NASA SBIR 2008 Phase I Solicitation

O1.04 Miniaturized Digital EVA Radio

Lead Center: JSC

Participating Center(s): GRC

Lunar outpost surface operations pose unique challenges that demand a compact, power-efficient, and adaptive S-band EVA digital radio with built-in navigation capability. High-performance criteria, tight power constraints, and multi-mode functionality are making mobile terminals increasingly complex. Therefore, NASA needs to advance next-generation digital radio technologies to meet the stringent demands of ultra low power, high reliability, and small form factor. More than a conventional system, the EVA radio infrastructure supports relative navigation, high resolution image processing, voice encoding, networked based IP communications, and dynamic quality of service. By leveraging RF micro-electromechanical system (MEM) components, intelligent middleware, and location aided networking, this solicitation aims to reach TRL 5 by 2012 with breakthrough radio metrics- less than four watts of total power consumption and cell-phone sized form factor.

Operating at 2.4-2.483 GHz (S-band), the digital radio must support multiple bandwidth and data transmissions of voice, telemetry, and video- standard as well as high definition- to fixed and mobile assets, including lunar base station, landers, habitat, rovers, and other astronauts.

To extend battery life, the EVA digital radio must incorporate middleware that optimizes power needed to maintain link quality. Under harsh lunar environmental conditions, the cognitive middleware must optimally match the QoS requirement, the channel condition, and the interference environment as well as select the mode with the least energy profile for power efficiency. As a result, this EVA radio must dynamically and adaptively conserve power on a packet-by-packet basis.

During contingency mode, EVA digital radio will transmit voice and data in half-duplex mode. With novel wireless communication network concepts, the offeror should propose solutions to enable position determination and relative navigation out to a distance of 10km with accuracy of 100 meters (3 sigma).

The Phase 1 effort defines an ultra low-power, high-performance, compact digital radio that incorporates innovative components and novel approaches to meet the above requirements for a single fault tolerant architecture. To achieve dramatic reductions in power and volume, solutions must exploit MEMS for cell phones and handheld (e.g., MEM filters, tunable matching elements, etc.) and other advanced analog/digital components, advanced digital signal processing, as well as next-generation processing elements such as FPGAs and multi-core processors.

Moreover, one must select a promising modular candidate architecture for the above requirements, exploiting emerging commercial wireless network technologies such as WLAN and WWAN. This encompasses identifying transceiver hardware, firmware, and all platform integration issues.

For this solicitation, one can assume EVA digital radio will be part of a mobile ad hoc network infrastructure that is self-configuring, self-discovering, and self-healing. Where all nodes can act as routers for other low power mobile nodes and network coverage has no limit for wireless communications. In other words, the diameter of the network can be increased by adding more nodes.

Research should be conducted to demonstrate technical feasibility during Phase 1 and show a path toward Phase 2 hardware and software demonstration and delivering a demonstration unit or software package for NASA testing at the completion of the Phase 2 contract.

Phase 1 Deliverables:

Conduct design tradeoffs 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 including lunar propagation effects and comprehensive simulations to ensure achievable performance and power goals. Consider IP voice as an optional feature.

As a prerequisite to Phase 2, one must select a promising architecture that balances ultra low power, mass, size, performance, functionality, and reliability. In fact, the offeror must demonstrate the ability to achieve significant advantages in compactness over a non-MEMS approach and address power efficiency and reliability. Special interests include single-chip design/packaging and integrated circuit-level implemenation of RF MEMS.

Propose a preliminary design approach for the next-generation digital EVA radio, leveraging commercial multimedia cellular and WLAN technology. Operating at S-band (2.4- 2.483 GHz), MEM filters should be considered to achieve low power consumption and compact, cell-phone sized form factor. Determine the suitability and usage of ultra low power digital devices, compact RF systems, and novel configurations when recommending candidate architectures.

For the middleware, conduct trade-offs and identify the set of required parameters for the ideal radio. Quantify performance in terms of energy savings and the ability to maximize connectivity and throughput in an ad hoc network.

Develop communications and 3D navigation tracking ad hoc network concepts and algorithms that validate the feasibility of the approach. Without GPS, integrated low-power communication and navigation surface assets must track, locate, and identify tagging assets with multiple routes over an operational range of 10 km, even if astronauts descend into craters. Assume the availability of digital terrain maps. Consider low-power approaches that exploit bread crumbs, active/passive RFID systems for ID, position, sensing, etc and expand investigation to modulated retroreflectors based upon MEMS technology or solar-powered beacons.

Simulate the performance of a robust integrated communications and navigation network architecture and conduct preliminary sensitivity analysis for parameterization of the selected implementation strategy. Specifically, describe the division of functionalities between the various components (fixed and mobile) as well as segments (inter-vehicle and mobile-to-fixed node on planetary surface as well as surface-to-orbit (lunar relay satellites).

Phase 2 Deliverables:

Demonstrate RF performance and total 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). Within power budget allocation, verify performance and reliability for multiple bandwidth and data transmissions of telemetry, voice, and high-rate video.

Develop a reliable, intelligent, and power-efficient EVA digital radio prototype unit and demonstrate robust power management and optimization feasibility of the Phase 2 middleware and ad hoc network approach.

Explore radiometric tracking techniques and benefits from location-aided networking to support (limited) relative navigation using an ad hoc network infrastructure during EVA walkback. Moreover, a simulation capability must demonstrate node discovery, location awareness, and route re-configurability as nodes enter and leave the network. Testing will be conducted at an approved site and should comprise of a variety of nodes (fixed and mobile) as well as a suite of applications (non-real time data as well as real-time voice and video).

Develop and demonstrate a working ad hoc network prototype that allows characterization of the following metrics in a static deployment: a) network range, b) aggregate throughput and throughput per user, and c) node and network lifetime.

Deliver open middleware and supporting IP solutions.

Where costs preclude full implementation of all component technologies, provide analysis to extrapolate the performance of a complete design.

Commercial Potential:

Adaptive radios potentially offer significant cost savings to a wide spectrum of commercial markets including telecommunications and consumer electronics. They also provide for enhanced interoperability and spectrum reuse for Homeland Security applications. New component technologies and radio infrastructures are needed to extend the programmable capabilities into long battery life handsets.