A Low-Noise Active Receiving Antenna Using a SiGe HBT

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***Abstract*— A low-noise active receiving antenna based on a printed dipole and a Si/SiGe HBT in the 5.8-GHz band is presented. A power gain of 8.3 dB compared to the respective passive antenna and a noise figure of 1.4 dB at center frequency were achieved. To improve the antenna gain, two of these components were combined to a small array with reduced beamwidth and comparable noise figure.**

***Index Terms*— Active antenna, HBT, low-noise amplifier, printed dipole.**

I. Introduction

Microwave antennas integrated with active elements—or active antennas—have found a wide interest in the last years [1]. Most of them are transmitting antennas incorporating Gunn elements or field effect transistor (FET) oscillators; some of them are operated in a receiving mode [2]. Due to the microwave frequency range, most active elements are based on GaAs. For mobile communication or local area network (LAN) applications, silicon still is the preferred material due to its mature technology and its compatibility with digital integrated circuits [3]. With increasing frequency, Si/SiGe heterobipolar transistors (HBT's) have proven as an alternative to GaAs MESFET's; even low-noise performance has been demonstrated [4], [5]. Therefore, Si/SiGe HBT's are investigated as active elements in a low-noise active receiving antenna in the 5.8-GHz range, which is of interest for LAN and applications such as identification cards or intruder alarm.

II. Description of the Circuit

As an antenna element, a dipole was used printed on a thin dielectric sheet and placed a quarter wavelength in front of a metal plate (Fig. 1). In the area of the amplifier, an additional backside metallization of the substrate is provided. For low-noise performance, the input impedance of the dipole has to match the impedance for minimum noise figure of the transistor. In Fig. 2, the impedances of dipoles with different lengths at 5.8 GHz as well as the impedance range of the HBT for minimum noise figure are plotted. For the antenna presented here, a dipole length of $1/\lambda = 0.28$ was chosen. The optimal impedance was achieved with a shunt inductance realized by a thin microstrip line stub. Output matching is done with a stub, too. Stability of the amplifier was assured employing a series resistor (330 Ω) at the collector and a 50-Ω resistor in series with a capacitor to ground placed at the "cold" position of the input matching stub. This last measure did not affect the amplifier at the center frequency of 5.8 GHz, nor did it deteriorate the noise figure, but contributed considerably to stability outside the band of operation. The complete layout of the amplifier including additional discrete quasiconcentrated devices and the dc network is presented in Fig. 3. There should not be any difficulty to integrate the amplifier monolithically on a high-resistivity silicon substrate.

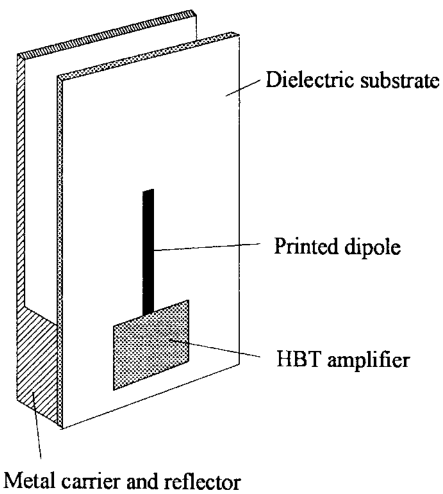

Fig. 1. Basic setup of active antenna.

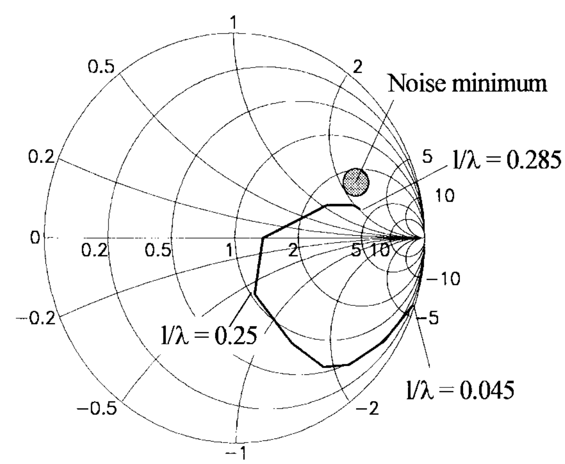

Fig. 2. Input impedances for different lengths of dipole and range of optimal impedance for minimum noise figure of the HBT at 5.8 GHz.

Manuscript received September 18, 1996.
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Publisher Item Identifier S 1051-8207(97)01774-1.

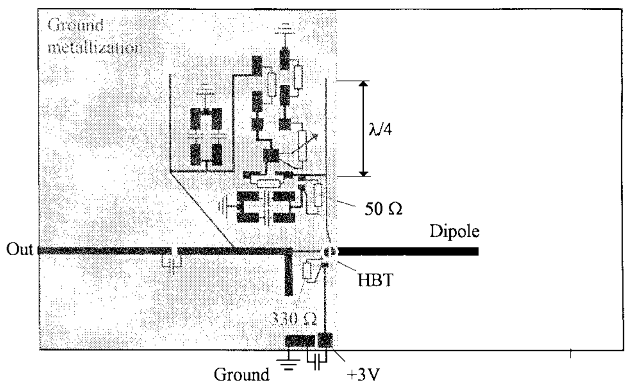

Fig. 3. Basic layout of active receiving antenna.

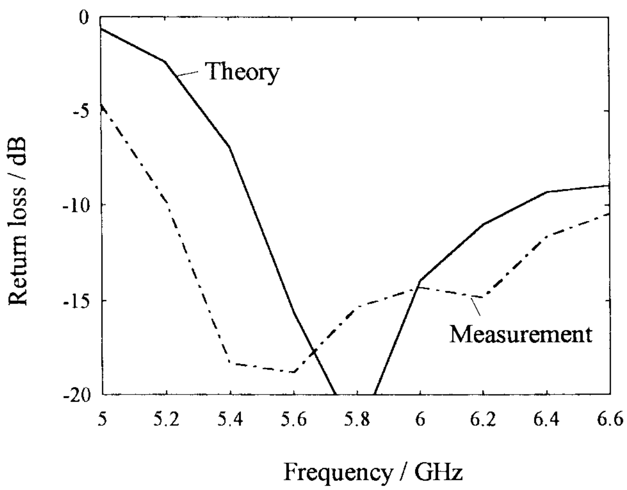

Fig. 4. Output return loss of active antenna.

III. Results

Fig. 4 shows the output return loss of the active antenna. The experimental results indicate a -15 dB bandwidth of about 15%. At 5.8 GHz, the power gain compared to a passive, impedance matched antenna amounts to 8.3 dB and the noise figure to 1.4 dB, very close to the minimum noise figure of the HBT (Fig. 5). The noise figure was measured radiating an amplified noise signal to the active antenna, calibrating the resulting excess noise ratio (ENR) with a passive antenna again [2]. As a consequence, the noise figure does not include losses of the dipole itself; these, however, should be very small. The theoretical noise figure was calculated based on the measured noise performance of the HBT. Due to a slightly different radiation diagram of the passive antenna with increasing frequency (different impedance match and therefore slightly different current distribution on the dipole), the evaluation of the experimental noise figure resulted in a value a little bit too low at 6.2 and 6.4 GHz.

The radiation diagrams of the active antenna in E- and H-plane are plotted in Figs. 6 and 7, showing, as expected for the small antenna size, wide beamwidths. The ripple in the curves is due to the finite size of the backside reflector plate.

Finally, two active antennas as described above were combined to a small array. The distance between the two dipoles was chosen as $5/8\lambda$. To guarantee impedance match for

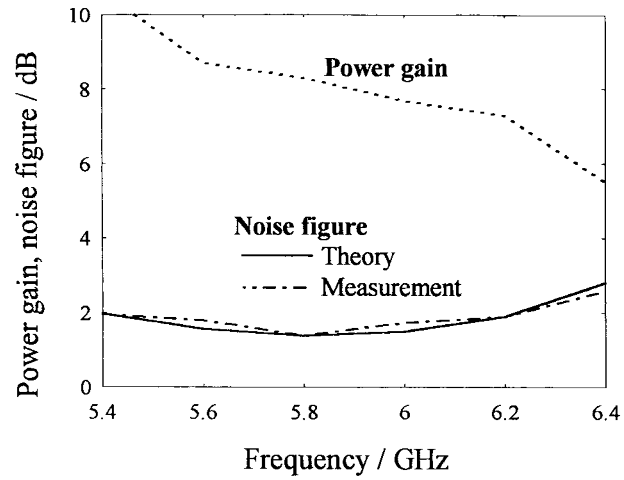

Fig. 5. Experimental power gain (compared to a passive antenna) and noise figure of the active antenna.

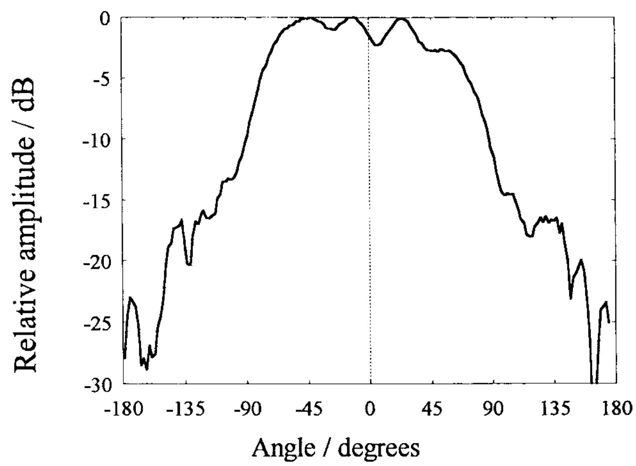

Fig. 6. E-plane radiation diagram of the active antenna ($f = 5.8$ GHz).

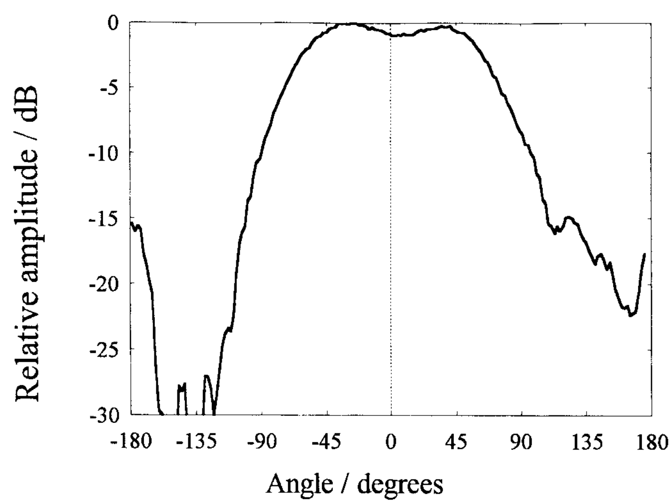

Fig. 7. H-plane radiation diagram of the active antenna ($f = 5.8$ GHz).

minimum noise figure, the mutual impedances of the dipoles were included in the design, resulting, however, only in minimal changes. The output signals of the two amplifiers were combined using a Wilkinson power divider/combiner. The resulting noise figure of the array amounted to 1.5 dB

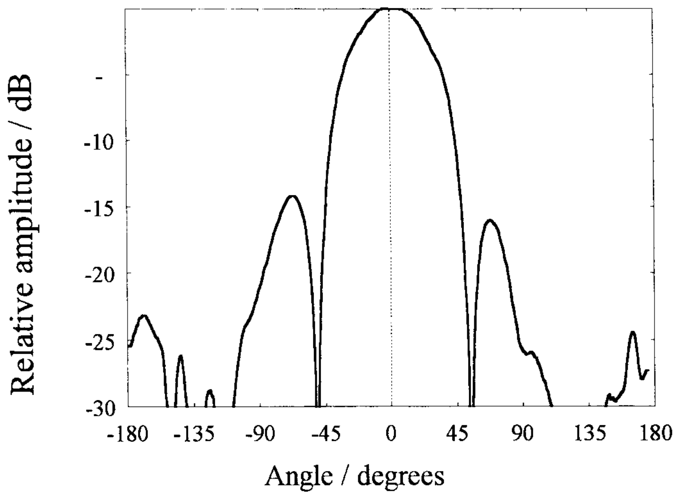

Fig. 8. H-plane radiation diagram of the two element active antenna ($f = 5.8$ GHz).

at 5.8 GHz; the resulting radiation diagram in the H-plane is plotted in Fig. 8.

ACKNOWLEDGMENT

The authors would like to thank A. Gruhle and U. Koenig from the Daimler-Benz Research Institute, Ulm, Germany, for providing the Si/SiGe-HBT's.

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