NASA SBIR 2009 Phase I Solicitation

O1.02 Antenna Technology

Lead Center: GRC

Participating Center(s): AFRC, 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; antenna adaptive beam correction with pointing control; parallelized numerical solvers for antenna modeling and design; and communication antennas with improved performance.

Phased Array Antennas

High performance phased array antennas are needed for (1) high-data rate communication and (2) remote sensing applications. The frequencies of interest are P-, L-, C-, S-, X-, Ku-, Ka-, and W-band. Potential communications applications include: lunar and planetary exploration, landers, probes, Lunar Relay Satellites, lunar rovers, lunar habitats, lunar surface EVA, suborbital vehicles, sounding rockets, balloons, unmanned aerial vehicles (UAV's), TDRSS communication, and expendable launch vehicles (ELV's). Potential remote sensing applications include: radiometers, passive radar interferometer platforms, and synthetic aperture radar (SAR) platforms for planetary science.

Multi-band phased array technology such as S- and Ka-band phased array antennas, which can dynamically reconfigure active element coupling in order to operate in either band as required in order to maximize flexibility, efficiency and minimize the mass of hardware delivered to the moon for lunar surface system operations, are of interest. The goal is to maximize flexibility and capability to share lunar communications infrastructure and therefore minimize mass of radio components that must to be delivered to the lunar surface.

There is also a high interest in developing phased array antennas for space-based range applications to accommodate dynamic maneuvers.

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/tradeoffs to be addressed are achieving low mass, low cost, high power efficiency, thermal stability of active array electronics, and coverage area (i.e., highly steerable arrays). Active arrays with features such as T/R module self-calibration for thermal stability, true time delay (TTD), low-cost highly-integrated MMIC-based T/R modules (e.g., SiGe/GaAs technology), multiple beam-forming capability, low-loss feeds for radiometer applications are also of interest. Advances in digital beam-forming techniques, including those based on superconducting digital signal processing methods, are also desirable.

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 at higher frequencies 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 challenge 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 if 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.

High-Efficiency, Miniature Antennas

High efficiency, low-cost, low-mass, broadband or dual-band miniaturized antennas (UHF or X-band) that radiate circular polarization with full hemispherical coverage are desirable. These antennas must be able to withstand launch and re-entry environments and must be low profile/conformal.

The emergence of frequency-agile radios increases emphasis of antenna capable of bidirectional communications across multiple bands. Accordingly, emphasis on small size, high efficiency and low cost of ownership is desirable. Miniaturization of L-, S-, and C- band for Micro Air Vehicles is also of interest.

Miniaturized antennas that are wearable or can be highly integrated into the host structure/entity, are also desirable. Examples include EVA's space suits made with textile antennas, fractal antennas, or visor mounted antennas. These miniaturized antennas should also be multi-directional to support astronaut mobility, support multi-band operation, and/or possess a 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).

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 multi-beam 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. The antenna shall also be highly directive, multi-frequency and compatible with the Multiple Input Multiple Output (MIMO) concept.

Large Aperture Inflatable/Deployable Antennas

Large aperture inflatable/deployable 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.,

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

Membrane materials for large inflatable membrane antennas for remote sensing applications for earth and planetary science missions are of particular interest to the Science Mission Directorate. The current state of the art for mechanical deployable antennas is reaching limits on packaging efficiencies. Reflectors manufactured from polymer films could enable greater packaging efficiencies due to their low mass, high packaging efficiencies, solar radiation resistance, and cryogenic flexibility. However, most polymer films, including polyimide polymer films, have many challenges that limit their usefulness in practical space applications. Active membrane control system concepts, developed to reduce shape errors, often add unwanted bulk and mass to the antenna system. While other concepts will be entertained, specific membrane material technology innovations of interest are listed below:

- Polymer membrane (0.5 mil to 2.0 mil) material exhibiting zero or near-zero Coefficient of Thermal Expansion (CTE).
- Polymer membrane material exhibiting durability to the space environment, including atomic oxygen, VUV, solar particulate radiation, and temperature extremes.
- Thin film deployment methods that deploy the antenna surface substantially free of wrinkles.

- Innovative intrinsically electroactive polymer membrane actuation mechanisms that can be used to shape-correct the antenna surface.

Additionally, composite materials for large deployable antenna reflector structures for remote sensing applications for earth and planetary science missions with high specific stiffness composite materials that can be packed compactly and deployed multiple times for ground evaluation of the antenna structure prior to launch and deployment in space are of interest. Investigators should consider materials that can be folded and deployed on the order of 5 to 10 times with up to 180 degree bends that retain their structural integrity and shape accuracy upon final deployment. The deployment of these materials should require low energy. Rigidizable materials (Shape Memory Polymers, Shape Memory Composites, UV Activated Composites, etc.) could be considered to obtain the appropriate structural stiffness and post-deployment precision.

Prospective proposers are advised to review Subtopic S1.02, Active Microwave Technologies, for additional remote sensing applications needs, and indicate applicability in their proposal(s).

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.,

Parallelized Numerical Solvers for Antenna Modeling/Design

Development of full 3-D electromagnetic (EM) solvers that take advantage of new software engineering approaches (e.g., object oriented programming) and parallel computing resources for fast and accurate modeling/design of antennas, antennas with feed structures, and antennas in multi-path environment are of interest. Numerical solvers offering fast and accurate synthesis via search algorithms (e.g., genetic algorithm) of patch arrays and waveguide slot arrays, to reduce design time, are also of interest. All solvers must aim toward experimental validation of actual antenna concept being simulated.

Communication Antennas with Improved Performance

High performance, low-cost antennas are needed for a variety of missions for communicating with TDRSS, GPS (L1, L2, and L5 bands), or the Deep Space Network (DSN). The frequency bands of interest are L-, S-, X-, Ku-, and Ka-band. Antenna concepts that offer significant improvement in cost and performance (e.g., mass, gain, efficiency, VSWR, axial ratio, bandwidth, power handling, vibration tolerance, etc.) over existing off-the-shelf antennas would be of interest. Novel isoflux antennas at S- and X-band would also be of interest. Antennas must be able to withstand launch environments.

Deliverables and Development Timeline

After a possible Phase 3 development activity, these technologies are expected to ready for insertion at TRL 6 by 2015. Therefore a TRL progression from an entry TRL of 1 - 2 for Phase 1 in January 2010 followed by an exit TRL of 3 - 4 after Phase 2 is reasonable.

For all above technologies, 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

A final report containing optimal design for the technology concept including feasibility of concept and 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

A working proof-of-concept demonstrated and delivered to NASA for testing and verification.