Books & Reports

VCO PLL Frequency Synthesizers for Spacecraft Transponders

Two documents discuss a breadboard version of advanced transponders that, when fully developed, would be installed on future spacecraft to fly in deep space. These transponders will be required to be capable of operation on any deep-space-communications uplink frequency channel between 7,145 and 7,235 MHz, and any downlink frequency channel between 8,400 and 8,500 MHz. The document focuses on the design and operation of frequency synthesizers for the receiver and transmitter. Heretofore, frequency synthesizers in deep-space transponders have been based on dielectric resonator oscillators (DROs), which do not have the wide tuning bandwidth necessary to tune over all channels in the uplink or downlink frequency bands. To satisfy the requirement for tuning bandwidth, the present frequency synthesizers are based on voltage-controlled-oscillator (VCO) phase-locked loops (PLLs) implemented by use of monolithic microwave integrated circuits (MMICs) implemented using inGaP heterojunction bipolar transistor (HBT) technology. MMIC VCO PLL frequency synthesizers similar to the present ones have been used in commercial and military applications but, until now, have exhibited too much phase noise for use in deep-space transponders. The present frequency synthesizers contain advanced MMIC VCOs, which use HBT technology and have lower levels of flicker (1/f) phase noise. When these MMIC VCOs are used with high-speed MMIC frequency dividers, it becomes possible to obtain the required combination of frequency agility and low phase noise.

This work was done by Scott Smith, Narayan Mysoor, James Lux, and Brian Cook of Caltech for NASA's Jet Propulsion Laboratory. For further information, contact iaoffice@jpl.nasa.gov.
NPO-42909

Wide Tuning Capability for Spacecraft Transponders

A document presents additional information on the means of implementing a capability for wide tuning of microwave receiver and transmitter frequencies in the development reported in the immediately preceding article, "VCO PLL Frequency Synthesizers for Spacecraft Transponders" (NPO-42909). The reference frequency for a PLL-based frequency synthesizer is derived from a numerically controlled oscillator (NCO) implemented in digital logic, such that almost any reference frequency can be derived from a fixed crystal reference oscillator with microhertz precision. The frequency of the NCO is adjusted to track the received signal, then used to create another NCO frequency used to synthesize the transmitted signal coherent with, and at a specified frequency ratio to, the received signal. The frequencies can be changed, even during operation, through suitable digital programming.

The NCOs and the related tracking loops and coherent turnaround logic are implemented in a field-programmable gate array (FPGA). The interface between the analog microwave receiver and transmitter circuits and the FPGA includes analog-to-digital and digital-to-analog converters, the sampling rates of which are chosen to minimize spurious signals and otherwise optimize performance. Several mixers and filters are used to properly route various signals.

This work was done by James Lux, Narayan Mysoor, Biren Shah, Brian Cook, and Scott Smith of Caltech for NASA's Jet Propulsion Laboratory. For further information, contact iaoffice@jpl.nasa.gov.
NPO-43000

Adaptive Deadband Synchronization for a Spacecraft Formation

A paper discusses general problems in estimation and control of the states (positions, attitudes, and velocities) of spacecraft flying in formation, then addresses the particular formation-flying-control problem of synchronization of deadbands. The paper presents a deadband-synchronization algorithm for the case in which the spacecraft are equipped with pulse-width-modulated thrusters for maintaining their required states. The algorithm synchronizes thruster-firing times across all six degrees of freedom of all the spacecraft. The algorithm is scalable, inherently adapts to disturbances, and does not require knowledge of spacecraft masses and disturbance forces. In this algorithm, one degree of freedom of one spacecraft is designated the leader, and all other degrees of freedom of all spacecraft as followers. The Cassini adaptive optimum deadband drift controller is the subalgorithm for control in each degree of freedom, and the adaptation is run until each spacecraft achieves a specified drift period. The adaptation is critical because a different disturbance affects each different degree of freedom. Then the leader communicates its thruster-firing starting times to the followers. Then, for each follower, a deadband-synchronization subalgorithm determines the shift needed to synchronize its drift period with that of the leader.

This work was done by Daniel Scharf, Fred Hadaegh, and Bryan Kang of Caltech for NASA's Jet Propulsion Laboratory.

The software used in this innovation is available for commercial licensing. Please contact Karina Edmonds of the California Institute of Technology at (626) 395-2322. Refer to NPO-43258.

Analysis of Performance of Stereoscopic-Vision Software

A team of JPL researchers has analyzed stereoscopic vision software and produced a document describing its performance. This software is of the type used in maneuvering exploratory robotic vehicles on Martian terrain. The software in question utilizes correlations between portions of the images recorded by two electronic cameras to compute stereoscopic disparities, which, in conjunction with camera models, are used in computing distances to terrain points to be included in constructing a three-dimensional model of the terrain. The analysis included effects of correlation-window size, a pyramidal image down-sampling scheme, vertical misalignment, focus, maximum disparity, stereo baseline, and range ripples. Contributions of sub-pixel interpolation, vertical misalignment, and foreshortening to stereo correlation error were examined theoretically and experimentally. It was found that camera-calibration inaccuracy contributes to both down-range and cross-range error but stereo correlation error affects only the down-range error. Experimental data for quantifying the stereo disparity error were obtained by use of reflective metrological targets taped to corners of bricks placed at known positions relative to the cameras. For the particular 1,024-by-768-pixel cameras of the system analyzed, the standard deviation of the down-range disparity error was found to be 0.32 pixel.

This work was done by Won Kim, Adnan Ansar, Robert Steele, and Robert Steinke of Caltech for NASA's Jet Propulsion Laboratory. For further information, contact iaoffice@jpl.nasa.gov
NPO-42487

Estimating the Inertia Matrix of a Spacecraft

A paper presents a method of utilizing some flight data, aboard a spacecraft that includes reaction wheels for attitude control, to estimate the inertia matrix of the spacecraft. The required data are digitized samples of (1) the spacecraft attitude in an inertial reference frame as measured, for example, by use of a star tracker and (2) speeds of rotation of the reaction wheels, the moments of inertia of which are deemed to be known.

Starting from the classical equations for conservation of angular momentum of a rigid body, the inertia-matrix-estimation problem is formulated as a constrained least-squares minimization problem with explicit bounds on the inertia matrix incorporated as linear matrix inequalities. The explicit bounds reflect physical bounds on the inertia matrix and reduce the volume of data that must be processed to obtain a solution. The resulting minimization problem is a semidefinite optimization problem that can be solved efficiently, with guaranteed convergence to the global optimum, by use of readily available algorithms. In a test case involving a model attitude platform rotating on an air bearing, it is shown that, relative to a prior method, the present method produces better estimates from few data.

This work was done by Behçet Açikmeşe, Jason Keim, and Joel Shields of Caltech for NASA's Jet Propulsion Laboratory.

The software used in this innovation is available for commercial licensing. Please contact Karina Edmonds of the California Institute of Technology at (626) 395-2322. Refer to NPO-43631.

Spatial Coverage Planning for Exploration Robots

A report discusses an algorithm for an onboard planning and execution technology to support the exploration and characterization of geological features by autonomous rovers. A rover that is capable of deciding which observations are more important relieves the engineering team from much of the burden of attempting to make accurate predictions of what the available rover resources will be in the future. Instead, the science and engineering teams can uplink a set of observation requests that may potentially oversubscribe resources and let the rover use observation priorities and its current assessment of available resources to make decisions about which observations to perform and when to perform them.

The algorithm gives the rover the ability to model spatial coverage quality based on data from different scientific instruments, to assess the impact of terrain on coverage quality, to incorporate user-defined priorities among subregions of the terrain to be covered, and to update coverage quality rankings of observations when terrain knowledge changes. When the rover is exploring large geographical features such as craters, channels, or boundaries between two different regions, an important factor in assessing the quality of a mission plan is how the set of chosen observations spatially cover the area of interest. The algorithm allows the rover to evaluate which observation to perform and to what extent the candidate observation will increase the spatial coverage of the plan.

This work was done by Daniel Gaines, Tara Estlin, and Caroline Chouinard of Caltech for NASA's Jet Propulsion Laboratory.

The software used in this innovation is available for commercial licensing. Please contact Karina Edmonds of the California Institute of Technology at (626) 395-2322. Refer to NPO-44282.

Increasing the Life of a Xenon-Ion Spacecraft Thruster

A short document summarizes the redesign of a xenon-ion spacecraft thruster to increase its operational lifetime beyond a limit heretofore imposed by nonuniform ion-impact erosion of an accelerator electrode grid. A peak in the ion current density on the centerline of the thruster causes increased erosion in the center of the grid. The ion-current density in the NSTAR thruster that was the subject of this investigation was characterized by peak-to-average ratio of 2:1 and a peak-to-edge ratio of greater than 10:1. The redesign was directed toward distributing the same beam current more evenly over the entire grid andinvolved several modifications of the magnetic-field topography in the thruster to obtain more nearly uniform ionization. The net result of the redesign was to reduce the peak ion current density by nearly a factor of two, thereby halving the peak erosion rate and doubling the life of the thruster. (Note: NSTAR stands for NASA SEP Technology Application Readiness; SEP stands for solar electric propulsion.)

This work was done by Dan Goebel, James Polk, Anita Sengupta, and Richard Wirz of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to:

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