March 8, 1955 G. WILKES 2,703,882

RADIANT ENERGY TRANSMISSION SYSTEM

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FIG. 1

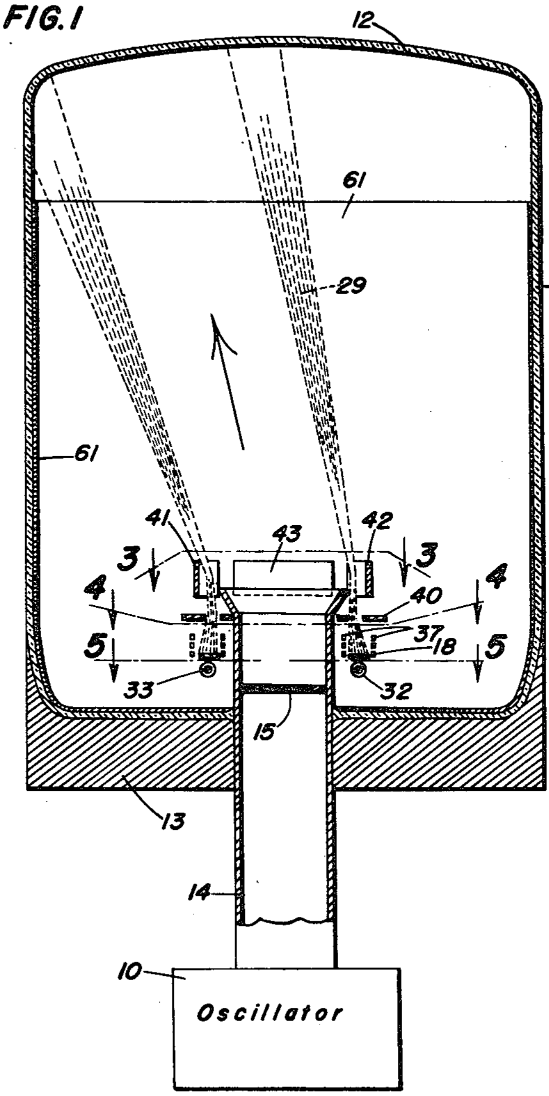


FIG. 3

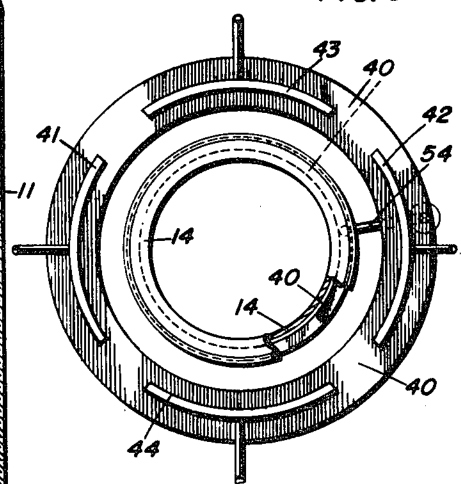


FIG. 4

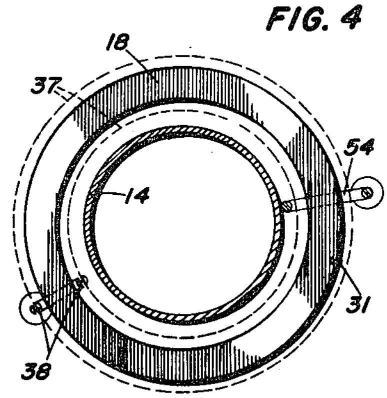
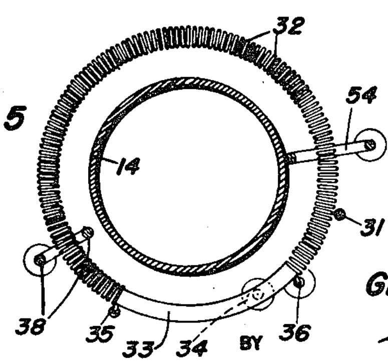


FIG. 5



INVENTOR

GILBERT WILKES

BY R. D. O'Brien

ATTORNEY

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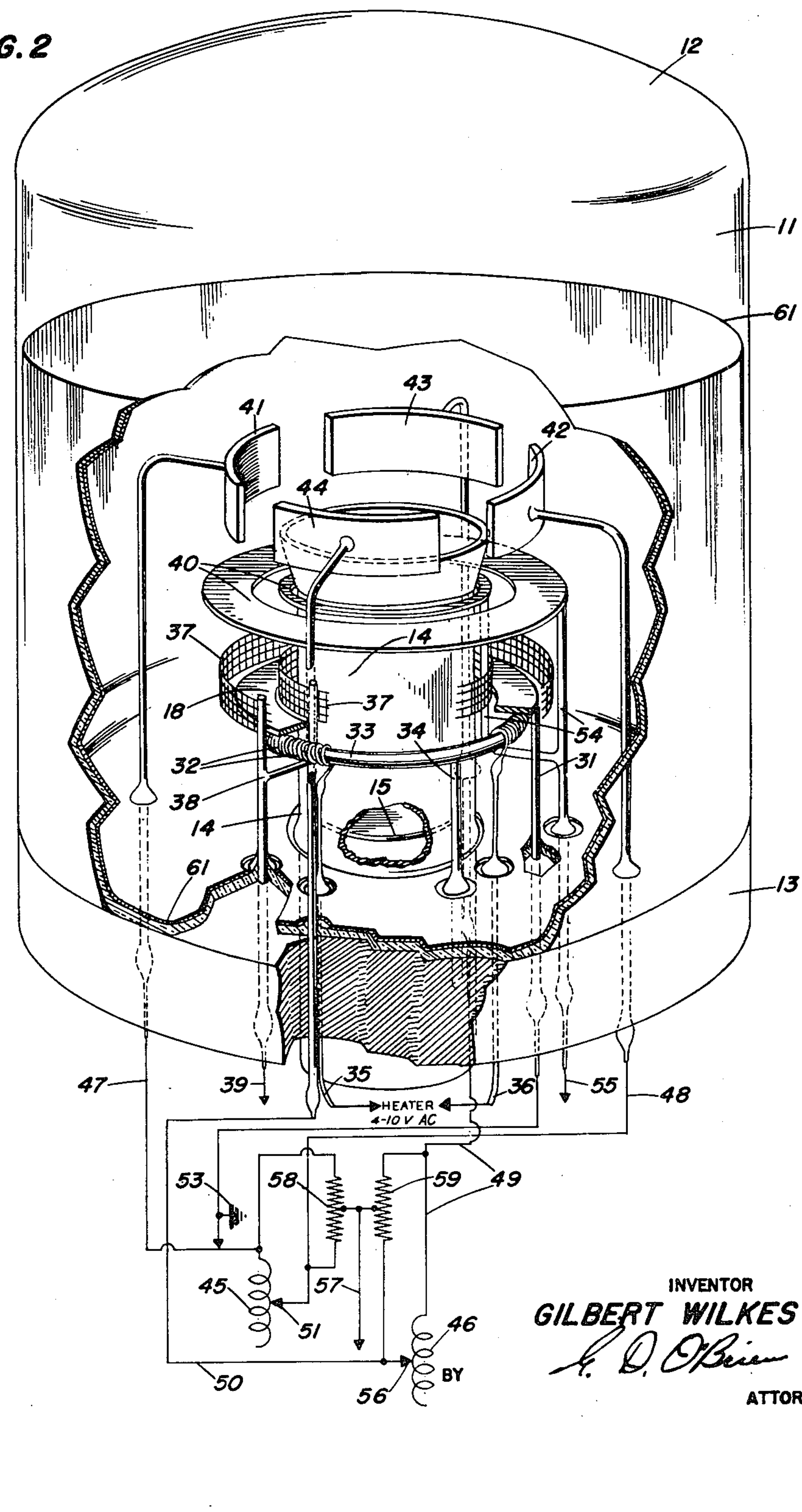
FIG. 2



INVENTOR
GILBERT WILKES
BY
ATTORNEY

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RADIANT ENERGY TRANSMISSION SYSTEM

Gilbert Wilkes, Washington, D. C., assignor to the United States of America as represented by the Secretary of the Navy

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19 Claims. (Cl. 343—100)

The present invention relates to apparatus and processes concerning radiant-energy transmission systems. It contemplates the provision of an artificial electron cloud for reflecting high frequency electromagnetic waves. It also embraces the provision of such an electron cloud for guiding or confining a radiant-energy beam along a predetermined path of travel or within a chamber. In its broad aspect the invention comprises means and processes for artificially providing an electron cloud and for so controlling that cloud as to attenuate, guide, reflect, confine or otherwise direct electromagnetic wave energy.

The cloud may be used as a wave guide, as an attenuator, as a confining portion of a wave guide, as a choke or as a reflector. Since such a cloud may be deflected by the application of suitable magnetic or electrostatic potentials, this invention in a more narrow aspect comprises means and processes for artificially providing an electron cloud whereby to direct a high-frequency electromagnetic wave, and for deflecting that cloud, whereby the direction of travel of the wave is varied. Since the cloud is substantially inertialess, this invention provides a means and method for changing the direction of travel of electromagnetic wave energy, which means and method do not suffer from the disadvantages attendant upon the use of mechanical systems.

While this invention has a wide range of prospective application, it is of particular utility as embodied in a nutator. The development of a nutator free from the limitations inherent in the inertia, friction and elastance parameters of mechanical systems posed the problem solved by this invention. The invention is herein described, by way of illustration and not of limitation, as incorporated in a nutator. It will be understood by those skilled in the fire-control radar art that a nutator is a device employed in radio direction and ranging systems for searching and scanning a target. Prior-art nutators have been premised on mechanisms for angularly so moving an antenna assembly or other radiating expedient that the axis of a beam of electromagnetic energy (hereinafter referred to as the "radar beam") generates a cone of circular or elliptic section. The position of the target is precisely ascertained by means of associated signal circuits which respond to the behavior of the echo signals as the radar beam is nutated.

The above-mentioned mechanical nutators are subject to the following major disadvantages: (1) the rapidity of their action is limited by their inertia; (2) they require complex arrangements of gears, shafts, eccentrics and the like for moving the radiating member; and (3) they also involve complicated means for preventing transmission losses of electromagnetic energy, discontinuities and resultant undesired wave reflections.

It is an object of this invention to provide a novel electrical device for confining electromagnetic wave energy.

Another object of this invention is to provide a novel device for attenuating wave energy.

It is also an object of this invention to provide a novel electrical device for reflecting electromagnetic wave energy.

A further object of this invention is to provide a novel electrical device for guiding electromagnetic wave energy.

Another object of this invention is to provide a substantially inertialess device for changing the direction of propagation or reception of electromagnetic wave energy.

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A primary object of this invention is to provide an electronic device for controlling the direction of propagation of radiant energy.

A secondary object of this invention, as embodied in a nutator, comprises the providing of a novel wave guide having such operation that it rapidly responds to control signals to change the direction of transmission of electromagnetic wave energy.

Such objects also include the providing of a nutator having no moving parts.

Another object of this invention is to provide an improved electronic tube for controlling a characteristic of an electromagnetic wave beam.

Among the objects of this invention is the providing of a novel combination of a tube for controlling a characteristic of a radar beam or the like and a conventional wave guide for introducing the beam into the tube.

Other objects are the providing of processes for accomplishing the above-mentioned objectives and of means for avoiding the disadvantages and limitations of prior-art nutators.

For an understanding of the present invention together with other and further objects thereof reference is made to the following specification, to the claims appended thereto, and to the accompanying drawings in which:

Figure 1 illustrates a radiant-energy transmission system in accordance with this invention, a conventional high-frequency electromagnetic energy source being shown in block form and this improved nutating device being shown in section;

Figure 2 is a perspective view, partly broken away, of this improved nutator, showing in detail the electron gun structure thereof; and

Figures 3, 4 and 5 are sectional views of the nutator taken on the planes indicated by the lines 3—3, 4—4, and 5—5, respectively, of Fig. 1, looking in the direction of the arrows.

Referring now specifically to Fig. 1 there is illustrated in block form an oscillator **10**, which may be a conventional source of high frequency electromagnetic energy. The numeral **11** represents an evacuated envelope having an end portion **12** which is transparent to and readily passes electromagnetic wave energy of the frequency employed in radar beams.

A suitable base **13** is provided for carrying the terminals of the tube electrodes. Centrally located in this base is an opening for a wave guide **14**, here shown as circular in cross-section. This tubular metallic wave guide **14** is sealed vacuum-tightly into the envelope **11** at the place where it enters the latter. The tube is closed by a partition **15**, which forms a tight joint with the wall of the wave guide **14**. This partition is made of non-conducting material, to minimize obstruction of the energy entering the tube envelope **11** through the wave guide **14**. This energy would be short-circuited or reflected in an undesirable manner if the partition **15** were made of conductive material. The positions and thicknesses of the partition **15** and of the end wall **12** are so determined as to eliminate any undesired reflection which might otherwise be set up between them. The wave guide **14** is coupled to the radio frequency energy source **10** by any suitable conventional expedient.

A flat, ring-shaped cathode **18**, of the indirectly heated type, is mounted radially outwardly from and coaxially with that portion of the wave guide **14** which projects within envelope **11**. The cathode **18** is mounted on a suitable support **31**, as shown in Fig. 2. The cathode **18** is grounded as indicated at **53**. A cathode heater element **32** is wound on a suitable circular supporting form **33** and the latter is secured to the tube base by any suitable mounting expedient **34**. Conductors **35** and **36** connect the heater to any suitable power source (4–10 volts, alternating current). Also disposed radially outwardly from and coaxially with the wave guide **14** is a focusing grid **37** suitably mounted on a support **38**. The grid **37** comprises two flanged portions, one located radially inwardly from cathode **18** and the other located radially outwardly from the cathode. The grid **37** is negatively charged in order to compress the electron flow as desired. The grid **37** is connected to the negative terminal of a suitable source of biasing potential (0–100 volts) by conductor **39** and the positive terminal of this source is grounded. The electron gun structure is completed by an accelerating anode **40**, which has flange portions located radially inwardly and outwardly of cathode **18** and is mounted on an appropriate support **54**. The accelerating anode **40** is connected to the + terminal of a suitable source of space current (100–500 volts, positive with respect to cathode) by conductor **55**. This electron gun structure differs from the conventional electron gun primarily in the respect that it produces a stream of electrons in the form of a tube rather than in the form of a beam or pencil. For the purpose of deflecting this stream there are provided a set of left-right deflecting plates **41—42** and a set of up-down deflecting plates **43—44**. As best seen in Fig. 3, each of these plates is bent into an arc to the end that the circular shape of the electron stream may be maintained. The sets of plates are in space quadrature. Time-quadrature voltages are produced individually in the inductances **45**, **46** by a suitable alternating current source. One of these quadrature beam-deflecting voltages is applied to plates **41—42** by conductors **47, 48**. The other of these deflecting voltages is applied to plates **43—44** by conductors **49, 50**. In order to vary the beam deflecting potentials, sliders **51, 56** are provided. For the purpose of controlling the desired flaring of the electron cloud or horn **29**, a positive potential is applied to all of the plates **41—44** by a suitable direct current source (not shown) through a network comprising conductor **57** and resistors **58** and **59**, resistor **58** being connected across conductors **47, 48**, resistor **59** being connected across conductors **49, 50** and conductor **57** being connected to center taps on resistors **58, 59**. When all of the plates are made more positive, the electron horn is made more divergent.

A conductive coating **61** is provided on the interior surface of the envelope **11** to act as a collector electrode and to afford a return path to the cathode circuit for the cathode-ray beam current. This coating may be of a conventional type consisting of a layer of graphite applied to the inside surface of the glass.

The degree of evacuation of the envelope is important. To reflect a wave of a definite frequency a definite electronic concentration is necessary at which transmission by penetration of the wave through the electron cloud is nil and reflection is lossless. To reflect a wave of a definite power, a definite depth of electron cloud is necessary, below which partial transmission (i. e., penetration of the wave through the electron cloud) will occur. The walls of the electronic wave guide **29** must therefore have at least a minimum concentration and thickness in order to handle a given wave of electromagnetic energy, which requirement results in relatively high cathodic current for the usual radar beams unless the bulk of this concentration is obtained by secondary ionization. On the other hand, high power energy waves will spontaneously ionize the gas in a poor vacuum such as is used in neon illuminating tubes and will cause cut off of said energy. A vacuum is provided such that the residual gas pressure lies between 10^{-3} mm. and 2×10^{-2} mm. of mercury.

Such an atmosphere is found in the usual cathode-ray tube. It will not ionize spontaneously when subjected to high power waves. When proper potentials are applied to the cathode and to the control grid **37**, the tube produces a cathode-ray beam consisting of emitted electrons plus the positive ions generated thereby. This beam is tubular and it acts as a wave guide extension for energy propagated through the wave guide **14** in the direction indicated by the large arrow. The cathode ray beam **29** serves as an extension of the wave guide **14**. This extension or horn formed by the cloud **29** has several interesting properties. First, it is a flexible extension because it can be deflected by the application of suitable potentials to the deflecting plates **41—44**, which potentials are applied in a manner well known to those skilled in the cathode ray tube art. For example, if equal alternating current voltages in time quadrature are applied to the deflecting elements **41—42, 43—44**, the axis of the cathode ray tube beam will describe a constructive circular trace on the end **12** of the envelope. If one of the two deflecting potentials is of higher magnitude than the other, an elliptic trace will result, and so on. These facts provide the proper basis for nutation. The reason for this is that as the beam **29**, which acts as a wave guide extension, is nutated, so too the radiant energy beam which passes through the wave guide and extension is nutated.

Additionally, by varying the electronic concentration of the cloud **29**, the attenuation of the electromagnetic energy originating in source **10** and propagated through guide **14** and cloud **29** may be varied.

The actual dimensions of the metallic wave guide and the length and flare of the electronic horn ultimately depend on whether a round or rectangular wave guide is employed and on the type of secondary focusing means incorporated. For purposes of illustration, a circular wave guide having an inner diameter of 1.15″ and an electron horn flaring to 1.75″, inner diameter, are suitable.

The parameters hereinabove mentioned are given by way of illustration and not of limitation and this invention is not limited to the particular dimensions given or to the particular application shown. This invention resides in the providing of an electron cloud for deflecting, reflecting and/or attenuating in a controllable fashion electromagnetic waves, and in the provision of means for controlling the electron cloud, and should not be limited by the structure of any particular electron gun. Moreover, while it is not desired to be limited to any particular scientific theory for explaining the operation of this invention, it is believed that the thickness of the electron cloud required for complete reflection is a function of the energy concentration to be reflected. It is indicated in the classical treatises on electromagnetic theory that total reflection occurs from a cloud of electrons for a given frequency and that the phenomenon is a surface one without any penetration. However, it is currently considered that reflection does not occur at the cloud surface when the energy of the electromagnetic beam becomes great. Applying elementary mechanics to the motion of an electron under the influence of the potential only at a 50 kw. 3 cm. wave, it is found that a cloud of 10^{13} electrons per cubic centimeter will be penetrated to a depth of 0.25 cm. before sufficient electron weight is encountered totally to reflect the wave potential. It is possible that later investigations will reveal that the electrons oscillate in circular paths due to the magnetic field of the wave, as well as in the linear paths required by the potential of the wave. Advanced researches made at a later time may permit the provision of an electron cloud of lesser thickness than the one indicated above.

A certain gas pressure cannot be exceeded for a given energy without incurring the risk of auto-ionization. This pressure is a function of the molecular spacing and the maximum electronic oscillation under the influence of the electromagnetic wave. For 50 kw. waves this pressure lies well under 5 mm. of mercury. For low energy waves spontaneous ionization is not to be feared, and any pressure is acceptable from this standpoint.

On the other hand the lower the pressure, the longer the free path, the greater the electron velocity and the higher the cathode current requisite to establish the desired concentration. Argon has been found to be the most satisfactory of the gases employed in practice. The presence of mercury is valuable in shortening the mean free path of electron travel. In practice, excellent results have been obtained with argon at a pressure in the neighborhood of 1 mm. with mercury added. An electron flow of 300 milliamperes with a potential gradient of 1.2 volts per cm. has been obtained. An electron cloud set up in this manner is sufficient to form the horn **29** of the nutator.

It will be seen that means have been disclosed herein for providing electrical nutation of a stream of radiant energy without using any mechanically moving parts. Since the cathode ray beam comprises solely electrons and ions, its inertia is very small and the pattern of nutation may be changed abruptly, thus avoiding the delays due to inertia in mechanical-type nutators heretofore employed. This feature saves important seconds otherwise lost in combat operations during the shift from elliptic to circular nutation and thus decreases the danger of losing the target at such time. Moreover, this nutator is exeremely fast-acting and can be operated at a high nutation rate.

While the embodiment disclosed herein appears at present to the preferred form of the present invention, it will be obvious to those skilled in the art that various changes and modifications may be made therein without departing from the spirit of the invention and it is, accordingly, intended that the appended claims cover also all such changes and modifications. The invention resides broadly in novel arrangements and processes for causing the reflection and/or attenuation of an electromagnetic wave by an electron cloud. It will also be obvious to those skilled in the art that magnetic beam-deflecting members may be substituted for the electrostatic beam-deflecting elements shown.

What is claimed is:

1. The process of deflecting a radiant energy beam which comprises projecting said beam through an opening extending through an electron cloud and controlling said cloud together within its opening to vary the deflection of said beam.

2. In combination, means for producing a radiant-energy beam and means for producing a cloud of electrons having a passage extending therethrough, the last-named means being so positioned with respect to the first-named means that said beam passes through said passage and is surrounded by the cloud.

3. In combination, means for producing a radiant-energy beam, means for producing an apertured cloud of electrons, the last-named means being so positioned with respect to the first-named means that said beam passes through an aperture in said cloud, and means for varying a characteristic of said cloud, thereby to determine a characteristic of said beam.

4. The combination in accordance with claim 3 and in which the last-named means is for deflecting said cloud and the position of said aperture, thereby to determine the direction of transmission of said beam.

5. In combination, cathode-ray tube means for producing a tubular deflectable electron beam, and means for projecting electromagnetic wave energy through said tubular portion of said beam.

6. The process of guiding high-frequency electromagnetic energy which comprises the steps of forming an ionized space charge as a conduit and introducing the energy to be guided into one end of said conduit.

7. The process of guiding high frequency energy which comprises the steps of producing in a low-pressure aeriform medium a tubular inertialess guide having a bore comprising electrons and ions and introducing the energy to be guided into said guide, whereby substantially total internal reflection confines the high frequency energy within said bore of said guide, thereby to determine the direction of transmission of said energy.

8. The process in accordance with claim 7 and in which said guide is electrostatically deflected.

9. An electronic tube for providing a tubular cloud of electrons and ions comprising an envelope, a wave guide having a portion extending into said envelope, and an electron gun structure surrounding said portion.

10. In a radiant-energy transmission system a wave guide comprising a solid reflecting portion and a reflecting portion consisting solely of an artificially produced electron cloud, said cloud constituting a tube which forms a continuation of the solid portion of the wave guide.

11. In a radiant-energy transmission system a wave guide comprising a solid reflecting portion and a reflecting portion consisting entirely of a controllable electron cloud, of such shape and configuration that it constitutes a continuation of the wave guide.

12. In a radiant-energy transmission system, a wave guide comprising a solid reflecting portion and a reflecting portion consisting wholly of an artificially produced electron cloud, constituting a tubular wave guide portion forming an extension of the said solid portion of the guide and means for controlling a characteristic of said cloud, thereby to control a characteristic of the transmission of said radiant energy.

13. A radiant-energy confining arrangement comprising a rigid wave guide and means for producing an electron cloud in continuity with said wave guide, said cloud and said wave guide cooperating to confine said energy.

14. The process of guiding high frequency electromagnetic energy, which consists in producing a tubular field having a bore, comprising electrons and positive ions, in a low pressure gaseous medium, deflecting said tubular field by means of electric and/or magnetic fields, and introducing the energy into the bore of said tubular field, whereby substantially total internal reflection will confine the high frequency energy within said bore.

15. An electronic tube for providing a tubular field of ions and electrons, said tube comprising a gas-tight envelope, a wave guide extending through said wall of said envelope and having a portion projecting into the interior thereof and a set of electrodes, including, a cathode and control electrodes surrounding said portion of said wave guide, said envelope having a suitable degree of partial vacuum therein.

16. The method of deflecting a radiant-energy beam which comprises the steps of projecting a radiant-energy beam through a tubular stream of electrons, and deflecting said tubular stream of electrons to secure displacement of the apparent source of said radiant-energy beam.

17. The method of deflecting a radiant-energy beam which comprises forming a tubular stream of electrons to guide a beam of radiant-energy fed to the center of said tubular electron stream, and deflecting said tubular electron stream in any desired fashion and rate so as to cause the apparent source of said radiant-energy beam to be displaced in any desired fashion.

18. In combination, a wave guide having a first passageway extending therethrough, and means for producing an electron cloud at one end of said wave guide, said cloud having a second passageway extending therethrough, said second passageway being arranged to be an extension of said first passageway in said wave guide, whereby electromagnetic energy can be propagated through said passageways of said wave guide and said electron cloud.

19. In combination, a wave guide having a first passageway extending therethrough, and cathode-ray tube means for producing a deflectable electron beam, said beam having a second passageway extending therethrough, said second passageway being arranged so that it is a continuation of said first passageway in said wave guide, whereby electromagnetic energy can be propagated through said passageways of said wave guide and said electron beam.

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