INSIDE THE CAST 5000 SIMULATOR:

Replicating End-to-End CRPA Signal Wavefront in Jamming Environments

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The CAST 5000 GPS Wavefront Generator is a first-of-its kind high accuracy and high precision simulator for testing individual CRPA-equipped receivers, embedded GNSS/INS (EGI) and combined EGIs with additional equipment or an entire system.

The growing dependency on and increased application of Global Navigation Satellite System (GNSS) signals carries with it a parallel concern about intentional or unintentional interference. In today's environment, the Controlled Reception Pattern Antenna (CRPA) array is considered the best protection against jamming vulnerability.

While the development of CRPA arrays is a mature field, testing CRPA-equipped GNSS receivers to verify that they can under the changing threat environments is still a challenge because of the many external factors that affect navigational accuracy.

Ensuring that a system will perform properly both under ideal conditions and under the influence of external influences requires a controlled and repeatable environment, such as a simulator. Unfortunately, most simulators are not able to produce multiple coherent GNSS signals and thereby test and eliminate interference wavefronts.

In response, CAST Navigation developed the first-of-its kind CAST 5000 GPS Wavefront Generator, a next generation high accuracy and precision simulator for CRPA and attitude determination receiver testing.

THE CRPA CHALLENGE

First integrated with GNSS receivers in the 1980s, CRPA arrays are ideally designed to process, phase-shift and combine signals (gains and nulls) in the array radiation pattern to reject out-of-phase signal combinations. The more antenna elements that are available, the more chance there is to prevent jamming. The number of antenna elements within a CRPA array and the need to evaluate coherent interference signals limit reliable testing options for verifying CRPA performance under varied conditions.

The conventional approach to performance testing, antenna integration and validation of a CRPA-equipped GNSS receiver is a dynamic physical flight test on a range with a vehicle and jamming systems or access to an anechoic chamber to test the antenna, electronics and receiver. While effective, these practices are time consuming, labor intensive and can limit the practitioners' ability to simulate and mitigate real-world threats.

Historically, GNSS simulators capable of testing CRPA-enabled receivers have had limited appeal because they typically aren't able to produce all coherent interference signals that can be counter-acted by a CRPA. For effective CRPA-equipped receiver testing, the simulator must have the ability to simulate the GPS and interference signals so that the CRPA, antenna electronics and the GPS receiver can be tested as a unit while specifying interference levels and signal transition.

SIMULATOR BASICS

The CAST 5000 GPS Wavefront Generator is a 6-degree-of-freedom (DOF) motion generator that provides a true replica of the signal wavefront under numerous user dynamics.

The simulator is able to operate in either canned or real-time mode with a minimal-error intercard carrier-phase signal. It can generate a GNSS solution and up to four coherent jamming signals (i.e., CW, pulsed CW, swept CW FM noise and pulsed FM noise) per frequency band (i.e., L1 + L2) for each CRPA antenna element (up to seven), which are referenced to the phase center of the antenna.

Further, the simulator contains up to seven complete GPS L1/L2 output elements that can be individually delayed. In total, the simulator can produce up to 32 complete GPS channels (16 for L1 and 16 for L2) and up to eight jammer waveform types (four for L1 and four for L2) per frequency, per antenna element (up to seven) for a total of 224 GPS channels and 56 jammer channels.

The RF to each antenna element is then offset from the antenna's phase center by a lever arm correction. Through simulator system synchronization, the GPS signals and the jamming signals for each antenna element are coherent (in-phase) with each other, creating a GPS/jamming signal waveform that is seen by the CRPA antenna. The GPS/jammer waveforms are generated separately for each CRPA antenna element thus ensuring a coherent solution.

The CRPA antenna, antenna electronics and the GPS receiver can be tested as a unit with or without radiating signals.

BUILT FOR CUSTOMIZATION

Besides tailoring a coherent waveform, the multi-output wavefront simulator includes options for simulating potential conditions and customizing CRPA antenna patterns.

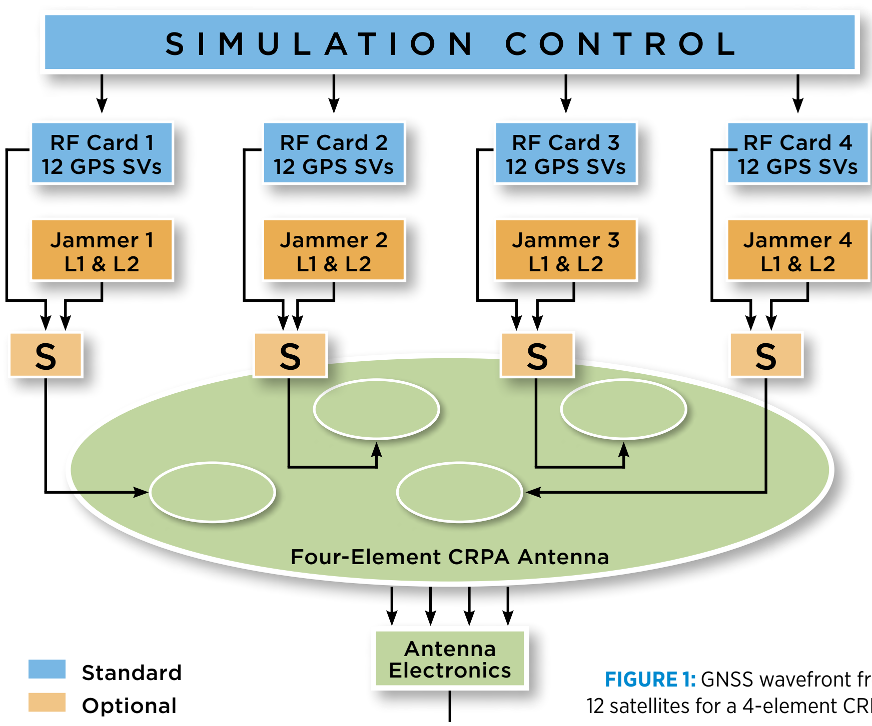

FIGURE 1: GNSS wavefront from 12 satellites for a 4-element CRPA.

Antenna Pattern Modeling

Within the CAST 5000, the operator can model each CRPA element separately and support either 2-D or 3-D antenna gain patterns. The type of pattern used is both selectable and modifiable. As well, antenna gain pattern entry is an interactive process that allows the user to define an independent azimuth gain, elevation gain and phase.

The CAST 5000 contains an interactive editor which allow the user to

SYSTEM CONFIGURATION

- GPS Satellites Generated 12 to 84 L1 and L2
- Size (H x W x D) 31″ x 24″ x 32″
- Weight (approximate) 250 lbs
- Power Required 110/220 VAC 50/60 Hz, 600 W
- Operating System Windows, Lynx

SYSTEM FEATURES

- Generates Single Coherent Wavefront of GPS
- 6-DOF Motion Generation Capability
- Complete SV Constellation Editing
- Post Mission Processing via ICD-GPS-150/153
- Differential/Relative Navigation
- Antenna Pattern Modeling
- Waypoint Navigation
- RAIM Events
- Multipath Modeling
- Spoofer Simulation
- Satellite Clock Errors
- External Trajectory Input
- External Ephemeris and Almanac
- Several Iono and Tropo Models
- Modifiable Navigation Message
- Modeled Selective Availability
- Time-tagged Satellite Events
- Selectable Host Vehicle Parameters

The CAST 5000 is able to tailor errors sources to a simulation, equations that are driving the antenna electronics and recreate interference anomalies.

specify the detailed characteristics and parameters associated with the desired test, including sensors/systems to be simulated and their associated error parameters, space and control segment errors for GPS, initial conditions and characteristics for the host vehicle being modeled, interfaces desired, RF signal simulator setup parameters, satellite selection criterion (minimum GDOP, PDOP, HDOP, or modified tetrahedron), Interference / spoofing environment (if applicable), antenna shadowing, and antenna gain pattern.

Vehicle Silhouette

The CAST 5000 supports a vehicle silhouette function, which allows the user to specify up to 99 antenna gain models per scenario. Users are able to interactively define shadows from vehicle components (e.g. tailfins, wings) in individual five-degree points about the vehicle body.

The RAIM Range

The CAST 5000 is equipped to simulate all types of receiver autonomous integrity monitor (RAIM) events (i.e., range step, drift and noise) to evaluate the integrity of the GPS signals.

- **Range Step (R)**

The range step event causes the pseudorange of the designated satellite to be adjusted by the defined range step at the designated simulation time. The same range step adjustment will be made to all subsequent pseudorange values for the designated satellite until another RAIM range step event is found for the satellite. In addition to adjusting the satellite pseudorange by the designated range step, the simulator allows the operator to adjust the satellite pseudorange rate by the range step size divided by the update period of the signal simulator, ensuring that a smooth transition to the new pseudorange occurs.

SYSTEM SPECIFICATIONS

Output Frequency

- GPS L1 1575.42 MHz
- GPS L2 1227.60 MHz

Maximum Dynamics

- Velocity > 60,000 m/s
- Acceleration ± 150,000 m/s2
- Jerk ± 150,000 m/s3

Signal Level

- GPS L1 C/A Code -160 dBW
- GPS L1 P Code -163 dBW
- GPS L2 P Code -166 dBW

Signal Level Control

- Range ± 30 dB
- Resolution 0.1 dB

L1/L2 Differential Delay

- Range ± 0.3 m
- Resolution < 1 mm

Signal Accuracy

- Pseudorange 1 mm
- Pseudorange Rate 1 mm/s
- Delta Pseudorange 1 mm
- Interchannel Bias < 1 mm
- Uncontrolled Bias < 1 mm
- Bias Repeatability (initial) < 1 mm
- Bias Stability (operational) < 1 mm

Signal Quality

- Spurious < -45 dBc
- Harmonics < -50 dBc
- Reference Oscillator 100 MHz OCXO
- Frequency Stability 3x10-8 per day

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- **Range Drift (D)**

A range drift event causes the pseudorange and pseudorange rate of the designated satellite to be adjusted by the drift rate starting at the designated event time and continuing for the defined event period. Once the final pseudorange resulting from the range drift has been achieved, the simulator will make a total range adjustment to all subsequent pseudoranges for the satellite until another RAIM event occurs. A range drift event will only result in changes to the pseudorange and pseudorange rate of the designated satellite.

- **Range Noise (N)**

The range noise event causes the pseudorange and pseudorange rate of the designated satellite to be adjusted by a random rate change every simulator update cycle for the defined noise period. As each pseudorange rate change is computed, the pseudorange for the period is adjusted for the rate change. When all pseudorange rate adjustments have been made, the final pseudorange adjustment is made to all subsequent pseudoranges until another RAIM event occurs. Range noise will be computed at random times, at user entered magnitude times, and at a fixed noise rate (0.01 meters/second).

When the user has completed the entry of a RAIM event and confirmed the entry, the RAIM Conditions Editor will be re-displayed. The event that is entered is placed in the list of RAIM conditions, and the list is sorted for time and satellite PRN number order as illustrated below. If two or more events are found for the same time, and the same satellite with different event types, they will be combined into a single entry. If two entries are found for the same time, and satellite with the same event type, only the last entry made will be retained.

Multipath

A multipath channel is a satellite signal simulator which has been removed from use as a normal channel and will be used to produce the signal of a transmitting GPS satellite offset in range from the original satellite. When a channel is designated by the user as a multipath channel the user will be queried for characteristics of the multipath signal including the ID of the transmitter ID to be simulated, the transmitter power offset from the true transmitter (-30 to 0 dB), the initial range offset from the true transmitter (0 to 40,000 meters), the rate at which the range is to change (ffl100 meters/second), and the limit of the range change from the initial range (0 to 40000 meters). All other characteristics of the multipath transmitter (shading, power changes, rise/set, etc.) will be copied from the selected transmitter.

Spoofers

A spoofer is a jammer that transmits a GPS-like signal that is phase-shifted relative to the true GPS signal. In the CAST 5000, the phase shift is a sawtooth function of time plus a delay that depends on the positions of the spoofer, the user, and satellite being spoofed. The CAST 5000 simulates moving spoofers and computes the power and phase of the signal received by the user from each spoofer throughout the duration of the scenario.

CAST systems are able model three different types of spoofers: tracker, repeater or open loop. A tracker, by tracking the user and the satellite, controls its transmitted phase so that the spoofing signal phase received by the user is nominally equal to the true GPS phase. A repeater acquires the satellite to be spoofed and uses it to control its own transmitted phase. An open-loop spoofer transmits a given satellite's P code at nominally the same time as the satellite.

AN END-TO-END SIMULATION

The customizable CAST 5000 GPS Wavefront Generator can tailor each error source to a simulation as required. Since the RF cable plugs directly into the antenna electronics, the operator can test the equations that are driving the antenna electronics. And of course, the CAST 5000 is designed to recreate anomalies, allowing repeatable play back to help understand and solve a problem.

The CAST 5000 simulator is ideal for aircraft integrators, avionic manufacturers, navigator manufacturers who build embedded INS/GPS (EGI) systems. The simulator lets operators test individual receivers, embedded GNSS/INS (EGI) and combined EGIs with additional equipment—or an entire system. From a CRPA-equipped helicopter with dual EGI to a UAV with a CRPA antenna, the CAST 5000 GPS Wavefront Generator is built to test the interference boundaries of your CRPA-equipped GNSS receiver.

ABOUT CAST NAVIGATION

As GNSS/INS simulation specialists, CAST Navigation is one of the leading innovators in GNSS/INS simulation in the world. Its carefully-designed navigation simulators are honed by engineers into powerfully accurate aviation testing tools, EGI integration tools, EGI diagnostic tools, EGI support equipment, JDAM testing and more. The company offers full-service training, upgrade, maintenance and repair services to help you make the most of our technology. ◆