NASA SBIR 2008 Phase I Solicitation

O1.02 Antenna Technology

Lead Center: GRC

Participating Center(s): ARC, GSFC, JPL, JSC, LaRC

NASA seeks advanced antenna systems in the following areas: phased array antennas; ground-based uplink antenna array designs; high-efficiency, miniature antennas; smart, reconfigurable antennas; large aperture inflatable/deployable antennas; and antenna adaptive beam correction with pointing control.

Phased Array Antennas

Low cost phased array antennas are needed to enable communication capabilities in the following areas: lunar and planetary exploration, including links between astronauts, landers, habitats, probes, orbiters, suborbital vehicles such as sounding rockets, balloons, unmanned aerial vehicles (UAV's), and expendable launch vehicles (ELV's). The frequencies of interest are S-, X-, Ku-, and Ka-band.

The arrays are required to be aerodynamic or conformal in shape for sounding rockets, UAV's, and expendable platforms. They must also be able to withstand the launch environment. The balloon vehicles communicate primarily with TDRS and can tolerate a wide range of mechanical dimensions. The main challenges to be addressed are low mass, low cost, high power efficiency (i.e., > 40%), and coverage area (i.e., highly steerable). A significant cost reduction for MMIC based arrays is highly desirable. (Typical NRE is ~ $1000.00/element.) Advances in digital beam-forming techniques, including those based on superconducting digital signal processing methods, are also desirable. The expected exit technology readiness level (TRL) is 4.

Ground-based Uplink Antenna Array Designs

NASA is considering arrays of ground-based antennas to increase capacity and system flexibility, to reduce reliance on large antennas and high operating costs, and eliminate single point of failure of large antennas. A large number of smaller antennas arrayed together results in a scalable, evolvable system which enables a flexible schedule and support for more simultaneous missions. Some concepts currently under consideration are the development of medium-size (12-m class) antennas (hundreds of them are expected to be required) for transmit/receive (Tx/Rx) ground-based arrays. A significant challenge is the implementation of an array for transmitting (uplinking), which may or may not use the same antennas that are used for receiving. The uplink frequency will be in the 7.1-8.6 GHz range (X-band) in the near term, and may be higher frequencies in in the future; it will likely carry digital modulation at rates from 10 kbps to 30 Mbps. An EIRP of at least 500 GW is required, and some applications contemplate an EIRP as high as 10 TW. A major challenges in the uplink array design is minimizing the life-cycle cost of an array.

Other challenges for ground-based antennas include the development of low cost, reliable components for critical antenna systems; advanced, ultra-phase-stable electronics, and phase calibration techniques; improved understanding of atmospheric effects on signal coherence; and integrated low-noise receiver-transmitter technology. Phase calibration techniques needed to ensure coherent addition of the signals from individual antennas at the spacecraft are also required. It is important to understand whether space-based techniques are required or ground-based techniques are adequate. In general, a target spacecraft in deep space cannot be used for calibration because of the long round-trip communication delay.

Design of ultra-phase-stable electronics to maintain the relative phase among antennas is also needed . These will minimize the need for continuous, extensive and/or disruptive calibrations. A primary related effort currently underway is understanding the effect of the medium (primarily the Earth's troposphere) on the coherence of the signals at the target spacecraft. Generally, turbulence in the medium tends to disrupt the coherence in a way that is time-dependent and site-dependent. A quantitative understanding of these effects is needed. Consequently, techniques for integrating a very low-noise, cryogenically cooled receiver with a medium power (1-200 W) transmitter, are desired . If transmitters and receivers are combined on the same antenna, the performance of each should be compromised as little as possible, and the low cost and high reliability should be maintained.

Under the ground-based antenna area, the exit TRL should be greater than or equal to 4.

High-Efficiency, Miniature Antennas

High efficiency, low-cost, low-weight, miniaturized antennas that are wearable antennas or can be highly integrated into the structure. Example of EVA's space suits made with textile antennas or visor mounted antennas. The antennas may be fractal antennas but also multi-directional to support astronaut mobility, multiband operation and/or broad bandwidth. Antennas should be low/self-powered, small, and efficient, and compatible with communication equipment that can provide high data rate coverage at short ranges (~1.5-3 km, horizon for the Moon for EVA). In-situ low-gain antenna (UHF or X-band) that provide circular polarization with full hemispherical coverage (zenith as well as over the horizon) are desirable.

Smart, Reconfigurable Antennas

NASA is interested in smart, reconfigurable antennas for applications in lunar and planetary operations. The characteristics to consider include the frequency, polarization, and the radiation pattern. Low-cost approaches are encouraged to reduce the number of antenna apertures needed to meet the requirements associated with lunar and planetary surface exploration (e.g., rovers, pressurized surface vehicles, habitats, etc.). Desirable features include multibeam operation to support connectivity to different communication nodes on lunar and planetary surfaces or in support of communication links for satellite relays around planetary orbits. Also the antenna shall be highly directive, multi-frequency and compatible with Multiple Input Multiple Output (MIMO) concept.

The exit TRL should be 4.

Large Aperture Inflatable/Deployable Antennas

Large deployable or inflatable membrane antennas to significantly reduce stowage volume (packaging efficiencies as high as 50:1), provide high deployment reliability, and significantly reduced mass density (i.e., < 1kg/square meter) are needed. These large Gossamer-like antennas are required to provide high-capacity communication links with low fabrication costs from the Moon/Mars surface to relay satellites or Earth. These membrane antennas are deployed from a small package via some inflation mechanism. Techniques for rigidizing these membrane antennas without the use of gases (e.g., ultraviolet curing), as well as thin-membrane tensioning and support techniques to achieve precision and wrinkle-free surfaces, in particular for applications at Ka-band or higher frequencies is desirable.

Novel materials (including memory matrix materials), low fabrication costs and deployment and construction methods using low emissivity materials to enable passive microwave instrument application are also beneficial. Structural health monitoring systems, needed to support pre-flight integration / test activities and determine health of system in-flight, are of interest. The challenge is to generate designs incorporating structural considerations (e.g., aero-braking for deep space planetary missions).

Antenna Adaptive Beam Correction with Pointing Control

Antenna adaptive beam correction with pointing control that can provide spacecraft knowledge with fine beam pointing with sub-milliradian precision (e.g., < 250 micro-radians) in order to point large spacecraft antennas (e.g., 10-m diameter) in Mars' vicinity is also desirable under this subtopic. The challenges include reduced antenna reflector surface distortions in a space environment; compensation techniques to optimize antenna beam patterns; ground- and space-based methods to monitor spacecraft antenna distortions; and advanced technologies that enable antenna pointing accuracies in the sub-milliradian range for Ka-band spacecraft applications. Methods of dealing with extreme latency (e.g., 20 minutes) in beacon and monopulse systems are of interest. Advances would lead to enhanced space communication links. The resulting developments should be at TRL 4. Size weight and power requirements are of concern.

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.

Development Timeline: After a possible Phase 3 development activity, these technologies are expected to ready for insertion at TRL 6 by 2014. Therefore a TRL progression from an entry TRL of 1-2 for Phase 1 in January 2009 followed by an exit TRL of 3 - 4 after Phase 2 is reasonable.

Phase 1 Deliverables:Â A final report containing optimal design for the technology concept including feasibility of concept, a detailed path towards Phase 2 hardware and/or software demonstration. The report shall also provide options for potential Phase 3 funding from other government agencies (OGA).

Phase 2 Deliverables:Â A working proof-of-concept demonstrated and delivered to NASA for testing and verification.

The proposer to this subtopic is advised that the products proposed may be included in a future small satellite flight opportunity. Please see the SMD Topic S4 on Small Satellites for details regarding those opportunities. If the proposer would like to have their proposal considered for flight in the small satellite program, the proposal should state such and recommend a pathway for that possibility.