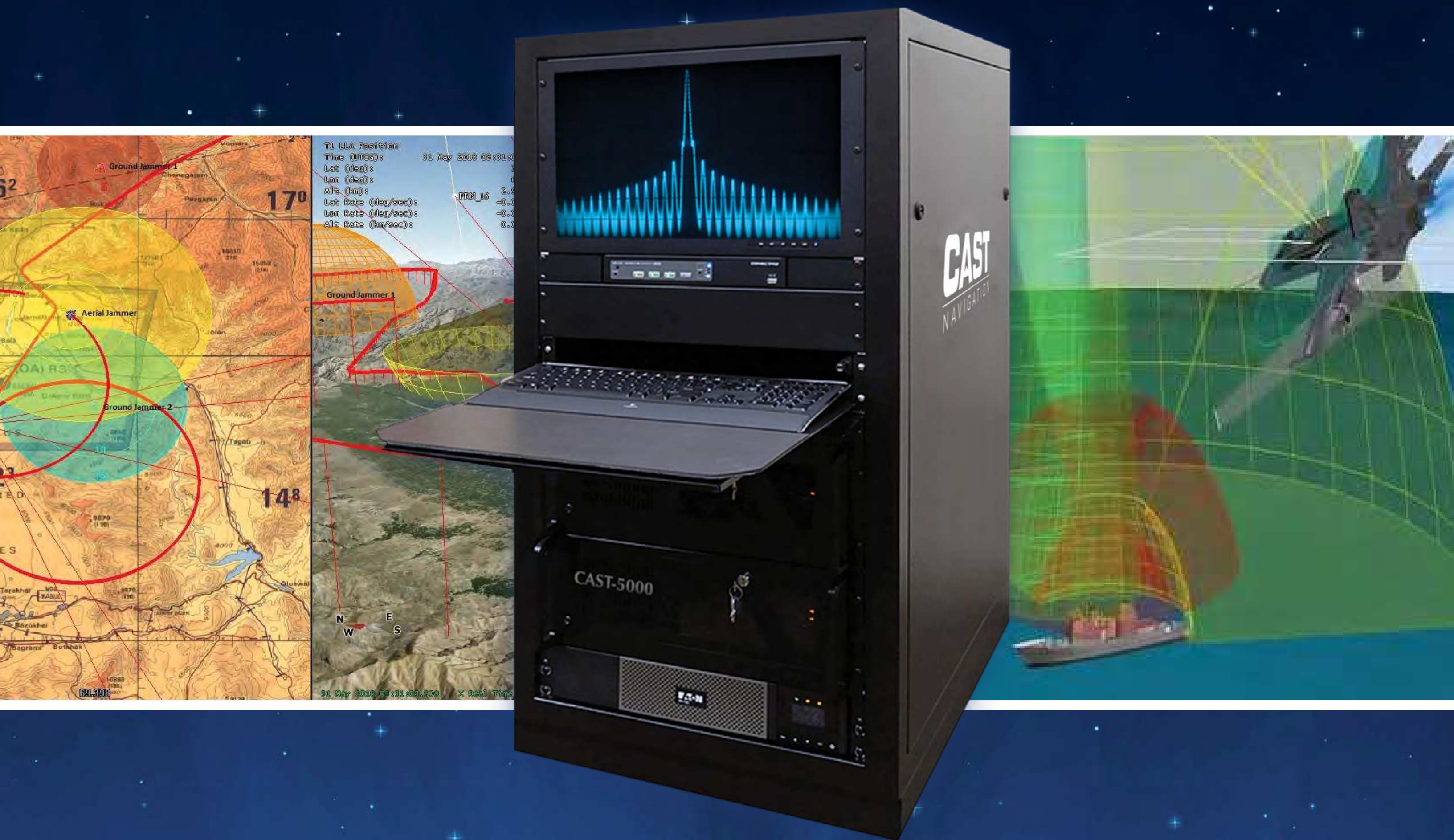
CAST NAVIGATION

MODELING THE UNEXPECTED

Next Gen Simulator Pushes GNSS Condition Boundaries



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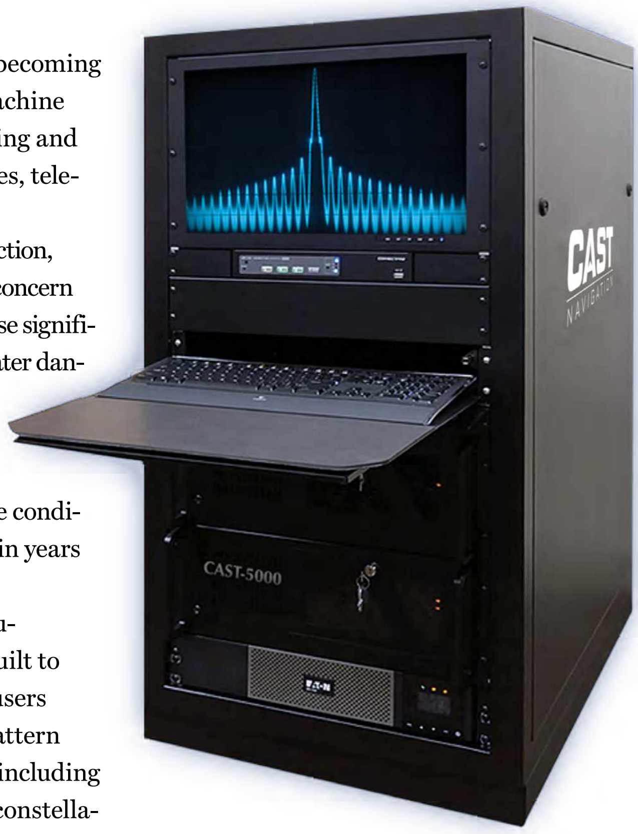
Beyond conventional land, aircraft and seafaring purposes, GNSS is fast becoming an integral part of every facet of our lives. Applications range from 3D machine controlled heavy machinery in construction to semi-autonomous harvesting and planting in agriculture. GNSS is at the heart of tracking goods and services, telecommunications and, in the near future, self-driving cars.

The continued demand for, assimilation of and reliance on GNSS in construction, agriculture, transportation and, of course, military applications, creates some concern about signal reliability. A loss of signal while harvesting acres of land could cause significant time and cost issues while signal loss to aircraft or vehicles holds even greater danger. Recall the recent story about a truck driver with a $50 jammer that interrupted signals at a nearby airport operation. In many cases, those reliant on GNSS for navigation and timekeeping cannot afford operational disruptions.

The best way to test GNSS receiver capabilities and potential interference conditions is through simulation. While simulator algorithms have been limited in years past limiting testing scope and scale, that's not the case anymore.

The CAST-5000 GPS Wavefront Generator, a next generation high accuracy and precision simulator, does more than recreate ideal conditions. Built to simulate open sky, urban, rural pedestrian and rural vehicle users, fixed users and aeronautical conditions, the CAST-5000 is a Controlled Reception Pattern Antenna (CRPA) tester that simulates all manner of potential conditions including jamming/spoofing, multipath, atmospheric, environmental and satellite constellation perturbation for virtually any commercial and military scenario.

The following provides an inside look into some of the top simulation capabilities that are possible in the advanced CAST-5000 solution.



CAST-5000

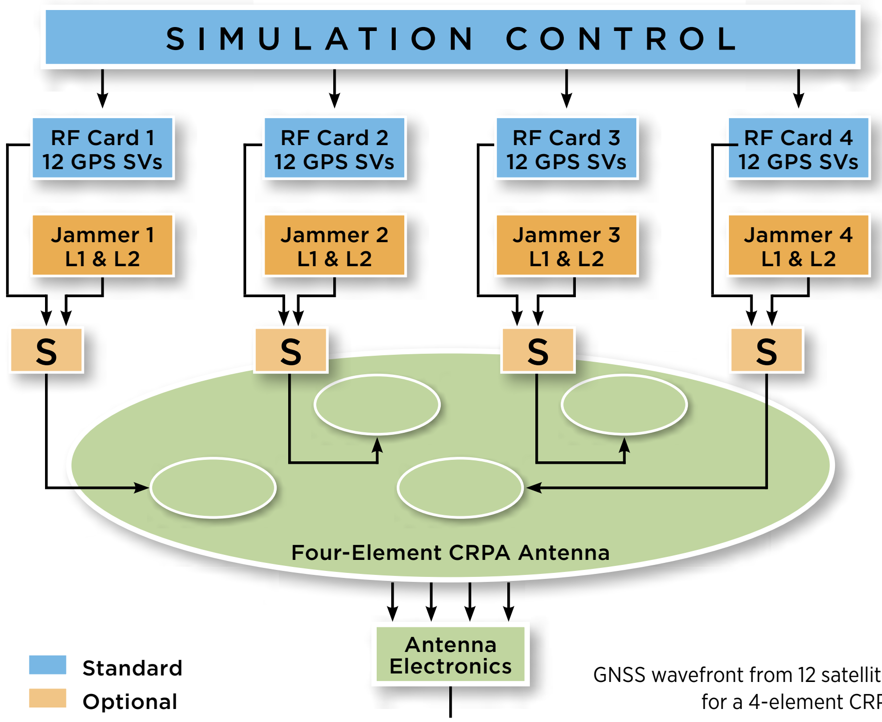
END-TO-END TESTING

The CAST-5000 simulator produces a single coherent wavefront of GPS RF signals to provide repeatable testing in the laboratory environment or anechoic chamber. It is the only Controlled Reception Pattern Antenna (CRPA) tester that allows a full end-to-end test of the antenna system.

The standard CAST-5000 system supports a twelve (12) satellite constellation (L1, L2, CA-Code, P-Code and AESM {M-Code}Y-code, SAASM and M-Code SDS are optional) with the ability to test up to seven CRPA elements. The simulator is able to generate seven independent, coherent simulations that reference a single point with an intercard carrier phase error of less than one centimeter. Each generator card set provides a set of GPS satellites that is combined coherently with each of the associated interference signals. Several RF generator card sets may be utilized together, thus providing a phase coherent output signal to the unit under test.

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

In addition to generating single coherent GPS wavefront, the CAST-5000 has a host of other features that position it as a best-in class device. These features include 6-DOF motion generation capability, post mission processing, multipath modeling, time-tagged satellite events, and a modifiable navigation message. The CAST-5000 is designed to



GNSS wavefront from 12 satellites for a 4-element CRPA

recreate real-world anomalies, providing repeatable playback to understand and solve a problem.

One of the most common test scenarios is to test antennas in uncertain conditions, such as jamming or spoofing.

SIGNAL INTERFERENCE

The incidence of signal jamming (i.e., intentional or unintentional satellite signal interference) and signal spoofing (i.e., the duplication of signals to misrepresent locations) is ever increasing.

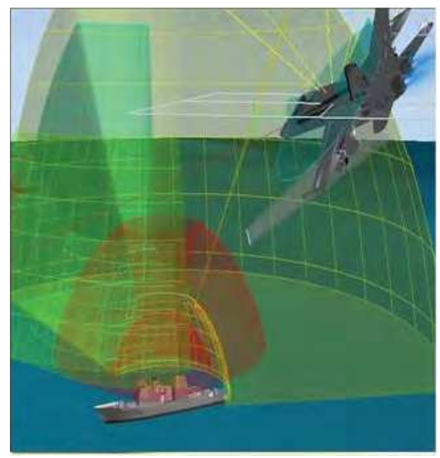
Jamming/spoofing device development has progressed significantly in the last 20 years moving from single tone disruptions to complete spectrum interference that looks exactly like a GNSS signal. From low-cost scramblers to high-power GNSS jamming systems in conflict zones, problems continue to arise. Ideally, developers need to simulate all the likely jamming possibilities such as random noise, random pulse, rotary, pulse or spark scenarios.

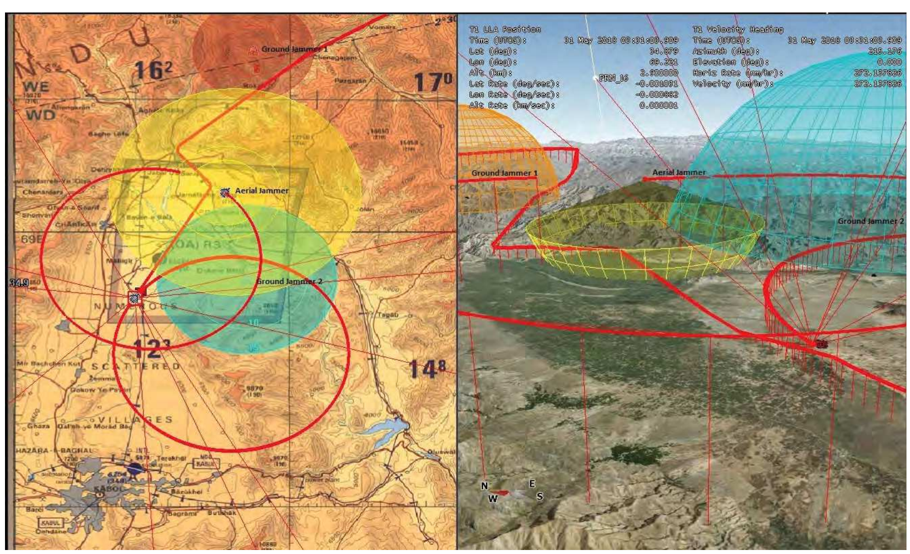
Within the CAST-5000 simulation, an operator can simulate the beginning of interference (yellow dome) as well as the point in time when there will be a complete loss of signal (red dome)—and thus test the value of the non-signal receiving navigation aids.

Like anti-jamming technology, GNSS simulators have advanced to better replicate anticipated conditions and/or test solutions intended to prevent or discard interferences. Flexibility is key.

The CAST-5000 is designed to model the position and motion of a jammer as needed and move a GPS-equipped system into and out of the area of concern.

Consider an aircraft moving on a predeteremined path comes across a jammer that is moving in a straight line at a programmed speed and heading or in a racetrack formation. As a GNSS-equipped craft enters the jam-





CAST-5000 is able to simulate sample trajectory with range spheres.

mer area-of-influence, the operator can directly see the effects of the jammer to the antenna and model different interference signals within the racetrack boundaries.

Terrain can also interrupt satellite signals. The CAST-5000 incorporates a Terrain Obscuration Program (TOP) effect of signals effected by geography. With TOP, the simulator will automatically check line of site to satellites throughout a mission. The simulator algorithms automatically turn off/on signals as those satellites move in and out of visibility.

For instance, an aircraft flying through a valley might lose a satellite due to terrain shading. If a satellite is blocked at any time during the predetermined path, the simulator will automatically remove that satellite during that time.

Another scenario where TOP is beneficial is in cases where unusual terrain surrounds an unfriendly jammer position. Developers can model the loss of a whole satellite constellation as the vehicle approaches an interference environment, thus calculating the effect of satellite visibility due to terrain and GPS degradation due to interference simultaneously.

Once a jammer target is known, it's relatively straightforward to remove that jamming interference. A follow-on consideration to jamming is the pop-up jammer condition.

SIGNAL DUPLICATION

Today, simulators like the CAST-5000 have the ability to model customized almanac and ephemeris data in any receiver as a way to test a receiver's anti-spoofing ability.

The CAST-5000 is designed to model multiple complex spoofer conditions by simulating moving spoofers and computing the power and phase of the signal received by the user from each spoofer throughout the duration of the scenario.

CAST simulators compute the phase of a signal received from a spoofer using one of three methods, depending on the spoofer type (open-loop, repeater, or tracker).

An open-loop spoofer transmits a given satellite's P code at nominally the same time as the satellite.

The user receives the following phase (expressed in units of distance):

$$ø = d - \Delta(t)$$

(d = distance from spoofer to user; Δ(t) = sawtooth phase lead (a periodic waveform whose phase limits and slope are specified by the operator))

A repeater acquires the satellite to be spoofed and uses it to control its own transmitted phase. The phase received by the user is:

$$ø = PRS + d - \Delta(t)$$

(PRS = pseudo-range received by spoofer)

By tracking the user and the satellite, a tracker controls its transmitted phase so that the spoofing signal phase received by the user is nominally equal to the true GPS phase:

$$ø = PRU - \Delta(t)$$

(PRU = ideal pseudo-range received by user)

A common test is to model a spoofer that is transmitting false data, such as incorrect data flags, while the simulated satellite is transmitting correct ephemeris data to see the reaction of the receiver under test. The operator can also introduce small clock errors (e.g., bias, noise) during a simulation.

THE POP-UP PROVISION

An aircraft flying across hundreds of miles of terrain will likely encounter mountain ranges and curved valleys, depending on the flight path—and GNSS signals are commonly lost and reacquired throughout any given scenario.

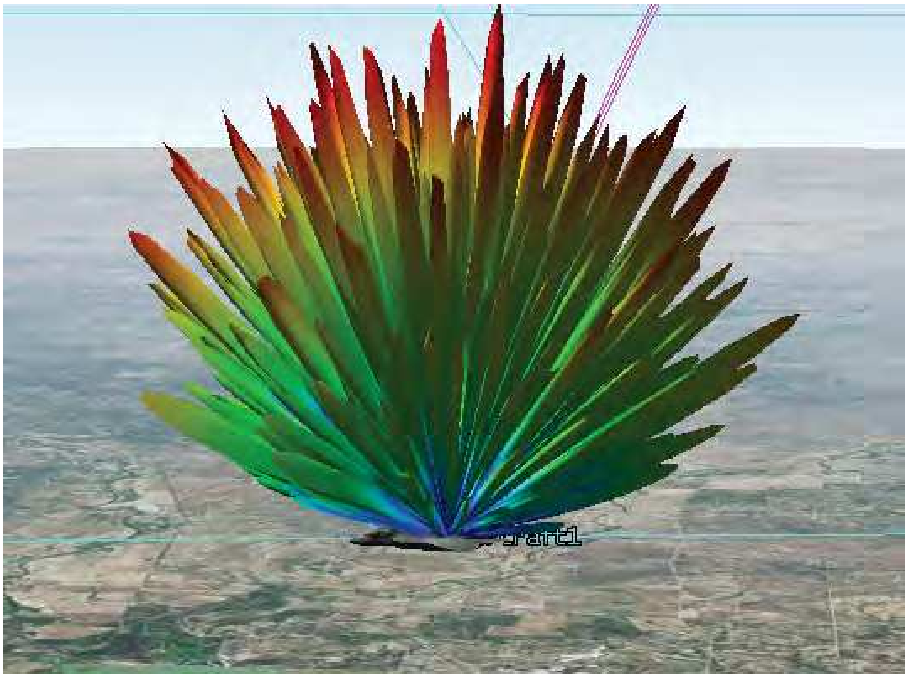
A common real-life condition is the observation of pop-up jammers along a route, such as might occur when an aircraft rises over a ridgeline and gets hit by interference energy that wasn't visible or expected. Or another common military condition is an aircraft flying in a combat zone encounters a jammer at the mouth of a cave with visual site of 240 degrees.

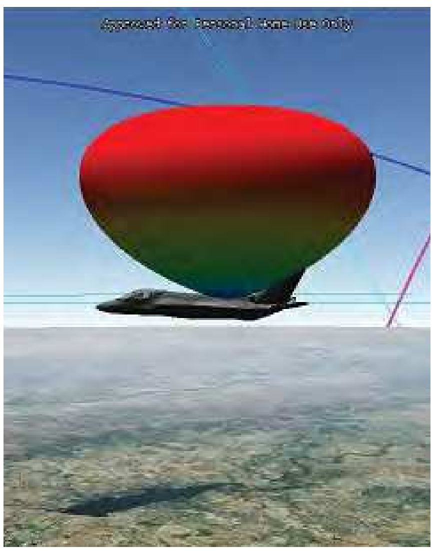
The CAST-5000 simulator can create virtually unlimited real-life scenarios to a high degree of accuracy to support mission planning and test the capabilities of antennas.

SIMULATING SIGNAL REFLECTIONS

Multipath signals, or those signals that are reflected off of an object, are also a common and familiar condition in urban and rural environments. Buildings, trees and mountains can block satellite line of site to a receiver. Often, the signal from the satellite is reflected by these objects causing radio signals to travel further to a receiver, effecting the phase and code measurements, increasing the possibility of position errors or creating GPS jumps in measurements.

The CAST-5000 replicates multipath conditions from multiple sources, moving sources and multi-path sources. Modeling a moving multipath source is also possible. Imagine driving on a highway near a large truck that is causing some signal interference and signal reflection, thus causing posi-





TOP: The CAST-5000 simulator can create real-life conditions to evaluate CRPA antenna responses. **BOTTOM:** It can also simulate the low elevation angle coverage of a FRPA antenna.

tion inaccuracy. The distance between the truck and a vehicle is constantly changing, thus the multipath ranges are also continuously changing.

The simulators can also model multiple multipath sources from three or four different reflection points (e.g., a building 50 yards away).

ATMOSPHERIC SIMULATIONS

GNSS signals have to pass through the ionosphere causing the modulation of a GNSS signal to be delayed in proportion to the electron density (speed of propagation through the ionosphere is referred to as the group velocity). The same condition causes an equivalent RF carrier phase advancement.

Scintillating GNSS signals disrupt a receiver's tracking ability, leading to loss of signal lock, causing degraded accuracy, availability and reliability. Scintillating GNSS signals are a safety critical concern for operations such as aviation applications.

As well, geomagnetic storms, which can last from a few hours to a week, can also increase electronic density in the ionosphere and cause delays. These can result in widespread degradation of PVT solution accuracy and reliability for an extended period of time and create jamming-like effects if accompanied by Radio Blackout Storms.

The CAST-5000 is able to model multiple ionospheric and tropospheric conditions with editable variables. It has the ability to modify almanac and ephemeris data, data and signal health, insert clock errors and complete constellation geometry errors (e.g., cross track, along track, down track).

Simulating constellation perturbation is all about duplicating a multi-constellation environment.

The CAST-5000 presents the receiver unit with the signals commensurate with the way it receives them, giving the end user a way to evaluate receiver performance under many different operating conditions.

TAILORED FOR VERSATILITY

The CAST-5000 GPS Wavefront Generator is built for testing versatility, designed to facilitate simulations of jamming, spoofing, constellation perturbation, multipath, environmental condition as well as antenna placement.

Operators 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. It can recreate anomalies, facilitating repeatable and accurate playback to help understand and solve a problem or an antenna functionality.

The CAST-5000 simulator is ideal for aircraft integrators, avionics manufacturers, navigation 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. ◆

For more information, contact

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