

April 14, 1959

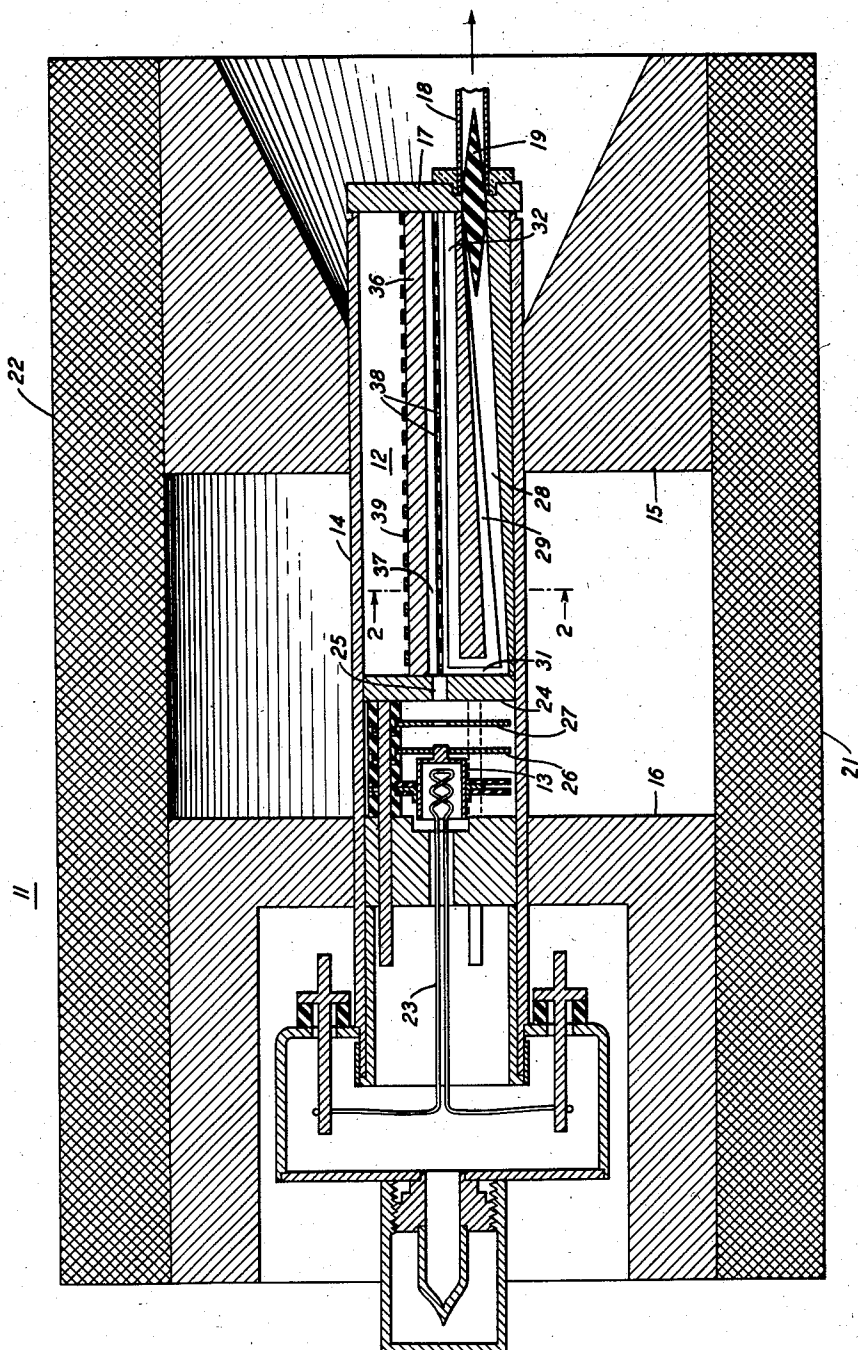
A. KARP ET AL
TRAVELING WAVE TUBE

2,882,438

Filed April 12, 1954

2 Sheets-Sheet 1

FIG. 1



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FIG. 2

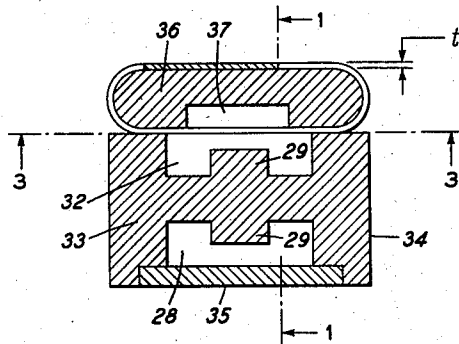


FIG. 3

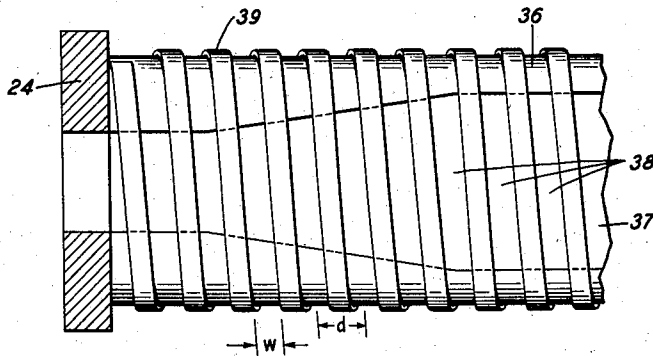
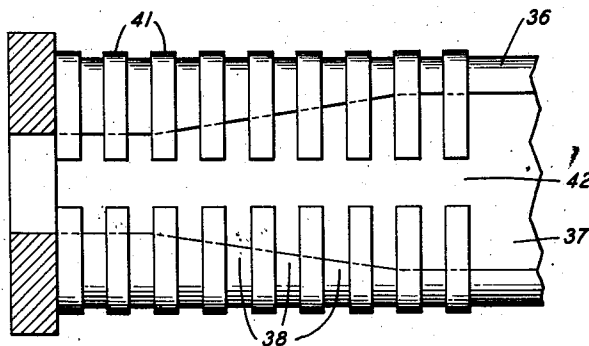


FIG. 4



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2,882,438

TRAVELING WAVE TUBE

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Application April 12, 1954, Serial No. 422,613

15 Claims. (Cl. 315—3.5)

This invention relates to high frequency electron devices and more particularly to those devices of the so-called traveling wave type.

The principal object of this invention is to simplify the structure of traveling wave tubes operating at extremely short wave lengths.

Another object is to provide a traveling wave tube which may be operated at any one of a large number of different operating frequency bands.

A still further object of this invention is to achieve broad band amplification in traveling wave tubes without sacrificing gain and ease of construction.

Heretofore, traveling wave tubes, to secure gain, have commonly utilized the interaction of an electron stream with an electromagnetic wave traveling at approximately the same velocity as the electrons in the stream, the wave being slowed down to the velocity of the electrons by passing it along a specialized wave guiding circuit such as a helix of proper pitch. While such an arrangement is well suited for amplification of waves longer than, for instance, several centimeters wave length, the difficulty of making a tube with its essential elements small enough for operation at shorter wave lengths has placed a practical upper frequency limit on the utility of traveling wave tubes of the helix type. For example, a traveling wave tube for operation at one-half centimeter wave length would have a helix, the optimum diameter of which would be roughly of the order of that of the shaft of a common straight pin, and the individual turns of the helix would be almost impossible to discern with the human eye. It is obvious that such a small structure would have limited power handling capacity, and its construction would be extremely difficult.

In one of its more important aspects, the present invention relates to a novel traveling wave tube which is operable at these very short wave lengths, providing good gain-bandwidth characteristics, and yet which is quite easy to build.

The traveling wave tube of the present invention utilizes the spatial harmonic principle in its operation. Traveling wave tubes utilizing this principle are known, one such tube being described in an article entitled "A Spatial Harmonic Traveling Wave Amplifier for Six Millimeter Wave Lengths" by S. Millman appearing in the Proceedings of the Institute of Radio Engineers, volume 39, page 1040, September 1951. In order to understand better the present invention, a brief description of the spatial harmonic principle of operation is felt to be in order.

In a traveling wave tube which relies upon the transfer of electrical energy between an electron stream and an electromagnetic wave, the taking of energy from the electron stream by the wave is accompanied by a net slowing down of the electron flow in its passage from the electron source to the collector electrode. In order for this transfer of energy to occur, the electromagnetic wave must be so phased along its propagation path that the

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electron stream interacting therewith will receive an average deceleration. A conventional helix traveling wave tube achieves this phasing by causing the electromagnetic wave to travel along a helix of such a pitch that the component of wave phase velocity along the electron path is approximately equal to the electron velocity, which may, for example, be one-tenth of the speed of light. A spatial harmonic traveling wave tube achieves this necessary phasing between the electrical field of the wave and the electrons by propagating a relatively faster electromagnetic wave which, for instance, may have a fundamental phase velocity only a little less than the speed of light along a wave circuit having sharp discontinuities therein. These discontinuities are so chosen that there exists near each of them a component of electrical field parallel to the direction of electron flow while no such component exists elsewhere. By adjusting the velocity of the electron stream, a given electron can be made to reach each discontinuity at a time when the phase of electrical field intensity at that discontinuity is the same as it was at the preceding discontinuity when this electron arrived there. Thus, the electrons can be synchronized with any wave propagating along these discontinuities with a phase velocity equal to the velocity of the electrons plus a velocity such that the electric vector rotates any multiple of plus or minus 360 degrees between successive interaction intervals.

Traveling wave tube structures which embody the spatial harmonic principle have advantages not otherwise obtainable through the use of conventional traveling wave tubes of the helix type at millimeter wavelengths since they are more rugged and have larger dimensions than the latter, with a consequent greater ease of construction. Even with this greater ease of construction, however, since the structure is necessarily complex and exacting tolerances are required, the spatial harmonic type of traveling wave tube is still difficult and tedious to make. One purpose of this invention, therefore, is to alleviate this difficulty and to reduce the expense of manufacture.

In accordance with the present invention, a spatial harmonic traveling wave tube of a type similar to that shown in the copending application of Arthur Karp, Serial No. 328,625, filed December 30, 1952, is supplied with a removable cap member having the required discontinuities on the side thereof adjacent the wave guiding portion of the tube. The tube may be constructed so as to conduct a large range of frequencies, and a plurality of cap members may be made for the tube. Thus, when operation in a particular frequency band is desired, the cap which is so constructed and which has its discontinuities so spaced as to accommodate this particular band may be mounted adjacent the wave guiding portion of the tube. When it is desired to change frequency bands it is only necessary to change caps, each cap being so constructed as to accommodate a particular frequency band.

A more complete understanding of the nature and objects of this invention may be gained from the following description given in connection with the accompanying drawings of illustrative embodiments thereof in which:

Fig. 1 is an elevation view of the present invention as used in the backward traveling wave tube oscillator;

Fig. 2 is a cross section view taken along the lines 2—2 of Fig. 1;

Fig. 3 is a plan view of one embodiment of the present invention; and

Fig. 4 is a plan view of a second embodiment thereof.

The operation of the embodiment of Fig. 1 will best be understood by consideration of the mathematical analysis contained in the aforementioned Arthur Karp application, Serial No. 328,625, filed December 30, 1952. In

that analysis it is shown that near the slot discontinuities in the wave guide there appears to be an infinite number of spatial harmonic components of the fundamental wave, each traveling at a different phase velocity. It is also shown that there are harmonic components whose phase velocity is in a forward direction, that is, the direction of group velocity or power propagation, and harmonic components having a phase velocity in the backward direction or a direction opposite to the direction of power propagation. At the same time the group velocity of the waves is in the direction of power propagation including those harmonics having a negative phase velocity. In the vicinity of the guide wall between slots, that is, the metal region between slots, the electrons "see" substantially no longitudinal component of electrical field, and while passing over a slot opening they "see" a strong longitudinal component of electrical field which is a necessary condition for interaction. This alternate passage from drift space to interaction space is analogous to a stroboscopic light flashing on a patterned wheel, the duration of each flash corresponding to the time the electrons are in the reaction space of the slot opening, the interval between flashes corresponding to the time it takes an electron to go from one slot center to the next, and the angular velocity of the wheel corresponding to the phase velocity of the fundamental field component of the traveling wave. For a given wheel velocity there will be several discrete stroboscopic frequencies to which the wheel appears stationary and each of these apparent non-rotations of the wheel corresponds to synchronism between the phase of a harmonic of the wave and that of the electron stream. In this synchronous condition a single electron "sees" the same field vector, as it passes each slot opening, and therefore the requirement for an electromagnetic wave-electron stream interaction is met.

By assuming that the group velocity of the wave propagating down the guide is opposite to the velocity of the electron flow, it can be seen, following the above analogy, that the electron scan be synchronized with a spatial harmonic of the wave having a negative phase velocity relative to the group velocity. When such conditions actually exist in a spatial harmonic tube, it is possible to have the electromagnetic power flow from the collector end to the gun end of the tube. This mode of operation is useful for amplification of the wave energy up to a critical value of beam current. Above this critical value of beam current this mode of operation is useful for obtaining oscillations since the necessary feedback for sustaining the oscillations is automatically provided by the electron stream.

Turning now to the drawings, in Fig. 1 there is shown a backward traveling wave oscillator 11 embodying the present invention. A traveling wave circuit 12 and an electron source 13 for projecting an electron beam along circuit 12 are enclosed in an air-tight enclosure by means of a sleeve 14 mounted between magnets 15 and 16. Sleeve 14 may be of any suitable material, either magnetic or non-magnetic. One end of sleeve 14 is sealed by a metallic plate 17 through which the output of circuit 12 connects to a wave guide 18. The other end of sleeve 14 is sealed in any manner suitable for maintaining a reduced air pressure, that here shown being by way of example only. The output connection between circuit 12 and wave guide 18 is maintained air tight by a tapered plug member 19. Plug member 19 may be of any material suitable for maintaining an air-tight seal while at the same time permitting passage of wave energy there-through. In practice, ceramic has been found to work exceedingly well. In order to provide a better seal with plate 17, the plug 19 may be metallized along that portion of its surface which contacts plate 17. The tapering of plug 19 serves to greatly reduce energy reflections, thereby permitting practically lossless energy transfer between circuit 12 and wave guide 18. The entire structure is

made rigid by means of non-magnetic members 21 and 22 which are joined to magnets 15 and 16.

The means for generating, focusing, and directing an electron beam along circuit 12 comprises electron source 13 and a heating element 23 therefor. An anode 24, having a hole 25 therein serves as the target for the electrons emitted from the source 13, the hole 25 permitting passage of electrons through the anode toward plate 17. Focusing electrodes 26 and 27 serve to focus the electrons into a beam suitable for interaction with circuit 12.

The structure of circuit 12 can more readily be understood by reference to Figs. 1 and 2 together. Circuit 12 comprises a first rectangular wave guide member 28 having a tapered ridge 29 therein extending from plate 17 toward anode 24. Ridge 29 serves primarily to broaden the useful operating frequency bandwidth of the circuit, and to furnish a concentration of electric field near the center of guide 28 when wave energy is being propagated therein. The tapering of ridge 29 serves to afford a proper impedance match with the unridged guide 18. Near the anode 24, guide 28 and ridge 29 undergo a bend of 90° or more to form a short vertical section of ridged guide 31 which in turn undergoes a 90° bend to form a section of ridged guide 32. Guides 28, 31 and 32 may be constructed as shown in Fig. 2, the side walls 33, 34 and ridge 29 being formed from a single piece of non-magnetic conducting material. It is not necessary that the wave guides be formed in this manner, nor is it necessary that ridge 29 be integral therewith, the structure here shown being merely by way of example. The lower wall of guide 28 may be formed from a separate piece 35 of non-magnetic conducting material to facilitate construction, although, as was the case with side walls 33, 34 and ridge 29, this is not a necessary form of construction but is merely one example of a practical arrangement. The internal cross-sectional dimensions of guides 28, 31 and 32 are so chosen that a transverse electric wave can propagate therethrough with its electric field parallel to the side walls 33 and 34. The dimensions of the guides 28, 31, and 32 and the ridge 29 are determinative of the lower cut-off frequency of the guides. The upper wall of guide 32 is formed by a cap member 36 having a longitudinal slot 37 therein and a plurality of spaced discontinuities 38 extending along its length. Cap 36 is constructed from a suitable non-magnetic conducting material, and is, preferably, of the same material as walls 33, 34 and 35. The width of slot 37 is determinative of the upper cut-off frequency of operation of circuit 12. Any suitable means, not shown, may be used to mount cap 36 in place, preferably some means which permits easy removal and replacement of cap 36, it being readily apparent that several caps 36, having different dimensions for slot 37, may be utilized with guides 28, 31 and 32, thus, permitting operation with any one of a plurality of upper cut-off frequencies. The gain-bandwidth characteristic may be optimized by properly proportioning the dimensions of ridge 29. In practice, it has been found that this is accomplished by making ridge 29 approximately one-half the width of slot 37, and making its separation from tape 39 as small as possible without blocking the electron beam.

The nature of the discontinuities 38 may best be seen by reference to Fig. 3, which shows a preferred form of construction of cap 36. The discontinuities 38 are formed on cap 36 by helically winding a tape 39 of conducting material thereon, as shown in Fig. 3, forming a series of spaced slots 38. The slot width w and the slot spacing d are determinative, to some extent, of the operating characteristics of the circuit, in a manner which will be more fully explained hereinafter. Tape 39, after winding, is permanently affixed to cap 36 by any suitable means such as brazing or the like. Instead of the tape 39, cap 38 may be wound with circular wire of diameter equal to $(d-w)$.

Slot 37 is tapered near the anode end of cap 36 to

afford an impedance match with guide 31. The tapering of slot 37 to a narrower dimension serves to lessen the effects of the mismatch between guides 31 and 32 which otherwise would act as an abrupt discontinuity. As an alternative to tapering the slot 37, anode 24 may be provided with an overhang having a slot with tapered lips. It is obvious that many other alternatives may be used; however, in practice, the tapering of slot 37 has been found to be the most feasible impedance matching arrangement.

In the operation of oscillator 11, the electron source 13 and electrodes 24, 26 and 27 coact to direct a beam of electrons toward plate 17. A longitudinal magnetic field set up between magnets 16 and 15 acts upon the beam to prevent dispersion thereof, and, as a result, the beam travels along ridged guide 32 and slot 37 toward plate 17. In practice, it has been found that there is sufficient noise in the beam to generate wave energy in the region of the discontinuities, which is sufficient to start the tube to oscillating. Alternatively, any suitable means, not shown, may be used to introduce wave energy into circuit 12 for interaction with the electron beam. When the arrangement of Fig. 1 is operating, the electron stream interacts with wave energy generated in guide 32 or introduced into guide 32 at the end thereof adjacent plate 17, which wave energy is flowing along guide 32 towards the anode end thereof.

As was pointed out in the foregoing, near the regions of discontinuities, there appears to be an infinite number of spatial harmonic components of wave energy, some with a phase velocity in the direction of propagation of the wave energy and others with a phase velocity opposite to the direction of propagation of the wave energy. As wave energy flows toward the anode end of the circuit, spatial harmonic interaction with the electron stream causes an increase in the wave energy. At the same time this interaction causes a bunching of the electron stream which, in turn, carries energy towards the other end, that is, towards plate 17, and thus the feedback necessary to sustain oscillations is automatically provided by the electron stream, it being necessary, however, in order to maintain oscillations, that the beam current exceed a certain minimum value. Since the frequency of oscillation is determined principally by the electron velocity for a given structure and since this velocity is easily varied electrically over a wide range, the frequency may be continually varied over a broad band. The wave energy which travels along guide 32 toward the anode end negotiates the bend between guides 32 and 31, then negotiates the bend between guides 31 and 28, and finally travels along guide 28 through plug 19 into guide 18. The double bend arrangement forms a simplified apparatus for extracting the wave energy from guide 12.

In some applications, it is necessary to place an absorptive element in guide 32 adjacent plate 17 to absorb wave energy reflected back from the output circuit. The structure herein shown is such that it is not necessary to use such an absorptive element, inasmuch as the actual length of the structure is sufficiently greater than the interaction length that substantially complete attenuation of reflected waves takes place in this added length. In addition, by virtue of this added length, the electron beam, after passing magnet 15, is permitted to spread out, thus greatly defocusing the beam and effectively preventing any further interaction with circuit 12. As a result, the electrons are collected by plate 17 and member 14 with a minimum of secondary emission.

While the arrangement of Fig. 1 shows a backward traveling wave oscillator, the tube 11 can be easily adapted to function as an amplifier by joining guide 32 to an external guide, not shown. In the event that the tube 11 is used as an amplifier wave energy could then be introduced into either guide 32 or guide 28, and extracted from the other guide.

From an inspection of the figure, it is apparent that, for a given spacing d , somewhere between the condition where the slot width w is almost equal to d , in which case, the amount of spatial harmonic field is almost negligible, and there is substantially no interaction between the electromagnetic wave and the electron stream, and the condition where width w of the slot opening is almost zero, in which case the impedance approaches zero and interaction is likewise negligible, there must be some ratio of slot width to slot spacing which gives optimum interaction if there is to be any net gain. It can readily be shown that the electron velocity V_e required for synchronization is given by

$$V_e = \frac{\omega d}{(2\pi n + \theta)} \quad (1)$$

where ω is the radian frequency, d the center to center slot spacing, n an integer, and θ the fundamental phase displacement between slots, usually

$$\frac{\pi}{4} \text{ to } \frac{\pi}{2}$$

It can be further shown that the amplification of the electromagnetic wave interacting with the electrons is proportional to

$$\text{Gain} = K \frac{\sin \frac{[(2\pi n + \theta)w]}{2d}}{\frac{(2\pi n + \theta)w}{2d}} \quad (2)$$

where K is a proportionality constant and w is the width of a slot opening. By differentiating this last equation with respect to

$$\frac{w}{d}$$

and setting the result equal to zero, the gain is seen to be maximum when

$$\frac{w}{d} = \frac{2.33}{(2\pi n + \theta)} \quad (3)$$

As mentioned previously, practical values of θ may be roughly between

$$\frac{\pi}{4} < \theta < \frac{\pi}{2}$$

and so from Equations 1 and 3 w can be determined for a given electron velocity V_e , a given value of n and a given frequency of operation. A study of Equation 2 shows that, for small values of n , as

$$\frac{w}{d}$$

is varied about the optimum the gain does not fall off very rapidly, hence, in the case of an amplifier it is not necessary to hold the ratio

$$\frac{w}{d}$$

to close tolerances. The slot spacing may be designed according to Equation 1 and

$$\theta = \frac{2\pi d}{\lambda_g} \quad (4)$$

where λ_g is the guide wave length of the fundamental wave, for synchronization of the electrons with forward or backward traveling spatial harmonic waves.

An alternative structure for cap 36 is shown in Fig. 4. Instead of a helically wound tape 39, the discontinuities 38 are formed by a series of spaced rings 41 which may be brazed in place. The rings 41 are split down the center of slot 37 by a longitudinal slot 42. The purpose of slot 42 is to provide a mechanically free space for passage of the electron beam but it has been found in practice that this modification is not necessary to proper operation of the invention. Alternatively, the discon-

tinuities may be formed by a single sheet of thin metal having the slot-like apertures cut therein by photoengraving, milling, or the like. The sheet may then be brazed to the cap member.

In the embodiments of Figs. 2, 3 and 4, the metallic members 39 or 41 all lie in a single plane over slot 37. In certain applications or under certain conditions, operation of the arrangement can be improved by bending every other turn of tape 39 or every other ring 41 into slot 37, and bending the remaining turns or rings slightly outward from slot 37. If, then, the electron beam is directed substantially down the center of the loops formed by such bends, it is possible to achieve greater interaction between the electron beam and the electromagnetic wave.

It is evident from the foregoing description of the illustrative embodiments of the invention that this invention is not limited solely to these embodiments, nor is it limited to spatial harmonic circuits of rectangular cross section. It is equally obvious that the input and output connections and the various components of the tube structure might easily be replaced by corresponding components which function as well, without departing from the spirit and scope of the invention. It is intended that the foregoing description and drawings are to be taken as merely illustrative of the invention and not to be taken as limiting the invention to the embodiments shown.

What is claimed is:

1. An electronic device comprising a wave guide for propagating an electric wave including a member forming one wall of said wave guide, said member having a plurality of transverse slots forming a series of electrical discontinuities extending longitudinally of said wave guide, means for fixing the transverse dimension of said slots comprising a longitudinally extending slot in said member, and means for forming and projecting an electron stream parallel to the direction of wave propagation in said wave guide and in coupling relation to said series of slots whereby interaction between said electron stream and an electromagnetic wave propagating in said guide takes place.

2. An electronic device according to claim 1, wherein said transverse slots are formed by conductive tape helically wound on said member.

3. An electronic device according to claim 1, wherein said transverse slots are formed by a plurality of spaced rings mounted on said member.

4. An electronic device according to claim 1, wherein said transverse slots are formed by a conductive wire helically wound on said member.

5. An electronic device according to claim 1, wherein said transverse slots are formed by a sheet of conductive material mounted on said member and having slots cut therein.

6. In an amplifying device, conductively bounded rectangular wave guide means adapted to propagate there-through an electromagnetic wave, said wave guide means including a member forming one wall thereof, said member having a plurality of transverse slots forming a series of electrical discontinuities extending longitudinally of said wave guide means, means for fixing the transverse dimension of said slots comprising a longitudinally extending slot in said member, a raised conducting ridge in said wave guide means opposite said transverse slots, and means for forming and projecting an electron stream parallel to the direction of wave propagation in said wave guide means and in coupling relation to said series of slots whereby interaction between said electron stream and an electromagnetic wave propagating in said guide takes place.

7. In a traveling wave tube, a ridged conductive member having a longitudinal section and a transverse bend at one end, a conductive cap positioned in contact with the longitudinal section of said ridged conductive member for defining a longitudinal wave guiding path therewith, a linear array of electrical discontinuities extending across

said wave guiding path, means for fixing the transverse dimension of said electrical discontinuities comprising a longitudinally extending slot in said cap, the ridge of said conductive member being opposite the slot in the cap, said slot being tapered to a narrower dimension at the end of the longitudinal section adjacent the transverse bend, and means positioned adjacent the bent end of the ridged member for providing an electron beam for flow past the linear array of electrical discontinuities.

8. In a traveling wave tube, a ridged conductive member having a longitudinal section and a transverse bend at one end, a conductive cap positioned in contact with the longitudinal section of the ridged conductive member for defining a longitudinal wave guiding path therewith, a linear array of tape elements forming electrical discontinuities extending along said wave guiding path, means for fixing the transverse dimension of said discontinuities comprising a longitudinal slot in said cap having its edges in contact with said tape elements, the ridge of the conductive member being opposite the slot in the cap, the slot being tapered to a narrower dimension at the end of the longitudinal section adjacent the transverse bend and means positioned adjacent the bent end of the ridged member for providing an electron beam for flow past the linear array of tape elements.

9. In a traveling wave tube, a ridged conductive member having a longitudinal section and a transverse bend at one end, a conductive cap positioned in contact with the longitudinal section of the ridged conductive member for defining a longitudinal wave guiding path therewith, a linear array of tape elements helically wound on said cap member and forming electrical discontinuities extending across said wave guiding path, means for fixing the transverse dimension of said discontinuities comprising a longitudinal slot in said cap having its edges in contact with said tape elements, the ridge of the conductive member being opposite the slot in the cap, the slot being tapered to a narrower dimension at the end of the longitudinal section adjacent the transverse bend and means positioned adjacent the bent end of the ridged member for providing an electron beam for flow past the linear array of tape elements.

10. In a traveling wave tube, a ridged conductive member having a longitudinal section and a transverse bend at one end, a conductive cap positioned in contact with the longitudinal section of the ridged conductive member for defining a longitudinal wave guiding path therewith, a linear array of tape elements forming electrical discontinuities extending across said wave guiding path, said tape elements comprising a plurality of rings mounted on said cap, means for fixing the transverse dimension of said discontinuities comprising a longitudinal slot in said cap having its edges in contact with said tape elements, the ridge of the conductive member being opposite the slot in the cap, the slot being tapered to a narrower dimension at the end of the longitudinal section adjacent the transverse bend and means positioned adjacent the bent end of the ridged member for providing an electron beam for flow past the linear array of tape elements.

11. In a traveling wave tube, a ridge conductive member having a longitudinal section and a transverse bend at one end, a conductive cap positioned in contact with the longitudinal section of the ridged conductive member for defining a longitudinal wave guiding path therewith, a linear array of tape elements forming electrical discontinuities extending across said wave guiding path, means for fixing the transverse dimension of said discontinuities comprising a longitudinal slot in said cap having its edges in contact with said tape elements, every other tape element in the region of the slot being bent inwardly of said slot and the remaining tape elements in the region of said slot being bent outwardly therefrom, the ridge of the conductive member being opposite the slot in the cap, the slot being tapered to a narrower dimension at the end of the longitudinal section adjacent the transverse bend

and means positioned adjacent the bent end of the ridged member for providing an electron beam for flow past the linear array of tape elements.

12. In a traveling wave tube oscillator, a first conductively bounded wave guide member having a longitudinal section and a transverse bend at one end, a second conductively bounded wave guide member having a longitudinal section and a transverse bend at one end, said first member being coupled to said second member by a third section of conductively bounded wave guide connecting the bends in said first and second members, a conductive cap positioned in contact with the longitudinal section of said first wave guide member forming one wall thereof, means forming a linear array of electrical discontinuities in the region bounded by said wave guide member and said cap, means for fixing the transverse dimension of said electrical discontinuities comprising a longitudinally extending slot in said cap, means for forming and projecting an electron stream parallel to the direction of wave propagation in said first wave guide member and in coupling relation to said electrical discontinuities whereby interaction between said electron stream and an electromagnetic wave in said guide takes place, and a tapered plug member in the end of said second wave guide member opposite the bent end for coupling to an output circuit.

13. In a traveling wave tube oscillator, a first conductively bounded wave guide member having a longitudinal section and a transverse bend at one end and having a conductive ridge extending longitudinally therein, said ridge being tapered from a maximum height at the bent end of said second wave guide member to a minimum height at the opposite end of said wave guide member, said first member being coupled to said second member by a third section of conductively bounded wave guide connecting the bends in said first and second members, a conductive cap positioned in contact with the longitudinal section of said first wave guide member forming one wall thereof, means forming a linear array of electrical discontinuities in the region bounded by said wave guide member and said cap, means for fixing the transverse dimension of said electrical discontinuities comprising a longitudinally extending slot in said cap, means for forming and projecting an electron stream parallel to the direction of wave propagation in said first wave guide member and in coupling relation to said electrical discontinuities whereby interaction between said

electron stream and an electromagnetic wave in said guide takes place, and a tapered plug member in the end of said second wave guide member opposite the bent end for coupling to an output circuit.

14. In a traveling wave tube, a conductively bounded wave guide for the propagation of electric waves comprising a member having a longitudinally extending slot therein, a linear array of elements forming electrical discontinuities extending across said slot, means for fixing the effective length of said elements for controlling the upper frequency limit of an operation of said tube comprising a cap member forming one wall of said wave guide, said cap member having spaced portions in contact with said elements and a central portion removed from said elements, and means for forming and projecting an electron stream parallel to the direction of wave propagation in said wave guide and in coupling relation to said electrical discontinuities whereby interaction takes place between said electron stream and an electromagnetic wave propagating in said wave guide.

15. In a traveling wave tube, a conductively bounded wave guide for the propagation of electric waves comprising a member having a longitudinally extending slot therein, a linear array of elements forming electrical discontinuities extending across said slot, means for fixing the effective length of said elements for controlling the upper frequency limit of said tube comprising a cap member forming one wall of said wave guide, said cap member having spaced portions in contact with said elements and a central portion removed from said elements, said elements being mounted on said cap member, and means for forming and projecting an electron stream parallel to the direction of wave propagation in said wave guide and in coupling relation to said electrical discontinuities whereby interaction takes place between said electron stream and an electromagnetic wave propagating in said wave guide.

References Cited in the file of this patent

UNITED STATES PATENTS

Re. 23,647	Lindenblad	Apr. 21, 1953
2,511,407	Kleen et al.	June 13, 1950
2,590,511	Craig et al.	Mar. 25, 1952
2,683,238	Millman	July 6, 1954
2,687,777	Warnecke et al.	Aug. 31, 1954
2,745,984	Hagelbarger et al.	May 15, 1956
2,768,322	Fletcher	Oct. 23, 1956
2,812,468	Robertson	Nov. 5, 1957
2,820,170	Robertson	Jan. 14, 1958