Ripple: Communicating through Physical Vibrations

Nirupam Roy, Mahanth Gowda, Romit Roy Choudhury

University of Illinois at Urbana-Champaign
Vibration Motor

Accelerometer
Radio-Frequency

Optical

Vibratory Communication through Solids

Acoustic

Magnetic
Radio-Frequency Optical

Vibratory through Solids

Acoustic Magnetic

Why do we care?
Applications: Mobile Money Transfer
Applications: Mobile Money Transfer
Applications: Authentication with Ring
Applications: Authentication with Ring

Vibratory Passcode Detected
Applications: Authentication with Ring
Applications: Body-Area Network
Again, we don’t know the killer-app.
Morse-code  Single-Carrier  Multi-Carrier  Multi-dimension  Phy-Security

Regulated Input

Vibration Braking
Morse-code  Single-Carrier  Multi-Carrier  Multi-dimensional  Phy-Security
Morse-code  Single-Carrier  Multi-Carrier  Multi-dimension  Phy-Security

0  30  60  90  120 ms

100 Hz

200 Hz

300 Hz
Morse-code + Single-Carrier + Multi-Carrier + Multi-dimension Phy-Security

...
Morse-code  Single-Carrier  Multi-Carrier  Multi-dimension  Phy-Security
Morse-code  Single-Carrier  Multi-Carrier  Multi-dimension  Phy-Security
Morse-code  Single-Carrier  Multi-Carrier  Multi-dimension  Phy-Security

Phase lag  Spilled signal
Morse-code  Single-Carrier  Multi-Carrier  Multi-dimension  Phy-Security

Y signal

Y-axis

Y spill

Z-axis
Y signal

Z spill

2h

Z signal

Y spill

2h

Y-Axis

Z-Axis

h

2h

Z spill

Y signal

2h

Y-Axis

h

4h

2h

Scaled Y signal

2 \times 2 =
Morse-code  Single-Carrier  Multi-Carrier  Multi-dimension  Phy-Security

Y signal

2h

Z spill

h

2h

Z signal

Y spill

Y-Axis

h \otimes 2 = 4h

Y signal

Scaled Y signal

4h

2h

Z-Axis

Y-Axis

\oplus

Z signal

Z-Axis

\oplus
Morse-code  Single-Carrier  Multi-Carrier  Multi-dimension  Phy-Security

Y signal

2h

Z spill

Y-Axis

h ⋆ 2 = 4h

Z signal

2h

Z spill

Y-Axis

h

Y spill

Z-Axis

Scaled Y signal

Interference free

Y signal

3h
Physical Layer Security
Morse-code Single-Carrier Multi-Carrier Multi-dimension Phy-Security

Correlated
Morse-code  Single-Carrier  Multi-Carrier  Multi-dimension  Phy-Security

Vibration sound

Speaker sound
Audio Sample Buffer

Audio Clock

Morse-code
Single-Carrier
Multi-Carrier
Multi-dimension Phy-Security

S6  S5  S4  S3  S2  S1  S0
Morse-code  Single-Carrier  Multi-Carrier  Multi-dimension  Phy-Security

Vibration sound  Speaker sound

[Diagram showing waveforms for different sounds]
Morse-code  |  Single-Carrier  |  Multi-Carrier  |  Multi-dimension  |  Phy-Security

Anti-sound start

Vibration start

Frequency switch
Evaluation

Single-carrier

![Graph showing bit error rate vs. bit rate for different methods: Basic, Ripple, Ideal.](#)

![Heatmap showing transmitted symbol # vs. received symbol # with varying colors representing different values.](#)
Evaluation

Multi-carrier

![CDF Graph](image)

![Bit Error Rate vs. Carrier Frequency](image)
Summary

Vibratory Radio

Morse-code  Single-Carrier  Multi-Carrier  Multi-dimension  Phy-Security
Thank You

(SyNRRG Hardware Lab, UIUC)