1.0 TECHNOLOGY NAME: X-Band Phased Array Antenna (XPAA)

2.0 SPONSORSHIP:

2.1 IPDT SPONSOR: NMP Communications IPDT

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3.0 OVERVIEW

Phased array antennas with electronically scanned beams and associated high-efficiency RF power amplifiers are seen as a solution to the problems associated with providing high gain for science downlinks without the deployable structures, moving parts and torque disturbances that are associated with current mechanically steered high-gain antennas. They are seen as particularly applicable to NASA's new generation of small yet highly capable science spacecraft. Phased arrays of this type and for the communications application have not flown in space before.

Necessary validation of this technology goes beyond the demonstration that the hardware will perform in space. The significant benefits of phased arrays, besides reducing spacecraft impacts of flying high performance communications links, involve operational benefits of simultaneous instrument data collection and downlink communication, reduced contact times and minimized ground station requirements, as well as reduced I&T costs due to the elimination of articulating mechanisms. In sum, these benefits have the potential for major cost savings during the life cycle of a mission.

The phased array technology proposed here is based on an aeronautical system that has significantly different operating environment than that of space. Space flight testing and validation is crucial to the adoption of this potentially high payoff/low cost technology. The proof of this saving in its totality requires space flight demonstration.

4.0 INTRODUCTION

When compared to many past and current missions, future science spacecraft (for which NMP/EO-1 is a pathfinder) will be extremely compact, and will have limited resources available in terms of weight, space, and DC power for the communications subsystem. Despite their small size, these spacecraft will generate ever increasing volumes of science data (NMP/EO-1 will generate upwards of 40 Gb/day) which must be returned to Earth. It is also anticipated that increasing numbers of end users such as universities will desire direct access to spacecraft instruments using low-cost ground stations, which will increase the burden on the spacecraft end of the communications link.

This departure from past methods necessitates a re-evaluation of all aspects of the mission, including the enabling space and ground communications systems. One part of this re-evaluation concerns the use of higher frequency band systems that will represent a major shift in NASA's space communications frequencies. Future science spacecraft will require peak data rates of tens to hundreds of megabits/second, which must be accomplished with high-gain onboard antennas of a size dictated by the small dimensions of the small spacecraft. These size restrictions and the increasing international competition for RF spectrum will ultimately force all users to utilize current allocations more efficiently and develop the technology to use frequencies such as X-band (8 GHz) and Ka-band (25-27 GHz).

5.0 TECHNOLOGY DESCRIPTION

The phased array antenna system (XPAA) will provide an additional high data rate channel for the return of science data.

The antenna for this application is composed of a flat grid of many radiating elements whose transmitted signals combine spatially to produce the desire antenna directivity (gain). The phases of each of these radiating elements is varied by computer to point its beam in the desired direction. This antenna takes the place of the traditional parabolic antenna, which is used on many satellites. For EO-1, the radiating elements are combined with low power, high-efficiency solid sate amplifiers (as mentioned above) to achieve the required RF power output level. The antenna is nadir mounted to allow communications with ground stations.

Engineering model phased array designs currently existing at Boeing Defense and Space Group (Seattle, WA) are used as the baseline for a flight phased array having 64 elements and an effective isotropic radiated power of not less than 22 dBW. This Boeing effort as a part of the Communications IPDT uses existing element module GaAs MMIC designs as well as existing basic designs for element modules and the overall antenna. Interfaces are a low level modulated X-band excitation, 28 Vdc power, and 1773 command and telemetry interface using a Government furnished Essential Services Node (ESN).

Mechanical designs are modified as required for the spacecraft thermal and vibration environment.

This approach does not directly affect or detract from the existing S-band approach as it provides an additional communication channel. X-band modulation and excitation functions are required in addition to the IPDT supplied XPAA. The hardware to implement these functions is supplied by the spacecraft mission team. The low-level X-band signal from the exciter is fed to the phased array via a coaxial cable where it is amplified and radiated. The higher gain of the phased array as compared to the S-band system enables operational quality communications links to the proposed Spitzbergen ground station at rates of 105 Mbps.

6.0 VALIDATION OBJECTIVES

6.1 Validate the communications link error performance of this type of phased array. Phased arrays are unique in that they cause phase disturbances in the emitted signal whenever the beam position is changed. This disturbance has the potential to cause errors in received data, and can be corrected by appropriate error correction coding of the data. This objective will also validate whether the error correction coding used by NMP/EO-1 is adequate for the task of correcting phased array induced errors as well as those caused by atmospherics, RF interference and other traditional sources.

6.1.1 Required data/measurements: Measurement and tabulation of basic bit error rate (BER) and error burst length data during science downlinks. No validation unique transmission are required for this validation.

6.1.2 Approach: Bit error statistics resulting from normal ground operations using Reed Solomon coding will be evaluated for degradation over time. On occasion, the IPDT will ask that corrected and uncorrected Reed Solomon frames be compared to yield bit and burst error positions as well as basic BER. I&T measurements of burst and bit error statistics will be compared with ground station measurements taken over the life of the mission.

6.1.3 Anticipated Results: Degradation in bit and burst error performance of the communications link, (if any), will be assessed and documented. In particular, the unique effects of phased array antenna scanning on bit errors will be evaluated.

6.1.4 Supporting I&T Data: Error performance while transmitting data under scan will be performed on engineering models and the flight unit, probably at the Lewis Research Center in Cleveland, OH, before delivery of the flight unit to the spacecraft team.

6.1.5 Rationale: Validation results will show the on-orbit bit and burst error performance of the Boeing phased array. This data addresses issues that are fundamental to all phased arrays used in a communications application.

6.2 Validate the antenna pattern scan performance of the phased array. Phased arrays are unique in that the antenna gain and EIRP change with pointing angle. It must be shown that this performance can be reliably predicted and maintained during the life of a mission.

6.2.1 Required data/measurements: Main lobe antenna gain measurements taken on the ground and in space.

6.2.2 Approach: Ground measurements of antenna scan performance taken during manufacture will be compared with relative measurements made at the ground station while the spacecraft is on orbit, at several times during the mission lifetime.

6.2.3 Anticipated Results: Ability of the antenna to maintain design scan performance over the mission lifetime will be verified. Anomalies in this data will be indicative of hardware or software degradation on the array in space and used to diagnose the source.

6.2.4 Supporting I&T Data: Antenna pattern measurements made and documented during acceptance testing at the contractor facility.

6.2.5 Rationale: Validation results will show the on-orbit scan performance of the Boeing phased array.

6.3 Validate the performance and reliability of the software and controller of the array in the space environment.

6.3.1 Required data/measurements: Results of self test diagnostics associated with the antenna controller, as well as confirmation of commands received by the array and those sent to the individual elements.

6.3.2 Approach: Received commands, results of internal diagnostics, and contents of element commands and calibration tables will be sent to ground via TT&C telemetry.

6.3.3 Anticipated Results: State of functioning of controller will be determined to validate the reliability of the software and hardware and to facilitate troubleshooting of performance issues with the array.

6.3.4 Supporting I&T Data: Baseline performance of these items documented during I&T.

6.3.5 Rationale: Besides validation of the function of the controller and software, this information is necessary in assuring that RF performance issues which may be attributed to the transmit elements are not actually errors due to incorrect programming from the controller.

6.4 Validate the basic functioning of the array (particularly thermal) over the mission lifetime. Array function after turn on at temperature extremes is an issue.

6.4.1 Required data/measurements: Array current, voltage, temperature, radiation dose, BER performance after turn on (6.1).

6.4.2 Approach: Basic data measured aboard spacecraft will be telemetered via the TT&C link. BER performance will be correlated with turn-on temperature of array.

6.4.3 Anticipated Results: Changes in power consumption over mission lifetime will be documented. RF performance of array will be documented over temperature.

6.4.4 Supporting I&T Data: Parameters will be measured during I&T and thermal vacuum testing.

6.4.5 Rationale: Performance of the distributed amplifiers over thermal extremes is an issue both for the individual components and for their combined performance as an array.

7.0 SCHEDULE (ASSUMES DECEMBER 99 LAUNCH)

Mar 97	EM testing at LeRC for initial data on 6.1, 6.2 complete
Apr 97	Contract for flight article signed with vendor
Oct 98	Flight unit delivered to mission team
TBD 98	I&T testing, verification data for 6.3-6.4
Dec 99	Launch
Mar 00	Baseline data completed
Jul 00	Mid mission evaluation
Dec 00	End of basic mission evaluation