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METHOD OF PRODUCING IONIZATION AND LUMINOUS EMISSION IN A GAS OR VAPOR AND APPARATUS FOR USE THEREIN

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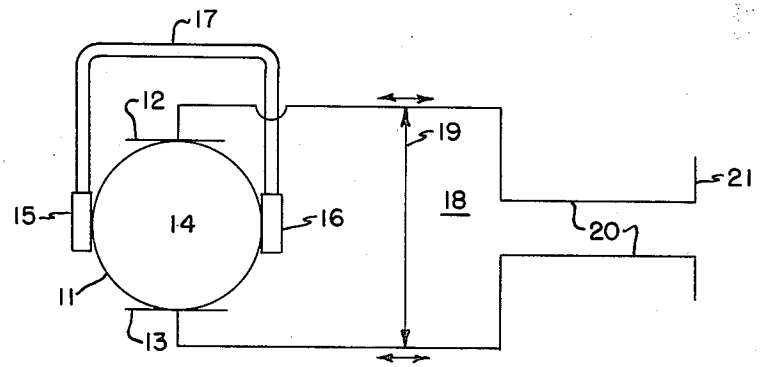


Fig. 1

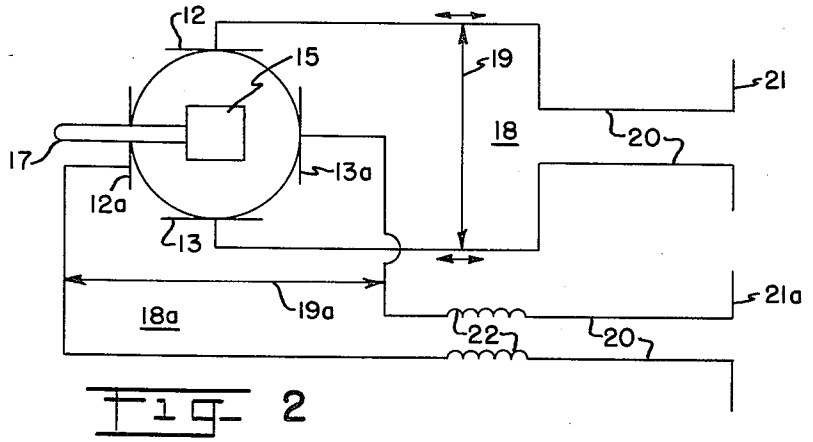


Fig. 2

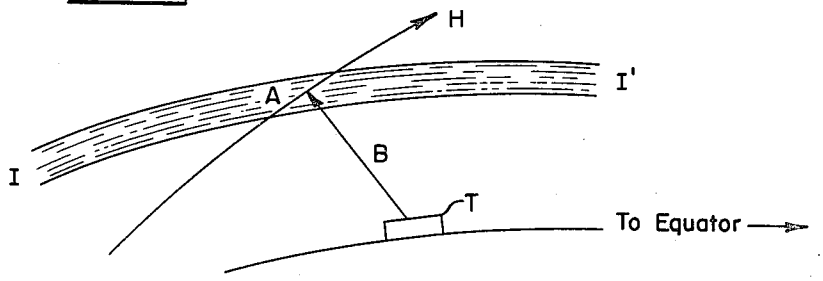


Fig. 3

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METHOD OF PRODUCING IONIZATION AND LUMINOUS EMISSION IN A GAS OR VAPOR AND APPARATUS FOR USE THEREIN

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Continuation of application Ser. No. 701,493, Dec. 9, 1957. This application Nov. 4, 1963, Ser. No. 322,005

Claims priority, application Italy, Dec. 15, 1956, 563,365

21 Claims. (Cl. 343—100)

This application is a continuation of U.S. patent application Serial No. 701,493, filed December 9, 1957, and now abandoned, which application refers to an application filed in Italy on December 15, 1956, which has matured into Italian Patent No. 563,365.

This invention is directed to a method for producing luminous emission in a gas or vapor and more particularly to the production, at great distances, of ionization and/or luminous emission in a gas or vapor by means of magnetic fields and radio waves and apparatus for carrying out the method.

It is well known that an electric field, if sufficiently intense, can cause ionization and electrical discharge in a gaseous medium. The energies required heretofore to produce this phenomenon have been too excessive to be practical and the field voltages, whether A.C. or D.C. must of necessity be high. In consequence, it has not proved economical or practical to produce sustained discharges, in a gaseous medium, by means of propagated radio waves at great distances from the transmitter.

It should be noted that the few solutions to the problem of illumination at considerable distances, through the use of electro-magnetic waves, adopted to date, have all been based on a transmission of electrical energy using radio waves of great power. In spite of that, it has never been possible to reach beyond a few hundreds yards from the transmitter even using transmitting powers of the order of tens or hundreds of kilowatts. The difficulty is explained by the existence of a fundamental law according to which the electro-magnetic field at a given point is directly proportional to the square root of the irradiated power. According to the present invention, the production of ionization and/or luminescence in a gaseous medium is not dependent on the actual transmission of an electro-magnetic field but rather the luminous electrical discharge is caused at great distance by the combined effect of crossed magnetic and radio-electric fields produced by the radiative component of the transmitted signal rather than, as heretofore, the inductive component.

It is an important object of this invention to provide an improved method of producing ionization and/or luminous emission by means of propagated radio waves in a gaseous medium located remote of the radio wave transmitter which is economical and practical.

It is a further important object of of the invention to provide an improved method of producing ionization and/or luminous emission in a gaseous medium at great distances from a transmitter which requires a minimum amount of power expenditure.

It is a further important object of the invention to provide apapratus peculiarly adapted to carrying out the method of this invention and which is characterized by its simplicity of construction, high operating efficiency and low cost of maintenance.

In accordance with one embodiment of the present invention, the method comprises applying transmitted radio wave energy to a gaseous medium, under reduced pressure, normal to a magnetic field acting on the gaseous medium, of a frequency of oscillation at about the gyro-

frequency of the gaseous medium as determined by the strength of the magnetic field acting thereon, to produce ionization of the gaseous discharge and in certain instances luminous emission.

These and other objects and advantages of the present invention will be better understood from the following detailed description when taken in connection with the accompanying drawings:

FIGURE 1 shows one form of the apparatus of the invention schematically.

FIGURE 2 shows another embodiment of the apparatus according to the invention.

FIGURE 3 illustrates schematically how the method of the invention may be applied to unconfined rarefied gases as in the ionosphere to produce ionization with the earth as the source of the magnetic field.

In the presence of a magnetic field of intensity H, where H is expressed in gauss, a free electron in a gaseous medium will travel in circular or spiral paths around the magnetic lines of force, with a frequency of 2.8 H megacycles per second, the so-called "gyrofrequency." It has been found that if a radio wave of a frequency near the "gyro" value is employed and applied at right angles to the magnetic lines of force, a resonance effect occurs, which enables the electrons, even in a weak A.C. field, to acquire substantial energies. The gaseous medium becomes ionized and luminescence may result. It has been further found that the electrical discharge occurs more easily and at a much lower tension when the radiative rather than the inductive component of an electromagnetic field is made to act on the gas. In fact, the radiative component having extremely low power can be used and consequently the discharge potential acquires a considerably reduced value as compared with that when the inductive component is used.

Referring to FIGURE 1, there is represented, in schematic form, the apparatus of the invention. A container 11 for gas, of any convenient shape, a sphere being shown, is provided having on either side two similar metallic plates 12 and 13, which comprise the plates of a condenser 14, whose dielectric consists of the container 11 and its contents. Plates 12 and 13 may conveniently be positioned within container 11, with electrical connection of a pass-through variety provided in the walls of the container and connected to each of the plates. Plates 15 and 16 are magnetic pole pieces attached to magnet 17, which may conveniently be of the horseshoe or U-shaped type. Usually magnet 17 will be of the permanent variety, but an electromagnet may be used. Plates 15 and 16 are positioned with respect to condenser plates 12 and 13 such that the magnetic field within container 11 is substantially perpendicular to an electric field to be generated between condenser plates 12 and 13.

Each plate, 12 and 13 of the condenser is connected to the tuned RF circuit 18 which consists of a sliding wire 19 or bar in shunt with the condenser field. Wire 19 is adjustably positioned to obtain a maximum voltage on condenser plates 12 and 13. Other combinations of inductances may be used to achieve a similar result, but because of its high efficiency this arrangement is to be preferred. The input of the tuned RF circuit 18 is connected by means of a suitable cable 20, of any convenient length, to an antenna 21. This antenna may consist of several elements, to give maximum gain, as generally employed in television, radar and the like. The antenna may be of a tuned variety, such as a yagi, to provide high gain at the "gyrofrequency."

The container 11 is filled with air or other gas, and/or with vapors of such substances as mercury or sodium, under low pressure. Since the container fulfills the primary function of retaining the gas or vapor, under low pressure,

it is immaterial whether either or both pairs of plates are positioned inside or outside container **11**. With this arrangement, when the antenna **21** receives an RF signal substantially at the gyrofrequency and slide wire is adjusted for maximum voltage on plates **12** and **13**, the gaseous medium is ionized and luminescence may result depending on the gaseous medium being utilized in container **11**. The container **11** is preferably made of a transparent material, such as plastic, and to achieve maximum luminescence, the inside of the transparent container **11** may be coated with appropriate phosphors which fluoresce on being excited by the ionized gas. For example, a transparent plastic sphere having high insulating properties and approximately one foot in diameter was filled with dry air at a pressure of between 1.2×10^{-3} and 2.0×10^{-3} millimeters of mercury, these pressures being suitable for a sphere not less than 4½ inches in diameter. Condenser plates **12** and **13** on the order of one foot in diameter were used and plates **15** and **16** of magnet **17** were about six inches in diameter and concave to conform to the surface of the spherical container **11**. Magnet **17** has a field strength H of about 18 gauss. An RF signal was transmitted to antenna **21** of 2.8 H megacycles (about 50 megacycles) and slide wire **19** adjusted to tune RF circuit **18** to the transmitted frequency. With a transmitted RF signal at about 50 megacycles of approximately 70 watts and with a distance of approximately 3000 feet between the transmitting antenna and antenna **21**, considerable ionization and luminescence was observed of the gas in container **11**.

FIGURE 2 illustrates a somewhat complex but more efficient arrangement. The container **11**, condenser plates **12** and **13**, magnetic pole pieces **15** and **16**, magnet **17**, tuned circuit **18**, cable **20** and antenna **21** are essentially identical with items noted in FIGURE 1. However, a second set of condenser plates **12***a* and **13***a*, with tuned circuit **18***a*, lead in cable **20***a* and antenna **21***a*. For a circular polarized beam incident on the antenna, antenna **21** and **21***a* may be dipoles or equivalent antennas positioned perpendicular to one another. For other polarization, especially linear, it may be necessary to introduce the appropriate delay circuit **22**, to provide the necessary phasing of the incoming signals on each antenna, such that the electric fields between the two pairs of condenser plates are out of phase. In consequence, the electric field, thus created inside container **11** rotates while remaining perpendicular to the magnetic field.

The magnetic field of the earth may be substituted for that of the magnet **17**, if the frequency of the incident radio wave is chosen to equal the terrestrial gyrofrequency and if the condenser plates are set as nearly as possible perpendicular to the lines of magnetic force. The terrestrial gyrofrequency will vary with latitude since the strength of the earth's magnetic field as well as inclination thereof varies from the equator to the poles. The intensity H will vary from about 0.7 gauss at the poles to about 0.3 gauss at the equator and will have a strength of 0.57 gauss at Washington, D.C. and a gyrofrequency of about 1.6 megacycles at Washington.

If the container **11** is sufficiently large, considerable inclination is permissible between the lines of force of the magnetic field and the normal to the radio-electric field.

With a large container and sufficiently powerful transmitter, the ionization and luminescence may be achieved by omitting the condenser plates, antennas, and connecting wires, whose primary purpose is to increase the intensity and control the direction of the radio-electric field. If this is done, however, the radio waves must be polarized so that the desired perpendicularity can be achieved between the static magnetic field and the electric vector of the incident radio-electric beam. The field may conveniently have either linear or polar polarization.

An extreme example of the basic principle occurs in the earth's ionosphere where the pressure is sufficiently

low that the container itself is not necessary and the earth supplies the magnetic field. It has been theoretically proved that when a radio wave of great power and of a frequency almost equal to the local gyrofrequency incides on the ionosphere, due to the effect to the terrestrial magnetic field, it is able to provoke an electrical discharge and consequently determine a luminous zone at a certain distance from the earth's surface. Thus, by employing the general magnetic field of the earth and a high-power radio transmitter on the desired gyrofrequency, with directional antenna designed to emit polarized radio waves whose electric vector incides with the ionosphere near perpendicular to the magnetic field in the ionosphere, a discharge may be produced.

Allowance must be made for ionospheric refraction, which tends to bend the waves and change the angle of incidence thereof with respect to the magnetic field. These field lines, except at the North and South poles, are inclined toward the equator. Referring to FIGURE 3, there is a representation of how this may be accomplished schematically. H represents the direction of the magnetic field and T the transmiter and antenna system, generating radio beam B, which intersects the ionosphere I–I′ in the neighborhood of A. Note that the transmitter must be on the equator side of A and that the direction of the beam from the antenna should lie in the magnetic meridian, with horizontal or circular polarization.

The enhanced ionization thus produced in the ionosphere has a potential practical use of increasing the range of radio frequencies that the region A can reflect and thus make possible radio communication on a wider frequency range. An increased aurora or airglow may accompany the phenomenon. It may be further noted that this procedure enables the control or maintenance of constant ionization in a region of the ionosphere that otherwise would be subject to marked diurnal variations.

The character of the radio waves may conveniently be of several forms. It is possible to employ a CW transmitter operating on the gyrofrequency, however, much greater efficiency results, for given total power expended, from pulsed transmissions of high peak power.

Alternatively, a basic radio-wave on UHF and VHF may be used, preferably pulsed with high peak power, and modulated by the desired gyrofrequency. This method has the special advantage of permitting the use of narrowly confined beams, and the use of high gain antennas which are easier to achieve on UHF and VHF than on lower frequencies.

To achieve maximum luminescence in the devices of FIGURES 1 and 2, the inside of the transparent container **11** may be coated with a suitable phosphor which phosphoresces when excited by the ionized gas. Thus the device of this invention with suitable antenna may be used to provide illumination in open country without the expense of transmission lines and the like utilizing the radiated power from low frequency radio transmitters, pulsed to peak power and modulated with the local gyrofrequency. This may be accomplished without interfering with normal broadcasting.

While preferred embodiments of the invention have been disclosed, it is intended that the invention not be limited thereto, but only by the true spirit and scope of the appended claims.

I claim:

1. A method for producing luminosity and ionization locally in the ionosphere which comprises propagating into a portion of the ionosphere a radio wave having a frequency between about 30 and about 3000 megacycles/sec. and modulated at about the local gyrofrequency.

2. The method of claim **1** wherein said radio wave is polarized.

3. The method of claim **1** wherein said radio wave is pulsed.

4. The method of claim **3** wherein said radio wave is polarized circularly.

5. The method of claim 4 wherein said modulation is at about 1.6 megacycles/sec.

6. The method of claim 5 wherein said radio wave has a frequency between about 30 and about 300 megacycles/sec.

7. A method for reflecting electro-magnetic waves from the ionosphere which comprises (a) producing a zone of locally enhanced ionization in the ionosphere by propagating into a portion thereof a radio wave having frequencies between about 30 and about 3000 megacycles/sec. and modulated at about the local gyrofrequency, and (b) impinging electro-magnetic waves against said zone of enhanced ionization.

8. The method of claim 7 wherein said radio wave is polarized.

9. The method of claim 8 where said radio wave is pulsed.

10. The method of claim 9 wherein said radio wave is polarized circularly.

11. The method of claim 10 wherein said modulation is at about 1.6 megacycles/sec.

12. The method of claim 10 wherein said radio wave has a frequency between about 30 and about 300 megacycles/sec.

13. A method for controlling changes caused by diurnal variations in the reflectivity of the ionosphere towards electromagnetic waves which comprises producing a zone of locally enhanced ionization in the ionosphere by propagating into a portion thereof a radio wave having a frequency between about 30 and about 3000 megacycles/sec. and modulated at about the local gyrofrequency, and adjusting the resulting ionization to compensate for diurnal variations.

14. The method of claim 13 wherein said radio wave is pulsed.

15. The method of claim 14 wherein said radio wave is polarized circularly.

16. Apparatus for the production of induced ionization and luminous emission comprising in combination a container adapted to contain a gas under reduced pressure, a magnet having a pair of pole pieces located relative to the container in such a manner that the magnetic lines of force intersect the container, at least one pair of parallel condenser plates located relative to the container in such a manner that a line joining the centers of the condenser plates is normal to the magnetic lines of force, and an antenna adapted to receive the radiative component of radio-electric energy at a predetermined frequency for application across said condenser plates.

17. Apparatus as set forth in claim 16, wherein the magnet is a permanent magnet and the condenser plates

are provided with a tuned RF circuit adapted to be tuned to a selected frequency.

18. Apparatus as set forth in claim 17, wherein two pairs of condenser plates, cable means and antennas are provided positioned relative to the container such that lines connecting each center of a pair of plates intersect at an angle normal to the magnetic lines of force and the cable means connecting one pair of condenser plates to its respective antenna includes a delay line such that the radio-electric energy received by one pair of condenser plates is out-of-phase with respect to the energy reaching the other pair.

19. Apparatus for the production of induced ionization and luminous emission comprising in combination a container containing a gas under reduced pressure, magnet means located relative to the container providing magnetic lines of force passing through the gas in the container, condenser means located relative to the container to provide an electric field through said container intersecting the magnetic lines of force within said gas in the container, and antenna means for receiving the radiative component of radio-electric energy at the gyrofrequency of said gas in the magnetic field for application thereof across said condenser means.

20. Apparatus as defined in claim 19 wherein the condenser means includes tuned radio frequency circuit means adapted to be tuned to a selected frequency.

21. Apparatus as set forth in claim 20 wherein the magnet means is a permanent magnet having a pair of pole pieces and the condenser means includes a pair of parallel plates.

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