Dec. 16, 1969 G. K. FARNEY 3,484,649

HELIX COUPLED VANE CIRCUIT WITH THE HELIX CONNECTED CENTRALLY OF THE VANES

Filed Aug. 14, 1967

FIG. 1 PRIOR ART

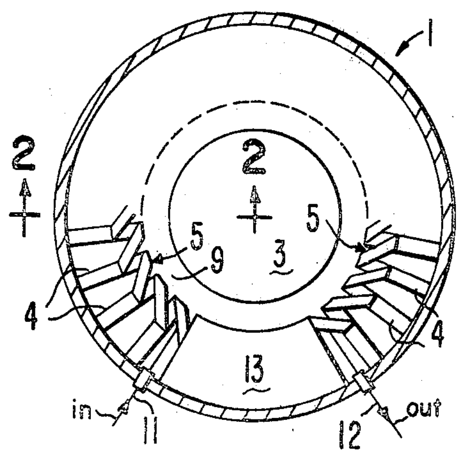


FIG. 2 PRIOR ART

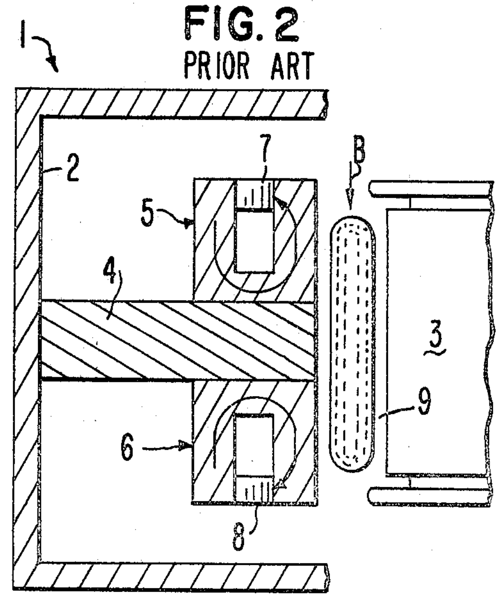
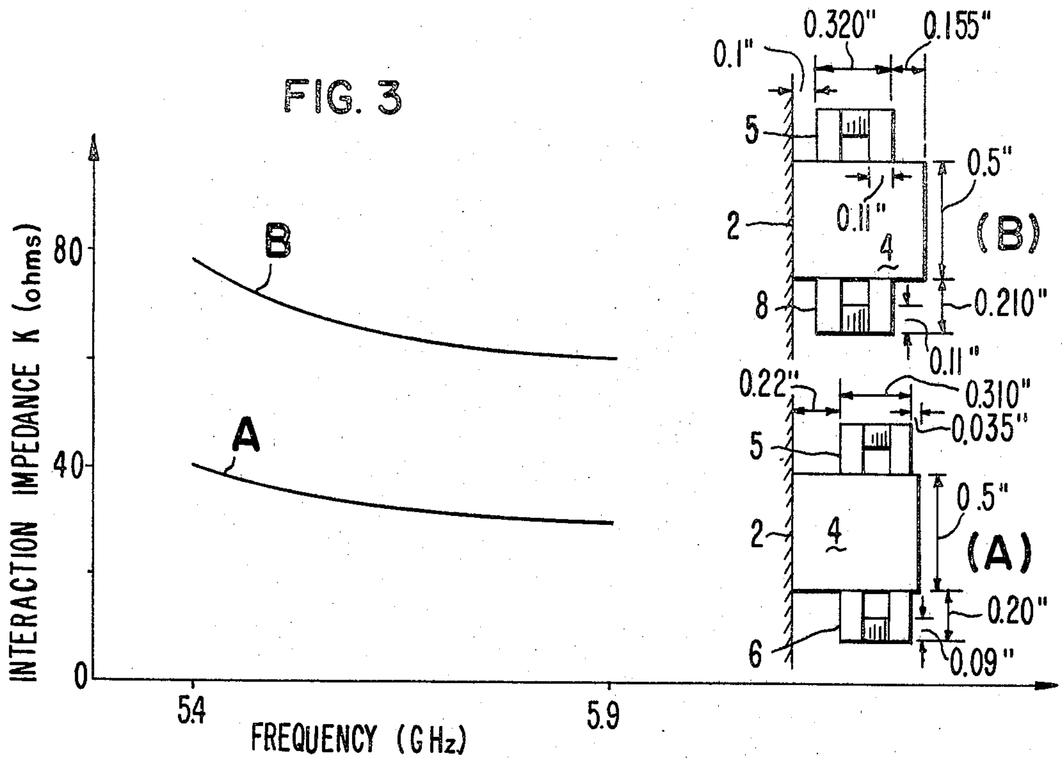


FIG. 3



INVENTOR.
GEORGE K. FARNEY

BY

ATTORNEY

United States Patent Office

3,484,649

Patented Dec. 16, 1969

1

3,484,649

HELIX COUPLED VANE CIRCUIT WITH THE HELIX CONNECTED CENTRALLY OF THE VANES

George K. Farney, New Providence, N.J., assignor, by mesne assignments, to Varian Associates, Palo Alto, Calif., a corporation of California

Filed Aug. 14, 1967, Ser. No. 660,270
Int. Cl. H01j 25/34
U.S. Cl. 315—39.3 6 Claims

ABSTRACT OF THE DISCLOSURE

Helix coupled vane type slow wave circuits are disclosed, together with tubes using same. The helix coupled vane circuit is characterized by an array of vane resonators coupled together by means of one or more helices. Electronic interaction with the slow wave circuit is obtained between the fringing fields at the tips of the vanes and a stream of electrons adjacent the tip of the vanes. This type of slow wave circuit is especially useful in magnetron-type tubes operating at microwave frequencies as the helices improve the mechanical and thermal properties of the circuit. The interaction impedance of the helix coupled vane slow wave circuit is improved by coupling the helices to the vanes at a point approximately midway along the length of the vanes, whereby the vane segment between the helices and the vane tips serves to provide an impedance transformer to increase the electric field intensity at the tips of the vanes and, thus, improve the interaction impedance of the circuit.

DESCRIPTION OF THE PRIOR ART

Heretofore, helix coupled vane slow wave circuits have been employed for interaction circuits in microwave tubes. Such circuits are disclosed and claimed in U.S. patent application 454,140, now Patent No. 3,387,170 filed May 7, 1965 and U.S. 514,088 now Patent No. 3,427,495 filed Dec. 15, 1965, both assigned to the same assignee as the present invention. In these prior slow wave circuits the helix was connected to the vanes near the tips of the vanes. The problem with this arrangement is that the resultant slow wave circuit has a relatively low interaction impedance such as, for example, an impedance of 40 ohms. While such circuits have extremely good mechanical and thermal properties combined with relatively wide band operation, it is desirable to improve their interaction impedance.

SUMMARY OF THE PRESENT INVENTION

The principal object of the present invention is the provision of improved helix coupled slow wave circuits and tubes using same.

One feature of the present invention is the provision, in a helix coupled vane slow wave circuit, of connecting the helix centrally of the vane members, whereby the portion of the vane extending from the helix to the tips of the vanes serves as an impedance transformer for increasing the electric fields developed by the circuit and, thus, the interaction impedance.

Another feature of the present invention is the same as the preceding feature wherein the circuit includes a pair of contrawound helices connected intermediate the length of the vanes as aforedescribed for improving the interaction impedance.

Another feature of the present invention is the same as any one or more of the preceding features wherein the helix coupled circuit is arranged in a cricular array for interaction with an electron stream in a magnetron-type interaction region to produce a microwave output signal.

2

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 cross-section view of a magnetron-type tube employing a prior art helix coupled vane circuit,

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, and

FIG. 3 is a plot of interaction impedance in ohms vs. frequency in gHz. for the prior art helix coupled vane circuit depicted in Insert A and for the helix coupled vane circuit of the present invention shown in Insert B.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to FIGS. 1 and 2, there is shown the prior art helix coupled vane circuit as employed for the interaction circuit of a crossed-field amplifier **1**. More specifically, cross-field amplifier tube **1** includes a cylindrical vacuum envelop **2**, as of copper, evacuated to a suitably low pressure such as 10^{-9} torr. A cylindrical cathode emitter **3** is centrally disposed of the envelope **2**. An array of conductive vanes **4** project inwardly toward the cathode emitter **3** from the inside wall of the cylindrical vacuum envelope **2**. A pair of contrawound helices **5** and **6** are disposed on opposite sides of the vanes **4** and serve to electromagnetically couple adjacent vane members **4**.

The helices **5** and **6** are conveniently made by means of a pair of metal toroids of rectangular cross-section which are brazed to the vanes near the tips thereof. The toroids are then axially slotted from the vane **4** toward the outer axial ends of both toroids such that each toroid has three of its sides slotted in alignment with the slots between adjacent vane members **4**. The outer axial walls of the toroids are then slotted by an array of diagonal slots having a pitch such that the member defined between adjacent slots serves to interconnect adjacent turns of the helix. The diagonal slots for the upper toroid **5** define diagonal members **7** to produce a helix having a first sense of rotation, whereas the diagonal slots in the lower toroid define diagonal interconnecting members **8** causing the helix **6** to advance with the opposite sense of rotation. As a result, contrawound helices **5** and **6** are formed on the helix coupled vane structure. The contrawound helices serve to prevent setting up of certain undesired modes of propagation on the helix coupled circuit which might otherwise tend to cancel the desired electric fields at the tips of the vanes **4**.

An annular magnetron-type interaction region **9** is defined in the space between the slow wave circuit which is operated at anode potential and the cathode **3**. A magnet, not shown, produces an axially directed magnetic field B in the magnetron interaction region **9**. An input terminal **11** is provided at one end of the slow wave circuit and an output terminal **12** is provided at the other end of the circuit. A circuit sever **13**, as of copper, is provided in the anode between the input terminal **11** and the output terminal **12** to prevent RF feedback from the output end of the slow wave circuit to the input end which would otherwise produce oscillations which would interfere with proper operation of the crossed-field amplifier tube **1**.

Referring now to FIG. 3, Curve A shows the interaction impedance versus frequency for a prior art C-band dual helix coupled vane circuit having dimensions as shown in Insert A. More particularly, it is seen that the interaction impedance for the circuit, as indicated in A, is about 40 ohms. The circuit of the present invention is shown in insert B and is essentially the same as that of the prior art except that the dual helices are connected to the vanes at a point substantially midway along the length of the vane **4** such that a short transformer section **15** is provided between the helices and the tips of the vanes **4**. These transformer sections **15** serve to transform the relatively low voltages developed near the helices **5** and **6** into relatively higher voltages at the tips of the vanes **4**. The dual helix coupled vane circuits having dimensions as indicated in insert B provided a measured interaction impedance as shown by curve B. By comparing curves A and B it is seen that providing the impedance transformer sections **15** approximately doubles the interaction impedance of the circuit. Increasing the interaction impedance of the circuit improves the electronic efficiency and, thus, the power output and gain that can be obtained for a given circuit length. The circuit of the present invention has substantially the same improved mechanical and thermal properties of the prior art circuit exemplified by detail A.

In a preferred embodiment, the helices **5** and **6** are preferably connected substantially midway along the length of the vanes **4**. However, it is not necessary that the helices be connected precisely midway of the length of the vanes **4**. More specifically, helices may be connected such that the spacing from the helix to the back wall **2** is from one-third to three times the spacing from the helix to the tips of the vanes **4**. The aforecited measurements are made in the direction along the vane from the nearest side of the helix to the wall or to the vane tip. The helices **5** and **6** should not be too closely spaced to the backwall **2** as this tends to short out the helices.

Although the present invention has been depicted employing dual helices for coupling the vane array, the circuit may employ only a single helix for coupling the vane array. In such a case, the helix would be coupled to the vane array in the same manner as previously described with regard to insert B. The circuit is useful in linear beam tubes as well as in circular beam tubes.

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. In a high frequency apparatus, means forming a conductive wall structure, means forming an array of conductive members connected to and projecting away from said wall to define root portions of said members where they are connected to said wall and tip portions at the opposite ends of said members, means forming a conductive helix structure interconnecting said members

of said array, means for producing a stream of electrons adjacent said tip portions of said array of conductive members for interaction with the radio frequency fields on said helix coupled array of members to produce a radio frequency output, the improvement wherein, said helix is connected to said members intermediate their length with the spacing from said helix to said wall taken in a direction along said members being from one-third to three times the spacing from said helix to said tip portion of said members taken in the direction along said members.

2. The apparatus of claim **1** wherein the spacing from said helix to said wall is approximately equal to the spacing from said helix to said tip portions.

3. The apparatus of claim **1** wherein said conductive members are vanes.

4. The apparatus of claim **1** wherein said helix structure includes a pair of contrawound helices disposed on opposite sides of said conductive members.

5. The apparatus of claim **1** wherein said helix coupled members are vanes, said array is a curved array, and said means for producing a stream of electrons includes means for producing an axially directed magnetic field and a radially directed electric field to produce a magnetron-type interaction region adjacent said tip portions of said curved array of vanes.

6. The apparatus of claim **5** including means forming an input terminal on said helix coupled array for applying radio frequency signals to be amplified, means forming an output terminal on said helix coupled array for extracting the amplified radio frequency output signal, and means forming a circuit sever disposed between said input and said output terminals of said helix coupled array for preventing propagation of radio frequency output signals to said input terminal.

References Cited

UNITED STATES PATENTS

2,939,035	5/1960	Reverdin	315—3.5
3,054,017	9/1962	Putz	315—3.6

FOREIGN PATENTS

1,074,092	1/1960	Germany.

HERMAN K. SAALBACH, Primary Examiner

S. CHATMON, Jr., Assistant Examiner

U.S. Cl. X.R.

315—3.6; 333—31