NASA SBIR 2006 Phase I Solicitation

O1.04  Antenna Technology for Spacecraft and Planetary Surface Vehicles

Lead Center: GRC

Participating Center(s): GSFC, JPL, LaRC

NASA seeks advanced antenna systems for use in spacecraft and planetary surface vehicles used in science, exploration systems, and space operations missions. Future manned missions to the Moon and Mars will have stringent communication requirements. Highly robust communication networks will be established in the vicinity of the planet to support long-term human interplanetary mission. Such networks will consist of a large number of communication links that connect the various network nodes. Some of these nodes must also maintain continuous high data rate communication links between the moon and the Earth. Great demands will be placed on these communication systems to assure crew safety, robustness in harsh environments, and high reliability for long duration manned missions.

Areas of interest include lightweight deployable antenna systems, high-gain antenna architectures, multi-frequency and dual polarized antennas, self-orienting systems, reconfigurable antennas, novel concepts, antennas that can adapt to failed components without compromising performance and operability (e.g., smart antennas that include structural health monitoring and active control). NASA seeks to develop a lightweight scanning phased array antenna system that enables assured communication links for human interplanetary exploration.

NASA is also interested in technologies enabling direct conversion of RF signals to digital and advanced concepts wherein such systems are integrated with novel smart antenna concepts to allow true interoperability and reconfigurability in the sense of software radios.

Antenna systems for novel navigation concepts (e.g. pulsar beacons) as well as integrated communications and navigation architectures are desirable.

Large inflatable membrane antennas to significantly reduce stowage volume, provide high deployment reliability, and significantly reduced mass (i.e.

High efficient, miniature antennas with smaller than lambda square aperture size, to provide astronauts and robotics communications for surface to surface and surface to orbit for lunar, Mars, and planetary exploration missions. Recent new antenna research and development has shown that it is possible to design and build
aperture antennas with smaller than the minimum effective apertures size of dipoles. This new class of antennas can provide higher antenna gains (> 2.5 dBi) than the dipole antenna in much smaller aperture size (\(d<2\))

The architecture for lunar exploration as defined by the Space Communication Architecture Working Group (SCAWG) is expected to involve a layered communications and navigation network. This network may include lunar vicinity relay satellites at L1 and L2 Lagrange points as well as lunar polar orbiting satellites. The lunar proximity network must be able to access dedicated assets such as Malapert Station and eventually include human assets, such as crewed rovers, as relay nodes. Consequently there is an interest in antenna technologies that enable low cost but reliable reconfigurable and agile antennas at frequencies up to 38 GHz. Another component technology that shows high interest in the area of Earth and planet science is thin-membrane mountable T/R modules, phase shifters, beam former, control circuitry, etc. for future deployable/inflatable large-aperture phased array application. This topic seeks novel smart antenna concepts to address the aforementioned requirements.

There is also interest in space-to-surface links at 25.5 GHz and 37 GHz. The size of reflector antennas is limited by the accuracy of the reflector surface that can be achieved and maintained on-orbit. Development of special materials and structural techniques to control their environment, etc., reduces environmentally induced surface errors and increases the maximum useable reflector size. Distortions caused by thermal gradients are inherently a large scale phenomenon. The reflector surface is usually sufficiently accurate over substantially large local areas but these areas are not on the same desired parabolic surface. An array of feed elements can be designed to illuminate the reflector with a distorted spherical wave. This distortion can be used to compensate for large scale surface error introduced by thermal gradients, gravitational and other forces, and manufacturing. Topics of interest include but are not limited to: Compensating Feed System for an Antenna Reflector Surface With Large Scale Distortions; Techniques for the remote Measurement of Satellite Antenna Profile Errors; Determination of Orbiting S/C Antenna Distortion by Ground-Based Measurements; Measuring and Compensating Antenna Thermal Distortions; Reflector Measurements and Corrections using arrays; Reflector Distortion Measurement and Compensation Using Array Feeds.

NASA is interested in low cost phased array antennas for suborbital vehicles such as sounding rockets, balloons, UAV’s, and expendable vehicles. The frequencies of interest are S-band, Ku-band, and Ka-band. The arrays are required to be aerodynamic in shape for the sounding rockets, UAV’s, and expendable platforms. The balloon vehicles primarily communicate with TDRS and can tolerate a wide range of mechanical dimensions.

Antenna pointing techniques and technologies for Ka-band spacecraft antennas that can provide spacecraft knowledge with sub-milliradian precision (e.g.,

NASA is designing arrays of ground-based antennas to serve the telecommunications needs of future space exploration. Medium-size (12m class) antennas have been selected for receiving, and arrays of hundreds of them are expected to be required. Applications include communication with distant spacecraft; radar studies of solar system objects; radio astronomy; and perhaps other scientific uses. 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 band (X-band) in the near term and may be in the 31.5 - 33.0 GHz band (Ka-Band) 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. It is also desirable to support as many as ten simultaneously-operating deep-space missions from one complex on Earth, and to have at least three geographically separated complexes so communication is possible with a given spacecraft at any time of the day. The major open questions in the uplink array design are:
Minimizing the life-cycle cost of an array that produces a given EIRP by selecting the optimum combination of antenna size, transmitter power, and number of antennas. This becomes much more difficult if the option of using the same antenna for both uplink and downlink is considered;

Identifying/developing low-cost, highly reliable, easily serviceable components for key systems. This could include highly integrated RF and digital signal processing electronics, including mixed-signal ASICs. It could also include low-cost, high-volume antenna manufacturing techniques. (For the receiving array, another key component is a cryogenic refrigerator for the 15 - 25K range.) Also, low-cost transmitters (including medium-power of the order of 100s of Watts) amplifiers are key;

Phase calibration techniques are required to ensure coherent addition of the signals from individual antennas at the spacecraft. 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. These will minimize the need for continuous, extensive and/or disruptive calibrations;

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 this is needed; and

Techniques for integrating a very low-noise, cryogenically-cooled receiver with medium power (1W to 200W) transmitter. If transmitting and receiving are combined on the same antenna, the performance of each should be compromised as little as possible while maintaining low cost and high reliability.

Research should be conducted to demonstrate technical feasibility during Phase 1 and show a path toward a Phase 2 hardware demonstration that will, when appropriate, deliver a demonstration unit for testing at the completion of the Phase 2 contract.