Turbo Product Code (TPC) Application Note

Introduction

A **Product Code** is an array of block codes, built from smaller code word blocks characterised by (n,k) notation, where n is the block length after encoding (with error correction added) and k is the input message length. Encoding is implemented as a binary block code firstly on rows and then on columns for 2D arrays, and rows, columns and z-axis for 3D codes. Decoding is performed iteratively one block at a time with rows decoded first followed by columns (and z-axis if appropriate for 3D codes). This decoding process is iterated several times, feeding the decoder output back to the input, to maximise performance of the decoder, and because of the parallels with a turbocharger on an engine (where the exhaust drives the inlet) this error correcting scheme has been given the name **"Turbo Coding"**.

As with other error correcting schemes such as Viterbi or Sequential, code rate is commonly used to describe the ratio of bits after encoding to the number of bits before encoding (e.g. a Rate ¾ code produces 4 bits out for each 3 bits into the encoder). However, there is no international standard for Turbo Codes and there are a number of ways of implementing the codes, with column or row shortening to modify the code rate and code strength. Paradise Datacom support the "de facto" Rate ¾ Turbo Code and other useful code rates.

Performance of Turbo Codes

Turbo codes are extremely powerful in correcting errors, and can allow the communication system to operate at very low Eb/No conditions, but, as always with satellite systems, operating margins must be included within link budgets to maintain acceptable quality of service.

The figure adjacent shows guaranteed bit error rate performance achievable with 2D codes available now.

The performance of Turbo Codes can be varied and optimised by modifying the code array parameters, and Paradise Datacom will be providing a range of code rates and code variants to suit a variety of applications.

Paradise P300 Turbo Bit Error Rate
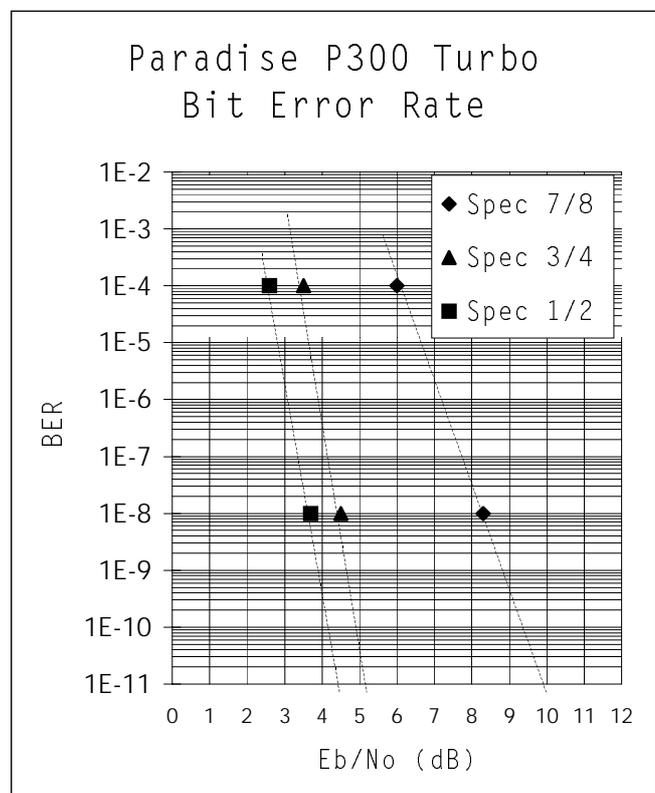
Benefits of Turbo Codes

❖ **33% Reduction in Space Segment Costs:** Paradise Turbo Rate ¾ offers a 33% reduction in occupied bandwidth ***combined*** with a 2dB (37%) reduction in satellite power compared with Viterbi Rate ½.

❖ **50% Increase in Throughput:** Existing leases using Viterbi Rate ½ may be simply re-engineered using Paradise Turbo Rate ¾ for a **50% increase** in data rate using the same uplink EIRP and with **no increase in space segment cost.**

❖ **Rain fade induced outages reduced by a factor of 10:** The 3dB improvement in link margins provided by Paradise Turbo Rate ½ may be used to achieve a massive 10-fold reduction of link outages using the same antenna size and satellite lease when replacing Viterbi Rate ½.

❖ **30% Reduction in Receive Antenna Size:** Paradise Turbo Rate ½ offers a BER of 1×10^{-6} at an amazingly low Eb/No of only 3.0dB. For example, use a 2.4m antenna (to meet local planning/zoning requirements) combined with Paradise Turbo Rate ½ to achieve the ***same*** performance with the ***same*** space segment costs as a 3.2m antenna using Viterbi Rate ½.

❖ **Reduced uplink EIRP leading to lower cost SSPA:** Satellite links engineered for the same link margin with Paradise Turbo Rate ½ will typically need ***half*** the uplink power compared with Viterbi Rate ½.

BER Comparison with other FEC Schemes

	BER	Rate 1/2	Rate 3/4	Rate 7/8	Rate 2/3
Viterbi QPSK	1×10^{-4}	4.7dB	6.1dB	7.1dB	
(all rates)	1×10^{-8}	7.2dB	8.8dB	9.5dB	
Sequential QPSK	1×10^{-4}	4.3dB	5.4dB	6.4dB	
(64kbps)	1×10^{-8}	6.4dB	7.3dB	8.6dB	
Sequential QPSK	1×10^{-4}	5.6dB	6.1dB	6.9dB	
(2048kbps)	1×10^{-8}	7.5dB	8.1dB	8.4dB	
Turbo (TPC) QPSK	1×10^{-4}	2.6dB	3.5dB	6.0dB	
(all rates)	1×10^{-8}	3.7dB	4.5dB	8.3dB	
8PSK/TCM	1×10^{-3}				6.3dB
(all rates)	1×10^{-8}				10.4dB
8PSK/TCM+Reed-Solomon	1×10^{-4}				6.1dB
(all rates)	1×10^{-10}				7.3dB

Turbo Code Availability

Turbo coding is available on all P300 Modem models including P310 L-band and the P300i Internet Router Modem. All modulation modes are available with Turbo if required, and Turbo Modems are available with Viterbi, Sequential and Reed-Solomon error correction to facilitate progressive changeover to Turbo in existing systems. Turbo functionality requires a hardware option to be installed within the Modem. Full datasheet available from the Paradise Datacom website or by contacting the sales offices: