MagEar: Eavesdropping via Audio Recovery using Magnetic Side Channel

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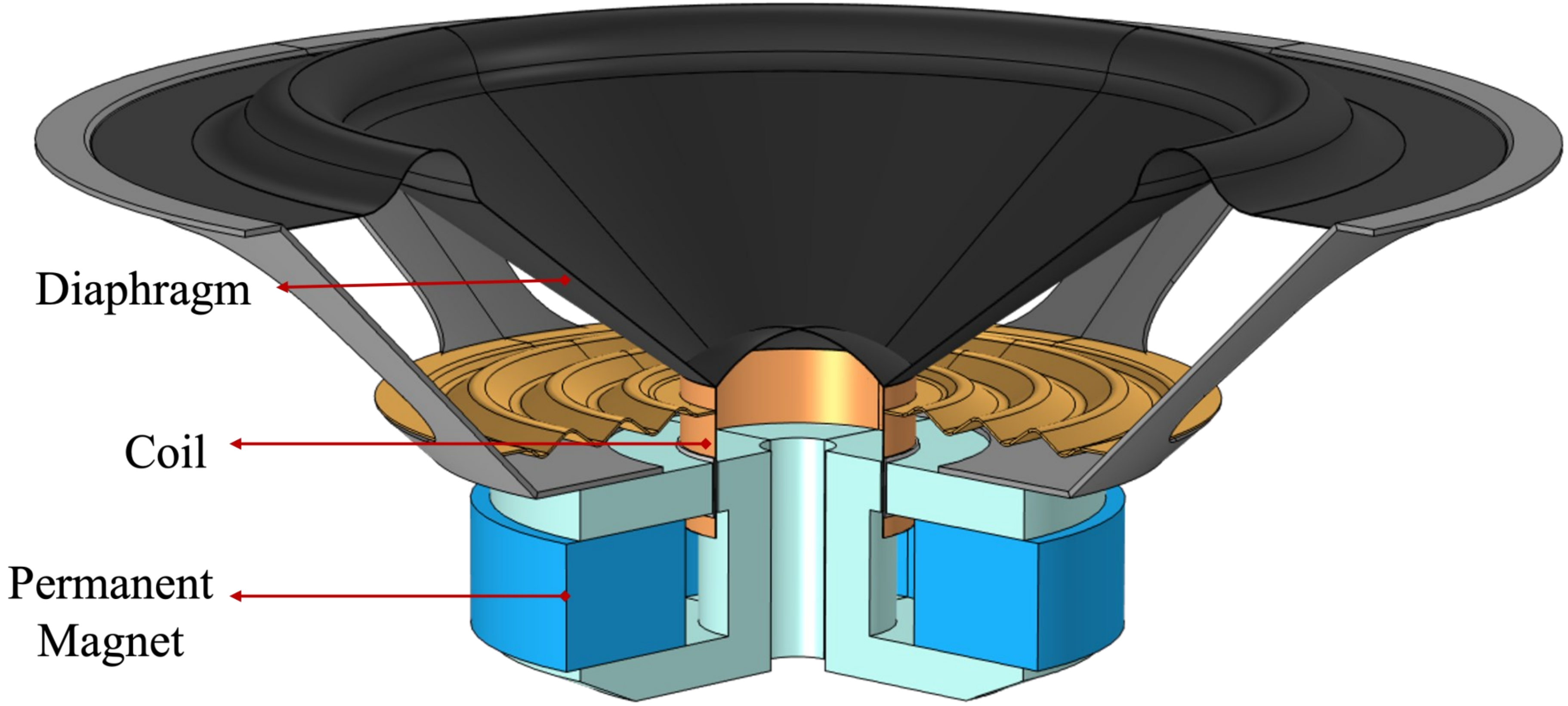
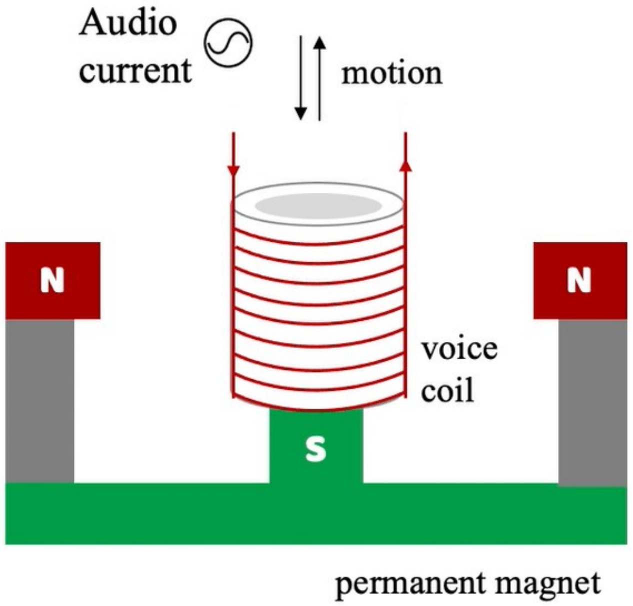
Loudspeaker Structure

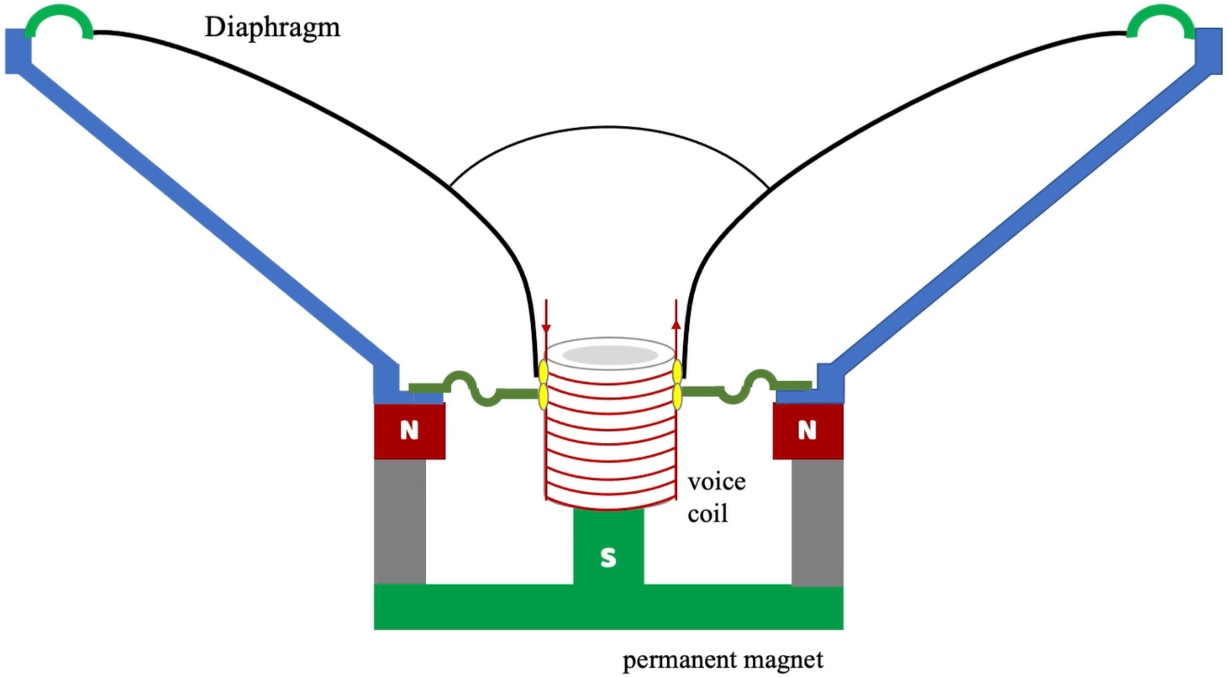


Loudspeaker working principle

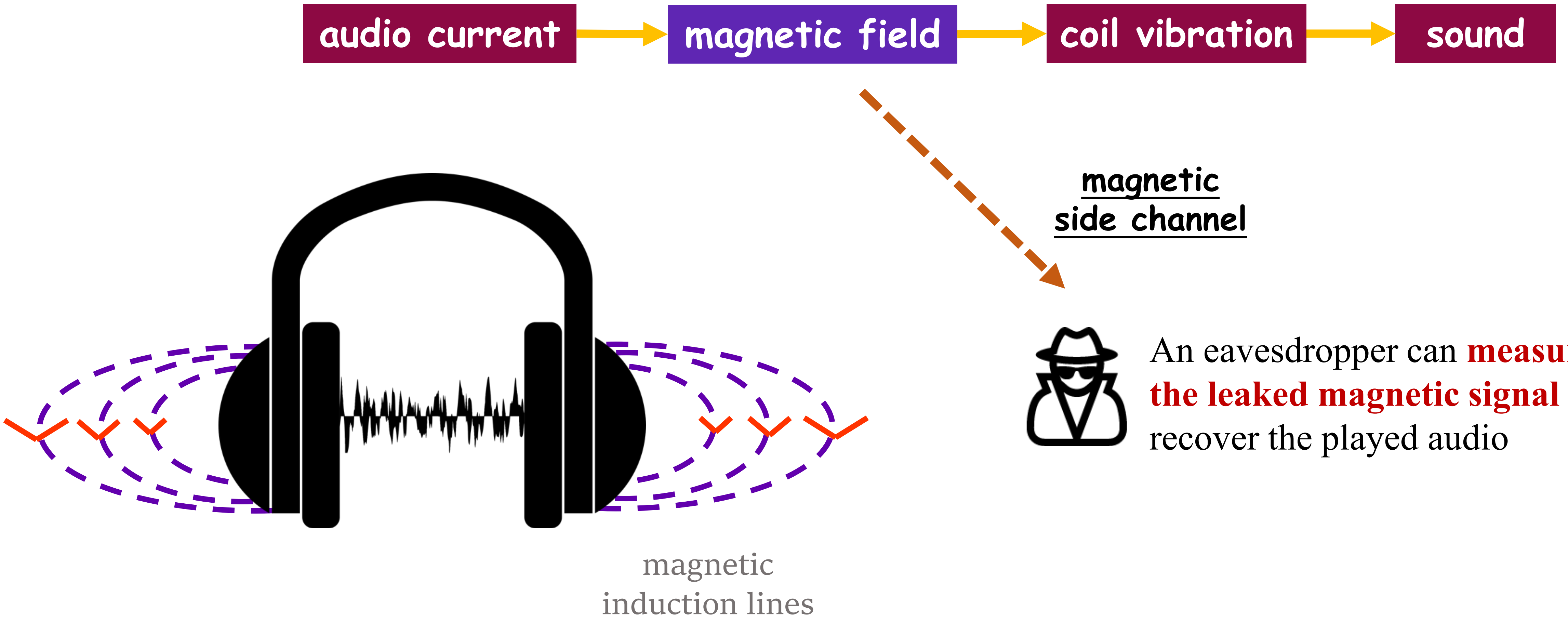
applying audio curren



diaphragm vibration



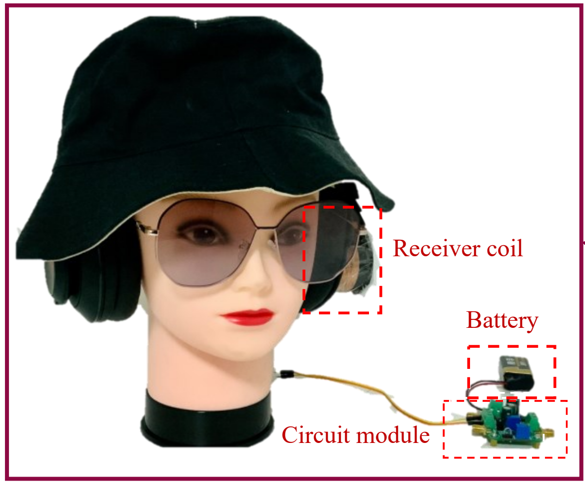
Motivation



An eavesdropper can **measure the leaked magnetic signal** to recover the played audio

MagEar: Eavesdropping via Audio Recovery using Magnetic Side Channel

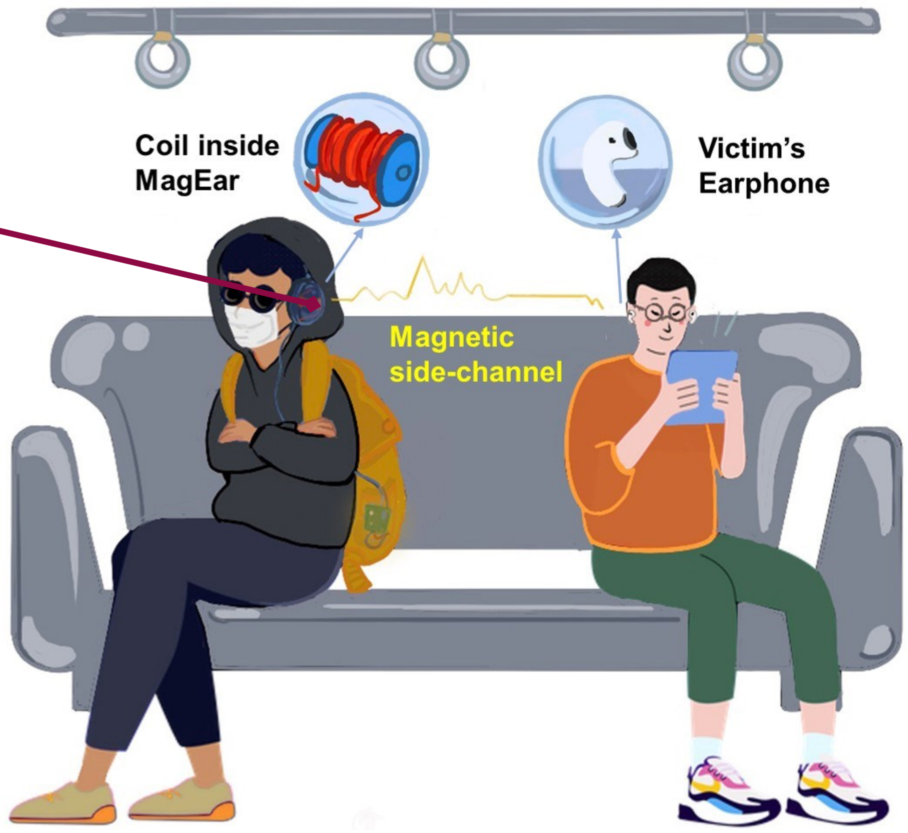
1. Geometric Shape
2. Spiral or Cylindrical
3. Geometric Size
4. Sensitivity and SNR



receiver coil design

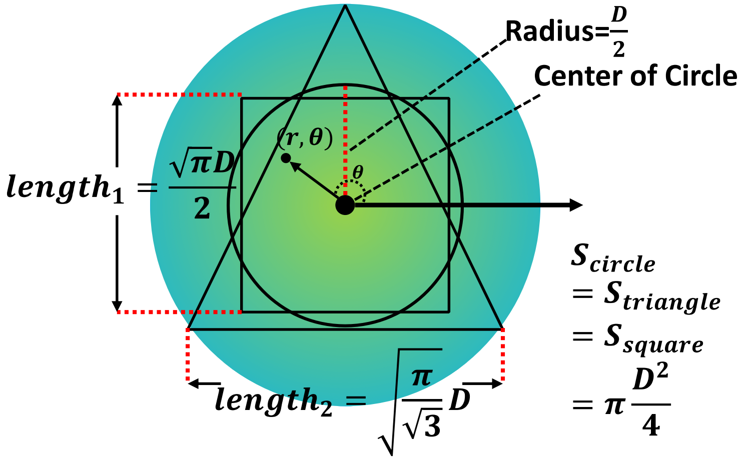
1. Frequency band Adjustment
2. Interference Confrontation
3. Frequency Response Equalization
4. Angle Adjustment

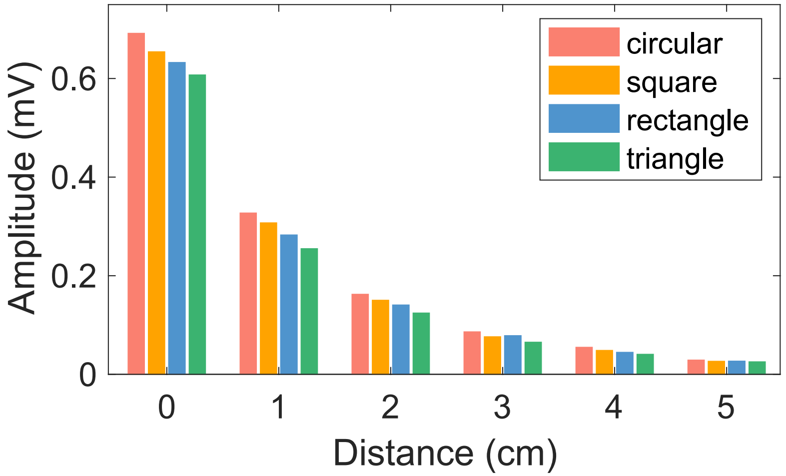
system design



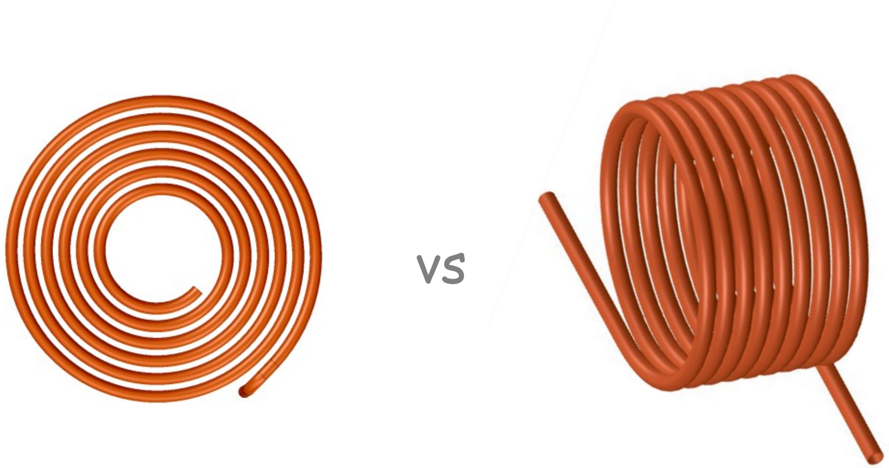
Coil Design

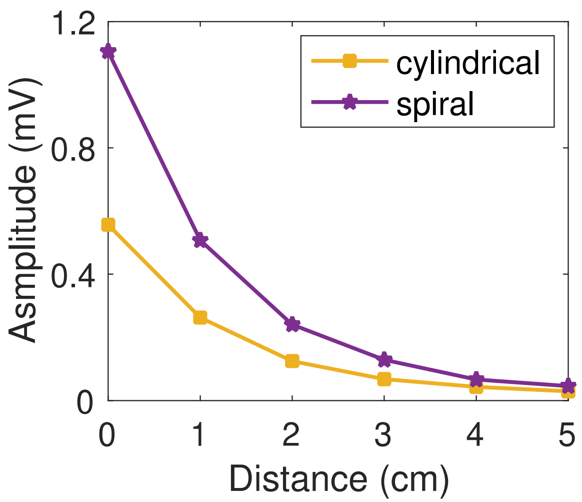
1. Geometric Shape





2. Spiral or Cylindrical coil





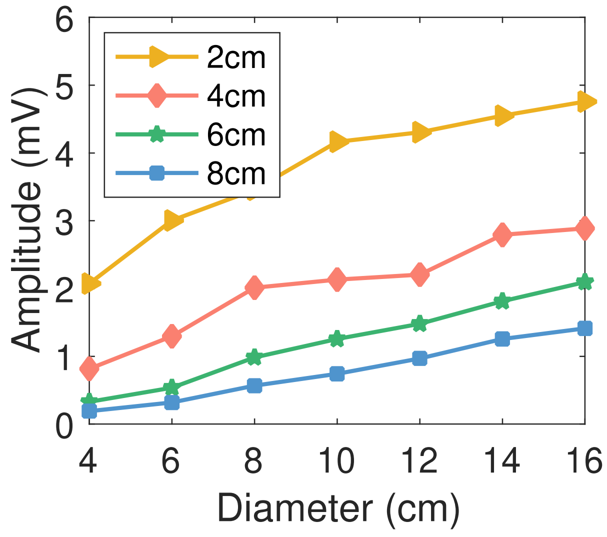
Coil Design

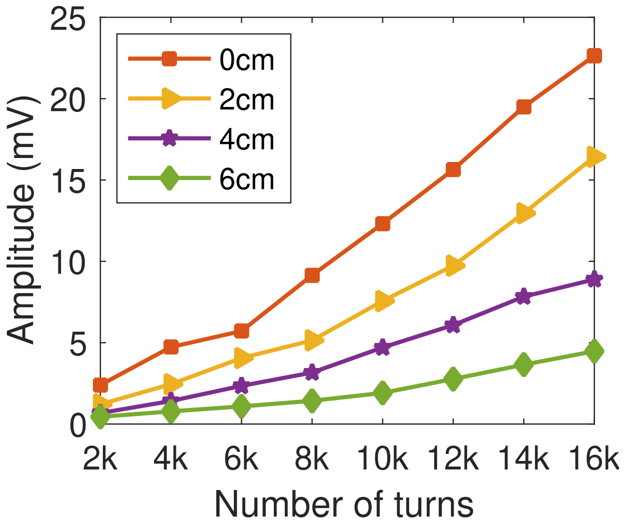
3. Geometric Size

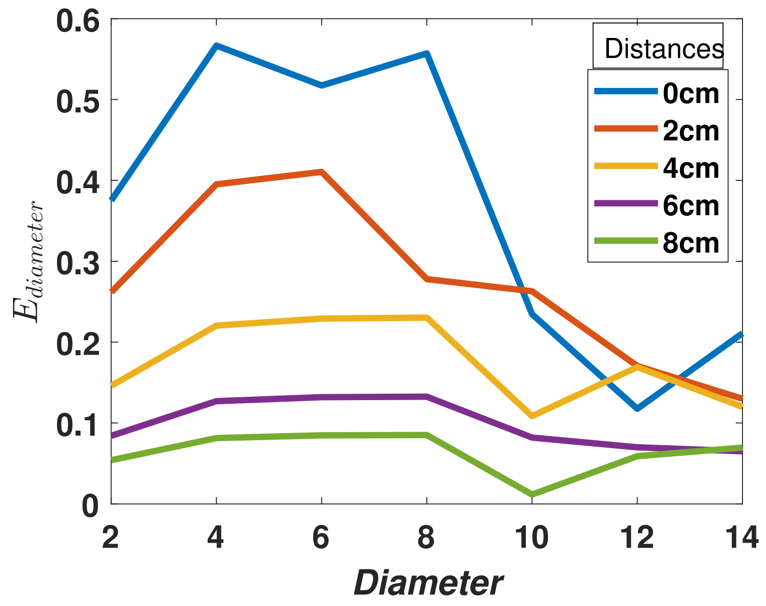
induced voltage $V_m = \frac{1}{2}\pi^2 f N D^2 B_m$

$$B + dB = B + \left(\left(\frac{1}{dD}\right)^3\right)^2 = B + \frac{1}{dD}$$

$$E_{diameter} = \frac{\Delta V}{\Delta D}$$







Coil Design

4. Sensitivity

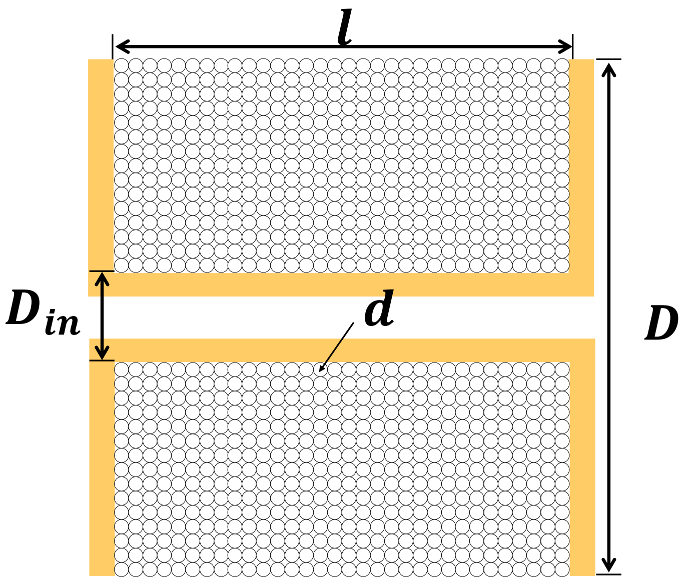
$$Sensitivity = \frac{Vm}{Bm} = \frac{\pi^2}{8}\frac{l(D - D_{in})(D + D_{in})^2}{kd^2}f$$

$$reach\ maxmimum\ when\ \boldsymbol{D_i/D = 1/3}$$

5. Signal-to-noise ratio

$$SNR = \frac{V_m}{V_T} = \frac{\pi^2 B_m f}{16k\sqrt{2k_B T\rho\Delta f}}\sqrt{l(D - D_{in})(D + D_{in})^3}$$

$$reach\ maxmimum\ when\ \boldsymbol{D_i/D = 1/2}$$



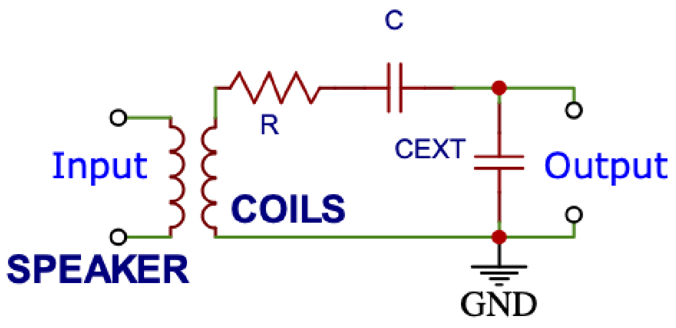
D: outer diameter
D_{in}: inner diameter
l: coil height
d: wire diameter

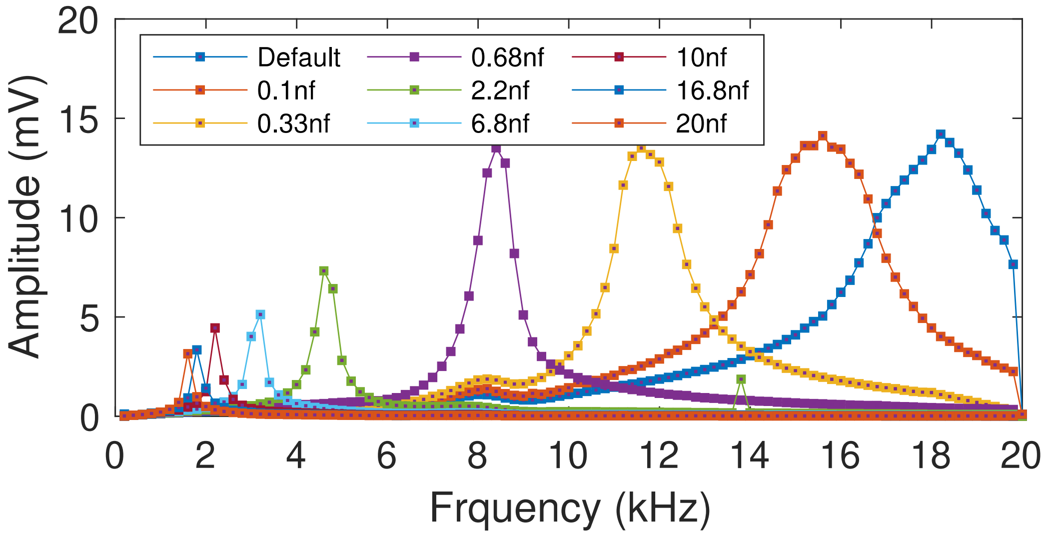
Feature Enhancement

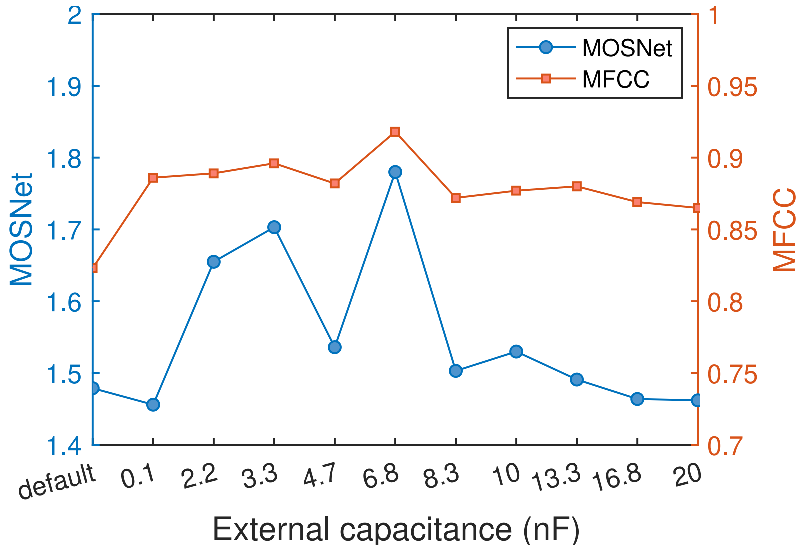
1. Frequency band Adjustment

resonant frequency $f_0 = \frac{1}{2\pi\sqrt{LC}}$

$$f_0 \propto \frac{1}{\sqrt{C_{EXT}}}$$



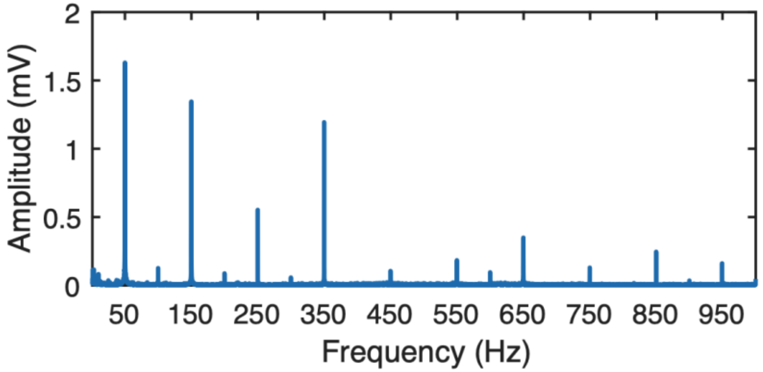


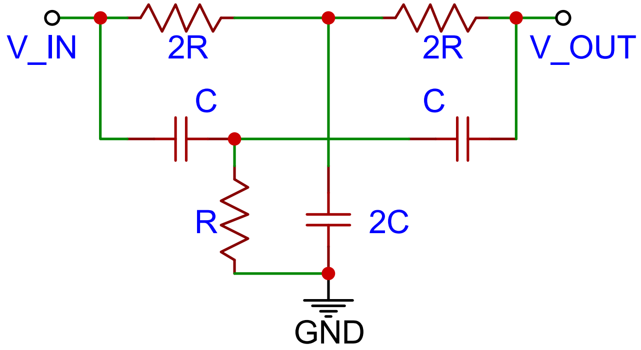


Feature Enhancement

2. Interference Confrontation

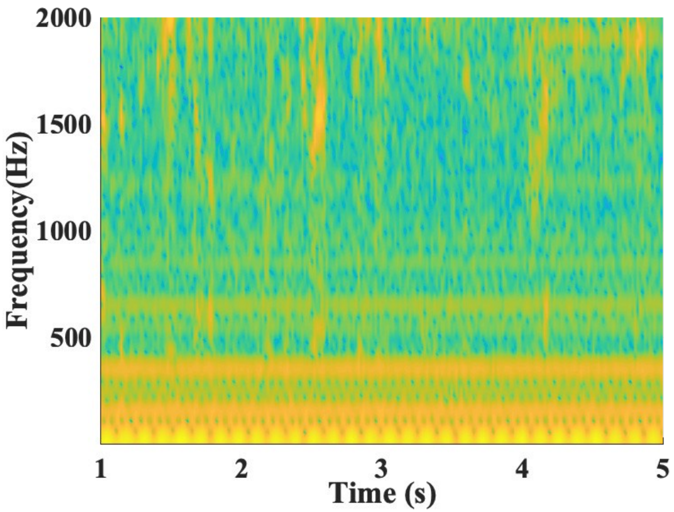
- notch filter

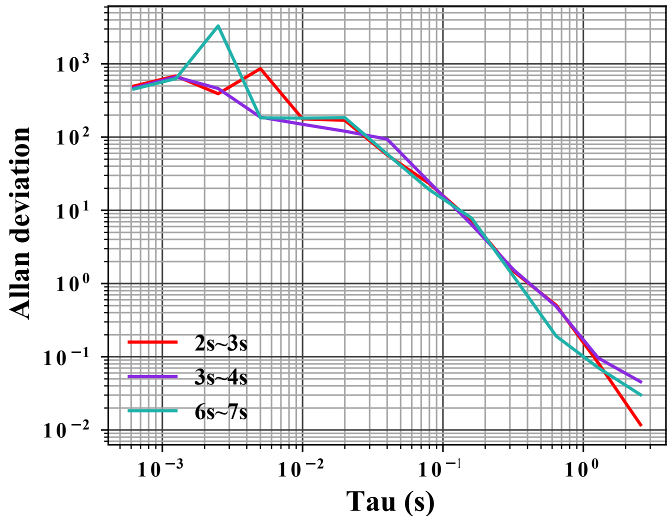




- spectral subtraction

$$|X(\omega)|^2 = \begin{cases} |Y(\omega)|^2 - \alpha|D(\omega)|^2 & |Y(\omega)|^2 > (\alpha+\beta)|D(\omega)|^2 \\ \beta|D(\omega)|^2 & else \end{cases}$$

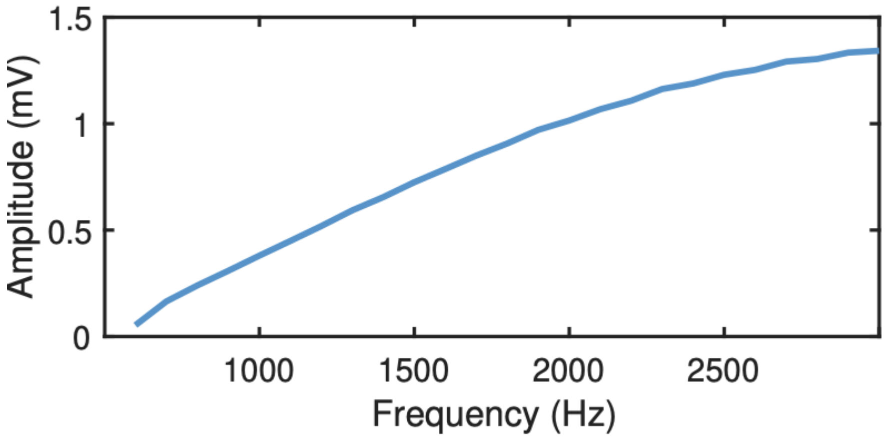


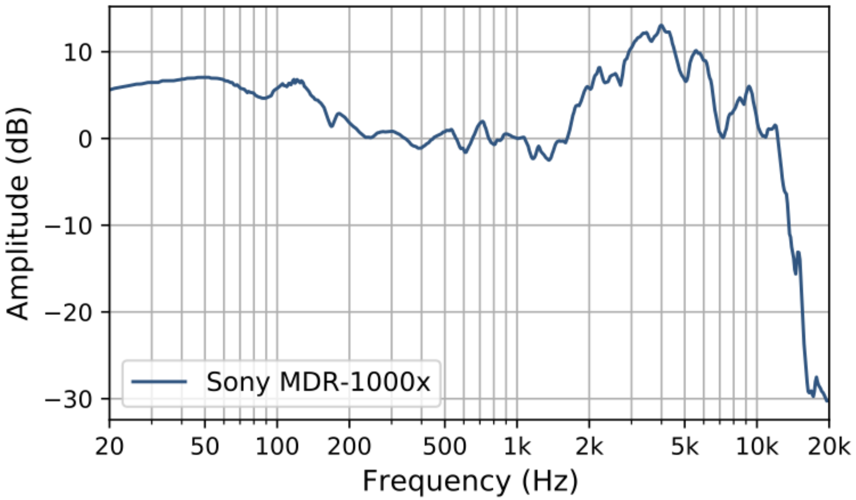


Feature Enhancement

3. Frequency Response Equalization

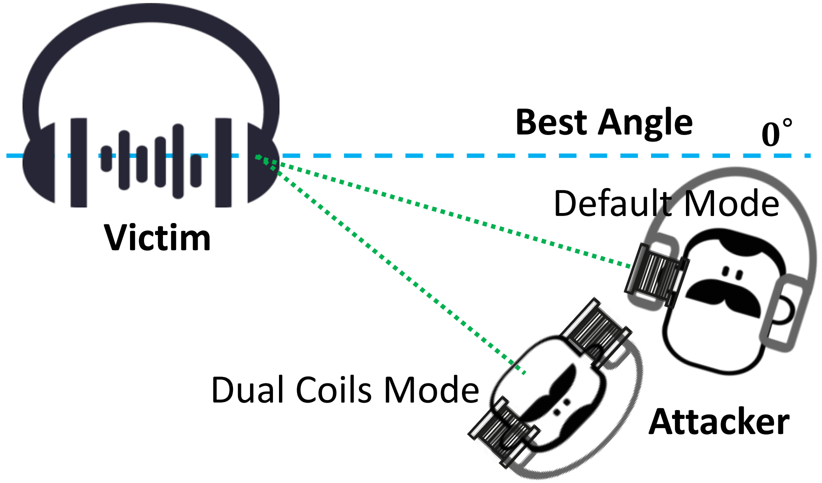
$$V = \omega NSI_{\max}\cos(\omega t + \varphi)$$

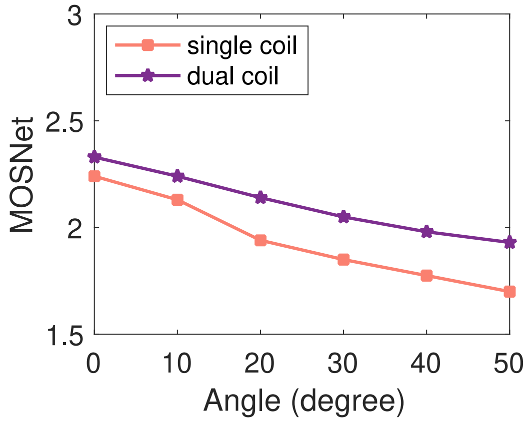




4. Angle Adjustment

Two coils mode





Receiver coil

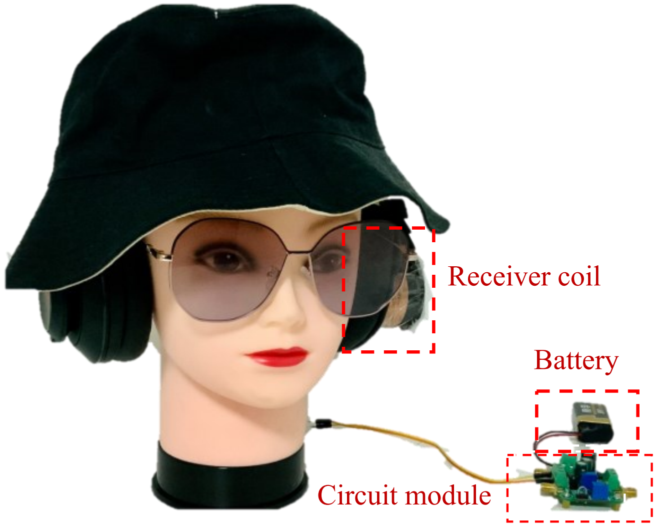
Evaluation - setup

Dataset

- English speech audio from LibriTTS

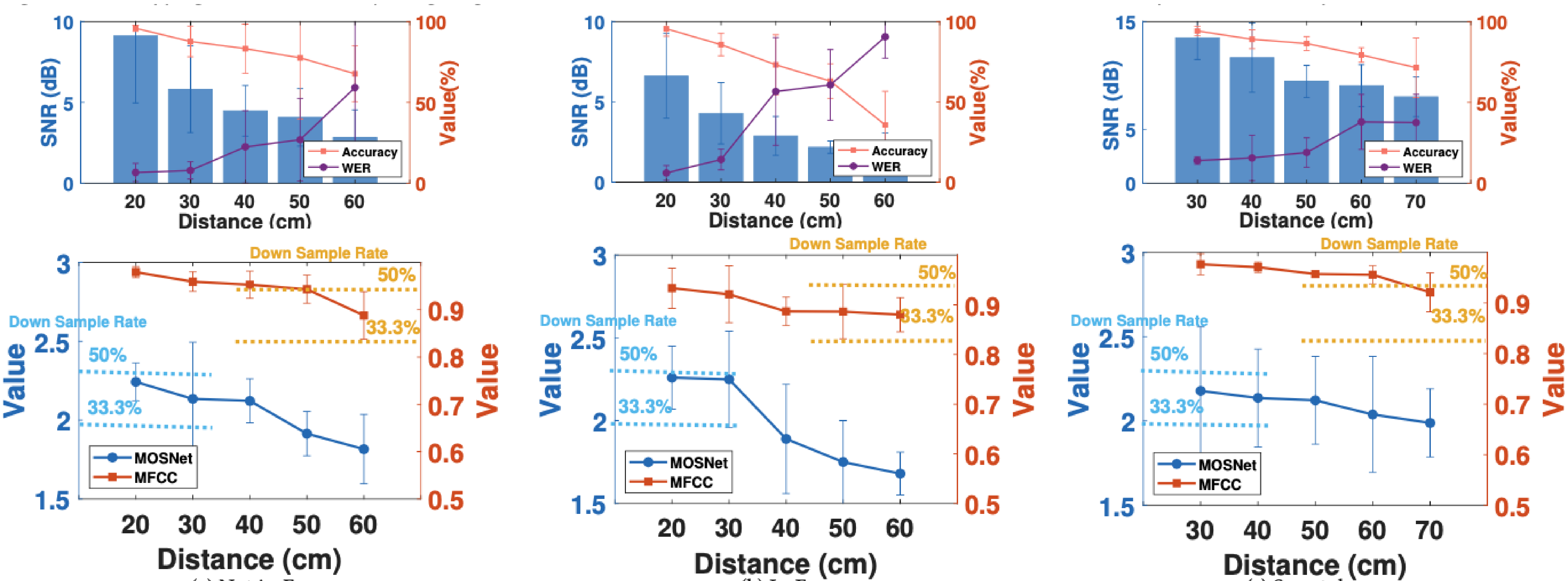
Speech metrics

- MFCC
- MOSNet
- Automatic speech recognition
  - Accuracy
  - Word Error Rate



Eavesdropping on different speakers

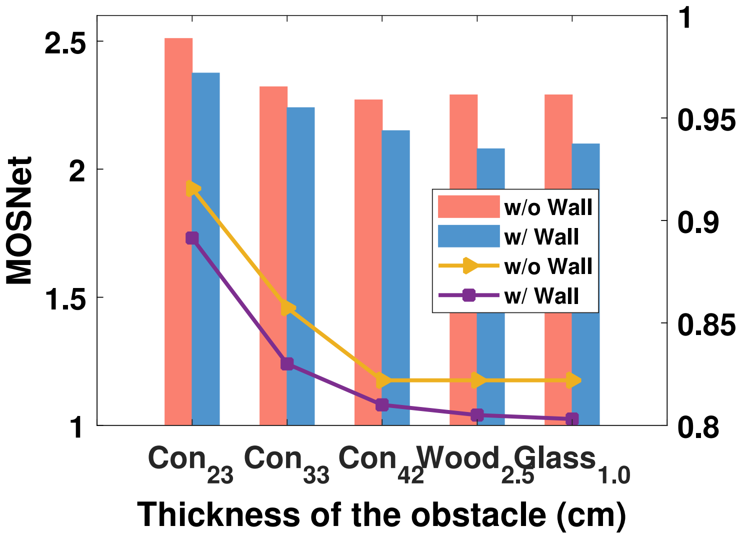
1. Performance in phone call eavesdropping with different distances between the speaker and MagEar.



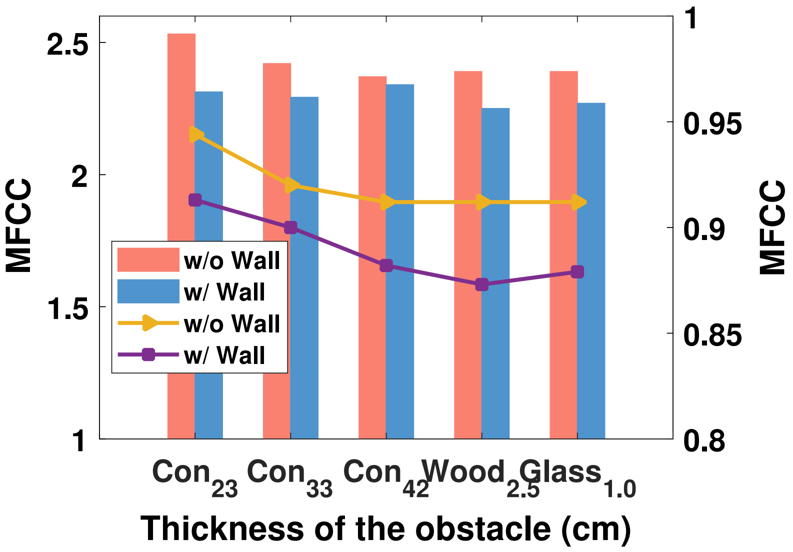
(a) Not in-Ear (b) In-Ear (c) Smartphone

Physical obstacles & Environments

2. Results of eavesdropping through various obstacles.



Airpods



Iphone

3. Eavesdropping performance in different environments .

	Airpods		Iphone	
Scenarios	MFCC	MOSNet	MFCC	MOSNet
Laboratory (49 dB)	0.85	1.86	0.88	1.92
Home (44 dB)	0.867	1.993	0.907	2.109
Park (52 dB)	0.89	1.928	0.95	2.2
Restaurant (66 dB)	0.82	1.52	0.84	1.78
Coffee Shop (60 dB)	0.83	1.6	0.87	1.98

Table 1: Eavesdropping performance in different environments for Airpods and the iPhone Xs (distance=40 cm)

Thank you for your listening!