a resolution of 2 ns.

2. Waveforms from the various antennas are paired and temporally aligned with each other according to the 2-ns-resolution DTOAs.
3. The waveforms are windowed to prevent the introduction of extraneous frequency components.
4. A fast Fourier transform (FFT) is computed for each waveform. Because the receivers at the antennas operate in the 30-to-38- and 110-to-200-MHz frequency bands only, it is possible to limit the FFTs to these frequency bands, without loss of signal information, to reduce the computational burden.
5. Within each pair, the phase difference between the FFTs of the two signals is computed for each frequency. For each pair, the time difference that corresponds to the phase difference for each frequency is calculated, then an effective delay for the pair is calculated as a weighted sum of the time differences in all of the FFT frequency intervals.
6. For each pair, the effective delay is added to the starting 2-ns-resolution DTOA to obtain a more precise DTOA.

This work was done by Pedro J. Medelius and Stan Starr of Dynacs, Inc., for **Kennedy Space Center**. *Further information is contained in a TSP [see page 1].*
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P-Code-Enhanced Encryption-Mode Processing of GPS Signals

This is an improved method of processing without knowledge of the encryption code.

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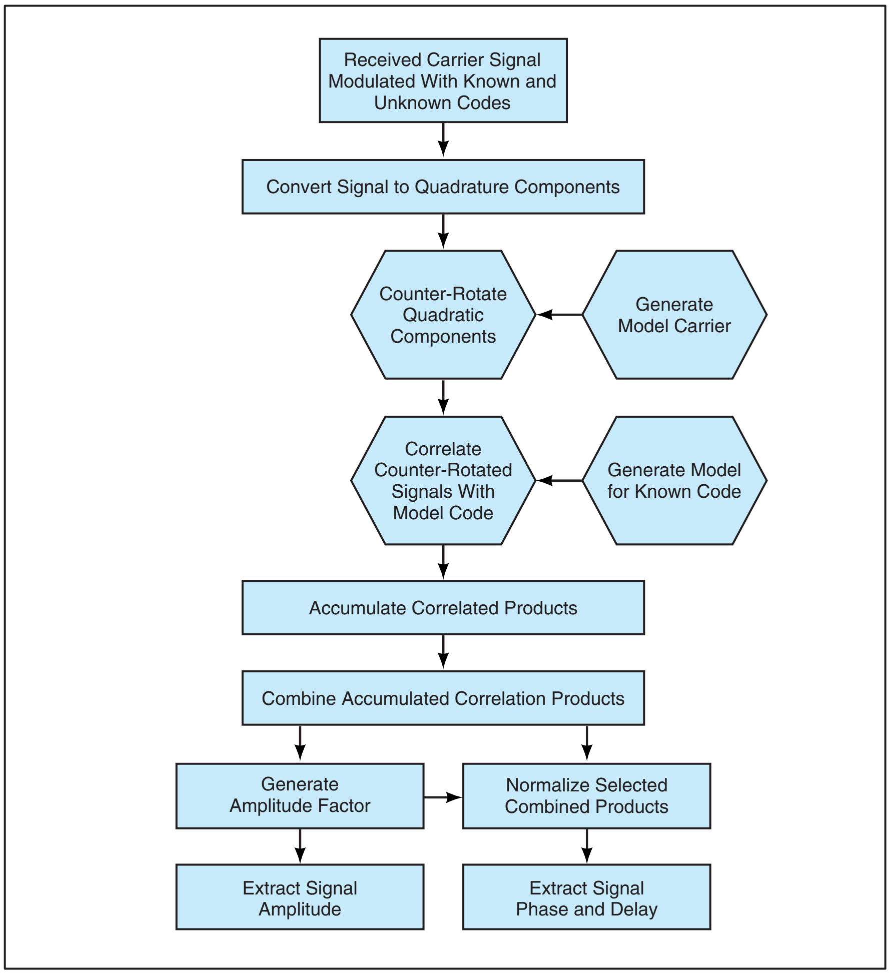

P-Code-Enhanced Encryption-Mode Processing of GPS signals according the present invention involves this sequence of steps.

A method of processing signals in a Global Positioning System (GPS) receiver has been invented to enable the receiver to recover some of the information that is otherwise lost when GPS signals are encrypted at the transmitters. The need for this method arises because, at the option of the military, precision GPS code (P-code) is sometimes encrypted by a secret binary code, denoted the A code. Authorized users can recover the full signal with knowledge of the A-code. However, even in the absence of knowledge of the A-code, one can track the encrypted signal by use of an estimate of the A-code. The present invention is a method of making and using such an estimate. In comparison with prior such methods, this method makes it possible to recover more of the lost information and obtain greater accuracy.

The limitation on space available for this article precludes a description of the prior methods. However, a description of pertinent generally applicable aspects of GPS signals and signal processing is presented in the next three paragraphs because it is prerequisite to a meaningful summary of the present method.

Each GPS satellite transmits two L-band signals, denoted L1 (at a carrier frequency of 1.57542 GHz) and L2 (at a carrier frequency of 1.2276 GHz). The L1 carrier is phase-modulated with two binary pseudorandom-noise codes that contain GPS information: (1) the coarse-acquisition (C/A) code, characterized by a chip rate of 1.023 MHz and (2) the precise (P) code, characterized by a chip rate of 10.23 MHz and modulated in quadrature with the C/A code. The L2 carrier is modulated with the P code only. The signals from different satellites are distinguishable from each other because each satellite transmits a unique C/A and a unique P code. Although the limitation on space also precludes a detailed description of the C/A and P codes, it can be said here that names of these codes convey an approximate idea of the roles played by these codes and of the relationship between them. The C/A and P codes of all the satellites are further modulated with a common binary code that conveys information about the satellites, their orbits, their clock offsets, and their operational statuses.

The basic principle of GPS receiver signal processing is to determine the time and the position of the GPS receiver from times of arrival of signals transmitted from several different GPS satellites. This basic principle is implemented, in practice, by use of correlations between (1) the received GPS signals and (2) model signals in the receiver constructed from model carriers modulated by model C/A, and P (and, when applicable, A) codes.

Processing is said to be done in a code mode when the receiver "knows" the code in question. Because the C/A code is not encrypted, C/A modulation is usually processed in the code mode, using the published C/A code. Processing is said to be done in an encryption mode when the receiver does not "know" the code in question. More specifically, processing is said to be done in an encryption mode when the receiver does not "know" the A code with which the P code is modulated. Hence, the present invention is characterized as a method of encryption-mode processing.

The figure is a block diagram of signal processing according to the invention. The received GPS signal is down-converted from radio frequency (RF) to baseband to obtain two pairs of quadrature components — one pair for L1, the other for L2. Unlike in some prior methods, there is no cross-processing of signals between the L1 and L2 P channels. Instead, each of the two quadrature components obtained from each RF signal, independently of the other components, is counterrotated with its respective model phase, correlated with its respective model P code, and then successively summed and dumped over pre-sum intervals substantially coincident with chips of the respective encryption code. In the encryption mode, the effect of the unknown A-code sign flips is reduced, for each quadrature component of each RF signal, by combining selected pre-sums. The resulting combined pre-sums are then summed and dumped over longer intervals and further processed to extract the amplitude, phase, and delay for each RF signal. The precision of the resulting phase and delay values is approximately four times better than that obtained from conventional cross-correlation of the L1 and L2 P signals.

In comparison with prior encryption-mode receivers, a receiver according to this invention offers greater signal-to-noise ratios for the L1 and L2 P signals, and greater precision in the phases and delays of these signals. Unlike the prior receivers, this receiver offers the capability for separate and independent tracking of the L1 and L2 P signals to eliminate fading crossover, separate and independent measurement of the L1 and L2 P amplitudes, the option of dual-band measurements without a separate L1 P channel, removal of a half-cycle ambiguity in the L2 P phase, and the option of operation in either the code mode or the encryption mode with maximum commonality of hardware and software between modes. Finally, this processing method would still work even if the L1 and L2 P codes were to be encrypted with different A codes.

This work was done by Lawrence Young, Thomas Meehan, and Jess B. Thomas of Caltech for **NASA's Jet Propulsion Laboratory**. *Further information is contained in a TSP [see page 1].*

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Integrated Formulation of Beacon-Based Exception Analysis for Multimissions

BEAM has become a broadly applicable, highly capable means of automated diagnosis.

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Further work on beacon-based exception analysis for multimissions (BEAM), a method of real-time, automated diagnosis of a complex electromechanical systems, has greatly expanded its capability and suitability of application. This expanded formulation, which fully integrates physical models and symbolic analysis, is described architecturally in the figure.

In a typical application, BEAM takes the form of an embedded software suite executing onboard the system under study, though many off-board data analysis engines have been constructed as well. The BEAM software performs real-time fusion and analysis of all system observables. BEAM is intended to reduce the burden of diagnostic data collection and analysis currently performed by both human operators and computers. In the case of a spacecraft or aircraft, BEAM enables onboard identification and characterization of most anomalous conditions, thereby making telemetry of larger quantities of sensor information to ground stations unnecessary. Previously BEAM has been described in several prior *NASA Tech Briefs* articles: "Reusable Software for Autonomous Diagnosis of Complex Systems" (NPO-20803) Vol. 26, No. 3 (March 2002), page 33; "Beacon-Based Exception Analysis for Multimissions" (NPO-20827), Vol. 26, No. 9 (September 2002), page 32; and "Wavelet-Based Real-Time Diagnosis of Complex Systems" (NPO-20830), Vol. 27, No. 1 (January 2003), page 67.

The new formulation of BEAM expands upon previous advanced techniques for analysis of signal data, utilizing mathematical modeling of the system physics, and expert-system reasoning. These components are integrated seamlessly, making possible analysis of varied information about the monitored system, including time-correlated signal performance, state information, software execution, operator command execution, and convergence to state and physical models. BEAM software is highly adaptable and can be implemented at relatively low cost in terms of processor power and training, and does not require special sensors. Unlike some prior methods of automated diagnosis, BEAM affords traceability of its conclusions, which allows system experts to completely reconstruct its decision path for greater operator confidence or to aid analysis of novel conditions. Principal among BEAM's strengths is its excellent performance in detection and classification of such novelty, meaning faults of previously unknown — and untrainable — type.

In the BEAM architecture, discrete sensor information, state information, and commands are fed as input to the symbolic model, and quantitative sensor data is input to a simplified physical model of the system. These modules are designed to leverage existing system models, which can be high or low fidelity. The symbolic model aids signal-based analysis in terms of mode selection or other discrete outputs. The physical model improves sensitivity through separation of predictable and unpredictable signal components.

Time-varying quantities are analyzed in two groups: (1) signals with a high degree of correlation to others, or signals that are not isolated in a diagnostic sense, are passed to the coherence-analysis component of BEAM; (2) signals that may uniquely indicate a fault, as well as those already suspected to be faulty, are passed through