COgnitive and Reconfigurable Embedded Systems (CORES) Lab

Multiple Antenna Cyclostationary Spectrum Sensing Based on the Cyclic Correlation Significance Test
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Abstract
We propose and analyze a spectrum sensing method based on cyclostationarity for receivers with multiple antennas. This method is based on the eigenvalues of the cyclic covariance of received signals. The cyclic correlation significance test (CCST) is used to detect a specific signal-of-interest by exploiting knowledge of its cyclic frequencies. Analytical expressions for probability of detection and false-alarm for spatially uncorrelated or correlated noise are derived and verified by simulation. Rayleigh flat-fading performance is found and verified through simulations. One advantage of the proposed method is independence of the detection threshold to both the number of samples and the SNR, making it robust to noise uncertainty. Performance is shown to be better than similar existing approaches.

Problem Statement
\[ X(n) = \sum_{j=1}^{M} h_j s_j(n) + \eta(n) \]

Channel Vector PU Signal Noise

• Spectrum sensing is essential to cognitive radio
• Multiple antennas improve robustness to multipath fading by introducing diversity
• Cyclic features (present in all digital modulations) eliminate the performance limit due to inaccurate noise estimation (SNR wall)

Proposed Algorithm
1. Conventional covariance matrix:
   \[ \hat{R}_{xx}(\tau_0) = \frac{1}{N} \sum_{n=1}^{N-\tau_0} x(n)x^H(n-\tau_0) \]
2. Cyclic covariance matrix:
   \[ \hat{R}^{\mu}_{xx}(\tau_0) = \frac{1}{N} \sum_{n=0}^{N-\tau_0} x(n)x^H(n-\tau_0)e^{-j2\pi \mu n} \]
3. Calculate the test statistic by finding the eigenvalues \( \mu \) of:
   \[ \hat{R} = \hat{R}^{\mu}_{xx} \hat{R}_{xx}^{\mu} \hat{R}_{xx}^{\mu} \]
4. Bartlett’s Test of Significance:
   \[ T_{xx}^\mu = -N \ln \left( 1 - \mu \right) \sim \chi^2 \text{ with } M^2 \text{ d.o.f.} \text{ under } H_0 \]

Results and Discussion

Figure 1. Receiver Operating Characteristic (ROC) of different cyclostationary-based spectrum sensing algorithms under Rayleigh flat-fading (SNR = -10 dB, N = 4000).

Figure 2. Effect of the number of antennas on probability of detection of EV-CSS and BMRC-MSDF. (SNR = -10 dB, N = 4000).

Figure 3. Effect of spatial correlation. (N = 1000, SNR = -10 dB).

Figure 4. Effect of noise uncertainty, \( \Delta \). Noise uncertainty is assumed to be uniformly distributed over an interval, \([\text{SNR} - \Delta, \text{SNR} + \Delta]\) (N = 1000 samples).

Conclusions
• The method outperforms similar existing approaches.
• Algorithm requires substantially less multiplications than the best existing algorithm that uses MRC.
• The detection threshold for CFAR is independent of the noise variance or the number of samples.
• The proposed method has also shown to be highly robust to the effects of noise uncertainty.

References