

July 29, 1941.

R. S. OHL

2,250,934

SYSTEM AND METHOD FOR PRODUCTION OF ELECTROMAGNETIC WAVES

Filed June 14, 1939

FIG. 1

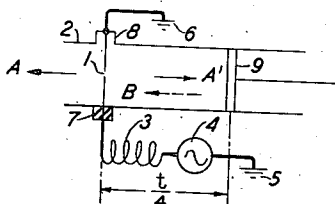


FIG. 2

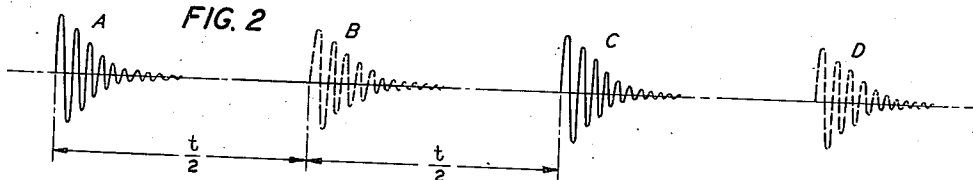


FIG. 3

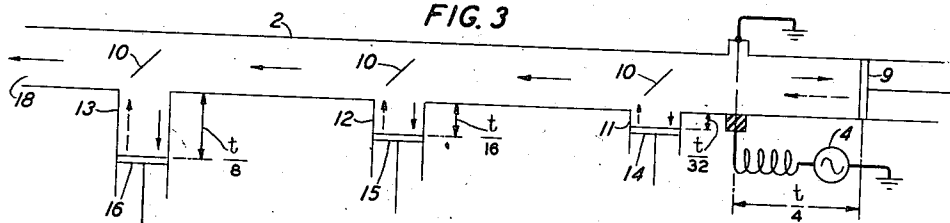


FIG. 4

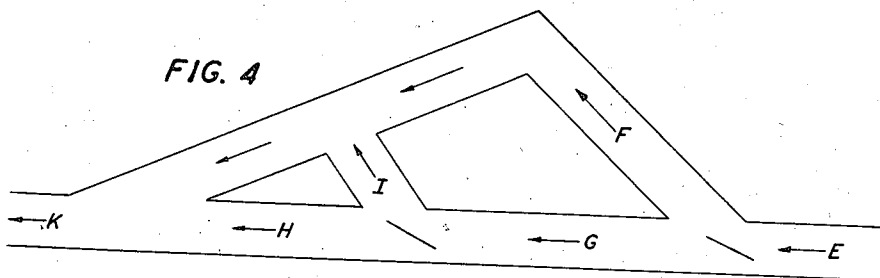
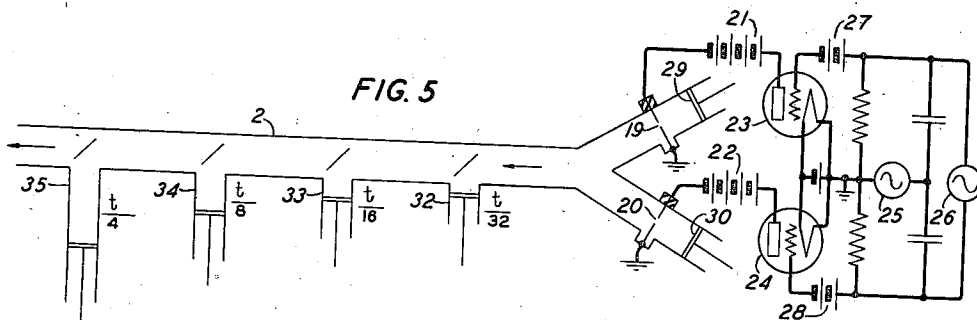


FIG. 5



INVENTOR
R. S. OHL

BY

E. V. Briggs
ATTORNEY

UNITED STATES PATENT OFFICE

2,250,934

SYSTEM AND METHOD FOR PRODUCTION
OF ELECTROMAGNETIC WAVES

Russell S. Ohl, Little Silver, N. J., assignor to Bell
Telephone Laboratories, Incorporated, New
York, N. Y., a corporation of New York

Application June 14, 1939, Serial No. 279,063

11 Claims. (Cl. 178—44)

This invention relates to systems for production of electromagnetic waves and, more particularly, to systems in which the group wave energy from spark discharge sources is redistributed more uniformly with respect to time.

An object of the invention is to increase the power available from spark discharge oscillation systems.

An additional object of the invention is to provide substantially continuous waves in the millimeter wave-length range.

An additional object is to insure that initiation of an individual group of waves generated by a spark discharge oscillator is so timed that the individual waves of a group are correctly phased with respect to the individual waves of preceding and succeeding groups.

A further object of the invention is to permit the use of spark discharge systems for substantially continuous energy transmission while, at the same time, permitting the discharge gap activity to periodically cease in order to preclude undue heating and ionization at the gap.

In accordance with the invention, part of the wave energy of a discharge gap oscillator which produces intermittent groups of waves separated by blank intervals is radiated in a desired direction. Another part of the energy from the same groups of waves radiated in a different direction impinges upon a reflector so positioned with respect to the radiator that the reflected energy is returned toward the radiator in the desired direction of propagation. The length of the path from the radiator to the reflector is such that the reflected waves arrive at the radiator at a time when the radiator is inactive, thus tending to fill in the blank or inactive period. If the reflected wave excites the radiator into oscillation and the oscillation continues until about the time when a new discharge is due to occur, the oscillation voltage in conjunction with the impulse applied to the gap to produce a discharge may initiate or trigger off the new discharge, thus causing the train of waves resulting therefrom to have correct phasing with respect to oscillations of the preceding group. In order to enable the discharge gap to have sufficient inactive time to insure that there be no undue heating or pitting of the gap or excessive ionization of the atmospheric medium in its vicinity, additional gaps may be associated with a common transmission medium and they may be arranged to operate sequentially so that each may rest while another is active. The directly radiated waves and the reflected waves may be in-

5 introduced into a network or complex path having a plurality of paths of individually different transmission time lengths such that wave energy divided between the paths is more evenly distributed with respect to time as it emerges from the network.

In the drawing,

Fig. 1 illustrates schematically a spark gap discharge oscillator with a reflector system for improving the distribution of wave energy with respect to time.

Fig. 2 is a diagram to assist in explaining the operation of the system of Fig. 1.

Fig. 3 illustrates a short wave system of the type shown in Fig. 1 including a transmission path for redistributing energy of periodic groups of waves with respect to time.

Fig. 4 shows a mesh or network having a plurality of separate paths for converting separate trains of high frequency waves into more evenly distributed wave energy, and

Fig. 5 shows a portion of a transmission system embodying a plurality of spark discharge oscillators so related as to cooperate in the transmission of increased high frequency wave energy.

Referring specifically to Fig. 1, a spark gap discharge device 1 is mounted within a tube 2 of electrically conducting material and is connected in circuit with a high frequency choke coil 3 and a source 4 of discharge electromotive force. The circuit is completed by the ground connections 5 and 6. Electrical connections to the discharge gap are effected by lead-in wires passing through the insulator 7 and the metallic sleeve element 8. The electrodes of the spark discharge device 1, together with the section of tube 2, may constitute an oscillation frequency-determining circuit for oscillations of extremely high frequency as, for example, of wave-lengths of a few millimeters. The high frequency choke coil 3 permits alternating electromotive forces having frequencies of the order of 100 megacycles to be applied by source 4 to the discharge gap 1 but prevents escape of the millimeter wave-length energy by the same path. The electric discharge oscillator including the electrodes of gap 1 may be designed as explained in my co-pending application Serial No. 280,044, filed June 20, 1939 to serve as a linear radiator. Energy of the millimeter wave-length will accordingly be radiated toward the left as indicated by the arrow A and toward the right as indicated by the arrow A'. The right-hand end of the tube is closed by a slidable reflector 9 which is adjustable to any desired distance with respect to the

discharge gap 1. Assume, for instance, the minimum time interval between wave train initiating discharges at the gap 1 as determined by the frequency of the electromotive force supplied by source 4, the breakdown electromotive force of the gap and the number of wave train initiating discharges occurring during the period that a half cycle electromotive force from the source 4 exceeds the breakdown voltage to be t . The reflector 9 may be adjusted to such a position that the travel time of electromagnetic wave energy from the gap 1 to the reflector 9 is $t/4$. Wave energy radiated in the direction of A' will accordingly be incident upon the reflector 9 at an instant occurring $t/4$ after its initial radiation from the source 1. It will be reflected by reflector 9 in the direction of the broken line arrow B and the reflected energy will arrive at the plane of the discharge gap at a time $t/2$ after its initial radiation. It will be apparent therefore that the reflecting system enables the directly radiated energy A and the reflected energy B both to be propagated in the desired direction toward the left at times which are separated by a half of the period between successive wave trains.

Fig. 2 illustrates the condition in which the trains A and C of directly radiated waves are intermingled with the intervening reflected wave groups or wave trains B and D. It is, of course, obvious that the reflector 9 might be placed closer to the gap 1 in which case the reflected wave trains B and D would approach more nearly the direct trains A and C, respectively. On the other hand, the reflector 9 might be placed at a somewhat greater distance from the discharge gap 1 so that each reflected wave train would be somewhat more closely adjacent to the succeeding directly radiated wave train. If, for example, the reflector 9 be placed sufficiently far from the gap 1 the reflected wave train B may arrive at the gap 1 at an instant which is just prior to the initiation of the train C. With the proper adjustment of the apparatus it will be possible to utilize the reflected waves to excite the gap 1 to a degree which is sufficient in conjunction with the electromotive force of the source 4 to trigger off the discharge for the wave train C. Under these circumstances, phasing of the individual waves of the direct train C may be controlled by the phasing of the waves of the reflected train B thus enabling each train to fix the phasing of the individual waves of the succeeding train.

Fig. 3 illustrates a system which may employ the identical spark gap oscillator and reflector of Fig. 1. The tube 2 is extended to the left to constitute a wave transmission path for additional redistribution of the energy of the spaced wave trains. For this purpose the tube is provided with lateral chambers 11, 12 and 13 each with its individually adjustable reflector 14, 15 and 16, respectively. Wave trains of the form illustrated in Fig. 2 in their propagation to the left in the tube 2 successively pass the reflecting chambers 11, 12 and 13. At the junction point of chamber 11 with the tube 2 a partial reflector 10 is provided. The reflector may comprise a half wave-length radiator inclined at 45 degrees to the direction of wave propagation or a similarly inclined partially silvered mirror or sheet of dielectric material. The energy of a wave train traveling along the tube is, accordingly, divided and a small portion of it proceeds downwardly in the chamber 11 and is reflected by the reflector

14 with a delay equivalent to twice the time required for electromagnetic waves to traverse the length of the chamber. If, for example, the chamber 11 be adjusted, as illustrated, to have a length measured in propagation time equivalent to $t/32$ the reflected energy will arrive back in the tube 2 at an interval $t/16$ after the directly propagated energy has passed that point. Similarly, a portion of each wave train passing chamber 12 will be delayed by an interval $t/8$ and a portion of the energy passing through chamber 13 by an interval $t/4$. It will be apparent, therefore, that the effect of each of the reflecting chambers is to add a new wave train at the expense of energy of each wave train that passes it. It follows that the energy emitted at the opening 18 of the tube 2 will be so redistributed as to simulate a continuous wave. Not only does this permit the production of substantially continuous waves of wave-lengths beyond those readily attainable by electron discharge devices of the type commonly employed, but it also greatly increases the power which may be transmitted by discharge gap systems. This is for the reason that extremely high potential gradients may be applied to an electric discharge gap if the gap be given a sufficiently long inactive period following the discharge to permit tendencies toward excessive ionization to subside. The system disclosed enables the discharge gap to rest during the intervals between discharges for a sufficiently long time to be highly effective when the next discharge is due to occur.

Fig. 4 discloses an alternative to the reflector chamber system of Fig. 3. The discharge gap and its reflector 9 are not illustrated in this figure but it will be understood that they are identical in character with those of Fig. 3 and are to be associated with the wave transmission path of Fig. 4 in the same manner as is the reflecting chamber system of Fig. 3. The energy from the discharge oscillator and reflector system proceeding in the direction indicated by the arrow E will divide as indicated by arrows F and G. The wave train represented by arrow F transverses the longer path and will therefore experience a phase shift or delay with respect to that of the wave train G. Similarly, at the next junction point there is a division between wave trains H and I, the latter taking the longer path. It will be readily apparent that when all these wave trains reunite as indicated at K those which have proceeded by the direct paths will be followed by those which have taken the longer paths. Accordingly, a redistribution of the energy will have occurred in which the initial groups A and C of directly radiated waves have been divested of a considerable portion of their energy to form intervening groups of waves or wave trains which serve to substantially fill up the time intervals between the original groups.

Fig. 5 illustrates a system similar to that of Fig. 3 in which two spark discharge gaps 19 and 20 each having its own oscillation generating system and both the systems designed to operate at the same frequency are associated with a common energy transmission and redistribution system. The discharge gaps are each supplied with energy from an individual source 21, 22 connected in the plate circuit of triodes 23 and 24, respectively. The triodes 23 and 24 have their grid cathode circuits connected in parallel to an impulsing source 25 corresponding in frequency and wave form to the source 4 of Figs. 1 and 3.

Amplified impulsing frequency or exciting electromotive forces appearing in the plate circuits of the triodes are of sufficient intensity to exceed the breakdown voltage of the gaps 19 and 20 and, accordingly, one or more discharges, each with its train of oscillations, will be generated at a gap during the impulse. In order to permit one gap to rest while the other is operating a switching source 26, which may be of a very much lower order of frequency, is connected to impress an electromotive force differentially upon the input circuits of the triodes so that one triode is effectively paralyzed while the other is active. The proportioning of the electromotive forces of the sources 25 and 26 to accomplish this in conjunction with the normal grid bias sources 27 and 28 will be obvious to those skilled in the art of electron discharge devices. It will only be necessary that during one-half cycle of the source 26 the net grid circuit electromotive force is sufficient to enable a breakdown electromotive force to be applied by source 21 to gap 19 while, at the same time, the net grid circuit electromotive force of the device 24 prevents application of a breakdown potential to gap 20 by source 22. Preferably the source 26 is of a type generating square-topped waves so that the switching action takes place so rapidly as not to introduce substantial intervals of simultaneous inactivity of the two discharge gaps. Each gap is provided with its individual reflector 29 and 30. Inasmuch as the two gaps 19 and 20 operate sequentially and each discharge gives rise to many trains of waves by virtue of the action of the reflectors 29 and 30 and of the reflecting chambers 32, 33, 34 and 35 associated with the transmission path 2, the energy emerging from the open end of the transmission path 2 may closely simulate a continuous wave even though the individual gaps 19 and 20 each be inactive for considerable periods between discharges.

Although certain preferred embodiments of the invention have been shown and described it will be noted that various modifications and changes may be made therein within the scope of the appended claims without departing from the spirit of the invention.

What is claimed is:

1. In combination, an electric discharge gap, a source of periodic electromotive force connected in circuit therewith of sufficient peak electromotive force to exceed the breakdown potential of the gap, the gap having electrodes to serve as radiating elements and constituting a source of discrete electromagnetic wave trains, and a reflector associated with the gap and spaced therefrom a distance substantially equal to that over which a wave train may be propagated during a quarter of the period between successive discharges across the gap.

2. The combination of a wave generation system comprising a source of trains of high frequency oscillations which trains are separated by substantially blank intervals, with a wave transmission system associated with the source and disposed to receive wave energy therefrom and to guide it to a remote point, the transmission system comprising a plurality of paths whose lengths correspond to different transmission times, the difference in lengths of two of the paths being such that when a given wave train is transmitted to the remote point over both paths that portion arriving over the longer path arrives at the point during the otherwise blank

interval succeeding the arrival of the portion arriving over the shorter point.

3. In combination, an electric discharge gap, a source of electromotive force connected in circuit therewith to periodically impress an electromotive force in excess of the breakdown voltage of the gap, an oscillatory system connected to the gap whereby trains of waves are produced with a train periodicity corresponding to that of the discharges across the gap and a wave frequency corresponding to the natural frequency of the oscillatory system, and means including a reflector associated with the gap to redistribute the wave train energy after its generation with respect to time so as to cause it to be propagated more nearly in the manner of continuous waves.

4. In combination, an electric discharge gap, means for producing discharges thereacross at periodic intervals to set up a train of oscillations at each discharge and a wave transmission system coupled in energy receiving relation thereto, the system including means for dividing the energy of each train of oscillations into a plurality of portions and delaying some of said portions with respect to others to distribute the total energy of each train more evenly with respect to time.

5. The method of wave propagation which comprises generating periodic groups of oscillations separated by voids, subjecting the groups of oscillations to an energy division, and delaying different parts of the divided energy differently to fill in portions of the voids whereby effectively continuous waves are produced.

6. In combination, a source of high frequency oscillations capable of producing intermittent wave trains of oscillations of a predetermined frequency separated by blank intervals, means for radiating the wave trains in a plurality of directions including a desired direction of propagation and means for intercepting energy radiated in a direction other than a desired direction and for reradiating it in the desired direction in the blank intervals.

7. A radio transmission system comprising a source of intermittent trains of waves with intervening time intervals, means connected thereto for radiating a portion of the energy of the wave trains in a desired direction, and means for delaying substantially all of the remaining energy of the wave trains and for radiating it in the desired direction during the intervening time intervals.

8. A short wave system comprising a plurality of sources of intermittent trains of waves of like frequency, means for energizing each of said sources, means coupling said sources together in a manner to effect paralysis of each source during periods of activity of any other source, and a transmission path coupled in energy transfer relation to each of said sources so as to be excited by one source during the paralysis of another and thus to transmit a more uniform flow of energy.

9. The method of generating and transmitting high frequency energy which comprises producing a series of pulses of oscillations of a given frequency, the pulses occurring at a definite periodicity, suppressing production of oscillations of the pulse series for definite time intervals between the pulses to permit conditions of oscillation production to return to normal, producing another series of pulses of oscillations of the same frequency during the time intervals be-

tween the pulses of the first series and transmitting oscillations from both series over a common path to effect a more nearly uniform flow of oscillation energy than would be afforded by either of the individual series of pulses.

10. The method of generating and transmitting high frequency energy which comprises producing a first periodic sequence of energy pulses at a certain frequency, separated by blank intervals, deriving from said first sequence a second periodic sequence of like pulses at the same frequency but delayed with respect to pulses of said first sequence by one half of the pulse period, and transmitting pulses of said derived sequence and said original sequence in succession over the same path. 15

11. The method of generating and transmitting high frequency energy which comprises producing a primary periodic sequence of energy pulses at a certain frequency, separated by blank intervals, deriving from said first sequence a plurality of secondary periodic sequences at the same frequency, delaying pulses of each of said secondary sequences by unequal fractions of a period with respect to corresponding pulses of said primary sequence, so as substantially to fill the blank intervals of the primary sequence with pulses of the derived sequences, and transmitting the pulses of all of said sequences together.

RUSSELL S. OHL.