Nonlinear Design and Experimental Results of a Low–Noise Varactor Tunable Oscillator using a Coupled Microstrip Resonator

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Abstract **– A varactor tunable oscillator with a coupled microstrip resonator was designed, using a nonlinear predictor–corrector method. Calculated and measured tuning characteristic agree better than 1%. Even at a low quality factor of the varactor the oscillator has the very low phase noise of –95dBc/Hz at 100KHz offset frequency.**

Introduction

A planar varactor tuned oscillator with coupled microstrip resonator was designed for optimum tuning range. Compared with a single microstrip line resonator the coupled microstrip line resonator used in the design exhibits a steeper phase slope of its impedance and consequently yields lower phase noise.

The stationary state of oscillation and the tuning characteristic of the oscillator were computed with the FATE–method [1]. With the predictor– corrector method the computation time for the determination of the solution branch was reduced to about 25% of the time required by the commonly used point–by–point computation.

Resonator Design

An oscillator in common source configuration with capacitive series feedback requires a series resonant circuit at the gate terminal, to obtain oscillation. We chose a coupled microstrip line resonator together with a varactor diode. The varactor diode and the gate terminal of the MESFET are each connected to different microstrip lines of the coupled line. The remaining terminals of the coupled microstrip line are left open, which is useful for monolithic integration. Fig. 1 shows the circuit diagram of the oscillator.

The resonator structure shown in Fig. 2 was analyzed and optimized for maximum tuning bandwidth. The coupled microstrip line resonator is loaded by the varactor diode at the distance x from the left end. The ports 1, 2, 3 are open. The series resonance frequencies at port 4 were calculated. The tuning bandwidth, i.e. the difference of maximum and minimum resonance frequency for minimum and maximum varactor voltage was calculated as a function of the position x of the varactor diode, the microstrip line width and the gap width between the coupled microstrip lines.

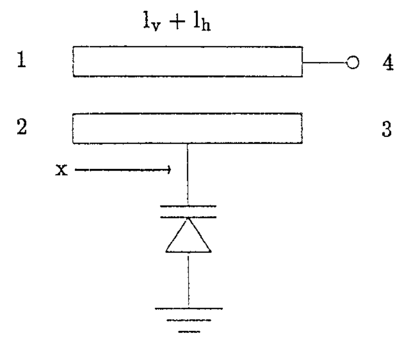

Fig. 2: The coupled microstrip resonator including the varactor diode

Maximum tuning bandwidth is achieved for small line width and small gap width, while the limitation of about 60μm is given by the thin film fabrication. Fig. 3 shows the dependence of maximum and minimum resonance frequency on the varactor position x.

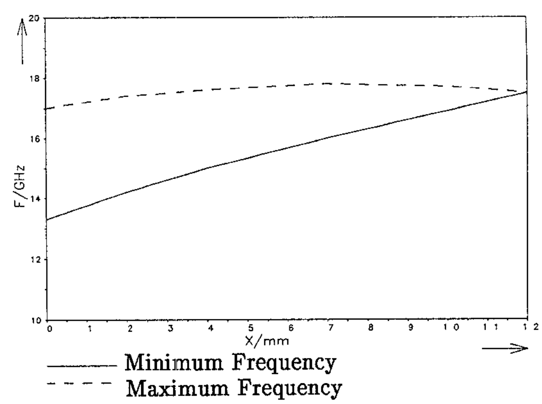

Fig. 3: Maximum and minimum frequency in dependence on the varactor position

To achieve maximum tuning bandwidth, the varactor must be positioned at the end of the microstrip lines.

Nonlinear oscillator calculation

Tuning characteristic and output power were computed with the FATE–method [1]. The varactor–diode was modeled according to [2], for the GaAs–MESFET a modified SPICE–model was used [3,4]. The FATE–method reduces the evaluation of the oscillators steady–state to the computation of the zeroes of a high–dimensional function, say $\mathbf{U}(\mathbf{z}) = 0$, where $\mathbf{z}$ is a vector both of Fourier–coefficients and state–variables.

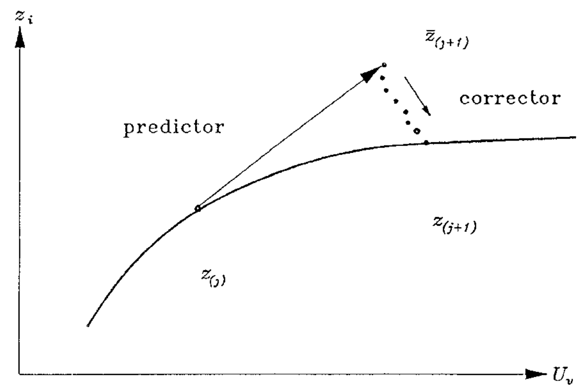

Fig. 4: The predictor–corrector method for the computation of solution branches

Since in the FATE–method the Jacobian $\partial\mathbf{U}/\partial\mathbf{z}$ is available, this method may be very efficiently used for the computation of the parameter–dependent solutions $\mathbf{U}(\mathbf{z},\eta)=0$, where η is the free parameter, see Fig. 4. Therefore a method of the predictor–corrector–type is used, where the predictor estimates the solution for a next parameter step $\bar{z}_{(j+1)}$ from the tangential vector at the actual parameter value η_j. Predictors of higher order can be adapted easily and lead to a more precise estimation value $\bar{z}_{(j+1)}$. The corrector transforms the estimated value $\bar{z}_{(j+1)}$ to the exact solution $z_{(j+1)}$ .For the corrector the Newton algorithm is used, producing as a by–product the Jacobian matrix $\partial\mathbf{U}/\partial\mathbf{z}$ at the next step η_{j+1}. Since the computation of the tangential vector needs only a few computation time and the corrector converges within a few steps this predictor–corrector–method requires only 25% of the computation time for the determination of the solution–branch compared with a simple point–by–point computation.

Oscillator circuit

Using the described resonator at the gate terminal of the MESFET together with a varactor with $C_{max}/C_{min} = 10 : 1$, an oscillator circuit with capacitive feedback at the source terminal and the output at the drain terminal was designed. The optimized oscillator circuit is fabricated in hybrid integrated technology on semi–insulating GaAs–substrate. The oscillator is shown in Fig. 5.

Results

Calculated and measured tuning characteristics are shown in Fig. 6. The oscillator is tunable from 12.7GHz to 14.8GHz with a linear tuning characteristic. Using a new technological process for mounting the transistor chips into the planar microwave circuit [5], the tuning bandwidth is increased by a factor of 1.5. This is achieved by reduction of the bond inductances at the transistor terminals. Calculated and measured tuning characteristic are in very good agreement. The maximum deviation is about 1%. The oscillator shows an average output power of 11dBm over the total tuning range. The single sideband phase noise of the oscillator is shown in Fig. 7 measured on an HP3048 system. The very low value for varactor tuned oscillators of –95dBc/Hz at an offset frequency of 100kHz was achieved. This value was taken at a low tuning voltage which corresponds to a low value of the quality factor of the varactor. In case of higher tuning voltage corresponding to a higher quality factor even lower phase noise is expected.

Conclusion

A varactor tuned oscillator was designed using a nonlinear design approach. Compared to conventional methods, computation time is reduced to 25% using a predictor corrector method for the determination of the tuning characteristic. Calculated and measured tuning characteristic agrees in a range of 1%. The merits of the integrated oscillator are low phase noise and medium tuning bandwidth.

Acknowledgement

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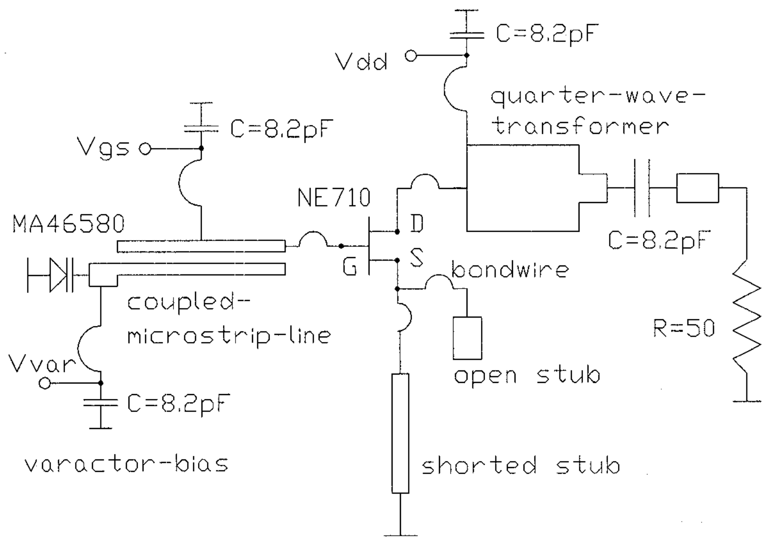

Fig. 1: The oscillator circuit

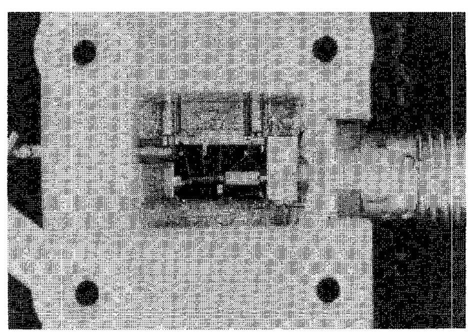

Fig. 5: A photograph of the oscillator circuit

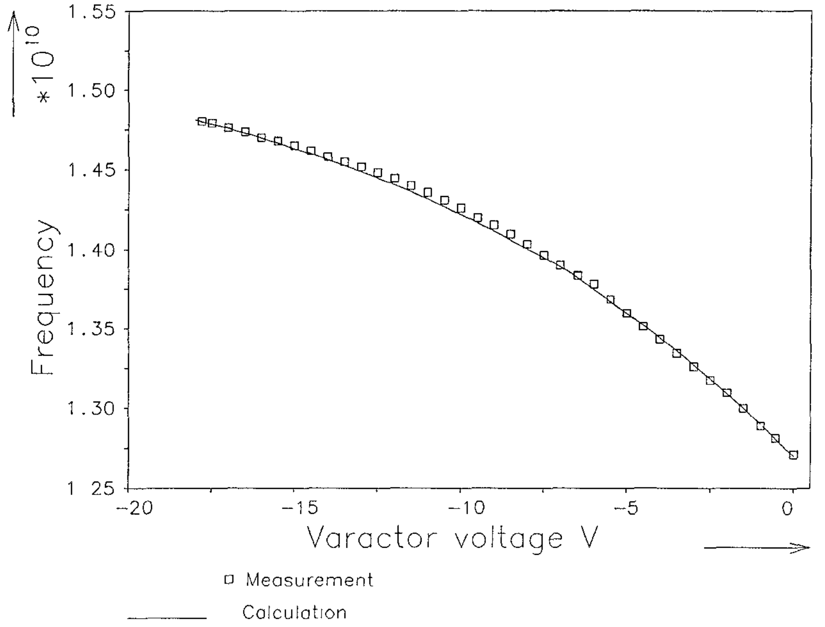

Fig. 6: The tuning characteristic of the oscillator

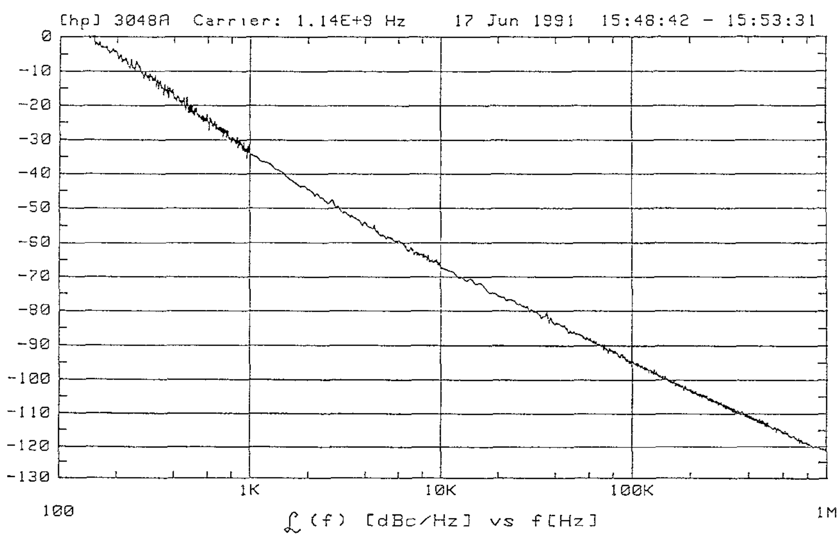

Fig. 7: Single–Sideband Phase noise