

**SRI International**



# 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.

<b>TYPICAL 4 GByte DATA DOWNLOAD</b>			
<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

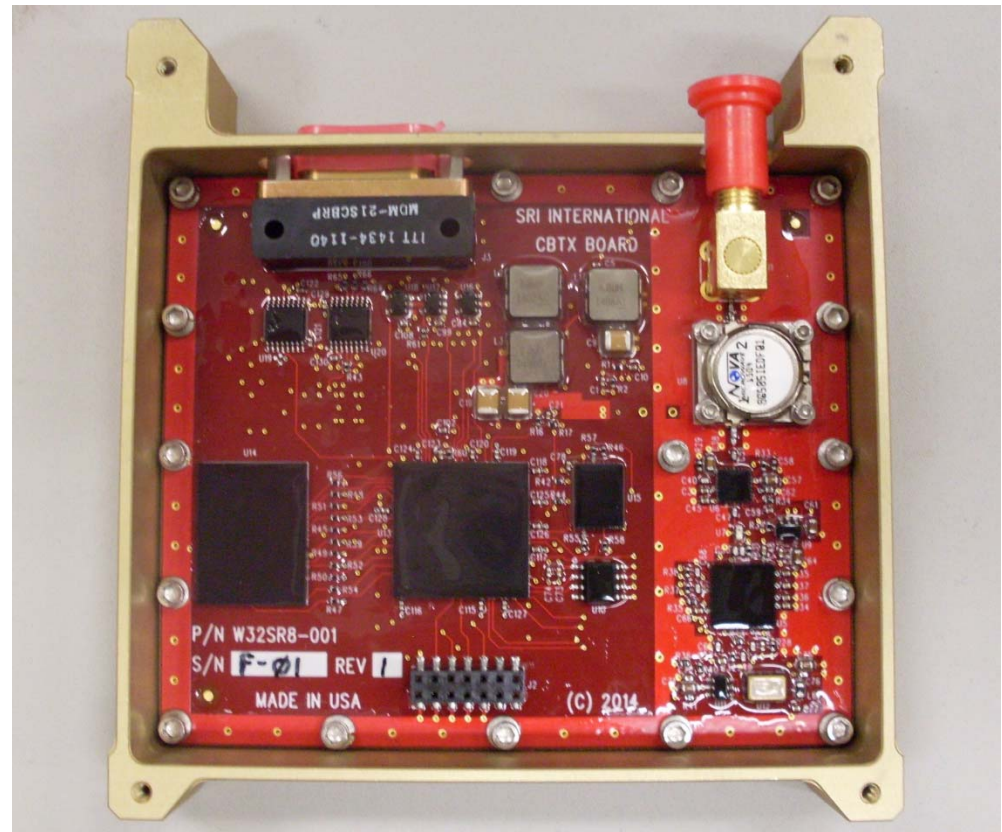
- This is the *Transmit* portion of the data link
- Requirements
  - Optimize SWAP for CubeSat platform
  - Simple interface - minimal impact on Payload/Bus configuration
  - Ability to support high data rates: Goal is 20 Mbps
- Solution: C-Band Transmitter
  - C-Band - more spectrum available
    - 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*

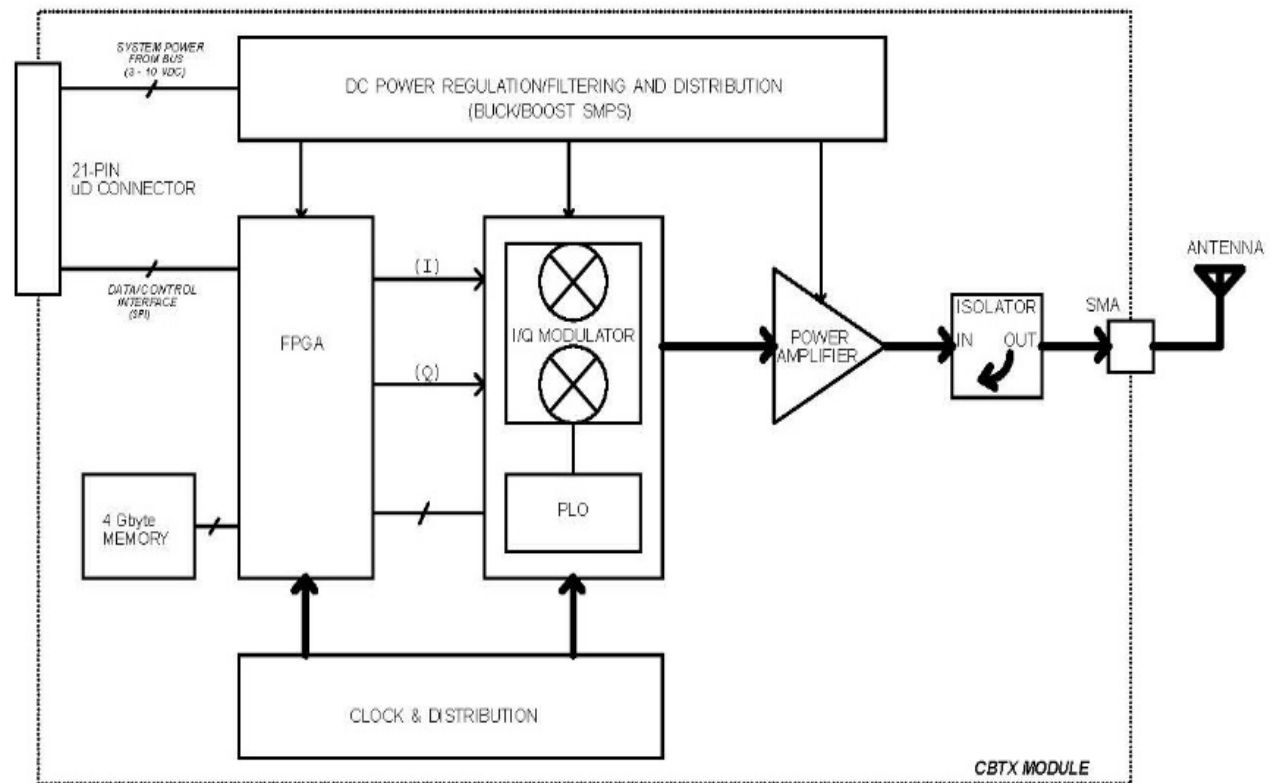


20 Mbps QPSK w/Convolutional Encoding



# 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 ( $\geq 20$  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-EI 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>Allen Telescope Array</p>	<p>Location: Northern California            RX only (0.5 to 11.5 GHz)            42 individual 6m antennas with H/V cryogenic feeds            Aperture: 28 m<sup>2</sup> (6m dia.)            Sys Temp: 70 K            Beam Size: 0.6°            Sky Coverage: ± 70°</p>
 <p>Jamesburg Earth Station</p>	<p>Location: Northern California            RX and TX operation at C-Band            Polarization: RHCP or LHCP            Aperture: 706 m<sup>2</sup> (30m dia.)            Sys Temp: 140 K            TX Power: 100 W            Beam Size: 0.13°            Sky Coverage: ± 75°</p>
 <p>Arecibo Observatory</p>	<p>Location: Puerto Rico            RX only at C-Band            Polarization: RHCP or LHCP            Aperture: 73,000 m<sup>2</sup> (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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