Poster #7: Advanced Ultrasonic Jamming Technology for Privacy Protection: Dynamic Inter-modulation Modulation (DIM)

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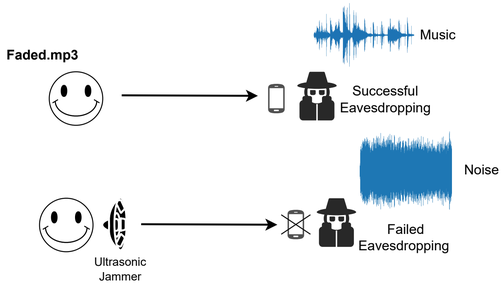
Abstract

✳ We proposed a novel **Dynamic Inter-modulation Modulation (DIM)** algorithm combats unauthorized audio surveillance by generating complex harmonic patterns.

✳ The DIM algorithm demonstrates enhanced efficacy over traditional fixed-frequency jammers, disrupting a **wide range** of microphone technologies.

Motivation

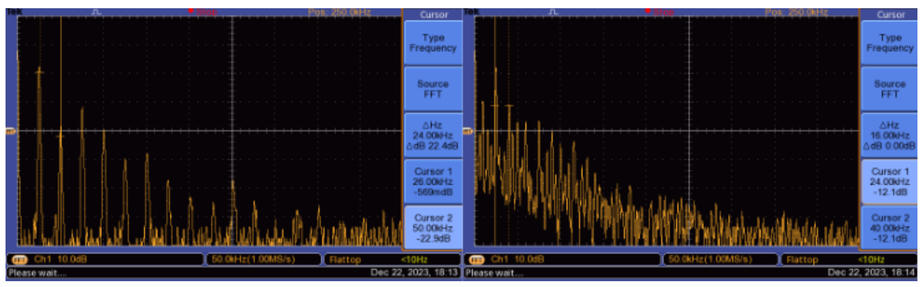
- DIM algorithm aims to create mutable and complex frequency patterns to counter sophisticated eavesdropping [1].
- With advanced nonlinear acoustic effects, we craft more effective countermeasures against AI-based signal processing to enhance eavesdropping protection [2], as shown in figure below.



Anti-eavesdropping via Ultrasonic Jammer

Jamming Effects

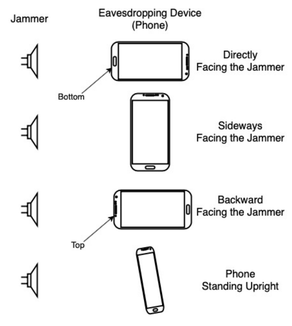
- Here illustrates the responses captured by the oscilloscope between the fixed frequency intermodulation algorithm and the DIM algorithm.
- As shown, the DIM exhibits more complex and stronger energy components at the baseband, resulting in more effective interference.



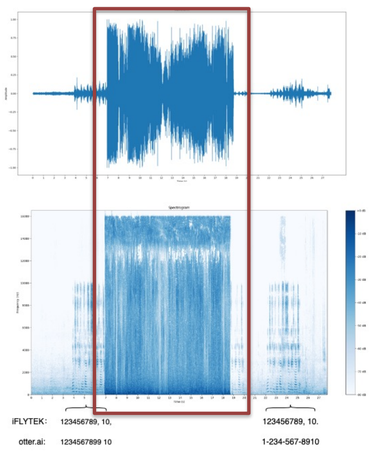
Fixed Frequency Intermodulation V.S. DIM
Testing microphone model: MEMs ADMP 401

DIM Jammer V.S. Commercial Jammer with Different STT(Speech-to-text) Models

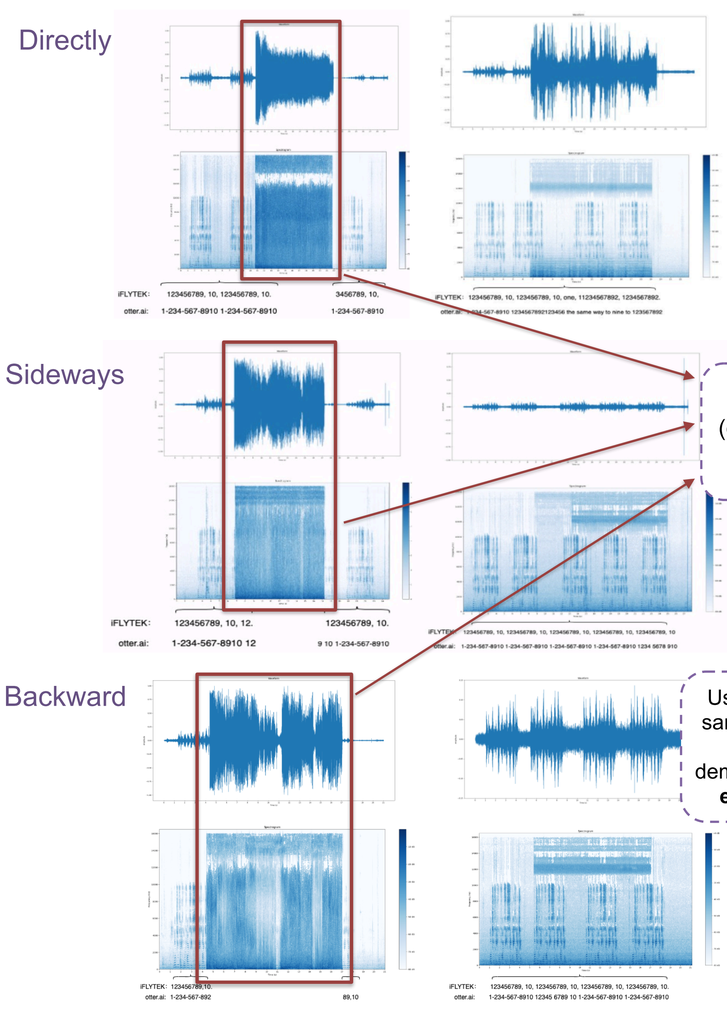
Left : Our Jammer
Right: Commercial one



Test with Different angles



Phone Standing Upright

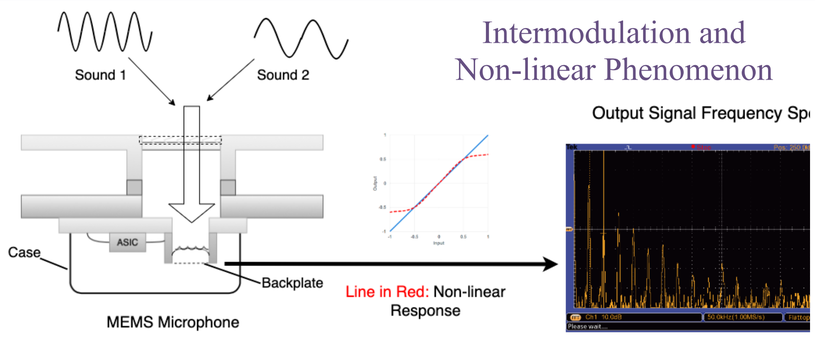


- We utilize two AI speech-to-text (STT) models, **iFLYTEK** and **Otter.ai**, to transcribe audio under various conditions.
- The background audio consistently features a repeating sequence of numbers from '**1 to 10**'.

As depicted in the figures, when our jammer is activated (**components in the boxed area**), **neither** of the models can recognize the sound meaning.

Using **commercial jammer** under the same conditions, both STT models can still recognize the information, demonstrating that **our jammer is more effective at causing interference.**

DIM Algorithm



Intermodulation and Non-linear Phenomenon

✦ Non-linear phenomena occur because the interference signal frequency exceeds the microphone diaphragm's designed capture frequency, resulting in abnormal deformation

Non-linear Response : $S_{out} = A_1 S + A_2 S^2 + A_3 S^3 + \ldots + A_N S^N$

$$S_{out} = A_1(\cos(2\pi f_1 t) + \cos(2\pi f_2 t)) + A_2(1 + 0.5(\cos(2\pi 2 f_1 t) + \cos(2\pi 2 f_2 t)) + \cos(2\pi(f_1 + f_2)t) + \cos(2\pi(f_1 - f_2)t))$$

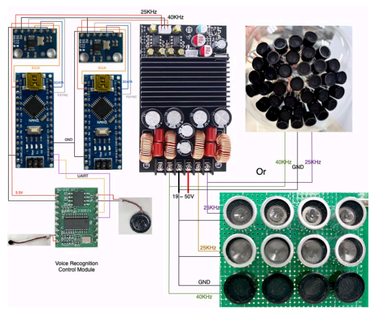
Two signals of different frequencies are combined

f_1 and f_2 are **dynamically** changing, resulting in the interference having **more complex** characteristics

(f_1 - f_2) represents the primary disruptive component in the baseband (20~20,000 Hz)

Implementation

✤ Here is our implementation of the **DIM** with a **spherical** microphone array, which supports voice-controlled interference modes.



Jammer Device Connection Diagram

Ethical Considerations

- Verify the legality of ultrasonic jammers in your jurisdiction, ensuring all operations are authorized and comply with relevant regulations.
- Respect and protect individual privacy rights, informing all affected parties about the use and intentions of the ultrasonic jamming devices.

Demonstration

All audio results, spectral figures and draft poster are available for viewing at the following link: https://github.com/Moriartysherry/Ultrasonic_Jammer .

Reference:
[1] P. Huang, Y. Wei, P. Cheng, Z. Ba, L. Lu, F. Lin, F. Zhang, and K. Ren, "InfoMasker: Preventing Eavesdropping Using Phoneme-Based Noise," in Proc. NDSS, 2023.
[2] Y. Chen, H. Li, S. Nagels, Z. Li, P. Lopes, B. Y. Zhao, and H. Zheng, "Understanding the Effectiveness of Ultrasonic Microphone Jammer," arXiv preprint arXiv:1904.08490, 2019.