High Gain PHEMT Frequency Doubler for 76 GHz Automotive Radar

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***Abstract* — A one-stage 38.25/76.5 GHz frequency doubler has been developed with a maximum conversion gain of 1 dB. The doubler achieves a saturated output power of 9 dBm for 12 dBm input power. Two complex transmit MMICs consisting of a 38 GHz amplifier, the frequency doubler and 76 GHz amplifiers with increased output power of 14 dBm and 10 dB conversion gain have been developed for automotive applications.**

I. INTRODUCTION

Frequency doublers for a fundamental input frequency of 38.25 GHz are key components of complex transmit MMICs which are used in several chip sets for 76.5 GHz automotive radar applications [1, 2]. Frequency doublers make it feasable to generate the VCO signal at lower frequencies which permits the use of standard components for low phase noise signal generation. Only a few 76 GHz fundamental VCOs are published today [3, 4] which have the potential for a significant reduction of the necessary area and cost of an automotive radar MMIC chipset.

Passive frequency doublers have the advantage of a less complex fabrication technology and high output power capability [5] but they suffer from a relatively high conversion loss. Active frequency doublers at 76 GHz are fabricated using sophisticated PHEMT process technologies. They have the advantage of lower conversion loss and can in principle achieve conversion gain. A published coplanar PHEMT frequency doubler [6] demonstrated a state of the art output power of 10 dBm at 76 GHz for 16 dBm input power and a maximum conversion gain of –4 dB. The developed frequency doubler shown in Fig. 1 achieves a maximum conversion gain of +1dB and a saturated output power of 9 dBm for 12 dBm input power. This is to our knowledge the highest published conversion gain of comparable single HEMT 38/76 GHz frequency doublers. This circuit is a key component of a complex transmit MMIC for automotive radar which is described in the content. The 38 GHz input signal of the transmit MMIC is multiplied by two and split into one antenna output and a second output for the LO driver of a downconverter mixer.

II. FREQUENCY DOUBLER

The high gain frequency doubler is fabricated using the Infineon Technologies HEMT110 process technology. The delta doped double heterojunction pseudomorphic AlGaAs/InGaAs HEMTs are fabricated on 4" GaAs wafers in a 6“ wafer production line. The short gate length of 0.12 µm is achieved by optical stepper lithography using phase shift masks and a sidewall spacer process. Typical dc and rf process data are a f_T of 110 GHz (V_{DS}=2 V, I_{DS}=250 mA/mm), f_{max} exceeds 200 GHz, the extrinsic transconductance achieves 700 mS/mm and the saturation current is 600 mA/mm.

A chipphoto of the frequency doubler is depicted in Fig. 1 (chipsize 1.2 x 1.4 mm²). The circuit was designed using finite ground coplanar transmission lines. The active element is a PHEMT with 4x60 um gate width. Operating conditions near the pinch off region (V_{GS}=-0.5 V, V_{DS}=3 V) were chosen to generate high even harmonic power levels.

A simplified circuit schematic of the multiplier is shown in Fig. 2. The output matching network consists of two parallel λ/4 long open stubs (l4) which supress the 38.25 GHz fundamental and odd harmonics. One additional λ/4 open stub (l8) was necessary to achieve a high supression of the 38.25 GHz fundamental in the output signal of more than 30 dBc. The output is matched at 76.5 GHz with the shorted transmission line l6 which is also used for the drain bias.

The input matching network fulfills the requirements of stabilization in the whole frequency range, matching at the 38.25 GHz fundamental and optimum load at 76.5 GHz [7]. The resistor R2 stabilizes the PHEMT at very low frequencies and the parallel combination of R1 and C1 at higher frequencies. The shorted transmission line which consists of l2 and l3 provides the optimum load at 76.5 GHz and is used for the gate bias. The input match at 38.25 GHz is realized with the capacitor C2.

An in house developed large signal HEMT model was used in the circuit simulation which was performed with a commercial program. The design goal was a frequency doubler with high conversion gain and very good fundamental supression in the output signal. Some of the transmission line length have been optimized using harmonic balance simulation with the goal to achieve maximum output power at 76.5 GHz.

Fig. 3 shows the measured output power and conversion gain of the frequency doubler as a function of the input power level at 38.25 GHz. The MMIC achieves a maximum conversion gain of +1 dB for 5dBm input power. The saturated output power at 76.5 GHz is 9dBm for 12 dBm input power.

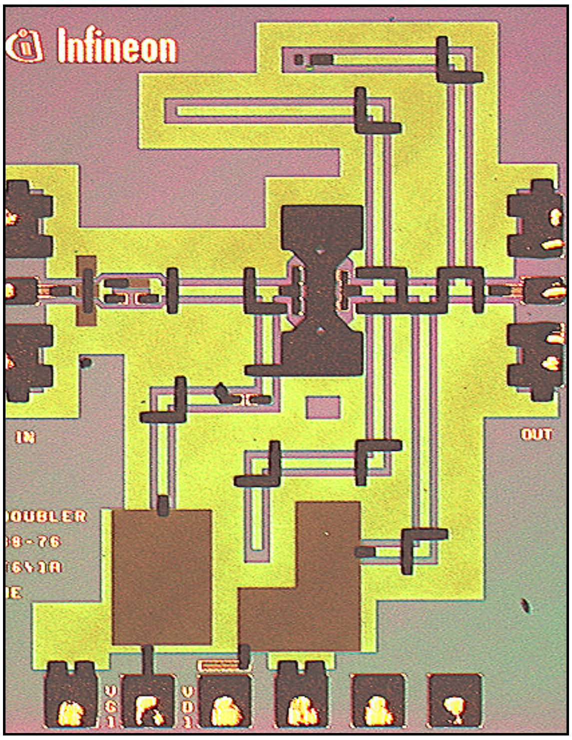

Fig. 1. Chipphoto of the 38/76 GHz frequency doubler.

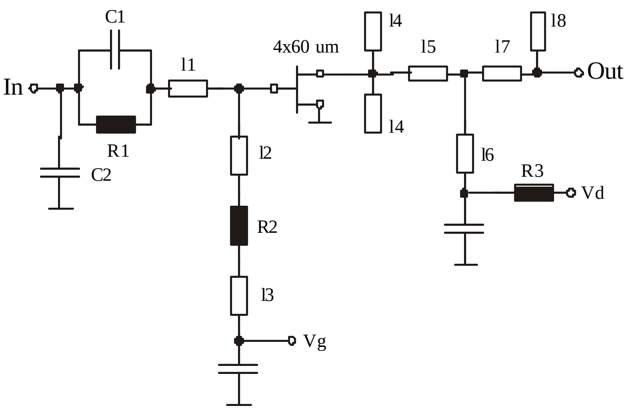

Fig. 2. Simplified circuit schematic of the 38/76 GHz frequency doubler.

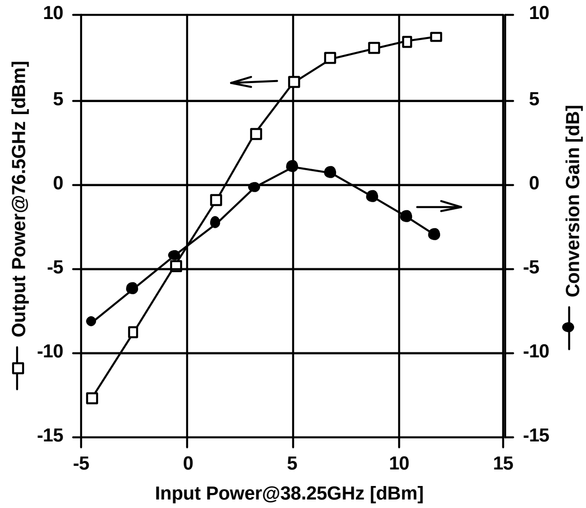

Fig. 3. Measured output power and conversion gain of the 38/76 GHz frequency doubler.

III. 76 GHZ TRANSMIT MMIC

The frequency doubler is a key component of two more complex transmit MMICs for automotive radar applications. The MMIC which is depicted in Fig. 4 consists of the series connection of a 38 GHz amplifier, the frequency doubler and a 76 GHz output amplifier. The 38 GHz input signal is transformed with 7 dB conversion gain in a 76 GHz output signal with typical 12 dBm output power.

The second 38/76 GHz transmit MMIC is shown in Fig. 5. It consists of the previously described transmit MMIC and in series two parallel 76 GHz medium power amplifiers. The 76 GHz signal is split with a wilkinson power divider in front of the parallel two stage amplifiers. One 76 GHz output is connected to the transmit antenna and the other is used as the LO signal for the receive mixer. This 38/76 GHz transmit MMIC achieves 10 dB conversion gain in conjunction with up to 14 dBm output power in each branch.

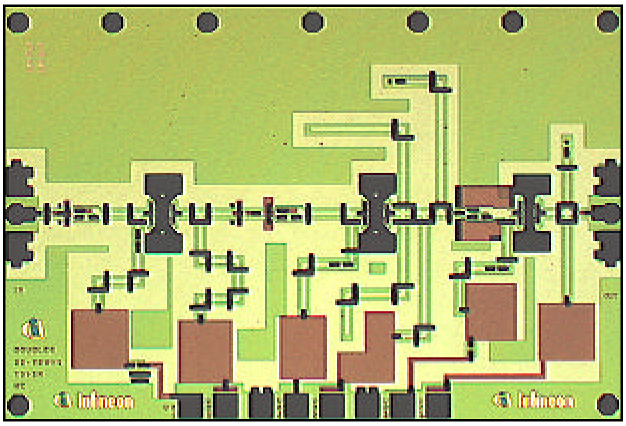

Fig. 4. Chipphoto of a transmit MMIC consisting of a 38 GHz amplifier, 38/76 GHz frequency doubler and a 76 GHz amplifier.

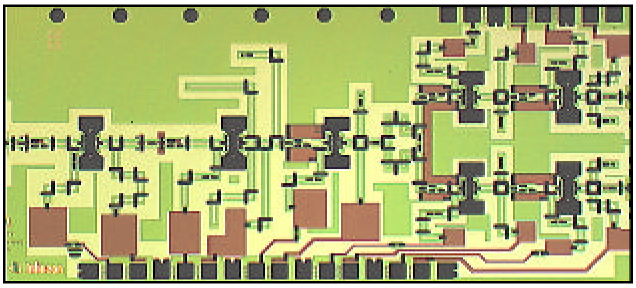

Fig. 5. Chipphoto of a 38/76 GHz transmit MMIC with two parallel output amplifiers.

IV. CONCLUSION

A 38/76 GHz frequency doubler was designed in coplanar technology and optimized using harmonic balance simulations. The fabricated MMIC demonstrates a maximum conversion gain of +1 dB. This is to our knowledge the highest published conversion gain of comparable single HEMT 38/76 GHz frequency doublers. The frequency doubler is a key component of more complex transmit MMICs which were developed for 76 GHz automotive radars. A single ended and a balanced transmit MMIC for this application demonstrated 10 dB conversion gain and up to 14 dBm output power at 76 GHz.

REFERENCES

[1] K. Maruhashi, N. Shida, et. al., "Miniature front-end MMIC's for 76-GHz-band automotive radar applications", *IEEE European Microwave Conference Digest*, pp. 9-12, 1999.

[2] M. Camiade, D. Domnesque, et. al., "Full MMIC millimeter-wave front-end for a 76.5 GHz adaptive cruise control car radar", *IEEE MTT-S Int. Microwave Symp. Dig.*, pp. 1489-1492, 1999.

[3] H. Kondoh, K. Sekine, et. al., "77 GHz fully-MMIC automotive forward-looking radar", *IEEE GaAs IC Symposium Dig.*, pp. 211-214, 1999.

[4] H. J. Siweris, H. Tischer, et. al., "A monolithic W-band HEMT VCO with feedback topology", *IEEE MTT-S Int. Microwave Symp. Dig.*, pp. 17-20, 1999.

[5] G. L. Tan, G. M. Rebeiz, "High-power millimeter-wave planar doublers. *IEEE MTT-S Int. Microwave Symp. Dig*, pp. 1601-1604, 2000.

[6] Y. Campos-Roca, L. Verweyen, et. al., "Coplanar pHEMT MMIC frequency multipliers for 76-GHz automotive radar", *IEEE Trans. on MWGL*, vol. 9, No. 6, pp. 242-244, 1999.

[7] D. G. Thomas, G. R. Branner, "Optimization of active microwave frequency multiplier performance utilizing harmonic terminating impedances", *IEEE Trans. Microwave Theory and Tech.*, vol. 44, No. 12, pp. 2617-2624, 1996.