

Aug. 27, 1940.

T. M. GLUYAS, JR

2,213,104

CONTROLLABLE ENERGY DISSIPATOR

Filed March 15, 1939

2 Sheets-Sheet 1

Fig. 1.

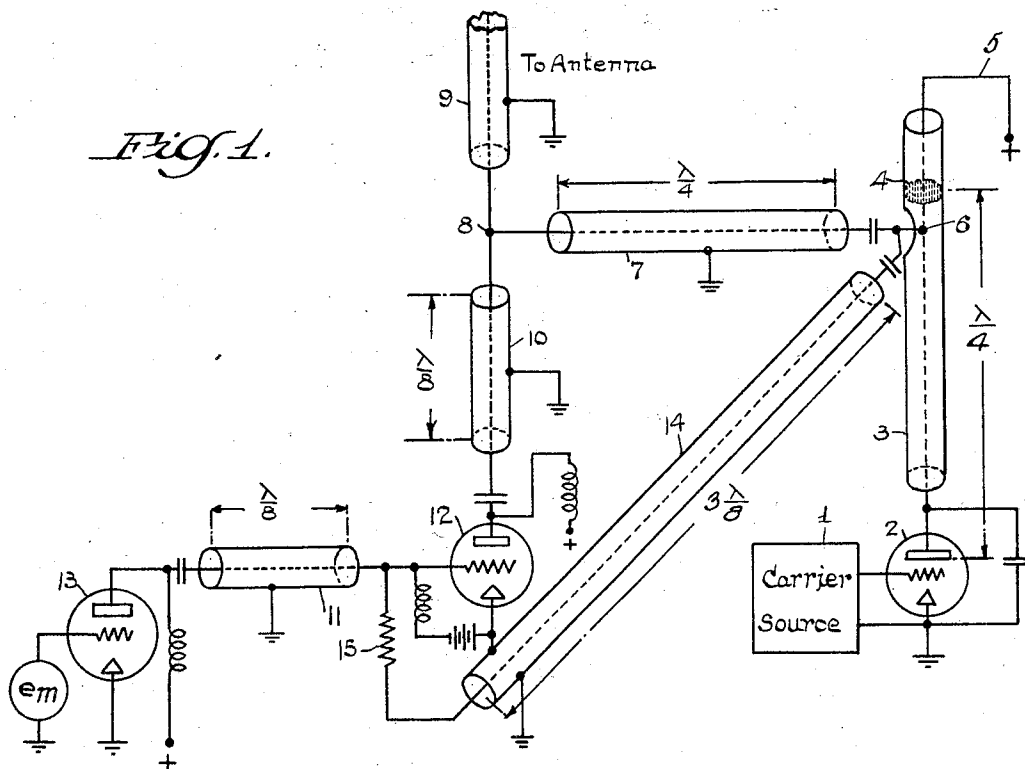


Fig. 1A.

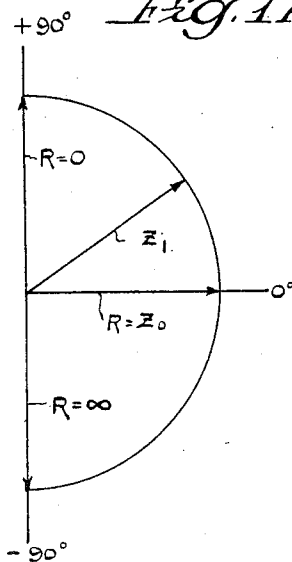
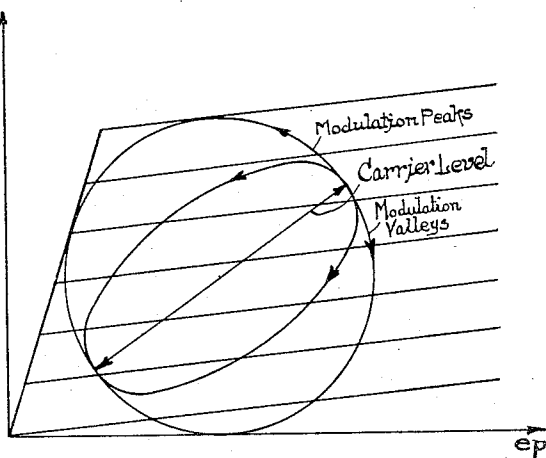


Fig. 1B.



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2 Sheets-Sheet 2

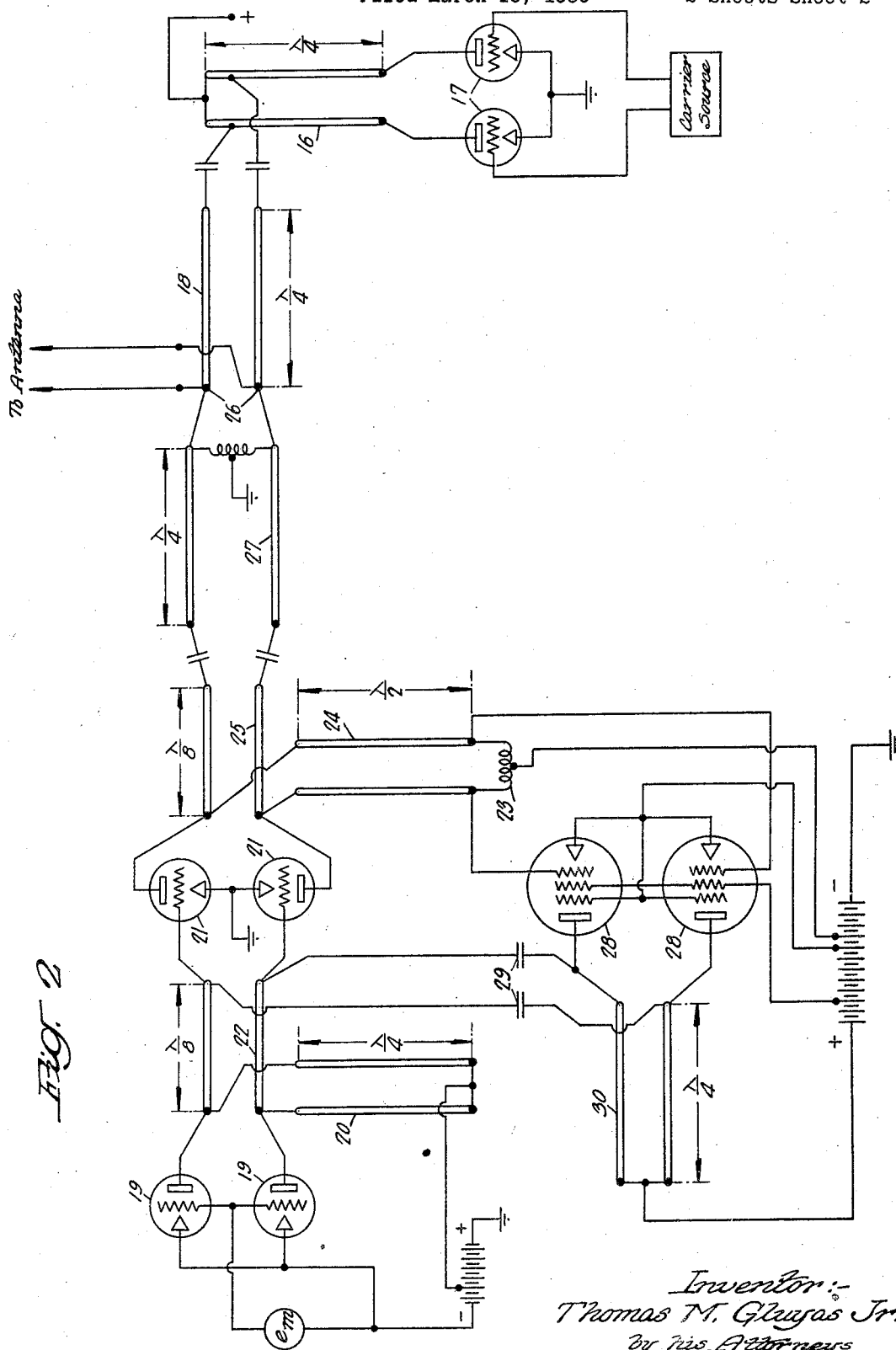


Fig. 2

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UNITED STATES PATENT OFFICE

2,213,104

CONTROLLABLE ENERGY DISSIPATOR

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Application March 15, 1939, Serial No. 262,042

11 Claims. (Cl. 179—171.5)

This invention relates to a method of and means for forming a controllable dissipating means for electrical energy. It is particularly applicable to a system such as that disclosed and claimed in the copending application of William N. Parker, Serial No. 84,534, filed June 10, 1936. The said Parker application discloses a modulating system which is particularly useful in the generation of a modulated high frequency carrier signal for television where a wide band of frequencies must be transmitted for satisfactory picture reproduction. In that application, there are provided means for accomplishing modulation at a high level and with considerably greater efficiency, as well as for a wide band of frequencies. The principal feature of the Parker system resides in shunting a high impedance source of carrier frequency energy by a variable energy dissipating impedance which is controllable in response to the modulating signal. In order that the system shall function with maximum efficiency and be capable of yielding one hundred per cent modulation of the carrier wave, it is desirable that this impedance shall be reducible to zero for a particular value of the modulating signal. The Parker application provides means for obtaining such an impedance by inverting the impedance of one or more vacuum tubes. The plate impedance of these tubes can readily be made substantially infinite by applying a sufficiently negative control voltage to the grids, although it cannot be made to approach zero very closely by applying even a large positive voltage. However, by inverting the tube impedances through quarter wave-length transmission lines or equivalent means, an impedance is obtained which can be varied from zero to a very large value according to the amplitude of the control signal applied to the grids of the tubes.

With such a system, the current drawn by the modulating impedance from the carrier source is zero for peaks of modulation and a maximum for valleys, while for carrier level the current drawn by the modulating impedance is equal to that drawn by the antenna or other useful load. Accordingly, the energy dissipation of the modulating impedance is zero for peaks and valleys of modulation and is equal to that of the antenna at carrier level. In order that this may obtain, it follows that the tubes which make up the energy dissipating modulating impedance must draw maximum current for peaks, half maximum for carrier level, and zero current for valleys of modulation.

The object of the present invention is to pro-

vide a modulating impedance in which the energy dissipating tube operates over a different portion of its plate current-grid voltage characteristic, whereby the current drawn by the tubes over the modulation cycle varies to a lesser extent than in the Parker system. From one point of view, the modulating impedance of the present invention may be regarded as a modification of that of the Parker system in which modification the energy-dissipating tubes are inserted in the middle of the quarter-wave impedance-inverting transmission line. The rate at which they dissipate energy is controlled by applying the modulating signal through tubes placed in the same position as the modulating tubes in the Parker system but which dissipate comparatively little energy. The mode of operation of the invention will more readily be understood by reference to the following description and the accompanying drawings in which:

Fig. 1 is a diagram of a modulating system embodying one form of modulating impedance according to the invention.

Figs. 1A and 1B are explanatory diagrams which will be referred to in describing the invention;

Fig. 2 is a diagram of a modulating system employing another embodiment of a modulating impedance according to the method of the invention.

Referring first to Fig. 1, there is shown a modulating system which resembles in many respects that disclosed in the aforementioned Parker application. The carrier signal from the source 1 is applied to the grid of the tube 2, the plate of which is coupled to the transmission line 3 functioning in the capacity of a tank circuit. The line may be tuned by means of the shorting disc 4 so that its effective electrical length, as modified by the output capacity of the tube 2, is equal to a quarter wave-length of the carrier frequency signal. Plate voltage may be supplied to the tube 2 by means of the connection 5 to the transmission line as shown. Carrier power is derived from the tank circuit at a point 6 near the end of the line 3, whereby the tank circuit presents a low impedance to the transmission line 7 which supplies the power to the load point 8. Line 7 may be a quarter-wave line, or one having an electrical length equal to an odd number of one-quarter wave lengths at the carrier frequency, for the purpose of inverting the low impedance of the tank circuit to form a high impedance source at the point 8. Power may be supplied from the load point to an antenna or other signal utilization means through a transmission line 9, as

shown, or by other suitable means. It will be noted that the lines shown are coaxial and their outer conductors may be grounded as is common practice in the art; however, the use of coaxial lines is not an essential feature of the invention, and open wire lines may be used where convenient. Coupling condensers are also used where necessary to restrict D. C. to those portions of the circuit in which it is desired.

That portion of the system of Fig. 1 which has so far been described is identical in function to the Parker system. Considering now the modulating impedance, it will be seen to consist essentially of the two one-eighth wave-length lines 10 and 11, the energy-dissipating tube 12 inserted between them, and the control tube 13 to the grid of which is supplied the modulating signal from the source e_m . It has already been observed that most of the energy dissipated in the process of modulation is absorbed in the tube 12. The tube 13 serves to control the rate of energy flow into the tube 12. The behavior of the modulating impedance is dependent, in the main, upon a very interesting and useful phenomenon which obtains with respect to transmission lines, or equivalent circuits, whose electrical length is equal to an odd number of one-eighth wave-lengths of the frequency impressed upon them. If any impedance which is purely resistive be shunted across one end of the one-eighth wave-length line and its magnitude be varied, the impedance seen when looking into the other end of the line will appear constant in magnitude but variable in phase in accordance with variations in the magnitude of the resistance. Why this obtains will clearly be seen upon reference to the well-known impedance formula for transmission lines which is here given in its simplified form for the non-dissipative case:

$$Z_1 = Z_0 \frac{Z_2 \cot \theta + jZ_0}{Z_0 \cot \theta + jZ_2} \quad I$$

In this relation, Z_1 is the impedance observed at one end of a transmission line whose electrical length is θ , whose characteristic impedance is Z_0 , and across the far end of which is shunted an impedance Z_2 . Now a one-eighth wave-length line will have θ equal to 45° and, if we make Z_2 a pure resistance equal to R , the equation reduces to:

$$Z_1 = Z_0 \frac{R + jZ_0}{Z_0 + jR} \quad II$$

The modulus of this expression is the same for all values of R and is equal in magnitude to the characteristic impedance but varies in phase, as is clearly shown in Fig. 1A. Thus, when R is zero, Z_1 is purely inductive; when R is equal to the characteristic impedance of the line, Z_1 is resistive; and when R approaches ∞ Z_1 tends to become purely capacitive. Conversely, if an impedance of constant modulus and variable phase were placed at one end of a one-eighth wave-length line, a pure resistance of varying amplitude would be obtained at the other end.

This, in brief, is the function of the line 10 in Fig. 1, whose electrical length is equal to an odd number of one-eighth wave lengths at the carrier frequency. A variable resistance must appear shunted across the load point 8 in order to obtain the desired amplitude modulation of the carrier signal supplied to that point. In order that this may obtain, the phase of the plate current of the tube 12 is caused to vary with respect to the carrier frequency voltage applied to the

plate by means of the transmission line 10. This phase shift may be achieved by applying to the control grid of the tube 12 a signal of carrier frequency which is variable in phase with respect to that appearing on the plate. One method of accomplishing this is to feed back carrier frequency current through an impedance whose phase is variable, and impress the resulting voltage on the grid. The phase of the grid voltage will vary as the phase of the impedance is varied. According to the system disclosed, it is desired to vary the phase of the grid voltage independently by means of this impedance but to leave the amplitude unaffected. Hence, the modulus of the variable impedance in the grid circuit must be constant. Such an impedance may be obtained, as shown in Fig. 1, by transforming a variable resistance through a second one-eighth wave-length line or its equivalent. In the embodiment shown, a resistance which varies in response to the modulating signal may be the plate resistance of tube 13 which is transformed to an impedance of variable phase and constant modulus by means of the line 11, and appears in the grid circuit of the tube 12. It will, of course, be understood that it may be necessary to vary the actual lengths of any or all of the lines to compensate for the fortuitous tube capacities in which the lines are terminated. Furthermore, when operating the system at certain frequencies, it may be convenient to replace the transmission lines by their equivalent circuits comprising lumped reactive elements.

Returning again to the consideration of the modulator tube 12, the chief problem is to supply to its grid circuit a current of carrier frequency, the phase of which is the same as that of the voltage applied to the plate. According to theory, this signal should also have variations in amplitude corresponding to those of the plate voltage, but in practice it has been found that this is not essential and that the signal may be derived at a point in the system at which the departure from this mode of variation is not too great. For example, as shown in the figure, a line 14 whose electrical length is equal to an integral number plus three-eighths wave-length of the carrier frequency, has one end coupled to the tank circuit at the point 6 and its other end coupled to the grid of the modulating tube through a resistance 15. This resistance is preferably large compared to the combined impedance consisting of that placed across the grid by the line 11 and that of the line 14, so that the current through it will be in phase with the carrier signal on the plate of the tube. When this obtains, the voltage applied to the grid will be in phase with that on the plate when the impedance in the grid circuit is purely resistive, and will assume a reactive component as the phase of this impedance is varied. The result will be to vary the phase of the plate current in the tube with respect to the plate voltage, or to alter the load line upon which the tube operates for various points in the modulation cycle.

This is clearly shown in Fig. 1B which shows an idealized triode plate family, upon which are superimposed the load lines traced for various points in the cycle. For peaks and valleys of modulation, the load line will be a circle, the only difference between peaks and valleys being in the direction of traversal of this line which is counter-clockwise for peaks and clockwise for valleys, as indicated in the diagram. At carrier level, the load line will be straight, as shown,

indicating that the tube dissipates energy like a pure resistance. Intermediate points in the modulating cycle will, of course, correspond to elliptical paths as shown. The location of the load lines with respect to the characteristics will depend upon the magnitude of the direct voltage applied to the plate of the tube 12. It is immediately apparent from the diagram that the minimum plate current swing over a carrier frequency cycle is

$$\frac{1}{\sqrt{2}}$$

times the peak occurring at modulation peaks and valleys, and that this minimum obtains at carrier level.

Referring now to Fig. 2, there is shown a further embodiment of the invention. In this instance, the carrier is tapped off at a low impedance point on the quarter-wave line 16 which is connected to the plates of the tube 17, the grids of which are supplied with carrier from a convenient source. The quarter-wave line 18 inverts the low impedance of the tank circuit in the same manner as in the previous embodiment. The modulating signal is applied to the grids of the control tubes 19 in parallel, the plates of which are conveniently supplied with D. C. by connecting them to a quarter-wave line 20. The line may be shorted at its far end to which D. C. is supplied, and presents an open circuit at its other end. The plates are coupled to the grids of the modulating tubes 21 by means of the one-eighth wave-length line 22. The tubes 21 are supplied with D. C. through the center tap to the choke 23 shunting the far end of a one-half wave-length line 24, the near end of which is connected to the plates of the tubes 21, and the further function of which will be considered presently. The plates of tubes 21 are also coupled to one end of a line 25 whose electrical length is equal to one-eighth wave-length, or an odd number of one-eighth wave-lengths, at the carrier frequency. The other end of line 25 may be coupled to the load point 26 through an impedance inverting line 27, whose electrical length is equal to a quarter-wave length, or an odd number of quarter wave-lengths, and whose characteristic impedance may be so chosen as to provide the desired impedance across the load point. It will appear that it will also be desirable to match the impedance of the one-eighth wave-length line 25 to that presented by the tubes 21. Since the impedance of the line will, in general, be low, it may be convenient to reverse the positions of the lines, placing the quarter-wave impedance-inverter adjacent the tubes and the one-eighth wave-length line adjacent the junction point 26. The operation of the system will not, in effect, be altered, and it may be more convenient to match the one-eighth wave-length line to the impedance at the junction point. Hence, the line functions in the capacity of an impedance transformer.

The significant feature wherein this embodiment differs from that of Fig. 1 is in the means used to feed back the carrier frequency current to the grid circuits of the modulator tubes. This is accomplished by means of the pentodes 28 which, because of their high plate impedances act, when their grids are excited by a voltage of carrier frequency, as generators of carrier frequency current, the amplitude of which is independent of external impedance in their plate circuits. A suitable means of exciting the grids

of tubes 28 is by means of the one-half wave-length line 24 from the plates of the modulator tubes 21. When this means is employed, the grid voltage and the plate voltage of the modulator tubes 21 will differ in amplitude by a factor proportional to the amplitude of the impedance presented by the end of the one-eighth wave-length line 22, and will differ in phase by the phase angle of that impedance. In the present case, since the modulus of the impedance is constant, the variation in amplitude of this voltage will correspond to that of the carrier frequency voltage applied to the plates of the tubes 21. The D. C. voltage applied to tubes 28 must be adjusted properly with respect to those on the tubes 21 since no blocking condensers have been provided except at 29 where the plates are connected to the grids of the modulator tubes 21. Plate voltage may be supplied via the shorted quarter-wave line 30; however, it will, of course, be understood that any of the means for supplying the tubes with the proper voltages may be replaced by equivalents, and that there is no intention to restrict the invention to those shown.

The above description of the invention has been limited to the application of the novel modulating impedance in a particular modulating system. Furthermore, only one means has been shown for obtaining an impedance of constant modulus but variable phase for inclusion in the grid circuit of the energy-absorbing tubes. It will, however, be understood that my invention is applicable to any system of absorption modulation and that equivalent means may be used subject only to the restrictions imposed by the appended claims.

I claim:

1. In a modulating system; a source of wave energy having a frequency within a certain frequency range; and means coupled to said source for controllably dissipating energy from said source in response to a control signal, said means comprising a controllable energy-dissipating space discharge device, said space discharge device having at least an anode, a cathode, and a control grid, and having an effective impedance variable in phase in accordance with the phase of the signal applied to its grid for frequencies within said range, means for varying the phase of signals within said range in response to a control signal, means for deriving from said system a signal having substantially the frequency of said wave energy, means for supplying said derived signal to said phase-varying means, a source of a control signal, means for applying said control signal to said phase-varying means to vary the phase of said derived signal, means for applying the signal whose phase is thus varied to the grid of said space discharge device, and means coupling said space discharge device to said first-mentioned source, and adapted to transform the effective impedance of said space discharge device to an impedance of varying magnitude.

2. In a modulating system; a source of wave energy having a frequency within a certain frequency range; and means coupled to said source for controllably dissipating energy from said source in response to a control signal, said means comprising a controllable energy-dissipating space discharge device, said space discharge device having at least an anode, a cathode, and a control grid, and having an effective impedance variable in phase in accordance with the phase

of the signal applied to its grid for frequencies within said range, means for varying the phase of signals within said range in response to a control signal, means coupled to the anode of said space discharge device for deriving a signal having the frequency of said wave energy, means for supplying said derived signal to said phase-varying means, a source of a control signal, means for applying said last-named control signal to said phase-varying means to vary the phase of said derived signal, means for supplying the signal whose phase is thus varied to the grid of said space discharge device to vary the phase of the effective impedance thereof, and means coupling said space discharge device to said first-mentioned source, and adapted to transform the effective impedance of said space discharge device to an impedance of varying magnitude.

3. In a modulating system; a source of wave energy having a frequency within a certain frequency range; and means coupled to said source for controllably dissipating energy from said source in response to a control signal, said means comprising a controllable energy-dissipating space discharge device, said space discharge device having at least an anode, a cathode, and a control grid, and having an effective impedance variable in phase in accordance with the phase of the signal applied to its grid for frequencies within said range, means for varying the phase of signals within said range in response to a control signal, high impedance space discharge means coupled to the anode of said space discharge device for deriving a signal having the frequency of said wave energy, means for supplying said derived signal to said phase-varying means, a source of a control signal, means for applying said last-named control signal to said phase-varying means to vary the phase of said derived signal, means for supplying the signal whose phase is thus varied to the grid of said space discharge device to vary the phase of the effective impedance thereof, and means coupling said space discharge device to said first-mentioned source, and adapted to transform the effective impedance of said space discharge device to an impedance of varying magnitude.

4. In a modulating system; a source of wave energy having a frequency within a certain frequency range; and means coupled to said source for controllably dissipating energy from said source in response to a control signal, said means comprising a controllable energy-dissipating space discharge device, said space discharge device having at least an anode, a cathode, and a control grid, and having an effective impedance variable in phase in accordance with the phase of the signal applied to its grid for frequencies within said range, means for varying the phase of signals within said range in response to a control signal, means for deriving from said system a signal having the frequency of said wave energy, means for shifting the phase of said derived signal by a predetermined fixed amount, means for applying said derived and phase-shifted signal to said phase-varying means, a source of a control signal, means for applying said control signal to said phase-varying means to vary the phase of said derived and phase-shifted signal, means for supplying the signal whose phase is thus varied to the grid of said space discharge device to vary the phase of the effective impedance thereof, and means coupling said space discharge device to said first-mentioned source, and adapted to transform the

effective impedance of said space discharge device to an impedance of varying magnitude.

5. In a modulating system; a source of wave energy having a frequency within a certain frequency range; and means coupled to said source for controllably dissipating energy from said source in response to a control signal, said means comprising a controllable energy-dissipating space discharge device, said space discharge device having at least an anode, a cathode, and a control grid, and having an effective impedance variable in phase in accordance with the phase of the signal applied to its grid, a source of a signal of varying phase, means for applying said signal to the grid of said space discharge device to vary the phase of the effective impedance thereof, and means coupling said space discharge device to said first-mentioned source, and adapted to transform the effective impedance of said space discharge device to an impedance of varying magnitude.

6. In a modulating system; a source of wave energy having a frequency within a certain frequency range; and means coupled to said source for controllably dissipating energy from said source in response to a control signal, said means comprising a controllable energy-dissipating space discharge device, said space discharge device having at least an anode, a cathode, and a control grid, and having an effective impedance variable in phase in accordance with the phase of the signal applied to its grid, a source of a signal of varying phase, means for applying said signal to the grid of said space discharge device to vary the phase of the effective impedance thereof, and means coupling said space discharge device to said first-mentioned source, said last means comprising a transmission line having an electrical length substantially equal to an odd number of one-eighth wave lengths at a frequency within said range, for transforming the effective impedance of said space discharge device to an impedance of varying magnitude.

7. In a modulating system; a source of wave energy having a frequency within a certain frequency range; and means coupled to said source for controllably dissipating energy from said source in response to a control signal, said means comprising a controllable energy-dissipating space discharge device, said space discharge device having at least an anode, a cathode, and a control grid, and having an effective impedance variable in phase in accordance with the phase of the signal applied to its grid, a source of signal of varying phase, means for applying said signal to the grid of said space discharge device to vary the phase of the effective impedance thereof, and means coupling said space discharge device to said first-mentioned source, said last means comprising an impedance transformer device and an impedance inverter device adapted cooperatively to change the effective impedance of said space discharge device to an inverted impedance of varying magnitude.

8. In a modulating system; a source of wave energy having a frequency within a certain frequency range; and means coupled to said source for controllably dissipating energy from said source in response to a control signal, said means comprising a controllable energy-dissipating space discharge device, said space discharge device having at least an anode, a cathode, and a control grid, and having an effective impedance variable in phase in accordance with the phase of the signal applied to its grid, a source of sig-

nal of varying phase, means for applying said signal to the grid of said space discharge device to vary the phase of the effective impedance thereof, means for transforming the effective impedance of said space discharge device to an impedance of varying magnitude, and impedance inverter means for inverting the impedance thus transformed so as to produce an impedance varying throughout a predetermined range of impedances, said last two means coupling said space discharge device to said first-mentioned source.

9. In a modulating system; a source of wave energy having a frequency within a certain frequency range; and means coupled to said source for controllably dissipating energy from said source in response to a control signal, said means comprising a controllable energy-dissipating space discharge device, said space discharge device having at least an anode, a cathode, and a control grid, and having an effective impedance variable in phase in accordance with the phase of the signal applied to its grid, a source of a signal of varying phase, means for applying said signal to the grid of said space discharge device to vary the phase of the effective impedance thereof, means for inverting the effective impedance of said space discharge device to produce an impedance having a magnitude within a predetermined range, and means for transforming the impedance thus inverted so as to produce an impedance of varying magnitude, said last two means coupling said space discharge device to said first-mentioned source.

10. In a modulating system; a source of wave energy having a frequency within a certain frequency range; and means coupled to said source for controllably dissipating energy from said source in response to a control signal, said means comprising a controllable energy-dissipating space discharge device, said space discharge device having at least an anode, a cathode, and a control grid, said anode being coupled to said source, and said space discharge device having an effective impedance variable in phase in accordance with the phase of the signal applied to its grid, a second space discharge device having an anode, a cathode, and a control grid, and having an effective impedance variable in magnitude in accordance with the magnitude of the signal ap-

plied to its grid, means coupling said last-named space discharge device to the grid of said first space discharge device, said coupling means being adapted to transform the effective impedance of said second space discharge device to an impedance of varying phase, means for deriving from said system a signal having the frequency of said wave energy, means for applying said signal to the grid of said first space discharge device, a source of a control signal of varying magnitude, and means for applying said control signal to the grid of said second space discharge device to vary the phase of said transformed impedance and thereby to vary the phase of the signal applied to the grid of said first space discharge device.

11. In a modulating system; a source of wave energy having a frequency within a certain frequency range; and means coupled to said source for controllably dissipating energy from said source in response to a control signal, said means comprising a controllable energy-dissipating space discharge device, said space discharge device having at least an anode, a cathode, and a control grid, said anode being coupled to said source, and said space discharge device having an effective impedance variable in phase in accordance with the phase of the signal applied to its grid, variable impedance means having the magnitude of its impedance variable in response to a control signal, means coupling said variable impedance means to the grid of said space discharge device, said coupling means comprising a transmission line having an electrical length substantially equal to an odd number of one-eighth wave lengths at a frequency within said range for transforming said impedance variable in magnitude to an impedance variable in phase, means for deriving from said system a signal having the frequency of said wave energy, means for applying said signal to the grid of said space discharge device, a source of a control signal, and means for applying said control signal to said variable impedance means to vary the magnitude of its impedance and thereby to vary the phase of the signal applied to the grid of said space discharge device.

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