Advanced Hardware-In-The-Loop RF Testing Assures Communication System Mission Success

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Whenever transmitters and receivers are in motion with respect to each other…
• Special test needs exist
  – Doppler shift
  – Range delay
  – Range attenuation
  – Noise
  – Interference
  – Etc.

  Dependent on flight path and ground locations.

  Nominal conditions
  Worst-case conditions

• RF Hardware
• Digital Hardware
• Firmware / Software

  Initial development tests
  Regression tests
  Compliance tests
  Stress tests

• Strong need for economical / fast automated test
  – Run often to detect problems as early as possible
Stimulus

Device Under Test

Analysis

IF, RF

Ethernet, USB, GPIB, RS-232

HW, FW, SW Development

Test Automation Computer

Test Automation Software

Pass

Fail

Detailed Reports
• Special test needs exist
  
  – Doppler shift
  – Range delay
  – Range attenuation
  – Noise
  – Interference
  – Etc.

Dependent on flight path and ground locations.

Nominal conditions
Worst-case conditions

**Diagram:**

- **Stimulus**
- **Device Under Test**
- **Analysis**

**Steps:**

1. **Test Automation Computer**
2. **Test Automation Software**
3. **Pass**
4. **Fail**
5. **Detailed Reports**
Special test needs exist

- Doppler shift
- Range delay
- Range attenuation
- Noise
- Interference
- Etc.

Doppler, delay & attenuation generation is difficult & time-consuming

- Know and understand flight paths
- Pay careful attention to physics
- Phase-continuous, smooth, highly interpolated
- High resolution control and output

Channel Simulators to the rescue!
Stimulus

Chan Sim.

Device Under Test

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Test Automation Computer

Test Automation Software

Pass

Fail

Detailed Reports
• Doppler Shift: 1.5 GHz carrier, 800 km circular orbit

\[ F_s = F_a \times \frac{V}{c} \]

- Large Doppler shift range to accommodate \( F_a \) and \( V \)
- Fast slew rate to accommodate \( F_a \) and \( V \) at closest approach
- Phase-continuous
- High resolution smooth interpolation
• Key Channel Simulator Capabilities
  – Doppler shift is frequency dependent → not identical across signal BW
  – Data rate is affected by Doppler too
  – Signal agnostic
  – Adequate BW
• Delay: 1.5 GHz carrier, 800 km (R) circular orbit

\[ D = \frac{R}{c} \]

• Key Channel Simulator Capabilities
  – Large delay range to accommodate distance range
    – 3 \( \mu \)s \( \approx \) 1 km, 1.4 s \( \approx \) 420 km
  – Bent pipe simulation, \( R = \) Uplink Range + Downlink Range
  – Phase-continuous
  – High resolution smooth interpolation
• Attenuation: 1.5 GHz (F) carrier, 800 km (R) circular orbit

\[ L = 32.4 + 20 \log F + 20 \log R \]

- Key Channel Simulator Capabilities
  - Large attenuator range to accommodate maximum delta attenuation
    - 12 dB ≈ 800 km circular @ 1.5 GHz
    - Bent pipe simulation, \( R = \text{Uplink Range} + \text{Downlink Range} \)
  - Phase-continuous
  - High resolution smooth interpolation
• **Key Channel Simulator Capabilities**
  – Modular to accommodate multiple projects and test scenarios
  – Easily reconfigurable
  – Standard inputs / output
  – IF (cable), RF (cable), RF (near-field), RF (far-field)
• Key Channel Simulator Capabilities
  – GUI for control and monitoring
  – Scenario Files
    – Doppler
    – Delay
    – Attenuation
    – Noise
    – Interference
    – Fading (weather, plume, obscura, etc.)
  – Ethernet programmable
    – TCP/IP Sockets, ASCII, Binary
Key Channel Simulator Capabilities
  - Interface to industry standard software
    - National Instruments LabView
    - Agilent VEE
    - Microsoft Excel
    - MathWorks MATLAB

File-level connectivity
Direct control
• Key Channel Simulator Capabilities
  – Strong scenario creation and visualization
  – Flight paths and ground locations are not easily translated to Doppler, Delay, Attenuation, Etc.
• Key Channel Simulator Capabilities
  – Real-time control from visualization and modeling packages
• Key Channel Simulator Capabilities
  – Physics-based RF and antenna geometry/positioning modeling
U.S. Air Force Academy, FalconSat-5

Educational Use Only

Stimulus

Direct Channel Simulator Control

IF In

RF In

RF Down Conversion

Σ

Noise

Doppler, Delay, Attenuation

Σ

RF Up Conversion

IF Out

RF Out

Link Interference or Test Signals

Receiver Interference or Test Signals

Spectrum Analyzer

13 August, 2009 swilliams@rtlogic.com
U.S. Air Force Academy, FalconSat -5

Stimulus

Direct Channel Simulator Control

13 August, 2009

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• Summary
  – Tests need to be automated
  – Tests need to be frequent and recurring
  – Tests need to be realistic, but cover nominal and worst-case scenarios

  – Channel Simulators should be used for realism
    – Save time, saves cost, prevents over-design and under-design
    – Flexible and modular for reuse on same or different projects
    – Physics-based implementation is vital

  – Channel Simulators must be easy to use
    – Keep engineers focused on their jobs, not on how to make the tools work

  – Additional Information
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