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Wireless LANs

An Improved Rate Signalling Scheme

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Abstract

In this submission, we present a robust method for rate signaling in 802.11a packet. The proposed method utilizes bi-orthogonal Hadamard coding and OFDM modulation to achieve a high degree of reliability in both flat AWGN and fading channels. The proposed scheme is easy to implement and requires no overhead relative to the current method. The scheme can be easily extended to convey 5 bits of information.

1. Introduction

The robustness of the rate-signalling field is critical for the performance of the 802.11a wireless LAN. In a recent submission (document IEEE802.11- 98/369) it was shown that, unless specific bit assignments are used, the errors in the rate field are the limiting factor in severe multipath conditions and low data rates.
Choosing the bit assignment mentioned in document 98/369 could improve robustness, but even so the results are not satisfactory. In addition, it is not clear if the method described in 98/369, is applicable in the case where only one short sequence is used as a guard between the channel estimation section and the rate field.
We are therefore motivated to seek more reliable schemes for the rate field. One such scheme is discussed in the following sections.

2. Proposed Scheme

The proposed method utilizes bi-orthogonal Hadamard coding and OFDM modulation to convey the four bits of rate information. The rate field consists of a 1.6 uS data section (S1 in figure 1) and a 0.8 uS cyclic prefix to achieve a total length of 2.4uS. It is located immediately after the channel estimation section. (Refer to figure 1).

When compared with current scheme (shown in the figure2), it can be observed that the overall length is the same of current proposal (t10+s1+s2).

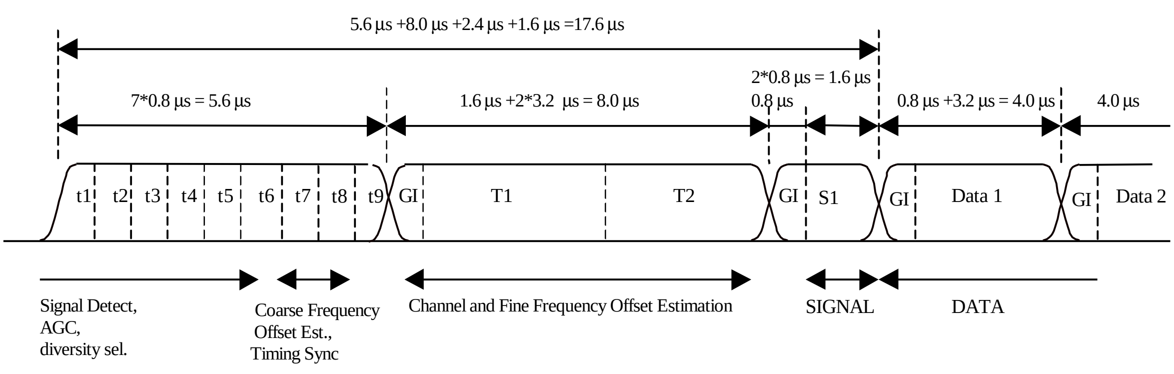


Figure 1: Preamble structure: Proposed scheme

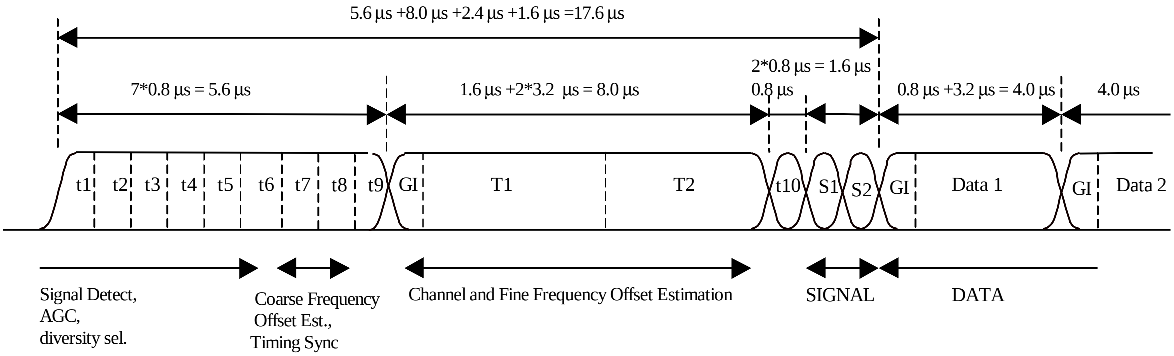


Figure 2: Preamble structure: current scheme

2.1. Encoding and modulation

The encoding and modulation procedure is as follows.

1. The three LSB s of the 4 bits rate field are used to select one of eight rows of the Hadamard H_8 matrix given by:

H_8=

$$\begin{vmatrix} 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 1 & -1 & 1 & -1 & 1 & -1 & 1 & -1 \\ 1 & 1 & -1 & -1 & 1 & 1 & -1 & -1 \\ 1 & -1 & -1 & 1 & 1 & -1 & -1 & 1 \\ 1 & 1 & 1 & 1 & -1 & -1 & -1 & -1 \\ 1 & -1 & 1 & -1 & -1 & 1 & -1 & 1 \\ 1 & 1 & -1 & -1 & -1 & -1 & 1 & 1 \\ 1 & -1 & -1 & 1 & -1 & 1 & 1 & -1 \end{vmatrix}$$

1. Change the polarity of selected row according to the MSB. Thus, bi-orthogonal modulation is accomplished. Let $\boldsymbol{h}=\{h_0,h_1,\ldots,h_7\}$, denote the resulting vector.

2. Concatenate ***h*** with replicas of itself to produce the vector ***p=[h h h].***

3. Multiply the elements of the vector ***p*** with the cover sequence: c_i={ -1,1,-1,-1,1,-1,-1,-1,1,-1,1,1, 1,-1,-1,-1,1,1,1,-1,-1,-1,1,1,-1} to produce the vector $\boldsymbol{d}=\{d_0,d_1,\ldots,d_{23}\}$ *where* $d_i=c_i*p_i$. The purpose of the cover sequence is to insure that all possible keywords have a low peak to average power ratio.

4. Use the vector ***d*** to modulate the 24 <u>even</u> subacrriers, skipping the DC carrier. Let the 24 odd subcarriers have a zero value.

5. Perform IFFT to the resulting vector. Since only the even subcarriers were modulated, the time domain vector is composed of two identical halves.

6. The first half is prepended with a 16 point cyclic extension and the resulting 48 samples vector is transmitted.

2.2. Demodulation and decoding

The demodulation scheme is outlined below

1. The 32 samples of the rate field are cyclically extended to produce a 64-point vector with two identical halves.

2. A IFFT is performed on the 64 point vector

3. The 24 in-band even spectral lines are multiplied by the cover sequence.

4. The 24 in-band even spectral lines are combined to produce the 8 point vector ***h'*** which is an estimate to the vector ***h.***

5. A Fast Hadamard Transform (FHT) is applied to ***h'***. The location of the peak of the FHT output determines the LSBs of the rate field and the sign of the peak determines the MSB.

3. Performance

In this section we consider the performance of the new scheme by comparing the error probability in the rate field to the error probability in the data section in 6Mb/s mode.

3.1. Performance in flat AWGN channels.

The performance in flat AWGN channels is analysed in terms of the free Euclidean distance of the code.

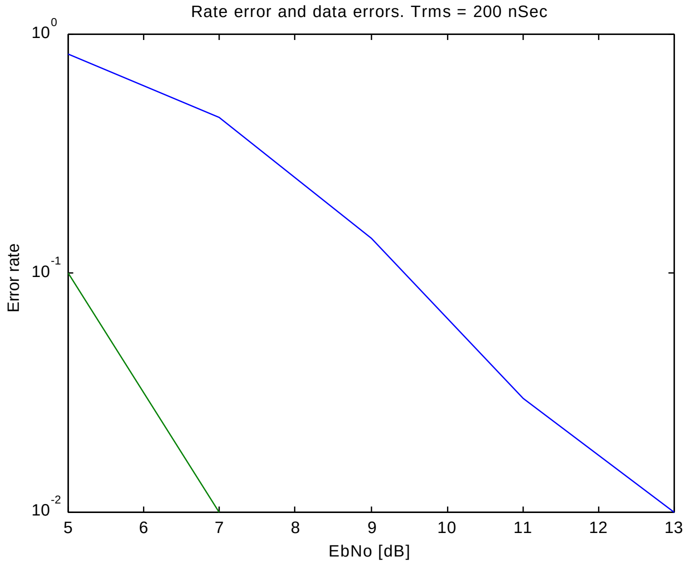
First, we should note that the signal to noise ratio per spectral line, is the same for both the rate field and the data section. Thus, we can compare the free distance in terms of the spectral line power, denoted by E_s.

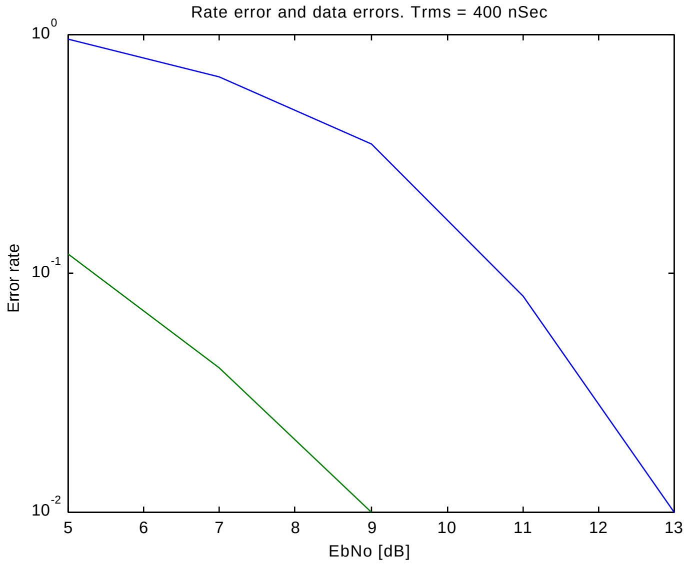
The free distance of the rate ½ k=7 convolution code is $d^2_{free}{}^{con}= 10*4E_s=40E_s$. The free distance of the Hadamard code is $d^2_{free}{}^{hadamard} =2*8*3*E_s=48E_s$, where $8*3*E_s$ is the energy in each codeword and the factor 2 is due to the orthogonality of the codewords.

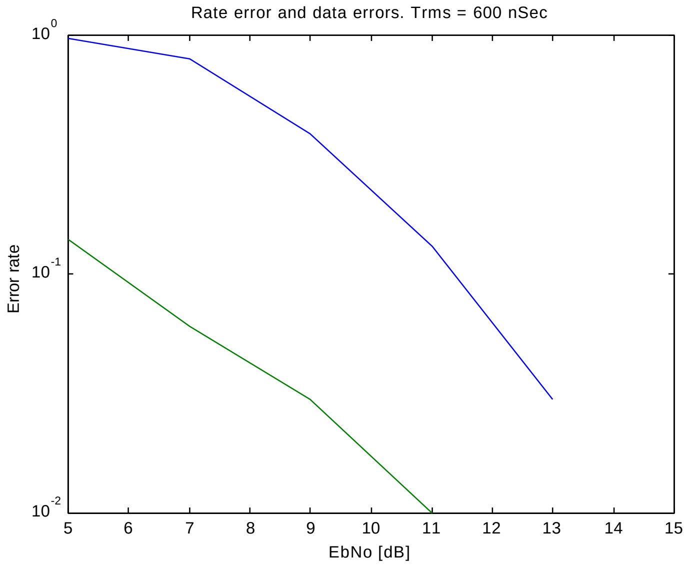
As a conclusion, the free distance of the Hadamard code used in the rate field is 0.8dB higher than that of the convultional code used for the data section.

3.2. Performance in fading channels

The performance under fading conditions cannot be easily analyzed. Instead, several simulation experiments were performed, the results of which are shown below. In the simulations, the error rate of the rate field was compared with the error rate of the data section. The simulated data rate was 6Mb/s and the packet size was 64bytes. The delay spread under consideration was in the range 200nS…600nS.







Green: rate field errors. Blue: Data errors.

3.3. Peak to average power ratio

Finally, we shall consider the peak to average ratios of the all the possible codewords. These are listed in the following table:

Codeword	PAP [dB]
1	3.2 dB
2	3.7 dB
3	4.6 dB
4	3.7 dB
5	3.2 dB
6	4.2 dB
7	4.6 dB
8	3.7 dB

It can be observed that the PAP is not higher than 4.6dB.

4. Extension to 5 signalling bits

Due to the proliferation of data and code rates and of possible future introduction of additional coding schemes, it would be advantageous to be able to transmit more than 4 bits of signalling. The proposed scheme can be easily extended to carry 5 bits of information. This extension can be achieved by using both inphase and quadrature components. The coding is performed by using the 3 LSBs to select the Hadamard row. The selected row is multiplied by a QPSK symbol selected by the 2 MSBs.

Decoding is performed by a complex 8-point FHT. The location of the peak is used to select the 3 LSBs and the phase of the peak is used to select the 2MSBs.

The free distance of this code is as before $d^2_{free}{}^{hadamard} = 2*8*3*E_s = 48E_s$. This is because modulating the H_8 rows with any phase does not change the orthogonality, and hence does not change the distance. It should be noted that the number of neighbouring codewords with the minimum distance is increased by a factor of two. Hence a slight degradation in performance is expected.

5. Conclusions

A new scheme for conveying the data rates was presented. This scheme achieves a high level of robustness in both flat and fading channels. It requires no overhead relative to the current scheme. The modulation and demodulation operations are similar to those of the data section and require no additional H/W. The coding and decoding are performed by an 8 point Fast Hadamard Transform which is simple to implement. A simple extension permits transmitting 5 bits of information.