Correlation Based Signal Detection Schemes in Cognitive Radio

ABSTRACT:

We address the signal detection problems, relevant to cognitive radio, from two perspectives, single detector and cooperative detectors.

For the detection schemes happened on the single detector, we mainly discuss two approaches, the Low-Complexity Cyclostationarity Feature detection and Dual-Stage detection, both included in the practical coexistence between UWB system and IMT-Advanced system. We utilize such two detection schemes as the detection approaches in Detect and Avoid (DAA) of UWB system. The localized Single-carrier Frequency Division Multiple Access (SC-FDMA) signal is used as the target signal to be detected.

On the other hand, we also discuss the cooperative signal detection (Spectrum sensing) problem from a finite random matrix theoretical (RMT) perspective. Specifically, we employ recently-derived closed-form and exact expressions for the distribution of the standard condition number (SCN) of uncorrelated and semi-correlated random dual central Wishart matrices of finite sizes in the design Hypothesis-Testing algorithms to detect the presence of PU signals.

In particular, two algorithms are designed, with basis on the SCN distribution in the absence and in the presence of PU signals, respectively. It is also shown that the proposed finite RMT-based algorithms outperform all similar alternatives currently known in the literature, at a substantially lower complexity.
Several new results on the distributions of eigenvalues and SCNs of random Wishart Matrices are also offered.

Conclusions:

The signal detection (spectrum sensing) schemes for single detection and cooperative detection have been discussed in this thesis.

The energy detection method and low-complexity cyclostationarity feature detection method are selected to be coarse detection and refined detection, respectively. 10MHz SC-FDMA uplink signal is utilized to evaluate the proposed scheme. The dual-stage detection scheme with the threshold factor and the probability of indefinite detection has been discussed in this article. The tradeoff between the detection performance and the computational complexity can be achieved by setting the parameter of the probability of indefinite detection.

A low-complexity cyclostationarity feature detection scheme has been discussed in this article. The inherent frequency distribution of the target signal is utilized to generate the cyclostationarity feature. The detection of the SC-FDMA uplink signal with the proposed method is focused when the coexistence issues of the UWB systems and the IMT-Advanced systems need to be dealt with. The theoretical analysis has been given to indicate that the proposed scheme is low computational complexity, especially when the target bandwidth is large. At the cost of low complexity, the detection performance of the proposed scheme slightly decreases shown in the simulation results. The proposed detection scheme also can be considered as the substitute for the energy detection in DAA mechanism when the transmission environment is not ideal.

We presented new blind spectrum sensing algorithms based on finite random matrix theory.
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The algorithm utilizes recently-derived ¥emph{closed-form} and ¥emph{exact} expressions for the CDF of the SCN of dual random Wishart matrices of finite size, both uncorrelated central and semi-correlated central (which approximates the non-central case).
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Based on these new models, hypothesis tests are formulated around both the hypothesis $¥mathcal{H}_0$ that no PU signal is present, and the hypothesis $¥mathcal{H}_1$ that a PU signal (random or constant) is present .

Similar to previous methods based on asymptotic RMT, the proposed algorithms admits for either a tolerated probability of false alarm $¥alpha$ or a probability of miss-detection $¥delta$ to be accounted for by design.
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Simple relationships between these two design parameters were also provided.
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It was shown, however, that the new finite-RMT algorithms not only outperforms known asymptotic-RMT alternatives, but also that the blind approach of employing $¥mathcal{H}_0$ tests is the best choice overall (optimum at low SNR's or nearly optimum in the high SNR regime).

In passing, a comprehensive account of all random matrix-theoretical models relevant for the spectrum sensing applications if given, with several additional (albeit it small) offered.

The James-Edelman framework was invoked to obtain exact and closed-form expressions for the distributions of the ¥emph{smallest} eigenvalues of central non-correlated Wishart matrices.

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In light of the existence of similar results for the ¥emph{largest} eigenvalues, this yields a unified and highly convenient method to characterize the statistics of the extreme eigenvalues of such matrices.

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The expressions are tractable enough to allow a number of derivative results such as the distribution of condition numbers ¥cite{MyListOfPapers:RatnarajahSIAM2004, MyListOfPapers:MatthaiouTCOM10}.

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As an illustration, we have applied the distributions to the spectrum sensing problem, ultimately finding the method to be far superior to existing alternatives based on asymptotic Random Matrix Theory.