Optimum Pre-DFT Combining with Cyclic Delay Diversity in OFDM Based WLAN Systems

Muhammad Imadur Rahman\textsuperscript{1}, Klaus Witrisal\textsuperscript{2}, Suvra Sekhar Das\textsuperscript{1}, Frank H.P. Fitzek\textsuperscript{1}, Ole Olsen\textsuperscript{1}, Ramjee Prasad\textsuperscript{1}

\textsuperscript{1}WINGlab, Department of Communications Technology Aalborg University, Denmark
\textsuperscript{2}Institute of Telecommunications and Wave Propagation Graz University of Technology, Austria

Contact address: imr@kom.aau.dk; ph: +45 9635 8668
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MRC = Maximum Ratio Combining
EGC = Equal Gain Combining
CDD = Cyclic Delay Diversity
MARC = Maximum Average Ratio Combining
Orthogonal Frequency Division Multiplexing (OFDM) is very effective in mitigating multipath effects of a broadband wireless channel.

OFDM has been successfully used in Wireless Local Area Networks (WLANs).

The IEEE 802.11a WLAN standard specifies channel coding and frequency interleaving to exploit the frequency diversity of the wideband channel.

Efficiency can only be achieved if the channel is sufficiently frequency-selective.

In a flat fading situation (or in relatively lesser frequency-selective fading situation which we often encounter in indoor wireless scenario), all or most subcarriers are attenuated simultaneously leading to long error bursts.
Introduction

1. Introduction
2. Proposed solutions
   - Traditional space-diversity schemes (MRC, EGC, SC) – means more than one DFT module is required, which is costly.
   - Space Time Coding, such as Alamouti scheme, has the same requirement.
   - Delay Diversity schemes (reduced length of CP).
3. Cyclic Delay Diversity (Witrisal et al. 2001)
   - Signal is cyclically shifted – no restrictions for the delay times.
   - Signal processing is performed in time domain – lower computational cost compared conventional diversity schemes.
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Traditional Post-DFT MRC Scheme

- **M** number of receive antennas
- Separate OFDM demodulation and co-phasing on Rx signals
- Important: Knowledge of CSI is required.
- Combining at subcarrier level
- Antenna weight factors are decided based on the instantaneous SC signal power.

**Figure: Post-DFT MRC Receiver Structure**
CDD Transmitter Diversity

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FFT-output:

M transmit antennas  
the number of shift is limited to $N_{SC}$.  
only one DFT module in Rx.  
CSI is not known  
Fixed cyclic delays
Goal

- Post-DFT MRC is highly complex

- Finding a solution that is less complex (cost and power) and simultaneously achieving similar results as the Post-DFT MRC approach

- In this work, we introduce a scheme named Pre-DFT Maximum Average Ratio Combing (Pre-DFT MARC), which is basically application of CDD in an OFDM receiver.
M receive antennas are available.
- CSI estimated to determine delay and gain factor
- optimized $g$ and $\tau$ by using instantaneous SNR averaged over all OFDM SC
- Combining prior to DFT
Simulations

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**Channel Model**
- Second order stochastic channel (WSSUS) model suitable for Rayleigh and Ricean fading distribution.
- Time variability was neglected, since it is assumed that perfect CSI is available.
- Frequency-selectivity is described by Space-Frequency Correlation Function and by the Delay Power Spectrum (DPS).
- In the simulations, realizations of CTFs are generated directly, based on the normalized (or average) received power, the Ricean K-factor and the RMS delay spread.

**Simulation Parameters** (taken based on IEEE 802.11a WLAN standard)
- 64 SC with 48 data SC, 4 pilot SC and 12 null SC, with duration of 3.2µs
- CP length is 16 samples, with duration of 0.8µs
- Complete OFDM symbol duration 4.0µs (= 3.2µs + 0.8µs)
- QPSK symbol mapping with ½ rate convolutional coding and frequency interleaving (i.e. 12 Mbps raw bit rate at the receiver)
- 20 MHz of system bandwidth.
Channel Responses after Combining

Post-DFT MRC shows better channel responses, though Pre-DFT MARC and Pre-DFT EGC is also very close.
Analysis & Discussions (2/5)

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NOTE: On the Ricean channel, the performance with Tx-CDD is even worse, because the combined channel has deeper fades than the component channels.
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Coded FER Rayleigh fading, ½ rate convolutional coding with a constraint length of 5, frequency interleaving

Coded BER Rayleigh fading, ½ rate convolutional coding with a constraint length of 5, frequency interleaving
When number of SC increases, relative processing cost (in terms of number of multiplications required) is drastically reduced for Pre-DFT MARC.
Conclusion

- CDD is a good technique for relatively flat fading channels.

- Optimized combining schemes for antenna diversity were derived, based on cyclic delays and weight factors introduced to the time-domain OFDM signals.

- Though the best performance is achieved using ‘traditional’ receiver diversity based on maximum ratio combining (MRC) at subcarrier level (Post-DFT MRC), simpler and less complex implementation of our innovative diversity schemes may justify the trade-off.

- For Ricean channel a clear advantage is observed for the optimized techniques, since cyclic delay diversity with fixed delays causes combined channels with deeper fades than before diversity combining.
Thank you.

Any questions?
Diversity is required to improve link quality
- Coded OFDM exploits frequency diversity
- Only works well if channel is frequency selective

### Proposed solutions
- Traditional space-diversity schemes (MRC, EGC, SC)
  - means more than one DFT module is required, which is costly.
- STC, such as Alamouti scheme, has the same requirement.
- Delay Diversity schemes (reduced length of CP).

### Cyclic Delay Diversity (Witrisal et al. 2001, Dammann et al. 2001)
- Signal is cyclically shifted – no restrictions for the delay times.
- Signal processing is performed in time domain – lower computational cost compared to STBC and conventional diversity schemes.
When **OFDM symbols/packet** increases, Relative processing cost (in terms of number of multiplications required) is drastically reduced also for Pre-DFT MARC.