Comparing On-Orbit and Ground Performance for an S-Band Software-Defined Radio

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Overview

- **Introduction to Software Defined Radio (SDR)**
  - Why SDR?
  - Space Communications and Navigation (SCaN) Testbed

- **Pre-launch Characterization**

- **Design of a Received Power Estimator**
  - Ground development
  - Space performance
Why Software-Defined Radio?

- Software-defined radio (SDR) – a modern communication platform
  - Radio frequency module
  - Signal processing module [waveform]
  - General processing module

- SDR is...

ADAPTABLE!

FLEXIBLE!

PREDICTABLE…?
NASA’s SCaN Testbed (STB)

- Space Communications and Navigation (SCaN) Testbed
  - External payload on the International Space Station (ELC-3 location)

SCaN Testbed installed to the ExPRESS Logistics Carrier-3

SCaN Testbed hardware block diagram
STB Experiment Communication
Jet Propulsion Laboratory (JPL) SDR – part of STB
- S-band transceiver (7 Watts) with L-band receive capability
- 66 MHz SPARC (RTEMS) processor and 2 Virtex-II FPGAs

Three JPL SDRs!
- Flight model (FM)
  - Radio Frequency Module, Global Positioning System Module, Baseband Processing Module, Power Amplifier / Power Supply Module
- Engineering model (EM)
  - Same as FM, except commercial grade parts.
- Breadboard
  - Baseband Processing Module only.
Ground Testing

Flight model SDR testing prior to launch
- Establish a performance baseline in a controlled environment
- Collect data useful for future waveform capabilities

Lesson Learned – test the hardware independent of the waveform
- Test very close to hardware interfaces
- Do not make testing dependent on software implementation

Diagram:
- JPL SDR
  - Diplexer
  - PLL / Down-conversion
  - AGC
  - ADC
  - Signal Processing Module
  - PA
  - PLL / Up-conversion
  - DAC

Abbreviations:
- ADC – Analog-to-Digital Converter
- DAC – Digital-to-Analog Converter
- PLL – Phase Lock Loop
- AGC – Automatic Gain Control
- PA – Power Amplifier
Estimating received power is a useful diagnostic feature

- Uses existing waveform despreader digital filters
  - Performed at the intermediate frequency (IF) after downconversion
  - BPSK filter bandwidth = \(2\times\text{(signal bandwidth)} + \text{(Doppler allowance)}\)
  - Despreader PN generator is bypassed for non-spread modes.
PE Ground Calibration

- Performed testing on the engineering model
  - Map the “Integrate & Dump” value to the corresponding input power
  - Swept input power level across realistic space received power range
  - Power Estimate = Signal Power + Noise Power
- Waveform “mode” → data rate, frequency, spreading, etc.

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<th>Spread</th>
<th>Symbol Rate (ksps)</th>
<th>Freq. MHz</th>
<th>Filter BW (kHZ)</th>
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PE Space Test Considerations

- **Limited power range and test time in space**
  - Space link varies by ~2 dB due to distance over ~40 minutes
  - NASA satellites have 2 fixed transmit power levels

- **Implemented spiral motion on the MGA**
  - Swept elevation over a wide range of power (~20 dB) during 1 pass
  - Used 1-degree lap size based on in-situ antenna pattern
Spread-spectrum results versus engineering model performance

- 0.1 dB error
- 0.3 dB error
- 0.6 dB error
- 0.8 dB error
Non-spread BPSK results versus engineering model performance

2.2 dB error

1.5 dB error

0.4 dB error

11 dB error
Results

*Overall the power estimator performance is acceptable.*
  - Spread waveform modes show less than 1 dB average error
  - Non-spread modes show 1 to 2 dB average error (except mode H)

*The power estimator is sensitive to AGC fluctuation.*
  - AGC level directly affects the IF power level
  - Mode H has a very low AGC set point → 11 dB average error!

*Future work*
  - Improve understanding of how wideband noise affects the AGC algorithm
  - Incorporate AGC level into the power estimator
  - Look into narrower filter bandwidths for lower received power levels