OPTICAL COMMUNICATION TRANSCEIVER FOR X2000; SECOND DELIVERY PROGRAM

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Abstract

Conceptual design of a multi-functional optical instrument is underway for the X2000 - Second Delivery Program. The transceiver will perform both free-space optical-communication and science imaging by sharing a common 10-cm aperture telescope. A single focal-plane array (such as, APS- Active Pixel Sensor) in conjunction with a filter wheel will be used to perform the two functions. Targeted values for the transceiver's weight and power consumption are: 4 Kg, and 14 W. This transceiver would be capable of delivering greater than 10 Kbps to a 3.5-m diameter receiving station from the range of 2 AU during day-time.

Introduction

Optical communications provides a compact transceiver with potential for light-weight and low power consumption. Moreover, with the addition of a filter-wheel to the transceiver design, it also functions as a high-resolution, multi-color imager. The downlink operation of the transceiver consists of tracking a laser beacon (emanated from earth) or the sun-illuminated earth image beacon, and transmitting a signal back to the ground station.

Requirements

The top level requirements for the transceiver are:

- Multi-functionality: optical communication and at least narrow-angle science imaging
- downlink capability of 10's of kbps and uplink reception capability of 2 kbps from 2 AU
- Acquisition, tracking and reception of uplink command while transmitting a strong downlink signal through the same aperture
- proper pointing of the highly collimated laser beam to earth while the host spacecraft is oscillating, jittering, contracting and expanding. Maintaining pointing of the transmit signal during daytime reception with an absolute accuracy on the order of a few micro-radians.

- Acquisition and tracking of the ground receiver locations, from deep space, for a wide range of Sun-Earth-Probe (SPE) angles.
- Simultaneous two-way ranging and communication support
- Adequate level of built-in reliability to survive the targeted mission period and to remain opto-mechanically and thermo-mechanically stable during launch, cruise and intense operation phases of the mission.

Link Analysis

To minimize size, weight and power consumption, a small transmit/receive aperture along with low average output transmit laser power were assumed. Major assumptions for the link analysis are:

Transmitter/receiver aperture = 10 cm
Laser transmitter average power = 1 W
Modulation format = 256 (8-bit) PPM
Transmitter pointing losses = - 2 dB
Coding = Reed-Solomon

Link range = 2 AU
Receiver diameter = 3.5 m
Daytime ground reception
Bit error rate = 1 E-5
Link Margin = 3 dB

With these and certain assumptions on transmit, receive and atmospheric losses, a date rate of greater than 10 kbps is calculated. Larger ground-based receiver apertures (such as 10-m photon bucket) in conjunction with night-time reception result in a calculated data-rate capability of greater than 140 kbps.

Conceptual Optical Configuration

An optical block diagram for the transceiver is shown in Figure 1.

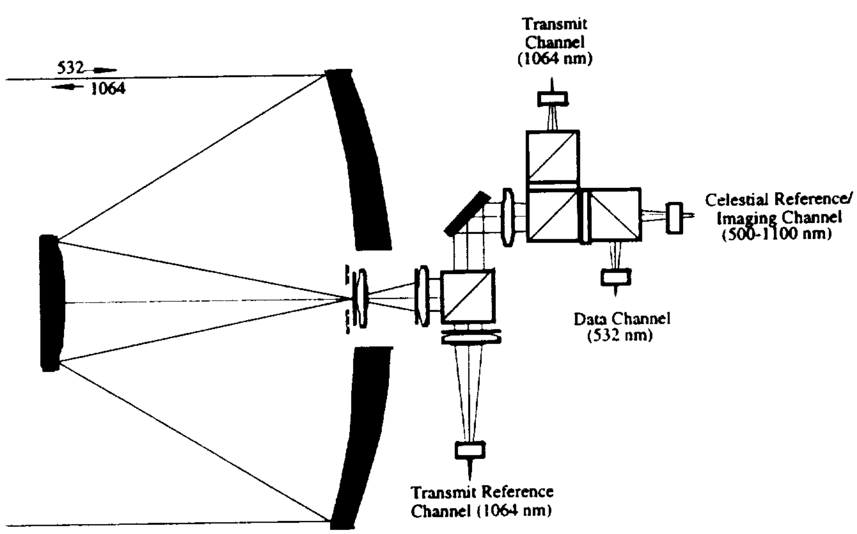

Figure 1. Conceptual Optical Diagram for the Transceiver

The optical system consists of four optical channels.

The transmit channel consists of an optical path to relay a transmit signal from the output of the laser transmitter to the exit aperture of the optics. This channel provides fine-pointing capability to control the downlink over the entire system field-of-view.

The data detector receive channel consists of a receive optical path to collect the incident photons from the input aperture and transfer them to the data detector. This path provides narrow-band filtering to reduce the amount of background radiation, and provides the field-of-view necessary to cover the spacecraft deadband cycle.

The tracking receive channel consists of an optical path that images the telescope field-of-view onto the celestial reference detector. A 1024x1024 detector array with 20 micron pixel size is currently baselined and covers the 9 mrad x 9 mrad field-of-view.

The tracking reference channel consists of a tracking reference path that images a small portion of the transmit signal (after the fine-pointing mirror) onto the tracking detector. The instantaneous direction of the downlink signal is measured in this channel.

The dynamic range of the tracking signal can vary by 2 to 3 orders of magnitude over the large distances expected, and particularly when earth image tracking is required. Current CCD and APS technology do not permit operation over different frame rates for the two signals. Thus, the transceiver is equipped with a separate imager that images the tracking reference signal.

The transmit signal must be pointed ahead (or behind) the apparent position of the ground station to compensate for any cross velocity. The initial acquisition and coarse pointing of the transceiver is achieved using the spacecraft attitude itself. Fine pointing of the transmit signal is achieved using a two-axis steering mirror in the transmit channel. Following sensing of the position of the beacon image on the focal-plane-array detector relative to the reference location for the center of the receive channel, the steering mirror can be used to correct the pointing of the transmit channel towards the ground station.

Weight and power-consumption goals for the transceiver are: 4 kg and 14 W, respectively. The largest dimension is estimated as 25 cm.

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