Aug. 10, 1943. R. K. CROOKS 2,326,622

RAILWAY TRAFFIC CONTROLLING APPARATUS

Filed Feb. 13, 1942

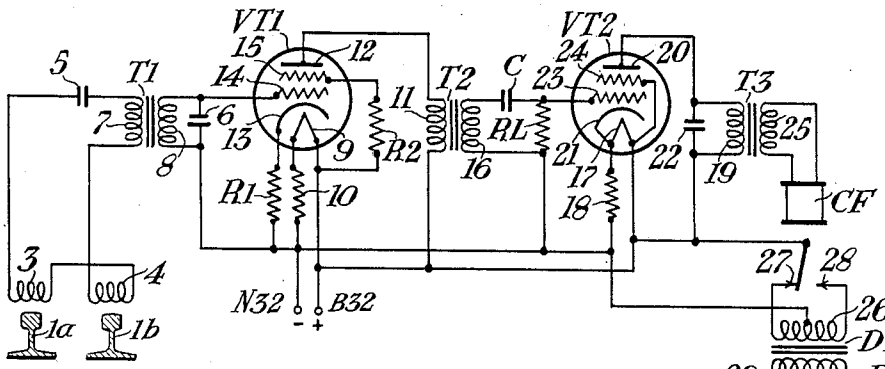


Fig. 1.

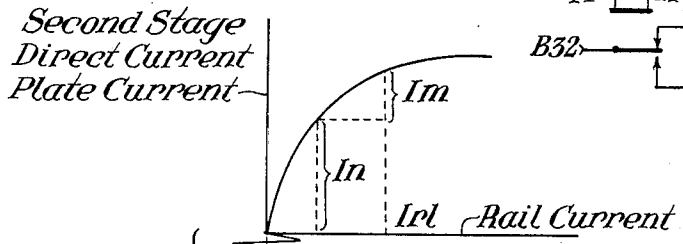
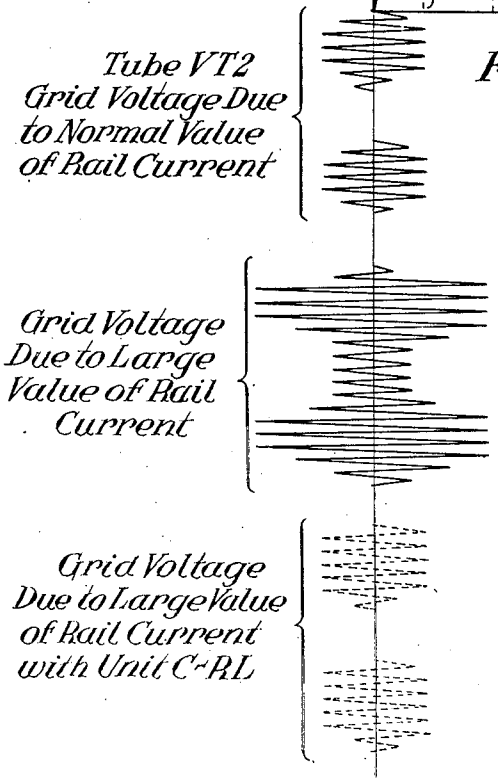


Fig. 2.



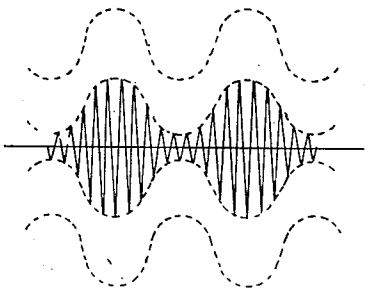


Fig. 3.

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RAILWAY TRAFFIC CONTROLLING APPARATUS

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6 Claims. (Cl. 246—63)

My invention relates to railway traffic controlling apparatus, and more particularly to train carried train control apparatus responsive to coded energy.

Train carried train control apparatus responsive to coded alternating current often includes in the receiving circuit a filter tuned to resonance at the frequency of the alternating current with the result that the oscillations that persist after the current is interrupted at the end of each on code period may create code distortion when the magnitude of the rail current becomes relatively large as may be the case when the train is close to the exit end of a track section and the rail impedance is shunted out. Rail current of such large magnitude so excites the filter that its oscillatory condition tends to fill in the valleys (off periods) of the envelope of the received electromotive force. Again, it has been proposed to use amplifier tubes operative from the usual 32 volt train carried generator or battery without voltage converters. Variations in the amplification factor of such tubes due to the voltage variations of such current source may cause over and under excitation of the usual code following relay governed by the amplifier. If the energization of the relay exceeds its predetermined value any one on code period, the operation of the relay at the next off code period is delayed due to the longer time for the energization to die down to the operating value of the relay and code distortion results. Under-energization of the relay may likewise cause code distortion and of course may cause failure of the relay to operate. Hence the amplifier gain must be controlled if uniform energization of the code following relay is to be assured over the usual range of voltages of the train carried source and also if over-energization of the relay at the higher values of rail current is to be avoided.

In view of the foregoing conditions in railway traffic controlling apparatus of the type here contemplated, a feature of my present invention is the provision of train carried train control apparatus incorporating a novel and improved electron tube amplifier wherewith code distortion due to the oscillatory condition of the receiving circuit is minimized.

Another feature of my invention is the provision of train carried train control apparatus incorporating a novel electron tube amplifier requiring but a single 32 volt source of direct current and energy from the usual 32 volt train carried generator can be used without voltage converters, and which amplifier provides inverse feed-back to compensate for the changes in the amplifier gain due to variations in voltage of the direct current source, and also due to changes in the operating characteristics of individual tubes.

Again, a feature of my invention is the provision of train carried train control apparatus incorporating an electron tube amplifier wherein an additional capacitance-resistance biasing means is applied to the final stage tube and substantially uniform voltage is applied to the code following relay notwithstanding the received electromotive force may vary over relatively wide limits.

Another feature of my invention is the provision of a relatively simple, inexpensive and rugged amplifier for train carried train control apparatus.

Other features, objects and advantages of my invention will appear as the specification progresses.

The above features, objects and advantages of my invention I obtain by providing a two-stage amplifier using low voltage indirect heater type of electron tubes and whose plate and heater circuits are effectively excited when connected to a 32 volt source of direct current. The first stage tube is provided with separate and distinct filament (heater) and plate circuits connected in multiple across the 32 volt source of direct current. A resistor is included in the plate circuit adjacent the cathode of the tube, and this resistor is also included in the control grid circuit which is coupled to the receiving circuit. The plate current flowing in this resistor provides a direct voltage which normally biases the first stage tube to function as a class A amplifier and provides an alternating bias voltage when coded energy is received which bias alternating voltage assures a substantially uniform amplifier gain over a relatively wide variation of voltage of the direct current train carried source. Such inverse feed-back also minimizes the effects of variations in the operating characteristics of different tubes when a tube has to be changed.

Furthermore, the first stage tube is provided with an auxiliary or screen grid that is connected in a circuit including a resistor connected between the screen grid and the direct current source. This special screen grid circuit serves to control the flow of current in the control grid circuit and thereby governs the dampening of the receiving circuit to minimize code distortion when a rail current of large damping is interrupted at the end of each on code period and

oscillations tend to persist in the receiving circuit due to its resonant condition.

The second stage tube is normally biased to function as a class C amplifier and is provided with an additional capacitance-resistance biasing unit whose time constant is such that the voltage developed across the capacitance is retained with little loss during the complete code cycle and is added to the normal bias voltage to effect substantially the same amplifier gain for large values as for normal values of the electromotive force picked up from the rails.

I shall describe one form of apparatus embodying my invention and shall then point out the novel features thereof in claims.

In the accompanying drawing, Fig. 1 is a diagrammatic view showing one form of apparatus embodying my invention when used with train carried train control apparatus. Figs. 2 and 3 are diagrams illustrating operating characteristics of the apparatus of Fig. 1.

Referring to Fig. 1, the reference characters 1*a* and 1*b* designate the track rails of a railway. These rails 1*a* and 1*b* would be formed by the usual insulated rail joints into consecutive track sections. Coded alternating current is supplied across the rails at the exit end of each track section so that such current flows in the rails in series. The alternating current may be of any convenient frequency and may be, for example, of the order of 100 cycles per second. The trackway apparatus for supplying coded current to the rails 1*a* and 1*b* is not shown since it forms no part of my present invention and may be any one of several well-known arrangements. For example, the arrangement of such trackway apparatus may be that disclosed in Letters Patent of the United States No. 2,250,191, granted July 22, 1941 to myself for Railway traffic controlling apparatus. It is sufficient for the instant application to point out that the track rails 1*a* and 1*b* are supplied with alternating current of a preselected frequency coded at different code rates and such current flows in the rails in series and varies in magnitude due to the different values of the rail impedance in the circuit as the train moves from the entrance end to the exit end of the track section and also because of changes in ballast resistance and other conditions.

Two inductors 3 and 4 are mounted on the train in advance of the leading pair of wheels in inductive relation to track rails 1*a* and 1*b*, respectively. Inductors 3 and 4 are connected in series in a receiving circuit which also includes a filter comprising transformer T1 and condensers 5 and 6. As here shown inductors 3 and 4, condenser 5 and primary winding 7 of transformer T1 are connected in series and condenser 6 is connected across secondary winding 8 of transformer T1. This receiving circuit is tuned to resonance at the frequency of the rail current. For example, when alternating current of 100 cycles per second is used then this receiving circuit is tuned to resonance at 100 cycles per second. It follows that an electromotive force is picked up by the inductors 3 and 4 and a corresponding electromotive force appears across secondary winding 8 of transformer T1, such picked up electromotive force being of the frequency and code of the rail current and of a magnitude proportional to the magnitude of the rail current. Secondary winding 8 and condenser 6 in multiple are connected to the input terminals of an amplifier which I shall shortly describe.

It is to be observed that oscillations may persist subsequent to the interruption of the rail current due to the oscillatory nature of the receiving circuit. Furthermore, when the rail current is large these oscillations persist for a correspondingly longer interval because of the increased charge built up on the condenser. Especially will this be true at the lower code rates and the on code period is of a correspondingly longer interval to build up the charge on the condenser. In other words, the oscillatory nature of the receiving circuit tends to fill in the valleys of the envelope of the electromotive force appearing at the terminals of secondary winding 8 of transformer T1 when large rail currents flow. Looking at Fig. 3, the full line envelope represents that of the electromotive force across secondary winding 8 due to a normal value of rail current, while the dotted lines represent in outline the envelope of the electromotive force resulting when the rail current is of a large magnitude. Under normal conditions the oscillations during the off code period are of such low value that they can be neglected as far as their influence on the amplifier. However, the amplitude of the oscillations in the valleys of the envelope when large rail currents flow may be substantially equal to the maximum amplitude of the electromotive force during the on period under normal rail current. Such filling in of the valleys of the envelope when large rail current flows causes code distortion and in extreme cases may result in unsatisfactory operation of the train carried apparatus.

The train carried amplifier comprises two stages which include electron tubes VT1 and VT2, respectively. Tubes VT1 and VT2 may take different forms and may be indirect heater pentodes adaptable of operation on relatively low voltage such as 32 volts. Looking at tube VT1 of the first stage of the amplifier, its filament 9 is connected across the current source whose terminals are indicated by the reference characters B32 and N32, and which may be the terminals of the usual train carried 32 volt direct current generator. A current limiting resistor 10 is preferably included in this filament circuit. The plate circuit for tube VT1 extends from positive terminal B32 over primary winding 11 of a coupling transformer T2, plate 12 of tube VT1, intervening tube space to cathode 13, a resistor R1 and to the negative terminal N32. It is clear, therefore, that tube VT1 is provided with a filament and a plate circuit which are separate and distinct and which are connected across the B32—N32 current source in multiple. Tube VT1 is provided with a control grid circuit including control grid 14, condenser 6 and secondary winding 8 of transformer T1 in multiple, resistor R1 and cathode 13. An auxiliary or screen grid 15 of tube VT1 is included in a circuit connected to the positive terminal B32 of the current source over a resistor R2. Control grid 14 is provided with a normal grid bias voltage equal to the direct voltage drop across resistor R1 due to the normal plate current flowing therethrough. The parts are so proportioned that the normal bias voltage developed across resistor R1 causes tube VT1 to function as a class A amplifier and hence when an alternating signaling electromotive force appears across secondary winding 8 of the receiving circuit a corresponding alternating current component of the plate circuit current of tube VT1 is created and a corresponding

alternating electromotive force appears across secondary winding 16 of the coupling transformer T2. When such alternating current component is created in the plate circuit current, the direct voltage drop across resistor R1 is reduced while an alternating voltage is created and which alternating voltage is substantially 180 degrees out of phase with the signaling electromotive force. The effective alternating voltage impressed on control grid 14 is then the difference between the signaling electromotive force derived from the receiving circuit and the biasing alternating voltage derived from resistor R1. This biasing, known as "inverse feed back" serves to minimize the effects of variations in the tube characteristics upon the overall amplifier gain. For example, an increase of voltage of the B32—N32 current source would increase the normal plate current to increase the tube gain. Such increase of plate current develops a larger alternating voltage across resistor R1 and with a given signal voltage reduces the effective alternating voltage impressed upon control grid 14. However, the amplifier gain of tube VT1 would not be lowered greatly by such decrease in the impressed alternating voltage because of the higher gain at which the tube is operated. I have found that such inverse feed back causes the tube to operate at substantially the same amplifier gain with the voltage of the B32—N32 current source varying from a minimum of 26 volts to a maximum of 40 volts. Also the amplifier gain is not affected materially by variations in operating characteristics of different tubes due to manufacturing variations.

Screen grid 15 and its circuit including resistor R2 serve to reduce the effects of the oscillatory condition of the receiving circuit and avoid code distortion. When the rail current is relatively large, control grid 14 is driven positive by the positive half cycles of the signaling electromotive force and hence grid current flows and acts as a load across the receiving circuit filter. The presence of the load on the receiving circuit serves to damp the oscillations and they persist a shorter interval than would be the case if there was no load. When the control grid 14 is driven positive by the incoming signaling electromotive force, the plate to cathode voltage is at a minimum value. The screen grid current tends to be a maximum, but due to the voltage drop in resistor R2 the screen grid voltage is reduced during this interval. With the lowering of plate and screen grid voltages, control grid draws more current than is normally the case and offers more of a load on the filter of the receiving circuit. This increase in the load on the receiving circuit causes greater damping of the oscillations and lessens the code distortion. That is, the screen grid circuit serves to increase the damping of the receiving circuit and to minimize code distortion caused by the oscillatory condition of the receiving circuit at the higher values of the rail current.

The second stage tube VT2 is provided with a filament circuit for heating its filament 17 and with a plate circuit both of which include a resistor 18, as will be readily understood by an inspection of Fig. 1. Cathode 21 of the second stage tube VT2 is connected to the negative terminal of filament 17, while screen grid 24 is connected to the positive terminal of filament 17.

Secondary winding 16 of coupling transformer T2 is connected across control grid 23 and cathode 21 of the second stage tube VT2, the heater circuit resistor 18 being also included in this control grid circuit. The parts are so proportioned that the voltage drop across resistor 18 due to the heater circuit current flowing therein biases the tube VT2 to substantially zero plate current and thereby causes tube VT2 to function as a class C amplifier.

An additional biasing unit comprising a condenser C and a resistor RL are connected to the control grid circuit of tube VT2 to provide an additional biasing voltage for the tube, condenser C being connected in series with the control grid 23 and resistor RL being connected as a grid leak resistor. When the electromotive force appearing across secondary winding 16 of transformer T2 is that created by a normal value of rail current, grid 23 is not driven positive in potential with respect to cathode 21 and no grid current flows. However, grid 23 is driven in the positive direction during the positive half cycles of the electromotive force appearing across secondary winding 16 and plate current flows, the plate current having a predetermined average value to which it builds up during each on code period and from which it decays during each off code period. When the signaling electromotive force appearing across secondary winding 16 of transformer T2 is large due to rail current of large magnitude, grid 23 is driven positive in potential with respect to cathode 21 during the higher values of each positive half cycle of the signaling electromotive force, and grid current flows and condenser C is charged. The time constant of the unit comprising condenser C and resistor RL is made such that the potential developed across condenser C during an on code period is retained with little loss during the next off code period, with the result the bias voltage of the C—RL unit is added to the normal bias voltage derived from resistor 18. The resultant bias voltage tends to reduce the plate current and a nearly uniform change in the average value of the plate current takes place over a relatively wide variation in the magnitude of the rail current.

Referring to Fig. 2, the plate current of the second stage tube VT2 is shown as a function of the rail current. When a normal value of rail current flows, the alternating voltage applied to control grid 23 of tube VT2 is represented by the two graphs just below the horizontal axis, that is, the alternating voltage for two code cycles is illustrated. Under such values of the applied voltage, the change in the average value of the plate current for tube VT2 is represented by I_n, such change being due to the bias voltage derived from resistor 18 alone because at such value of rail current the applied voltage is not sufficient to drive grid 23 positive in potential with respect to cathode 21. Rail current of a large magnitude tends to create an alternating voltage across secondary winding 16 as illustrated by the two center graphs of Fig. 2, that is, two code cycles are illustrated. The maximum value of the voltage is increased, but due to the possible code distortion the minimum value to which the voltage may fall during the off code periods may be relatively large, and hence the change of the plate current may be that illustrated by I_m of Fig. 2, and which change may be less than that effected by rail current of normal value. Under conditions of large rail current the voltage applied to tube VT2 is such that grid 23 is made positive during the higher values of the positive half cycle and grid current flows to charge condenser C with

the result that unit C—RL serves to provide an additional grid bias voltage. Due to this additional grid bias voltage effected through the unit C—RL, the applied voltage to tube VT2 corresponds to that illustrated by the two lower graphs of Fig. 2, that is, two code cycles are illustrated. Under this condition, the change in the average value of the plate circuit current remains substantially the same as that effected in response to the rail current of normal value.

A code following relay CF of the usual type is connected to secondary winding 25 of output transformer T3 whose primary winding 19 is interposed in the plate circuit of the second stage tube VT2 and across which primary winding a condenser 22 is preferably connected. Relay CF is operated in response to the voltage induced in secondary winding 25, due to the changes in the average value of the plate current flowing in primary winding 19, the arrangement being such that relay CF is energized at a polarity to operate the relay to close its normal polar contact 27 when current builds up in the plate circuit of tube VT2 and is energized at a polarity to operate the relay to close reverse polar contact 28 when the plate current dies away. Code following relay CF governs the supply of direct current to the primary winding 26 of a decoding transformer DT, current being alternately supplied to the two portions of primary winding 26 over normal contact 27 and reverse contact 28, respectively. The alternating electromotive force induced in secondary winding 29 of decoding transformer DT is applied to a decoding unit shown conventionally at DU and which decoding unit may be of the well-known form of tuned circuits for selectively controlling three relays A, R and L according to the code rate at which the relay is operated. For example, when the usual code rates of 180, 120 and 75 are provided for the rail current, then relays A and L are picked up and relay R is released for the 180 code rate, relays R and L are picked up and relay A is released for the 120 code rate, and relay L is picked up and relays A and R are released for the 75 code rate. When relay CF is inactive, then all three relays A, R and L are released. Relays A, R and L are used to govern the operating circuits of a train controlling device, such as a cab signal CS, the operating circuits of which cab signal are arranged in the usual well-known manner, as will be readily understood by an inspection of Fig. 1.

Train carried train control apparatus here disclosed has the advantages that it is simple, inexpensive and rugged, and is excited by a single 32 volt source of direct current. The electromotive force picked up by the usual train carried receiving circuit when a predetermined value of rail current flows is amplified at relatively high gain without code distortion to apply a predetermined voltage to the code following relay for operating that relay at a rate corresponding to the code rate of the rail current. Variations in amplification gain of the first stage tube caused by increase in voltage of the direct current source of supply is compensated by the inverse feedback provided for the first stage tube. Code distortion at the higher values of the rail current due to the oscillatory condition of the receiving circuit is minimized by the control of the damping of the receiving circuit through the means of a screen grid circuit including a resistor of a predetermined value. Substantially equal changes in the plate current of the final stage tube are effected by the additional capacitance-resistance biasing unit which serves to increase the negative grid bias of the final stage tube when rail current of larger magnitude prevails.

Although I have herein shown and described only one form of railway traffic controlling apparatus embodying my invention, it is understood that various changes and modifications may be made therein within the scope of the appended claims without departing from the spirit and scope of my invention.

Having thus described my invention, what I claim is:

1. In controlling apparatus for use with alternating current coded at a preselected code rate and supplied to a receiving circuit tuned to reonance at the frequency of said alternating current, the combination comprising; an electron tube having a plate, a cathode, a control grid and a screen grid; a plate circuit for said tube including a source of direct current, a control grid circuit connected across said control grid and cathode and coupled to said receiving circuit to cause in the plate circuit current an alternating current component of a code corresponding to that of the alternating current, another grid circuit including a resistor connected between said screen grid and said direct current source independent of the other circuits of the tube to control the damping of said receiving circuit for minimizing code distortion due to the resonant condition of the receiving circuit, and a code following relay coupled to said plate circuit and governed by said coding of the alternating current component of the plate circuit current for operation of the relay at said code rate.

2. In controlling apparatus for use with coded alternating current that is supplied to a receiving circuit tuned to resonance at the frequency of said alternating current, the combination comprising; an electron tube having a plate, a cathode, a control grid and a screen grid; a plate circuit for said tube including a source of direct current and a resistor disposed adjacent said cathode, a control grid circuit for said tube coupled to said receiving circuit and including said plate circuit resistor to provide a control grid bias voltage derived solely by the voltage drop across the resistor due to the plate circuit current for effecting a substantially uniform amplifying gain for the tube over a relatively large variation in the voltage of said direct current source, another circuit including another resistor connected between said screen grid and said direct current source to control the damping of said receiving circuit for minimizing code distortion due to the resonant condition of the receiving circuit, and a code following relay coupled to said plate circuit and energized due to code rate variations of the plate circuit current caused by the coded alternating current component of the plate circuit current.

3. In controlling apparatus for use with coded alternating current which is supplied to a receiving circuit tuned to resonance at the frequency of said alternating current, the combination comprising; an electron tube having a filament, a plate, a cathode, a control grid and another grid; a source of direct current, separate and independent filament and plate circuits for said tube connected in multiple across said direct current source, a first resistor interposed in said plate circuit adjacent said cathode, a control grid circuit for said tube including said first resistor and coupled to said receiving circuit to amplify

in the plate circuit current the coded current supplied to said receiving circuit, another grid circuit for the tube independent of said filament circuit and including a second resistor connected between said other grid and the positive terminal of said direct current source, said plate circuit current flowing in said first resistor to create a direct and alternating bias voltage to provide a substantially uniform amplifying gain for said tube, said other grid circuit current flowing in said second resistor to control the damping of said receiving circuit to minimize code distortion when the coded current is of relatively large magnitude, and a code following relay coupled to said plate circuit energized due to the code rate variations of the plate circuit current caused by the coded alternating current component of the plate circuit current.

4. In controlling apparatus for use with a coded alternating current which is supplied to a receiving circuit tuned to resonance at the frequency of said alternating current, the combination comprising; an electron tube having a filament, a plate, a cathode, a control grid and a screen grid; a source of direct current of a preselected voltage, separate and distinct filament and plate circuits for said tube connected in multiple across said direct current source, a first resistor interposed in said plate circuit adjacent said cathode, a control grid circuit for said tube including said first resistor and coupled to said receiving circuit to cause in the plate circuit an alternating current component of a code corresponding to that of said alternating current, a screen grid circuit independent of said filament circuit and including a second resistor connected between said screen grid and the positive terminal of said direct current source, said control grid provided with a direct and an alternating bias voltage derived solely by the plate circuit current flow in said first resistor to maintain a substantially uniform amplifying gain for the tube when the voltage of said direct current source varies from said preselected voltage, said screen grid circuit to control the damping of the alternating voltage applied to said control grid to minimize code distortion due to the resonant condition of said receiving circuit when the coded current is of large magnitude, and a code following relay coupled to said plate circuit and energized due to the coded alternating current component thus caused in the plate circuit.

5. In controlling apparatus for use with a transmitting circuit supplied with coded alternating current and a receiving circuit in inductive relation to said transmitting circuit, the combination comprising; a two stage amplifier each of which stages includes an electron tube, a source of direct current, separate and independent filament and plate circuits for the first stage tube connected in multiple across said direct current source, a control grid circuit for said first stage tube coupled to said receiving circuit, a first resistor common to the plate and control grid circuits of the first stage tube to provide a grid bias voltage due solely to the plate circuit current flowing in said first resistor for governing the amplifying gain of the first stage tube, a plate and a filament circuit for said second stage tube connected to said direct current source, a control grid circuit for said second stage tube coupled to the plate circuit of the first stage tube; a second resistor common to the filament, plate and control grid circuits of the second stage tube to provide a negative grid bias voltage that normally effects zero plate current; an additional biasing unit consisting of a condenser and a resistor interposed in the control grid circuit of the second stage tube and provided with a time constant such that the voltage developed across the condenser is retained during a complete code cycle of said coded alternating current to effect a substantially uniform change of the second stage tube plate circuit current over a relatively wide range of values of said coded current, and an electromagnetic relay coupled to the second stage tube plate circuit and energized due to the change in the current flowing therein.

6. In controlling apparatus for use with a transmitting circuit supplied with coded alternating current and a receiving circuit in inductive relation to said transmitting circuit, the combination comprising; a two stage amplifier each of which stages includes an electron tube, said first stage tube having a screen grid as well as a control grid, a source of direct current, separate and independent filament and plate circuits for the first stage tube connected in multiple across said direct current source, a control grid circuit for the first stage tube coupled to said receiving circuit, a first resistor common to the plate and control grid circuits of the first stage tube to provide a grid bias voltage due solely to plate current flowing in said first resistor to maintain a substantially uniform amplifying gain for the first stage tube over a relatively large variation of voltage of said direct current source, a screen grid circuit independent of said filament circuit and including a second resistor connected between said screen grid and said direct current source to control the damping of said receiving circuit and reduce code distortion caused when said coded alternating current is of large magnitude, a plate and a filament circuit for said second stage tube connected across said direct current source, a control grid circuit for said second stage tube coupled to the first stage tube plate circuit; a third resistor common to the filament, plate and grid circuits of the second stage tube to normally bias said second stage tube to zero plate current; an additional biasing unit consisting of a condenser and a resistor interposed in the second stage tube grid circuit to effect an additional grid bias voltage and maintain substantially the same change in the second stage tube plate circuit current when the coded alternating current is of large magnitude as when the coded current is of normal value, and signaling means coupled to the second stage tube plate circuit governed by the change in circuit flowing therein.

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