University Defence Research Centre (UDRC)
In Signal Processing

Sponsored by the UK MOD

[O19] Recognition of Orthogonal Frequency-Division Multiplexing (OFDM) in Low SNR and Dense Signal Environments

Theme: Detection, Localisation & Tracking Theme

PI: Mathini Sellathurai, Heriot-Watt University

Researchers: Dr. Chadi Khirallah and Fiona Ni Mhearain

Project Objectives

Apply novel real-time programmable signal processing techniques to recognize and estimate parameters of OFDM signals in low SNR. The proposed scheme divides the identification of OFDM signals into 3 levels: (1) Signal Detection (2) Classification between OFDM, and other single/multicarrier systems (3) Estimation of the OFDM parameters e.g. block size etc.

Problems in Spectrum Sensing

- ❖Very low signal to noise ratio (SNR). In the 802.22 standard, the sensing sensitivity requirement is about -20dB.
- ❖ Propagation channel uncertainty(multipath fading).
- ❖ Noise power uncertainty.
- ❖Interferences from intentional or unintentional transmitters.

General Model of Sensing

❖The signal received by a CR user,

$$x(k) = s(k) + v(k),$$

where $s(k)$: signal samples
$v(k)$: noise samples

❖ Two-hypothesis testing model can be defined as

$$H_0 : x(n) = v(k) \quad \text{(signal does not exist)}$$
$$H_1 : x(n) = s(k) + v(k) \quad \text{(signal exists)}$$

❖ The sample covariance matrix of the received signal :

$$\hat{R}_{xx} = \frac{1}{n}\sum_{k=1}^{n} x(k)x^{\dagger}(k) \qquad , n\hat{R}_{xx} = XX^{\dagger} = W$$

Test Statistics | Complexity

Energy Detector: $T_{ED} = \frac{1}{n}\sum_{k=1}^{n}|x(k)|^2$

n-1: Additions
n : Multiplications

Test static for eigen value based methods:

MED Method: $T_{MED} = \lambda_1 / {\sigma_n}^2$

GLRT Method: $T_{GLRT} = \frac{\lambda_1}{\sum_{i=1}^{m}\lambda_i}$

MME Method: $T_{MME} = \frac{\lambda_1}{\lambda_m}$

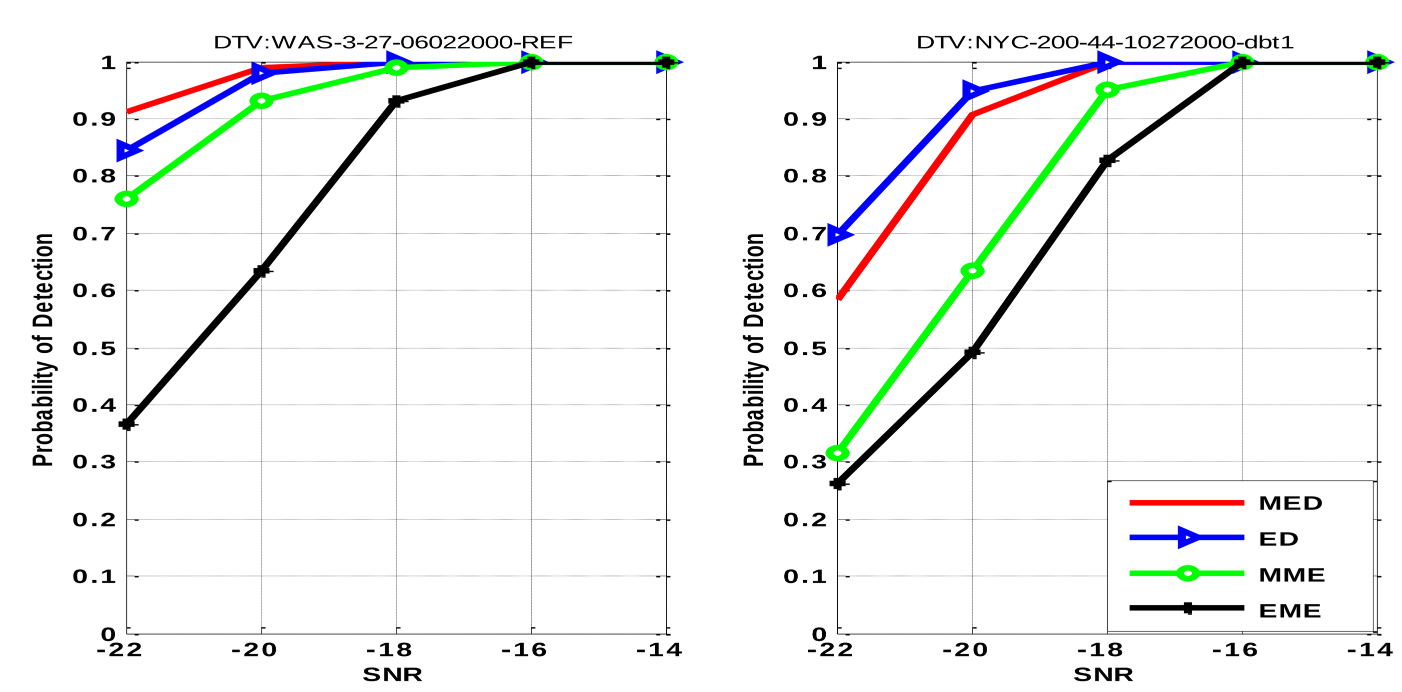
EME Method: $T_{EME} = \frac{T_{ED}}{\lambda_m}$

L(n-1) : Additions
Ln : Multiplications
O(L³) : Eigen value decomposition of the covariance matrix

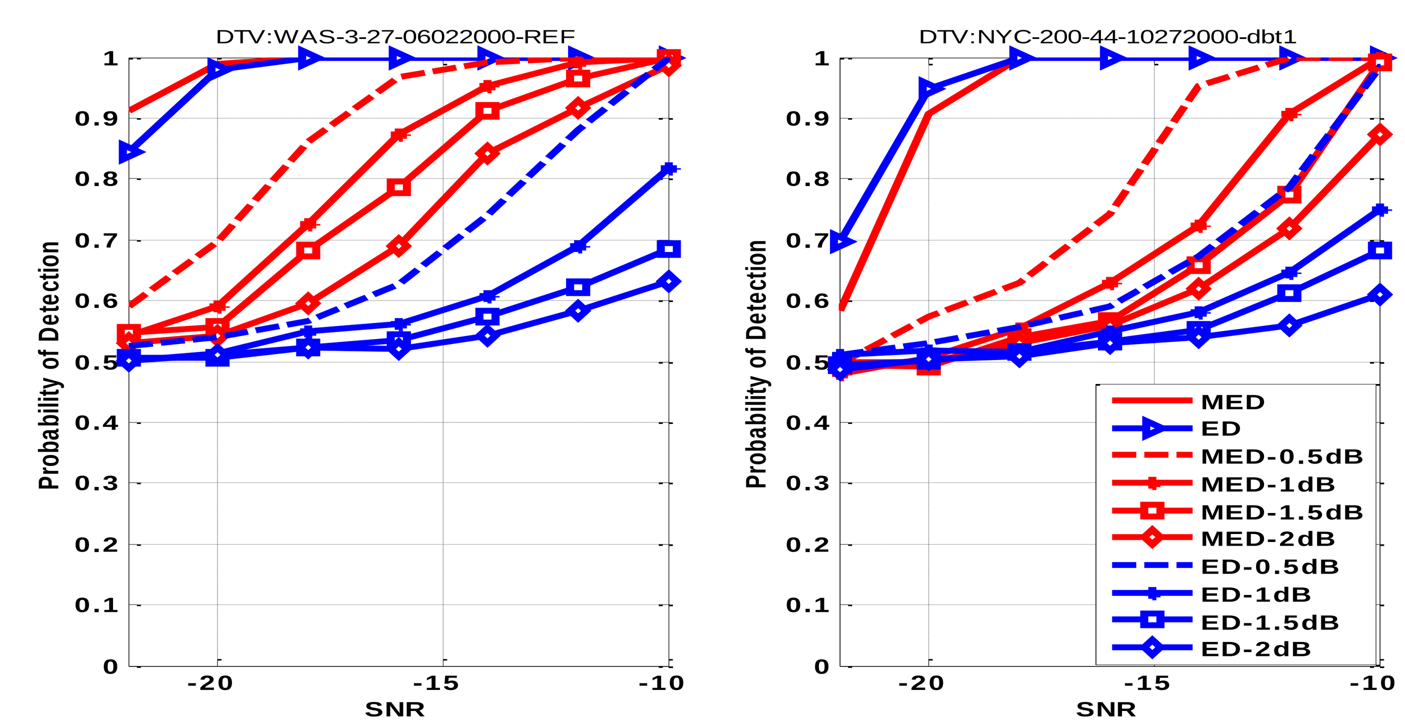
where L is smoothing factor in estimating covariance matrices

Simulation Results

❖ **Perfect knowledge of noise**



❖ **Noise uncertainty Results**



Feature Based Detection for OFDM

❖The baseband OFDM modulated signal can be expressed as

$$s_n(m) = \frac{1}{\sqrt{L}}\sum_{k=0}^{L-1} S_{n,k} e^{\frac{j2\pi mk}{L}} \qquad , m = 0, \ldots, L-1$$

❖The *n*th transmitted OFDM block can be represented as

$$s_n = \left[s_n(L-1)\ldots s_n(0)\, \underbrace{s_n(L-1)\ldots s_n(L-L_p)}_{\text{Cyclic Prefix}} \right]^T$$

❖Cyclostationary signal analysis can be used to identify OFDM signals and parameters.

❖ Feature based algorithms such as Cyclic Prefix correlation coefficient based method(CPCC) and Multipath Correlation coefficient based method(MPCC)can be exploited to achieve better performances.

❖ It is still unknown how to set the signal detection threshold and the analytic expressions for the Probability of Detection (P_D) and Probability of False Alarm (P_{fa}).

❖ If the noise is not stationary (impulsive) the spectral correlation density (SCD) function of the noise may not be zero at some cycle frequencies.

dstl

EPSRC
Engineering and Physical Sciences Research Council

2007 - 2013

CROWN

This work was supported by the Engineering and Physical Sciences Research Council (EPSRC) and the MOD University Defence Research Centre on Signal Processing (UDRC).

MINISTRY OF DEFENCE