June 17, 1941. J. P. BLEWETT 2,246,121

HIGH FREQUENCY APPARATUS

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Fig. 1.

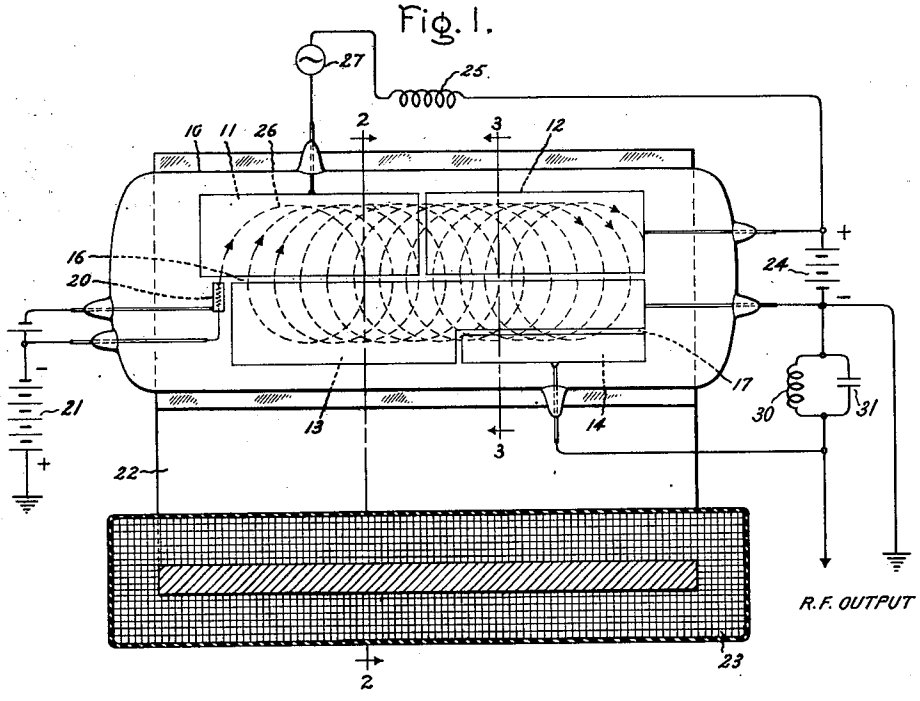


Fig. 2.

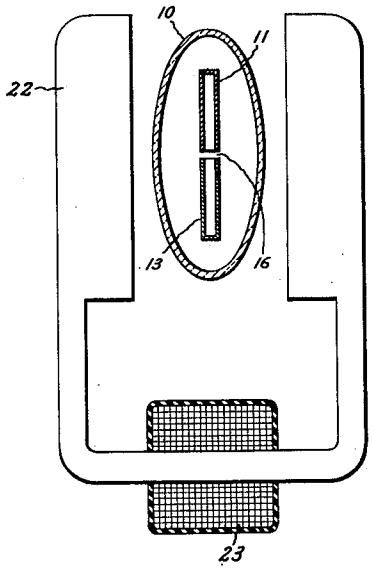
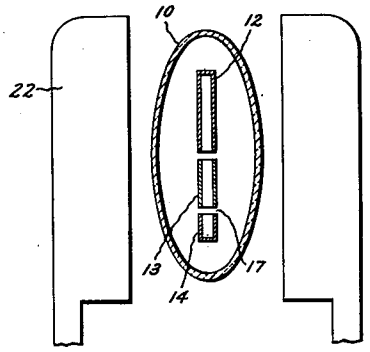


Fig. 3.



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Fig. 4.

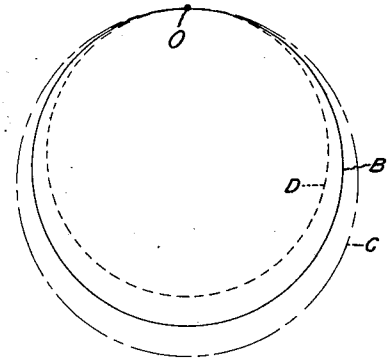
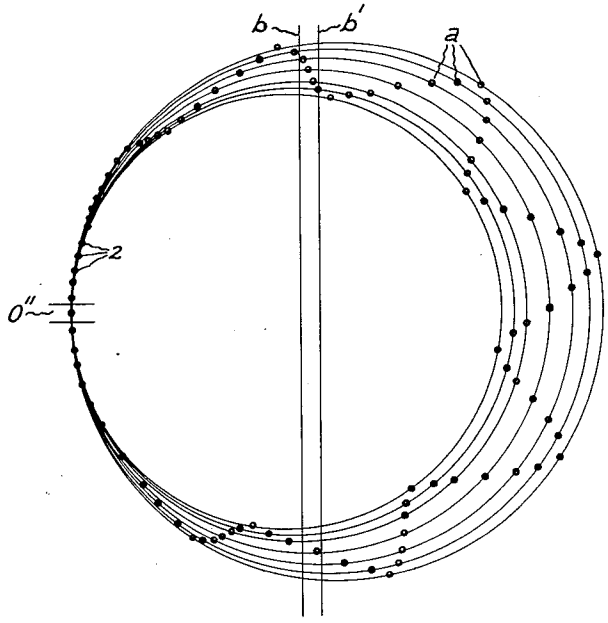


Fig. 5.



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2,246,121

HIGH FREQUENCY APPARATUS

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Application May 24, 1940, Serial No. 337,043

6 Claims. (Cl. 179—171)

The present invention relates to improvements in electronic apparatus for use at ultra-high frequencies.

The invention makes use of so-called "velocity modulation" principles which are described in Patent 2,220,839, granted November 5, 1940 in the name of W. C. Hahn. It is a primary object of this invention to provide a novel and compact tube structure in which such principles may be applied. To this end use is made of a flattened, relatively wide and long chamber through which a stream of charged particles is caused to move along a path of generally trochoidal character. By this means, one is enabled to provide a stream path of relatively great length and to achieve amplification effects depending upon this factor in spite of the use of a very compact tube structure.

The features which I desire to protect herein are pointed out with particularity in the appended claims. The invention itself, together with further objects and advantages thereof, may best be understood by reference to the following description taken in connection with the drawings in which Fig. 1 is a longitudinal view in partial section of a discharge device suitably embodying the invention, Fig. 2 is a cross-sectional view taken on line 2—2 of Fig. 1, Fig. 3 is a cross-sectional view taken on line 3—3 of Fig. 1, and Figs. 4 and 5 are diagrammatic representations useful in explaining the invention.

Referring particularly to Fig. 1, there is shown a relatively elongated envelcpe 10 which has a flattened cross-section as indicated in Fig. 2. Within the envelope there are provided a plurality of conductive parts, numbered 11 to 14 inclusive, which conjointly define a hollow chamber of flattened configuration. These conductive parts, the relationship of which is best shown in Figs. 2 and 3, are mutually insulatingly spaced so as to provide gaps 16 and 17 which extend parallel to the longitudinal axis of the envelope. The extremities of the parts adjacent the ends of the envelope 10 are preferably closed by means of transverse wall portions (not shown) so that the chamber defined by the parts is of substantially completely enclosed character.

At one end of the envelope there is provided an electron gun 20. This is not illustrated in detail, but it will be understood that it may comprise a cathode and one or more focusing and accelerating electrodes serving to produce an electron stream. The cathode element of the gun is maintained at an appropriate negative potential by means of a battery 21 and the axis of the gun is so directed that the initial path of the stream produced thereby is transverse to the principal axis of the envelope.

In accordance with my present invention the electron stream thus produced is caused to move longitudinally through the chamber formed by the parts 11—14 along a path which is of generally trochoidal character. This may be accomplished in one way by the use of a magnetic field having its flux lines extending parallel to the short dimension of the chamber, such a field being produced, for example, by a U-shaped magnetic structure indicated at 22. It will be understood that it is the function of the magnetic structure to transform the linear motion of the electrons projected from the gun 20 into orbital motion by the action of its magnetic field. The magnetic structure may be excited by means of a coil 23.

In order to assure progressive motion of the axis of gyration of each electron in a direction parallel to the long dimension of the envelope 10, a unidirectional potential is applied between the conductive part 13 and the parts 11 and 12 which are in juxtaposition thereto. This potential is provided, for example, by means of a battery 24 which is shown as being connected directly to the part 12 and indirectly to the part 11 through a choke coil 25. The potential is in such a direction as to produce a positive gradient acting on the electrons as they leave the confines of the conductive part 13 and traverse the gap 16. As a result of this gradient, the velocity, and consequently the radius of gyration, of any given electron tends to increase as the electron leaves the part 13. On the other hand, since the same electron is decelerated at the gap 16 at the instant when it next enters the gap (i. e. upon leaving the part 11) its radius of gyration will be again diminished. As a consequence of this action, which is repetitive for each passage of the electron across the gap 16, the forward movement which the electron experiences in the upper half of its orbit will be less than the regressional movement which occurs in the lower half of the orbit, and a resultant progression of the electron will occur, as indicated by the dotted line 26 of Fig. 1. The various elements of the electron stream may be collected on the end walls of the parts 12, 13 and 14 after they have traversed the entire length of the chamber enclosed thereby.

For producing high frequency effects by means of the structure above described, a cyclically varying potential may be applied between the parts 11 and 13, for example, by means of a

signal input source 27. As a result of the variable potential gradients produced in this manner across the gap 16, the various electrons which traverse the gap will be differently affected in velocity depending upon the part of the potential cycle at which they reach the gap. Specifically, certain electrons will be accelerated above the average stream velocity and others will be decelerated below such average velocity. Consequently, the beam will become velocity modulated in the sense of having recurrent variations in velocity from point to point along the beam path.

With a structure such as that shown it is apparent that each electron is caused to traverse the gap 16 a number of times. Consequently, if the average orbital transit time of the electrons is correlated to the frequency of the input signal applied from the voltage source 27, the velocity-varying effects experienced by a given electron may be made cumulative for each traversal of the gap. In the case illustrated, wherein the orbital path of the electrons is controlled by means of a uniform magnetic field, little difficulty is experienced in assuring a desired correlation between the orbital transit time of the electrons and the rate of potential variation of the input signal. This is due to the fact, demonstratable mathematically, that the time required for the various electrons to complete a single orbital turn is controlled exclusively by the strength of the magnetic field and is independent of the electron velocity. Consequently, for a given field strength, irrespective of the velocity with which a given electron may leave the gap 16, it will return to the gap within a fixed and invariable time. Therefore, if the strength of the magnetic field is properly adjusted to cause the time of orbital transit of each electron to correspond to some whole number of cycles of the operating frequency, the effect of the input system upon such electron will be additive for each of its successive traversals of the gap.

The matters referred to in the preceding paragraph may be more clearly understood by referring to Fig. 4. In this figure the solid line B may be taken to represent the path of a circularly moving electron whose velocity corresponds to the average or unmodulated velocity of the electron stream of which it forms a part. The point O is considered to represent a region at which the stream is subjected to a high frequency modulating potential.

An electron which passes the modulating agency in such time phase as to be accelerated thereby, may be expected to follow a path of somewhat greater radius than the path B, such enlarged path being represented, for example, by the dotted line C. On the other hand, decelerated electrons will describe a smaller orbit, as indicated by the dotted line D. Theoretical analysis shows, however, that each electron will require precisely the same time to traverse its orbit and return to the point O.

In order to understand the possibility of obtaining amplification effects as a result of the considerations discussed in the foregoing, it will be helpful to refer to the action of a circularly moving electron stream which is caused to traverse a modulating gap at which it is subjected to cyclically varying potential gradients. This situation is illustrated diagrammatically in Fig. 5, which may be taken to show the conditions existing at various points around the orbit of an electron stream which is caused to traverse a modulating gap at O''. For the case illustrated it is assumed that the frequency of potential variation across the gap is such that eight complete cycles of variation occur during the time required for a single electron to traverse its orbit. The small circles *a* may be taken to represent individual electrons, and, considered in the aggregate, they show the condition of the beam at a particular instant of time. As the various electrons move orbitally, those whose velocity exceeds the average beam velocity, seek an orbit of greater radius, while the decelerated electrons seek an orbit of reduced radius. As a consequence of this action, observations taken between various closely spaced azimuthal planes will show that the electron density measured at most points around the electron path varies materially with time. This variation is mainly a function of the relative displacement of the centers of gyration of the various electrons and is found to be greatest between planes which are located approximately ninety mechanical degrees from O'', such planes being indicated at *b* and *b'*. It will be noted that at the instant which is represented in Fig. 5, considerable bunching of the electrons exists between the planes *b*—*b'* at the upper side of the electron orbit, while a relative paucity of electrons exists between the same planes at the opposite side of the orbit. On the other hand, this situation would be found to be reversed at an instant taken a half-cycle later. It is, therefore, apparent that on either side of the electron orbit the portion of the beam between the planes *b*—*b'* will be characterized by the occurrence of "charge density modulation," that is, cyclical variation of electron density with time. While the charge density modulation observed between the planes *b*—*b'* is variable with the velocity modulation which produces it, it may, under practically attainable conditions, be of a higher order of magnitude; that is, even relatively slight velocity modulation produced at the gap O'' may be made to cause relatively great charge density variations in the region *b*—*b'*. Therefore, if some means are provided by which the charge variations at *b*—*b'* can be utilized in an appropriate manner, the system as a whole may be employed for amplification purposes.

In order to make use of the above-described phenomena in connection with the apparatus of Fig. 1, an output circuit comprising the parallel combination of an inductance 30 and a condenser 31 may be connected across the gap 17 which separates the conductive parts 13 and 14. It will be noted that this gap intercepts the various electron orbits at points approximately ninety degrees displaced from the points of their traversal of the gap 16. Therefore, for the reasons given in connection with the disclosure of Fig. 5, velocity variations produced by the gap 16 will produce corresponding charge density variations in the portion of the stream which traverses the gap 17. These variations will, in turn, induce currents in the conductive parts 13 and 14 and thus cause excitation of the output circuit 30, 31. The output mechanism thus provided is especially effective due to the fact that each element of the electron stream repetitively traverses the gap 17. Consequently, each electron of the stream has an opportunity to affect the output structure a number of times. With a proper adjustment of the orbital velocity of the stream this will result in cumulative effects being obtained.

While the invention has been described in connection with a pure electron discharge, it is considered to be equally applicable in connection with other types of charged particles, such as positively or negatively charged ions. Moreover, the particular structure illustrated is in no way essential to the practice of the invention, and I aim in the appended claims to cover all such equivalent variations of structure as come within the true spirit and scope of my invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. In combination, means for generating a stream of moving charges, means for causing the stream to follow a path of generally trochoidal character, modulating means acting on the stream at an initial portion of its path to produce high frequency variations in the stream velocity, and means coupled to a portion of the stream previously affected by the said modulating means for abstracting energy therefrom.

2. In combination, means for generating a stream of electrons, means for causing the various electrons in the stream to follow paths of generally trochoidal character, modulating means acting on the stream at a point relatively near its origin to produce high frequency variations in electron velocity, and means coupled to the stream at a point relatively more remote from its origin for abstracting high frequency energy therefrom.

3. In combination, means for generating a stream of electrons, means defining a flattened, relatively wide and long chamber to be traversed by the stream, means including a magnetic-field-producing structure for causing the said stream to move longitudinally of the chamber along a path of generally trochoidal character, means acting on the stream at a point relatively near its origin for producing high frequency variations in the electron velocity, and means coupled to the stream at a point relatively more remote from its origin for abstracting high frequency energy therefrom.

4. In combination, a gas-tight envelope defining a flattened, relatively wide and long enclosure, means for generating a stream of charged particles and for causing the said stream to move longitudinally of the enclosure along a path of generally trochoidal character, spaced conductive members with the envelope defining a gap in proximity to the stream path, means for impressing a cyclically varying potential between the said members to produce high frequency variations in the velocity of the components of the stream which successively pass the gap, and output means for abstracting energy from the stream after its passage of the said gap.

5. In combination, means for generating a stream of moving charges, conductive parts defining a flattened, relatively wide and long chamber which is traversed by the stream, certain of the said parts which comprise the principal lateral walls of the chamber being insulatingly spaced to provide a narrow gap which extends longitudinally of the chamber, means for applying cyclically varying potentials between the parts which bound the said gap, means for causing the said stream to move longitudinally of said chamber along a generally trochoidal path which passes in proximity to the said gap, and output means excited by variations which exist in the said stream after it has passed the said gap.

6. In combination, means for generating a stream of moving charges, conductive parts defining a flattened, relatively wide and long chamber which is traversed by the stream, certain of said parts being insulatingly spaced to define at least two mutually offset gaps which extend longitudinally of the principal lateral walls of the chamber, means for causing the said stream to move longitudinally of the chamber along a generally trochoidal path which passes in proximity to the said gaps, means for applying a high frequency input potential between the conductive parts which define one of said gaps, and output means connected across the other of said gaps and adapted to be excited by the variations produced in the said stream by the said input potential.

JOHN P. BLEWETT.