Distribution-Free Spectrum Sensing for Full Duplex Cognitive Radio

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Abstract

Currently, non-parametric sensing techniques like energy detection and its modified techniques are implemented for FDCR. In this paper, we introduce a Goodness of Fit based distribution-free sensing in FDCR. With Monte Carlo simulations and analytical approximation, we show that the proposed technique outperforms energy detection and other goodness-of-fit based sensing algorithms for FDCR.

Literature review

- Energy Detection (ED) for spectrum sensing in FDCR has been explored in [1].
- Non-parametric GoF testing for HDCR was introduced in [2] with the Anderson-Darling (AD) test. It also includes analytical bounds.
- Proposed Kolmogorov-Smirnov (KS) test for HDCR [3]
- The application of the Zhang statistic to HDCR was investigated in [4] and analytical expressions for the Zhang statistic based sensing scheme were derived in [5].

System Model

Consider a standard AWGN channel

$$\mathbf{y} = \sqrt{\rho_p}\, h_p \,\mathbf{x} + \sqrt{\rho_s}\, h_s \,\mathbf{d} + \mathbf{n} \tag{1}$$

where, $\mathbf{x} = [x_0\ x_1\ \dots\ x_{N-1}]^T$: the transmitted PU signal;
$\mathbf{d} = [d_0\ d_1\ \dots\ d_{N-1}]^T$: the signal transmitted by SU;
$\mathbf{y} = [y_0\ y_1\ \dots\ y_{N-1}]^T$: the received samples;
ρ_p, ρ_s : the SNR of PU and SU signal at the SU sensing antenna;
h_p, h_s : the channel coefficient of PU and SU transmit antenna and the SU sensing antenna;
$\mathbf{n} = [n_0\ n_1\ \dots\ n_{N-1}]^T$ is the noise.

Case 1: $\mathbf{n} \sim \mathcal{CN}(0,1)$
Case 2: $\mathbf{n} \sim MiddletonClassA(A, \Gamma)$

LRS-G² Based Sensing for Full Duplex Radio

Hypothesis testing problem:

$$H_0 : \mathbf{y} = \sqrt{\rho_s}\, h_s \,\mathbf{d} + \mathbf{n}; \quad \text{PU is absent}$$
$$H_1 : \mathbf{y} = \sqrt{\rho_p}\, h_p \,\mathbf{x} + \sqrt{\rho_s}\, h_s \,\mathbf{d} + \mathbf{n}; \quad \text{PU is present}$$

Since, the test is defined over real values, we concatenate real and imaginary parts:

$$\mathbf{v} = [\Re(y_0)\ \dots\ \Re(y_{N-1}),\ \Im(y_0)\ \dots\ \Im(y_{N-1})]^T \tag{2}$$

The LRS-G² based statistic [4]

$$Z = \sum_{i=1}^{2N} \left[\log \left\{ \frac{F_0(v_i)^{-1} - 1}{(2N - \frac{1}{2})/(i - \frac{3}{4}) - 1} \right\} \right]^2 \tag{3}$$

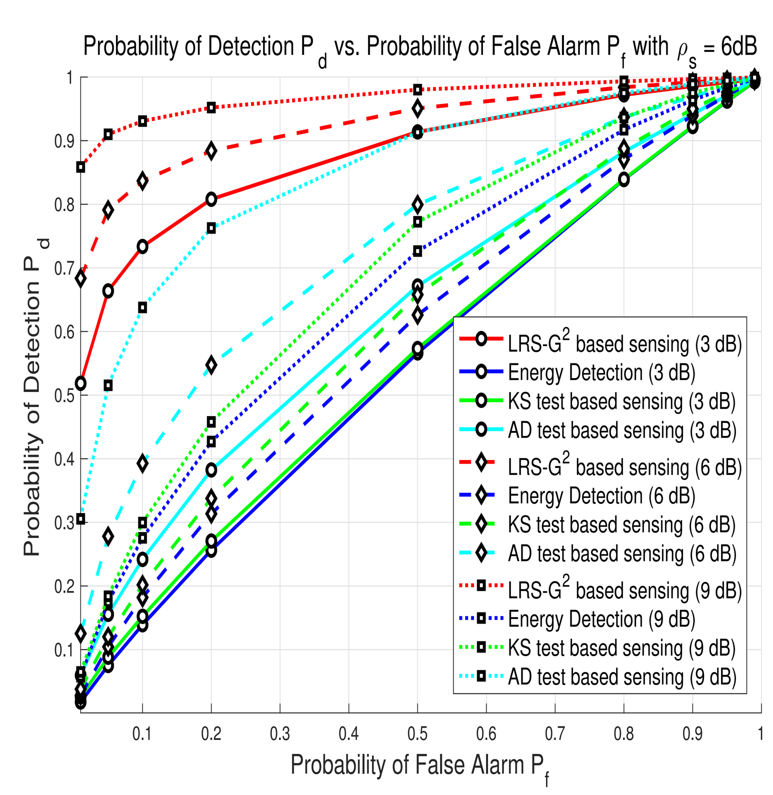
where, $F_0(x)$ is CDF at null hypothesis.
Case 1: IID Complex Gaussian Noise

$$F_0(x) = \frac{1}{\sqrt{\pi(\rho_s + 1)}} \int_{-\infty}^{x} \exp\left(-\frac{u^2}{\rho_s + 1} \right) du$$

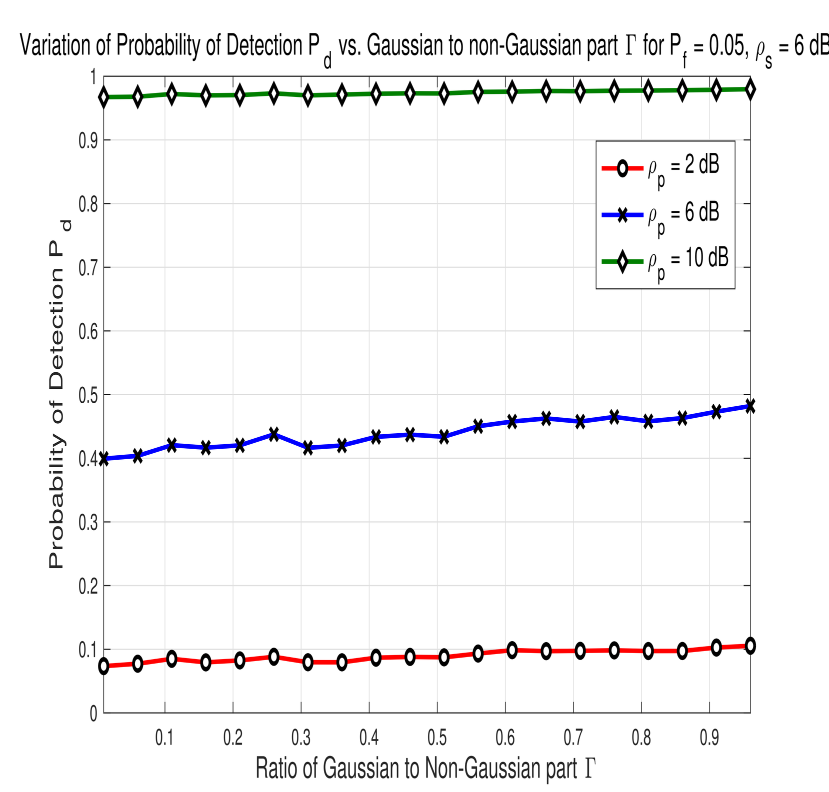
Case 2: Middleton Class A noise

$$F_0(x) = e^{-A} \sum_{m=0}^{\infty} \frac{A^m}{m!} \left[\frac{1}{\sqrt{\pi(2\sigma_m^2 + \rho_s)}} \int_{-\infty}^{x} \exp\left(-\frac{u^2}{2\sigma_m^2 + \rho_s} \right) du \right]$$

Results



(a) Simultaneous sensing and transmission



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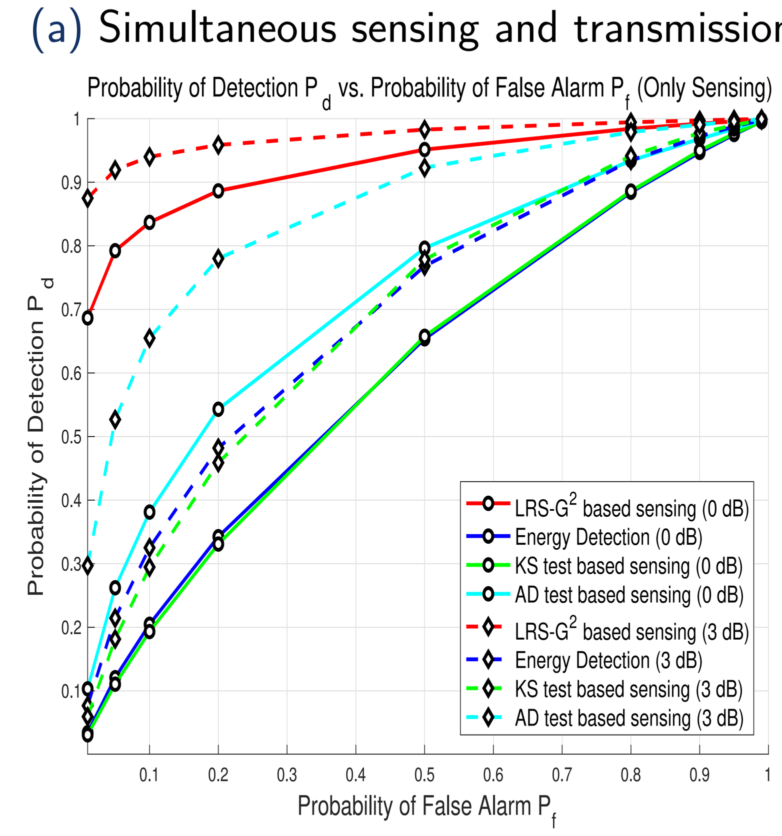
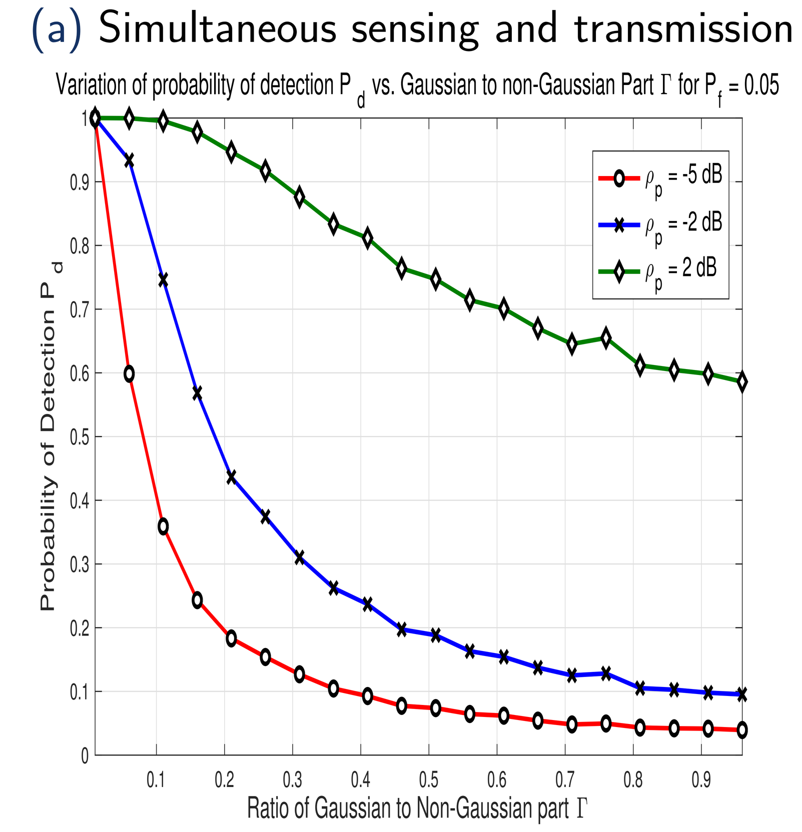


(b) Sensing only



(b) Sensing only

Figure: ROC curves for $\rho_s = 6$ dB and $N = 5$.

Figure: P_d vs. Γ of proposed scheme for different values of ρ_p with $P_f = 0.05$ and $\rho_s = 6$ dB.

Analytical Performance

- The distribution of the statistic Z can not be derived analytically [6]
- We model the distribution of the statistic Z by means of Monte Carlo simulations (with 100,000 iterations)
- Generate the large sample set of the statistic Z under hypothesis H1 and fit to the distribution models.
- The analysis indicate that the statistic Z can be modeled as a log-normal distribution.

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