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[54] COAXIAL ASSEMBLY FOR MOUNTING A VARACTOR DIODE

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Related U.S. Application Data

[60] Continuation of Ser. No. 677,466, Oct. 23, 1967, which is a continuation of Ser. No. 478,499, May 24, 1965, which is a division of Ser. No. 101,441, Apr. 7, 1961, Pat. No. 3,194,976.

[52] **U.S. Cl.** ..... **333/97 R**, 174/88 C

[51] **Int. Cl.** **H01p 5/00**

[58] **Field of Search** ..... 321/69 W, 69 NL; 329/162; 333/7, 31, 97, 97 S; 307/320; 174/88 C

[56] **References Cited**

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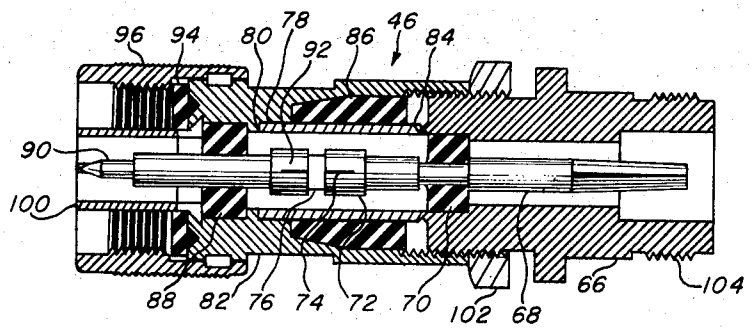
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Primary Examiner—Paul L. Gensler

[57] **ABSTRACT**

A subcombination of a coaxial broadband frequency multiplier, the subcombination consisting of coaxial connector jack and plug bodies connected together in electrical engagement with each other and having an axially aligned opening through the entire jack and plug bodies, the opening carrying along the axis thereof a varactor having oppositely disposed terminals with a first center conductor in electrical engagement with one of the terminals and extending axially in one direction in the opening and a second center conductor in electrical engagement with the other terminal and extending axially in the opposite direction in the opening, and an insulator in the jack and plug bodies fixing the respective center conductors in place in the opening and separated from the jack and plug bodies.

1 Claim, 3 Drawing Figures



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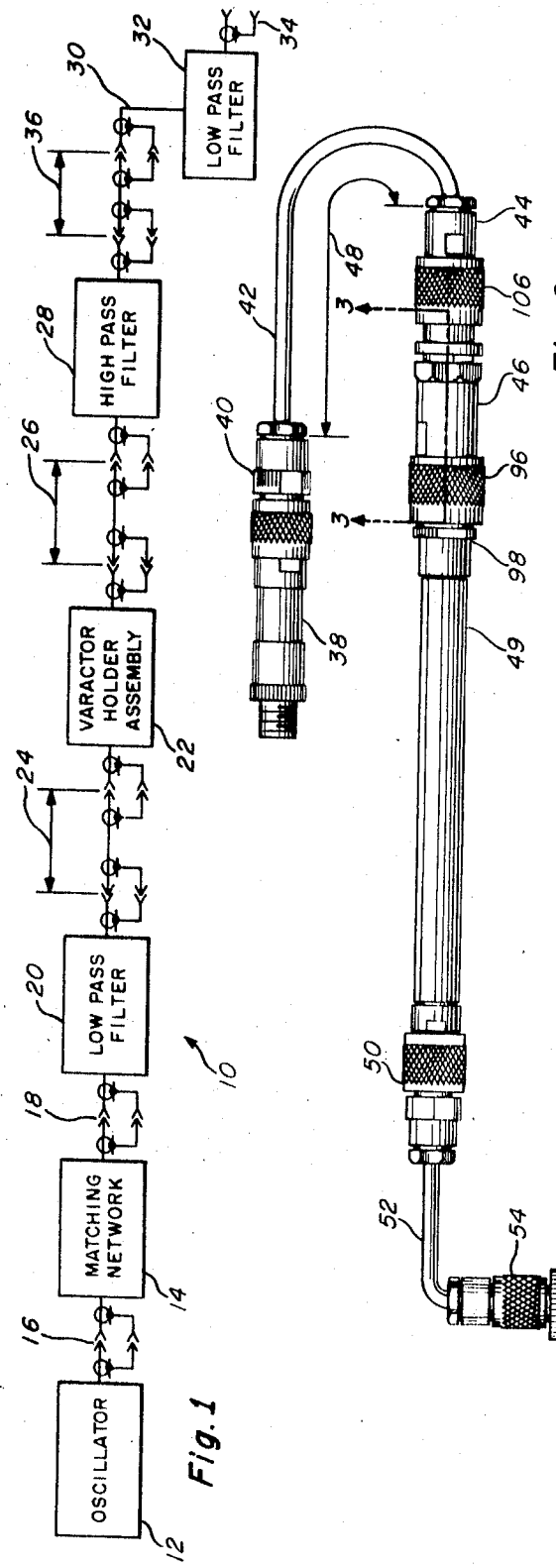


Fig. 1

Fig. 2

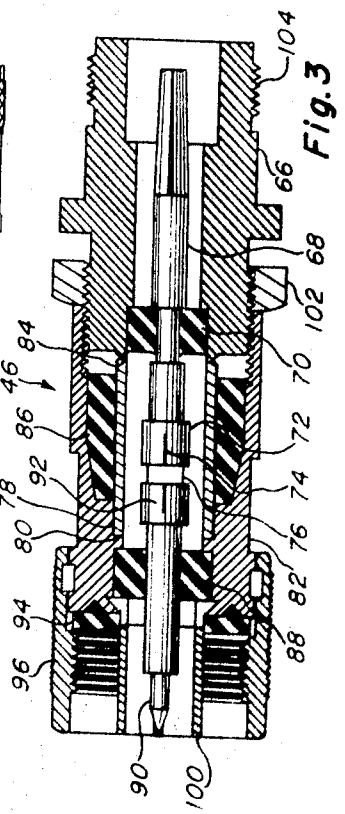


Fig. 3

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COAXIAL ASSEMBLY FOR MOUNTING A VARACTOR DIODE

This is a continuation of application No. 677,466 **filed Oct.** 23, 1967, which is a continuation of application No. 478,499 filed May 24, 1965, which is a division of application No. 101,441, **filed Apr.** 7, 1961, which issued on July 13, 1965 as patent No. 3,194,976.

This invention relates to passive frequency multipliers and more particularly to coaxial broadband frequency multipliers utilizing non-linear voltage variable circuit elements. By broadband as herein used is meant a capability of an operating frequency range equal to at least ten percent of the mean operating frequency. The term passive as herein used is meant a capability for operation without source of energy other than input signal energy of the signal to be multiplied as distinguished from the need for outside power supplies such as required by electronic tubes which are herein referred to as structures which are active in their operation.

In the input frequency range below 1,000 megacycles it becomes impractical to create frequency multipliers constructed with conventional rectangular waveguide due to prohibitively large physical size required. Also because of inherent capacitive loading and other limitations at these high frequencies, it becomes impractical and undesirable to use active multiplier devices such as triodes as distinguished from passive devices such as voltage variable capacitors, herein termed varactors.

A primary object of the present invention is the provision of a subcombination which makes possible a coaxial broadband frequency multiplier which is passive in its operation.

Another object is the provision of a subcombination which makes possible a coaxial broadband frequency multiplier which is highly efficient in its operation, that is, it has a relatively high ratio of output signal energy level to input signal energy level.

And a further object is the provision of a subcombination which makes possible a coaxial broadband frequency multiplier which is extremely long lived.

Another object is the provision of a subcombination which makes possible a coaxial broadband frequency multiplier which incorporates the reliability of solid state harmonic frequency generating structures.

And a still further object is the provision of a subcombination which makes possible a coaxial broadband frequency multiplier which has relatively high power output capabilities.

And another object of the present invention is the provision of a subcombination which makes possible a coaxial broadband frequency multiplier which is relatively compact and rugged in its construction capable of withstanding impact and vibration without malfunction.

And a still further object is the provision of a subcombination which both lends itself and makes possible a coaxial broadband frequency multiplier which lends itself to construction from generally available commercial components and requires relatively little adapting fabrication.

These objects, features and advantages are achieved generally by providing a signal input circuit, a non-linear voltage variable capacitor, and an output circuit for a harmonic of the input signal frequency, the signal input circuit being arranged to excite the voltage variable capacitor over a selected frequency band and the output circuit being arranged to pass a selected harmonic of all excitation frequencies within said band.

By making the non-linear voltage variable capacitor of the subcombination in the form of a varactor, a passive, highly efficient and long lived frequency multiplier is thereby achievable.

By providing a coaxial connector with the varactor in series with the center conductor in the connector, a desirably separable component of the overall combination is thereby achieved.

By using a bulkhead receptacle having a female center conductor contact embedded in a glass bead in one end of a plug body of the coaxial connector and carrying a varactor holder, a fixed reference location for the varactor is thereby achieved.

By providing an axially slidable male contact center conductor member in a dielectric spacer sleeve in the other end of the plug body, and with provision for holding the other terminal of the varactor diode, a secure self aligning mounting arrangement for the varactor in the coaxial connector is thereby achieved.

By providing an internal conductor sleeve fixed in a resilient dielectric bushing surrounding the varactor and having an internal diameter whose ratio with respect to the outside diameter of the varactor is substantially the same as that of the corresponding coaxial transmission line dimension ratio, substantially constant impedance is thereby retained.

By providing recessed and slotted end portions in the male and female contacts in the coaxial connector for receiving the respective terminals of the varactor diode, suitable spring holders and electrical contacts for holding the varactor diode electrically and physically in place, thereby with the associated elements achieves a desirable varactor holder assembly or subcombination.

By providing a low-pass filter in the signal input circuit which passes only the fundamental frequency, with the filter an electrical distance from the varactor of the subcombination such that a voltage minumum is reflected at the varactor by the filter for the desired output harmonic and for other harmonics below the desired output harmonic, a structure whereby harmonics higher than the fundamental frequency are prevented from reaching the signal source from the varactor and in which maximum input signal power reaches the varactor is achievable.

By providing an impedance matching element interposed between the low-pass filter and signal source, suitable isolation of the signal source from the subsequent circuitry is thereby achieved so as to permit use of the present subcombination invention in a workable passive multiplier even where signal sources affected by changing load conditions are used.

By providing a bandpass filter at the output side of the varactor of the subcombination arranged to pass only the band of desired output frequencies, all undesired outputs may be prevented from raching the load.

By providing an electrical length of transmission line between the varactor of the subcombination and the band-pass output filter such that the impedances (reflected from this band-pass filter at the fundamental frequency and at the harmonic frequencies below the desired output harmonic frequency) are proper to simultaneously resonate with the average capacitance of the varactor at each of these above mentioned frequencies, maximum output power over the selected output frequency band of the frequency multiplier utilizing the subcombination is thereby achievable. For multipliers of order greater than two, this electrical length condition results in the production of an idler current through the varactor of the subcombination at harmonic frequencies of the input below the desired output harmonic. These configurations on the input and output circuitry provide a structure for achieving maximum operating efficiency of the frequency multiplier.

By making the band-pass filter in the form of two series coupled filters, namely a high-pass filter and a low-pass filter, readily available commercial filters may thereby be used in the frequency multiplier carrying the subcombination.

These features, objects and advantages will be better understood from the following description taken in connection with the accompanying drawings of preferred embodiments of the invention and wherein:

FIG. 1 is a block diagram of a frequency multiplier constructed in accordance with the present invention of a subcombination thereof;

FIG. 2 is a plan view of a frequency tripler embodiment of embodying the invention;

FIG. 3 is cross section taken on line 3—3 of FIG. 2 to more clearly show construction of a the subcombination invention portion of the embodiment shown in FIG. 2.

Referring to FIG. 1 in more detail, a frequency multiplier made in accordance with the present subcombination inven-

tion is illustrated generally by the numeral 10. The frequency multiplier 10 is fed by a conventional oscillator 12 through an impedance matching network 14 coupled by a coaxial connector 16 to the oscillator 12 and a coaxial connector 18 to a conventional low-pass filter 20 whose upper frequency marks the upper frequency of the selected band of frequencies from the oscillator 12 to be fed to the frequency multiplier 10.

The low-pass filter 20 is coupled to a varactor holder assembly 22 forming the subcombination invention, to be hereinafter further described in connection with FIG. 3, by a length 24 of a coaxial transmission line such that a voltage minimum is reflected from the low-pass filter 20 to the varactor holder assembly 22 for the selected output harmonic and for other harmonic frequencies below the selected harmonic of the input signal frequency band. This proper length of line 24 may be found with the aid of a standing wave detecting slotted transmission line by which voltage standing wave patterns of the low-pass filter 20 are determined at the harmonic frequencies. Having found the desired length of transmission line 24 from the slotted transmission line measurements, the standing wave detecting transmission line is replaced with an actual length of coaxial transmission line 24 which is then empirically adjusted to compensate for discontinuity in connectors, differences in the slotted line and actual coaxial transmission line 24, and lead inductance to the varactor holder assembly 22, to produce thereby maximum power output at the selected harmonic.

In similar manner, a coaxial transmission line having a length 26 is used to couple a varactor holder assembly 22 to a high-pass filter 28 so as to reflect to the varactor holder assembly 22 an impedance proper to resonate with the average varactor impedance at each of the harmonic frequencies below the desired harmonic and at the fundamental frequency. The high-pass filter 28 is coupled by a coaxial transmission line 30 to a low-pass filter 32 having a signal output coupling 34 to a desired use device or load such as a mixer (not shown) or other desired equipment, as a frequency source for the equipment.

The coaxial transmission line 30 has an electrical length 36 which is empirically adjusted for maximum power output of the separate filter components 28 and 32 to thereby permit the use of commercially available filters in place of a single lumped band pass output filter which would necessarily be custom built at substantially greater expense than the construction herein described.

In the operation of the FIG. 1 embodiment, input signal frequencies from the oscillator 12 are fed through the coaxial coupling 16 and impedance matching network 14, and coaxial coupling 18, through the low-pass filter 20 where frequencies above the selected band of input frequencies are attenuated. The desired frequencies on the input band are then fed from the low-pass filter 20 through the length of coaxial transmission line 24 to the varactor holder assembly 22 so as to excite the varactor in the varactor holder assembly 22 to produce harmonics of the input frequency signals. These harmonics are fed from the varactor holder assembly 22 through coaxial transmission line 26 to the high-pass filter 28 where frequencies below the desired output frequency band are reflected. The frequencies above the reflected frequencies are passed through the coaxial transmission line 30 to the low-pass filter 32 which prevents the passage of frequencies higher than those selected for the output so as to pass to the connector output 34 the selected harmonics in the band of frequencies selected for the frequency multiplier 10.

Referring more particularly to FIG. 2, there is illustrated a frequency tripler which is a specific embodiment of the general construction shown in FIG. 1. In the frequency tripler in FIG. 2, a low-pass filter 38 which may for input frequencies of 700 megacycles be of the commercially available type identified as model number LA-1ST, available from Microlab Corp., 570 W. Mt. Pleasant Avenue, Livingston, N. J.

The low-pass filter 38 may be coupled through a type BNC connector 40 to a type RG55/U coaxial transmission line 42 to a type N connector 44 into a varactor holder assembly 46 forming the subcombination invention, to be hereinafter further described in connection with FIG. 3. The coaxial line 42 has an electrical length 48 described above in connection with transmission line 24.

The varactor holder assembly 46 is coupled through an adapter which will be described in connection with FIG. 3 to a high-pass filter 49 which is coupled through a type BNC connector 50 to a type RG55/U coaxial transmission line 52 and a type TNC male connector 54 into a type TNC female and type N male adapter 56 into a type N right angle elbow 58 and into a low-pass filter 60 through a type N connector 62 into the output type N connector 64. The high and low pass filters 49 and 60 may be of the type identified as model F-40 and LTP respectively, available from RLC Electronics Inc., 805 Mamaroneck Ave., Mamaroneck, N. Y.

It should be understood that the references herein made to specific commercially available components are for illustration of an important feature of this invention which is that of its adaptability to construction with readily available elements. These references to specific commercially available components are not intended as a limitation since other suitable components may also be used.

Referring to FIG. 3 in more detail, the varactor holder assembly 46 is a bulkhead type receptacle having a jack body 66 with a female contact 68 running axially thereof as a center conductor and rigidly fixed in place by a fused glass bead 70. The center conductor 68 has integrally therewith at its other end a recessed varactor holder 72 carrying axial slots 74 which permit sufficient spring action in the varactor holder 72 to electrically and mechanically engage and hold in place a varactor 76 by one of its terminals in a fixed reference position. Concentrically about the varactor 76 is an electrically conductive sleeve 78 which forms the outer coaxial conductor at the varactor 76. The sleeve 78 is held rigidly in place between a shoulder 80 in a plug body 82 and a tapered end 84 of the jack body 66. A teflon alignment gasket 86 holds the sleeve 78 in place during disassembled condition of the varactor holder assembly 46 and provides sufficient resilience to properly compensate for tolerances at the tapered end surface 84 to insure proper assembly.

The plug body 82 has a dielectric alignment bushing 88 of such material as teflon which to facilitate assembly slidably retains a combined male contact 90 and a varactor holder 92 similar to the varactor holder 72 and in proper alignment therewith for engaging the other terminal of the varactor 76. A rubber seating bushing 94 is provided at the end of the plug body 82 for achieving a water tight seal when by means of the knurled nut 96 it is screwed onto the threaded end of a jack body 98 on the end of the high-pass filter 49, at which time provision for contact with an outer conductor 100 fixed to the end of jack body 82 provides coaxial line continuity in conventional manner of coaxial couplings.

In the assembly of the bulkhead receptacle or varactor holder assembly 46, the jack body 66 is screwed into the end of the plug body 82 until firm engagement is made with the internal sleeve 78 at the tapered surface 84. A nut 102 is then tightened against the plug body 82 to lock the assembly firmly in place.

The internal diameter of the sleeve 78 is proportioned with respect to the diameter of the varactor 74 and varactor holders 72 and 92 to retain impedance continuity with that of the adjoining coaxial transmission line.

This invention is not limited to the particular details of construction and operation herein described as equivalents will suggest themselves to those skilled in the art.

What is claimed is:

1. For a coaxial frequency multiplier with input frequency under 1,000 megacycles, the combination of a coaxial connector plug body and a coaxial connector jack body coupled together and having an axially aligned opening therethrough, a varactor in said opening and having a pair of terminals, a first center conductor in electrical engagement with one of said

terminals and in the form of a female center conductor extending from said terminal in axial alignment with said opening in the direction of said jack body, a second center conductor in electrical engagement with the other of said terminals and in the form of a male center conductor extending from said other terminal in axial alignment with said opening in the direction of said plug body, a dielectric member coupled to the inside of said jack body and to said female center conductor rigidly fixing said female center conductor in place as a reference for said varactor, a second dielectric member in said plug body mounting said male center conductor to slide in said axial alignment with said opening, a sleeve of electrically conductive material in said plug body forming the part of said axially aligned opening circumscribing said varactor and having a cross-sectional relation to the cross section of said varactor substantially the same as the cross-sectional relation of the remainder of said axially aligned opening to the cross section of said center conductors, and a bushing of resilient material about said sleeve in said plug body for holding said sleeve in said axial alignment in said plug body in the absence of said jack body.

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