

April 20, 1948.

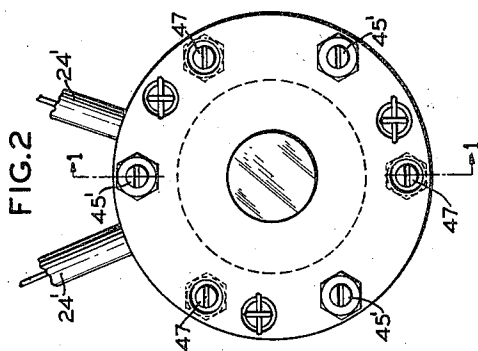
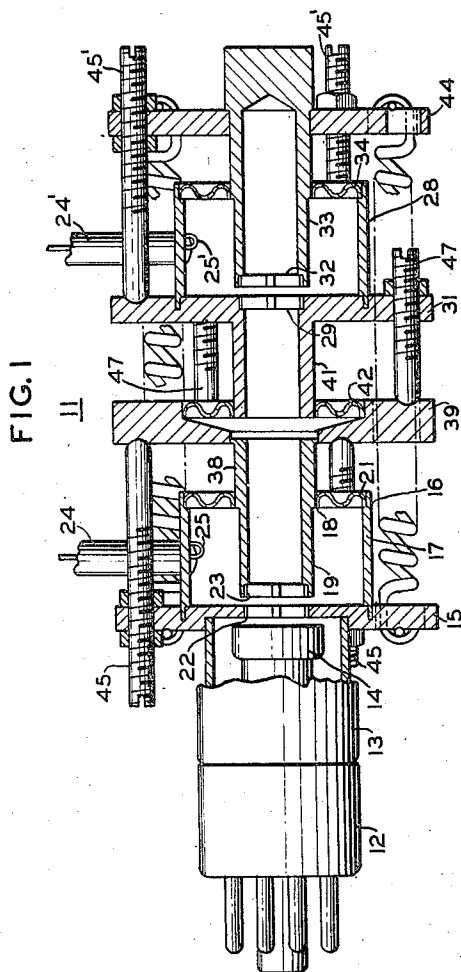
S. F. VARIAN ET AL

2,439,831

HIGH FREQUENCY APPARATUS

Filed June 28, 1944

2 Sheets-Sheet 1



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FIG.4

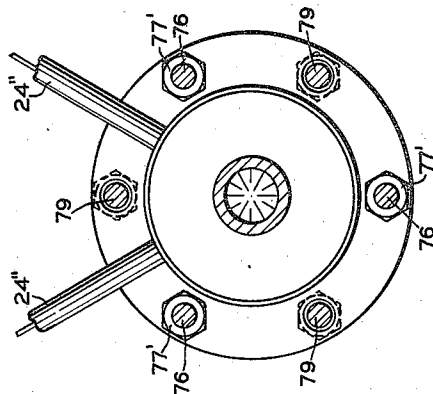
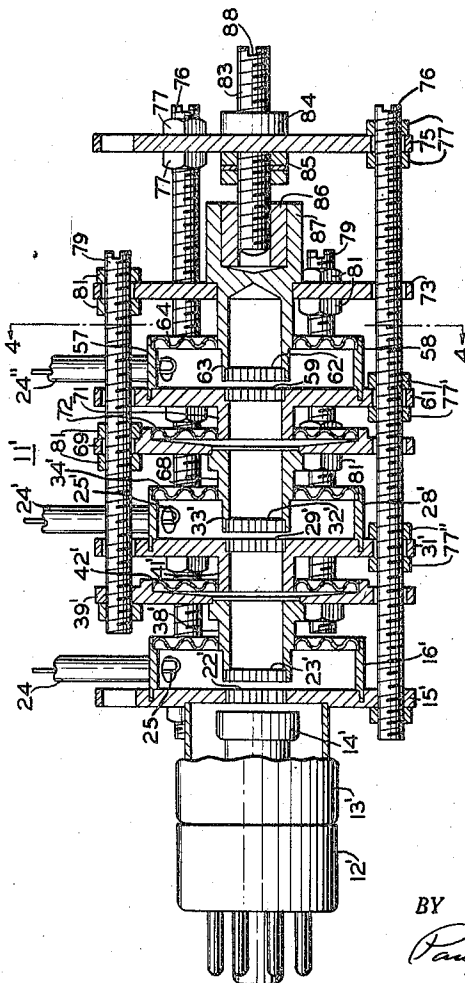


FIG.3



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2,439,831

HIGH-FREQUENCY APPARATUS

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Application June 28, 1944, Serial No. 542,550

14 Claims. (Cl. 315-5)

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The present invention relates to ultra high frequency electron discharge apparatus and, more particularly, to velocity variation electron discharge devices known to the art as klystrons.

The present invention constitutes an improvement on U. S. Patent 2,242,275, granted May 20, 1941, to R. H. Varian, and includes an evacuated electron discharge device employing a heated cathode, an input cavity resonator and an output cavity resonator, so arranged that electrons projected from the cathode through the input resonator and thence through the output resonator are velocity modulated by an ultra high frequency field in the input resonator, the electrons thereafter becoming segregated in bunches which pass through the output resonator in such a manner as to deliver ultra high frequency energy thereto. The input resonator and the output resonator of the above patent may be electromagnetically coupled together to provide a complete oscillatory circuit.

The input and output resonators of such an electron discharge device usually are tuned to resonance at the same or harmonically related frequencies. A high direct voltage is applied between the cathode and the resonators, the cathode being made negative with respect to the resonator structure for accelerating the electrons emitted by the cathode toward the resonators. Each resonator usually includes a first or entrance grid and a second or exit grid in closely spaced relation. The second grid of the input resonator is spaced an appreciable distance from the first grid to the following resonator. This intervening space between the successive resonators of the electron discharge device usually is referred to as the "electron drift space."

In previous constructions of velocity variation electron discharge devices, the length of the electron drift space has been fixed in the manufacture of the device by incorporation of a rigid metal connection between the resonators. In some cases, a metal cylinder of diameter substantially equal to or greater than the resonator grids was used as a rigid link between resonators. Such a cylinder was known as a "drift tube." In other cases, the resonators were made with adjoining walls, or an outer metal cylinder was used to connect the resonators together. Various forms of construction of such velocity variation devices are shown in U. S. Patent 2,311,658, issued February 23, 1943, to W. W. Hansen et al.

At a predetermined ultra high frequency input resonator excitation level, the operation of velocity variation electron discharge devices of the

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present type is greatly dependent on the value of accelerating voltage applied between the cathode and the resonators. This voltage must be so adjusted as to provide such an average electron transit time between the exit grid of the input resonator and the entrance grid of the following resonator, that the electrons arrive at the space between the first and second grids of the output resonator in compact bunches in accordance with the above-outlined principles of operation. Thus, for a given operating frequency and input power level, and for a given set of dimensions of the electron discharge device, the accelerating voltage ordinarily is varied over a wide range until a value is found at which maximum output is obtained with stable operation.

The above well-defined value of accelerating voltage for best performance is particularly dependent on the dimensions of the electron discharge device, especially on the length of the electron drift space between the successive resonators. Thus, two tubes which are identical in all respects except for a slight difference of drift tube length are not fully interchangeable since the optimum accelerating voltage requirements of the two tubes are different for a given excitation level and frequency.

Accordingly, in mass production of velocity variation electron discharge devices of the well known types which have no provision for adjustment of drift space length, the small variations within the manufacturing tolerance among the different tubes of a common type may require that apparatus designed for use with the devices be provided with a special accelerating voltage adjuster and with indicating means to permit adjustment of the accelerating voltage to an optimum value. It is therefore desirable that means be devised to permit adjustment at the factory of the evacuated electron discharge device for optimum performance at predetermined standard levels of excitation and electron accelerating voltage, in order to insure the complete interchangeability of the devices.

Furthermore, it is often found that if a dry-cell battery is employed for maintaining the cathode of the electron discharge device at high negative potential with respect to the cavity resonators, certain specific voltages are directly available from the battery without the use of special voltage adjusting circuits for adaptation of the electron discharge device. For example, many batteries are now produced which deliver voltages at fixed steps such as 45 volts, 90 volts, 135 volts, etc. Thus, it may be desirable to provide an

electron discharge device adjusted for maximum efficiency at one chosen voltage in such a series of steps.

In the present invention, a flexible electrically conductive mechanical structure is provided intermediate two successive resonators of an evacuated velocity variation electron discharge device, so arranged as to permit movement of one resonator toward or away from the other resonator. Thus, the electron drift space of the high-vacuum electron discharge device may be shortened or extended, so that an optimum relation of drift space length to the electron accelerating voltage may be obtained during operation of the device at a desired frequency, without necessity of variation of the accelerating voltage.

Furthermore, the extensible drift tube structure provided by the present invention between the successive resonators of an ultra high frequency electron discharge device permits the use of a greatly improved gang tuning system for simultaneously tuning two or more resonators of the device at equal rates of change of resonant frequency. Heretofore, as pointed out above, due to the rigid mechanical connections between successive resonators of such electron discharge devices, the distance between the exit grid of one resonator and the entrance grid of the next resonator has been fixed in the manufacture of the device. To tune the resonators of such a structure toward a higher frequency, the entrance grid of the first resonator was moved toward the cathode, and thus away from the two rigidly connected grids mentioned above, while the exit grid of the next resonator was moved away from the cathode, increasing the spacing of this movable grid also from the rigidly connected grids of the two resonators.

For gang tuning such a structure, then, mechanism was required for producing exactly equal and opposite movements simultaneously of the entrance grid of one resonator and the exit grid of a following resonator with respect to the rigidly connected exit and entrance grids of the respective resonators. Such apparatus was necessarily complicated by the requirement of the opposite directions of movement.

With three successive resonators employed in an electron discharge device—an input resonator adjacent the cathode, an intermediate resonator, and an output resonator, the problem of gang tuning all of the resonators of the device was even more complicated. As in the case of the two-resonator device, equal and opposite movements of input resonator entrance grid and intermediate resonator exit grid were required with respect to the rigidly spaced respective exit and entrance grids of these two resonators. Moreover, due to the further rigid connection usually provided between intermediate resonator exit grid and output resonator entrance grid, and the resulting movement of the latter grid along with the intermediate resonator exit grid, it was necessary to provide a doubled rate of movement of the output resonator exit grid in the direction of movement of the intermediate resonator exit grid, in order to provide a rate of change of spacing between output resonator grids equal to the rate of change of spacing of the grids of the two preceding resonators.

The complicated gang tuning requirements pointed out above are the result of an undesirable order of connections of the relatively movable tuning elements, such as the grids, of the successive resonators. It is readily seen that in a three-

resonator electron discharge device, for example, considering the resonator grids in order from that nearest the cathode as the first to the exit grid of the output resonator as the sixth and last grid, the first grid was usually rigidly positioned with respect to the cathode, the second and third grids were rigidly interconnected, and the fourth and fifth grids were rigidly interconnected. A much more desirable arrangement of an electron discharge device for gang tuning of all resonators is provided if the first, third and fifth grids are rigidly interconnected, and the second, fourth and sixth grids are similarly rigidly interconnected. Then equal movements in one direction are employed in all resonators to maintain the proper tuning relations among the resonators.

By the use of the flexible or extensible connecting elements of the present invention between successive resonators of an electron discharge device having two or more resonators, the entrance grid of each resonator may be rigidly connected to the entrance grid of each other resonator, and the exit grid of each resonator may be rigidly connected to the exit grid of each other resonator. An increase of the spacing between the entrance and exit grids of one resonator is then accompanied by an equal increase of spacing between the grids of every other resonator. Such a gang tuning movement requires an equal decrease of spacing between the exit grid of one resonator and the entrance grid of a following resonator; this decrease of spacing is readily permitted by the flexible interconnecting element provided by the present invention between successive resonators, as will be described.

By the use of an extensible conductive connection between the resonators of a velocity variation electron discharge device, the advantage of adjustment of the device for optimum performance at a fixed voltage, and the further advantage of simple and direct gang tuning connections of successive resonators, may readily be realized in accordance with the present invention.

It is accordingly an object of the present invention to provide an improved electron discharge device employing a drift tube defining a drift space between an input resonator and an electron utilization device such as a second resonator, of such construction that the length of the drift tube or drift space conveniently may be varied over a desired range of adjustment.

It is a further object to provide an improved method and apparatus for varying the electron transit time from one portion of an electron discharge device to another.

Another object is to provide an improved electron discharge device having an extensible electron drift tube.

Yet a further object is to provide improved apparatus for synchronously or gang tuning two or more resonators embodied in an electron discharge device.

It is another object to provide improved apparatus for gang tuning two or more cavity resonators adapted for electronic coupling.

It is a further object to provide an electron discharge device having two or more resonators wherein movement of rigidly interconnected parts of said resonators with respect to other rigidly interconnected parts of said resonators provides simultaneously gang tuning of the resonators of said device.

These and further objects will be made clearly apparent by the following description of the pres-

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ent invention, two embodiments of which are shown in the drawings, wherein:

Fig. 1 is a side elevation, partly in section, and Fig. 2 is an end view of an electron discharge device having an input resonator and a following or output resonator, connected together by an extensible drift tube in accordance with the present invention; and

Fig. 3 is a side elevation, partly in section, and Fig. 4 is a cross-sectional view of a somewhat different embodiment of the present invention, wherein three consecutive cavity resonators are arranged along the electron path, and are provided with interconnecting extensible drift tubes in accordance with the present invention; the version of Figs. 3 and 4 being provided with means for gang tuning the three resonators in such a way as to maintain these resonators substantially in resonance during tuning adjustments.

Referring now to Figs. 1 and 2, an electron discharge device 11 is shown including a base 12, a glass tubular portion 13, and a cathode structure 14 rigidly supported from base 12. The base of this device is also rigidly connected to the end plate 15 of an input cavity resonator 16. This resonator 16 includes outer cylindrical wall 17, reentrant portion 18 including the inner tubular portion 19 and a flexible metal diaphragm 21, and first and second grids 22 and 23 positioned within end plate 15 and inner cylinder 19, respectively. Electromagnetic input coupling loops 25, one of which is visible in Fig. 1, project within the annular space enclosed by resonator 16. Each input coupling loop is connected to a coaxial line 24 employing a glass vacuum seal between inner and outer conductors for rigidly positioning the inner conductor within the outer conductor thereof.

A second resonator 28, generally similar to the input resonator 16, is provided in the electron discharge device 11. This second resonator comprises a first grid 29 positioned within end plate 31, closely adjacent to the second grid 32 which is supported in tubular member 33 which in turn forms, together with flexible diaphragm 34, a reentrant electrically conductive member in the second resonator 28. The second resonator 28 is also provided with an electromagnetic coupling loop 25' and a coaxial output connection 24'.

The inner tubular portion 19 of input resonator 16 is extended beyond this resonator as cylindrical drift tube portion 38, to the opposite end of which is attached a rigid disc member 39. A second tubular member 41 is attached to the end wall 31 of the second resonator 28, extending from this wall toward the junction between disc 39 and tubular extension 38. Tubular member 41 is connected to the disc member 39 by a flexible diaphragm 42, which serves both as an electrical connection and as a vacuum seal between the respective tubular members 38 and 41. The structure including elements 38, 39, 41 and 42 thus forms an extensible conductive electron drift tube connecting the input resonator 16 to the following resonator 28.

Three screws 45 may be provided in suitable tapped holes through end wall 15 of input resonator 16, for providing convenient adjustment of the separation between input resonator first and second grids 22 and 23, respectively, and thus for tuning the input resonator 16. A second set of three screws 45' in suitably tapped holes through an output resonator tuning disc 44 rigidly connected to the inner tubular member 33 of output

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resonator 28, may be provided for similarly tuning the output resonator 28.

A third set of adjusting screws 47 may be provided in the rigid end wall 31 of the output resonator 28, bearing against rigid disc 39 for conveniently adjusting the length of the extensible drift tube 38, 39, 41, 42 and thus for adjusting at will the distance between the second grid 23 of input resonator 16 and the first grid 29 of output resonator 28. One or more electromagnetic coupling loops 25' may project within the second cavity resonator 28, for extracting energy from the output resonator during passage therethrough of a suitably bunched electron stream in accordance with the foregoing explanation of the electron discharge device.

In operation, the structure of Fig. 1 may be employed in ultra high frequency apparatus, as, for example, an ultra high frequency transmitter. This device 11 is suitable for use either as an oscillator or as an amplifier. If the device is used as an oscillator, one of the output electromagnetic coupling loops 25' may be connected through a coaxial output connector 24' and a section of coaxial line to an input coaxial connector 24 of the input resonator 16. If the device is used as an amplifier, a source of ultra high frequency excitation is connected to an input coaxial connector 24 and a utilization device may be connected to an output connector 24'.

The input resonator 16 is tuned for resonance at the desired frequency of operation of the electron discharge device 11, by adjustment of input tuning screws 45. A direct-current high-potential source is connected between cathode structure 14 and the continuous metallic structure including resonators 16 and 28, so as to make the cathode potential negative with respect to the resonators.

The output resonator 28 is tuned to resonance with the input resonator 16, by rotation of tuning screws 45'. Some ultra high frequency output should be detected at a coaxial output connector 24' as by means of an ultra high frequency detector, such as a crystal detector unit connected to a direct-current galvanometer in a well-known manner.

The electron discharge device 11 may then be adjusted for best performance by rotation of the drift tube extension adjusting screws 47, which adjust the distance between input resonator 16 and output resonator 28; and particularly between the second grid 23 of the input resonator and the first grid 29 of the output resonator. Thus, for a predetermined excitation input level applied to the device through the coaxial connector 24, the device may be adjusted for best performance without the necessity of any variation of the direct-current accelerating voltage applied between the cathode and the resonator structure.

This, of course, represents a particularly advantageous construction for mass production, since the interchangeability of a quantity of electron discharge devices intended to bear similar type designations may be insured by adjustment at the factory of the drift tube extension control screws 47 for optimum performance of the device at a standard set of conditions including a predetermined excitation level and a predetermined electron accelerating voltage.

A further important use of the extensible drift tube construction in a velocity variation electron discharge device is shown in Figs. 3 and 4, wherein is provided a gang tuning mechanism for si-

multaneously and synchronously tuning three consecutive resonators over the wide tuning range of an electron discharge velocity variation device, by the rotation of a single tuning screw.

The three-resonator klystron structure designated 11' in Figs. 3 and 4 embodies a tube base 12', a glass sleeve 13', and a cathode 14', arranged in a compact rigid structure.

Input resonator 16', having first and second grids 22' 23' respectively, is provided with a rigid end wall 15' and an input coupling connector 24, substantially in the same manner as the first resonator 16 of the electron discharge device 11 shown in Fig. 1. A second resonator 28' is similarly provided with a rigid end wall 31', first and second grids 29' and 32', and a flexible reentrant structure including tubular member 33' supported in flexible diaphragm 34'. One or more coaxial connectors 24' may be provided with electromagnetic coupling loops 25' for external coupling to resonator 28'. An extensible drift tube structure 38', 39', 41', 42' is provided between the input resonator 16' and the following resonator 28' in exactly the same manner as in electron discharge device 11 of Fig. 1.

A third resonator 58 is provided in the electron discharge device 11'. This resonator includes first and second grids 59 and 62 respectively, supported in a rigid end wall 61 and an inner tubular member 63 respectively. A flexible diaphragm 64 supports the inner tubular member 63 within the outer cylindrical wall 57 of resonator 58, serving as an electrical connection and as a vacuum seal between the outer wall 57 and the inner tubular member 63.

A second extensible drift tube structure 68, 69, 71, 72 is provided between resonators 28' and 58, permitting variation of the distance between the second grid 32' of resonator 28' and the first grid 59 of resonator 58. A rigid end wall 73 is connected to the inner tubular member 63 of resonator 58 for movement thereof nearer to or farther from the end wall 61 of resonator 58.

A tuning reference plate 75 is rigidly connected to the base structure 12', 13' of the electron discharge device 11' by three screws 76 provided in tapped holes of the first resonator end wall 15' and secured to the reference disc 75 by locking nuts 77. The screws 76 are similarly secured by locking nuts 77' to the end wall 61 of the output resonator 58, and by locking nuts 77'' to the end wall 31' of the intermediate resonator 28'.

Accordingly, the first grids 22', 29' and 59 of the input resonator, the following resonator and the output resonator, respectively, are fixedly positioned by means of the screws 76 to the base and cathode structure 12', 13' and 14'.

A second set of three screws 79 are inserted in tapped holes through the rigid disc 39', and are fixedly connected to the rigid disc 69 and rigid disc 73 by suitable locking nuts 81. These screws 79 provide a rigid connection of the second grids 23', 32' and 62 of the three respective resonators, so that these grids may be moved as a unit with respect to the first grids 22', 29' and 59, respectively.

A single axial tuning screw 83 is provided through a clearance hole of the tuning reference disc 75, and is prevented from axial movement with respect to disc 75 by upper bushing 84 and lower locking nut 85. Screw 83 extends into a suitable tapped bushing 86 fixed within extension 87 of the output resonator tubular member 63, and similarly fixed to the rigid tuning disc 73. Rotation of tuning screw 83 by means

of a screw driver inserted in slot 88 then provides coordinated movement of the exit grids 23', 32' and 62 with respect to the entrance grids 22', 29' and 59 of the input resonator, the following or intermediate resonator and the output resonator, respectively.

If desired, any predetermined frequency versus temperature characteristic may be provided in the simultaneous tuning of the three resonators by careful choice of the material and the length between plate 75 and bushing 86 of tuning screw 83. For this purpose if no single metal is found to be satisfactory, the screw 83 may be made in sections of different metals, suitably joined and threaded. By this means is insured the application of equal temperature compensating adjustments by temperature-expansive screw 83 to all chambers alike.

The three-resonator electron discharge velocity variation device 11' thus includes a first extensible drift tube 38', 39', 41', 42' extending between the input resonator 16' and the following resonator 28'; and a second extensible drift tube 68, 69, 71, 72 extending between and connecting the resonator 28' to the output resonator 58. The freedom of movement provided by these extensible drift tubes between grids 23' and 29', and similarly between grids 32' and 59, is essential for the simultaneous or gang tuning of the three resonators 16', 28' and 58 by means of the single tuning screw 83, the rotation of which produces a unidirectional axial movement of the similar movable portions of the three resonators through the rigid connecting screws 79.

It will be readily apparent that such a gang tuning structure may be applied to an electron discharge device having only two resonators, or to versions having more than three resonators, if desired.

It will also be readily apparent that while similar resonators especially suited for operation at a single frequency are shown in the electron discharge velocity variation device 11', the gang tuning structure could be applied to resonators designed for higher harmonic frequency relations, provided that such resonators are designed for maintaining harmonic frequency relation with equal axial tuning movements.

The provision of three resonators in the velocity variation device 11' makes this device suitable for use in a variety of ultra high frequency applications. For example, the coaxial coupler 24' of the second resonator 28' may be connected to the coaxial excitation input coupler 24 for operation of resonators 28' and 16' in a well-known manner as an oscillator system. Output coaxial coupler 24'' may then be connected to an ultra high frequency energy utilization device, providing isolation of such a utilization device from the oscillator system including the input resonator and the following resonator, and also providing amplification of the ultra high frequency signal intensity developed in the intermediate resonator 28'.

Alternatively, an external ultra high frequency excitation source may be connected through the coaxial coupler 24 to the input resonator 16' of the electron discharge device 11' and the output resonator 58 may be coupled to an energy utilization device, as above stated, through coaxial connector 24''. If desired, the coaxial connectors 24' of the intermediate resonator 28' may be left unused in this type of operation. With the input resonator 16', the following resonator 28'

and the output resonator 58 then tuned to resonance with the external source of ultra high frequency excitation, an amplified version of the ultra high frequency excitation may be developed within resonator 28' by the electron stream projected from the cathode 14' and velocity modulated by resonator 16'. The amplified voltage developed in resonator 28' is effective on the electron stream for producing electron bunching of even greater intensity in the region between the first and second grids 59 and 62 of output resonator 58, and thus for delivering an output signal of further amplified intensity through output resonator 58. Different drift distances are usually desirable for these two types of operation, which different distances may be obtained by independently adjusting the two variable drift tubes of the device.

The provision of the adjustable locking nuts 77' and 77'' on the fixed connecting screws 76, and the similar provision of adjustable locking nuts 81 on the movable connecting screws 79, permits a wide flexibility of adjustment of the gang tuning electron discharge device 11'. By varying the positions of these adjustable locking nuts, resonance of each resonator with the other resonators may be maintained while a desired average drift space distance may be provided between successive resonators—that is, between the input resonator 16' and the intermediate resonator 28', and between resonator 28' and the output resonator 58.

Accordingly, the advantages described above, as provided by adjustment of the drift tube length for optimum performance at a standard set of conditions including the electron accelerating voltage, may be realized along with the advantages of the simple and effective gang tuning unit employing rotation of a single screw for gang tuning all of the resonators of the velocity variation electron discharge device.

As 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. Electron discharge apparatus comprising means for projecting a stream of electrons along a path, a first resonator positioned adjacent said electron projecting means along said path for velocity modulating said electron stream to form bunches therein, a second resonator positioned along said path for deriving a signal from said bunched electron stream, an extensible hollow element connecting said first and second resonators whereby the spacing between said resonators may be varied, and means coupled to said extensible element for varying the length thereof and thereby varying said spacing.

2. Electron discharge apparatus comprising means for projecting a stream of electrons along a path, means adjacent said electron projecting means for controlling the movement of said electrons, utilization means positioned along said path for deriving a signal from said controlled electron stream, hollow extensible means surrounding said path between, and connected to, said controlling means and said utilization means for providing variable spacing between said controlling means and said utilization means, and means coupled to said extensible means for vary-

ing the length thereof and thereby varying said spacing.

3. Electron discharge apparatus comprising means for projecting a stream of electrons along a path, an ultra high frequency resonator positioned along said path for velocity modulating said electron stream, utilization means positioned along said path beyond said resonator for deriving a signal from said electron stream, hollow conductive extensible means surrounding said path between, and connected to, said resonator and said utilization means for varying the electron path length between said resonator and said utilization means, and means coupled to said extensible means for varying the length thereof and thereby varying said path length.

4. Electron discharge apparatus comprising means for projecting a stream of electrons along a path, a first resonator positioned along said path for velocity modulating said electron stream, a second resonator positioned along said path for deriving a signal from said velocity modulated stream, extensible hollow means mechanically connecting said first and second resonators, said first resonator having a fixed portion and a relatively movable portion, said second resonator having a portion rigidly fixed with respect to said fixed portion of said first resonator and also having a movable portion rigidly connected to said movable portion of said first resonator, and adjustable means coupled to said portions for moving said movable portions with respect to said fixed portions of said resonators for synchronously tuning said resonators.

5. Electron discharge apparatus comprising means for projecting a stream of electrons along a path, a first cavity resonator including a pair of electron-permeable walls located along said path and defining a gap therebetween, a second cavity resonator including a pair of electron-permeable walls located along said path and defining a second gap, and means for simultaneously varying said gaps in like sense to gang tune said resonators, comprising means rigidly connecting one wall of said first resonator to one wall of said second resonator, means rigidly connecting the other walls of said resonators together, and adjustable means coupled to said connecting means for adjusting the spacing between the unit consisting of one pair of rigidly connected walls and the second unit consisting of the other pair of rigidly connected walls.

6. Electron discharge apparatus comprising means for projecting a stream of electrons along a path, a first resonator having an electron entrance grid and an electron exit grid positioned along said path, a second resonator having an electron entrance grid and an electron exit grid positioned along said path, and means coupled to said grids for moving said first resonator exit grid and said second resonator exit grid as a unit along said path with respect to said first resonator entrance grid and said second resonator entrance grid as a unit, for gang tuning said first and second resonators.

7. Ultra high frequency electron discharge apparatus comprising means for projecting a stream of electrons along a path, a first resonator having an electron entrance grid and an electron exit grid positioned along said path for modulating said electron stream, a second resonator having an electron entrance grid and an electron exit grid positioned along said path for interaction with said modulated electron stream, means connecting said first resonator exit grid

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to said second resonator exit grid whereby the spacing between said exit grids is rigidly fixed, means connecting said first resonator entrance grid and said second resonator entrance grid whereby the spacing between said entrance grids is rigidly fixed, and adjustable means coupled to said connecting means for adjusting the spacing between said connected entrance grids and said connected exit grids of said respective resonators, whereby said resonators may be gang tuned through a desired frequency range.

8. Electron discharge apparatus comprising means for projecting a stream of electrons along a path, a first grid positioned along said path adjacent said projecting means, a second grid positioned along said path beyond said first grid, a third grid and a fourth grid positioned in sequence along said electron path, means rigidly spacing said first grid from said third grid along said path, means rigidly spacing said second grid from said fourth grid along said path, and adjustable means coupled to said spacing means for varying the spacing between said first and second grids, whereby the spacing between said third and fourth grids is similarly varied.

9. Electron discharge apparatus comprising means for projecting a stream of electrons along a path, a first grid positioned along said path adjacent said projecting means, a second grid positioned along said path beyond said first grid, electric circuit means connecting said first grid to said second grid, a third grid positioned in turn along said electron path and rigidly spaced from said first grid, a fourth grid along said path rigidly spaced from said second grid, electric circuit means connecting said third grid to said fourth grid, and adjustable means coupled to said first and second grids for varying the spacing between said first and second grids, whereby the spacing between said third and fourth grids is similarly varied.

10. Electron discharge apparatus comprising an input resonator, an intermediate resonator, and an output resonator; means adjacent said input resonator for projecting a stream of electrons through said input resonator, said intermediate resonator and said output resonator in turn; each of said resonators comprising an entrance grid and an exit grid positioned respectively nearer to and farther from said electron-projecting means, means interconnecting said electron entrance

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grids for rigidly fixing the spacing thereamong, means interconnecting said exit grids rigidly fixing the spacing thereamong, and adjustable means coupled to both said interconnecting means for adjusting the spacing between said connected entrance grids and said connected exit grids for simultaneously tuning all said resonators.

11. Electron discharge apparatus comprising a cathode, four grids successively spaced from said cathode, and adjustable means coupled to said grids for moving alternate ones of said grids with respect to the remaining ones of said grids for similarly and simultaneously varying the spacing between the grids of each pair of adjacent grids.

12. Electron discharge apparatus comprising means for projecting a stream of electrons along a path, a first resonator having an electron exit grid positioned along said path, a second resonator spaced from said first resonator and having an electron entrance grid, a tubular conductor fixed exteriorly to said first resonator and surrounding said exit grid, a second tubular conductor fixed exteriorly to said second resonator and surrounding said entrance grid and coaxial with respect to said first conductor, and flexible means joining said two conductors to permit adjustable separation of said grids.

13. Apparatus as in claim 12 wherein said flexible means vacuously seals said conductors, whereby said conductors may form part of a vacuum envelope surrounding said stream.

14. Apparatus as in claim 12, wherein said flexible means comprises a flexible diaphragm mounted in a plane perpendicular to said stream path and having an inner portion fixed to one of said conductors and an outer portion fixed to the other of said conductors.

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