Carrier Interferometry for High Speed Wireless Communications

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- Interferometry Code
  - Code construction
  - Performance measures
  - The advantages and disadvantages
- Research directions
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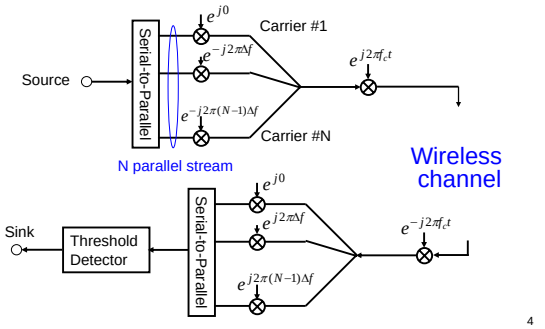
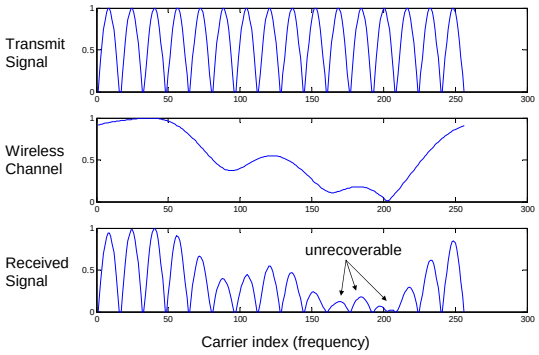
Wireless Communication Systems

- DS-CDMA (Direct Spread Code Division Multiple Access)
  - 3G Mobile Communications
- OFDM (Orthogonal Frequency Division Multiplexing)
  - Wireless LAN
  - Digital Terrestrial Television Broadcasting
- MC-CDMA (Multicarrier CDMA)
  - Beyond 3G Communications systems

OFDM Principles



Wideband Wireless Channel

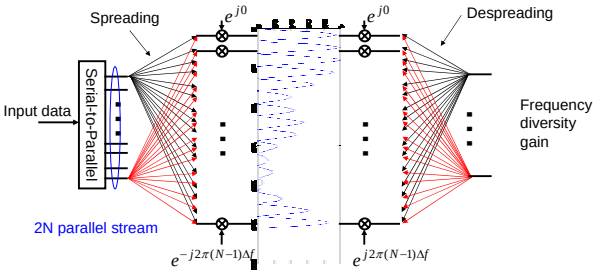


Frequency Diversity

- The symbol at highly attenuated carrier can not be recovered correctly
- Frequency selectivity of the wireless channel can be exploited to gain frequency diversity

Transmitting individual symbol through all carriers
Spread the information symbol over the whole band

PO-CI/OFDM Principles

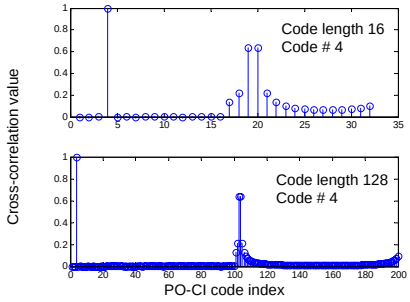


The spreading code is designed so as to eliminate peaks at IFFT output while simultaneously minimize the cross correlation

Cross Correlation Properties

The cross correlation decreases with increasing code length

Reduced co-channel interference



PO-CI Codes Generation

- Emerged from Interferometry Principles
  - Constructively combine wanted multicarrier signals with carefully chosen phase offsets
- Code construction

$$c_k = \{e^{j(\frac{2\pi}{N}k.0+\Delta_\theta.0)}, e^{j(\frac{2\pi}{N}k.1+\Delta_\theta.1)}, e^{j(\frac{2\pi}{N}k.2+\Delta_\theta.2)}, ..., e^{j(\frac{2\pi}{N}k.(N-1)+\Delta_\theta.(N-1))}\}$$

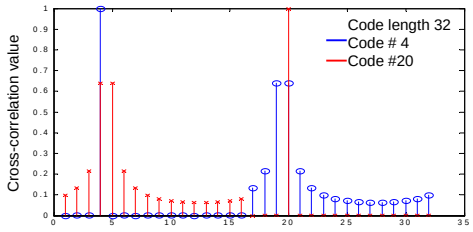
$$\Delta_\theta = \begin{cases} 0, & k = 0,1,...,N-1 \quad orthogonal \\ \pi/N, & k = N, N+1,...,2N-1 \quad pseudo-orthogonal \end{cases}$$

N : Code length (arbitrary) contributes to flexible system design

The codes is distributed on the perimeter of unit circle

Cross Correlation Properties

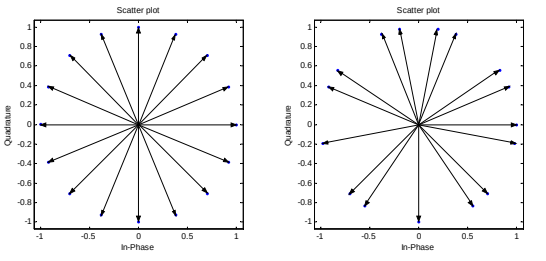
The cross correlation of the 2nd code group is a cyclical sift by the code length, N, of that of the 1st code group



PO-CI Codes : Example

Spreading code length 16

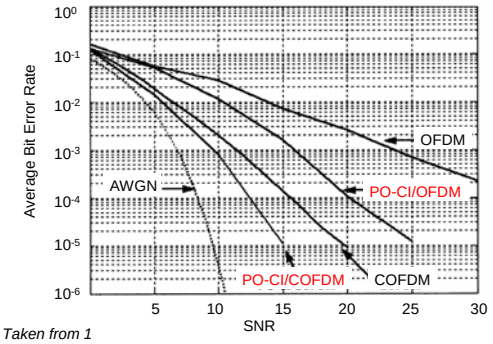
Number of spreading code 16



Constellation of code #4

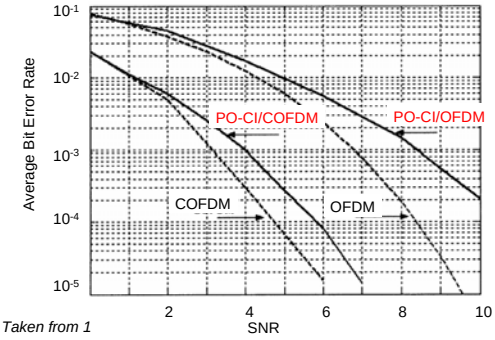
Constellation of code #(4+16)

Performance in Frequency Selective Fading Channel



Taken from 1

Performance in AWGN (Flat Fading) Channel



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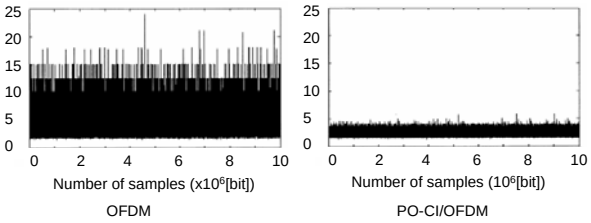
Instantaneous PAPR Values

PAPR: Peak to Average Power Ratio
Indicates how efficient the modulation technique can utilize the amplifier
The lower the better



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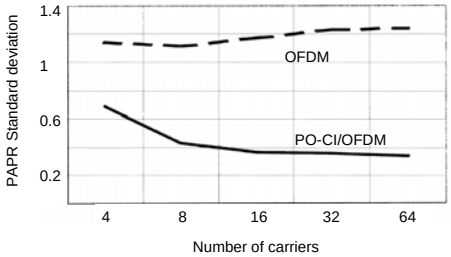
PAPR vs. Number of Carriers

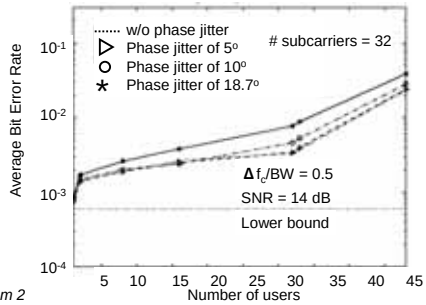
PAPR standard deviation:
OFDM : increases with increasing number of carrier
PO-CI/OFDM : decreases with increasing number of carrier



Taken from 1

Effect of Phase Jitter

PO-CI/OFDM performance is affected by the phase jitter
Low phase jitter (<5°) is desirable



Taken from 2

PO-CI/OFDM Characteristics

- Advantages
  - Double the system capacity/speed by exploiting the frequency diversity
  - Low Peak to Average Power (PAPR)
  - Multiple access provision (Code Division Multiplexing)
  - Arbitrary code length, i.e., number of carriers
- Disadvantages
  - Susceptibility to phase jitter
  - The performance gain diminish with diminishing frequency diversity

Investigation on Phase Jitter Effect

- The longer the codes the closer their constellation
  - ➡ Increased susceptibility towards phase jitter
- Need to quantify how much CI/OFDM can withstand phase jitter by increasing the number of carriers (code length)
- Devise sophisticated phase jitter compensation technique so as to guarantee the performance

Investigation on Transmit Diversity Effect

- Channel frequency selectivity is a natural phenomenon which is time and location dependent
- Channel delay profile determines frequency selectivity
- CI/OFDM exhibit performance loss in the absent of the wireless channel frequency selectivity
- Deliberately introduce frequency selectivity. via transmit diversity.

  ➡ To ensure that CI/OFDM can exploit the frequency diversity

Reference

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5. H. Sari et al, "Extending the capacity of multiple access channels", IEEE Commun. Mag. vol.38, pp.74-82, Jan. 2000
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Advanced Detection Techniques

- A consequence of code division multiplexing is multiuser interference (MUI)
- Optimum Maximum Likelihood Sequence Detection (MLSD)
  - Gives the best BER (Bit Error Rate) performance
  - High complexity
- MMSE Multiuser Detection
  - Suboptimum performance
  - Reasonable complexity

Conclusion

- The concept of Pseudo Orthogonal Carrier Interferometry (PO-CI)/OFDM is presented
- PO-CI/OFDM
  - Increase spectral efficiency by exploiting frequency diversity
  - Decrease PAPR value by ingenious code design
  - Multiple access provision via spreading code assignment
- Several research directions towards the implementation are introduced