Technology Focus: Data Acquisition

High-Rate Digital Receiver Board

This board converts a personal computer into a versatile telemetry-data-acquisition system.

Goddard Space Flight Center, Greenbelt, Maryland

A high-rate digital receiver (HRDR) implemented as a peripheral component interface (PCI) board has been developed as a prototype of compact, general-purpose, inexpensive, potentially mass-producible data-acquisition interfaces between telemetry systems and personal computers. The installation of this board in a personal computer together with an analog preprocessor enables the computer to function as a versatile, high-rate telemetry-data-acquisition and demodulator system. The prototype HRDR PCI board can handle data at rates as high as 600 megabits per second, in a variety of telemetry formats, transmitted by diverse phase-modulation schemes that include binary phase-shift keying and various forms of quadrature phase-shift keying. Costing less than $25,000 (as of year 2003), the prototype HRDR PCI board supplants multiple racks of older equipment that, when new, cost over $500,000. Just as the development of standard network-interface chips has contributed to the proliferation of networked computers, it is anticipated that the development of standard chips based on the HRDR could contribute to reductions in size and cost and increases in performance of telemetry systems.

The circuitry on the HRDR board includes an analog-to-digital converter (ADC) and two high-rate digital demodulator (HRDD) application-specific integrated circuits (ASICs). The HRDR board accepts a baseband radio frequency telemetry modulation signal as input. The ADC ASIC samples the input, and the sampled data is demultiplexed and sent to the two HRDD ASICs, which demodulate the signal, recover the clock and data components of the modulation, bit-synchronize the data, and serialize and forward the data to the next stage. In addition, the HRDD ASICs remove Doppler shifts from the carrier and data signals. Within each HRDD ASIC, the data are further demultiplexed by a factor of two so that the HRDD processing takes place in a total of four streams — each stream at a quarter of the incoming-data rate. Processing in multiple streams at a rate lower than the incoming-data rate makes it possible to use complementary metal oxide/semiconductor processing circuitry that is relatively inexpensive and could not perform adequately at the incoming-data rate.

The HRDR board outputs, depending on output interface setup, one or two synchronous differential emitter coupled logic (ECL) clock and data output streams. The output interface can be programmed to process and output demodulated telemetry data in multiple ways — for example, to perform CCSDS standard Viterbi decoding of convolutionally encoded data using either 3 bit soft symbols or hard symbols as inputs, interleave data I and Q channels into a single output stream, or to output each channel independently. The user can easily choose the output format by means of a simple graphical user interface.

This work was done by Parminder Ghuman, Thomas Bialas, and Clifford Brambora of **Goddard Space Flight Center** *and David Fisher of QSS Group, Inc. For further information, access the Technical Support Package (TSP)* ***free on-line at www.techbriefs.com/tsp*** *under the Electronics/Computers category.*
GSC-14780-1

Signal Design for Improved Ranging Among Multiple Transceivers

Acquisition, ranging, and telemetry signals are always present.

NASA's Jet Propulsion Laboratory, Pasadena, California

"Ultra-BOC" (where "BOC" signifies "binary offset carrier") is the name of an improved generic design of microwave signals to be used by a group of spacecraft flying in formation to measure ranges and bearings among themselves and to exchange telemetry needed for these measurements. Ultra-BOC could also be applied on Earth for diverse purposes — for example, measuring relative positions of vehicles on highways for traffic-control purposes and determining the relative alignments of machines operating in mines and of construction machines and structures at construction sites. Ultra-BOC provides for rapid and robust acquisition of signals, even when signal-to-noise ratios are low. The design further provides that each spacecraft or other platform constantly strives to acquire and track the signals from the other platforms while simultaneously transmitting signals that provide full range, bearing, and telemetry service to the other platforms. In Ultra-BOC, unlike in other signal designs that have been considered for the same purposes, it is not necessary to maneuver the spacecraft or other platforms to obtain the data needed for resolving integer-carrier-cycle phase ambiguities.

A prior design provided for the broadcasting of acquisition signals, followed by rough-clock-synchronization signals, followed by ranging and telemetry signals. In contrast, in Ultra-BOC, the acquisition, ranging, and telemetry signals are always present: Ultra-BOC combines the BOC structure with constant transmission of unmodulated tones (that is, subcarrier signals) as acquisition signals, plus low-rate clock synchronization data, a pseudorandom-noise (PRN) precise-ranging code, and telemetry. A unique combination of code-division multiple access and frequency-division multiple access are employed to support simultaneous transmission and reception of these signals by many radio transceivers in the same allocated frequency band while enabling the use of the signals for precise metrology.

The acquisition signals (unmodulated tones) do extra duty by making it possible to increase the precision of range and bearing measurements: The ranging code used in Ultra-BOC is adequate to resolve the ambiguity of a synthesized delay formed by a pair of closely-spaced unmodulated BOC tones. This delay is used to resolve the ambiguity on a more widely spaced pair of tones. This process is continued with increasingly widely spaced tones until either the range and bearing precision requirements are satisfied by use of such pairs of tones or the integer-cycle ambiguities in the phases of the carrier signals are resolved. The range measurements made in this manner can be more precise than are those that can be made by use of the PRN codes alone, because (1) the delays synthesized from pairs of tones have smaller errors attributable to system noise and (2) multipath-induced errors are the leading errors in ranging by use of PRN and the delays synthesized from pairs of tones are less susceptible to multipath-induced errors.

This work was done by Lawrence Young, Jeffrey Tien, and Jeffrey Srinivasan of Caltech for **NASA's Jet Propulsion Laboratory**. *Further information is contained in a TSP (see page 1).*
NPO-40569

Automated Analysis, Classification, and Display of Waveforms

Trends in operation of systems that generate waveforms can be spotted in real time.

John F. Kennedy Space Center, Florida

A computer program partly automates the analysis, classification, and display of waveforms represented by digital samples. In the original application for which the program was developed, the raw waveform data to be analyzed by the program are acquired from space-shuttle auxiliary power units (APUs) at a sampling rate of 100 Hz. The program could also be modified for application to other waveforms — for example, electrocardiograms.

Before this program became available, the raw APU waveforms were recorded on paper strip charts — a practice that imposed a substantial workload on human operators and was not conducive to consistently accurate, real-time analysis and classification. The program reduces the operator workload, increases the accuracy of classifications, and presents results in real time.

The program begins by performing principal-component analysis (PCA) of 50 normal-mode APU waveforms. Each waveform is segmented. A covariance matrix is formed by use of the segmented waveforms. Three eigenvectors corresponding to three principal components are calculated. To generate features, each waveform is then projected onto the eigenvectors. These features are displayed on a three-dimensional diagram, facilitating the visualization of the trend of APU operations.

It is necessary to classify each of the normal-mode waveforms as being characteristic of one of three mode types known among APU specialists as "nominal," "engine," or "aero." For this purpose, each waveform is segmented and its average energy is computed. For engine and aero modes, time information is also used, and information about peaks in the waveforms is used to determine which mode is present.

It is also necessary, when there is a malfunction, to classify waveforms as being characteristic of one or more error mode(s). To enable such classification of a waveform in real time, it is necessary to prepare the software and associated data base in a prior process that includes a careful analysis of the waveform known to be associated with each of at least five known error modes to which the APUs are subject. For each error mode, some distinct features of the waveform are extracted. Thereafter, in operation, a waveform is automatically classified as belonging to an error mode according to a few rules based on these features.

This program was written by Chiman Kwan, Roger Xu, David Mayhew, and Frank Zhang of Intelligent Automation, Inc., and Alan Zide and Jeff Bonggren of the Boeing Co. for **Kennedy Space Center**.

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:

Intelligent Automation, Inc.
Attn. Chiman Kwan
7519 Standish Place, Suite 200
Rockville, MD 20855
Phone: (301) 294-5238
E-mail: ckwan@i-a-i.com

Refer to KSC-12568, volume and number of this NASA Tech Briefs *issue, and the page number.*

Fast-Acquisition/Weak-Signal-Tracking GPS Receiver for HEO

Goddard Space Flight Center, Greenbelt, Maryland

A report discusses the technical background and design of the Navigator Global Positioning System (GPS) receiver — a radiation-hardened receiver intended for use aboard spacecraft. Navigator is capable of weak signal acquisition and tracking as well as much faster acquisition of strong or weak signals with no *a priori* knowledge or external aiding. Weak-signal acquisition and tracking enables GPS use in high Earth orbits (HEO), and fast acquisition allows for the receiver to remain without power until needed in any orbit. Signal acquisition and signal tracking are, respectively, the processes of finding and demodulating a signal. Acquisition is the more computationally difficult process. Previous GPS receivers employ the method of sequentially searching the two-dimensional signal parameter space (code phase and Doppler). Navigator exploits properties of the Fourier transform in a massively parallel search for the GPS signal. This method results in far faster acquisition times [in the lab, 12 GPS satellites have been ac-