The Modular S-Band Radio Suite

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Presented by Scott McDermott
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Background

- One of the primary obstacles for nanosatellites is a lack of suitable miniature components
  - Limited resources for new components
  - Must focus on components that are most common among a variety of missions and provide maximum benefit

- Every mission has a need to communicate, yet no suitable radio subsystems exist for nanosatellites
  - Conventional radios are designed to try and fit the largest number of vehicles types and mission scenarios possible
  - Tend to be “all things to all situations” and end up higher in mass, power consumption, complexity, cost, and less capable
  - These hits in performance are show-stoppers for nanosatellites

There is a need for a radio designed specifically to address the requirements of small spacecraft
A Different Approach

- A radio can be thought of as an ensemble of well-defined modules rather than a monolithic device
  - Designers can simply build an appropriate radio using modules that meet individual performance needs
  - Converting between radio configurations is as simple as removing one module and replacing it with another

- AeroAstro’s Modular S-Band Radio Suite (MSBRS) is a set of very small radio modules
  - Specifically intended to address needs of nanosatellites
  - Capable enough to accommodate needs of larger spacecraft

MSBRS is a solution flexible enough to suit existing and future nanosatellite comms needs
Comms Modules

- Use only the modules needed for a mission
- Built around a core S-Band RX/TX
- Common RF, IF, and digital interfaces
- Common microcontroller
- Common form factor (3”x2”x1”)
- Common mounting
Goals and Assumptions

- A single architecture for LEO-to-Earth, MEO-to-Earth, GTO-to-Earth, and inter-satellite communications

- Specific mission performance parameters:

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lifetime</td>
<td>up to 10 years</td>
</tr>
<tr>
<td>Data Throughput</td>
<td>up to 100 Mbps</td>
</tr>
<tr>
<td>Bandwidth</td>
<td>up to 100 MHz</td>
</tr>
<tr>
<td>Electrical Interface</td>
<td>RS422 (typical)</td>
</tr>
<tr>
<td>Mechanical Interface</td>
<td>Modular</td>
</tr>
<tr>
<td>Vibration Levels</td>
<td>20g rms (90 sec/axis)</td>
</tr>
<tr>
<td>Shock Levels</td>
<td>500g</td>
</tr>
<tr>
<td>Single Event Upsets (SEU’s)</td>
<td>Tolerant</td>
</tr>
<tr>
<td>Single Event Latch-Ups (SEL’s)</td>
<td>Autonomous detection and mitigation</td>
</tr>
<tr>
<td>Total Ionizing Dose (TID)</td>
<td>5 krad (component level)</td>
</tr>
</tbody>
</table>
Design Approach

- Modularity
- Small and lightweight
- Low power consumption
- Latch-up detection and mitigation (LDM)
- Optional DC/DC converter module
- Programmable transmit and receive frequencies
- Fly-lead interfaces
- Elimination of the need for a diplexer
- Use of commercial technology

The MSBRS architecture relies on several key design features
Receiver Block Diagram

- **RF i/p**
- **BPF**
- **AMP**
- **MIX**
- **SAW**
- **PIC**
- **UHF PLL**
- **VCXO (REF)**
- **PICS-band PLL**
- **PLL**
- **Loop**
- **VCXO (REF)**
- **Rx Data O/P**
- **Rx CLK O/P**
- **BPF**
- **Tone Ranging O/P**
- **Diff. Decod**
- **Rx Data O/P**
- **Rx CLK O/P**
- **LO Verror**
- **Bit Sync (4kbps)**
- **LDM cct.**
- **DC ccts**
- **AGC/Carrier Demod**
- **I/Q**
- **S-band PLL**
- **BPSK sub-carrier Demod**
- **+V**
- **DC ccts**

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# Receiver Specifications

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulation</td>
<td>BPSK (factory preset)</td>
</tr>
<tr>
<td>RX Frequency Range</td>
<td>2025 MHz to 2120 MHz</td>
</tr>
<tr>
<td>Data Rate Range</td>
<td>1 kbps - 4 kbps</td>
</tr>
<tr>
<td>Carrier Tracking Threshold</td>
<td>-116 dBm</td>
</tr>
<tr>
<td>Sensitivity</td>
<td>-110 dBm (BER-1e-6) @ 2 kbps</td>
</tr>
<tr>
<td>Lockup Time</td>
<td>&lt; 50 msec (typical)</td>
</tr>
<tr>
<td>Sub-Carrier</td>
<td>16 kHz</td>
</tr>
<tr>
<td>Noise Figure</td>
<td>6 db</td>
</tr>
<tr>
<td>Dynamic Range</td>
<td>+38 dB (SFDR)</td>
</tr>
<tr>
<td>Input Intercept Point</td>
<td>-8dBm (±500 kHz of channel)</td>
</tr>
<tr>
<td>Spurious Response</td>
<td>&lt; -50 dBc</td>
</tr>
<tr>
<td>Mass</td>
<td>180 grams</td>
</tr>
<tr>
<td>Power</td>
<td>160ma@5VDC</td>
</tr>
<tr>
<td>Volume</td>
<td>3” x 2” x 1” (L x W x H)</td>
</tr>
</tbody>
</table>
Transmitter Block Diagram

- Data I/P
- Osc PLL
- BPF
- I/Q Mod
- BPF
- AMP
- RF o/p
- Tone Ranging I/P
- ATTN
- BPF
- BPF
- LDM cct.
- DC ccts
- +V
## Transmitter Specifications

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>TX Frequency Range</td>
<td>2200 Mhz to 2300 MHz</td>
</tr>
<tr>
<td>Modulation</td>
<td>BPSK</td>
</tr>
<tr>
<td>Data Rate Range</td>
<td>2 kbps - 10 Mbps</td>
</tr>
<tr>
<td>Filtering</td>
<td>Baseband roofing filter (linear phase)</td>
</tr>
<tr>
<td>RF Output Power</td>
<td>500 mW and 20 mW (adjustable)</td>
</tr>
<tr>
<td>Spurious Specification</td>
<td>&lt; -50 dBC</td>
</tr>
<tr>
<td>Mass</td>
<td>180 grams (total)</td>
</tr>
<tr>
<td>DC Power Consumption</td>
<td>800 mA @7.5 VDC</td>
</tr>
<tr>
<td>Volume</td>
<td>3” x 2” x 1” (L x W x H)</td>
</tr>
</tbody>
</table>
HPA and DC/DC Converter Diagrams

High-Power Transmit Amplifier

- Sequential Logic
- DC ccts
- +V
- HPA RF i/p
- AMP
- LPF
- 5W HPA O/P

DC-to-DC Converter

- DC/DC
- Tx +28V
- Rx +28V
- +10V TRANSMITTER
- +5V RECEIVER
- +10V
- +5V
## HPA Specifications

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>TX Frequency Range</td>
<td>2200 MHz to 2300 MHz</td>
</tr>
<tr>
<td>Output Power</td>
<td>5 W (+37 dBm)</td>
</tr>
<tr>
<td>Linearity Class</td>
<td>Linear (class A / AB)</td>
</tr>
<tr>
<td>DC Power Consumption</td>
<td>&lt; 25 Watts (varies with supply voltage)</td>
</tr>
<tr>
<td>IP3</td>
<td>+ 49 dBm (min)</td>
</tr>
<tr>
<td>Supply Voltage</td>
<td>+ 7.5 V to +16 V (rated)</td>
</tr>
<tr>
<td>Mass</td>
<td>&lt; 200 grams (total)</td>
</tr>
<tr>
<td>Volume</td>
<td>3” x 2” x 1” (L x W x H)</td>
</tr>
</tbody>
</table>
Benefits

- **Flexibility**
  - Operation in several bands
  - Various physical configurations
  - Mission orbits

- **Small size**

- **Small mass**

- **Low power consumption**

- **Reduced complexity**

*Flexibility is the most important advantage of the MSBRS design over other radio designs*
Heritage

- AeroAstro developed two S-Band transmitters for CSA and UTIAS for the MOST mission to provide primary on-orbit downlink.
- These transmitters are precursors for the MSBRS Transmitter Module.
- The transmitters were built in less than three months, at low cost.
- They have been operating nominally since launch in July 2003.

The MOST mission provided flight heritage for the S-Band Transmitter.
Status

➢ AeroAstro recently completed a Phase I DARPA SBIR contract

➢ The S-Band Receiver Module design was completed, and prototype hardware was fabricated and tested successfully

➢ Proposed Phase II funding would allow for completion of module designs, fabrication and testing