

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

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**David Falconer
Carleton University
Dept. of Systems and Computer Engineering
Ottawa, Ont. Canada K1S 5B6**

**Voice: (613) 520-5722
Fax: (613) 520-5727
E-mail: ddf@sce.carleton.ca**

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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.

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

D. Falconer, Carleton University, Ottawa, Ont.

S.L Ariyavisitakul, Home Wireless Networks, Norcross,
Ga.

ddf@sce.carleton.ca

Background

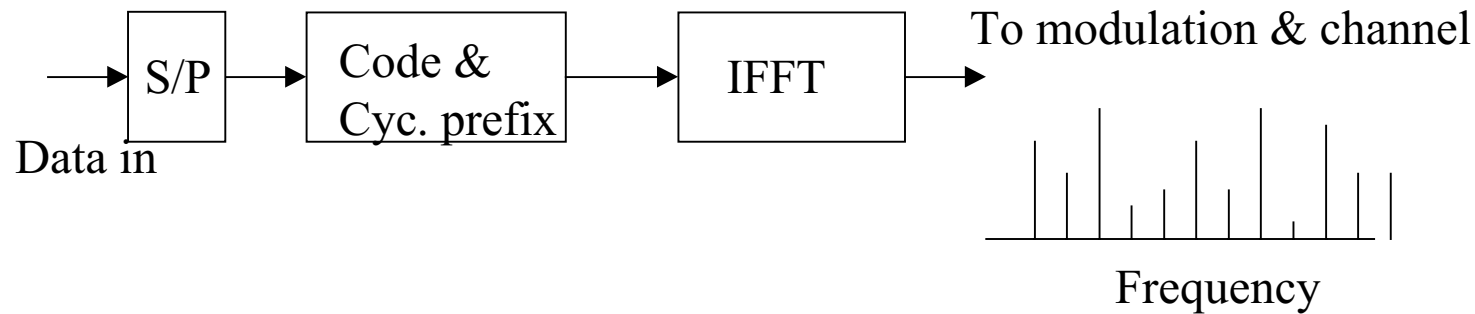
- 2-11 GHz systems may operate on NLOS conditions, in which severe multipath is encountered. Multipath delay spread is a major transmission problem, which affects the design of modulation and equalization.
- Delay spread varies with environment and characteristics of transmit and receive antennas. In typical MMDS operating conditions, avg. delay spread $\sim 0.5 \mu\text{s}$, 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

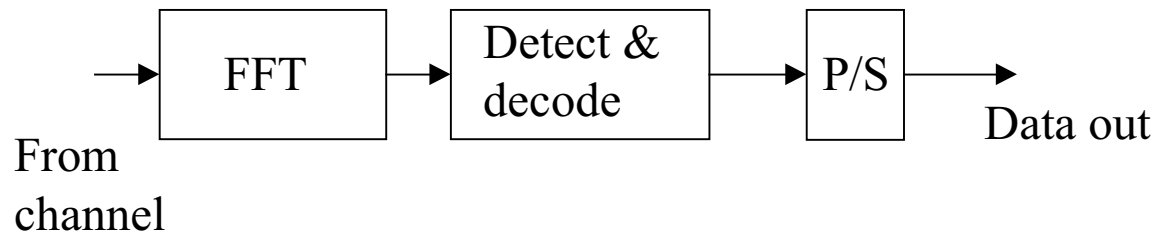
- Restrict MMDS deployment to situations where delay spread is small, requiring no equalization, or very simple equalization.
- OFDM (Orthogonal frequency division multiplexing).
- Single carrier modulation, with receiver decision feedback equalization (DFE) in time domain.
- Single carrier modulation,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

OFDM

Transmitter:



Receiver:

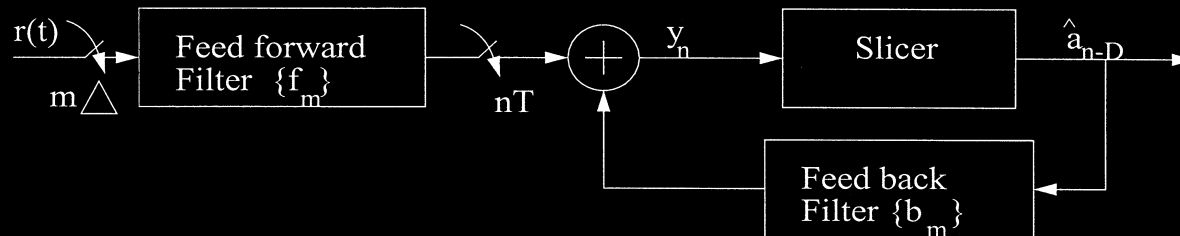


Process M -symbol blocks, with complexity $\sim M \log M$ (M typically about 5 to 10 times the max. expected delay spread).

Nonadaptive OFDM has same bit rate on each subcarrier.

Adaptive OFDM optimizes bit rate on each subcarrier.

A quick tour of DFE



(Block Diagram)

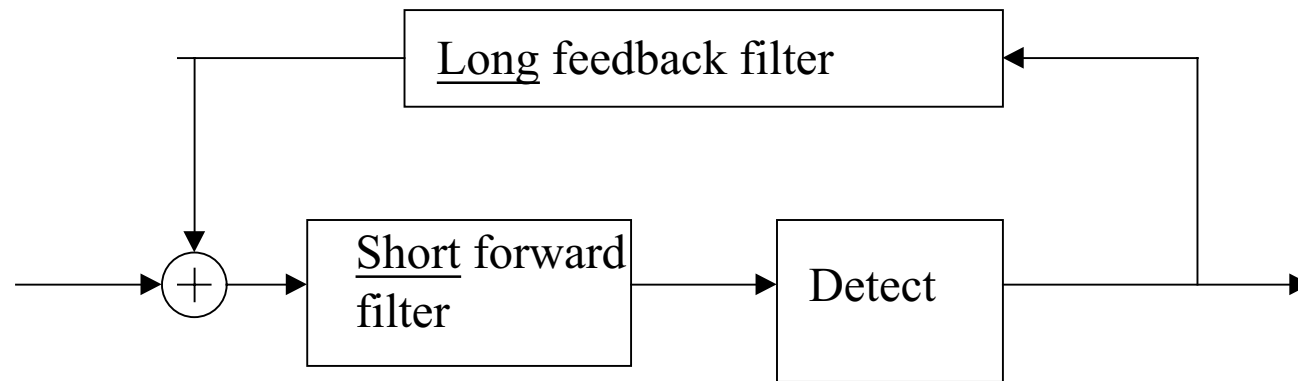
- Decodes the channel output on a symbol by symbol basis and uses past decisions to remove the post cursor ISI for better performance.

- Basic Equations involved:

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

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

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

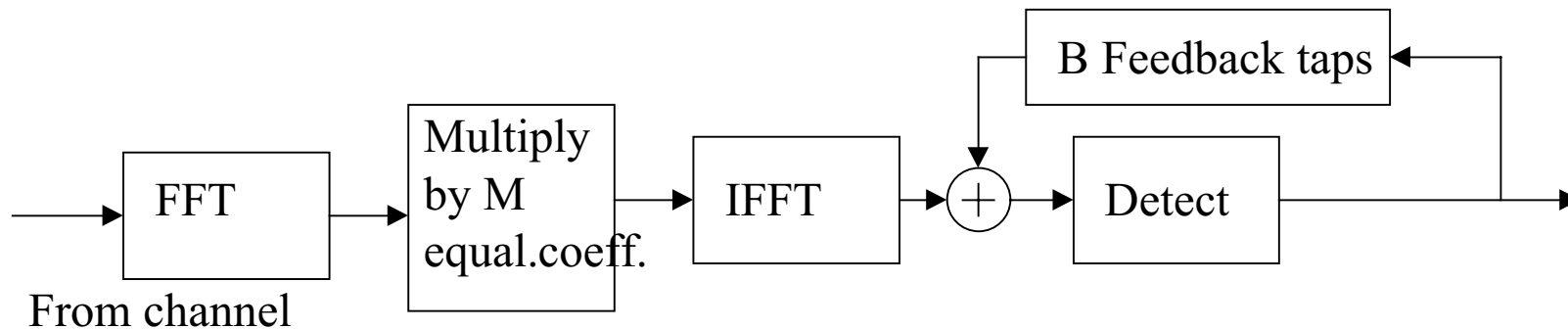


Feedback filter length \sim max. expected delay spread. Feedback multipliers are binary.

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 $\sim M \log M + M + BM$

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.