

## ❶ Coding for Communication Channels With Dead-Time Constraints

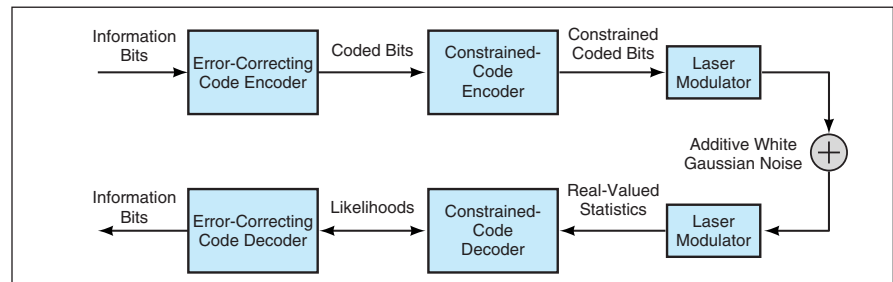
Novel coding schemes may offer significant advantages in some applications.

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Coding schemes have been designed and investigated specifically for optical and electronic data-communication channels in which information is conveyed via pulse-position modulation (PPM) subject to dead-time constraints. These schemes involve the use of error-correcting codes concatenated with codes denoted constrained codes. These codes are decoded using an interactive method.

In pulse-position modulation, time is partitioned into frames of  $M$  slots of equal duration. Each frame contains one pulsed slot (all others are non-pulsed). For a given channel, the dead-time constraints are defined as a maximum and a minimum on the allowable time between pulses. For example, if a  $Q$ -switched laser is used to transmit the pulses, then the minimum allowable dead time is the time needed to recharge the laser for the next pulse. In the case of bits recorded on a magnetic medium, the minimum allowable time between pulses depends on the recording/playback speed and the minimum distance between pulses needed to prevent interference between adjacent bits during readout. The maximum allowable dead time for a given channel is the maximum time for which it is possible to satisfy the requirement to synchronize slots. In mathematical shorthand, the dead-time constraints for a given channel are represented by the pair of integers  $(d, k)$ , where  $d$  is the minimum allowable number of zeroes between ones and  $k$  is the maximum allowable number of zeroes between ones.

A system of the type to which the present schemes apply is represented by a bi-



**Error-Correcting and Constrained PPM Codes** are concatenated at the transmitting end of a communication channel.

nary-input, real-valued-output channel model illustrated in the figure. At the transmitting end, information bits are first encoded by use of an error-correcting code, then further encoded by use of a constrained code. Several constrained codes for channels subject to constraints of  $(d, \infty)$  have been investigated theoretically and computationally. The baseline codes chosen for purposes of comparison were simple PPM codes characterized by  $M$ -slot PPM frames separated by  $d$ -slot dead times.

Another category of codes investigated was that of synchronous truncated pulse-position modulation (STPPM), which is generated by implementing synchronous variable-length PPM codes in a new way. In a synchronous variable-length PPM code,  $mp$  bits are mapped to  $mq$  bits, where  $m$ ,  $p$ , and  $q$  are positive integers,  $p$  and  $q$  are fixed, and  $m$  is allowed to vary. Such a code is characterized by, among other things, a rate (average number of bits per slot) of  $p/q$ . In generating a STPPM code, a procedure based partly on a binary tree is followed in mapping un-

constrained binary sequences into the applicable constraint. In addition to the dead-time constraint, the code words involved in the mapping are subject to some mathematical constraints, a description of which would greatly exceed the space available for this article.

The advantages and disadvantages of the schemes investigated are not subject to any single, simple characterization. In general, it was found that for constrained PPM codes concatenated with error-correcting codes at the transmitting end and iterative decoding at the receiving end, there are advantages over baseline schemes with respect to error rate at a given signal-to-noise ratio, throughput at a given error rate, and complexity relative to prior schemes that include iterative decoding.

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

*This software is available for commercial licensing. Please contact Don Hart of the California Institute of Technology at (818) 393-3425. Refer to NPO-30524.*

## ❷ System for Better Spacing of Airplanes En Route

Deviations from preferred trajectories can be reduced.

Ames Research Center, Moffett Field, California

An improved method of computing the spacing of airplanes en route, and software to implement the method, have been invented. The purpose of the

invention is to help air-traffic controllers minimize those deviations of the airplanes from the trajectories preferred by their pilots that are needed to

make the airplanes comply with miles-in-trail spacing requirements (defined below). The software is meant to be a modular component of the Center-