

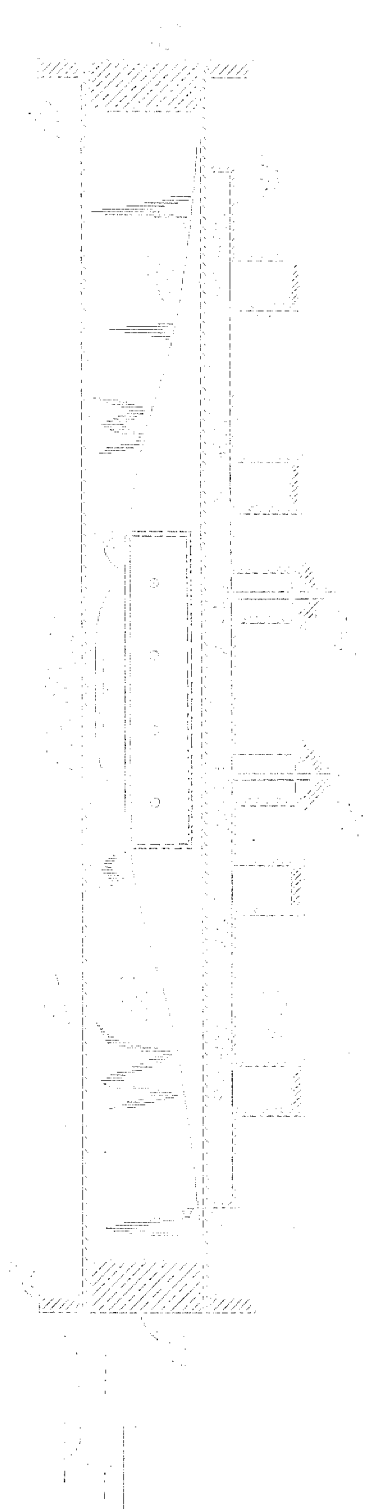
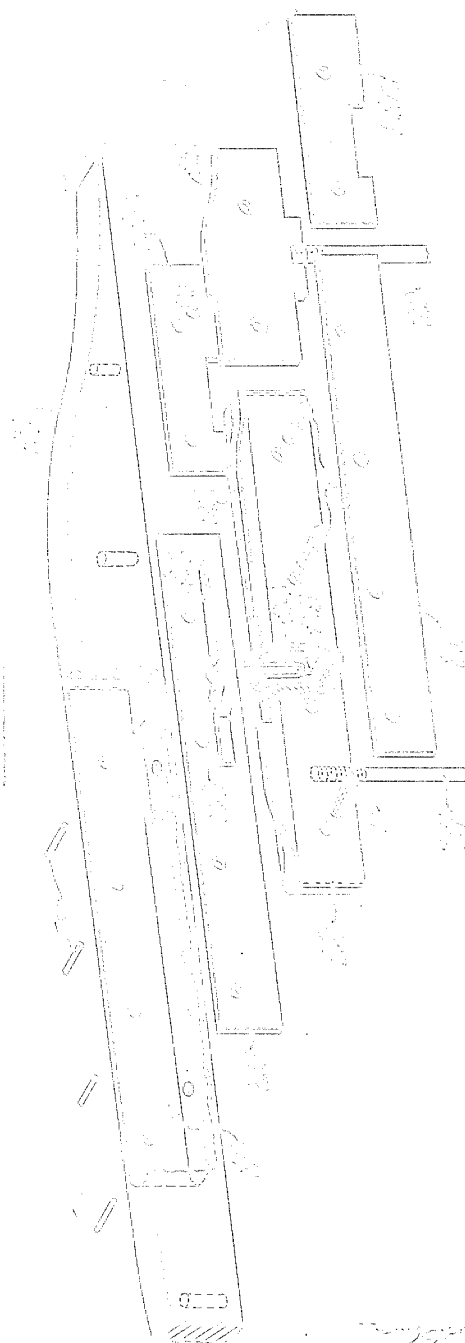
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IN THE DISTRICT COURT OF THE UNITED STATES FOR THE DISTRICT OF COLUMBIA
WESTMINSTER POWER SOURCE

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3 Sheets-Sheet 1

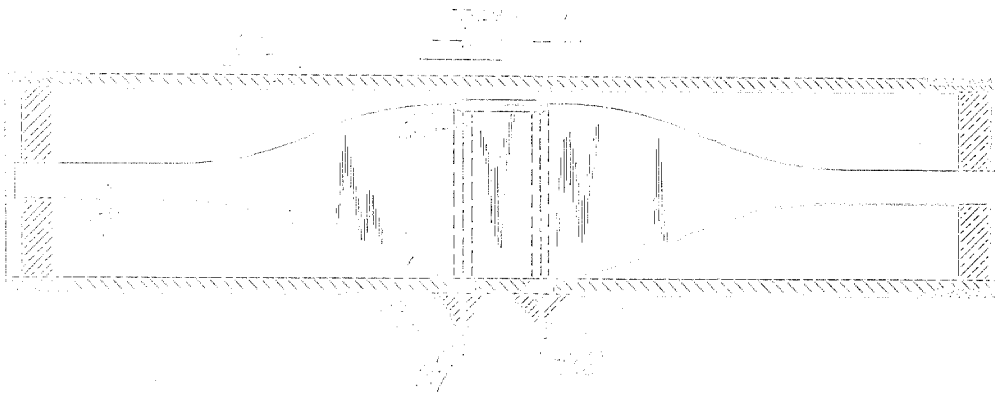
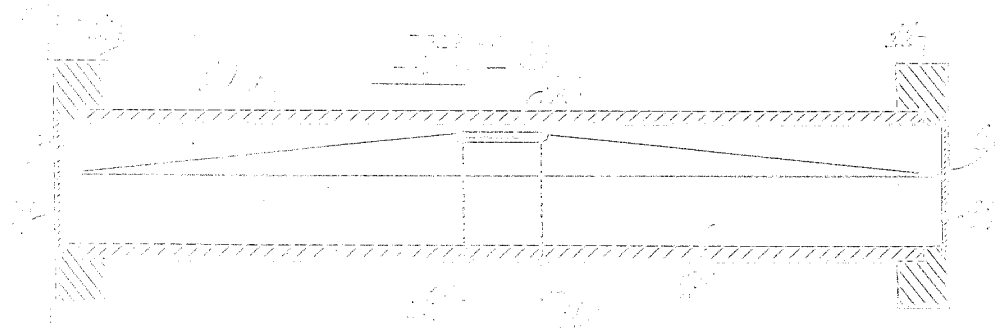
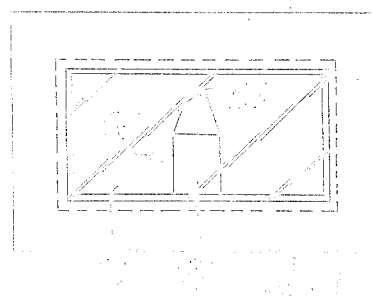


IN WITNESS WHEREOF
I have hereunto set my hand and the seal of the Court
this 10th day of June 1900
BY
[Signature]
CLERK OF COURT

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DEVELOPING FOREIGN SOURCE

4 Sheet 4-Sheet 5



1. 1. The first part of the paper is a review of the literature on the topic of the paper.
 2. 2. The second part of the paper is a description of the methodology used in the study.
 3. 3. The third part of the paper is a presentation of the results of the study.
 4. 4. The fourth part of the paper is a discussion of the results of the study.
 5. 5. The fifth part of the paper is a conclusion.
 6. 6. The sixth part of the paper is a list of references.
 7. 7. The seventh part of the paper is an appendix.
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Patented Apr. 12, 1955

2,637,003

UNITED STATES PATENT OFFICE

3,327,363

IMPROVED NOISE SOURCE

Kenneth Johnson, Princeton, and Kenneth H. De Haven, Princeton Junction, N. J., assignors to Radio Corporation of America, a corporation of Delaware

Application August 27, 1948, Serial No. 118,758

17 Claims. (Cl. 315-32)

This invention relates to electron discharge devices and more particularly to vacuum tubes of special application used for generating noise currents.

In determining the noise factor of radio circuits and components, particularly receivers, it is desirable to use, as test signals, noise currents generated from thermionic sources such as a diode vacuum tube. This is because of the fact that the magnitudes of noise currents so generated can easily be predetermined with considerable precision. However, in seeking to utilize such a thermionic source in any of the conventional forms in which such sources have existed in the past, it has been found very difficult to connect it into the input circuit of the component under analysis so as to cause the test signal source to duplicate the impedance and other conditions "seen" by the input circuit in the normal operation of the component.

For example, the following difficulties have been encountered in two kinds of systems: in balanced input systems, e. g., systems fed over parallel conductor transmission lines, in which it has been found that a conventional noise diode adds shunt capacity which must be tuned out and that its filament-heater and anode-energizing connections offer the possibility of unbalancing the line; and in waveguide systems, in which it has been found that the bodily insertion of a conventional noise diode into a guide between two of its opposite walls produces a marked discontinuity. Known arrangements by which a conventional diode might be connected into the system necessitate the use of transformer sections, matching devices, and the like, most of which besides being cumbersome have narrow-band operating characteristics. In the case of coaxial input systems similar problems have been solved in part by the recent invention of a number of special coaxial noise diodes. However, even when these special diodes are used, it is not possible fully to duplicate the normal operating conditions "seen" by the input circuit of the component under analysis. The following explanation of this will be best understood by reference to U. S. Patent 2,438,387 and co-pending application Serial Number 792,436, now U. S. Patent 2,503,644, dated May 6, 1951, both of which have been assigned to the assignee herein.

The patent and the application referred to above disclose coaxial thermionic noise sources which were devised to be directly connectable into standard coaxial transmission systems as integral sections thereof and to perform therein without giving rise to some of the difficulties which have been encountered in the past. Each of the sources which they disclose consists of a section of coaxial line which comprises a built-in diode. The outer conductor of the section constitutes the anode for the built-in diode while its cathode

consists of a circular thermionic filament which surrounds and is supported from the inner conductor. The inner conductor serves as a direct current heater lead to one side of the filament while the other heater lead is led through an axial duct formed inside the same inner conductor. While these noise diodes have many desirable features, they all have the disadvantage that the filament, since it is positioned between the inner and outer conductors of the coaxial section, will unavoidably be immersed in any electro-magnetic field existing therebetween and will produce an impedance discontinuity.

As is known, the greatest impedance discontinuities are produced by protrusions which extend into the dielectric medium, in which the electromagnetic energy is propagated, in the same directions as the lines of electric force set up by that energy. Therefore, so long as the circular filament is very thin in terms of wavelength, and is concentric with the conductors of the line, it will not itself be the principal cause of the discontinuity. Instead, the main cause is the protrusion of two supports which extend radially between the ends of the filament and the inner conductor. Of course, at super high frequencies the situation is worsened by the fact that the filament ceases to be very thin. Thus it is apparent that the discontinuity produced by the filament of one of these coaxial diodes is of very substantial proportions where the system is used for transmitting super higher frequencies. Because of this these noise sources, though they are very useful in the ultra high frequency region between 300 and 3000 megacycles, cease to be satisfactorily useful in the super high frequency range between 3000 and 30,000 megacycles, i. e., in the range in which it is essential to use waveguides. In addition, apart from frequency considerations coaxial diodes are generally unsuitable in waveguide systems since to so employ one will necessitate the use of transformer sections, matching devices, and the like.

It is an object of the present invention to devise an improved coaxial noise diode suitable for use at super high frequencies.

It is a further object of this invention to devise an improved coaxial noise diode which may be used as an integral part of a transmission system and in which no substantial impedance discontinuity is introduced into the system by the cathode, the cathode supports, or the cathode heater leads.

It is a further object of this invention to devise a thermionic noise source suitable for use in waveguide systems.

It is a further object of the present invention to devise a waveguide section which comprises a built-in noise diode and may be directly connected into a waveguide system, the diode being so arranged within the section that it does not

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produce a substantial impedance discontinuity therein.

It is a further object of this invention to devise a waveguide section which comprises a built-in noise diode and may be directly connected into a waveguide system, the diode being arranged within the section so that it does not produce a substantial impedance discontinuity therein and so that at the same time it is efficiently operable as a source of noise currents.

A particular feature of the invention is that the cathode of a noise diode is built into a hollow conductor of a super-high frequency transmission system, is shielded from abrupt physical protrusion into the dielectric propagation medium therein, and therefore from close enough parallel coupling to any electromagnetic fields which may be present therein to cause a substantial discontinuity in the impedance of the system at the point where the diode is built in.

Another particular feature of the invention is an arrangement of the built-in diode with a very short inter-electrode spacing to afford two simultaneous advantages: (1) that the diode will function efficiently to produce relatively large noise currents over a wide band of frequencies, and (2) that the electron stream will not be able to absorb much energy from any electromagnetic fields which may exist within the hollow conductor, i. e., that the electron stream will be loosely coupled to that energy and therefore will not substantially alter the impedance of the system at the point where the diode is built in.

Another particular feature of the invention is an arrangement whereby the shunt impedance presented to the diode by the section of the system into which it is built has a suitably high value for developing useful amounts of noise power, despite an extreme reduction of an internal dimension of the hollow conductor of that section to provide a short discharge space for the diode, while at the same time the shunt impedance which the diode presents to the system is relatively high due to its operation with temperature limited emission.

Other objects will be apparent from the following description of the invention pointed out with particularity in the appended claims and taken in connection with the accompanying drawing in which:

Fig. 1 is a side view of a noise diode constructed in accordance with a preferred embodiment of the invention, the diode being incorporated into a section of waveguide portions of which are shown cut away to expose internal structural features;

Fig. 2 is an exploded view of some of the component parts of the noise diode shown in Fig. 1 to illustrate structural details;

Fig. 3 is a side view of a noise diode constructed in accordance with another embodiment of the invention;

Fig. 4 is a cross-sectional view taken through the structure shown in Fig. 3 along the line 4-4;

Figs. 5 and 6 are respectively a top view and a cut-away side view of a portion of the structure shown in Figs. 3 and 4;

Fig. 7 is a longitudinal sectional view of a noise diode built into a section of coaxial line in accordance with another embodiment of the invention; and

Figs. 8 and 9 represent a modification of the embodiment of Fig. 1, Figure 8 being a section

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taken along line 8-8 of Figure 9, and Figure 9 being a left end view of Figure 8.

Similar reference characters are applied to similar elements throughout the drawings.

Referring to Fig. 1, the diode comprises a wave guide section 10 which in the present embodiment is of the rectangular type and preferably is of some standard size and which also functions as part of the tube envelope. Section 10 carries at its opposite ends flanges 11 and 12 by which it may be readily connected into a standard waveguide transmission system. The flanges 11 and 12 may include R. F. (radio frequency) chokes or any other desirable known features for assisting coupling. In the diode shown in Fig. 1 a portion 13 of the inner wall of the top of waveguide section 10 acts as the anode. Since ordinarily the metallic tubes comprising a waveguide system are grounded, the energizing potential for this diode will preferably be applied as a negative potential to its cathode (filament 14). However, if desired, the entire section 10 may be D. C. insulated from the rest of the waveguide system so that it will be possible to apply the energizing potential to it as a positive potential. In either case the portion 13 of the inner wall of the section will be at a higher potential than the diode-cathode.

For efficient operation it is essential that the inter-electrode space for this diode be very short. If the transit time from the cathode to the anode is gradually increased it will be noted that when it is equal to about one-half of one period corresponding to the center frequency of the operating band, or, to be more exact, when it is equal to 3-5 radians at that frequency, the noise current will be down very markedly, more particularly the mean squared noise current ($\bar{I}^2$) will be down by 50% and will be decreasing at a rapid rate. The mean noise current may be considered as an integration of random current impulses each of which is produced during the transit of an individual electron from the cathode to the anode. According to Fourier, if the transit times are very short the current impulses will include many high frequency components having significant magnitudes whereas if they are long this will not be true. Thus, when the noise current drops because of increases in transit time the loss is mostly in its high frequency components. Accordingly it is desirable for the diode to have a short transit time. Moreover, it is desirable for the transit time to be short for another reason, this being that its duration affects the A. C. plate resistance of the diode in such a manner that even if it is operated with temperature-limited emission it can seriously load the guide if the transit time is too long. But this of itself does not mean that the interelectrode space must be short, since it is possible to decrease the transit time by increasing the electron velocity, i. e., by using larger and larger potential gradients between the cathode and the anode. However, if the discharge space is over the full distance from the bottom to the top of a standard waveguide, the potential necessary for a transit time of less than 3.5 radians is so great as to be impractical and uneconomical.

Accordingly the present arrangement provides for a very small interelectrode discharge space. Moreover, it provides the small discharge space without entailing any protrusion of the cathode into the dielectric transmission medium in the section. To this end the cathode, which in the

background; and the filament is formed as a long, narrow filament 14, is mounted on the top of a tapered waveguide ridge 15 close to the area portion 12 and it is mounted thereon to bridge straight across a shallow recess 16 formed in the top surface of the ridge in such a manner that it does not protrude above the highest parts of that surface. Ridge 15 is fastened to the inside of the bottom of the section 10 along the center line thereof.

This results in the attainment of a large amount of useful noise power at the input of the component under test, or, as it is sometimes expressed, a large amount of "available noise power." This is true because of the fact that narrowing the top-to-bottom dimension of a guide for only a small fraction of its width will reduce its impedance by a very much smaller factor than narrowing this dimension over the full width thereof. Thus it is possible to use a thin ridge for supporting the filament 14 in very close proximity to the area portion 12 without causing the diode to be shunted by an excessively low guide impedance. This is important since the noise power which the diode can deliver to the input of the component under test is an

$$\frac{P_{av}}{R_{in}}$$

function of the load impedance which it "sees." Moreover the guide impedance is highest at its center and due to the axial positioning of the filament 14 along the center of the guide the sheet-shaped (or wedge-shaped) electron stream of this diode will be produced where the maximum noise power can be transformed to the system. If it were carried either crosswise to the guide or axially along it far to one side of its center line, the side portions of the transverse electron stream, or all of the axial beam, as the case may be, would transfer very little noise power to the system because the electrons thereof would move through a very low impedance portion of the guide. Moreover, of course, to support the filament crosswise would require a ridge of much greater height and therefore the diode would "see" a very low shunt guide impedance.

The filament as a whole must be insulated from the section 10 as to D. C., so that a negative energizing potential may be applied to it, and each of its ends must be insulated from the other (except for their interconnection over the relatively high resistance of the filament itself), so that heater potential may be effectively applied to it. Moreover it is essential to do this without interrupting the R. F. continuity of the path up the slope of the ridge 15, along the filament 14, and down the other side of the ridge, since as is known, a centrally-positioned waveguide ridge must be able to carry axial R. F. currents of large magnitudes. For this reason we have devised a particular structure which is to be disclosed below and which is best understood with reference to Fig. 2.

The advantages of the present type of construction for the ridge 15 are best understood in view of certain disadvantages of a simpler arrangement which one might wish to try. Consider an arrangement comprising a vertical hole through the ridge near to each end of the filament; a dielectric sleeve lining each hole; conductive rod through each sleeve; a shallow depression (like 16 of Fig. 1) along the top of the ridge to avoid short-circuiting and grounding the filament along the top of the ridge; a filament fastened across the top of the rods in the desired position near the

top surface of the ridge so that the filament itself constitutes the top surface of the ridge as to R. F. currents; and extensions of the rods through holes in the bottom of the waveguide for connection to external circuits. In such an arrangement, each end of the filament and the adjacent portion of the top surface of the ridge would be somewhat capacitively coupled but the value of the capacity would be very small and as a result R. F. reflections would be produced at each of the ends of the filament due to a high in-series capacitive reactance.

On the contrary, the arrangement shown herein provides low impedance R. F. continuity along the full length of the top surface of the ridge 15 as well as up its sides and across this top surface.

The ridge 15 comprises a ridge base 17 deeply slotted vertically in its central portion to form a narrow recess 18 for receiving a ridge insert 19. The ridge insert 19 is carried within the recess 18 between two flat sheets 20 of material, such as mica, having a high dielectric constant. The ridge insert 19 is not as long or as deep as the recess 18 so that it may be positioned in the recess with its ends and bottom out of D. C. contact with the ridge base 17. The ridge insert may be held in this position in any suitable manner, for example, by being press-fitted into the recess or by being riveted in place with transverse pins 21 surrounded by dielectric sleeves 22. Since the entire ridge insert is isolated as to D. C., it can be used as a D. C. terminal for one end of the cathode. To this end the left end of the cathode is directly connected to the ridge insert 19. In this arrangement radio frequency currents moving along the top surface of the ridge base, or up its sides, will readily flow onto the top surface of the ridge insert because of the very low in-series capacitive reactance between the two elements, and these currents will flow directly onto the filament without the need for traversing a capacitive gap. To provide the required insulation between the two ends of the filament the ridge insert 19 is made up of two separate metallic parts which mechanically are joined together but electrically, as to D. C., are insulated from one another. The smaller of the two parts is a minor insert 21 which fits into a central vertical slot 22 cut for some distance into the ridge insert 19 from its right end. The minor insert is carried in the slot 22 between two sheets of mica 23, or other suitable insulating material of high dielectric constant, to provide a large capacitance between the main portion of ridge insert 19 and the minor insert 21.

Provision is made to keep the filament taut at all times despite the changes in its length which occur during heating and cooling. To this end, the right-hand end of the filament 14 is welded directly to point 24 at the top of the minor insert, and its left-hand end is welded to the top of the right-hand side of an S-shaped spring 25 which is slightly spring-loaded to keep the filament under tension. The ridge insert contains a small cavity 26 into which the spring 25 is fitted, the left-hand side of the spring 25 being welded to an inside wall of the cavity. A corrugated metal ribbon 26 serves to provide low impedance R. F. continuity along the top of the ridge insert from the left edge of the shallow depression 16 onto the left end of the filament 14 (thus making it unnecessary for the R. F. currents to flow down into the cavity 26 and up the spring 25). The corrugation 26 is formed to be compliant in directions along the axis of

the filament 14. It is welded to the ridge insert on one of its ends and to the right hand side of the S-shaped spring 24 and/or to the left end of the filament 14 on its other end.

A rod 27 is affixable to the bottom of ridge insert 18. When the diode is assembled this rod extends from the insert 18 to the space outside of the diode, where it may serve as a terminal for connection to appropriate outside circuits, through registering holes in the bottoms of recess 18 and waveguide section 19. Rod 27 is insulated from the sides of these holes by a dielectric sleeve 28. A similar rod 29 is affixable to the minor insert 21 and, when the entire diode is assembled, similarly extends through a dielectric sleeve 30 to the space outside of it without making D. C. contact with any other element of the entire assembly. Thus, heater current may be applied to the filament 14 through the rods 27 and 29, and the energizing potential for the diode may be applied to either of these rods.

We have found that it is desirable that the filament 14 be emissive only from its top surface. If electrons are emitted from the underside of the cathode their paths of travel are circuitous and therefore their transit times are not reliably controllable and are excessively long. For this reason a preferred type of filament is one formed of tantalum with a coating of thorium on its top surface. However, if this type of filament is used, certain precautions must be observed in assembling the diode. It will not be proper to perform soldering or brazing operations which involve the possibility of considerable heat being conducted to the filament. This is due to the fact that, though this kind of a tantalum filament may be operated at incandescence in a vacuum, it will be seriously damaged if it is heated to a very much smaller extent in an air atmosphere.

Therefore steps described below are recommended for assembling the diode to provide it with a vacuum-tight enclosure.

The waveguide section 19 is vacuum sealed at one of its ends, the other end being temporarily left open to permit insertion of the guide ridge 15. The seal may be an electromagnetic-energy-permeable window 31 of the kind shown in Fig. 1 and more fully described in co-pending application Serial Number 96,091 filed May 28, 1949.

This consists of a plate of sponge-glass material so formed that the ratio of the volume of solid vitreous material to that of interstitial space is small enough to afford a dielectric constant very close to 1.

This material may be utilized to provide a good vacuum seal, while at the same time it will not produce any substantial impedance discontinuity. Another suitable type of window is one formed of a thin sheet of mica fused with a vitreous material into a shallow recess in the end surface of the coupling flange. A thin mica sheet used for this purpose is to be preferred to a thin sheet of solid glass as it is tougher and more resilient and therefore less likely to be broken. As is known, the dielectric constant of a thin window may be very high without its producing any substantial impedance discontinuity.

When all of the parts of the ridge 15 are fully assembled together, except that the rods 27 and 29 remain unscrewed from the ridge insert 18 and the minor insert 21 respectively, the ridge 15 is inserted into the waveguide section 19

through the end which as yet is not sealed off. The ridge is fastened into place along the center of the bottom of section 19 by any suitable means such as screws 32. Since it is not permissible to seal the screw heads to the bottom of the section by soldering or brazing, or the like, because of the possibility of injuring the filament 14, we have employed the remaining steps which are described below.

A shallow box 33 is affixed to the outside surface of the bottom of the section 19 with vacuum-tight junctures all the way round its top edge. The shallow box 33 is large enough and is properly positioned to cover all of the heads of the screws 32. If the box 33 is brazed or soldered into place, obviously this should be done prior to the insertion of the ridge 15. Extending from the box 33 are several tubular extensions 34 which are soldered, welded or brazed, or in any other suitable manner connected to the bottom of the box 33 each with a vacuum-tight juncture and each in alignment with the position for one of the screws 32 or with one of the two holes made in the bottom of section 19 for receiving the rods 27 and 29. Accordingly, the screws 32 may be set in position and tightened by working through the extensions 34. Similarly both the bushings 28 and 30 and the rods 27 and 29 may be inserted into position and screwed into place through the appropriate ones of the extensions 34. Each of the extensions is thereafter sealed off in some appropriate manner: for example, those positioned over the screws 32 may be sealed by soldering plugs in their ends, whereas those through which the rods 27 and 29 extend may be sealed with glass beads. In sealing the extensions it is preferred to use R. F. heating as this induces intense heat so quickly that there is very little time for it to be conducted to the tantalum filament. As an added precaution the upper portions of the extensions may be wrapped with cloth soaked with cold water. If desired, one of the extensions by be left open for connection to a vacuum pump to be pinched off after evacuation.

After the ridge 15 is installed the open end of the waveguide section is sealed with another electromagnetic-energy-permeable window 31. The problem of preventing too much heat from being conducted to the filament may be met in this case by using a long enough section of waveguide so that there is considerable distance between the end at which this second window is installed and the location of the filament and also by using a wet cloth.

The diode is now complete except for evacuation and degassing, which may be performed in accordance with usual practice.

It will be seen from the foregoing that the ridge 15 provides a support for the cathode 14 which accurately positions it near to the underside of the top of section 19. In one experimental diode which operates very satisfactorily this interelectrode spacing is about 10 mils. This provides a sufficiently short transit time for an anode-cathode voltage difference of only 300 volts at an operating frequency of 10,000 megacycles. In addition the ridge 15 affords a non-reflecting structure which shields both the cathode and its heater and energizing leads from protrusion into the dielectric propagation medium inside the guide and in addition gradually transforms the impedance at the center of the guide from that for the full height thereof to that for the reduced spacing at the filament and then gradu-

ally transforms it back again. Thus, the ridge is a support, a shield and a transformer. The impedance of the center portion of the guide at the location of the diode is much lower than the plate resistance of the diode so that the transformations performed by the ridge may be accomplished by normal tapering.

In Figs. 2, 4, 5 and 6 an alternate type of waveguide noise diode is shown. It comprises a thin fin-like element 45 carried vertically within the section along the center thereof and tapered on both ends for a sufficient distance to function in a manner corresponding to the functioning of the ridge 12 in the embodiment of Fig. 1. Element 45 performs in full two of the same functions as the ridge 12, that of supporting the filament and that of transforming impedances in the guide. In addition it shields the filament. However, since the element 45 is not connected to the bottom of the waveguide it can not be used to shield the filament leads. For if the leads were disposed as in the Fig. 2 embodiment, portions of them would be exposed between the bottom edge of the element 45 and the bottom of the waveguide. Since these portions would cross the dielectric propagation medium within the guide in the same direction as the lines of electric force, they would cause reflections. For this reason we have employed the arrangement shown in Figs. 2 and 4 in which unshielded heater leads cross the air-insulated space inside the section 10 at right angles to the lines of electric force.

The element 45 consists of two similarly formed thin plates 46, 47 which are mechanically joined together but electrically insulated from one another by a thin sheet of dielectric material 48. A shallow depression is formed along the top edge of the element 45 at the intended position for the filament 14 for reasons explained above with respect to the embodiment of Fig. 1 (see shallow depression 13). Similarly, a cavity, like the cavity 14 of Fig. 1, is formed between the plates 46, 47 for receiving the S-shaped spring 34 and the corrugation 35 which in the present embodiment may be of similar design and perform the same functions as those mentioned above for the earlier-described embodiment.

However, the S-shaped spring 34 and the left-hand end of the corrugation 35 in this embodiment are welded only to the plate 46 and they are positioned so as not to make D. C. contact with the plate 47 whereas the right-hand end of the filament 14 is welded to, and contacts, only the plate 47. In this way heater current may be applied to the filament 14 by connecting each of the terminals of a source of potential to one of the plates 46, 47.

In order to provide heater-current connections to these plates, two rods 49 and 50 are provided each of which may be screwed into the outward-facing surface of one of the plates 46, 47 and may be sealed through the corresponding side wall of the waveguide section. To protect the filament from heat used in sealing the rods 49, 50 to the section 10, the seals 51, 52 are formed on the ends of cylindrical extensions 53, 54 rather than directly on the side walls. In assembling this diode the rods 49, 50 may be pushed through cylindrical extensions 55, 56 to engage threaded holes in the plates 46, 47, and, after they are screwed firmly into these holes, the seals 51, 52 may be formed. Though two rods are sufficient to provide all the needed electrical connections to the cathode, others may be employed for helping to support the element 45 within the wave-

guide section. In the example shown in Fig. 2 two additional rods are used, one of which, rod 51, appears in the drawing. All such additional rods should be insulatingly connected to the sides of the section 10, for example, they may be sealed to its side walls by glass beads in the same manner as the rods 49, 50, this being desirable in order to preserve D. C. isolation for the plates 46, 47.

Fig. 7 shows what may be considered either as an improved coaxial noise diode or as another form of waveguide noise diode which comprises coaxial line input and output sections. The envelope of the diode comprises a section of hollow conductor 59. The central portion of the hollow conductor 59 is in structure and function very much the same as a ridged circular waveguide while each of its end portions clearly functions as the outer conductor of a coaxial line section, and each end of its ridge 62 is an extension of the inner conductor of one of the coaxial sections.

In the embodiment of the Fig. 7 the top surface of ridge 62 tapers downward only far enough to smoothly join inner conductor 61, while its bottom surface, instead of extending for the full length of the ridge along the wall of the hollow conductor in a manner corresponding to the arrangement in Fig. 1, has an end portion which tapers upwards so that it and said upper surface converge symmetrically together to the point where they both smoothly join inner conductor 61. In the central portion of the ridge 62 its bottom surface, or edge, is conductively attached to a portion of the inner surface of the hollow conductor 59 on the opposite side thereof from the portion which serves as the diode-anode. Because of this arrangement the ridge 62 may serve as a shield for the heater leads in a manner corresponding to that of the embodiment of Fig. 1.

The construction of the ridge 62 will not be described in detail. Its construction may be any adaptation of that utilized for the ridge 12 of Fig. 1 which embodies the principles disclosed herein. In order to simplify the drawing, the arrangement of this embodiment of the invention is only schematically represented by Fig. 3, for example, the structural details of the ridge 62 are not shown and the filament leads are shown to be directly sealed to the hollow conductor rather than sealed in some more elaborate manner which might be required in order to follow the earlier-described process for assembling the diode.

Figs. 8 and 9 represent a modification of the embodiment of Fig. 1. In this embodiment a ridge 63 is formed to be in all respects similar to the ridge 12 of Fig. 1 except for the long, tapered end portions. The section 12a is made equal in length to the foreshortened ridge so that the vacuum seals 58 at its ends abut directly against blunt ends 64 of the ridge. As is known, the presence of an untapered ridge in a waveguide loads it and has the effect of extending the frequency band over which it will have practical utility for transmitting energy providing the section containing the ridge is appropriately connected into the system utilizing it. As a result, a noise diode made according to this modification of the present invention will have an extended frequency range of operation in different parts of which it can be made to serve as a signal source by attaching different appropriate transmitting and coupling sections into its input and

output ends according to principles known to the waveguide art. If it should be desired to utilize the diode in the same frequency range as that over which the embodiment of Fig. 1 is useful, all that is necessary is to add to the ends of the section 18a two sections of waveguide which contain the long, tapered end portions so that, when the three sections are connected together, the result will be the electrical equivalent of the diode of Fig. 1. Obviously it is desirable that the break between such attachable tapered end portions and the blunt ends 67 be as small as possible. For this reason thin vacuum seals, such as mica windows, are to be preferred for embodiments of this type. On the other hand, if it should be desired to operate the diode over an extended band of frequencies or over a band of frequencies not entirely within the operating band of an embodiment of the Fig. 1 type, different types of attachable sections should be connected to the ends of the diode such as impedance transformers containing appropriately tapered extensions for the ridge 65, or other transforming devices known to the art.

Although our improved diode has been described in connection with its use as a noise diode for the purpose of making certain tests and measurements, it is evident that a device of this type may have various other applications wherever it is desirable to maintain a certain circuit impedance and have at the same time an electron discharge device in this circuit without disturbing the transmission characteristics thereof. It will also be evident that, instead of being limited to a two-element tube, other elements may be incorporated in our tube. Therefore, while we have indicated the preferred embodiments of our invention of which we are now aware and have also indicated only certain specific applications for which our invention may be employed, it will be apparent that our invention is by no means limited to the exact forms illustrated or the use indicated, but that many variations may be made in the particular structure used and the purpose for which it is employed without departing from the scope of our invention as set forth in the appended claims.

What I claim is:

1. A ridge structure for a hollow conductor which encloses an electron discharge device comprising a thin elongated ridge base, a ridge insert carried by the central portion of the ridge base, with relatively large portions of its surface closely-juxtaposed to surfaces of said ridge base, insulating material having a high dielectric constant interposed between said juxtaposed surfaces whereby the ridge base and the ridge insert are coupled as to R. F. energy by a large capacitance but are isolated as to D. C., the ridge insert comprising a principal portion and a minor insert carried by the principal portion but insulated therefrom as to D. C., an elongated cathode having its respective ends directly connected electrically to the two portions of the ridge insert, and a recess in the ridge insert extending along it for all of the length of said cathode intermediate its ends whereby except for said ends said cathode is not in direct electrical contact with any conductive portion of the ridge structure.

2. A ridge structure for a hollow conductor which encloses an electron discharge device comprising a thin elongated ridge base having a central portion of given height and tapering gradually in height from said central portion to its two

extremities, a ridge insert carried by said central portion with relatively large portions of its surface closely-juxtaposed to surfaces thereof, insulating material having a high dielectric constant interposed between said juxtaposed surfaces whereby the ridge base and the ridge insert are coupled as to R. F. energy by a large capacitance but are isolated as to D. C., the ridge insert comprising a principal portion and a minor insert carried by the principal portion but insulated therefrom as to D. C., an elongated filament having its respective ends directly connected electrically to the two portions of the ridge insert, and a recess in the ridge insert extending along it for all of the length of the filament intermediate its said ends whereby except for said ends said filament is not in direct electrical contact with any conductive portion of the ridge structure.

3. A ridge structure for a hollow conductor which encloses an electron discharge device comprising a thin elongated ridge base, a ridge insert carried by the central portion of the ridge base with relatively large portions of its surface closely-juxtaposed to surfaces thereof, insulating material having a high dielectric constant interposed between said juxtaposed surfaces whereby the ridge base and the ridge insert are coupled as to R. F. energy by a large capacitance but are isolated as to D. C., the ridge insert comprising a principal portion and a minor insert carried by the principal portion, a filament having its respective ends directly connected electrically to the two portions of the ridge insert, the ridge insert being formed with a shallow depression along its top surface between the points of connection of the respective ends of the filament whereby except for its said ends the filament is not in direct electrical contact with any of the conductive portion of the ridge structure, and means for supporting the filament under tension between the ends of the depression to bridge it so that as to R. F. currents the filament will act as the top surface of the ridge structure.

4. A ridge structure for a hollow conductor which encloses an electron discharge device comprising a thin elongated ridge base, a ridge insert carried by the central portion of the ridge base with relatively large portions of its surface closely-juxtaposed to surfaces thereof, insulating material having a high dielectric constant interposed between said juxtaposed surfaces whereby the ridge base and the ridge insert are coupled as to R. F. energy by a large capacitance but are isolated as to D. C., the ridge insert comprising a principal portion and a minor insert carried by the principal portion but insulated therefrom as to D. C., a filament having its respective ends directly connected electrically to the two portions of the ridge insert, the ridge insert being formed with a shallow depression along its top surface between the points of connection of the respective ends of the filament whereby except for its said ends the filament is not in direct electrical contact with any of the conductive portion of the ridge structure, means for supporting the filament under tension between the ends of the depression to bridge it so that as to R. F. currents the filament will act as the top surface of the ridge structure, the ridge insert being formed to define a cavity for receiving an element of said supporting means consisting of a slightly loaded spring connected to one end of the filament to keep it under tension, and a corrugated metal ribbon connected between said one end of the

filament and one edge of said depression to shield the filament in bridging it.

8. An electron discharge device comprising a hollow conductor sealed at its two ends with an electromagnetic-energy-permeable vacuum seal, an emissive cathode and heater leads therefor, a ridge within the hollow conductor including means for supporting said cathode with its emissive surface in substantially the same plane as adjacent surfaces of the ridge and adjacent to an inside surface of the hollow conductor which acts as an anode for receiving electrons emitted thereby, the ridge surrounding and shielding said heater leads, and the ridge including tapered end portions for transforming impedances within the hollow conductor.

9. An electron discharge device including a hollow conductor vacuum sealed at both of its ends with electromagnetic-energy-permeable material, a ridge carried within the hollow conductor and comprising a thin elongated ridge base which in its central portion is nearly as high as the inside height of the hollow conductor, a ridge insert carried by said central portion with relatively large portions of its surface closely juxtaposed to surfaces thereof, insulating material having a high dielectric constant interposed between said juxtaposed surfaces whereby the ridge base and the ridge insert are coupled as to R. F. energy by a large capacitance but are isolated as to D. C., the ridge insert comprising a principal portion and a minor insert carried by the principal portion but insulated therefrom as to D. C., an elongated cathode having its respective ends directly connected electrically to the two portions of the ridge insert, a recess in the ridge insert extending along it for all of the length of said cathode intermediate its ends whereby except for said ends said cathode is not in direct electrical contact with any conductive portion of the ridge.

10. An electron discharge device as in claim 9 in which said hollow conductor is a section of waveguide.

11. An electron discharge device including a hollow conductor vacuum sealed at both of its ends with electromagnetic-energy-permeable material, a ridge carried within the hollow conductor and comprising a thin elongated ridge base which in its central portion is nearly as high as the inside height of the hollow conductor, a ridge insert carried by said central portion with relatively large portions of its surface closely juxtaposed to surfaces thereof, insulating material having a high dielectric constant interposed between said juxtaposed surfaces whereby the ridge base and the ridge insert are coupled as to R. F. energy by a large capacitance but are isolated as to D. C., the ridge insert comprising a principal portion and a minor insert carried by the principal portion but insulated therefrom as to D. C., an elongated filament having its respective ends directly connected electrically to the two portions of the ridge insert, a recess in the ridge insert extending along it for all of the length of the filament intermediate its said ends whereby except for said ends said filament is not in direct electrical contact with any conductive portion of the ridge, said filament being supported so near to the inner surface of the top of the hollow conductor that electrons accelerated by potentials of the order of several hundred volts will pass from it to said inner surface in transit times no longer than 3.5 radians.

12. An electron discharge device comprising an

envelope including a section of waveguide vacuum sealed at both of its ends with electromagnetic-energy-permeable material, a ridge carried within the section and comprising a thin elongated ridge base which in its central portion is nearly as high as the inside height of said section, the ridge base tapering gradually in height from said central portion to its two extremities, a ridge insert carried by said central portion with relatively large portions of its surface closely juxtaposed to surfaces thereof, insulating material having a high dielectric constant interposed between said juxtaposed surfaces whereby the ridge base and the ridge insert are coupled as to R. F. energy by a large capacitance but are isolated as to D. C., the bottom surface of the ridge being directly connected electrically over all of its length along the center of inner surface of the bottom of the section, a cathode carried on top of the ridge insert in direct electrical contact therewith and adjacent to the inner surface of the top of said section, at least one lead for carrying electrical current to heat the cathode which lead extends from said cathode through the bottom of said section to a pair of external terminals, means including at least one lead duct contained within the ridge and extending from the top to the bottom surface thereof for shielding said lead, and said envelope including means for insulatingly vacuum-sealing said lead through the bottom of said section.

13. An electron discharge device including a hollow conductor vacuum sealed at both of its ends with electromagnetic-energy-permeable material, a thin elongated ridge carried within the hollow conductor, the ridge being nearly high enough in its central portion to reach from one inside surface of the hollow conductor to the opposite one, said ridge gradually tapering in height from said central portion to its two extremities, the ridge including two portions which are insulated from each other as to D. C., an elongated cathode having its respective ends directly connected electrically to the two portions of the ridge, a recess in the ridge extending along it for all of the length of said cathode intermediate its ends whereby except for said ends said cathode is not in direct electrical contact with any conductive portion thereof, the tapering of the ridge being symmetrical in that its top-edge and bottom-edge surfaces gradually approach one another from said central portion and meet at its ends, the ridge being supported within the hollow conductor by elements which are insulatingly joined to opposite walls thereof and extend inwardly to points of connection with opposite sides of the ridge, said elements crossing the dielectric propagation medium inside the hollow conductor in directions perpendicular to electric lines of force which would be defined if radio frequency energy were propagated through the conductor.

14. An electron discharge device as in claim 13 in which two of said elements are respectively connected to said two portions of the ridge and extend outside of said hollow conductor to provide terminals for supplying heater current to said cathode.

15. An electron discharge device including a hollow conductor, a vacuum seal of electromagnetic-energy-permeable material at each end of the conductor, a ridge carried within the hollow conductor and comprising a thin elongated ridge base which is nearly high enough in its central portion to reach from one inside surface of the hollow conductor to the opposite one, the ridge

base tapering gradually in height from said central portion to its two extremities, a ridge insert carried by said central portion with relatively large portions of its surface closely-juxtaposed to surfaces thereof, insulating material having a high dielectric constant interposed between said juxtaposed surfaces whereby the ridge base and the ridge insert are coupled as to R. F. energy by a large capacitance but are isolated as to D. C., the ridge insert comprising a principal portion and a minor insert carried by the principal portion but insulated therefrom as to D. C., an elongated filament having its respective ends directly connected electrically to the two portions of the ridge insert, a recess in the ridge insert extending along it for all of the length of the filament intermediate its said ends whereby except for said ends said filament is not in direct electrical contact with any conductive portion of the ridge, the bottom of said central portion being directly connected axially along an inner surface of the conductor, and two inner coaxial conductors each sealed through one of said vacuum seals and extending into one end of the hollow conductor to a point at which it is joined to an end of said ridge, the tapering of the ridge being symmetrical in that on each of its ends its top-edge and bottom-edge surfaces gradually approach one another from said central portion so as smoothly to join one of said inner conductors.

13. An electron discharge device comprising an evacuated hollow conductor, a ridge connected axially along an inner wall of the hollow conductor, a cathode having an emissive surface, the ridge being adapted to support the cathode with its emissive surface adjacent to a portion of the opposite inner wall of the conductor which constitutes an anode for the device and with said surface in substantially the same plane as adjacent surfaces of the ridge, heater leads extending from the cathode, the ridge surrounding and shielding the heater leads, the ridge having at least one blunt end flush with an end of the hollow conductor to extend the frequency band over which the conductor is operative to propagate electromagnetic energy, and an electromagnetic-energy-permeable vacuum seal at each end of the conductor at least one of the seals abutting against a blunt end of the ridge.

14. An evacuated electron discharge device including a tubular anode of predetermined cross section suitable for connection into an R. F. transmission system as a hollow conductor therefor, a cathode within said tubular anode, a support for said cathode comprising a conducting member having a central portion and tapered end portions and extending along said tubular anode with a minimum of spacing between the central portion thereof and said tubular anode, said cathode being supported adjacent to said anode in said central portion of said support in insulating relation as to D. C. with said anode, means providing large capacity R. F. coupling between the cathode and the support, said support having a recess in which said cathode is mounted with the emissive surface thereof in substantially the same plane as adjacent surfaces of the support.

15. An electron discharge device including a tubular conductor, electromagnetic-energy-permeable means hermetically sealing the ends of said conductor, a cathode within said tubular conductor, said tubular conductor serving as an anode for said cathode, an elongated support supporting said cathode closely adjacent the inside

surface of said tubular conductor, said support having an enlarged central portion supporting said cathode and tapered end portions, said tapered end portions serving as impedance transformers when said device is utilized in an R. F. transmission system.

16. An electron discharge device comprising an envelope including a section of wave guide sealed at both of its ends with electromagnetic-energy-permeable material, electron-receiving means including an elongated surface extending along the inside of a wall of the section of wave guide and facing toward the inside of its opposite wall to serve as an anode for the discharge device, said section containing an elongated ridge having a bottom side which is physically attached to said inside of said opposite wall in such a position that a central portion of the top side of the ridge registers with said elongated surface to act as a support for a cathode to cooperate with that surface, the height of the ridge as measured between its top and bottom in its central portion being large enough so that in said central portion its top is closely juxtaposed to said elongated surface while its height in its end portions progressively lessens until it is negligibly small at its two extremities, means providing direct current insulation and radio frequency capacitive coupling between said inside of said opposite wall and at least the central portion of the top side of the ridge, a thermionically emissive surface carried on said central portion of the top of said ridge in close juxtaposition to and facing toward said elongated surface to act as a cathode in co-operation therewith, means for heating said emissive surface by the use of an externally supplied electrical current, said means including a resistive filament and a heater lead connected to one of the ends thereof and extending to a terminal on the outside of said envelope, said lead passing within the ridge between its top and bottom to be shielded therewithin and extending through said opposite side of the section of wave guide to said terminal.

17. An electron discharge device comprising an elongated hollow conductor, an elongated conducting ridge extending longitudinally within said conductor, one transverse dimension of said ridge being almost as great as the corresponding dimension of said conductor, at least one side edge of said ridge being located in close spaced relation with said conductor, the transverse dimension of said ridge at right angles to said first-named dimension being only a small fraction of the corresponding dimension of said conductor to minimize the reduction of the impedance of said conductor due to the presence of said ridge, and a cathode supported on said side edge of said ridge.

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