OFDM for 5 GHz

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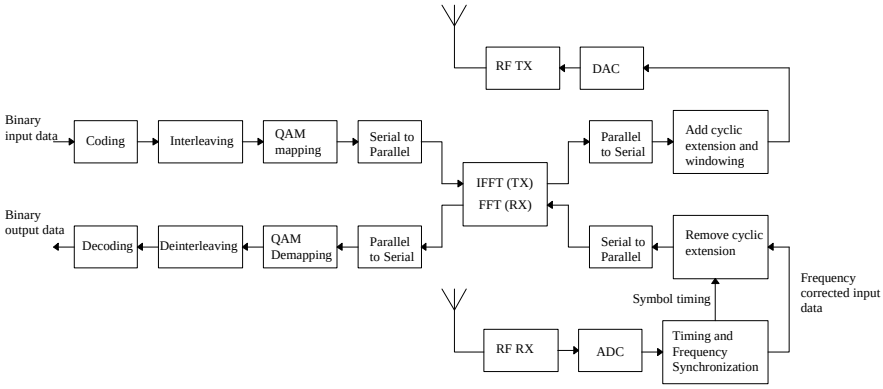
Introduction

OFDM can achieve large delay spread tolerance at high bit rates by:

- Converting single bit stream in *N* parallel bit streams
  - Symbol duration is increased, so relative delay spread decreases
  - Each parallel bit stream is modulated on one of *N subcarriers*
- Adding a guard time to each OFDM symbol
  - Intersymbol interference is avoided
  - Guard loss is made small (<1 dB) by choosing *N* large enough
  - Simple and effective way to deal with multipath; avoids need for equalizer and equalizer training, which may take too much training overhead
- Use coding to correct for subcarriers in deep fades
  - In a multipath channel, subcarriers have different amplitudes
  - By using coding, performance is determined by average received power rather than lowest subcarrier power

OFDM Transceiver

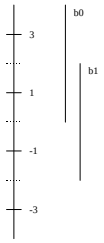


OFDM Signal Processing

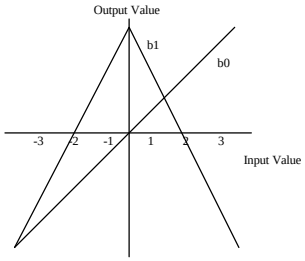
- FFT / IFFT : 64 point FFT in 4.8 μs = 53 M real multiplications per second : comparable to load of existing Digital Video Broadcasting chips, which do 8192 point FFT in 1 ms (100 M multiplications per second).
- Decoding : Standard code, soft decision decoding chips already exist for speeds up to 60 Mbps. A binary code is used; QPSK and 16-QAM formed by 2 or 4 binary values, respectively.
- Synchronization: Can be done similar to synchronization of a direct-sequence spread-spectrum receiver, see later slide.

QAM Mapping

- Modulation options are QPSK, 16-QAM (possibly 64-QAM)
- Same binary coder / decoder is used for all modulations
- Use Gray mapping to map 4 binary inputs to 16-QAM
- In receiver, 16-QAM symbol is split into 4 binary metrics, which are the inputs for the soft decision Viterbi decoder (see IEEE Trans. on Comm., vol. 43, no.6, June 1995, pp. 2001-2004, 'Coded QAM Using a Binary Convolutional Code', by Q. Wang and L. Onotera.)

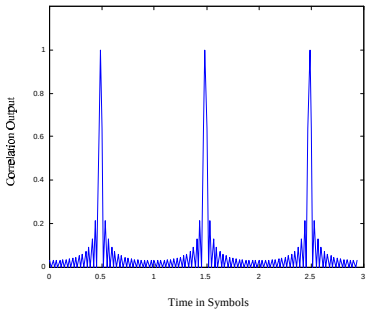


Mapping 2 bits onto 4-PAM metrics

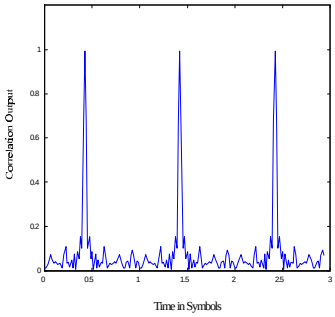


Demapping 4-PAM into 2

Timing and Frequency Synchronization



Correlation function of OFDM signal



Correlation function with {0,1,-1} taps

- Correlate with a known OFDM training symbol before doing FFT, so OFDM symbol is used in same way as the Barker code in a 802.11 direct-sequence system
- Use peak to determine timing, phase shift between peaks gives frequency offset
- Simple correlator with {0,1,-1} tap values can be used

Fallback Rates

- In single carrier systems, equalizer breaks down when delay spread gets too large because of error propagation in equalizer.
- Hence, fallback rates not possible, which is very undesirable for a practical system; users which experience more than 100 ns delay spread get no connection !
- In OFDM, 30 Mbps up to 175 ns delay spread,
  20 Mbps up to 225 ns
  10 Mbps up to 500 ns
- So OFDM does provide a reliable connection for all users, even if they cannot send at the highest rate because of a bad channel

Complexity

- Key difference between OFDM and single carrier proposals is FFT versus equalizer
- FFT complexity = 64 complex multiplications per 4.8 μs = = 53 million real multiplications per second
- 16 taps Equalizer at 25 MHz means 2*16*25 = = 800 million real multiplications per second
- OFDM order of magnitude less complex!
- Fast equalizer training is more complex than equalizer itself, so real complexity difference is even larger

Summary

Main advantages of OFDM over single carrier are:

- Less complex
- Can tolerate higher delay spreads, especially in fallback modes, which are not possible for single carrier
- More channels, better total capacity