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F. S. BRYANT, JR

3,345,528

MAGNETRON INJECTION GUN HAVING A VANED NEGATIVE CONTROL GRID

Filed Nov. 14, 1966

2 Sheets-Sheet 1

PRIOR ART

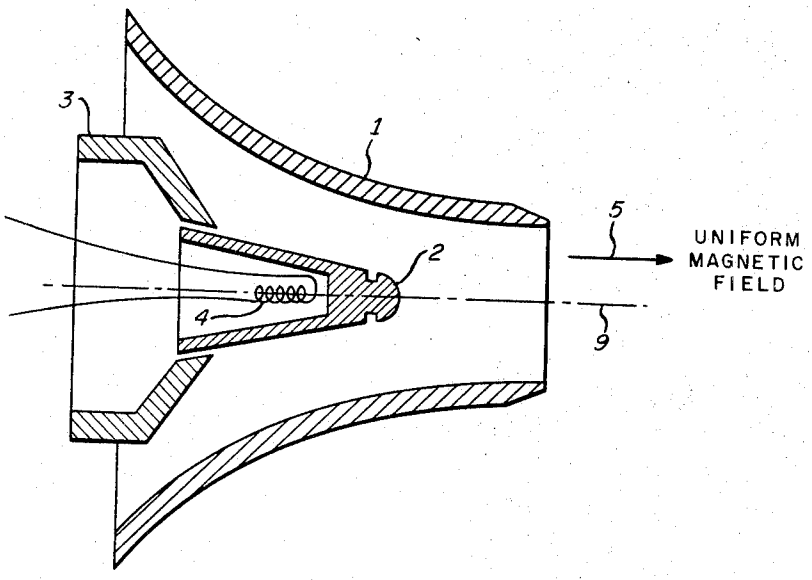


FIG. 1.

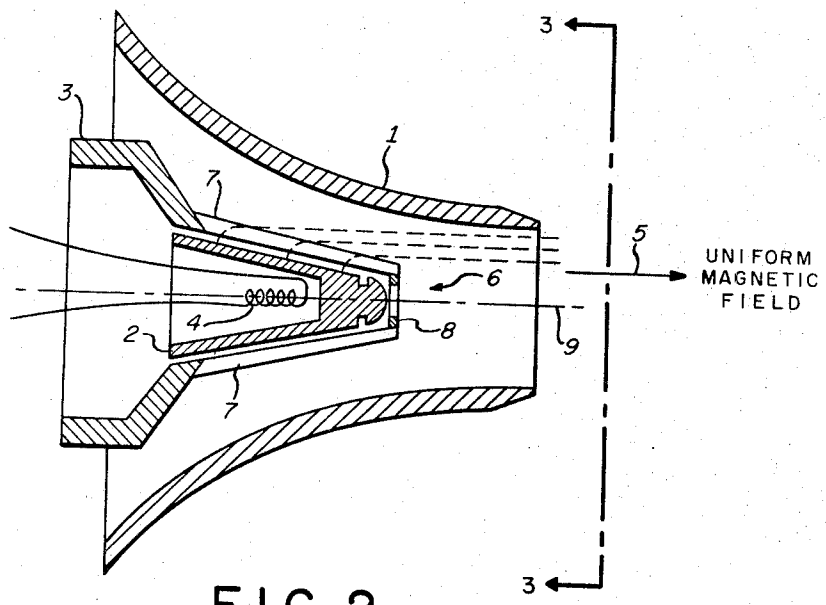


FIG. 2.

INVENTOR.
FURNIE S. BRYANT JR.
BY
Robert J. Hearn
ATTORNEY

Oct. 3, 1967

F. S. BRYANT, JR
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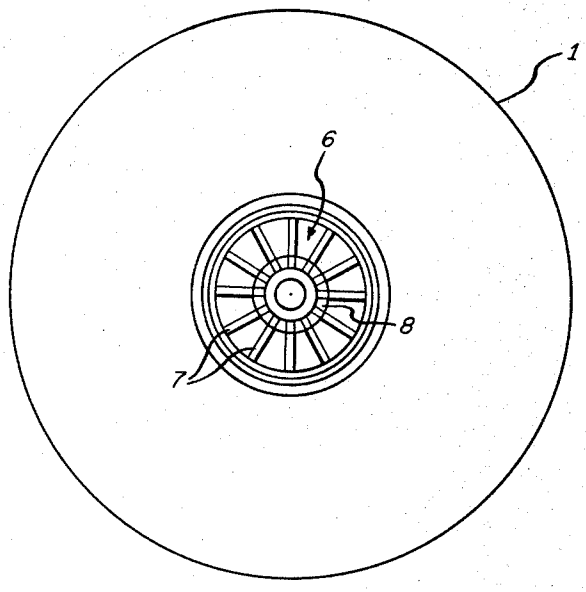


FIG. 3.

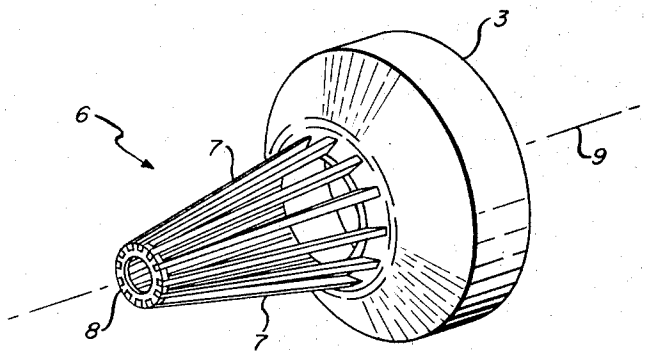


FIG. 4.

INVENTOR.
FURNIE S. BRYANT JR.
BY
Robert J. Haase
ATTORNEY

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MAGNETRON INJECTION GUN HAVING A VANED NEGATIVE CONTROL GRID

Furnie S. Bryant, Jr., Gainesville, Fla., assignor to Sperry Rand Corporation, a corporation of Delaware

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5 Claims. (Cl. 313—82)

The present invention generally relates to microwave amplifier tubes having electron guns of the magnetron injection type and, more particularly, to such an electron gun provided with a negative control grid to modulate the electron beam.

Microwave amplifier tubes for use in high power radar applications often are required to posses both high duty cycle and high repetition rate capabilities. Particularly in such applications, it is desirable to employ an electron gun of high perveance and to provide means for pulsing the electron beam without seriously reducing the perveance value. Magnetron injection guns are known to have perveance values exceeding that of other designs. Thus, it is desirable to provide means for pulsing the electron beam of a magnetron injection gun which does not compromise the inherently high perveance of the gun.

Beam modulation by the technique of anode modulation requires a large voltage swing. The consequence is that excessive modulator power is dissipated in charging and discharging the anode electrode capacity. A substantial saving in modulator power can be achieved by utilizing a control grid. Control grids may be either of the positive type which intercepts beam electrons or of the negative type which suppresses electron emission from the cathode. The latter type is preferred in high power applications inasmuch as it avoids the grid power and grid secondary emission problems of the beam intercepting type of grid. Ordinarily, however, a substantial reduction of perveance is associated with the use of a negative control grid. In order to fully exploit the potential advantages of the addition of a negative control grid to an electron gun of the magnetron injection type, it becomes necessary to discover means whereby gun perveance is not seriously reduced.

It is the principal object of the present invention to provide an electron gun of the magnetron injection type equipped with a negative control grid for modulating the electron beam without seriously degrading gun perveance.

Another object is to provide an electron gun of the magnetron injection type equipped with a negative control grid characterized by a constant cutoff M_u.

A further object is to provide an electron gun of the magnetron injection type having a negative control grid introducing a low grid-to-cathode mask ratio.

An additional object is to provide an electron gun of the magnetron injection type having a negative control grid introducing minimum perturbation of the longitudinal electric field above the cathode of the electron gun.

These and other objects of the present invention, as will appear from a reading of the following specification, are accomplished in the preferred embodiment by the provision of a negative control grid structure in a conical cathode magnetron injection gun. The control grid structure comprises a number of conductive vanes mounted at one end on the focus electrode and extending along the length of the cathode with the narrower dimension of the vane facing the cathode. The vanes are assembled in the outline of a truncated cone to form a cage which surrounds the conical cathode of the magnetron injection gun. In order to achieve constant cutoff M_u, the broad dimension of each vane is tapered along the length of the cathode. The broad dimension of each vane is less at the smaller diameter end of the cathode than at the larger diameter end of the cathode.

For a more complete understanding of the present invention, reference should be had to the following specification and to the figures of which:

FIGURE 1 is a simplified sectional view of a typical prior art magnetron injection gun;

FIGURE 2 is a simplified sectional view of the magnetron injection gun of the present invention having a vaned negative control grid;

FIGURE 3 is an end view of the embodiment of FIGURE 2; and

FIGURE 4 is a perspective view of the grid and focus electrode structure utilized in the embodiment of FIGURES 2 and 3.

The typical magnetron injection gun represented in the simplified sectional view of FIGURE 1 comprises tapered conical anode **1**, conical cathode **2**, apertured conical focus electrode **3** and heater element **4**. The electron gun members **1**, **2**, **3** and **4** are positioned relative to each other in the manner shown by conventional structure omitted from the figure for the sake of exposition. An electron gun of the aforementioned type is described in the paper, "The Design and Performance of a Magnetron-Injection Gun," by Kino et al., IRE Transactions on Electron Devices, vol. ED-9, No. 1, January 1962, pages 1–11.

As is well understood in the art, the electric field in the region between cathode **2** and anode **1** consists of components which are both parallel and perpendicular to the cathode surface. Therefore, as a given electron is emitted from the cathode, it will experience both radial and axial accelerations. The radial acceleration vector is perpendicular to the axial magnetic field represented by the vector **5** in FIGURE 1. The resultant Lorentz force causes the electron trajectory to curve around the cathode. The presence of the axial component of the electric field between cathode **2** and anode **1** causes the electrons to be ejected from the gun region without being intercepted by anode **1**. When the cathode is truncated, as it is in the case of cathode **2**, the ejected beam is hollow. In accordance with the present invention, a negative control grid structure is added to the prior art gun of FIGURE 1 in such a way as to minimally affect the electron dynamics thereof. More particularly, the invention provides for the negative control grid modulation of the electron beam without serious degradation of the inherently high gun perveance.

The effectiveness of a grid in controlling cathode current is a function of several parameters. Such parameters include the distance of the grid above the cathode, the grid pitch and the grid shape. In particular, where the perveance of the electron gun is to be maintained at a high value, a low grid-to-cathode mask ratio is desired. Said ratio is defined as the ratio of the projected grid area to the projected cathode area on a plane perpendicular to the electron gun axis and spaced from the cathode. Generally speaking, gun perveance reduction is minimized by a control grid design whose grid-to-cathode mask ratio approaches the value of the screening fraction. The screening fraction is defined as the ratio of the cross-sectional area of the total grid to the cross-sectional area of the cathode of the electron gun.

The above desiderata are met by the provision of the vane cage structure **6** shown in FIGURES 2, 3 and 4. Said structure comprises a plurality of thin conductive vanes **7** which are assembled in the outline of the truncated cone with the aid of apertured end ring **8** and focus electrode **3**. Twelve vanes are shown by way of example in the illustrated embodiment. The narrow dimension of each vane faces cathode **2** with the broad dimension of each vane being directed approximately radially relative to the axis **9** of the electron gun. For operation, positive and

negative potentials are applied to the anode and cathode, respectively, of the electron gun. The focus electrode **3** is quiescently maintained at about the potential of cathode **2** at times when the electron gun generates an electron beam and is pulsed by a negative potential relative to the potential of cathode **2** during the times when the electron beam is cutoff. The biasing and pulsing means are of conventional design and are omitted from the figures.

As was mentioned earlier, the trajectory of an electron emitted from cathode **2** involves both radial expansion and angular acceleration about axis **9**. Inasmuch as a negative control grid is a non-intercepting grid, the emitted electrons must rise above the grid structure in order to escape and form the emergent electron beam. The orientation of the individual vanes **7** whereby the broad dimension of each lies along an approximately radial plane containing the axis **9** minimally interferes with the normal approximately radial trajectories of the emitted electrons when the electron gun is turned on. The result is that the high perveance value inherent in the magnetron injection gun is not seriously reduced by the presence of the control grid.

In order that the control grid cage structure **6** sharply cutoff the electron beam upon the application of the negative potential to focus eletcrode **3** relative to potential of cathode **2**, it is necessary that electron emission be suppressed at essentially the same time along the entire length of cathode **2**. It will be observed that the separation between cathode **2** and anode **1** varies as a function of the longitudinal position along axis **9**. The cathode-anode separation is maximum at the large diameter at the end of the cathode and decreases as the smaller diameter end is approached. A sharp electron beam cutoff characteristic is achieved in accordance with the present invention by tapering the larger dimension of each of the vanes **7**. The tapered (smaller) end of each vane is adjacent the narrow diameter end of the cathode. It has been observed that in the absence of vane tapering, the electron emission adjacent the small diameter end of the cathode decreases more rapidly than does the emission from the center and from the large diameter end of the cathode as an increasingly negative potential is applied to the control grid in the direction of electron beam cutoff. The tapering of the vanes produces essentially simultaneously electron emission cutoff along the entire length of cathode **2**. In particular, a vane taper of 33% was found satisfactory in one design.

While the invention has been described in its preferred

embodiments, it is to be understood that the words which have been used are words of description rather than limitation and that changes within the purview of the appended claims may be made without departing from the true scope and spirit of the invention in its broader aspects.

What is claimed is:

1. A magnetron injection gun comprising

a hollow conical anode,

a conical cathode,

a hollow conical focus electrode,

said electrode surrounding one end of said cathode and said anode surrounding all of said cathode, said anode, cathode and electrode being coaxial, and

a control grid structure attached at one end to said electrode and extending axially along said cathode to form a cage about said cathode,

said structure comprising a plurality of conductive vanes, each said vane extending axially along said cathode,

the narrow edge of each said vane facing said cathode.

2. The magnetron injection gun defined in claim **1** wherein the broad side of each said vane is directed approximately radially from said cathode.

3. The magnetron injection gun defined in claim **1** wherein the broad side of each said vane is tapered to a reduced dimension in a direction away from said electrode.

4. The magnetron injection gun defined in claim **1** wherein said control grid structure is of the form of a truncated cone coaxial with said cathode.

5. The magnetron injection gun defined in claim **1** wherein

the broad side of each said vane is directed approximately radially from said cathode,

said broad side of each said vane is tapered to a reduced dimension in a direction away from said electrode, and

said control grid structure is of the form of a truncated cone coaxial with said cathode.

References Cited

UNITED STATES PATENTS

2,828,437	3/1958	Dailey	313—82 X
3,258,626	6/1966	Kino et al.	313—82

JAMES W. LAWRENCE, *Primary Examiner.*

R. SEGAL, *Assistant Examiner.*