ZERO POWER CONSUMPTION Si/SiGe HBT SPDT T/R ANTENNA SWITCH

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ABSTRACT

Design and performance of a new transmit/receive (T/R) antenna switch for mobile communication systems at $1.8 GHz$ using Si/SiGe Heterojunction Bipolar Transistors (HBT) are described. The switch is designed to be a part of a transceiver front end for DECT and DCS 1800 applications. This circuit requires no external DC bias. The insertion loss in the receive arm is $<1.5 dB$ and the isolation $>25 dB$ at the operating frequency.

INTRODUCTION

Minimal size, low power consumption and low cost are driving forces in the design of battery-powered communication systems. Thus, a switch for integration in a one chip transceiver front end in Si/SiGe HBT technology was developed.

A single-pole, double-throw (SPDT) T/R antenna switch requires high isolation in the receive arm to protect the receiver front end from damage when the transmitter is operating, and sufficient isolation in the transmit arm to isolate the receiver from variations in the transmitter's output impedance.

SI/SIGE HBT PROCESS

The Si/SiGe HBT process and MBE growth have been previously described in detail elsewhere [1], [2]. The MBE profile incorporates a base thickness of $25 nm$, uniformly boron doped to $8 \cdot 10^{19} cm^{-3}$, and a $300 nm$ collector with an antimony doping of $5 \cdot 10^{16} cm^{-3}$. The base is using a layer of $Si_{1-x}Ge_x$ with constant 30% Ge. The resulting HBTs achieve an f_T and f_{max} of $35 GHz$ and $70 GHz$ respectively for a $1 \times 10 \mu m^2$ two finger HBT device.

CIRCUIT DESCRIPTION

The basic circuit configuration of the novel T/R switch is shown in Fig. 1. A similar concept with a different aim is published in [3]. The resonant circuits are adjusted at $1.8 GHz$, and the HBTs are in inverse common base configuration (base grounded). In this circuit no DC power is required.

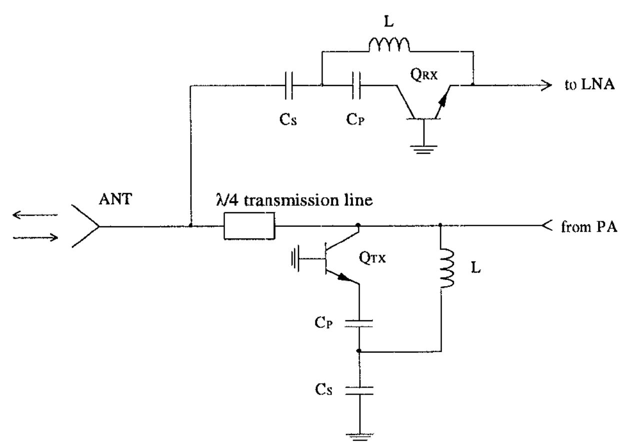

Fig. 1. Basic circuit configuration

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The operation of the switch is as follows:
Receive mode: The low power receive signal (up to -8*dBm*) does not turn the transistors in the ON-mode. Also, the impedance at the collector terminal is very high and the signal can reach the LNA through the serial resonant circuit (C_S and L) in the receive arm. The short circuit for signals with low power in the transmit arm is transformed to an open circuit by a quarter wavelength transmission line. The quarter wavelength transmission line may also be realized by a waveguide with lumped elements.

Transmit mode: For transmit signals >-8*dBm*, the HBT's switch into saturation. Due to the resulting high differential conductance between collector and emitter, C_P and L form parallel resonant circuits. Now the resonant circuit in the receive arm protects the LNA from damage, while its high input impedance at the resonant frequency in the transmit arm has no influence on the transmit signal.

In case of a monolithic integration with an HBT power amplifier, the transmit arm could be omitted, because of the high output impedance of the PA during the receive mode.

PERFORMANCE

The prototype of the switch was fabricated in hybrid technology using an RT Duroid substrate (ε_r=2.33, h=0.79*mm*). Fig. 2 shows the layout of this prototype. The capacitances are realized as chip-capacitors, the inductances as spiral-inductors. The Q factor of the spiral-inductors at 1.8*GHz* was extracted to be between 7 and 12. The Si/SiGe HBTs have been bonded in the circuit.

Fig. 3 shows the calculated isolation versus the input power of the single receive and transmit arms.

The isolation is input power dependent. A rising amplitude of the input signal causes an increasing isolation in the receive arm and a decreasing isolation in the transmit arm.

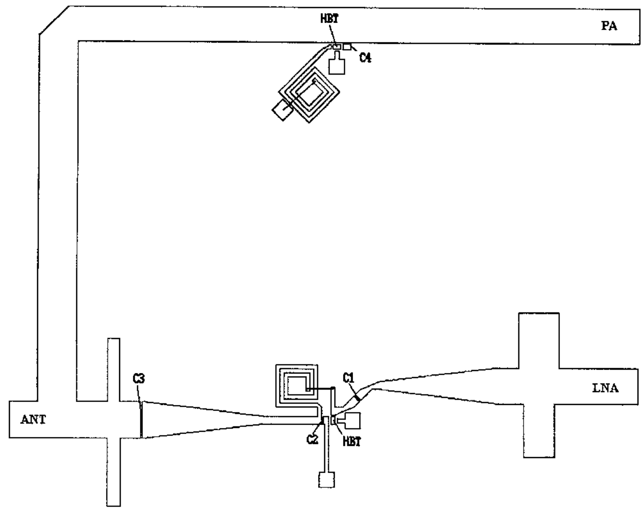


Fig. 2. Layout of the prototype on RT Duroid

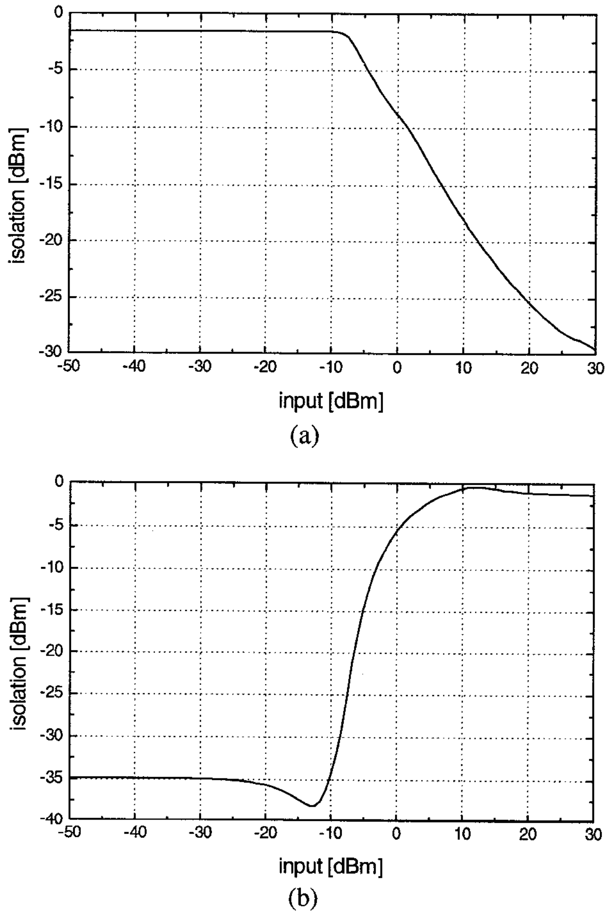
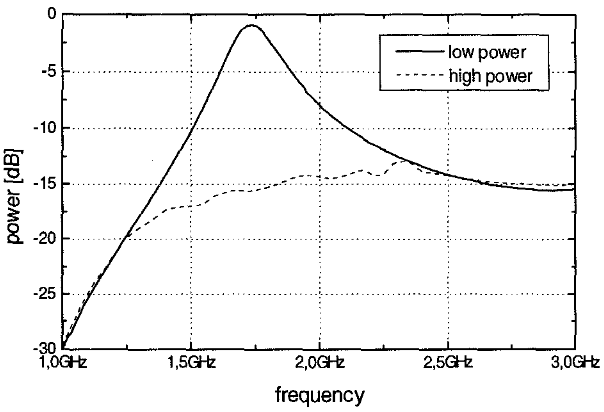
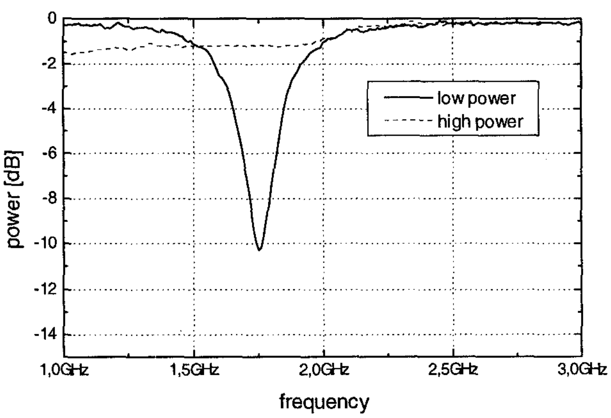


Fig. 3. Simulated isolations versus input power of the receive arm (a) and the transmit arm (b) at 1.8*GHz*

Fig. 4 shows the measured results of the T/R switch. The output power in the receive and transmit arms is normalized to facilitate comparison at different curves. In Fig. 4a the insertion loss in the receive arm at the operating frequency is 1.2*dB* and the isolation for a signal with a power of +15*dBm* is 15*dB*. The isolation increases with the power level as shown in Fig. 3 and will reach 30*dB* at a power level of 30*dBm*. Thus, no more than 0*dBm* will reach the LNA. Fig. 4b shows the insertion loss versus the frequency for the transmit signal (P = +15*dBm*) with less than 1.5*dB* and the isolation for the receive signal. 10*dB* of isolation in the transmit arm is sufficient to prevent any variation in the output impedance of the PA from affecting the performance of the receiver.



(a)



(b)

Fig. 4. Measured output power versus the frequency at two different power levels (low: -20*dBm*, high: +15*dBm*) for the receive arm (a) and the transmit arm (b).

CONCLUSION

A new architecture for a zero power consumption Si/SiGe HBT SPDT transmit/receive switch has been developed and experimentally verified. A monolithic realization of the switch and a co-integration with the power amplifier will be the next steps.

ACKNOWLEDGEMENT

Thanks to F. Beißwanger for supplying the HBTs also Dr. Arndt and Dr. Höppner for project support.

REFERENCES

[1] A. Gruhle, H. Kibbel, U. König, U. Erben, E. Kasper: MBE grown Si/SiGe HBTs with high β, f_T and f_{max}. Electronic Device Letters, 13, 206-208 (1992)

[2] A. Gruhle: SiGe Heterojunktion Bipolar Transistor, in Silicon-Based Millimeter-Wave Devices, ed. by J.-F. Luy and P. Russer, Springer Verlag (1994)

[3] T. Tokumitsu, I. Toyoda, M. Aikawa: A Low-Voltage, High-Power T/R-Switch using LC Resonators. IEEE Transactions on Microwave Theory and Techniques, Vol. 43, No. 5, pp. 997-1002 (1995)