May 10, 1949. J. C. FERGUSON ET AL 2,470,023

MODULATING SYSTEM

Filed Nov. 1, 1944 3 Sheets-Sheet 1

FIG. 1

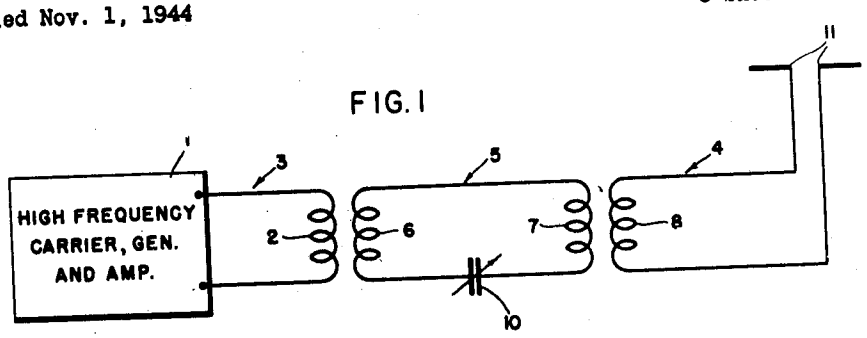


FIG. 2

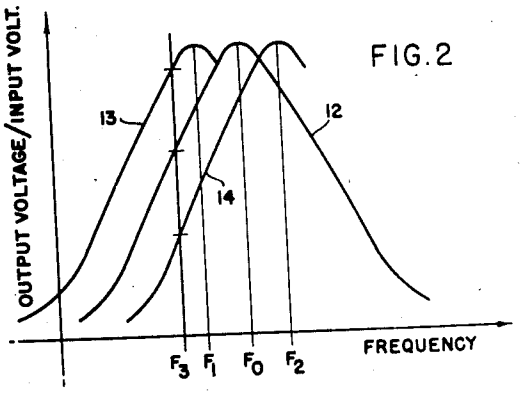


FIG. 3

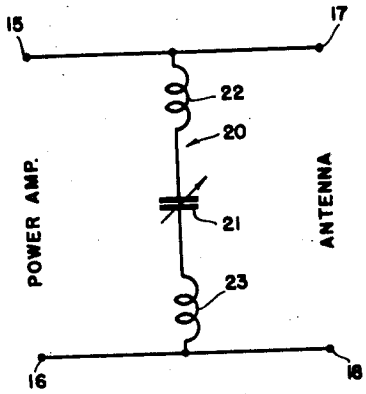
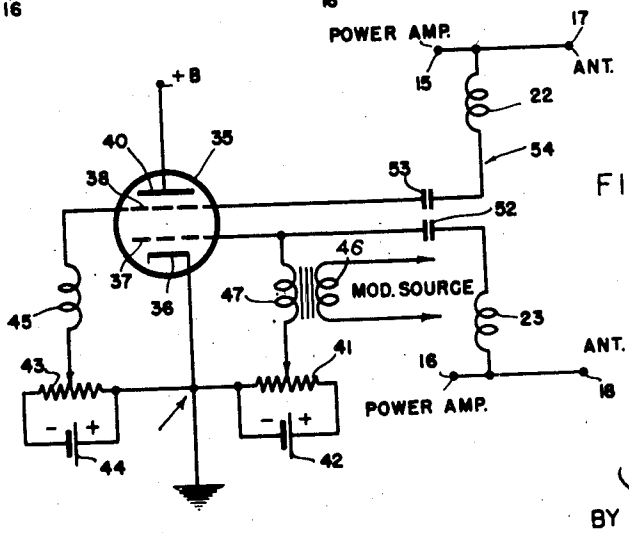


FIG. 5



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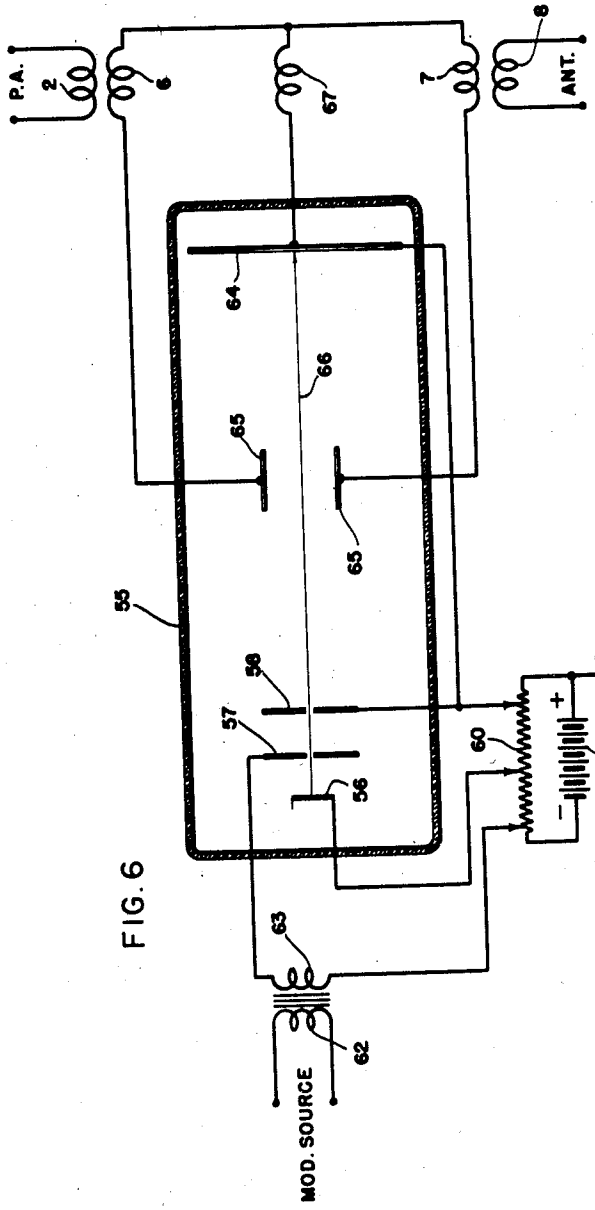
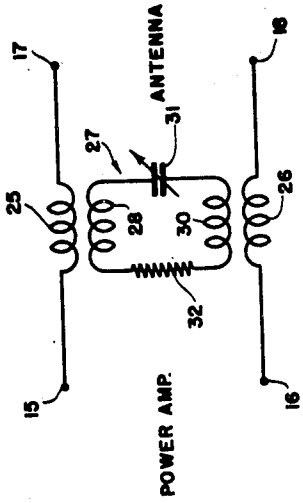


FIG. 6

FIG. 4



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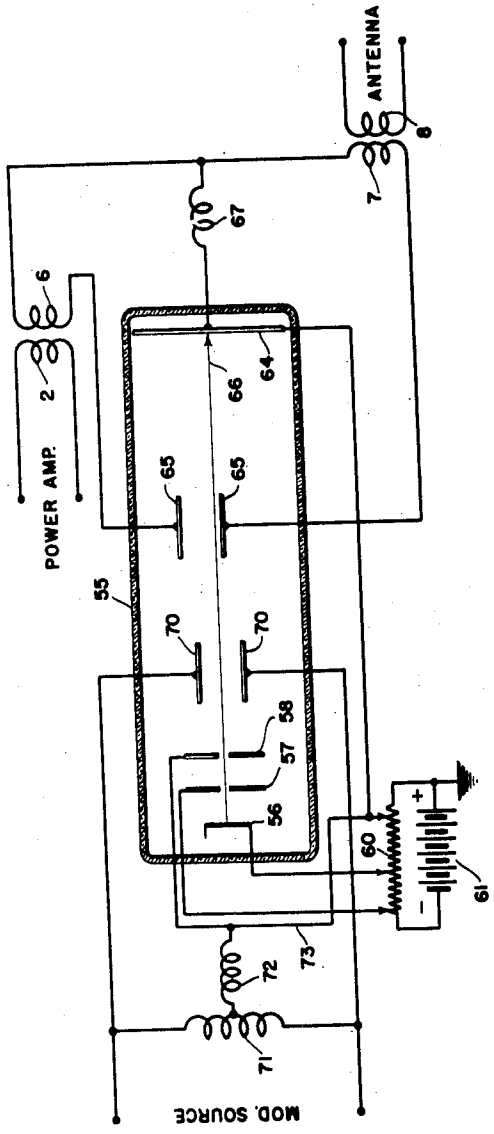


FIG. 7

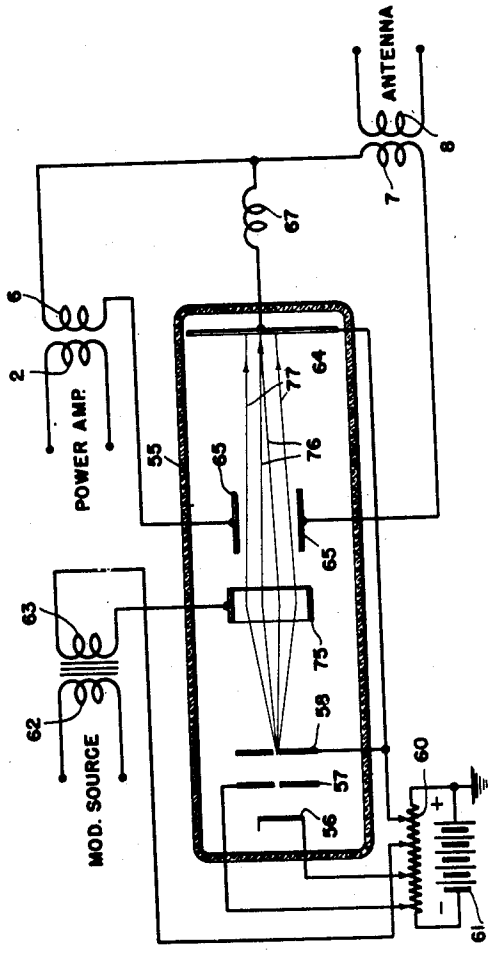


FIG. 8

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UNITED STATES PATENT OFFICE

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MODULATING SYSTEM

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Application November 1, 1944, Serial No. 561,354

6 Claims. (Cl. 332—58)

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This invention relates to signal-modulating systems and more particularly to a novel method and system for wide-band amplitude modulation of a carrier signal.

Modulation systems of this type are used for obtaining amplitude-modulated carrier signals for radio and television transmission. Wide-band modulation is essential for the faithful reproduction of the picture signals in high definition television systems. A conventional amplitude modulating system operates on the principle of absorbing energy from the carrier signal output in order to obtain modulation thereof. This is effected by providing controllable variable resistors for bypassing a larger or smaller portion of the carrier energy developed by a power amplifier. Space discharge tubes are provided which act as variable resistors, the value of which is varied in accordance with a modulating signal. However, a system of this type has the drawback that the resistance of space discharge tubes can only be varied within certain limits. Although the resistance of a discharge tube can be made to approach infinity, its value can not be decreased below a certain limit which is of the order of magnitude of several hundred ohms. It has also been suggested to invert the impedance represented by the resistance of the discharge tubes by a suitable transmission line. Even with this modification, however, the resistance can only be varied within certain narrow limits which imposes a definite limitation on the percentage modulation obtainable with this system.

It is an object of the present invention, therefore, to provide a novel system for obtaining wide-band amplitude modulation of a carrier signal.

Another object of this invention is to provide a signal-modulating system for obtaining a high percentage modulation of an ultra-high carrier frequency.

A further object of this invention is to provide a network including a capacitance, the value of which may be varied over a wide range at high or low frequency rates in response to an electrical modulating signal.

In accordance with the present invention there is provided a signal modulating system comprising an input circuit and an output circuit. The input circuit is coupled to the output circuit by

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means including a variable capacitance element. Electronic means are provided for varying the capacitance element in accordance with a modulating signal applied to the input circuit. In this manner an amplitude-modulated carrier signal is developed in the output circuit which is then utilized, for instance, in a transmitting antenna.

In accordance with an embodiment of the invention the variable capacitance element provided for coupling the input circuit to the output circuit includes two spaced electrodes. Means are provided for introducing free electrons between the electrodes, and the capacitance of the element is varied by influencing the free electrons in accordance with a modulating signal. In accordance with the present invention this may be accomplished by developing an electron beam and passing it between the electrodes of the capacitance element. This electron beam may be deflected, or the density of the electron beam may be varied, or the width of the electron beam may be varied all in accordance with a modulating signal.

According to another embodiment of the invention an electron cloud is created between the electrodes of the variable capacitance element. Means are provided for controlling the density of the electron cloud in accordance with a modulating signal.

It will be seen that in each of the foregoing embodiments of the invention free electrons are introduced between the electrodes of a capacitance element. The density or the relative position of the electrons with respect to the electrodes is varied in accordance with a modulating signal. In this manner the capacitance of the electrodes can be varied within comparatively wide limits at high and low frequency rates.

For a better understanding of the invention, together with other and further objects thereof, reference is made to the following description, taken in connection with the accompanying drawings, and its scope will be pointed out in the appended claims.

In the accompanying drawings:

Fig. 1 is a circuit diagram of a modulating system embodying the present invention;

Fig. 2 is a set of curves referred to in explaining the operation of the invention;

Fig. 3 is a circuit diagram of another modulat-

ing system in accordance with the invention including a tuned shunt;

Fig. 4 is a circuit diagram of a modulating system including a tuned circuit arranged for absorbing energy;

Fig. 5 is a circuit diagram of a modulating system employing an electron discharge tube for coupling a carrier signal generator to a transmitting antenna;

Fig. 6 is a circuit diagram of a modulating system including a cathode ray tube arranged for controlling the intensity of the electron beam thereof;

Fig. 7 is a circuit diagram of a modulating system including a cathode ray tube arranged for controllably deflecting the electron beam; and

Fig. 8 is a circuit diagram of a modulating system including a cathode ray tube wherein means are provided for controlling the width of the electron beam.

Referring now more particularly to Fig. 1 of the drawings, there is shown a modulating system including a high frequency carrier generator and amplifier 1 for developing a carrier signal. Any conventional carrier signal generator may be used for this purpose such as a power amplifier. The carrier signal developed by generator and amplifier 1 is impressed upon coil 2 of input circuit 3. Input circuit 3 is coupled to output circuit 4 through tuned circuit 5. Tuned circuit 5 includes coil 6 inductively coupled to coil 2 of input circuit 3 and coil 7. Coil 7 is inductively coupled to coil 8 of output circuit 4. Tuned circuit 5 is tuned by variable condenser 10. Output circuit 4 is connected to transmitting antenna 11.

In accordance with the present invention amplitude modulation of the carrier signal developed by generator 1 is effected by controllably detuning circuit 5 which couples input circuit 3 to output circuit 4. Circuit 5 is detuned by varying the capacitance of condenser 10 electronically, in a manner to be described hereinafter.

Fig. 2 shows a set of curves illustrating the relationship between the ratio of the output voltage present in output circuit 4 divided by the input voltage present in input circuit 3 and the frequency of a tuned circuit of the type shown in Fig. 1. Curve 12 shown in Fig. 2 represents the output voltage for a constant input voltage plotted against frequency of circuit 5 tuned to a certain frequency f_0. When tuning condenser 10 is varied so that the resonant frequency of the circuit is now f_1, the relationship between the output voltage for a constant input voltage and frequency is represented by curve 13. As is well known the resonant frequency of tuned circuit 5 decreases when the capacitance of condenser 10 increases. Similarly, by decreasing the capacitance of condenser 10 the resonant frequency of the tuned circuit can be increased to a higher value f_2 and now the relationship between output voltage and frequency is represented by curve 14.

We may now assume that the frequency of the carrier signal developed by generator 1 is f_3 shown in Fig. 2. Preferably the carrier frequency f_3 is different from the resonant frequency f_0 of tuned circuit 5 when condenser 10 is adjusted to its normal value. It will be evident that by varying the capacitance of condenser 10 about its normal value, which makes tuned circuit 5 resonant at the frequency f_0, the impedance of tuned circuit 5 is changed. Hence, tuned circuit 5 transmits a larger or smaller amount of carrier signal energy from generator 1 to output circuit 4 and, hence, to transmitting antenna 11.

In accordance with the invention the input circuit may also be coupled to the output circuit of the modulating system by means of a tuned shunt. Such an arrangement is illustrated in Fig. 3. The carrier signal generator and amplifier is connected to input terminals 15, 16, while the useful load or antenna is connected to output terminals 17, 18. Tuned shunt 20 shunts input terminals 15, 16. Tuned shunt 20 includes variable condenser 21 and coils 22 and 23 arranged symmetrically about the condenser 21. Tuned shunt 20 can be detuned by varying condenser 21. Preferably, the normal value of condenser 21 is such that shunt 20 is not exactly tuned to the frequency of the carrier signal. Leads 15 and 16 should each contain a series impedance which, however, will always be present in the carrier signal generator. Therefore, no series impedances have been shown in Fig. 3. By increasing or decreasing the capacitance of tuning condenser 21 a larger or smaller amount of energy of the carrier signal is shunted, and thus the carrier signal appearing across output terminals 17, 18 is amplitude-modulated. The capacitance of tuning condenser 21 may be varied electronically.

Still another modulating system in accordance with the invention is illustrated in Fig. 4. Here a power amplifier or carrier signal generator is connected to input terminals 15, 16. Input terminals 15, 16 are connected to output terminals 17, 18 through coils 25, 26, respectively. A tuned resonant circuit 27 includes coils 28 and 30, tuning condenser 31 and resistor 32. Coil 28 is inductively coupled to coil 25 connecting terminals 15 and 17. Similarly, coil 30 is inductively coupled to coil 26 connecting terminals 16 and 18. The resonant frequency of tuned circuit 27 can be varied by changing the capacitance of tuning condenser 31. Thus, a larger or smaller amount of power can be absorbed by tuned circuit 27, and this power is dissipated in load resistor 32. Hence, a modulated carrier signal is developed across output terminals 17, 18 which may be connected, for instance, to a transmitting antenna.

In accordance with the invention various means may be utilized for electronically varying the capacitance of the tuning condensers shown in the modulating systems of Figs. 1, 3 and 4. Such means are illustrated in Figs. 5, 6 and 7. The embodiment of the invention illustrated in Fig. 5 utilizes a "virtual cathode" which is created in an electron discharge tube. This "virtual cathode" is controlled in accordance with a modulating signal for varying the capacitance between electrodes or grids of the tube. It is well known that in some types of high vacuum electron discharge tubes, including triodes, tetrodes, pentodes and hexodes an electron cloud can be created between certain electrodes or grids thereof. An electron cloud of this type has sometimes been referred to as a "virtual cathode." The name has originated because this electron cloud may serve as a source of electrons and thus acts as a cathode. By changing the potentials applied to the electrodes of the tube the density of this electron cloud can be varied. In accordance with the invention this variable electrode capacitance is utilized for coupling a high frequency carrier signal generator to a useful load, such as an antenna.

As shown in Fig. 5 there is provided an electron discharge tube 35 of the tetrode type. Tetrode 35 has a cathode 36, control grid 37, screen

grid 38 and anode 40. Cathode 36 is connected to ground, as shown. Control grid 37 is supplied with a positive potential from potentiometer 41 connected to battery 42 having its negative terminal grounded, as shown. Screen grid 38 is supplied with negative potential through potentiometer 43 connected to battery 44 having its positive terminal grounded, as shown. High frequency choke 45 is connected between potentiometer 43 and screen grid 38. Anode 40 is connected to a source of positive potential +B.

An electron cloud is formed in tube 35 between control grid 37 and screen grid 38. The density of this electron cloud can be varied by varying the potential supplied to control grid 37. In accordance with the invention a modulating source is connected to coil 46 inductively coupled to coil 47 which is arranged between potentiometer 41 and control grid 37. The varying potentials created by the modulating source will change the control potential applied to control grid 37. Hence, the density of the electron cloud arranged between control grid 37 and screen grid 38 varies in accordance with the modulating source. It follows from the previous explanation that the value of the capacitance between grids 37 and 38 changes in accordance with the density of the electron cloud therebetween, that is, in accordance with the modulating source.

This variable capacitance may be utilized in the tuned shunt illustrated in Fig. 3. To this end coils 23 and 22 are connected, respectively, to grids 37 and 38 through blocking condensers 52 and 53. Blocking condensers 52 and 53 serve for separating the direct current potentials supplied to grids 37 and 38 from tuned shunt 54. The capacitances of condensers 52 and 53 should be relatively large in comparison with the capacitance of electrodes 37, 38. Coil 22 is connected between input terminal 15 and output terminal 17 and coil 23 is connected between input terminal 16 and output terminal 18. A power amplifier or ultra-high frequency carrier generator may be connected to input terminals 15, 16, while output terminals 17, 18 may be connected to a useful load, such as a transmitting antenna.

The operation of the circuit illustrated in Fig. 5 will now be evident. The modulating source connected to coil 46 impresses voltage variations upon coil 47 and thus modulates the control potentials applied to control grid 37. Consequently, the density of the electron cloud between grids 37 and 38 is varied which in turn changes the capacitance of the two grids. Variations of the capacitance of grids 37 and 38 changes the resonant frequency of tuned shunt 54 and, therefore, the impedance of shunt 54 is varied in accordance with the modulating source. In this way a larger or smaller amount of power is bypassed by shunt 54 and, therefore, the carrier signal developed across output terminals 17, 18 is amplitude modulated.

Instead of a tetrode as illustrated in Fig. 5, a triode or a pentode or other multi-grid electron discharge tube may be used for creating an electron cloud and varying the density thereof.

In accordance with the present invention the value of a capacitance may also be varied electronically by means of an electron beam. The embodiment of the invention illustrated in Fig. 6 shows means for varying the intensity of an electron beam. In Fig. 6 there is shown a cathode ray tube comprising an evacuated envelope 55. An electron beam is developed and focused by cathode 56, control grid 57 and first anode 58. By

means of potentiometer 60 connected to battery 61 anode 58 is maintained at a positive potential with respect to cathode 56, and control grid 57 at a negative potential with respect to cathode 56.

A modulating source is connected to coil 62 inductively coupled to coil 63. Coil 63 is arranged between potentiometer 60 and control grid 57. Voltage variations developed across coil 62 are impressed upon coil 63 and thus vary the potential applied to control grid 57. This in turn varies the density or the intensity of the developed electron beam. The electron beam is collected by collector anode 64 which is held at the same potential as first anode 58. Electrodes 65, 65 are spaced symmetrically about the electron beam indicated at 66. Electrodes 65, 65 are connected in a resonant circuit including coils 6 and 7. Coil 6 is inductively coupled to coil 2 connected to a power amplifier and coil 7 is inductively coupled to coil 8 which may be connected to a transmitting antenna. Carrier frequency choke 67 is connected between coils 6 and 7 and collector anode 64, and blocks oscillations at carrier frequency from collector anode 64, while passing the direct current supplied from battery 61 through potentiometer 60 so that electrodes 65 are maintained at the same potential as anodes 64 and 58.

Electrodes 65 and coils 6, 7 represent a tuned circuit, such as circuit 5 shown in Fig. 1. The capacitance of electrodes 65 can be varied by varying the intensity or density of the electron beam 66 as explained previously. This is accomplished by varying the potential applied to control grid 57. Hence, the capacitance of electrodes 65 is varied in accordance with the modulating source, and an amplitude-modulated carrier signal is impressed upon coil 8.

Instead of varying the density of the electron beam the electron beam may be deflected to vary the capacitance of electrodes arranged unsymmetrically about the electron beam. Such an arrangement is shown in Fig. 7. The modulating circuit shown here includes a cathode ray tube 55 having a cathode 56, control grid 57 and first anode 58 which are supplied with suitable potentials from potentiometer 60 connected to battery 61. Electron beam 66 is collected by collector anode 64 which is maintained at the same potential as first anode 58. Deflecting plates 70, 70 are provided for deflecting the electron beam. Deflecting plates 70 are connected to a modulating source which is shunted by coil 71. Audio frequency choke 72 is connected between the center tap of coil 71 and lead 73 connecting potentiometer 60 to first anode 58. Hence, deflecting plates 70 are held at the same potential as first anode 58 and collector anode 64.

Electrodes 65, 65 are arranged unsymmetrically about electron beam 66. In other words, electron beam 66 in its undeflected position is nearer one electrode than the other one. Electron beam 66 is deflected by deflecting plates 70 in accordance with voltage variations generated by the modulating source. By deflecting electron beam 66 the capacitance of electrodes 65 is varied in accordance with the modulating source. In a similar manner as illustrated in Fig. 6 electrodes 65 are connected in a tuned circuit including coils 6 and 7 inductively coupled to input coil 2 and output coil 8, respectively. Carrier frequency choke 67 is arranged between coils 6 and 7 and collector anode 64. Otherwise, the circuit operates in the same manner as explained in connection with Fig. 6.

In accordance with the present invention the

value of a capacitance may also be changed by varying the width of an electron beam. As shown in Fig. 8, there is provided a cathode ray tube 55 including cathode 56, control grid 57 and first anode 58 which are maintained at suitable potentials by potentiometer 60 connected to battery 61. The electron beam is collected by collector anode 64. In order to vary the width of the electron beam there is provided a focusing ring 75. Focusing ring 75 is connected to coil 63 coupled to coil 62 which in turn is connected to a modulating source. Coil 63 and focusing ring 75 are connected to potentiometer 60 and are maintained at a potential between that of anode 58 and collector anode 64 on the one hand, and cathode 56 on the other hand. The potential which is supplied to focusing ring 75 is modified or varied by the modulating source through coils 62 and 63. Thus the focusing of the electron beam is changed. For a certain potential on focusing ring 75 electron beam 76 is focused on collector anode 64 while for another potential applied to ring 75 the electron beam represented by lines 77 would be focused behind collector anode 64. Hence, the width of the electron beam is varied between electrodes 65 which are disposed symmetrically about the electron beam. Accordingly, the capacitance of electrodes 65 is varied in accordance with the modulating source.

In the same manner as described in connection with Fig. 6 electrodes 65 are connected to a tuned circuit including coils 6 and 7 inductively coupled to coils 2 and 8, respectively. Carrier frequency choke 67 is arranged between coils 6 and 7 and collector anode 64. The modulating circuit of Fig. 8 operates substantially in the same manner as the one illustrated in Fig. 6 with the exception that the capacitance of electrodes 65 is varied by varying the width of the electron beam.

Throughout the figures like components have been designated by the same reference numerals.

It is to be understood that an electronically variable capacitance obtained according to any of the embodiments of the invention shown in Figs. 5, 6, 7 and 8 may be used with any of the signal modulating circuits illustrated in Figs. 1, 3 and 4. Instead of the signal modulating circuits of Figs. 1, 3 and 4, other circuits can be devised where an electronically variable capacitance is utilized for coupling an input circuit to an output circuit for developing a carrier signal in the output circuit that is amplitude modulated in accordance with changes of the variable capacitance.

While there has been described what are at present considered the preferred embodiments of the invention, it will be obvious to those skilled in the art that various changes and modifications may be made therein without departing from the invention, and it is, therefore, aimed in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of the invention.

What is claimed is:

1. A signal modulating system comprising an input circuit and an output circuit, means for applying a carrier signal to said input circuit, means including a variable capacitance element for coupling said input circuit to said output circuit, said variable capacitance element including two spaced electrodes, means for developing an electron beam and for passing it between said electrodes, and means for deflecting said electron beam in accordance with a modulating signal to vary the capacitance of said electrodes, thereby to develop an amplitude-modulated carrier signal in said output circuit.

2. A signal modulating system comprising an input circuit and an output circuit, means for applying a carrier signal to said input circuit, a tuned circuit for coupling said input circuit to said output circuit, said tuned circuit including a variable lumped capacitance element comprising two spaced electrodes, means for developing an electron beam and for passing it through the space between said electrodes without impacting said electrodes, and means for varying the relative position of said electron beam with regard to said electrodes in accordance with a modulating signal to vary the capacitance of said electrodes, thereby to develop an amplitude-modulated carrier signal in said output circuit.

3. A signal modulating system comprising an input circuit and an output circuit, means for applying a carrier signal to said input circut, means including a variable element having only lumped capacitive reactance for coupling said input circuit to said output circuit, said variable element comprising two spaced electrodes, means for developing an electron beam and for passing it through the space between said electrodes without impacting said electrodes, and means for varying the width of said electron beam in accordance with a modulating signal to vary the capacitance of said electrodes, thereby to develop an amplitude-modulated carrier signal in said output circuit.

4. A signal modulating system comprising an input circuit and an output circuit, means for applying a carrier signal to said input circuit, a tuned circuit for coupling said input circuit to said output circuit, said tuned circuit including a variable lumped capacitance element comprising two spaced electrodes, means for developing an electron beam and for passing it through the space between said electrodes without impacting said electrodes, and means for varying the width of said electron beam in accordance with a modulating signal to vary the capacitance of said electrodes, thereby to develop an amplitude-modulated carrier signal in said output circuit.

5. A signal modulating system comprising an input circuit and an output circuit, means for applying a carrier signal to said input circuit, a resonant circuit for coupling said input circuit to said output circuit and including a variable lumped capacitance element comprising two spaced electrodes, means for developing an electron beam and for passing it through the space between said electrodes without impacting said electrodes, and means for varying the spacing between said electrodes and the outer elemental portions of said electron beam in accordance with a modulating signal to vary the capacitance of said electrodes, thereby to develop an amplitude-modulated carrier signal in said output circuit.

6. A signal modulating system comprising an input circuit and an output circuit, means for applying a carrier signal to said input circuit, means coupled to said input and output circuits and including a variable element having only lumped capacitive reactance and comprising two spaced electrodes, means for developing an electron beam and for passing it through the space between said electrodes without impacting said electrodes, and means for varying the positions of elemental portions of said electron beam relative to said electrodes in accordance with a modulating signal to vary the capacitance of said elec-

trodes, thereby to develop an amplitude-modulated carrier signal in said output circuit.

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