United States Patent

Hentschel

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[54] **CROSSED-FIELD NOISE GENERATOR TUBE EMPLOYING A HIGH MAGNETIC FIELD INTENSITY**

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[52] **U.S. Cl.**..**331/78,** 315/39.3

[51] **Int. Cl.**..**H03b 29/00**

[58] **Field of Search**...................................315/39.3; 331/78

[56] **References Cited**

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[57] **ABSTRACT**

A crossed-field noise generator tube having substantially improved efficiency is disclosed. The noise generator tube includes a cylindrical cathode emitter surrounded by a slow-wave circuit to define an annular crossed-field interaction region therebetween. The slow-wave circuit is a fundamental forward wave circuit provided with a circuit sever to define an upstream end and a downstream output end for the circuit. A resistive termination is provided at the upstream end of the circuit and an output terminal is provided at the downstream end of the circuit for extracting r.f. noise output. A magnetic circuit is provided for producing an axially directed magnetic field in the crossed-field interaction region between the anode and cathode. The intensity of the axial magnetic field produced in the interaction region is greater than ten times the cut-off magnetic field intensity for crossed-field interaction region. Use of this exceptionally high axial magnetic field intensity produces an unexpected substantial enhancement in the efficiency of the noise generator. It is believed that this improved efficiency is due to a resultant decrease in the thickness of the rotating hub of space charge in the crossed-field interaction region, thereby yielding a more efficient noise transfer mechanism for transfer of noise energy from the turbulent electron flow in the space charge to the synchronous waves on the slow-wave circuit.

6 Claims, 5 Drawing Figures

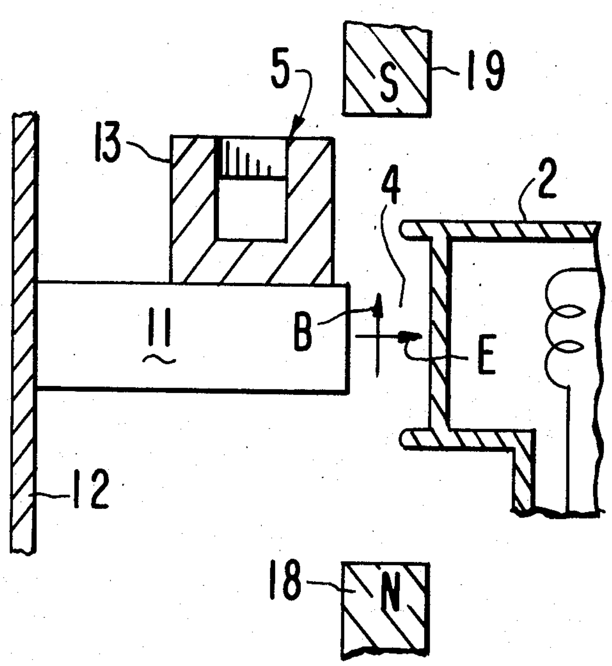


FIG. 1

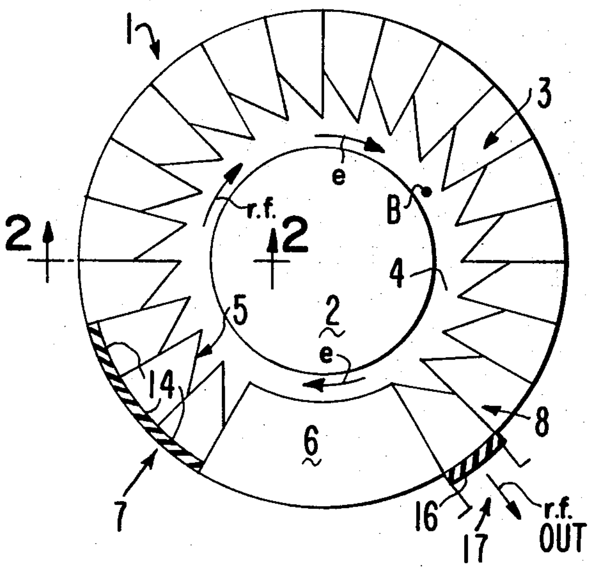


FIG. 3

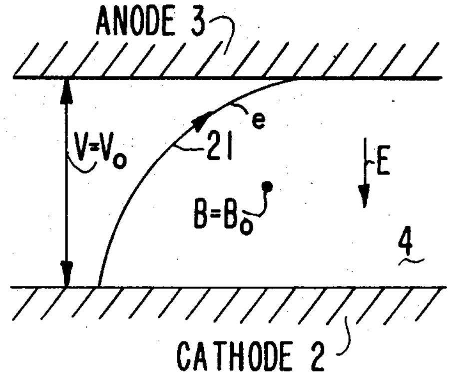


FIG. 2

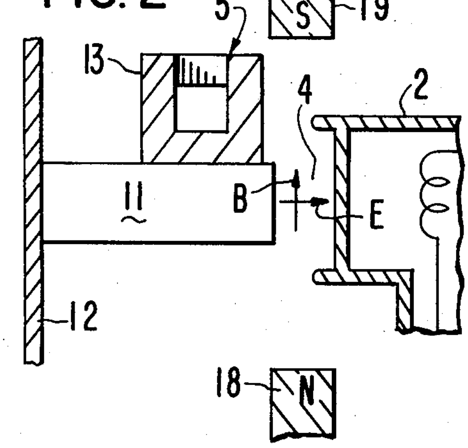
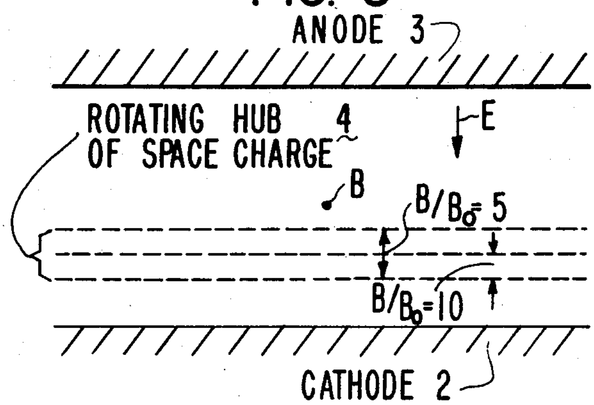


FIG. 5



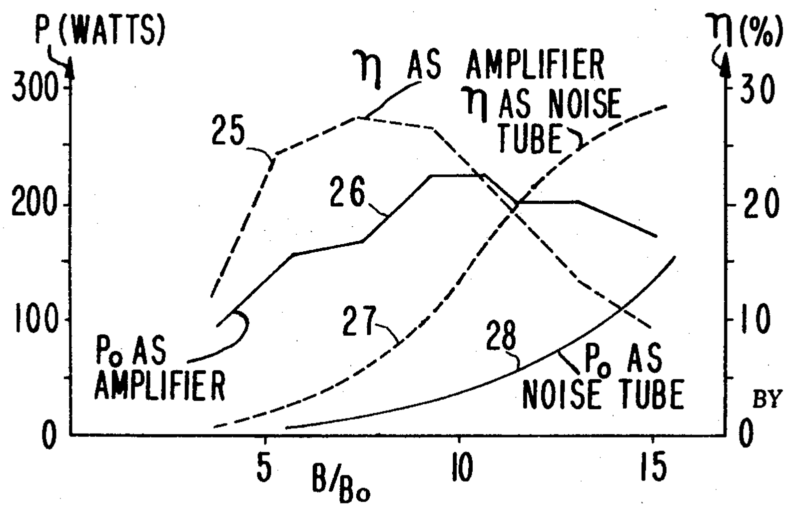


FIG. 4

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CROSSED-FIELD NOISE GENERATOR TUBE EMPLOYING A HIGH MAGNETIC FIELD INTENSITY

DESCRIPTION OF THE PRIOR ART

Heretofore, crossed-field noise generator tubes have been proposed wherein noise energy present in the turbulent flow of the re-circulating hub of space charge in a crossed-field interaction region is synchronously interacted with a forward slow-wave circuit to transfer r.f. noise wave energy to the slow-wave circuit. The output noise energy was extracted from the output terminal of the slow-wave circuit for application to a suitable load. Such tubes typically operated with an axial magnetic field intensity in the crossed-field interaction region which was approximately four to five times the cut-off magnetic field intensity Bo. Such prior art noise generator tubes produced a relatively low efficiency as of only 1 or 2 percent with relatively low power outputs as of a few watts over the entire operating band. The relatively poor power output and efficiency was not understood because when such tubes were operated as power amplifiers with the same ratio of axial magnetic field intensity B to cut-off magnetic field intensity Bo, namely, a ratio of approximately 4 to 1, the tubes had efficiencies of approximately 20 percent with power outputs of hundreds of watts.

Therefore, a need exists for improving the efficiency of crossed-field noise generator tubes.

SUMMARY OF THE PRESENT INVENTION

The principal object of the present invention is the provision of an improved crossed-field noise generator tube.

One feature of the present invention is the provision, in a crossed-field noise generator tube, of an axial magnetic field intensity B in the crossed-field interaction region which is greater than 10 times the cut-off magnetic field intensity Bo for the interaction region and slow-wave circuit, whereby the efficiency and power output of the noise tube is substantially enhanced.

Other features and advantages of the present invention will become apparent upon a perusal of the following specification taken in connection with the accompanying drawings wherein:

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic transverse sectional view of a field noise generator tube employing features of the present invention,

FIG. 2 is an enlarged sectional view of a portion of the structure of FIG. 1 taken along line 2—2 in the direction of the arrows,

FIG. 3 is a schematic linearized line diagram of a crossed-field interaction region depicting the trajectory of an electron for an axial magnetic field B equal to the cut-off magnetic field intensity Bo,

FIG. 4 is a plot of power output in watts and efficiency in percent vs the ratio of the magnetic field intensity B in the interaction region to the cut-off magnetic field intensity Bo for an amplifier tube and for a noise generator tube, and

FIG. 5 is a diagram similar to that of FIG. 3 depicting the thickness of the hub of rotating space charge for two different ratios of magnetic field intensity B to cut-off magnetic field intensity Bo.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to FIG. 1 there is shown a crossed-field noise generator tube 1 incorporating features of the present invention. The tube 1 includes a cylindrical cathode emitter 2 of the thermionic type or of the secondary emission type. An anode structure 3 surrounds the cathode emitter 2 in a concentric manner and in radially spaced relation to define an annular crossed-field interaction region 4 in the space between the anode 3 and the cathode 2.

The anode structure 3 includes a slow-wave circuit portion 5 and a circuit sever portion 6 serving to sever the slow-wave circuit section to form an upstream end 7 and a downstream output end 8. The slow-wave circuit 5 can be any one of a number of forward slow-wave circuits such as, for example, a helix-coupled vane circuit as shown in FIG. 2 and schematically indicated in FIG. 1, or a meander-line circuit, not shown.

The helix-coupled van circuit 5 includes an array of conductive vane members 11 inwardly projecting from a conductive back wall 12. The back wall 12 forms the main body and the vacuum envelope of the tube structure. A conductive helix 13 extends around the vane array and is conductively connected to each of the vanes with one turn of the helix being positioned between each vane so that the helix is connected to successive vanes on each turn of the helix. The upstream end 7 of the slow-wave circuit 5 is provided with a resistive matched termination 14 for absorbing wave energy traveling on the circuit at the upstream end 7 and, therefore, preventing reflections of wave energy from the circuit sever 6 such that the tube does not break into unwanted oscillations. The downstream end of the tube 8 includes a microwave window 16 and an output terminal 17 for extracting r.f. noise output signals from the slow-wave circuit 5 for transmission to a suitable load, not shown.

A pair of annular magnetic pole pieces 18 and 19 are disposed at opposite ends of the crossed-field interaction gap 4 for producing an axially directed magnetic field B in the crossed-field interaction region 4. According to the present invention, the magnetic poles 18 and 19 are energized with a sufficient magneto motive force by either a permanent magnet or a solenoid, not shown, to produce an axially directed magnetic field intensity B in the cross-field interaction region 4 which is greater than 10 times the cut-off magnetic field intensity Bo.

Referring now to FIG. 3, there is shown a schematic linearized line diagram of a crossed-field interaction region 4 for containing crossed magnetic and electric fields and depicting the trajectory 21 of an electron emitted from the cathode 2 into the crossed-field region 4 for a cut-off magnetic field condition, namely, the unidirectional magnetic field B is equal to the cut-off magnetic field intensity Bo. The cut-off magnetic field intensity Bo is that value of magnetic field for the crossed-field region 4 which will cause the electron trajectory 21 to just graze the anode 3 when the voltage V supplied between anode 3 and cathode 2 is equal to the synchronous voltage for the anode circuit 5. The synchronous voltage Vo for the anode circuit 5 is that voltage through which an electron must fall in order to have a velocity equal to the phase velocity of a wave on the slow-wave circuit 5 to be synchronously interacted with the electron.

Referring now to FIG. 4, there is shown a plot of power output and efficiency vs the ratio of axial magnetic field B to Bo in the interaction region 4 for a pair of equivalent tubes, one operated as an amplifier and the other operated as a noise tube of the type shown in FIG. 1 and 2. The curves for the tube operating as an amplifier are shown as lines 25 and 26. In this particular case, the synchronous voltage Vo for the slow-wave circuits is 218 volts, and the cut-off magnetic field intensity Bo is 655 gauss. The input drive power to the amplifier is 25 watts. Typically, such tubes have been operated in the past at ratios of B/Bo of about 4 or 5 to 1, which yields, in the case of the amplifier, efficiencies of about 20 percent, and power outputs with 25 watts of drive, of about 125 watts. As seen from curves 25 and 26 the efficiency begins to drop off substantially for values of B/Bo greater than 10, and the power output begins to drop off for values of B/Bo greater than 10.

However, the curves for the similar tube employed as a noise generator is depicted by curves 27 and 28. As seen from curves 27 and 28, the efficiency begins to substantially increase with values of magnetic field intensity B greater than 10 times the cut-off magnetic field intensity Bo. The efficiency improves to approximately 30 percent for values of B/Bo equal to 15. Likewise, the power output of the noise tube begins to substantially improve for values of B/Bo greater than 10 to produce power outputs of about 150 watts for values of B/Bo equal to 15.

Referring now to FIG. 5, there is shown a schematic linearized version of the crossed-field interaction region 4 indicating the thickness of the rotating hub of electronic space charge for two conditions of B/Bo, namely, B/Bo = 5 and B/Bo = 10. When B/Bo is equal to 5, the radial thickness of the rotating hub of space charge occupies approximately 20 percent of the space between the anode and cathode. On the other hand, when the ratio of B/Bo is approximately 10, the thickness of the rotating hub of space charge is about half the thickness for B/Bo equal to 5 and, thus, occupies approximately 10 percent of the space between the anode and cathode. In other words, the hub of rotating space charge is substantially thinner for increased values of B/Bo. It is believed that the propagation of space charge waves in the hub of rotating space charge is better if the hub is thinner; therefore, it is believed that the improved efficiency and power output for the noise generator tube 1 operating at ratios of B/Bo greater than 10 is due to the enhanced propagation of the noise space charge waves in the hub of rotating space charge. It is believed that the thinner electron stream is not necessarily desirable for an amplifier tube since, in the amplifier tube, a drive signal is present on the slow-wave circuit. This drive signal produces an r.f. field which extends into the rotating hub of space charge for grouping the space charge into spokes which cumulatively interact with the wave on the slow-wave structure to produce amplification of the signal applied to the slow-wave circuit. Thus, for an amplifier tube, it is desirable that the slow-wave circuit be closer to the rotating hub of space charge such that the r.f. fields of the slow-wave circuit are more intense in the region of the hub which, of course, is the case when the rotating hub of space charge is thicker.

In operation, the noise tube of FIGS. 1 and 2 produces an r.f. noise output by the turbulent motion of the electrons, in the rotating hub, causing a noise space charge wave to propagate through the hub of space charge. The space charge wave interacts synchronously with the slow-wave circuit to excite a circuit wave on the slow-wave circuit 5 and to, thus, transfer energy from the noise space charge wave to the slow-wave circuit. The noise energy is extracted at the output terminal 17 and fed to a suitable load.

Although the present invention has been explained as employed in a circular tube geometry employing a re-entrant electron stream, this is not necessary. A linear crossed-field tube may also employ ratios of B/Bo greater than 10 for improving the efficiency and power output of the tube.

Since many changes could be made in the above construction and many apparently widely different embodiments of this invention could be made without departing from the scope thereof, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. The method for generating a radio frequency noise output comprising the steps of, producing a stream of electrons in a crossed-field interaction region of space having crossed unidirectional electric and magnetic fields, synchronously interacting radio frequency noise components in the electron stream with the slow-wave circuit to excite noise waves on the circuit and to couple noise energy from the electron stream to the slow-wave circuit, extracting radio frequency noise energy from the slow-wave circuit, the improvement comprising, causing the unidirectional magnetic field intensity B to have an intensity in the interaction region which is greater than 10 times the cut-off magnetic field intensity Bo in the interaction region, whereby the efficiency of the radio frequency noise generation is enhanced.

2. The method of claim 1 wherein the unidirectional magnetic field intensity B is between 10 and 15 times the cut-off magnetic field intensity Bo.

3. The method of claim 1 including the steps of, causing the electron stream to recirculate around an annular crossed-field interaction region.

4. The method of claim 3 wherein the noise energy in the electron stream is interacted with a forward traveling wave on a slow-wave circuit, and including the step of resistively terminating the upstream end of the slow-wave circuit in a non-reflective wave termination.

5. The method of claim 3 including the step of, causing portions of the electron stream to back-bombard a cathode secondary emitter electrode structure to cause the electron stream to be continuously replenished by secondary emission from the cathode electrode as the electron stream is recirculated around the crossed-field interaction region.

6. In a cross-field noise generator tube, means forming a cathode emitter electrode structure, means forming an anode structure spaced from said cathode emitter to define a crossed-field magnetron type interaction region in the space between said anode and cathode structures and containing crossed unidirectional electric and magnetic fields, said anode structure including a slow-wave circuit for synchronous interaction between radio frequency wave energy traveling on said slow-wave circuit and electrons emitted from said cathode emitter to produce transfer of noise energy from the electrons to said slow-wave circuit, the improvement comprising, means for producing the unidirectional magnetic field B in the crossed-field interaction region, which is greater than 10 times the intensity of the cut-off magnetic field intensity Bo for the crossed-field interaction region and said slow-wave circuit.

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