The RT Logic 400 Real Time Channel Simulator (T400CS) is a powerful, yet economical communications link simulator that addresses a broad range of IF and RF hardware-in-the-loop test, operational, and training applications.

The T400CS creates RF and/or IF signals that precisely match those that occur when transmitters and receivers are in motion with respect to one another. By accurately duplicating the motion effects and RF channel physics effects on an RF link, the T400CS allows bench testing of what once required actual motion and distance between a transmitter and receiver.

T400CS channel effects include physics-compliant, phase-continuous, real-time carrier and signal Doppler shift, range delay, range attenuation, fading, and noise. In addition, multiple test and/or interference signals can be generated with the optional multi-channel Signal Generator. A comprehensive selection of upconverters and downconverters are also available, allowing signals to be generated or received in a wide range of frequency bands (UHF, L, S, C, X, and Ku).

The T400CS enables comprehensive test and training activities without actual flights of satellites, missiles, UAVs, targets, and aircraft carrying transmitters or receivers under test. Because the T400CS enables real-time, hardware-in-the-loop emulation of propagation effects rather than computer-based, off-line simulation, the T400CS is the cost-effective alternative between computer-based simulation and leasing flight time or satellite bandwidth.
Software Architecture

The T400CS client/server software architecture facilitates a wide range of local and remote control options. Local control is provided by an easy-to-use RT Logic Graphical User Interface (GUI). Users can also create their own channel simulation profiles, from a comma-separated listing of RF effects values. Programmatic control capabilities include a well-documented control protocol and an optional RT Logic plugin to Analytical Graphics, Inc.’s Systems Tool Kit® (STK). This provides a seamless real-time connection between the motion effects and RF modeling included in STK and T400CS real-world creation of the physics-compliant channel effects.

Channel Simulator

The RT Logic T400CS generates physics-compliant, phase-continuous, real-time carrier and signal Doppler shift, range delay, range attenuation, fading, and Additive White Gaussian Noise (AWGN). These effects can be individually applied or in combination. Together, they precisely duplicate propagation effects encountered in LEO, MEO, HEO, and GEO satellite applications, as well as aircraft, UAV, missile, target, and range test scenarios.

The T400CS is expandable, allowing the system to cover a wide range of channel counts, functions, and frequencies. One channel simulator card is typically configured in a T400CS system to emulate a single communication path, for example, an uplink or a downlink. A single channel simulator card can also be used to simulate both uplink and downlink through bent-pipe transponders. When emulating a bidirectional or full duplex communication link, the T400CS system is typically configured with two channel simulator cards. Signal recorders/players, signal generators, and spectrum analyzers can also be included in the T400CS system, further expanding its testing capabilities. The T400CS can be inserted into a system under test in multiple ways, including direct cabling or utilizing amplifiers, signal conditioners, and antennas for over the air operations.

Local control of the T400CS is accomplished through the use of the included GUI or simulation (SIM) files. Static control of the channel simulator can be accomplished through the GUI. SIM files are utilized for real-time recreation of signals between transmitters and receivers in motion. SIM files are created in standard Comma Separated Value (CSV) format, and can be based on range, frequency, and time information, or can be built with time, Doppler, delay, attenuation, and noise values directly. SIM files can also be created from STK reports. SIM files allow developers to build nominal, worst-case, and mission-specific scenarios, providing precise, repeatable, phase-continuous local control of the T400CS.

Programmatic control of the T400CS is facilitated over an Ethernet connection utilizing a control protocol or optional RT Logic plugin to AGI’s STK software. When using STK and RT Logic’s plugin as the T400CS front-end control software, the Channel Simulator produces IF/RF signals with exacting signal behavior for any scenario. RT Logic’s STK plugin provides real-time, phase-continuous control of the T400CS when playing STK scenarios. STK provides intuitive, quick visual development of communication link scenarios, without requiring user expertise in channel models, propagation effects, link budgets, or orbital/flight science. Users with expertise in these areas can utilize their own simulation software or test executive, programmatically linking with the T400CS through the control protocol.

When Communication Really Counts

- Develop and test realistically, thoroughly, quickly, and easily, under the most punishing RF and complex motion conditions imaginable, without ever leaving the lab.
- The T400CS adds dynamic, phase continuous, physics-compliant signal and carrier Doppler shift, delay, path loss, noise, and interference to test signals.
- Seamless integration with AGI’s STK simulation software allows the communication link parameters of a scenario to become programming parameters for hardware in-the-loop testing. Key scenario parameters include antenna properties, troposphere effects, refraction, fog, rain, clouds, body shielding, and finite ray multi-path.
- The T400CS low-noise, wide-bandwidth, physics-compliant RF signal path allows system testing indistinguishable from actual, ground-to-space, space-to-ground, ground-to-air, air-to-ground, and air-to-air deployment.
- The T400CS is a specialized single piece of test equipment that economically and efficiently replaces an assemblage of non-specialized test equipment typically utilized in communication system testing.
Signal Generator
The T400CS Signal Generator provides test and/or interference signal generation capability. The Signal Generator cards are capable of producing up to eight (8) signals with independently adjustable frequency offset, modulation type, data rate, PRN code (and trigger delay), amplitude, and filtering. These signals can be used as nominal test signals, or can be configured to represent worst-case signal conditions for comprehensive receiver system testing, diversity combiner testing, jammer rejection tests, etc. These signals can also be configured as interfering signals to test avoidance/mitigation capabilities.

Spectrum, Signal, and Interference Analyzer
The T400CS Spectrum, Signal, and Interference Analyzer provides complete signal analysis and automated spectrum monitoring capabilities. Advanced features include display of C/No, Eb/No, BER, and C/I metrics, as well as determination of carrier standard and inner coding schemes.

Sophisticated interference analysis processing allows identification and study of jammer, covert or accidental interference sources, and their impacts on signals of interest. Carrier-Under-Carrier analysis supports the identification and study of signals that might intentionally or unintentionally appear beneath the main signal.

Frequency Converters
RF up/downconverters are available for a wide range of input and output frequencies. This allows the T400CS to generate RF signals for realistic receiver testing. Frequency up/downconverters are useful when tests need to be run at RF, and when the IF of the devices to be tested is not accessible or differs from the Channel Simulator IF. Additionally, in-house or third-party up/downconverters can often be used in conjunction with the T400CS.

Realistically Test
A UAV sensor video being relayed via satellite might be transmitted by the UAV, as shown in the top panel (UAV Transmit). This depicts good video clarity and a QPSK modulation with very low Error Vector Magnitude (EVM). The same signal, after traveling through the atmosphere and space to reach the operations center, is affected by RF channel dynamics. These effects include carrier and signal Doppler shift, delay, AWGN, atmospheric refraction, and fading. Additional perturbations include noise sources on the transponder and receiver, as well as fading components related to body shielding of the antenna and boresight pointing errors. The net impact can be degradation of the signal, as shown in the lower panel (Ops Center Receive). The QPSK modulation now has high EVM and poor video clarity. The T400CS provides a simple, cost-effective means of bench-testing critical communication systems under realistic conditions. When communications really count, rely on the RT Logic T400CS for rigorous, realistic testing.
Hardware Architecture

At a high level, the T400CS Channel Simulator contains Analog-to-Digital (ADC), Digital Signal Processing (DSP), memory, and Digital-to-Analog (DAC) components, along with a processor and an external control interface. Optionally, the T400CS can include:

- RF up/downconverters: Convert signals between their native frequencies and the IF used within the Channel Simulator.
- Signal Generator: Provides test and/or interference signal generation capability.
- Spectrum Analyzer: Provides signal analysis capabilities in the frequency and/or time domains.

The T400CS hardware is implemented with a series of compact PCI (cPCI) modules controlled by a cPCI CPU running Microsoft® Windows® 7. The flexible architecture of the T400CS allows for multiple channel simulator cards, signal generator cards, spectrum analyzers, frequency converters, etc.

Key Specifications

Channel Simulation

<table>
<thead>
<tr>
<th>Bandwidth (3 dB)</th>
<th>40 MHz (0.5 dB flatness available)</th>
<th>85 MHz (0.5 dB flatness available)</th>
<th>250 MHz</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intermediate Frequency</td>
<td>70 MHz</td>
<td>160, 266 MHz</td>
<td>1200 MHz</td>
</tr>
<tr>
<td>Delay</td>
<td>Range: 3 μs - 1.25 s</td>
<td>3 μs - 1.25 s</td>
<td>3 μs - 2.01 s</td>
</tr>
<tr>
<td>Resolution</td>
<td>14 ps</td>
<td>14 ps</td>
<td>38 fs</td>
</tr>
<tr>
<td>Velocity</td>
<td>146.4 km/s</td>
<td>146.4 km/s</td>
<td>36.6 km/s</td>
</tr>
<tr>
<td>Phase</td>
<td>Range: 0-360 degrees</td>
<td>0-360 degrees</td>
<td>N/A</td>
</tr>
<tr>
<td>Carrier Doppler</td>
<td>Range: +/-20 MHz</td>
<td>+/-42.5 MHz</td>
<td>+/-125 MHz</td>
</tr>
<tr>
<td>Resolution</td>
<td>25 MHz (0.8 MHz**))</td>
<td>25 MHz (0.8 MHz**)</td>
<td>93 MHz</td>
</tr>
<tr>
<td>Signal Doppler</td>
<td>Range: +/-20.5 kHz</td>
<td>+/-20.5 kHz</td>
<td>+/-15.2 kHz</td>
</tr>
<tr>
<td>Attenuation</td>
<td>Range: -60 dB</td>
<td>-60 dB</td>
<td>-60 dB</td>
</tr>
<tr>
<td>Resolution*</td>
<td>0.001 dB</td>
<td>0.001 dB</td>
<td>0.001 dB</td>
</tr>
<tr>
<td>AWGN</td>
<td>Range: -168 to -102 dBm/Hz</td>
<td>-168 to -102 dBm/Hz</td>
<td>-168 to -102 dBm/Hz</td>
</tr>
<tr>
<td>Resolution*</td>
<td>0.5 dB</td>
<td>0.5 dB</td>
<td>0.5 dB</td>
</tr>
</tbody>
</table>

* typical
** in geosynchronous mode (with reduced Doppler range)

Intermediate Frequency (IF) performance stated in table. Contact RT Logic for RF converter

T400CS

Channel Simulator

**RF Frequency Coverage**

Ranges available using optional RT Logic upconverters and downconverters.

<table>
<thead>
<tr>
<th>RF Band</th>
<th>Input Range</th>
<th>Output Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>UHF-Band</td>
<td>225-400 MHz</td>
<td>225-400 MHz</td>
</tr>
<tr>
<td>L/S-Band</td>
<td>900-2,450 MHz</td>
<td>900-2,450 MHz</td>
</tr>
<tr>
<td>C-Band</td>
<td>3,400-4,200 MHz</td>
<td>5,850-6,425 MHz</td>
</tr>
<tr>
<td>X-Band</td>
<td>7,250-7,750 MHz</td>
<td>7,900-8,400 MHz</td>
</tr>
<tr>
<td>Ku-Band</td>
<td>10,700-12,750 MHz</td>
<td>13,750-14,500 MHz</td>
</tr>
</tbody>
</table>

Other ranges available using non-RT Logic converters.

**Signal Generation**

- Channels, 8 per card
- Standard modulation types, BPSK, QPSK, OQPSK, SOQPSK-TG and SOQPSK-MIL, 8PSK, 16APSK, 16QPSK, 32APSK, MSK, FSK, AM, FM, CW, PCM-FM
- Standard filter types, rectangular, raised cosine (cutoff 0.5, rolloff 0.3), root-raised cosine (cutoff 0.5, rolloff 0.3614)
- Data rates, modulation type dependent
- Frequency offset, 0 KHz ±20/42.5 MHz
- Internal and external trigger for PRN start
- Independent trigger delay per channel
- AM and FM depth controls for AM and FM modulation mode

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