VARIABLE TRANSCONDUCTANCE AMPLIFIER, MODULATOR TUBE

Filed Feb. 28, 1955

Fig. 1A.

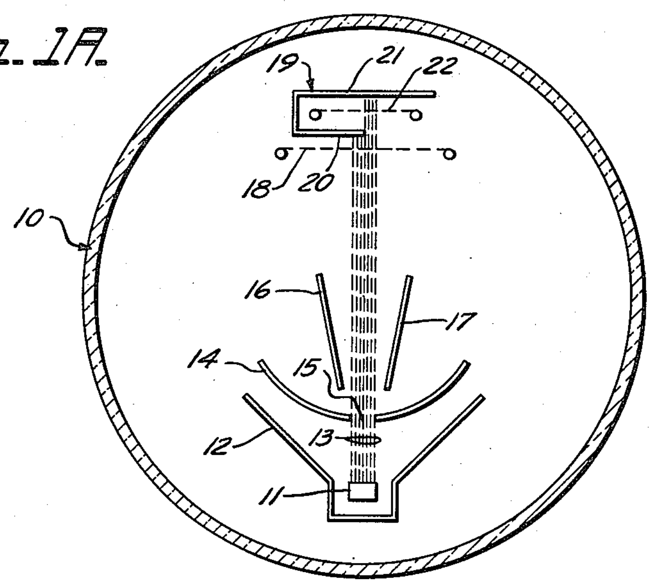
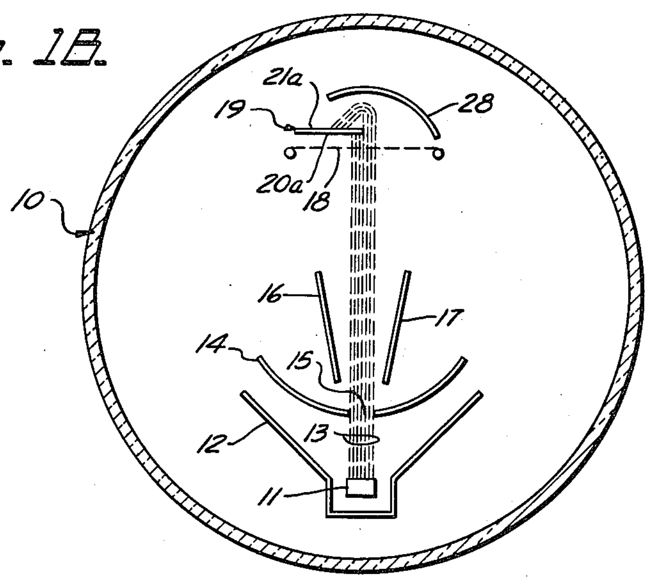


Fig. 1B.



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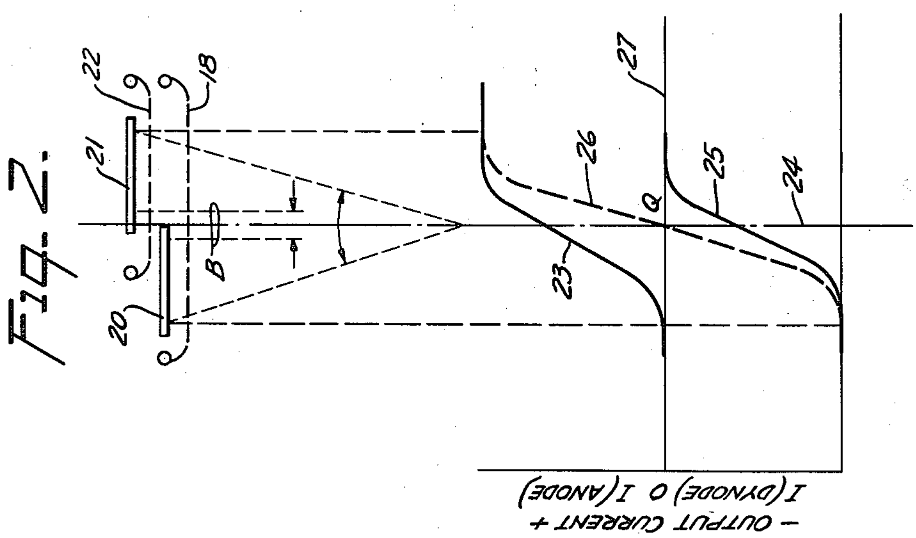

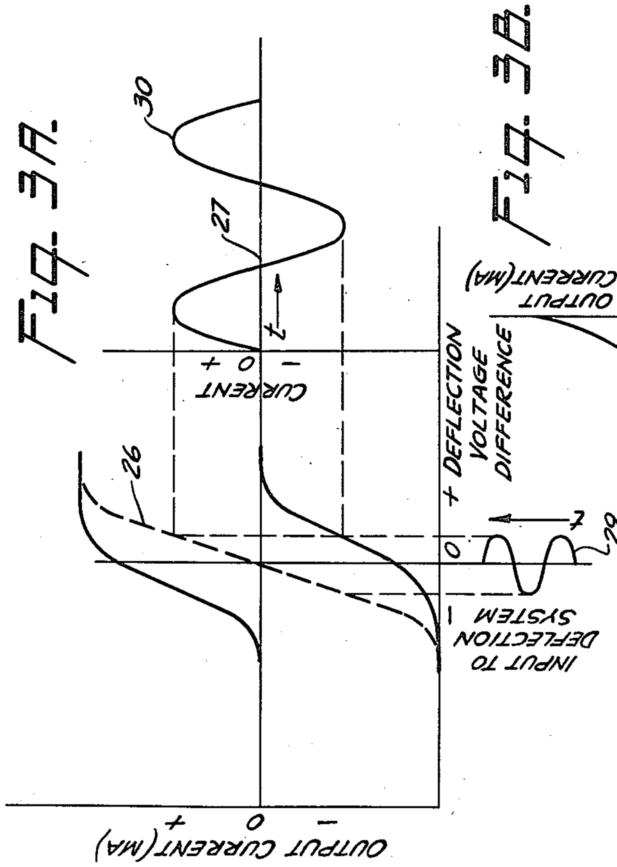

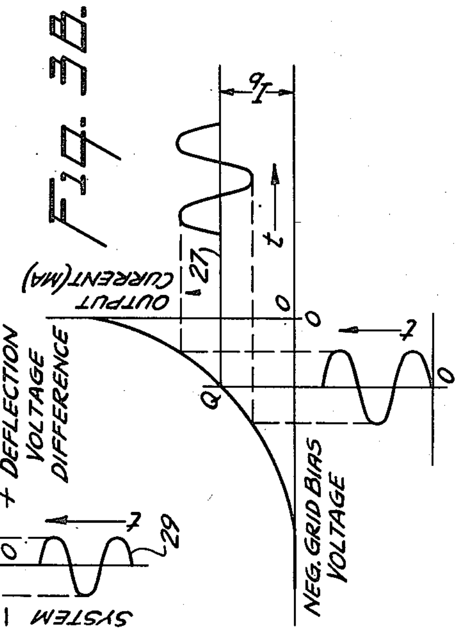

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VARIABLE TRANSCONDUCTANCE AMPLIFIER, MODULATOR TUBE

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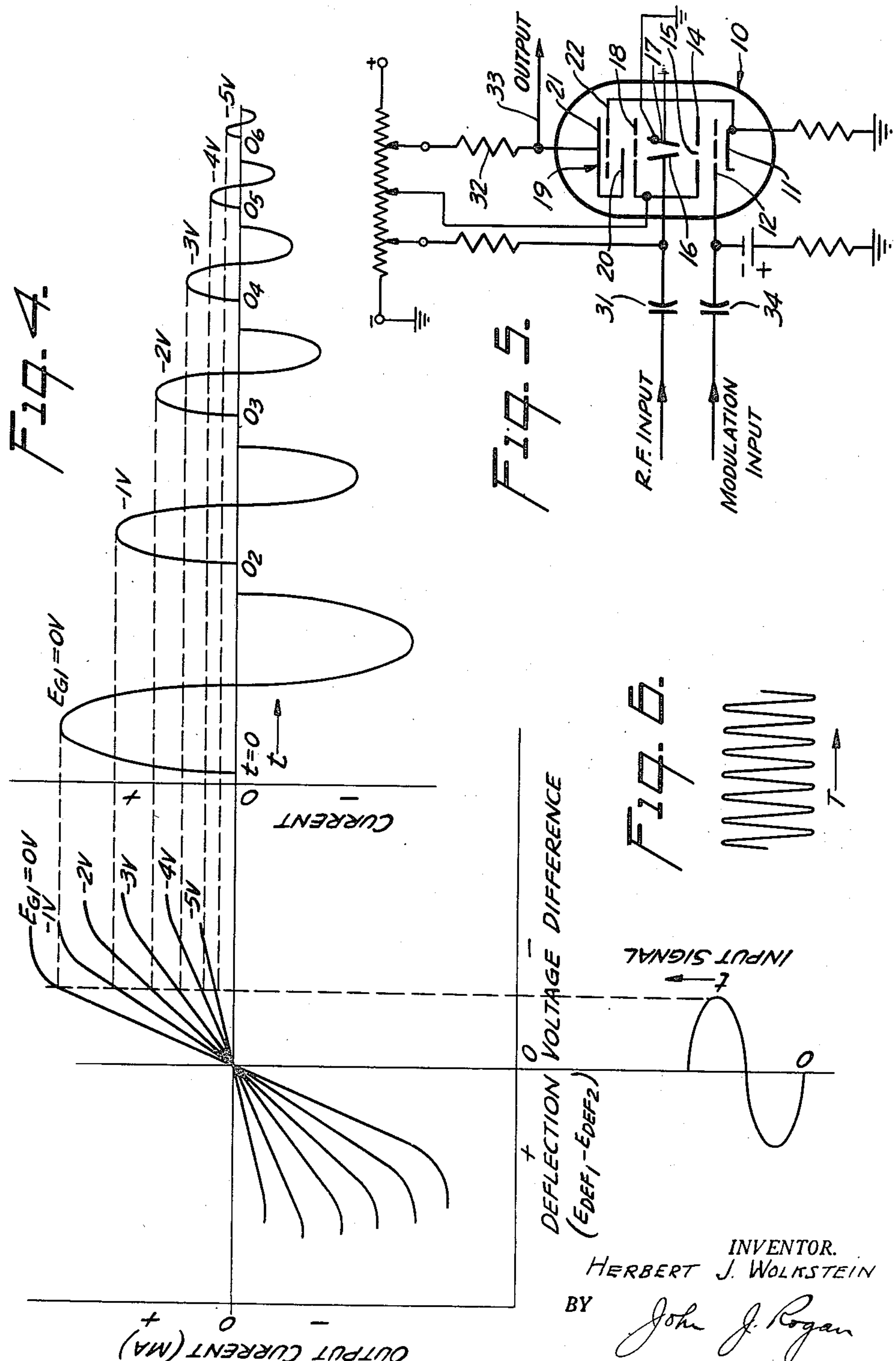

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May 13, 1958 H. J. WOLKSTEIN 2,834,910

VARIABLE TRANSCONDUCTANCE AMPLIFIER, MODULATOR TUBE

Filed Feb. 28, 1955 4 Sheets-Sheet 4

Fig. 7A.

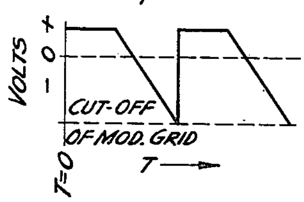


Fig. 8A.

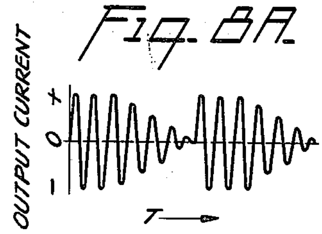


Fig. 9A.

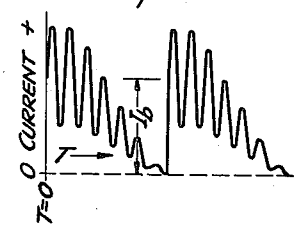


Fig. 7B.

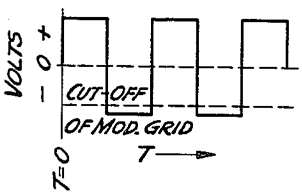


Fig. 8B.

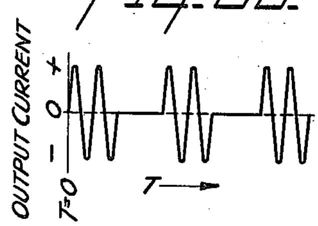


Fig. 9B.

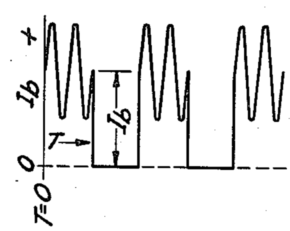


Fig. 7C.

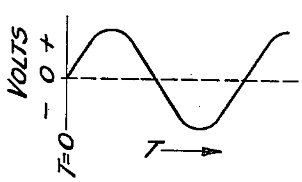


Fig. 8C.

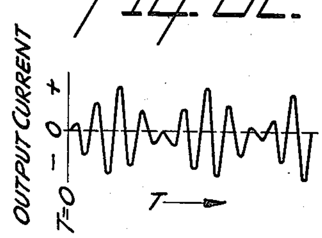


Fig. 9C.

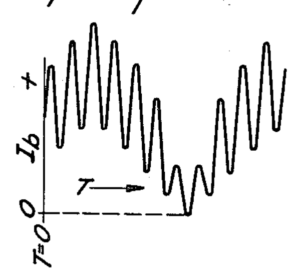


Fig. 7D.

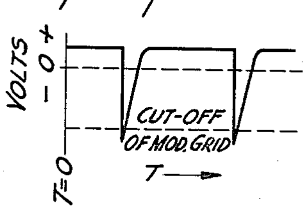


Fig. 8D.

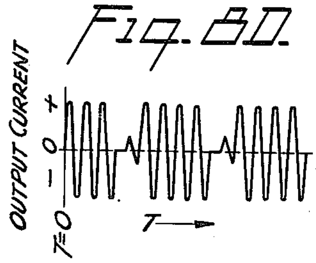
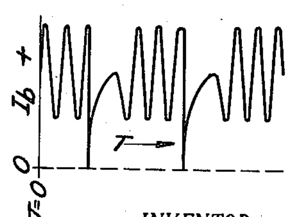


Fig. 9D.



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United States Patent Office

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2,834,910

VARIABLE TRANSCONDUCTANCE AMPLIFIER, MODULATOR TUBE

Herbert J. Wolkstein, Newark, N. J., assignor to National Union Electric Corporation, Orange, N. J., a corporation of Delaware

Application February 28, 1955, Serial No. 490,984

8 Claims. (Cl. 315—12)

This invention relates to electron discharge tubes and more especially it relates to such tubes for use as amplifiers or modulators.

A principal object of the invention is to provide an improved variable transconductance tube whereby an extremely wide variation of transconductance can be achieved without materially shifting the operating point on the input-output current characteristic curve.

Another object is to provide a novel form of amplification tube employing a primary and a secondary emissive output target or electrode, whereby the signal output of the tube is achieved around zero net direct current flow.

A feature of the invention resides in an improved amplifier or modulator system embodying a novel tube construction whereby the system can be switched from its operating quiescent state to cut-off without any substantial rise or fall in the voltage at the plate or output electrode; thus eliminating the transients which usually accompany such change-over with conventional tubes.

Another feature relates to an improved amplifier or modulator system employing a novel tube construction, whereby amplification of modulation can be achieved without any substantial direct current load dissipation.

A further feature relates to a novel electron tube whereby push-pull class "A" amplification can be achieved with only a single-ended output, while at the same time this output is obtained at zero net direct current flow.

A still further feature relates to the novel organization, location, and interconnection of parts which cooperate to provide an improved variable transconductance tube.

Other features and advantages not particularly enumerated will be apparent after a consideration of the following detailed descriptions and the appended claims.

In the drawing, which shows by way example certain preferred embodiments,

Fig. 1A is a schematic plan view of a tube embodying the invention;

Fig. 1B is a schematic plan view of a modification of the tube of Fig. 1A;

Fig. 2 is a composite schematic diagram and graph explaining the operation of the tubes of Figs. 1A and 1B;

Fig. 3A is a graph showing certain operating characteristics of the tubes of Figs. 1A and 1B;

Fig. 3B is a graph showing the characteristics of a conventional grid-controlled amplifier tube;

Fig. 4 is a series of interrelated graphs explaining how the transconductance control of the tubes of Figs. 1A and 1B is achieved;

Fig. 5 is a schematic wiring diagram of a modulation system employing the tube of either Fig. 1A or Fig. 1B;

Fig. 6 is a wave diagram showing the amplitude of the radio frequency carrier applied to the input of Fig. 5;

Figs. 7A, 7B, 7C, and 7D are respective wave diagrams showing various forms of modulation wave inputs applied to Fig. 5;

Figs. 8A, 8B, 8C, and 8D are respective wave diagrams of the output currents in the system of Fig. 5 corresponding to the respective modulation input waves of Figs. 7A–7D;

Figs. 9A, 9B, 9C, and 9D are wave diagrams of the output current of a conventional modulator not employing a tube according to the invention.

Referring to Fig. 1A, the numeral **10** represents a suitable evacuated enclosing bulb or envelope which encloses a series of electrodes according to the invention. These electrodes comprise any well known heatable electron emitting cathode **11** associated with which is a control grid or electrode **12**. Preferably this electrode is of a shape such that it electrostatically forms the electrons from the cathode **11** into a linear well-defined beam **13**. Located within the path of the beam **13** is an electron acceleration electrode **14** having an opening **15** through which the beam passes. The beam then passes between a pair of electrostatic deflection plates **16**, **17**, which are located on opposite sides of the beam trajectory and are energized by a voltage to deflect the beam **13** perpendicular to its trajectory, namely in a direction parallel to the plane of the sheet of drawing.

The beam **13** then passes through a foraminous electron collector electrode **18** which may be in the form of a woven or mesh wire grid. The collector electrode **18** can be connected to the acceleration electrode **14** so that it collects the secondary electrons and returns them to ground, thus preventing their reaching the deflection plates **16** and **17**.

Located on the opposite side of the grid **18** from the plates **16** and **17** is an output anode or target electrode **19**. This electrode may be in the form of a metal plate bent back upon itself so that it is provided with a front bent-back portion **20** and a rear portion **21**, both of which are substantially parallel to each other or normal to the beam trajectory. The portion **20** of the electrode **19** is shorter in length than the portion **21**. The length of portion **20** for example may be one-half the length of portion **21**. The electrode **19** is mounted symmetrically with respect to the plates **16** and **17** so that when the beam **13** is in its normal or undeflected position, half of the beam is intercepted by the portion **20** and the remaining half of the beam is intercepted by the portion **21** of the output electrode **19**.

In accordance with the invention, the front surface of portion **20**, that is the portion facing the cathode **11**, is coated or treated in any well known manner so as to make it an efficient emitter of secondary electrons. As is well known in the electron tube art, such a surface, when impinged upon by the high velocity primary electrons in the beam **13**, emits secondary electrons in a ratio greater than one, so that the potential of the portion **20** swings in a positive direction in proportion to the quantity of primary electrons impinging thereon from the beam **13**. On the other hand, the forward surface of portion **21** facing the cathode **11** is uncoated so that it does not act as a secondary electron emitter. However, in order to take care of any incidental or undesirable reversely moving electrons that may be emitted or reflected from the portion **21**, there is located in spaced relation to the front face of portion **21** any well known conductive foraminous grid or mesh electrode **22** which acts as a secondary electron suppressor only for the anode surface of the element **21**. By suitable energization and biasing of the various electrodes with respect to the cathode **11**, it will be clear that the instantaneous potential of the target electrode **19** will be a function of the position of the beam **13**. In other words, the portion **20** of the output anode **19** acts as a dynode tending to change the potential of the said target electrode in a positive direction as the intercept between the portion **20** and the beam **13** increases and conversely the potential of the target **19** swings in a negative direction as the intercept between the portion **21** and the beam **13** increases. The portions **20** and **21** are, of course, directly connected together by being formed from the same bent back metal sheet. However, if desired, the portions **20** and **21** may be in the form of separate metal sheets which are directly connected together by a suitable conductive strap so that the electrode **19** constitutes a single output electrode connected to a common output load circuit.

Thus, deflection of the beam **13** by the plates **16** and **17** provides for addition of the currents at the portions **20** and **21** through the common load.

Fig. 2 shows the relation between the position of the beam **13** with respect to the target **19** and the current in the output circuit. In Fig. 2 the curve **23** shows the relation between the current from the portion **21** (which for convenience will be referred to as the anode) and the position of the beam **13**. The dot-dash line **24** represents the position of the center line of the beam in its normal or undeflected condition, wherein the beam is equally intercepted by the dynode **20** and the anode **21**. Therefore, as the beam **13** is deflected towards the right the positive component of the output current rises. The curve **25** represents the relation between the beam position and the dynode current from which it will be seen that as the beam **13** is deflected to the right the negative current from the dynode decreases while the positive current from the anode increases. The net result of the combined currents from the anode and dynode are thus represented by the dotted curve **26** which is symmetrical about the zero net direct current line **27**. It will be observed that the leveling off of the primary and secondary currents at both extremes of the beam deflection indicates saturation. For convenience of description, the composite curve **26** is referred to herein as the "anodyne" characteristic curve. For purposes of illustration, the primary maximum current at the anode **21** resulting from the primary electrons in the beam striking the anode **21** is equal to the secondary maximum component achieved by the impingement of the beam **13** on the dynode **20**. This, of course, occurs only if the secondary emission ratio of the surface **20** is equal to two at the operating voltage of the surface **20**. This mode of operation allows twice the deflection transconductance obtainable over conventional beam deflection amplifiers which do not have the anodyne composite characteristic above described. In such conventional beam deflection amplifiers, only the anode portion **23** of the characteristic curve of Fig. 2 is obtainable.

Fig. 1B illustrates a modification of the electrode arrangement of Fig. 1A. The elements of Fig. 1B which are the same as those of Fig. 1A are designated by the same numerals. However, the anode-dynode operation is achieved by using the same physical element both for the anode and the dynode. Thus, as shown in Fig. 1B, the forward surface of the target **19** is coated or treated to act as a dynode, while the rear surface of the target **19** is uncoated so that it does not act as a secondary emitter. The beam **13** is arranged to strike the dynode surface of target **19** directly whereas the anode surface **21*a*** of the target **19** cooperates with a curved electrostatic deflector plate **28** to cause the primary electrons in the beam **13** to be deflected towards the anode surface **21*a*** without, of course, striking the deflector plate **28**. Otherwise the operation of the tube of Fig. 1B is identical with that of Fig. 1A.

Fig. 3A shows the relation between the output current and an input signal voltage across the plates **16** and **17**. In this figure the graph **29** represents the input deflection voltage applied across the said deflector plates **16** and **17** and the curve **30** represents the output current at the common load circuit. It will be observed that with this arrangement it is possible to operate on the linear portion of the composite output curve **26** and the output current is symmetrical with respect to the zero direct current line **27**.

Fig. 3B shows the grid-transfer characteristics of a conventional modulator tube from which it will be seen that the tube must operate on the curved portion of the characteristic resulting in a non-symmetrical output current with respect to the zero line **27**. In other words, the modulation can be achieved in the tubes, according to the present invention, while operating on a linear portion of a characteristic curve, whereas in a conventional tube modulation is achieved by operation on a curved portion of the characteristic curve.

Fig. 5 shows schematically a typical system for using the tubes of Figs. 1A and 1B as a modulator. The elements of Fig. 5, which are the same as those of Figs. 1A and 1B, are designated by the same numerals. The radio frequency or carrier input voltage from any well known source may be applied through a coupling condenser **31** across the deflector plates **16** and **17**. In the well known manner, plate **17**, for example, may be grounded and the potential of plate **16** may be varied above and below ground by means of the radio frequency input voltage. The cathode **11** is biased with respect to ground by any well known self-biasing circuit, and likewise the control grid **12** is negatively biased with respect to ground by any well known biasing circuit. The accelerating electrode **14** and the collector electrode **18** likewise are biased positively with respect to the cathode. The suppressor grid **22** can be directly connected to the cathode **11**. The composite dynode-anode target **19** is connected to a suitable positive potential through a load resistor **32**, and the common output circuit is connected directly to the electrode **19** by the conductor **33**. The modulation signal from any suitable input source is applied through a coupling condenser **34** to the grid **12**.

For dynamic operation of the tube, the various biasing potentials are adjusted so that the beam deflection is centered with respect to the surface **20** and **21**, and the net current through the output circuit is zero corresponding to point Q of Fig. 2. This mode of operation therefore allows signal modulation with no direct current load dissipation.

Fig. 4 illustrates the relation between an input signal applied to grid **12** and output signal from electrode **19** for different negative biases applied to grid **12**. The interpretation of Fig. 4 is that it is possible to obtain infinite variation of transconductance without production of undesirable transients in the output circuit. Operation of the system around the zero net direct current flow permits modulation of the beam current by the control grid **12** without producing an output transient or change in direct current voltage output level through the load. At balance, namely when primary current component from element **21** is equal to secondary electron current from element **20**, any reduction in the total beam current does not affect the conditions of net zero load current. This clearly is illustrated by the series of curves of Fig. 4. Maximum output is obtained at zero grid bias for a given deflection modulating voltage. For smaller values of beam current, that is with an increased negative bias on the grid **12**, less output is obtained. The control of beam current magnitude, as indicated, thus regulates the transconductance of the device without shifting the operating point. In conventional amplifier tubes, changing the bias of the amplifier control grid necessarily shifts the operating point. This condition in a conventional amplifier is even more pronounced when the amplifier is driven from its operating point to cut-off. Under that condition, a sharp rise in plate voltage takes place.

The relative operations of the system of Fig. 5, as compared with a conventional modulator tube for different shapes of input modulation waves, is illustrated in Figs. 7A–7D, 8A–8D, and 9A–9D. Assume that the radio frequency or carrier input is of constant peak amplitude and wave shape as illustrated in Fig. 6, and let it be assumed that the wave shape of the modulation signal is that illustrated in Fig. 7A. Fig. 8A shows the corresponding output of the system of Fig. 5, whereas Fig. 9A shows the corresponding output for a conventional modulator tube. A comparison of these respective output characteristics indicates that the contour of the radio frequency output of the system of Fig. 5 follows the wave shape applied to the control grid. Thus, if a square modulation wave input is used, as shown in Fig. 7B, a square wave of radio frequency output free from transients is produced as illustrated in Fig. 8B. On the other hand, with the conventional amplifier, non-square wave output is obtained with substantial transients. Similarly, if the modulation input wave is a sine wave, as illustrated in Fig. 7C, the output of Fig. 5 produces similar sine wave characteristics which vary symmetrically with respect to the zero line. An entirely different characteristic is obtained with the conventional modulator, as is illustrated by the curve of Fig. 9C. Furthermore, the application of a negative linear pulse to the control grid **12** of Fig. 5 as illustrated by the signal curve of Fig. 7D, produces a linear variation of transconductance from a maximum value ot a zero value without affecting output linearity or producting transients, as is shown by Fig. 8D. On the contrary, when such an input negative pulse is applied to the conventional modulator, it produces a non-symmetrical output and transients, as illustrated by Fig. 9D.

The tubes and system of this invention have been used in practical laboratory circuits to eliminate undesirable noise and transient conditions encountered in various radio receiver equipments. It was found that conventional tubes used for similar noise suppression circuits produced undesirable transient and noise conditions when blanking wave shapes are applied to eliminate the original noise. Furthermore, as indicated in the above description, the tubes according to the invention have excellent characteristics for low level balance modulation purposes.

Various changes and modifications may be made in the disclosed embodiments without departing from the spirit and scope of the invention. It will be understood, of course, that the invention is not limited to the use of the tube wherein the ratio of secondary emission to primary emission is 2 which, of course, represents the ideal case for optimum symmetry. This ratio may be any other desired value consistent with the percentage of symmetry desired in the output of the tube. Thus, operation about zero load current is achieved, in practice, by deflection centering the line beam on the target current. This provides for no-load dissipation and linear operation at a position slightly off the center line of the target.

What is claimed is:

1. Electron tube apparatus comprising, means to develop a deflectable electron beam, electrode means to control the beam current, target electrode means having front and rear portions with respect to the beam trajectory one portion being a dynode and the other an anode, said target means being mounted transversely of the beam trajectory so that when the beam is in its normal undeflected position it impinges in a predetermined ratio on both the dynode and the anode to produce a zero combined current from the dynode and the anode, means to deflect the beam to vary said ratio of interception and thereby to vary the said combined current, means connecting the dynode and anode in common to the same output load, and the entire dynode surface impinged upon by the beam having substantially uniform secondary emission characteristics.

2. Electron tube apparatus according to claim 1 in which a secondary electron suppressor is provided for said anode only.

3. Electron tube apparatus according to claim 1 in which said beam in its normal undeflected position equally intercepts the anode and dynode, and the dynode has a secondary-to-primary emission ratio of approximately two.

4. Electron tube apparatus comprising, a cathode to develop a deflectable electron beam having a substantially linear trajectory, a beam control electrode negatively biased with relation to said cathode to determine the beam intensity, output target electrode means comprising a dynode and an anode in lateral spaced relation with respect to the beam trajectory and conductively connected to form a single output electrode, said beam in its normal undeflected position impinging in a predetermined ratio on both the dynode and the anode, means connecting both the dynode and the anode together and in common to the same load so that both the dynode and the anode are at the same direct current potential when not impinged upon by said beam, a secondary electron suppressor electrode for said anode only, and signal-controlled means to deflect the beam to produce in said load a single composite current which is the resultant of the combined variable intercept of said beam by the dynode and the anode respectively.

5. Electron tube apparatus comprising, a cathode to develop a deflectable electron beam having a substantially linear trajectory, a beam control electrode negatively biased with relation to said cathode to determine the beam intensity, output target electrode means comprising a first surface extending transversely to the beam trajectory and variably intercepting the beam in accordance with the extent of beam deflection, said first surface being a dynode, said target means having a second surface also variably intercepting the beam in accordance with the extent of deflection of the beam, said surfaces being located in lateral spaced relation to each other in the path of the beam so that when the beam is in its normal position it is intercepted in a predetermined ratio by both surfaces, means connecting both surfaces directly electrically and to a common load circuit so that both surfaces are at the same direct current potential when not impinged upon by the beam, means to deflect the beam to produce in said load circuit a single composite direct current which is a resultant of the combined intercepts of the beam by said surfaces, a suppressor electrode located between said surfaces, and an electron collector electrode located in front of both said surfaces on the side facing the cathode.

6. Electron tube apparatus comprising, a cathode to develop a deflectable electron beam having a substantially linear trajectory, a beam control electrode negatively biased with relation to said cathode to determine the beam intensity, output target electrode means comprising a first surface extending transversely to the beam trajectory and variably intercepting the beam in accordance with the extent of beam deflection, said first surface being a dynode, said target means having a second surface also variably intercepting the beam in accordance with the extent of deflection of the beam, a secondary electron suppressor for said second surface only, said surfaces being located in lateral spaced relation to each other in the path of the beam so that when the beam is in its normal position it is intercepted in a predetermined ratio by both surfaces, means connecting both surfaces directly electrically and to a common load circuit so that both surfaces are at the same direct current potential when not impinged upon by the beam, means to deflect the beam to produce in said load circuit a single composite direct curent which is a resultant of the combined intercepts of the beam by said surfaces, and both said surfaces are in the form of plates which are located forwardly and rearwardly of each other along the beam trajectory, said plates extending parallel to each other but being directly electrically joined so as to be at the same direct current potential when not impinged upon by said beam.

7. Electron tube apparatus comprising, a cathode to develop a deflectable electron beam having said substantially linear trajectory, a beam control electrode nega-

tively biased with relation to said cathode to determine the beam intensity, output target electrode means comprising a first surface extending transversely to the beam trajectory and variably intercepting the beam in accordance with the extent of beam deflection, said first surface being a dynode, said target means having a second surface also variably intercepting the beam in accordance with the extent of deflection of the beam, a secondary electron suppressor for said second surface only, said surfaces being located in lateral spaced relation to each other in the path of the beam so that when the beam is in its normal position it is intercepted in a predetermined ratio by both surfaces, means connecting both surfaces directly electrically and to a common load circuit so that both surfaces are at the same direct current potential when not impinged upon by said beam, means to deflect the beam to produce in said load circuit a single composite direct current which is a resultant of the combined intercepts of the beam by said surfaces, and both of said

surfaces are formed from a single metal plate bent back upon itself with one bent-back leg shorter than the other leg from which it is spaced.

8. Electron tube apparatus according to claim 7 in which a secondary electron suppressor grid is located between the said bent-back portions of said plate, and an electron collector electrode is located in front of both said bent-back portions on the side facing the cathode.

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