170 GHz Passive Tripler Based on Schottky Barrier Diodes

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September 23, 2021

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Abstract- **In this paper, a 170GHz frequency tripler is designed by using the collaborative simulation method of "field" and "circuit". The frequency multiplier adopts reverse-paralleled diode-pair structure to realize frequency tripling without bias. When the input driving power of the designed 170GHz tripler is about 100mW, the efficiency can reach 9%.**

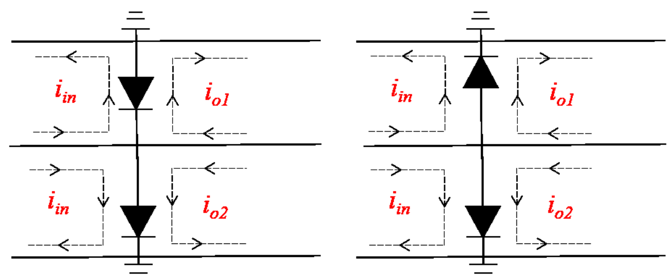
Keywords—Terahertz, frequency multiplier, passive tripler.

I. Introduction

Terahertz wave refers to electromagnetic waves with a frequency of 0.1 to 10 THz, and the spectrum is between millimeter and infrared light [1]. Terahertz technology is an important extension of electronics and photonics research because it has both advantages of microwave and light waves and has unique characteristics [1-3]. Terahertz wave has shorter wavelength and higher frequency band compared to microwave and millimeter wave. In addition, terahertz wave has a strong transmission characteristic and low photon energy compared with light waves. These unique advantages of terahertz waves include radio astronomy [4], terahertz communications [5], atmospheric and environmental monitoring [6], radar imaging [7], and a wide range of applications widely used in homeland security, counterterrorism operations [8] and medical diagnosis [9-10]. By the continuing progress of terahertz semiconductor devices, radiation sources, detectors and systems during the past 20 to 30 years, terahertz technology has become a very active frontier field that has an important impact on science and technology and has great application value for national economy and national security.

Frequency multiplier refers to the functional circuit to do integer multiples of frequency from input to output. It is mainly used in the transceiver circuit, and it is also an essential part in communication, radar and other systems. In general, the frequency multiplier is a passive device operating on the basis of nonlinear effects. In the terahertz long wave band (100GHz-300GHz), the fundamental frequency power is easier to obtain, so the terahertz source is mostly realized in the form of doublers and triplers. At the very beginning, due to the limitation of processing technology and assembly technique, such circuits are mostly designed by using single diodes. However, with the development of semiconductor industry, more and more circuit topology are applied [11-12].

This work is supported by the National Natural Science Foundation of China under Grant No. 61771116, No. 62022022, and the National Key R&D Program of China under Grant No.2018YFB1801502. This work is also supported by China Postdoctoral Science Foundation under Grant No. 2021TQ0057.



(a) reverse-paralleled topology (b) inverse-paralleled topology

Figure 1 schematics of frequency tripler

Figure 1 showed two different topology of frequency triplers, both of them are un-balanced circuit. However due to the reason that the two topology have different arrangement of diodes, the properties of the output harmonics are different. Suppose that the two diodes have the same transmission function, the output current of reverse-paralleled circuit can be expressed as

$$i_{out} = i_{o1} + i_{o2} = f(v_{in}) + \left[-f(-v_{in})\right] = 2(a_1 v_{in} + a_3 v_{in}{}^3 + \cdots$$

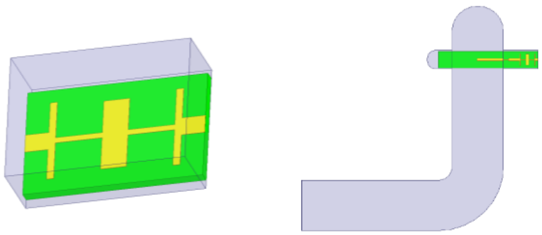
It can be seen that in the output circuit, even harmonics cancel each other, but the second circuit cannot achieve this function. However, there are a lot of reports on the design of the two circuits at home and abroad. This is because the first circuit can suppress even harmonics, but the RF ground and DC ground are separated, so it needs DC isolation and signal isolation respectively, and the circuit form is complex, It is very demanding in terahertz band. In this paper, the DC bias is removed to reduce the processing and packaging requirements of the frequency tripler, which greatly reduces the complexity of the frequency tripler circuit.

II. Design and Analysis

A. Scheme of Miniaturized integrated Front End

The input duplexer consists of a waveguide-microstrip transition structure and a low-pass filter, as shown in Fig. 2 (a). The input waveguide is a standard WR-15 waveguide, and the filter is shown in Fig. 2 (b).The simulation result is shown in Figure 3.

It can be concluded from the simulation results that the signal can be transferred from the probe structure to the microstrip structure well in the pass band range.



（a） （b）

Figure 2 input duplexer

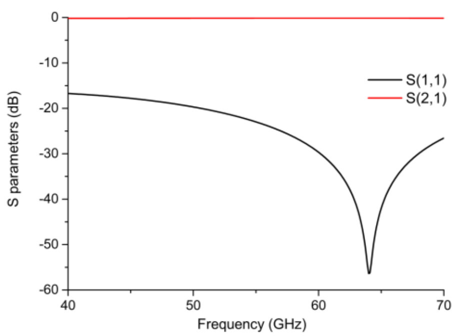
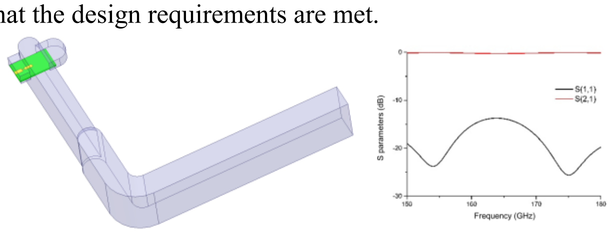


Figure 3 filter simulation result

The output probe transition is the microstrip to output waveguide transition, which is used to convert the third harmonic signal from the microstrip quasi-TEM mode to the waveguide TE10 mode. The output is through the WR-5 standard waveguide. The structure and simulation result are shown in Figure 4. It can be seen from the simulation results that the design requirements are met.



（a） （b）

Figure 4 Output probe structure and simulation results

S parameters of each passive circuit are simulated in HFSS and then exported, packaged as SNP packets, combined with the model of diode-pair. The simulation used harmonic balance method in ADS, as shown in Fig. 5. By optimizing the input and output matching circuit size and input power of the diode pair, the desired efficiency and output power can be obtained. In order to reduce the number of SNP packets and improve the accuracy of simulation, the waveguide-microstrip transition structure and the fundamental low-pass filter are packaged into one SNP file. The simulation results are shown in Figure 5, and the final circuit structure of tripler is shown in Figure 6 [5].

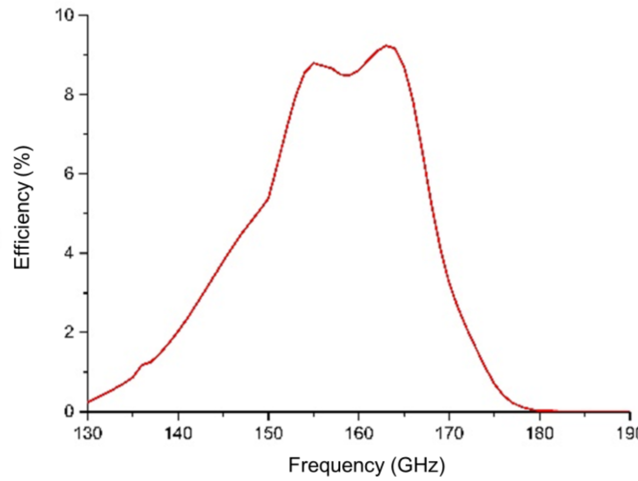


Figure 5 Simulated efficiency of the tripler

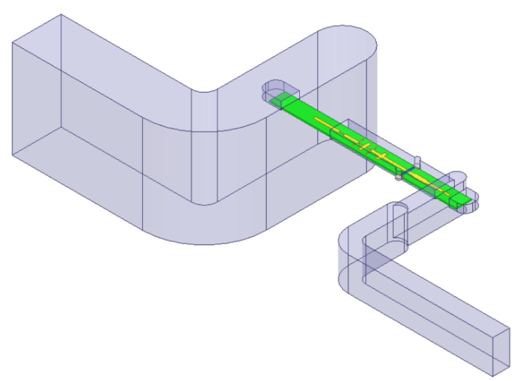


Figure. 6 Structure of passive tripler

III. Conclusion

In this paper, a 170GHz tripler is designed by using the collaborative simulation method of "field" and "circuit". The tripler adopts the reverse parallel diode pair structure, which can work without bias. When the driving power is about 100mW, the designed 170GHz tripler can achieve the power output efficiency of more than 9%. In the future work, further simulation on matching circuit will be carried out, in order to achieve higher output efficiency.

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