Microwave and Millimeter-Wave Signal Power Generation

Among the major limitations in high-speed communications and high-resolution radars is the lack of efficient and powerful signal sources with low distortion. Microwave and millimeter-wave (mm-wave) signal power is needed for signal transmission. Progress in signal generation stems largely from the application of novel materials like gallium nitride (GaN) and silicon-carbide (SiC) and fabrication of indium phosphide (InP) based transistors. One goal of this thesis is to assess GaN HEMT technology with respect to linear efficient signal power generation. While most reports on GaN HEMT high-power devices concentrate on single-tone performance, this study also encompasses two-tone intermodulation distortion measurements. An 8GHz two-stage power amplifier (PA) MMIC was developed. Harmonic tuning was performed to enhance the power-added efficiency (PAE). The transistors were biased in deep class-AB where low distortion and high PAE were observed. The estimated output power of 42.5 dBm and PAE of 31.3% are comparable to the state-of-the-art results reported for GaN HEMT amplifiers. Wireless communication systems planned in the near future will operate at E-band, around 71-86 GHz, and require mm-wave-PAs to boost the transmitted signal over distances of 1-2 km. The second goal of this thesis is technology study and development of an InP HBT based E-band PA. The InP HBT technology was chosen based on the high voltage operation reported for these devices. Characteristics of a 1.5\textmu m InP HBT and a 0.21\textmu m SiGe HBT were compared by means of their models. For that purpose, the SiGe HBT was accurately characterized using VBIC95 model. The modeling work included developing a de-embedding method and application of direct parameter extraction. The comparison between the HBTs revealed, among other things, that the SiGe HBT operates at much higher current density and develops lower temperature than the InP HBT. The InP HBT offers, however, higher voltage operation.

A two-stage InP HBT PA was developed. Record performance levels were simulated: an output power of \( \approx 150 \) mW with PAE of 15%. The measured gain was 7.5 dB at 77 GHz and relative bandwidth was 45%. Resistive loadings were used to ensure even and odd-mode stability. Another need in many direct conversion systems and image reject receivers is to generate signals with accurate quadrature offset. Only limited work has been published on design and analysis of mm-wave quadrature voltage controlled oscillators (QVCOs). Third goal of this thesis is to deal with these problems. Deleterious effects of interconnects and HBT parasitics on a differential oscillator were analyzed. The developed QVCO comprises two coupled differential InP HBT LC-oscillators. A simple method of predicting unwanted oscillations was proposed. The frequency tuning combines modulation of the coupling strength and modulation of the HBT capacitances. The developed QVCO demonstrated around -14.7 dBm power per single-ended output and state-of-the-art frequency and tuning range, 37-47.8 GHz. Simulated phase noise ranged from -85 to -88 dBc/Hz at 1MHz offset from the carrier.

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