Pilot Symbol Based Detection and Synchronization for OFDM WLANs

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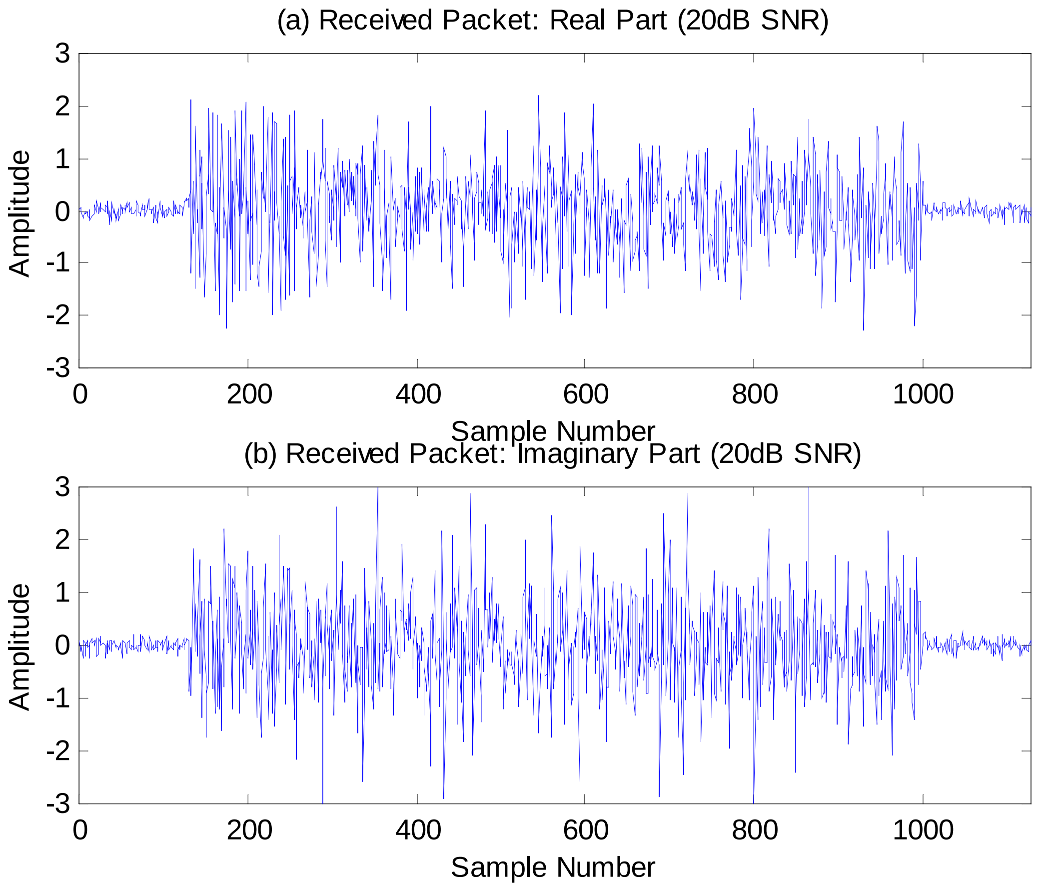
Introduction

- Detection and synchronization: problem definitions
- Pilot symbol assisted reception
- Correlation-based algorithms: descriptions
- Detection and synchronization: performance results
- Bit error rate performance: comparison of ideal, analytical and simulation results

The Detection Problem



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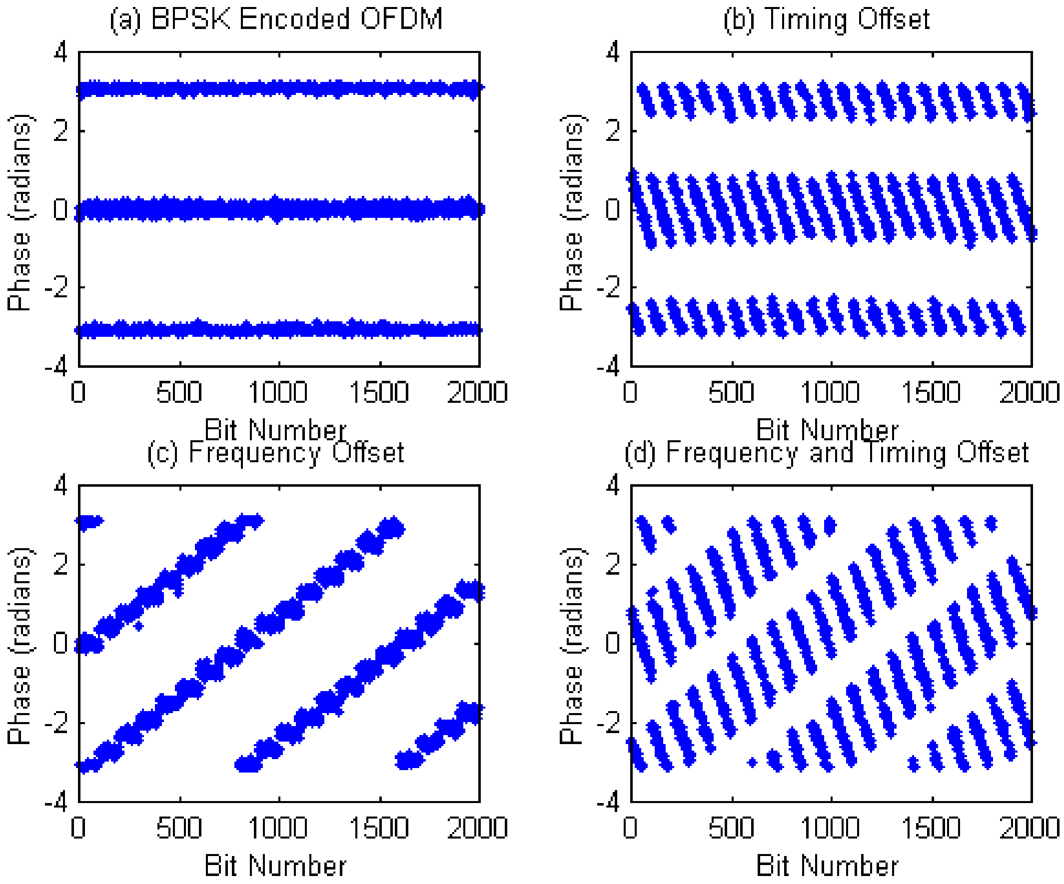
The Synchronization Problem



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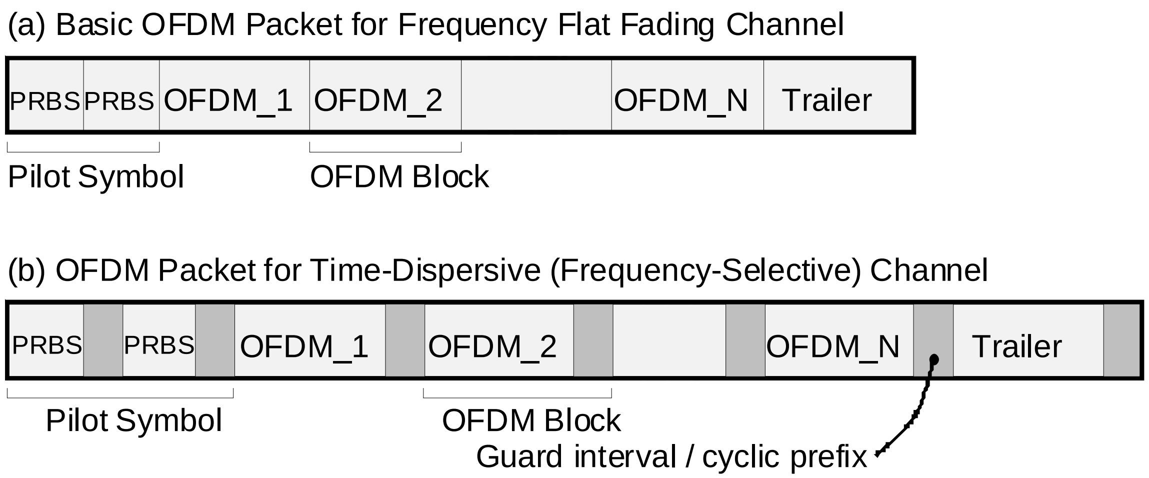
The Tools

1. Pilot Symbol



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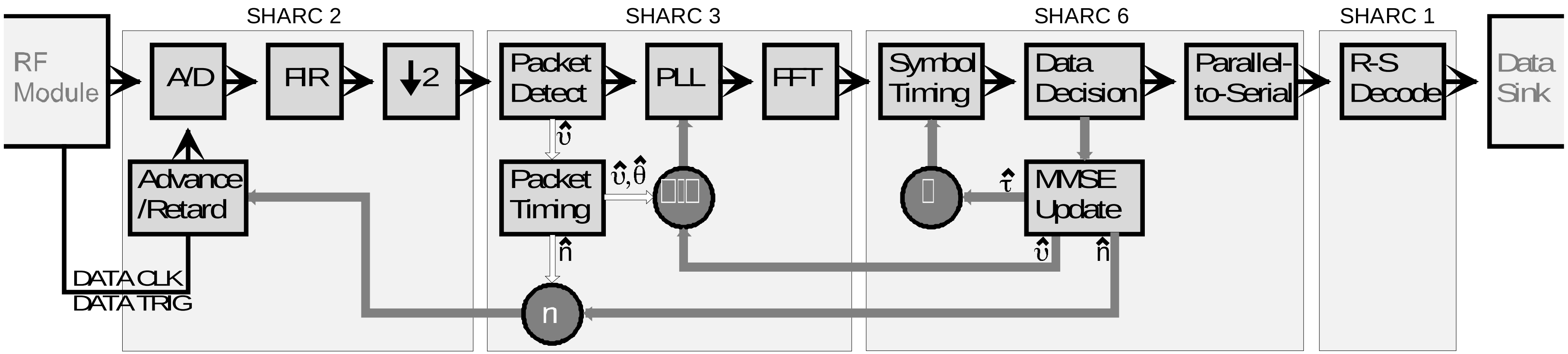
The Tools

2. OFDM Receiver Architecture



Received Signal: $r^{\delta}(t)=\sum_{n} r(t)\exp(j[2\pi\upsilon t+\theta])\,\delta(t-nT-\tau)$

The Algorithms (1)

Received sampled signal (flat fading), *n*th sample

$$r_n = as\left(nT - \tau_S\right)e^{-j\left[2\pi\nu\left(nT-\tau_S\right)+\theta\right]} + \eta\left(nT\right)$$

L length, L lag sliding window correlation product

$$P_l = \mathbf{r}_l{}^H \mathbf{r}_{l+L}$$
$$\approx \left(L - \left|l\right|\right)a^2 S^2 e^{-j2\pi\nu LT} + \eta$$

L length, 0 lag sliding window correlation product

$$R_l = \mathbf{r}_l{}^H \mathbf{r}_l$$
$$\approx L\left(a^2 S^2 + 2\sigma_w{}^2\right) + \mathrm{Re}\left\{\eta\right\}$$

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The Algorithms (2)

Detection variable 1 (positive means detection)

$$X_l = |P_l| - T_{C1}\sqrt{R_l R_{l+L}}$$

Frequency offset estimate

$$\hat{\nu} = \frac{1}{2\pi LT}\operatorname{atan}\left(\frac{\operatorname{Im}\{P_l\}}{\operatorname{Re}\{P_l\}}\right)$$

L length matched filter correlation product

$$Q_l = \mathbf{n}^H \mathbf{r}_l$$

$$\approx LaS^2 \operatorname{sinc}\left(l - \frac{\tau_S}{T}\right) e^{-j\left[2\pi\nu(lT - \tau_S) + \theta + \phi\frac{L-1}{2L}\right]} + \sqrt{L}S\eta$$

The Algorithms (3)

Detection variable 2 (positive means detection)

$$Y_l = \left|Q_l + Q_{l+1}\right| - T_{C2}\sqrt{L}S\sqrt{R_l}$$

Phase offset estimate

$$\hat{\theta} = \operatorname{atan}\left(\frac{\operatorname{Im}\{Q_l\}}{\operatorname{Re}\{Q_l\}}\right)$$

Timing offset estimate:

MMSE fit to phase of frequency domain data

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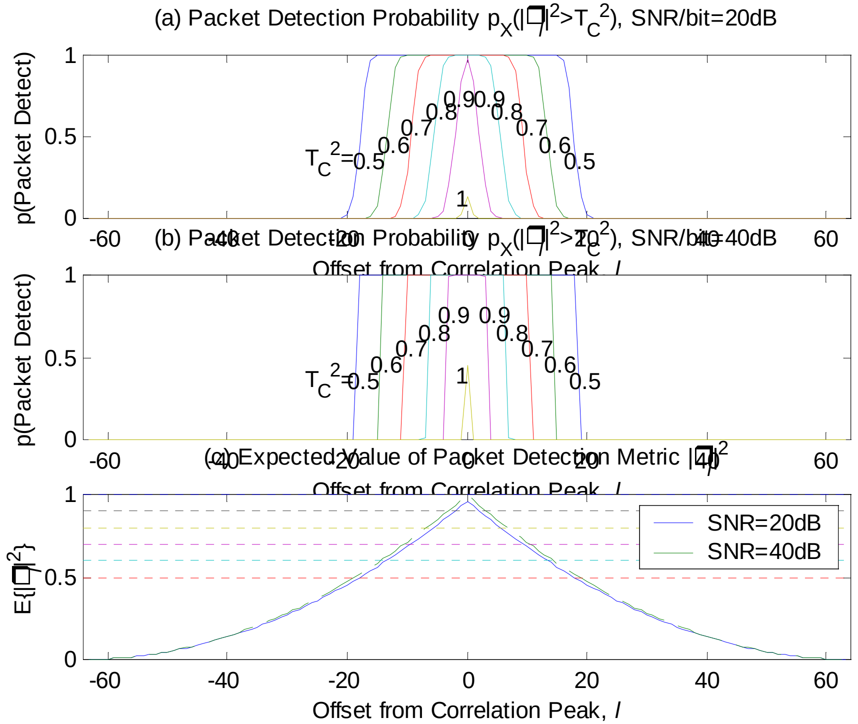
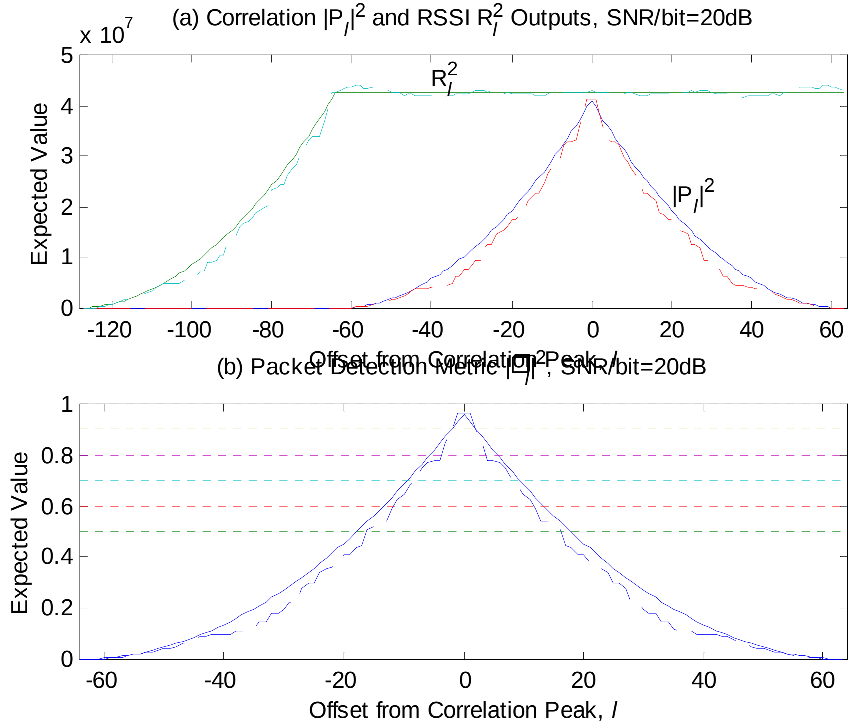
Results: Detection 1

1. Detection statistics



2. Experimental comparison



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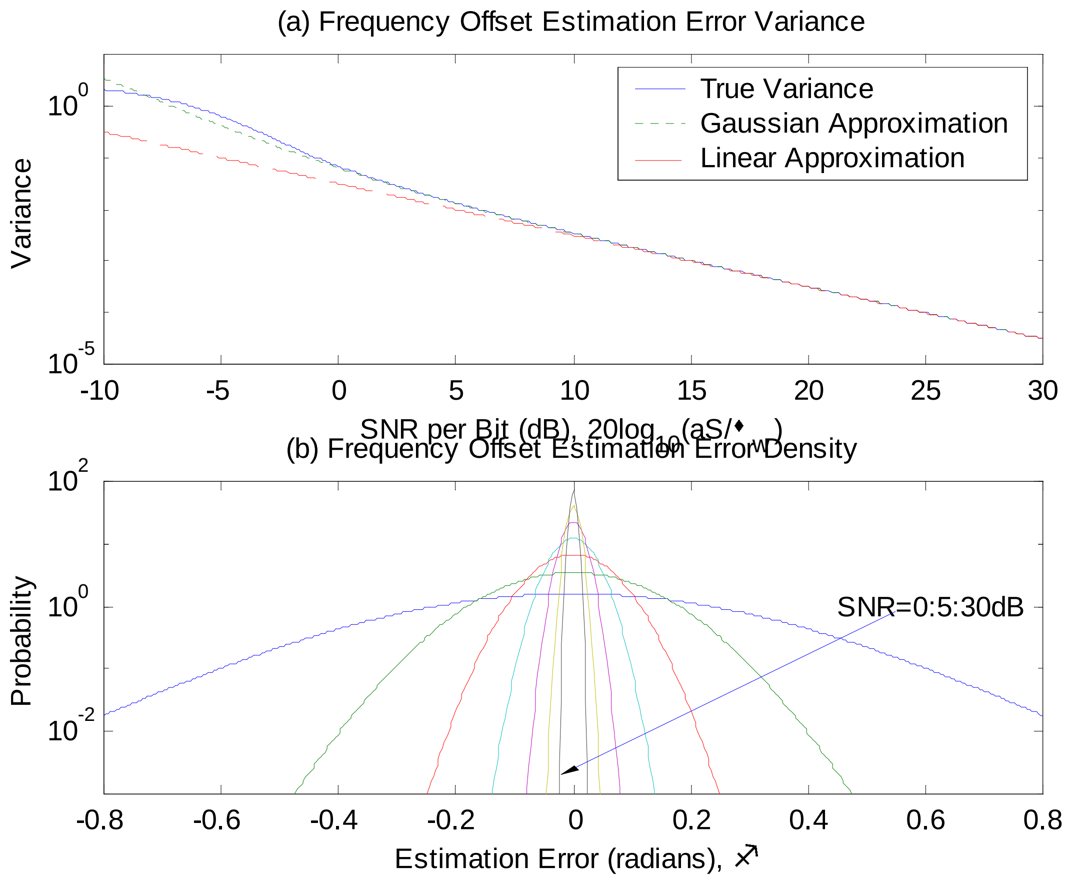
Results: Frequency Offset Estimation



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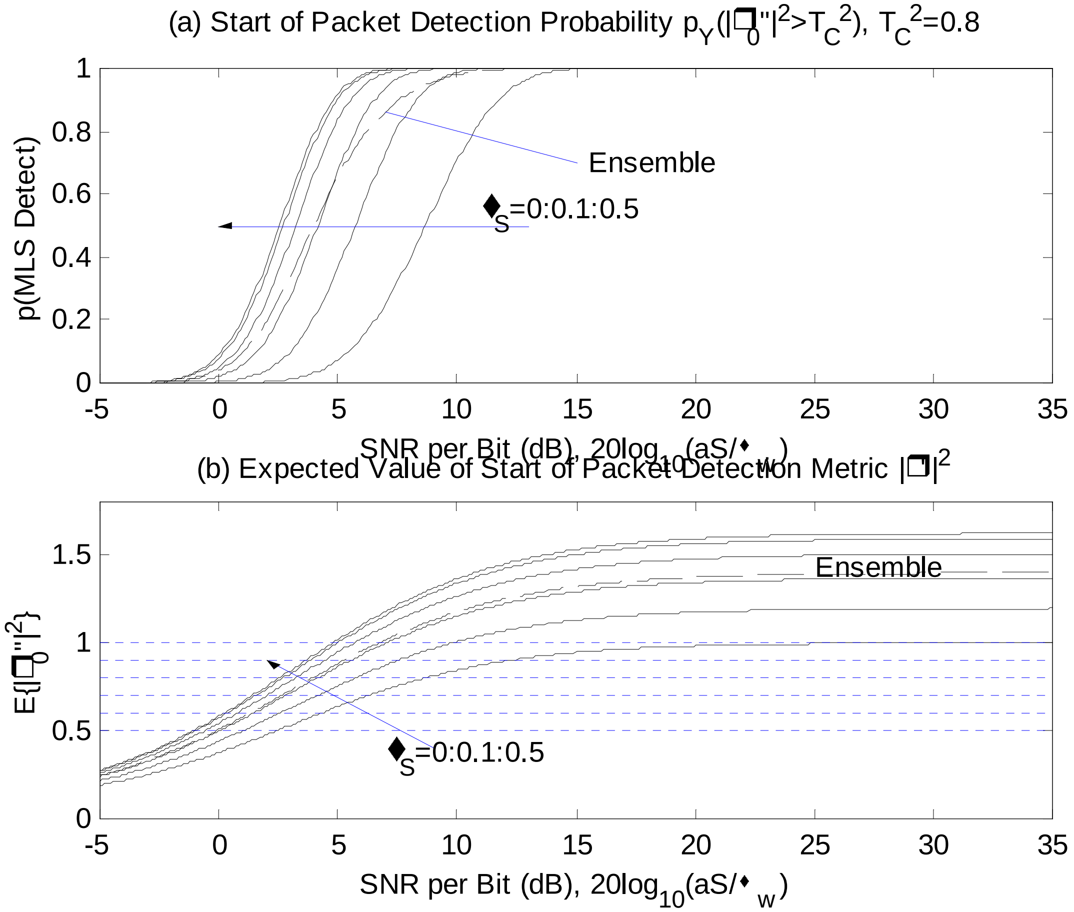
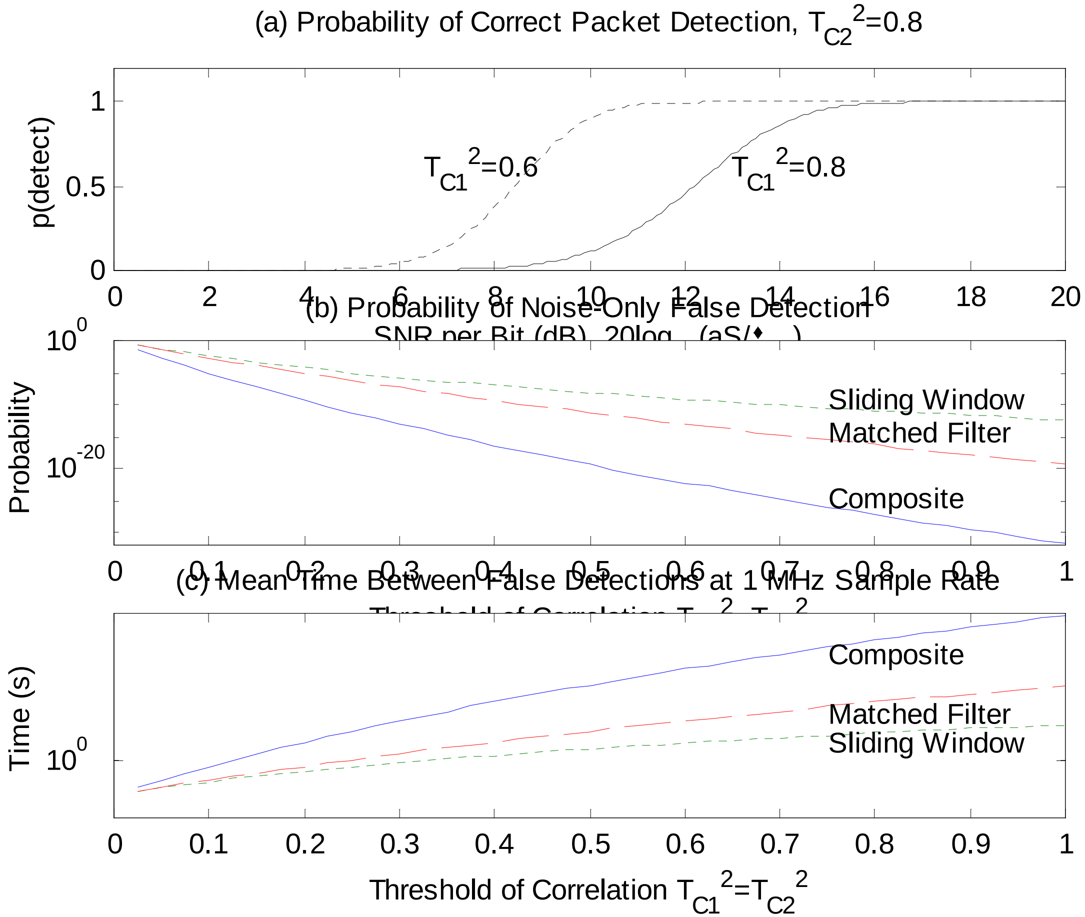
Results: Detection 2



Results: Composite Detection



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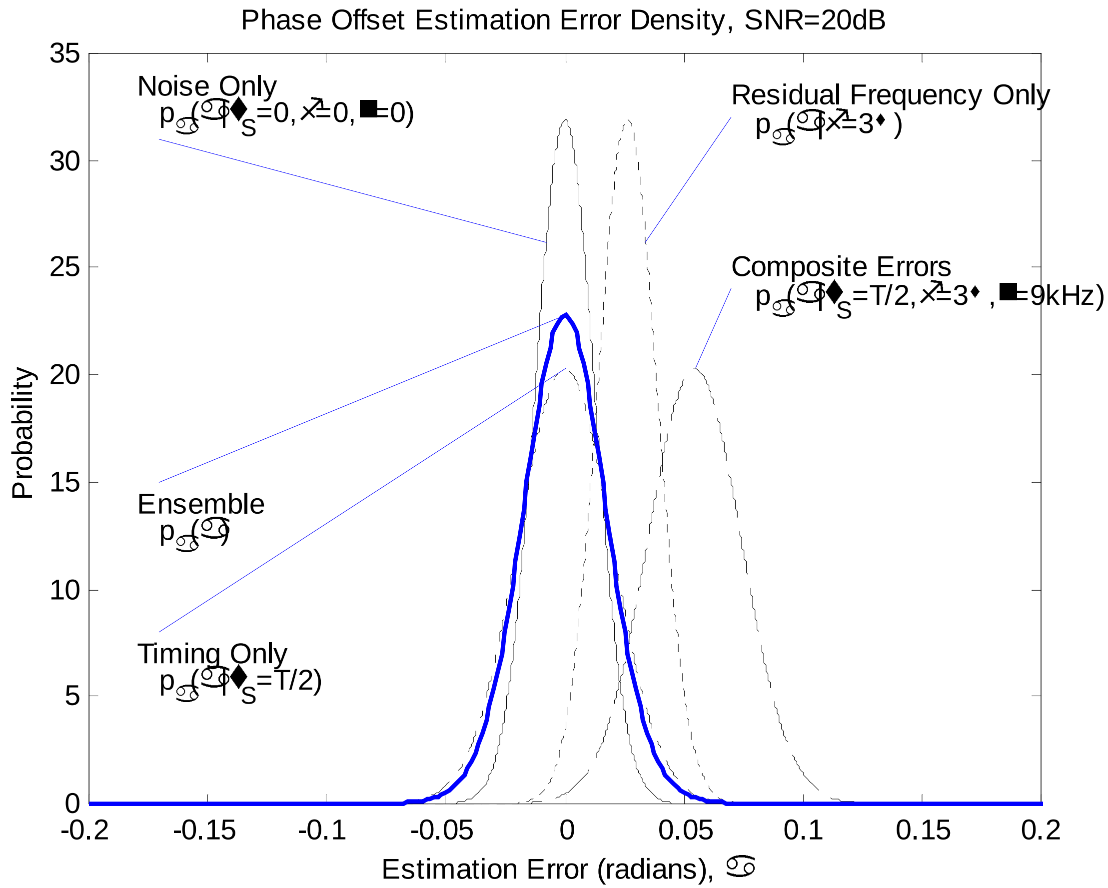
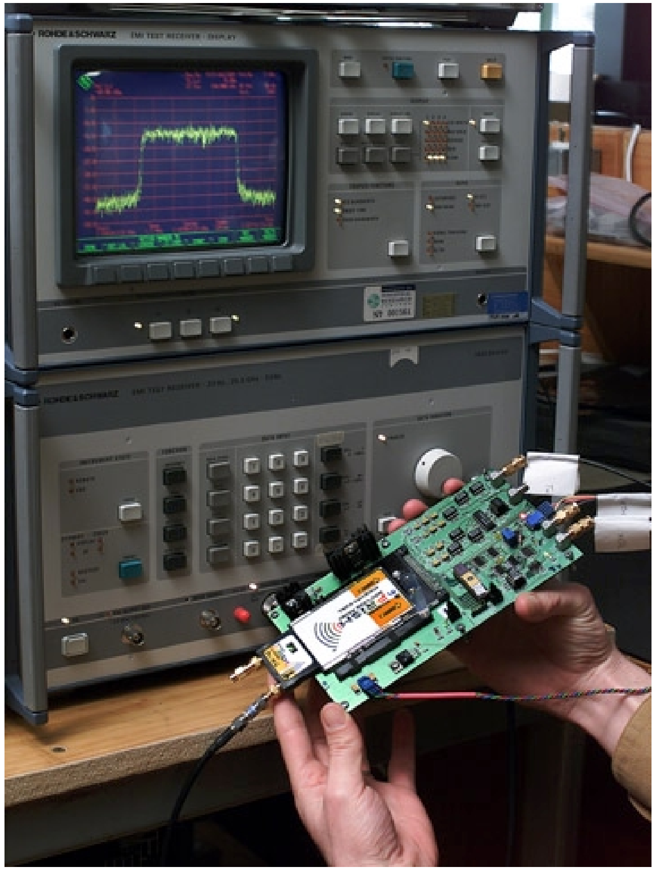
Results: Phase Offset Estimation



Demonstration System



OFDM Tx spectrum

Prototype set-up

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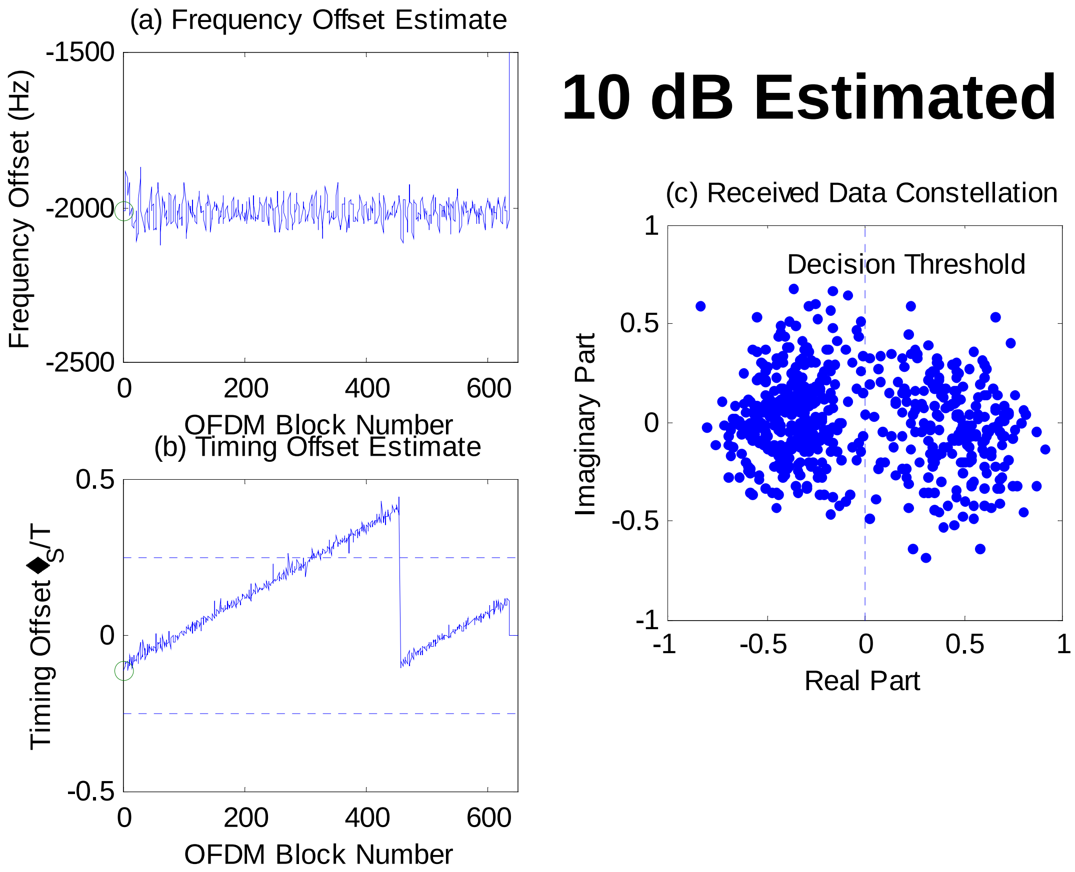
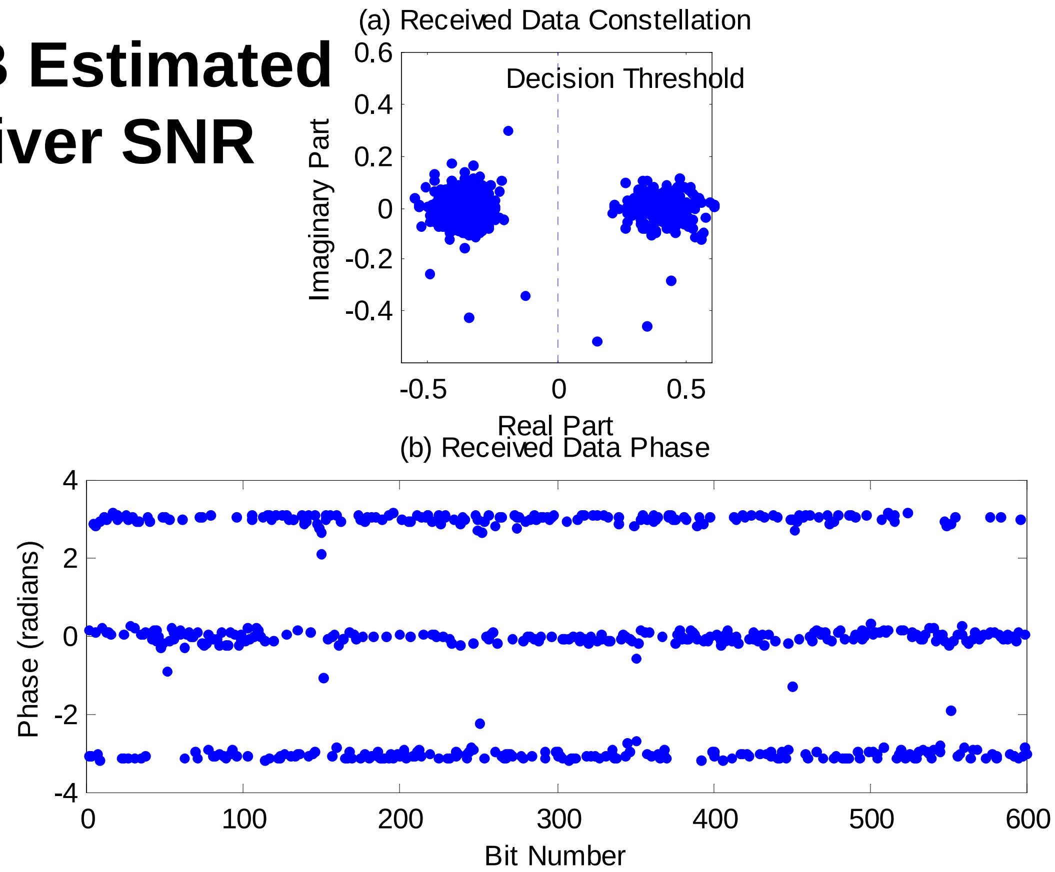
Results: Experimental Data 1



10 dB Estimated Receiver SNR

Results: Experimental Data 2

20 dB Estimated Receiver SNR



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Bit Error Rate Performance: Analytical

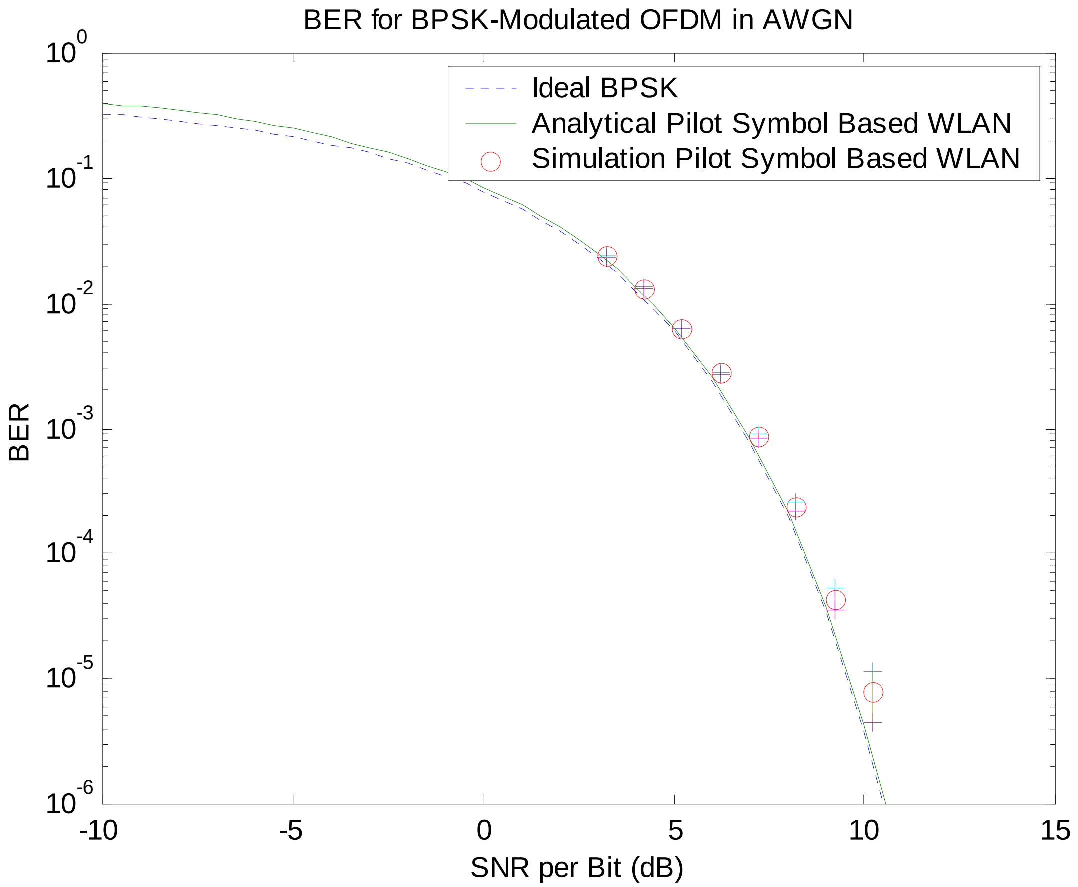
BER for BPSK OFDM with frequency-, phase- and timing-offset estimation errors in an AWGN channel is

$$p_e(\gamma_b) = \int_{-\pi}^{\pi}\int_{-\pi}^{\pi}\int_{-T/2}^{T/2} \frac{1}{2}\operatorname{erfc}\left(\frac{\mu w_0 w_P w_T}{\sqrt{2\left(\sigma^2 + \sigma_{ISI}{}^2\right)}}\right)$$

$$\times p_\tau(\tau)\, p_\alpha(\alpha)\, p_\phi(\phi)\, d\tau\, d\alpha\, d\phi.$$

where second line functions are densities of parameter estimation errors

Bit Error Rate Performance: Results



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Summary

- Detection and synchronization: fundamental to WLAN operation
- Pilot symbol assisted reception using correlation-based algorithms: analysis facilitates setting of key threshold parameters
- Bit error rate performance: analytical and simulation results closely approach ideal BPSK in an AWGN channel.