



## **NASA SBIR 2009 Phase I Solicitation**

### **01.04 Miniaturized Digital EVA Radio**

**Lead Center:** JSC

**Participating Center(s):** GRC

As NASA embarks upon deep space human exploration, the next-generation EVA radio will be a pivotal technology and integral part of lunar surface systems success. It will facilitate surface operations, enable crew mobility, and support point to multi-point communications across rovers, landers, habitat, and other astronauts. Driven by Communications, Command, Control, and Information (C3I) interoperability, tight power budgets, and extreme miniaturization, this mobile radio platform must be power efficient and highly adaptive. With a scant EVA radio power budget of less than four watts, the S-band (2.4 - 2.483 GHz) adaptive radio must deliver voice, telemetry, and high-definition motion imagery transmissions. To surmount interference, the radio must support frequency diversity over the specified S-band spectrum of 2.4 - 2.483 Ghz. During nominal operations, it is designed to operate with a mobile ad hoc network (MANET) so the coverage for communications can be extended indefinitely with node additions. It will communicate to fixed and mobile nodes, including lunar base stations, landers, habitats, rovers, and other astronauts. Therefore, it must support multiple bandwidths, waveforms, and energy profiles. To achieve the overarching communication goals of small form factor, ultra-power , and reconfigurability, NASA needs to extend the state-of-the art in two key areas:

#### **Tunable RF Front End and Transceiver**

The major impetus behind the MEMS technology stems from compactness which leads to lower power dissipation, higher levels of integration, lower weight, volume, and cost. To shrink form factor and enable efficient surface operations, one of the cornerstone radio components of this radio is the tunable filter. Recent advances in RF MEMs filters and resonator technology have permitted very high quality factors (>1000) at GHz frequencies. Achieving high and excellent tuning range (>2:1 ) to bandwidth ratio without cryogenic cooling is now viable for the S-band frequency. For reliability, the tunable filter should employ a contact-less tuning scheme.

Also, a new class of MEMS-based frequency synthesizers offers dramatic reduction in noise, power, and form factor. One should leverage emerging microscale resonator technologies to the maximum extent. Low phase noise synthesizers running at ultra low power levels are viable using high Q resonator technologies MEMS resonators-based phase lock loop offers compelling power and noise performance enhancements.

#### **Power-Aware Processing**

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To support QoS of different applications, it's not enough to optimize power at design time, but dynamic power management must be employed to ensure power efficiency. To maximum power efficiency, it must be able to adjust power and update rates to suit diverse missions. Users should be able to specify Quality of Service (QoS) for different data streams. The radio must have the capability to scale power, select the optimum mode of operation, and minimum energy profile. During low-rate-processing intensive modes, including local processing and compression of telemetry data and voice, highly energy-efficient low-voltage, low-performance modes must be used. For high-rate-processing intensive modes, like advance signal encoding of high motion imagery, medium performance modes must be used; and during active communication modes (which may have a low duty-cycle), ultra-high-performance modes must be used. Accordingly, the digital platform must be highly agile and use-case aware to continuously minimize energy. Below are the desirable technology features.

Bear in mind, research should be conducted to demonstrate technical feasibility during Phase 1 and to show a path towards a hardware and software demonstration unit or software package for NASA testing at the completion of the Phase 2 contract.

### Phase 1 Deliverables

Conduct design trade analyses between power, performance, and flexibility. Estimate mass, volume, power, max/min range, and data rates for dynamic quality of service- voice, telemetry, video- standard and high definition TV at S-band (2.4 - 2.483 GHz), backed with analyses and simulation to ensure achievable performance and power goals.

Develop a promising MEMS-based system-on-chip radio design with the following features:

- **Variation-tolerant, performance-scalable architectures:** Hardware must sense its own limitation at a dynamically varying, performance-driven optimal energy operating point, and reconfigure accordingly. If variability is stressed at the low-voltage operating point, redundant hardware should be used to improve reliability; if throughput is stressed at the high-performance operating point, redundant hardware should be used to increase parallelism.
- **Highly agile platform components (SRAM and logic):** Circuits should use functionality assists, including selective biasing, leakage-control, routine resources, etc., that get engaged dynamically depending on the operating point.
- **Energy-aware algorithms for adaptive hardware:** Algorithms must be aware of the different hardware operating-points and associated architecture. For instance, during low-power modes targeting voice and data (for telemetry), occasional high through-put applications (like high motion imagery) should dynamically switch to algorithms employing extreme parallelism in order to support a minimum operating voltage.
- **Extreme power converters:** To minimize off-chip components, DC-DC converters should use a single reconfigurable architecture that efficiently delivers load powers ranging from micro-Watts, at low-voltages, to Watts, at high voltages.
- **High performance ultra-low power ADCs:** Exploit novel ADCs with sampling frequencies in tunable multi GHz range (preferable double digits). Variable resolution up to 20 bits or higher with ultra-low power jitters for finer resolutions at higher bits and comparators managed for higher bits with minimum power overheads. A high sampling rate is desirable. SNR optimizations and efficient signal recovery demonstration is a requirement for validating ADC capabilities.

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- **Modularity and extensibility:** Enabling platform must support open architecture and accommodate rapid upgrades, multiple protocols, new technology advances, complete re-configurability of functionality, and evolution of lunar communications and network infrastructure.

One significant prerequisite to Phase 2 is the development of most promising MEMS-based transceiver system-on-chip (SoC) architecture. The offeror must demonstrate the ability to achieve significant advantage in compactness and ensure power efficiency and reliability.

### **Phase 2 Deliverables**

Develop a reliable, intelligent, and power-efficient MEMS-based EVA digital radio prototype unit, demonstrating robust and dynamic power management. The miniaturized radio technology must reach TRL=5 at the end of Phase 2.

Demonstrate RF performance and power consumption of less than four watts, delivering voice, telemetry, and standard and high-definition video motion imagery at 2.4 - 2.483 GHz (S-band). With power constraints of under four watts, performance and reliability must be assured for multiple bandwidths and data transmissions of telemetry, voice, and high-rate video.