United States Patent

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[54] GANG TUNER FOR A MULTICAVITY MICROWAVE TUBE

7 Claims, 5 Drawing Figs.

[52] **U.S. Cl.** **315/5.47,** 315/537, 330/44, 74/569
[51] **Int. Cl.** **H01j 25/10**
[50] **Field of Search** 315/5.46, 5.47, 5.48, 5.39; 330/44

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ABSTRACT: A multicavity microwave amplifier tube is disclosed. The tube includes a plurality of cavity resonators successively arranged along a beam path for successive electromagnetic interaction with the beam to produce output-amplified microwave energy. Translatable cavity tuners are provided within a plurality of the cavity resonators for tuning the frequency of the resonators. The external tuning structure includes a plurality of rotatable cam wheels mechanically interconnected for synchronous rotation. Each cam wheel includes a set of cams. A plurality of cam followers are connected to the cavity tuners and each includes a bearing surface for engaging one of the cams in one the set of cams for tuning the respective cavity resonators in accordance with the position of the respective cam in the set of cams on the cam wheel. Means are provided for disengaging the cam followers from the cams before rotation of the cam wheels to new tuner positions. A stop is provided for the preventing rotation of the cam wheels while the cam followers are in engagement with the cams to alleviate wear on the engaging surfaces of the cams and the cam followers, whereby the microwave amplifier tube can be precisely and repeatedly tuned to certain preselected channel frequencies within a band of frequencies.

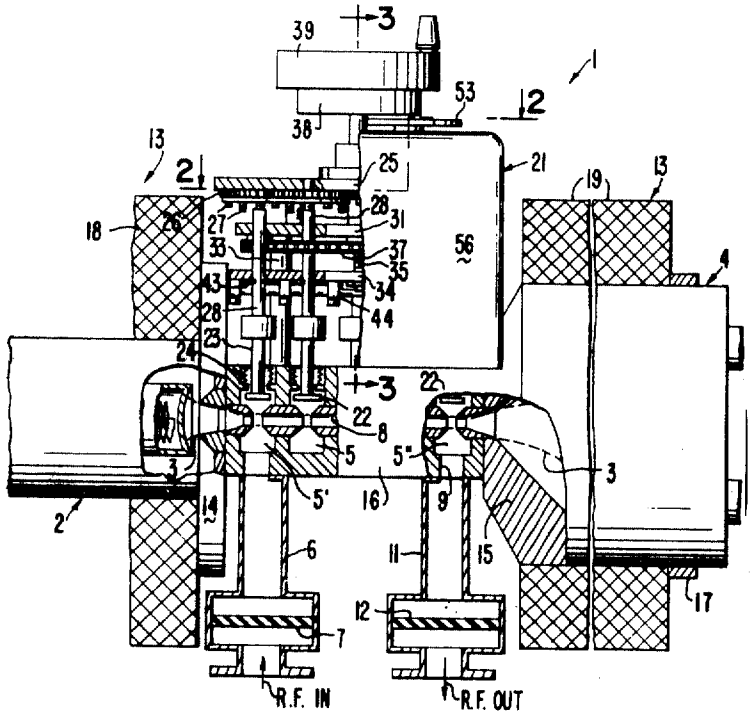
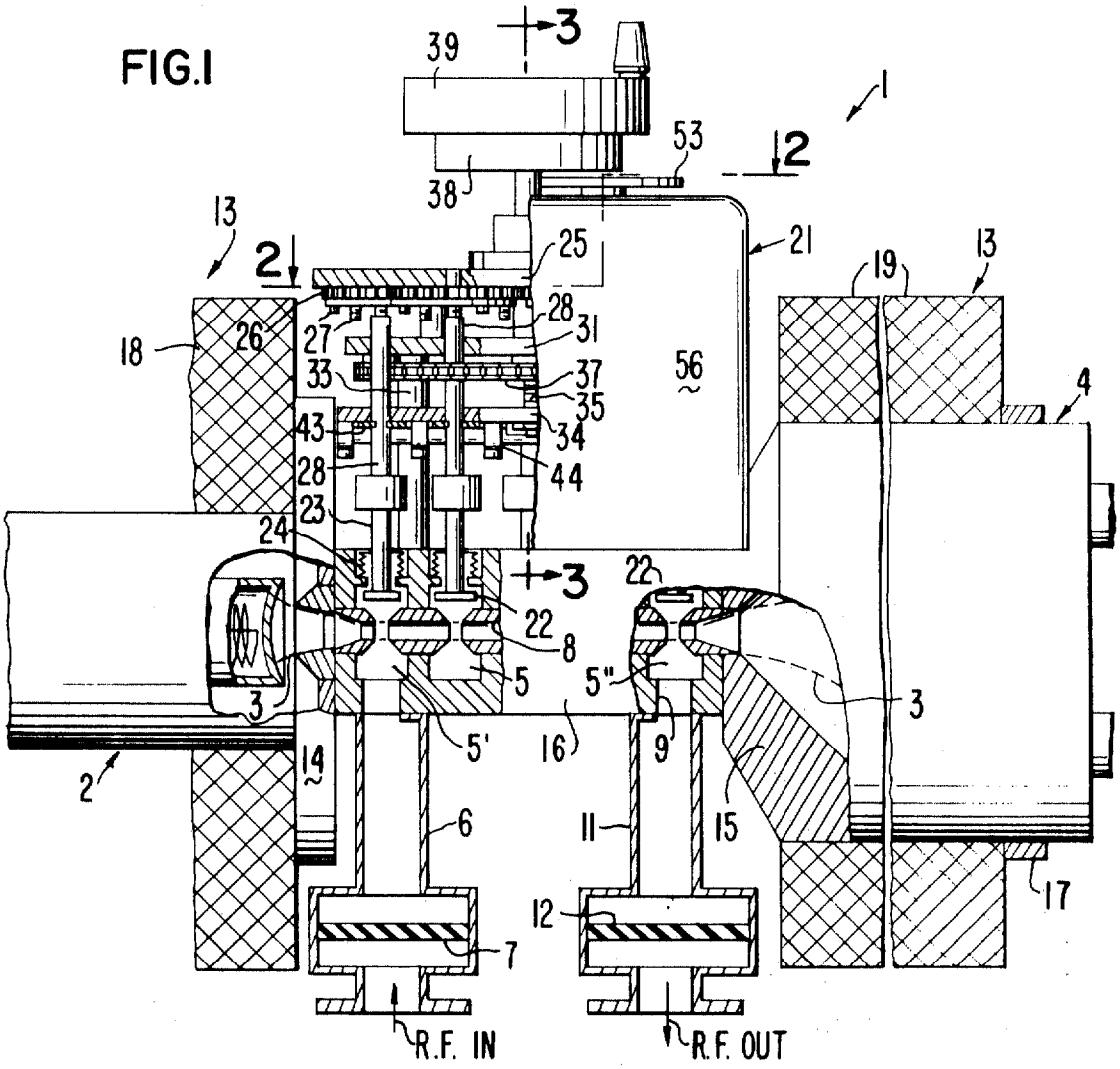


FIG.1



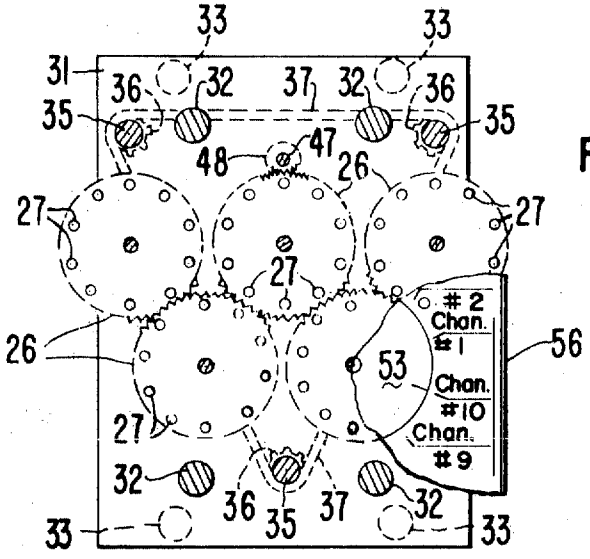
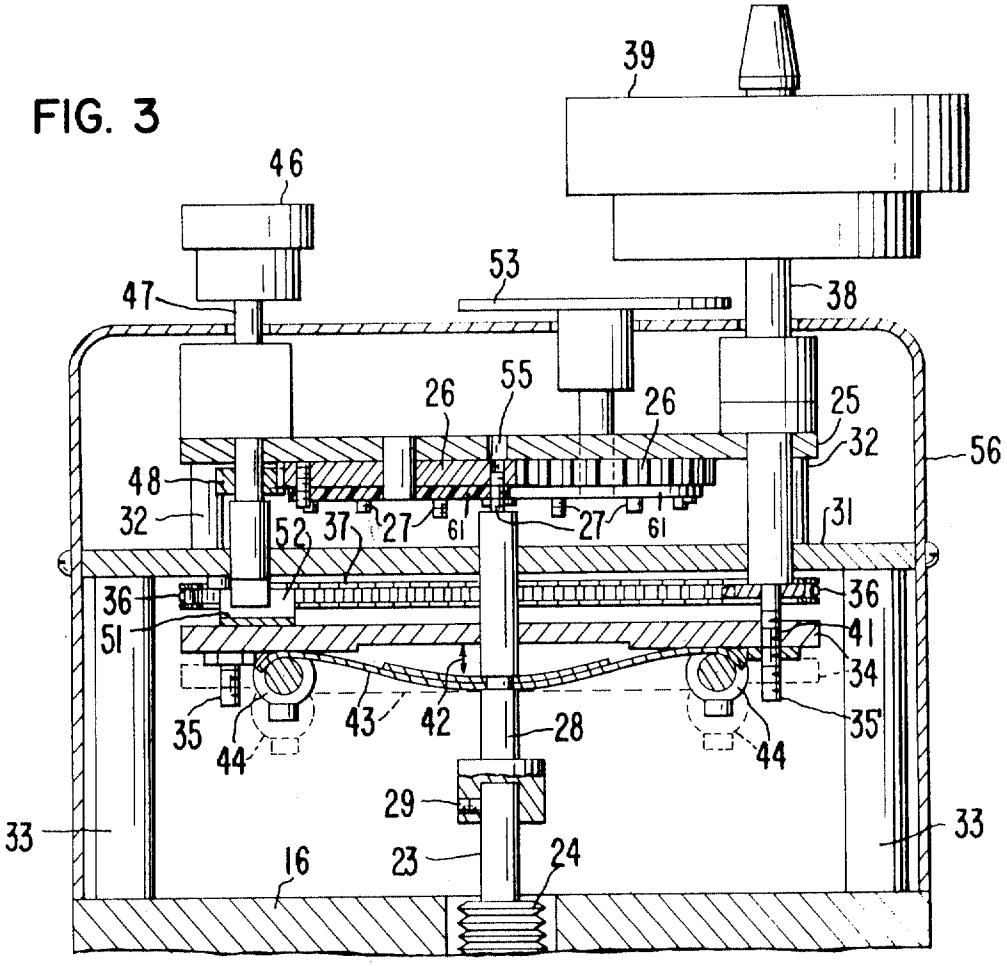


FIG. 2

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FIG. 3



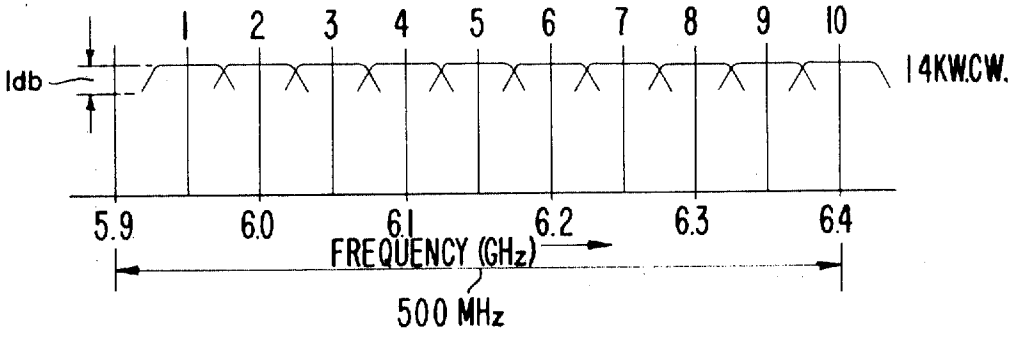
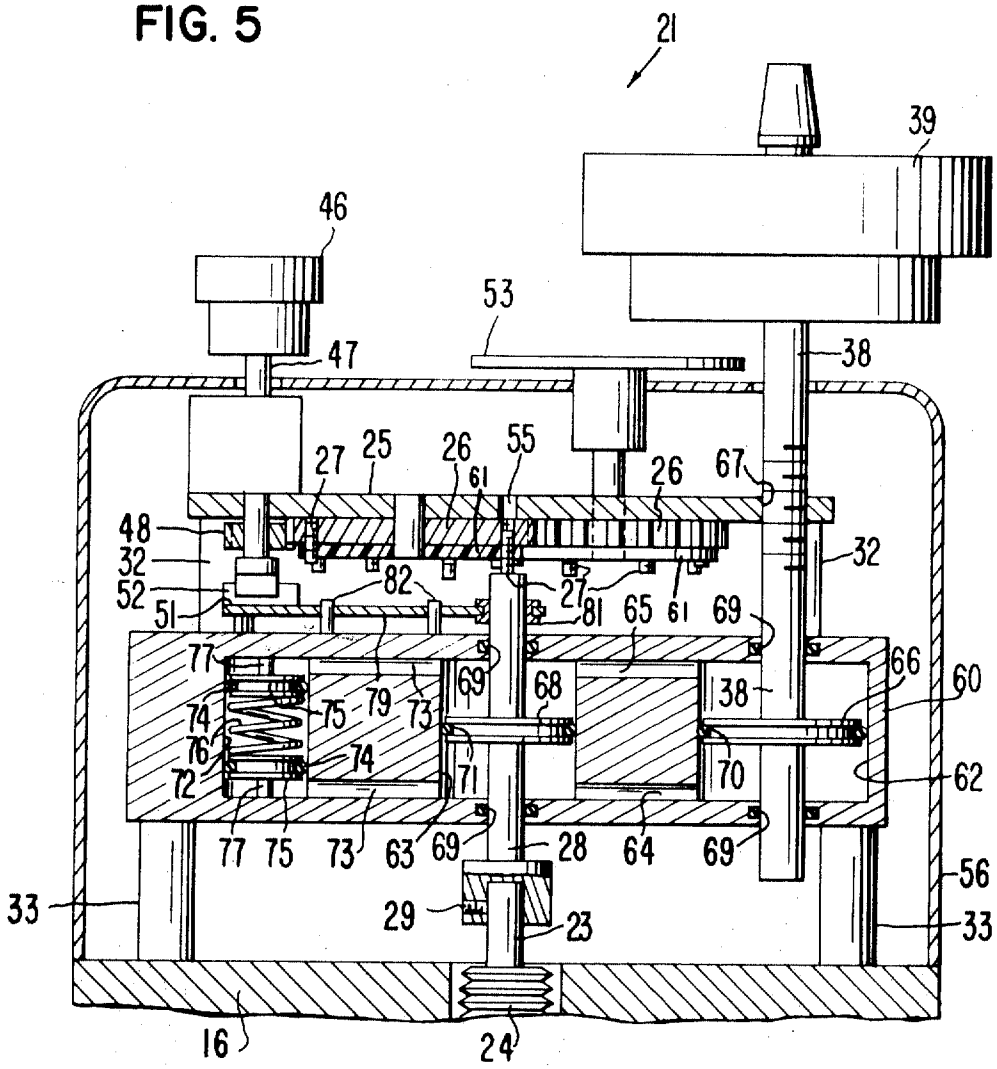


FIG. 4

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FIG. 5



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GANG TUNER FOR A MULTICAVITY MICROWAVE TUBE

DESCRIPTION OF THE PRIOR ART

Heretofore, reflex oscillator tubes have been provided with a cam wheel containing a spoke-type arrangement of cams arranged for successive engagement with a cam follower coupled to a tuning screw in the external cavity of the reflex oscillator. In one embodiment of the prior art, a lever was provided which was coupled to the cam follower and by manual depression of the lever the cam follower was disengaged from the cam to permit rotation of the cam wheel to a new tuner position corresponding to a different frequency. While such a tuning structure is adequate for tuning reflex oscillators where the cam wheel can conveniently completely surround the external cavity of the reflex tube, it is generally unsuited for use in relatively large multicavity klystron amplifier tubes where a plurality of such tuners would have to be ganged together and where a magnetic beam focus solenoid and yoke structure closely approaches the body of the tube along at least two sides of the tube body.

Heretofore, multicavity klystron amplifier tubes have been ganged tuned. More specifically, one such prior art tube included a capstan disposed at one end of the tube with a plurality of metallic bands wound on the capstan and extending lengthwise of the tube to selected ones of the cavity tuners for translating the tuners in accordance with rotation of the capstan. Those portions of the capstans underlying the respective ones of the bands was contoured about its periphery to form a cam to compensate for the various different tuning rates of the various different cavity tuners to produce a certain desired tuning arrangement over a relatively wide tunable band. Such a tube and tuner arrangement is disclosed and claimed in U.S. Pat. No. 3,132,280issued May 5, 1964and assigned to the same assignee as the present invention. The problem with this tuner that it is extremely difficult to maintain the required degree of precision in the adjustment of the various tuners when the cam followers are flexible bands and extend the full length of the tube structure.

Therefore, a need exists for an improved gang turner for multicavity microwave amplifier tubes.

SUMMARY OF THE INVENTION

The principal object of the present invention is the provision of an improved gang tuner for ,multicavity microwave amplifier tubes.

One feature of the present invention is the provision, in a multicavity microwave amplifier tube of a plurality of rotatable cam wheels mechanically interconnected for synchronous rotation, each wheel carrying a set of cams to engage a set of cam followers connected to cavity tuning structures, and including means for disengaging the cam followers from the cams and for preventing rotation of the cam wheels while the cam followers are in engagement with the cams to alleviate wear on the engaging surfaces of the cams and the cam followers whereby the microwave amplifier tube can be precisely and repeatedly tuned to certain preselected channel frequencies within the band of frequencies.

Another feature of the present invention is the same as the preceding feature wherein the cam wheel are meshed gears of a gear train, the cam wheels being substantially coplanar and disposed in a plane parallel to the beam path with the cam followers extending transversely of the beam path into engagement with the cams carried by the cam wheels.

Another feature of the present invention is the same as any one or more of the preceding features wherein the cam followers are moved into and out of the engagement with the cams by means of a plurality of slave hydraulic pistons coupled to the respective cam followers and the slave pistons being in fluid communication with a master hydraulic piston, such that movement of the master piston controls movement of the slave pistons and the corresponding cam followers.

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

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a fragmentary longitudinal view, partly in section, depicting a multicavity klystron tube incorporating features of the present invention,

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

FIG. 3 is a transverse sectional view of the structure of FIG. 1 taken along line 3—3 in the direction of the arrows,

FIG. 4 is a plot of gain versus frequency for the amplifier tube of FIG. 1 depicting the various tuned channels, and

FIG. 5 is a view similar to that of FIG. 3 depicting an alternative tuner structure of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to FIG. 1, there is shown a multicavity klystron amplifier 1 incorporating features of the present invention. The klystron amplifier 1 includes electron gun assembly 2 disposed at one end of the tube for forming and projecting a beam of electrons 3 over an elongated beam path to a beam collector structure 4 disposed at terminal end of the beam for collecting and dissipating the energy of the beam. A plurality of reentrant cavity resonators 5 are axially spaced apart along the beam path 3 for successive electromagnetic interaction with the beam of electrons.

Input microwave energy to be amplified is applied to the upstream cavity 5' by means of an input waveguide 6 containing a microwave window 7. The input microwave energy excites the upstream cavity resonator 5' to produce velocity modulation of the electron beam 3. In the field-free drift space 8 between the upstream cavity 5' and the next cavity 5 the velocity modulation is transformed into current density modulation of the beam, which excites the second resonator 5. The fields of the excited second resonator 5 further serve to velocity modulate the beam. This process is repeated in tow additional successive cavity resonators, not shown, to further increase the current density modulation of the beam as it enters the final or output cavity 5''. The bunched beam excites the output resonator 5'' and the microwave energy in the excited resonator is extracted by an output coupling iris 9 and transmitted via an output waveguide 11 containing a microwave window 12 to a suitable utilization device or load, not shown.

A beam focus electromagnet structure 13 is coaxially disposed of the tube 1 for producing an axially directed beam focusing magnetic field within the beam path between a pair of reentrant conical magnetic pole pieces 14 and 15. The magnetic field confines the beam to a desired diameter throughout the interaction circuit formed by the plurality of reentrant cavities 5 contained within a main body block portion 16. A rectangular yoke structure 17, only partially shown in FIG. 1, interconnects the ends of a pair of spaced solenoids 18 and 19 to provide a flux return path for the beam focus electromagnet structure 13. The rectangular yoke structure 17 is disposed in a plane substantially perpendicular to the paper such that the waveguides 6 and 11 are accessible from one side of the open rectangular yoke 17 and a tuning structure 21 is accessible from the opposite open side of the rectangular yoke 17.

The tuning structure 21 is provided for tuning the various cavity resonators 5 to certain frequencies within an operating band of frequencies. The tuning structure 21 includes a plurality of cavity tuner members 22 disposed within the cavity resonators 5. The cavity tuning members 22 may take any one of a number of various forms. More specifically, the tuner 22 may be of a capacitive type wherein it forms a capacitive member bridging across the gap between the end of the reentrant portions of the cavity 5, as shown, or it may comprise a deformable wall of the cavity for changing the inductance or

volume of the cavity resonator or the tuning member 22 may comprise combinations of both the deformable wall or movable wall with a capacitive member. The tuning member 22 includes a conductive extension 23 extending transversely of the beam axis outwardly through the block body 16 and vacuum envelope of the tube. The tuner extension 23 is sealed to the vacuum envelope of the main body 16 by means of a metallic bellows 24.

Referring now to FIGS. 1–3 the external portion of the tuning structure 21 will be more fully described. THe external tuning portion of the tuning structure 21 includes a rectangular cam support platform 25 having a plurality of cam wheels 26 pivotably mounted from the lower side of the cam support platform 25. The cam wheels 26 are in the form of gears with the teeth of the gear provided at the periphery of the wheels 26 and the gears meshing with the adjacent wheels 26 to provide a gear train as shown in FIG. 2. A plurality of cams 27, in the form of screws, are threaded into the peripheries of the cam wheels 26. The cam screws 27 extend axially of the cam wheels 26, to engage the upper surface of the cam followers 28 which take the form of rods having a socket portion at their lower extremity which receives the outer end of the tuning plunger 23. A setscrew 29 passes through the socket portion of the cam follower 28 to fixedly secure the tuning plunger 23 to the cam follower 28. The cam support platform 25 is fixedly secured to a second plate-shaped platform 31 via studs 32. The second platform 31 is fixedly secured to the block body 16 of the tube via studs 33.

A yoke plate 34 is suspended below plate 31 via the intermediary of three jackscrews 35. Sprockets 36 are fixedly secured to the jackscrews 35 and a drivechain 37 interconnects the three sprockets 36. One of the jackscrews 35' includes a drive extension 38 which passes through an opening in the cam support platform 25 and which is provided with a knob 39 at its outer end to permit turning of the jackscrew 35' and, thus, turning of all three jackscrews 35 due to the interconnection thereof by the drive chain 37. The jackscrews 35 threadably mate with the threaded apertures 41 in the yoke plate 34 and the jackscrews 35 are restrained against axial movement by means of retaining rings, not shown. Thus, rotation of knob 39 causes yoke plate 34 to travel parallel to the axis of the cam followers 28, as indicated by the arrows 42.

The yoke plate 34 is coupled to the cam followers 28 via a plurality of leaf springs 43 which are captured at their ends via rods 44 which serve to capture the downwardly turned ends of leaf springs 43 between the rods 44 and the yoke plate 34. The central portion of the leaf springs 43 are fixedly secured to the cam followers 28 as by retaining rings, not shown.

A channel selector knob 46 is coupled to the end of a rotatable drive rod 47 carried from the cam support platform 25. A drive gear 48 is fixedly secured to the channel selector drive rod 47. The drive gear 48 meshes the with teeth of one of the cam wheels such that by turning channel selector knob 46 the meshed cam wheels 26 are turned in synchronism to advance successive cam screws 27 into position over the cam follower 28. A stopblock 51 is fixedly secured to the yoke plate 34 and includes a transverse slot 52 into which the flattened end of the channel selector drive shaft 47 can ride. The stop block 51 prevents rotation of the channel selector shaft 47 until the yoke plate is retracted sufficiently such that the flattened end of the drive shaft 47 disengages the slot 52 in the stopblock 51. The slot 52 is made sufficiently deep such that before the channel selector shaft 47 becomes free from the stopblock 51 the cam-following surface on the end of the cam follower 28 is sufficiently retracted from the end of the cams 27 to prevent interference between the longest cam 27 and the end of the cam follower 28.

A channel indicator dial 53 is coupled to one of the cam wheels 26 such that the indicator dial 53 turns in synchronism with rotation of the cam wheels 26. The cam support platform 25 includes a row of access apertures 55 in axial alignment with the ends of each of the cam followers 28 such that the cam screws 27 may be adjusted by means of a screwdriver which reaches the cam screws 27 through the access apertures 55. A sheet metal housing 56 covers the external tuning structure 21 and includes channel selector indices, as shown in FIG. 2, for the identifying the various channels corresponding to the positions of a certain set of cam screws 27.

In operation, control knob 39 is turned to cause the yoke plate 34 to retract the cam follower 28 out of engagement with the cam screws 27. The retracted position is indicated in dotted lines. The channel selector knob 46 is then turned to advance a certain predetermined set of cam screws 27 to positions in axial alignment over the cam followers 28. The control knob 39 is then turned in the opposite direction to cause the yoke plate to be pulled toward the cam support platform 25, thereby pulling the cam follower 28 into engagement with the ends of the preselected set of cam screws 27. After engagement is obtained between the ends of the cam screws 27 and the cam follower 28, the control knob 39 is continued to be turned until the leaf spring 43 is sufficiently deflected, as shown in the drawing, to produce a substantial pressure between the engaged cam follower 28 and the cam screw surfaces. In this manner, a very precise positioning of the tuning member 22 within each resonator 5 is obtained without producing wear on the cam follower 28 or cam screw 27 which could serve to alter the position of the tuning element.

In a typical multicavity klystron amplifier application, as depicted in FIG. 4, the tube has an instantaneous bandwidth of approximately 60 megahertz between minus 1 db. points on a given channel. The center frequencies of the channels, as indicated by numbers 1 through 10, are tunable over a relatively wide band, as of 500 megahertz. At any given channel frequency, where the channel frequency is the center frequency of the passband of the tube 1, the cavities 5 will be tuned to slightly different frequencies over the passband. More specifically, the first and last cavity 5' and 5'' are typically tuned to the center frequency of the channel, whereas the second cavity and the third cavity are typically tuned by approximately equal amounts, as of 25 megahertz, below and above the center frequency of the channel. The fourth cavity is tuned outside the upper band edge of the passband, namely, approximately 40 megahertz above the center frequency for the channel. It is desired to maintain this relative frequency separation over the wide band of channels having a bandwidth of approximately 500 megahertz. However, each of the cavity tuners 22 has a slightly different tuning rate and, thus, each of the cavity tuners will have a unique position which must be precisely set to within a few ten-thousandths of an inch for each channel setting of the tube. Over the entire tuning band of the tube, i.e., from the first channel to the last the typical cavity tuner moves approximately sixty–seventy-thousandths of an inch and its position must be uniquely determined to within a few ten-thousandths of an inch. The precisely predetermined unique settings for the cam screws 27 are arrived at by monitoring the output band-pass characteristics of the tube for each of the channels and setting each of the cam screws 27 to obtain the desired response. The cam screws 27 are locked into position by means of a ring of nylon 61 affixed to the lower side of the cam wheels 26. The nylon ring is drilled and threaded to threadably mate with the cam screws 27 which pass through the cam wheel 26 and nylon ring 61.

Referring now to FIG. 5, there is shown an alternative external tuning structure 21 of the present invention. More specifically, the structure 21 is substantially identical to that of FIGS. 1–3 with the exception that the yoke plate 34 and leaf spring arrangement are replaced by a master hydraulic piston 66 and a plurality of slave pistons 68. More specifically, a hydraulic block body 60 is fixedly secured to the block body 16 of the tube 1 via support stubs 33. The cam support platform 25 is supported from the hydraulic block 60 via studs 32. The hydraulic block 60 includes a master cylinder 62 and a plurality of slave cylinders 63, there being one slave cylinder 63 for each of the cavity tuners 22. Fluid passageways 64 and 65 communicate between the master cylinder 62 and each one of the slave cylinders 63. The master piston 66 is fixedly secured

to an axially translatable drive shaft **38** which threadably mates with a threaded aperture **67** in the cam support plate **25**. Slave hydraulic pistons **68** are fixedly secured to each of the cam follower shafts **28**. The shafts **28** and **38** are sealed to the hydraulic block via O-ring seals **69** and the hydraulic pistons **66** and **68** are sealed in a fluidtight manner to the inside walls of cylinders **62** and **63** via O-rings **70** and **71**, respectively.

A pressure relief chamber **72** is contained within the hydraulic block **61** and is in fluid communication with each of the slave cylinders **63** via fluid passageways **73**. The pressure relief chamber **72** includes a pair of hydraulic pistons **75** sealed to the inside wall of the chamber **72** via O-rings **74**. A compression spring **76** is positioned between the two pistons **75** for urging same against a pair of centrally disposed axially directed studs **77** serving as stops at the ends of the cylinder **72**.

The stopblock **51** is fixedly secured to the end of an arm **79** which is carried at the upper end of the cam follower shaft **28** via a pair of retaining rings **81**. A pair of guide rods **82** affixed to the block **61** pass through aligned openings in the arm **79** to prevent twisting of the arm **79** about the cam follower shaft **28**.

In operation, control knob **39** is turned in such a direction to retract master drive rod **38** out of the master cylinder **62** causing the displaced hydraulic fluid to flow through passageways **65** and to push the slave pistons **68** in the downward direction to cause disengagement of cam follower **28** with the cam screws **27**. In case excessive pressure tends to be created, as by some object preventing the movement of the cam follower rods **28**, the pressure release spring **76** will be compressed to prevent excessive pressure being generated within the system. When the master piston **66** has been sufficiently retracted such that the cam follower shafts have been retracted to disengage the stop slot **52** from the end of the channel selector rod **47**, the channel selector knob **46** can be turned to advance the proper set of cam screws **27** into position over the ends of the cam followers **28**. Control knob **39** is then turned in such a direction as to cause the master piston **66** to move in the downward direction which forces the hydraulic fluid through passageway **64** and against the bottom side of the slave piston **68** causing the cam follower shafts **28** to move upwardly into engagement with the lower ends of the cam screws **27**. Upon engagement of the cam follower **28** with the cam screws **27**, the control knob **39** is continued to be rotated in the same direction to build up hydraulic pressure, as determined by the compression of the compression spring **76**, thereby forcing the cam followers **28** into a firm engagement with the cam screws **27** and assuring a precise positioning of the cam follower **28** and, thus, the tuning members **22** within each of the resonators **5**.

The gang tuner of the present invention is especially desirable for tuning a klystron amplifier tube to certain preselected channels to avoid traffic in satellite communication or to change the frequency of a radar to avoid jamming or interference. By parting the interface between the cam follower **28** and the cam screws **27** before any adjustment is made by rotation of the cam screws **27**, wear is prevented on the cam interface surfaces, thereby assuring precise frequency settings over many cycles of operation of the tuner.

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

What is claimed is:

1. In a multicavity microwave amplifier tube, electron gun means for forming and directing a beam of electrons over an elongated beam path, collector means at the terminal end of the beam path for collecting and dissipating the energy of the beam, a plurality of cavity resonators arranged along the beam path for successive electromagnetic interaction with the beam to produce velocity modulation of the beam, means for extracting output microwave energy from the beam for transmission to a utilization device, tuner means associated with a plurality of said cavity resonators for tuning the frequency of said cavities and for tuning the center frequency of the instantaneous electronic passband of the amplifier within a wider tunable band of frequencies, THE IMPROVEMENT WHEREIN, said tuner means includes a train of gears meshed for synchronous rotation, each of said gears having a set of independently adjustable cams rotationally spaced therearound, each set of cams being so spaced the same as every other set of cams, a plurality of cam follower means, each of said cam followers being connected to one of said cavity tuner means and extending transversely of the beam path into engagement with one of said cams in one of said set of cams for tuning the respective cavity resonator to a certain frequency in accordance with the position of the respective cam in said set of cams, means for disengaging said cam followers from said cams and for preventing rotation of said cam wheels while said cam followers are in engagement with said cams to alleviate wear on the engaging surfaces of said cams and cam followers, whereby the microwave amplifier tube is precisely tuned to certain preselected channels within a frequency band.

2. The apparatus of claim 1 wherein said plural gears are substantially coplanar and disposed on a plane parallel to the beam path.

3. The apparatus of claim 1 including means for forcing said cam followers into engagement with said cams.

4. The apparatus of claim 3 wherein said engagement-forcing means comprises a plurality of leaf springs, one of said leaf springs coupled to a respective one of said cam followers.

5. The apparatus of claim 3 wherein said engagement-forcing means comprises a plurality of slave hydraulic pistons, one of said slave pistons coupled to a respective one of said cam followers, a plurality of hydraulic cylinders for containing each of said slave pistons with each of said slave pistons being sealed across each of said cylinders and being slidably operable therewithin, means for selectively applying fluid to either side of said slave pistons to selectively move said coupled cam followers into and out of engagement with said cams.

6. The apparatus of claim 5 wherein said means for selectively applying fluid to said slave pistons includes a master cylinder in fluid communication with said plurality of slave pistons and cylinders, a master piston in said master cylinder, means for selectively moving said master piston in said master cylinder to cause said slave pistons and coupled cam followers to move into and out of engagement with said cams in accordance with movement of said master piston.

7. The apparatus of claim 6 including a fluid pressure relief means in fluid communication with the fluid in said master cylinder to prevent excessive pressure from being exerted on said cams and cam followers.

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