HETEROSTRUCTURE BARRIER VARACTOR FREQUENCY TRIPLERS AND QUINTUPLERS FOR THz ELECTRONICS

Arne Øistein Olsen, Mattias Ingvarson, Erik Kollberg, and Jan Stake

**Microwave Electronics Laboratory, Department of Microtechnology and Nanoscience,
Chalmers University of Technology, SE-412 96 Göteborg, Sweden**
oistein@ieee.org

SUMMARY

A fixed tuned tripler and a quintupler using the Heterostructure Barrier Varactor (HBV) diode are presented. The tripler utilise a novel arrangement of antipodal finline, for waveguide to microstrip transition, and microstrip elements for the diode matching. An output power of -0.8 dBm at 128 GHz was measured for the tripler, which is close to the simulated performance. For the quintupler, an output power of 5.6 dBm at 98 GHz is predicted when ideal circuit elements are used.

INTRODUCTION

Harmonic sources in the form of multipliers are commonly used as power sources at sub-millimetre wavelengths, due to the lack of fundamental solid-state sources in this frequency region. Schottky diodes are usually used in frequency multipliers, but competitive results have been produced with the introduction of the Heterostructure Barrier Varactor (HBV) diode [1]. The HBV operates unbiased, exhibits a symmetric C-V characteristic and an asymmetric I-V characteristic. Only odd harmonics are produced contrary to the Schottky diode, and several epitaxial layers can be stacked to improve the power handling capability. These features make the HBV well suited for the realisation of higher order multipliers such as triplers ($\times 3$) and quintuplers ($\times 5$) [2–4].

Several advantages can be accomplished by using a planar circuitry, which is inserted in the E-plane of a waveguide for connection to existing equipment. The circuit fabrication can be carried out using simple photolithographic techniques, and the waveguide dimensions can be relaxed since the power is confined in the planar circuit. Although these circuits exhibit a higher loss compared to waveguide circuits, fixed tuned multipliers are easier to design using conventional matching elements. Furthermore, various technologies can be integrated on the same chip, thereby providing completely integrated systems.

TRIPLER CIRCUIT

The HBV tripler circuit consists of a back-to-back configuration of a waveguide to microstrip section, where the diode and the impedance matching section are located between the transitions. The circuit is shown in Fig. 1, and it is fabricated on a 100 μm thick quartz substrate ($\varepsilon_r = 3.78$) plated with gold.
The input and the output waveguide to microstrip transitions consist of an antipodal finline taper, where the gap is tapered down to the required microstrip width, and a mode transducer in the form of a semi-circle. The finline taper can be designed by using optimisation [5], or by using synthesis [6]. It typically exhibits a high-pass filter characteristic with a low insertion loss and reflection coefficient across the whole waveguide frequency band. A semi-circle completes the transition and its position and size is set to prevented unwanted resonance peaks in the required frequency band [7]. The HBV diode is flip-chip mounted using solder in the microstrip section, where conventional matching elements are used to

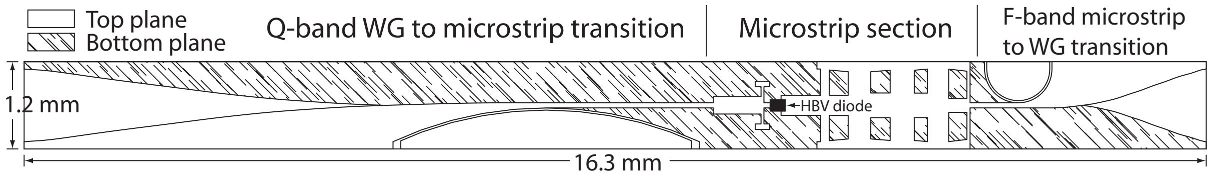


Figure 1: Tripler circuit with waveguide to microstrip transitions and RF matching section.

provide the required embedding impedances. Shunt connected hammer-head stubs and a band-pass filter are used to provide the RF ground, since the diode is mounted in a series configuration. The band-pass filter is also an impedance transformer and together with a quarter-wave transformer and short inductive lines, the impedances for the third harmonic and the fundamental frequency are provided. A custom made waveguide block with a WR-8 (F-band) output waveguide and a WR-22 (Q-band) input waveguide is used. Fig. 2 shows the circuit located in the E-plane of the block, where the height of the input Q-band waveguide is reduced to prevent excessively large mounting grooves.

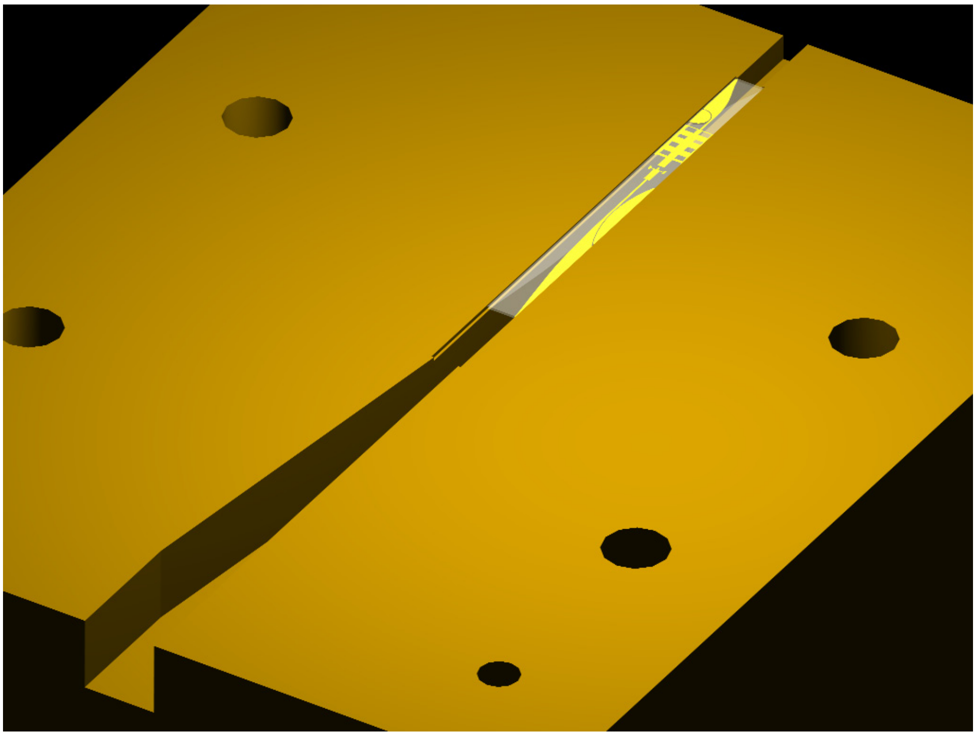
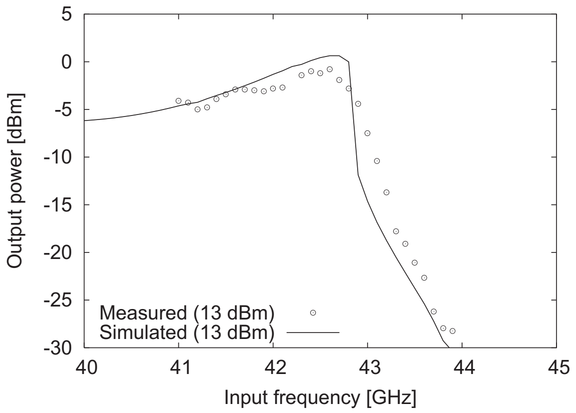
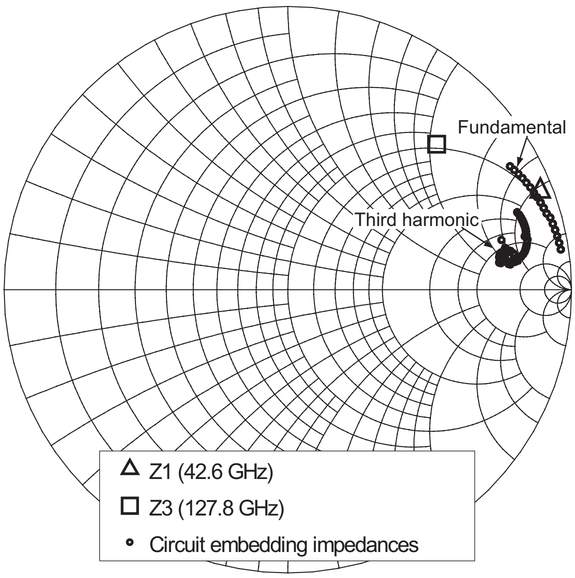


Figure 2: HBV tripler circuit inserted into the E-plane of the waveguide block.

The circuit was simulated using the Ansoft High Frequency Structure Simulator, where the diode was represented by a port, resulting in a 3-port S-parameter matrix. This matrix was then imported to Microwave Office, where Harmonic Balance was used to evaluate the circuit and the diode together. The measurement was carried out using a klystron and an Anritsu power meter, and both simulated and measured results are shown in Fig. 3(a).
The simulation and the measurement show a good agreement, where a measured peak-to-peak efficiency of 4.2% at 128 GHz was obtained with an input power of 13 dBm. Fig. 3(b) shows the required optimum impedances together with the circuit embedding impedances. It can be seen that the optimum impedances are not provided by the circuit, since in this case the circuit was not designed for the particular diode used. Hence the efficiency can be improved greatly by redesigning the circuit for this particular HBV diode.



(a)

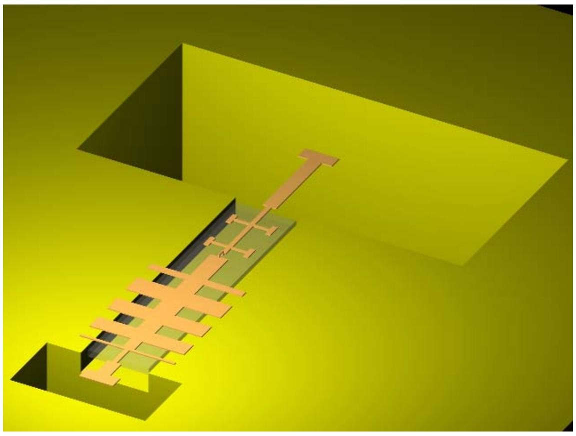


(b)

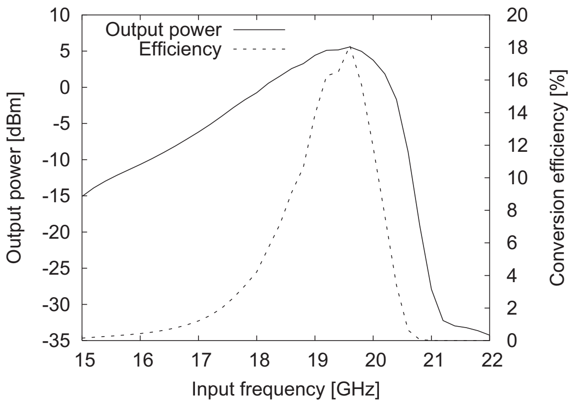
Figure 3: (a) Measured and simulated output power versus input frequency for an input power level of 13 dBm. (b) The optimum impedances along with the circuit embedding impedances.

QUINTUPLER CIRCUIT

Research on HBV quintupler circuits has been limited, and so far only one practical HBV quintupler has been presented [8]. Several quintupler designs are under investigation at Chalmers, with the purpose to find a suitable topology for integration and frequencies above 500 GHz. A potential quintupler is shown in Fig. 4(a).



(a)



(b)

Figure 4: (a) A possible realisation of a quintupler circuit inserted in the waveguide mount. (b) Simulated output power versus input frequency for the ideal quintupler with an input power level of 13 dBm.

The quintupler is similar to the tripler with respect to the matching network, but uses conventional microstrip probes at the input and output. Furthermore, a matching network for the idler (third harmonic) circuit must also be included. This design is suitable for a monolithical integration of the HBV diode, and it uses beam-leads for elimination of a large portion of the substrate. A frequency scaled model is currently under investigation, and the simulated frequency response using ideal elements is shown in Fig. 4(b). A conversion efficiency of 18% at 19.6 GHz input frequency is obtained with an input power of 13 dBm.

CONCLUSION

A tripler design using a microstrip section sandwiched between two finline waveguide to microstrip transitions has been presented. A conversion efficiency of 4.2% at 42.6 GHz input frequency with an input power of 13 dBm was measured, but an efficiency above 20% and hence an output power around 4 mW should be possible with a properly designed circuit. Furthermore, a potential quintupler circuit based on the tripler was presented. Preliminary simulations of a 100 GHz quintupler predict a maximum conversion efficiency of 18% at 19.6 GHz input frequency and with 13 dBm input power. Both the tripler and the quintupler is highly suitable for monolithical integration.

ACKNOWLEDGEMENT

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