Demo: Riding the Non-linearities to Record Ultrasound with Smartphones

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ABSTRACT

We demonstrate that high frequency ultrasonic sounds can be designed to become recordable by unmodified smartphone microphones, while remaining inaudible to humans. The core idea lies in exploiting non-linearities in microphone hardware with a combination of ultrasound frequencies. These frequencies can be regulated to carry data bits, thereby enabling an acoustic (but inaudible) communication channel to today's microphones. Other applications include jamming spy microphones in the environment, live watermarking of music in a concert, and even acoustic Denial-of-Service (DoS) attacks.

System Overview

Microphones, like human ears, operate at audible frequencies, hence cannot record ultrasonic sounds (>24kHz). *BackDoor* [1] shows the possibility of designing ultrasonic signals that humans cannot hear but microphones can record. The core intuition is to exploit the inherent non-linearities in the diaphragm and the amplifiers of the microphones. *BackDoor* generates a set of carefully modulated frequencies, which, due to these non-linearities, produces predictable "*shadow*" frequencies within the recordable range of the microphone. In the simplest case, *BackDoor* plays two tones at say 40kHz and 50kHz. When these tones arrive together at the microphone's power amplifier, they are amplified as expected, but also multiplied due to fundamental non-linearities in the system. Multiplication of frequencies f_1 and f_2 result in frequency components at $(f_1 - f_2)$ and $(f_1 + f_2)$. Given that $(f_1 - f_2)$ is 10kHz in this case, well within the microphone's range, the signal passes unaltered through the low pass filter (LPF). Human ears, on the other hand, do not exhibit such non-linearities and the 40kHz and 50kHz sounds remain inaudible. Figure 1 illustrates the effect. Importantly, the microphone does not require any modification, enabling billions of phones, laptops, and IoT devices to leverage the capability. This opens new applications in security and communications.

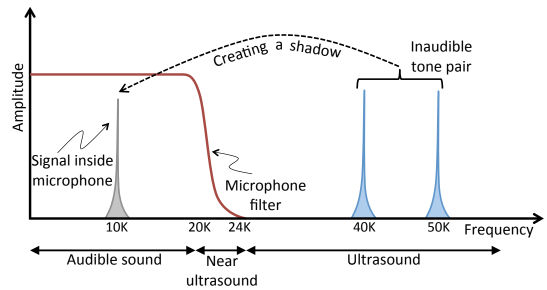

Figure 1: The main idea underlying *BackDoor*.

Given microphones record these inaudible sounds, it should be possible to silently jam spy microphones from recording. Military and government officials can secure private and confidential meetings from electronic eavesdropping; cinemas and concerts can prevent unauthorized recording of movies and live performances. On the other hand, *BackDoor* can utilize the entire microphone spectrum for inaudible acoustic communication that enables an alternative channel for the IoT devices. In this demonstration we explain the core intuitions behind *BackDoor* and show its initial prototypes.

Demonstration

We develop three different transmitter prototypes – (1) a pair of fixed frequency tone generators to demonstrate the nonlinearity in microphones, (2) a frequency modulated (FM) transmitter setup for communication, and (3) a speaker array for jamming. A programmable waveform generator drives the speakers with frequency modulated signals. The audience can receive BackDoor signals on their smartphones to experience the inaudible jamming effect. We have also developed an android application to demonstrate the communication prototype.

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1. REFERENCES

[1] Roy, N., Hassanieh, H., and Roy Choudhury, R. Backdoor: Making microphones hear inaudible sounds. In *Proceeding of the 15th annual international conference on Mobile systems, applications, and services* (2017), ACM.

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