March 11, 1947. H. BENIOFF 2,417,052

HIGH-FREQUENCY SPARK CIRCUIT

Filed Feb. 25, 1942 3 Sheets-Sheet 1

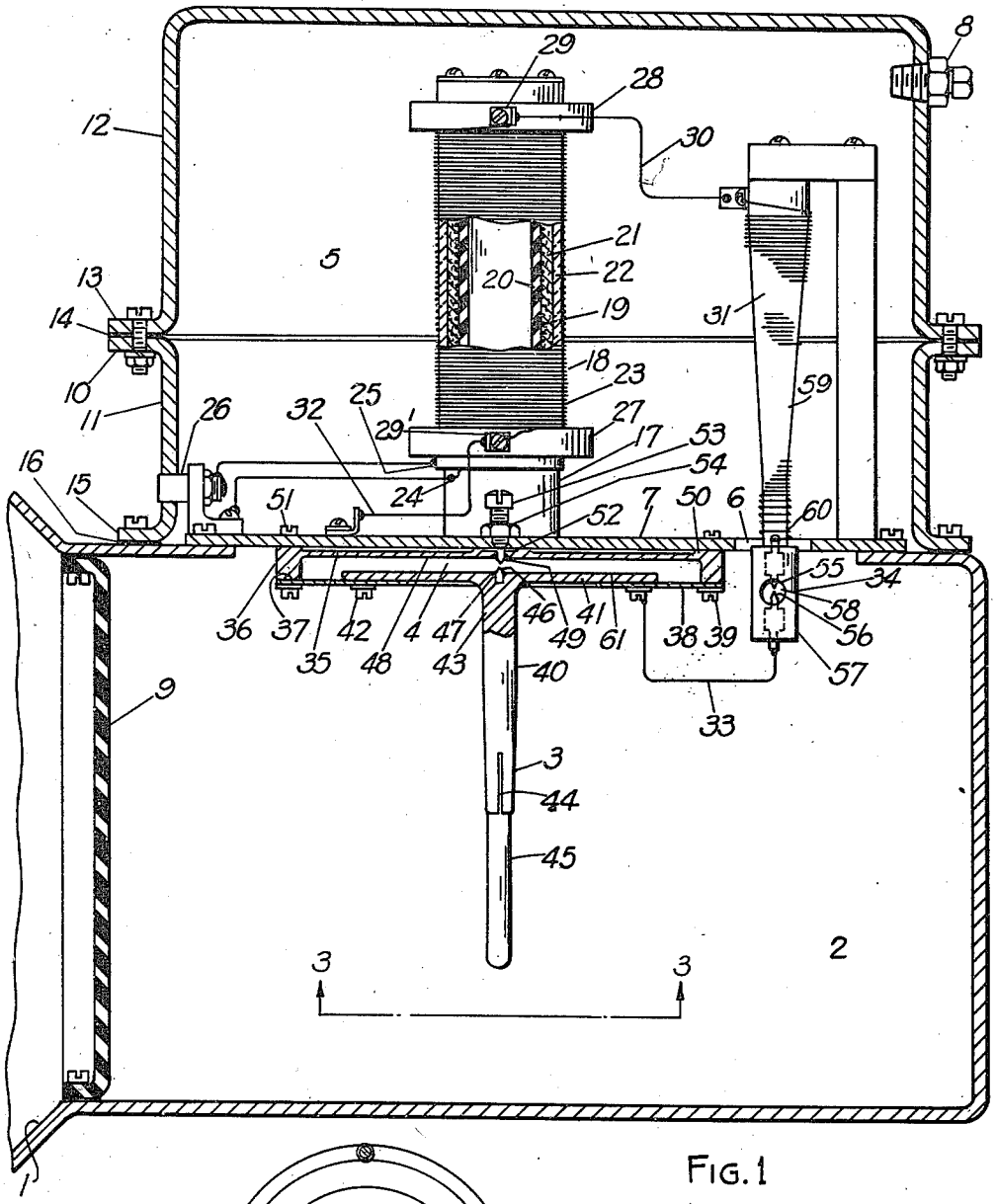


FIG. 1

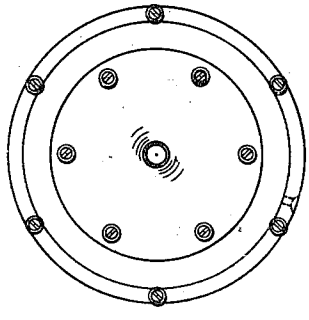


FIG. 3

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HIGH-FREQUENCY SPARK CIRCUIT

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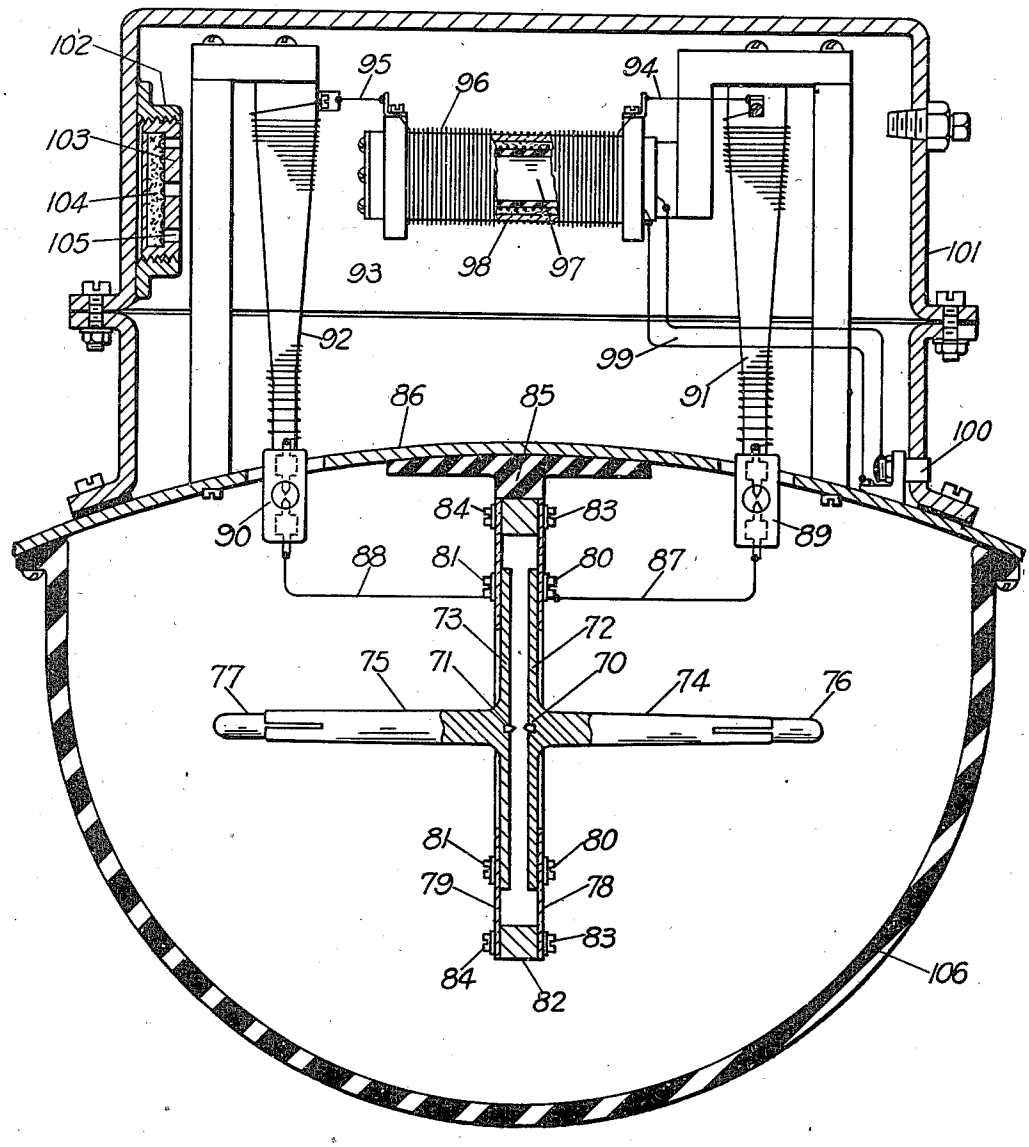


FIG. 2

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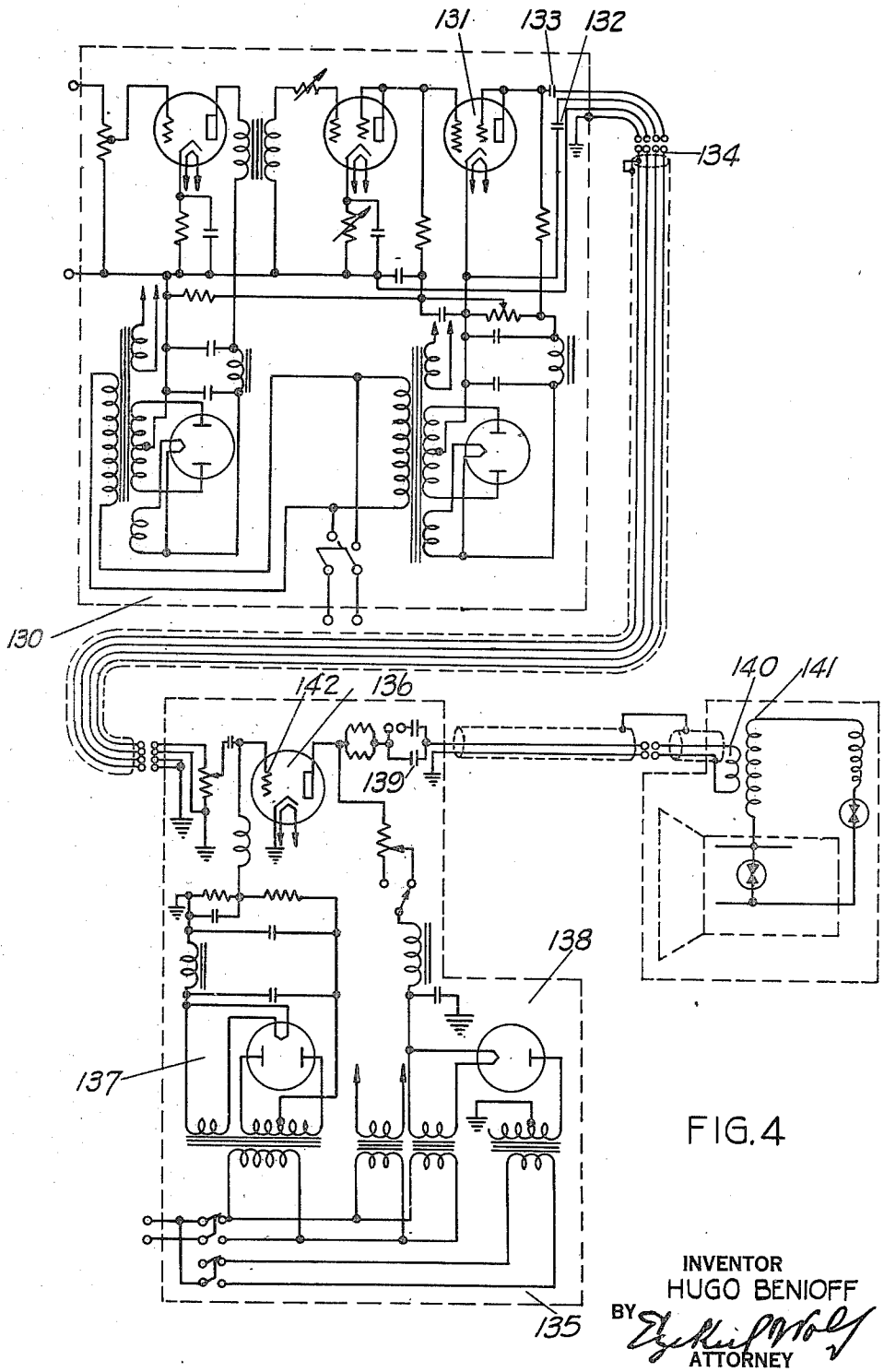


FIG. 4

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UNITED STATES PATENT OFFICE

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HIGH-FREQUENCY SPARK CIRCUIT

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Application February 25, 1942, Serial No. 432,293

15 Claims. (Cl. 250—38)

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The present invention relates to apparatus for producing high frequency electromagnetic waves and relates more particularly to short wave apparatus in the one-meter range and lower, or 300 megacycles and higher.

The present invention further applies to damped wave trains as contrasted to the production of continuous oscillations and is an improvement along the lines of the apparatus disclosed in my copending applications Serial Nos. 362,434, filed October 23, 1940, and 391,153, filed April 30, 1941.

In the earlier developments in radio transmission, spark circuits were used quite extensively. In such spark circuits resonance was chiefly controlled by a coil and a condenser in series with the spark gap and for the most part other distributed capacities and inductances could be neglected. In a spark oscillator the available output energy is derived from the electrostatic energy stored in the capacity of the system at the moment the spark breaks down the gap. In an oscillator designed for extremely high frequencies the capacity for resonance is necessarily extremely small and consequently the oscillator should be constructed in such a form to provide a maximum capacity for the required frequency which is one of the chief objects of the present invention.

The applicant has also discovered that due to the fact that currents of extremely high radio frequencies flow on the surface of the conducting elements, resistances of large magnitudes may accidentally be incorporated in the high frequency circuits on account of fissures, cracks or poor joints in the surface of the electrical conducting elements. These flaws may not be particularly visible to the eye and yet they may be sufficient to cause the current to flow by longer paths and thereby introduce resistance and reactance in the oscillatory circuit which may change the frequency or even prevent oscillations entirely. It is particularly important in places where the current density in the system is high, as, for instance, around the sparking points which should be of tungsten or other high melting-point metals, that the surface be particularly smooth and free from flaws or cracks, as cracks in these portions of the surfaces are particularly effective in increasing the electrical losses in the oscillatory circuit.

The present invention is particularly adaptable for transmitting signals in a radio distance measurement system operating by means of the time of travel of a radio wave to and from a radio

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reflecting object. For this purpose there is incorporated in the present invention a special trigger circuit including a gaseous control tube having a grid control element which brings about a rapid discharge of a condenser through one circuit causing a charging of the capacity in the radio frequency oscillating circuit. The control grid in the trigger circuit is energized by repeated peaked periodic impulses which initiate the discharge of the condenser in the circuit coupled to the radio frequency oscillating circuit.

The system according to the present invention may be operated with any suitable kind of indicating mechanism for measuring the time interval between the transmission of the direct wave train and the receipt of the reflection. Such indicating mechanism, for instance, may include a cathode ray tube in which the motion of the spot on the face of the tube may be controlled to provide the time interval measurement.

Other advantages of the present invention will be more fully understood in connection with the specifications set forth in the description below taken in connection with the drawings showing an embodiment of the invention in which Fig. 1 shows the invention partially in fragmentary section; Fig. 2 shows a modification of the construction shown in Fig. 1; Fig. 3 shows a detail view looking upwards along the line 3—3 of Fig. 1; and Fig. 4 shows a circuit diagram for operating the apparatus of Figs. 1 and 2.

Referring in particular to Fig. 1, 1 represents a radiating horn in the throat of which is positioned a sealed housing comprising a chamber 2 containing the antenna elements 3 and the oscillator 4 and an additional chamber 5 containing high voltage supply apparatus. These two chambers are open one to the other through the perforation 6 in the supporting partition 7 and may be filled with a gas such as nitrogen or oxygen through the valve 8, or they may be evacuated to low vacuum, if desired. The chamber 2 is sealed off from the throat of the horn by a member transparent to radio waves as, for instance, a rubber or Bakelite plate 9. The chamber 5, it will be noted, may be formed of two parts, a collar section 11 with a flange 10 and a cap section 12 with a flange 13 so that the chamber may be opened for the purpose of making changes or substituting or renewing parts therein. The flanges may be made airtight by sealing them with a gasket 14 in between, and, similarly, the flange 15 of the collar may be sealed to the outer wall of the chamber 2 with an airtight gasket 16 in between the flange and the wall. Mounted on

the partition 7 is an insulating block 17 providing the support in connections for the impulse transformer 18. This transformer comprises a low-voltage primary 19 wound on a Bakelite tube 20 about which is a layer of wax 21 separating and spacing the Bakelite tube 20 from the glass tube 22 on the exterior of which is wound the high-voltage coil 23. Connections to the low-voltage coil 19 are brought out to the terminals 24 and 25 on the supporting block 17 from which connections are made to the supply terminals and switch 26 at the side wall of the chamber 5. The terminals 29 and 29' of the high frequency coil 23 are mounted on the insulating rings 27 and 28 at the ends of the glass shell. Power is conducted to the terminal 29 over the line 30 from the choke coil 31 which will presently be described. The secondary circuit is completed at its other end over the connector 32 to the spark oscillator 4 over the conductor 33 and through the auxiliary spark gap 34 to the other end of the choke coil 31.

The oscillator in the present case may comprise a plate 35 of conductive material having integral therewith at its periphery a flange member 36 extending outward from the surface of the plate. The flange member 36 has a flat end surface 37 upon which is mounted a flat annular member 38 preferably of mica or some material having good insulating qualities. This annular mica flat member is held fast to the surface 37 of the flange 36 by means of suitable screws 39 or by any other suitable means and supports nearer its inner periphery a component part 40 of the tank circuit. This part 40 comprises a flat conductive disc element 41 which is held near its periphery by the screws 42 to the mica member 38. The flat disc 41 has projecting from the center thereof and integral therewith the antenna or rod element 43 which may be perforated and slotted in slots 44 at the end to receive an adjustable member 45 for tuning the antenna. Opposite this antenna member 43, where it projects from the disc 41 and on the inner surface of the disc, is a sparking point 46 which is preferably made of tungsten or other material having a very high melting point. This tungsten point 46 is carefully mounted in the face of the disc 41 first by welding nickel to tungsten, then silver soldering nickel to the plate, as indicated in Fig. 1. After this, the whole disc and point are turned down until all cracks and fissures have been removed so as to permit a free flow of current from the point to the adjacent surface of the disc 41. The surface of the disc 41 is placed in opposite and parallel relationship to the inner surface 48 of the plate 35. At the center of the surface 48 of the plate 35 there is mounted a tungsten point 49. The same care is taken with the construction and mounting of this point as with the point 46. The plate 35 is spaced slightly away at its periphery from the partition 7 by the rearwardly extending peripheral ring 50 through which the oscillator is clamped to the partition by means of the groups of screws 51 passing through the partition into the end ring 36. The plate 35 is also provided with a central boss element 52 against which a set screw 53 passing through the partition 7 presses. This set screw may be used to adjust the distances between the two sparking points 46 and 49 to the desired distance which usually is approximately ten thousandths of an inch. After the desired setting has been obtained, the locking nut 54 may be used to lock the screw in position. The apparatus is also provided with an auxiliary spark gap 34, as mentioned above, which has two point electrodes 55 and 56. These electrodes may be encased in an insulating tube 57 which is provided with an opening or window 58 through which the points may be observed to see that they are properly spaced. The points may be held in the tubes in a drive fit so that the distance of the sparking points may be properly adjusted.

The elecetrode 55 is connected to the choke coil 31 which may be of a special construction comprising a tapered core member 59 wound with coarser turns 60 at its small high voltage end gradually becoming finer as the tapered diameter increases. The purpose of this choke is to prevent the high frequency current from flowing back into the supply circuit. The spacing between turns is greatest at its small end nearest the oscillator since the danger of spark-over is the greatest there. By this construction the impedance coil will have less loss than otherwise in the high frequency circuit and will also stand up more efficiently against the higher voltage. The oscillatory circuit in the present instance comprises the surface 48 of the plate 35 and the surface 61 of the disk 41 with the sparking points 46 and 49 and the gap as the central part of the system. Coupled to this oscillatory circuit is a second oscillatory circuit tuned to it, by means of which the radio waves are radiated into the propagating medium. This circuit comprises the antenna element made up of the pole member 43 with its adjustable extensible rod 45 and the outer surface of the plate 41. The pole member 43 with its extension 45 is approximately $\lambda/4$ or one-quarter of the wave length corresponding to the frequency of the oscillatory circuit. The surface of the plate from the pole out to the edges furnishes the counter-poise for the pole, making an oscillatory node somewhere near the base of the pole member 43. This last circuit is coupled to the oscillatory circuit previously described and through this coupling the energy is delivered from the oscillatory circuit including the spark gap to the antenna oscillatory circuit including the pole from which the electromagnetic waves are radiated. The energy stored up in the oscillatory circuit between the surfaces 61 and 48 is in the form of an electrostatic field produced between these opposing surfaces and this circuit is coupled to the antenna circuit through the potentials and current set up on the opposite surfaces of the plate 41 by reason of the conductive coupling between the inner and outer surfaces of plate 41 at the edge of the plate. When the charge existing between the plates 35 and 41 is such as to cause a break-down of the resistance across the sparking points, the charges on the plate produce or result in surface currents which flow back and forth across the spark gap with the frequency established by the capacity and inductance of the circuit which depends upon the dimensions and shape of the resonating structure and dielectric constant of the medium between the plates.

In the operation of the circuit there is evidence that in addition to its other functions the auxiliary gaps have the effect of increasing the rate at which the oscillatory circuit charges which aids in building up the potential across the plates of the oscillatory circuit to a maximum value at the point when the discharge occurs.

The resonance established by the osillator embracing the surfaces 61 and 48 of the plate and the sparking points is that of one-half wave

length, the extending rod element 43 and its extension 45 forming an approximately one-quarter wave length member and the outside surface of the disc 41 furnishing the counter-poise.

In the arrangement shown in Fig. 2 the oscillatory circuit is symmetrical on both sides of the sparking electrodes 70 and 71. Each of these electrodes 70 and 71 is mounted at the center of opposing plates 72 and 73, respectively. From the outer surface at the center of these plates extend the radiating antennae 74 and 75, respectively, which are tunable by the adjustable rods 76 and 77, respectively, which may be moved outward or inward in recesses formed at the ends of the rods. The plates 72 and 73 are held in position, each by annular mica flat members 78 and 79 to which the plates 72 and 73 are clamped by means of the screws 80, 80, etc., and 81, 81, etc., respectively. These mica annular flat members are supported by a ring 82 to which the members 78 and 79 are clamped near their outer periphery by the screws 83, 83, etc., and 84, 84, etc., respectively. The ring 82 is supported by an insulating member 85 to which it may be clamped or cemented and which, in turn, is clamped or cemented to the reflecting parabola 86 at its center. High-tension voltage is conducted to the oscillatory circuit formed by the plates 72, 73 and the electrodes 70 and 71 over the wires 87 and 88 which are connected to the auxiliary spark electrodes 89 and 90, respectively, which, in turn, respectively are connected in the chamber 93 to the chokes 91 and 92. The high-tension winding 96 of the impulse transformer has its terminal leads 94 and 95 connected respectively to the chokes 91 and 92. The impulse transformer 97 is similar to the one described in connection with Fig. 1 and is provided with a primary winding 98 to which power is supplied by the lines 99 from the switch 100 which connects to leads externally of the hermetically sealed casing 101.

The chamber 93 may also contain gases under pressure but if it is desired to permit the chamber to be exposed to the atmosphere, provision is made for inserting a moisture-absorbing substance within the casing. For this purpose a threaded cylindrical holder 102 may be mounted at the side of the casing and may contain a cartridge 103 containing some moisture-absorbing substance 104, for instance, calcium chloride or the like. This substance in the cartridge is exposed through perforations 105 therein to the air or other gas medium in the chamber without, of course, permitting the substance to drop or fall out of the cartridge into the chamber. The oscillatory circuit may also be sealed by placing a hood 106 of insulating material over the front of the parabola at the center where the oscillatory circuit is placed. If the apparatus is used without special gas pressure, it is still desirable, in order to exclude the moisture, to enclose the oscillatory circuit and the other high-voltage apparatus.

In the arrangement indicated in Fig. 2 the radiating members 75 and 77 and the outside of the plate 73 and the radiating members 76 and 74 and the outside of the plate 72 form resonant circuits tuned with and coupled to the oscillatory circuits formed by the internal surfaces of the plates 72, 73. The resonance of the oscillating circuit formed by the inner surfaces of the plates 72 and 73 and the sparking electrodes establish the oscillatory frequency of the high frequency radio circuit. The energy stored up by

virtue of the charge across the plates 72 and 73 is the maximum amount of energy obtainable in the oscillatory circuit which commences to oscillate at the instant that the discharge occurs across the sparking electrodes. The external circuit just previously mentioned is coupled to this circuit and acts to radiate the high-frequency electromagnetic waves.

In the arrangement indicated in Fig. 2, two auxiliary sparking electrodes 89 and 90 are employed as well as two choke coils 91 and 92 which are of the same type previously described in connection with Fig. 1.

In the arrangement indicated in Fig. 4 there is shown an operating circuit for operating the apparatus shown either in Figs. 1 or 2. This circuit comprises in the main two parts, one a sweep circuit 130 which is of the normal type producing a square-top wave from the output of the tube 131. This square-top wave is somewhat modified by the condensers 132 and 133 to produce a peak on the forward corner of the square-top wave so that in the output lines 134 the wave may simply be represented as a sharp peak. The firing circuit is shown within the dotted-line diagram 135 and comprises a gaseous control tube 136 whose input circuit is biassed by rectified current supplied through a low-voltage rectifier 137. A high-voltage rectifier 138 is used to energize the condenser 139 which is carged through the primary 140 of the impulse transformer 141 corresponding to that indicated in Figs. 1 and 2. When the peak of the control wave from the circuit 130 is impressed upon the grid 142 of the thyratron 136, the tube 136 fires with the result that the charge on the condenser 139 is discharged through the primary 140 of the impulse transformer, thus setting up a high-voltage discharge across the secondary of the transformer which rapidly builds up to a break-down the potential across the sparking electrodes of the oscillatory circuit. The thyratron tube 136 may be operated periodically at the rate of oscillations in the sweep circuit 130. This period may be 5000 or 10,000 vibrations a second, if desired. The length of the discharge across the high-frequency oscillatory circuit may be of the order of one micro-second and the frequency established by the oscillatory circuit may have a wave length of ten centimeters or more or less, if desired, corresponding to 3000 megacycles or somewhat more or less, whatever may be desired.

Having now described my invention, I claim:

1. A short wave oscillatory spark circuit comprising means providing two flat surfaces, means centrally located on said surfaces and projecting therefrom forming a spark gap, means insulatingly supporting said first means with said two flat surfaces in closely spaced opposed relationship to each other, said surfaces, the space between them and said spark gap means being dimensioned with respect to the wave length of the oscillations to be generated so as to form upon current flow across the gap an oscillatory circuit resonant at the frequency of said oscillations, and an energy-radiating circuit tuned to the same frequency as said oscillatory circuit conductively coupled to the latter.

2. A short wave oscillatory spark circuit comprising means providing two flat surfaces, means forming a spark gap located substantially between the centers of said surfaces, means insulatingly supporting said first means with said two flat surfaces in closely spaced opposed relationship with each other, said surfaces, the space

between them and said spark gap means being dimensioned with respect to the wave length of the oscillations to be generated so as to form upon current flow across the gap an oscillatory circuit resonant at the frequency of said oscillations, and conducting means extending outwardly from said first means at least from one of said opposed surfaces and forming with the opposed surface from which it extends a radiating means resonantly coupled with said resonant oscillatory circuit.

3. A short wave oscillatory spark circuit comprising two flat plates, means forming a spark gap located at the centers of the surfaces of said plates, means insulatingly supporting said first means with the flat surfaces of said plates in closely spaced opposed relationship to each other, said surfaces, the space between them and said spark gap means being dimensioned with respect to the wave length of the oscillations to be generated so as to form upon current flow across the gap an oscillatory circuit resonant at the frequency of said oscillations, and an energy-radiating circuit tuned to the same frequency as said oscillatory circuit conductively coupled to the latter, said radiating circuit including a conducting member extending outwardly from at least one of said plates substantially opposite the location of said spark gap and the outer surface of the plate from which it extends.

4. A short wave oscillatory spark circuit comprising two flat plates, means insulatingly supporting said plates with the inner surfaces thereof in closely spaced opposed relationship to each other, a pair of sparking electrodes one mounted on and projecting from the inner surfaces of each of said plates substantially at the center thereof, said surfaces, the space between them and said spark gap means being dimensioned with respect to the wave length of the oscillations to be generated so as to form upon current flow across the gap an oscillatory circuit resonant at the frequency of said oscillations, and an energy-radiating circuit tuned to the same frequency as said oscillatory circuit conductively coupled to the latter, said radiating circuit including a radiating pole member projecting from the outer surface of one of said plates substantially opposite the point of the sparking electrodes.

5. A short wave oscillatory spark circuit comprising two flat plates, means insulatingly supporting said plates with the inner surfaces thereof in closely spaced opposed relationship to each other, a pair of sparking electrodes one mounted on and projecting from the inner surfaces of each of said plates substantially at the center thereof and a pole member projecting from the outer surface of one of said plates substantially opposite the point of the sparking electrodes, said pole member with the external surface of said plate forming a radio frequency radiating resonator and the inner surfaces of said plates together with the sparking electrodes forming an oscillatory resonator, both of said circuits being adjusted for substantially the same resonant frequency.

6. A short wave oscillatory spark circuit comprising means providing two flat surfaces, means forming a spark gap located substantially between the centers of said surfaces, means insulatingly supporting said first means with said two flat surfaces in closely spaced opposed relationship with each other and conducting means extending outwardly from said first means at least from one of said opposed surfaces, said conducting means and the surface from which it extends forming a tuned radiating radio frequency oscillatory circuit and said opposed surfaces with said spark gap forming a tuned oscillatory circuit, said circuits being coupled together and tuned substantially to the same resonating frequency.

7. A short wave oscillatory spark circuit comprising two flat plates, means insulatingly supporting said plates with the inner surfaces thereof in closely spaced opposed relationship to each other, a pair of sparking electrodes one mounted on and projecting from the inner surfaces of each of said plates substantially at the center thereof, said surfaces, the space between them and said spark gap means being dimensioned with respect to the wave length of the oscillations to be generated so as to form upon current flow across the gap an oscillatory circuit resonant at the frequency of said oscillations, and an energy-radiating circuit tuned to the same frequency as said oscillatory circuit conductively coupled to the latter, said radiating circuit including pole members projecting from the outer surfaces of said plates substantially opposite the position of said sparking electrodes.

8. A short wave oscillatory transmitter comprising two flat plates having pole members extending outwardly from the surface of said plates, means insulatingly mounting said plates with the other surfaces in closely spaced parallel opposed relationship to each other and means forming sparking electrodes at the center of said plates between said opposed surfaces, said surfaces, the space between them and said sparking electrodes being dimensioned with respect to the wave length of the oscillations to be generated so as to form upon current flow across the electrodes an oscillatory circuit resonant at the frequency of said oscillations and said pole members and the outer surfaces of said plates being dimensioned to form a second oscillatory circuit resonant at substantially the same frequency as said first oscillatory circuit, and means for energizing said first oscillatory circuit.

9. A short wave oscillatory circuit comprising two flat plates having pole members extending outwardly from the surface of said plates, means insulatingly mounting said plates with the other surfaces in closely spaced parallel opposed relationship to each other and means forming sparking electrodes at the center of said plates between said opposed surfaces comprising a pair of projecting electrodes of a substantially high melting-point metal mounted on and projecting from the center of the opposed surfaces of said plates, said surfaces, the space between them and said sparking electrodes being dimensioned with respect to the wave length of the oscillations to be generated so as to form upon current flow across the electrodes an oscillatory circuit resonant at the frequency of said oscillations and said pole members and the outer surfaces of said plates being dimensioned to form a second oscillatory circuit resonant at substantially the same frequency as said first oscillatory circuit, and means for energizing said first oscillatory circuit.

10. A short wave oscillatory circuit comprising two flat plates having pole members extending outwardly from the surface of said plates, means insulatingly mounting said plates with the other surfaces in closely spaced parallel opposed relationship to each other and means forming sparking electrodes at the center of said plates between said opposed surfaces comprising a pair of projecting electrodes of a substantially high melting-

point metal mounted on and projecting from the center of the opposed surfaces of said plates, said sparking electrodes and said plates joining each other in a substantially smooth surface, said surfaces, the space between them and said sparking electrodes being dimensioned with respect to the wave length of the oscillations to be generated so as to form upon current flow across the electrodes an oscillatory circuit resonant at the frequency of said oscillations and said pole members and the outer surfaces of said plates being dimensioned to form a second oscillatory circuit resonant at substantially the same frequency as said first oscillatory circuit, and means for energizing said first oscillatory circuit.

11. A short wave oscillatory circuit comprising a pair of electrically conductive disk members each having pole elements extending from the surface of said disks on one side at the center thereof, a pair of sparking electrodes mounted on the other side of said disks at the center thereof, a pair of flat annular insulating elements clamped to said disks, a ring member supporting said flat annular members, said elements together positioning said disks with the surfaces on which said electrodes are mounted in closely spaced parallel relationship with each other with the sparking electrodes in opposed positions and electrical conducting means connected to said disk members at their peripheries for supplying power to said oscillatory circuit.

12. A short wave oscillator circuit comprising a pair of electrically conductive disk members each having pole elements extending from the surface of said disks on one side at the center thereof, a pair of sparking electrodes mounted on the other side of said disks at the center thereof, a pair of flat annular insulating elements clamped to said disks, a ring member supporting said flat annular members, said elements together positioning said disks with the surfaces on which said electrodes are mounted in closely spaced parallel relationship with each other with the sparking electrodes in opposed positions and electrical conducting means connected to said disk members at their peripheries for supplying power to said oscillatory circuit, the said pole members having adjustable extension means for varying the effective length thereof whereby the radiating circuit formed by the pole members and the external surfaces of the disks may be adjusted to the natural frequency of the oscillatory circuit.

13. A short wave oscillatory spark circuit comprising a pair of plate members, means mounting said plate members insulatingly supporting one from the other with the surfaces thereof in parallel opposed spaced relation to each other, a pair

of sparking electrodes supported at the center of said surfaces in opposed relation to each other and a pole member extending from one of said plates from one of the unopposed surfaces and means mounted opposite the back of the other of said plates for adjusting the position of one of said electrodes with relation to the other thereof, said surfaces, the space between them and the sparking electrodes being dimensioned with respect to the wave length of the oscillations to be generated so as to form upon current flow across the electrodes an oscillatory circuit resonant at the frequency of said oscillations, and said pole member and the outer surface of the plate from which it extends being dimensioned to form a second oscillatory circuit resonant at substantially the same frequency as said first oscillatory circuit, and means for energizing said first oscillatory circuit.

14. A short wave oscillatory spark circuit comprising a plate member having a normally extending flange at the periphery from one surface thereof, a second plate member and an insulating annular element supporting said plate member to said flange whereby said plate members are disposed with opposed surfaces in closed parallel relationship to each other, a pair of electrodes mounted on said opposed surfaces and extending towards each other and means mounting said first plate element having means positioned opposite the location of said electrodes at the back of said first plate for adjustably moving said plate at its center whereby the distance of said electrodes may be adjusted one to the other.

15. In an ultra high frequency spark oscillator, the combination of a metallic plate and a sparking electrode of high melting-point metal different from that of the plate mounted thereon, said electrode and the surface of the plate being part of an ultra high frequency circuit, and the surface of the joint between said electrode and said plate being smooth and continuous.

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