A Low-Loss Broadband Quadrature Signal Generation Technique for Highly Balanced Signals

Enabling efficient, wide bandwidth for mm-wave applications

This technology is a novel design for highly balanced quadrature signal generation on integrated circuits across millimeter (mm) wave frequencies. Georgia Tech's innovation enhances the phase and the amplitude matching of quadrature signals with lower insertion loss over broader bandwidth than is possible with conventional polyphase quadrature generation methods. The network also has reduced sensitivity to process variations compared to these methods, and each stage of the network enhances the image rejection ratio (IRR). These advances over other quadrature generation methods make it a promising solution for mm-wave applications, as it eliminates the need for extra calibration and tuning.

Georgia Tech's network employs two couplers to generate narrowband in-phase/quadrature (I/Q) signals, which are then applied to a quadrature-hybrid ring (QHR) that combines the signals and compensates their quadrature errors. This provides I/Q signals over a broad bandwidth. The network can cascade several QHR stages to provide more balanced I/Q signals. Phase matching at mm-wave frequencies is challenging, since any small length mismatch in the layout will introduce a large phase error. Therefore, a symmetric implementation is essential for providing highly balanced signals at these frequencies. Georgia Tech's innovation addresses this challenge with a design that features a common centroid layout for the QHR and the core transistors to provide accurate quadrature signals. Compared to available calibration techniques, this method is more efficient due to superior linearity, frequency scalability, design simplicity, and zero static-power consumption.

Summary Bullets

- **Superior**: Provides lower loss, wider bandwidth, better mismatch reduction, zero power consumption, and more balanced quadrature signals compared with other currently available technologies
- **Validated**: Achieves an average IRR of 37.5 dB across 40-76 GHz and 33.5 dB across 40-102 GHz, with each stage of the network enhancing IRR by approximately 8 dB in verification of proof-of-concept image-reject mixers
- **Convenient**: Eliminates the need for additional calibration and tuning and has reduced sensitivity to fabrication process variations

Solution Advantages

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- **Convenient**: Eliminates the need for additional calibration and tuning and has reduced sensitivity to fabrication process variations
- **High-speed**: Features a quadrature hybrid ring that can be tuned to any frequency, including mm-wave frequencies, enabling multi-Gb/second data rates
- **Platform-independent**: Can be implemented in any integrated circuits technology platform
- **Economical**: Has a smaller footprint and lower fabrication costs compared with other methods, in particular microwave transformer designs

Potential Commercial Applications

Georgia Tech's innovation is broadly applicable to any system requiring quadrature signals for operation at mm-wave frequencies as well as digital signal processing applications, such as:

- Wireless networks
- Next-generation communication systems (e.g., 5G cellular networks and integrated circuits)
- Digital communication systems
- Radar systems
- Time difference of arrival processing in radio direction finding schemes
- Coherent pulse measurement systems
- Antenna beamforming applications
- Single sideband modulators

Background and More Information

Wireless networks and next-generation mobile communication systems require broad bandwidths and high data rates. This is possible by migrating to mm-wave frequencies, making multi-Gb/second data rates feasible. Advanced modulation techniques are needed to obtain high spectral efficiency, which impose stringent requirements on the accuracy of the I/Q signal generation. From a system-level perspective, imbalances in the I/Q signals shift and degrade the I/Q constellation, leading to potential data corruption. Georgia Tech's innovation is a direct response to the demanding accuracy specifications required by mm-wave systems, with many advantages over other conventional methods.

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IP Status

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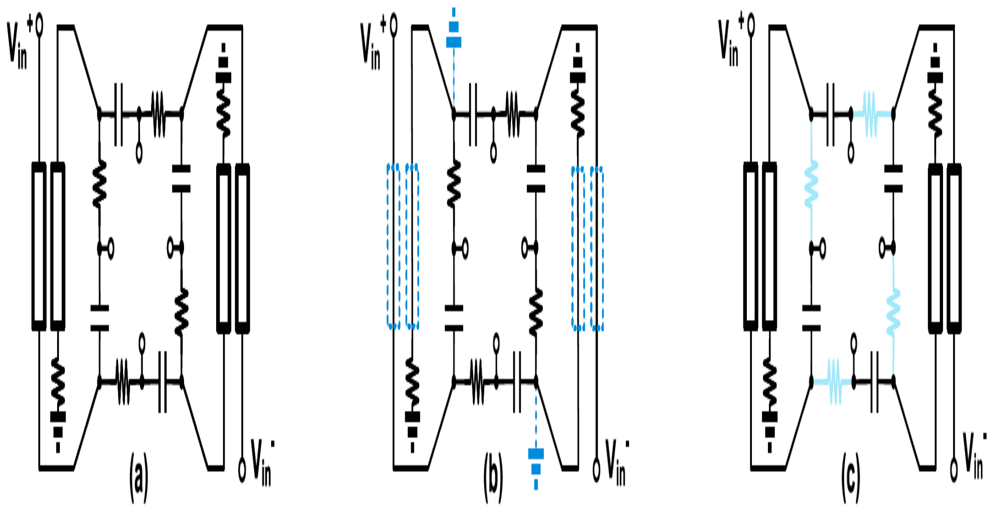
Publications

A Low-Loss Broadband Quadrature Signal Generation Network for High Image Rejection at Millimeter-Wave Frequencies, IEEE Transactions on Microwave Theory and Techniques - September 27, 2018

Images



(a) A simplified schematic of Georgia Tech’s dual-band quadrature signal generation network. (b) At low frequencies, the transmission lines of the coupled-line couplers are ideally short-circuited. (c) At high frequencies, the capacitances of the polyphase filters are ideally short-circuited.

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