AHA Application Note

“enhanced”
Turbo Product Codes (eTPCs)
# Table of Contents

1.0 **Introduction** ................................................................. 1  
2.0 **eTPCs** ................................................................. 1  
   2.1 Flexibility ............................................................. 2  
   2.2 Performance ............................................................ 2  
3.0 **Summary** ............................................................... 4  
4.0 **Products Available with eTPC** ..................................... 4  
5.0 **About AHA** ............................................................. 4
List of Figures

Figure 1: 2D (8,4)x(8,4) TPC Encoded Block .................................................. 1
Figure 2: eTPC Encoded Block (8,4)x(8,3) ..................................................... 2
Figure 3: 2K Block TPC and eTPC Example ................................................... 3
Figure 4: 1K Block TPC and eTPC Example ................................................... 3
1.0 INTRODUCTION

This application note discusses an enhancement to the Turbo Product Code block structure known as “enhanced Turbo Product Codes” or eTPCs. These new codes supplement the coding structure offered by conventional Turbo Product Codes (TPC), also referred to as Block Turbo Codes, and provide performance improvements and flexibility in code construction.

Turbo Product Codes are based on 2-dimensional (2D) and 3-dimensional (3D) blocks of extended Hamming and parity codewords. Their performance has been shown to be very close to the theoretical “Shannon Limit” as measured by Bit Error Rate (BER). For a more complete description of TPCs, please refer to the AHA Application Note “TPC Primer” (ANTPC01).

An example of an encoded 2-dimensional TPC block of (8,4)x(8,4) extended Hamming constituent codes is shown below.

![Figure 1: 2D (8,4)x(8,4) TPC Encoded Block](image)

In this coding example, there are 16 input data bits (denoted D) and 48 computed ECC bits (denoted E) for a total block size of 64 bits to be transmitted through the communications channel. The code rate of this example is 1/4.

2.0 eTPCs

The eTPC codes are a parity code applied along a diagonal traverse through the TPC block (also referred to as “hyper diagonal parity”). This coding is applied on top of the TPC coding to give an added degree of error correction power. During eTPC encoding a parity bit is computed for each diagonal through the TPC encoded block and included as an additional parity row (in the case of 2D eTPCs) or an additional parity plane for 3D eTPCs in the encoded block. This is shown for a 2D eTPC block below. The code rate of the example eTPC is now 3/16.
2.1 FLEXIBILITY

The addition of the enhanced TPC coding to the TPC block slightly reduces the code rate of the block code. However, it offers another degree of coding flexibility in creating a block code targeted at a specific data size and code rate.

2.2 PERFORMANCE

The additional coding dimension offered by the eTPC diagonal parity improves the weight enumeration of the minimum weight codewords. The diagonal axis effectively lowers the number of Hamming distance ($d_{\text{min}}$) codewords. The benefit of using the eTPCs can be observed graphically on the BER vs. Eb/No plot. When eTPCs are added to a TPC block the slope of the asymptotic bound for eTPCs is steeper than the non-eTPC block. The location of the asymptotic bound is also lower (at a smaller BER value) for the eTPC code. One case where the use of eTPC technology is often used is when a very high rate code is desired (e.g. above rate .90). An example of this is shown in Figure 3. In this example 2 codes are shown for a block size of 2k bits. The first code is a conventional TPC code of (64,57)x(32,31) for a code rate of .95. The BER performance of this code is plotted for 8 decoder iterations in an AWGN channel with BPSK modulation. Also plotted is the performance of an eTPC (64,57)x(32,30) code with 8 iterations and a code rate of .92. As can be seen on the plot, the performance of the eTPC is considerably better (over 1 dB) than the conventional TPC even though the code rate is only slightly less. Another condition where the use of eTPC coding offers performance advantages is when very small BER values are required in the system. This is typically at BER values smaller than $10^{-7}$. An example is shown in Figure 4 for a (32,26)x(32,26) TPC and eTPC code. The code rate of the TPC code is .66 while the code rate of the eTPC code is .63. The BER performance of the conventional TPC approaches an asymptotic bound at a BER of approximately $10^{-6}$ and then a slight flare is encountered. The eTPC code does not encounter any flaring until much smaller BER values and as a result its performance is considerably better than the conventional TPC for these small BER values. The eTPC code performance would encounter a region of flaring approximately four decades lower. For the system requiring small BER values, eTPCs can significantly improve the overall BER performance.
Figure 3: 2K Block TPC and eTPC Example

Figure 4: 1K Block TPC and eTPC Example
3.0 SUMMARY

In this application note we have shown how eTPC codes are constructed. We have also demonstrated two cases where they offer a performance advantage over conventional TPCs. Although not appropriate for every application, enhanced TPCs offer the system engineer yet another coding choice.

4.0 PRODUCTS AVAILABLE WITH eTPC

The AHA products listed in the table below contain the eTPC technology as a coding option.

<table>
<thead>
<tr>
<th>PRODUCT</th>
<th>DESCRIPTION</th>
</tr>
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<tbody>
<tr>
<td>AHA4524</td>
<td>50 Mbits/sec TPC Encoder/Decoder device</td>
</tr>
<tr>
<td>AHA4540</td>
<td>155 Mbit/sec TPC Encoder/Decoder device</td>
</tr>
<tr>
<td>AHA4541</td>
<td>311 Mbits/sec TPC Encoder/Decoder device</td>
</tr>
<tr>
<td>Galaxy</td>
<td>eTPC encoder and decoder cores</td>
</tr>
</tbody>
</table>

5.0 ABOUT AHA

The AHA Products Group (AHA) of Comtech EF Data Corporation develops and markets superior integrated circuits, boards, and intellectual property cores for improving the efficiency of communications systems everywhere. AHA has been setting the standard in Forward Error Correction and Lossless Data Compression for many years and provides flexible and cost effective solutions for today’s growing bandwidth and reliability challenges. Comtech EF Data is a wholly owned subsidiary of Comtech Telecommunications Corporation (NASDAQ” CMTL). For more information, visit: www.aha.com.