Radio Frequency Subsystem (RFS)

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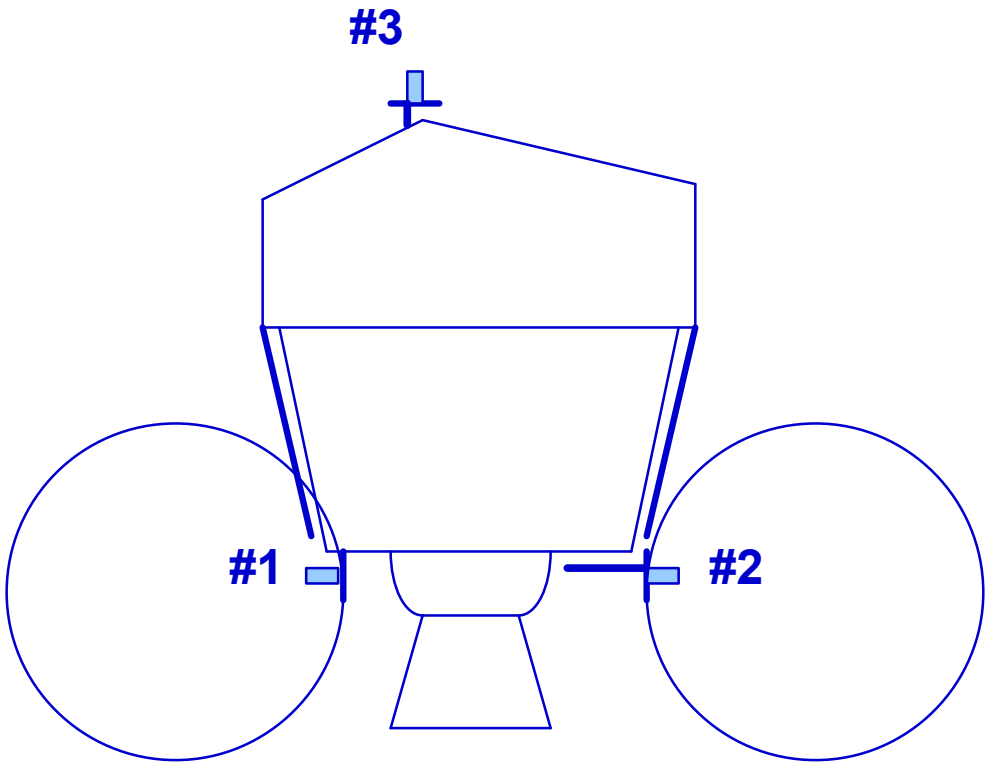
Top Level Requirements

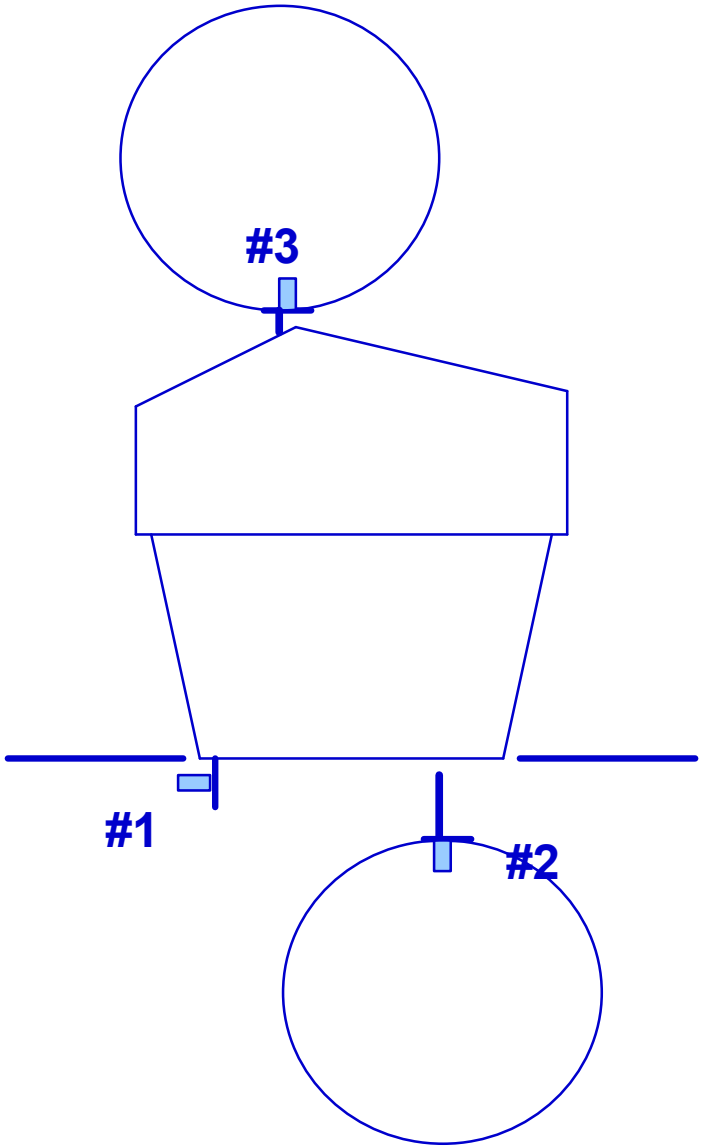
- Provide Spacecraft 2 kbps Command Capability at Any Vehicle Orientation
- Provide Low Rate 1 kbps Minimum Telemetry for Emergency, Safe-Hold and Initial Acquisition Operations at Any Vehicle Orientation
- Provide High Rate Data Downlink at 409 kbps
- Provide Coherent Spacecraft Range and Range Rate Capability
- Compatible With NASA (STDN) and NRL Ground Stations
- CCSDS Compatible
- Comply With NTIA Frequency Management Regulations

Current Baseline/Approach

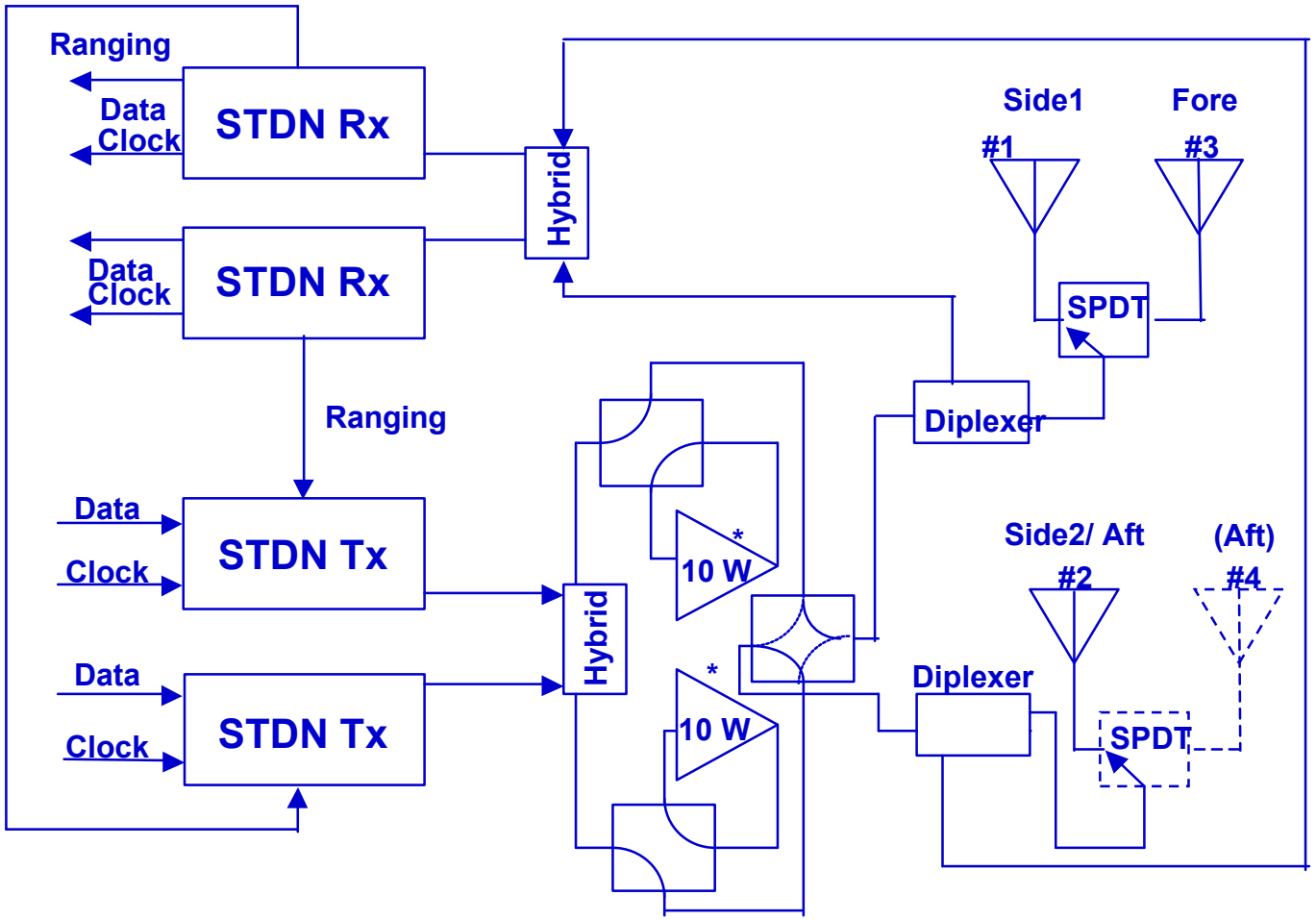
Launch / Insertion Configuration



Operational Configuration

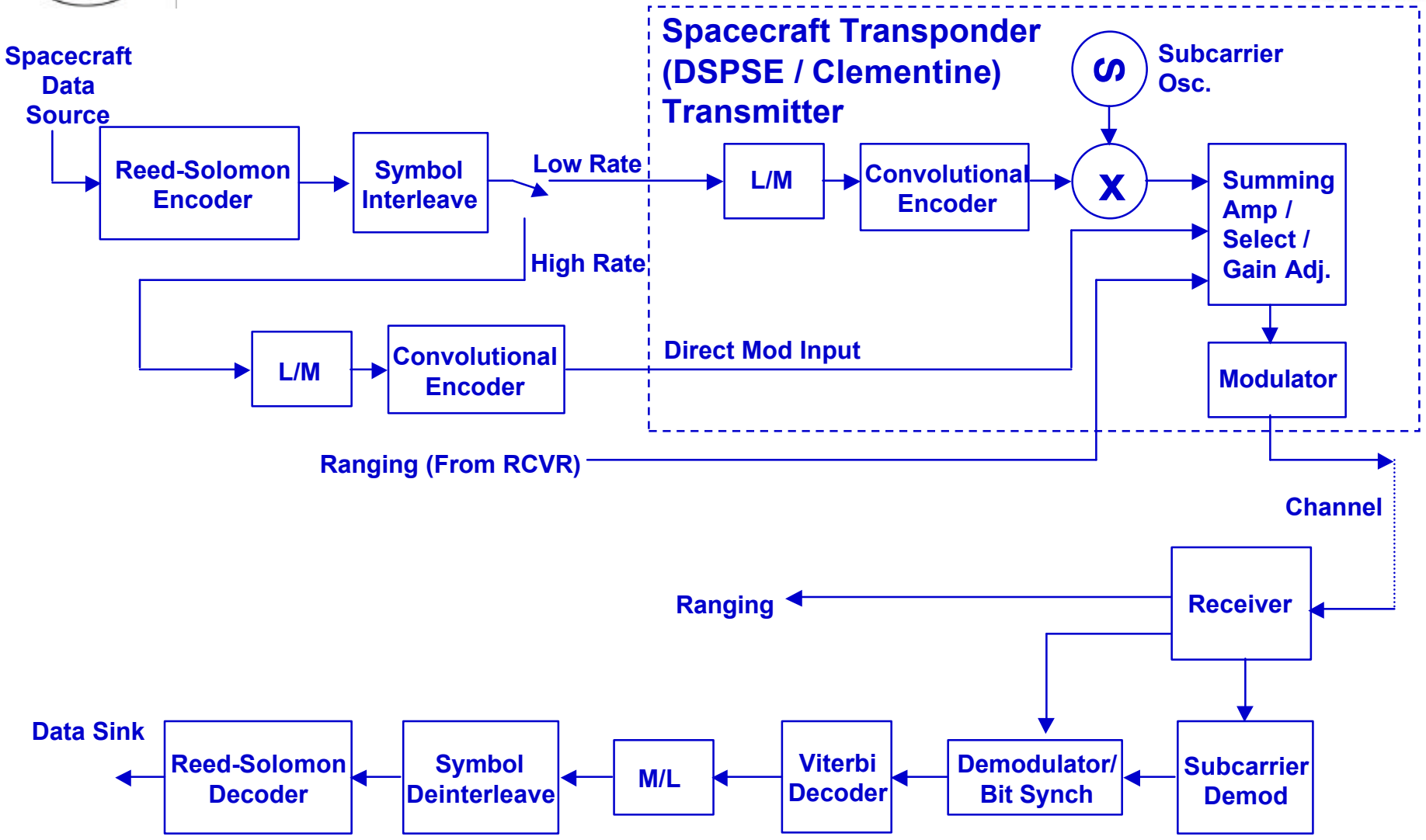


RF Subsystem Block Diagram

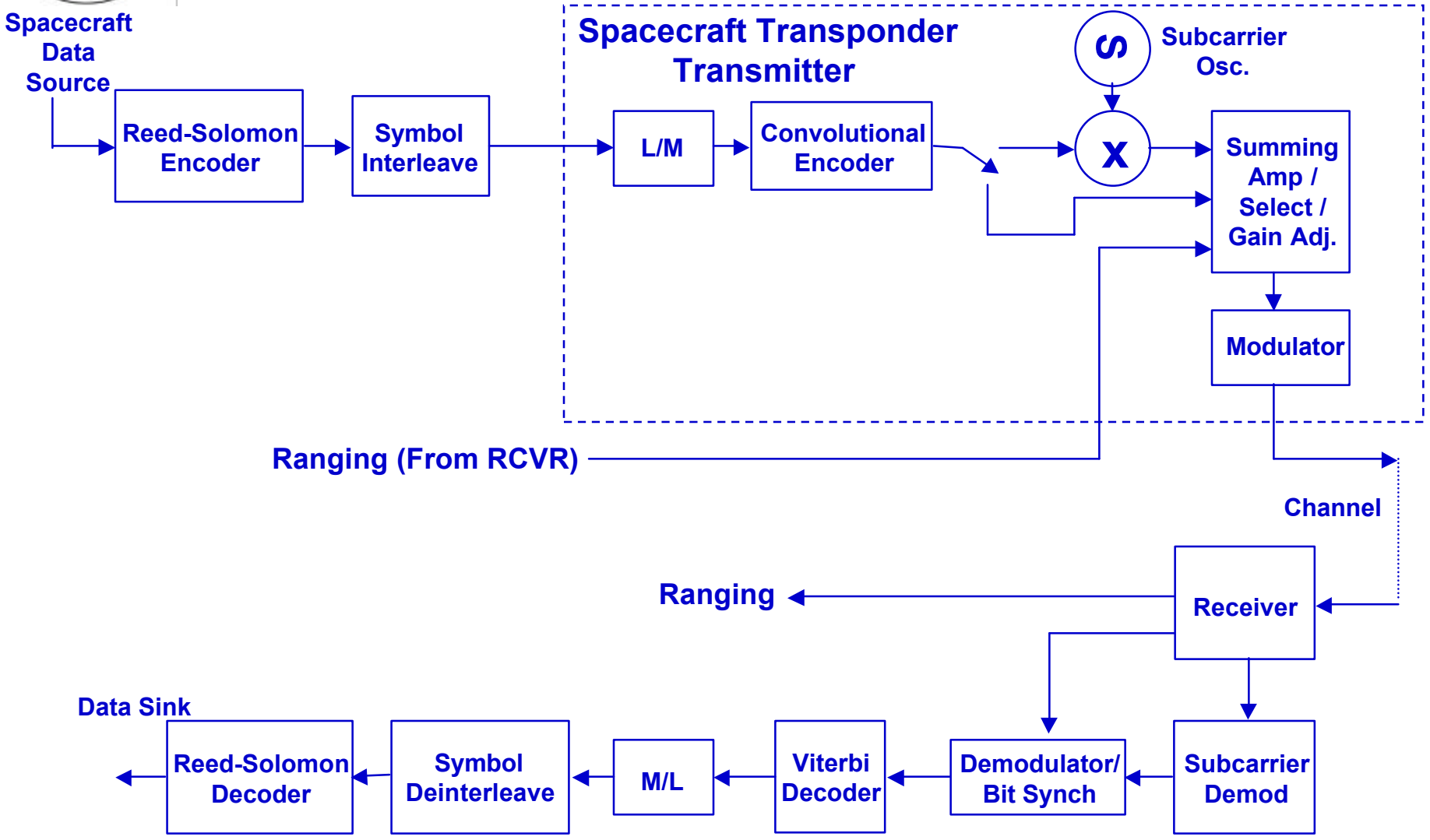


- Power Amps Operated Separately During Normal Operation
- Safety Interlock and Internal Limiting Prevent Accidental Overstress of the Amplifier in the Event That the Output Is Connected to the Input With DC Power Applied

Data Flow (Baseline)



Data Flow (Single Input Option)



Uplink

- S-Band Uplink (2025 to 2120 MHz)
- Command Data = 2kbps, NRZ-M Data BPSK Modulated Synchronously on a 16kHz Sinewave Subcarrier
- Uplink Subcarrier Modulation Index = 1 Radian Peak
- Output to CTDH

Data	RS-422	NRZ-L
Clock	RS-422	Rising Edge of Clock at Midpoint of Data Bit
Subcarrier Lock	TTL	
Receiver Lock	TTL	

Downlink

- S-Band Downlink 2200 to 2300 MHz (Turnaround Ratio 240/221)
- Low Rate Data
  - 1kbps (2.29ksps) NRZ-M, BPSK Modulated Onto 1.7 MHz Subcarrier
  - Phase Modulated Onto S-Band Carrier at Mod Index of 1.6 Radians Peak
- High Rate Data
  - 409kbps (936.8ksps) NRZ-M, BPSK Modulated Onto S-Band Carrier
- Input From CTDH (Same for Both Low Rate and High Rate)

Data	RS-422	NRZ-L
Clock	RS-422	Rising Edge at Mid-Point of Data Bit

Ranging

- Ranging Signal Phase Modulated Directly Onto Uplink Carrier at Mod Index of .5 Radian
- Sequential Square Wave Ranging (1.01 kHz to 515 kHz)
- Ranging Signal Demodulated From Uplink and Phase Modulated Directly Onto Downlink Carrier at Mod Index of .5 Radian
- Downlink Carrier Reference Generated From Uplink Carrier for Coherent Operation
- Non-Coherent Downlink Operation Using On-Board Reference Oscillator When Uplink Is Not Present

Uplink Budget (Omni, Geo)

Transmitter Power (200 W)	53.0 dBm
Line & Diplexer Loss	-2.0 dB
Antenna Gain (10 m)	44.0 dBi
Free Space Loss (Geosynch at 5 Deg Elev)	-190.3 dB
Minimum Antenna Gain	-15.0 dBi (Includes Hybrid Loss)
- Receiver Sensitivity	-(-118.0 dBm)
Margin	7.7 dB

Downlink Budget (409kbps, Geo)

Transmitter Power (w/ SSPA)	40.0 dBm (10W)
Diplexer & Switch Loss	-1.5 dB
Line Loss	-2.0 dB
Antenna Gain	-1.0 dBi
Free Space Loss (5 Deg Elev)	-191.8 dB
Atmosphere Loss (5 Deg Elev)	-0.5 dB
Data Rate	-56.1 dB Hz
Receive G/T	22.3 dB/K
Boltzmann's Constant	198.6 dBm/Hz/K
Eb/No	8.0 dB
Implementation Los	-2.0 dB
Required Eb/No (10^{-6} BER)	-3.0 dB
Margin	3.0 dB

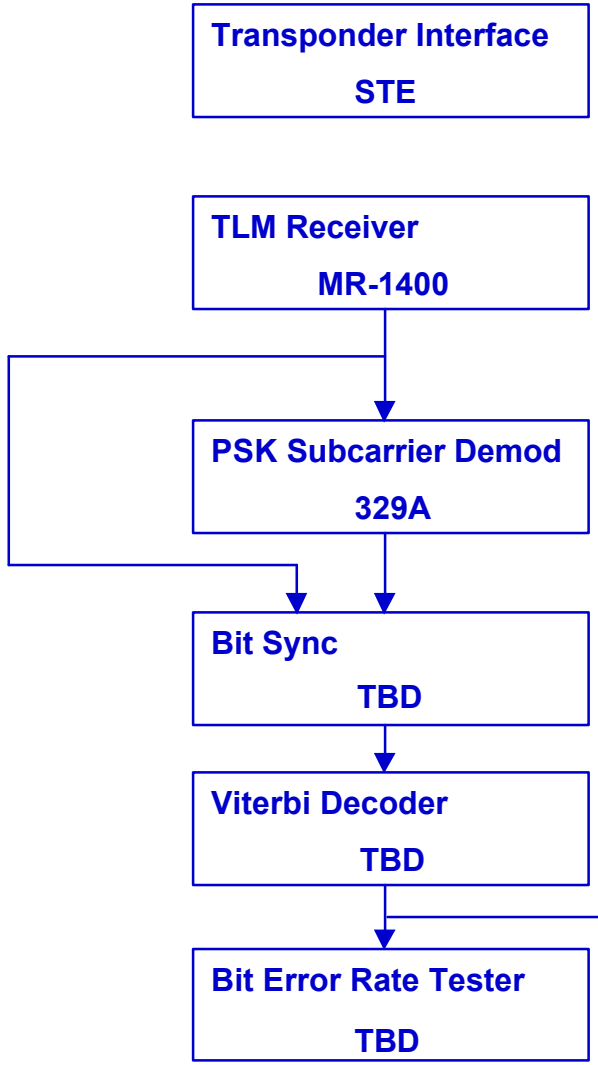
Downlink Budget (1kbps, Geo)

Transmitter Power	33.0 dBm (2W)
Modulation Loss	-2.3 dBm
Diplexer & Switch Loss	-1.5 dB
Line Loss	-2.0 dB
Antenna Gain	-15.0 dBi (Includes Hybrid Loss)
Free Space Loss (5 Deg Elev)	-191.8 dB
Atmosphere Loss (5 Deg Elev)	-0.5 dB
Data Rate	-30.0 dB Hz
Receive G/T	22.3 dB/K
Boltzmann's Constant	198.6 dBm/Hz/K
Eb/No	8.8 dB
Implementation Loss	-2.0 dB
Required Eb/No (10^{-6} BER)	-3.0 dB
Margin	3.8 dB

RF Subsystem Electrical I/O

- Transponder Commands: 26 V Pulses to Latching Relays
- Transponder Telemetry: Discrete 5 V, 0 – 5 V Analog, and Passive Analog for Temp Monitoring
- Uplink Command Output
  - Clock and Data, RS-422, NRZ-L
  - Receiver Lock and Subcarrier Lock, TTL
- Downlink Data Input
  - Clock and Data, RS-422, NRZ-L
- SSPA On/Off: 26 V Pulses to Latching Relay
- Transfer Switches and SPDT RF Switches: 26 V Pulses to Latching Relays
- DC Power
  - XMTR, 24 W @ 22 – 36 V
  - RCVR, 4 W @ 22-36 V
  - SSPA, 63 W @ 22-36 V (80 W for ICM SSPA)

RF Test Rack



Test Interface to Send Commands and Monitor Telemetry of Transponder During Test

S-Band Receiver, PM / BPSK
Downconverts RF to IF
Demodulates Direct BPSK and Outputs NRZ-M Baseband or Outputs BPSK Modulated 1.7 MHz Subcarrier

Demodulates 1kbps BPSK From 1.7 MHz Subcarrier
Outputs NRZ-M Baseband

Translates NRZ-M Baseband to TTL Clock & Data
2ksps / 818ksps (Encoded) or 1kbps / 409kbps (Unencoded)

Decodes Clock & Data Symbols and Provides TTL Clock & Data Output at 1kbps or 409kbps

Clock & Data to Frame Sync

Bit Error Rate Tester, Capable of CCSDS Convolutional Encoding, 2kbps for Uplink Test, 1kbps, and 409kbps for Downlink Tests

Trade Studies

- 4 Antenna Configuration vs. 3 Antenna Configuration
  - Advantages — Removing Mechanical Deployment Mechanism Improves Overall Reliability, Reduces Cost
  - Disadvantages — Requires Additional Antenna and RF Switch
- NRL SSPA vs. ICM SSPA
  - Advantages — NRL Design Approximately One Fifth the Parts Count of ICM Improved Reliability, Less Risk Due to Simpler Design; Leverage Development Costs From Mini-Radar Amplifier 20 to 25% Less DC Power
  - Disadvantages — Currently No Space Heritage or Qualification on NRL Design
- Single Data Input vs. Separate Low Rate and High Rate Inputs
  - Advantages — Saves Unnecessary Duplication of Circuitry, Simplifies CTDH Option Previously Built Into Other Versions of This Transponder
  - Disadvantages

Issues

- **Ranging and Range Rate System Needs to Be Finalized**
- **NTIA Frequency Assignment (Request Submitted to NTIA in May by NASA)**

Top Level Schedule