Wireless Synchronization of mm-wave Arrays in 65nm CMOS

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Introduction

This paper presents the first wireless synchronization of a mm-wave array, eliminating the need for connecting wires between the array elements. Wireless injection locking of a single chip is successfully demonstrated and a frequency stability of 400Hz at a carrier frequency of 50GHz is achieved (stability of 8ppb). This work sets the foundation for increasing the element spacing of an array through wireless injection locking, extending traditional array systems into the high-resolution, narrow-beamwidth regime.

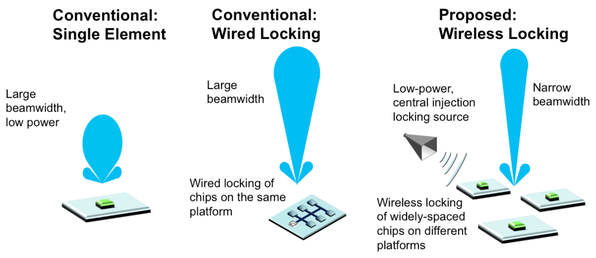


Fig. 1. Radiation pattern of single-chip vs. wired locking vs. wireless locking. Wireless locking of widely-spaced chips results in significantly reduced beamwidth.

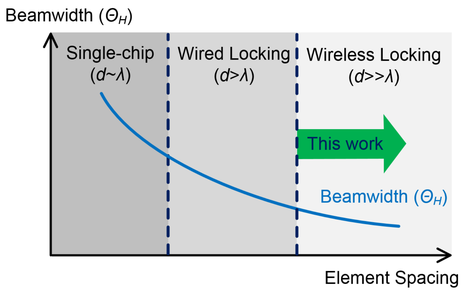


Fig. 2. The beamwidth is inversely proportional to the element spacing, which is reduced significantly by wireless locking.

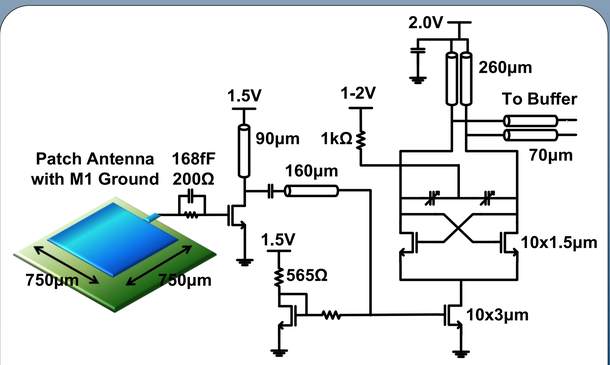


Fig. 4. Simplified schematic of the injection-locked receiver. The wireless signal is injected at the tail of the IL-VCO.

Transceiver Architecture

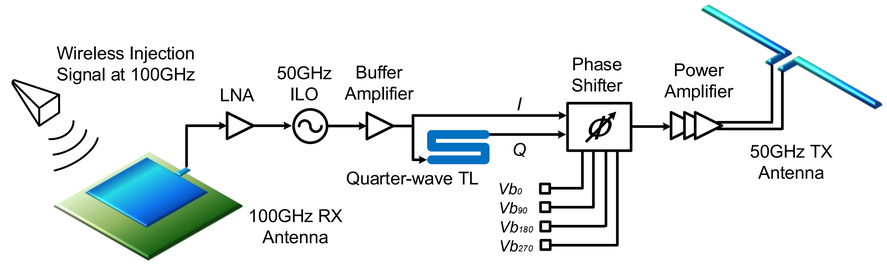


Fig. 3. Transceiver architecture. The reported transceiver includes a receiving on-chip antenna, an LNA, an injection-locked VCO, a buffer amplifier, an I/Q generator, a phase-shifter, a power amplifier, and a transmitting on-chip antenna.

Circuit Design

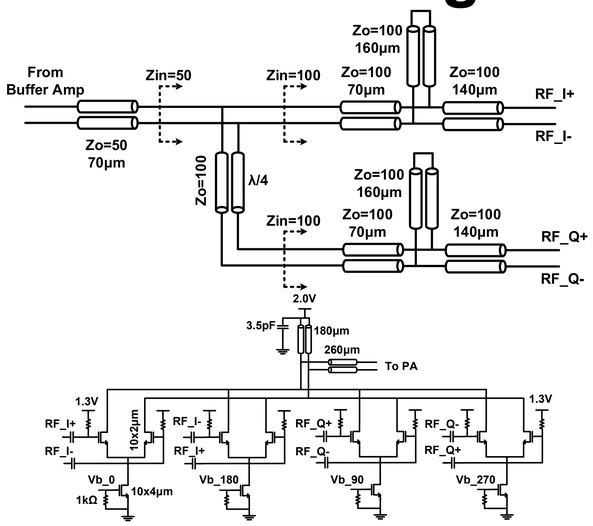


Fig. 5. Schematic of quadrature generator and phase shifter.

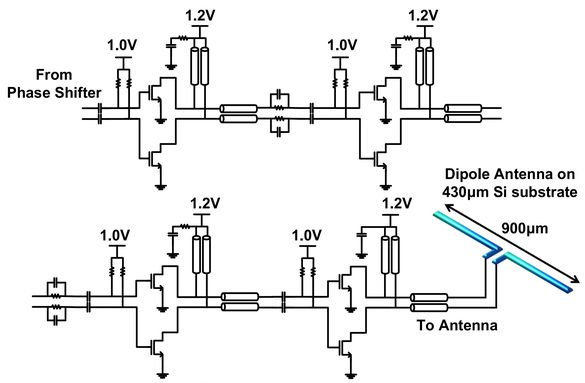


Fig. 6. Schematic of the 4-stage PA and the dipole antenna.

Antenna Design

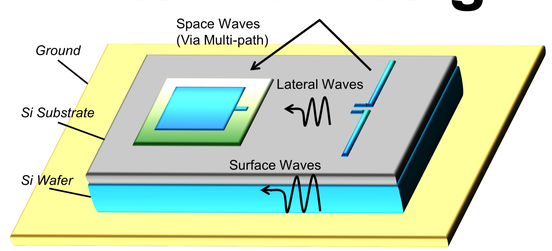


Fig. 7. Illustration of undesired TX-RX feedback via lateral, surface, and space waves that may cause injection pulling or self-oscillation.

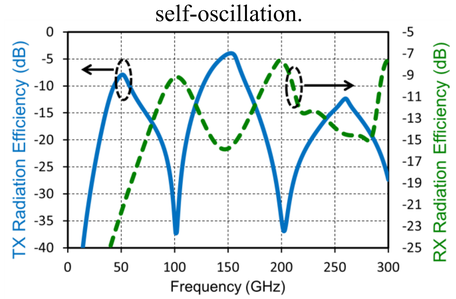


Fig. 8. Simulated efficiency of the TX dipole (solid) and the RX patch antenna (dashed). Orthogonal radiation efficiency reduces TX-RX coupling due to space waves.

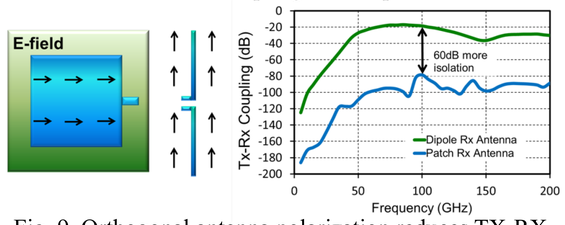
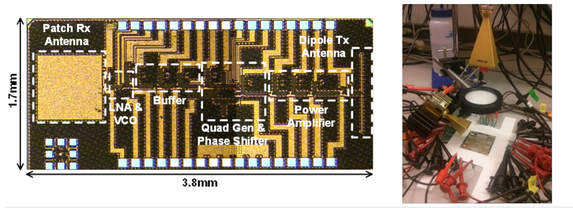


Fig. 9. Orthogonal antenna polarization reduces TX-RX coupling due to lateral and surface waves.

Measurements



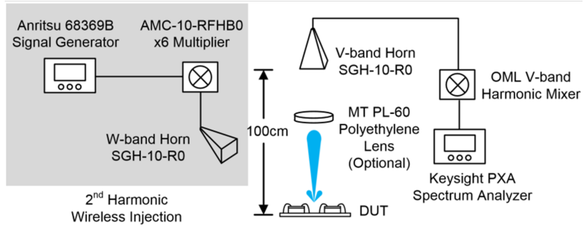


Fig. 10. Chip micrograph and measurement setup. Signal can be measured at 100cm without lens. The total radiated power is -5dBm and the received signal at the antenna is -23dBm.

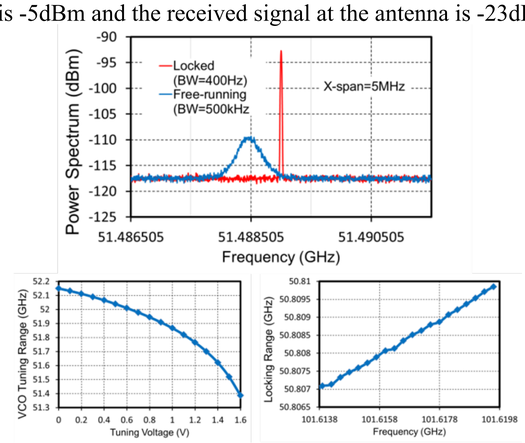


Fig. 11. Top: Spectrum of free-running vs. injection-locked transceiver. Bottom: VCO tuning and injection-locking range. The linear locking range demonstrates successful locking.

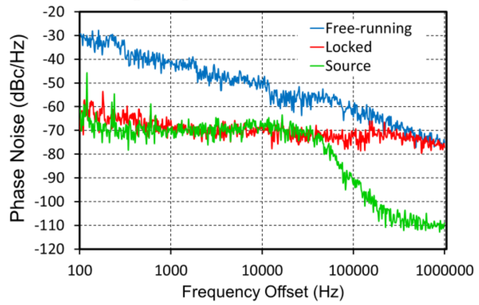


Fig. 12. Phase noise measurement results. The phase noise is reduced upon injection of the wireless signal (40dB at 100Hz offset, 23dB at 1kHz offset).