

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.



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Overview

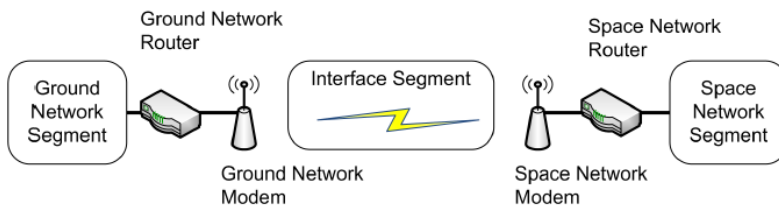
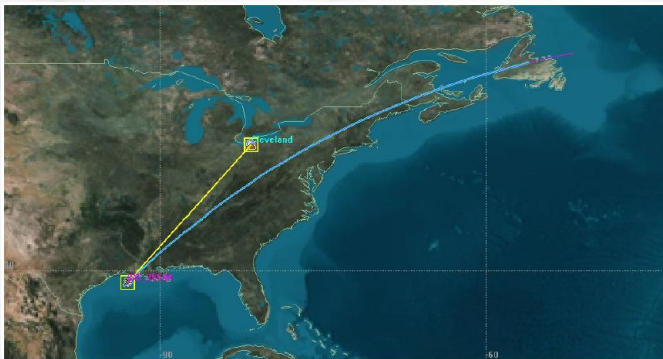
- Introduction
- System Model
 - Direction Communication Channel Model
 - Bent-pipe Communication Channel Model
- Space-Link Emulation
 - Hardware
 - Software Modeling
- Results

Introduction

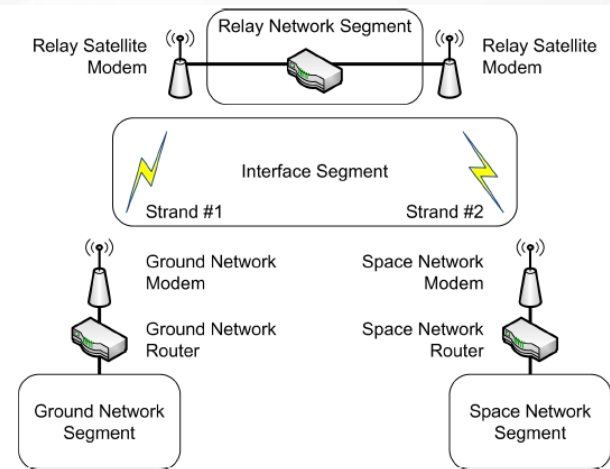
- Emulation vs. Simulation
 - Emulation must be high-fidelity
 - Can interact with field equipment
 - Emulation must be performed in real-time
- Benefits of emulation:
 - Testing on hardware in the field can be prohibitively expensive
 - Testing of 'non-ideal' scenarios is feasible
- Challenges for Emulation:
 - 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

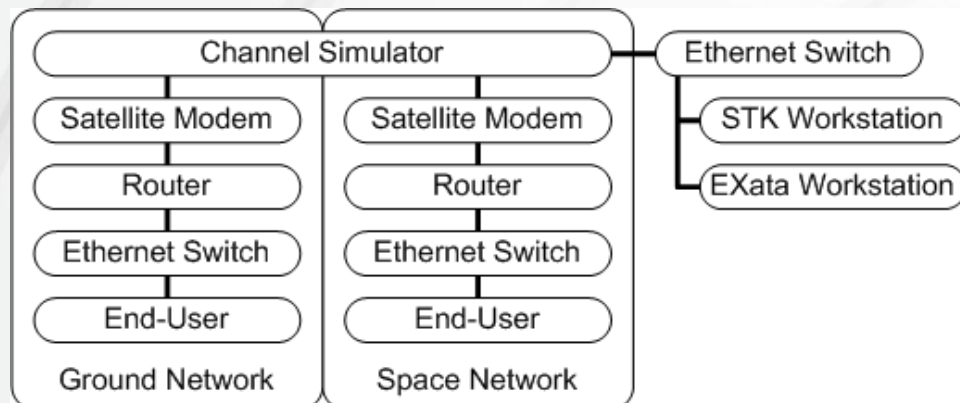


- Bent-Pipe Channel Emulation
 - Relay Comm. through Tracking and Data Relay Satellite (TDRS)
 - Four Channels:
 - Forward to Relay, Forward to Satellite
 - Return to Relay, Return to Ground
 - Increased latency / path Loss for extended contact time



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

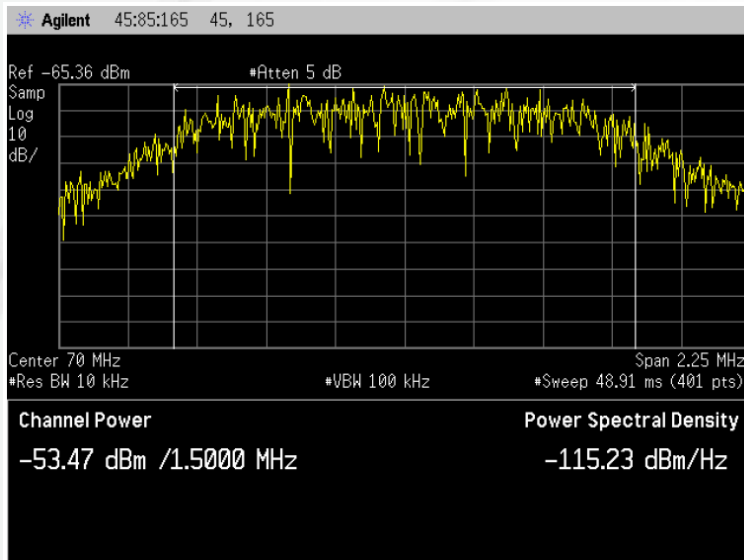
| | |
|--|-------------------|
| EIRP | 69.04 dBW |
| Free-Space Loss | -185.82 dB |
| Atmospheric Loss | -0.91 dB |
| Rain Loss | -13.57 dB |
| Scintillation Loss | -2.80 dB |
| Receiver Gain | 41.04 dB |
| Carrier Power at Receiver | -93.02 dBW |
| Carrier Power at Receiver | -63.02 dBm |
| Receive 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

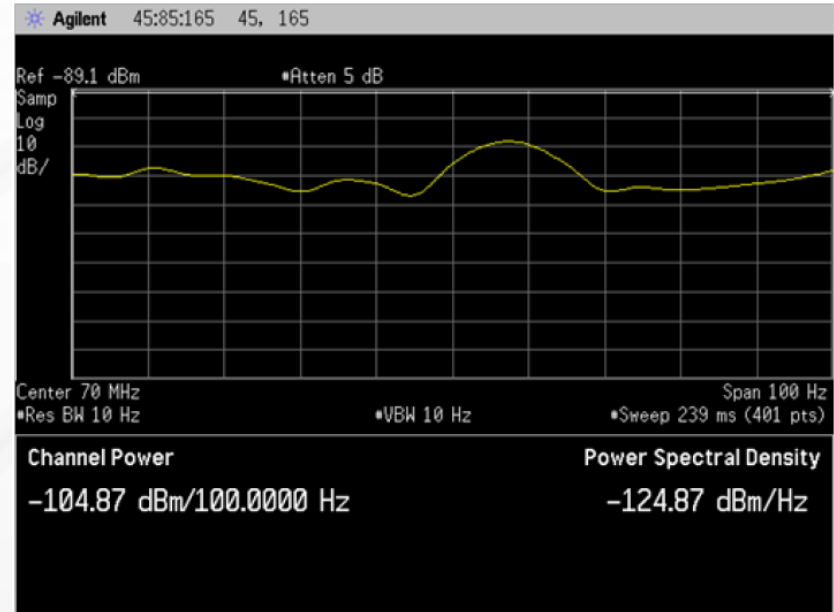
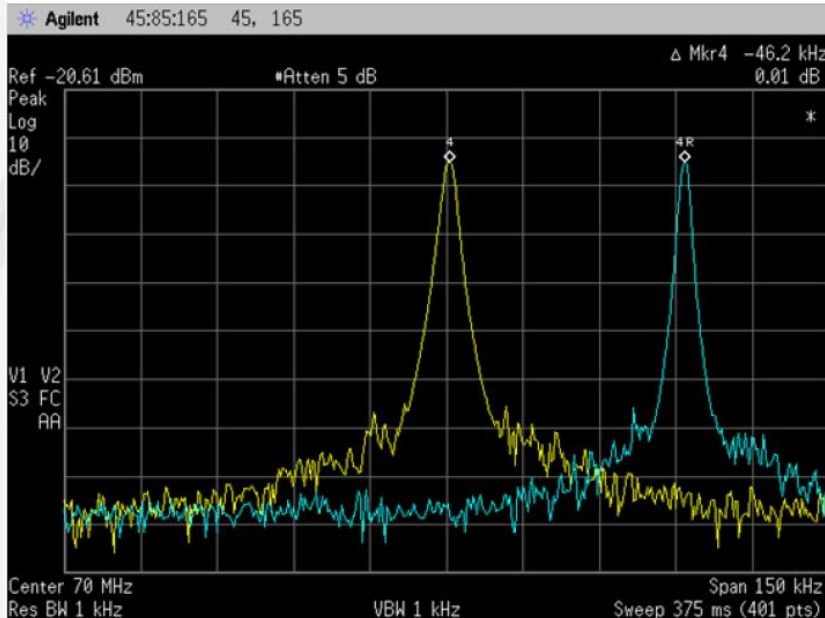


| RT-Logic Calculations | |
|----------------------------|-----------|
| STK Estimation | -93.02 dB |
| Gain Offset | 75.12 dB |
| Input to Channel Simulator | -17.9 dB |

| 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 |

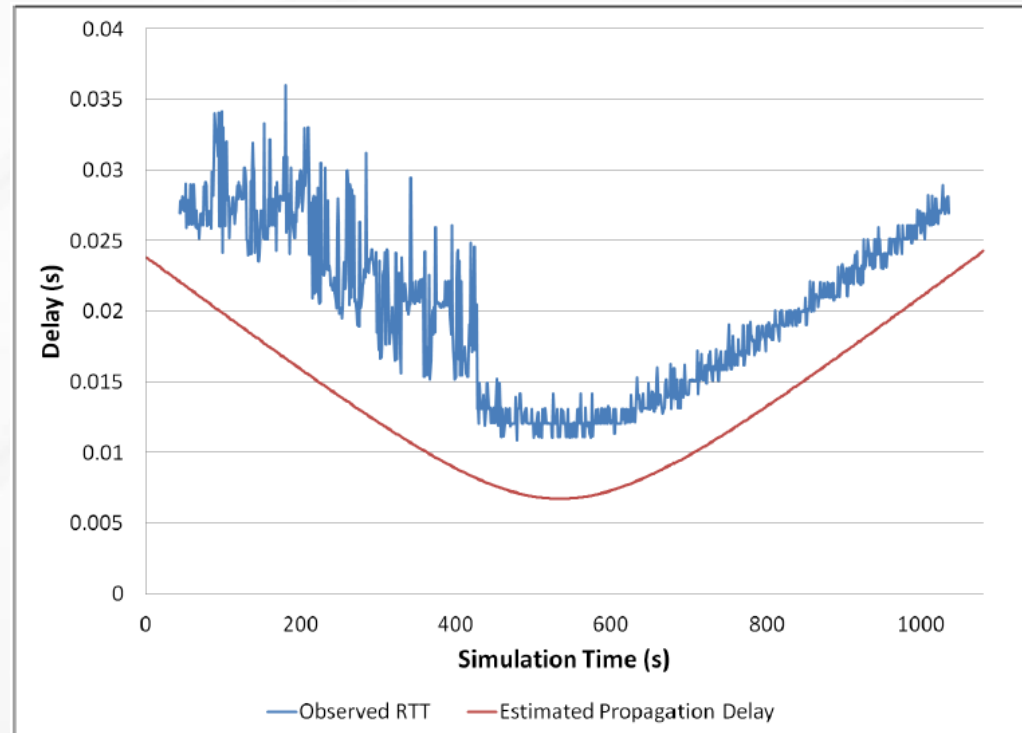
Hardware / Software Integration

- 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



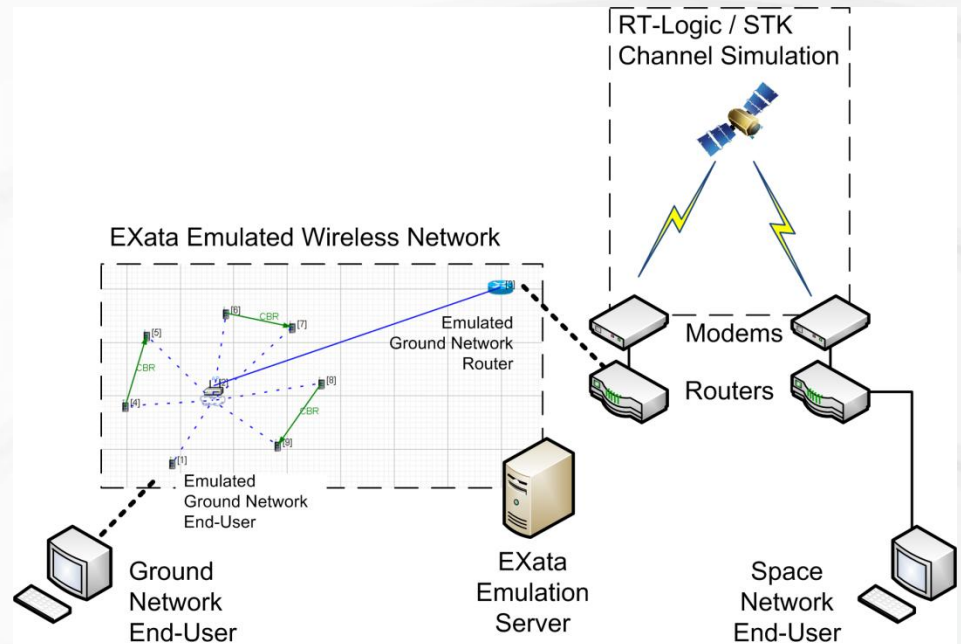
Hardware / Software Integration

- 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



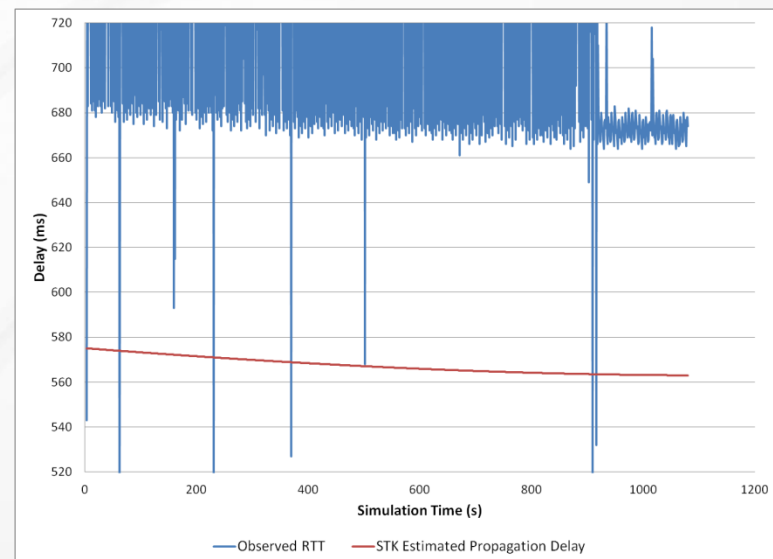
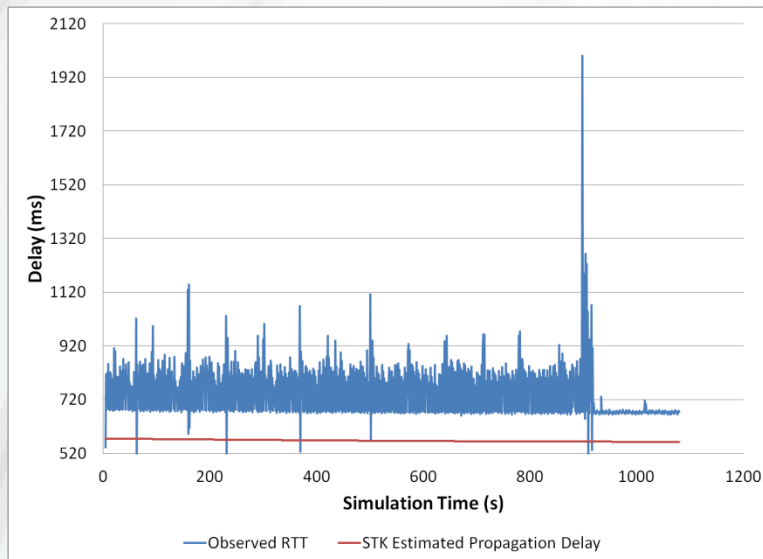
Ongoing Research

- 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

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Thank you!

Questions?