

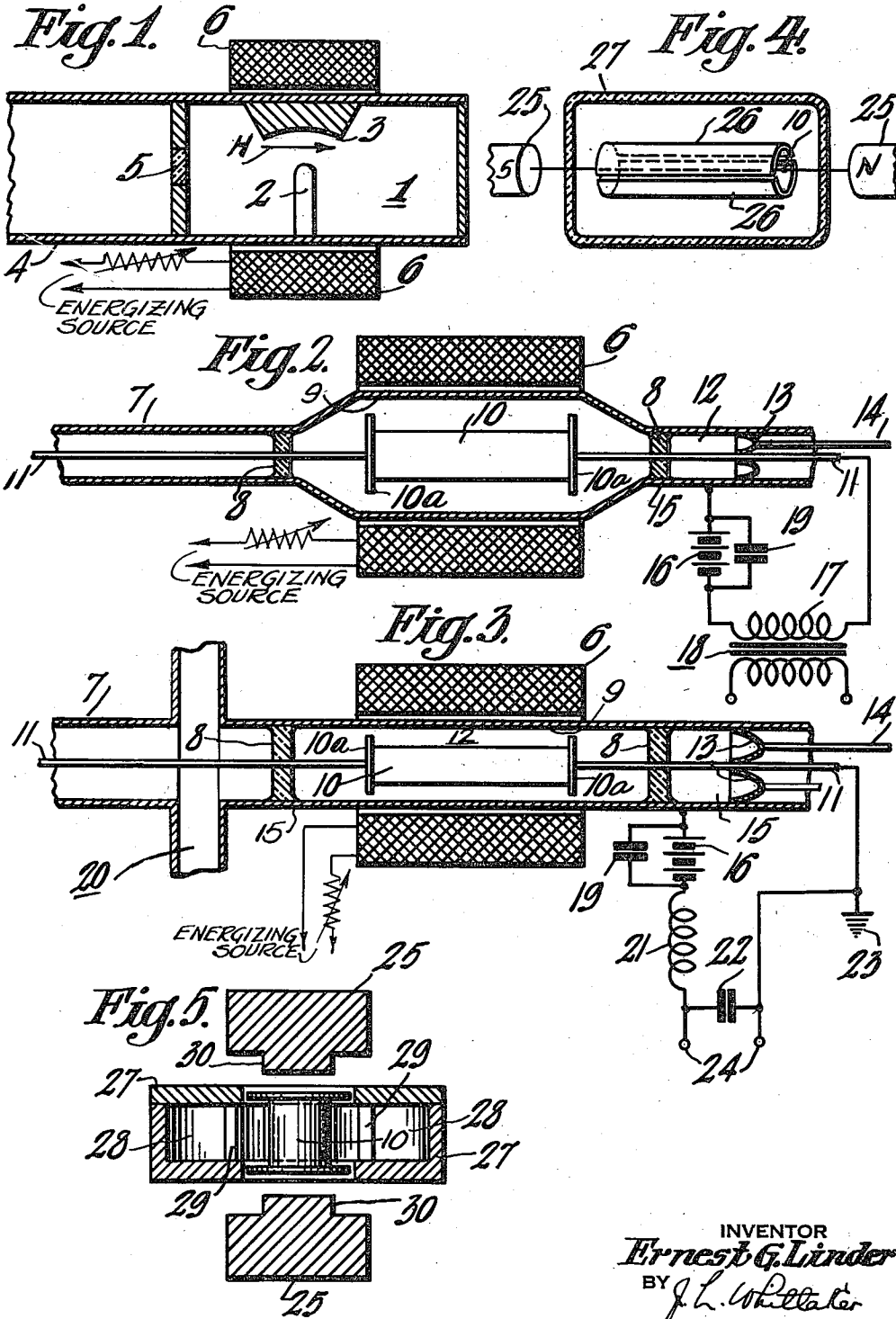
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E. G. LINDER

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APPARATUS FOR UTILIZING CUMULATIVE IONIZATION

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INVENTOR
Ernest G. Linder
 BY *J. L. Wheeler*
 ATTORNEY

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APPARATUS FOR UTILIZING CUMULATIVE
IONIZATIONErnest G. Linder, Princeton, N. J., assignor to
Radio Corporation of America, a corporation
of Delaware

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This invention relates generally to high-frequency radio devices and more particularly to such devices in which ionization of the medium within a tube of the device is involved in the operation of the device.

In my copending U. S. patent applications, Serial Numbers 49,736 and 66,113, filed on September 17, 1948, and December 18, 1948, respectively, now respectively Patents Nos. 2,548,225 and 2,540,537, there were disclosed and claimed certain radio tubes and associated circuits that depended for their operation on the cumulative ionization of the medium within the tubes, which ionization was produced by the "trapping" of the electrons within the tube envelopes.

In the present invention, a high frequency electric field is combined with a magnetic field of critical intensity value, proportional to the frequency of the electric field, whereby a resonance condition is produced between the orbits of the electrons and the applied radio frequency electric field. Under these conditions the electrons will absorb energy from the high frequency field and this energy is available for ionization. With this ionization, the ion density is increased rapidly and a short build-up time is had.

Under these critical operating conditions, it is not necessary either to coat the cathode or heat the cathode as the increased ionization starting from residual free electrons in the medium becomes a new source of electrons for the cumulative ionization.

My discovery is applicable generally to high frequency devices that depend for their operation on cumulative ionization. For example: the efficiency of operation of a transmit-receive (TR) tube in a radar system, used to isolate the receiver from the transmitter during transmission periods, depends upon increases in ion densities and the rapidity of ionization and deionization of the medium within the tube. I have increased the rapidity of these functions and increased the ion density by applying a magnetic field generally at right angles to the plane of the paths of the electrons in the medium within the tube and adjusting the strength of the magnetic field to such a value that the frequency of electron motion is equal to the operating frequency of the system. With such an arrangement it is practical to operate the tube at lower pressures.

It has been discovered that when this resonance relation of the frequency of electron motion to the operating frequency is applied to a device or system, a much more positive or augmented ionization occurs and an improvement in operating efficiency is had.

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The frequency of electron motion under the influence of a magnetic field is in accordance with the equation:

$$f = \frac{He}{2\pi m} \quad (1)$$

where H is the strength of the magnetic field, e is the charge of the electron, m is the mass of the electron, all in MKS system units. As it has been found that the critical optimum operating condition of the device is had when the frequency of operation is equal to the frequency of electron rotation, the strength of the magnetic field for the improved optimum operation will be in accordance with the equation:

$$H = \frac{2\pi fm}{e} \quad (2)$$

where f is the operating frequency of the device in cycles per second and H, m and e are in MKS units, as in Equation 1.

In the remainder of this specification and the appended claims, this equation will be identified as "Equation 2."

This discovery is applicable with equally beneficial results in operation, to other high-frequency devices, such as demodulators, rectifiers and magnetrons, as will be fully described hereinafter.

The principal object of the invention is to provide an improved method of and means for increasing the efficiency of operation of high frequency radio tube devices operating with intermittent ionization, by applying thereto magnetic fields of critical values.

Another object of the invention is to provide an improved method of and means for increasing the efficiency of operation of said high frequency radio tube device by applying thereto magnetic fields of a strength proportional to the frequency of electron rotation frequency of the device.

Another object of the invention is to provide an improved methods of and means for increasing the efficiency of operation of said high frequency radio tube devices by applying thereto a magnetic field of a strength represented by Equation 2 hereof.

A further object is to provide improved methods of and means for operating cold cathode tubes in a manner wherein the charged particles due to ionization traverse orbits resonant to the operating frequency.

Other objects of the invention will be apparent from the various embodiments and features of the invention as will be described in detail hereinafter and by reference to the accompanying drawings in which:

Figure 1 is a line sketch of a TR tube coupled to a wave guide and upon which tube is impressed a magnetic field;

Figure 2 is a line sketch of a demodulator tube and associated circuits, upon which tube is impressed a magnetic field;

Figure 3 is a line sketch of a coaxial conductor on an evacuated portion of which is impressed a magnetic field, the coaxial conductor being connected to associated circuits to form a high frequency rectifier;

Figure 4 is a line sketch in perspective of a novel ionizable split anode magnetron upon the medium of which is impressed a magnetic field; and

Figure 5 is a line sketch in cross section of a novel ionizable multicavity magnetron upon which is impressed a magnetic field.

Like reference characters refer to like elements throughout the drawings.

With reference to Figure 1, numeral 1 represents the cavity resonator of a TR tube or box in which are positioned the electrodes 2 and 3. This tube 1 is connected physically to wave guide 4 and is coupled thereto through window 5. Around the two electrodes 2 and 3 are positioned the magnet coil 6. The strength of the magnetic field is adjusted in accordance with Equation 2 hereof.

The magnetic field is indicated by the arrow H as being generally at right angles to the paths of electrons from electrode 2 to electrode 3. Due to the general shape of electrode 3 in relation to that of electrode 2, the magnetic field could be impressed upon the medium at right angles to that shown by the arrow H.

In operation: When a voltage difference first appears between electrodes 2 and 3 due to the voltage rise at the beginning of a transmitter pulse, a few free electrons start to flow therebetween.

In all TR tubes, the density of the electrons flowing between the electrodes must rise to a considerable value before the medium becomes sufficiently conductive. In accordance with the instant invention, by applying a magnetic field of the critical value to the medium as hereinbefore defined, the free electrons are trapped within the medium, their paths become much longer and ionization of the medium occurs at a greater rate.

It has been found in operation that when a critical magnetic field is impressed on the tube, the pressure within the tube can be lower than that usually required for these tubes. The mean free path for molecular collision is longer for the lower pressures and provides faster deionization. Gas pressures of 10^{-2} and 10^{-3} mm. of Hg have been found to give excellent results.

My discovery has been applied to a section of a coaxial line conductor to provide, with outside circuits, a more efficient demodulator, which provides better high frequency response and eliminates the necessity for a hot cathode. In Figure 2, a section of the coaxial conductor 7 is blocked off by glass beads 8 and the outer section of the conductor is expanded to form the anode-envelope 9. Cold cathode 10 is positioned axially the envelope 9 and is connected to the axis conductor 11. A magnetic field is impressed upon the medium within envelope 9 by the electromagnetic coil 6.

Connected to envelope 9 and cathode 10 is an adjustable section shown generally at 12, which is tuned for optimum operation by moving the piston 13 by handle 14.

In operation: The outer conductor 15 of the resonant section 12 is maintained positive by the electric source 16, which is connected also through the primary 17 of transformer 18 to the axial conductor 11. Capacitor 19 parallels electric source 16 to by-pass the demodulated frequencies. The output energy is withdrawn from the circuit from the secondary of transformer 18. The ionization of the medium and the trapping of the electrons within envelope 9 are as previously disclosed, with the efficiency of the arrangement augmented at the frequency:

$$f = \frac{He}{2\pi m} \quad (1)$$

My discovery has been applied to a high-frequency rectifier, as shown in Figure 3, which operates under the same general principles including a magnetic field, as the demodulator shown in Figure 2, except that the arrangement operates over other portions of the characteristic curves of the tube, as is well known in the art. However, the efficiency of the arrangements, as in the case of the demodulator is increased when a magnetic field of critical value is applied to the medium between glass beads 8 in which is located the cathode 10 which includes contiguous end plates 10a. The anode 9 is a section of the outer conductor 15, separated physically from the conductor 7 by capacitor connection 20. The resonant cavity 12 is tuned by sliding piston 13 which is moved by handle 14. Outer anode conductor 15 is maintained at a positive potential from source 16, which is by-passed by capacitor 19. The output of the rectifier is through a filter comprising inductor 21 and capacitor 22. One side of capacitor 22 is connected to ground 23, to cathode lead 11, and to one of the outlet terminals. 24. The other side of capacitor 22 is connected to one end of inductor 21 and the other outlet terminal 24. The other end of the inductor 21 is connected to the anode 15 through the electric source 16 and capacitor 19.

In Figures 4 and 5 are shown magnetrons of the split anode type and the resonant multicavity type, respectively. These differ from the conventional types in that, among other things, they have gaseous media of a predetermined very low pressure range. In applying my discovery to magnetrons, the magnetic field is made to serve two purposes. First, it is used to provide the operating field of the tube and secondly, it is used to provide the trapping magnetic field of the critical value whereby ionization of the gaseous medium of the tube is accomplished.

In Figure 4, the magnetic field is applied by magnet poles 25 upon the medium of the tube between cathode 10 and split anode section 26. The magnetic field may also be produced and adjusted to the critical value for the frequencies involved, by substituting an electromagnetic coil and a source of variable electric power.

In Figure 5, there is shown the application of my discovery to a multicavity magnetron. The magnetic field is applied by permanent magnet poles 25 to the magnetron through the nonmagnetic material forming the envelope and body 27 of the magnetron. Cathode 10 is mounted in the axis of the central resonance chamber which is in communication with cavities 28 through slits in the main body. Slits 29 connect the central chamber with other cavities, not shown. As hereinbefore pointed out the cathode 10 need not be coated or heated. The pole pieces 25 may be shaped, such as is shown at 30, to apply a non-

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uniform magnetic field to the magnetron. Higher efficiencies may be obtained, especially with magnetrons operating with gases at relatively low pressure values, when the magnetic field is not uniform and is concentrated along the axis of the magnetron.

The relation between the variables as defined in Equation 1, does not apply strictly to the multicavity type of magnetron as the interaction between cavities in a multicavity magnetron is well known to be different from the interaction between circuits connected to a multisector or split anode type of magnetron. However, there does exist for the multicavity magnetrons a relation between the operating frequency, the anode voltage and the impressed magnetic field as expressed by the equation:

$$V_p = 300\pi \frac{(r_p^2 - r_a^2)}{n\lambda_0} \left(B_z' - \frac{10463}{n\lambda_0} \right) \quad (3)$$

where V_p is the anode voltage, r_p is the anode radius, r_a is the cathode radius, n is the ratio of the angular frequency of the electron to the angular velocity of the electron, λ_0 is the operating wave length and B_z' is the magnetic field (see "Vacuum Tubes" by Spangenberg, equation 18.98b, page 662).

In the claims appended hereto, this equation will be identified as "Equation 3."

There is thus provided methods of and means for operating high-frequency radio tubes at greater efficiencies and using gaseous mediums at relatively low pressures, by applying critical values of magnetic fields to the medium of the tubes, defined by the Equations 2 and 3 hereof, to effect prompt trapping of the electrons in resonant orbits within the medium of the tube and thereby cause cumulative ionization.

I claim as my invention:

1. A transmit-receive switch for a high-frequency wave guide system comprising: means forming a cavity resonator tuned by dimensions to said frequency, means coupling said cavity resonator to said guide, two electrodes mounted respectively on opposite electric-field sides of said cavity resonator and in spaced relation to each other, and means adjacent said electrodes for applying a magnetic field upon the medium within the cavity resonator.

2. A transmit-receive switch for a high-frequency wave guide system comprising: means forming a cavity resonator tuned by dimensions to said frequency, means coupling said cavity resonator to said guide, two electrodes mounted respectively on opposite electric-field sides of said cavity resonator and in spaced relation to each other, and means adjacent said electrodes for applying a magnetic field upon the medium within the cavity resonator, and generally at right angles to the electro-static field between said electrodes.

3. A transmit-receive switch for a high-frequency wave guide system comprising: means forming a cavity resonator tuned by dimensions to said frequency, means coupling said cavity resonator to said guide, two electrodes mounted respectively on opposite electric-field sides of said cavity resonator and in spaced relation to each other, means adjacent said electrodes for applying a magnetic field upon the medium within the cavity resonator, and generally at right angles to the electrostatic field between said electrodes, and means connected to said magnetic

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field means for adjusting the intensity H of said field in accordance with the equation

$$\frac{H = 2\pi fm}{e}$$

where e is the charge and m is the mass of the electron in MKS units, and f is the frequency in cycles per second of electron orbital motion, whereby the electrons are trapped between said electrodes an cumulative ionization of said medium occurs.

4. A demodulator device including a high-frequency coaxial conductor system, means pressure isolating a section of said system, the pressure within the said isolated section being less than atmospheric pressure, a cold emission cathode within said section connected to the axial conductor of said system, an anode coupled to the outer conductor of said system, a tunable resonant coaxial conductor section coaxial with and connected to said pressure isolated section, an output circuit connected to said tunable section, and means adjacent said section for applying a magnetic field upon the medium within the said pressure isolated section.

5. A demodulator device including a high-frequency coaxial conductor system, means pressure isolating a section of said system, the pressure within the said isolated section being less than atmospheric pressure, a cold emission cathode within said section connected to the axial conductor of said system, an anode coupled to the outer conductor of said system, a tunable resonant coaxial conductor section coaxial with and connected to said pressure isolated section, an output circuit connected to said tunable section, means adjacent said section for applying a magnetic field upon the medium within the said pressure isolated section, and means for adjusting the intensity H of said magnetic field in accordance with the equation

$$\frac{H = 2\pi fm}{e}$$

where e is the charge and m is the mass of the electron in MKS units, and f is the frequency in cycles per second of electron orbital motion, whereby the electrons are trapped in resonant orbits between said electrodes and cumulative ionization of said medium occurs.

6. A rectifier device for a high-frequency coaxial conductor system comprising: means pressure isolating a section of said system, the pressure within the said isolated section being less than atmospheric pressure, a cold emission cathode within said section connected to the axial conductor of said system, an anode capacitatively coupled to the outer conductor of said system, a tunable resonant coaxial conductor section coaxial with and connected to said isolated section, an output circuit connected to said tunable section, and means adjacent said section for applying a magnetic field upon the medium within the said pressure isolated section.

7. A rectifier device for a high-frequency coaxial conductor system comprising: means pressure isolating a section of said wave guide, the pressure within the said isolated section being less than atmospheric pressure, a cold emission cathode within said section connected to the axial conductor of said system, an anode capacitatively coupled to the outer conductor of said system, a tunable resonant coaxial conductor section coaxial with and connected to said isolated section, an output circuit connected to

said tunable section, means adjacent said section for applying a magnetic field upon the medium within the said pressure isolated section, and means for adjusting the intensity H of said magnetic field in accordance with the equation

$$\frac{H}{e} = \frac{2\pi fm}{e}$$

where e is the charge and m is the mass of the electron in MKS units, and f is the frequency in cycles per second of electron orbital motion, whereby the electrons are trapped between said electrodes and cumulative ionization of said medium occurs.

8. A high-frequency radio circuit including a tube having a pair of cold electrodes and which depends for its operation upon charged particles produced by ionization of the medium contained within the tube comprising: means connected to said tube for impressing high frequency wave energy upon said medium, means including said electrode for generating charged particle cold emission within said medium, means connected to said electrodes for accelerating said emission, means adjacent said electrodes for impressing a magnetic field on said medium, means connected to said magnetic field means for adjusting the in-

tensity of said field to cause said emission to follow orbits resonant to the frequency of said high-frequency energy whereby said emitted charged particles absorb a portion of said high-frequency wave energy and whereby said absorbed energy provides for cumulative ionization of said medium whereby the ion density therein is rapidly increased when said high-frequency energy is applied thereto.

ERNEST G. LINDER.

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