An Improved Rate Signalling

• The reliability of the rate-signaling scheme is crucial for the performance of the 802.11a Wireless LAN.
• We propose a new reliable scheme based on bi-orthogonal Hadamard coding and OFDM modulation.
• No overhead relative to current scheme
• Simple to implement.
Overview of current scheme

• 4 bits are conveyed by QPSK modulating the sequences S1 and S2.

• t10 serves as a guard interval.

• Overall length 0.8uS+0.8uS+0.8uS=2.4uS.

• In AWGN: same error rate as rate \( \frac{1}{2} \) BPSK OFDM. (6Mb/s).

• Non satisfactory performance under severe multipath conditions.
Proposed Scheme

- 4 bits are conveyed by the sequence S1 spanning 1.6uS.
- Additional guard interval of 0.8uS.
- Overall length 2.4uS – same as before.
Coding and Modulation

- 3 LSB select one row of Hadamard 8 matrix.
- The MSB selects sign.
- The 8 binary symbols are repeated 3 times to form 24 vector.
- The vector is multiplied with a cover sequence.
- The result is used to modulate the even subcarriers of a 64 point OFDM symbol. The time domain vector has two identical halves.
- The time domain vector is cyclically extended and a window is applied to truncate it to length 2.4uS.
Decoding and Demodulation

• The 32 samples signal is cyclically extended to provide 64 samples.
• A 64-point FFT is used to demodulate.
• The even subcarriers are multiplied by the cover sequence.
• The subcarriers are combined to produce an 8-point vector.
• A Fast Hadamard Transform is applied.
• The location of peak determines 3 MSBs. The sign of the peak determines the MSB.

• Both modulation and demodulation require existing H/W: namely the 64 point FFT/IFFT
• Coding and decoding require an 8 point fast Hadamard transform.
Performance in flat AWGN

- Let $E_s$ denote the power per spectral line.

- Then for rate $\frac{1}{2}$ k=7 BPSK we have $d^2_{\text{free}}=10*4E_s=40E_s$.

- For bi-orthogonal coding we have $d^2_{\text{free}}=2*8*3*E_s=48E_s$.

$\Rightarrow$ The bi-orthogonal scheme is better by 0.8dB than the coding scheme of the data section.
Performance in severe multipath

Simulation results: 64bytes packets, 6Mb/s.
Green: errors in rate field. Blue: errors in data.
Peak to Average Power Ratio

The cover sequence assures good PAP ratios for all codewords.

<table>
<thead>
<tr>
<th>Codeword</th>
<th>PAP [dB]</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>3.2 dB</td>
</tr>
<tr>
<td>2</td>
<td>3.7 dB</td>
</tr>
<tr>
<td>3</td>
<td>4.6 dB</td>
</tr>
<tr>
<td>4</td>
<td>3.7 dB</td>
</tr>
<tr>
<td>5</td>
<td>3.2 dB</td>
</tr>
<tr>
<td>6</td>
<td>4.2 dB</td>
</tr>
<tr>
<td>7</td>
<td>4.6 dB</td>
</tr>
<tr>
<td>8</td>
<td>3.7 dB</td>
</tr>
</tbody>
</table>

PAP = 3.2dB… 4.6dB.
Extension to 5 bits

• Due to the proliferation of codes and data rates, (1/3, 9/16 etc.) there is a need to convey more than 4 bits.
• The proposed scheme can be easily extended to support 5 bits.
• Performed by QPSK modulating the $H_8$ row.
• Decoding by complex 8-point FHT.
• Same minimum free distance of $48E_s$. Double number of minimum distance neighbours => Slight degradation in performance.
Conclusions

- A reliable method for transmitting the 4 bits of the rate field.
- Requires no overhead relative to the current scheme.
- Much lower error rate than the data section even in the most reliable mode, both under flat channel and under severe multipath conditions.
- Simple to implement. Uses existing modulation and demodulation mechanisms.
- Requires Fast Hadamard Transform to be implemented.

Simple extension to 5 bits.