Dec. 23, 1941. A. M. SKELLETT 2,267,579

ONE WAY AT THE TIME REPEATER

Filed April 18, 1940 2 Sheets-Sheet 1

FIG. 1

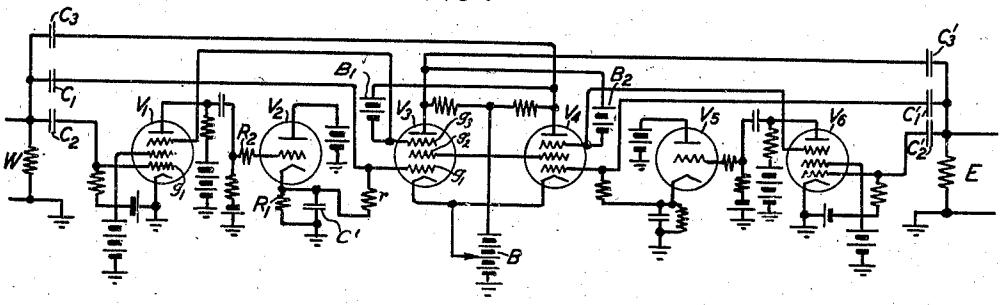


FIG. 2

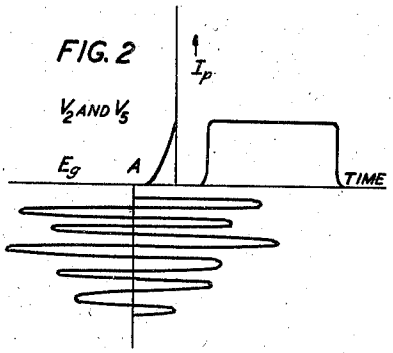


FIG. 3

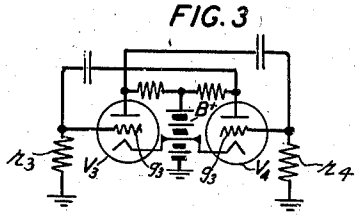


FIG. 4

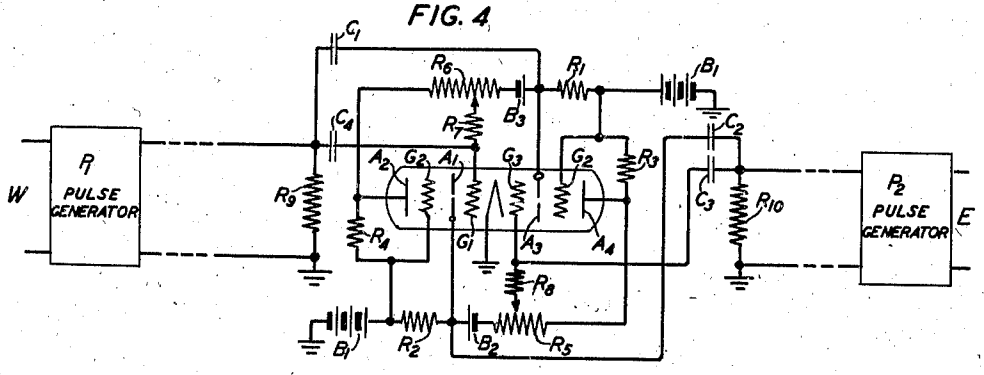
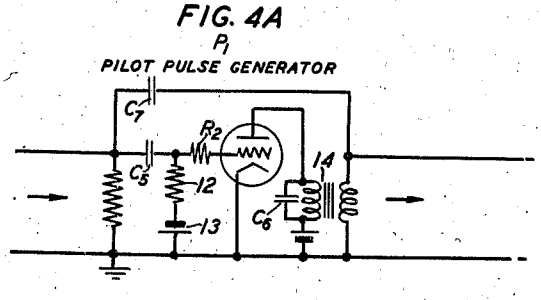


FIG. 4A



INVENTOR
A.M. SKELLETT
BY H. A. Burgess
ATTORNEY

Dec. 23, 1941. A. M. SKELLETT 2,267,579

ONE WAY AT THE TIME REPEATER

Filed April 18, 1940 2 Sheets-Sheet 2

FIG. 5

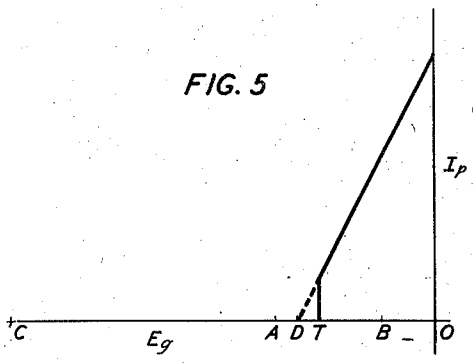


FIG. 6

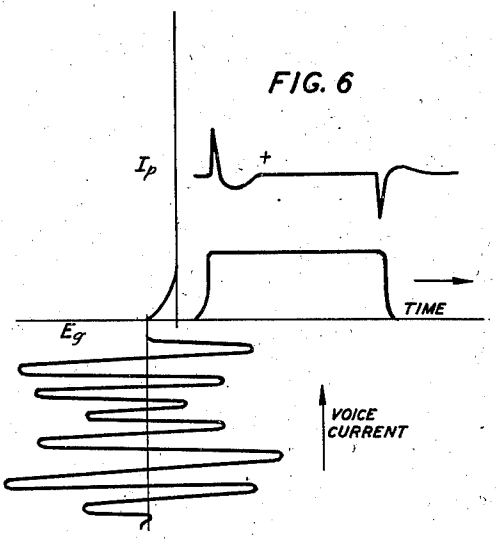


FIG. 7

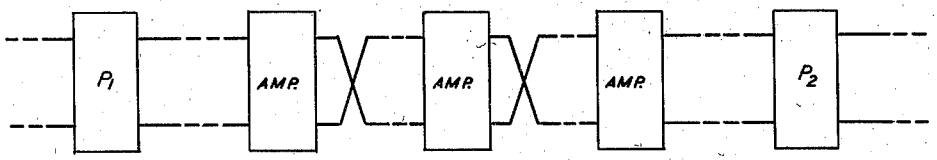
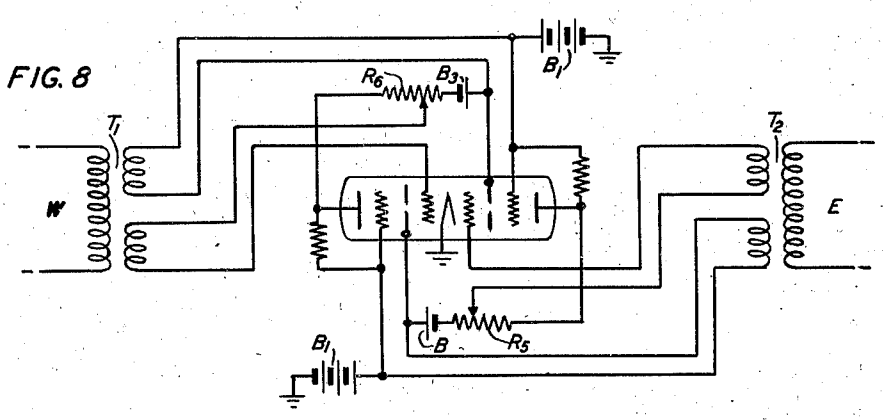


FIG. 8



INVENTOR
A.M. SKELLETT
BY
K. A. Burgess
ATTORNEY

Patented Dec. 23, 1941 2,267,579

UNITED STATES PATENT OFFICE

2,267,579

ONE WAY AT THE TIME REPEATER

Albert M. Skellett, Madison, N. J., assignor to Bell Telephone Laboratories, Incorporated, New York, N. Y., a corporation of New York

Application April 18, 1940, Serial No. 330,262

7 Claims. (Cl. 179—170)

This invention relates to signal transmission systems and its purpose is to provide simple and efficient means for accomplishing such transmission especially over circuits used for two-way signaling over a single pair of conductors.

More specifically its purpose is to provide a repeater or repeaters for direct insertion into a two-way two-wire transmission line without the necessity at the repeater point of going to a four-wire basis and without the necessity of using hybrid coils or their equivalent at any point along the main transmission line.

Another purpose is to maintain the repeaters during no-signal condition at infinite loss for both directions, thus eliminating the disadvantages of noise and cross-talk during such intervals.

Still another purpose is to so adjust the gain around the repeater loop circuit that there is a net loss thus avoiding the need of careful balancing arrangements or the use of echo suppressors and other equivalent elements to prevent singing.

The invention will be better understood from the specification and accompanying drawings in which:

Fig. 1 shows one circuit arrangement for accomplishing the purposes of my invention;

Fig. 2 shows the characteristic of one of the tubes in the circuit of Fig. 1;

Fig. 3 is a modification of a portion of the circuit of Fig. 1;

Fig. 4 is a second circuit for accomplishing the purposes of my invention in which use is made of a tube of special construction;

Fig. 4*a* is a detail of a portion of Fig. 4;

Fig. 5 shows one of the characteristics of the special tube of Fig. 4;

Fig. 6 shows the characteristic of one of the tube circuits in Fig. 4;

Fig. 7 shows the use of a plurality of repeaters of the type of Fig. 4; and

Fig. 8 is a modification of Fig. 4.

Referring more particularly to Fig. 1 there is shown a transmission line for two-way conversation from west to east and the reverse. Two main amplifier tubes V_3 and V_4 constitute the primary tubes of a repeater set. These tubes are pentodes, each containing, in addition to the usual filament and plate, a control grid g_1, a screen grid g_2 and a suppressor grid g_3. V_3 is connected for west-east transmission and V_4 for east-west transmission. In the no-signal condition these tubes are both biased to cut-off so that there is an infinite loss through each. Signal coming from west is impressed on the control grid g_1 through blocking condenser c_1. A grid leak for this grid is provided through the series resistances r and R_1 and a negative bias provided from a portion of the battery B is sufficient to bring the tube to well below cut-off. The signal train arriving from the west is also impressed, through the condenser c_2, on control grid g_1 of the tube V_1, this latter tube being also a pentode similar in its properties to V_3. In the no-signal condition this tube is biased to a point where it will satisfactorily amplify the incoming signal, the amplified signal being in turn impressed on the grid circuit of tube V_2. The tube V_2 is a conventional three-electrode tube supplied with a low plate battery voltage the external load circuit consisting of the resistance R_1 shunted by the condenser C'. The tube is just biased to cut-off and in the gird circuit there is introduced a large resistance R_2. The behavior of the tube under these circumstances is illustrated in Fig. 2, the left portion of the figure showing the I_p—E_g characteristic and the right portion showing the plate current as a function of time while signal is being received. It will be evident that when the grid of this tube goes positive it immediately starts collecting electrons whereupon the voltage drop through R_2 resulting from the flow of these electrons prevents the grid from ever going more than slightly positive. As a result if an irregular signal, such as that illustrated in the lower part of Fig. 2, is impressed on the input circuit, the current through R_1 as a function of time is that shown in Fig. 2, constituting a pulse of current which is sustained during the interval of signal reception. Fluctuations in the current flowing through R_1 are substantially wiped out by the condenser C'.

It will be observed that the voltage drop through R_1 is impressed on the grid g_1 of tube V_3 and is in such a direction as to raise its potential, doing this by a sufficient amount to bring V_3 to a point of normal gain. A signal train coming through the condenser c_1 is then amplified and transmitted to the east section of the line through the condenser c'.

When the gain of V_3 has been brought to normal condition and a signal is being transmitted the potential of its plate drops by a substantial amount. This drop in potential is transmitted to the suppressor grid g_3 of the tube V_4 and, combined with the negative potential of the battery B_2, so biases the tube V_4 that no transmission therethrough can occur no matter how large a potential may be impressed on its

control grid. The negative potential of the suppressor grid of V_4 is also passed on to the suppressor grid of V_6 thus disabling that tube also. The arrangement of the circuit for transmission from east to west is identical in every respect.

Under these circumstances it will be seen that in the no-signal condition the repeaters are adjusted for infinite loss in both directions. If signal arrives from the west a biasing pulse is immediately generated to unblock the primary amplifying tube for transmission from west to east. Signal coming to the control grid of V_3 is amplified and transmitted to the east. At the same time a biasing voltage derived from the tube V_3 is impressed on tubes V_4 and V_6 to further block transmission from east to west as long as signal is arriving from the west. On termination of the signal wave train from the west the plate current of V_2 falls to zero and all tubes are restored to the no-signal condition.

The voltage supplied to the various plates and various grid elements are those appropriate for the particular type of tubes used to bring each tube to the desired point on its operating characteristic.

In Fig. 1 there are two batteries B_1 and B_2 in circuit as floating batteries for biasing of the suppressor grids of V_3 and V_4. In some cases it will be considered undesirable to use such floating batteries and they may be avoided by the circuit of Fig. 3 in which certain of the essential elements only are illustrated. The suppressor grids are shown as connected through resistances r_3 and r_4 to ground, it being noted that the cathodes of the tubes V_3 and V_4 are at a higher potential than ground. Thus the grids g_3 are at a negative potential with respect to the cathodes. The connections may be made directly to the cathodes instead of to ground. A drop in the potential of the plate of V_3 is transferred through a condenser to the suppressor grid of V_4, thus lowering the bias of V_4 in the manner already described.

The circuit of Fig. 4 is a modification of that of Fig. 1. The primary amplifying device consists of two amplifiers within one envelope using a single common cathode. One of these comprises an electron discharge device comprising a cathode, a control grid G_1, a first anode A_1, a second grid G_2, and a second anode A_2. The first anode A_1 has an aperture through which a portion of the electrons from the cathode may pass to the second anode A_2 which anode is floating and is specially prepared to permit a large ratio of secondary to primary electrons. The detailed construction and the functioning of this tube is fully described in my copending application Serial No. 321,852, filed March 2, 1940, and need not here be repeated in full. It is sufficient for this disclosure to state that the tube has certain trigger characteristics. Normally the grid G_1 is biased to cut-off. If a positive pulse of sufficient magnitude is impressed on the grid G_1 the tube is triggered on in the sense that some of the electrons traveling towards the anode A_1 pass to the second anode A_2 and in cooperation with the grid G_2 give rise to secondary emission. Immediately the bias of the grid G_1 rises to an operating value corresponding to B of Fig. 5 and the electron current then flowing to anode A_1 is subject to control of potential variations on the grid G_1. Under these conditions the characteristic of the tube is that shown in Fig. 5.

With the circuit connections shown in Fig. 4 both control grids G_1 and G_3 are biased to cut-off so that there is infinite loss in transmission through the circuit in both directions. In order to bring one or the other of the amplifiers into amplifying or triggered-on condition it is necessary to have a triggering impulse. This I provide by means of the pilot pulse generators P_1 and P_2, one on each side of the repeater. These pulse generators may be placed immediately adjacent to the repeater or may be at remote points out on the line in the two directions. Preferably they would be placed at or near the extreme ends of the transmission system.

The pilot pulse generator, shown in detail in Fig. 4*a*, comprises a conventional three-electrode tube supplied with a low plate voltage, a blocking condenser C_5, a grid leak **12** and biasing battery **13**. A high resistance R_2 is connected from the condenser C_5 to the grid. If a positive impulse arrives on the grid it collects electrons and a voltage drop incident thereto prevents the grid from becoming more than slightly positive. The characteristic of the tube under these conditions is shown in Fig. 6 where the I_p—E_g characteristic is shown to the left and the plate current as a function of time is shown at the right. The plate current flows through the primary of the transformer **14**, the ordinary signal variations being by-passed by the condenser C_6. Across the secondary of the transformer there will then appear a sharp positive pulse at the beginning of the signal train and a sharp negative pulse at the termination of the wave train as shown at the top of Fig. 6. These pulses are transmitted over the transmission line and between them there will be the signal message by-passed around the pulse generator by the condenser C_7.

Referring more particularly to this Fig. 4, it will be noted that there are two biasing batteries B_2 and B_3 the positive ends of which are connected to the first anodes of the opposite sides of the tube and these batteries in part determine the bias of the control grids with respect to their common cathode. With no signals flowing through the repeater the two sections of the tube will have their control grids biased to point A on Fig. 5. Their first anodes will therefore receive no current and will be at approximately the potential of the battery B_1. Actually they will be a volt or two higher than this because of the voltage drops in R_1 and R_2 due to the bleeder currents which flow through these resistances. The bleeder circuit traces through B_3, R_1, R_3, R_5, B_2, R_2, R_4, R_6. Although separate plate batteries B_1 are shown in order to simplify the circuit diagram, it is understood that only a single battery will be needed.

If now west starts to talk a positive pulse will enter the repeater at the left and will be applied to the first grid G_1 through condenser C_4. This sharp pulse, which will be of a larger positive value than any attained by the speech signal itself, will then trigger on that side of the tube by raising the bias of G_1 to T of Fig. 5 which is sufficient to cause a small electron flow and the bias of G_1 then jumps to point B and the circuit will then operate as a linear amplifier. Signal is transmitted to the east through condenser C_2. The ensuing flow of electrons to the first anode A_1 causes its potential to drop from near the battery voltage to the operating voltage and, through battery B_2, a portion of resistances R_5 and R_8, this decrease in potential is applied to the grid g_3 of the right-hand side of the tube. The bias of grid g_3 will then swing negatively to point C on Fig. 5 and the potential of the floating anode A_4 will drop to a point making it im-

possible to trigger this side on no matter how high a positive signal is applied to the grid. The repeater is now in condition to amplify in the west-east direction and is cut off in the east-west direction. This action takes place in a time interval substantially less than one millisecond so that no appreciable part of the speech is lost.

As soon as the voice currents cease the negative pulse swings the grid G_1 to point D on Fig. 5 and the left-hand side of the tube triggers off. The potential of A_1 will now swing positively back to near battery voltage but because of the condenser C_2 and the rest of the circuit connected to it, it will take a longer time to return to its no-signal value than for the triggering action. The right side of the tube cannot be triggered on until A_1 is nearly at its normal condition because the potential of the floating anode A_4 does not reach a value to permit this until the grid bias is nearly back to point A on Fig. 5. The time constants of A_1 and G_3 which depend on C_2 and C_3 and their associated resistances may be adjusted so that the positive pulse impressed on G_3 as A_1 is returning to normal, is too small to trigger the right side on by the time the floating anode reaches a sufficiently low potential.

It is apparent that a plurality of repeaters of the type shown in Fig. 4 may be connected in tandem, suitably spaced over a long transmission line as shown in Fig. 7. One pulse generator at each end of the line will be required and at each repeater the triggering pulses are transmitted on in the same way as the signal train. When several such repeaters are operated in tandem on the line, the line terminals must be reversed between repeaters since each repeater is equivalent to a single tube amplifier and thus changes the phase by 180 degrees of the triggering pulses as well as the voice currents.

Also in some cases it may be advantageous to use transformers in certain places. Thus, in Fig. 8 which shows parts of the circuit only, the resistances R_1 and R_2 are replaced by transformers with the secondaries connected to the outgoing lines. In this case also the high resistances R_9 and R_{10} may be omitted. In addition the resistances R_7 and R_8 may be replaced by transformer windings.

What is claimed is:

1. A two-way repeater for insertion between two sections of a two-way line adjusted for infinite loss for both directions during no-signal intervals and comprising space discharge apparatus including cathode means having connection to one conductor of each line section, two anodes connected individually to the opposite conductor of the respective line sections, two control grids connected individually to the respective side of the line section such that one grid and cathode means are connected across each line section, a pulse generator on each side of the repeater for generating from the signal train traveling toward the repeater a pulse at the beginning of the signal train and transmitting said pulse to the repeater to condition the repeater for transmission in one direction and to further prohibit transmission in the other, said pulse generator generating from said signal train a pulse of opposite sign at the end of the signal train and transmitting said latter pulse to the repeater to restore the repeater to its normal no-signal interval condition.

2. A two-way repeater for insertion between two sections of a two-way line adjusted for infinite loss for both directions in no-signal intervals and comprising space discharge apparatus including cathode means having connection to one conductor of each line section, two anodes connected individually to the opposite conductor of the respective line sections, two control grids connected individually to the respective side of the line section such that one grid and cathode means are connected across each line section, a pulse generator on each side of the repeater for generating at the beginning of a signal train traveling toward the repeater a pilot pulse of one polarity and at the end of the signal train a pilot pulse of the opposite polarity traveling toward the repeater, the first pulse conditioning the repeater for transmission in the direction of the pulse and prohibiting transmission in the other direction and the second pulse restoring the repeater to no-signal condition.

3. A two-way repeater for insertion between two sections of a two-way line comprising two electronic amplifying devices with trigger characteristics whereby the two devices are at infinite loss during no-signal intervals, each requiring a substantial positive pulse to trigger on the device to a high gain condition and a substantial negative pulse to trigger it off to infinite loss condition, cathode means in said devices having connection to one conductor of each line section, two anodes connected individually to the opposite conductor of the respective line sections and two control grids connected individually to their respective side of the line section, a pulse generator on each side of the repeater for generating at the beginning and at the end of a signal train pilot pulses of opposite polarity traveling toward the repeater, the pulses being of such magnitude that the arrival of the first triggers on the repeater for transmission in the direction of the pulse and prohibits transmission in the other direction and the second pulse restores the repeater to no-signal condition.

4. A two-way repeater for insertion between two sections of a two-way line adjusted for zero gain for both directions in no-signal intervals and comprising space discharge apparatus, including cathode means having connection to one conductor of each line section, two anodes connected individually to the opposite conductor of the respective line sections, two control grids connected individually to the respective side of the line section such that one grid and cathode means are connected across each line section, a pulse generator on each side of the repeater for generating at the beginning of a signal train traveling toward the repeater a pilot pulse of one polarity and at the end of the signal train a pilot pulse of the opposite polarity traveling toward the repeater, the first pulse acting to trigger on the repeater for transmission in the direction of the pulse and further prohibiting transmission in the other direction, and the second pulse acting to trigger off the repeater and restore it to no-signal condition.

5. In a two-way telephone circuit, an amplifying device transmitting signals in either direction, said device in the no-signal condition being inoperative for signal transmission in either direction, means for generating at the beginning of a signal train from the signal train a pulse to render the said device operative for signal in the direction of the transmission of the signal and for generating at the end of the signal train a pulse to restore the said device to a no-signal condition in that direction, the pulses traveling throughout over the same path as the signal.

6. A signal transmission line system for two-way signaling, a plurality of two-way repeaters spaced at intervals along the line, each repeater comprising two electronic trigger amplifying devices, one for transmission in each direction, each device furnishing a definite amount of amplification to a signal wave train when preceded by a triggering pulse but presenting infinite attenuation to a signal wave train when not so preceded, a pulse generator at each end of the transmission line for generating a triggering pulse at the beginning of a signal wave train to be transmitted, means for impressing said pulse on the transmission line, said pulse acting as a pilot pulse in front of the signal train to trigger, in succession, all said amplifying devices pointing in the direction of transmission into their amplifying condition and to further prohibit all such devices pointing in the opposite direction from being triggered into their amplifying condition.

7. A signal transmission line system, for two-way signaling, a plurality of two-way repeaters spaced at intervals along the line, each repeater comprising two amplifying devices, one for transmission in each direction, each device having trigger characteristics by which in no-signal intervals all are at infinite loss condition, a pulse generator at each end of the transmission line for generating at the beginning of a signal wave train to be transmitted a pulse and at the end of the train a second pulse, means for impressing the said pulses on the transmission line, the pulses serving as pilot pulses in front of and behind the signal wave to trigger on in succession the amplifying devices pointing in the direction of transmission and to further prohibit triggering on of the devices pointing in the other direction and to restore the devices in succession to no-signal condition.

ALBERT M. SKELLETT.