RIPPLE

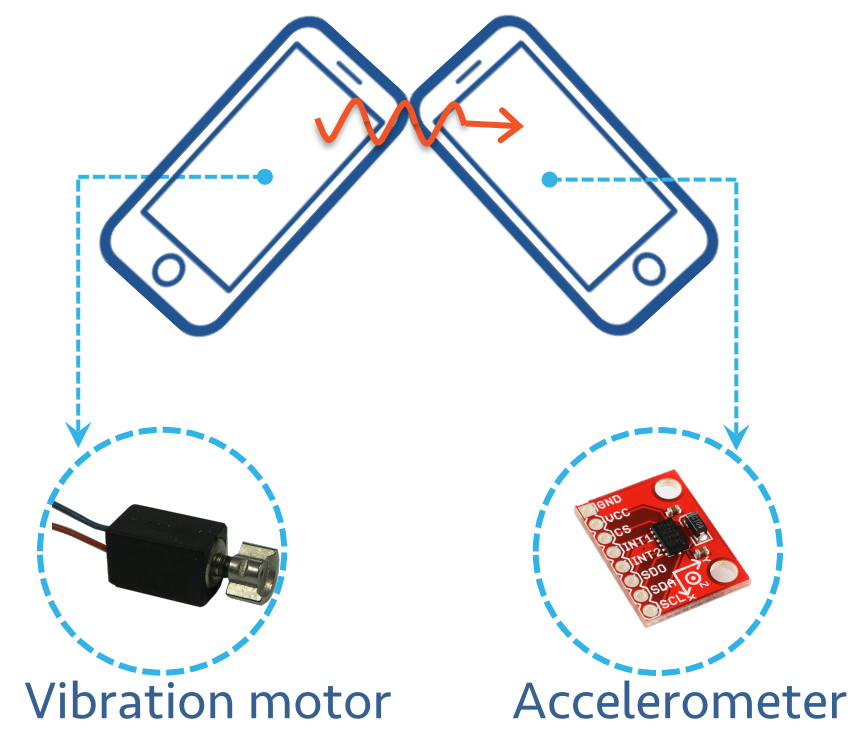# Vibration: A New Mode of Communication

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Short range: a new need

The advancement of sensors and mobile devices in the past decade has created the need of short range communication.
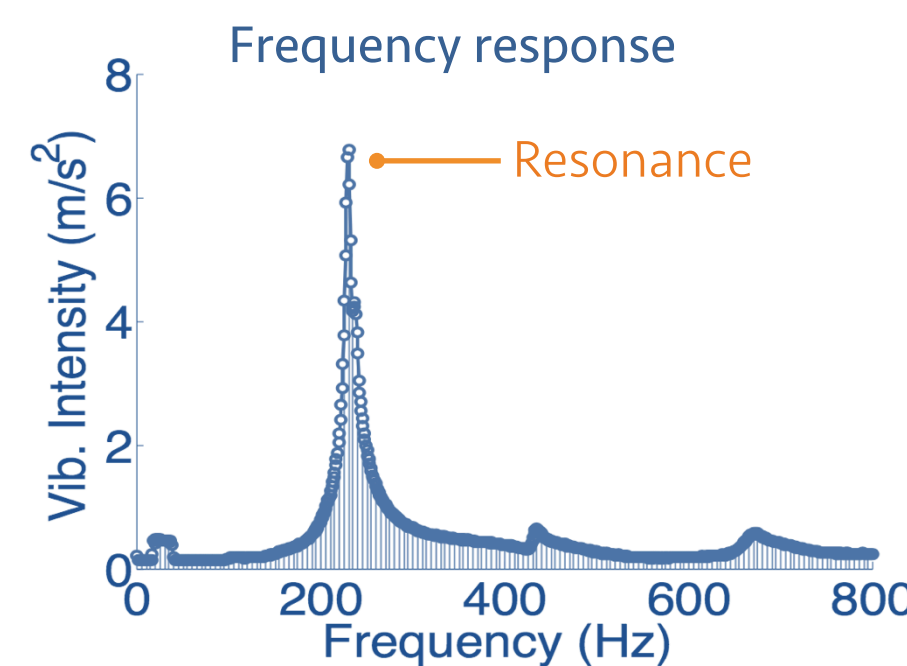
It also fuelled the search for new modes of communication that are appropriate for short range data exchange, in terms of usability, security, and power.

Visible Light   Acoustic NFC

We explore physical vibration for communication

Vibration motor   Accelerometer

Working principle

Voice coil   Magnetic mass
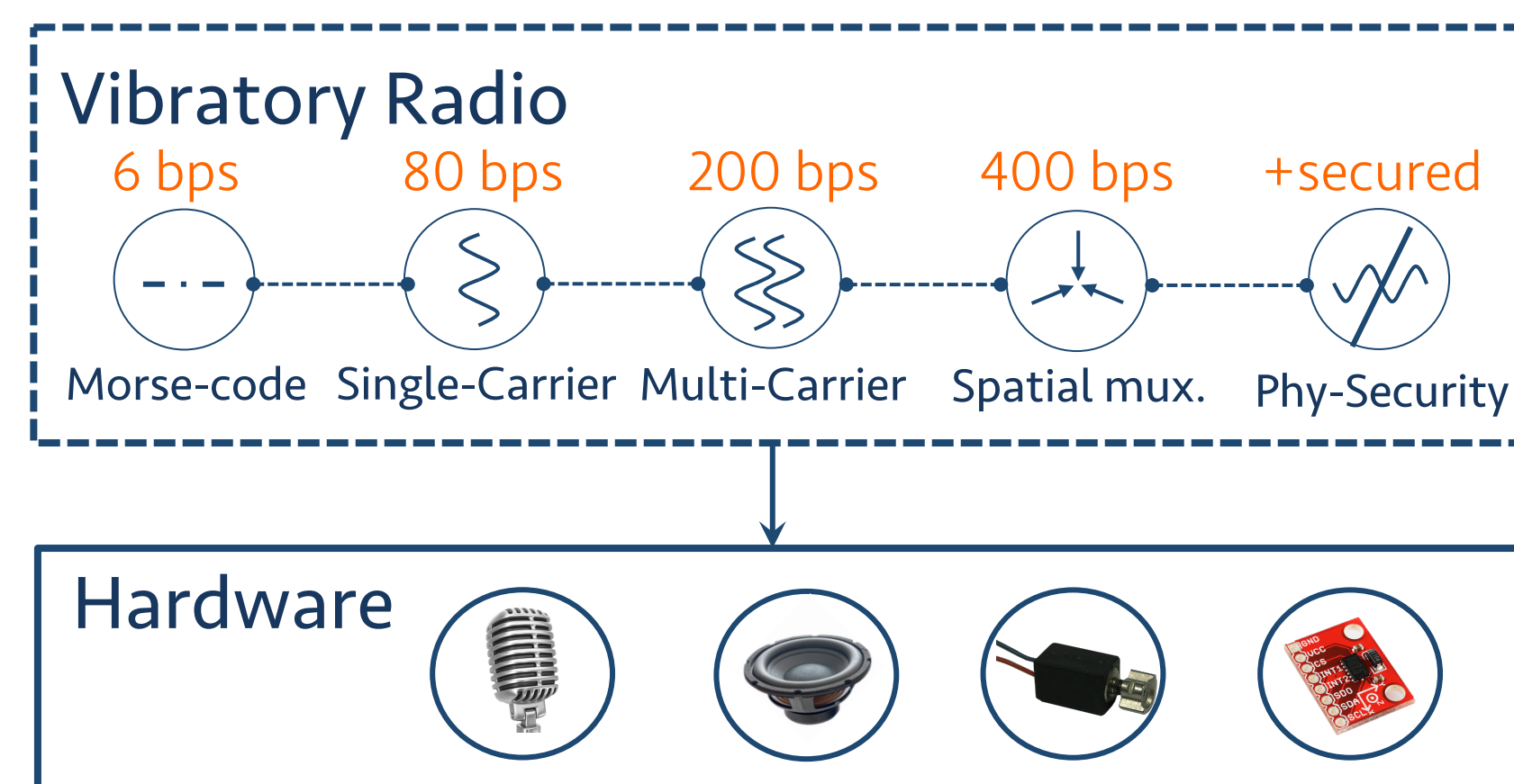
A vibration motor (also called "vibra-motor") is an electro-mechanical device that moves a metallic mass rhythmically around a neutral position to generate vibrations.

Frequency response

Resonance

Accelerometer as vibration sensor

Vibratory Radio

6 bps	80 bps	200 bps	400 bps	+secured
Morse-code	Single-Carrier	Multi-Carrier	Spatial mux.	Phy-Security

We develop Ripple, a system that achieves up to 400 bits/s of secure transmission. It implements multi-carrier modulation, orthogonal vibration division, vibration braking, and side-channel cancellation/ jamming.

Hardware

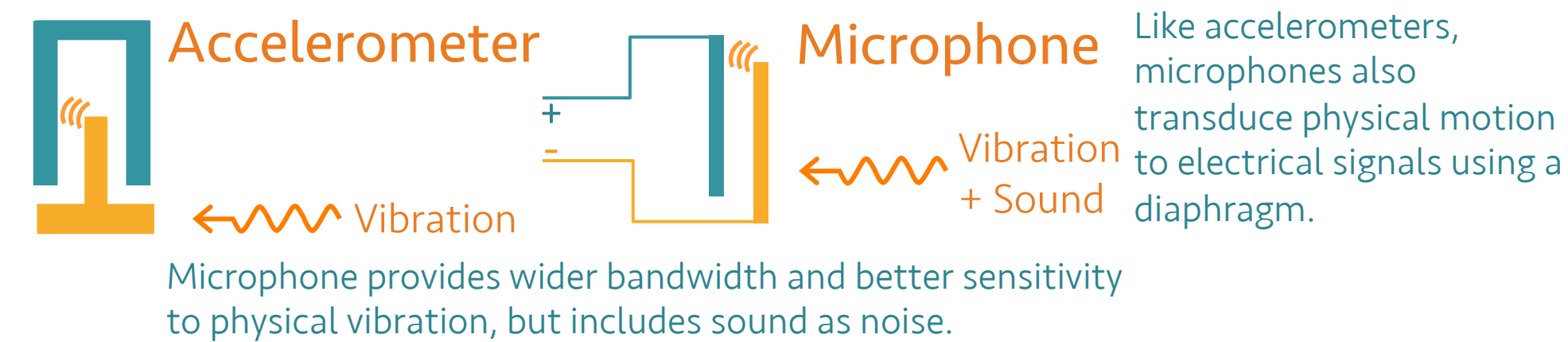## 32Kbps with vibration
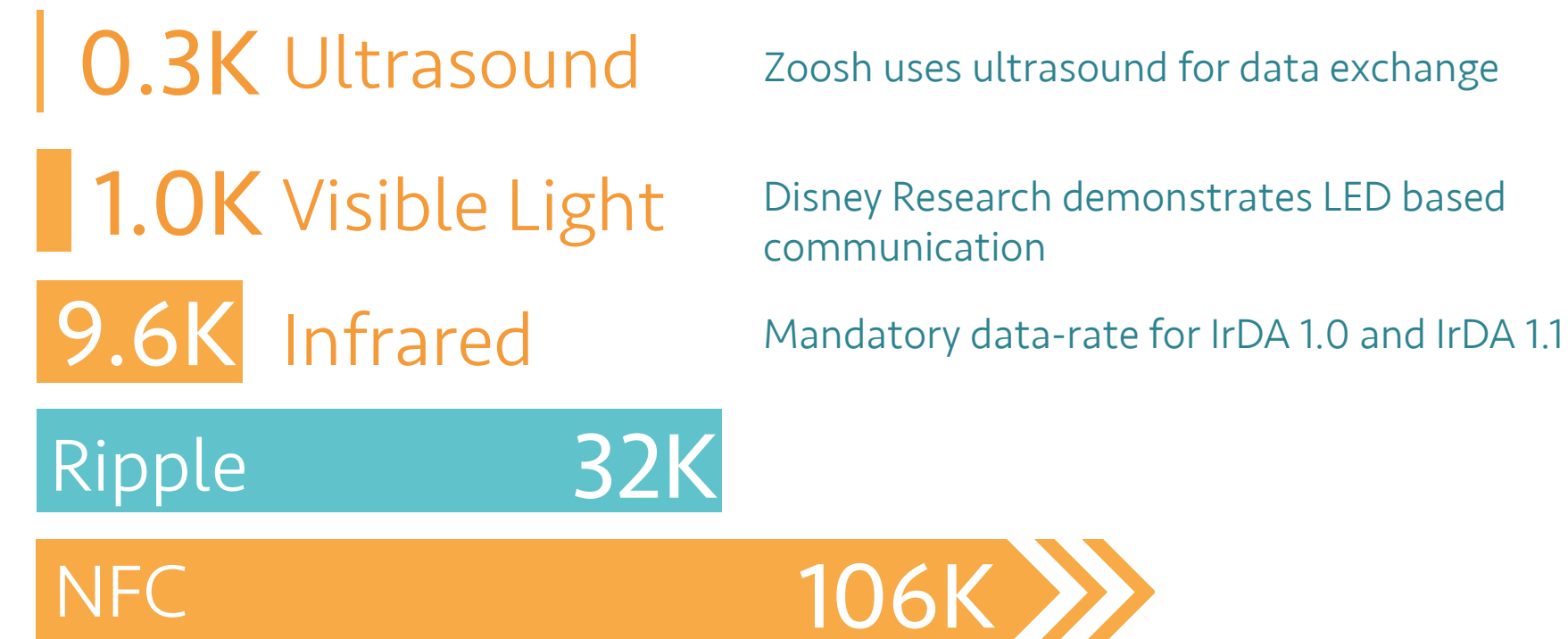
0.3K	Ultrasound	Zoosh uses ultrasound for data exchange
1.0K	Visible Light	Disney Research demonstrates LED based communication
9.6K	Infrared	Mandatory data-rate for IrDA 1.0 and IrDA 1.1
Ripple	32K	
NFC	106K	

PHY layer design

Microphone as vibration sensor

Accelerometer   Microphone

Vibration   Vibration + Sound

Like accelerometers, microphones also transduce physical motion to electrical signals using a diaphragm.

Microphone provides wider bandwidth and better sensitivity to physical vibration, but includes sound as noise.

Erroneous symbol detection

Vibration   Primary mic.

Sound   Secondary mic.

Frequency domain coefficients

Deconvolution & Thresholding

Erroneous coefficients

The erroneous OFDM symbol coefficients are identified using the static nature of the channel between the two microphones.

Deconvolution leads to constant value in error free cases.
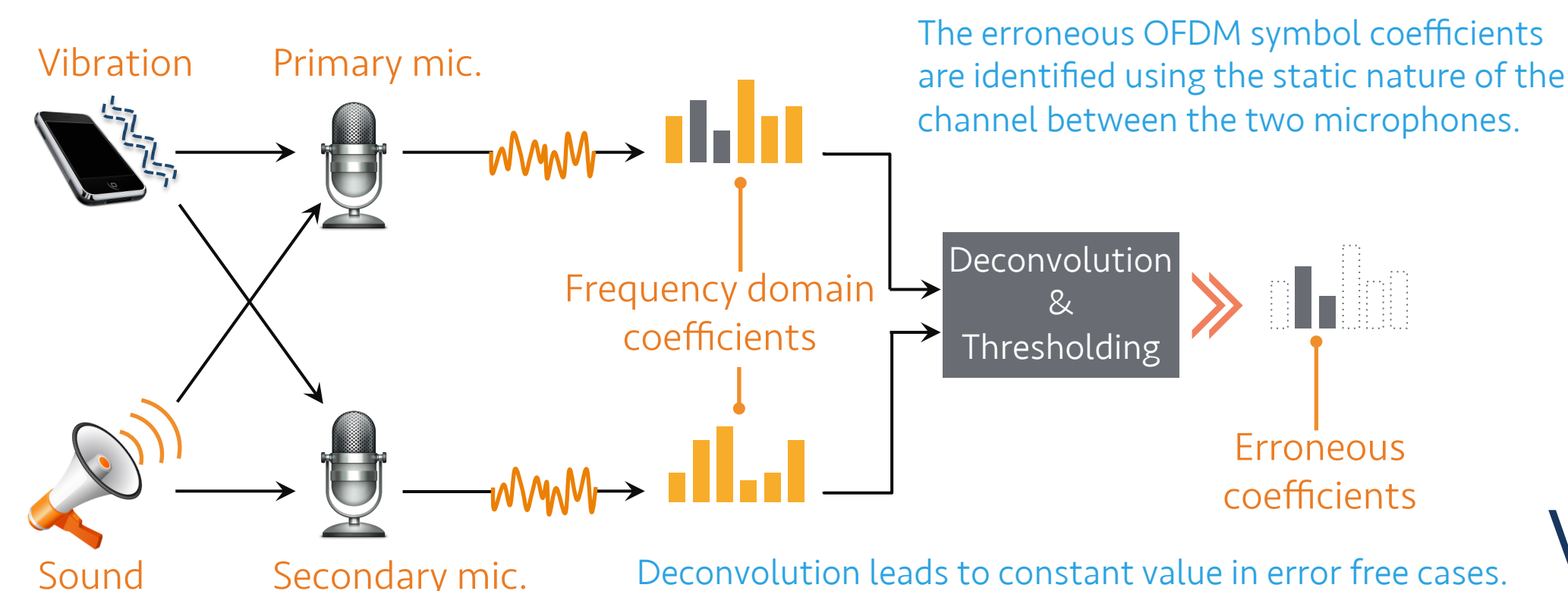
Adaptive symbol correction

Selected coefficients (primary mic.)

Adaptive Filter

Corrected coefficients

Selected coefficients (secondary mic.)

Only the erroneous coefficients from both the sensors are converted to the time domain and fed to the adaptive filter.
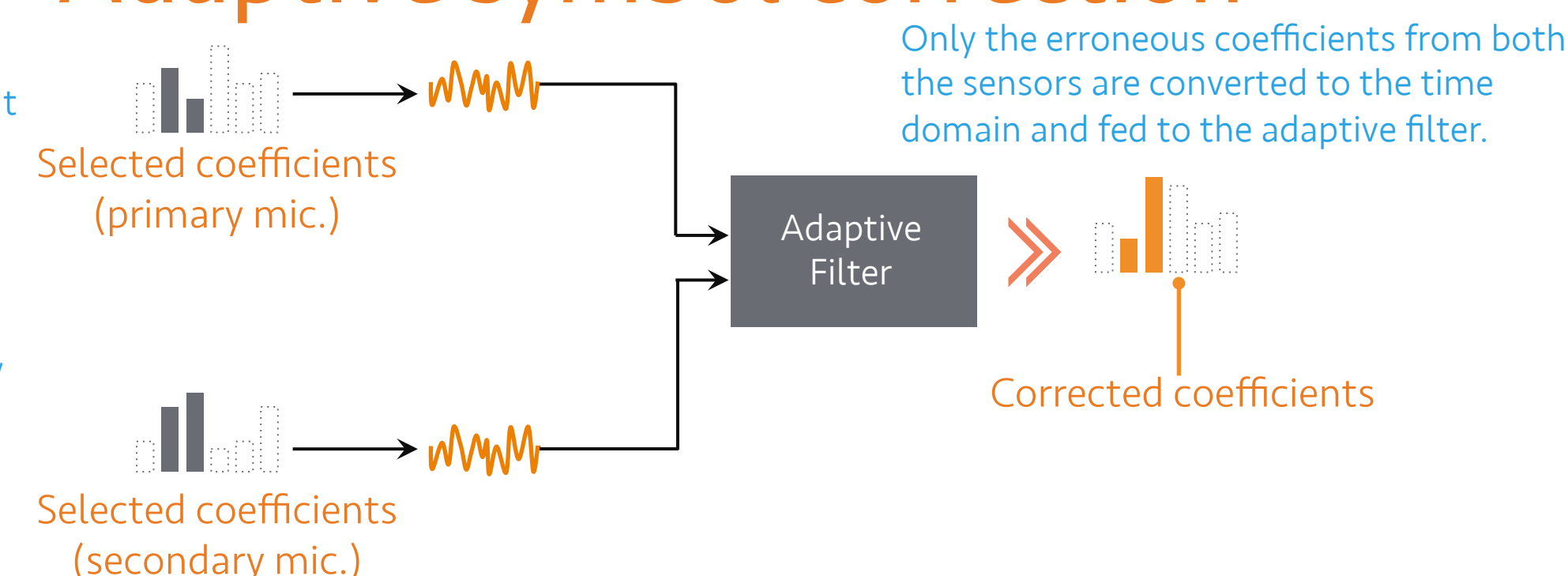
MAC layer design

Noise sensing with a motor

Ambient vibration and sound move the motor mass

Voltage from the relative motion between the coil and the magnetic mass

Back-EMF = Ambient noise
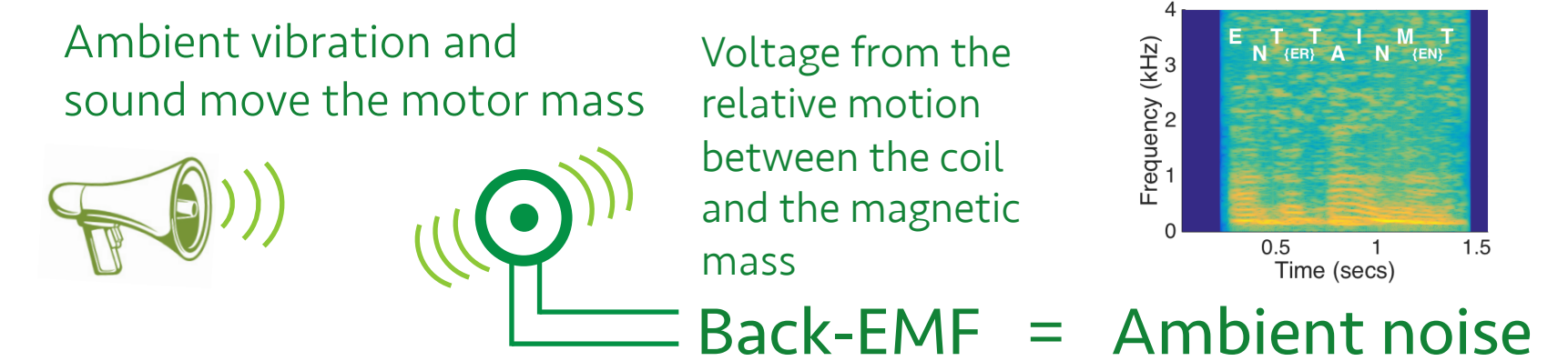
Please visit the page to listen to the voice recorded with vibration motor.:
http://synrg.csl.illinois.edu/vibraphone/

Corrupted symbol identification

An empirical threshold is used to predict the noise level and identify the corrupted symbol

| Symbol 07 | Symbol 06 | Symbol 05 | Symbol 04 | Symbol 03 | Symbol 02 | Symbol 01 |

| Symbol 06 | Symbol 05 |

| Symbol 02 |

| Symbol 09 | Symbol 08 | Symbol 06 | Symbol 05 | Symbol 02 | Symbol 07 |

OFDM symbols   corrupted symbols   Symbol retransmission

Only the selected symbols are scheduled for retransmission. The receiver identifies retransmission through implicit control signals.

Implicit flag for retransmitted symbols

Symbol 01   ol 01

Only half of the symbol is spread over the spectrum

Signal gets two identical parts in the time domain

Schmidl-Cox sync. algo.

A spike in the output indicates retransmitted symbol
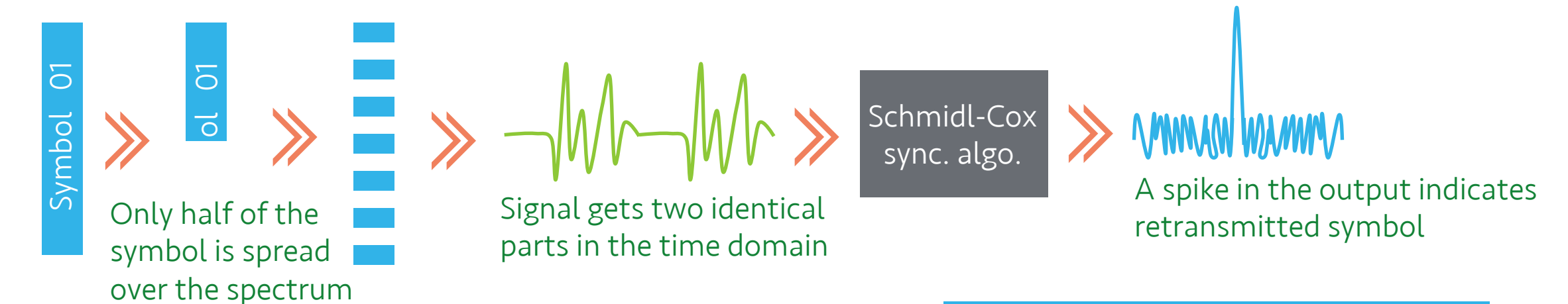
Vibrations do not broadcast

Unlike other modes, in principle vibratory communication does not broadcast the signal. Hence, it can be useful for some security sensitive applications.

Bone conduction

Vibration can travel through bone conduction. Users do not perceive the vibration if it is above 600Hz.

Demo

Please visit the project webpage for more information on Ripple and video demos:
http://synrg.csl.illinois.edu/ripple/