Power Spectral Density based Wireless Microphone Sensing

Ashwin Revo
arevo@winlab.rutgers.edu

Advisor: Prof. Predrag Spasojevic
spasojev@winlab.rutgers.edu

Problem Statement

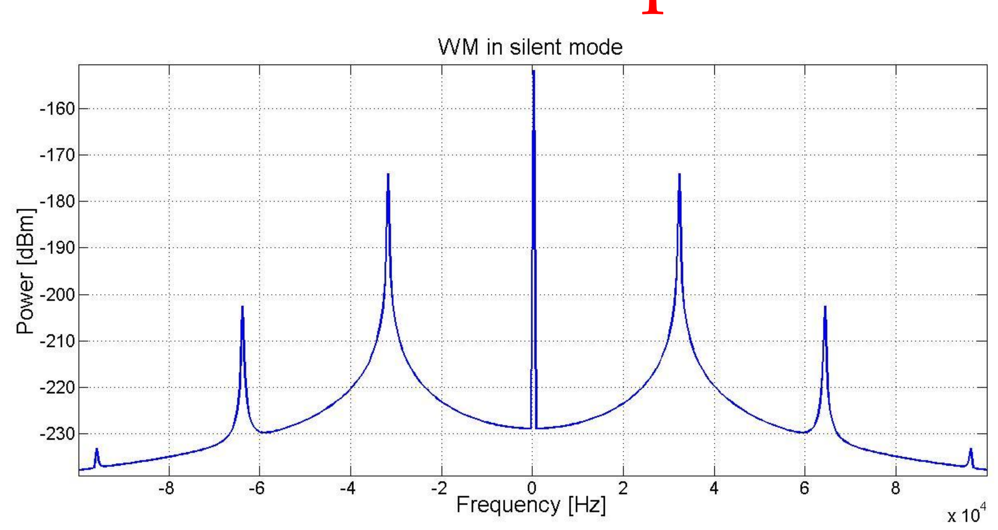
- Implementation of dynamic spectrum access in TV frequency band being explored by FCC
- Wireless microphone (WM) is one of the incumbent devices present in TV frequency band
- Technical paper explores power spectral density (PSD) based sensing algorithm for detecting wireless microphone
- Performance of PSD based sensing algorithms along with different combining rules studied

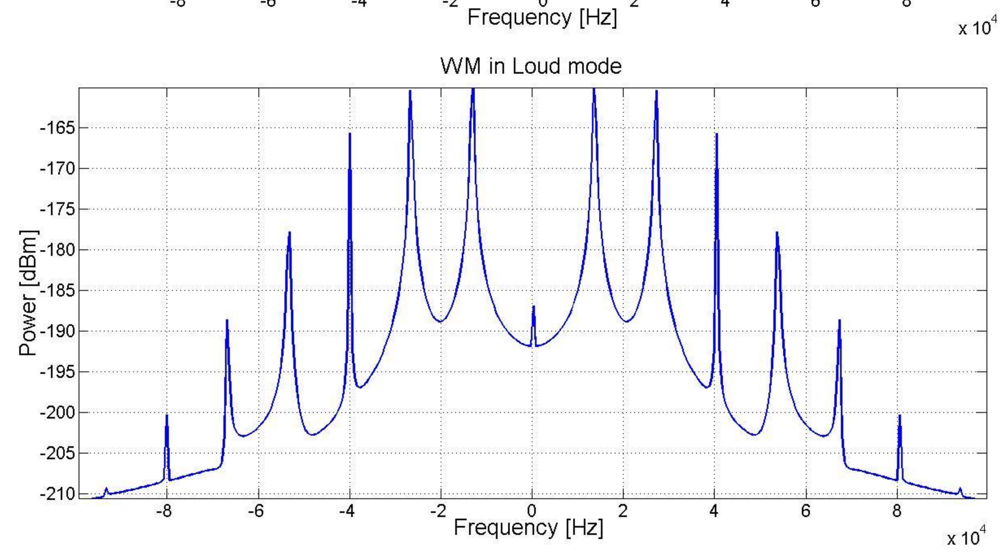
Wireless Microphone Simulation

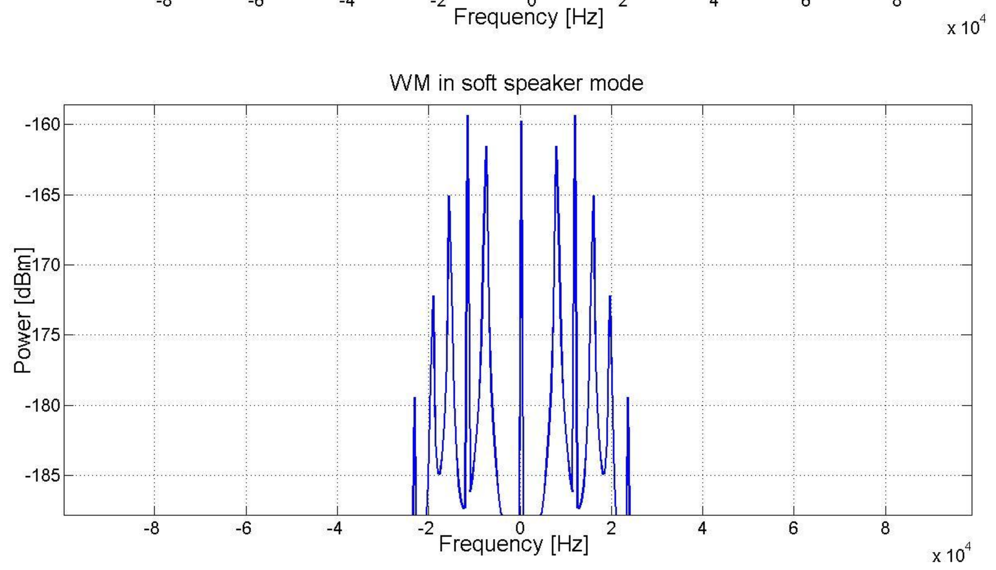
- WM typically employ analog frequency modulation (FM) for transmission
- Three modes of operation considered to simulate wireless microphone operation
- Silent: WM is turned ON but the speaker is silent
- Soft: WM is turned ON with soft speaker
- Loud: WM is turned ON with loud speaker

	Silent	Soft	Loud
Tone frequency	32 kHz	3.9 kHz	13.4 kHz
Frequency deviation	+/- 5kHz	+/- 15kHz	+/-32.6 kHz

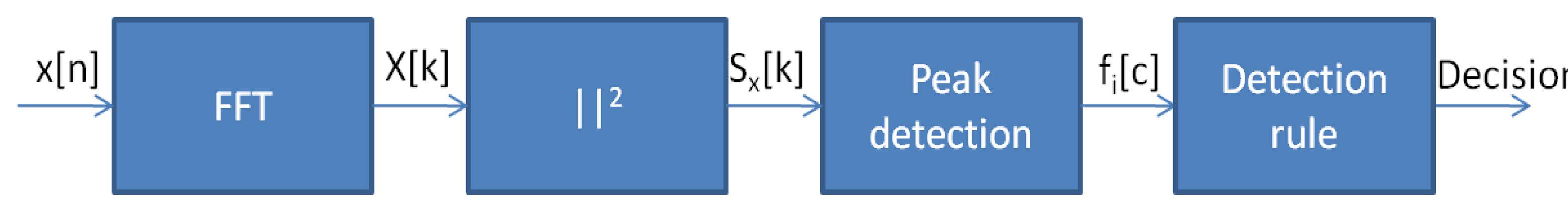
Wireless Microphone PSD







Power Spectral Density based Detector



Block diagram of PSD based detector

- PSD estimated using periodogram technique
- FFT block: Fast Fourier transform (FFT) operation is performed on the received signal samples x[n]
- $|\,|^2$: Coefficients of FFT X[k] are squared to calculate periodogram
- Peak detection block: Energy in individual frequency bins compared to threshold to detect presence of peaks in PSD
- Detection rule block: One of three detection rules, OR rule, 2 out of N rule, Soft fusion rule applied on output of peak detection block

Distribution of Power in PSD

- $H_0 : x[n] = w[n]$ signal is absent

  where n = 1, 2, … N is the number of observed samples at the receiver

  $x \sim N(0, \sigma_n^2)$ under H_0

  $x \sim N(0, \sigma_n^2 + \sigma_s^2)$ under H_1
- Distribution of coefficients of Fourier series

  $X(k) \sim N(0, N\sigma_n^2)$ under H_0
- The periodogram is calculated as

  $$S_x = \frac{\text{abs}(X(k))^2}{M}$$

- $S_x \sim N(\sigma_n^2, \sigma_n^4 / M)$ under H_0

  where M is the number of averages
- Given the distribution of power in the frequency bins of the PSD we can determine the threshold for peak detection using Neyman Pearson method

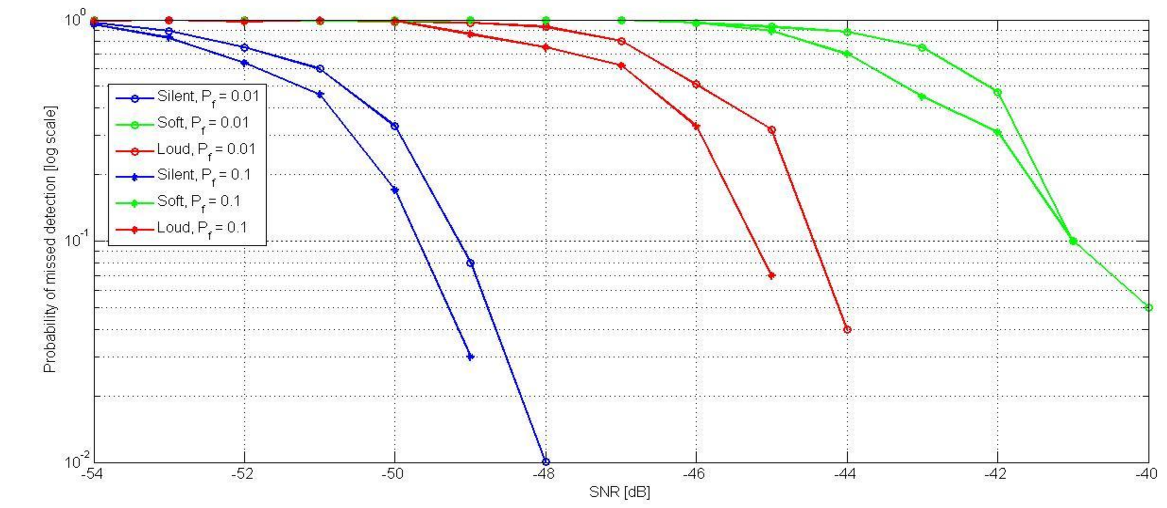
Decision Combining Rules

- OR rule: If any one frequency bin has energy greater than threshold then WM is present. It has highest probability of detection and false alarm

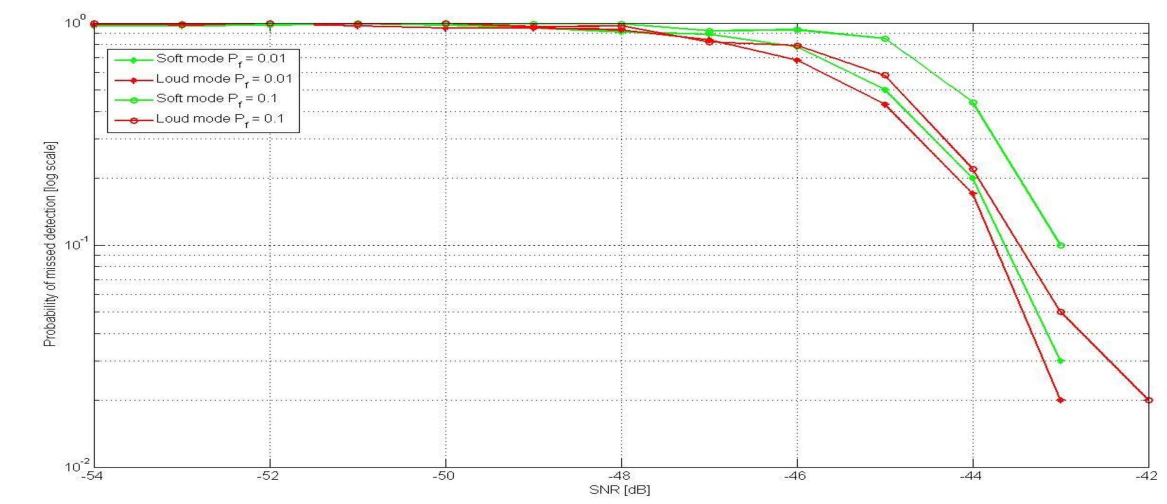
  $P_{FA} = 1 - (1 - P_f)^N$
- 2 out of N rule: If any two frequency bins have energy greater than threshold then WM is present. It is more robust in presence of colored noise

  $P_{FA} = 1 - (1 - P_f)^N - N \times P_f \times (1 - P_f)^{N-1}$
- Soft rule: If the cumulative energy of frequency bins chosen by a pre-defined mask is greater than threshold then WM is present . Pre-defined spectral mask chosen based on WM operation mode characteristics

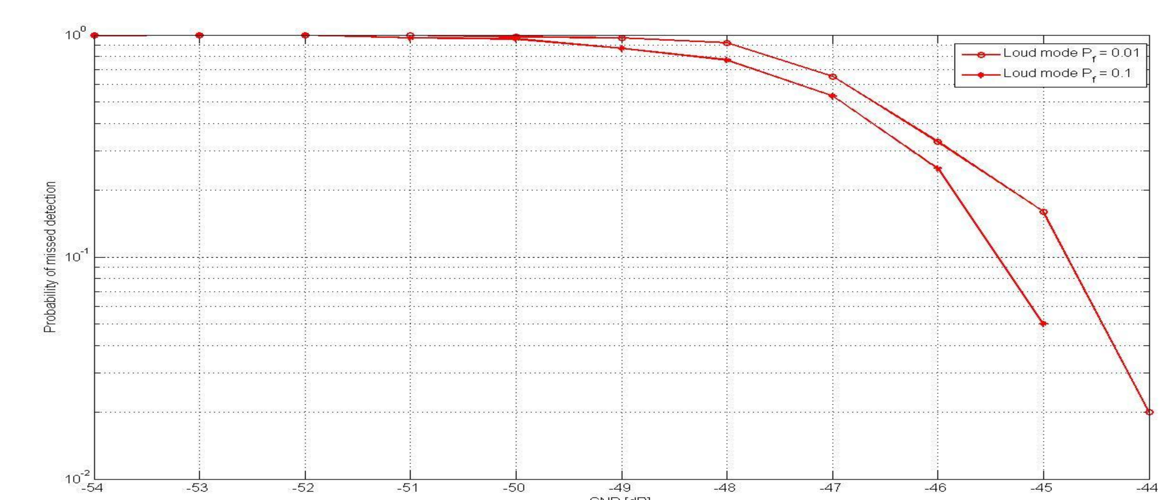
Results



Performance of OR fusion rule



Performance of 2 out of N fusion rule



Performance of soft fusion rule

Operation mode	Decision rule	SNR [dB]
Silent	OR	-54
Soft	OR	-45
Soft	2 out of N	-47
Loud	OR	-49
Loud	2 out of N	-47.5
Loud	Soft decision	-49.5

Conclusions

- Comparing the performance of detection rules for loud mode, soft rule decision has better performance
- However soft fusion rule requires additional signal information such as frequency deviation
- In silent mode only one frequency bin has high energy, hence performance of 2 out of N detection rule is poor
- OR rule performs better in silent WM case because the energy is concentrated in a single frequency bin

Important References: [1] H. Chen, W. Gao, D. G. Daut, “Spectrum Sensing for Wireless Microphone Signals”, Sensor, Mesh and Ad Hoc Communications and Networks Workshops, 2008. SECON Workshops '08.

[2] C. Clanton, M. Kenkel and Y. Tang, “Wireless Microphone Signal Simulation Method,” IEEE 802.22-07/0124r0, March 2007.