SPECTRUM SENSING BASED ON CORRELATION MATCHING: 2D CANDIDATE METHODS

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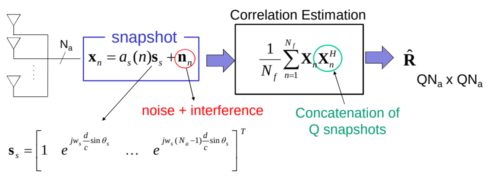
ABSTRACT

This paper addresses the problem of spectrum sensing in Open Spectrum Communications. A new spectral estimation procedure which exploits frequency, time and angle diversity is presented. The procedure is a feature-based method able to detect predetermined spectral shape, providing at the same time an estimate of its power level, an estimate of its frequency location and an estimate of its angle of arrival.

SYSTEM MODEL

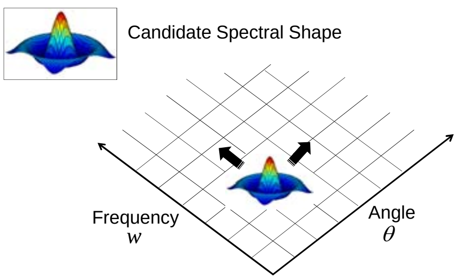
- The space-time-frequency spectrum sensing will be computed using multiple snapshots of measurements from a uniformly spaced linear array (ULA):



CANDIDATE AUTOCORRELATION MATRIX

__BASIC IDEA__: correlation matching, changing the traditional single frequency scan to a spectral scan with a particular shape (**CANDIDATE spectral shape**).

A frequency scanning and an angle scanning is developed using the candidate spectral shape:



$\mathbf{R}_b$: ***Candidate autocorrelation defined in base band***.

The only prior knowledge we have. (mostly depends on the energy spectrum of the modulation pulse and the baud rate r=1/T)

$\mathbf{R}_b$ is modulated by a rank-one matrix formed by the scanning frequency vector at the sensed frequency 'w'

$$\mathbf{R}_c = \left[\mathbf{R}_b \odot \mathbf{e}\mathbf{e}^H\right]$$

with $\mathbf{e} = \left[1 \quad e^{jw} \quad \dots \quad e^{j(Q-1)w}\right]^T$ Steering frequency vector

To deal with the angle diversity: $\mathbf{R}_{cm} = \mathbf{S}\mathbf{R}_c\mathbf{S}^H$

where $\mathbf{S} = \mathbf{I}_Q \otimes \mathbf{s}_d$ Steering angle vector

Identity matrix

$$\mathbf{s}_d = \left[1 \quad e^{jw_o\frac{d}{c}\sin\theta} \quad \dots \quad e^{jw_0(N_a-1)\frac{d}{c}\sin\theta}\right]^T$$

* $\odot$ Elementwise product of two matrices

* w_0 Central frequency of the RF band under scrutiny

CANDIDATE SPECTRUM SENSING

The corresponding model for the data autocorrelation matrix is given by:

$$\hat{\mathbf{R}} = \gamma(w_s)\mathbf{R}_{cm} + \mathbf{R}_n$$

Power level at frequency w_s — noise + interference autocorrelation matrix

An estimate of the power level can be obtained as,

$$\min_{\gamma} \Psi\left(\hat{\mathbf{R}}, \gamma(w)\mathbf{R}_{cm}\right) \quad \text{where } \Psi(\cdot,\cdot) \text{ is a similarity function.}$$

CANDIDATE-F

Minimum **Frobenius norm** of the difference between the two matrices

$$\min_{\gamma}\left\|\hat{\mathbf{R}} - \mathbf{R}_{cm}\right\|_F \quad \Longrightarrow \quad \gamma_F = \frac{\mathrm{Trace}(\mathbf{R}_{cm}\hat{\mathbf{R}})}{\mathrm{Trace}(\mathbf{R}_{cm}^2)}$$

CANDIDATE-G

Minimum **Geodesic distance** between the two matrices.

$$\min_{\gamma}\left\|\hat{\mathbf{R}} - \mathbf{R}_{cm}\right\|_G \quad \Longrightarrow \quad \gamma_G = \left(\prod_{m=1}^{Q}\lambda_m\right)^{\frac{1}{Q}} \qquad d^2_{Geo,\min} = \sum_{m=1}^{Q}\left|\lambda_m/\gamma_G\right|^2$$

where $\hat{\mathbf{R}}\mathbf{e}_m = \lambda_m\mathbf{R}_{cm}\mathbf{e}_m$

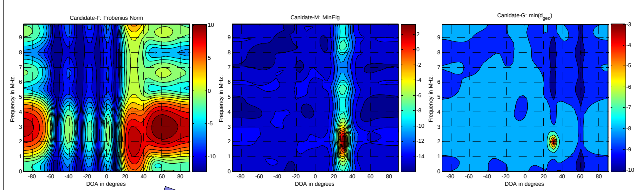
CANDIDATE-M

Force a **positive semidefinite difference** between the two matrices

$$\max_{\gamma\geq 0}\gamma \quad s.t.\ \hat{\mathbf{R}} - \gamma\mathbf{R}_{cm} \succ 0 \quad \Longrightarrow \quad \gamma_M = \lambda_{\min}\left(\hat{\mathbf{R}}, \mathbf{R}_{cm}\right)$$

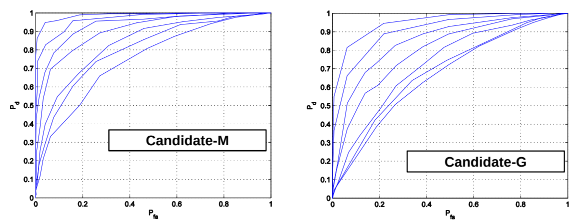
SIMULATION RESULTS

	Desired User	Interference
Mod	BPSK	Pure Tone
Freq	2 MHz	3 MHz
DOA	30º	60º
SNR	10 dB	10 dB



Receiver Operating Characteristics (ROC)

SNR ranges from -20dB to -14dB



CONCLUSIONS

- 3 dimensions are exploited: Time, Frequency and Angle.
- Candidate-F show low resolution and weaknesses to interference rejection.
- Candidate-M provides better performance than Candidate-F but shows lower resolution than Candidate-G. However, Candidate-M shows high robustness to noise compared with Candidate-G.

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