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VARACTOR–TUNED PLANAR W–BAND OSCILLATOR

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ABSTRACT

A planar integrated VCO for the W–Band on high resistivity silicon substrate was fabricated. For that purpose an oscillator circuit for fixed frequency CW operation was extended. Frequency variation is obtained by coupling a radial line sector to a disc resonator via a varactor diode. As the active device a Si–MBE (molecular beam epitaxy) made Quasi Read Double Drift IMPATT diode is used. A hyperabrupt doping profile is used in the varactor diode. The hybrid integrated VCO is fabricated on a 10000 Ω·cm silicon substrate. The chip size is 6·4.5 mm^2. A tuning range of 380 MHz around 80.2 GHz with an output power of 18 mW is obtained.

INTRODUCTION

For many applications in communication, radar and sensor systems tunable millimeter–wave sources are needed. Recently integrated voltage controlled oscillators based on FETs and Gunns in the Ka–Band [1] and IMPATT based VCOs at 47 GHz [2] and at 55 GHZ [3] were reported. Tunable oscillators with reasonably high power for planar integrated W–band transmitter and receiver circuits are also required. Especially for small distance applications millimeter–wave systems have some advantages compared with microwave and optical systems. As shown in some previous papers [4–8] IMPATT–oscillators integrated on a high resistivity silicon substrate are a good choice as millimeter–wave sources. The millimeter–wave integration allowes also to integrate planar antenna structures because of their small size [7].

OSCILLATOR DESIGN

The oscillator circuit for CW operation at a fixed frequency described in [5–7] is extended to obtain frequency variation by voltage control. The planar oscillator structure consists of a disc resonator, which can be considered as a lossy radial waveguide, a tapered transmission line coupled to the disc via a gap, a radial line sector coupled to the disc via a varactor diode, and dc bias networks coupled directly to the disc and to the radial line sector respectively. In Fig. 1 the layout of the VCO is depicted and Fig. 2 shows a photo of the planar circuit. The load of the radial waveguide, i.e. the radiation resistance [5] and the external load formed by the tapered microstrip line [7] and the varactor coupled radial line sector, was determined and then the input impedance of the resonator was calculated. From these results the oscillatior circuit was designed.

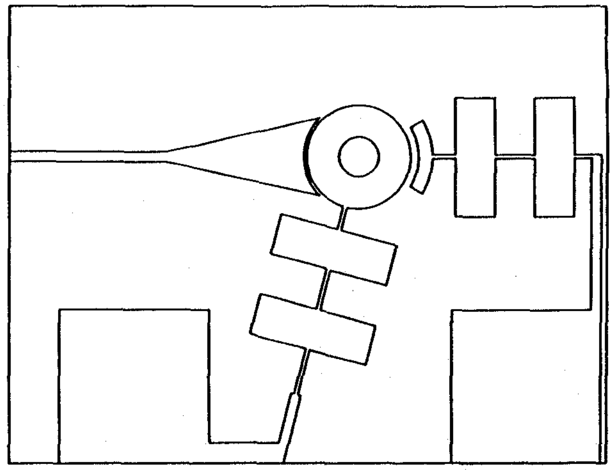

Fig. 1: Layout of the integrated VCO

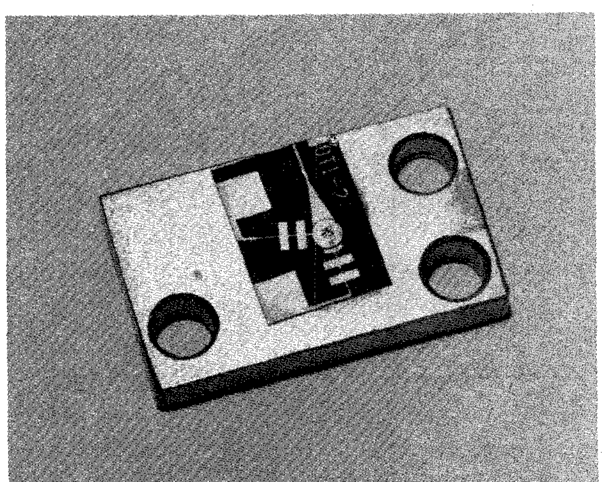

Fig. 2: Photo of the integrated VCO

EXPERIMENTAL RESULTS

The hybrid integrated varactor–tuned oscillator was fabricated on a 10000 Ω·cm silicon substrate. The substrate was thinned to a thickness of 100 μm and mounted on a copper carrier which serves for mechanical stabilization and as the heat sink for the active device.

The chip size is 6·4.5 mm². As the active device a Si–MBE (molecular beam epitaxy) made Quasi Read Double Drift IMPATT diode with a diameter of 46 μm is used. A hyperabrupt doping profile is used in the varactor diode which is produced by Si–MBE. A typical C–V curve of a small area varactor diode is depicted in Fig. 3.

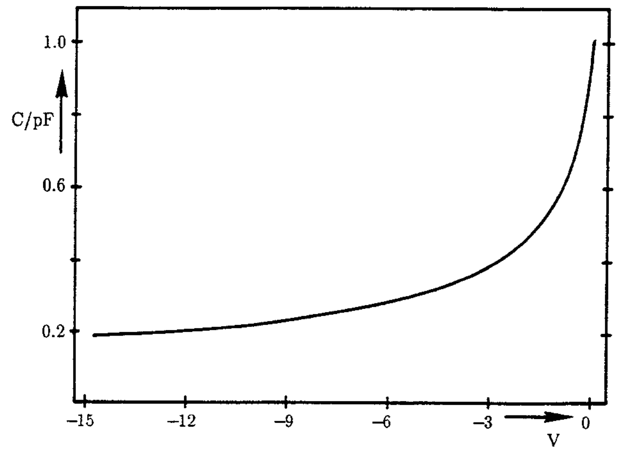

Fig. 3: Varactor diode capacitance versus reverse voltage
Diode diameter: 38 μm

A quadratic dependence of the capacitance on the voltage is observed according to the predictions from the doping profile. Varactor diodes with different sizes were used during the investigations of the tunable oscillator. A 38 μm varactor has a zero bias capacitance of 0.2 pF and a 5:1 capacitance range from 0 – 12 VDC. Fig. 4 showes the RF results which were achieved with this varactor diode.

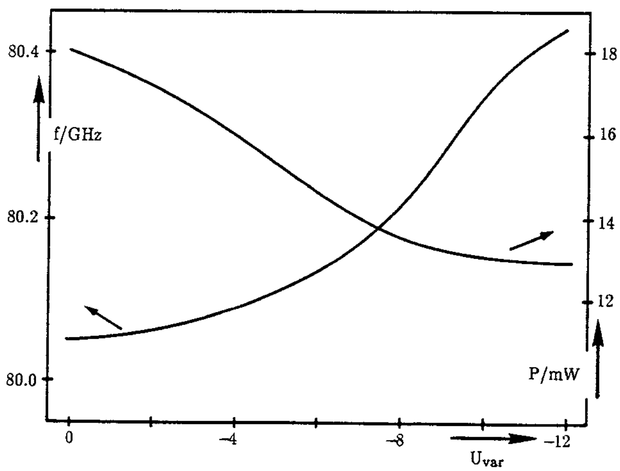

Fig. 4: Measured oscillation frequency and CW output power of the tunable planar oscillator as a function of the varactor voltage

Without any varactor tuning the oscillation frequency is 80.05 GHz at an IMPATT diode current density of 10 kA/cm². The corresponding output power is 18 mW in CW operation. With increasing the absolute value of the varactor voltage up to 12 V the oscillation frequency increases by 380 MHz up to 80.43 GHz while the output power decreases to 13 mW. During the tuning the bias current of the IMPATT diode was unchanged. In accordance to the theory the tuning range is smaler using larger area varactor diodes. With a varactor diode diameter of 160 μm corresponding to a capacitance variation of 5 pF to 30 pF the tuning range was 150 MHz. Fig. 5 shows the spectrum of an oscillator with a 38 μm varactor diode, where the bias current density of the IMPATT diode was 7.5 kA/cm² and no varactor voltage was applied. The CW output power was 8 mW. However, during the tuning of the oscillator the spectrum does not vary significantly.

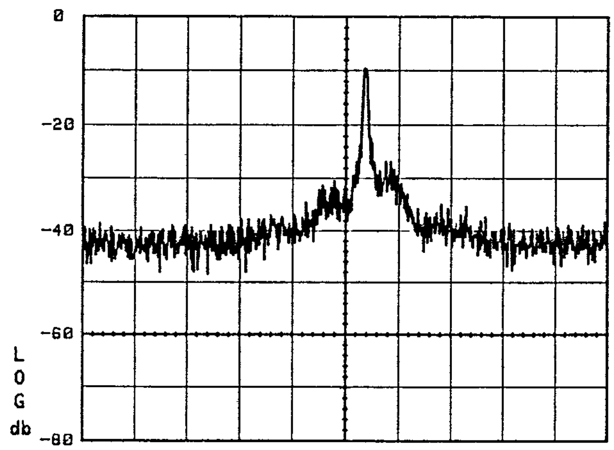

Fig. 5: Spectrum of the VCO; center frequency: 79.8 GHz, freq. span/div: 1 MHz, resolution BW: 100 kHz

ACKNOWLEDGMENT

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REFERENCES

[1] R. Goldwasser et al., "Monolithic Ka–Band VCOs", IEEE 1988 Microwave and Millimeter–Wave Monolithic Circuits Symposium, pp. 55–58
[2] N.L. Wang et al., "Millimeter–Wave Monolithic GaAs IMPATT VCO", IEEE 1988 Microwave and Millimeter–Wave Monolithic Circuits Symposium, pp. 59–62
[3] B. Bayraktaroglu, "V–Band Monolithic IMPATT VCO", 1988 IEEE MTT–S Digest, pp. 687–690
[4] J. Buechler et al., "Silicon high–resistivity–substrate millimeter–wave technology", IEEE Trans. Microwave Theory Tech., pp. 1516–1521, Dec. 1986.
[5] J. Buechler et al., "Silicon Millimeter–Wave Circuits for Receivers and Transmitters", IEEE 1988 Microwave and Millimeter–Wave Monolithic Circuits Symposium, pp. 67–70
[6] J. Buechler et al., "70 GHz Integrated Silicon Oscillator", Electronics Letters, pp. 977–978, July 1988
[7] J. Buechler et al., "Planar W–Band Receiver and Oscillator", 18th EuMC,1988, pp. 364–369
[8] J.F. Luy et al., "Silicon Monolithic Millimeter Wave IMPATT Oscillators", 18th EuMC, 1988, pp.382–387