

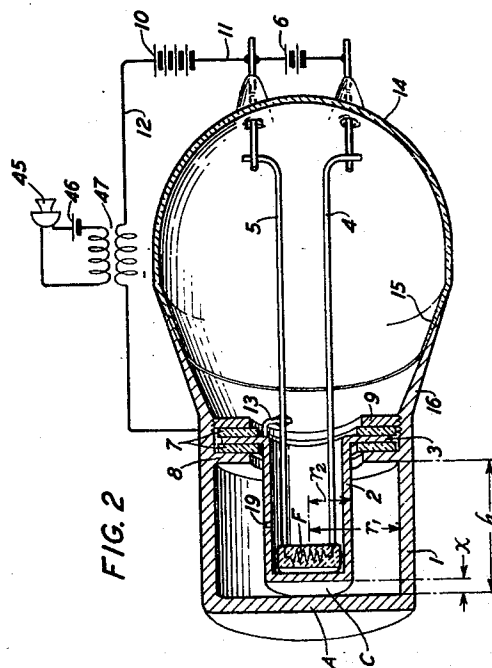
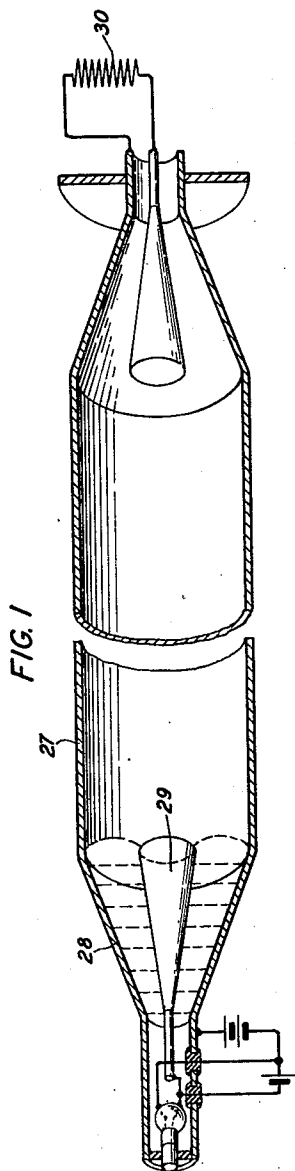
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DIODE OSCILLATOR

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DIODE OSCILLATOR

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This invention relates to oscillators where the wave-lengths contemplated may be as short as ten centimeters and under when desired, therefore extending to a wave-length range in which, before the advent of the principle here utilized, it has been impracticable to operate. More specifically, the invention relates to what are known in the ultra-short wave art as "diode oscillators" and therefore to the configuration of two electrodes in an evacuated space and the relative mechanical and electrical design of an associated resonating system whereby the organization as a whole is adapted to generate stable waves of the type above indicated.

This application is a division of my copending application Serial No. 156,647, filed July 31, 1937, which eventuated into Patent 2,190,668, February 20, 1940. It discloses and claims the species of invention illustrated by Fig. 9 of the parent application.

It is believed that applicant's invention illustrates a maturity of development of diode oscillators not heretofore approximated in the art. The uniqueness and distinctive character of his invention results from his having been able to combine an electron discharge with low-loss circuit configurations and to analyze the prior art circuits and provide quantitative electrical and mechanical dimensions, configurations, etc. as above, so as to be able to predetermine the characteristics of operation of his oscillator.

Accordingly, the principal object of the invention is to provide a stable frequency oscillator capable of generating waves of the order of ten centimeters and less long.

Subsidiary objects of the invention are to improve the operational characteristics of preexisting diode oscillators to the extent of providing greater frequency stability, increased energy output and better modulation, and to improve their structures in the interest of increased facility of manufacture, longer life, and adaptability, by extension of the principle to variant alternative forms, to a greater variety of uses.

An object of the invention, more specific to the modification to be herein illustrated than the above objects, is to provide an organization including a diode oscillator having the above characteristics and attributes together with efficient means for deriving and utilizing the output energy of the oscillator.

Specifically, the diode oscillator of the invention, in one aspect here given priority of description as possibly being the simplest and most

easily understandable, comprises two electrodes in an evacuated space, the negative resistance imputed to the space therebetween being a function of certain precise conditions affecting the electrodes. For instance, there must be a uniform flow of electrons from one such electrode, which simulates to that extent the function of the usual electron tube cathode, to the other electrode on which a positive potential is impressed relatively to the cathode in order to promote this flow, said positive electrode therefore simulating the usual electron tube anode. The requisite uniformity of electron flow requires practically that the emitting surface of the cathode be smooth and relatively extensive as distinguished from, for example, a small filamentary cathode associated with a planar anode. This ultimately means that the cathode must have a shape of the same type as that of the anode, both constituting regular, smooth, relatively flat surfaces. To promote further the uniform flow, the anode surface should be very closely equidistant at all points from that of the cathode, that is, the two surfaces should be uniformly spaced.

Concomitantly with the above purely structural requisites there must be the condition, brought about by the appropriate relative design of said structure and the potentials applied thereto, that the transit time of the electrons between the two electrodes is approximately 5, 9, 13, 17, etc., quarter-cycles of the high frequency current which it is intended to produce.

A negative resistance being provided by the satisfaction of the above considerations, a self-contained, or self-excited oscillator results from the further extension of the principle to the design of a cooperating external circuit and structure. For instance, the interelectrode space, above cited as the negative resistance, strictly partakes of the electrical characteristics of a circuit constituted by a negative resistance and a capacitance in series; therefore, the perpetuation of the oscillations implied by the negative resistance, per se, requires that this capacitance be constituted a part of a series resonant circuit the resistance of which, that is, the positive resistance of which, is less than the negative resistance imputed to the electrode space.

The consummation of the invention so far as it pertains to the diode oscillator element, therefore, results from the design of an inductive reactance so electrically dimensioned as to resonate with the interelectrode capacitance and which is almost wholly devoid of resistance.

The inductor of said reactance, because of this necessary condition, that is, because of its very high ratio of reactance to resistance at the oscillation frequency which ratio is sometimes denominated "Q," tends to be very distinctive not only in its design but also in its physical appearance.

The diode oscillator organization above characterized has been claimed in the parent application or will be claimed in another divisional application. The invention that will be disclosed herein and claimed contemplates the addition to the diode structure per se, above contemplated, of an output circuit for efficiently deriving the energy from the diode oscillator per se. The particular type of output circuit here in mind is a wave guide coupled to the diode oscillator in an efficient manner. This specific invention evinces the recognition of the importance of radiation resistance and the means for reducing it. This is because in the absence of an output circuit in some such form as illustrated by a wave guide, a certain portion of the energy generated by the diode oscillator will inevitably be radiated into space and largely represents wastage. For instance, the opening in an otherwise closed physical structure embodied in the oscillator, resulting from the necessity for effectively isolating one portion from another, provides opportunity for escape of energy. The use of the wave guide type of output circuit or the equivalent may be thought of as not only a means for salvaging this otherwise wasted energy but as providing a circuit into which the oscillator feeds which has such a coupling to the oscillator as to provide the most efficient generation of energy by said oscillator.

Other features of the invention are illustrated in the accompanying drawing, in which:

Fig. 1 illustrates, partially diagrammatically and in section, a simple, but effective, embodiment of the principle of the combination of diode oscillator and wave guide output circuit of the invention; and

Fig. 2 illustrates in detail the diode oscillator element of Fig. 1.

Although any type of diode oscillator disclosed in the parent application could be used as the prime source of energy in the organization of Fig. 1, the particular form of diode oscillator illustrated in Fig. 2 is well adapted for inclusion in the said Fig. 1 organization. It corresponds to that illustrated by Fig. 1 of the parent application. This choice is made not only as being very well adapted for its purposes, but because in the parent application, the analysis used, as illustrative of the principles of the invention generally, was made to conform more particularly to the species illustrated by said Fig. 1. Such analysis will not be repeated in this application for that reason, but may be conveniently referred to if that much detail of analysis is desired. Herein there will be included, however, a complete teaching of the principles of the diode oscillator per se and in combination with the wave guide output circuit, and therefore the end product of the analysis given in the parent application; therefore, the teachings herein will be found to be complete enough to enable one skilled in the art to practice the invention. For convenience of disclosure, the diode oscillator element per se of the combination of Fig. 1, said element being illustrated in Fig. 2, will be treated preliminary to the treatment of the combination in which it is included as illustrated in said Fig. 1

in which the invention to be claimed in this divisional application inheres.

It has been found that a uniform stream of electrons moving between two equidistant surfaces exhibits the property of negative resistance within a series of high frequency bands. This property has been used, by applicant, for the production of oscillations at a wave-length of the order of ten centimeters and is suitable for the production of considerably shorter or longer waves.

Referring to Fig. 2, the coaxial conductors 1 and 2 whose lengths and diameters are small as compared with the wave-length of the desired resultant oscillations are closed at one end by the annular ring or flange 3 and are terminated at the other end by the disc members C and A. These disc members constitute the diode electrodes. Between these diode electrodes there is, of course, a capacitance the value of which is determined by the dimensions and spacing of the electrodes and, as will be shown, there also exists therebetween under critical environmental conditions of circuits and structure a negative resistance, this of course implying the possibility of developing oscillations.

The electron discharge, on which all of the diode oscillator functions are presupposed, takes place between these disc elements C and A. In Fig. 2 the element C constitutes an electron emitter and the other element A is biased at a positive potential relative thereto. That is, disc element C is the cathode and disc element A is the anode, as is indicated by their literal designations although the converse could be true. The cathode C is coated with a material processed in a well-known manner to produce a copious emission of electrons when heated to emitting temperature by filament F fixed in close contiguity to the cathode in, for example, a ceramic mounting. The filament is energized through leads 4 and 5 from source 6. It should be noted that in the converse relation where the exterior electrode would be the cathode and the interior electrode the anode, care should be taken that electrons are emitted only from the portion of the cathode that is opposite to the anode as otherwise a large number of stray electrons would tend to produce a non-uniform discharge which would tend to affect the stability of the operation and induce temperature effects which would have the character of wastage of energy. The closure element 3, while closing the end of the coaxial conductor system with relation to the emission of large radiation and stray fields, is conductively separated from the conductor 1, which is effectively an extension of the anode A, by ceramic or the like annular elements 7 engaged between the shoulder or flange 8 of conductor 1 and the screw-threaded adjustable conducting ring 9, these elements 8 and 9 being effectively extensions of the conductor 1. Because of the conductive separation, that is, insulation, at this point a direct current difference of potential may be applied between the two sections of the imputed resonant circuit or cavity comprising the two coaxial conductors and the diode electrodes, and therefore between the cathode and anode, as by the source 10 and leads 11 and 12, the positive terminus of the source 10 being thus effectively connected to the anode 8 through the secondary winding of the transformer 47, to be described presently. The circuit is completed by the connection 13 between the filament lead and

the coaxial conductor 2 whereby the cathode C is placed at the potential of the filament.

In order that the electron discharge may occur in an evacuated space, which is a requisite, the physical structure as a whole, as has already been described, is sealed to the evacuated glass or like member 14 by a hermetic joint, or seal, at the neighborhood 15 between said bulb or container and the flange-like extension 16 of the coaxial conductor 1, and evacuated by a pump acting through a tubulation which may be attached to the bulb and afterwards sealed off. A small hole 19 in the surface of the inner cylinder 2 allows evacuation to occur within the resonant cavity between the cylinders 1 and 2.

It will be appreciated that the above recited smallness of the dimensions of the coaxial system as compared with the oscillation wave-length has been assumed solely for the purpose of simplifying the significance of the design formulas to be given and that structures whose dimensions are not small as compared with the wave-length may be employed satisfactorily consistently with design formulas which are longer than the ones to be given, but which may be derived readily therefrom by those skilled in the art by the use of well-known methods. For example, reference may be given for such an elaboration of the design analysis to a paper by S. A. Schelkunoff in the Bell System Technical Journal for October 1934 and to a paper by Carson, Mead and Schelkunoff in the April 1936 issue of the same journal. Incidentally, a more complete mathematical analysis, by applicant of the operation of vacuum tubes at ultra-high frequency, comprehending the diode oscillator principle, than is to be contained in the present specification, or as is required to be contained therein, may be found in his paper "Operation of Ultra-High-Frequency Vacuum Tubes" in the October 1935 issue of the Bell System Technical Journal, this paper being based upon, but carrying forward the analysis as in accordance with a more mature conception of, his paper "Vacuum Tube Electronics at Ultra-High Frequencies" in the January 1934 issue of the same journal.

The general method of attack in the development of a diode within which a negative resistance occurs, and the relative development of associated circuits and structure so as to perpetuate the oscillations implied by the negative resistance involves, as a first step, the finding of the power generated by the negative resistance, assuming an arbitrary magnitude for the high frequency current through it, and then the computing of the power dissipated in all of the positive resistances of the system by the currents flowing through them. For the production of oscillations this latter power must, of course, be less than the former. There are other necessary subsidiary conditions and steps in the development as will be pointed out in the more detailed later treatment.

As has been pointed out, the detailed theoretical analyses of the invention, which are not necessary over and above what will be disclosed in this divisional application to enable one normally skilled in the art to practice the present invention, will be found in the parent application.

The output power of the diode oscillator in general reaches a maximum when the potential applied to the anode is such as to cause the effective transit time to be $1\frac{1}{4}$, $2\frac{1}{4}$, $3\frac{1}{4}$, etc., cycles, as explained above, and falls off or ceases altogether between these values of potential. This

property may be employed to modulate the output wave in accord with speech or other signaling wave. Thus, in Fig. 2, the signal may be introduced at 45 through a microphone and amplifier system in conjunction with a constant potential source 46 to act through the windings of a transformer 47 and cause variations in accord with the signal to be impressed upon the anode potential of the diode. The source 10 is then adjusted so that the output amplitude in the absence of modulating signal is approximately half of the maximum. Under these conditions, the modulating signal causes the output amplitude to vary proportionately thus producing an amplitude modulation of the high frequency output which has been found to be relatively free from amplitude distortion and frequency modulation.

In the development of this Fig. 2 circuit, which incidentally has been built and found effective by applicant when caused to oscillate with a wave-length of ten centimeters and with a transit angle of five quarter-cycles, certain possibilities for further improvement were suggested. For instance, since a diode oscillator is essentially a low impedance device, even a small amount of radiation resistance may be sufficient to cause overloading or even to stop oscillations altogether, this of course suggesting the diminution of radiation. As one example, with a tube essentially the same as the one illustrated in Fig. 2, it was found that nearly five hundred mils of anode current were necessary for the production of oscillations when the tube was allowed to radiate in free space, as there disclosed, but that only one hundred twenty mils were required when the tube was connected into a wave guide which eliminated much of the radiation resistance. Moreover, in the latter arrangement, and with only two hundred mils of current, a much greater amount of power was available for useful application than when the tube was allowed to radiate into space. This will introduce the combination illustrated by Fig. 1 since this figure illustrates the combination of a wave guide output circuit with a diode oscillator of the type illustrated by Fig. 2.

Fig. 1 illustrates the use of a circuit network coupled to the diode oscillator to stabilize and enhance the circuit characteristics thereof. In this instance the network is a wave guide. A wave guide may have a variety of forms, but in general comprises either a dielectric rod or a hollow conducting tube, into either of which an electromagnetic wave of high frequency is introduced. Wave guides generally, and specific forms of couplings and terminations for the same are disclosed, per se, in Southworth Patents 2,106,768 and 2,106,771, both issued February 1, 1938. A patent by applicant, 2,142,138, issued January 3, 1938, also discloses prior art forms of wave guides and Fig. 2 therein illustrates a means for coupling the wave guide to the wave source. Fig. 1 of the present application is the same as said Fig. 2 of said patent except as comprising a diode oscillator as the specific wave source.

The wave guide, per se, is constituted by a hollow conducting tube 27, or the like. The diode oscillator is shown in the constricted portion of this tube 27 at the extreme left of the figure, the transition between the tube 27 proper and this mounting portion having the form of a hollow cone 28. To prevent radiation losses from the diode oscillator, the coupling to the wave

guide is constituted by connecting it between the wave guide, at this conical portion 28, and the additional conducting cone 29. At the other end of the wave guide a similar pair of conical elements is employed to connect the guide with the energy receiver 30, here shown diagrammatically. When waves from the diode source reach the conical members at the end of the wave guide to which it is coupled, no severe reflection of the waves results. That is, when the ratio of the diameters of the large ends of the cones at the left end of the wave guide is adjusted to match the impedance of the wave guide while the ratio of the diameters of the small ends of the same two cones is adjusted to match the impedance of the diode oscillator, the conical members perform the function of an impedance transformer effectively coupling the diode oscillator with the wave guide.

From this description, it will be apparent that the combination of wave guide and diode oscillator may provide an operative and useful system in certain cases where practical limitations prevent the diode from operating effectively alone or in extreme cases may prevent the diode from oscillating at all. For example, it was cited in the foregoing specification that a particular diode was found to require a current of five hundred mills when operating alone and thus radiating too large a portion of its energy into free space, while the same diode operated easily and effectively with a current of two hundred mills when the excess radiation was confined by placing the diode within a wave guide. In the extreme cases just mentioned, it may be inconvenient or impractical to provide a source of electron emission capable of delivering the five hundred mills required for oscillations without the use of the wave guide, whereas the much more moderate current of two hundred mills is quite readily made available.

To a greater or lesser extent this same argument and practical advantages apply to the combination of diode oscillator and any effective form of shielding. The wave guide, however, has the particular advantage over other forms, that its use enables the output energy to be controlled and directed into useful load circuits, or to be radiated at will in controlled amount at the same time that it prevents the promiscuous loss of energy by unwanted or uncontrolled radiation.

What is claimed is:

1. In combination, an output circuit for an antecedent wave source, said circuit being closely adjacent to said source and coupled to it under conditions of approximate impedance matching, said wave source comprising a diode oscillator of the type characterized by comprising two uniformly spaced electrodes in an evacuated space with means for causing a flow of electrons therebetween in substantially straight lines and an associated resonating system, said resonating system being so electrically designed relatively to

the spacing of said electrodes and the transit time of electron flow therebetween that the organization as a whole is adapted to generate stable frequency waves.

2. In combination, a wave guide, and means adjacent one end thereof for impressing an electrical wave thereon, said means constituting a diode oscillator of the type characterized by comprising two uniformly spaced electrodes in an evacuated space with means for causing a flow of electrons therebetween in substantially straight lines and an associated resonating system, said resonating system being so electrically designed relatively to the spacing of said electrodes and the transit time of electron flow therebetween that the organization as a whole is adapted to generate stable frequency waves.

3. In combination, a diode oscillator and an output circuit therefor of the wave-guide type, said wave guide comprising a conducting hollow tube and a terminal structure therefor including a pair of tapered conducting members disposed coaxially one within the other with their larger ends juxtaposed and with the larger end of the outer of said members a continuation of said tube, and means connecting said diode oscillator, as by leads connected to the cathode and anode elements thereof, to said tapered members, the ratio of the diameters of the large ends of said tapered members being such as to match the impedance of the wave guide while the ratio of the diameters of the small ends of said members is adjusted to match the impedance of the diode oscillator, whereby efficient coupling between the oscillator and output circuit constituted by the wave guide is achieved and radiation losses from the diode oscillator are minimized.

4. The combination specified in claim 3 in which the end of the wave guide remote from the diode oscillator is terminated similarly as the other end, with an energy receiver connected to the tapered members at said remote end, the relationship of the diameters of the said tapered members to the impedances of the wave guide and energy receiver being similar to the relations as effecting similar elements at the diode oscillator end of the wave guide whereby a wave transmitted along the wave guide from the diode oscillator to the receiver is not reflected at the receiver.

5. In combination, a wave guide and means for impressing an electrical wave thereon, said means constituting a diode oscillator of the type characterized by comprising two uniformly spaced electrodes in an evacuated space with means for causing a flow of electrons therebetween in substantially straight lines, and an associated resonating system, said resonating system being so electrically designed relatively to the spacing of said electrodes and the transit time of electron flow therebetween that the organization as a whole is adapted to generate stable frequency waves.

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