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

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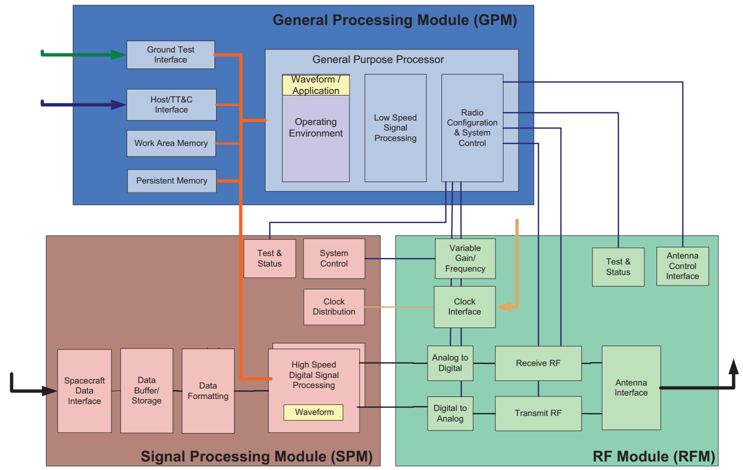
Overview

- **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

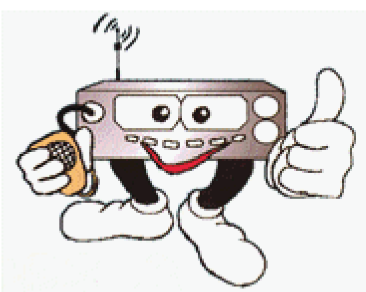
Why Software-Defined Radio?

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



- **SDR is…**

ADAPTABLE!



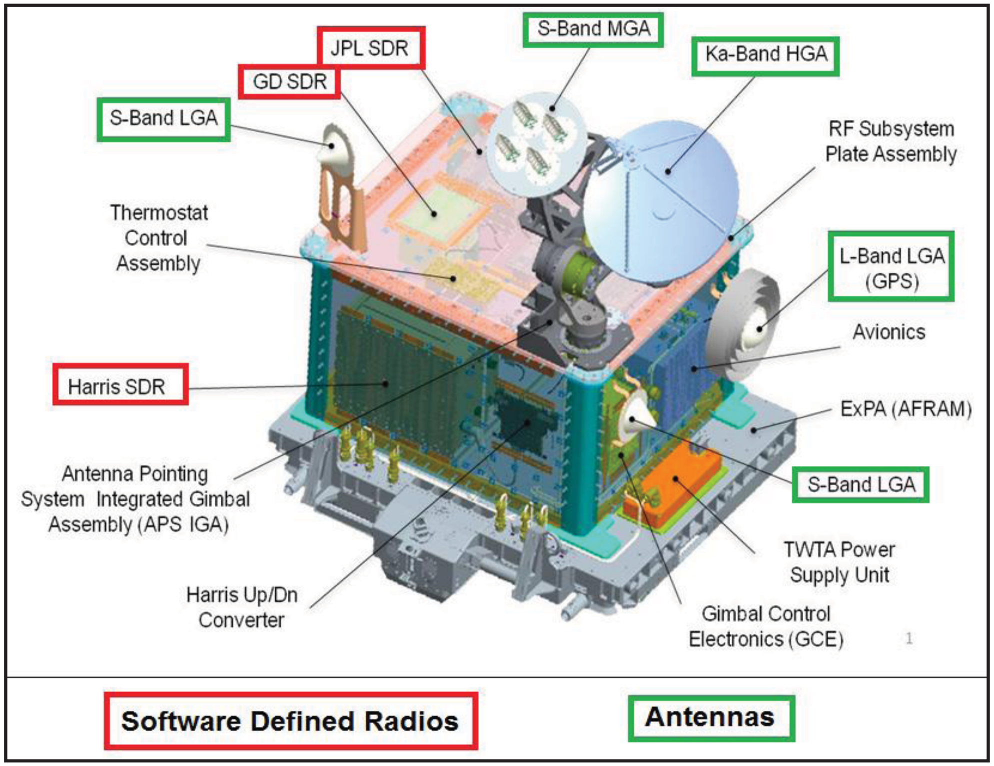
FLEXIBLE!

PREDICTABLE…?

NASA's SCaN Testbed (STB)

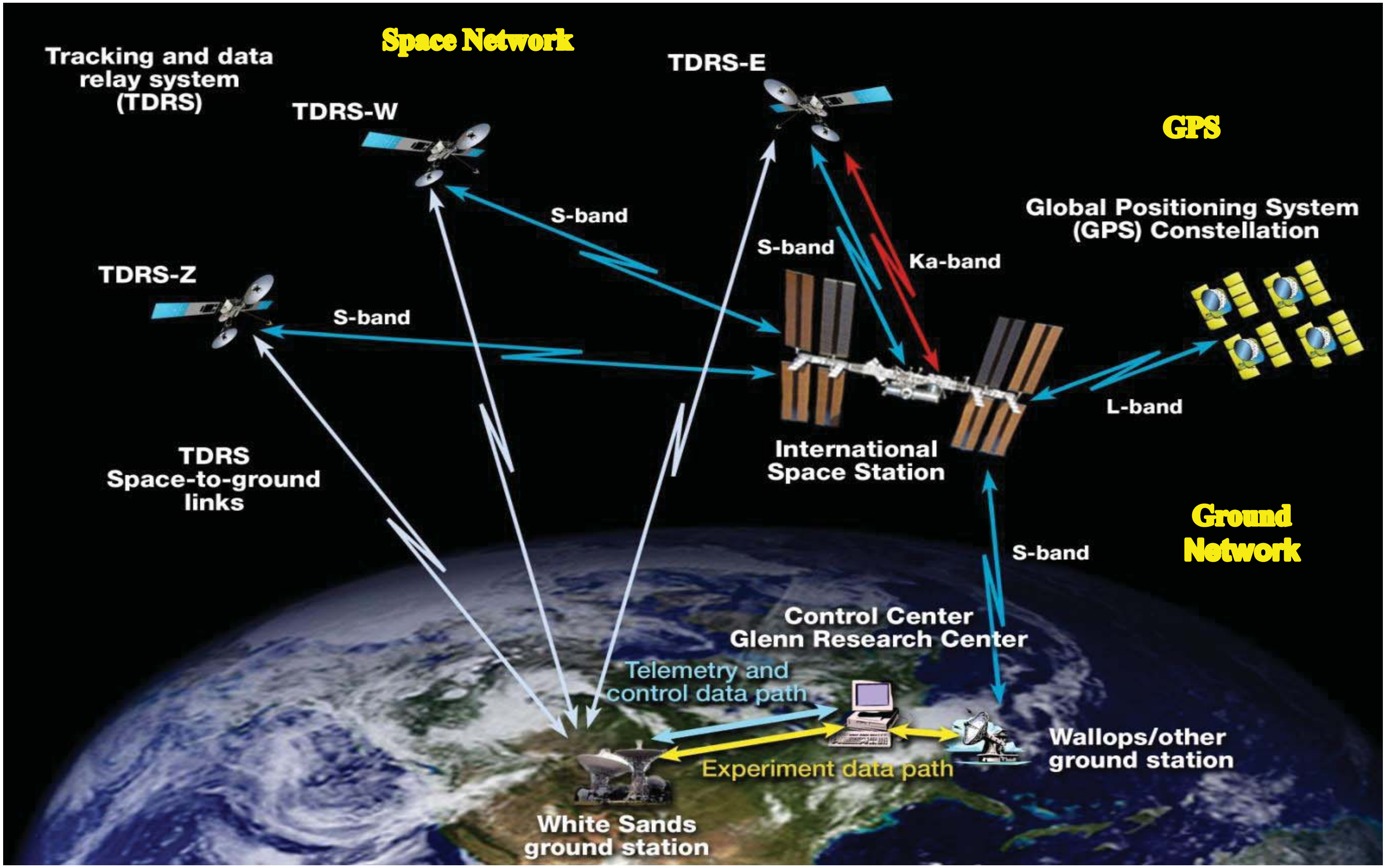
- **Space Communications and Navigation (SCaN) Testbed**
  - External payload on the International Space Station (ELC-3 location)

SCaN Testbed installed to the ExPRESS Logistics Carrier-3



SCaN Testbed hardware block diagram

STB Experiment Communication



STB – Jet Propulsion Laboratory SDR

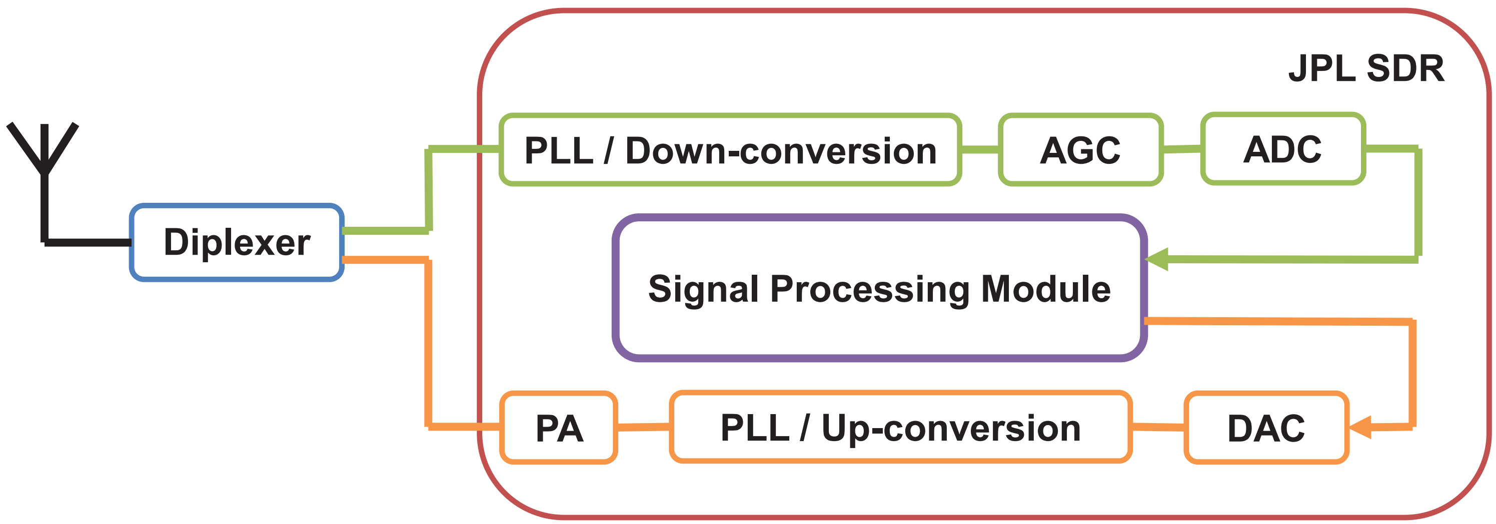
- **Jet Propulsion Laboratory (JPL) SDR – part of STB**
  - S-band transceiver (7 Watts) with L-band receive capability
  - 66 MHz SPARC (RTEMS) processor and 2 Virtex-II FPGAs

- **Three JPL SDRs!**
  - Flight model (FM) ← Int'l Space Station
    - Radio Frequency Module, Global Positioning System Module, Baseband Processing Module, Power Amplifier / Power Supply Module
  - Engineering model (EM) ← Ground
    - Same as FM, except commercial grade parts.
  - Breadboard ← Ground
    - 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

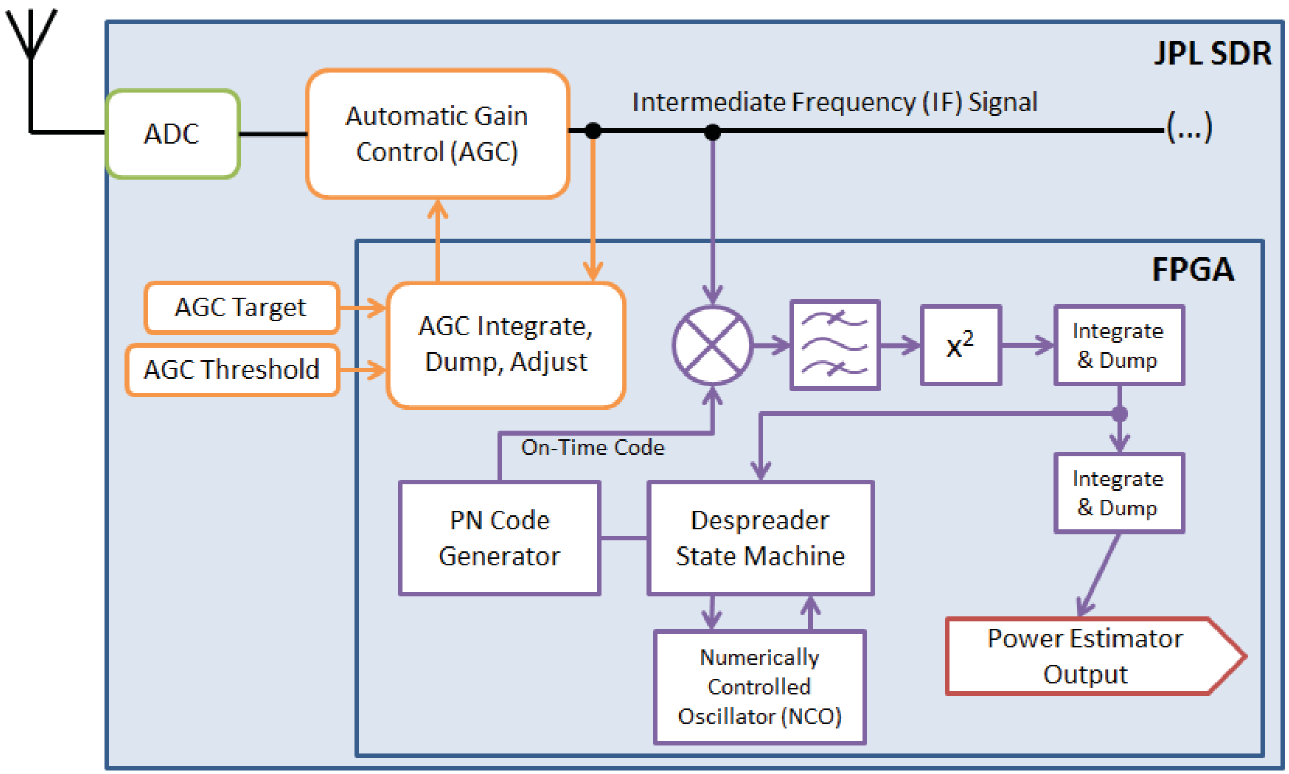
- **Lesson Learned – test the hardware independent of the waveform**
  - Test very close to hardware interfaces
  - Do not make testing dependent on software implementation



ADC – Analog-to-Digital Converter
DAC – Digital-to-Analog Converter
PLL – Phase Lock Loop
PA – Power Amplifier
AGC – Automatic Gain Control

Received Power Estimator (PE) Design

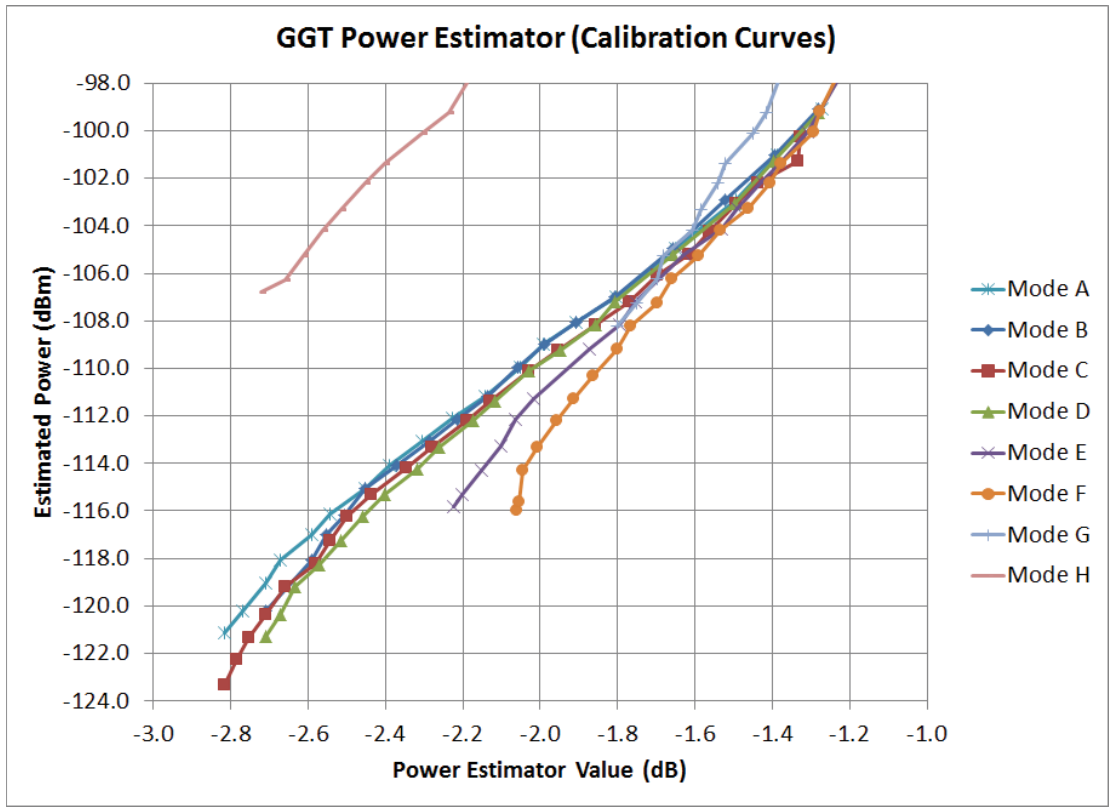
- **Estimating received power is a useful diagnostic feature**
- **Uses existing waveform despreader digital filters**
  - Performed at the intermediate frequency (IF) after downconversion
  - BPSK filter bandwidth = 2*(signal bandwidth) + (Doppler allowance)
  - Despreader PN generator is bypassed for 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.**

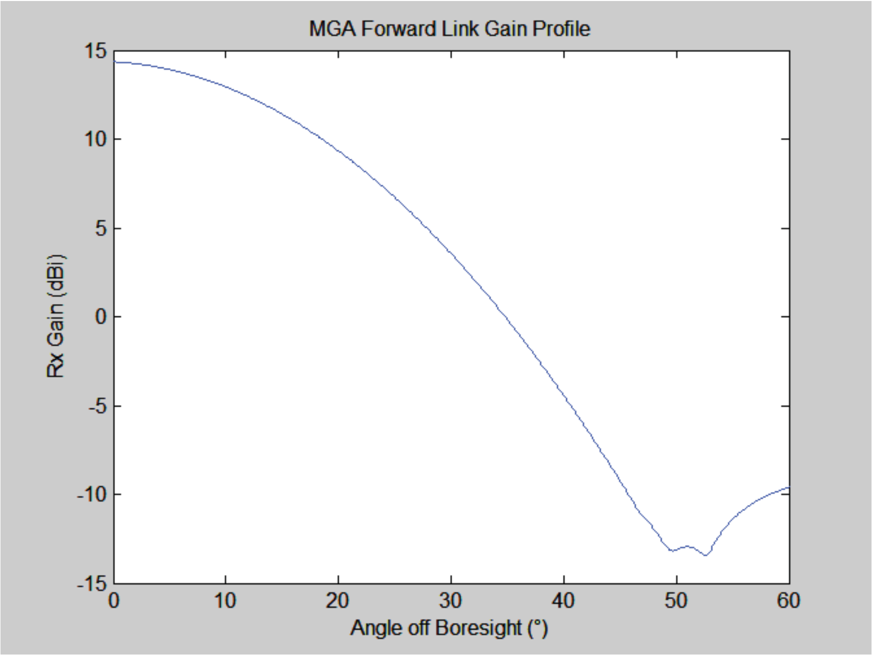
Mode	Spread	Symbol Rate (ksps)	Freq. MHz	Filter BW (kHZ)
A	Yes	18	2106	149
B	Yes	36	2106	188
C	Yes	18	2041	149
D	Yes	36	2041	188
E	No	155	2041	450
F	No	310	2041	789
G	No	769	2041	1793
H	No	1538	2041	3468

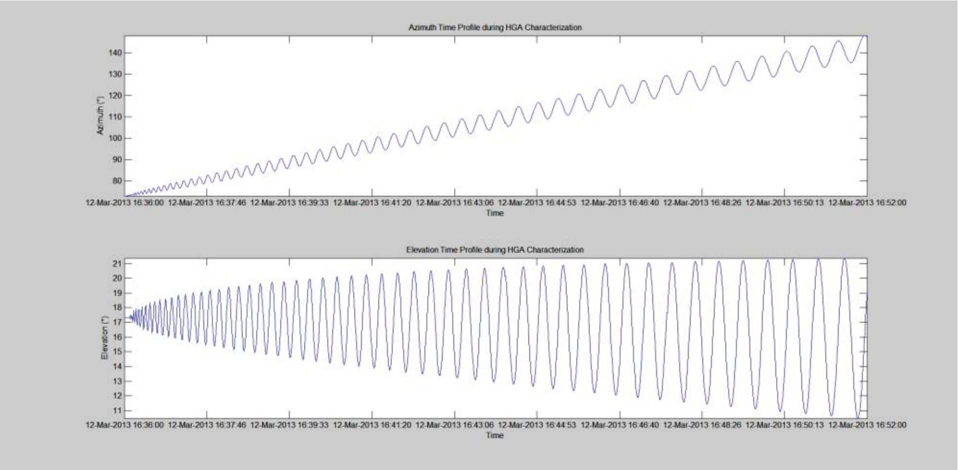


PE Space Test Considerations

- **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

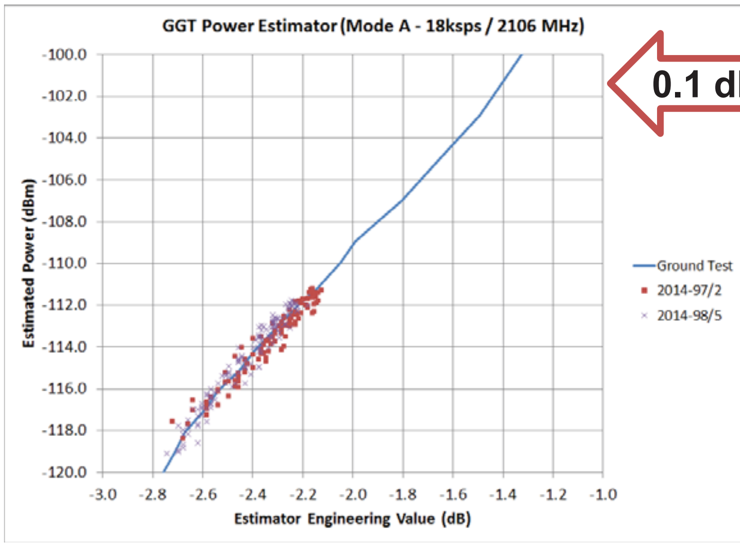
- **Implemented spiral motion on the MGA**
  - Swept elevation over a wide range of power (~20 dB) during 1 pass
  - Used 1-degree lap size based on in-situ antenna pattern



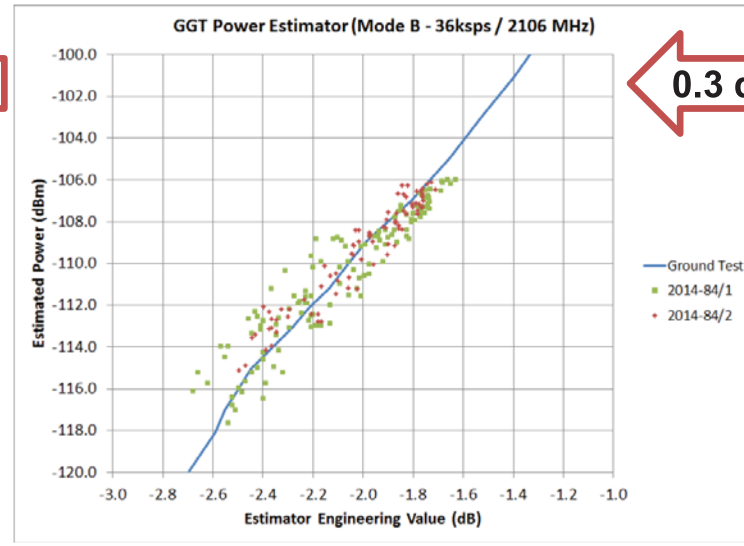


PE Space Test Results - Spread

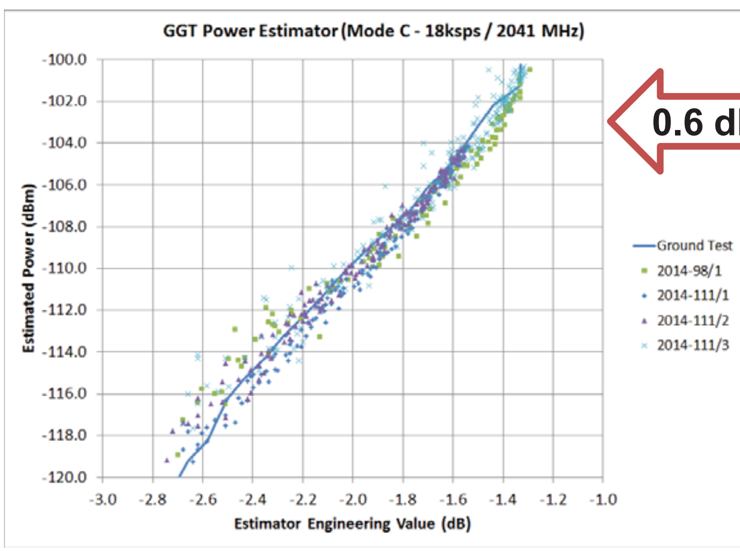
- Spread-spectrum results versus engineering model performance



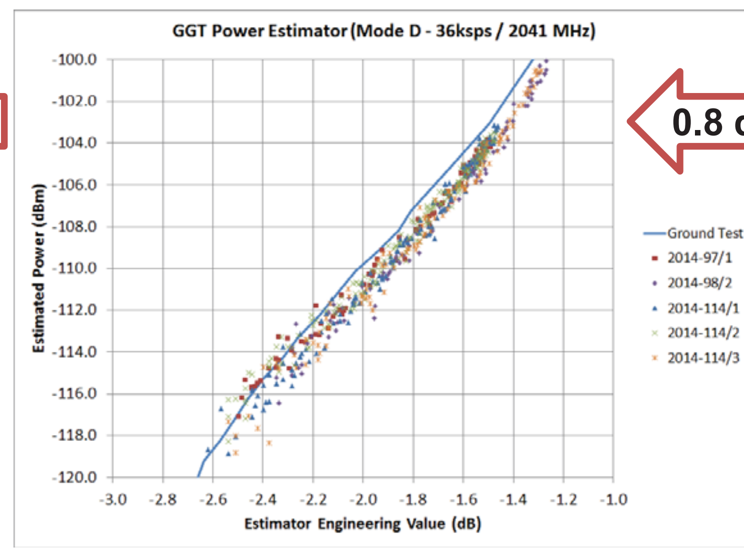
0.1 dB error



0.3 dB error



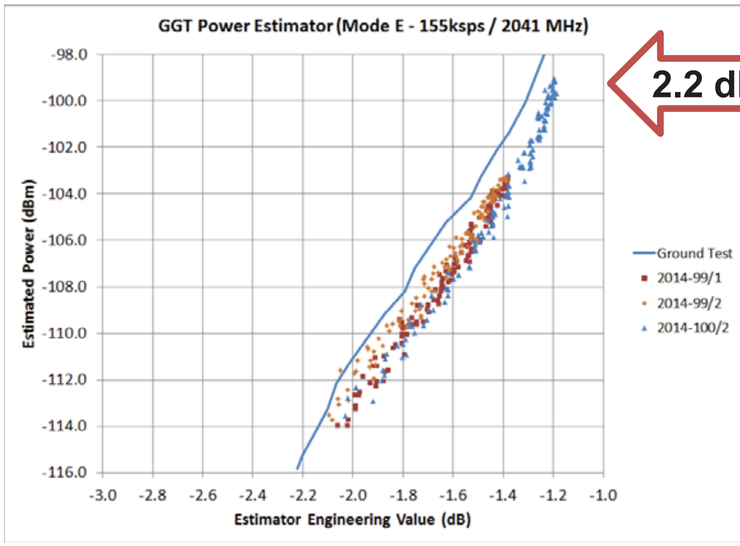
0.6 dB error



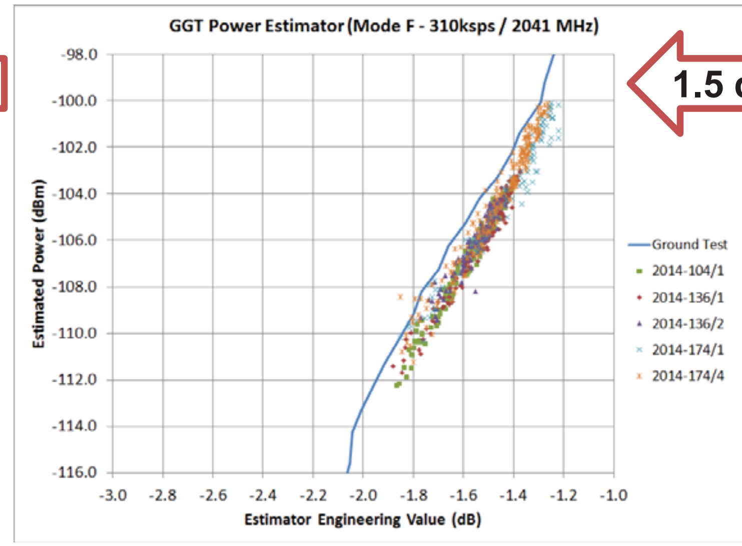
0.8 dB error

PE Space Test Results – Non-Spread

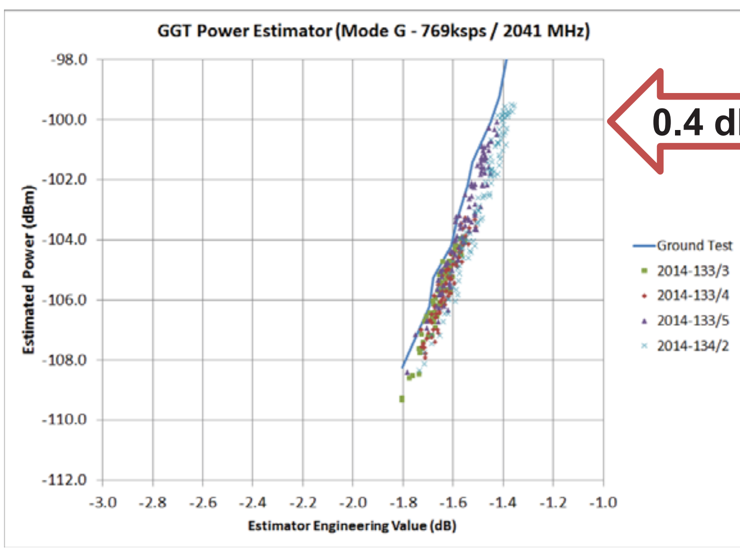
- Non-spread BPSK results versus engineering model performance



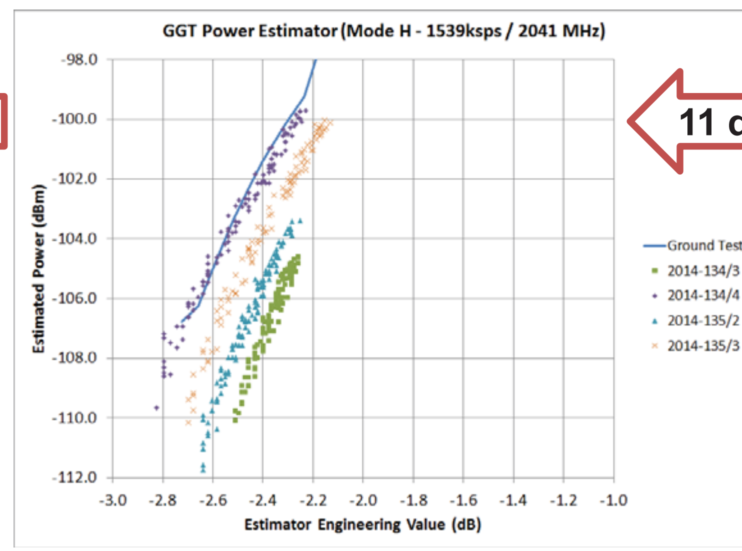
2.2 dB error



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