Rice Electronics – 6G Network Focus

○ 6G promises extreme bandwidth, but its utilization requires new technology and approaches.

○ Novel Intellectual Properties (IP) will play a role in 6G evolution.

○ Rice Electronics is engaged in the development of unique 6G network concepts, and supportive IP.

○ Critical portions of the IP include waveform structure and digital processing, as introduced herein.

○ The IP has application to;

- Personal communications
- Autonomous vehicles
- Wireless Data Centers
- Robotics
- Factory environments

Addressing 6G Challenges

○ The Company's developments address key challenges in the evolution of 6G, including;

- Rapid connectivity and network responsiveness (low latency)
- High densities of fixed and /or mobile Users
- Cost and power constraints of small platforms (e.g., supporting the Internet-of-Things (IoT))
- Physical limitations of 6G operating frequencies (i.e., millimeter wave)

○ The Company's IP extends into the following areas;

- Network Architecture* ("Net-Architecture")
- Digital Signal Processing (DSP)
- Waveform Design and Methodology

- NOTE: The term "Net-Architecture" used herein, is distinct from the term "Processing Architecture" as may used in other documents concerning Rice Processing IP.

Net-Architecture IP

○ The Company's Net-Architecture embodies unique User sharing of frequency, time and space domains. It allows;

- High density of Users (both mobile & fixed)
- Direct point-to-point communication among Users
- "Pop-Up" connectivity among Users (ad-hoc, spontaneous, direct communication linkage)
- Low latency connectivity with minimal overhead from resource allocation, beam management, et. al. (microseconds instead of milliseconds)

○ Users can be Senders or Receivers

- Sender role can be either "uni-cast" or "multi-cast"
- Numerous simultaneous Senders supported
- Receivers can connect to multiple Senders

○ Net-Architecture enables dynamic, adaptive comms systems

○ Net-Architecture is enabled by Waveform and DSP elements of the Company's IP base

IP for 6G Applications

○ The Company's IP includes two critical technologies which enable the Net-Architecture, these are;

- The Digital Signal Processing (DSP) IP
- The Waveform IP

○ The DSP IP enables,

- Wide-band, high-precision digital processing
- Massively parallel DSP for 6G antenna array signal paths
- Orders-of-magnitude reduction of cost/complexity relative to conventional digital technologies

○ The Waveform IP facilitates,

- Reduced power consumption / longer battery life
- Extremely rapid response time and direct User-to-User connectivity
- High densities of fixed or mobile Users

DSP IP

- The DSP IP, in conjunction with the Company's proprietary Net -Architecture;
    - Achieves 100s of Mhz real-time bandwidths
    - Reduces circuit complexity by orders of magnitude for beamforming, modulation / demodulation, waveform generation
    - Enables precision, parallel digital processing in RF antenna paths of mmw antenna arrays
- The DSP IP;
    - Targets wide-band digital processing tasks near "RF front-end"
    - Drastically reduces digital multiplication circuits (a critical factor in cost, size, power of DSP circuitry)
    - Is a fundamentally different form of DSP mathematics (e.g., not Cordic or Residue arithmetic)

Waveform IP

○ The unique Waveform IP allows operation at low peak-to-average-power (PAPR) levels;

- Extending battery life in small platforms
- Reducing power levels of RF environment
- Reducing cost and complexity of power amplifiers, especially for small platforms

○ The Waveform IP is based on “noise-like” spread-spectrum signals;

- Providing for multi-domain User access
- Enhancing noise resistance

○ The IP includes specialized waveforms for;

- Communications
- Network Maintenance (e.g., synchronization, calibration)
- Sensing

DSP and Passive Sensing

○ The Net -Architecture concepts include massively parallel DSP IP for 6G communications, on fixed or mobile User platforms.

○ Such DSP capability can also be used in passive sensor processing at the User platform, broadening the utility of the Net-Architecture.

○ Passive sensing can take the following forms;

- Velocity sensing, via processing of specialized User waveforms (a cooperative User-to-User technique)
- "Bi-static radar" (processing of energy reflected from objects illuminated by external RF source)
- Image processing (manipulation of 2-D signals from User internal imaging sensors)