



## 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](mailto: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](mailto: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 space-

craft 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