Variable Impedance Tuner for MMIC's

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Abstract—**A monolithic structure is presented for the tuning of MMIC's. With this tuner, either process deviations can be compensated or circuit parameters can be altered to meet different requirements. Measured results of a realized tuner agree well with the simulated model. Key design parameters are listed and a theoretical application for a narrow band amplifier at 27 GHz is simulated.**

I. Introduction

INTEGRATED CIRCUITS for micro and mm waves are currently realized on GaAs or InP substrates. Standard photolithography is used to define the metallization patterns for the passive parts of a circuit, like transmission lines, capacitors, and resistors. Elements like spiral inductors, which depend purely on geometric precision, are very well defined due to the high mask resolution. But deviations in process parameters, like layer thickness or doping concentrations, cause variations in overall circuit performance.

On-chip tuning by means of bond wires as on MIC's is no longer possible because of the small dimensions and possible damage to the MMIC. Electronically adjustable circuits are more suitable for monolithic integration and can be combined with the main circuit functions on the same chip [1]. A new concept for tuning elements was investigated. Practical results and design considerations are given.

II. Tuner Concept

Reactive matching networks, used for example in narrow band amplifiers, transform a real load into almost every complex reflection coefficient. Suitable elements were found to be a shunt-capacitance and a section of transmission line. The capacitance can be varied easily by means of a varactor diode, but in most cases selective ion implantation is required to get good varactors and good HEMT's on the same substrate. To avoid a separate varactor process, in this tuner concept the capacitance is fixed, but the location is shifted virtually along the transmission line (Fig. 1). One of several capacitors is switched on according to the desired length, while the others are off. The remaining line length changes inversly to the transforming section, but this has no effect when the line is terminated with its characteristic impedance.

Circuit models of the transistor in on- and off-state were extracted from a single transistor shunt switch [2], [3]. These models were applied to a schematic circuit of the tuner. Switching more than one capacitor (e.g. 2 or 4) moves the reflection coefficient in an orthogonal direction compared to the case of switching the position of one capacitor (Fig. 2).

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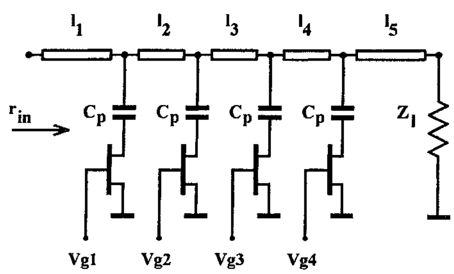

Fig. 1. Schematic circuit of tuner with four sections.

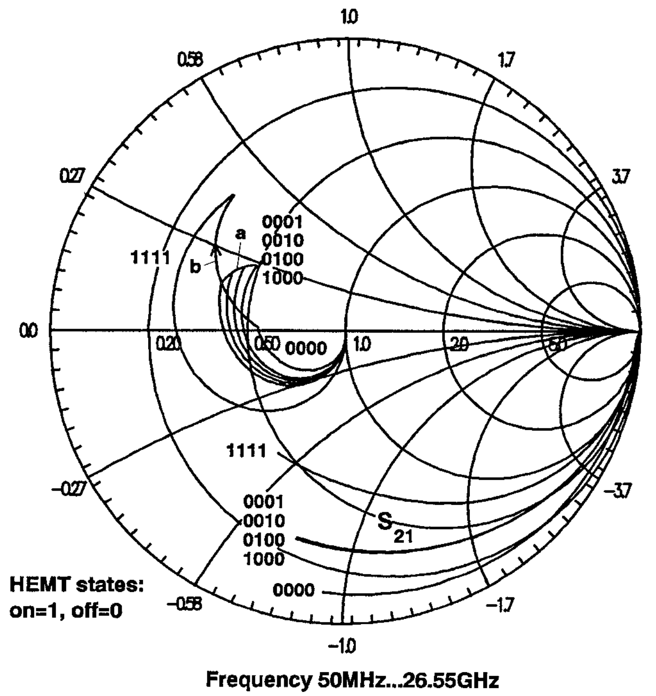

Fig. 2. Computed reflection and transmission coefficient. (a) Variation of capacitor position. (b) Variation of total capacitance.

III. Realization and Measurement

A tuner with four sections was designed and realized on a GaAs-substrate. The layout is very compact due to the coplanar waveguide design (Fig. 3). The switches are HEMT's with a gatelength of 0.5 μm and a gatewidth of 2*25 μm. They are placed symmetrically in the gap of the coplanar line. The MIM capacitors are fabricated with silicon-nitride dielectric. Total chip size was 1 mm × 1 mm, including DC-decoupling networks and pads for on-wafer measurement.

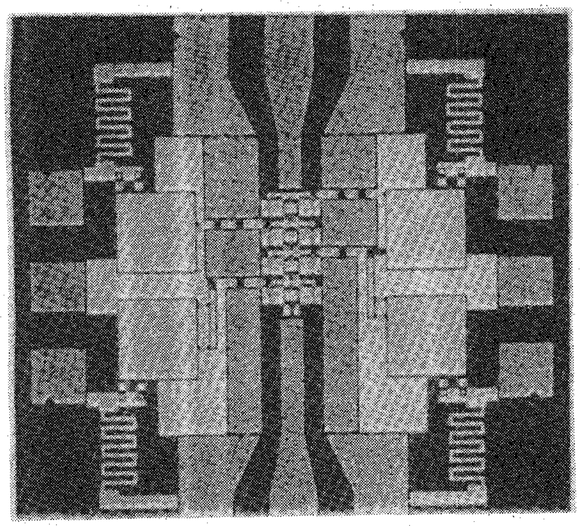

Fig. 3. The realized tuner chip measures 1 mm × 1 mm.

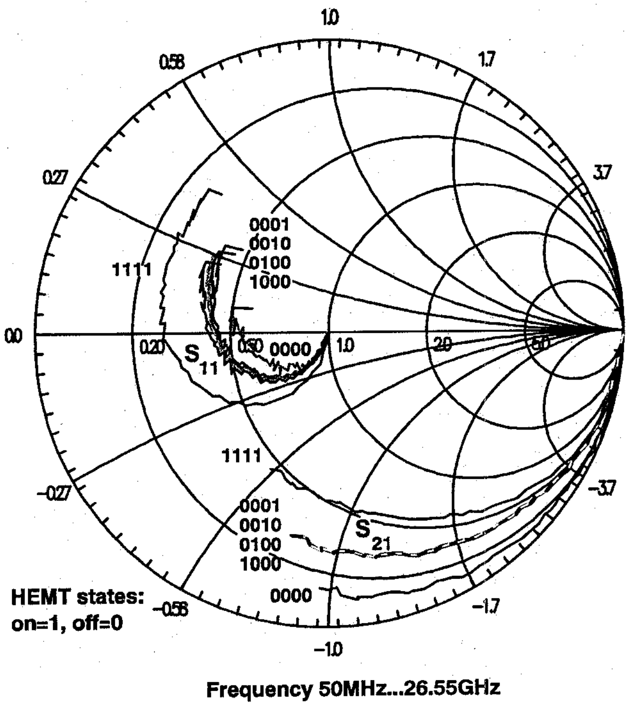

Fig. 4. Measured reflection and transmission of the tuner.

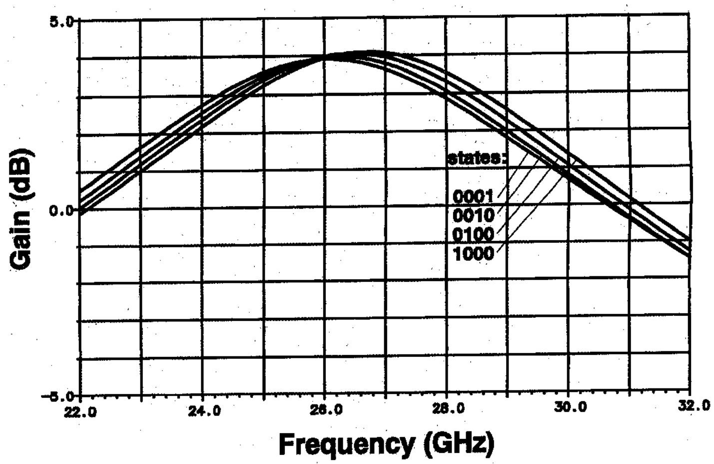

Fig. 5. Simulated amplifier gain with tuner model in the output matching network.

The tuner was measured on-wafer using a network analyzer. Different combinations of control voltages at gates 1 to 4 changed the electrical behavior of the circuit as expected (Fig. 4). Closing only one switch out of four moves the reflection coefficient, while transmission remains almost constant.

All measured states agreed well with the simulation using only one set of circuit parameters for the whole tuner. With this data, different tuner arrangements can be evaluated with a high degree of confidence.

In the prototype, a small gatewidth was used to give a narrow spacing of the stages. The resulting tuning resolution was high. For lower tuner insertion loss the on-resistance of the switches will be reduced with increased gatewidth. The switch spacing is maintained when HEMT's with multiple gatefingers are used in an optimized layout.

IV. Amplifier Application

Radio link equipment requires amplifiers with limited bandwith to suppress spurious signals and out of band noise. The shape of the gain curve has to be controlled carefully, especially in balanced amplifiers or phased arrays. As an example, a one-stage narrow band amplifier [4] is investigated. The output matching transformer of the amplifier is replaced by the tuner model. Deviations in process parameters change amplifier gain and center frequency. In Fig. 5, the circuit parameters are kept constant, while the tuner is changed to demonstrate the tuning range. In normal operation, one single state is choosen, which compensates the process deviations resulting in the same center frequency for every amplifier. The realized tuner covers up to +/−15% deviation in equivalent small signal transistor parameters. The narrow switch separation guarantees a small residual error in the desired center frequency.

V. Conclusion

A new concept for an electronically tunable MMIC was investigated. The behavior of the schematic circuit used in simulation is in close agreement to the measured data. Therefore, future applications can be predicted easily. Number of switch stages, separation of stages, and capacitance values are the key design parameters for this type of tuner. Applied to a simple amplifier, process deviations can be compensated. The tuner is compact and can be integrated easily with the main circuit function.

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