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| Abstract | This contribution addresses the problem of reducing the complexity and number of different modes that are currently specified in the 802.16a baseline OFDM PHY mode. It shows by simulation results that the concatenated convolutional / Reed Solomon code can be replaced by a simpler scheme without degrading the performance of the system. |
| Purpose | Reducing the implementation complexity of FEC schemes in OFDM PHY mode. |
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| Patent Policy and Procedures |  |

# Options and results for reducing FEC complexity in 802.16a OFDM modes

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## Introduction

In the current proposal for OFDM/OFDMA modes FEC there is a variety of different FEC parameters that are used to enable support of all transmission rates and block sizes. The main purpose of this contribution is to present some alternatives to the baseline scheme, as to reduce the number of modes in the FEC scheme, allowing a significant reduction in the complexity of the 802.16a specifications. The main issue addressed in this paper is the possibility to reduce the number of different codeword size options in the RS encoder/decoder in the concatenation scheme. Another issue addressed is the option to eliminate the RS outer code and replace the concatenation scheme with a simpler convolution-only scheme. The last issue was raised first by Tal Kaitz in his contribution [1] 802.16abc-01/08. By inspecting the simulation results shown is this contribution, it seems that the most logical conclusion is to eliminate the RS code and replace the concatenated scheme by a much simpler Convolutional Code (CC) only scheme. It should be noted that the simulation conditions and the system realization in these simulations, defer from the simulation shown by Tal Kaitz in [1], and therefore the performance results are not comparable, however a relative comparison between the baseline CC+RS scheme and a CC-only scheme shows similar behavior in both documents, hence the conclusion is supported also by the results shown in [1].

## Options for simplifying the FEC scheme

### *Option 1- reducing the number of RS modes*

The current proposal for concatenated FEC modes has 3 different CC codes and 6 different RS codes. These are shown in table 1.

| | Information block size (bytes) | Overall code rate | RS (N,K,t) | CC rate |
|---|---|---|---|---|
| QPSK | 24 | 1/2 | (34,24,4) | 2/3 |
| QPSK | 36 | 3/4 | (40,36,2) | 5/6 |
| 16QAM | 48 | 1/2 | (64,48,8) | 2/3 |
| 16QAM | 72 | 3/4 | (80,72,4) | 5/6 |
| 64QAM | 96 | 2/3 | (108,96,6) | 3/4 |
| 64QAM | 108 | 3/4 | (120,108,6) | 5/6 |

Table 1 – concatenated FEC modes: current 802.16a baseline

In order to enable a new scheme fit into the system without causing changes to other parameters, the coded (channel) block size should be an integer multiplication of 192 (the number of useful subcarriers in the mandatory FFT-256 mode). The following table shows a proposed new scheme that can support most of the functionality of the original scheme, using only 2 different CC and 2 different RS codes.

| | Overall code rate | RS (N,K,t) | CC rate | Interleaver size |
|---|---|---|---|---|
| QPSK | 1/2 | (16,12,2) | 2/3 | (16,2) |
| QPSK | 3/4 | (20,18,1) | 5/6 | (20,2) |
| 16QAM | 1/2 | (16,12,2) | 2/3 | (16,4) |
| 16QAM | 3/4 | (20,18,1) | 5/6 | (20,4) |
| 64QAM | 3/4 | (20,18,1) | 5/6 | (20,6) |

Table 2 – concatenated FEC modes: simplified scheme

The simplification is achieved by adding a byte interleaver between the CC decoder and RS decoder. This interleaver causes the burst errors at the output of the Viterbi decoder to be spread over multiple RS blocks thus reducing the number of errors in each RS block. Although by this scheme an additional interleaver is introduced into the system, it is clear that this is a very simple block interleaver and does not affect the system latency (since its size is the same as the original RS block size).

## *Option 2- Replacing the CC-RS scheme by an equivalent rate CC-only scheme*

In this option it is proposed to replace the concatenation scheme with a convolutional code only. Since the RS codes specified in the 802.16a baseline have relatively low rates, there is a possibility to decrease the CC rate and get additional coding gain from the covolutional code. The resulting CC codes are all based on the R-1/2 code that is used in the baseline document FEC with the same puncturing patterns. This scheme has a greater potential to reduce the receiver complexity further, since it eliminates the RS decoder.
The modulation/code rates for this option are shown in table 3 below.

| | Information block size (bytes) | Overall/CC code rate |
|---|---|---|
| QPSK | 24 | 1/2 |
| QPSK | 36 | 3/4 |
| 16QAM | 48 | 1/2 |
| 16QAM | 72 | 3/4 |
| 64QAM | 96 | 2/3 |
| 64QAM | 108 | 3/4 |

Table 3 – Convolutional code only FEC modes

## Simulation results

In the following, some simulation results are presented. These simulations where performed using a MATLAB model of the 802.16a system in the OFDM mode.
The following parameters and options where used:

- FFT size: 256 (192 useful subcarriers)
- Modulation/Coding: QPSK, 16QAM, 64QAM with concatenated code CC+RS
- FEC parameters where taken from the current 802.16a baseline (table 1), or alternatively from the new proposed scheme (table 2).
- An additional mode of a shorter RS code without interleaving was also added to simulation, to elaborate the coding gain increase associated with interleaving over several RS blocks.
- The data used for each simulation run consist of 10,000 packets of 1,000 bits each
- Each packet was received by a full receiver including independent synchronization and tracking of all parameters (e.g. frequency, phase, channel estimation).
- The performance degradation relative to ideal synchronization and perfect channel state information was checked, and found to be practically the same for all 3 FEC options, hence has not effect on relative performance.
- CC decoding uses 5 bits linear-quantized metrics and hard outputs.
- RS decoding is standard hard-decision decoding without erasures
- Only packet error rate (PER) was considered for results. In normal operation it was assumed that PER=0.01

### *Results for option 1:*

Figures 1, 2 and 3 show results of 3 comparisons, corresponding to QPSK-1/2, QAM16-1/2 and QAM64-3/4 modes, using AWGN and frequency-selective fading channels (SUI). The fading channels where generated according to the draft standard 802.16a channel model [2].

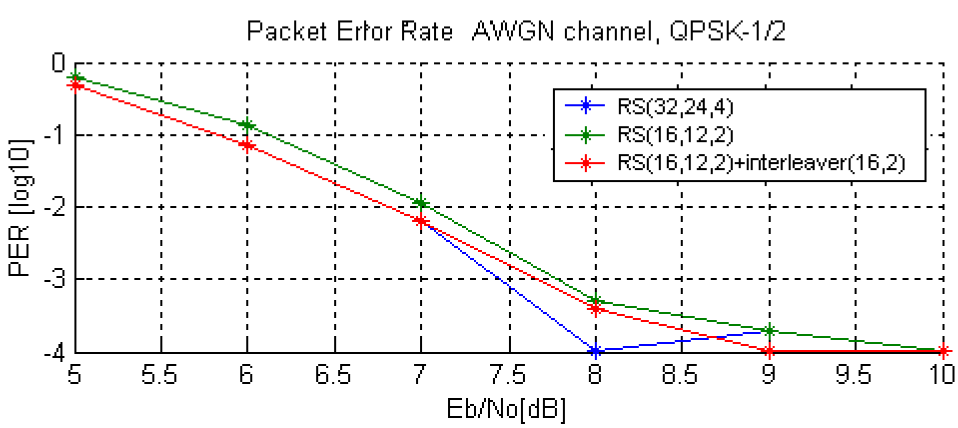


Figure 1- AWGN QPSK-1/2 results

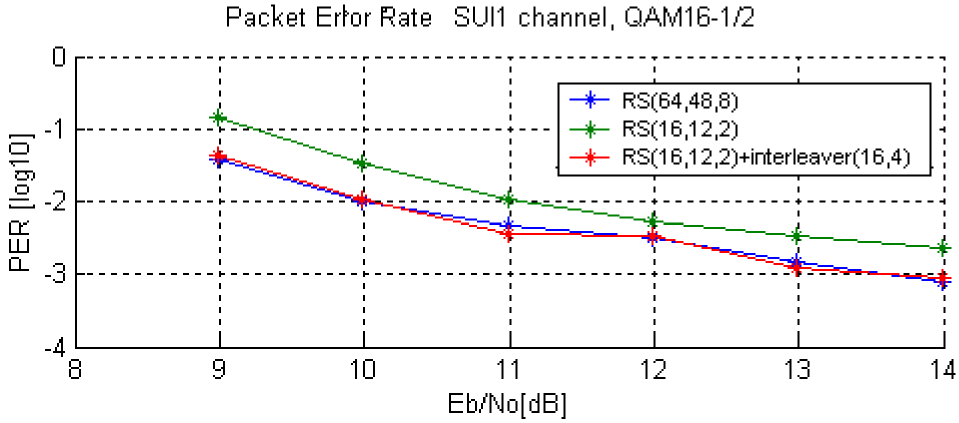


Figure 2- SUI1 QAM16-1/2 results

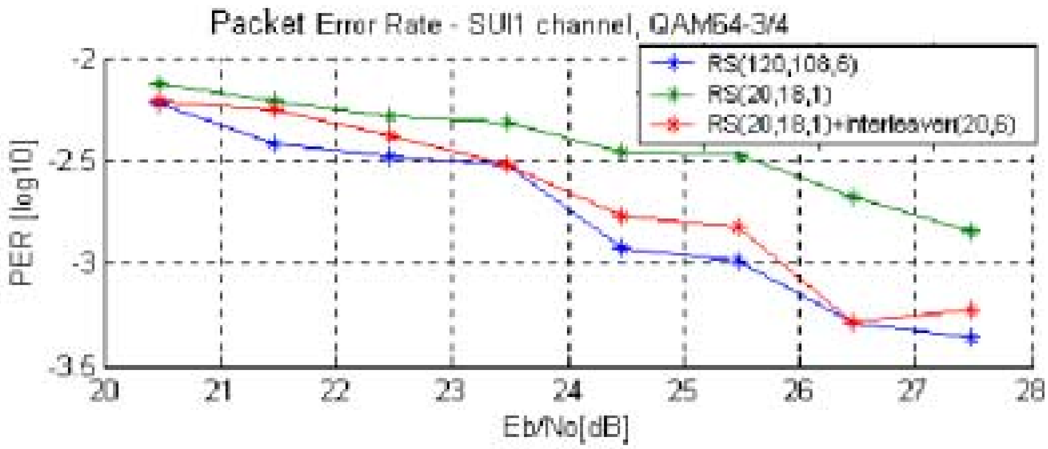


Figure 3- SUI1 QAM64-3/4 results

The results show no difference in performance between long RS and short RS+interleaver at AWGN (QPSK-1/2). It is also seen in figure 1, that the use of interleaver does not bye more than 0.25 dB.

The results with fading channel, shows more advantage of the long RS block (1 dB), as was notice by Tal Kaitz [1], but it can be seen that the use of an interleaver over several RS blocks can completely eliminate this difference. This is seen in figures 2 and 3 for QAM16-1/2 and QAM64-3/4 respectively.

## *Results for option 2:*

The results shown in figure 4 where obtained using the same system described in the previous paragraph, with the addition of new FEC mode (CC only) shown in table 3.

It can be seen clearly from this simulation that the CC only mode performs better in all modes and in SUI1 channel, by an amount of about 1 dB.

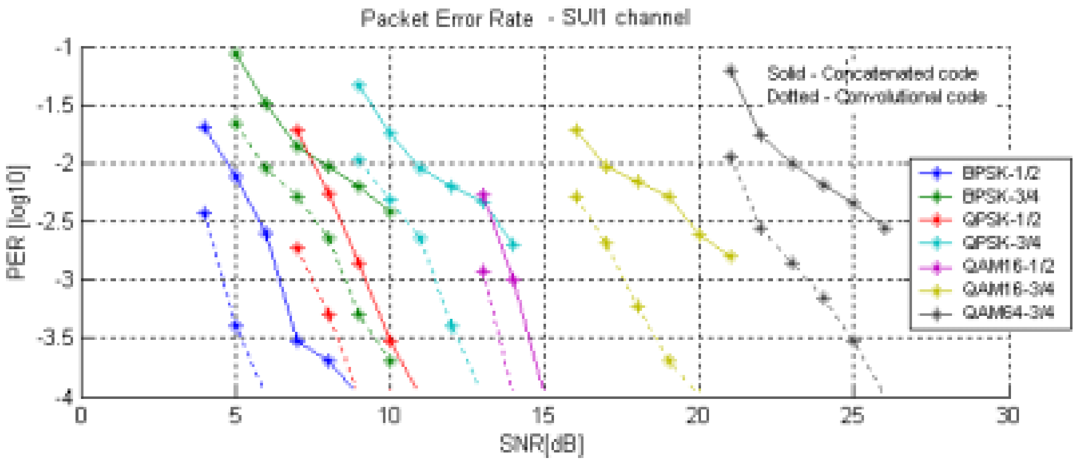


Figure 4- Concatenated vs. Convolutional only

## Conclusions

In this paper, some alternative to the baseline 802.16a forward error correction (FEC) schemes were presented. A simulation using a system model with non-ideal synchronization and channel state estimation was performed, in order to evaluate the relative performance of these optional schemes. The major conclusion that comes out from these simulations are as follows:

1. There is a possibility to simplify the concatenated FEC by reducing the number of RS modes and using short RS codes in conjunction with an additional interleaver, instead of the long RS codes.

2. More important then that is, that a rate-equivalent convolutional-code scheme can replace the concatenated code scheme without loss in performance (and in fact with possible gain as was seen by simulations with channel SUI1). It is true that the performance of the concatenated scheme may be somewhat improved by adding soft-output CC decoder and erasures in RS decoding, however this implies a significant complication to the FEC decoders and will not provide more then 1 dB increase for the concatenated scheme, nor change the basic conclusions.

These conclusions are in agreement with [1].

By this it seems logical to propose that the current baseline FEC scheme will be replace by the scheme summarized by table 3.

## References

[1] T. Kaitz, FEC performance for 802.16a OFDM IEEE document 802.16abc-01/08

[2] V. Erceg et al. ,Channel Models for Fixed Wireless Applications, IEEE document number 802.16.3c-01/29.