A Maximum Likelihood Convolutional Decoder Model vs Experimental Data Comparison

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This article describes the comparison of a maximum likelihood convolutional decoder (MCD) prediction model and the actual performance of the MCD at the Madrid Deep Space Station. The MCD prediction model is used to develop a subroutine that has been utilized by the Telemetry Analysis Program (TAP) to compute the MCD bit error rate for a given signal-to-noise ratio. The results indicate that the TAP can predict quite well compared to the experimental measurements. An optimal modulation index also can be found through TAP.

I. Introduction

A model has been developed (Ref. 1) that will be utilized by the Telemetry Analysis Program (TAP) to compute the maximum likelihood convolutional decoder (MCD) bit error rate (BER).

This report shows the comparison of an MCD Prediction Model and the actual performance of the MCD at the Madrid Deep Space Station (Ref. 2) and Merritt Island Goddard Space Flight Center Station (Ref. 3). The results show that the model can predict quite well when compared to the experimental measurements.

The MCD Performance Prediction Model was developed by L. Webster (Ref. 1), and a subroutine has been integrated into the TAP. With a specified energy per bit to noise spectral density ratio (Eb/No) as the MCD input, the model can predict the bit error rate as the output of the model. In order to use TAP efficiently, energy per symbol to noise spectral density ratio (STs/No) as measured at the input to the receiver is expected to be specified as the TAP input.

The telemetry system performance testing data that are used for comparison are from two sources (Refs. 2 and 3).

II. Comparison Objectives

The objectives of the comparison were:

(1) Given a bit error rate (obtained from measurement) compute the corresponding bit error rate and determine the required Eb/No (MCD model) measured at the MCD input and compare to the Eb/No (measurement).

(2) Given an Eb/No (obtained from measurement) compute the corresponding bit error rate (MCD model) and compare to the bit error rate (measurements).

(3) Determine the optimal modulation index as noted in Fig. 1 (Ref. 2).

To achieve the above objectives, we use the system setup conditions (Refs. 2 and 3) as the setup conditions for TAP.

Based on the test results (pp. 52-57, Ref. 2), we pick up a bit error rate as a reference, and by trying different *Sts/No* as TAP input, it is found that a typical *STs/No* MCD model input can generate a very close bit error rate with respect to our reference. With this typical *STs/No*, we can find an *Eb/No* measured at the input to MCD model that yields this required BER and compare it to the *Eb/No* measured at the input to the MCD at the station.

By the same procedure, we can pick an *Eb/No* (measured) converted to *Sts/No* as TAP input and compute the corresponding bit error rate from the MCD model. The bit error rate computed by the MCD model should be close to the measured BER. Since the output of the MCD model is a theoretical value, the deviation of *Eb/No* and bit error rate should indicate which modulation index is the optimal one (minimum system degradation).

III. Analysis

With the Telemetry Analysis Program, it is not difficult to find a specified *Eb/No* (or bit error rate) and its corresponding bit error rate (or *Eb/No*); comparison results are stated in Tables 1-3. Table 1 shows that at an optimal modulation index of 69 deg the $\Delta Eb/No$ (dB) comparison between the Performance Prediction Model and the actual data taken from DSS 62/63 (Spain) is approximately 0.165 dB average. Taking an average of the $\Delta Eb/No$ column shows that the Prediction Model predicts an average of 0.28 dB of $\Delta Eb/No$ over the optimal modulation index range at approximately 70 ± 1 deg (Fig. 1).

Table 2, which shows the deviation of bit error rate, again shows that at a modulation index of 69 deg, the deviation is smaller than any other measured modulation index; thus 69 deg was taken as the optimal modulation index (Fig. 1). Table 2 also shows that the theoretical value of bit error rate is always less than the actual bit error rate. Table 3 shows the comparison of the MCD model and the data from MIL 77 (Ref. 3).

Based on the data from Spain (Ref. 2), the MCD model predicts the bit error rate just as shown in Fig. 1. Moreover, examining the TAP printout carefully shows that the optimal modulation index should fall between 65 and 70 deg.

IV. Summary

Most of the comparison objectives were achieved. The MCD works quite well in predicting the performance of the on-station MCD. It also should be noted that the maximum likelihood convolutional decoder at the station can perform well, with a modulation index range from 67 to 70 deg and an MCD *Eb/No* input range from 4 to 6 dB. The bit error rate should be between 10^{-4} and 10^{-6}.

References

1. Webster L., "Maximum Likelihood Convolutional Decoding (MCD) Performance Due to System Losses," in *The Deep Space Network Progress Report 42-34*, pp. 108-118, Jet Propulsion Laboratory, Pasadena, Calif., Aug. 15, 1976.
2. Urech, J. M., and Delgado L., "Final Report on the DSN Performance for Convolutional Codes with a Viterbi Decoder," JPL System Engineering Section DSS 62/63, Madrid, Spain, Jan. 1976 (an internal document).
3. Kemp, R. P., "Telemetry System Performance Testing at MIL 71 Utilizing Convolutionally Encoded RN Data at Rate 7, 1/2 and 1/3 and the Maximum Likelihood Convolution Decoder," JPL Interoffice Memo 430B-77-044 May 18, 1977 (an internal document).

Table 1. Comparison of the MCD performance data from DSS 62/63 and the MCD Performance Prediction Model for optimum mod index, selected from Fig. 1

Mod index	Pt/No, dB	Bit error rate	Energy per bit to noise spectral density ratio (Spain), dB	Energy per bit to noise spectral density ratio (MCD model), dB	$\Delta Eb/No$, dB
69	39.67	1.19×10^{-5}	4.42	4.36	0.06
69	39.77	8.0×10^{-6}	4.43	4.47	0.06
69	39.82	3.45×10^{-5}	4.33	4.06	0.27
69	40.26	3.55×10^{-6}	4.97	4.68	0.29
70	39.67	2.04×10^{-5}	4.56	4.16	0.40
70	39.77	2.5×10^{-5}	4.30	4.12	0.18
70.8	39.82	4.56×10^{-5}	4.24	3.9	0.34
70	40.26	4.48×10^{-6}	4.94	4.58	0.36
71	39.67	5.36×10^{-5}	4.6	4.49	0.11
71	39.77	3.88×10^{-5}	4.42	3.93	0.49
71	39.82	3.4×10^{-5}	4.34	4.0	0.34
71	40.26	5.47×10^{-6}	5.06	4.5	0.56

Condition setup for TAP: refer to pp. 52-57, Ref. 2; system temperature, 20K.

Table 2. Comparison of the MCD performance data from DSS 62/63 and the MCD Performance Prediction Model for measured *Eb/No*

Mod index	Pt/No, dB	Eb/No (SSA), dB	Bit error rate (Spain)	Bit error rate (MCD model)	Bit error rate MCD less than Spain
69	39.67	4.42	1.19×10^{-5}	0.922×10^{-5}	Yes
69	39.77	4.53	8.0×10^{-6}	6.293×10^{-6}	Yes
69	39.82	4.33	3.45×10^{-5}	1.329×10^{-5}	Yes
69	40.26	4.97	3.55×10^{-6}	1.112×10^{-6}	Yes
70	39.67	4.56	2.04×10^{-5}	0.506×10^{-5}	Yes
70	39.77	4.30	2.5×10^{-5}	1.387×10^{-5}	Yes
70.8	39.82	4.24	4.56×10^{-5}	1.397×10^{-5}	Yes
70	40.26	4.94	4.48×10^{-6}	1.072×10^{-6}	Yes
71	39.67	4.6	5.36×10^{-5}	0.35×10^{-5}	Yes
71	39.77	4.42	3.88×10^{-5}	0.7088×10^{-5}	Yes
71	39.82	4.34	3.4×10^{-5}	0.923×10^{-5}	Yes
71	40.26	5.06	5.47×10^{-6}	0.518×10^{-6}	Yes

Table 3. Comparison of the MCD performance data from MIL 71 and the MCD Performance Prediction Model for specified *STb/No*

Bit rate	*Stb/No*, dB	Bit error rate, MIL 71	Bit error rate, MCD model
7200	1	2.0×10^{-4}	1.438×10^{-4}
	2	9.57×10^{-6}	3.8×10^{-6}
6400	1	5.7×10^{-4}	1.676×10^{-4}
	2	5.45×10^{-5}	0.465×10^{-5}
5600	1	3.98×10^{-4}	2.079×10^{-4}
	2	1.4×10^{-5}	0.6164×10^{-5}
3600	1	2.5×10^{-4}	6.735×10^{-4}
	2	2.5×10^{-5}	3.33×10^{-5}

RF band: S; mod index = 72°; data pattern = PN code.
Receiver: BLK III at 12 Hz Wlo; SDA: BLK III, medium.
SSA: BLK III NARROW/NARROW subcarrier frequency 1.44 MHz

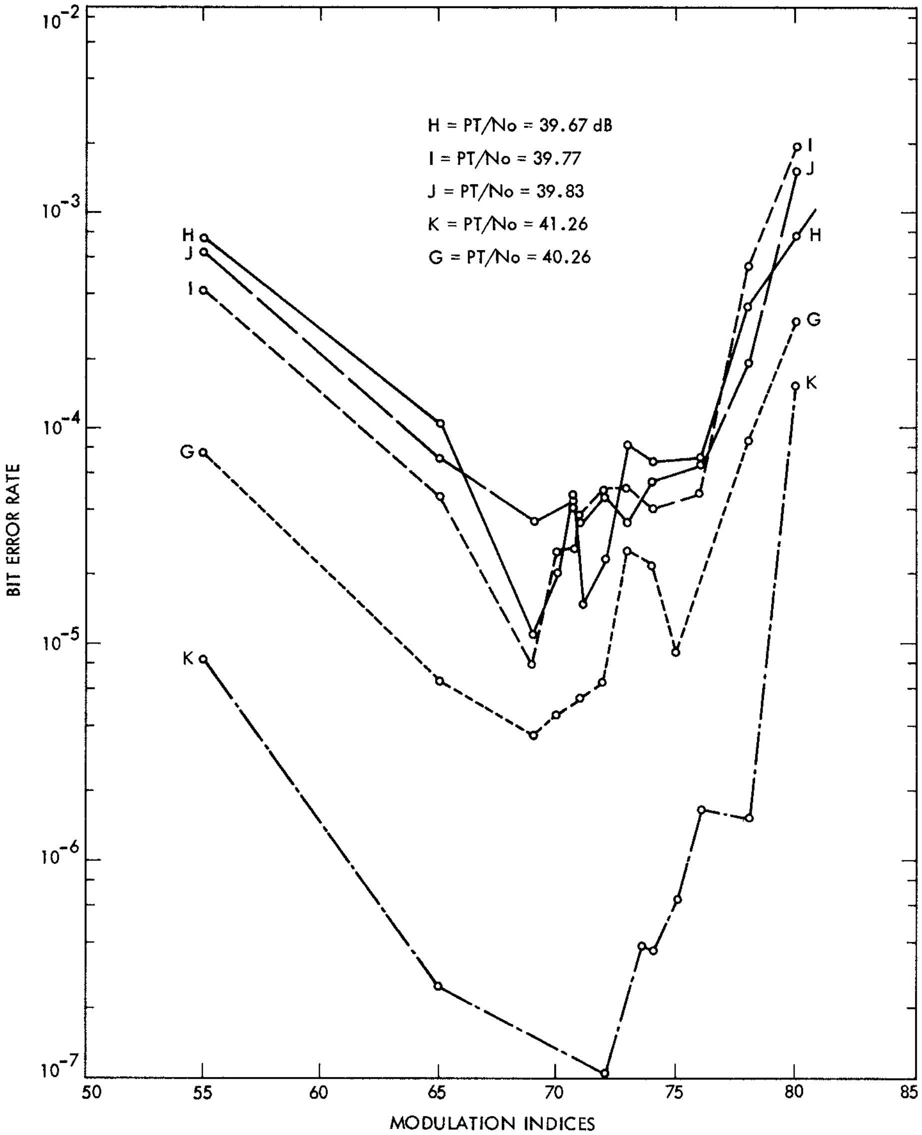

Fig. 1. Bit error rate vs modulation indices