Adaptive bit-loading scheme for BICM-OFDM system

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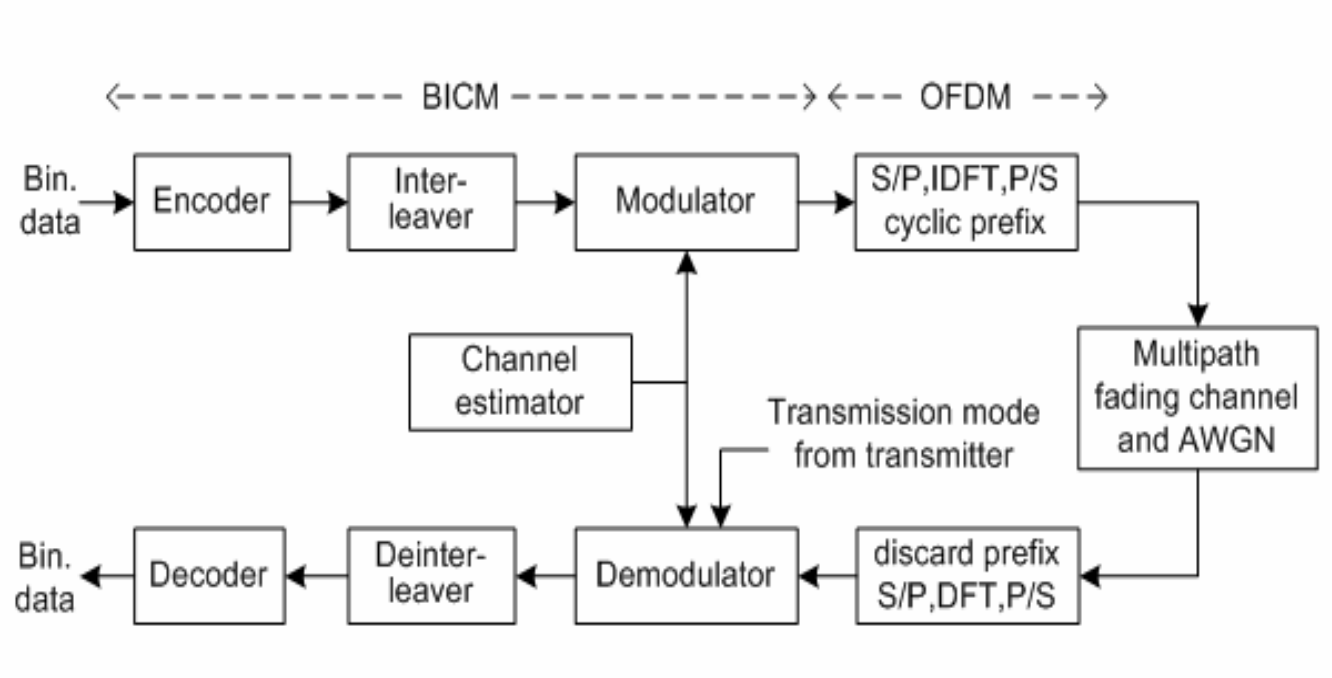
BICM-OFDM system

- Data transmission over wireless channel is limited by several reasons including multipath fading.
- OFDM system overcome ISI caused from multipath fading using large number of subcarrier and guard interval.
- Channel coding is essential for OFDM system to cope with faded subcarriers.
- BICM is suitable for OFDM because of capacity improvement in fading channel using bit-interleaver and simple encoder/decoder

Adaptive transmission for BICM-OFDM

- Adaptive transmission increase bandwidth efficiency by adjusting transmission parameter depending on channel state.
- Adaptive OFDM system adapt modulation or power of each subcarrier under the condition of constant BER or constant throughput.
- We consider constant throughput adaptation and minimize BER bound.
- Code rate and power are fixed for simplification of adaptive algorithm.

Adaptive BICM-OFDM system



Adaptive BICM-OFDM system (2)

- OFDM part of the system is represented by a set of parallel Gaussian channel.

$$y_k = h_k x_k + n_k, \qquad k = 0,1,\ldots,N\text{-}1$$

- We assume that transmitter and receiver know the channel state information (CSI) perfectly.
- Modulator choose modulation level for each subcarrier according to CSI and maps coded bits to QAM symbol using Gray labeling.
- Demodulate produces the bit metric for decoder.

$$\min_{z_k \in \chi_b^i} | y_k - h_k z_k |^2 \qquad \begin{matrix} k = 0,1,\ldots, N-1 \\ i = 1,2,\ldots, m_k \end{matrix}$$

Adaptation algorithm

- Adaptation problem is to minimize BER under the constant throughput.

$$\underset{m_0, m_1, \ldots, m_{N-1}}{Min} \quad BER$$

$$subject\ to \sum_{k=0}^{N-1} m_k = N_{\text{cbps}}$$

m_k : the number of coded bits for subcarrier k

N_{cbps} : total coded bits for OFDM symbol

- Assuming ideal bit interleaving, pairwise error probability of adaptive OFDM-BICM system is obtained by Chernoff bound.

$$f(d,\mu,\chi) \le E_{\underline{x},\underline{S},\underline{U}}[\exp(-\sum_{n=1}^{d} \frac{|h_n^{'}|^2}{4\sigma^2} |x_n - \hat{z}_n|^2)]$$

$$= \left(\frac{1}{N_{cbps}} \sum_{k=0}^{N-1} m_k E_{i,b,x}[\exp(-\frac{|h_k|^2}{4\sigma^2} |x - \hat{z}|^2)] \right)^d$$

Adaptation algorithm (2)

- Using Lagrange optimization, our adaptation problem is replaced by

$$\underset{m_0,m_1,\ldots,m_{N-1}}{Min} \sum_{k=0}^{N-1} H_k - \lambda \sum_{k=0}^{N-1} m_k \quad \Rightarrow \quad \underset{m_k}{Min} \; H_k - \lambda m_k, \quad k = 0,1,\ldots,N-1$$

$$where \quad H_k = m_k E_{i,b,x}[\exp(-\frac{|h|^2}{4\sigma^2}|x-\hat{z}|^2)]$$

- Lagrange multiplier λ is decided to satisfy the give constraint of total coded bits for OFDM symbol.
- Lambda theory used to find λ for discrete resource allocation problem.

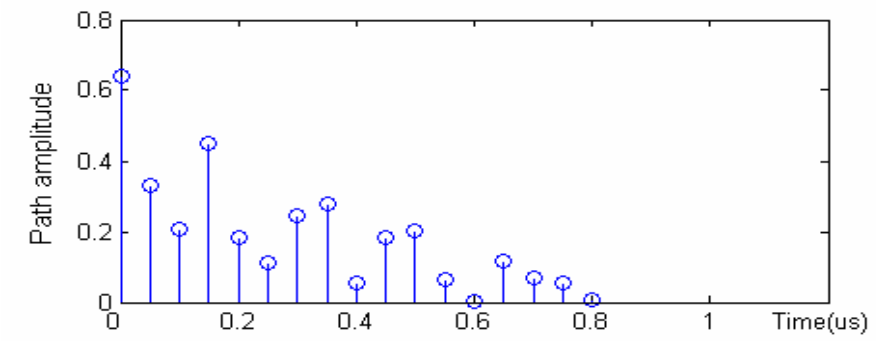
Finding λ using Lambda theory

- Example of finding λ iteratively given $N_{cbps} = 256$

iteration	λ	$\sum_{k=0}^{N-1} m_k$	$\sum_{k=0}^{N-1} H_k$
0	1.000000	336	70.939687
1	0.211130	214	4.676390
2	0.543142	281	29.234550
3	0.366540	242	12.005676
4	0.441766	261	19.545568
5	0.396836	256	17.418943

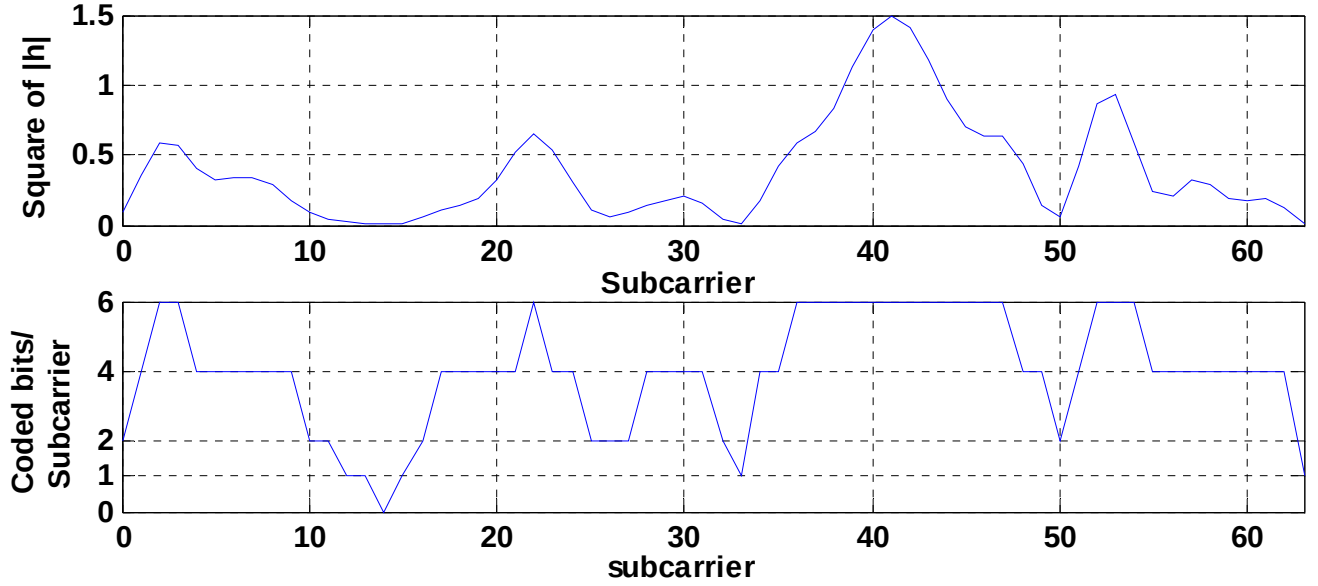
Simulation parameter

- Coded bits per Subcarrier, m = {0,1 2,4,6,8}
- 64 subcarrier, 4.0μs OFDM symbol duration
- Exponentially decaying multipath intensive profile (MIP)
- Delay spread of τ_{rms}= 0.2μs, τ_{max}= 0.8μs
- 64-state rate-1/2,2/3,3/4 convolutional code with generator (133_8,171_8)



Bit allocation result

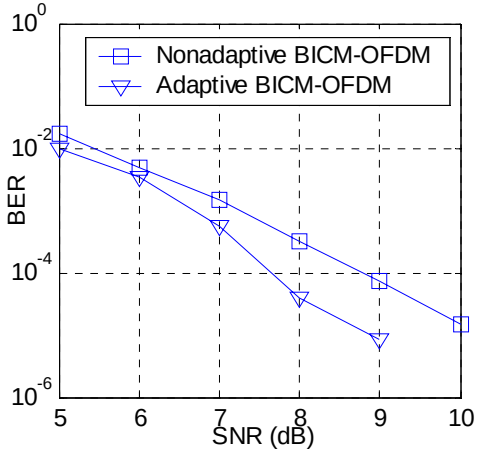
- Bit allocation result when SNR is 18 dB and the number of coded bits per OFDM symbol is 256.



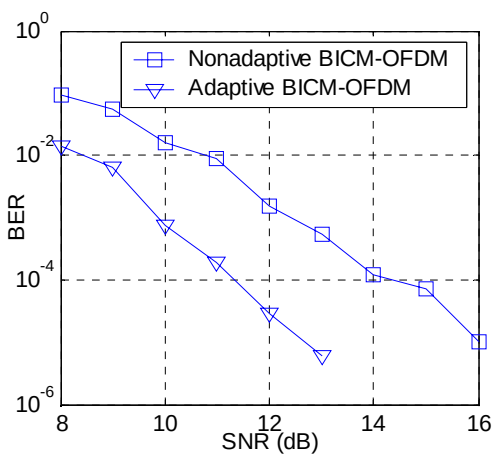
BER result

- Coded bits/OFDM symbol = 128

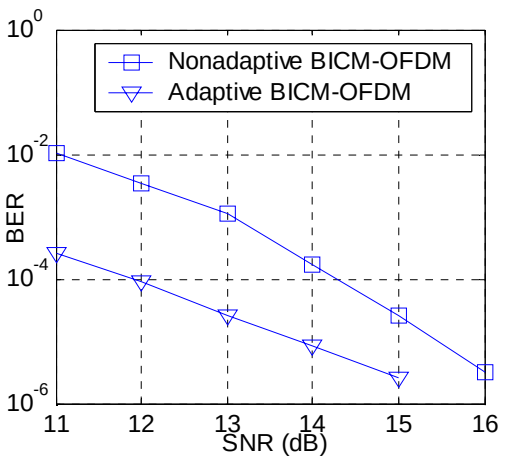
Code rate 1/2



Code rate 2/3



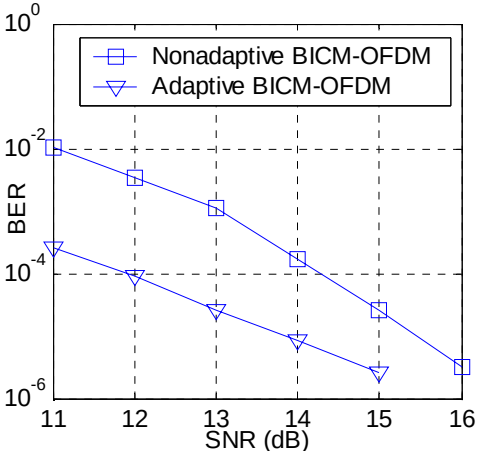
Code rate 3/4



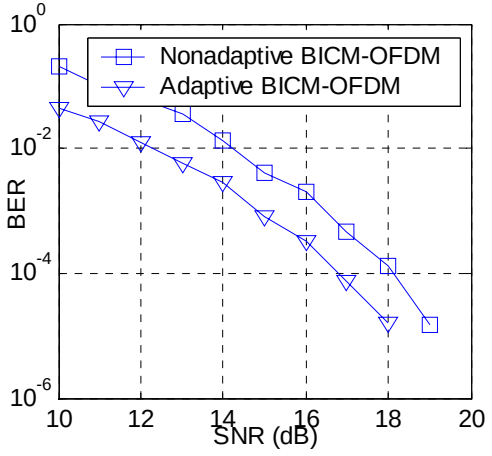
BER result (2)

- Coded bits/OFDM symbol = 256

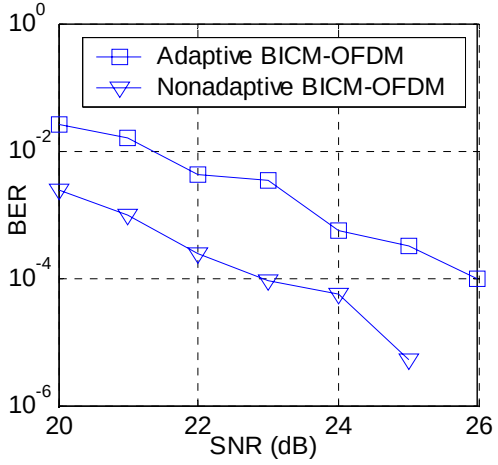
Code rate 1/2



Code rate 2/3



Code rate 3/4



Concluding remarks

- Adaptive bit-loading scheme for BICM-OFDM system was considered.
- BER bound is minimized under the constant throughput.
- Coded bits were allocated to each subcarrier using discrete Lagrange optimization.
- Simulation results show that adaptive BICM-OFDM system got the SNR gain by 2~3 dB over nonadaptive one.