May 10, 1949. J. F. GORDON 2,470,028

PULSE GENERATION

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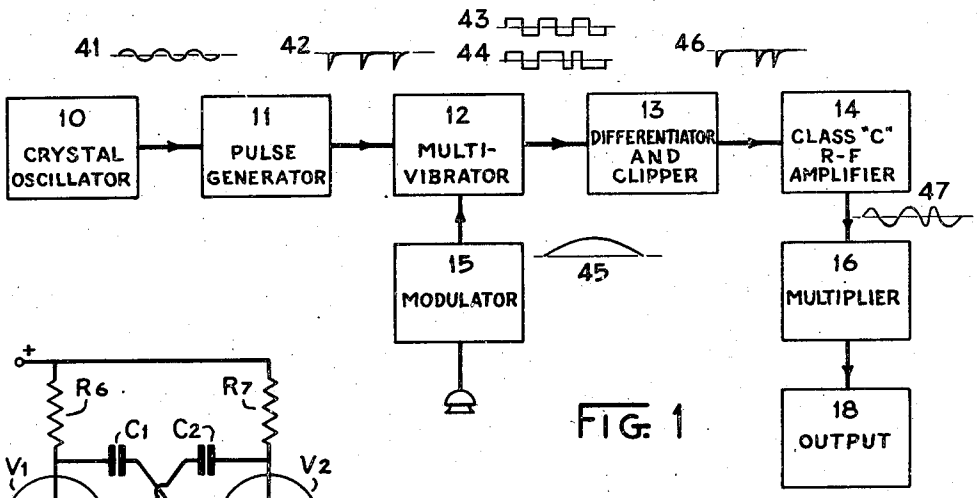


FIG. 1

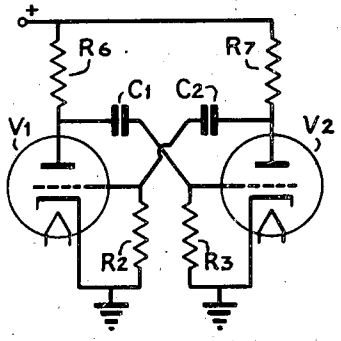


FIG. 2

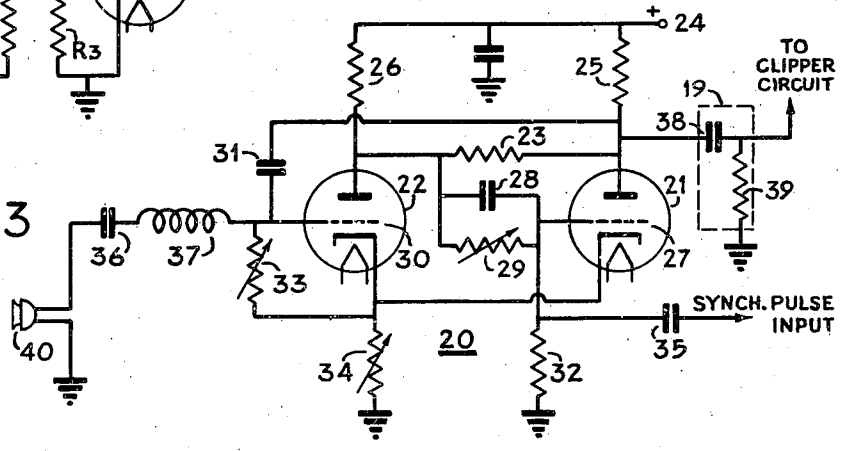


FIG. 3

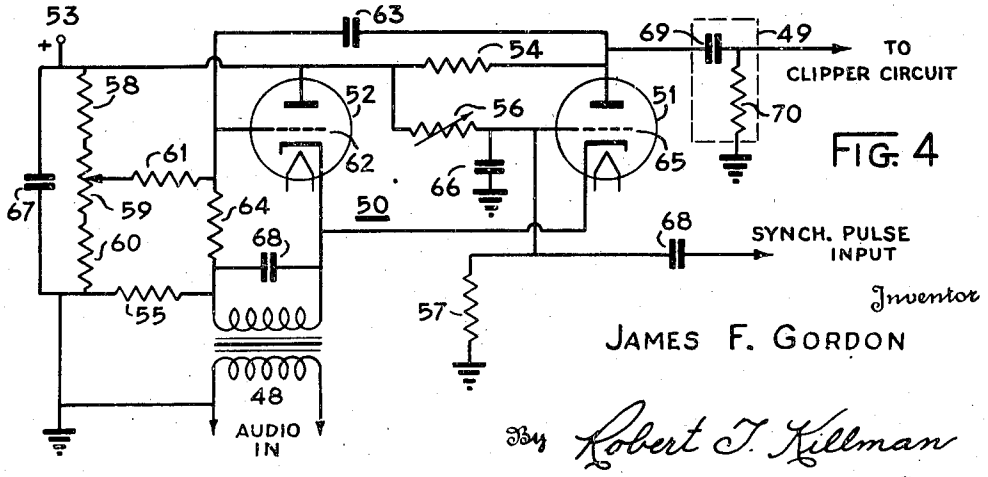


FIG. 4

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PULSE GENERATION

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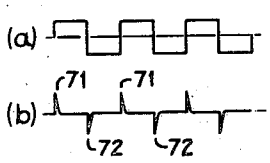


FIG. 5

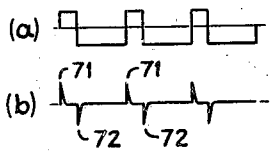


FIG. 6

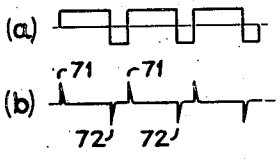


FIG. 7

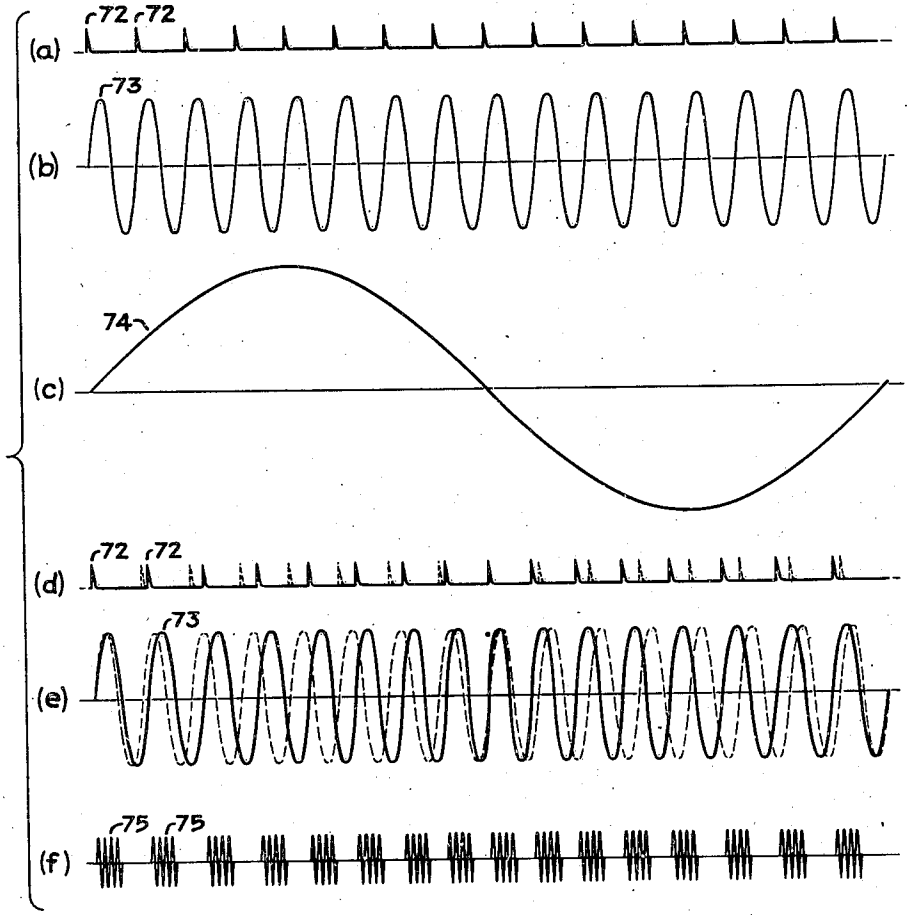


FIG. 8

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2,470,028

PULSE GENERATION

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Application January 18, 1946, Serial No. 641,945

4 Claims. (Cl. 332—14)

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This invention relates to a system for the generation of unidirectional pulses, whose spacing with respect to time is varied in accordance with a control voltage.

Systems of this kind may be used to advantage in the communication art, whenever it becomes necessary to vary one of the characteristics of a periodic wave, as for various types of modulation processes. Application of the invention to the phase modulation of a stabilized oscillation has proved particularly useful, since a relatively wide phase deviation may be accomplished without reaction on the frequency stabilizing apparatus. In order to develop the merits of the invention, this particular application will be considered first.

The conventional method of generating phase modulated waves makes use of a process which varies the phase of a current derived from a fixed frequency source by an amount directly proportional to the amplitude of the modulating current and inversely proportional to its frequency. The resultant phase shift is multiplied by a series of frequency multiplications to the degree necessary to produce the desired frequency change.

With the existing systems it has been difficult to obtain phase modulation exceeding thirty degrees without serious distortion, and to maintain the necessary stability of the mean or unmodulated carrier frequency. This is particularly true in the design of high frequency transmitters, which utilize a low-frequency crystal controlled oscillator, since undesired changes in the mean oscillator frequency are multiplied by the same factor as the desired step-up of the mean frequency.

One of the objects of the invention is to provide a method and means for generating unidirectional pulses and modifying their spacing with respect to time in accordance with a control voltage.

Another object of the invention is to provide a method and means for generating a radio wave and modifying its phase in accordance with the signal to be transmitted.

A further object of the invention is to provide a circuit of the multivibrator type for modifying the phase of a radio wave in accordance with the signal to be transmitted.

Still another object of the invention is to provide a method and means for phase modulating a radio wave over a greater angle of deviation than is at present obtainable by conventional transmission apparatus.

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Another object of the invention is to provide a method and means for producing wide frequency swings of a phase-modulated radio wave, while at the same time maintaining a high degree of stability of the mean frequency.

A further object of the invention is to provide a method and means for producing wide frequency swings of a phase-modulated radio wave, while keeping distortion at a low level.

Still another object of the invention is to provide a method and means for producing radio frequency pulses the positions of which with respect to time are modified in accordance with the signal to be transmitted.

With these and other objects in view, the invention consists of certain novel details of construction and combination of parts, hereinafter fully described and claimed, it being understood that various modifications may be resorted to within the scope of the appended claims without departing from the spirit or sacrificing any of the advantages of the invention.

Other objects and advantages of the invention will become apparent from a consideration of the following specification taken in conjunction with the drawings, in which:

Figure 1 is a block diagram of a phase modulated transmitter system in which the invention is used;

Figure 2 is a schematic diagram of a conventional multivibrator circuit;

Figure 3 is a schematic diagram of a multivibrator circuit, illustrating one mode of application of the invention;

Figure 4 is a schematic diagram of a multivibrator circuit, illustrating another mode of application of the invention;

Figure 5 is a graph illustrating the rectangular square wave generated by a relaxation oscillator whose coupling time constants are identical and the resulting symmetrical pulse series after differentiation;

Figures 6 and 7 are graphs showing rectangular square waves generated by a relaxation oscillator whose coupling time constants are not identical and the resulting pulse series after differentiation; and,

Figure 8 shows a series of graphs (*a*) to (*e*) illustrating in a time related manner various wave forms occurring in the system of Figure 1, and a graph (*f*) illustrating in a like manner the output wave form of a pulse generator triggered by the pulses of graph (*d*).

The invention involves modulation of the square wave forms comprising the output of a

frequency stabilized relaxation oscillator of the multivibrator type, in accordance with a modulating voltage applied thereto. The resulting output is then subjected to differentiation and clipping actions to produce a train of impulses the relative positions of which vary as a function of the modulating voltage and which may be employed for various purposes.

Referring now more particularly to the drawings, Figure 1 shows the general arrangement of a phase modulation transmitting system embodying the invention.

The system shown in Figure 1 includes a multivibrator **12**, the output of which would normally be a uniform rectangular wave form such as indicated by the graph **43**. However, by the application of a modulating voltage from the modulator **15**, in a manner to be described later, the relative durations of the positive and negative excursions of each cycle are altered as a function of the modulating voltage. The nature of the resultant wave form is indicated by the graph **44**. The wave form of the modulating voltage producing the output **44** is indicated by graph **45**.

The output **44** is differentiated and the positive pulses of the resulting wave form are clipped in the portion of the system represented by the block **13**. The result is a train of negative pulses, as indicated by graph **46**, the positions of which are varied about a means as a function of the modulating voltage. The polarity of the pulse train may, of course, be inverted if desired to fit the requirements of use.

These pulses are usable for various purposes, as pointed out above, being indicated here as applied, to a class C radio frequency amplifier **14**. If this amplifier be provided with a plate circuit resonant at the multivibrator frequency or any multiple thereof, the output of the amplifier will be a sine wave phase modulated in accordance with the modulating voltage applied to the multivibrator.

Means for stabilizing the frequency of the multivibrator are shown as comprising a crystal oscillator **10**, the output of which is indicated by graph **41**, triggering a pulse generator **11** to produce a train of negative pulses, as indicated by graph **42**, to which the frequency of the multivibrator is locked.

Before describing in detail the circuits employed in the generation of position modulated unidirectional pulses in accordance with the invention, a brief description of the principles underlying the invention will be given.

Consider first the normal operation of a simple conventional multivibrator circuit such as shown in Figure 2. The circuit and the interaction of its components being well known will not be described in detail. The normal output of the circuit is a square wave such as those shown in Figures 5*a*, 6*a*, and 7*a*. The degree of symmetry of the output wave form depends upon the values of the condensers and resistors shown. If the time constants of the combination R_6, C_1, R_3 and the combination R_7, C_2, R_2 are identical, the wave form will be symmetrical as shown by graph (*a*) of Figure 5. However, if for example, C_1 has more capacitance than C_2 or if R_3 has a higher resistance than R_2, then V_1 will have a longer conducting period than V_2. Thus V_1 will be cut off for a shorter period of time than V_2. The wave form of the output at the anode of V_1 will then appear as in graph (*a*) of Figure 6.

If conditions are reversed so that the time constant of the R_7, C_2, R_2 combination is greater than that of the R_6, C_1, R_3 combination, then V_1 will be cut off for a longer period of time than V_2 and the output at the anode of V_1 will appear as in graph (*a*) of Figure 7.

A similar variation in the relative cut-off time of the two tubes may be obtained by the application of a small variable voltage to the grid of either of the tubes. Thus the application of a modulating voltage as indicated in Figure 1 to the grid of either tube will cause the relative cut-off periods of the two tubes to vary in accordance therewith. By this means it is possible to vary the switch over time between relatively wide limits.

By differentiating the square wave form, a train of pulses of alternating polarity is obtained, positive pulses **71** marking the leading edges and negative pulses **72** marking the trailing edges of the positive excursions of the wave form. The positions of the positive pulses are unaffected by the modulating voltage, but the positions of the negative pulses vary in accordance with the modulating voltage as indicated in the lower graphs (*b*) of Figures 5, 6 and 7.

The elimination of the positive pulses by clipping or other means leaves available a train of position modulated negative pulses for use as desired.

It should be noted that, while in this description the modulation of the output wave form of the relaxation circuit is consistently spoken of as modulation of the trailing edge of the positive excursions, the same modulation may equally well be referred to as applying to the leading edges of the negative excursions. Furthermore, if the point at which the output is taken is shifted from the anode of one tube to the other, the wave form will be inverted, and modulation, for example, of the trailing edges of the positive excursions will become modulation, in inverted phase, of the leading edges of the positive excursions.

The invention may employ multivibrator circuits of either the balanced or unbalanced types as will be described hereinafter.

Referring now to Figure 3, there is shown a multivibrator circuit of the unbalanced type employed in accordance with the invention. This type of multivibrator is normally in a state of equilibrium with one tube conducting and the other cut off. Upon receipt of a triggering pulse of the proper polarity, the circuit is driven through one complete cycle of operation, returning again to the original state at the termination of the cycle. If synchronizing pulses are applied at a recurrence rate which is comparable to the natural frequency of the circuit, the end of each cycle can be made to coincide exactly with the succeeding synchronizing pulse and the frequency of the multivibrator will be locked to that of the synchronizing voltage.

The multivibrator **20** comprises a pair of electron discharge tubes **21** and **22**. Their anodes are connected together through resistor **23**, and connected to a power source **24** through the anode resistors **25** and **26** respectively. The control electrode **27** of tube **21** is joined to the anode of tube **22** through condenser **28** and the variable resistor **29**, which are connected in parallel. The control electrode **30** of tube **22** is connected through condenser **31** to the anode of tube **21**. The grid leak **32** grounds the control electrode **27** of tube **21**. The variable grid leak **33** connects the control electrode **30** of tube **22** to the cathode of the tube **22**. The cathode of tube **21** is grounded through the adjustable resistor **34**. Pulse signals are supplied to the grid **27** of tube **21** through capacitor

35. The modulation voltage is applied to the grid 30 of tube 22 from source 40 through capacitor 36 and inductance 37. The multivibrator output taken from the anode of tube 21 is supplied to the differentiating output circuit 19, consisting of capacitor 38 and the grounded resistor 39, and from there to the next stage of the transmitter system.

The negative synchronizing signal applied to the grid 27 of the multivibrator tube 21 effects a decrease in the anode current of tube 21 causing its anode voltage to increase, and by means of capacitor 31 the grid 30 of tube 22 (which is normally biased to or beyond cut-off) is driven positive, causing the anode current of tube 22 to flow. This anode current in tube 22 passes a negative signal through capacitor 28 and the parallel variable resistance 29 to grid 27 of tube 21, causing the anode current of tube 21 to further decrease. This regenerative action causes the anode current in tube 22 to rapidly reach a maximum, while the anode current in tube 21 is cut off. This circuit condition remains until the charge on the condenser 28 has leaked away through resistors 32 and 29 sufficiently to permit anode current to flow once more in tube 21. When this occurs the regenerative effect again takes place, but in the reverse direction. In order to allow the synchronizing pulses to control the operation of the multivibrator, its circuit is designed to oscillate at a frequency slightly less than the recurrence frequency of said synchronizing pulses. Thus, the multivibrator output frequency is identical to the initiating pulse repetition rate and is permanently locked to the frequency of the crystal oscillator. The application of control voltage from modulation source 40 to the grid 30 of tube 22 will cause the relative duration of the excursions of opposite polarity to vary in successive cycles of the multivibrator output in accordance with the amplitude variations of the control voltage.

The multivibrator output is applied to the differentiating output circuit 19, whose output will consist of a series of alternating positive and negative pulses, the equidistant positive pulses being time-position controlled by the stabilized oscillation of crystal oscillator 10, and the negative pulses by the modulation voltage.

The pulses are then fed through a clipper circuit, which clips the positive pulses, the remaining position modulated negative pulses being available for use.

In the particular mode of application, illustrated in Figure 1, the remaining negative pulses 72 are inverted and used to drive the grid of a class-C amplifier, the plate circuit of which is resonant at a frequency which corresponds to the repetition rate of the pulses driving the grid or a multiple thereof. The effects are shown in graphs (*a*) to (*e*) of Figure 8. Due to the initiating grid pulses 72 as shown in graph (*a*) and the inertia effect of the plate circuit, a sine wave 73 as shown in graph (*b*) will be generated in the plate circuit. As a result of the effect of the control voltage 74 (graph (*c*)) on the multivibrator output, changes in timing of the grid pulses 72 will occur as indicated by the solid line pips of graph (*d*) and will result in phase deviations of this sine wave, as shown by the solid line wave form of graph (*e*). The dotted line pips and sine wave form of graphs (*d*) and (*e*) are replicas of graphs (*a*) and (*b*) included for reference. These phase deviations will exactly follow the changes of the time constant of the second tube

circuit of the multivibrator. The mean frequency of the R.-F. energy generated in the plate circuit of the amplifier will be identical with the frequency of the crystal oscillator controlling the pulse repetition rate at which the multivibrator is actuated, or a multiple thereof. After multiplication to the required transmission frequency, the phase modulated radio wave can be radiated.

Figure 4 illustrates the employment of a multivibrator circuit of the balanced type in accordance with the invention. This type of multivibrator is normally free-running but for precise frequency control may be driven by a synchronizing arrangement such as shown in Figure 1. The multivibrator 50 comprises a pair of electron discharge tubes 51 and 52. The power source 53 is connected to the anode of tube 52, and through resistor 54 to the anode of tube 51. The cathodes of tubes 51 and 52 are connected together and grounded through resistor 55 and the secondary of transformer 48, and due to the voltage drop across these two elements the cathodes of both tubes are positive with respect to ground. Positive grid bias to each tube is supplied from the power source 53. The grid bias to tube 51 is controlled by the voltage divider network, consisting of the variable resistor 56 and the grounded resistor 57, and the grid bias to tube 52 is controlled by the voltage divider network consisting of resistor 58, the potentiometer 59, the grounded resistor 60, and the shunted resistors 61, 64 and 55. Resistor 61 prevents the grid circuit of tube 52 from being unduly loaded when potentiometer 59 is adjusted. The control electrode 62 of tube 52, grounded through grid leak resistor 64, and resistor 55, is connected through capacitor 63 to the anode of tube 51. Multivibrator coupling between the two tubes is by means of their common cathode resistor 55 and the secondary of transformer 48.

Synchronizing pulse signals are supplied to the grid 65 of tube 51 through capacitor 68. The modulation voltage is applied to the primary of transformer 48, whose secondary is connected between the grid 62 and the cathode of tube 52, the modulation voltage thus appearing between grid and cathode of both tubes. Capacitor 68 which parallels this secondary is a by-pass condenser at the multivibrator frequency. The impedance of the secondary of transformer 48 is kept very low. It thus prevents voltage variations from extraneous sources, such as filament A.-C. hum, etc., from appearing between cathode and grid of tube 52 in any appreciable magnitude where they would cause undesirable modulation of the circuit.

The anode current through tube 52 will now vary in accordance with the audio potentials applied to the transformer primary. This variation in plate current of tube 52 will cause the cathode of tube 52 to exhibit a proportional variation in voltage between cathode and ground. Since the cathodes of tubes 51 and 52 are connected together, this same voltage variation will take place between the cathode of tube 51 and ground, and this voltage variation controls the time at which tube 51 starts conducting after having been cut off by the negative synchronizing pulse. The multivibrator output is supplied to the differentiating output circuit 49, consisting of capacitor 69 and the grounded resistance 70, and from there to the next stage of the system.

The circuit of Figure 4 is arranged to minimize the introduction of distortion during modulation. The larger part of the distortion to be encoun-

tered from this source stems from the fact that the discharge curve of a capacitor is exponential rather than linear. For this reason the linearity of modulation depends largely upon how narrow a section of this exponential curve can be utilized for maximum phase swing.

The ratio of capacity **63** to resistance **64** is large, causing operation to take place on a very short and therefore practically straight portion of the condenser discharge characteristic. The resistance of resistor **64** is very low (preferably around 500 ohms or less) and the capacity of condenser **63** being large, distortion due to the flow of grid current is thus kept to a very low value.

The possibility of synchronizing pulses feeding through the multivibrator circuit to appear in the output of the system is minimized by the fact that synchronization is secured by the application of negative pulses to the grid of tube **51**. These pulses cut off tube **51**, initiating the positive excursion of the output wave form derived from the anode of that tube. This wave form then being differentiated and the positive pips of the differential wave being clipped, any carry through of synchronizing pulses is eliminated.

Among the many possible uses of the pulses generated in accordance with the invention is their application as triggering pulses to the pulse oscillator of an R.-F. pulse transmitting circuit. This will result in the positive modulation of the transmitted pulses in accordance with the requirements of pulse communication systems. Figure 8 illustrates in the time related graphs (*d*) and (*f*) the wave forms pertaining to this manner of employing the invention. The pulses **72** of graph (*d*) here control the production of the pulses **75** of R.-F. energy, shown in graph (*f*), which are position modulated in the same manner.

It will be obvious that many changes and modifications may be made in the invention without departing from its spirit as described in the foregoing description and in the appended claims.

What is claimed is:

1. In a system for generating position modulated energy pulses, the combination which comprises: a relaxation oscillator generating a square wave output, said relaxation oscillator comprising two electron discharge tubes, the anode of each of which is capacitively coupled to a control electrode of the other; means stabilizing the recurrence frequency of said square wave output by the application of synchronizing pulses to the control electrode of one of said electron discharge tubes; a source of modulating voltage; means varying the control electrode potential of the other of said electron discharge tubes in accordance with said modulation voltage; means differentiating the output of said relaxation oscillator, thus producing two alternating series of energy pulses, one of said series being of uniform spacing conforming to the spacing of said synchronizing pulses and the other position modulated as a function of said modulating voltage; and means eliminating said uniformly spaced pulses.

2. In a system for transmitting phase modulated oscillatory currents, the combination which comprises: a relaxation oscillator generating a square wave output, said relaxation oscillator comprising two electron discharge tubes, the anode of each of which is capacitively coupled to a control electrode of the other; means stabilizing the recurrence frequency of said square wave output; a source of modulating voltage; means varying the control electrode potential of one of said electron discharge tubes in accordance with said modulation voltage; means differentiating the output of said relaxation oscillator, thus producing two alternating series of energy pulses, one of said series being of uniform spacing and the other position modulated as a function of said modulating voltage; means eliminating said series of uniformly spaced pulses; means for generating radio frequency waves, said means having a natural frequency comparable to the recurrence frequency of said relaxation oscillator output and means synchronizing the output of said radio frequency wave generating means with the remaining series of energy pulses.

3. In a system for transmitting phase modulated oscillatory currents, the combination which comprises: a relaxation oscillator generating a square wave output, said relaxation oscillator comprising two electron discharge tubes; means stabilizing the recurrence frequency of said square wave output; a source of modulating voltage; means varying the grid potential of one of said electron discharge tubes in accordance with said modulation voltage; means differentiating the output of said relaxation oscillator, thus producing two alternating series of energy pulses, one of said series being of uniform spacing and the other position modulated as a function of said modulating voltage; means eliminating said series of uniformly spaced pulses; means for generating pulses of radio frequency oscillations and means for keying said pulse generating means by the remaining series of energy pulses.

4. In a system for generating position modulated energy pulses, the combination which comprises: a relaxation oscillator generating a square wave output, said relaxation oscillator comprising two electron discharge tubes, each having at least an anode, a cathode and a control electrode; means applying a synchronizing voltage to the control electrode of one of said tubes to stabilize the recurrence frequency of said square wave output; a source of modulating voltage; means applying said modulating voltage to the control electrode of the other of said tubes; means differentiating the output of said relaxation oscillator, thus producing two alternating series of energy pulses, one of said series being of uniform spacing as determined by the application of said synchronizing voltage and the other position modulated as a function of said modulating voltage; and means eliminating said uniformly spaced pulses.

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