X-BAND BALANCED FREQUENCY DOUBLER

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ABSTRACT OF THE DISCLOSURE

An X-band frequency doubler circuit of a balanced configuration employing dual varactors each having a separate variable bias source. The bias source varying the varactors impedance and maximizing the output power.

This invention relates generally to frequency multipliers and more particularly to frequency doublers capable of providing output signals of frequencies in the X-band range, i.e., approximately from 8 to 12.5 gigacycles.

Various devices are known in the prior art suitable for providing an output signal of frequency 2ω in response to an input signal of frequency ω. However, many of these devices are not capable of satisfactorily operating at frequencies as high as the X-band range. Moreover, those devices which are capable of operating at these frequencies are not usually capable of providing signal outputs as high as 1 watt at reasonable levels of efficiency.

In view of the foregoing, it is an object of the present invention to provide an improved frequency doubler capable of efficiently operating at X-band frequencies to provide a signal power output on the order of 1 watt or more.

In accordance with a preferred embodiment of the invention, a doubler structure is provided having a resonant input section which is coupled to an output waveguide by a balanced pair of variable nonlinear reactance elements, preferably varactors. The input section is formed by a coaxial line comprised of a central conductor supported within a hollow conductor or resonant cavity. A variable capacitor is provided in the central conductor to enable the input section to be tuned. In order to maximize efficiency, input energy is coupled into the coaxial line at a low impedance point. The energy in the coaxial line is coupled to the varactors through variable capacitances. Inasmuch as the varactors comprise nonlinear impedances, they generate harmonics of the input signal frequency. The waveguide is dimensioned to prefer the second harmonic of the input frequency.

In order to assure maximum efficiency, the varactors are matched to the waveguide by a sliding waveguide short. In addition, means are provided for applying a variable bias signal to the varactors thus enable their impedance to be varied and the output power to be maximized.

It is pointed out that the use of a balanced multiple varactor frequency doubler provides significant advantages over single varactor doublers which have been employed in the prior art. More particularly, for the same power output, use of multiple varactors enables more efficient operation while for the same level of efficiency, use of multiple varactors provides greater output signal power.

The novel features that are considered characteristic of this invention are set forth with particularity in the appended claims. The invention will best be understood from the following description when read in connection with the accompanying drawings, in which:

FIGURE 1 is a side view of a preferred embodiment of the invention;
FIGURE 2 is a sectional view taken substantially along the plane 2—2 of FIGURE 1; and
FIGURE 3 is a diagram of an electrical circuit generally equivalent to that represented by the structure illustrated in FIGURES 1 and 2.

Attention is now called to FIGURES 1 and 2 of the drawings which illustrate the structure of a preferred X-band doubler in accordance with the present invention. More particularly, the doubler 10 illustrated in FIGURES 1 and 2 is comprised of a block 12 of electrically conductive material, e.g., aluminum. Although the overall dimensions of the block 12 are not critical, it is pointed out that a typical block can have a height on the order of 2.4 inches, a width on the order of 1.6 inches, and a depth on the order of .75 inch.

Prior to discussing the structural details of the preferred embodiment of the invention, its general mode of operation will be mentioned. The doubler 10 includes an input section which has a resonant means tuned to the frequency ω of an input signal applied thereto. Means are provided for coupling the input section signal energy to first and second nonlinear impedance devices for producing harmonics of the frequency ω. These harmonics are coupled to an output section comprising a waveguide which preferentially passes the second harmonic.

Now considering the structure of the preferred embodiment in greater detail, it is to be noted that a cylindrical aperture 14 is defined in the block 12 extending downwardly from the top surface 16 thereof. The aperture 14, which it will be seen comprises a resonant cavity, communicates with a rectangular opening 18 (comprising a rectangular waveguide) extending between the front and rear surfaces 20 and 22 of the structure 10. Supported within the aperture 14 adjacent the top surface 16 is a conductive bushing 24. The bushing 24 defines a central opening 26. Extending through the opening 26 is a conductive sleeve 28. Slidably disposed within the sleeve 28, and in electrical contact therewith is a conductive plunger 32. The plunger 32 is physically coupled to a knurled knob 34. The plunger 32 is externally threaded adjacent the upper surface 16 of the block 12. A lock nut 36 is provided adapted to be threadedly engaged with the plunger 32 for retaining it in position.

Electrically connected to the conductive sleeve 28 is the central conductor 38 of a coaxial connector 40 which extends through an opening 42 from the surface 44 of block 12. Preferably, the central conductor 38 terminates in a U-shaped contact adapted to bear against and electrically engage the conductive sleeve 28 proximate to the bushing 24. In addition to the foregoing, a second plunger 46 is provided, being disposed in an aperture 48 extending through the block 12 between the upper surface 16 thereof and the rectangular opening 18. A knurled knob 50 is secured to the upper end of the plunger 46 to enable it to be pushed through the aperture 48, for reasons to be explained more fully hereinafter. A lock nut 52 is provided adapted to cooperate with the threads on the plunger 46 for locking it in position.

A flat U-shaped conductor 54 is connected to the lower end of the plunger 32 at 56. The free end of the conductor 54 terminates in plate 58 opposed to plate 60 carried by plunger 46. Plates 58 and 60 function as a capacitor whose capacitance value is of course determined by the spacing between them. By moving the plungers 32 and 46 up and down together, the value of the capacitance defined between plates 58 and 60 will remain unchanged. However, by differentially moving the plungers, the value of the capacitance can be varied.

The elements thus far described generally can be considered as comprising the doubler input section with aperture 14 defining a resonant cavity or outer conductor of a coaxial line, with plungers 32 comprising the central conductor. Input energy of frequency ω is coupled
through the coaxial connector 40 to the conductive sleeve 28. Inasmuch as the conductive bushing 24 acts to short the resonant cavity 14, a position on the conductive sleeve adjacent to the bushing 24 will comprise a low impedance point thereby enabling an efficient energy transfer from the connector 40 to the input section. By moving the plungers 32 and 46 to adjust the capacitance between the plates 58 and 60, the input section can be tuned to the input frequency.

As previously pointed out, the input signal frequency is coupled to the waveguide 18 through harmonic generating nonlinear impedances. In the preferred embodiment of the invention, first and second varactors 62 and 64 are used as nonlinear impedances. The first terminal 66 of each varactor is effectively grounded by being electrically connected to the conductive block 12. The second terminal of each varactor is positioned proximate to the U-shaped conductor 54. As a consequence, energy at the input signal frequency will be capacitively coupled from the conductor 54 to the first terminals of the varactors 62 and 64 through gaps 68 and 70. The capacitance value of gaps 68 and 70 of course depends upon the dimensions of the gap which can be varied by movement of the plungers 32 and 46. Thus, differential movement of the plungers 32 and 46 enables the capacitance between the plates 58 and 60 to be varied to thus enable the input section to be tuned. Coincidental movement of the plungers 32 and 46 on the other hand affects the capacitance between the input section and the varactors 62 and 64. The varactors comprise variable nonlinear reactances which respond to the signal or frequency coupled thereto to provide harmonics thereof. These harmonics are coupled into the output waveguide 18 which preferably is dimensioned to preferentially pass the second harmonic.

In order to enable the waveguide to be matched to the varactors 62 and 64, a waveguide extension 80 is provided. Mounted for slidable movement in the extension 80 is a shorting bar 82 having fingers 84 extending therefrom and bearing against the inner wall of the waveguide extension. A shank 86 is fixed to the shorting bar 82 and terminates in a knurled knob 88 which permits the shorting bar 82 to be manually moved in the waveguide extension 80. In this manner, the waveguide can be matched to the varactors to thereby assure an efficient coupling of energy theretoc.

In order to maximize the power output of the frequency doubler of FIGURES 1 and 2, it is advantageous to be able to apply a selected bias potential to the varactors to thereby establish a preferred impedance level. In order to apply such a bias potential, first and second conductive channel members 90 and 92 are provided in the waveguide 18 bearing outwardly against the walls thereof. The outer surface of each of the channel members 90 and 92 is coated with an insulating layer 94, such as Mylar, which electrically insulates the channel members from the block 12. The upper terminals of the varactors 62 and 64 are however electrically connected to the members 90 and 92. Coaxial conductors 96 and 98 are mounted within the block 12. The central conductors 100 and 102 thereof are insulated from the block 12 by insulation 104 but are connected to the channel members 90 and 92 by removing the insulation layer 94 adjacent thereto. In order to better form the electrical connection between the central conductors 100 and 102 and the channel members 90 and 92, filamentary electrically conductive means, similar to steel wool for example, can be provided between the central conductors and the channel members.

FIGURE 3 is a circuit diagram representing the circuit equivalent of the apparatus of FIGURES 1 and 2. In the circuit of FIGURE 3, the numeral 40' is used to represent the input connection to the conductive sleeve represented by the numeral 28' in FIGURE 3. It is to be noted that the input connection 40' is made at a low impedance point proximate to the shorted end of the resonant cavity represented by the numeral 24'. The input section is tuned by a capacitor 59' which is analogous to the capacitance defined between the plates 58 and 60. Variable capacitors 68' and 70', analogous to gaps 68 and 70 in FIGURE 2, couple the input section energy to varactors 62' and 64' which are respectively biased by input terminals 100' and 102'. The output of the varactors can be considered as being coupled to the waveguide 18 through a capacitance 106'.

From the foregoing, it should be appreciated that a frequency doubler structure has been shown herein which is relatively compact and simple in construction and therefore relatively inexpensive and highly reliable. Moreover, the frequency doubler structure illustrated is capable of operating to provide output signals of frequencies in the X-band range at relatively high power outputs, e.g., greater than 1 watt, and at relatively high efficiencies.

I claim:
1. A frequency doubler suitable for providing high power output signals at X-band frequencies, said doubler comprising:
a block of conductive material;
a first opening defining a waveguide extending through said block;
an aperture extending into said block and terminating in said opening;
a conductor centrally disposed in said aperture;
means for coupling signal energy to said central conductor;
variable reactance means responsive to signal energy coupled to said central conductor for coupling harmonics thereof to said first opening;
a first capacitor plate secured to the end of said centrally disposed conductor proximate to said first opening;
a second capacitor plate electrically connected to said block; and
means mounting said centrally disposed conductor for slidable movement parallel to said aperture whereby the spacing between said first and second capacitor plates can be varied.
2. The doubler of claim 1 wherein said variable reactance means includes first and second varactors each having first and second terminals;
means disposing said varactor first terminals proximate to said end of said conductor proximate to said opening; and
means electrically connecting said varactor second terminals to said block.
3. The doubler of claim 2 including means for biasing said varactors.
4. The doubler of claim 1 including a waveguide extension coupled to said opening; and
a shortening bar selectively positionable in said extension.

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