A Sub-Space Method to Detect Multiple Wireless Microphone Signals in TV Band White Space

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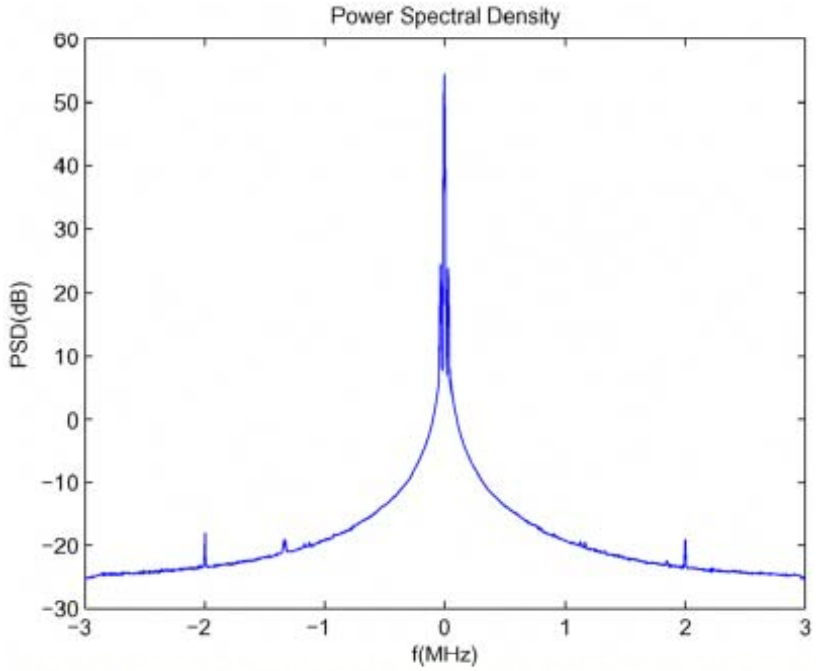
Organization

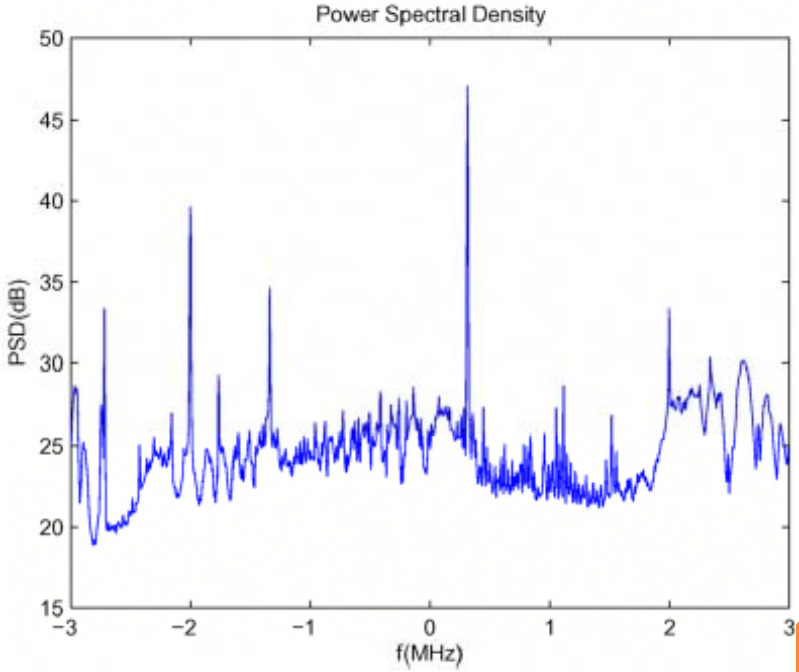
- Introduction
- Noise Characterization
- Singular Value Decomposition
- SVD-Based WM Sensing Algorithm
- Empirical Results
- Conclusion and Future Direction
- Acknowledgement

Introduction – Wireless Microphone Signals

- Analog wide-band FM: occupied bandwidth < 200kHz
- RF power ~50 mW
- Operate at frequency any multiple of 25 kHz in the high-band VHF and UHF TV bands



PSD of typical wireless microphone signal



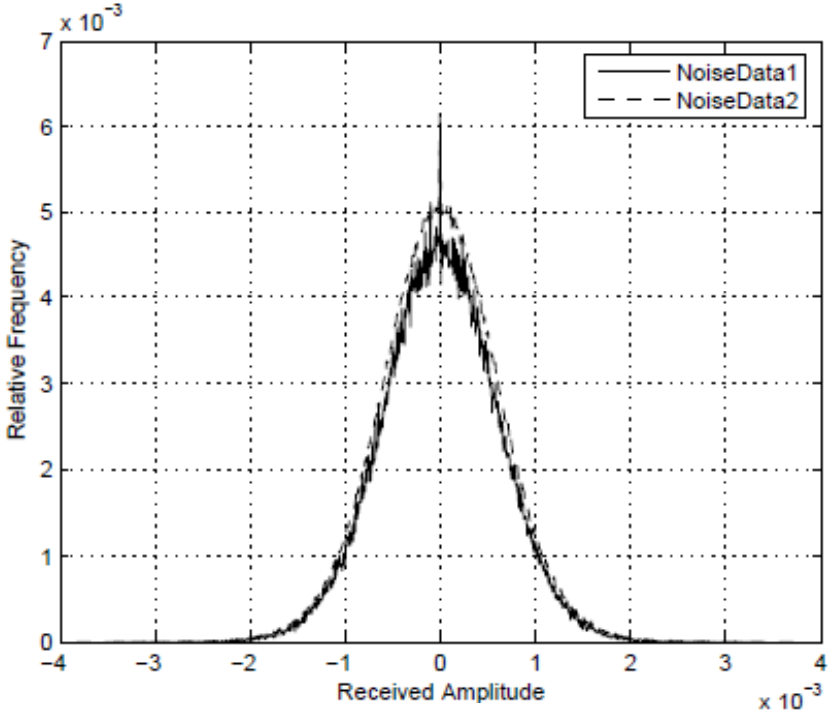
Wireless microphone signal in TV band with narrowband interference

Shellhammer, S.J.; Sadek, A.K.; Wenyi Zhang; , "Technical challenges for cognitive radio in the TV white space spectrum," Information Theory and Applications Workshop, 2009 , vol., no., pp.323-333, 8-13 Feb. 2009

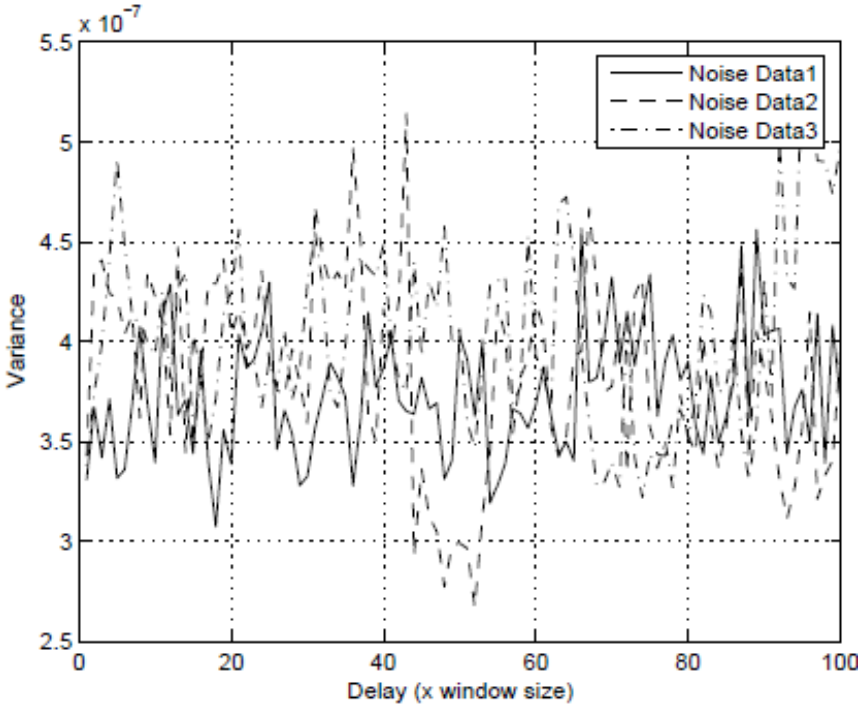
Introduction - Spectrum Sensing Algorithms

- Energy Detection
- Matched Filtering
- Cyclostationarity-based
- Eigenvalue-based
- Covariance-based

Noise Characterization – Statistical Properties



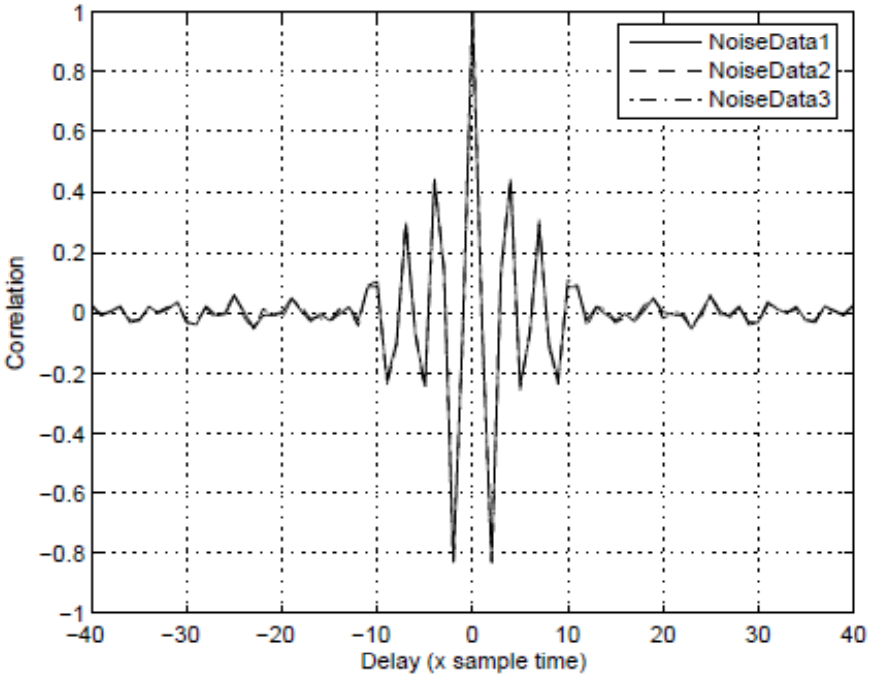
Histogram of background noise computed from measurement data.



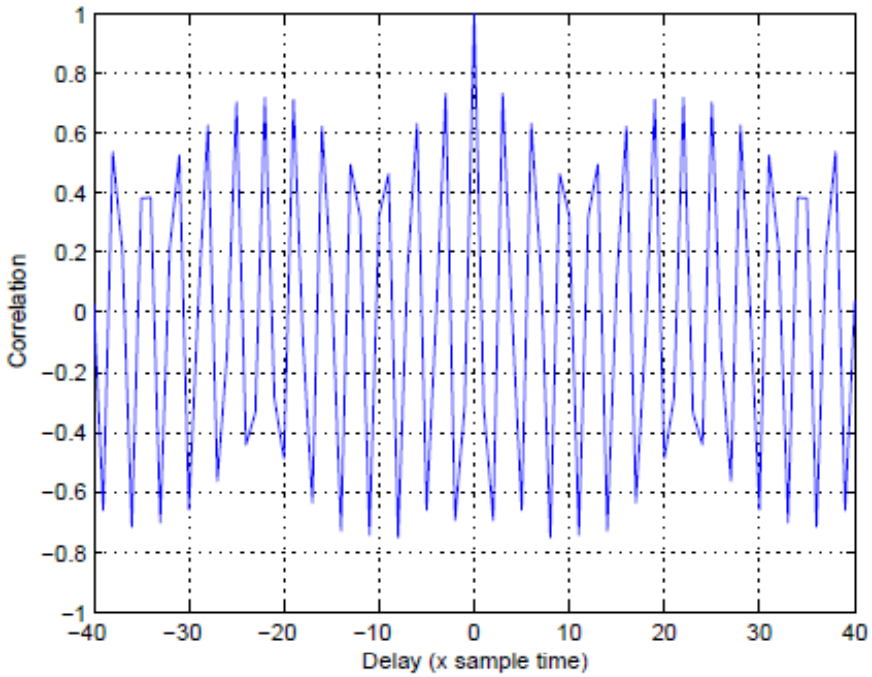
Variance of background noise at different time instances.

- Truncated Gaussian histogram
- Stationarity - Variance does not vary significantly with time

Noise Characterization- Autocorrelation

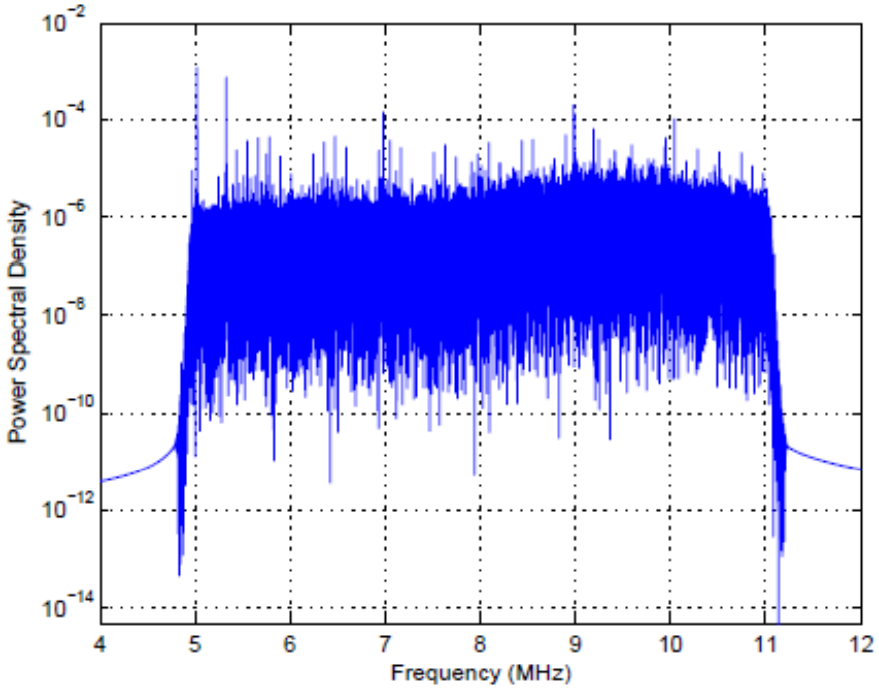


Autocorrelation of band-limited background noise samples.

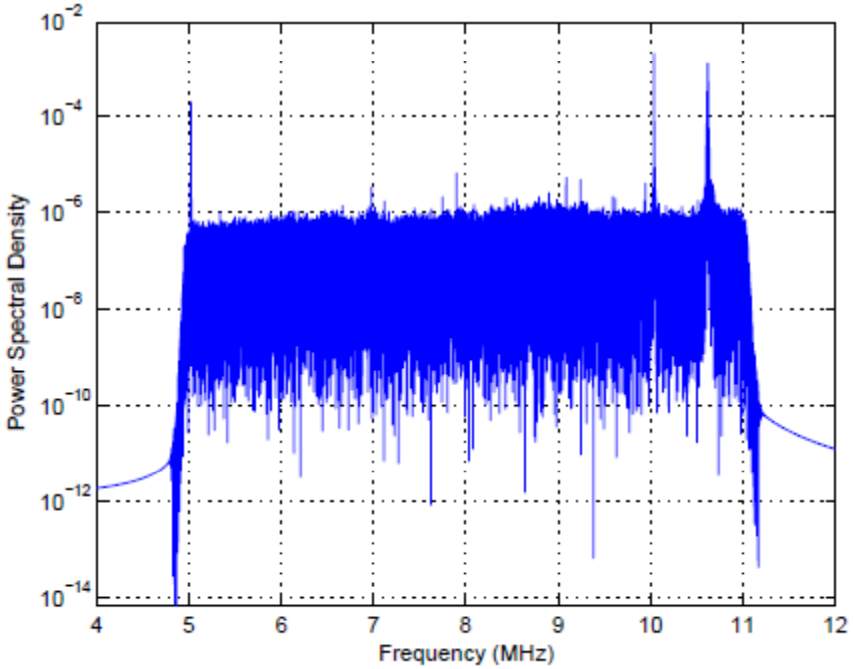


Autocorrelation of loud(modulated) WM signal with colored noise.

Power Spectral Density



PSD of band-limited background noise.



PSD of modulated WM signal with colored noise.

- No wireless microphone signal present
- Wireless microphone signal at 10.625 MHz

Singular Value Decomposition

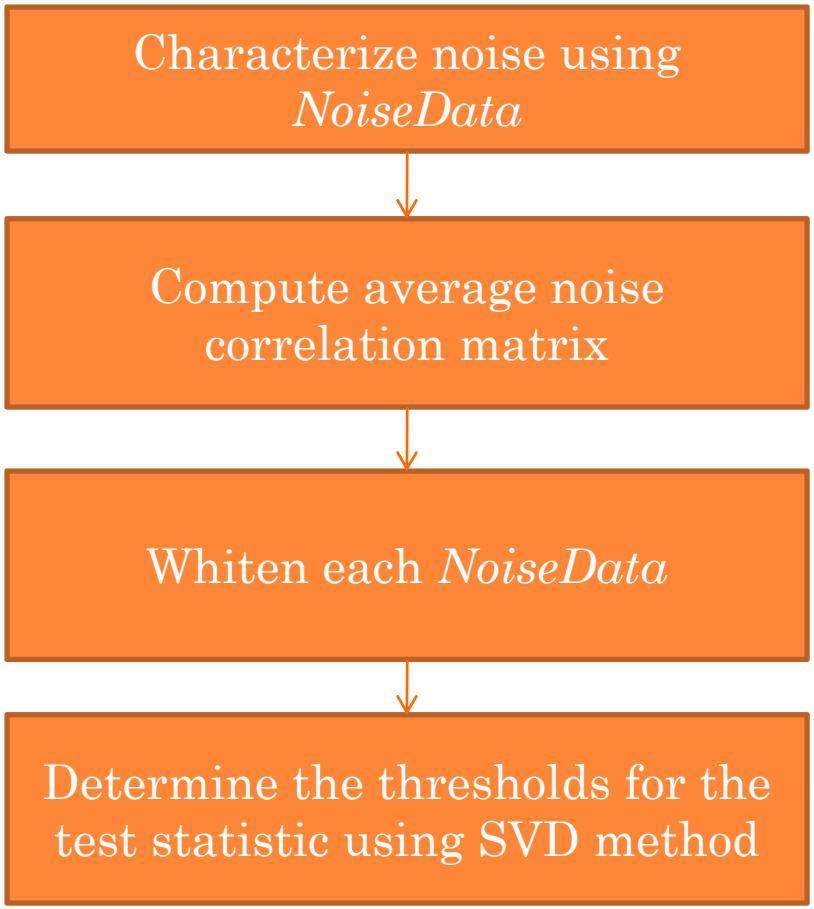
- SVD of a m x n matrix $\boldsymbol{M}$ gives the factorization

$$\boldsymbol{M} = \boldsymbol{USV}^*$$

  - $\boldsymbol{U}$ = an m x m unitary matrix
  - $\boldsymbol{S}$ = an m x n diagonal matrix with nonnegative real numbers on the diagonal
  - $\boldsymbol{V}^*$ = an n x n unitary matrix

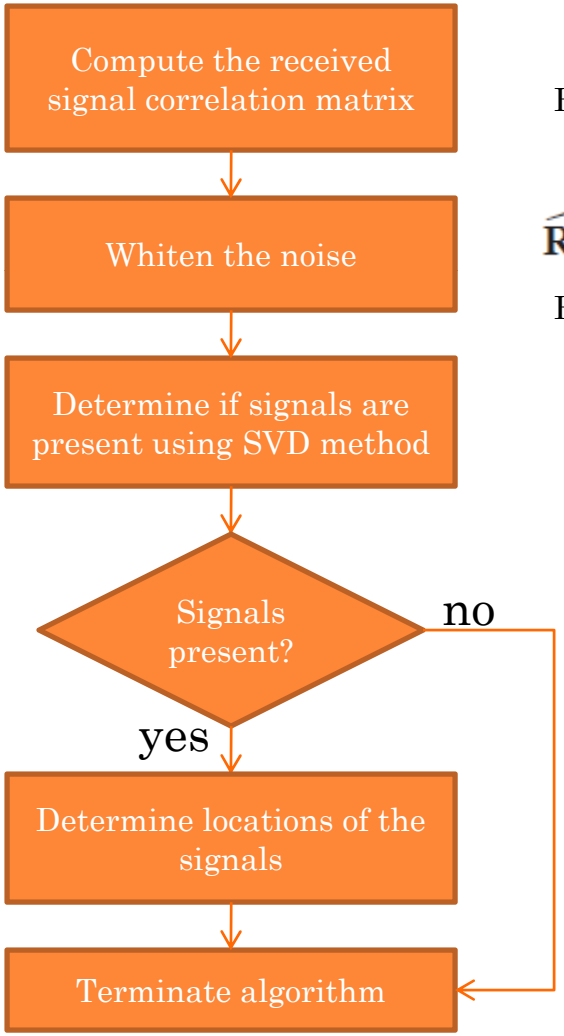
- Diagonal entries of $\boldsymbol{S}$ are singular values of $\boldsymbol{M}$

SVD Based WM Sensing Algorithm – Training Phase



$\widehat{\mathbf{R}}_{\eta}$ Average noise correlation matrix

SVD Based WM Sensing Algorithm – Detection Phase



Received signal correlation matrix $\mathbf{R}_x = \mathbf{R}_s + \mathbf{R}_\eta$

$$\widehat{\mathbf{R}_s} = \mathbf{R}_x - \widehat{\mathbf{R}_\eta} = \mathbf{R}_s + \mathbf{R}_\mu$$

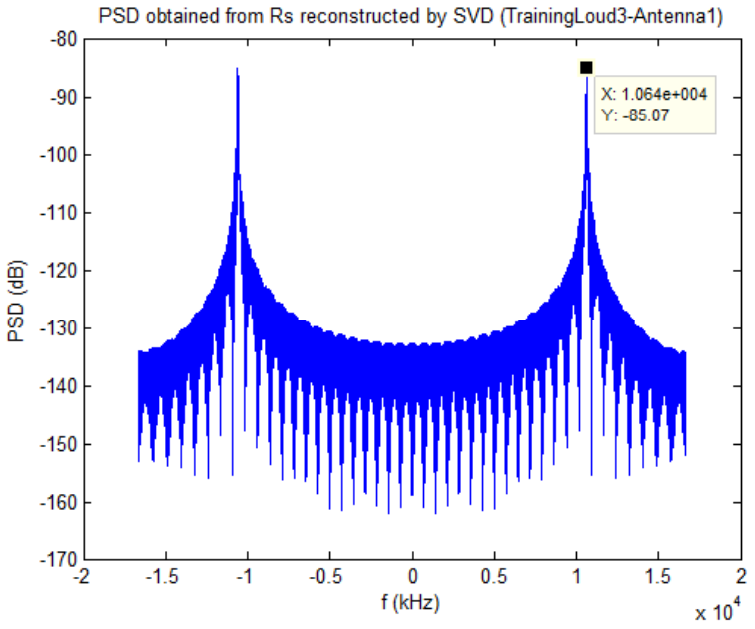
Rμ = Residual noise correlation matrix

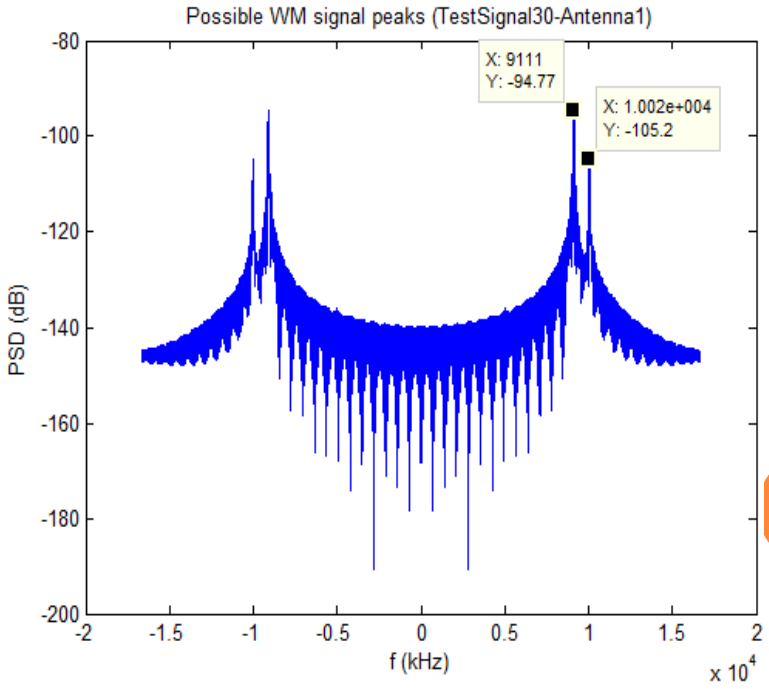
$$\widehat{\mathbf{R}_s} = \mathbf{U}\,\mathbf{S}\,\mathbf{V}^H = [\mathbf{U}_s\mathbf{U}_\mu]\begin{bmatrix}\mathbf{S}_s & 0\\ 0 & \mathbf{S}_\mu\end{bmatrix}[\mathbf{V}_s\mathbf{V}_\mu]^H$$

Correlation matrix of "cleansed" signal $\mathbf{R}_s = \mathbf{U}_s\,\mathbf{S}_s\,\mathbf{V}_s^H$

Empirical Results

- Multiple signals were detected
- Intermodulation components could not be distinguished from the wireless microphone signals





Conclusion

- Wireless microphone signals at low SNR can be detected using our method
- More measurements have to be conducted under different wireless environments to obtain more accurate test statistics thresholds
- Analysis of the complexity and performance tradeoffs need to be performed

ACKNOWLEDGEMENT

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Questions

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