July 9, 1968 H. PLUTCHOK 3,392,354

MULTIPLE-DIAMETER SMOOTH-SURFACE WAVEGUIDE TUNING POST

Filed Dec. 23, 1965 3 Sheets-Sheet 1

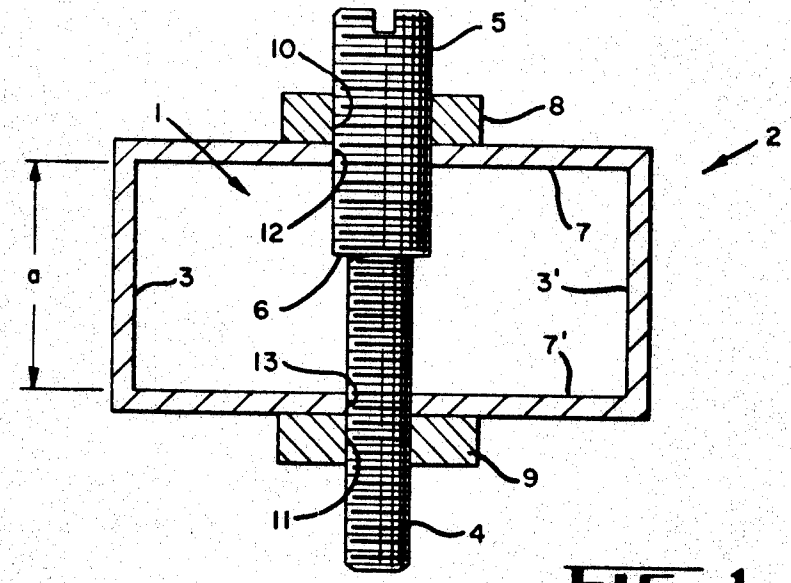


FIG-1

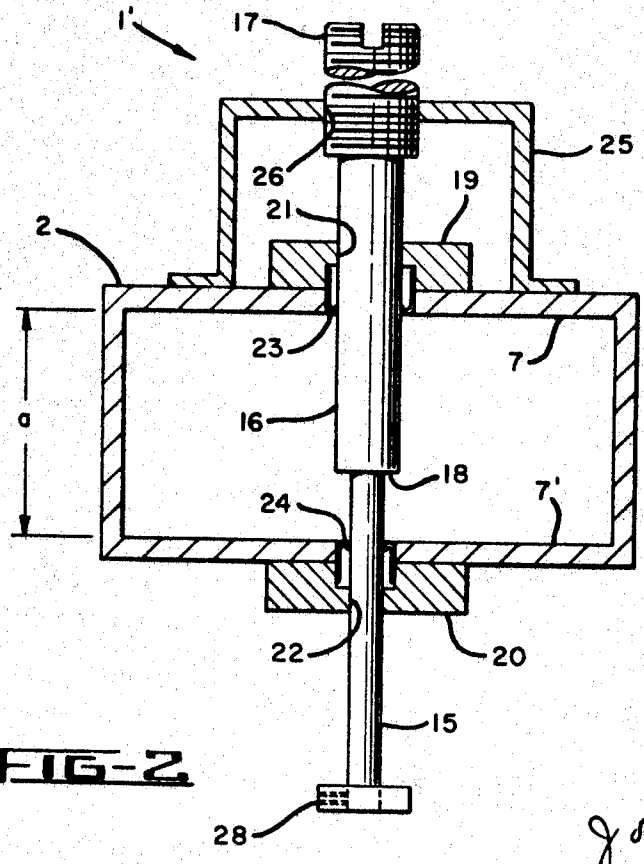


FIG-2

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MULTIPLE-DIAMETER SMOOTH-SURFACE WAVEGUIDE TUNING POST

Filed Dec. 23, 1965 3 Sheets-Sheet 2

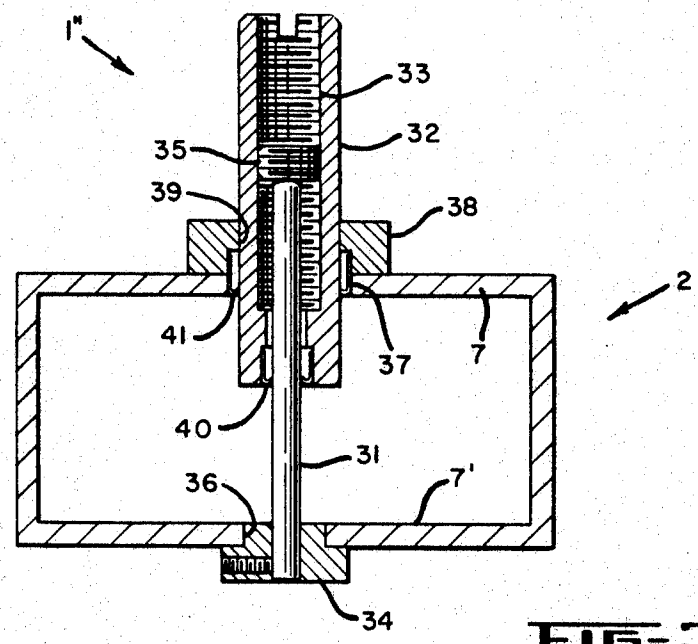


FIG-3

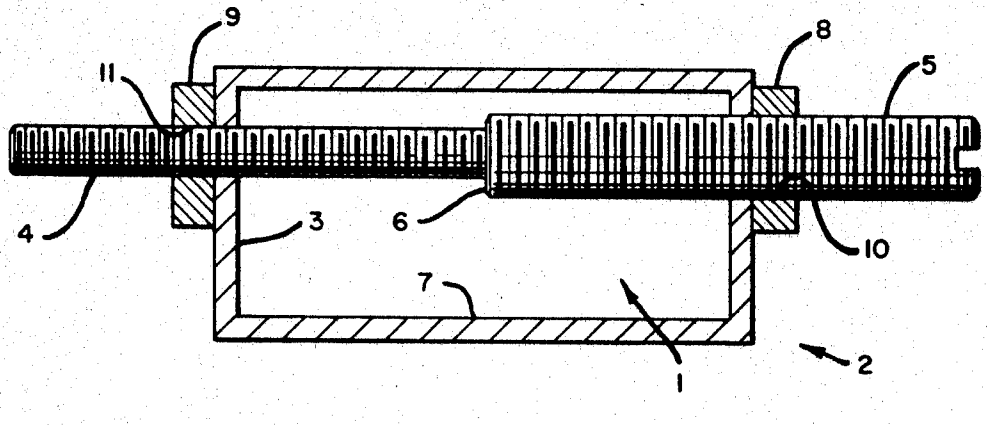


FIG-7

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MULTIPLE-DIAMETER SMOOTH-SURFACE WAVEGUIDE TUNING POST

Filed Dec. 23, 1965 3 Sheets-Sheet 3

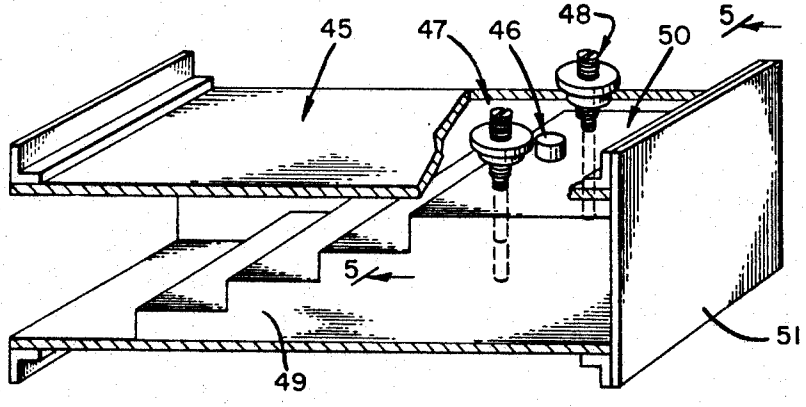


FIG-4

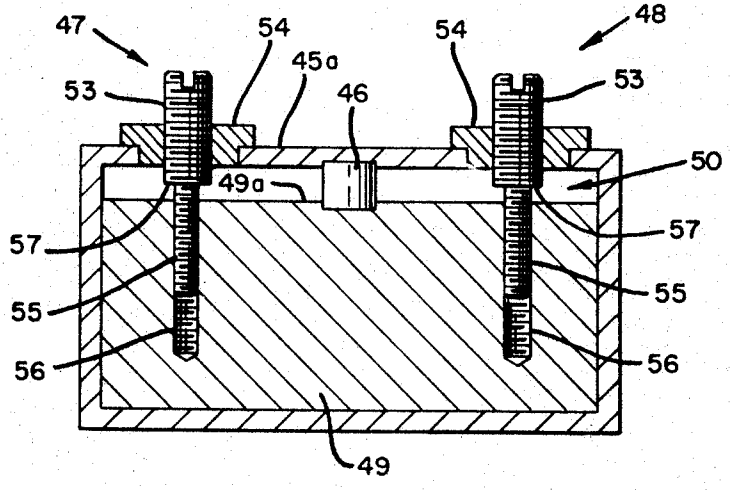


FIG-5

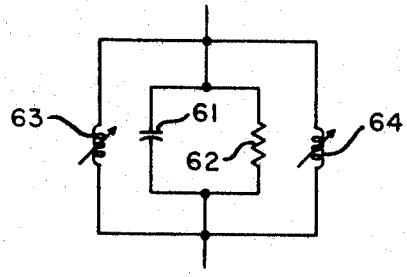


FIG-6

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United States Patent Office

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MULTIPLE-DIAMETER SMOOTH-SURFACE WAVEGUIDE TUNING POST

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ABSTRACT OF THE DISCLOSURE

An electrically conductive cylindrical post extends through openings in opposed walls of a waveguide. The post comprises sections of different diameter that are located in the waveguide. Spring finger contacts in the wall openings provide electrical connection between the post and waveguide. The post is moved transversely in the waveguide to vary the susceptance produced thereby.

This invention relates to waveguide and more particularly to tuning devices in waveguide.

An electrically-conductive post extending completely across a waveguide at right angles to the E-field and electrically connected to the waveguide walls provides a capacitive susceptance in the waveguide. Also, an electrically-conductive post extending completely across a waveguide parallel to the E-field and electrically connected to the waveguide walls provides an inductive susceptance in the waveguide. These posts may be employed for tuning and matching in waveguide devices such as tunnel diode amplifiers and for providing waveguide filters such as described in "Designing Narrow-Band Triple-Post Waveguide Filters" by Elio A. Mariani, Microwaves, August 1965, pages 93–97. The susceptance of a post as a function of the diameter and position of the post in the waveguide is tabulated in references such as Microwave Engineers Handbook and Buyers Guide, 1964, Horizon House-Microwave, Inc. The susceptance provided by a post having a fixed diameter and position in the waveguide, however, is non-variable. A problem encountered in the building of devices such as waveguide tunnel diode amplifiers is that the susceptance required to tune the amplifiers is not the same for each unit because the capacitive reactance of each diode is slightly different. It is desirable in such cases to have a waveguide post providing a variable susceptance. This invention is directed to the provision of such a device.

An object of this invention is the provision of a variable susceptance in a waveguide.

Another object is the provision of a waveguide post providing a continuously variable susceptance in a waveguide.

These and other objects are accomplished in accordance with this invention by an electrically conductive post having a variable cross-sectional area over its length and being located in a waveguide and electrically connected to opposite walls of the waveguide. The post is moved transversely in the waveguide to vary the volume of the post, and thus the effective cross-sectional area of the post in the waveguide, and the susceptance provided thereby.

This invention will be more fully understood from the following description of a preferred embodiment thereof, together with the accompanying drawings in which:

FIGURE 1 is a transverse section of a rectangular waveguide showing a post embodying this invention for providing a variable inductive susceptance in the waveguide;

FIGURE 2 is similar to FIGURE 1 showing a modified form of tuning post in a rectangular waveguide;

FIGURE 3 is another section similar to FIGURES 1 and 2 showing a third form of tuning post in a waveguide;

FIGURE 4 is a perspective view of a rectangular waveguide tunnel diode amplifier partially broken away and including a pair of tuning posts of this invention;

FIGURE 5 is a section of the waveguide tunnel diode amplifier taken on line 5—5 of FIGURE 4;

FIGURE 6 is a schematic diagram of the circuit equivalent of the amplifier of FIGURES 4 and 5; and

FIGURE 7 is a transverse section of a rectangular waveguide and a tuning post for providing a variable capacitive susceptance in the waveguide according to this invention.

Referring now to FIGURE 1, a post **1** is oriented transversely in a rectangular waveguide **2** with the longitudinal axis X—X of the post parallel to narrow walls **3** and **3'** of the waveguide. Post **1** comprises a first section **4** of comparatively larger diameter having a shoulder **6** at its junction with the first section. The post is threaded over its length with the threads of each section having the same pitch. The post may be cut from a single piece of electrically conductive bar stock or may be formed from two threaded lengths of such stock secured together in end-to-end relationship. The length of each of post sections **4** and **5** is greater than the short cross-sectional dimension *a* of the waveguide so that either post section may be positioned to extend across the full height of the waveguide. Nuts **8** and **9**, preferably made of brass, are rigidly secured to the exterior of broad walls **7** and **7'**, respectively, as by silver solder or brazing, and have threaded openings **10** and **11** aligned with openings **12** and **13**, respectively, in the broad walls of the waveguide. The threads in nuts **8** and **9** have the same pitch as the threads on post **1** to prevent interference when the post is rotated therein and may be formed simultaneously in the waveguide mounted nuts by means of a dual diameter tap. Alternately, post **1** may first be inserted into the waveguide through openings **12** and **13** until post shoulder **6** is between the broad waveguide walls, and thereafter the nuts **8** and **9** are threaded over the respective post section into tight abutment with the waveguide walls and are then soldered thereto.

In operation, the position of shoulder **6** in the waveguide is varied through rotation of the post. As the shoulder **6** moves, the effective diameter of the portion of the post that is within the waveguide changes. This change in the effective diameter of the post within the waveguide causes a corresponding change in the inductive susceptance that is provided in the waveguide by the post. When shoulder **6** is flush with the interior of waveguide wall **7**, only the smaller diameter post section **4** is located in the waveguide and a minimum inductive susceptance is provided. Conversely, maximum inductive susceptance is provided by the post when shoulder **6** abuts against the interior of wall **7'** and only the larger diameter post section **5** is in the waveguide.

A modified form of the invention is illustrated in FIGURE 2 wherein the surfaces of the post sections adapted to move within the waveguide are not threaded. Post **1'** comprises a first cylindrical section **15** joined at its inner end to a second cylindrical section **16** having a relatively larger diameter, and a threaded third section **17** extending from section **16**. The junction of sections **15** and **16** defined by shoulder **18** corresponds to shoulder **6** in FIGURE 1.

Guide blocks **19** and **20** are secured to the exterior of broad waveguide walls **7** and **7'**, respectively, and have openings **21** and **22** aligned with corresponding openings in these waveguide walls. Electrically conductive spring finger contacts **23** and **24** are mounted in apertures **21** and **22**, respectively, and engage the post to insure tight electrical contact between the post and waveguide.

A conductive channel shaped mounting flange **25** permanently secured to the outside of broad waveguide wall

7 has a threaded aperture 26 axially aligned with guide block openings 21 and 22 and formed with a thread pitch equal to that of section 17. A removable cap 28 is secured to the outer end of small post section 15. The length of each of post sections 15 and 16 is no less than the height *a* of the waveguide plus the thickness of one guide block.

The post 1' functions in the same manner as the post in FIGURE 1 to variably change the inductive susceptance in the waveguide as the position of shoulder 18 is moved entirely across the interior of the waveguide.

Another form of this invention is shown in FIGURE 3 as a post 1'' comprising a probe 31 and a cylindrical sleeve 32 having a threaded bore 33. Probe 31 has a cap 34 at one end and an enlarged threaded head 35 at the other. Probe 31 extends through opening 36 in waveguide wall 7' into threaded engagement with sleeve 32 within its bore 33 and the sleeve extends through opening 37 in waveguide wall 7 in axial alignment with the probe. Cap 34 on probe 31 is permanently secured to the outside of wall 7' so that the probe is stationary relative to the waveguide.

A guide block 38 secured to the exterior of the waveguide wall 7 has an opening 39 for snugly and slidingly receiving sleeve 32 and supporting the latter during its movement transversely of the waveguide. The length of probe 31 is such that its threaded head 35 does not extend within the waveguide and sleeve 33 is sufficiently long that it extends across the waveguide and abuts the interior of wall 7' at the limit of its inward movement. Spring fingers 40 and 41 insure firm sliding electrical contact between relatively moving parts of the probe, sleeve and wall 7. Rotation of sleeve 32 causes it to move across the waveguide to variably change the inductive susceptance.

A variable susceptance device embodying the invention has particular utility and advantage in a waveguide tunnel diode amplifier, see FIGURE 4. This amplifier comprises a waveguide 45, a tunnel diode 46, and a pair of tuning elements 47 and 48. For convenience of illustration, the DC bias circuit for tunnel diode 46 is not shown in the drawings.

In order to match the characteristically low impedance of the tunnel diode to the high impedance of standard waveguide, a step-type transformer 49 is included in the waveguide. This transformer reduces the height of the waveguide in a series of steps to a predetermined value to define a low impedance waveguide portion 50 having an impedance in the order of 20 ohms.

The tunnel diode 46 is disposed centrally within this low impedance waveguide between broad walls 45*a* and 49*a* and is spaced from a shorting plate 51 on the end of the waveguide by a quarter wavelength at the operating frequency. In order that this circuit be DC bias stable and that the junction capacitance of the tunnel diode not reduce the gain provided by the tunnel diode, it is desirable to provide an inductance, in shunt with the tunnel diode, that is shunt resonant with the junction capacitance at the design frequency to effectively remove the capacitance from the circuit. Since this capacitance varies from diode to diode and is generally quite small, in the order of 0.3 picofarad, a variable inductance element is needed. In order to provide such inductance, two posts 47 and 48 of the type described above are connected between the broad walls of the low impedance portion 50 on either side of the tunnel diode. The posts 47 and 48 are substantially identical in construction and therefore only one will be described in the following text, like reference characters indicating like parts in the drawings.

Each of the posts 47 and 48 has an upper part 53 extending through and threadedly engaging a plate 54 secured to waveguide wall 45*a*, and a lower part 55 of reduced diameter threaded into a tapped hole 56 in wall 49*a*. The shoulder 57 at the junction of the two post parts is thus positionable at selected heights within the waveguide simply by rotation of the post. The inductive susceptance required to tune the tunnel diode is thus readily achieved by such adjustment of both posts 47 and 48.

The equivalent circuit of the tunnel diode 46 and posts 47 and 48 in the waveguide is illustrated in FIGURE 6. Tunnel diode 46 is represented by capacitor 61 connected in parallel with a resistor 62 having a negative resistance. Posts 47 and 48 are represented by variable inductors 63 and 64, respectively, which are connected in parallel with resistor 62 and capacitor 61. "Negative resistor 62" is the only component of the circuit that provides amplification of an incident signal. When capacitor 61 is not resonated with an inductance, it actually causes degradation of the gain of the amplifier. It is desirable therefore to remove capacitor 61 from the circuit at the design center frequency of the amplifier. This is accomplished by adjusting the value of inductors 63 and 64 so as to be resonant with capacitor 61 at the design center frequency of the amplifier and thus effectively provide an open circuit in parallel with "negative resistor" 62. The operating center frequency of the amplifier is thus varied by simple rotational adjustment of the posts.

By way of example, a waveguide tunnel diode amplifier including a pair of dual diameter posts 47 and 48 of the type illustrated in FIGURES 4 and 5 and having the following dimensions and characteristics was constructed and successfully operated:

Waveguide, low height (X-band):
- Width ____ inch__ 0.900
- Height ____ do____ 0.020

Tunnel diode:
- General Electric TD 406 germanium micropill diode, R_j=−75Ω, C_j=0.25 pf., cutoff frequency ____ gc__ 30
- Axial position from 51 (see FIGURE 4) ____ inch__ 0.300
- Design frequency ____ gc__ 10–12.4

Posts 47 and 48:
- Diameter, section 55 ____ inch__ 0.112
- Diameter, section 53 ____ do____ 0.190
- Threads per inch ____ 40
- Distance from narrow walls 3 and 3' ____ inch__ 0.250
- 3 db bandwidth ____ mc__ ≈300
- Gain (at centre frequency f=12.4 gc.) ____ db__ 15
- Tuning range (caused by posts 47 and 48; center frequency) ____ gc__ 12 to 12.6

Alhough this invention has been described in relation to specific embodiments thereof, variations and modifications will be apparent to those skilled in the art. For example, post 1 illustrated in FIGURE 1 may obviously be located in waveguide 2 parallel to the field as illustrated in FIGURE 7 to provide a variable capactive reactance in the waveguide. Also, the posts may be made of a dielectrical material for providing a complex variable reactance in the waveguide. The scope and breadth of this invention is, therefore, to be determined from the following claims rather than from the above detailed description.

What is claimed is:

1. A microwave circuit comprising:
   - an elongated post made of electrically conductive material and having first, second and third sections and a longitudinal axis,
     - said first and second sections having cylindrical cross sections and different diameters and having smoth surfaces over at least a portion of their lengths,
     - the circumference of said third section being threaded over at least a portion of its length,
   - a waveguide for propagating electromagnetic waves, said waveguide comprising an electrically conductive sheath having first and second pairs of opposed walls, the walls of said first pair having aligned openings

receiving smooth sections of said first and second post sections, respectively, with the post extending through the waveguide transversely of the direction of wave propagation therein and perpendicular to the walls of said first pair, said post being located with said third section outside of the cavity formed by said waveguide walls,

first and second guide blocks secured to the exterior of said first pair of opposite walls, said blocks having openings therein axially aligned with said wall openings for receiving and guiding said portions of said first and second post sections having smooth surfaces,

electrically conductive spring finger contacts located in the openings in said waveguide walls and said guide blocks providing electrical continuity across the opening between said post and said waveguide walls during movement of said post in said waveguide, and

a mounting flange secured to one of the walls of said first pair of walls, said flange having a threaded opening remote from said waveguide and axially aligned with said waveguide wall openings receiving the threaded portion of said third section for moving said post in the interior of said waveguide for changing the length of said differently dimensioned first and second post sections within the waveguide to correspondingly vary the reactance produced by the post.

2. A microwave circuit comprising

an elongated post assembly made of electrically conductive material and comprising

a cylindrical probe having a smooth surface and having a threaded portion adjacent one end thereof, and

a cylindrical sleeve having an outer diameter larger than the diameter of said probe and having a smooth outer surface and a threaded bore engaging the threaded portion of said probe,

a waveguide for propagating electromagnetic waves, said waveguide comprising an electrically conductive sheath having first and second pairs of opposed walls, the walls of said first pair having aligned openings receiving smooth sections of said probe and said

sleeve, respectively, with the post extending through the waveguide transversely of the direction of wave propagation therein and perpendicular to the walls of said first pair,

first and second guide blocks secured to the exterior of said first pair of opposite walls and having openings therein axially aligned with said wall openings for receiving and guiding the smooth outer surfaces of said probe and said sleeve, respectively, the other end of said probe being secured in said first guide block,

first electrically conductive spring finger contacts located in the second opening in said second waveguide wall and said guide blocks providing electrical continuiity across the opening between said sleeve and said second waveguide wall during movement of said sleeve in said waveguide, and

second electrically conductive spring finger contacts located in the bore of said sleeve providing electrical continuity across the bore between said sleeve and said probe during movement of said sleeve in said waveguide,

rotation of said sleeve providing transverse movement of said sleeve in the interior of said waveguide for changing the length of said differently dimensioned probe and sleeve sections within the waveguide to correspondingly vary the reactance provided by the post assembly.

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