

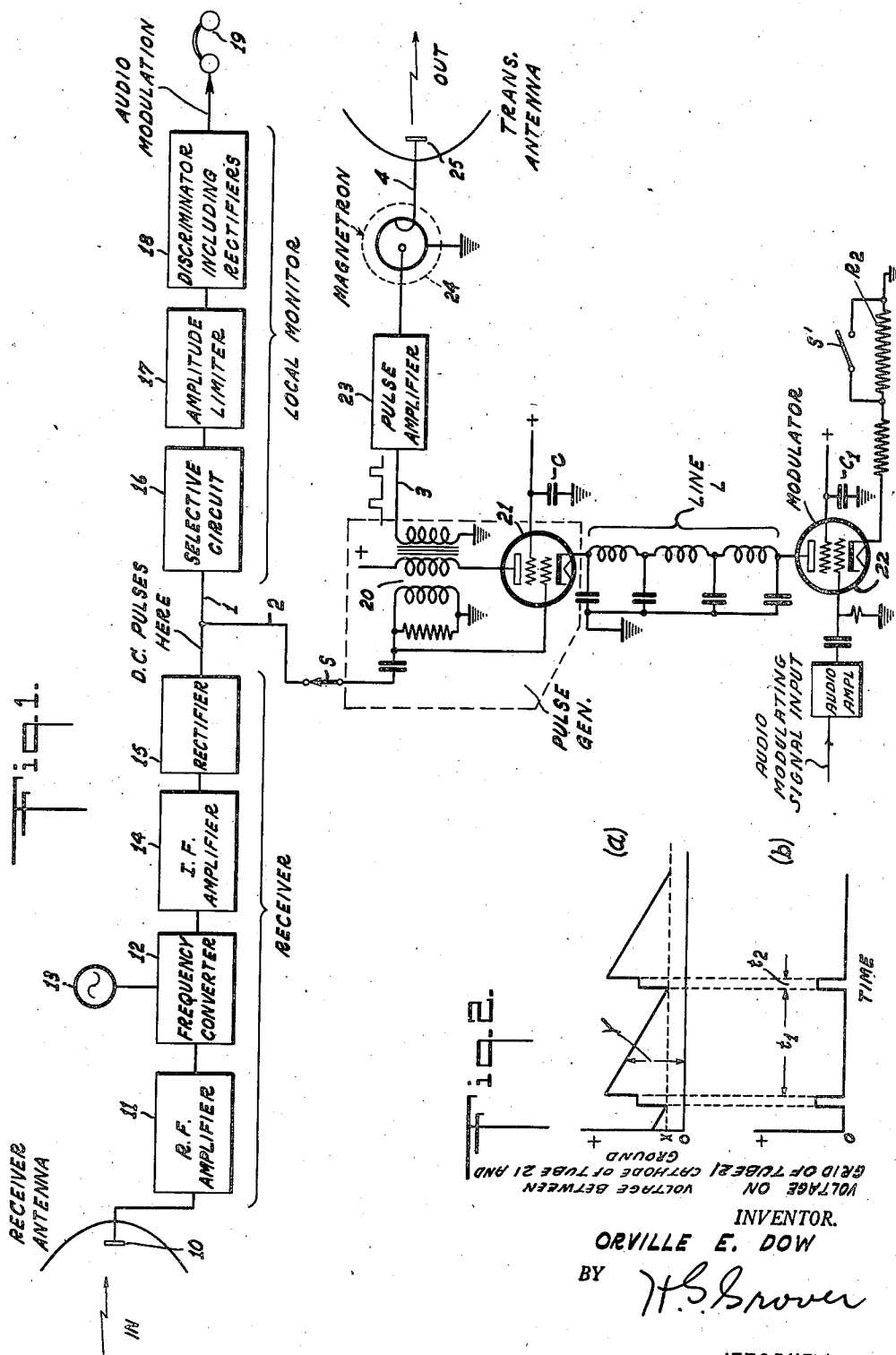
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PULSE REPEATER SYSTEM

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PULSE REPEATER SYSTEM

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1

This invention relates to a radio repeater station for repeating pulses of high frequency energy which are short compared to the time intervals between them.

One object of the present invention is to enable the efficient reception and retransmission of phase or frequency modulated signal pulses of high frequency energy in a radio system, while at the same time preventing the retransmission of extraneous pulses received during the intervals between signal pulses.

Another object is to provide a repeater station for use in a pulse communication radio system which has a continuously operative receiver whose output is employed to synchronize a pulse generator by means of the incoming signal pulses, but which pulse generator is insensitive to pulses received during the intervals between signal pulses.

A more detailed description of the invention follows in conjunction with a drawing, wherein Fig. 1 illustrates the pulse repeater system of the invention, in a sketch which is partly diagrammatic and partly schematic, and Fig. 2 graphically illustrates the operation of the pulse generator of Fig. 1.

The repeater system of Fig. 1 is adapted primarily to receive and retransmit pulses which are short compared to the time interval between them, and which pulses have their phase or pulse rate modulated by the intelligence to be conveyed. The short incoming pulses of radio frequency energy, preferably ultra high frequency energy, are received on antenna 10 and fed to radio frequency amplifier 11 from which the pulses are conducted to a frequency converter 12 where they beat with the energy from a heterodyne oscillator 13 to produce in the output of the frequency converter pulses of intermediate frequency energy. These pulses of intermediate frequency energy are amplified in intermediate frequency amplifier 14 and then passed on to a rectifier 15. By way of example, only, the incoming pulses which are collected on the receiving antenna 10 may have a duration of one microsecond and be spaced fifty microseconds apart. The pulse rate and the spacing of these incoming pulses will vary due to the modulation in the remote transmitter (not shown). The output of the rectifier 15 is in the form of direct current pulses, although it should be understood that these direct current pulses may start from a negative value and increase to a positive value. These direct current pulses are then supplied

2

over a path 1 to a local monitor circuit and over a path 2 to a pulse generator circuit.

The local monitor circuit includes a suitable selective circuit 16 which may be a band pass filter, and which will transform the direct current pulses substantially to a sinusoidal carrier. The output of the selective circuit 16 is transmitted through an amplitude limiter 17 to a discriminator and detector circuit 18. The limiter 17 and the discriminator and detector 18 may be of the same type as those commonly used in receivers built for phase modulation and/or frequency modulation purposes. Apparatus 18 may include that type of discriminator circuit which employs a pair of off-tuned circuits. The output of the discriminator 18 will contain the original audio modulation, which may be voice, and this audio modulation may be heard in a loudspeaker 19, which is illustrative of any suitable acoustic transducer.

The direct current pulses which are fed over path 2 to the pulse generator circuit 21 serves to synchronize this pulse generator at the frequency or pulse rate of the incoming pulses. Pulse generator 21 is in the form of a vacuum tube tetrode whose control grid and anode electrode are connected to separate windings of a three-winding pulse transformer 20. The output winding of the pulse transformer derives rectangular wave output pulses of short duration and supplies these pulses, by way of lead 3, to a pulse amplifier 23 for controlling a suitable ultra short wave generator such as a magnetron 24. The wave shape of these rectangular wave pulses is shown immediately above lead 3. The pulse transformer 20 is so coupled to the tetrode 21 that there is a regenerative action which gives very sharp increase of current in the tube 1 when the current is building up and very sharp decay when the current is decreasing, thus providing pulses having sharp slopes or edges.

In circuit with the cathode of the vacuum tube 21 is an artificial line L, one end of which is connected between the cathode and ground (as shown) and the other end of which is connected across a constant current modulator vacuum tube 22. In practice, the modulation tube 22 may be placed anywhere along the length of the line L and even at the cathode end of tube 21, if so desired. The line L is in the form of a low pass filter consisting of several sections, but may be of any suitable type. A coaxial line is not believed to be desirable for practical reasons because it would be too long and bulky compared to more compact available structure.

3

The internal plate impedance of the modulating tube 22 is designed to be high compared to the characteristic impedance of line L. A signal modulating circuit is coupled across the control grid and cathode of tube 22 through a suitable audio amplifier (not shown). The modulating signal may be speech or any other suitable signal for impressing a local modulation upon the outgoing signal. When the outgoing signal is being modulated locally, lead 2 is opened by means of switch S so that the received signal does not synchronize the pulse oscillator during this time.

The anode of tube 21 is supplied with a positive polarizing potential through one winding of the transformer 20. The same power supply may furnish a positive potential to the screen grid of the modulator 21 through a suitable circuit arrangement. Condensers C and C1 in the screen grid circuits of tubes 21 and 22, respectively, are by-pass condensers for these tubes. Condenser C1 is a by-pass condenser for the pulse frequency to maintain the screen grid of tube 22 at a constant potential insofar as pulse voltages are concerned. The cathode of tube 21 is always maintained at a positive potential relative to ground, and supplies the anode voltage for the modulator tube 22 through line L.

In the operation of the pulse generator, an increase of current through the central winding of transformer 20 will induce a voltage in the winding directly connected to the control grid of tube 21 in such direction as to place a positive pulse on the control grid which will hasten or expedite the flow of current through tube 21. The flow of current through tube 21 will cause a pulse of voltage to flow down line L from the cathode end to the other end at which the modulator tube 22 is located. When this traveling pulse of voltage reaches the end of the line, it will be reflected in phase and travel back along the line L to the cathode of tube 21, with a resultant voltage effectively double the initial voltage. When this resultant voltage reaches the cathode end of the line, it cuts off the current through tube 21. The initial pulse voltage produced at the cathode end of line L due to current flowing in tube 21 is of such relative polarity as to tend to cut down the current flow in the tube but is not of sufficient magnitude at this time to cut off the conductivity of the tube. But, when the pulse returns to the cathode from the other end of the line with a resultant magnitude of twice the initial magnitude, it is then of sufficient value to decrease the current flowing through the tube 21. When the current starts to decrease through tube 21 and through the central winding of transformer 20, the voltage induced in that winding in circuit with the control grid (by this decreasing current) will reduce the positive voltage on the grid and hasten the cut-off action. This regenerative action serves to give very sharp decay and very sharp increase of current in the tube 21.

The operation of the pulse generator is graphically illustrated in Fig. 2, wherein graph *a* shows the variations in the voltage between the cathode of tube 21 and ground, with respect to time, and graph *b* illustrates the variations in voltage on the control grid of tube 21 with respect to time. Point X on the ordinate of graph *a* is the cut-off voltage on tube 21. The distance Y on graph *a* represents the instantaneous value of voltage across the cathode end of the line L at any instant, as measured from the slope of the curve to the zero voltage line. Time *t*1 represents the

4

time during which no current flows in the tube 21, while time *t*2 represents the time of each pulse during which current does flow in tube 21. It will thus be seen that the duration of the pulse is determined by the electrical length of line L and that this time may be and is short compared to the time interval between pulses. The rectangular wave of graph *b* appears in the output of the pulse generator 1 and is available in lead 3. The time interval between pulses is determined, in part, by the average anode current in tube 22 as will be explained.

The effect of the pulse traveling down along the line L and back again is to charge up the capacity in the line to a value equal to the resultant voltage. This voltage on the line will keep the tube 21 cut-off until the voltage in the line dissipates to a value below the cut-off value of tube 21. This dissipation occurs through the modulator tube 22 and the time thereof may be increased or decreased by means of potentials applied between the control grid and cathode of tube 22. Modulator tube 22 provides a constant current flow therethrough for any fixed value of bias on the control grid thereof. It will thus be evident that variation in modulating potential applied to the control grid of tube 22 will vary the impedance of the tube 22 with a consequent variation in the dissipation rate of the voltage on line L, as a result of which the pulse rate of the pulses appearing in line 3 will be varied in dependence upon the modulating potentials.

When the system is acting as a repeater the average current of modulator tube 22 is set at a value that will make the natural period of the pulse generator longer than the longest time between two consecutive pulses of the received signal. Thus when the system is operating as a repeater, switch S is closed and switch S1 is open. The added resistance R2 in the cathode circuit of tube 22 decreases its average current and increases the natural period of the pulse oscillator. However, the pulse oscillator is not allowed to oscillate at its natural period. As the cathode voltage decreases following a pulse (Fig. 2, curve (a)) it approaches the value X where it will automatically generate another pulse. Before it reaches this value a pulse from the receiver drives the grid of tube 21 plus and causes the generator to produce a pulse in synchronism with the received pulse. Due to the high plus voltage on the cathode of the tube 21 immediately following a pulse it can not be tripped again. Thus energy from the transmitting antenna 25 which will get back into the receiving antenna 10 cannot cause the system to oscillate or sing.

It will at times be necessary for an operator or service man at a repeater station to modulate the outgoing signal. To do so the switch S, Fig. 3 is opened and switch S1 is closed. The pulse generator is now operating at its own natural period. To make this natural period equal to the average frequency of the received signal the cathode resistance of modulator tube 22 is decreased by shorting out R2. The frequency of the pulses generated by tube 21 is modulated in accordance with the voltages applied to the control grid of tube 22.

The pulses in lead 3 are amplified in pulse amplifier 23 and applied to the magnetron 24. This magnetron is shown diagrammatically only as having a cathode connected to the pulse amplifier 23 and a surrounding anode connected to ground. A magnetic coil producing flux lines substantially parallel to the axis of the cathode

5

is shown by a circle formed by a dash line. Output from the magnetron is taken from a loop located in the interior of the magnetron and connected to a lead 4 extending to the transmitting antenna 25.

This magnetron will be pulsed by the rectangular wave-form short-duration pulses impressed thereon by the pulse generator 21 to produce substantially corresponding length pulses of ultra short wave energy which are radiated from the antenna 25. These microsecond duration pulses generated by the pulse generator 21 will control the ultra high frequency oscillator 24 to produce substantially microsecond pulses of ultra short wavelength energy.

By way of example only, the incoming pulses may have a duration of one microsecond and be composed of a carrier wave of 500 megacycles. These pulses may be spaced approximately fifty microseconds apart, depending upon the phasing or pulse rate modulation impressed thereon at the remote transmitting station. The incoming pulses may be beat down by the frequency converter to produce intermediate frequency pulses whose carrier is 30 megacycles. The pulse generator 20, 21 may produce pulses at a rate of about twenty kilocycles per second. The artificial line may have a delay from one end to the other of about 0.5 microsecond.

When the system is acting as a repeater, the generation of the pulse generator 21 will be synchronized by the incoming pulses so that the pulses impressed on the transmitting antenna are at the rate of twenty kilocycles and synchronized with the incoming pulses. The local modulator circuit 22 provides one way by which local modulation may be applied to the transmitted pulses. Because the incoming signal is disconnected from the transmitter when it is desired to modulate the transmitter locally, the local modulator does not superimpose its own modulation on the relayed signals.

It should be noted that the receiver of the system of Fig. 1 is continuously operative to receive incoming signals. Due to the inherent delay in the various circuit elements of the system, however, the outgoing pulses radiated by the transmitting antenna 25 occur in the time intervals between the received incoming signal pulses. Due to the fact that the pulse generator 21 generates extremely short pulses during the time intervals t_2 (note graph b of Fig. 2) and is non-responsive during the time interval t_1 , there is less possibility of any extraneous incoming pulses impressed on the receiver affecting the pulse generator. Thus, noise or static pulses occurring after signal pulses cannot affect the pulse generator 21. In the absence of incoming signal pulses, the pulse generator 21 will function to continuously generate pulses at the rate of about twenty kilocycles per second. The antenna 19 and 25 are merely illustrative of any suitable type of directive energy collecting and radiating structures. This may be in the form of dipoles at or near the focus of the parabolic reflectors (as shown) or may be in the form of electromagnetic horns, any other suitable configuration.

I claim:

1. In a pulse communication system employing radio frequency energy pulses whose phase or frequency is modulated by intelligence, a repeater station comprising a receiving antenna, a continuously operative receiver coupled to said receiving antenna for converting the pulses of radio frequency energy to pulses of direct current, a

6

local monitor including a discriminator coupled to the output of said receiver for deriving the modulation components from said direct current pulses, a pulse generator also coupled to the output of said receiver and synchronized by the received pulses to produce a series of pulses which are short compared to the time intervals between them, said pulse generator being so constructed and arranged as to be non-responsive to pulses received during the intervals between incoming signal pulses, a radio frequency oscillator under control of the pulses produced by said pulse generator to thereby produce substantially corresponding duration pulses of radio frequency energy, and a transmitting antenna coupled to the output of said radio frequency oscillator.

2. In a pulse modulated radio communication system wherein the radiated carrier is broken up into equal length pulses of short duration compared to the time intervals between them, and the relationship of the pulses varied in accordance with the audio signal to be transmitted, a continuously operative receiver for said pulses including a receiving antenna, said receiver comprising a frequency converter and a rectifier, a discriminator circuit coupled to said rectifier for reproducing the audio modulation of the transmitted intelligence, an acoustic transducer coupled to the output of said discriminator circuit, a pulse regenerative oscillator coupled to the output of said rectifier and adapted to be synchronized by the incoming signal pulses, to thereby produce other pulses which have substantially the same short duration as the incoming pulses, said pulse generator being so constructed and arranged as to be non-responsive to pulses received during the intervals between incoming signal pulses, an ultra high frequency oscillator under control of the pulses produced by said pulse oscillator to thereby produce substantially corresponding duration pulses of radio frequency energy, and a transmitting antenna coupled to the output of said ultra high frequency oscillator.

3. In a pulse modulated radio communication system wherein the radiated carrier is broken up into equal length pulses of short duration compared to the time intervals between them and the relationship of the pulses varied in accordance with the audio signal to be transmitted, a continuously operative receiver for said pulses including a receiving antenna, said receiver comprising a frequency converter and a rectifier, a discriminator circuit coupled to said rectifier for reproducing the audio modulation of the transmitted intelligence, an acoustic transducer coupled to the output of said discriminator circuit, a pulse regenerative oscillator coupled to the output of said rectifier and adapted to be synchronized by the incoming signal pulses to thereby produce other pulses which have substantially the same short duration as the incoming pulses, said pulse generator being so constructed and arranged as to be non-responsive to pulses received during the intervals between incoming signal pulses, a local modulator circuit coupled to said pulse generator for varying the repetition rate of the pulses produced by said generator in accordance with audio modulation, an ultra high frequency oscillator under control of the pulses produced by said pulse oscillator to thereby produce substantially corresponding duration pulses of radio frequency energy, and a transmitter antenna coupled to the output of said ultra high frequency oscillator.

4. In a pulse modulated radio communication

7

system wherein the radiated carrier is broken up into equal length pulses of short duration compared to the time intervals between them and the relationship of the pulses varied in accordance with the audio signal to be transmitted, a continuously operative receiver for said pulses including a receiving antenna, said receiver comprising a frequency converter and a rectifier, a discriminator circuit coupled to said rectifier for reproducing the audio modulation of the transmitted intelligence, an acoustic transducer coupled to the output of said discriminator circuit, a pulse regenerative oscillator coupled to the output of said rectifier and adapted to be synchronized by the incoming signal pulses, to thereby produce other pulses which have substantially the same short duration as the incoming pulses, said pulse generator being so constructed and arranged as to be non-responsive to pulses received during the intervals between incoming signal pulses, said pulse oscillator comprising an electron discharge device having a cathode, an anode and a control grid, separate coils in circuit with said anode and grid which are coupled to each other, and a line of predetermined length connected at one end between said cathode and ground and unterminated at its other end such that a voltage wave traveling down the line from the cathode end will be reflected from said other end in-phase to produce a resultant voltage on said line effectively substantially double the initial voltage wave, an ultra high frequency oscillator under control of the pulses produced by said pulse oscillator to thereby produce substantially corresponding duration pulses of radio frequency energy, and a transmitting antenna coupled to the output of said ultra high frequency oscillator.

5. In a pulse modulated radio communication system wherein the radiated carrier is broken up into equal length pulses of short duration compared to the time intervals between them and the relationship of the pulses varied in accordance with the audio signal to be transmitted, a continuously operating receiver for said pulses including a receiving antenna, said receiver comprising a frequency converter and a rectifier, a discriminator circuit coupled to said rectifier for reproducing the audio modulation of the transmitted intelligence, an acoustic transducer coupled to the output of said discriminator circuit, a pulse regenerative oscillator coupled to the output of said rectifier and adapted to be synchronized by the incoming signal pulses to thereby produce other pulses which have substantially the same short duration as the incoming pulses, said pulse generator being so constructed and arranged as to be non-responsive to pulses received during the intervals between incoming signal pulses, said pulse oscillator comprising an electron discharge device having a cathode, an anode and a control grid, separate coils in circuit with said anode and grid which are coupled to each other, and a line of predetermined length connected at one end between said cathode and ground and unterminated at its other end such that a voltage wave traveling down the line from the cathode end will be reflected from said other end in-phase to produce a resultant voltage on said line effectively substantially double the initial voltage wave, a modulator coupled across said line, means for varying the conductivity of said modulator in accordance with a signal, an ultra high frequency oscillator under control of the pulses produced by said pulse oscillator to thereby pro-

8

duce substantially corresponding duration impulses of radio frequency energy, and a transmitting antenna coupled to the output of said ultra high frequency oscillator.

6. In a pulse modulated radio communication system wherein the radiated carrier is broken up into equal length pulses of short duration compared to the time intervals between them, and the relationship of the pulses varied in accordance with the audio signal to be transmitted, a receiver for said pulses including a receiving antenna, said receiver comprising a frequency converter and a rectifier, a discriminator circuit coupled to said rectifier for reproducing the audio modulation of the transmitted intelligence, an acoustic transducer coupled to the output of said discriminator circuit, a pulse oscillator coupled to the output of said rectifier and adapted to be synchronized by the incoming signal pulses, to thereby produce other pulses which have substantially the same short duration as the incoming pulses, said pulse generator being a screen grid vacuum tube and so constructed and arranged as to be non-responsive to pulses received during the intervals between incoming signal pulses, an ultra high frequency oscillator under control of the pulses produced by said pulse oscillator to thereby produce substantially corresponding duration pulses of radio frequency energy, and a transmitting antenna coupled to the output of said ultra high frequency oscillator.

7. In a pulse modulated radio communication system wherein the radiated carrier is broken up into equal length pulses of short duration compared to the time intervals between them, and the relationship of the pulses varied in accordance with the audio signal to be transmitted, a receiver for said pulses including a receiving antenna, said receiver comprising a frequency converter and a rectifier, a discriminator circuit coupled to said rectifier for reproducing the audio modulation of the transmitted intelligence, an acoustic transducer coupled to the output of said discriminator circuit, a pulse regenerative oscillator coupled to the output of said rectifier and adapted to be synchronized by the incoming signal pulses, to thereby produce other pulses which have substantially the same short duration as the incoming pulses, said pulse generator having regeneratively coupled coils and being so constructed and arranged as to be non-responsive to pulses received during the intervals between incoming signal pulses, an ultra high frequency oscillator under control of the pulses produced by said pulse oscillator to thereby produce substantially corresponding duration pulses of radio frequency energy, and a transmitting antenna coupled to the output of said ultra high frequency oscillator.

8. In a pulse modulated radio communication system wherein the radiated carrier is broken up into equal length pulses of short duration compared to the time intervals between them, and the relationship of the pulses varied in accordance with the audio signal to be transmitted, a continuously operative receiver for said pulses including a receiving antenna, said receiver comprising a frequency converter and a rectifier, a discriminator circuit coupled to said rectifier for reproducing the audio modulation of the transmitted intelligence, an acoustic transducer coupled to the output of said discriminator circuit, a pulse oscillator coupled to the output of said rectifier and adapted to be

synchronized by the incoming signal pulses, to thereby produce other pulses which have substantially the same short duration as the incoming pulses, said pulse generator being so constructed and arranged as to be non-responsive to pulses received during the intervals between incoming signal pulses, an ultra high frequency

oscillator under control of the pulses produced by said pulse oscillator to thereby produce substantially corresponding duration pulses of radio frequency energy, and a transmitting antenna coupled to the output of said ultra high frequency oscillator.

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