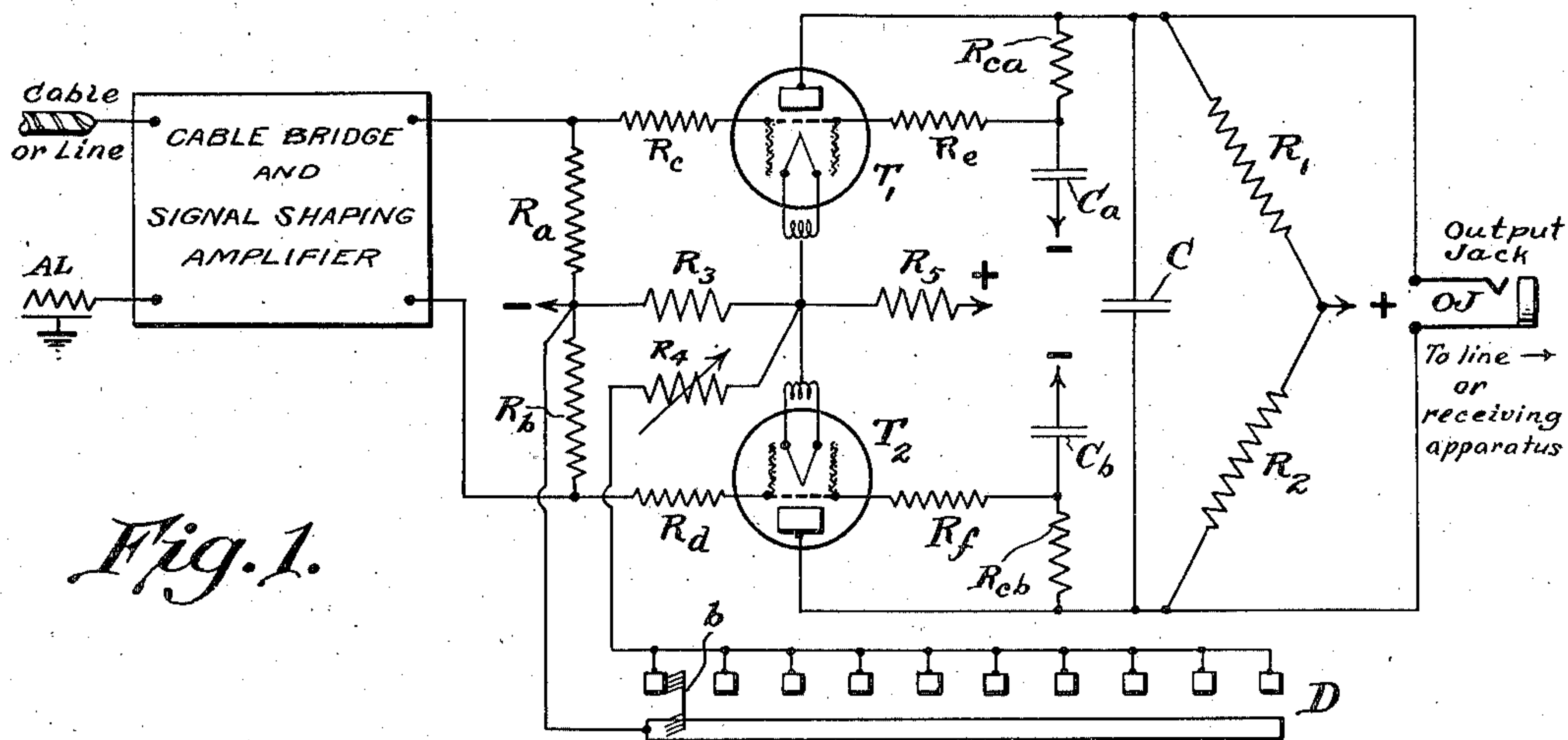


Fig. 1.

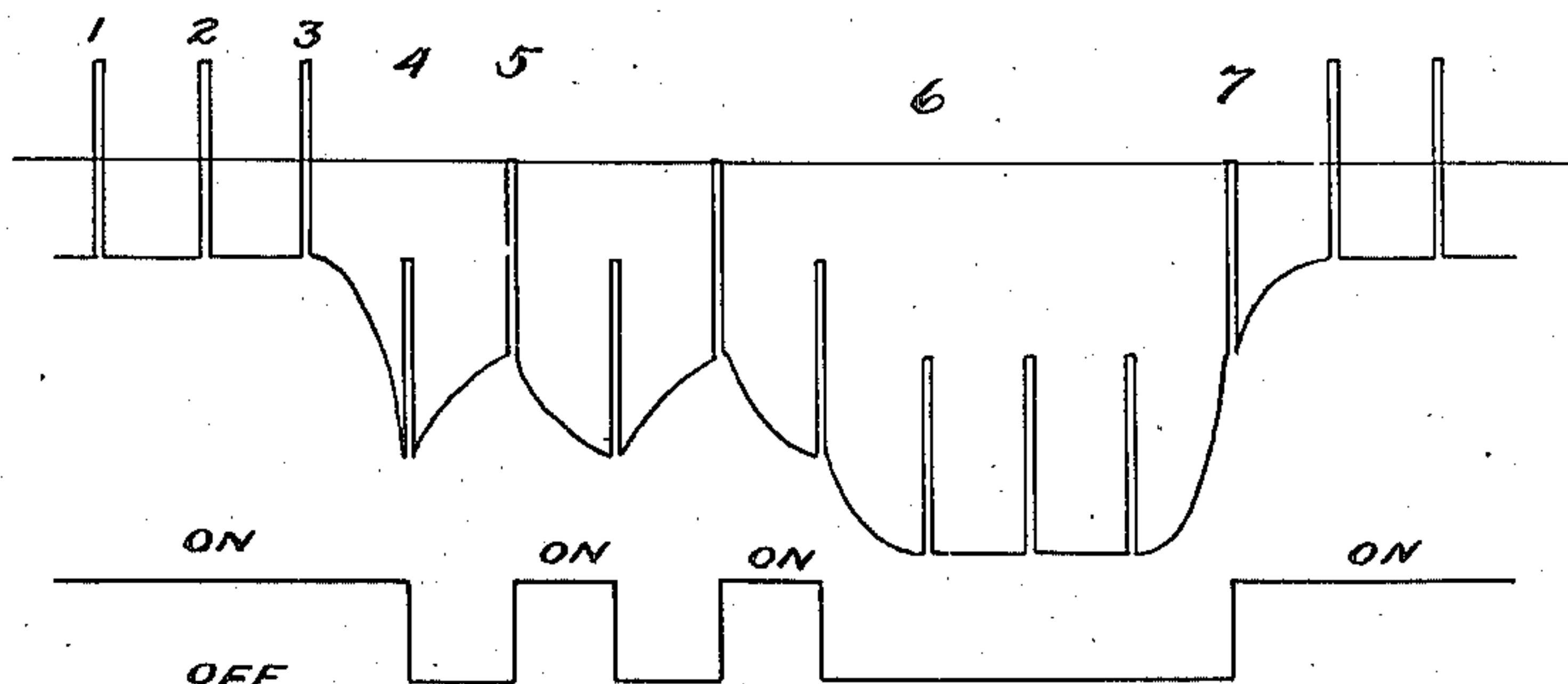
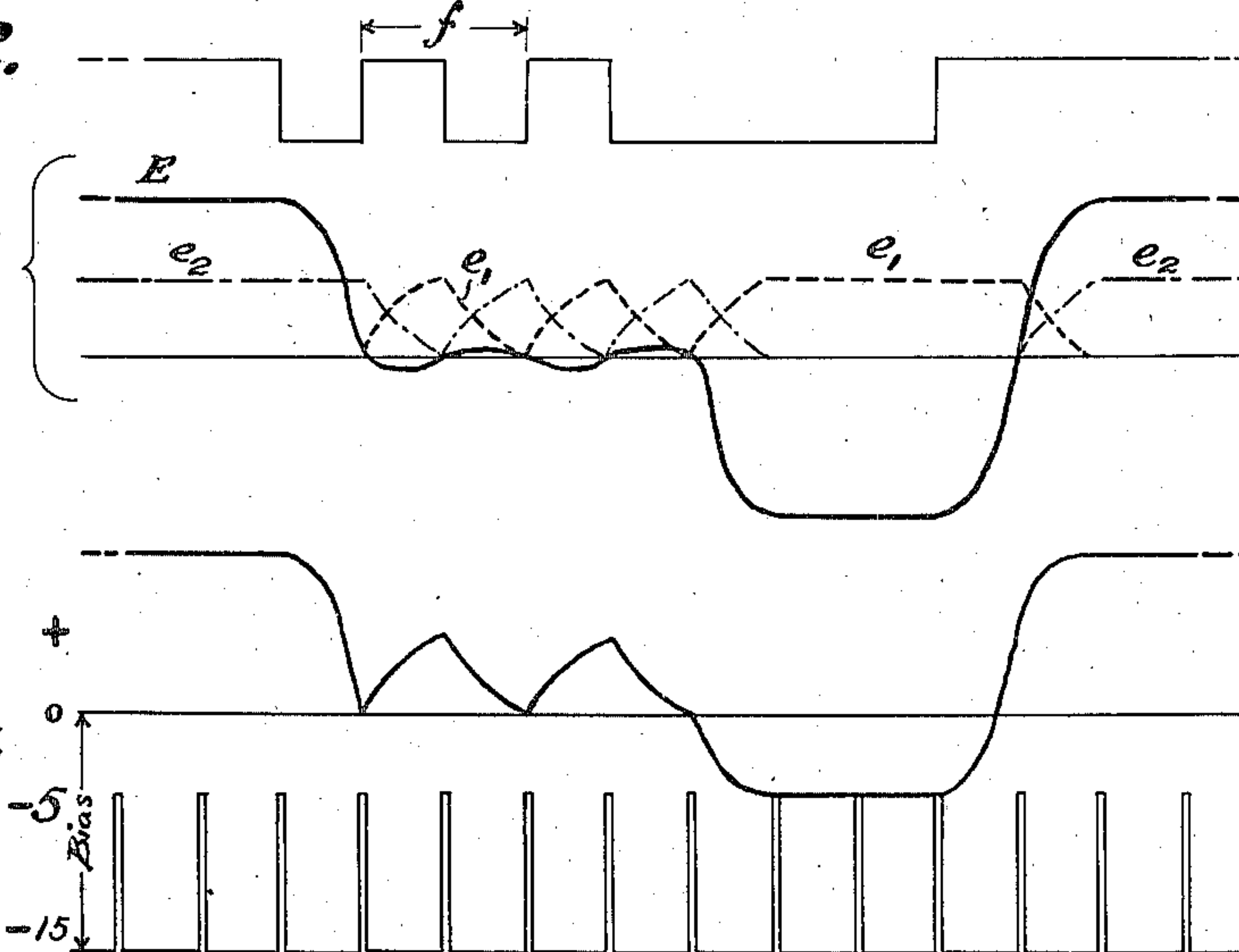
Fig. 2.

Fig. 3.

Fig. 4.

Fig. 5.

Fig. 6.



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UNITED STATES PATENT OFFICE

2,046,984

INTERPOLATING CIRCUIT

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Application April 5, 1934, Serial No. 719,193

9 Claims. (Cl. 178—70)

This invention relates to telegraph systems and particularly to circuit arrangements for receiving or repeating multiplex code signals wherein the impulses of the fundamental signal frequency that have become attenuated in transmission, are automatically interpolated.

It has been disclosed in recent patents, such as Haglund No. 1,901,296, that the rate of transmission over cables may be greatly increased by eliminating electro-magnetic relays and employing thermionic tubes or valves of the gaseous arc discharge type such as disclosed in reissue patent to Von Lieben et al., No. 13,779, more fully described in *Elektrotechnische Zeitschrift* of November 27, 1913, at page 1359; and the Langmuir Patent No. 1,289,823, described in the *Journal of the American Institute of Electrical Engineers* of November 1928 at page 802, together with other forms in which the characteristics of the Von Lieben tube when employed as a trigger device, are more fully set forth.

In the accompanying drawing, Figure 1 is a diagrammatic illustration of a circuit arrangement embodying my invention; Fig. 2 illustrates the wave shape of the signal impulses transmitted at the rate of the first harmonic signal frequency; and Figs. 3 to 6 illustrate graphically the various tube potential functions for the signal shown in Fig. 2.

The purpose of my invention is to provide a circuit arrangement which permits a much greater speed of signaling than has been possible heretofore, to render the reception more sensitive and to automatically interpolate the signal impulses of the highest frequency which have been attenuated to such a degree that the received energy level for signals of this frequency is so near the interference level as to preclude faithful operation of the receiving relay device.

Multiplex code signals are composed of impulses of a unit time duration of either positive or negative polarity in various combinations and are impressed upon the line or cable by the telegraph transmitter. In the following description of my invention I shall designate the most rapid alternations of positive and negative potential as the first harmonic signal frequency. Combinations of two positive impulses alternated with two negative impulses will be termed the second subharmonic signal frequency. Intermediate to these two frequencies there lies a frequency 1.33 times that of the second subharmonic which is composed of two like impulses followed by a single alternate impulse. Still lower frequency signal combinations will also occur.

Transmission lines absorb energy in an amount logarithmically proportional to the frequency of signaling. In the final analysis the speed of signaling will be limited because of attenuation as the receiving energy approaches the energy level of the interference within the useful frequency spectrum. For purposes of discussion, the minimum ratio of signal to interference will be said to be 10. To increase the speed of working beyond this limit, certain changes in the local receiving equipment are essential. This further development is embodied in my present invention.

The signaling speed may be increased until the intermediate signal frequency has suffered sufficient attenuation to bring its energy level to a value 10 times that of the interference, which is an approximation of the least ratio found practical in actual operation. The attenuation of the first harmonic signal frequency will now be such, that the received energy level for signals of this frequency will be so near the interference level as to preclude faithful operation of the receiving relay. If the receiving relay is now connected either mechanically or electrically to a rotating machine or commutator, held in synchronism with the telegraph transmitter, it may be caused to vibrate in phase with the first harmonic signal frequency if driven by an effective force one-half that of the signal force developed by the receiving equipment. Signals of a frequency less than the first harmonic will hold the relay on its pole or contact against the vibrating force.

To illustrate this method of multiplex signaling an actual case will be considered:—

The line is a non-loaded submarine cable—(Western Union, 1894)	35
Product of capacity and resistance. (KR) = 2.425	
Interference level.....	0.35 millivolt
Maximum signal frequency received and operating the relay.....	11.0 cycles
Received millivolts at this frequency for a sending battery of 70 volts and usual sending capacitive reactance.....	= 3.5
Ratio of signal to interference.....	= 10
Equivalent multiplex letters per minute....	= 264

To increase the speed, the method of signaling previously described and embodying the present invention will be compared below:—

The signal frequency is increased until the intermediate frequency only is operating the relay and the attenuated first harmonic is interpolated by the method herein disclosed.	50
Interference level remains at.....	0.35 m. v.

Signal level of first harmonic-- (16.5 cycles) 0.38 m. v.

Signal level of intermediate frequency--(11 cycles) 3.50 m. v.

8 Equivalent letters per minute----- 400

Gain in efficiency $\left(\frac{400 \times 100}{264} - 100\right)$ ----- =50%

Until recently an electromagnetic relay has been used exclusively as the output device operated by the signal amplified. The considerable power required to properly operate the relay and the difficulty of maintaining its mechanical functions, which are subject to failure and bias from either the mechanical or electromagnetic zero, can only be appreciated by the engineer or practical designer. At the higher signaling frequencies a disadvantage is incurred by the non-linearity of the impedance-frequency characteristic. A gaseous discharge tube or grid-controlled thermionic rectifier of the type referred to, is greatly superior to any magnetic relay in these characteristics. A material reduction in amplification results, as only one hundredth of a watt at ten volts is required to control a space current of several hundred milliamperes in the rectifier tube or valve. The control ratio of the valve or rectifier tube is a function of the mechanical spacing of the valve elements, the gas pressure and anode potential, and as these can be readily maintained reasonably constant in operation, the valve-tube cannot take up an equivalent bias. Making the grid-cathode external impedance non-inductive will produce a linear frequency-impedance input characteristic.

35 The present invention is a circuit arrangement employing gaseous discharge tubes which are caused to oscillate electrostatically in synchronism with the unit signaling frequency and to thereby interpolate the attenuated first harmonic signal frequency in multiplex signaling.

Referring to the drawing, the gaseous arc-discharge tube or valve T_1 , the resistance R_1 , the tube or valve T_2 and the resistance R_2 form the four arms of a Wheatstone bridge circuit. Only one tube is operated at any time so that an alternating potential will be observed across the diagonal of the bridge to which the output, represented by the jack OJ is connected. The grid of each valve is biased 15 volts negatively with respect to the cathode by the I R drop in resistance R_3 of the potentiometer $R_3 + R_4$. At the instant of "pick-up", this bias is reduced to one-half of the signal voltage, by shunting R_3 with resistance R_4 synchronously with the signaling frequency, as by means of the synchronous commutator D. Synchronous operation of the brush b with the transmitter may be obtained by a number of devices none of which it is necessary to describe here as they are generally well known in the art.

Let it be assumed that either tube will be operated if its effective grid-cathode potential difference is reduced to zero negative volts or to an actual positive potential. The resistances $R_a + R_b$ constitute the output impedance of the amplifier and may be of the order of 5000 ohms each. The grid potentiometers $R_c + R_e$ and $R_d + R_f$ are so proportionally adjusted that if a tube is extinguished, the maximum positive grid potential of that tube will rise to one-half the signal voltage. The time-constant of each circuit is so adjusted that the gradual rise in grid potential reaches a maximum in about 0.9 of the time required for the brush to pass from one pick-up segment to

an adjacent one. The two delay circuits are designated R_{ca} , C_a , and R_{cb} , C_b . The arc in the "on" tube or valve is instantly extinguished by the transient reversal of its anode potential caused by the discharge of condenser C, the instant the "off" tube is ignited, as is well known.

I have illustrated graphically in Figs. 3 to 6, various tube potential functions for the signal shown in Figure 2. The cycle shown at f in Fig. 2, illustrates signal impulses transmitted at the rate of the first harmonic signal frequency. As indicated in Fig. 3, the attenuation in transmission through the cable is so great that the amplitude of the received signals of first harmonic frequency is insufficient to actuate a relay. The graph of the signal E. M. F. shown at E in Fig. 3, is first positive for tube T_1 and, of course, is negative for tube T_2 as the grids of the tubes are connected in opposition across the output resistance $R_a + R_b$. In this description I shall consider only the potential on the grid of tube T_1 .

In Figure 4 the negative bias voltage set up across resistance R_3 is shown to be periodically decreased from -15 to -5 volts during the time that the pick-up brush b is in contact with a pick-up segment. The upper curve of Figure 4 represents the algebraic sum of the signal voltage E and the E. M. F. fed back to the grid by the potentiometer and delay circuit. This E. M. F. is indicated by the dotted line e_1 of Fig. 3 and rises to a maximum of five volts positive when the tube T_1 is "out" and T_2 is "on". Similarly, the feed back E. M. F. e_2 acts on the grid of tube T_2 but 180 electrical degrees out of phase with e_1 . If the delay circuits were omitted these E. M. F.'s would reach a maximum during the pick-up time and both tubes would come "on", thereby blocking the signals.

It will be convenient to refer to Figure 6 to observe the time during which tube T_1 is "on" and "off".

Only the actual potential difference between the grid and cathode of the tube is effective in its control and to show this controlling voltage both plots of Fig. 4 have been added algebraically as shown in Fig. 5. At the instant of pick-up numbered 1, 2 and 3, a positive signal of 10 volts is opposed by the negative 5-volt bias, momentarily reduced from 15 volts. The resultant positive five volt E. M. F. acting on the grid starts the tube T_1 . As a matter of fact, the grid of the tube cannot rise much above 2 volts positive because it is in contact with the arc discharge, but for the present discussion this may be neglected as the grid E. M. F. is not so affected during the "out" period preceding the discharge. At the instants 1, 2, and 3, it will be observed that the feedback E. M. F. e_2 on tube T_2 is positive at the moment of pick-up, but is more than overcome by the 10 volt negative signal. At the instant 4, however, the signal has dropped to zero and the tube T_2 starts. The reverse is true at 5 where e_1 is now a maximum and tube T_1 is operated, extinguishing tube T_2 . In this manner the tubes oscillate during the interval that the signal level is zero.

A negative signal at the instant 6, prevents the tube T_1 from being operated, for the effective grid bias is maintained highly negative at all times. The rise in a positive direction finally reduces the effective grid potential and the tube T_1 starts at instant 7.

I have described the circuit arrangement shown in the accompanying drawing in detail for the purpose of clearly disclosing one embodiment of my invention but it will be evident to

engineers that various changes and modifications can be made within the scope of my claims.

I claim:—

1. In a signaling system, means for producing groups of uniform numbers of selecting signal conditions, a line circuit including a gaseous conduction path, biasing means normally preventing a discharge across said path, means for periodically changing said biasing means in substantial synchronism with said selecting conditions to permit a discharge across said path and means for interrupting said discharge selectively in accordance with the polarity of the successive signal conditions.

2. In a signaling system, a source of periodic signals of positive and negative polarity, receiving apparatus for said signals comprising a gaseous conduction device for each polarity of signaling current, each device having anode, cathode and grid elements, means for normally applying a predetermined bias on said grids, means for periodically reducing the value of said bias to permit a discharge through one or the other of said devices in accordance with the signal polarity and means associated with said devices for causing the discharge through one tube to interrupt the discharge through the other tube.

3. In a signaling system, a source of periodic signals of opposite polarity, responsive apparatus for said signals comprising gaseous discharge tubes having control grids for initiating discharges through the tubes, one of such tubes being provided for each polarity of current, a common biasing means for the tubes, means operating in synchronism with the signals for periodically shunting said biasing means to permit a discharge through one tube in accordance with the polarity of the signal and circuit connections for causing the starting of one tube to interrupt the operation of the other tube.

4. In a signaling system, a source of periodic signals of opposite polarity, responsive apparatus for said signals comprising gaseous discharge tubes having control grids for initiating discharges through the tubes, one of such tubes being provided for each polarity of current, control circuits for said tubes associated with said grids for starting a discharge therethrough in accordance with the polarity of said periodic signals, circuit connections for causing the interruption of one tube upon the starting of the other tube, and storing means connected to each grid, operating to impress an electromotive force thereon of the proper phase and polarity to initiate a discharge through the interrupted tube in synchronism with the next succeeding signal.

5. In a signaling system, a source of periodic signals of opposite polarity, responsive apparatus for said signals comprising gaseous discharge tubes having control grids for initiating discharges through the tubes, one of such tubes being provided for each polarity of current, control circuits for said tubes associated with said grids for starting a discharge therethrough in accordance with the polarity of said periodic signals, circuit connections for causing the interruption of one tube upon the starting of the other tube, and means for impressing an electromotive force upon the grid of the interrupted tube of the proper phase and polarity to initiate

a discharge therethrough in synchronism with but irrespective of the next succeeding signal.

6. In a signaling system, a line circuit connected to a source of periodic telegraph signals of marking and spacing conditions, apparatus for receiving said signals, comprising an electrostatically controlled arc discharge tube for each polarity of current, biasing means connected to oppose the starting of both tubes, and means for periodically reducing the value of said biasing means by shunting said means in synchronism with the signal impulses, thereby causing the starting of one or the other tube in accordance with the signal condition.

7. In a signaling system, a line circuit a source of periodic signals of positive and negative polarity selecting conditions operating at a speed of transmission such that the signal impulses of fundamental frequency or unit time duration are attenuated below the effective operating level, means for interpolating said attenuated impulses, comprising an electrostatically controlled arc discharge tube for each polarity connected to the line, each tube having a grid controlling the starting of a discharge therethrough in accordance with each successive selecting condition, circuit arrangements for extinguishing one tube upon the starting of the other tube, and means for impressing an electrostatic charge upon the grid of the interrupted tube of the proper polarity to initiate a discharge therethrough when the next succeeding impulse is of unit time duration.

8. A signaling system as defined in claim 7, said means for impressing an electrostatic charge upon the grid of the interrupted tube operating upon each tube in succession to cause the tubes to oscillate in synchronism with the transmitted signals when the signal level falls below the effective operating level and thereby to interpolate the signal impulses of unit time duration.

9. In a signaling system, a line or cable, a source of periodic signals of positive and negative polarity operating at a speed of transmission such that the signal impulses of fundamental frequency or unit time duration are attenuated below the effective operating level, a second line or receiver, and means to repeat said signals from said first line or cable into said second line or receiver; comprising gaseous discharge tubes having control grids for initiating discharges through the tubes, a tube being provided for each polarity, the input of said tubes being continuously connected to said first line or cable and the output of said tubes being continuously connected to said second line or receiver, means for biasing said grids, means operating in synchronism with the fundamental signal frequency for periodically shunting said biasing means to permit a discharge through one or the other tube in accordance with the polarity of the signal impulse, circuit arrangements for extinguishing one tube upon the starting of the other tube, and means for impressing an electrostatic charge upon the grid of the interrupted tube of the proper polarity to initiate a discharge therethrough when the next succeeding impulse is of unit time duration.