Project	**IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>**
Title	**BTC, CTC, and Reed-Solomon-Viterbi performance on SUI channel models**
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Abstract	The BTC is shown to be a strong optional FEC, providing performance unobtainable by the mandatory FEC mode. While similar gains are obtainable via the optional CTC, latency and complexity become serious concerns, as pointed out in C802.16a-02/81.
Purpose	[Description of what the author wants 802.16 to do with the information in the document.]
Notice	
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Patent Policy and Procedures	

BTC, CTC, and Reed-Solomon-Viterbi performance on SUI channel models

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Introduction

This contribution presents simulation results for the three FEC modes available in P802.16/D5. The channel model considered is that presented in 802.16.3c-01/29r4. Only SUI-4 and SUI-5 models have been considered at this time. To distinguish between the SUI models in 802.16.3c-01/29r4 and those presented elsewhere, the models are labeled as Sui4M or Sui5M, with the "M" indicating the modified SUI model.

Simulation Conditions

It is the intention of this contribution to present as accurate results as is reasonably possible. This section presents the conditions used for each FEC mode.

The Reed-Solomon-Viterbi decoder simulated assumes no quantization of the soft data supplied to the Viterbi decoder. It is otherwise believed to be an accurate indicator of performance.

The BTC simulation is based upon hardware equivalent code. Four bits are used for receiving the soft LLR metrics, and 5 bits are used internally in the SISO decoders. A maximum of four iterations is performed on each coding frame, which is an un-necessary restriction placed upon the BTC.

The CTC simulation uses a tail-biting, rate ½ constituent code. The actual iterative decoding is handled by a software library from Canada Research Centre (CRC). This software takes as input a floating point soft LLR metric, and internally uses 16 bits of precision. A maximum of four iterations (eight half iterations) is performed on each coding frame. Brian Edmonston has stated that the CRC implementation yields results equivalent to his down to a BER of 1e-6. More information about the CRC implementation of the CTC is available on their website at http://www-ext.crc.ca/fec/.

All three FEC modes use an identical channel model, with identical equalization. The LLR computations for the BTC and CTC are identical, except that the LLR for the CTC is left unquantized. The soft metrics used by the Viterbi decoder are computed using the identical probability analysis, but are supplied to the decoder in a different (unquantized) form.

By using a single channel model implementation for all FEC modes, it is believed that these results most accurately reflect the performance obtainable for each mode. It is noted that both of the Turbo FEC modes are limited to 4 iterations. Considering the latency issues presented in C802.16a-02/81, it is possible for the BTC to run more than 4 iterations while still meeting latency constraints, and consuming modest silicon real estate. It is unclear whether modest silicon real estate is sufficient for the CTC to run even 4 iterations. Increasing the BTC iteration count beyond 4 may improve performance by an additional few tenths of a dB. Reducing the iteration count of the CTC below 4 iterations to satisfy latency may result is a significant performance loss, exceeding several tenths of a dB.

Simulation Results

The following plots indicate the advantage of using the optional BTC rather than the mandatory Reed-Solomon-Viterbi FEC. The plots show both bit error rate (BER) and packet error rate (PER) for each FEC mode. The codes used match the draft standard specifications for rate and size.

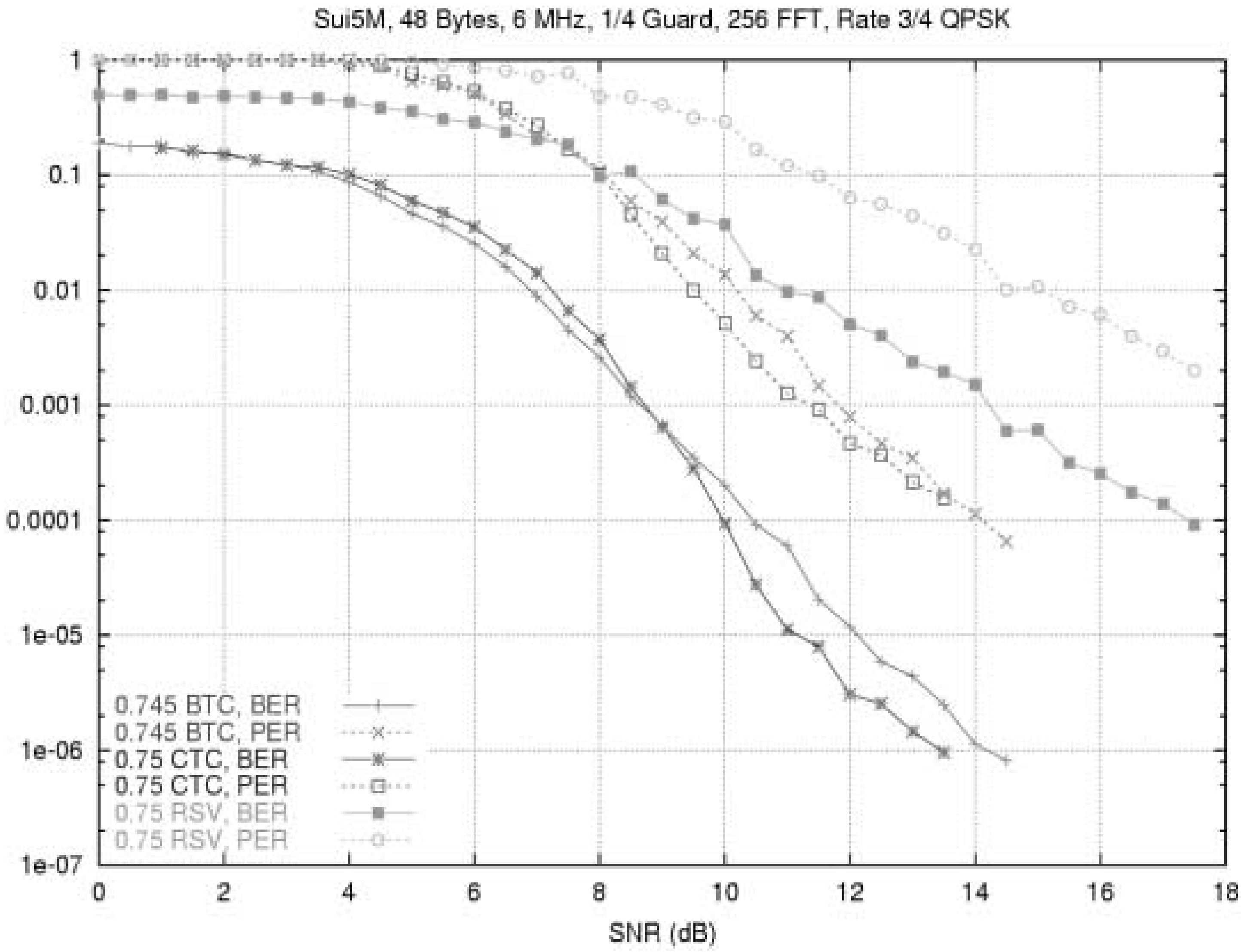

Figure 1 – Rate ¾ QPSK on Sui5M

Figure 1 indicates that the BTC and CTC offer in excess of 8 dB improvement over the mandatory FEC mode at a BER of 1e-4. At a more meaningful 1e-6, the gain over the mandatory mode is in the order of 10 dB! At 14 dB SNR, the BTC has obtained a PER of 1e-4. Based upon the slope of the CTC curve, it will also reach a PER of 1e-4 at 14 dB SNR.

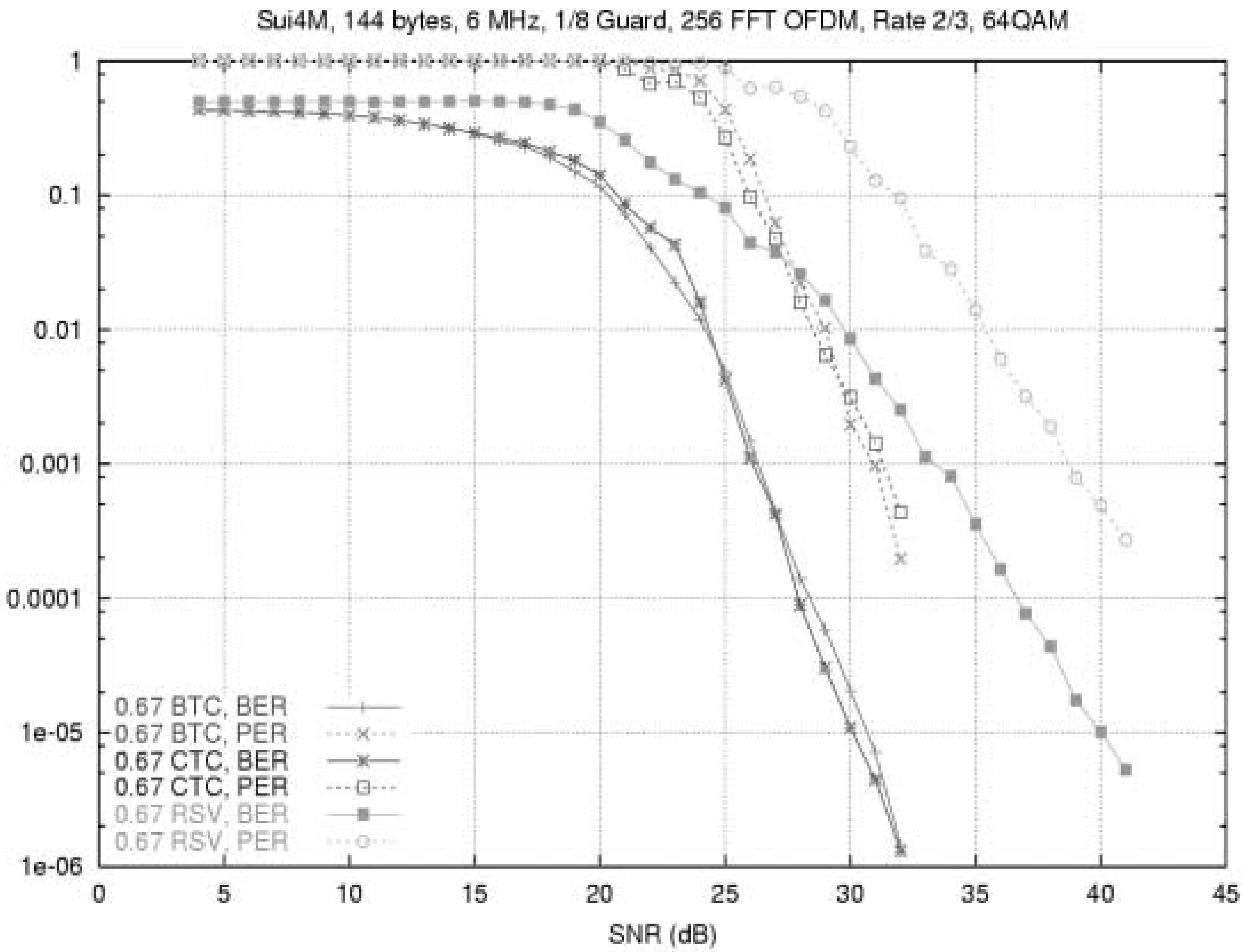

Figure 2 – Rate 2/3, 64 QAM on Sui4M

For obtaining maximum data throughput, higher order modulation is utilized. Figure 2 indicates the performance for the FEC modes when operating on 64QAM at a rate of 2/3. The BTC offers a gain of about 10 dB over the mandatory FEC mode.

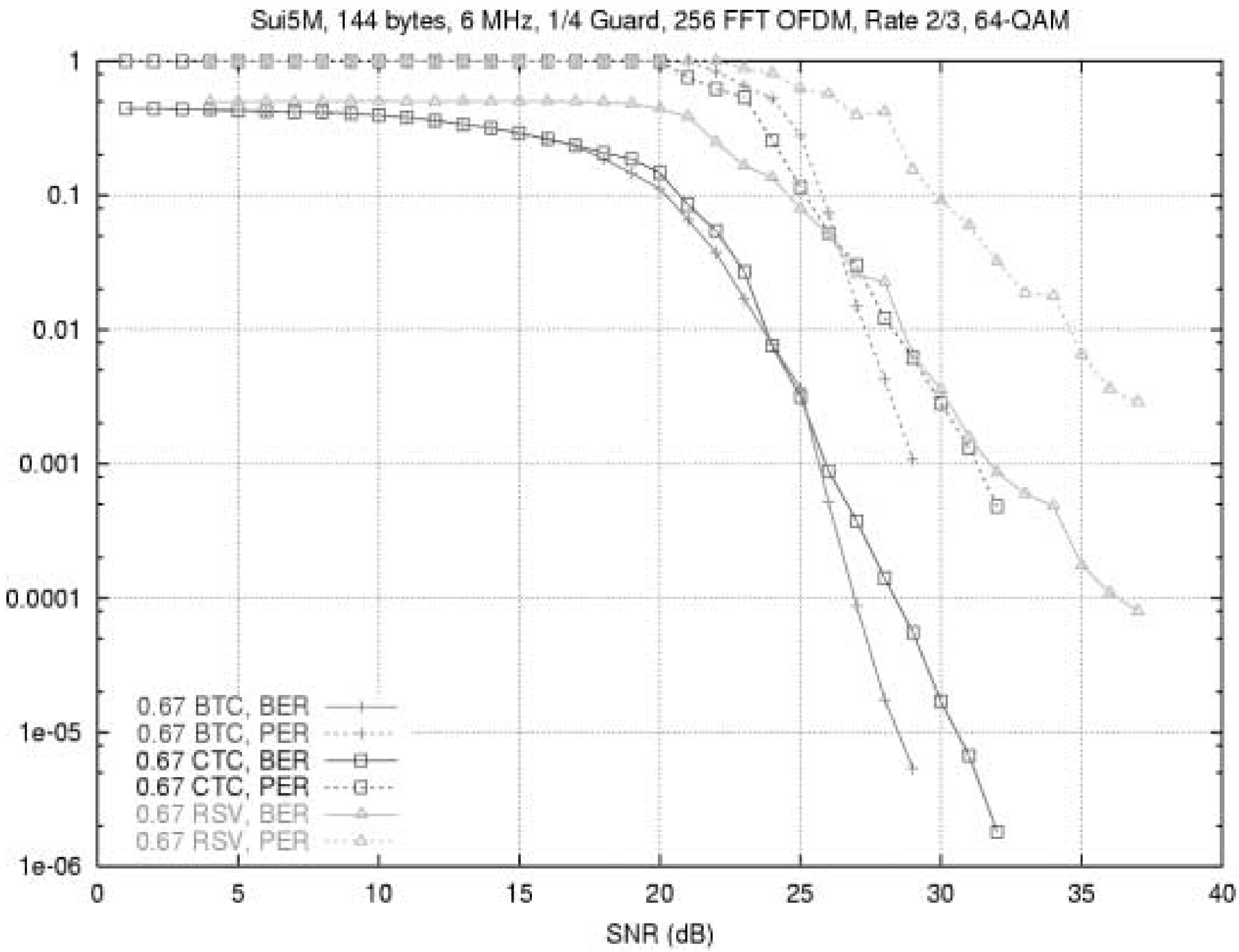

Figure 3 – Rate 2/3, 64-QAM on Sui5M

For the rate 2/3, 64QAM system on the SUI5 channel model, the optional BTC again offers a gain over the mandatory mode on the order of 10 dB. Compared to the optional CTC, the BTC offers an additional 2 dB at a BER of 1e-6, and may be a significantly larger gap at a PER of 1e-4. To re-emphasize the gains of the BTC over the mandatory mode, the BTC obtains a packet error rate of 1e-4 approximately 5 dB prior to the mandatory mode hitting a bit error rate of 1e-4.

Conclusion

Optional BTC FEC offers a significant performance gain over the mandatory FEC. We re-emphasize that the performance plots presented in this contribution are for 4 iterations for both optional coding methods.

Modulation	Data/Decoded Data (Bytes)	Rate	TPC "A" Latency/Mbps	TPC "B+" Latency	DVB_RCS "C" Latency/Mbps	DVB_RCS "D" Latency/Mbps
QPSK	24/48	1/2	3.7us/51Mbps	N/A	17.1us/11.3Mbps	45.9us/4.2Mbps
QPSK	36/48	3/4	4.1us/71Mbps	7us	23.6us/12.3Mbps	50.7us/5.7Mbps
16 QAM	58/96	3/5	5.7us/82Mbps	5.7us	35.2us/13.2Mbps	59.5us/7.8Mbps
16 QAM	77/96	4/5	5.9us/105Mbps	8.2us	45.3us/13.4Mbps	67.1us/9.2Mbps
64 QAM	92/144	2/3	9.5us/78Mbps	8.5us	53.3us/13.8Mbps	73.1us/10.1Mbps
64 QAM	120/144	5/6	9.5us/101Mbps	9.2us	68us/14.1Mbps	84.3us/11.4Mbps

Table 1: Latency and Data Rate Comparison – Used by permission of J. Simkins

Noting contribution C802.16a-02/81, the BTC is capable of performing additional iterations, further improving performance results, and still meeting latency requirements with reasonable complexity. It is not clear if the CTC can be made to satisfy latency constraints when performing even 4 iterations with reasonable complexity. The results presented are generated using conditions as identical as possible between the three FEC modes. The BTC is the only one of the three simulations to actually use fully hardware compatible simulations, placing it at a detriment when compared to the idealized environments of the CTC and mandatory FEC modes. Since we do not have access to the exact CTC specified for 802.16a, we have not allowed ourselves to optimize the BTC results in any way. This has been done in the interest of fair comparisons.