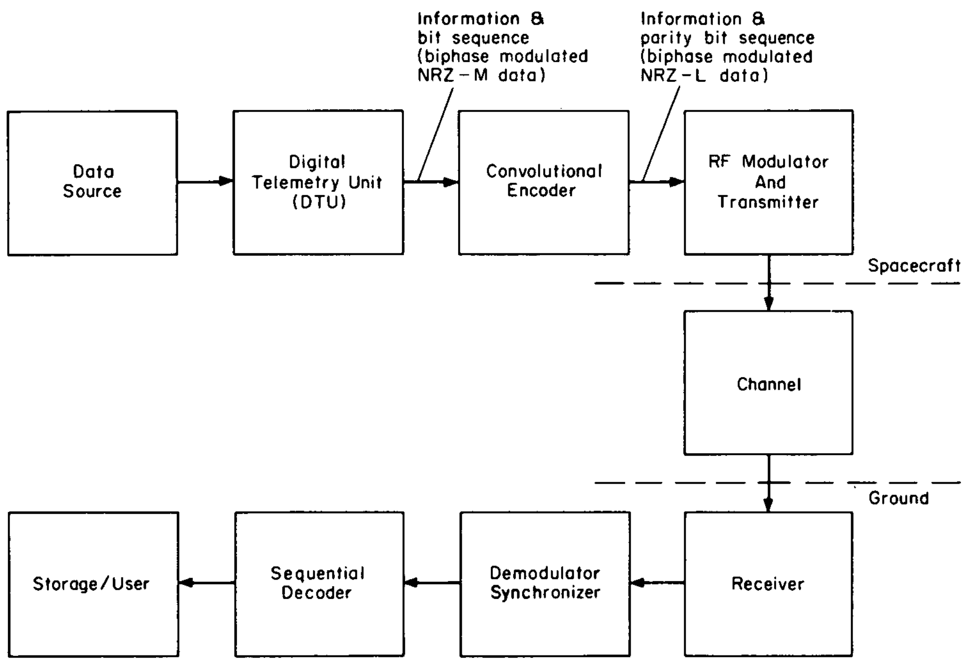
NASA TECH BRIEF

Ames Research Center

An Improved Telemetry System



The problem:

To increase the quantity and accuracy of data which can be transmitted by a pulse-code-modulated (PCM) telemetry system operating at a given power level.

The solution:

Transmission of parity bits together with data bits by a rate ½ convolutional code of 25-bit constraint length, with sequential decoding of the received signal. In the encoding process, information data are treated in accordance with a fixed rule to determine the proper parity bits that are to be transmitted.

How it's done:

When parity bits are transmitted along with data bits in a PCM telemetry signal of fixed power level, the available power per transmitted bit is less than when only data bits are transmitted. Since each bit is transmitted at a lower power level, the signal-to-noise ratio (S/N) is decreased and the probability that an information bit can be lost in noise is increased. Thus,

(continued overleaf)

in ordinary telemetry systems, the data modulator at the receiving end of a telemetry link would yield a larger bit-error rate with signals containing parity bits than with signals consisting only of data bits.

The improved system of telemetry shown in the appended figure utilizes a decoder which detects and corrects errors made by the demodulator and leads to a significant decrease in the overall bit-error rate. Computer analysis of the operation of the improved system indicates that the rate of data transfer can be doubled since the error rate for decoded parity-bit signals is so much less than the error rate for PCM signals with no parity bits. The theoretical analysis was verified by transmissions from the Pioneer IX deep space probe.

The encoder has access to all signals from the digital telemetry unit (DTU) such as bit-clock pulses and frame-rate pulses which are also available to scientific instruments. The information data input to the encoder is biphase modulated NRZ-M data from the DTU (see figure). The data output of the encoder is biphase modulated NRZ-L data which is fed to the RF modulator. Because of the error carryover effects produced by NRZ-M data, there is one pre-encoding function to be performed, namely, converting the biphase modulated NRZ-M data to NRZ-L data. This is done by sampling and holding at T-second intervals (where T is the inverse of the bit rate) to remove the subcarrier. A modulo-2 adder and one-unit delay take out the differential (NRZ-M) modulation.

The convolutional encoder unit itself consists of a 25-stage shift register with 15 stages tapped to compute parity; the parity bit is a logic "1" if there is an odd number of "1's" in the tapped stages and a logic "0" otherwise. Every information bit is transmitted unchanged with alternate transmitted bits being parity data. As far as the encoder is concerned, all data received from the DTU are information; that is, the encoder makes no distinction between actual sensor data bits and the DTU parity check bits or fixed words. The encoder shift register is reset to zeros once during every 224-bit frame (reset occurs between the fourteenth and fifteenth bits of the original frame) so that the decoding can be accomplished on a frame-by-frame basis.

The final step in the encoding process is to remodulate the encoded data onto a square-wave subcarrier. At information rates of 512 and 256 bps, the frequency of this subcarrier for the Pioneer IX is 2048 Hz; at the lower information rates (64, 16, and 8 bps), it is 512 Hz. The reason for this change is that the demodulator/synchronizer cannot meet its specifications for the required low S/N ratios at high subcarrier-to-bit ratios.

Since the encoder shift register is set to zeros every frame, the initial code synchronization can be done on a frame-by-frame basis in a way analogous to the conventional frame synchronization. The code synchronization routine must perform in a three-way search in order to determine: (1) The proper grouping of the information and parity bits in the pair, which is a 1-bit ambiguity; (2) whether the data demodulator locks up to the "in-phase" signal as transmitted or the "out-of-phase" signal; (3) the beginning of the encoded frame.

After the decoder is synchronized, data are decoded a frame at a time. If a frame is encountered that the decoder cannot completely decode in the time available, a set of zeros is stored in place of the decoded data and the decoder proceeds to the data of the next frame. This set of zeros constitutes a signaling guide for an off-line nonreal-time decoding mode at the tape processing station.

Notes:

1. The coding system has been used successfully with the Pioneer IX spacecraft. The 3 dB communication range extension for 512 bps obtained through coding was verified by direct comparison with 256 bps uncoded data.
2. The following documentation may be obtained from:

   National Technical Information Service
   Operations Division
   Springfield, Virginia 22151
   Single document price $3.00
   (or microfiche $0.95)
   References:
   NASA TN D-4105 (N67-33270), An Efficient Coding System for Deep Space Probes with Specific Applications to Pioneer Missions.
   NASA TN D-4402 (N68-18178), Performance of Several Convolutional and Block Codes with Threshold Decoding.
3. Requests for further information may be directed to:

   Technology Utilization Officer
   Ames Research Center
   Moffett Field, California 94035
   Reference: TSP71-10201

Patent status:

No patent action is contemplated by NASA.

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