



Radio Frequency Subsystem

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Top Level Requirements



- **Provide Spacecraft (2 kbps) Command Capability at Any Vehicle Orientation and Rotation Up to 60 RPM**
- **Provide Low Rate (approx. 1 kbps) Minimum Telemetry for Emergency Safe-Hold and Initial Acquisition Operations At Any Vehicle Orientation and Rotation Up to 60 RPM**
- **Provide High Rate (up to 409 kbps) Data Downlink**
- **Provide Coherent Spacecraft Range and Range Rate Capability**
- **Compatible With NASA (STDN) Ground Stations**
- **CCSDS Compatible Convolutional Encoding On Downlink $r=1/2$, $k=7$**
- **Comply With NTIA Frequency Management Regulations**



Top Level Requirements (2 of 2)



- **Link Margin Shall Show 5dB or Better Margin Worst Case for All Link Analyses Using A Threshold Of $1 \cdot 10^{-6}$.**
- **System Residual Bit Error Rate (Strong Signal) Shall Be $1 \cdot 10^{-9}$ or Better for Science Data Downlink And $1 \cdot 10^{-7}$ or Better for Low Rate Data and Uplink**
- **Total Mass of RF Subsystem Shall Be Less Than 17.29 kg (38.1 lbs)**
- **DC Power Maximum Requirements for RF Subsystem**
 - **Receive Only Mode** **8 Watts**
 - **Receivers and XMT Low Power (GTO/Safe-Hold)** **38 Watts**
 - **Receivers and XMT High Power (High Rate Science Data)** **111 Watts**



Derived Requirements (1 of 3)



Uplink

- **S-Band Uplink (2025 – 2120 MHz) Frequency to Be Selected By NASA**
 - **Uplink / Downlink Ratio 221/240**
- **AGC Enable/Disable**
- **Command Data = 2kbps, NRZ-M Data BPSK Modulated Synchronously Onto A 16 kHz 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	



Derived Requirements (2 of 3)



Downlink

- **S-Band Downlink 2200 to 2300 MHz (Turnaround Ratio 240/221)**
- **Low Rate Data (Approx. 1 kbps) Is Convolutional Encoded, NRZ-L to NRZ-M Converted, BPSK Modulated Onto 1.7 MHz Subcarrier and Phase Modulated Onto S-Band Carrier at A Mod Index of 1.6 Radians Peak**
- **High Rate Data (up to 409kbps) 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



Derived Requirements (3 of 3)



Ranging

- **Range Rate Measured By Carrier Doppler Measurement System Using Reconstructed Carrier From Ground Station Receiver**
- **Range Measurements Using Sequential Square Wave (1.01 kHz to 515kHz)**
- **Ranging Signal Phase Modulated Directly Onto Uplink Carrier at Mod Index of .5 Radian**
- **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**



Major Trade Studies



Parameter	NRL SSPA	Conic SSPA	Comments
DC Power for 20W RF	65 Watts	80 Watts	NRL SSPA Requires 18% Less DC Power
Mass	2.2 lbs for Dual SSPA	6.8 lbs for Two SSPAs	NRL SSPA Approximately 1/3 The Mass
Cost	380 K Includes Qual Unit	520 K No Additional Units	NRL SSPA Approx. 25% Less Conic SSPA Would Still Require NRL Engineering, QA, & Program Support \$\$
Complexity	Single Stage Standard Military Part DC/DC Converter Very Low Parts Count	3 Stage Design Discrete PS Matching Circuits ALC Loop	NRL Design Is Less Than 1/3 the Parts Count of the Conic Design
Qualification	Not Yet Qualified	Not Yet Qualified	Conic SSPA Was Supposed to Be Qualified on ICM But Has Not Yet Successfully Passed Qual Testing



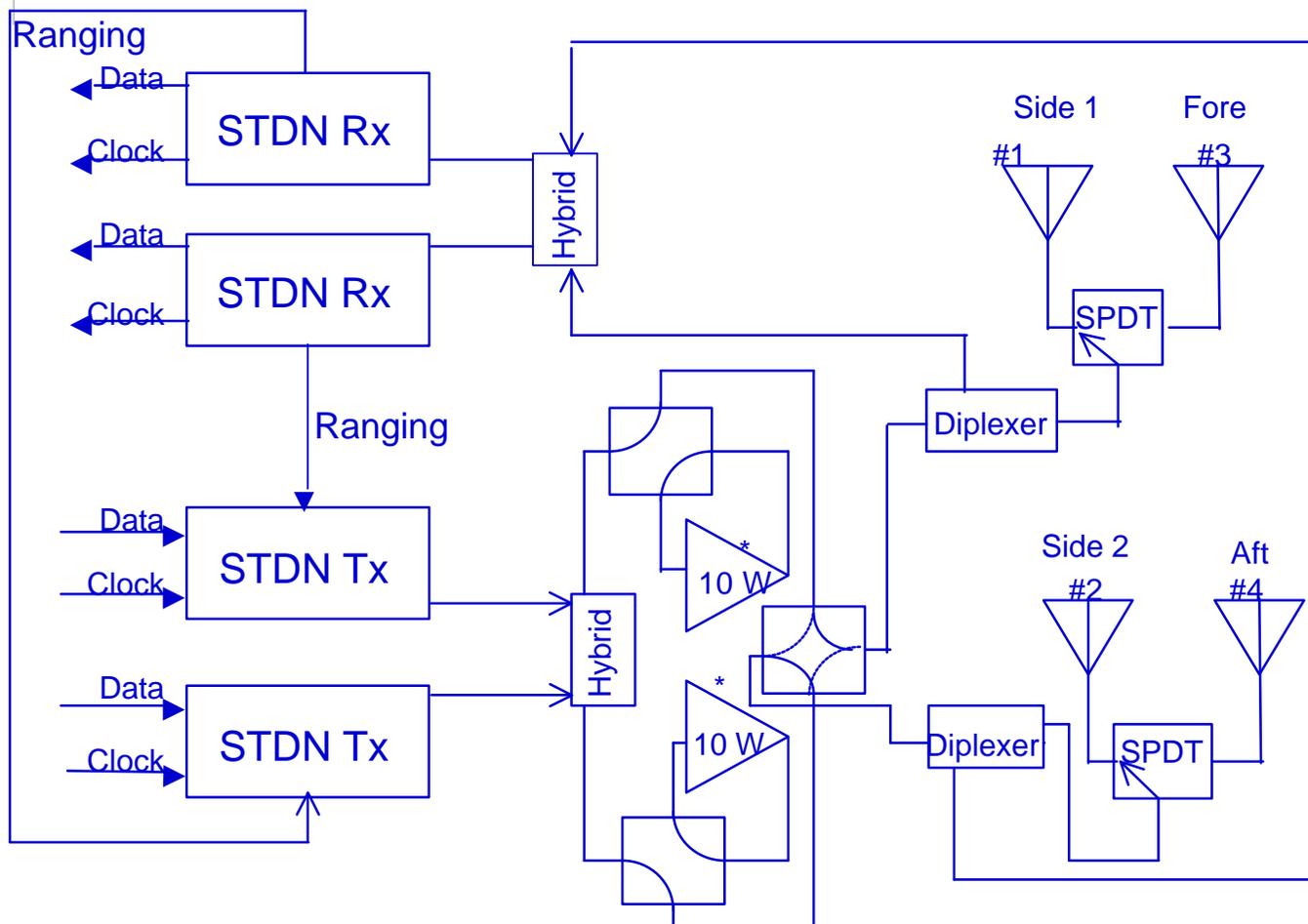
Issues



- **Antenna Pattern Distortion**
 - **Sun Shield**
 - **Marmon Clamp Ring**
 - **Spacecraft Structure and Instrument**
- **Thermal Qualification of Antennas**



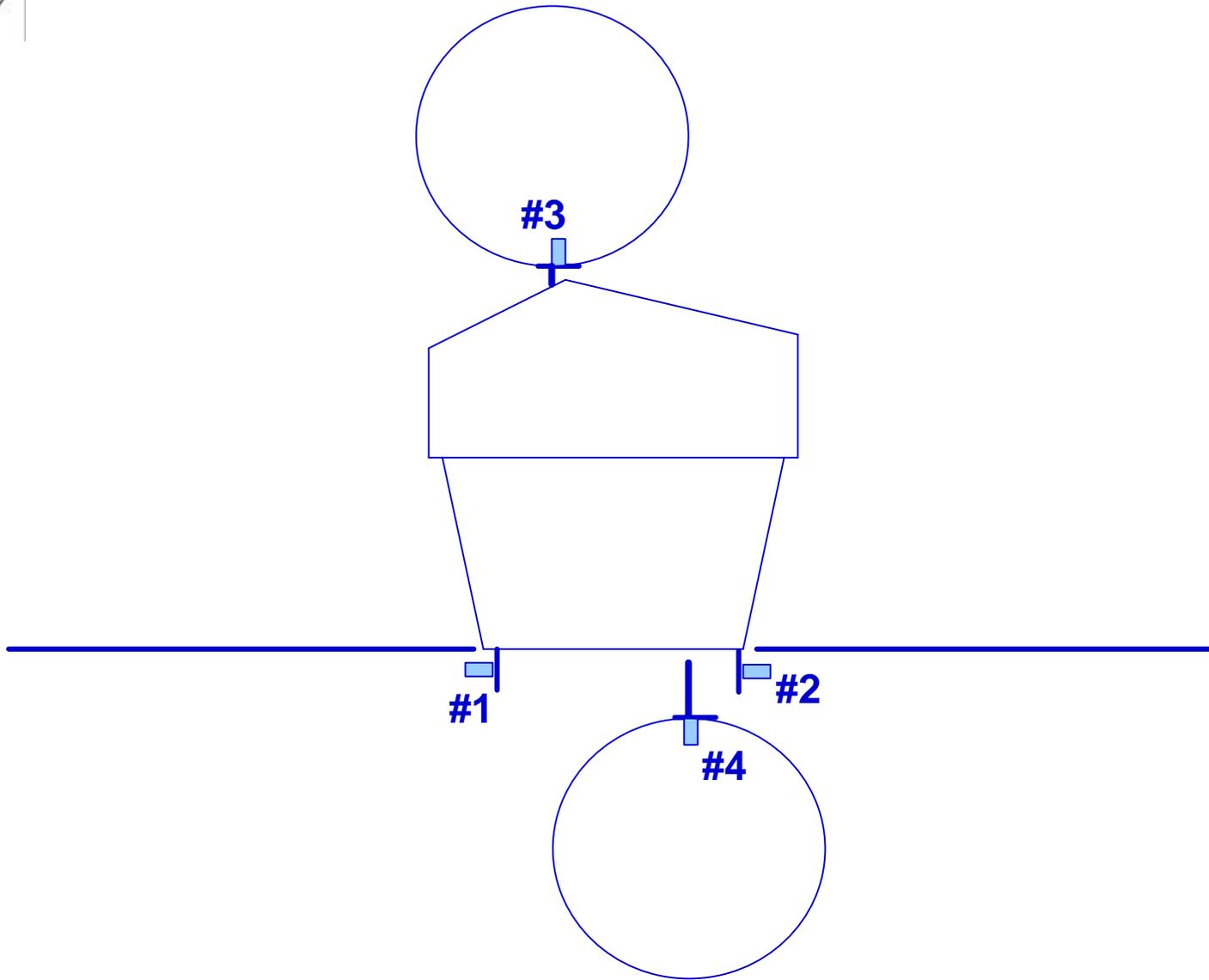
Backup



- **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.**



Backup





Uplink Budget (Omni, Geo)



• Transmitter Power (200 W)	53.0 dBm
• Line & Diplexer Los	-2.0 dB
• Antenna Gain (10 m)	44.0 dBi
• Free Space Loss (Geosynch at 5 deg elev)	-190.3 dB
• Atmosphere Loss (5 deg)	-0.5 dB
• Minimum Antenna Gain	-17.0 dBi (Includes Hybrid Loss)
– Receiver Sensitivity	-(-118.0 dBm)
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• Margin	5.2 dB



Downlink Budget (409 kbps, Geo)



• Transmitter Power (w SSPA)	43.0 dBm (20W)
• Diplexer & Switch Loss	-1.5 dB
• Line Loss	-2.0 dB
• Antenna Gain	-3.0 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
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• Eb/No	9.0 dB
• Implementation Loss	-2.0 dB
• Required Eb/No (10 ⁻⁶ BER)	-3.0 dB
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• Margin	4.0 dB



Downlink Budget (1kbps, Geo)



• Transmitter Power	36.0 dBm (4W)
• Modulation Loss	-2.3 dBm
• Diplexer & Switch Loss	-1.5 dB
• Line Loss	-2.0 dB
• Antenna Gain	-17.0 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
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• Eb/No	11.8 dB
• Implementation Loss	-2.0 dB
• Required Eb/No (10 ⁻⁶ BER)	-3.0 dB
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• Margin	6.8 dB



Mass Budget



ITEM DESCRIPTION	MASS lbs (ea)	QTY	TOTAL MASS	SOURCE
TRANSPONDER	8.5	2	17	Specification
DUAL SSPA	2.2	1	2.2	Estimate
ANTENNAS	2	4	8	Estimate
DIPLEXERS	0.4	2	0.8	Measured
XFER SWITCHES	0.25	3	0.75	Data Sheet
SPDT SWITCHES	0.125	2	0.25	Data Sheet
3dB RF HYBRIDS	0.1	2	0.2	Estimate
GORE RF CABLE (1ft)	0.08	80	6.4	Measured
TOTAL			35.6 lbs	
5% MARGIN			37.38 lbs	