Hardware and Software Integration to Support Real-Time Space Link Emulation

Prior to operational use, communications hardware and software must be thoroughly tested and verified. In space-link communications, field testing equipment can be prohibitively expensive and cannot test to non-ideal situations. In this paper, we show how software and hardware emulation tools can be used to accurately model the characteristics of a satellite communication channel in a lab environment. We describe some of the challenges associated with developing an emulation lab and present results to demonstrate the channel modeling. We then show how network emulation software can be used to extend a hardware emulation model without requiring additional network and channel simulation hardware.

Hardware and Software Integration to Support Real-Time Space Link Emulation

Authors: Robert Murawski, Kul Bhasin, David Bittner, Aaron Sweet, Rachel Coulter, and Devin Schwab

Presented by: Robert Murawski, Ph.D.

NASA Glenn Research Center

Overview

- Introduction
- System Model
  - Direction Communication Channel Model
  - Bent-pipe Communication Channel Model
- Space-Link Emulation
  - Hardware
 - Software Modeling
- Results

Introduction

- Emulation vs. Simulation
  - Emulation must be high-fidelity
    - Can interact with field equipment
  - Emulation must be performed in real-time
- Benefits of emulation:
  - Testing on hardware in the field can be prohibitively expensive
  - Testing of 'non-ideal' scenarios is feasible
- Challenges for Emulation:
  - Emulation uses real equipment
    - Routers, Modems, Switches, etc
  - Characteristics of emulation equipment should not impact emulation results
    - Have to account for these offsets in the link budget analysis

System Model

- **Single Channel Emulation**
  - Direct Comm. Ground Terminal (GT) to Low Earth Orbit (LEO) Satellite
  - Two Channels:
   - Forward and Return
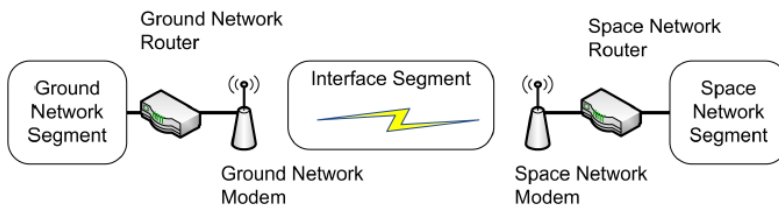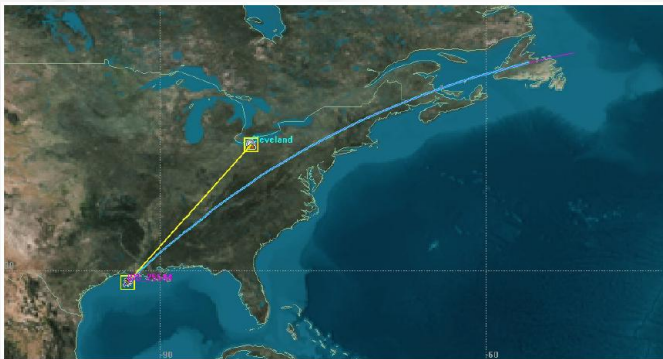
- **Bent-Pipe Channel Emulation**
  - Relay Comm. through Tracking and Data Relay Satellite (TDRS)
  - Four Channels:
    - Forward to Relay, Forward to Satellite
    - Return to Relay, Return to Ground
  - Increased latency / path Loss for extended contact time
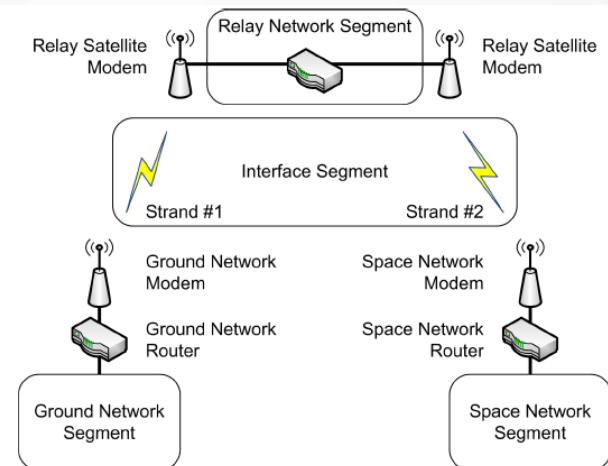
Emulation Hardware

- Emulation Equipment:
  - RT-Logic Channel Simulator
  - (2) Satellite Modem
  - (2) Routers
  - (2) Switches
  - User-Equipment (workstations)
- Simulation Equipment:
  - STK / EXata Workstations
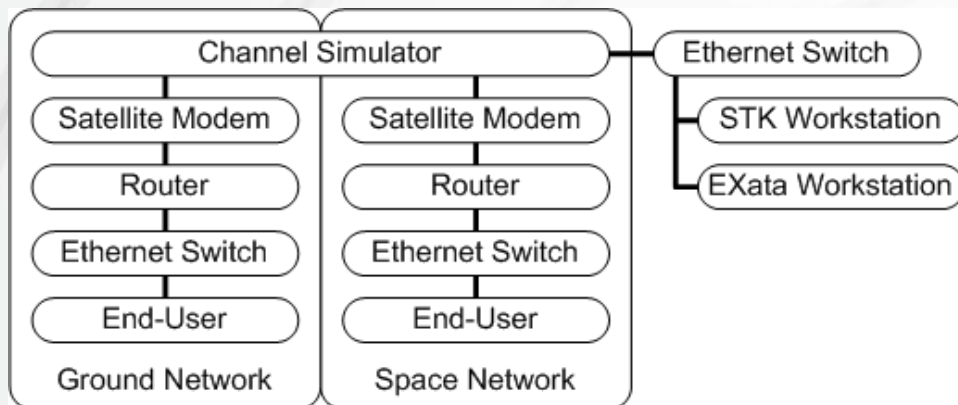
Functional Diagram of Emulation Setup

Lab Equipment

Hardware / Software Integration

- STK Reports Channel Estimations in Real-time
  - Carrier Power at the Receiver (dBW)
  - RT-Logic uses this value as the 'Fine Gain' (dB)
- Challenge:
  - Develop mapping to compensate for hardware
  - Goal:
    - Lab modem receive signal strength (RSS) == STK estimated RSS

STK Link Budget Calculations	
EIRP	69.04 dBW
Free-Space Loss	-185.82 dB
Atmospheric Loss	-0.91 dB
Rain Loss	-13.57 dB
Scintillation Loss	-2.80 dB
Receiver Gain	41.04 dB
Carrier Power at Receiver	-93.02 dBW
Carrier Power at Receiver	-63.02 dBm
Receive Signal Strength (w/ 10dB LNA)	-53.02 dBm

RT-Logic STK Plugin Offset Calculation	
Modem Output Power	25.0 dB
Pre-processor Gain	5.0 dB
dBW to dBm Conversion	30 dB
Cable / Insertion Losses	1.376 dB
Power Divider Losses	3.75 dB
LNA Gain	10.0 dB
Total Offset	75.126 dB

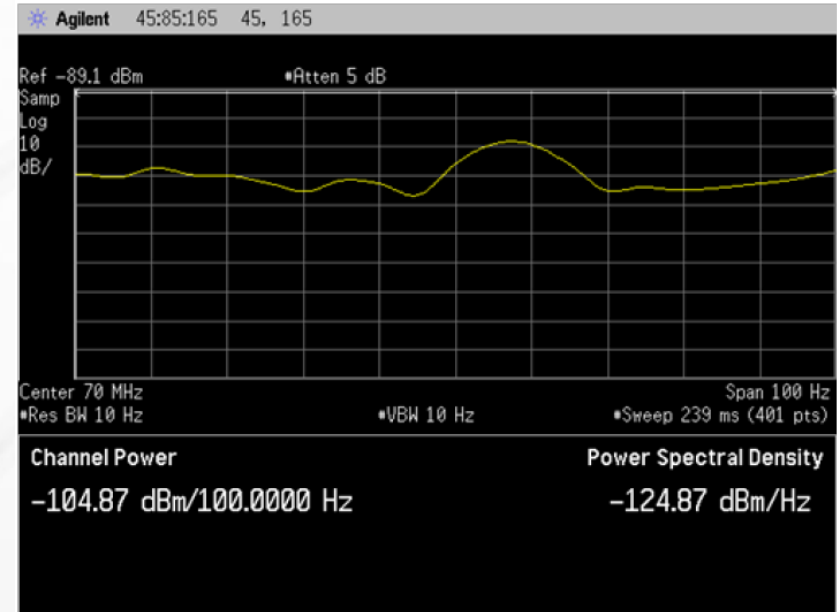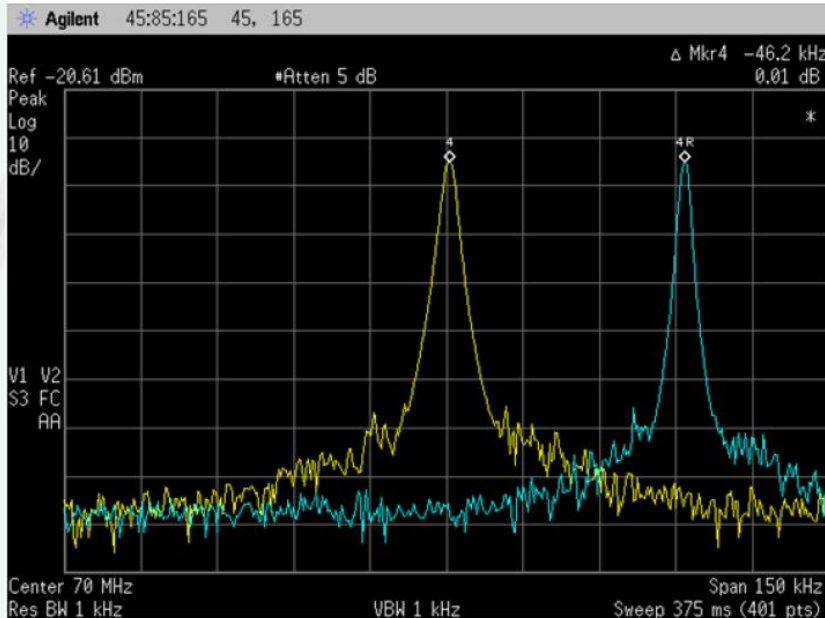# Hardware / Software Integration

- Gain offset applied directly to STK estimated Carrier Receive Power
  - STK estimated Receive Signal Strength: -53.02 dBm
  - Observed Receive Signal Strength: -53.47 dBm
  - Observation using Agilent Spectrum Analyzer Channel Power Measurement
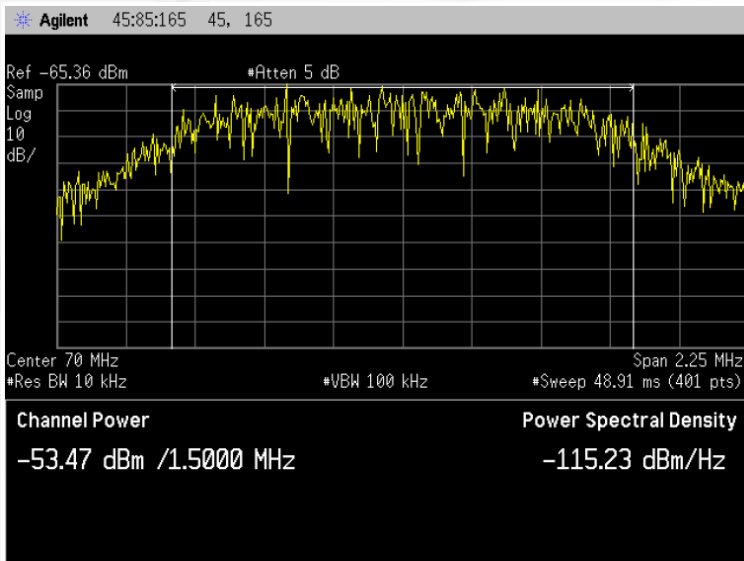
| RT-Logic Calculations	
STK Estimation	-93.02 dB
Gain Offset	75.12 dB
Input to Channel Simulator	-17.9 dB
Hardware Calculations	
Modem Output Power	-25.0 dBm
Cable Losses	-1.376 dB
Pre-processor Gain	-5 dB
Power Divider Losses	-3.75 dB
Channel Simulator Gain	-17.9 dB
Expected Observed Channel Power	-53.02 dBm

Hardware / Software Integration

- Other channel simulation characteristics:
  - Doppler Shift:
    - Apparent shift in frequency due to relative velocity of ground site / satellite
  - Noise Floor :
    - Power spectral noise of the channel noise

Hardware / Software Integration

- Channel delay:
  - Gathered using ICMP Ping through routers
  - Results: Delay follows the estimated STK channel delay
  - Additional Delay:
    - Modem Delay:
      - Channel Coding, Framing
   - Router Delay:
      - Queuing Delay
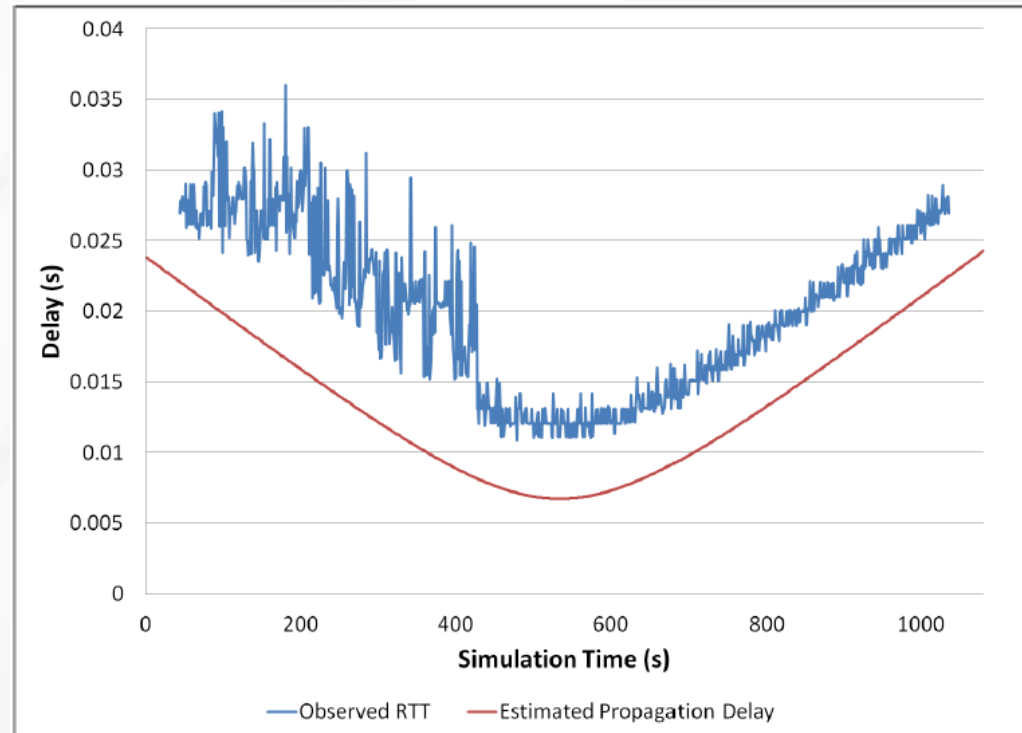
Ongoing Research

- Integration with network emulation software
- EXata
  - Discrete event simulator
  - Models network protocols
- Benefits of EXata:
  - Software channel modeling
    - Can add more channels without additional hardware
  - Model ground network
    - NASA Integrated Services Network (NISN)
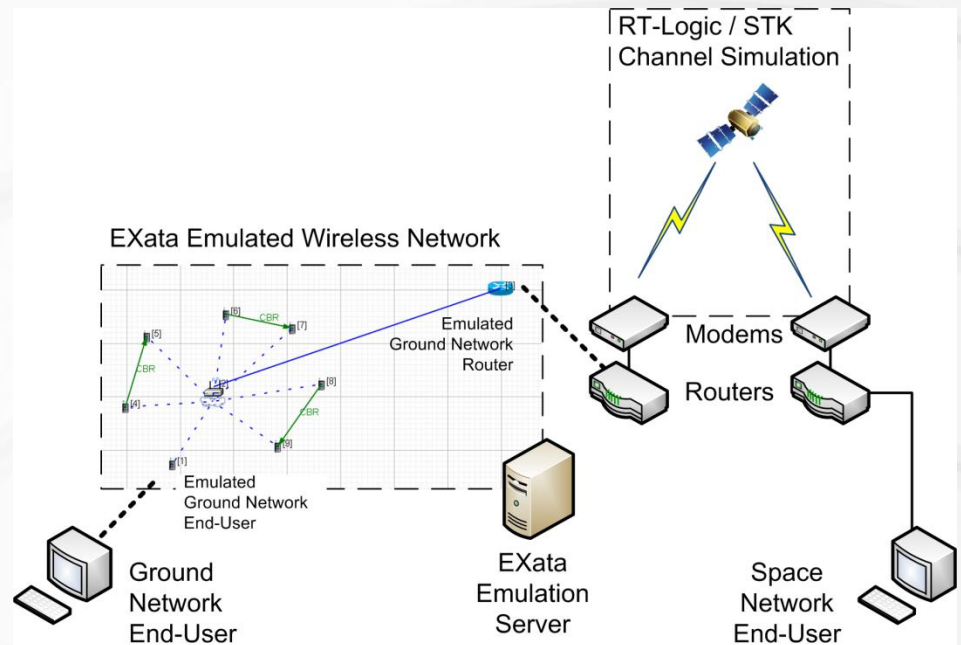
Ongoing Research

- Current results:
  - Excessive delay due to co-simulation: STK/EXata
  - Cannot meet real-time simulation requirements
  - Coordination between STK/EXata workstations = slow
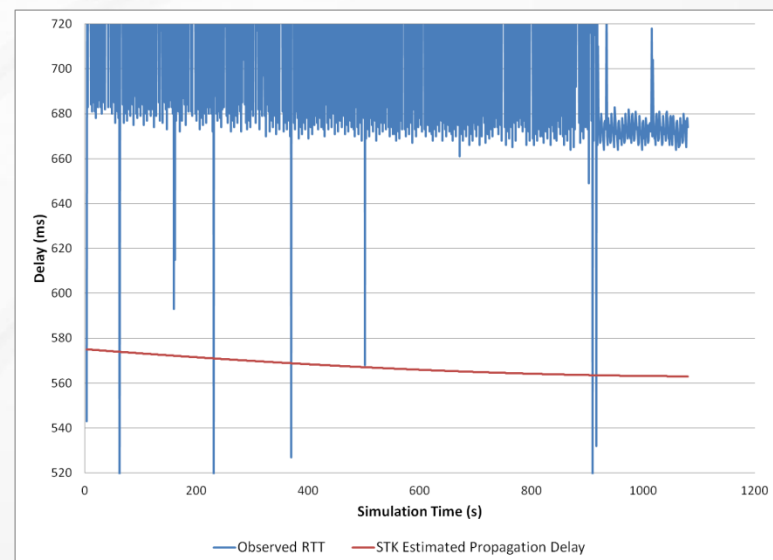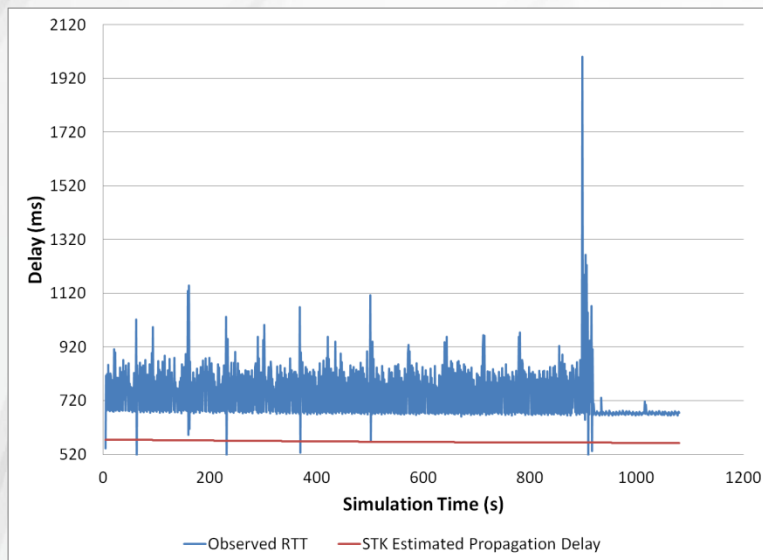
Future Work

- Improvement to custom EXata / STK interface
  - Reduce communication overhead between simulators
  - Meet real-time emulation requirement
- Is modeling received signal strength (RSS) sufficient?
  - Channel Bit Error Rate (BER) is affected by E_b/N_0
  - Noise floor of emulation equipment may not be the same as modeled field hardware.

Acknowledgements

This work was completed at

NASA Glenn Research Center

under the

Space Communication and Navigation (SCaN) Project

Thank you!

Questions?