# Rice IP for Wireless Communications

# (An Overview)

Rice Electronics is developing advances in wireless communications based on the IP Projects referenced at this site. This pertains to wireless systems and infrastructure including;

- Structures for High-Performance Modulation and Demodulation
- Structures for Unique Low-Power Waveform Encoding

A brief summary of these topics is presented below.

## Structures for Multi-Carrier Modulation/Demodulation

Many existing and evolving modulation/demodulation systems (such as 5G radio) are based on "multi-carrier" waveform formats. This includes OFDM and "OFDM-like" systems. Such systems employ intensive DFT and FFT computations. In particular, 5G systems may require FFT sizes as large as 4096 to 8192 points. At the same time, real-time processing bandwidth may reach 100s of Mhz. Conventional approaches to these requirements often consist of circuits composed of millions of transistors.

The Rice Processing IP provides unique solutions to these issues. It can address challenging 5G requirements with less than 10% of the complexity of traditional programmable or specialized processors.

The Rice Processing Architecture described at this site is capable of high-performance processing (e.g., FFTs) for modulation and demodulation in advanced OFDM systems. This is based on a processing "hierarchy" encompassing;

- an Architecture capable of large-scale (e.g. 4096 point) FFT execution where

- said Architecture consists of "DFT-like" building blocks, and

- said DFTs employ specialized multiplier structures

The Rice proprietary multipliers minimize complexity while maintaining performance. They achieve DFT multiplications (of 4 to 20 bit operands) with the equivalent of two to three addition operations, (while not using publicly known techniques such as "Cordic arithmetic" or "residue number systems"). The synchronous structures can render a product in typically 2 clock cycles.

Accordingly, for purposes of advanced modulation and demodulation functions, the Company's IP building blocks provide;

- Minimal Physical Complexity
- High Bandwidth/Performance
- Low Latency
- Scalability

Additionally, the flexibility and scalability of the Processing Architecture described at this site provides a foundation for future SDR and cognitive radio applications.

## Structures for Low Power Waveform Encoding

Spectral efficiency and power minimization are key drivers in the cost/performance of communications infrastructure. The Rice "Reduced Energy Encoding" IP (referenced at this site) can reduce power levels for various types of communication waveforms. The IP converts sequences of uniformly random data into sequences of non-uniform (e.g., Gaussian) data distribution.

The IP can be applied to QAM modulation for communications. It enables the mapping of arbitrary (e.g., random) sequences into QAM constellations, with up to 50% power reduction relative to conventional practices (as measured by ($I^2 + Q^2$) = sum of squares of QAM components).

For example, the IP may map 8-bit values into 256 level QAM states, with a resulting non-uniform distribution of these states. Power of the "IP-mapped" QAM sequences may be 50% less as compared to conventional direct data mapping to the QAM constellation. The proprietary combination of data encoding and constellation mapping can reduce power, with minimal reduction of channel capacity. As an example, mapping to the 256 level QAM may result in approximately 4% to 6% reduction of channel capacity.

As applied to OFDM waveforms, the Energy Reduction IP may be used for either “short” or “long” symbol generation. An example of the latter may be 5G radio systems employing symbols consisting of 100s or 1000s of orthogonally related “sub-carriers”. Each sub-carrier may be modulated by a unique QAM state. In this application, the Rice IP may be of particular value in controlling Peak-to-Average-Power-Ratios (PAPR) in the OFDM waveform. Reduction of average power and PAPR is critical to many aspects of wireless communication systems.

Accordingly, the unique IP can help optimize power features in wireless systems. Potential advantages include;

- Reduction of mutual interference in multi-user access environments
- Increased capacity in multi-user access systems
- Reduced average power and PAPR levels for various types of OFDM systems
- Extended battery life in compact and mobile communication platforms

In summary, the “Reduced Energy Encoding” IP provides structures and processes to enhance performance and physical aspects of numerous advanced communications systems.

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