

A High-Speed, Fully-Integrated, 180/195 GHz FSK Transmitter Using Coupled Oscillators

Samir Nooshabadi, *Student Member, IEEE*, Ehsan Afshari, *Senior Member, IEEE*,

Abstract—A novel design for a high-data rate, 180/195 GHz transmitter is described. The transmitter is based on a coupled oscillator topology, and is predicted to provide 15 Gbps communication over a 10cm channel. The topology exploits the fast-settling frequency modulation of mutually coupled oscillators. The system was designed and fabricated on a 65nm CMOS technology. Measurement results are pending. The total chip area for the fully-integrated transmitter is 0.6825mm².

Index Terms—coupled oscillators, mm-wave circuits, integrated transmitter

I. INTRODUCTION

AS communication systems edge closer and closer to Shannon's limit in conventional RF bands, new approaches must be taken to accommodate the increased demand for wireless communication throughput. In contrast to the scarcity of bandwidth in RF bands, millimeter-wave frequencies have vast amounts of unallocated spectrum available for high data-rate communication. Millimeter-wave transmitters have already been demonstrated on CMOS processes in several works, but suffer from either high-SNR requirements, [1], or high modulation loss, [2].

To solve the issue of modulation loss in low-SNR modulation schemes, it is advantageous to consider frequency-shift-keying modulation (FSK). FSK has not been used for high data-rate communication due to the long transient settling time of the oscillator during frequency modulation, as well as the power loss due to frequency tuning at mm-wave frequencies. Frequency tuning with minimal power loss can be accomplished, however, by using coupled oscillator schemes—making the topology an attractive high-power source for array structures [3]. This project aims to design a 180/195 GHz FSK transmitter using coupled oscillators, resulting in a scalable, high-power, 15 Gbps transmitter with low SNR requirements and low modulation loss.

II. SYSTEM DESIGN AND IMPLEMENTATION

To take advantage of the fast frequency settling time of the topology in Fig. 1, a direct-modulation FSK transmitter was designed. The transmitter consisted of three major blocks: the core oscillators, the phase shifters, and the antennas. All components were designed and fabricated on a 65nm CMOS technology.

S. Nooshabadi was with the Department of Electrical Engineering and Computer Science, University of Michigan, Ann Arbor, MI 48109 USA. He is now with the Department of Electrical Engineering, California Institute of Technology, Pasadena, CA 91125 USA.

E. Afshari is with the Department of Electrical Engineering and Computer Science, University of Michigan, Ann Arbor, MI 48109 USA.

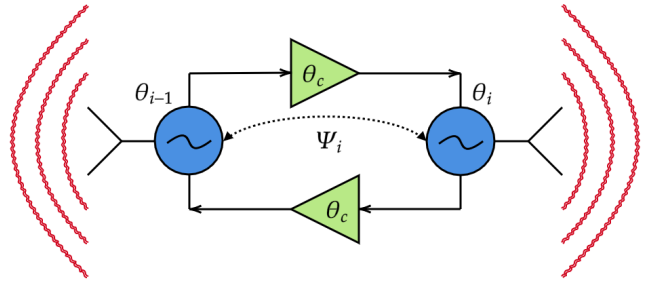


Fig. 1. Two mutually coupled oscillators. The frequency of the oscillators is varied via the phase shift imposed on the injecting currents θ_c . The phase difference, Ψ between the two oscillator waveforms is deterministic and fixed via frequency shift. The modulated data is transmitted via on-chip antennas.

A. Harmonic Oscillator Design

To achieve high-power out of each oscillator core at 190 GHz, an oscillator design that is optimized for second harmonic generation was used. Fundamental limits for second harmonic generation in CMOS oscillators are approximated in [4], and the design principles used there are adapted for this work. An oscillator core with roughly +1 dBm output power at the second harmonic (180/195 GHz) was designed.

B. Fast-settling Phase Shifter Design

The transient settling time of the topology in Fig. 1 is limited by the speed at which the phase shifter can settle during modulation. A resonant-amplifier phase shifter has been designed, where tunable varactors change the resonant frequency of the amplifier. A control voltage signal carries the data that is to be transmitted, and modulates the frequency of the entire loop in Fig. 1 via the phase-shifters. The control signal varies the capacitance in the tank, and provides a different phase shift for a given frequency. Varactors were sized to provide a large enough phase shift— $\approx 140^\circ$ between the two modes. Since the phase shifter needs to settle as fast as possible, the quality factor of the amplifier is intentionally degraded to make the phase shift large as well as decrease the settling time, since settling time is inversely proportional to tank Q .

C. Wideband Antenna Design

Each oscillator core is connected to an antenna for the transmitted signal to be radiated and for spatial power combining

