July 6, 1948. B. TREVOR 2,444,479

FREQUENCY MODULATED PULSE GENERATOR

Filed Jan. 8, 1944 3 Sheets-Sheet 1

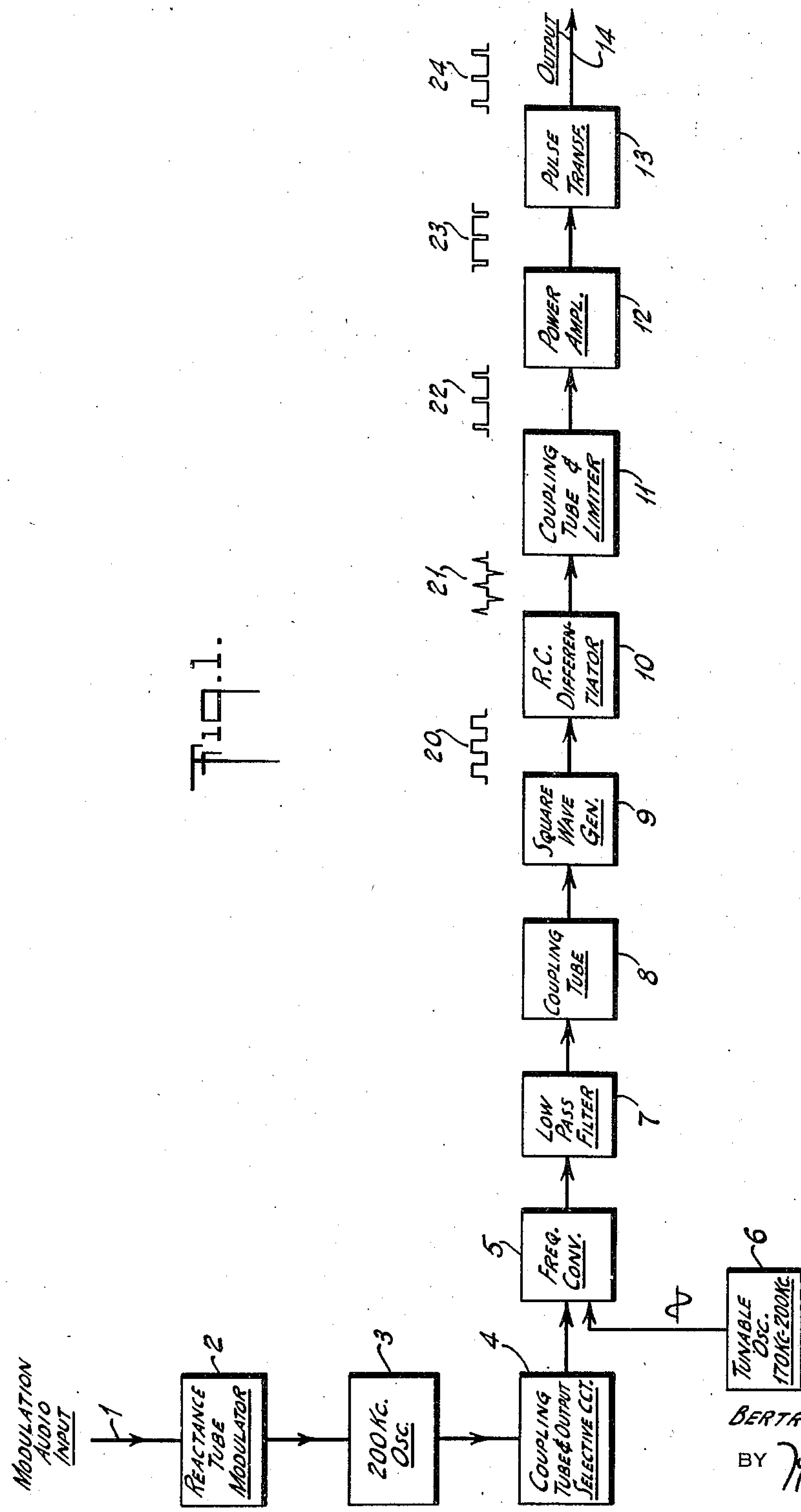

Fig. 1.

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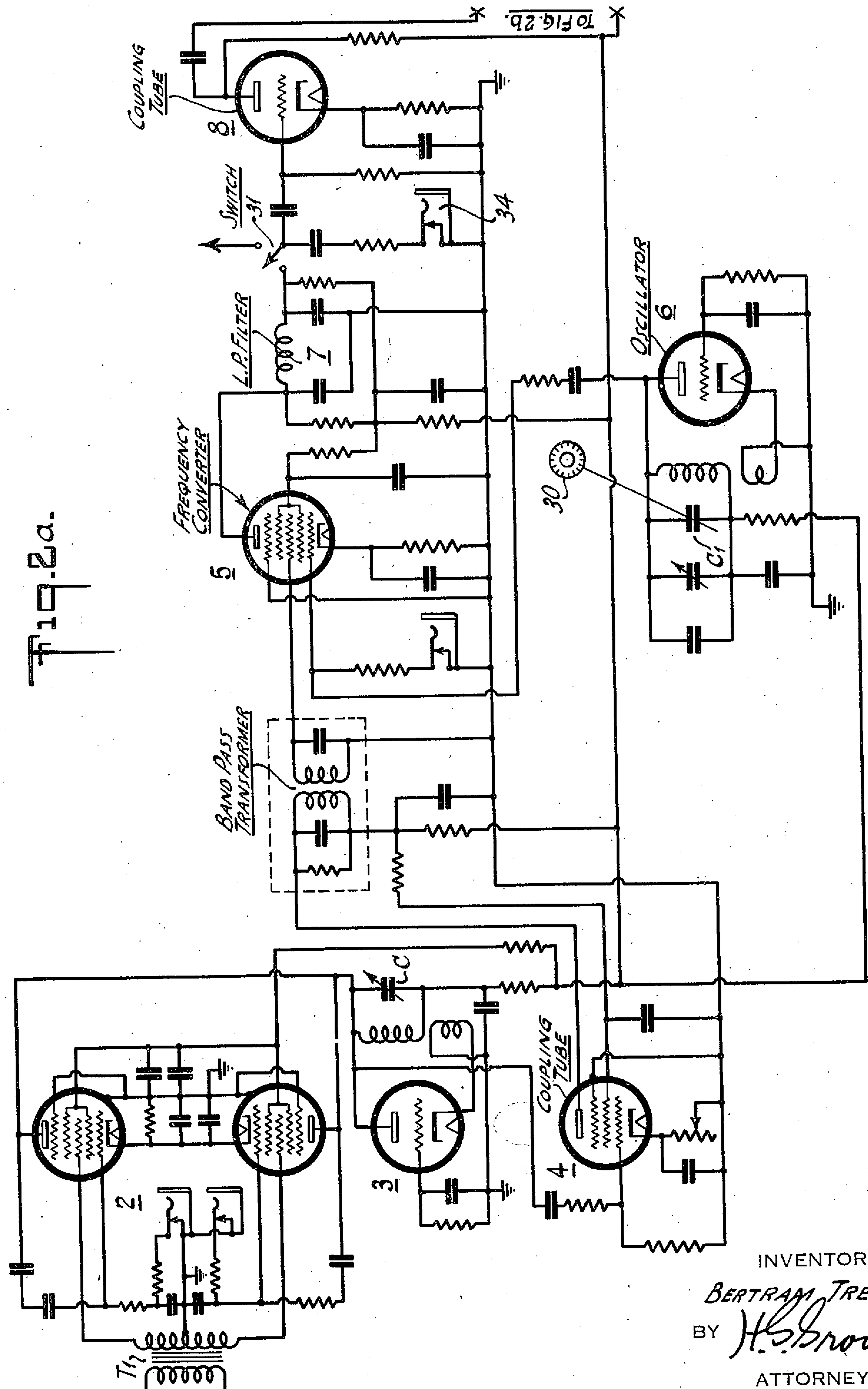

Fig. 2a.

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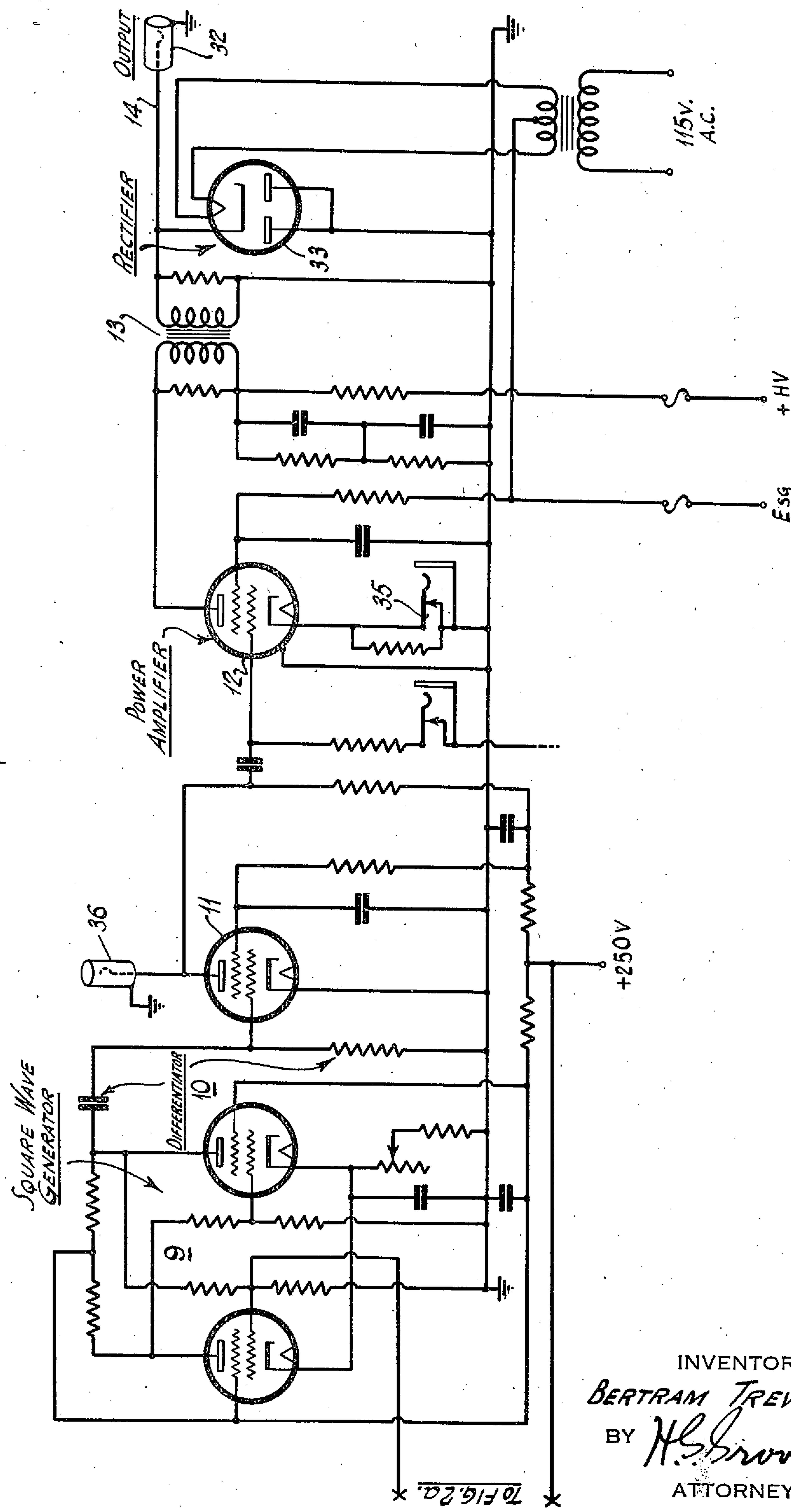
Fig. 2b.



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FREQUENCY-MODULATED PULSE GENERATOR

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7 Claims. (Cl. 179—171.5)

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This invention relates to a pulse generator system having means for generating pulses and for modulating the frequency or rate of recurrence of the generated pulses in accordance with the signal modulation.

An object of the present invention is to enable the generation of pulses whose pulse rate is adjustable over a desired range, and whose pulse rate can be frequency modulated by the intelligence to be conveyed.

A more specific object is to provide a system for generating pulses which are short compared to the time interval between them and whose pulse rate is adjustable over a range of kilocycles, and having means for modulating the frequency of the pulse rate up to a deviation of plus and minus several kilocycles.

Other objects will appear from a reading of the following description which is accompanied by a drawing, wherein:

Fig. 1 diagrammatically shows an embodiment of the present invention; and

Figs. 2*a* and 2*b* taken together illustrate the detailed circuits of the system of Fig. 1.

Broadly stated, the present invention includes a beat frequency oscillator whose output determines the pulse rate. The beat frequency output varies up and down from a desired mid frequency at a rate depending upon the modulation frequency which is applied to one of the beating oscillators. The other beating oscillator is adjustable in frequency by means of a dial calibrated over the desired beat frequency output range. The variable beat frequency output controls a square wave generator of the flip-flop type having two degrees of electrical stability. This square wave generator changes from one condition of stability to the other only in response to a wave of desired polarity. The output pulses from the square wave generator are passed through a differentiator which produces short sharp impulses from the edges or slopes of the square wave pulses. Certain ones of these short sharp impulses (i. e., those having a desired polarity and produced from the starting edge only of the square pulses) are selected and reshaped in form, amplified and then utilized. If desired, these reshaped short impulses, which are keyed direct current in character, can control a radio frequency generator to produce correspondingly short, spaced pulses of radio frequency energy. The spacing and duration of the short radio frequency pulses are identical with the spacing and duration of the short reshaped pulses. By way of example only, the final output

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pulses may have a length or duration of the order of two microseconds, and spaced from one another by a time interval of the order of 98 microseconds.

In the embodiment of the invention of Fig. 1, there are provided a pair of oscillators **3** and **6** whose outputs beat with each other in a frequency converter **5** to produce a difference frequency. Oscillator **3**, by way of illustration may generate oscillations of 200 kilocycles and is preferably non-tunable except for a vernier adjustment. Oscillator **6** is tunable and may generate oscillations in the range from 170 kilocycles to 200 kilocycles, depending upon its tuning. Oscillator **6** is provided with a tuning dial calibrated in the range from 0–30 kilocycles which is the range of the difference frequencies obtainable from converter **5**.

A coupling tube **4** serves to isolate the two oscillators **3** and **6** from each other; that is, to prevent interaction. A band pass selective filter in the output of tube **4** rejects the harmonics from oscillator **3**.

The oscillator **3** has its output frequency varied by a frequency modulator in the form of a reactance tube circuit **2** to whose input, in turn, is applied the audio modulation from lead **1**. This audio modulation may comprise speech covering a frequency range from zero to 3 or 5 kilocycles. The output from the frequency converter **5** is of sine wave form and has a frequency deviation determined by the audio input level to the frequency modulator **2**. This frequency deviation is fairly linear for deviations of ± 5 kilocycles from the mid or unmodulated frequency in the output of the frequency converter but departs slightly from linearity for higher deviations. It will thus be evident that the output of converter **5** comprises a beat frequency in the range from zero to thirty kilocycles, depending upon the tuning of oscillator **6**.

In order to eliminate the higher oscillator frequency components present in the output of the frequency converter **5**, there is provided a low pass filter **7** which passes frequencies only up to thirty kilocycles. The sine wave output from filter **7** with the radio frequency components removed is then passed on to a square wave generator **9** through a coupling tube **8**. Coupling tube **8** provides a little gain for the output from filter **7** and serves to isolate the square wave generator **9** from the filter **7**. Square wave generator **9** is a flip-flop multivibrator type of circuit having two degrees of electrical stability. This square wave generator remains in one condition of stability or the other until it is changed by an input wave. The output of generator **9** comprises direct current pulses **20** which may, if desired, be substantially 50% mark, and its pulse rate varies with and is determined by the beat frequency output of the frequency converter **5**. Thus, the pulse rate of the pulses produced by the square wave generator has an instantaneous value controlled by the modulation input frequency applied to the reactance tube modulator **2**. Since oscillator **3** is frequency modulated, the same modulation is applied to the square wave generator and controls its output pulse rate.

An RC differentiator **10** serves to differentiate the relatively long output pulses from the square wave generator, and produces short, sharp impulses **21** from the starting and trailing edges of the square wave pulses **20**. Only those sharp impulses which are obtained from the starting edges of the longer square wave pulses **20** are used to control a coupling tube and limiter **11** to produce short direct current pulses **22** each having a duration of about two microseconds. Apparatus **11** reshapes the short impulses, so to speak, so that they have a flat top and steep vertical sides.

A power amplifier **12** is provided to increase the voltage of pulses **22** from a value of, let us say, 250 volts to a value near 1,000 volts, depending upon the anode voltage of the amplifier. The pulses in the output of amplifier **12** are indicated at **23** and are of negative polarity. In order to obtain pulses of a positive polarity, these pulses **23** are passed through a pulse transformer **13**. The output pulses from transformer **13** are shown at **24**. The spacing and duration of the pulses **24** from pulse transformer **13** are identical with the spacing and duration of the pulses **22** from the coupling tube and limiter **11**.

The direct current positive pulses **24** carrying the signal modulation may be utilized to operate any desired type of circuit, such for example as a radio frequency generator, in order to produce correspondingly short and spaced pulses of radio frequency energy which in turn can be radiated from an antenna, if desired.

Figs. 2*a* and 2*b*, taken together, show the details of a circuit arrangement following the principles of Fig. 1. The same parts in both figures have been labeled with the same reference numerals.

Referring to Figs. 2*a* and 2*b* together, the audio input waves are applied through leads **1** to the primary of the transformer T_1. The secondary of the transformer T_1 supplies potentials of opposite phase to the No. 3 grids of a pair of tubes comprising the reactance tube modulator **2**. This modulator is a push-pull reactance tube circuit the anodes of which are directly connected together in order to be in parallel relation for the output currents. A push-pull modulator is employed instead of a single reactance tube circuit in order to compensate for variations in line voltage and to reduce unwanted modulations. It should be noted that the two reactance tubes are of opposite sign so that they combine in phase.

The oscillator **3** produces a relatively fixed frequency but is provided with a vernier adjustment in the form of a variable condenser C. The oscillator **6** is supplied with a dial **30** which is calibrated in kilocycles in the range from zero to thirty kilocycles. Dial **30** is linked to a variable condenser C**1** in order to enable adjustment of the oscillator **6** anywhere in the range from

170 to 200 kilocycles. The output of the oscillator **3** is passed through the coupling tube **4** and the band pass transformer selective circuit in the output of tube **4** to the No. 3 grid of the frequency converter **5**, while the output of the tunable oscillator **6** is coupled to the first grid of the frequency converter **5**. A band pass transformer in the output of coupling tube **4** removes any harmonics of the oscillator **3** which may be present therein. The output of the frequency converter **5** after passing through the low pass filter **7** is impressed upon the grid of the coupling tube **8** when the switch **31** is thrown to the left.

The output of the coupling tube **8** is fed to the square wave generator **9**, the latter comprising a pair of vacuum tubes whose grids and anodes are resistively interconnected to form a flip-flop circuit having two degrees of electrical stability. This square wave generator operates at a frequency determined by the sine wave frequency applied thereto from the coupling tube **8**. In the operation of the square wave generator **9**, one tube always passes current while the other is non-conductive and these current passing conditions are reversed upon the application of a wave of suitable polarity. Thus, the square wave generator will remain in one condition of stability until this condition is reversed by the external drive from the coupling tube **8**. The output pulses from the square wave generator are relatively long and may, if desired, be substantially 50% marking pulses. The frequency of the pulses from the generator **9** is determined by the beat frequency (difference frequency) of the oscillators **3** and **6** and the instantaneous value of this difference frequency is controlled by the modulation. Putting it in other words, the output pulse rate from the square wave generator depends upon the modulation applied to the frequency modulated oscillator **3**.

The output pulses from the square wave generator **9** are differentiated by the condenser-resistor combination labeled **10**, and the sharp impulses produced by the differentiator are applied to the first grid of the coupling tube and limiter **11**. Coupling tube **11** is operated with zero grid bias (the tube passes current) so that only the negative grid pulses produce an effect, the positive grid pulses being limited off. As a result, only positive pulses appear in the anode circuit of this tube. This is because the tube **11** normally passes current and only the negative grid pulses momentarily bias the tube **11** to cut off. The output from apparatus **11** is in the form of extremely short pulses of about two microseconds duration or so, and these short pulses are applied to the grid of power amplifier **12**. Amplifier **12** is normally biased beyond cut-off and passes current momentarily during the time the positive pulses are applied thereto from the coupling tube **11**. The anode of amplifier **11** may be operated with as much as 1500 volts applied to it. This tube serves not only as an amplifier but also as a limiter to square up the pulses applied to its grid by limiting on the peaks. The output of amplifier **12**, which is now in the form of short negative pulses, is passed through pulse transformer **13** in order to produce output pulses of positive polarity therefrom. The negative pulses appearing in the anode circuit of the amplifier **12** are thus reversed in polarity by the transformer **13**. A high voltage output, therefore, appears at the jack **32**. The rectifier tube **33** across the secondary of the pulse transformer **13** serves to remove the negative pulse appearing in the transformer output. The heater of this tube 33 is connected to a high voltage point in order to reduce the potential appearing between the heater and the cathode.

Switch 31 at the input of the coupling tube 8 is provided so that an external oscillator may be used to operate the pulsing circuits if for any reason it is not desired to use the internal beat frequency oscillator which comprises the two oscillators 3 and 6 and the frequency converter 5. If an external beat frequency oscillator is employed, however, it is not possible to frequency modulate the pulses. The use of this switch enables a degree of flexibility in the use of the equipment. Jack 34 in the input circuit of the coupling tube 8 enables a pair of headphones to be inserted in the circuit in order to listen to the audio beat frequency. By utilizing such a pair of headphones, it is a relatively simple matter to set the two oscillators 3 and 6 to zero beat with each other when the switch 31 is connected to the low pass filter 7. The jack 35 in the cathode circuit of the power amplifier 12 enables obtaining a low impedance source of positive pulses from the cathode resistor in the amplifier circuit 12. The jack 36 connected to the anode of the coupling tube 11 serves as a medium voltage source of direct current positive pulses whose pulse rate is modulated by the audio input.

In setting up the system of Figs. 2*a* and 2*b*, the dial 30 of the tunable oscillator 6 is first set to read zero, in which case both the oscillators 6 and 3 will generate 200 kilocycles oscillations and thus provide zero beat. In order to achieve this accurately, the zero adjustment condenser C of oscillator 3 is also adjusted so that this zero beat occurs. Since the dial 30 is directly calibrated to read the beat frequency in the range from zero to thirty kilocycles, the attendant need only turn the dial so as to adjust the oscillator 6 to that position which will give a desired beat frequency output. As an example, if it is desired to obtain a ten kilocycle beat frequency output, it is only necessary to move dial 30 to number 10, as a result of which the oscillator 6 will produce oscillations of 190 kilocycles, and the output of the beat frequency oscillator will be ten kilocycles, which is the difference between the 200 kilocycles produced by fixed oscillator 3 and the 190 kilocycles produced by the tunable oscillator 6. Now, by modulating the oscillator 3 in accordance with the signal impulse applied to the reactance tube circuit, there will be obtained a beat frequency output which varies up and down from ten kilocycles at a rate depending upon the modulation frequency.

It should be understood that the invention is not limited to any particular range of beat frequencies, or to any particular frequencies of operation of the oscillators 3 and 6 set forth in the foregoing description, inasmuch as the oscillators 3 and 6 may be designed to produce other frequencies and provide a beat frequency output in a range considerably higher than zero to thirty kilocycles, such for example as a range from zero to 100 kilocycles or so. The invention has application in a pulse frequency signal generator and is not limited for use in a communication system.

What is claimed is:

1. A frequency modulated pulse generator system comprising two oscillators producing oscillations of different frequencies, means for modulating the frequency of one of said oscillators in accordance with the signal modulation, a frequency converter coupled to the outputs of said two oscillators for producing a difference frequency, a coupling tube in the output of one of said oscillators for preventing interaction between said oscillators, a low pass filter in the output of said converter, and a square wave generator having two degrees of electrical stability coupled to said filter and under control of the output of said frequency converter.

2. A frequency modulated pulse generator system comprising two oscillators producing oscillations of different frequencies, a reactance tube modulator circuit including a source of audio input for modulating the frequency of one of said oscillators, means for tuning the other oscillator over a range of frequencies of the order of kilocycles, a frequency converter coupled to the outputs of both oscillators for producing a beat frequency which is variable in dependence upon the modulation frequency, a coupling tube in the output of one of said oscillators for preventing interaction between said oscillators, a pulse generator coupled to the output of said frequency converter for producing direct current pulses whose pulse rate is determined by the beat frequency, and a differentiator circuit in the output of said pulse generator for producing short pulses from the edges of said direct current pulses.

3. A frequency modulated pulse generator system comprising two oscillators producing oscillations of different frequencies, a reactance tube modulator circuit including a source of audio input for modulating the frequency of one of said oscillators, means for tuning the other oscillator over a range of frequencies of the order of kilocycles, a frequency converter coupled to the outputs of both oscillators for producing a beat frequency which is variable in dependence upon the modulation frequency, a coupling tube in the output of one of said oscillators for preventing interaction between said oscillators, a pulse generator coupled to the output of said frequency converter for producing direct current pulses whose pulse rate is determined by the beat frequency, a differentiator in the output of said pulse generator for producing short and sharp pulses from the edges of said direct current pulses, and an electron discharge device for converting those short sharp pulses which are of a predetermined polarity into short direct current pulses having relatively long time intervals between them.

4. A frequency modulated pulse generator system comprising two oscillators producing oscillations of different frequencies, a reactance tube modulator circuit including a source of audio input for modulating the frequency of one of said oscillators, means for tuning the other oscillator over a range of frequencies of the order of kilocycles, a frequency converter coupled to the outputs of both oscillators for producing a beat frequency which is variable in dependence upon the modulation frequency, a coupling tube in the output of one of said oscillators for preventing interaction between said oscillators, a pulse generator coupled to the output of said frequency converter for producing direct current pulses whose pulse rate is determined by the beat frequency, a differentiator in the output of said pulse generator for producing short and sharp pulses from the edges of said direct current pulses, an electron discharge device for converting those short sharp pulses which are of a predetermined polarity into short direct current pulses having relatively long time intervals between them, means for substan-

tially increasing the voltage of said short direct current pulses and for limiting the same, and a radio frequency oscillator under control of the output of said last pulses for producing correspondingly short, spaced pulses of radio frequency energy.

5. A frequency modulated pulse generator system comprising two oscillators producing oscillations of different frequencies, means for modulating the frequency of one of said oscillators in accordance with the signal modulation, a frequency converter coupled to the outputs of said two oscillators for producing a difference frequency, a square wave generator having two degrees of electrical stability under control of the output of said frequency converter, a differentiator in the output of said square wave generator for producing sharp pulses from the starting edges of pulses produced by said square wave generator, and means for reshaping said sharp pulses to square pulses which are considerably shorter than the time intervals between them.

6. A frequency modulated pulse generator system comprising two oscillators producing oscillations of different frequencies, means for modulating the frequency of one of said oscillators in accordance with the signal modulation, a frequency converter coupled to the outputs of said two oscillators for producing a difference frequency, a coupling tube and a selective circuit in the output of one of said oscillators for preventing interaction between said oscillators and for rejecting harmonics of said last one oscillator, a square wave generator having two degrees of electrical stability under control of the output of said frequency converter, to thereby produce direct current pulses of substantially 50% length, a differentiator in the output of said pulse generator for producing very short pulses from the starting and trailing edges of said direct current pulses, and means responsive to those very short pulses which are derived from only one of said edges for producing direct current pulses which are appreciably short compared to the time intervals between them.

7. A frequency modulated pulse generator system comprising two oscillators producing oscillations of different frequencies, a reactance tube modulator circuit including a source of audio input for modulating the frequency of one of said oscillators, means for tuning the other oscillator over a range of frequencies of the order of kilocycles, a frequency converter coupled to the outputs of both oscillators for producing a beat frequency which is variable in dependence upon the modulation frequency, a coupling tube in the output of one of said oscillators for preventing interaction between said oscillators, a pulse generator coupled to the output of said frequency converter for producing direct current pulses whose pulse rate is determined by the beat frequency, a switch between said pulse generator and said frequency converter, said switch having a pair of contacts and an arm adapted to engage either one of said contacts, a connection from one of said contacts to said frequency converter, a connection from the other of said contacts to a third oscillator, and a connection from said arm to said pulse generator, a jack in the output circuit of said frequency converter for enabling observation of the beat frequency, a differentiator in the output of said pulse generator for producing short and sharp pulses from the edges of said direct current pulses, an electron discharge device for converting those short sharp pulses which are of a predetermined polarity into short direct current pulses having relatively long time intervals between them, means for substantially increasing the voltage of said short direct current pulses and for limiting the same, a jack in circuit with said means for deriving direct current pulses of a predetermined polarity whose pulse rate is modulated by said audio input, and a radio frequency oscillator under control of the output of said last pulses for producing correspondingly short, spaced pulses of radio frequency energy.

BERTRAM TREVOR.

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