Convolutional Coding Results for the MVM '73 X-Band Telemetry Experiment

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This article presents results of simulation of several short-constraint-length convolutional codes using a noisy symbol stream obtained via the turnaround ranging channels of the MVM'73 spacecraft. First operational use of this coding technique is on the Voyager mission. The relative performance of these codes in this environment is as previously predicted from computer-based simulations.

This short article presents the results of simulations of several short-constraint-length convolutional codes using 70 min of noisy 5.8-kbps symbol stream recorded by the R&D 930 computer at DSS 14 on Jan 15, 1974. This data was obtained as part of an experiment intended to define the performance to be expected from X-band telemetry on the Voyager and subsequent missions. The simulated telemetry stream was originated on the ground and returned via the turnaround ranging channels of the MVM'73 spacecraft at both X- and S-band (Ref. 1). The same experiment was later performed with Viking (Ref. 2).

The data stream consisted of the repeated sequence 111010, modulated on a subcarrier. This sequence is a codeword of the K=7, rate 1/2 convolutional code now flying on Voyager, and also of two rate 1/3 codes at K=4, and K=5. The signal was processed at the time of reception as an uncoded bit stream and also via a hardware Viterbi decoder for the K=7, rate 1/2 code. It had been initially intended to also operate the JPL-designed K=5, rate 1/3 decoder (Ref. 3) in real-time, but this was not in fact pursued. The data recorded by the on-site SDS-930 computer as 6-bit quantized symbols was subsequently converted to a stream of 4-bit quantized channel-noise samples by extraction of the known data stream. This conversion was done to simplify processing in software through a variety of short-constraint-length convolutional codes. The use of 4-bit quantization compressed this data to two virtually full magnetic tapes, one each for S-band and X-band data.

Decoding from these tapes was performed using a software decoder in the Sigma 5 computer, at constraint lengths K=3 to K=9, rates 1/2 and 1/3 (Ref. 4 describes a 930 version of this decoder). The data was blocked into 5-min segments of approximately 2×10^6 symbols to obtain statistical averages for the coded P_e without masking variations that had been observed in the signal-to-noise ratio during the real-time experiment. Figure 1 shows a time-trace of the decoding results for the S-band data at rates 1/2 and 1/3. Figure 2 shows a similar time trace for the X-band data, decoded at rate 1/2 only. The SNR at S-band was too high to permit statistically significant results for the rate 1/3 codes.

The traces for several of the codes are not complete, work having been stopped pending resolution of the difference between hardware and software decoder performance. This problem has since been resolved (Ref. 5) and the software results shown to be correct, at least at K=7, rate 1/2, X-band.

Figure 3 summarizes the coded bit error probability seen for these codes as a "function" of the signal-to-noise ratio estimated by way of the (uncoded) symbol error rate. There are no real surprises in this figure. The performance of all codes tested, either rate 1/2 or rate 1/3, is comparable to their performance as seen in earlier simulation with computer-generated noise (Ref. 6).

References

1. Springett, J. C., and Kollar, F. J., "Results of the MVM'73 X-Band Telemetry Experiment," Document 615-149, Jet Propulsion Laboratory, Pasadena, Calif., May 1974 (an internal document).
2. Weber, W. J., et al., *Viking X-Band Telemetry Experiment Final Report*, TM 33-794, Jet Propulsion Laboratory, Pasadena, Calif., Sept. 1976.
3. Lushbaugh, W., *Hardware Version of an Optimum Convolutional Decoder*, TR 32-1526, Vol. II, pp. 49-55, Jet Propulsion Laboratory, Pasadena, Calif., April 1971.
4. Layland, J. W., Capabilities of an All-Software Optimum Convolutional Decoder, SPS 37-62, Vol. II, Jet Propulsion Laboratory, Pasadena, Calif., Mar. 1970.
5. Omura, Jim K., and Butman, S. A., "Foldover Effects on Viterbi Decoding," PR 42-34, pp. 27-32, Jet Propulsion Laboratory, Pasadena, Calif., Aug. 1976.
6. Layland, J. W., Performance of Short Constraint-Length Convolutional Codes and a Heuristic Code-Construction Algorithm, SPS 37-64, Vol. II, pp. 41-44, Jet Propulsion Laboratory, Pasadena, Calif., Aug. 31, 1970.

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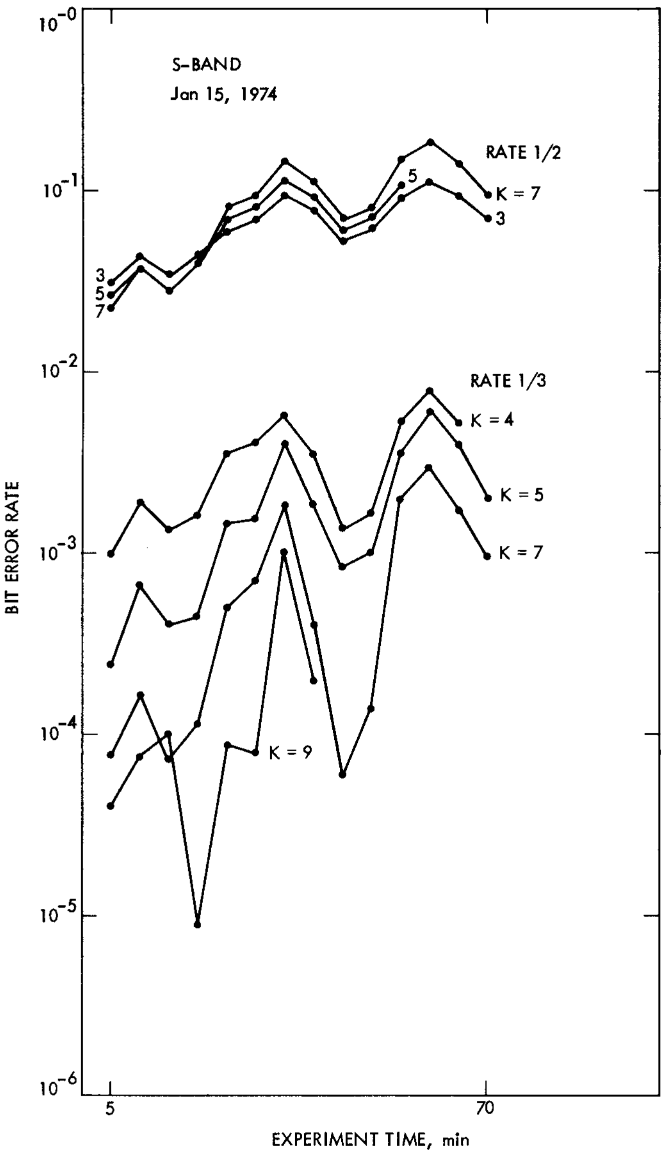

Fig. 1. Decoded bit error rate for S-band data

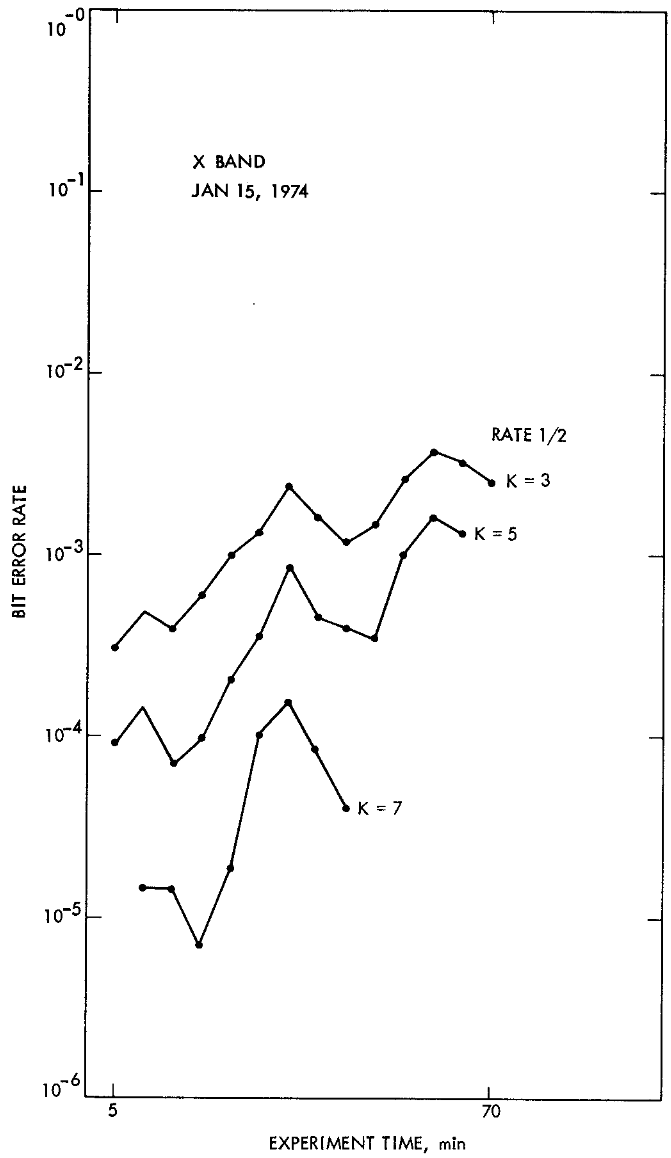

Fig. 2. Decoded bit error rate for X-band data

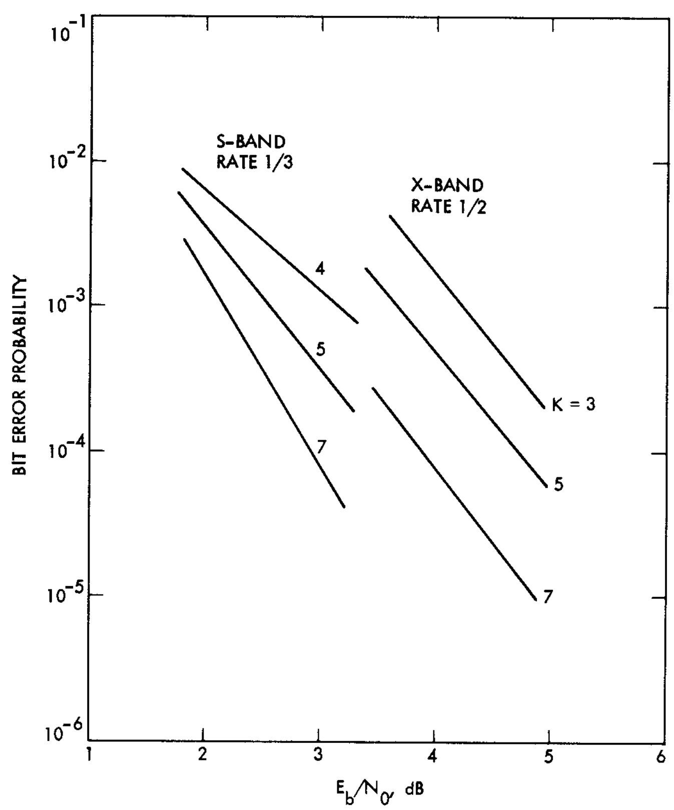

Fig. 3. Coded bit error performance vs SNR