Performance of Multiband OFDM In IEEE UWB Channel Models

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Purpose of The Study

- Investigate the performance of multiband-OFDM as a modulation technique for information transmission in the unlicensed band between 3.1 and 10.6 GHz.
Presentation Outline

- Ultrawideband (UWB)
- The multi-band Approach
- Multi-band OFDM Transmitter
- System Parameters
- System Assumptions
- Channel Model
- Uncoded multi-band OFDM System Performance
- Coded multi-band OFDM system Performance
- Future Work
Multiband Approach

- **Group A**: 3.1-4.9 GHz. Assigned for 1st generation devices
- **Group B**: 4.9-6 GHz. Designated for future use
- **Group C**: 6-8.1 GHz. Intended for devices with improved SOP (Simultaneously operating piconets) performance
- **Group D**: 8.1-10.6 GHz. Designated for future use
Pilot Distribution Pattern

- Channel is constant over the whole packet duration.
  A convenient pilot distribution pattern:
Only the first three bands are used i.e. Group A frequencies (3.1-4.9 GHz)
## System Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>fs: sampling frequency</td>
<td>528 MHz</td>
</tr>
<tr>
<td>$N_{DS}$: # of data subcarriers</td>
<td>100</td>
</tr>
<tr>
<td>$N_{PS}$: # of pilot subcarriers</td>
<td>12</td>
</tr>
<tr>
<td>$N_{TS}$: total # of subcarriers used</td>
<td>112</td>
</tr>
<tr>
<td>$\Delta F$: subcarrier frequency spacing</td>
<td>4.125 MHz ($= 528 \text{MHz}/128$)</td>
</tr>
<tr>
<td>$T_{FFT}$: FFT/IFFT period</td>
<td>242.424 ns ($1/4.125 \text{MHz}$)</td>
</tr>
<tr>
<td>$T_{GI}$: guard interval duration (prefix+postfix duration)</td>
<td>60.6 ns ($= 32 \text{ samples}/528 \text{ MHz}$)</td>
</tr>
<tr>
<td>$T_{GT}$: guard time</td>
<td>9.47 ns ($= 5 \text{ samples}/528 \text{ MHz}$)</td>
</tr>
<tr>
<td>$T_{SYM}$: total OFDM symbol duration</td>
<td>312.5 ns ($T_{SYM} = T_{FFT} + T_{GI} + T_{GT}$)</td>
</tr>
</tbody>
</table>

- Channel bit rate = 200 bits/312.5 ns = 640 Mbits/sec or 213.33 Mbits/sec/band
- Packet length = 1024 bytes equivalent to 41 OFDM symbols
System Assumptions

- Perfect time and frequency synchronization are assumed at the receiver.

- The transmitter’s and the receiver’s local oscillators are adjusted to use the same frequency at any time and assumed to be stable so that no phase noise is generated.

- Troubles that result from hardware nonlinearity and distortion caused by antennas are disregarded.

- The cyclic prefix is considered to be long enough so that no ICI and ISI problems are present.
The receiver

- At the receiver, the inverse transmitter’s operations are carried out
- A critical building block in the receiver is the channel estimation block
- Least Square estimation technique was implemented:

\[ H_{\text{LS}} = \frac{Y}{X} \]

Y: the average of received two training symbols
X: the transmitted information in the training symbols
Uncoded System Performance

- Four cases were investigated:
  - Perfect channel estimation without shadowing
  - Perfect channel estimation with 3 dB shadowing factor
  - LS channel estimation without shadowing
  - LS channel estimation with 3 dB shadowing factor
Uncoded System Results

- Perfect channel estimation, no shadowing:

![Graph showing BER vs. SNR for different channel models and QPSK on Rayleigh fading channel.](image)
Comparison of LS and perfect channel estimation in the presence of 3 dB shadowing
Uncoded System Results (cont'd)

- With perfect channel estimation and without shadowing, the system performance is similar to that of a Rayleigh fading channel.

- Including a 3 dB shadowing factor results in 1.5-2 dB shift to the right in the BER curve.

- LS estimation results in 1.5-2 dB worse performance in the BER curve whether shadowing is present or not.
The performance of the coded multiband OFDM system was investigated using:

- BCH codes with random interleaving
- Optimum Distance Spectrum (ODS) convolutional codes with block interleaving (32x24 block interleaver)
- BCH codes with hard decoding
- ODS codes with soft decoding
- Only case of perfect channel estimation and no shadowing
- Only ODS shown here!
ODS Convolutional Codes

- Conv (3,1,7) on CM1, 2, 3, 4

Bit Error Rate

BER of conv. code (3,1,7) with soft decoding, no shadowing and perfect channel estimation

Information Bit Rate $R_b = 273$ Mbits/sec

SNR per information bit
ODS Convolutional Codes (cont'd)

- \text{conv} (2,1) \text{ with different } k \text{ on CM4}

![Graph showing BER for convolution code (2,1) with different constraint lengths on CM4.]

Information Bit Rate \( R_b = 409.6 \text{ Mbits/sec} \)
ODS Convolutional Codes (cont)

- conv. Codes with $k=7$ and different rates on CM4

![Graph showing BER for different convolutional code rates with constraint length 7 on CM4]

- Theoretical BER for uncoded QPSK

- Code rates:
  - $1/2$, $(R_b = 409.6 \text{ Mbits/Sec})$
  - $1/3$, $(R_b = 273 \text{ Mbits/sec})$
  - $1/4$, $(R_b = 204.8 \text{ Mbits/sec})$
Future Work

- Investigating with PSK and QAM with higher constellation size
- Using different channel estimation techniques like MMSE
- Investigating with other FEC codes like Reed Solomon codes and punctured convolutional codes
- Interference from other pico-nets should be taken into account
Conclusions

- Multiband IR might be good for reasonably low rates when interpulse interference can be avoided
  - Should be studied in more detail with channel coding

- Multiband OFDM has great potential on UWB channels
  - Further optimization is needed
Forthcoming event

- Nordic Radio Symposium and Finnish Conf. on Wireless Communications (with PCC workshop) in Oulu August 16-18, 2004
  - 3 tutorials (UWB, MIMO, and Ad-hoc / sensor netw.)
  - 4 plenary speakers (Hagenauer, Fleury, van den Berg, Uusitalo)
  - http://www.cwc.oulu.fi/nrs04/

Sign up soon!
Questions, Remarks, Comments??