May 6, 1941. R. S. OHL 2,240,941

OSCILLATION SOURCE OF THE SPARK DISCHARGE GAP TYPE

Filed June 20, 1939 2 Sheets-Sheet 1

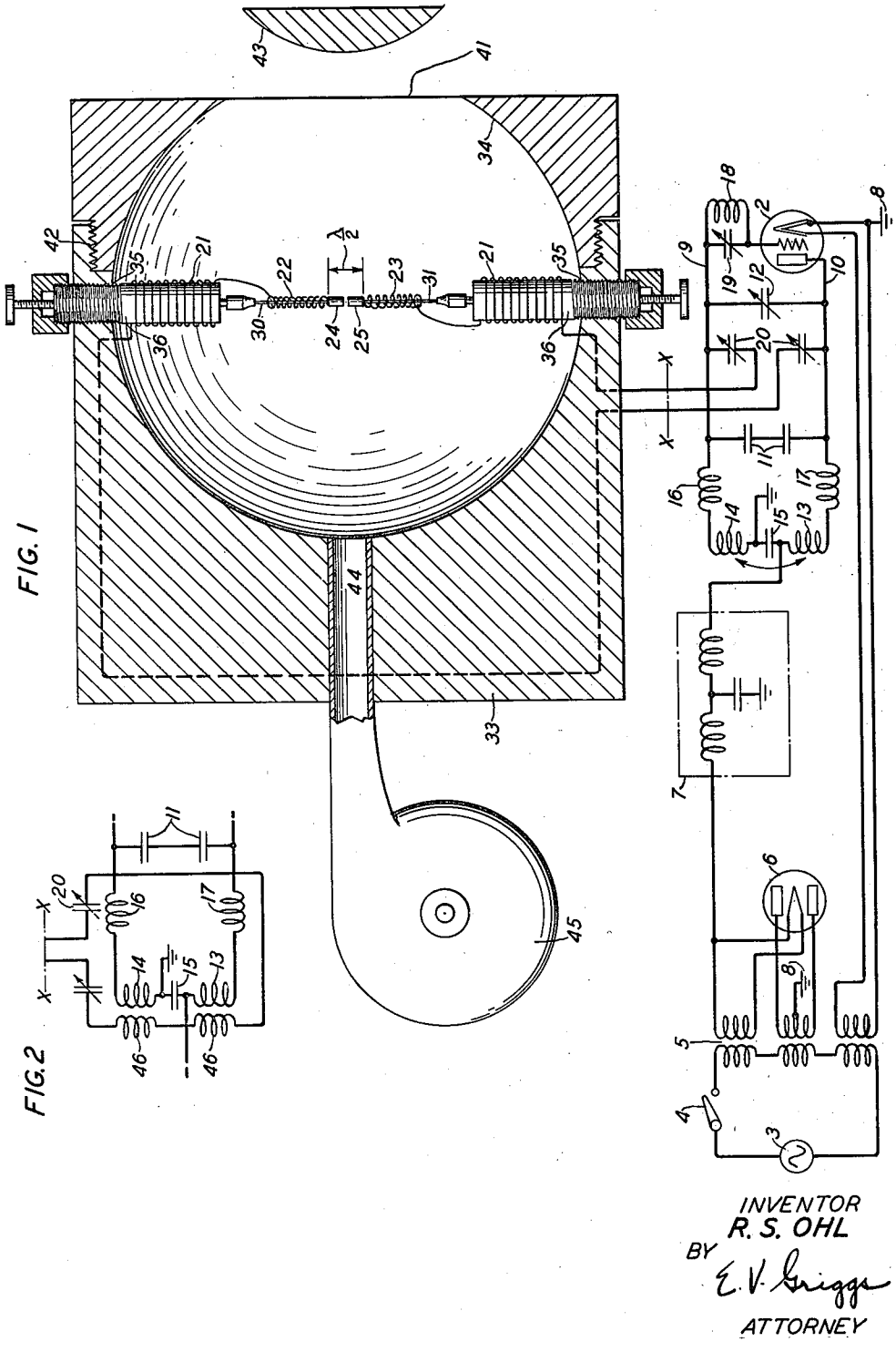

FIG. 1

FIG. 2

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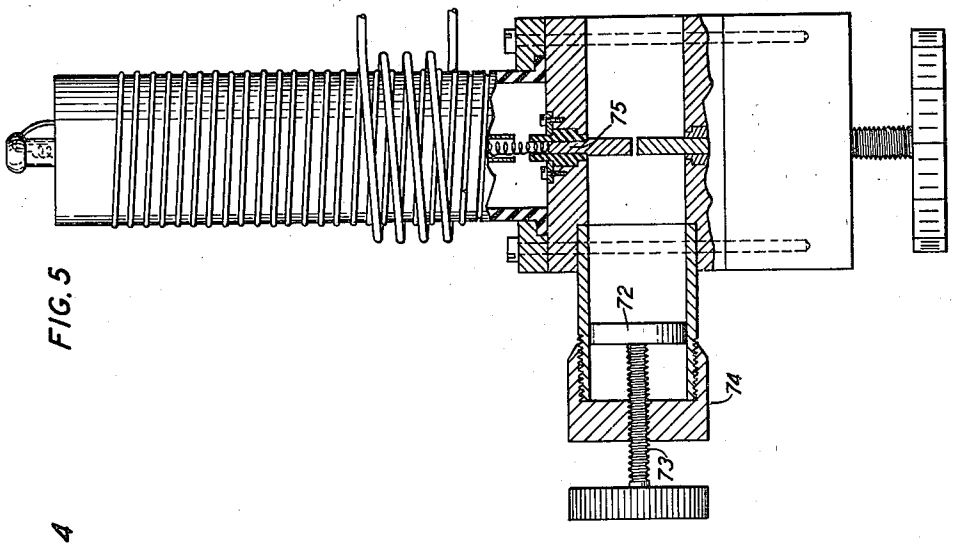

FIG. 5

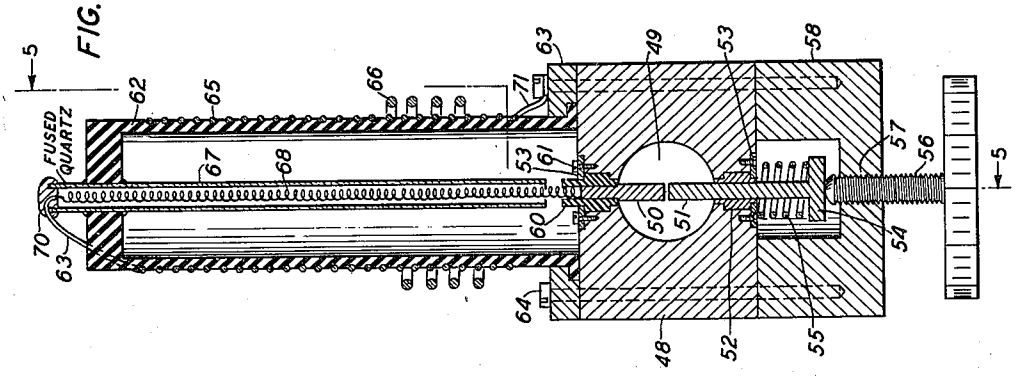

FIG. 4

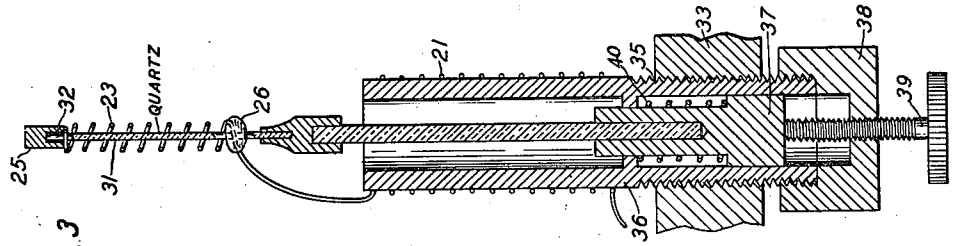

FIG. 3

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UNITED STATES PATENT OFFICE

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OSCILLATION SOURCE OF THE SPARK DISCHARGE GAP TYPE

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15 Claims. (Cl. 250—17)

This invention relates to sources of electric waves in the millimeter wave-length range and, more particularly, to oscillation sources of the discharge gap type.

The art of radio transmission began with relatively short waves generated in oscillation circuits so associated with electric discharge gaps that upon each discharge of the gap, the oscillation circuit is subjected to an impulse. Each impulse gives rise to a train of damped waves, the trains succeeding each other at the impulse frequency. For many reasons the development and use of such systems gave way to the much lower frequency systems producing undamped or continuous waves. With the present congestion in the range of broadcast frequencies and the so-called ultra-short wave-lengths ranging down to waves of one meter or shorter wave-length, it has become increasingly desirable to be able to utilize waves in the millimeter wave-length range. Moreover, there are a number of advantages inherent in the use of these shorter waves among which is the facility with which such waves may be directed to a particular point to the exclusion of other directions.

An object of the invention is to increase the number of discharges which a discharge gap oscillator may produce in a given time.

Another object of the invention is to prevent pitting of the electrode surfaces between which discharges pass so as to increase the life of the electrodes.

A further object of the invention is to enable the use of very high voltage gradients and very small discharge gaps while preventing ionization which would tend to preclude building up the desired voltage gradient.

An additional object is to provide a spark gap so short as to be comparable in its length with the mean free path of an electron in air in order to reduce ionization at the gap to a minimum.

In accordance with the invention, autoelectronic discharges are produced across a minute gap subjected to such a high electromotive force that the potential gradient is very large. The applied electromotive force is produced by an electron discharge oscillator which is periodically self-quenched sufficiently soon after the application of the electromotive force to the gap to preclude an undesirable degree of ionization in the gap. During that portion of each half cycle of the periodically quenched oscillations in which the impressed electromotive force exceeds the break-down potential of the gap, discharges occur across the gap and the millimeter wave oscillations are initiated. In one embodiment of the invention the oscillatory circuit for the millimeter waves comprises the gap itself and the discharge electrodes which are constructed of short rods of metal arranged in the form of a dipole oscillator so that the oscillations produced therein are radiated. A spherical conducting housing surrounds the discharge gap and serves as a reflecting device to concentrate the energy which may be radiated out through an opening in one side of the housing.

In the drawings,

Fig. 1 illustrates diagrammatically a discharge gap apparatus and the circuit of its energy supply system embodying features of the invention;

Fig. 2 shows a modification of a portion of the circuit of Fig. 1;

Fig. 3 illustrates the details of a portion of the discharge gap of Fig. 1; and

Figs. 4 and 5 illustrate a modification of the discharge gap shown in Figs. 1 and 3.

Referring to Fig. 1, the system comprises an alternating current supply circuit of well-known type, an electron discharge oscillator energized from the alternating current supply circuit and a discharge gap in a path connected to the oscillator. The electron discharge device 2 may be an ordinary triode or it may be of any of the more complex types. A source 3, which may represent the ordinary 60 cycle 110 volt house lighting mains, is associated through a switch 4 with the primary winding of a transformer 5, the secondary windings of which respectively serve to supply alternating current of suitable electromotive force to the cathode heater of device 2 and to supply cathode heating current and alternating current to be rectified to the full wave rectifying device 6 which provides space current for the oscillator tube 2. A smoothing filter 7 of conventional type is inserted between the rectifier 6 and the tube 2 and the return path for the rectified space current supply is by way of ground connections 8.

The oscillator for supplying quenched oscillation electromotive forces to the discharge gap comprises, in addition to the electron discharge device 2, a principal frequency-determining circuit and a group frequency or quenching frequency circuit which determines the periodicity of the quenching action. The principal frequency-determining circuit includes the linear conductors 9 and 10 respectively associated with the grid and anode of the device 2 and the capacity elements 11 which are of such magnitude as to constitute substantially a short circuit at

the principal frequency. The internal grid-anode impedance of the device 2, together with the variable capacity element 12, serves as the termination for the linear conductors 9 and 10 at their other ends. This principal frequency-determining circuit is preferably so designed and adjusted as to constitute a quarter wave-length circuit at a frequency of the order of 100 megacycles.

The group frequency or quenching frequency circuit constitutes with the device 2 an oscillator of the type illustrated in Hartley U. S. Patent 1,356,763, issued October 26, 1920. The quenching frequency circuit includes variably coupled inductances 13 and 14 to regulate the magnitude of the quenching oscillations, stopping condenser 15 which prevents the positive polarizing potential from reaching the grid lead, choke coils 16 and 17 which exclude oscillations of the principal frequency from the quenching and current supply circuits and the large capacity elements 11 which effectively divert the principal frequency oscillations from the quenching frequency circuit but which present substantial reactance at the quenching frequency.

In the path to the grid of the discharge device 2 and in series with the conductor 9 there is inserted an inductance element 18 shunted by a variable capacity element 19. The purpose of the inductance is to provide a path over which the quenching electromotive force may readily reach the grid but which will exclude the principal frequency electromotive force generated by the tube oscillator. The variable shunt capacity 19 presents a path for oscillations of the principal frequency and enables the magnitude of the principal frequency oscillations to be varied in order to control the intensity of the principal frequency electromotive force. This is desirable since it has been found that applying too much power or, in other words, too high an electromotive force to the discharge gap reduces the output of millimeter waves and tends to cause the gap electrodes to deteriorate.

As so far described, the discharge device 2 energized from the source 3 and rectifier 6 produces oscillations of a principal frequency of, for example, 100 megacycles with superposed or quenching oscillations of, say, 10 kilocycles frequency which periodically reduce the principal frequency oscillations to substantially zero magnitude in the manner well known in superregenerative amplifier practice. The periodically quenched principal frequency oscillations traversing the conductors 9 and 10 give rise to a difference of potential of like frequency across a shunt path including small variable capacity elements 20 in series with inductance coils 21, much smaller coils 22 and 23 and the discharge gap electrodes 24 and 25. The capacity elements 20 are of sufficiently high impedance to prevent an excessive current through the shunt path which includes the discharge gap. They are made variable in order to enable the impedance of the shunt path to be varied as may be desired. The series inductances 21 are predesigned for such magnitude that the portion of the path including these inductances and the capacity between the spark gap electrodes 24 and 25 is tuned to the principal frequency and, accordingly, very high resonance potentials are built up across the gap.

The small gap electrodes 24 and 25 shown in more detail in Fig. 3 are supported by small insulating rods 30 and 31 of fused quartz. These rods are cemented by a cement preferably consisting of aluminum oxide (Al_2O_3) and water glass into holes bored into the platinum electrodes as indicated at 32. Surrounding the electrode supports 30 and 31 are coil springs 22 and 23 consisting of fine tungsten wire hot coated with a composition known as No. 1 contact metal which is an alloy of gold, silver and platinum. Because of the excellent conductivity of this coating and the pressure which the fine wire spring is able to support even when heated by the discharge currents passing therethrough, it is possible to make good electrical contact between the springs and the electrodes without resorting to sweating or soldering which would be very difficult with structures of the small dimensions required by the high frequencies dealt with. Accordingly, the inner ends of the springs 22 and 23 bear against the electrodes 24 and 25 with a pressure of the order of 1200 pounds to the square inch but which is relatively small because of the minute area of the ends of the springs. At its other end each spring 22, 23 is held fixed with reference to the quartz supporting rod by a small mass 26 of water glass.

In order to produce autoelectronic discharge across the gap or, in other words, to draw from the cold discharge electrodes a sufficient supply of electrons, it is necessary that the gradient of the applied electric fields reach a value of about 5×10^5 volts per centimeter. A number of expedients may be employed to facilitate this result. To begin with, the source including the discharge device 2 which produces quenched principal frequency oscillations of, say, 100 megacycles frequency, may be so adjusted as to impress a suitable electromotive force upon the shunt path to the discharge gap through capacity elements 20. The inductive elements 21, 22, 23 in conjunction with the discharge electrodes 24, 25 may be so designed as to constitute a series tuned path at the principal oscillation frequency thus building up by resonance the electromotive force across the gap between the discharge electrodes 24, 25. Moreover, the length of the gap between the electrodes 24 and 25 may be made very small.

Another important consideration in the design of discharge gap systems in accordance with this invention is to enable the gap to operate as nearly as possible free from ionization. Ionization gives rise to a continuous conducting characteristic of the gap which results in loss of energy and, also, in heating and pitting of the electrodes. The high potential gradient involved, the extremely rapid recurrence of discharges and the magnitude of the energy transfer across the gap accentuate this problem. A number of expedients are available, however, to insure a satisfactory result. In the first place, the tendency toward ionization may be greatly reduced if the separation of the discharge electrodes be made as small as is expedient and preferably less than the mean free path of an electron in air. Fortunately, this requirement may be met by a gap spacing of the order of 5×10^{-4} centimeters which is also quite satisfactory for attaining the high electric field gradient required for autoelectronic discharge. In spite of the precaution of making the gap as small as possible, it will be found that with the high potential gradients employed there may occur in a relatively short time as, for example, 10^{-5} seconds, sufficient ionization to prevent the voltage gradient across the gap from again building up after a discharge has taken place. This tendency may be reduced by the extremely im-

portant expedient of quenching the principal frequency oscillations so as to give a rest period during which incipient ionization may be checked. An additional feature which will be subsequently described is the scavenging of the gap by a blast of oxygen.

In operation, the vacuum tube oscillator including the discharge device 2 supplies electromotive forces of a principal frequency of the order of 100 megacycles periodically quenched or modulated at any desired group frequency rate, say, 10 kilocycles to 100 kilocycles. The principal frequency oscillations thus broken up into groups with one group for each cycle of the quenching frequency are applied to the discharge gap 24, 25 with an electromotive force built up by the resonance of the shunt path. Since the discharge gap electrodes are similar in their characteristics breakdown of the gap may occur during either polarity of the applied electromotive force whenever the potential gradient exceeds the critical breakdown magnitude. One or more discharges across the gap will, therefore, occur during each half cycle of the applied principal frequency electromotive force which attains the critical breakdown intensity. Each of these discharges gives rise to a train of damped waves of the order of millimeter wave-length determined principally by the configuration of the discharge gap electrodes as will be subsequently explained.

The gap electrodes 24 and 25 preferably consist of platinum or pure tungsten as indicated in the drawings. The current supply for the discharge electrodes is, as has been explained, by way of the fine tungsten wire springs 22 and 23, the ends of which are in contact with the inner ends of electrodes 24 and 25 respectively. The transition in the electrical characteristics of the circuit at the contact between the springs and the electrodes enables these points to serve as the terminals of a half wave-length ($\lambda/2$) dipole radiator comprising the discharge electrodes 24 and 25 together with the intervening gap as indicated in the drawings. In practice in apparatus of this type the over-all length dimension of the half wave-length dipole radiator has ranged from 8 to 14 millimeters. In addition to serving as a radiator the dipole circuit serves when set into oscillation at its own natural frequency by the impulsive effects of the discharge of the extremely high gradient potential across the gap to produce oscillations in the millimeter wave-length range of the frequency to which it is resonant. The coil springs 22 and 23 serve as choking inductors at the millimeter wave-length oscillation frequency to prevent dissipation of these oscillations in the current supply circuit.

In addition to the oscillations of the discharge gap as a dipole there may occur contour oscillations having a wave-length approximately equivalent to the effective longitudinal contour of the electrodes 24 and 25 taken together. This amounts to approximately twice the combined length of the electrodes added to their combined diameters with the additional distance required to traverse the sides of the slots in which the quartz rods 22 are cemented. However, the slot dimension requires a correction because of the dielectric characteristic of the quartz within the slot.

In practice, small particles of metal are found to be disrupted from the electrodes of the gap when it is subjected to voltages sufficient to induce discharges by autoelectronic action, that is, while the electrode serving as the cathode is cold. If this condition is permitted to persist, bad pitting may occur with a building-up effect of material from one electrode upon the other. Upon reversal of polarity across the gap, the condition of the ensuing currents after such a pitting action may be very different from those which they succeed. This effect may be entirely prevented if an alternating electromotive force be utilized at the gap for producing the discharges and if no unidirectional current return path is present. The capacity elements 20 accordingly assist in preventing such pitting of the electrodes.

A housing 33 of electrically conducting material such as brass having an internal spherical reflecting surface 34 is provided to enclose the discharge gap. The housing 33 is provided with threaded openings 35 placed at diametrically opposite points with respect to the center of the reflecting surface and of such a size as to receive the threaded brass sleeves 36 which support inductance coil 21. The supports 36 are bored longitudinally to form guide ways for the plungers 37 which fit closely therein and carry the quartz rods 30 and 31. The outer ends of the sleeves 36 are provided with internally threaded caps 38. An adjusting screw 39 passing through a threaded central orifice of the cap 38 to engage the plunger 37 cooperates with compression spring 40 which is confined between the internal flange sleeve 36 and the head of plunger 37 to determine the position of the associated electrode 24 or 25. It is accordingly possible by manipulation of the screw 39 to adjust the position of the associated quartz rod 30 or 31 thus varying the spacing between gap electrodes 24 and 25. With the gap located at the center of the reflector so that energy radiated from the gap and incident upon the reflector surface may be reflected back to the region of the gap to be transmitted out through the opening 41, a beam of greatly augmented intensity and of highly directive characteristics may be obtained. The housing may comprise two parts threaded together, as indicated at 42 to facilitate manufacture and assemblage.

In front of the opening 41 a wax or other suitable refracting lens 43 may be placed to additionally concentrate the radiated energy into a more definite beam. When operating at wave-lengths of approximately 1 centimeter and with a maximum dimension of the concentrating lens 43 equal to about 8 wave-lengths it has been found that the intensity of the beam just beyond the lens is of the order of 26 decibels higher than that obtainable with the simple half-wave dipole radiator consisting of elements 24 and 25 without the reflector and lens.

In order to remove the heat which is generated during the operation of the apparatus the housing 33 is provided with a port 44 through which a blast of air or other gas, preferably oxygen, is introduced at high pressure by a blower 45 to condition the gap between the discharge electrodes. Although the reasons for the observed phenomena are not definitely known it has been found that a blast of oxygen is very effective while with a nitrogen stream the gap quickly ceases to be effective.

The apparatus described is effective to produce considerably greater power than had previously been attained in the millimeter wave-length range. The reason for this will be quite apparent when it is recalled that it has been customary in spark gap discharge systems to employ discharges occurring at 1,000 to 10,000 cycles per second. The present invention, because of the

minute gap employed, the extremely high potential gradient made available and the precautions taken for prevention of ionization, heating and pitting of the gap makes it possible to obtain 10^9 discharges per second. Each of these discharges gives rise to a group of damped oscillations. It will, therefore, be readily apparent that the facility of discharge gap apparatus for transmitting substantial amounts of power has been enormously increased by this invention.

Fig. 2 shows an alternative coupling between the vacuum tube oscillator and the spark discharge path in which the outer terminals of capacitances **20** are connected to a secondary winding **46** electromagnetically coupled to coils **13** and **14**.

Fig. 4 illustrates a modification of the discharge gap oscillator of Fig. 1 in which the gap is mounted in an electrically conducting tube which cooperates to determine the frequency of oscillations produced and to confine their energy to a restricted zone. As shown, the apparatus consists of a metal block **48** as, for example, of grass, having a circular bore **49** therethrough. Other materials than brass such as stainless steel and nickel are less corrodible but it is extremely difficult to tap small holes in these tougher materials. The discharge gap comprises two commercial platinum electrodes **50** and **51** extending diametrically across the tubular bore. Tungsten may be employed in lieu of platinum as the material of the electrodes but it is in general somewhat less satisfactory because of a tendency to lose metal which causes the gap to be short-circuited. The electrodes may be made of wire which is of very nearly the correct diameter. The metal is preferably cut to shape using a carboloy cutting tool which has been carefully sharpened on a 400 mesh diamond wheel. The ends of the electrodes are ground to a plane perpendicular to their lengths using a 400 mesh diamond wheel and thereafter polishing with the finest grade of French emery paper. Before assembly, the electrode parts should be carefully cleaned as, for example, in carbon tetrachloride. The lower electrode **51** slides through a close fitting bushing **52** of No. 1 contact metal seated in a radial opening in the block **48** and held therein by a retaining washer **53**. This grounds the electrode **51** to the block **48** and permits its position to be adjusted while it is held exactly in alignment with the fixed electrode **50**. The stem of the grounded electrode **51** is provided with an enlarged head **54** of brass or other suitable material which may be silver soldered to the platinum rod comprising the stem. If the electrode consists of tungsten the head may be forced on over the end of the stem or the tungsten metal may be first plated with No. 1 contact alloy in a small induction furnace and the head thereafter soldered in position. After the soldering operation the head **54** is turned in a lathe to give it a smooth face. The electrode must fit the gold contact metal bushing or sleeve **52** perfectly with no side motion and yet move freely along the axis of electrodes. A compression spring **55** placed between the block **48** and the head **54** of the electrode stem tends to move the lower electrode **51** downwardly. To regulate the position of the electrode, an adjusting screw **56** with very fine threads engages the interiorly threaded bore **57** in a housing member **58** and bears at its end against the outer surface of the head **54**.

The fixed upper electrode **50** is cemented firmly in place in an insulating sleeve **60** preferably consisting of fused quartz. This sleeve may be ground to size by a 400 mesh diamond wheel. It has been found that an effective cementing action may be had by first making slight indentations or depressions at a number of points along the stem of the fixed electrode in which the water glass Al_2O_3 mixture cement may obtain a better grip on the stem. Any excess cement must be very carefully cleaned off to prevent subsequent electrical leakage and, also, to insure that a good electrical contact may be had between the upper end of the electrode **50** and a spring which bears thereon. The quartz sleeve **60** is shaped like the metallic bushing **52** with end portions of reduced diameter and is similarly retained in position by a retaining washer **53** attached to the block **48** by small screws **61**.

Supported above the block **48** is a tubular dielectric element **62** which may, for example, be of a composition known as victron. Element **62** has an outwardly extending base flange at its lower end fitting under a sleeve or clamping ring **63**. Screws **64** of stainless steel extend through the clamping ring **63**, block **48** and into the housing **58** to hold these three members firmly fixed together.

The tubular element **62** is provided with an externally threaded groove and a winding **65** of enameled copper wire wound in the groove serves as the secondary winding of the power supply transformer. A primary winding **66** of the power supply transformer encircles the secondary winding **65** and may be supported from the structure in any suitable manner. The power supply circuit connected to primary winding **66** is omitted from the drawings and it is to be understood that it may be substantially identical with that of Fig. 1, the terminals of the primary winding **65** being connected respectively to the inner terminals of capacitances **20**. In practice, with apparatus of the type illustrated in Fig. 4 periodically quenched power supply current having a principal frequency of 40 megacycles has been employed.

A fused quartz tube **67**, within which is a small diameter spring **68** of tungsten wire hot plated with No. 1 contact metal, is supported centrally within the element **62**. The spring **68** is fastened to the top of the quartz tube by means of finely divided silver which is sintered to the quartz tube as indicated at **70**. The secondary winding **65** of the power supply circuit has one terminal connected to this silver seal and its other terminal connected by a lead **71** to the clamping ring **63**.

The power supply circuit of the electrodes of the discharge gap may be traced from the electrode **51** by way of the metallic bushing **52**, electrically conducting block **48**, clamping ring **63**, lead **71**, secondary winding **65**, silver seal **70**, the tungsten spring **68** to electrode **50**. The spring **68** serves to freely pass the power frequency current for the discharge device to the discharge gap but to exclude the radiation frequency energy from the power supply circuit and thus to prevent the escape of the energy of the millimeter waves set up in consequence of discharges at the gap.

Fig. 5 is a cross-sectional view along the plane **5—5** of Fig. 4. As is evident from the drawings, the right-hand end of the tubular block **48** is left open for propagation of energy and the left-hand end is provided with an extension closed by an adjustable reflector **72**, a screw-threaded stem **73** of which passes through the cap **74** of the tubular extension. The reflector **72** may be

set at a half wave-length distance along the tube from the spark gap, in which case it will reflect oscillations back to the gap to reinforce those traveling to the right, thus enabling the system to propagate wave energy unidirectionally. The reflector may alternatively be set at a greater distance to reflect the intermittent groups of waves so as to redistribute their energy in a more uniform manner as described in my copending application Serial No. 279,063 filed June 14, 1939.

It has been found that the wave-length of an oscillator of the type illustrated in Figs. 4 and 5 comprising a spark gap placed diametrically across the interior of a metallic tube is substantially .869 times the diameter of the tube. It is readily possible with apparatus of this type to produce electromagnetic oscillations having wave-lengths as low as two millimeters.

The dimensions of a typical apparatus constructed in accordance with the disclosure and operating to produce oscillations of approximately 4.34 millimeter wave-length are:

	Millimeters
Diameter of the tube 49	5
Diameter of the electrodes 50 and 51	.714

With 170 threads per inch on the adjusting screw 56, a displacement of the movable electrode 51 of approximately .0015 centimeter per turn of the screw 56 was obtainable.

Since electrode 51 is electrically connected to the housing 48 it is necessary if a high voltage is to be built up between the electrodes that the electrode 50 be so disposed as to render the capacitance between it and housing 48 small or, in other words, that the load comprising the electrodes and their connections present a high input impedance as viewed from the terminal of coil 53. Now the electrodes with the gap in effect constitute a series full wave-length path or a zero impedance section. The coaxial section comprising the stem 75 of the electrode 50 and the conducting block surrounding the insulating bushing 60 is accordingly short-circuited at its termination by the zero impedance section. The coaxial section may, therefore, be made to have high impedance if its electrical length taken as that of the stem 75 be made an integral odd multiple of a quarter wave-length. For this purpose a three-quarter wave-length dimension has been found convenient. This linear dimension of the stem 75 must, of course, be calculated, taking into account the dielectric constant of the insulating bushing 60 which in apparatus embodying the invention has been constructed of clear fused quartz.

This construction, because of the grounding of the adjustable electrode, has the important advantage of permitting adjustment of the spacing of the discharge gap without substantial variation of the other electrical characteristics of the oscillation source.

What is claimed is:

1. An electric discharge gap having substantially linear electrodes of a few millimeters length, each electrode having a plane free end surface, the surfaces of the electrodes being juxtaposed in parallel relation with a gap separation of less than .001 millimeter, the plane end surfaces having minimum lateral dimensions of at least five hundred times that of the gap separation means for impressing between the electrodes periodic electromotive forces sufficient to exceed the breakdown voltage of the gap, and an electric wave reflecting system substantially surrounding the gap and apertured in a desired direction of transmission.

2. An electric discharge gap comprising a dipole radiator having its two members separated by a minute space across which discharges may occur, each member having a socket on a face other than that adjacent the other member, insulating supports cemented into the sockets to hold the members in position, and conducting coils surrounding each support and making contact with the respectively associated members to conduct electric current thereto.

3. A system for producing electric waves comprising an electronic oscillator having a quenching frequency-determining circuit to enable production of oscillations of the order of 50 kilocycles frequency, an electrically conducting path connected thereto including a discharge gap, the path being tuned to a principal frequency of the order of 50 megacycles to enable oscillations of the principal frequency modulated at the quenching frequency to be generated therein and impressed across the gap, the gap comprising two separated members in linear alignment to serve as a dipole radiator of a few millimeters wave-length, and reactances in the path adjacent the members to prevent dissipation in the path of energy of the wave-lengths at which the dipole is adapted to operate.

4. In combination, an electric discharge gap, an electronic oscillator having two frequency-determining circuits of widely different frequencies to enable production of electromotive forces of the higher frequency modulated by the lower frequency, means for connecting the oscillator to the gap to impress the modulated electromotive forces thereupon, and means for controlling the magnitude of the modulated electromotive forces to cause them to attain an intensity suitable for the discharge gap.

5. An oscillation source comprising an electrically conducting chamber, a discharge gap having electrodes comprising rod-like members mounted in a diametrically aligned position within the chamber and having such lengths as together to constitute a dipole oscillator and radiator of one-half wave-length at the frequency of the oscillations to be produced at least one of the electrodes being insulated from the chamber, the length of the gap between the electrodes being less than that of the mean free path of an electron in air, a source of electromotive force of a high potential gradient electrically connected to the electrodes to produce electric discharges therebetween, and means in the circuit of the source to confine oscillations produced by discharges across the gap to the space within the conducting chamber.

6. The combination of claim 5, characterized in this, that one end of the chamber is open to permit propagation of energy therefrom and at the other, means is provided for introducing a blast of gas to flush the region within the gap to reduce incipient ionization.

7. The combination of claim 5, characterized in this, that one of the electrodes is electrically connected to the tube, the other is insulated therefrom and indirectly connected thereto through the source of electromotive force and both electrodes have longitudinally adjusting means to enable variations of the gap dimension to be made and variation of the position of the gap relative to the chamber walls to be effected.

8. An oscillation source comprising a pair of electrodes separated by a gap and constituting

with the gap a series circuit resonant at approximately the frequency of the oscillations to be produced by the gap, a source of electromotive force for producing electric discharge across the gap at a lower frequency and a conducting line section of a length electrically equivalent to an odd integral multiple of a quarter wave-length corresponding to said lower frequency, connecting the source to the electrodes whereby the line and electrodes present high impedance to the source.

9. An electric discharge system for the production of oscillations from discharges across a discharge gap comprising conduction members constituting an electrically resonant oscillation path, the members having parallel surfaces placed in juxtaposition and separated from each other by a spacing which is less than the mean free path of an electron in air whereby upon imposition of high potentials autoelectronic discharge with relatively little ionization occurs, the surfaces having lateral dimensions of the order of one hundred times as great as the dimension of the gap between them and the surfaces being so finely ground as to maintain the minute gap separation substantially constant throughout its area whereby a substantial amount of energy may traverse the gap without undue heating or localization of the discharge.

10. An electric discharge gap comprising two closely adjacent but electrically separated electrodes, means for applying therebetween an electric stress of the order of one-half million volts per centimeter, and means for periodically interrupting the application of the stress sufficiently frequently to preclude destructive ionization at the gap.

11. An electric wave radiating system which comprises two aligned linear electrodes, each a few millimeters in length, separated by a discharge gap of less than 0.01 millimeter length and a block of conductive material having an open substantially spherical recess therein, the electrodes being disposed at the center of the sphere, and the radius of the sphere being large compared with the length of the electrodes, whereby the recess serves as a reflector for radiations generated at the gap, the capacitance between the electrodes and the wall of the recess being negligibly small.

12. An oscillation source comprising an electrically conducting chamber, a discharge gap having electrodes comprising rod-like members mounted in a diametrically aligned position within the chamber and having such length as together to constitute a dipole oscillator and radiator of one-half wave-length at the frequency of the oscillations to be produced, at least one of the electrodes being insulated from the chamber, a source of electromotive force of a high potential gradient electrically connected to the electrodes to produce electric discharges therebetween, and means in circuit with the source to confine oscillations produced by discharges across the gap to that portion of the circuit within the conducting chamber.

13. Apparatus for the production of ultra-short radio waves, which comprises two electrodes separated by a gap, a resonance system associated with the gap and tuned to the frequency of the ultra-short waves to be radiated, a source of high frequency oscillations quenched at a lower frequency, and a circuit connecting the source to the electrodes for supplying excitation to the gap, said circuit being tuned to the frequency of the source oscillations but containing an inductor of reactance sufficiently high to prevent current surges from the source to the gap upon inception of a discharge, whereby discharges of the gap take place unhampered by a flow of energy from the source and are accompanied by like wave trains.

14. Apparatus for the production of ultra-short radio waves, which comprises two electrodes separated by a gap, a resonance system associated with the gap and tuned to the frequency of the ultra-short waves to be radiated, a source of high frequency oscillations, and a series circuit connecting the source to the electrodes, said circuit containing a small capacitance and a high inductive reactance, tuned to the frequency of the source oscillations, to conduct exciting oscillations to the gap but prevent current surges from the source to the gap upon the inception of a discharge, whereby discharges of the gap take place unhampered by a flow of energy from the source and are accompanied by like wave trains.

15. An electric discharge gap for the production of oscillations from discharges across the gap, comprising electrically conducting members having parallel surfaces placed in juxtaposition and separated from each other by a spacing which is less than the mean free path of an electron in air whereby upon imposition of high potentials autoelectronic discharge with relatively little ionization occurs, the surfaces having lateral dimensions of the order of one hundred times as great as the dimension of the gap between them, the surfaces being so finely ground as to maintain the minute gap separation substantially constant throughout its area whereby a substantial amount of energy may traverse the gap without undue heating or localization of the discharge, and means for varying the separation of the gap surfaces while maintaining them parallel.

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