



A High-Speed Data Downlink for Wide-Bandwidth CubeSat Payloads

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High Speed Data Downlink

- The need for wider bandwidth - supporting BIG data collectors
 - Earth Observation and Remote Sensing instruments collect a lot of data.
 - Currently available UHF or S-band radios can only support from 10 kbps up to about 1 Mbps download rates.
 - This limits the type of payloads that can be deployed on CubeSat platforms.
 - Limited downlink bandwidth means less experiment time
- This instrument will enable the BIG data collectors to remain in the CubeSat arena.

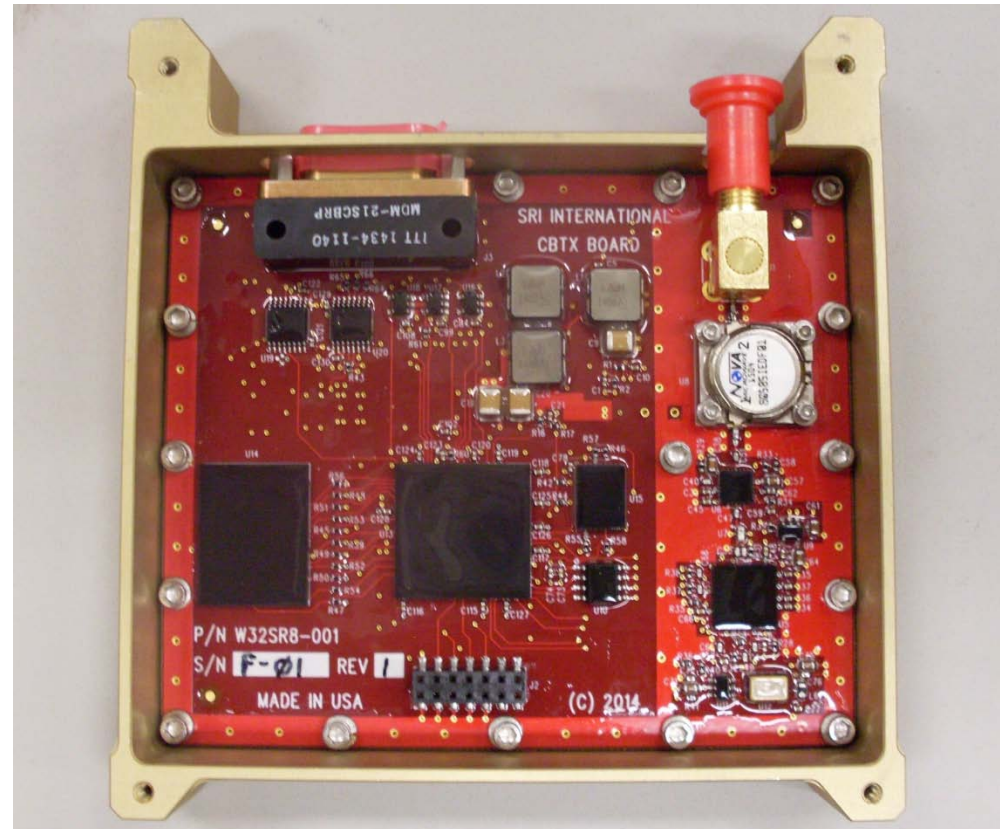
TYPICAL 4 GByte DATA DOWNLOAD			
<i>RATE</i>	<i>TIME TO DOWNLOAD</i>	<i>NUMBER OF PASSES (Assumes 13 min. window)</i>	<i>NUMBER OF DAYS (4 passes/day)</i>
10 kbps	53,000 min.	4000	1000
1 Mbps	530 min.	40	10
20 Mbps	26 min.	2	1
40 Mbps	13 min.	1	1

Space Segment

- This is the *Transmit* portion of the data link
- Requirements
 - Optimize SWAP for CubeSat platform
 - Simple interface - minimal impact on Payload/Bus configuration
 - Ability to support high data rates: Goal is 20 Mbps
- Solution: C-Band Transmitter
 - C-Band - more spectrum available
 - Easily Licensable
 - 5.25 - 5.57 GHz: Earth Exploration, Satellite & Space Research
 - 5.83 - 5.85 GHz: Amateur Satellite
 - Small Antenna
 - 12 x 12 mm patch
 - 14 mm monopole
 - Low power consumption ($\approx 6W$ in full TX)
 - Onboard Data Storage
 - Single Board in Aluminum Housing

Space Segment: C-Band Transmitter

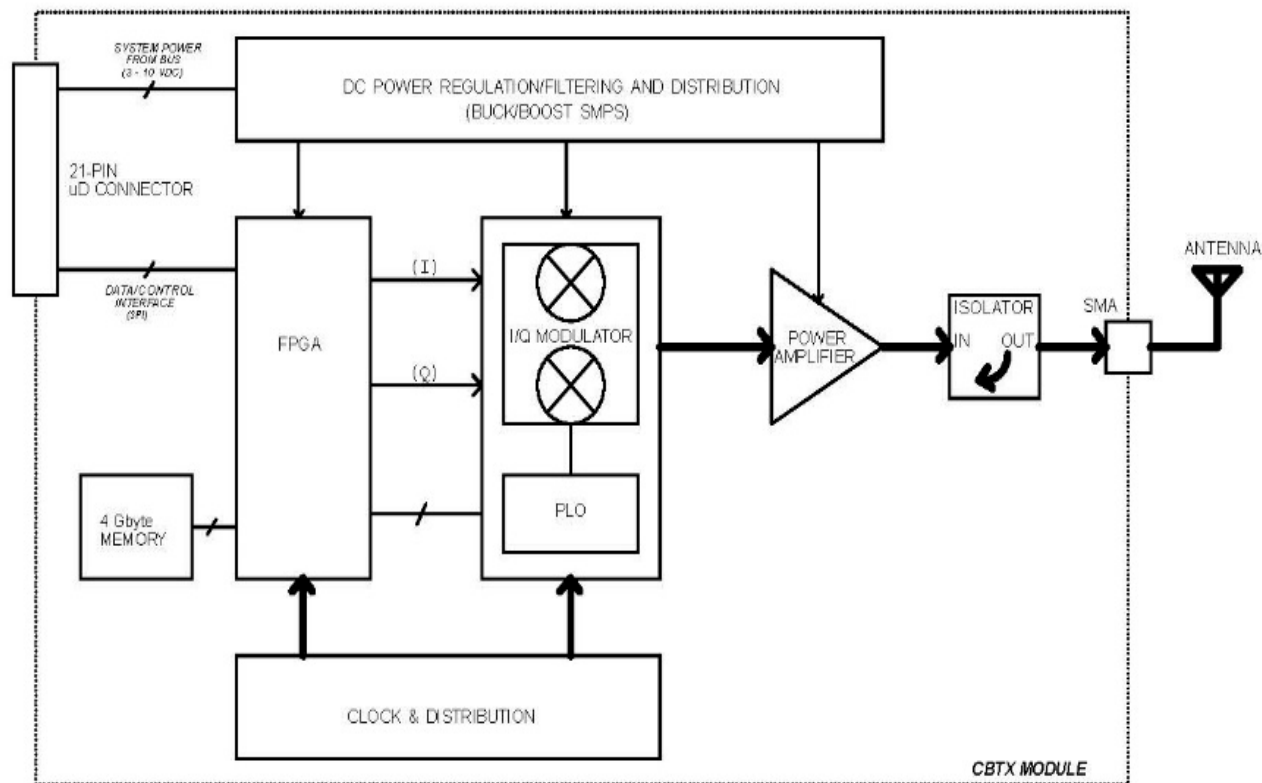
Included in SINOD-D demonstration
Manifested on NRO L-55 / GRACE for August 2015



20 Mbps QPSK w/Convolutional Encoding

Space Segment: C-Band Transmitter Circuit Description

- Interface Connections
 - Control/Data: 21-pin micro-D connector
 - RF: SMA-F
- Power Regulation/Filtering
 - Buck/Boost topology SMPS
 - 90% efficiency, typical
 - 3-10 V unregulated input
- FPGA (Artix-7)
 - SPI coms with host
 - Data handling - host to memory
 - I/Q symbol encoding
 - SPI config. of modulator
- Memory
 - 4 GByte, NAND Flash
- I/Q Modulator
 - Baseband inputs
 - Integrated Tunable PLO
- Reference Oscillator
 - 20 MHz TCXO (100 ppb)
- Power Amplifier
 - Single device (32 dB gain)
 - 1 Watt CW output
- Isolator
 - PA protection - load intolerance
- Health & Status monitoring
 - Board Temperature, Voltage, Current






Space Segment: C-Band Transmitter Specification

- Frequency: 4.900 - 5.875 GHz
- RF Bandwidth: 20 MHz, max.
- Phase Modulation
 - BPSK: Up to 20 Mbit/s (26 min. to download 4GB of data)
 - QPSK - raw: Up to 40 Mbit/s (13 min. to download 4GB of data)
 - QPSK - FEC (7-1/2 coding): Up to 20 Mbit/s (26 min. to download 4GB of data)
- RF Power Output: 1W CW, max.
- DC Supply: 3 - 10 VDC
- DC Input Power
 - Standby: 0.5 W
 - Full TX: 6 W
- Data/Control Interface: Serial SPI (40 Mbit/s)
- Packaging: Single PCB, Aluminum Housing
- Mass: 170g
- Dimensions: 9cm x 9cm x 2cm

Ground Segment

- This is the *Receive* portion of the data link
- Requirements
 - Sensitivity and Gain - must be compatible with 1W transmitter at 650km range
 - Wide bandwidth capability (≥ 20 MHz)
 - Accessibility - Antennas must be available for use within the science and educational community
- SRI Assets that are available to meet the ground segment requirements
 - Allen Telescope Array (ATA)
 - 42 individual 6m dish antennas with cryogenic feeds
 - 0.5 to 11.2 GHz (Receive only)
 - 5.8 GHz gain (1 dish): 49 dB
 - SNR (5.8 GHz, 1W Tx, 20 MHz BW - using 1 dish): 22 dB
 - Jamesburg Earth Station (JES)
 - 30 m diameter solid-surface reflector, full Az-El motion (1deg/sec)
 - Gain (5.8 GHz): 62 dB
 - SNR (5.8 GHz, 1W Tx, 20 MHz BW): 32 dB
 - Arecibo Observatory (AO)
 - 305 m diameter single spherical reflector
 - System noise temperature: 30K
 - Gain (5.8 GHz): 82 dB
 - SNR (5.8 GHz, 1W Tx, 20 MHz BW): 59 dB

Ground Segment

SRI Ground Assets Summary	
Site	Attributes
 <p>ATA</p>	<p>Location: Northern California RX only (0.5 to 11.5 GHz) 42 individual 6m antennas with H/V cryogenic feeds Aperture: 28 m² (6m dia.) Sys Temp: 70 K Beam Size: 0.6° Sky Coverage: ± 70°</p>
	<p>Location: Northern California RX and TX operation at C-Band Polarization: RHCP or LHCP Aperture: 706 m² (30m dia.) Sys Temp: 140 K TX Power: 100 W Beam Size: 0.13° Sky Coverage: ± 75°</p>
	<p>Location: Puerto Rico RX only at C-Band Polarization: RHCP or LHCP Aperture: 73,000 m² (305m dia.) Sys Temp: 30 K Beam Size: 0.02° Sky Coverage: ± 22°</p>

Future Plans

C-Band Regenerative Ranging Transponder

- Add Receive Capability
- Receive PN code from ground and regenerate on spacecraft for re-broadcast
 - Up to a 40 dB improvement in signal to noise
 - System designed for known latency
- Provides 2-way Range and Doppler information to aid orbit and trajectory analysis
 - Calculated Range Resolution
 - LEO: < 100 m
 - Lunar (382,260 km): 7km
 - Doppler Resolution: +/- 30 m/sec (based primarily on the accuracy of the transmitter frequency reference: +/- 0.1ppm)

Contact Information

We want to be part of your next mission.

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Thank You

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