

At low SNR, the receiver symbol synchronization loop will be increasingly sensitive to transmitter timing jitter. Excessive timing jitter can cause bit slips in the receiver synchronization loop, which will in turn cause frame losses and potentially lead to receiver and/or decoder loss-of-lock. Therefore, it is necessary to investigate what symbol timing jitter requirements on the satellite transmitter are needed to support the next generation of NASA coded modulation techniques.

Measurements of ground segment receiver sensitivity to transmitter bit jitter were conducted using a satellite transponder and two different commercial staggered quadrature phase-shift keying (SQPSK) receivers. The symbol synchronizer loop transfer functions were characterized for each receiver. Symbol timing jitter was introduced at

the transmitter. Effects of sinusoidal (tone) jitter on symbol error rate (SER) degradation and symbol slip probability were measured. These measurements were used to define regions of sensitivity to phase, frequency, and cycle-to-cycle jitter characterizations. An assortment of other band-limited jitter waveforms was then applied within each region to identify peak or root-mean-square measures as a basis for comparability.

Receiver clock recovery loops that operate in low SNR ratio environments require that transmit clock jitter be constrained by several measures on different dimensions and operating regions. In this work, effects of transmit phase jitter (PhJ), frequency jitter (FJ), and cycle-to-cycle jitter (CCJ) were studied for sinusoidal and multi-tone jitter profiles on receiver performance. It was demonstrated that the receiver must have a loop band-

width tight enough to avoid cycle slips, but loose enough to track some movement in the data signal. Movement that a tight loop cannot track is usually manifested first as intersymbol interference (ISI) (SER degradation) and then ultimately as cycle slipping in the receiver.

Results from the tests indicate that the receiver symbol synchronization loop is more sensitive to certain types of symbol jitter and jitter frequencies, depending on the selection of the loop filter and damping ratio. A framework is provided to properly compose a transmit jitter mask depending on receiver design parameters such as damping ratio in order to limit receiver performance degradation at low SNR regions.

This work was done by Chatwin Lansdowne and Adam Schlesinger of Johnson Space Center. Further information is contained in a TSP (see page 1). MSC-24810-1

Lightweight, Miniature Inertial Measurement System

Goddard Space Flight Center, Greenbelt, Maryland

A miniature, lighter-weight, and highly accurate inertial navigation system (INS) is coupled with GPS receivers to provide stable and highly accurate positioning, attitude, and inertial measurements while being subjected to highly dynamic maneuvers. In contrast to conventional methods that use extensive, ground-based, real-time tracking and control units that are expensive, large, and require excessive amounts of power to operate, this method focuses on the development of an estimator that makes use of a low-cost, miniature accelerometer array fused with traditional measurement systems and GPS. Through the use of a posi-

tion tracking estimation algorithm, onboard accelerometers are numerically integrated and transformed using attitude information to obtain an estimate of position in the inertial frame. Position and velocity estimates are subject to drift due to accelerometer sensor bias and high vibration over time, and so require the integration with GPS information using a Kalman filter to provide highly accurate and reliable inertial tracking estimations.

The method implemented here uses the local gravitational field vector. Upon determining the location of the local gravitational field vector relative to two consecutive sensors, the orientation of

the device may then be estimated, and the attitude determined. Improved attitude estimates further enhance the inertial position estimates. The device can be powered either by batteries, or by the power source onboard its target platforms. A DB9 port provides the I/O to external systems, and the device is designed to be mounted in a waterproof case for all-weather conditions.

This work was done by Liang Tang of Impact Technologies and Agamemnon Crassidis of the Rochester Institute of Technology for Goddard Space Flight Center. Further information is contained in a TSP (see page 1). GSC-16132-1

Optical Density Analysis of X-Rays Utilizing Calibration Tooling to Estimate Thickness of Parts

This method uses off-the-shelf data analysis software and a digitized x-ray for nondestructive testing.

John F. Kennedy Space Center, Florida

This process is designed to estimate the thickness change of a material through data analysis of a digitized version of an x-ray (or a digital x-ray) containing the material (with the thickness in question) and various tooling. Using this process, it is possible to estimate a

material's thickness change in a region of the material or part that is thinner than the rest of the reference thickness. However, that same principle process can be used to determine the thickness change of material using a thinner region to determine thickening, or it can

be used to develop contour plots of an entire part.

Proper tooling must be used. An x-ray film with an S-shaped characteristic curve or a digital x-ray device with a product resulting in like characteristics is necessary. If a film exists with linear

characteristics, this type of film would be ideal; however, at the time of this reporting, no such film has been known. Machined components (with known fractional thicknesses) of a like material (similar density) to that of the material to be measured are necessary.

The machined components should have machined through-holes. For ease of use and better accuracy, the through-holes should be a size larger than 0.125 in. (≈ 3 mm). Standard components for this use are known as penetrameters or image quality indicators. Also needed is standard x-ray equipment, if film is used in place of digital equipment, or x-ray digitization equipment with proven conversion properties. Typical x-ray digitiza-

tion equipment is commonly used in the medical industry, and creates digital images of x-rays in DICOM format. It is recommended to scan the image in a 16-bit format. However, 12-bit and 8-bit resolutions are acceptable. Finally, x-ray analysis software that allows accurate digital image density calculations, such as Image-J freeware, is needed.

The actual procedure requires the test article to be placed on the raw x-ray, ensuring the region of interest is aligned for perpendicular x-ray exposure capture. One or multiple machined components of like material/density with known thicknesses are placed atop the part (preferably in a region of nominal and non-varying thick-

ness) such that exposure of the combined part and machined component lay-up is captured on the x-ray. Depending on the accuracy required, the machined component's thickness must be carefully chosen. Similarly, depending on the accuracy required, the lay-up must be exposed such that the regions of the x-ray to be analyzed have a density range between 1 and 4.5. After the exposure, the image is digitized, and the digital image can then be analyzed using the image analysis software.

This work was done by David Grau of Kennedy Space Center. Further information is contained in a TSP (see page 1). KSC-13206

Fuel Cell/Electrochemical Cell Voltage Monitor

Lyndon B. Johnson Space Center, Houston, Texas

A concept has been developed for a new fuel cell individual-cell-voltage monitor that can be directly connected to a multi-cell fuel cell stack for direct sub-stack power provisioning. It can also provide voltage isolation for applications in high-voltage fuel cell stacks. The technology consists of basic modules, each with an 8- to 16-cell input electrical measurement connection port. For each basic module, a power input connection would be provided for direct connection to a sub-stack of fuel cells in series within the larger stack. This power connection would allow for module power to be available in the range of 9-15 volts DC.

The relatively low voltage differences that the module would encounter from the input electrical measurement connection port, coupled with the fact that the module's operating power is supplied by the same substack voltage input (and so will be at similar voltage), provides for elimination of high-common-mode voltage issues within each module. Within each module, there would be options for analog-to-digital conversion and data transfer schemes.

Each module would also include a data-output/communication port. Each of these ports would be required to be either non-electrical (e.g., optically iso-

lated) or electrically isolated. This is necessary to account for the fact that the plurality of modules attached to the stack will normally be at a range of voltages approaching the full range of the fuel cell stack operating voltages. A communications/data bus could interface with the several basic modules. Options have been identified for command inputs from the spacecraft vehicle controller, and for output-status/data feeds to the vehicle.

This work was done by Arturo Vasquez of Johnson Space Center. For further information, contact the JSC Innovation Partnerships Office at (281) 483-3809. MSC-24592-1

Anomaly Detection Techniques With Real Test Data From a Spinning Turbine Engine-Like Rotor

These techniques are suitable for engine manufacturers and industries in aerospace and aviation.

John H. Glenn Research Center, Cleveland, Ohio

Online detection techniques to monitor the health of rotating engine components are becoming increasingly attractive to aircraft engine manufacturers in order to increase safety of operation and lower maintenance costs. Health monitoring remains a challenge to easily implement, especially in the presence of scattered loading conditions, crack size, component

geometry, and materials properties. The current trend, however, is to utilize non-invasive types of health monitoring or nondestructive techniques to detect hidden flaws and mini-cracks before any catastrophic event occurs. These techniques go further to evaluate material discontinuities and other anomalies that have grown to the level of critical defects that can lead to failure. Gener-

ally, health monitoring is highly dependent on sensor systems capable of performing in various engine environmental conditions and able to transmit a signal upon a predetermined crack length, while acting in a neutral form upon the overall performance of the engine system.

Spin simulation tests were conducted on a turbine engine-like rotor with and