Modulation and Equalization Criteria for 2-11 GHz Broadband Wireless Systems

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Purpose:

Among the key characteristics of any 802.16.3 air interface standard are modulation and equalization. This document provides guidance and background on these topics for the evaluation of 802.16.3 PHY proposals.

MODULATION AND EQUALIZATION CRITERIA FOR 2-11 GHZ FIXED BROADBAND WIRELESS SYSTEMS

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Background

- 2-11 GHz systems may operate on NLOS conditions, in which severe multipath is encountered. Multipath delay spread is a major transmission problem, which affects the design of modulation and equalization.

- Delay spread varies with environment and characteristics of transmit and receive antennas. In typical MMDS operating conditions, avg. delay spread ~ 0.5 μs, but 2% of measured delay spreads > approx. 8-10 μs [Porter & Thweat].

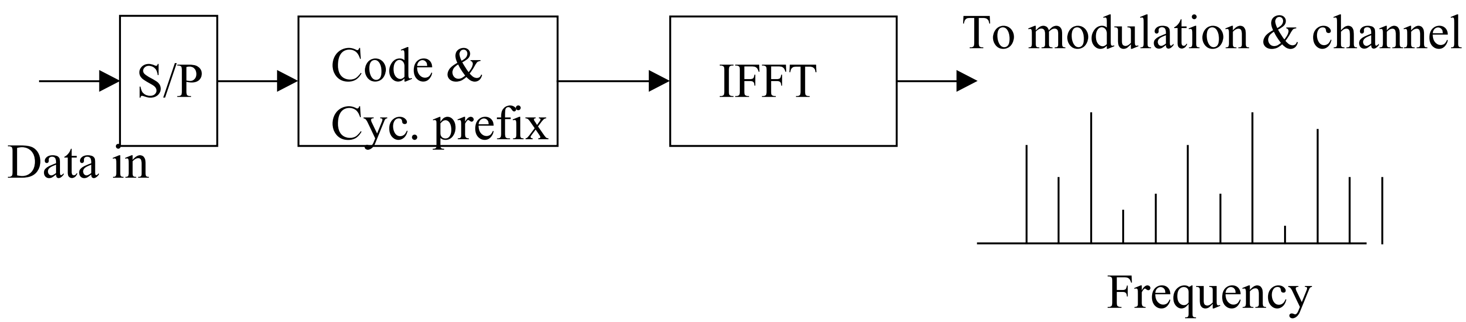
- Corresponding intersymbol interference @ 10 Megasymbols/s could span up to about 80-100 symbols.

Anti-Multipath Alternative Approaches

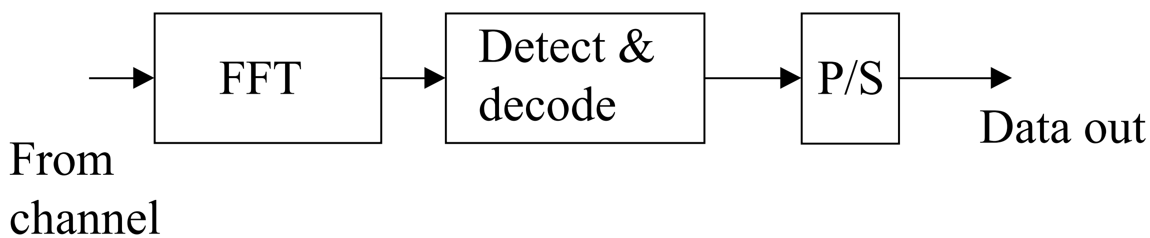
- Restrict MMDS deployment to situations where delay spread is small, requiring no equalization, or very simple equalization.
- OFDM (Orthogonal frequency division multiplexing).
- Single carrier modulation, with receiver decision feedback equalization (DFE) in time domain.
- Single carrier modulation, with receiver decision feedback equalization (DFE) in frequency domain.

OFDM

Transmitter:



Receiver:

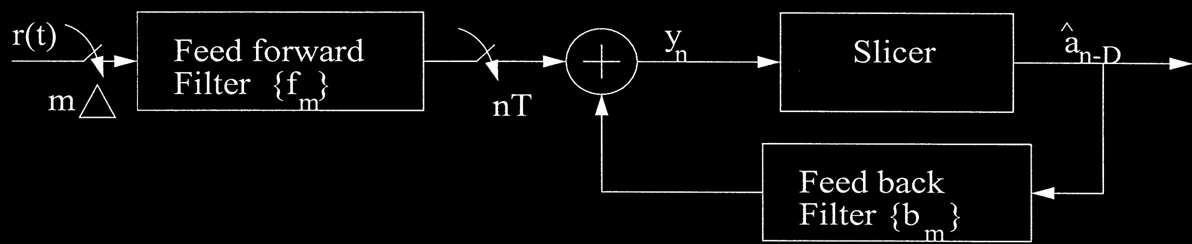


Process M-symbol blocks, with complexity ~ _ M log M (M typically about 5 to 10 times the max. expected delay spread).

Nonadaptive OFDM has same bit rate on each subcarrier.

Adaptive OFDM optimizes bit rate on each subcarrier.

A quick tour of DFE



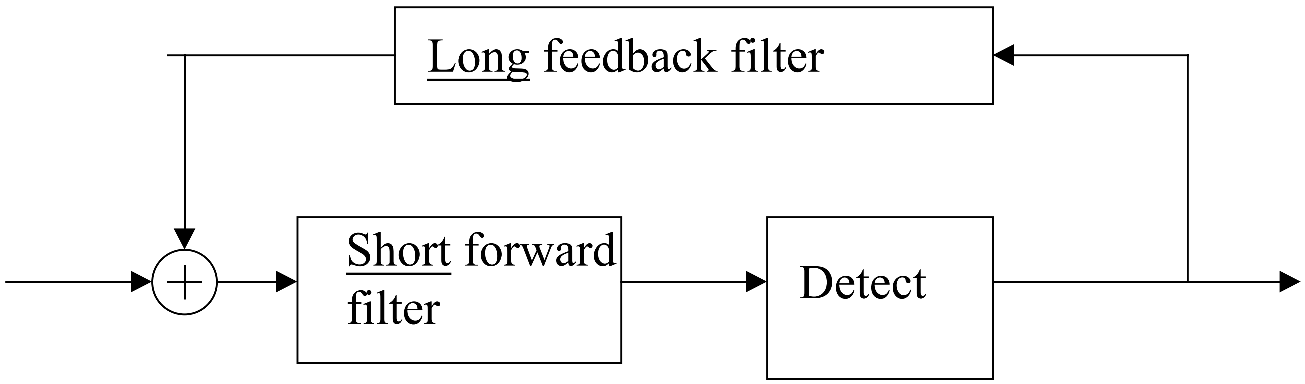
(Block Diagram)

- Decodes the channel out put on a symbol by symbol basis and uses past decisions to remove the post cursor ISI for better performance.
- Basic Equations involved:

Transmitted Signal: $s(t) = \sum_n a_n g(t - nT)$

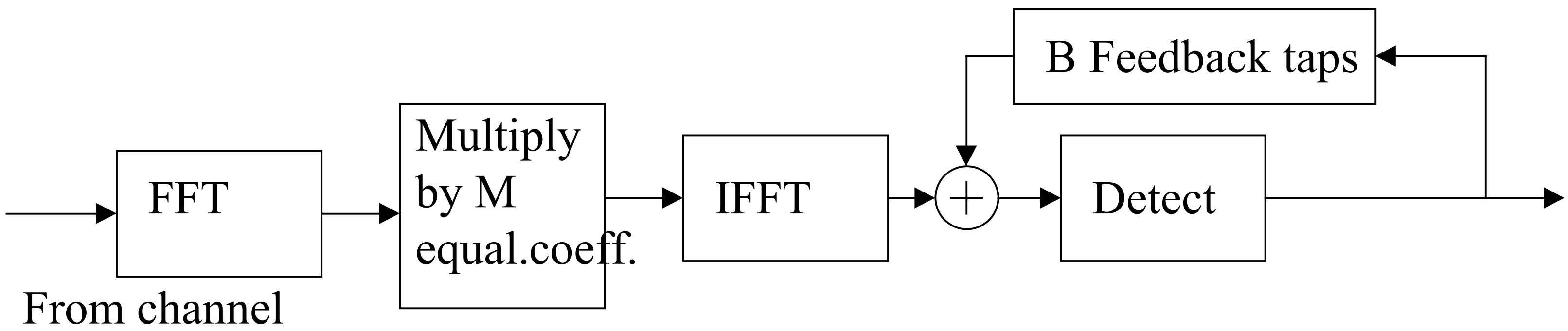
Received Signal: $z(t) = \sum_n a_n x(t - nT) + \eta(t)$ where $x(t) = g(t) \otimes h(t)$

Single-Carrier DFE Simplification: Time Domain DFE [Ariyavisitakul & Greenstein]



Feedback filter length ~ max. expected delay spread. Feedback multiplies are binary.
Short forward filter's job is to eliminate precursor ISI.
Example: 5 forward taps, 60 feedback taps for delay spread of 60 symbols.

Single-Carrier DFE Simplification: Frequency Domain DFE



Process M-symbol blocks

Total complexity ~ M log M +M + BM

Comparisons

	Non-adaptive OFDM	Adaptive OFDM	Low-complexity SC –time domain DFE	Freq. Domain DFE
Nonlin. sensitivity	X	X	✓	✓
Freq. Sensitivity	X	X	✓	✓
Coding optional	X	✓	✓	✓
Optimum performance in freq. sel. fading	X	✓	✓	✓
Training overhead	X	X	✓	X
Delay	X	X	✓	_
Est. relative complexity	1	~1.3	TBD(1)	1.5-2.0(2)

(1) Moderate, but depends on channel response.

(2) Closer to 1.5 for short feedback filter.

Summary and Conclusions

- For moderate multipath, single carrier modulation and DFE gives best performance/complexity tradeoff
- For severe multipath, consider single carrier QAM with simplified time-domain or frequency-domain DFE, as well as OFDM.
- OFDM is more sensitive to transmitter nonlinearity and frequency instability than comparable single-carrier approaches.
- All the considered equalizer techniques can be combined with spatial arrays at transmitter and/or receiver.