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A 285 GHz Tripler Using Planar Schottky Diode

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Abstract

In this paper, we present the design of a 285 GHz tripler realized by planar Schottky diode. The complete multiplying circuit and diodes is mounted on 50 um thick quartz substrate. The measured result shows that output power is achieved above 3.1 dBm in the range from 280 GHz to 290 GHz with a constantly 20 dBm driven power across the band. The peak power is 4 dBm in 285.6 GHz.

Keywords

Tripler, Schottky Diode, Terahertz Wave

1. Introduction

Terahertz waves are electromagnetic radiation (from 0.1 THz to 10 THz) spanning the gap between light and radio waves which is perhaps the least utilized electromagnetic band. Due to its special position in the electromagnetic spectrum, terahertz is widely used in all kinds of fields [1]. THz sources that are the most important portion of the THz system have attracted a great deal of attention in recent years. In many ways of generating THz waves, frequency multiplication of fundamental microwave sources has turned into the most popular method because of its high output power and efficiency. Sources based on frequency multiplication offer many odds for generating terahertz radiation. The fundamental microwave oscillators are a mature technology offering high output power and efficiency, low noise, electronic tuning and compact design [2]. Lots of researchers and institutes have focused and reported the methods of using solid-state circuit to construct THz sources.

Frequency multipliers at high millimeter wave and THz frequencies are generally based on Schottky varactor diodes [3] [4] [5], heterostructure barrier varactor diodes (HBVs) [6] [7], or Schottky varistor (mixer) diodes [8] [9] [10]. Schottky diodes can be used in all kinds of multipliers and have been developed over a wide frequency band spanning from the microwave range into a few THz. In this paper, hybrid integrated circuit is designed with planar Schottky diodes. All passive networks are analyzed and designed by HFSS simulators. The non-linear behavior of the Schottky diodes and optimization of the whole circuit is simulated by Agilent's ADS, which has function of harmonic balance analysis.

2. Circuit Design

A sketch and schematic diagram of the 285 GHz tripler circuit are shown below in **Figure 1**. The tripler comprises a metal waveguide housing split in the

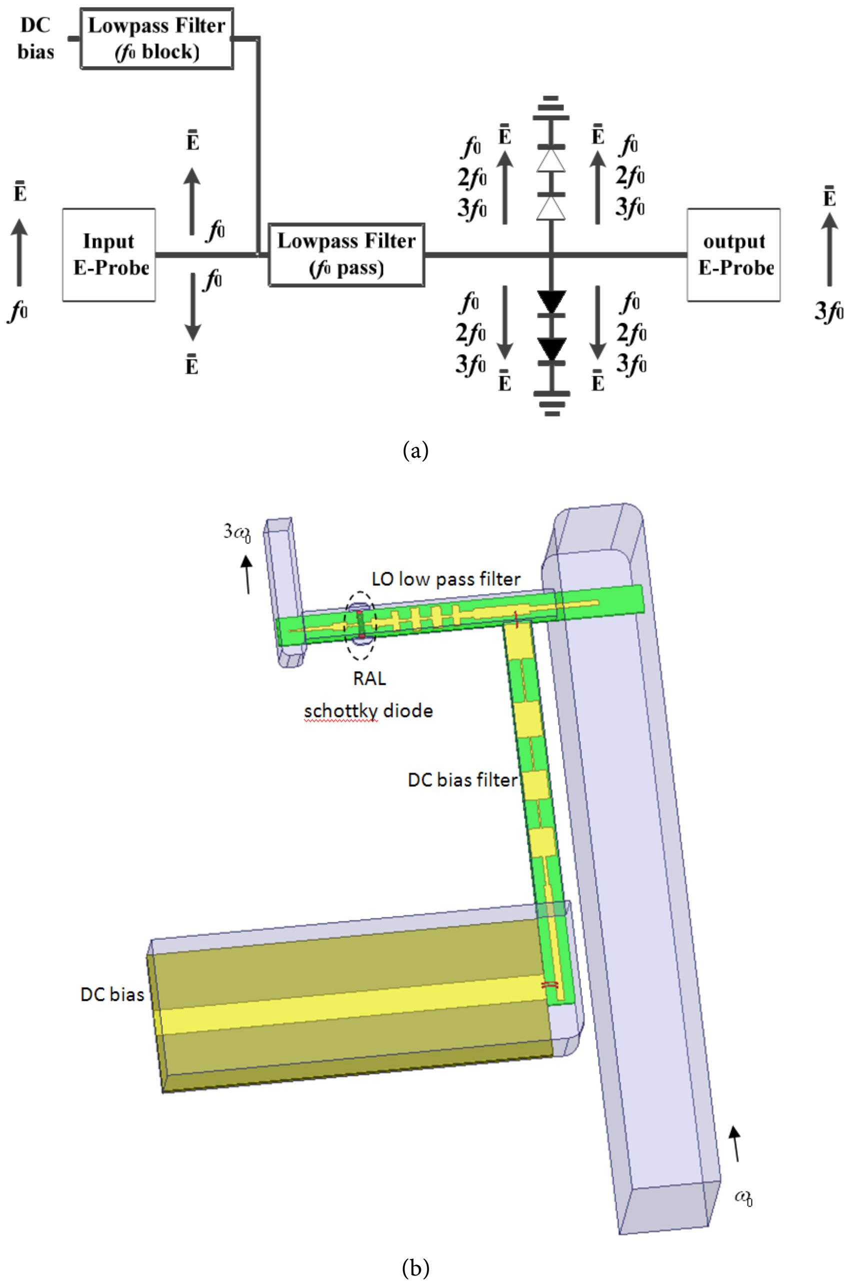

Figure 1. Sketch and schematic of the 285 GHz frequency tripler.

E-plane, a pair of quartz microstrip circuits, a RAL GaAs Schottky diode chip and a pair of bond-wires used in the DC bias network. The didoe is a planar flip-chip type with four anodes arranged in anti-series. The chip has a center pad that is soldered to the microstrip line on the quartz circuit and two outer pads that are soldered directly to the waveguide block. This is not a balanced arrangement, but rather the diodes are situated in parallel across an unbalanced microstrip line.

The fundamental excitation ω_0 transitions from the WR10 rectangular waveguide to the microstrip circuit via an E-plane probe. The signal propagates through the LO low-pass filter to the varactor diodes. Propagation in the side-channel is blocked by a lowpass DC bias filter. The output waveguide is cut-off at ω_0, and acts as a first harmonic backshort.

In **Figure 2**, the diode chips are discrete flip-chips that are soldered to the block and quartz embedding circuit. However, the diode could easily be integrated with the embedding circuit if desired with little change to the embedding circuitry [6]. Assembly is relatively simple. First, the circuits are aligned and glued into the block. The diode chip is then soldered to the block by heating the entire assembly. The varactor chip is aligned to small markers fabricated on the circuit. A pair of 1-mil wires are then bonded to the DC bias circuitry as illustrated in **Figure 1**.

3. Simulation and Measurement

The 3-D model of 285 GHz tripler as shown in **Figure 1**, are analyzed by HFSS simulators.

At first, the input waveguide section is simulated by using HFSS, as shown in **Figure 3**.

The simulation results are shown in **Figure 4**. The insert loss is lower than 0.1 dB, and the return loss is larger than 30 dB, which has better propagation characteristic. And the isolation of LO-DC is larger than 50 dB, and the fundamental excitation can be blocked to through with the DC channel.

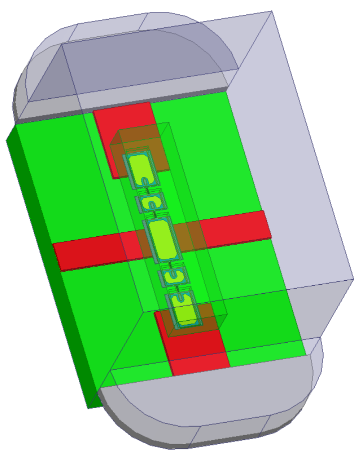

Figure 2. Configuration of the diode assembly.

The output waveguide section is simulated by using HFSS, as shown in **Figure 5**, and the simulation result is shown in **Figure 6**.

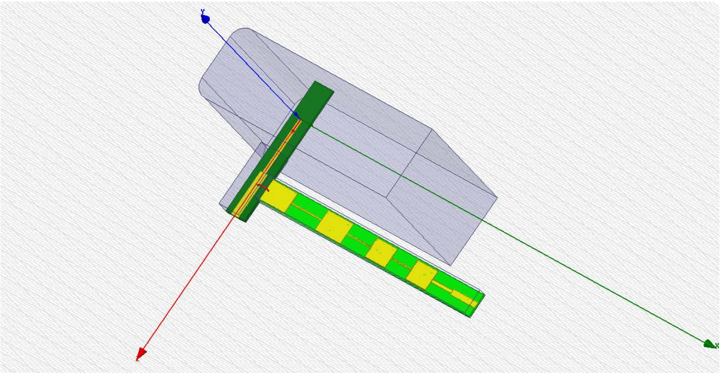

Figure 3. The input waveguide of 285 GHz tripler.

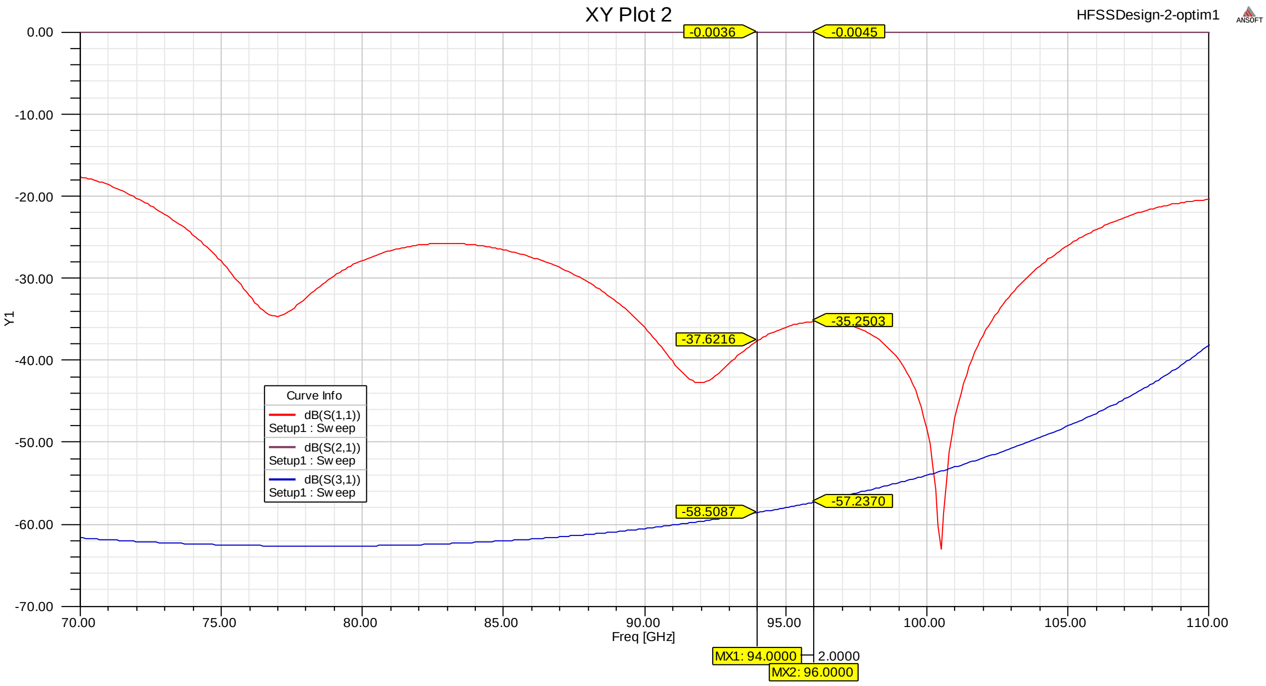

Figure 4. Simulation results of the input waveguide of 285 GHz tripler.

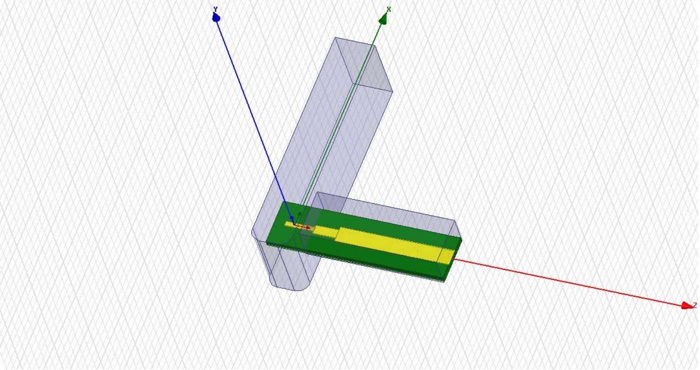

Figure 5. The output waveguide of 285 GHz tripler.

As shown in **Figure 6**, the insert loss is lower than 0.1 dB, and the return loss is larger than 30 dB, which has better propagation characteristic.

The ADS model is shown in **Figure 7**, including the input configuration,

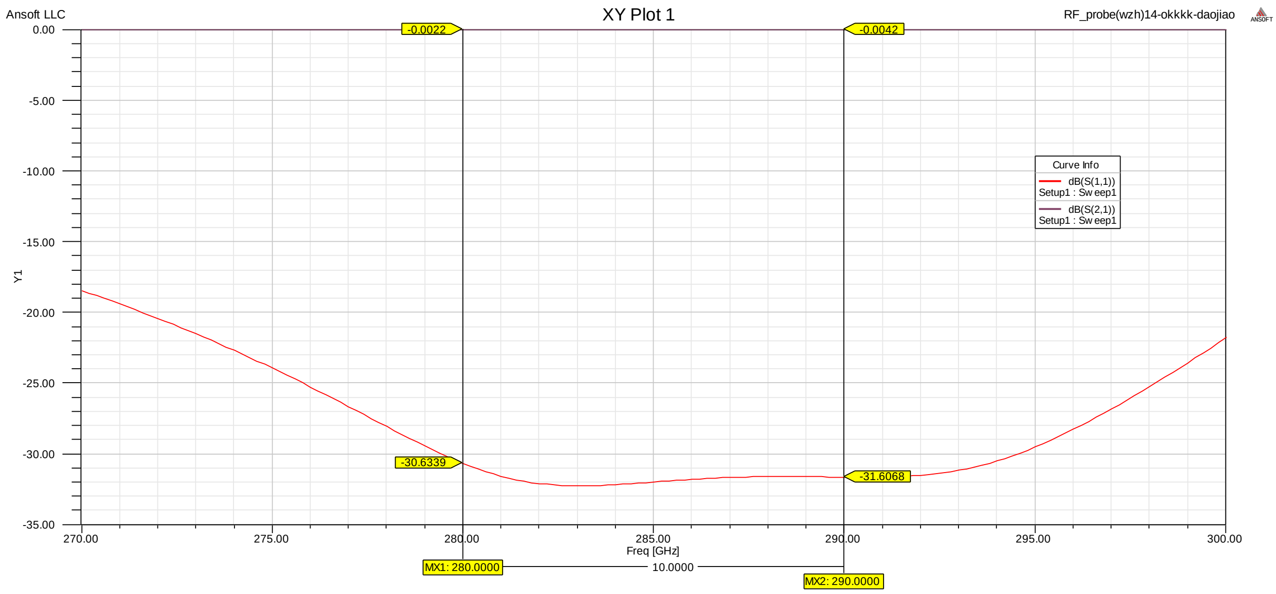

Figure 6. Simulation results of the output waveguide of 285 GHz tripler.

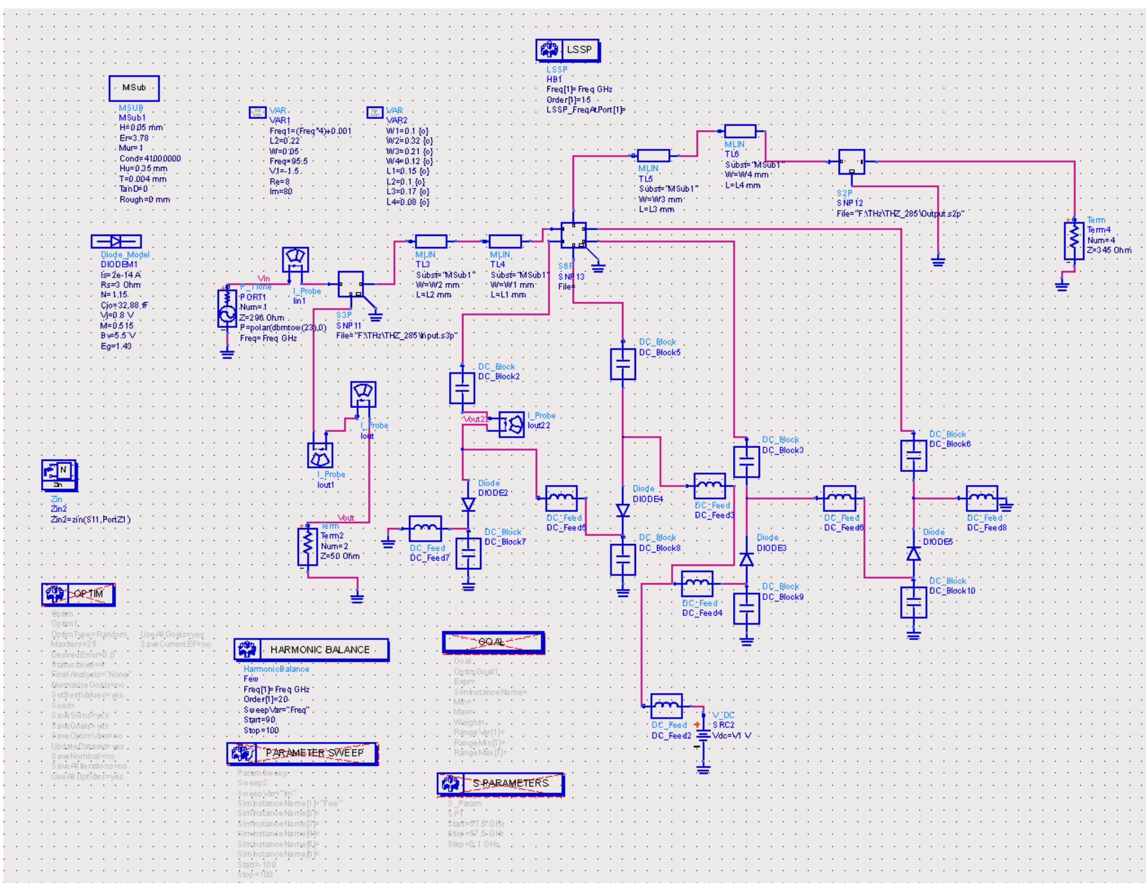

Figure 7. The ADS simulation model of 285 GHz tripler.

output section and the nonlinear diode section. The output power of tripler will be calculated by using the ADS, when the SNP file is obtained by using HFSS and put the SNP file in ADS. The varactor diode was terminated at each harmonic using the impedances determined in the linear microwave simulations. Voltage bias was optimized at each frequency to achieve the highest output power and efficiency.

Simulated output power for the 285 GHz frequency tripler using 20 dBm excitation is shown in **Figure 8**. The third harmonic wave output power is larger than 4 dBm at the 92 - 96 GHz.

By using the terahertz power meter AV2436A, the output power of 285 GHz tripler is obtained. **Figure 9** and **Figure 10** show the assembled tripler and test result. The measured result shows that output power is achieved above 3.1 dBm in the range from 280 GHz to 290 GHz with a constantly 20 dBm driven power across the band. The peak power is 4 dBm in 285.6 GHz.

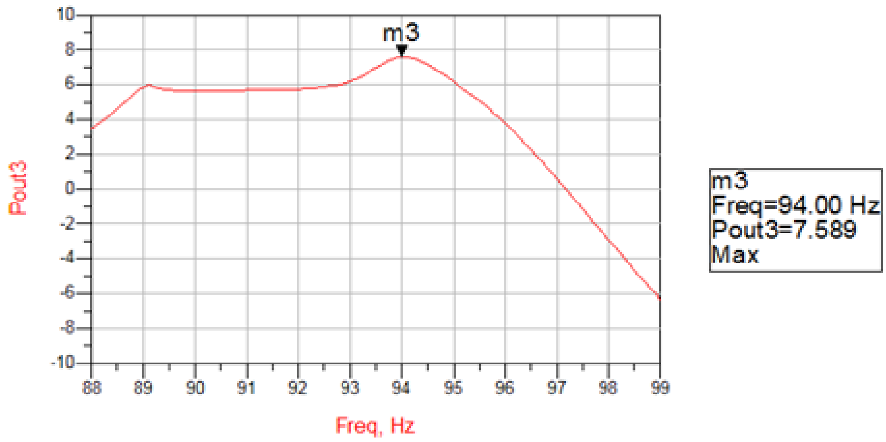

Figure 8. The simulation results of 285 GHz tripler.

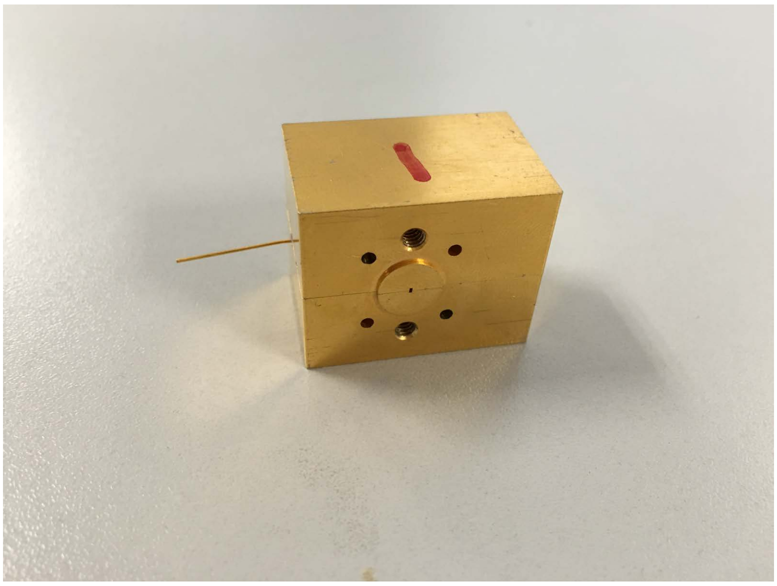

Figure 9. The assembled 285 GHz tripler.

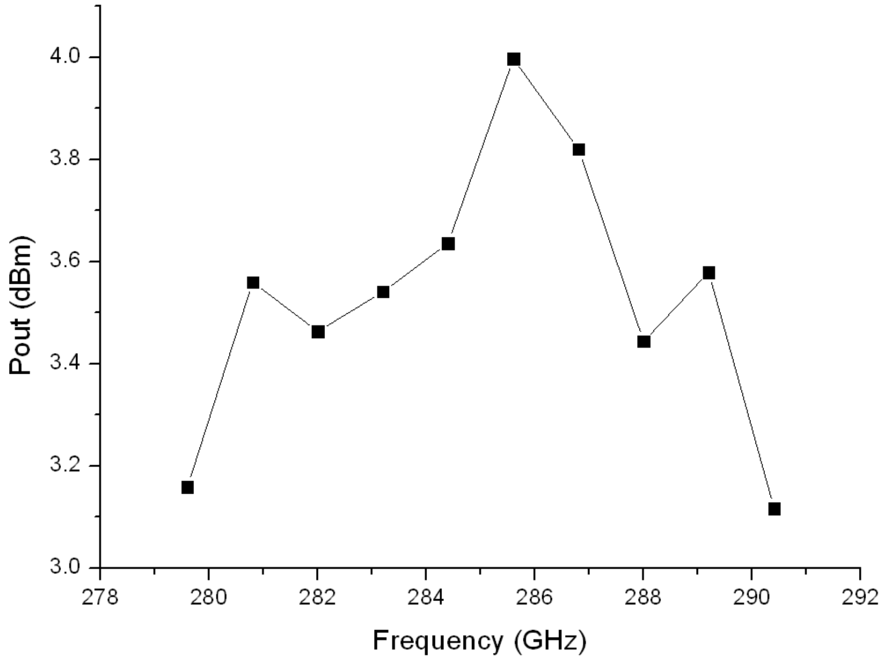

Figure 10. The test result of the 285 GHz tripler.

4. Conclusion

This paper represents the design of a 285 GHz tripler. The simulation result shows that an output power is achieved above 3.1 dBm in the range from 280 GHz to 290 GHz with a constantly 20 dBm driven power across the band. The peak power is 4 dBm in 285.6 GHz.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

References

[1] Crowe, T., Bishop, W., Porterfield, D., Hesler, I. and Weikle, R. (2005) Opening the Terahertz Window with Integrated Diode Circuits. *IEEE 1rnl. of Solid State Circuits*, **40**, 2104-2110. https://doi.org/10.1109/JSSC.2005.854599

[2] Porterfield, W. (2007) High-Efficiency Terahertz Frequency Triplers. *IEEE MTT-S International Microwave Symposium*, Honolulu, Hawaii, 337-340. https://doi.org/10.1109/MWSYM.2007.380439

[3] Erickson, N. (1990) High Efficiency Submillimeter Frequency Multipliers. IEEE/MTT-S Int. Microwave Symp. Dig., 1301-1304.

[4] Saini, K.S. (2003) Development of Frequency Multiplier Technology for ALMA. ALMA Memo 337.

[5] Porterfield, D.W., Crowe, T.W., Bradley, R.F. and Erickson, N.R. (1999) A High-Power, Fixed-Tuned, Millimeter-Wave Balanced Frequency Doubler. *IEEE Trans. Microw. Theory Tech.*, **47**, 419-425. https://doi.org/10.1109/22.754875

[6] Emadi, T.A., Vukusic, J., Ingvarson, M., Olsen, A., Bryllert, T., Kollberg, E. and

Stake, J. (2008) High Power HBV Multiplier for F- and G-Band Applications. *29th International Conference on Infrared, Millimeter and THz Waves*, 319-320.

[7] Vukusic, J., Bryllert, T., Arezoo, T., Sadeghi, M. and Stake, J. (2007) A 0.2-W Heterostructure Barrier Varactor Frequency Tripler at 113 GHz. *IEEE Electron Dev. Lett.*, **28**, 340-342. https://doi.org/10.1109/LED.2007.895376

[8] Morgan, M. and Weinreb, S. (2001) A Full Waveguide Band MMIC Tripler for 75 - 110 GHz. *IEEE MTT-S Int. Microw. Symp.* Dig., 103-106.

[9] Thomas, B., Treuttel, J., Alderman, B., Matheson, D. and Närhi, T. (2008) Application of Substrate Transfer to a 190 GHz Frequency Doubler and 380 GHz Sub-Harmomic Mixer Using MMIC Foundry Schottky Diodes. *Proc. SPIE.*, 70202E-1-70202E-9. https://doi.org/10.1117/12.789083

[10] Siles, J.V., Maestrini, A., Alderman, B., Davies, S., Wang, H., Treuttel, J., Leclerc, E., Närhi, T. and Goldstein, C. (2011) A Single-Waveguide In-Phase Power-Combined Frequency Doubler at 190 GHz. *IEEE Microwave and Wireless Components Letters*, **21**, 332-334. https://doi.org/10.1109/LMWC.2011.2134080