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RADIO OPTICAL MODULATION SYSTEM

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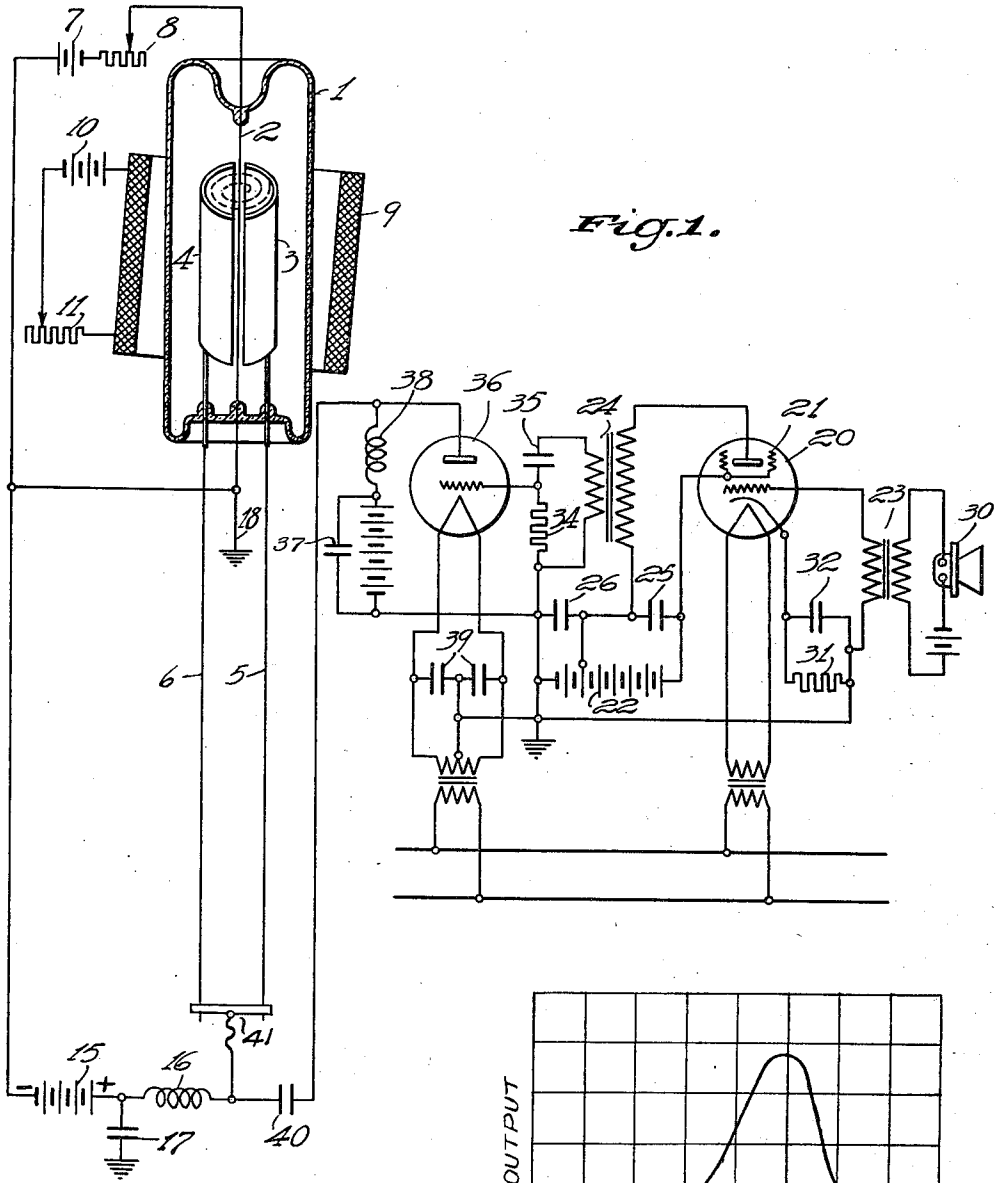


Fig. 1.

Fig. 2.

WITNESSES:

E. E. Leiding.

M. A. Whitten

INVENTOR

LaVerne R. Philpott.

BY F. W. Lyle.

ATTORNEY

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RADIO OPTICAL MODULATION SYSTEM

La Verne R. Philpott, Wilkinsburg, Pa., assignor to Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pa., a corporation of Pennsylvania

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This invention relates to a method of signalling by electro-magnetic waves. I propose to modulate the output of a generator of high frequency oscillations by means of oscillations of a lower frequency and to vary the modulation frequency in accordance with the signal.

If this proposal is applied to a generator of such frequencies as are usually used in radio signalling, the superposition of the modulation frequency upon the generated frequency gives rise to side bands which are objectionably wide. The regulations restrict the channel which may be occupied by a communication system to 10 kilocycles, which gives 5 kilocycles for a maximum modulation frequency.

If, on the other hand, a carrier frequency much greater than is ordinarily used for commercial radio signalling be selected, a much greater modulation frequency can be used without causing the width of the side band to be more than a very small percentage of the carrier frequency. Moreover, such carrier frequencies are beyond the range to which the above mentioned regulations apply, so that there is no legal objection to taking advantage of this percentage relation between side band and very high carrier frequencies.

It is an object of my invention to take advantage of the above described property of very high frequencies. Electromagnetic radiations, such as are ordinarily used for radio communication, have wave lengths from several thousand meters to approximately one meter. It is possible to use for communication radiations of a wave length shorter than this but still of greater wave length than ordinary light. Communication systems involving radiations of such wave lengths have become known to workers in the art as radio-optical systems. Such wave lengths are also spoken of as quasi-optical. This term is used, for example, in an article by Karplus in the "Electronics" for June, 1931.

The output from generations of oscillations of the frequencies ordinarily used for radio signalling can be modulated in ways which are well known. Modulation by varying the plate voltage has special advantages with generators of oscillations of quasi-optical frequencies. Accidental variations in the voltage supplied to the oscillation generator introduce unintended variations in the output which always confuse the modulation by distortion. These can be avoided with several types of generators of oscillations of radio-optical frequency.

Many generators of such frequencies depend upon electronic oscillations. Electronic oscillations are movements of the electron within the vacuum tube. Usually they include one or more reversals of the direction of motion of the electron before it reaches an electrode, but the term also includes other cyclic movements; for example, the travel of an electron over a spiral path from one electrode to another is called an electronic oscillation, even though no actual reversal of motion occurs.

In all such generators the period of the oscillations generated depends on the "flying time", that is, upon the time which is occupied by the travel of an electron from one electrode either to another electrode or back to the electrode from which is started. Other generators depend for their frequency upon the constants of the associated circuits, but generators depending upon electronic oscillations produce a frequency independent of the constants of the connected circuit and determined by the "flying time". The Barkhausen-Kurz generator is one example of a generator of this kind. A discussion of it can be found in an article in the Proceedings of the Institute of Radio Engineers for June, 1932, beginning at page 957. A different type of generator producing electronic oscillations is illustrated and described in an article beginning at page 1741 of the Proceedings of the Institute of Radio Engineers for November, 1932.

It is a property of certain types of generators of radio-optical frequency that their output varies with the plate voltage and becomes a maximum at one particular plate voltage. For voltages differing but slightly from that producing maximum output, the output falls to but a small percentage of said maximum. This property is illustrated by Fig. 13 on page 1748 of the abovementioned article in the November number of the Proceedings of the Institute of Radio Engineers. The curve marked "output" in this figure was obtained by setting the lecher wires at each plate voltage to the tuning which obtained largest output at that voltage. If the lecher wires were kept at a constant setting and the plate voltage alone varied, the curve for the output would have a much narrower peak than illustrated in this figure. I have found that the width of the peak is less than 10% of the plate voltage at maximum output.

As far as applicant is now aware all oscillation generators dependent upon electronic oscillations have this property. Although there are generators capable of producing oscillations of less than a meter in wave length which do not

possess this property, such generators do not act by means of electronic oscillations.

It is an object of my invention to utilize this property of generators of electronic oscillations to obtain what is in effect a periodic interruption of the output. I secure this result by superimposing upon the steady plate voltage a fluctuation which will carry it to or through a value for which the generator produces substantial output. During those portions of the cycle in which the plate voltage differs materially from that just mentioned, the output of the generator is practically interrupted.

I have provided a means for controlling the frequency of the periodic variations in plate voltage by means of a signal. Thus, the outgoing radiations are intermittent and the rate of interruption thereof is dependent upon the signal.

Details of the structure employed, the method of operation and other objects of the invention will be apparent from the following description and the accompanying drawing in which Figure 1 is a diagram of the apparatus and circuits, and Fig. 2 illustrates the variations in output of the electronic oscillator with changes in plate potential.

The tube 1 is an element of a magnetostatic oscillator like that described in the November 1932 Proceedings of the Institute of Radio Engineers, mentioned above. The tube contains a straight filament 2 and a divided cylindrical anode comprising two parts 3 and 4 supported by conductors extending through a press and connected to lecher wires 5 and 6. The filament is heated from a battery 7, the current being controlled by an adjustable rheostat 8. The tube is surrounded by a coil 9 which is at a small angle to the axis of the tube. A battery 10 and a rheostat 11 provide an adjustable current through the coil 9.

The plate potential upon the generator 1 is supplied from a battery 15 through a radio-frequency choke 16 which is connected to the adjustable connection 41 of the lecher wires 5 and 6 the lead to this connection being shown coiled or folded to indicate the ability of the cross bar or adjustable connection to slide along the lecher wires. The battery 15 is grounded through a suitable condenser 17 and the filament 2 is also grounded as shown at 18. The negative end of the battery is connected to the filament and thus to the ground 18 in a familiar way.

Instead of the magnetostatic oscillator illustrated, a Barkhausen-Kurz oscillator, or any other oscillator, having the characteristic relation between output and plate potential described above, may be used. This characteristic relationship is illustrated by the curve of Fig. 2 wherein output changes are indicated for only those voltages just on either side of that voltage which produces maximum output. As stated on page 1, the width of the peak of this curve has been found to be less than 10 percent of the value of the maximum output voltage.

The tube 20 is a dynatron oscillator. The screen grid 21 is connected to the most positive point of a battery 22. The negative terminal of this battery is grounded and is connected, through the secondary of a transformer 23, to the control grid of the tube 20. The plate of the tube 20 is connected, through the primary of a transformer 24, to an intermediate point of the battery 22. A condenser 25 shunting the major portion of the battery 22 connects the screen grid 21 and the primary of the transformer 24. A condenser 26 across the other portion of the battery 22 constitutes a bypass by which the control grid circuit and the plate circuit of the tube 20 are coupled. The cathode is preferably of the indirectly heated type, the heater being supplied with current through a transformer as shown.

These connections suffice to make the tube 20 a generator of oscillations. The control of these oscillations is effected from the microphone 30 which acts through the transformer 23 to produce changes of potential upon the control grid of the tube 20. The resistor 31 provides a negative bias upon the cathode of the tube 20, since the plate current must flow from the grounded end of the battery 22 through the resistor 31 to arrive at the cathode. The condenser 32 affords a bypass around the resistor 31 for both audio and super-audio frequencies.

Such a dynatron oscillator will change the frequencies generated in response to the changes in potential upon grid. See the "Review of Scientific Instruments", Vol. 3, page 230, May 5, 1932. This publication states that the frequency is dependent upon the internal impedance of the tube and it is well known that the internal impedance is altered by the grid potential.

The secondary of the transformer 24 is connected by the usual resistance and capacity coupling, including resistor 34 and condenser 35, to the grid of a connector tube 36. A battery, preferably shunted by a condenser 37 supplied plate potential for the tube 36. There will be substantially no reaction of tube 36 upon the tube 20. It can therefore act both as an amplifier and a buffer. The connections to the tube 36 include the usual radio-frequency choke 38 and the usual provision, comprising the condensers 39, for balancing the alternating-current effect in the filament.

The plate of the tube 36 is connected through a condenser 40 to the adjustable terminal of the lecher wires 5 and 6. The ground connection from the filament of the tube 36 and the ground connection through the condenser 17 completes a path for the output of the tube 36 by which the changes in plate potential are impressed upon the lecher wires and so upon the positive terminal of the generator 1. Stated from another viewpoint, the output of the tube 36 produces a drop across coil 16, which is superposed upon the potential of battery 15 to constitute the anode potential of the generator 1.

In the operation of the device, audio-frequency signals delivered in the microphone 30 cause a frequency modulation of the output of the dynatron oscillator 20. This change in frequency is accompanied by practically no change in amplitude. The potential delivered to the grid of the tube 36 is consequently of the frequency established by the dynatron oscillator, which frequency is modulated by the audio signal.

As the dynatron oscillator 20 oscillates, it causes periodic changes in the potential of the grid of tube 36 and so corresponding changes in the current from the plate over condenser 40, coil 16 and condenser 17 to ground. The potential across coil 16 is thereby periodically changed, the period of the change being that of the oscillator 20, and therefore controlled by the microphone.

The battery 15 establishes a potential across the generator 1 which is insufficient (say) to bring the tube 1 to an efficient oscillating state. When the potential across the coil 16 is a maxi-

mum and additively related to that of the battery 15, the impressed potential on the tube 1 exceeds that for which the tube delivers maximum output.

At some time, therefore, during the time in which the potential across the coil 16 is increasing and being added to that of the battery 15 the tube 1 reaches its maximum output. The output will have diminished again by the time the potential across coil 16 reaches its maximum. The generator will again have a maximum output when the sum of the battery potential and the potential across the coil 16 again passes the optimum value while the potential across the coil 16 is decreasing.

Other combinations of the direct-current potential and the periodic potential may produce the desired anode voltage for the generator. For example, the battery 15 may give a greater potential than corresponds to maximum output of the generator, and when the potential across coil 16 is opposed to the battery potential and increasing it will cause the resultant anode potential to pass through the value giving maximum output and to pass through it again when the potential across coil 16 decreases.

The variation in plate voltage need not be the full change required to pass from substantially zero output with plate voltage below the optimum to zero output again with it above the optimum but the modulation can be obtained by a change that departs from optimum by an insufficient degree to diminish the output to this extent. A very substantial diminution in output can be obtained by a much smaller change in plate voltage. If the smaller change be used, however, the advantage of security against undesirable effects from small accidental changes in the plate voltage, is lost.

Other changes, instead of those in plate potential can be used, if desired, to obtain the modulation.

The changes in impressed potential are sufficient to bring the generator 1 into a state in which its output is small during the intervals between maxima. The output from the generator 1 is, therefore, a succession of wave trains separated by periods of substantially zero output. The frequency of the waves in these trains is the frequency generated by the electronic oscillations of the tube 1. The frequency of the trains themselves is dependent upon that of the generator 20, which changes with the signal delivered to the microphone 30.

In the reception of signals from such a transmitter a detector capable of being influenced by the radio-optical oscillations should be inserted between the antenna and an ordinary receiving set. Any detector of sufficient sensitivity can be made to respond to such oscillations, but particularly suitable is the Barkhausen detector described in the above-mentioned article by Karlpus, and at page 5 of an article by Barkhausen and Kurz in Physikalische Zeitschrift, Vol. 21 (1920) beginning at page 1.

Radiations from the lecher wires 5 and 6 will deliver intermittent energy to the receiving antenna which will cause the detector to deliver intermittent current having substantially the frequency of the generator 20. An ordinary receiving set of any desired kind may be coupled to the output of such a detector and will respond to that output in the same way that it would respond to energy received directly from the tube 20 or the tube 36. While such energy does not have even approximately a sine wave-form, its fundamental frequency will be that of the generator 20 and the receiving set can distinguish between it and other signals by tuning in the same way as if the energy were of a sine wave-form.

It will be evident that several messages can be simultaneously delivered by several different microphones working with the same generator, but each associated with its own generator 20, the average frequency of the generator 20 being different in each case, and the frequency tuning of the receiving set can discriminate between them.

It will also be evident that the generator of radiations need not be of the magnetostatic type but that any generator having the property of delivering a maximum for a particular plate voltage and a much smaller output for voltages materially differing therefrom will cooperate with the rest of the system disclosed as readily as the generator illustrated.

A generator of the type dependent upon electronic oscillations is very sensitive to variations in plate potential in filament current, in grid potential and to magnetic or electrostatic fields that may be present. The plate potential, being frequently supplied over a line of substantial length or obtained from a commercial source is subject to unintended and unpredictable variations. By selecting a normal plate potential at which the generator will not operate and varying it past the potential at which the generator can be relied upon to produce its maximum output, a dependable system is obtained notwithstanding the sensitiveness of the generator.

In one particular embodiment of my invention which has been built and used, the resistor 31 was 1000 ohms, the condenser 32, 1 microfarad, the condensers 25 and 26 each 1 microfarad, the battery 22 provided 220 volts and the negative portion thereof provided 45 volts. The condenser 35 was .003 microfarad and the resistor 34 one-quarter of a megohm, the battery across condenser 37 was 400 volts and the condensers 17 and 40 were each .02 microfarad. Transformer 24 had a primary of 90 turns #36 enamel wire closely wound on a one-inch tube.

Another advantage resulting from the use of very high frequencies is that the frequency of the side bands is a very small percentage of the carrier frequency, and, therefore, does not materially broaden the communication channel occupied.

Other modifications will occur to those skilled in the art and the specific description and illustration of one particular form of my invention is not to be regarded as a limitation.

I claim as my invention:

1. In a signal device, a generator of oscillations of a type which produces a high power output at a particular impressed voltage and low power output substantially equivalent to an interruption at impressed voltages differing from said particular voltage by more than the ordinary unintended variations in said voltage, means for impressing a periodically varying voltage on said generator, the said periodic variation causing the impressed voltage to periodically transiently equal said particular voltage and to differ therefrom during a part of each period by more than the ordinary unintended variations in voltage supply and signal-responsive means for controlling the frequency of said periodic variation.

2. In combination with a high-frequency gen-

erator producing a materially greater output at a particular impressed voltage than at impressed voltages differing therefrom by more than ten per cent, a source of direct voltage, a source of periodic voltage, and means for impressing the resultant of said voltages upon said generator, the said direct voltage differing from said particular voltage by more than said ten per cent and said periodic voltage exceeding said difference.

3. In combination with a high-frequency generator producing a maximum output at a particular impressed voltage and materially smaller outputs at impressed voltages differing therefrom, a source of direct-current voltage differing from said particular voltage, a source of periodic voltage exceeding said difference, means for impressing the combination of said voltages upon said generator, and signal responsive means for controlling the frequency of said periodic voltage.

4. A generator of oscillations of a wave length of the order of a fraction of a meter of the type producing several times the output when the output circuit impressed voltage is of a particular magnitude which it produces for output circuit impressed voltages of substantially different magnitudes, a radiator operatively associated with said generator, means for causing the output circuit voltage impressed on said generator to so vary that it has at intervals said particular magnitude and between said intervals differs therefrom sufficiently to substantially interrupt radiation, said intervals being of super-audio frequency and means responsive to a signal of audio frequency for varying the frequency of said intervals.

5. The method of signalling by quasi-optical frequency radiations which consist in generating super-audio oscillations, producing quasi-optical radiations at each occurrence of a particular phase of said super-audio oscillation enduring only during said phase and controlling the frequency of said super-audio oscillations in accordance with the signal.

6. A transmitter comprising a high-frequency generator producing a maximum output at a particular voltage impressed between anode and cathode of said generator and negligible outputs at all impressed voltages differing therefrom by more than a predetermined slight value, said generator having a normally impressed voltage of a value which produces a negligible output, and means for varying said impressed voltage in accordance with a signal of frequency substantially below said high-frequency to approach said value of voltage which produces maximum output.

7. A transmitter comprising a generator of the type dependent upon electronic oscillations and having at least one anode electrode, a voltage impressed upon said anode electrode of a value which produces a negligible output and comprising means for varying said impressed voltage at a signal frequency substantially lower than the frequency of said oscillations to approach a value which produces maximum output.

8. In combination with a high-frequency generator producing a maximum output at a particular impressed voltage and materially smaller outputs at impressed voltages differing therefrom, a source of direct-current voltage differing from said particular voltage, a source of periodic voltage exceeding said difference, means for impressing the combination of said voltages upon said generator, and signal responsive means for controlling said periodic voltage.

9. In combination, a high frequency generator of the type dependent upon electronic oscillations, said generator including means for normally maintaining a negligible output therefrom, means for impressing upon the output circuit voltage variations large compared with any unintended variation of the voltage impressed on said output circuit and means for controlling said first-named means in accordance with a signal.

10. In combination with a high-frequency oscillator of the magnetron type having a maximum output at a particular impressed anode voltage and negligible outputs at impressed voltages differing slightly therefrom, said generator having a normally impressed voltage of a value which produces a negligible output, and means for varying the amplitude of said impressed voltage in accordance with a signal to approach said value of voltage which produces maximum output.

LA VERNE R. PHILPOTT.