incoming command is permuted by both the dynamic and private key. A person who records the command data in a given packet for hostile purposes cannot use that packet after the public key expires (typically within 3 seconds). Even a person in possession of an unauthorized copy of the command/remote-display software cannot use that software in the absence of the password.

The use of a dynamic key embedded in the outgoing data makes the central-processing unit overhead very small. The use of a National Instruments DataSocket™ (or equivalent) protocol or the User Datagram Protocol makes it possible to obtain reasonably short response times: Typical response times in event-driven control, using packets sized ≤300 bytes, are <0.2 second for commands issued from locations anywhere on Earth.

The protocol requires that control commands represent absolute values of controlled parameters (e.g., a specified temperature), as distinguished from changes in values of controlled parameters (e.g., a specified increment of temperature). Each command is issued three or more times to ensure delivery in crowded networks. The use of absolute-value commands prevents additional (redundant) commands from causing trouble. Because a remote controlling computer receives "talkback" in the form of data packets from the controlled computer, typically within a time interval ≤1 s, the controlling computer can re-issue a command if network failure has occurred.

The controlled computer, the process or equipment that it controls, and any human operator(s) at the site of the controlled equipment or process should be equipped with safety measures to prevent damage to equipment or injury to humans. These features could be a combination of software, external hardware, and intervention by the human operator(s). The protocol is not fail-safe, but by adopting these safety measures as part of the protocol, one makes the protocol a robust means of controlling remote processes and equipment by use of typical office computers via intranets and/or the Internet.

This work was done by Lewis Lineberger of **Kennedy Space Center**. *For further information, contact the Kennedy Commercial Technology Office at (321) 867-8130.*
KSC-12277

Coupled Receiver/Decoders for Low-Rate Turbo Codes

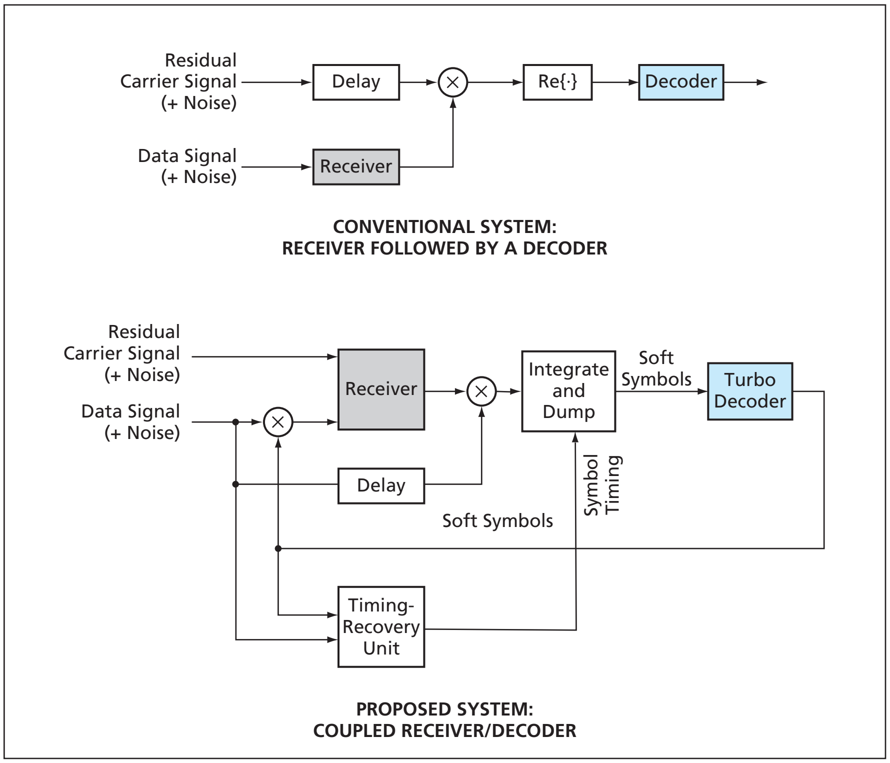
Residual carrier power needed for recovery of phase would be reduced.

NASA's Jet Propulsion Laboratory, Pasadena, California

Coupled receiver/decoders have been proposed for receiving weak single-channel phase-modulated radio signals bearing low-rate-turbo-coded binary data. Originally intended for use in receiving telemetry signals from distant spacecraft, the proposed receiver/decoders may also provide enhanced reception in mobile radiotelephone systems.

A radio signal of the type to which the proposal applies comprises a residual carrier signal and a phase-modulated data signal. The residual carrier signal is needed as a phase reference for demodulation as a prerequisite to decoding. Low-rate turbo codes afford high coding gains and thereby enable the extraction of data from arriving radio signals that might otherwise be too weak. In the case of a conventional receiver, if the signal-to-noise ratio (specifically, the symbol energy to one-sided noise power spectral density) of the arriving signal is below approximately 0 dB, then there may not be enough energy per symbol to enable the receiver to recover properly the carrier phase. One could solve the problem at the transmitter by diverting some power from the data signal to the residual carrier. A better solution — a coupled receiver/decoder according to the proposal — could reduce the needed amount of residual carrier power.

In all that follows, it is to be understood that all processing would be digital and the incoming signals to be processed would be, more precisely, outputs of analog-to-digital converters that preprocess the residual carrier and data signals at a rate of multiple samples per symbol. The upper part of the



A **Coupled Receiver/Decoder** would utilize data feedback from its turbo decoder, whereas a conventional receiver does not utilize data from the turbo decoder that follows it.

figure depicts a conventional receiving system, in which the receiver and decoder are uncoupled, and which is also called a non-data-aided system because output data from the decoder are not used in the receiver to aid in recovering the carrier phase. The receiver tracks the carrier phase from the residual carrier signal and uses the carrier phase to wipe phase noise off the data signal. The receiver typically includes a phase-locked loop (PLL) or Costas loop that requires no delay or perhaps a single sample delay.

The lower part of the figure depicts a basic coupled receiver/decoder — a data-aided system that would implement an iterative receiving/decoding process. The receiver would include a PLL or a Wiener filter that, to the extent possible, would track the residual carrier signal, wipe phase noise off the data signal, then send the result to the turbo decoder. Recovery of timing could be effected by, for example, a digital transition tracking loop (DTTL) or other, similar loop. The first iteration of turbo decoding would yield soft data symbols, which would be sent back to the receiver for use in softly wiping off the data signal in an effort to recover the residual carrier signal. The wiped signal would contain a relatively large carrier-phase component that could be tracked by use of a second Wiener filter.

The refined phase estimate generated by the second Wiener filter would be used to wipe the phase noise from a delayed replica of the incoming data signal. The resulting refined data signal would then be sent to the turbo decoder for the second iteration. The soft symbols from the second iteration would be sent back to the receiver as in the first iteration, and the process repeated.

For recovery of timing, the output of the turbo decoder would be used in place of what, in a usual DTTL, would be a transition-detector arm, in which hard decisions on consecutive symbols are based on raw symbol-by-symbol channel input, with no coding gain. The use of the turbo-decoder output would afford the benefit of the coding gain, thereby improving the output of the transition detector. Overall, the two-way communication between the receiver and the decoder would improve the performance of both the receiver and the decoder.

This work was done by Jon Hamkins and Dariush Divsalar of Caltech for **NASA's Jet Propulsion Laboratory**. *Further information is contained in a TSP (see page 1).*
NPO-40237

Processing GPS Occultation Data To Characterize Atmosphere

NASA's Jet Propulsion Laboratory, Pasadena, California

GOAS [Global Positioning System (GPS) Occultation Analysis System] is a computer program that accepts signal-occultation data from GPS receivers aboard low-Earth-orbiting satellites and processes the data to characterize the terrestrial atmosphere and, in somewhat less comprehensive fashion, the ionosphere. GOAS is very robust and can be run in an unattended semi-operational processing mode. It features sophisticated retrieval algorithms that utilize the amplitudes and phases of the GPS signals. It incorporates a module that, using an assumed atmospheric refractivity profile, simulates the effects of the retrieval processing system, including the GPS receiver. GOAS utilizes the GIPSY software for precise determination of orbits as needed for calibration. The GOAS output for the Earth's troposphere and mid-to-lower stratosphere consists of high-resolution (<1 km) profiles of density, temperature, pressure, atmospheric refractivity, bending angles of signals, and water-vapor content versus altitude from the Earth's surface to an altitude of 30 km. The GOAS output for the ionosphere consists of electron-density profiles from an altitude of about 50 km to the altitude of a satellite, plus parameters related to the rapidly varying structure of the electron density, particularly in the E layer of the ionosphere.

This program was written by George Hajj, Emil Kursinski, Stephen Leroy, Byron Iijima, Manuel de la Torre Juarez, Larry Romans, and Chi Ao of Caltech for **NASA's Jet Propulsion Laboratory**. *Further information is contained in a TSP (see page 1).*

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