Acoustic Communication

Linard Arquint
ETH Zürich

Motivation

Image: Getty Images

Image: Getty Images

Background

Sound

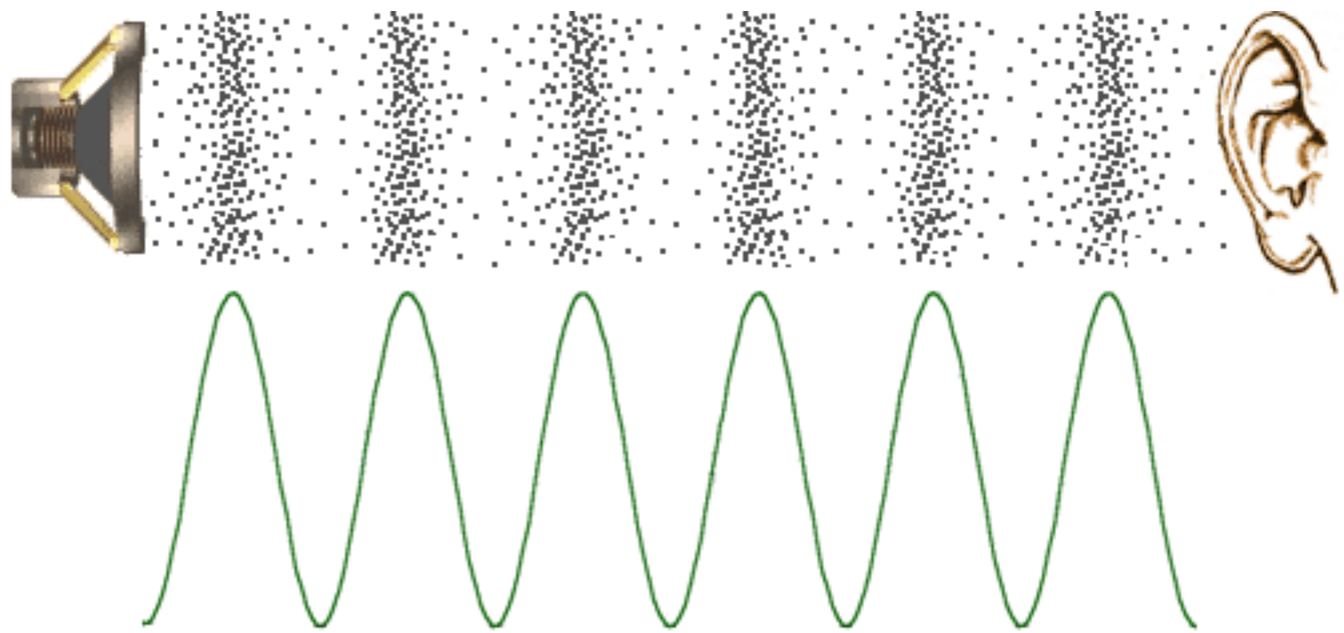


Image: https://www.mediacollege.com/audio/01/sound-waves.html

Capturing Sound

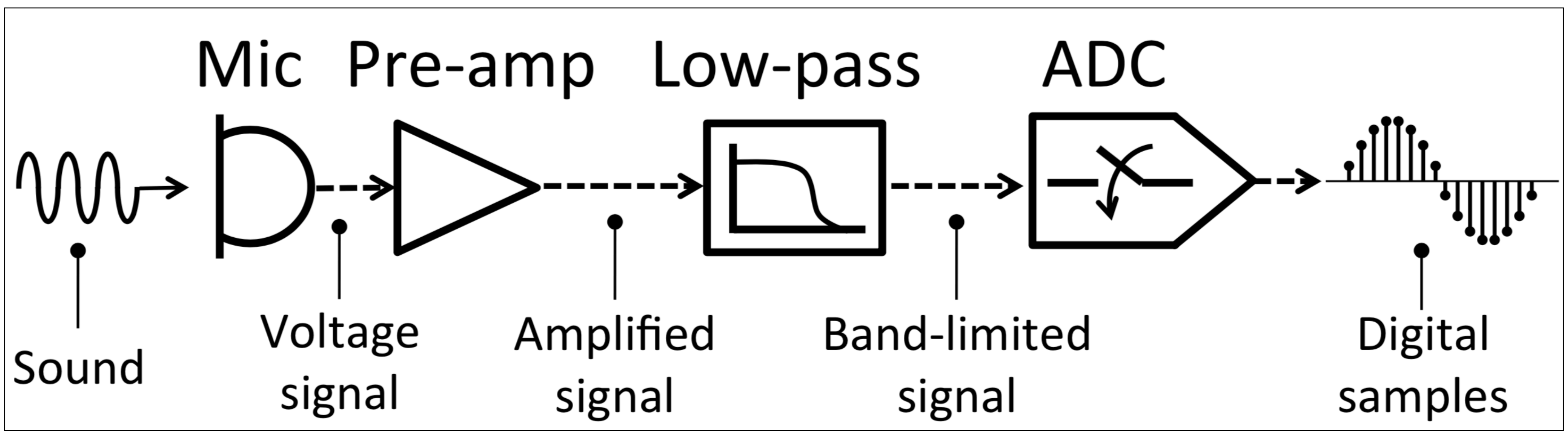
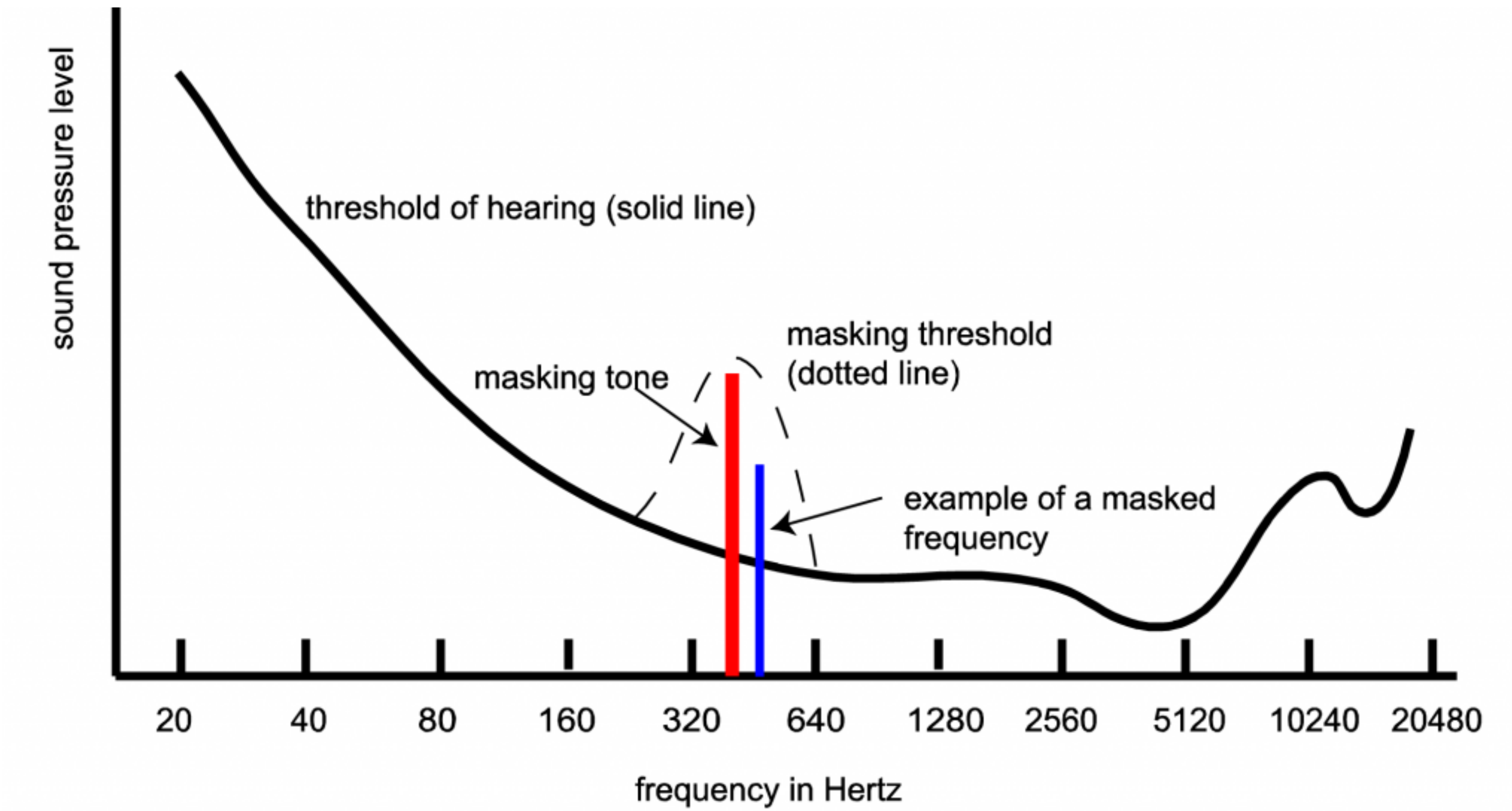


Image: BackDoor - Roy et al.

Human Auditory System

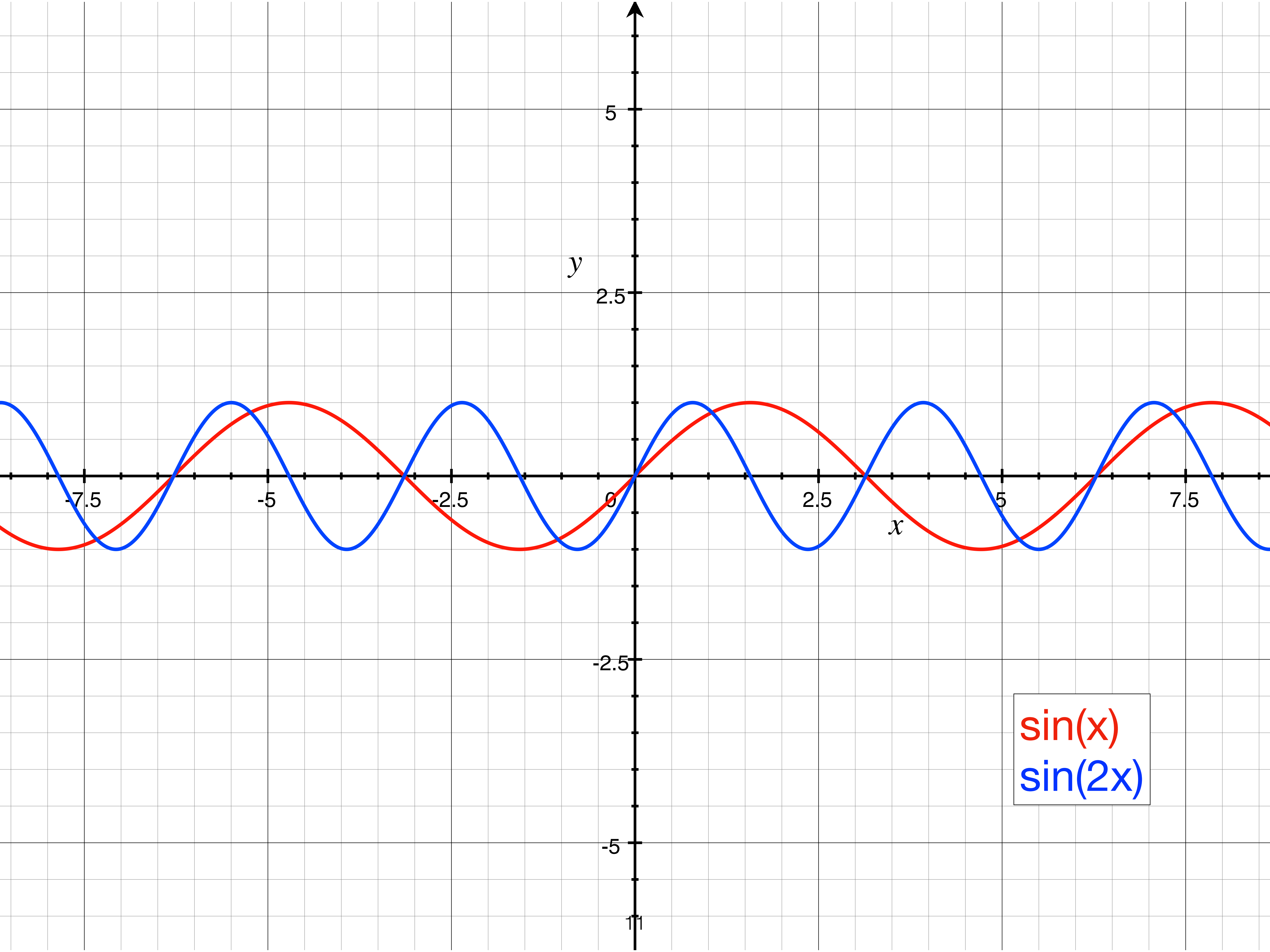
Frequency Masking

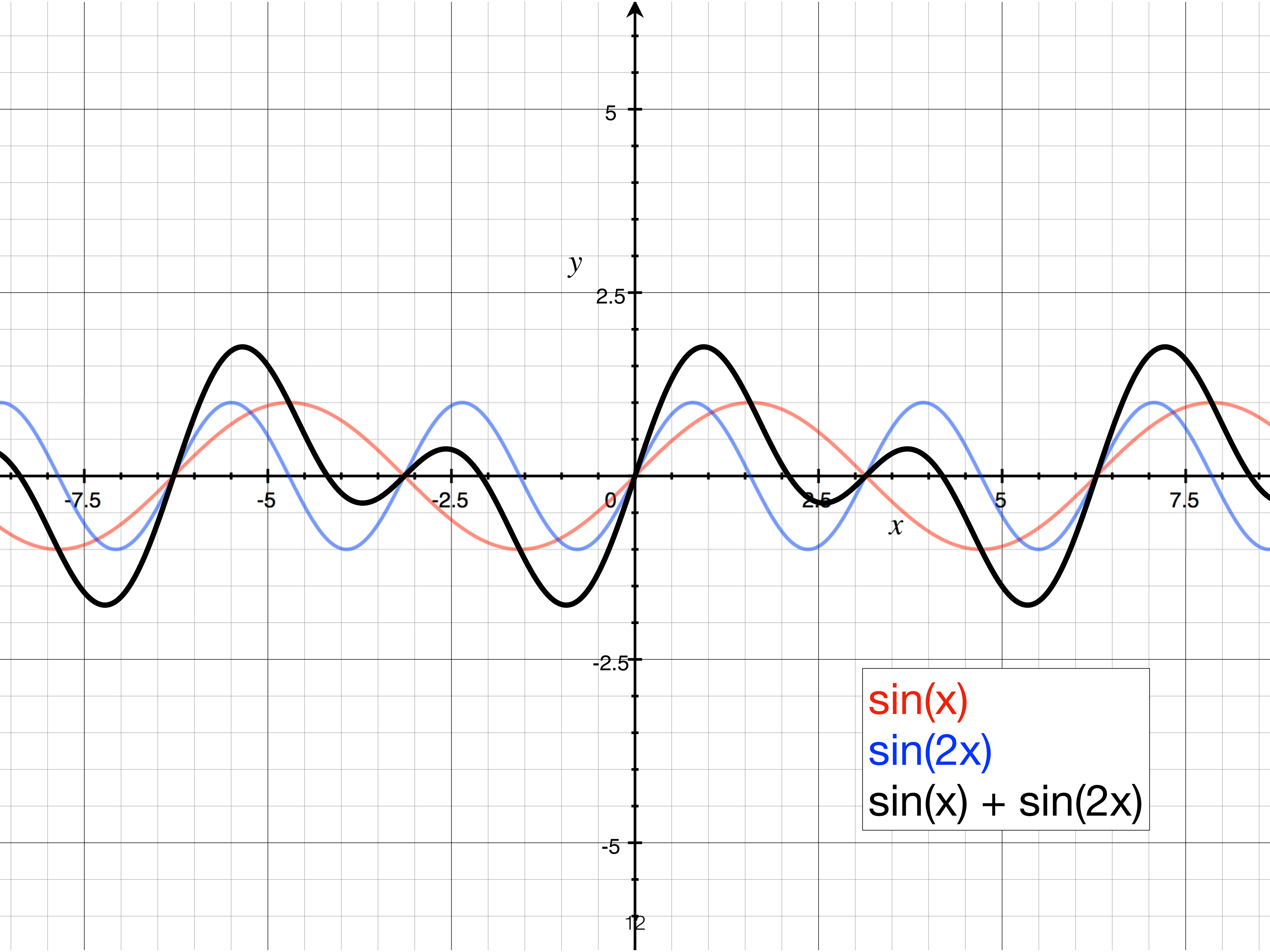


Audible up to 20 kHz

Image: http://digitalsoundandmusic.com/chapters/ch5/5-3/

Interference


y
x
5
2.5
-2.5
-5
-7.5
-5
-2.5
0
2.5
5
7.5
sin(x)
sin(2x)


y
5
2.5
-2.5
-5
x
-7.5
-5
-2.5
0
2.5
5
7.5
sin(x)
sin(2x)
sin(x) + sin(2x)

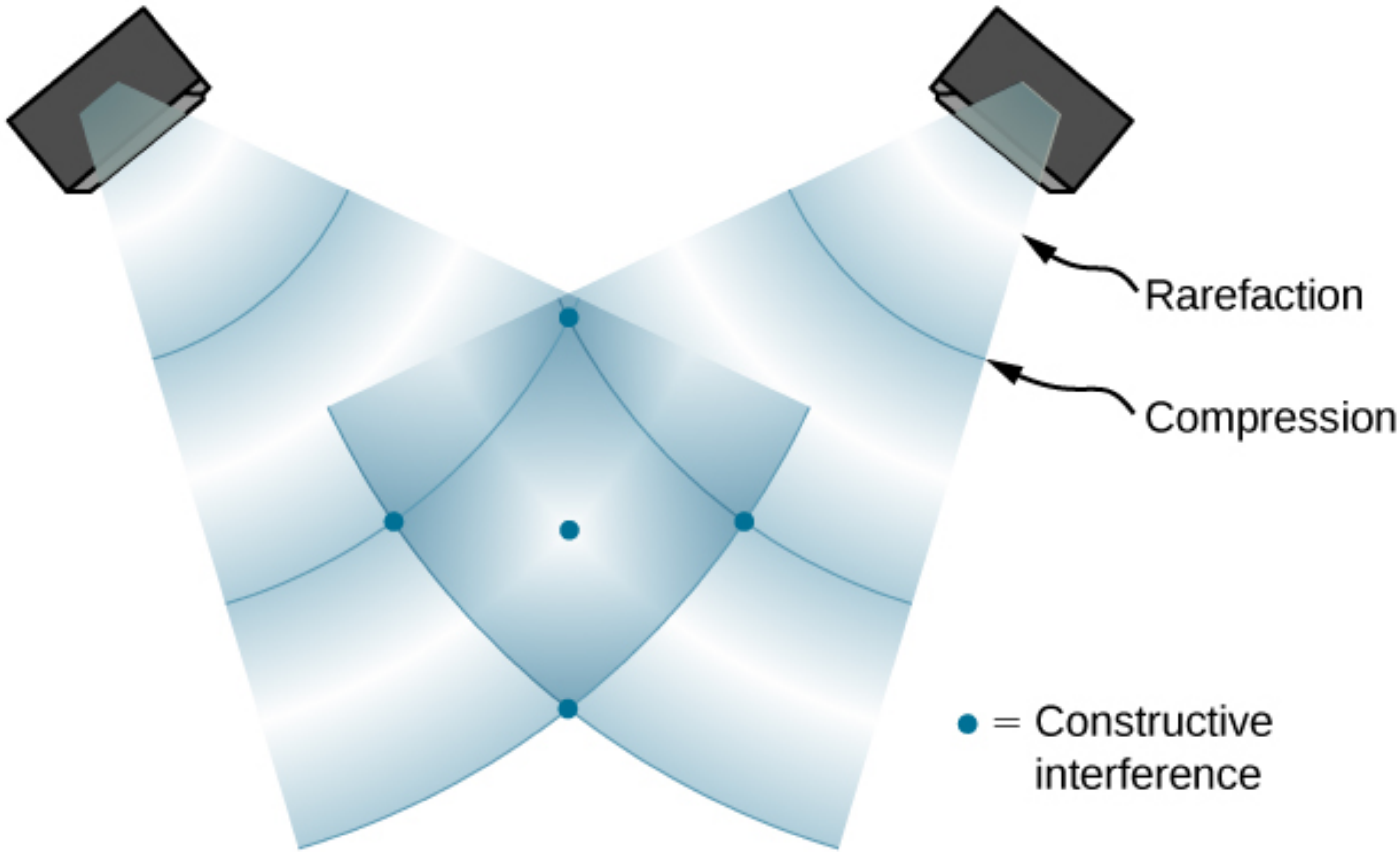


Image: http://www.quizover.com/ocw/mirror/col12031/m58378/CNX_UPhysics_17_04_SpeakInt.jpg

Embedding Data

Amplitude Modulation

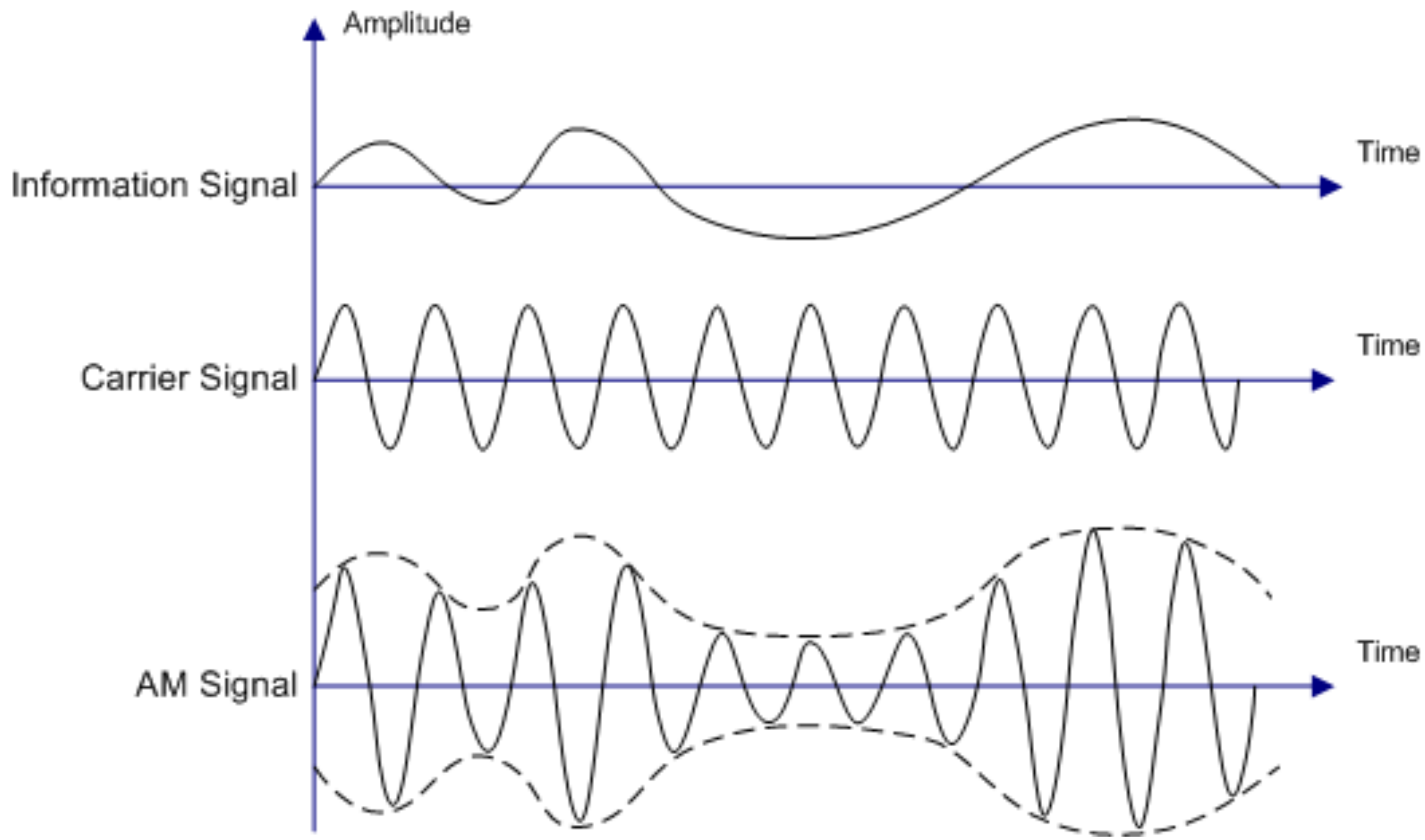


Image: https://en.wikipedia.org/wiki/Amplitude_modulation

Phase Modulation

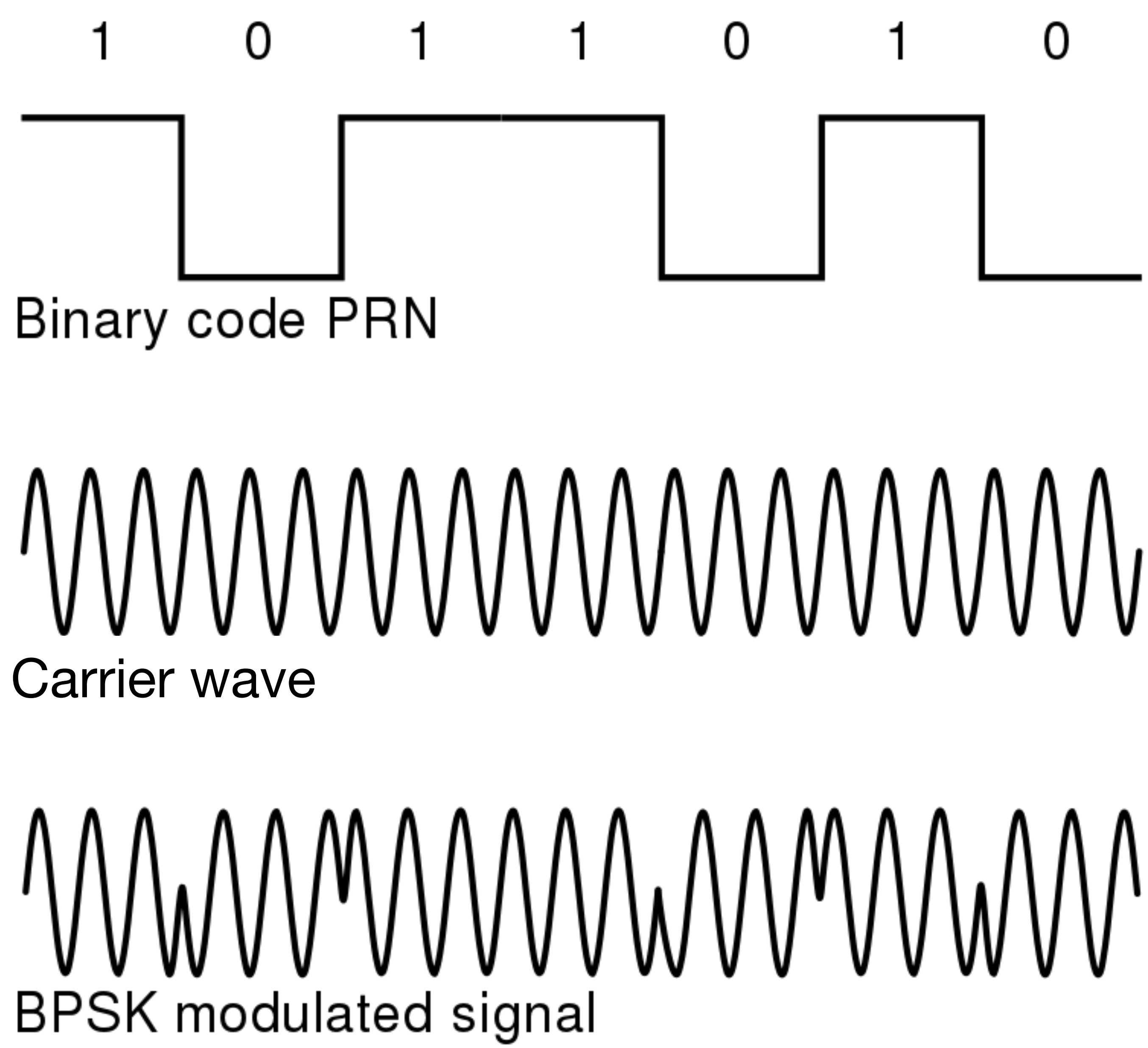
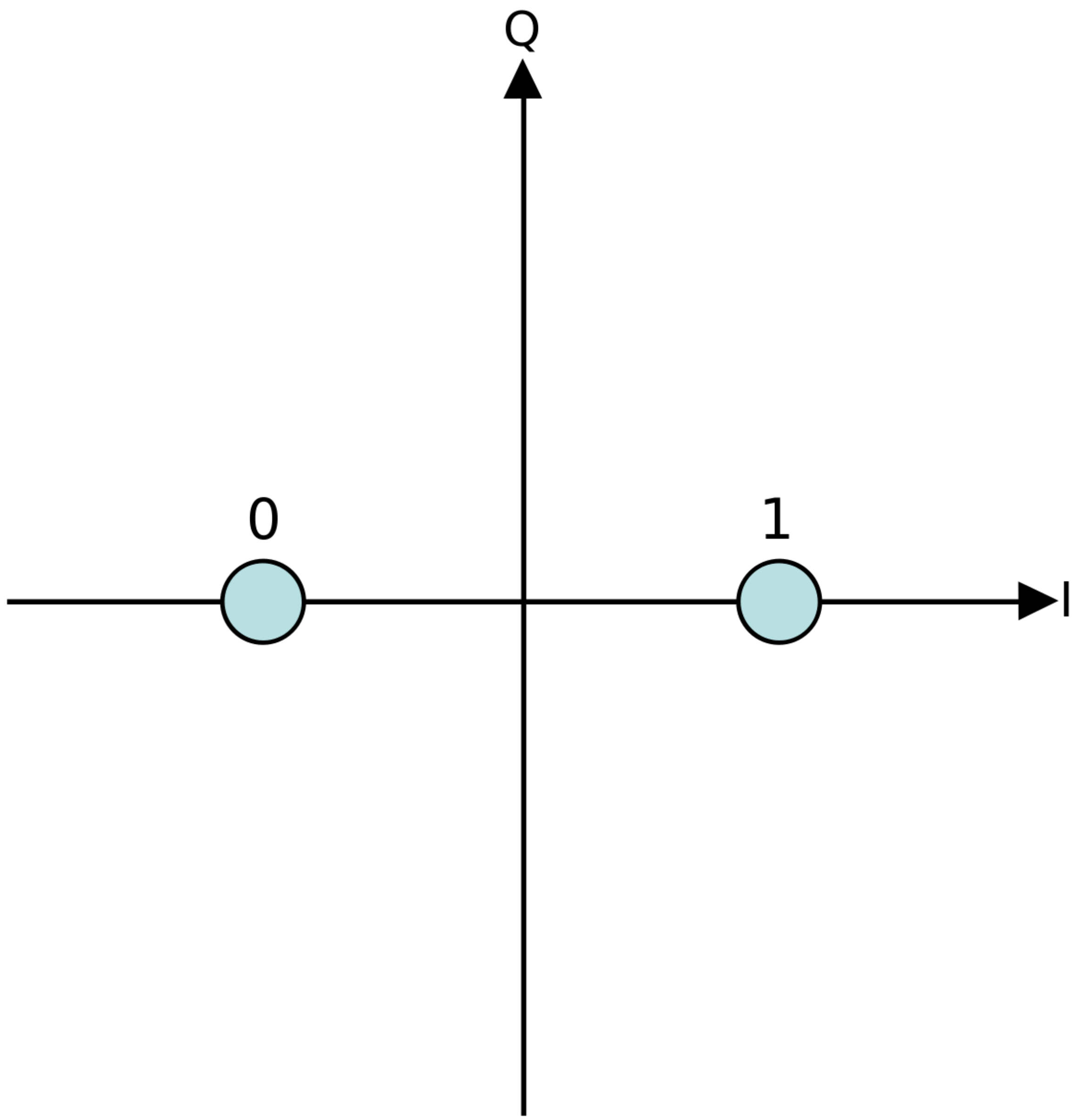
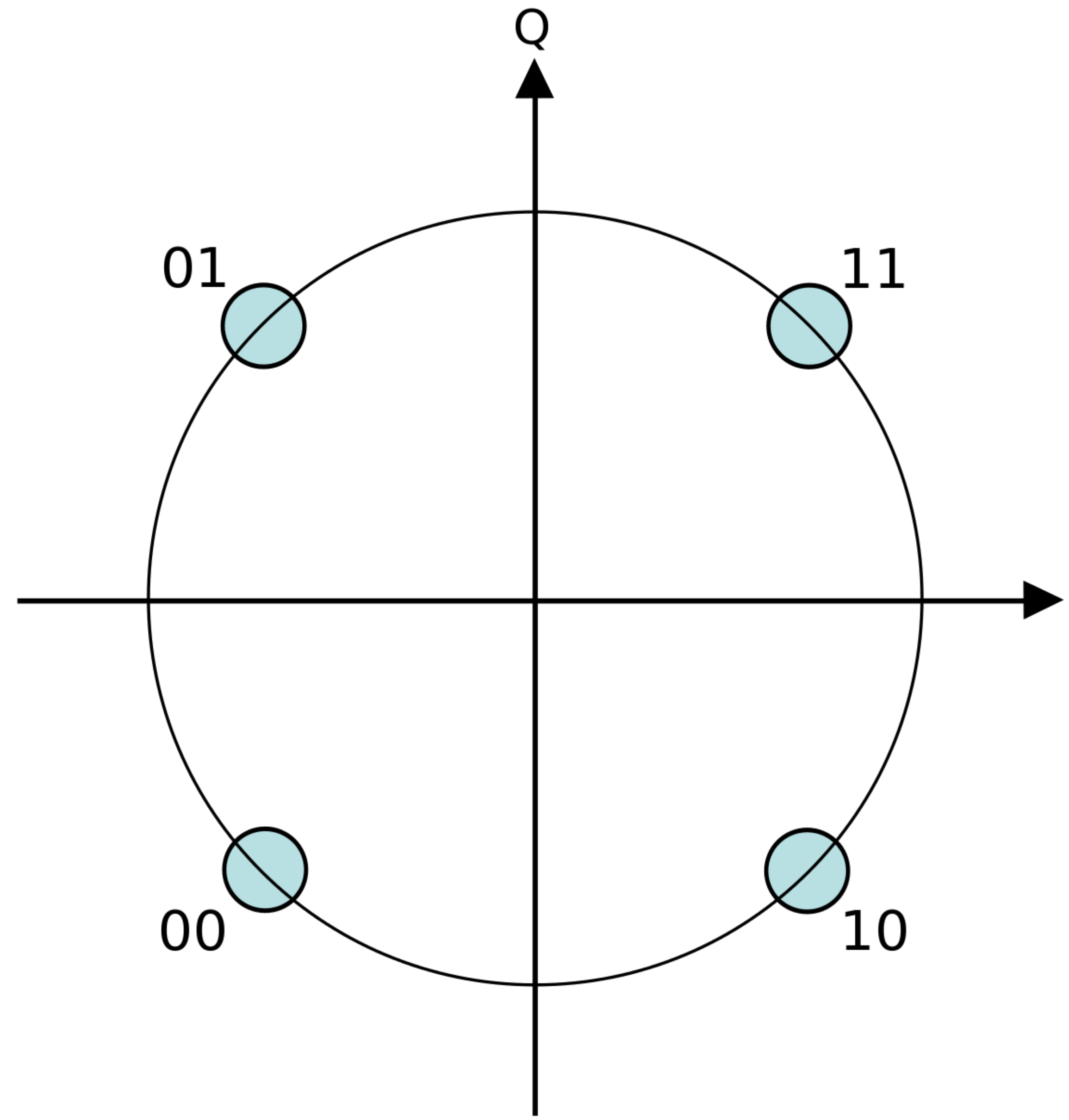


 Image: https://commons.wikimedia.org/wiki/File:Phase_modulation_BPSK_GPS.svg



Binary Phase-Shift Keying (BPSK)



Quadrature Phase-Shift Keying (QPSK)

Images: https://en.wikipedia.org/wiki/File:BPSK_Gray_Coded.svg
https://en.wikipedia.org/wiki/File:QPSK_Gray_Coded.svg

Frequency Modulation

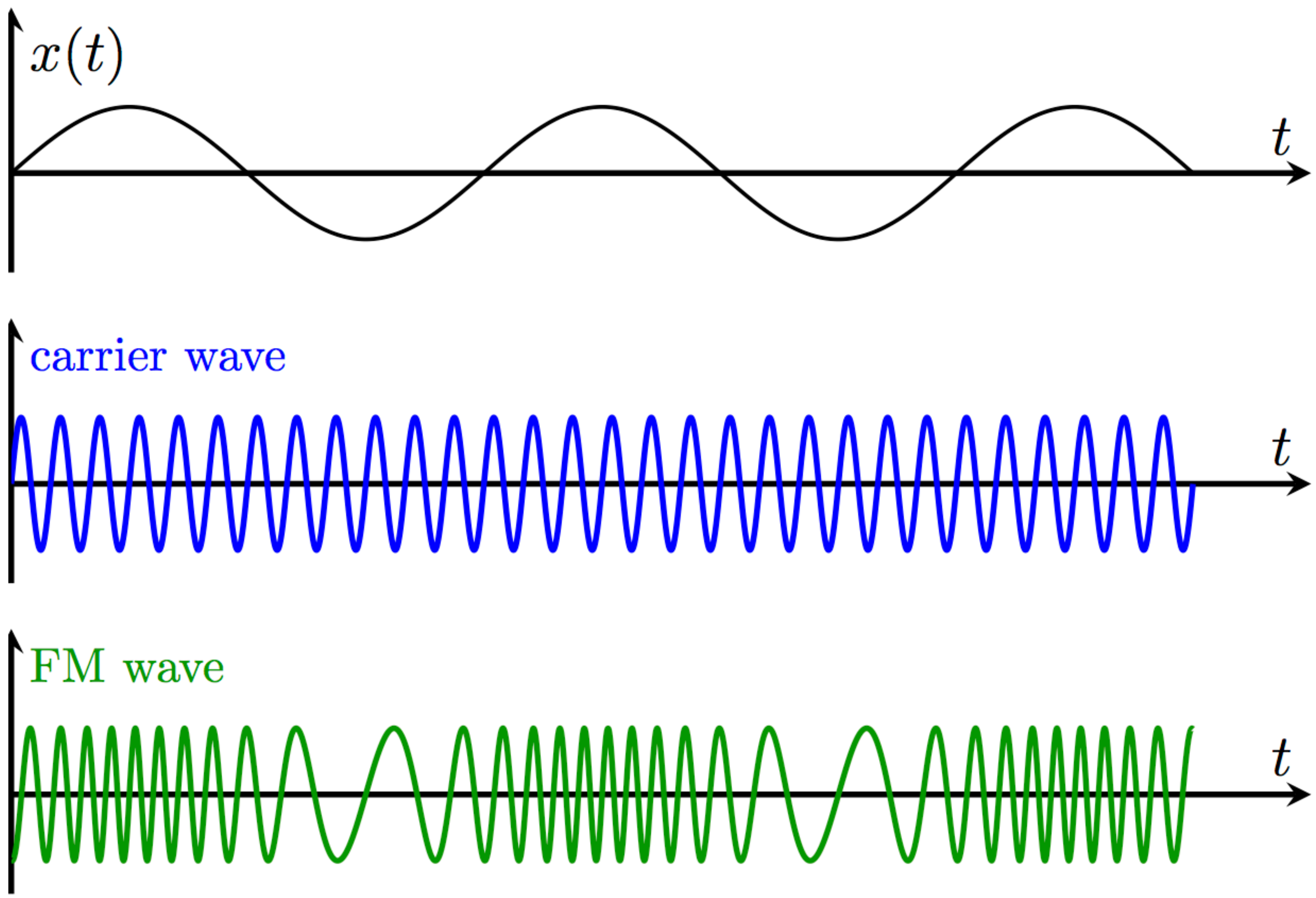
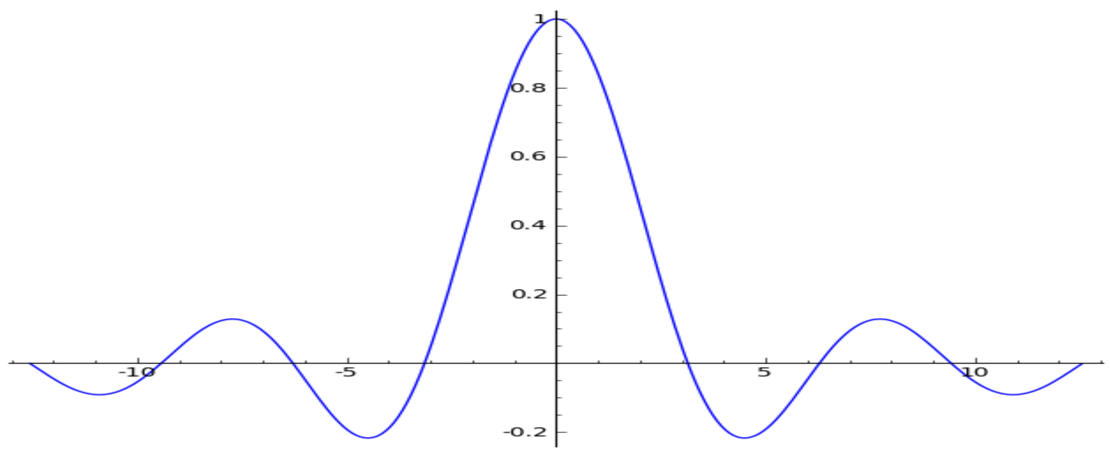
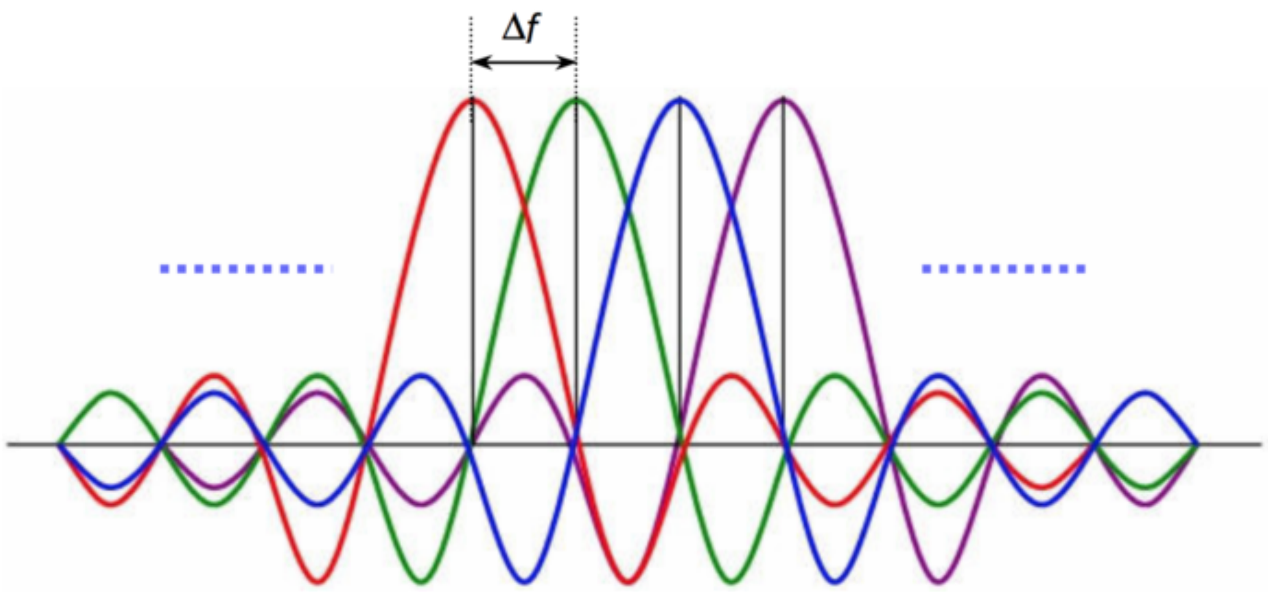


Image: https://github.com/PetarV-/TikZ/tree/master/Frequency%20modulation

Orthogonal Frequency Division Multiplexing (OFDM)

sin(x) / x





- Multiple Sub-Carriers
- Compensate severe Channel Conditions

Images: http://jean.thiery.pagesperso-orange.fr/fr/2012/sagemath/sinx_x.html & http://www.revolutionwifi.net/revolutionwifi/2015/3/how-ofdm-subcarriers-work

Ambient Noise

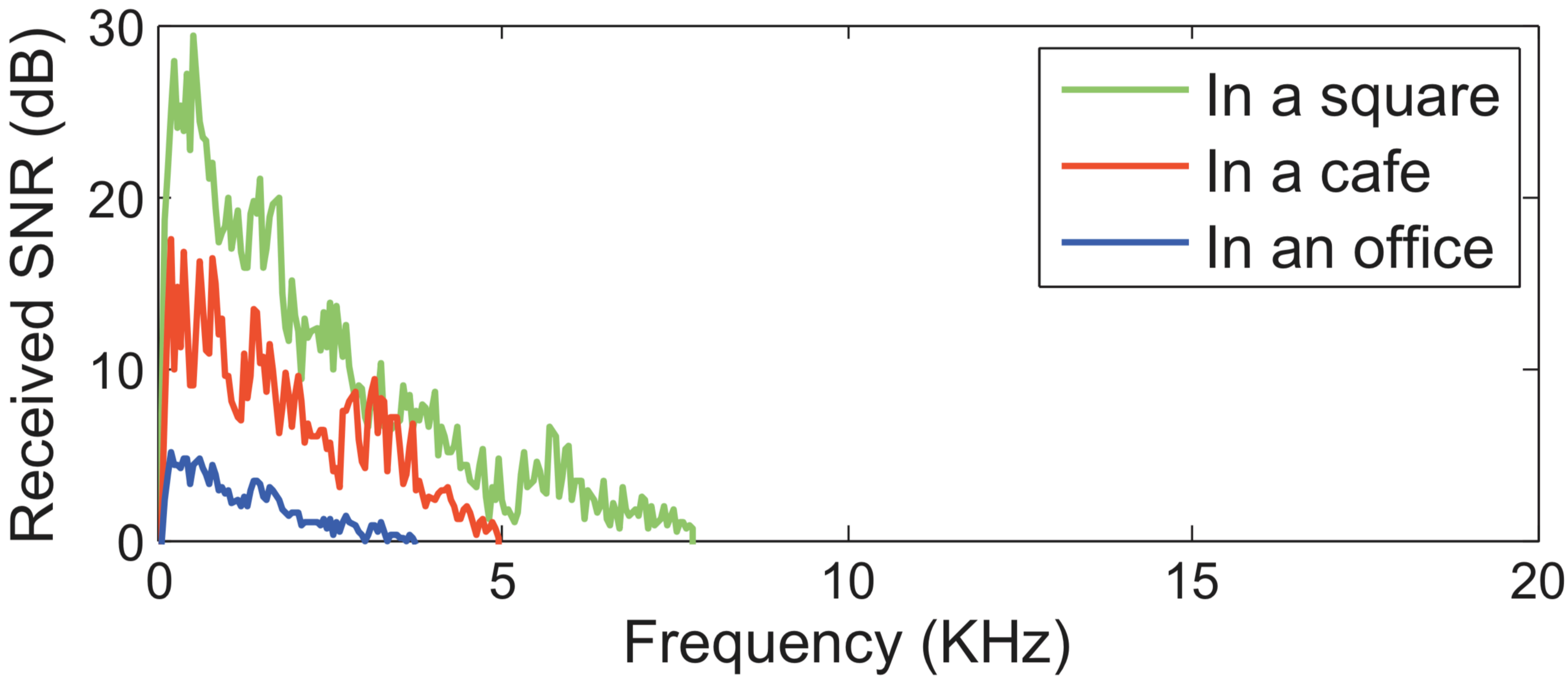


Image: Message Behind the Sound - Wang et al.

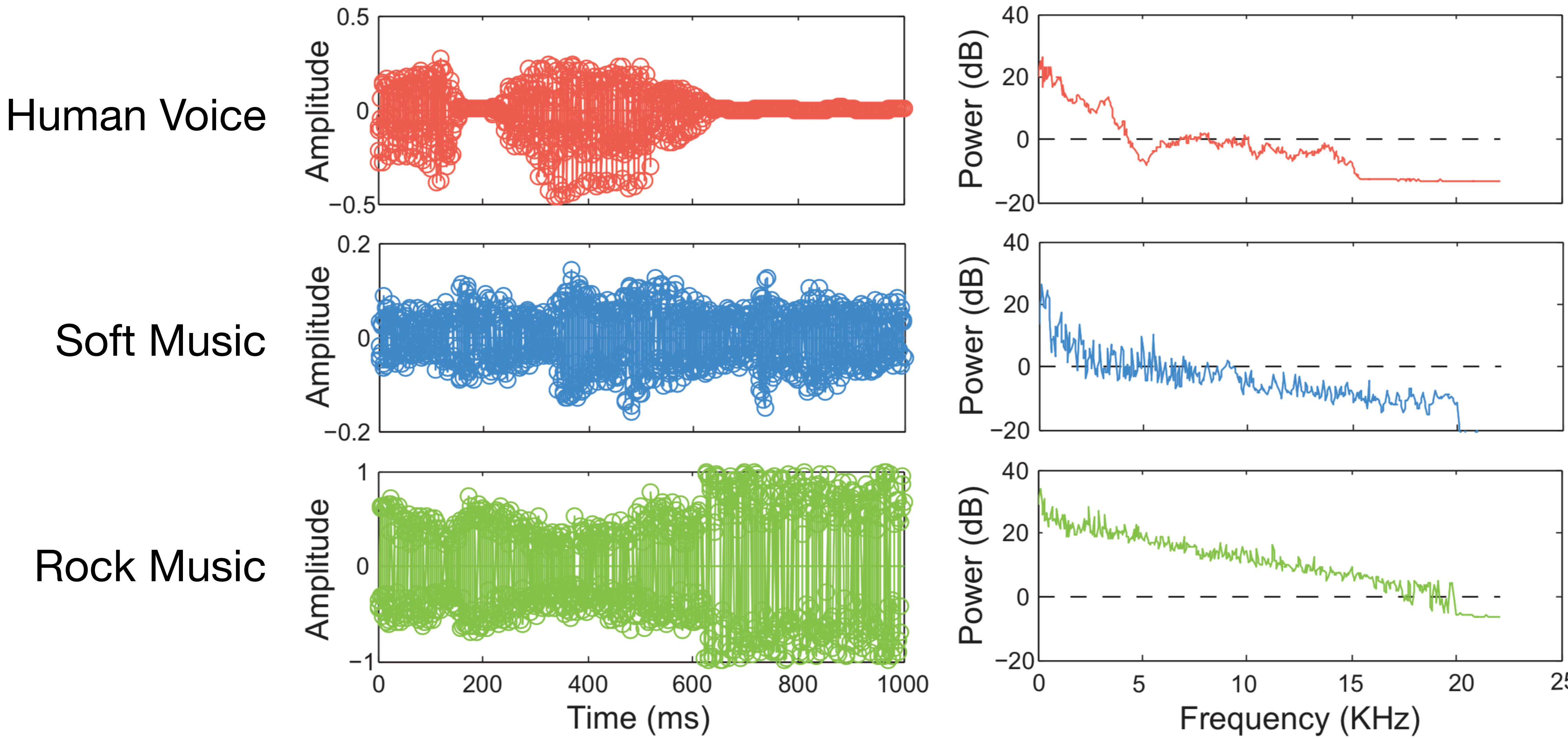


Image: Message Behind the Sound - Wang et al.

Messages Behind the Sound: Real-Time Hidden Acoustic Signal Capture with Smartphones

Qian Wang, Kai Ren, Man Zhou, Tao Lei, Dimitrios Koutsonikolas, Lu Su
Wuhan University & The State University of New York at Buffalo

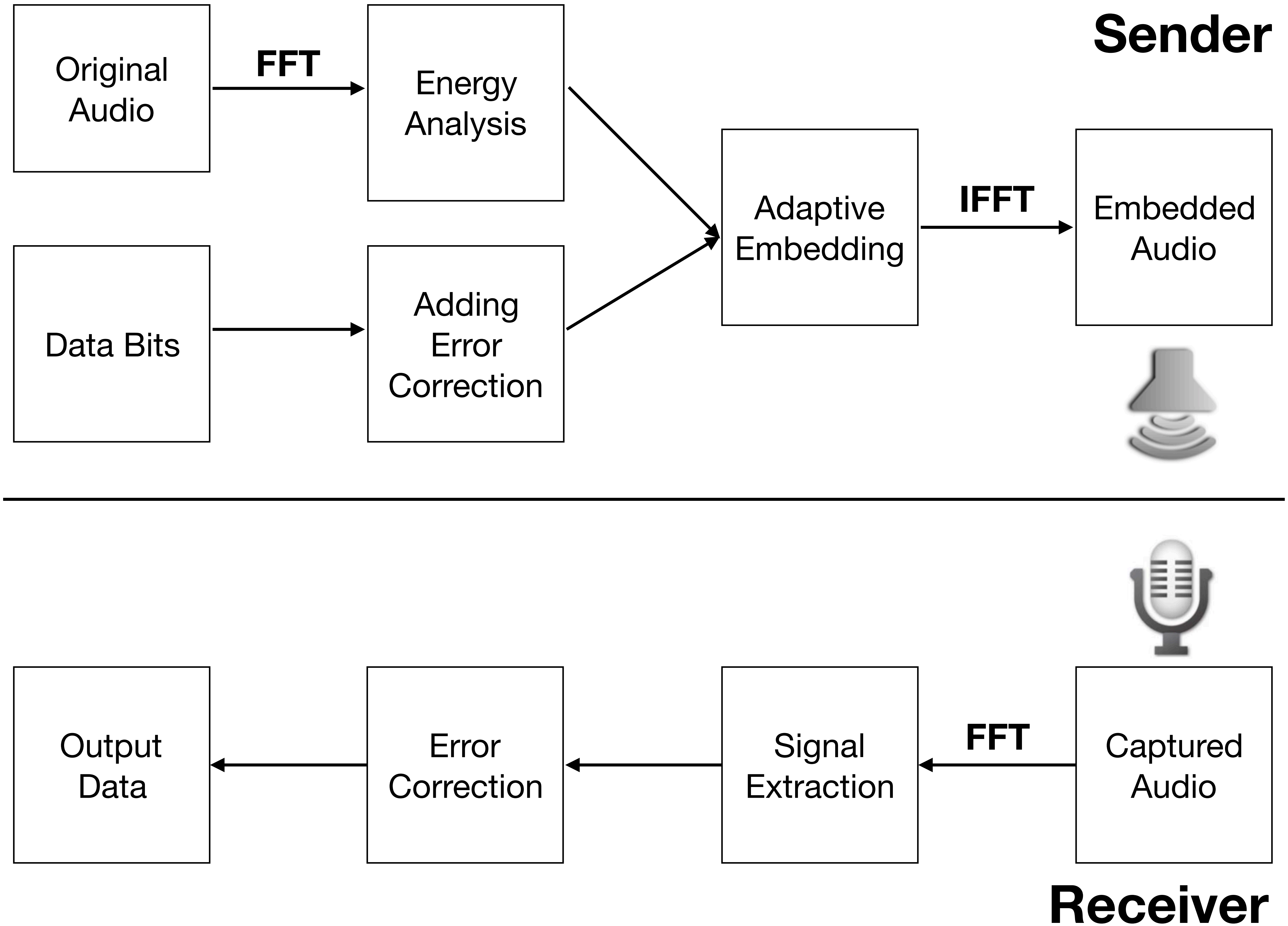


Image: Message Behind the Sound - Wang et al.

On-Off Keying

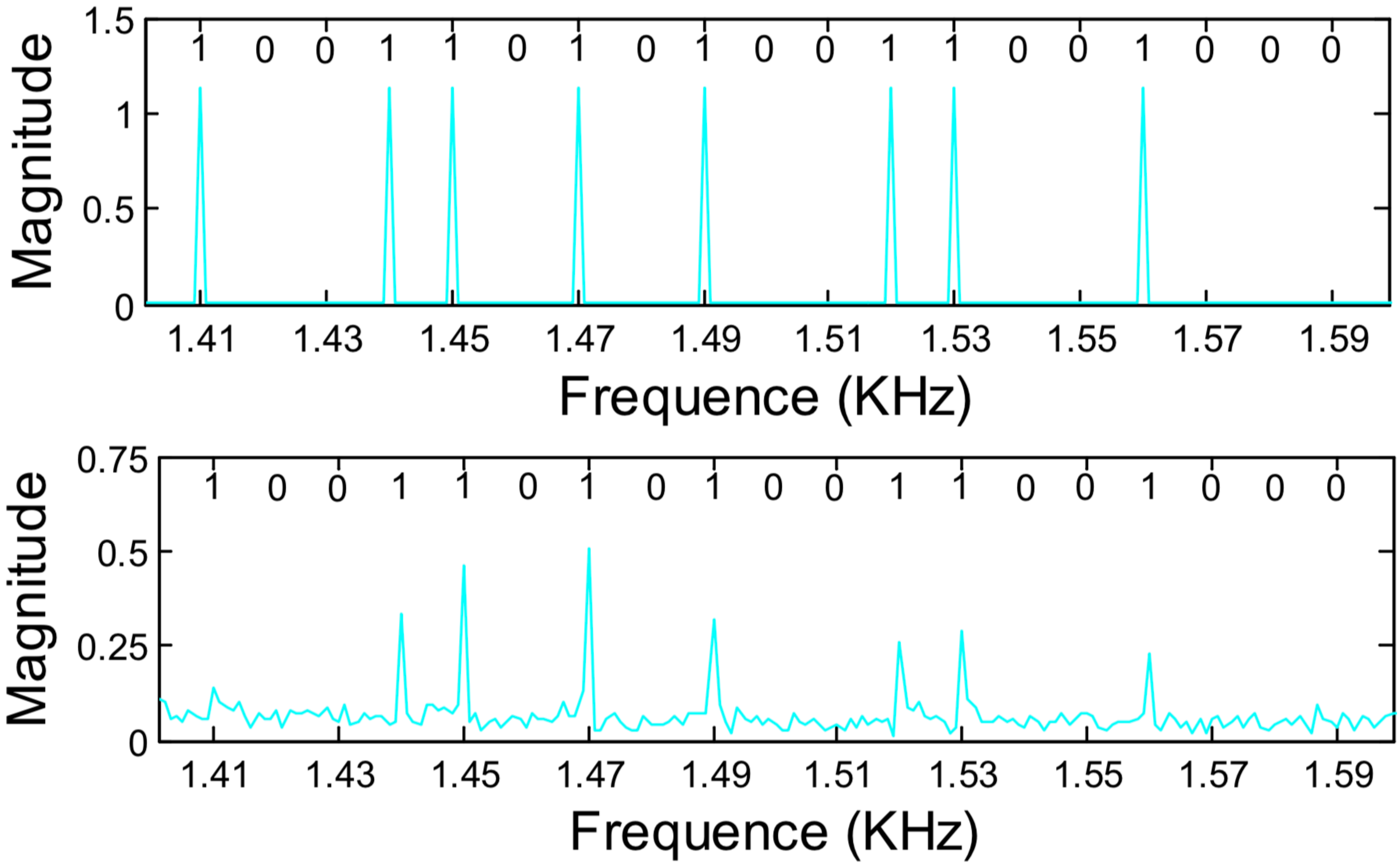


Image: Message Behind the Sound - Wang et al.

Energy Difference Keying (EDK)

Error Correction

- Intra Symbol
- Inter Symbol

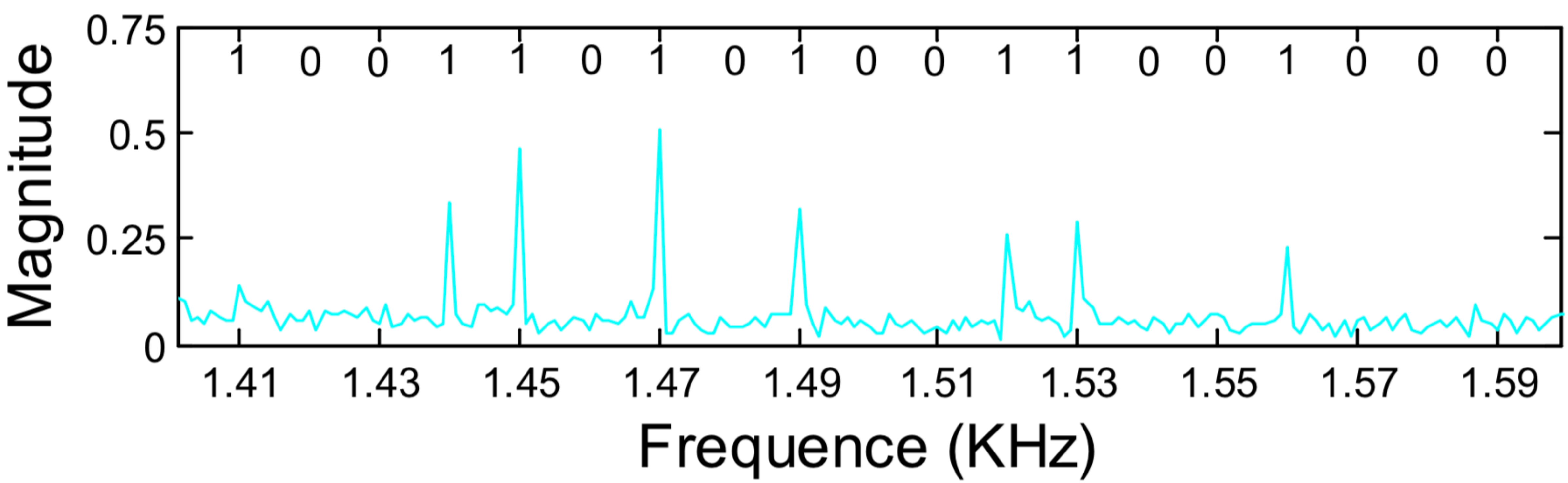


Image: Message Behind the Sound - Wang et al.

Results

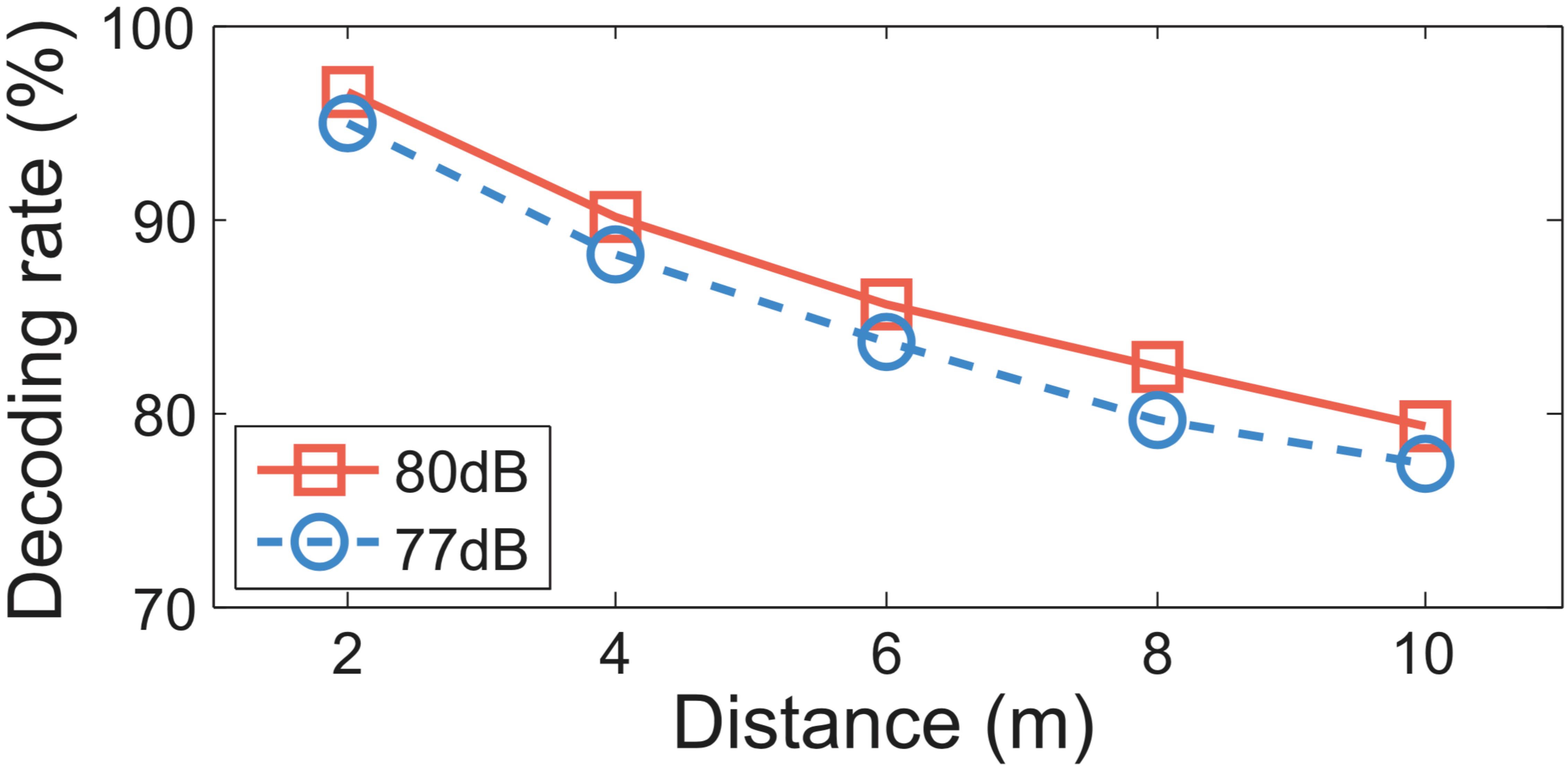


Image: Message Behind the Sound - Wang et al.

BackDoor: Making Microphones Hear Inaudible Sounds

Nirupam Roy, Haytham Hassanieh, Romit Roy Choudhury
University of Illinois at Urbana-Champaign

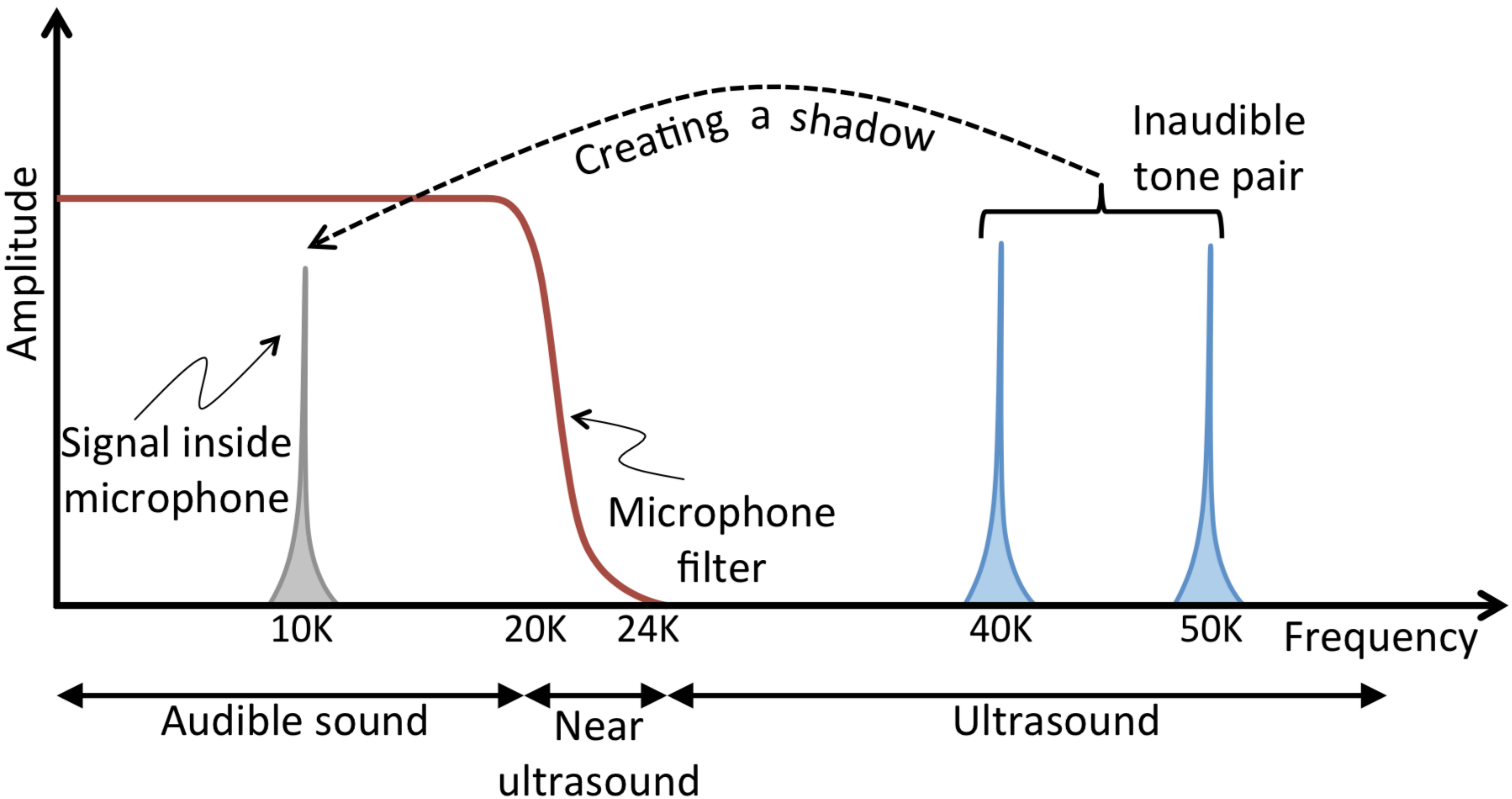
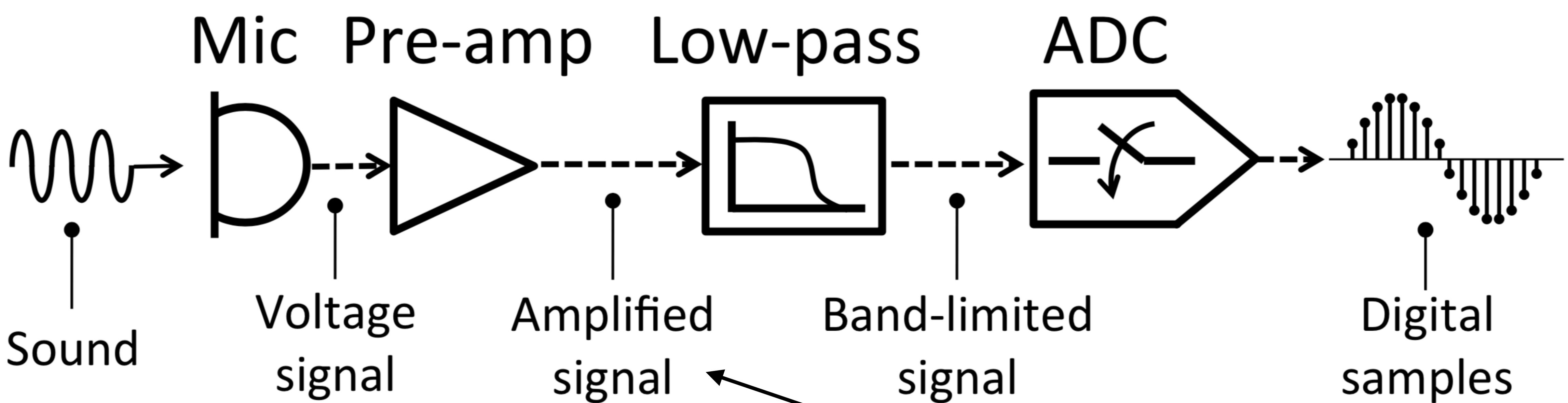


Image: BackDoor - Roy et al.

Perfect Pre-Amplifier



$S = \sin(\omega_1 t) + \sin(\omega_2 t)$

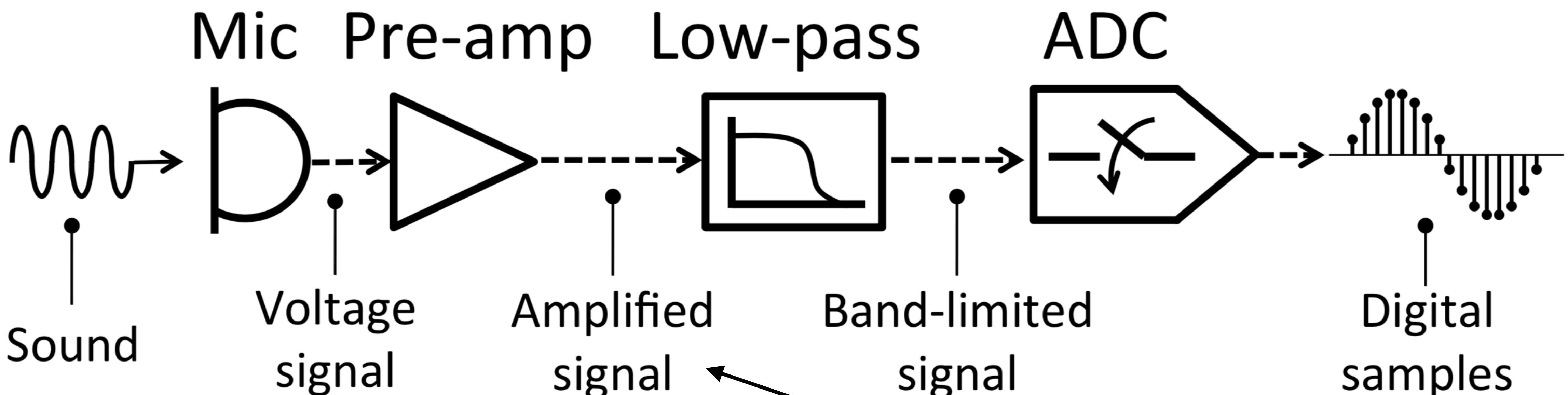
$\omega_1 = 2\pi * 40\text{kHz}$

$\omega_2 = 2\pi * 50\text{kHz}$

Amplified Signal = $A_1 S$

Image: BackDoor - Roy et al.

Non-Linearities



$S = \sin(\omega_1 t) + \sin(\omega_2 t)$
$\omega_1 = 2\pi * 40\text{kHz}$
$\omega_2 = 2\pi * 50\text{kHz}$

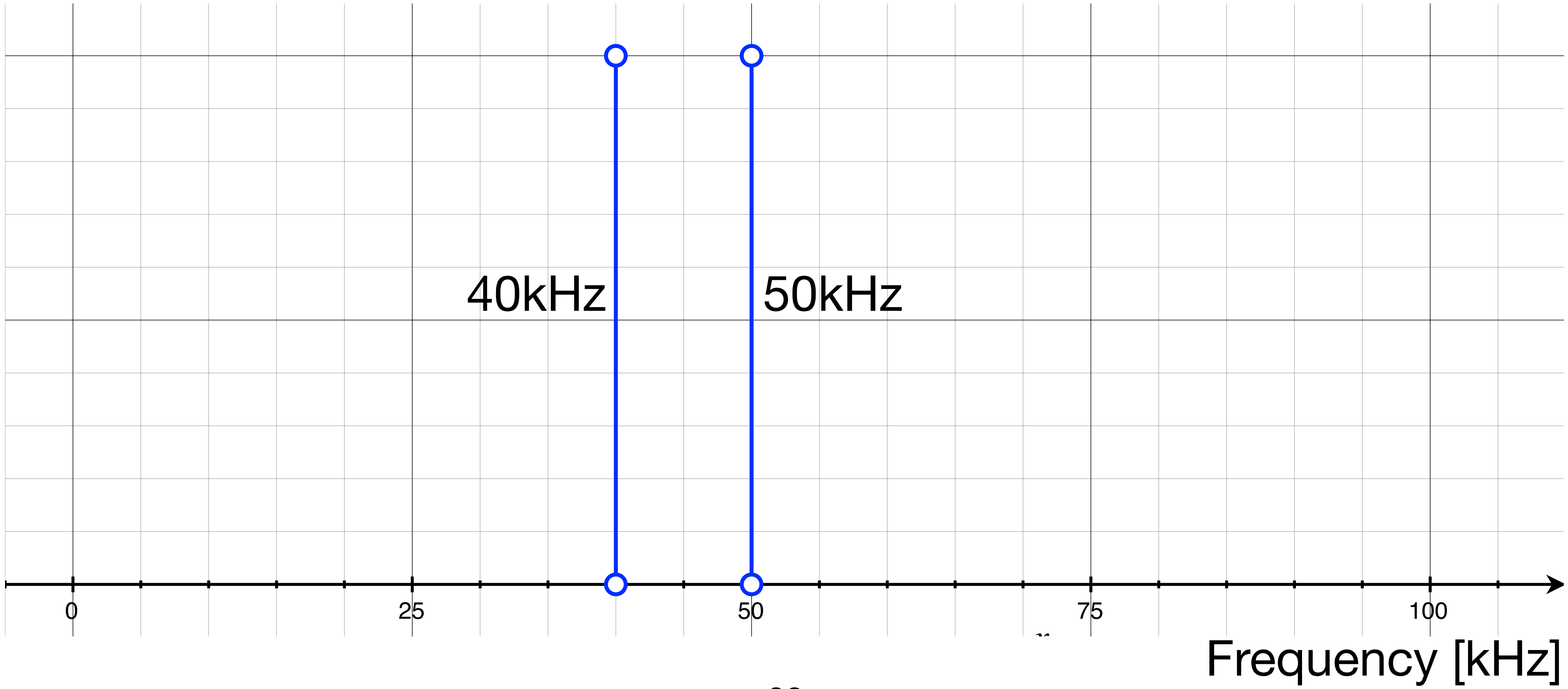
Amplified Signal =
$A_1 S + A_2 S^2 + A_3 S^3 + \ldots$

Image: BackDoor - Roy et al.

Non-Linearities

$A_1 S = A_1(\sin(\omega_1 t) + \sin(\omega_2 t))$

$\omega_1 = 2\pi * 40\text{kHz}$
$\omega_2 = 2\pi * 50\text{kHz}$

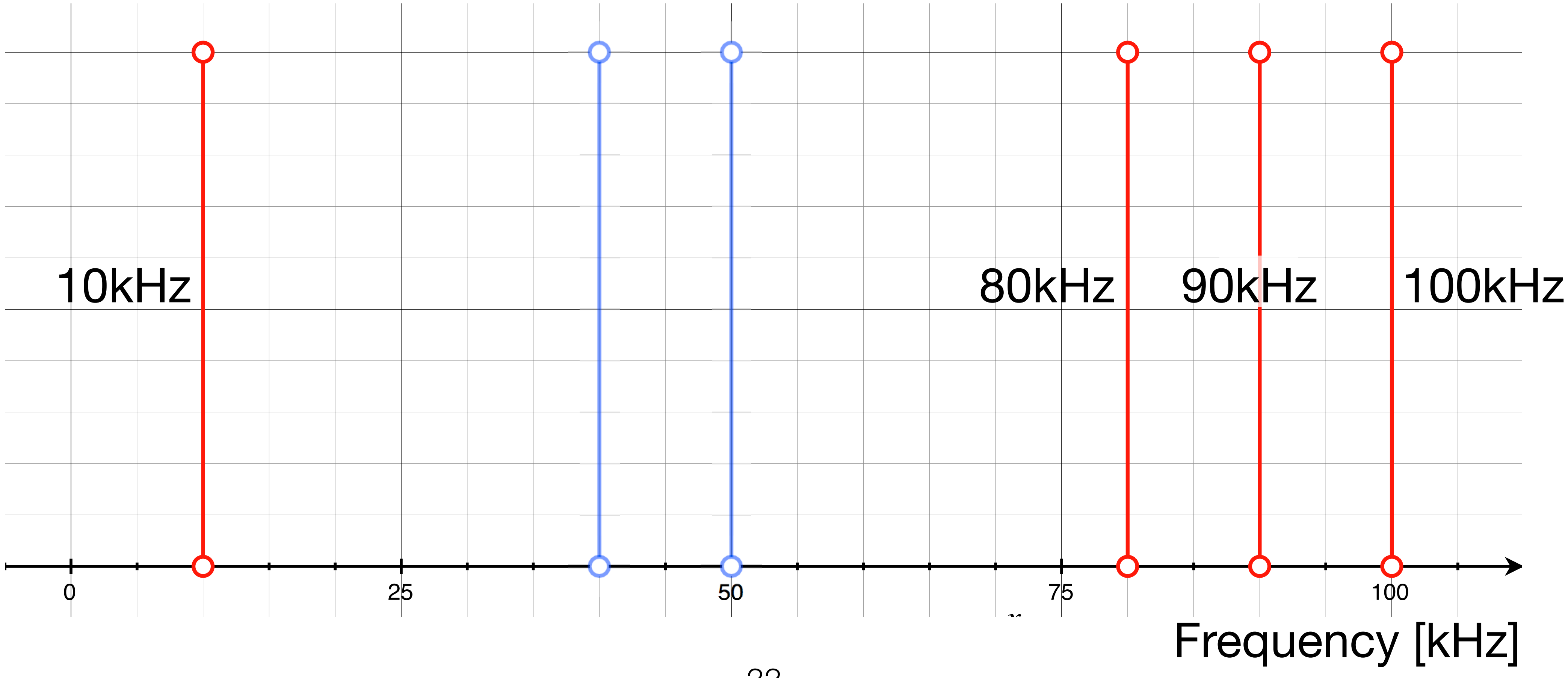


Non-Linearities

$A_1S = A_1(\sin(\omega_1 t) + \sin(\omega_2 t))$

$\omega_1 = 2\pi * 40kHz$
$\omega_2 = 2\pi * 50kHz$

$A_2S^2 = 1 + \cos(\omega_1 t - \omega_2 t) - ½\cos(2\omega_2 t)$
$- \cos(\omega_1 t + \omega_2 t) - ½\cos(2\omega_1 t)$



Non-Linearities

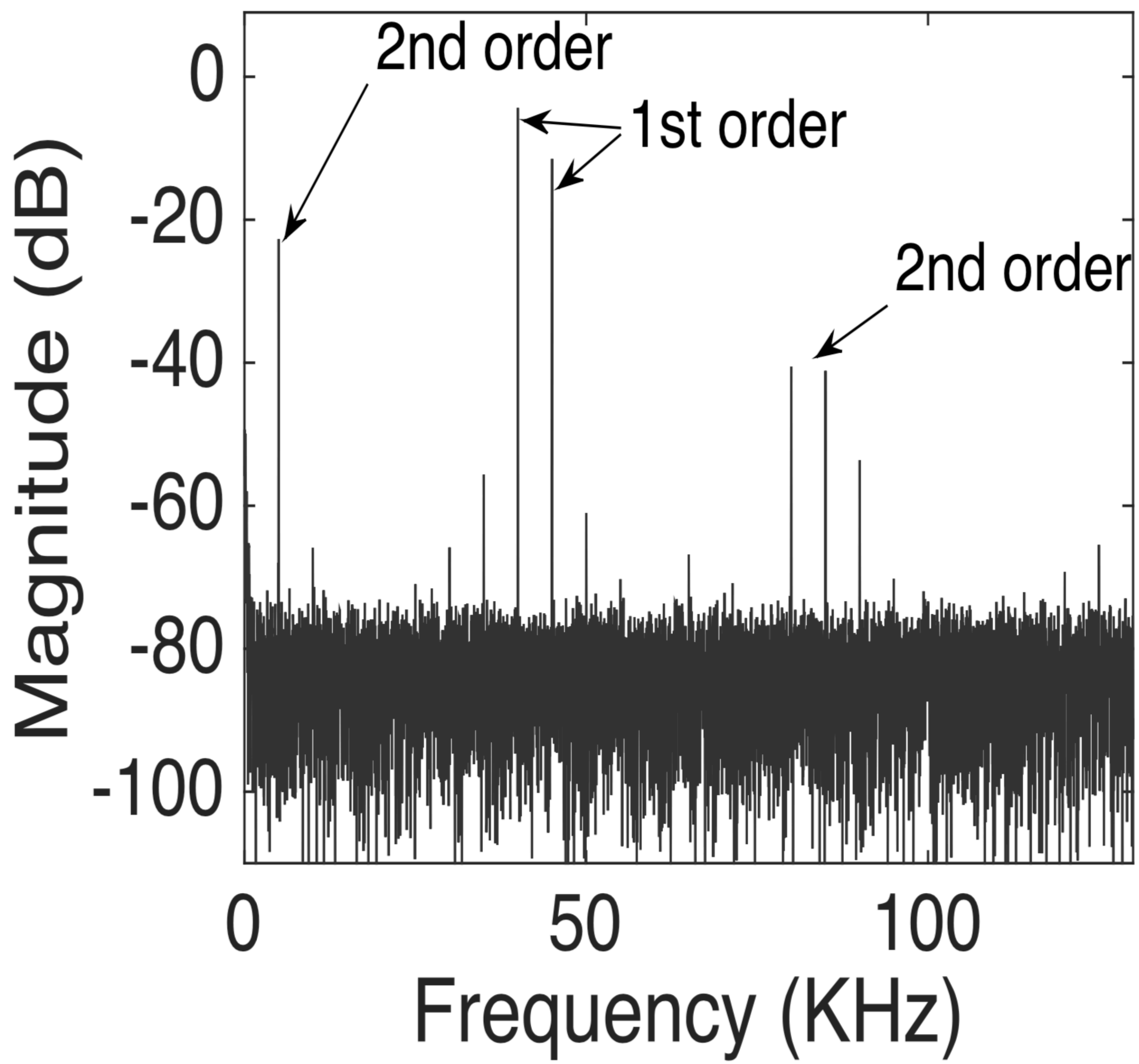
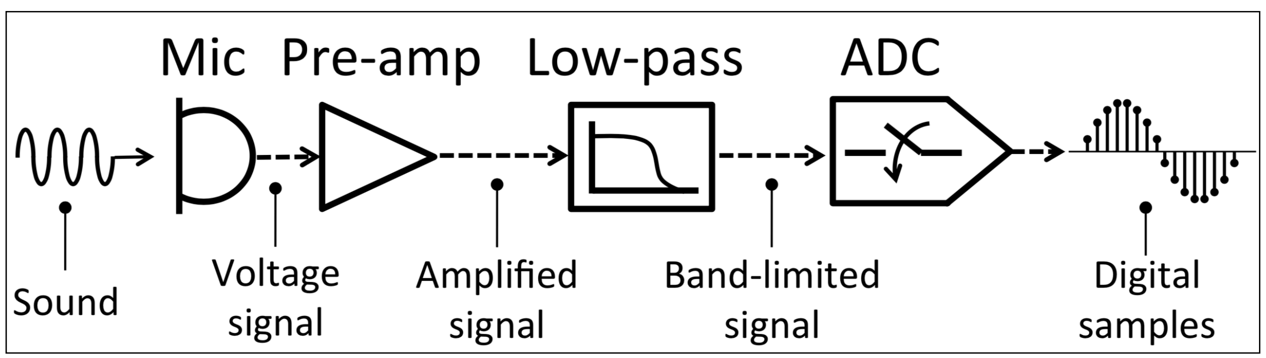


Image: BackDoor - Roy et al.

Non-Linearities



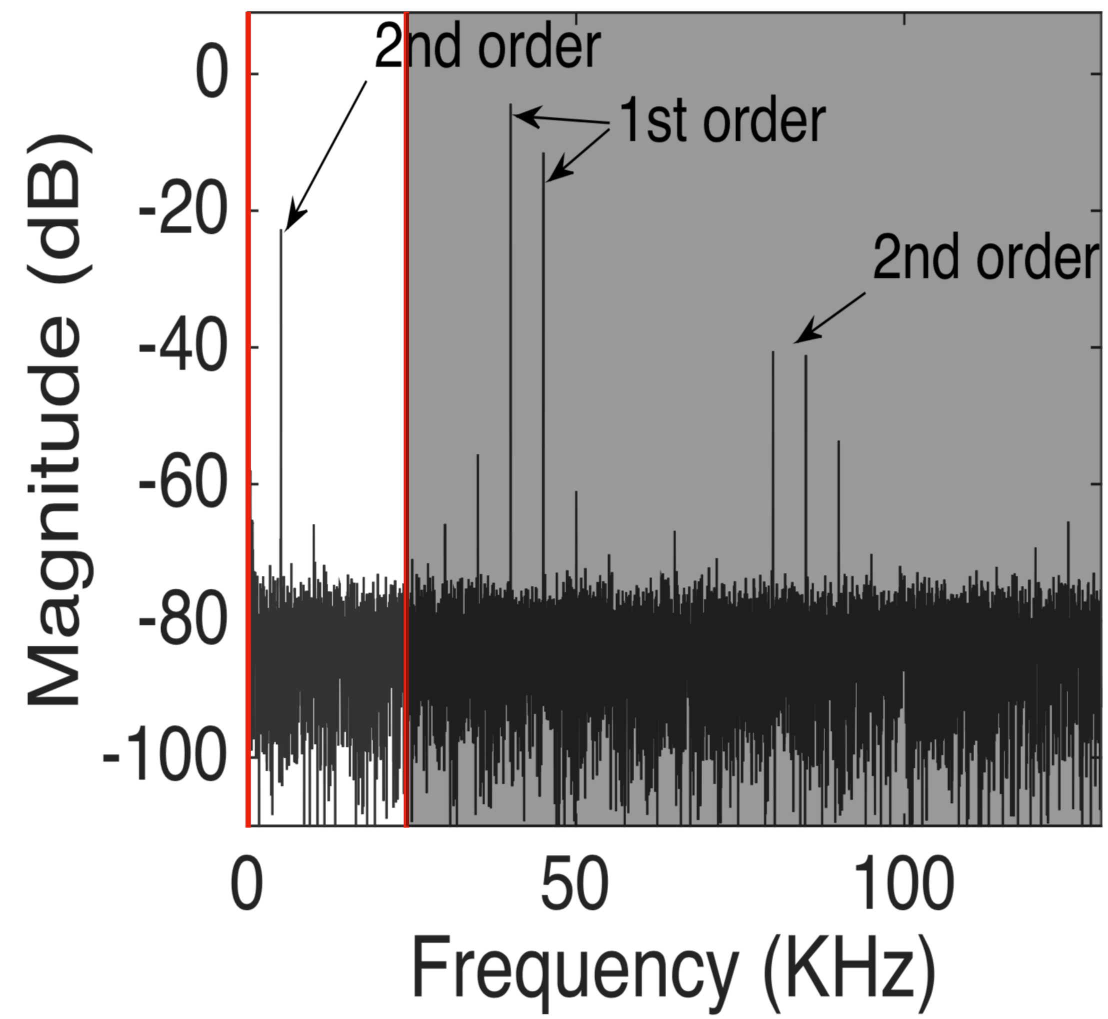


Image: BackDoor - Roy et al.

Results

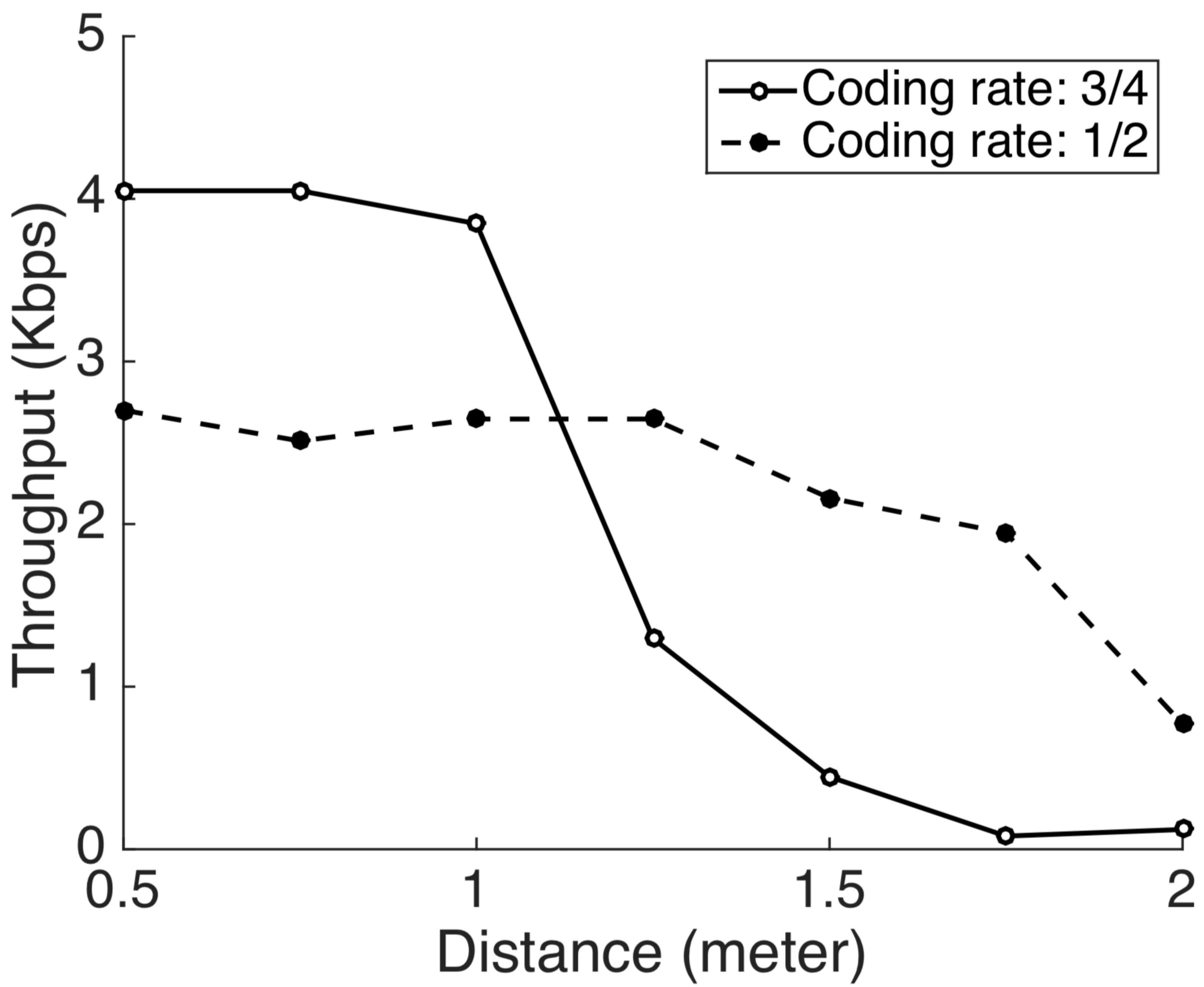


Image: BackDoor - Roy et al.

Jamming

- White Noise as ‘Data’
- Noise at [0,12]kHz at Eavesdropper

Dhwani: Secure Peer-to-Peer Acoustic NFC

Rajalakshmi Nandakumar, Krishna Kant Chintalapudi, Venkata N. Padmanabhan, Ramarathnam Venkatesan
Microsoft Research India

NFC

- Slow Adoption
- Specialized Hardware
- Man-in-the-Middle Attacks

JamSecure

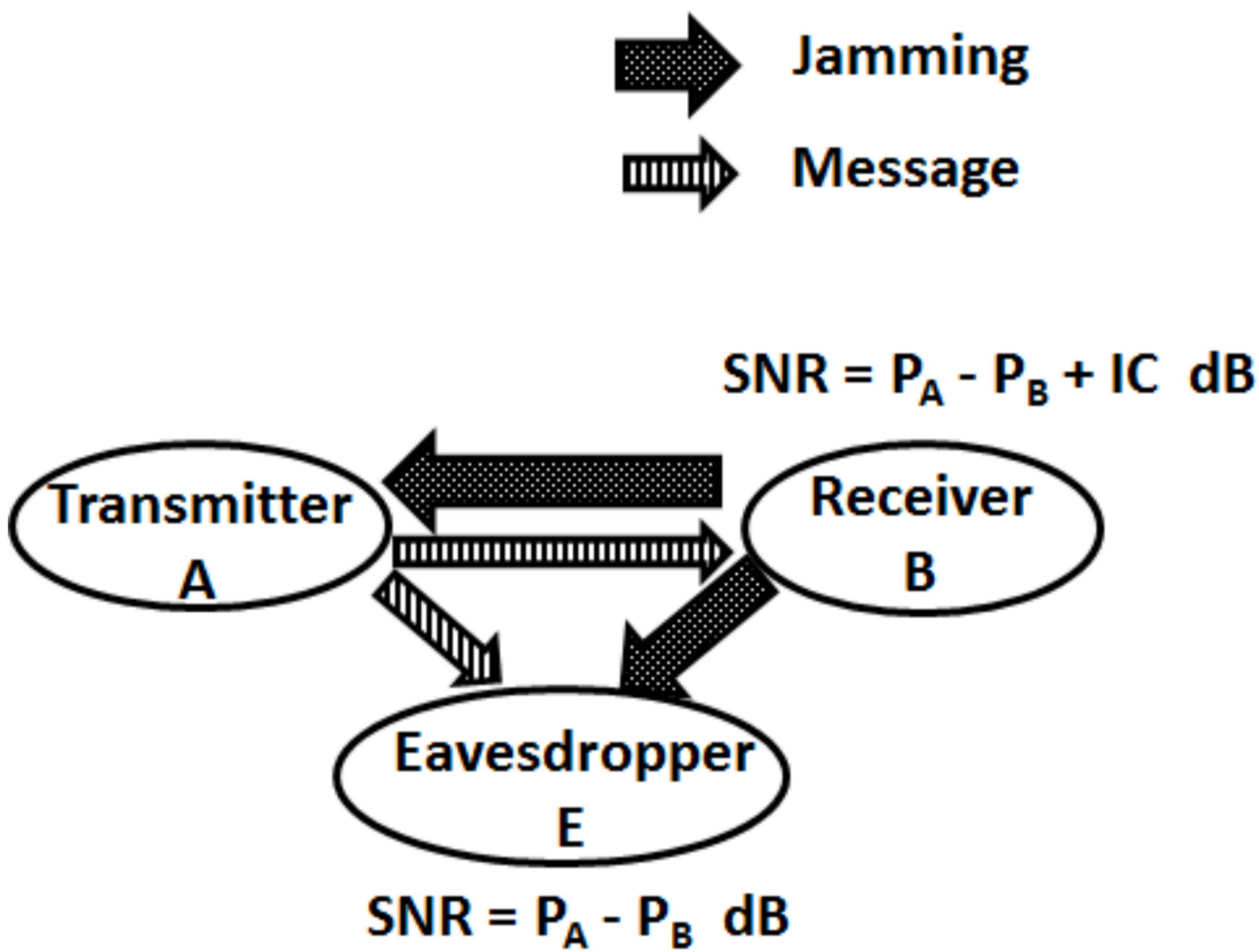


Image: Dhwani - Nandakumar et al.

Information-Theoretic Security

- Shanon's One-Time Pad Encryption
- Wyner's Wiretap Model

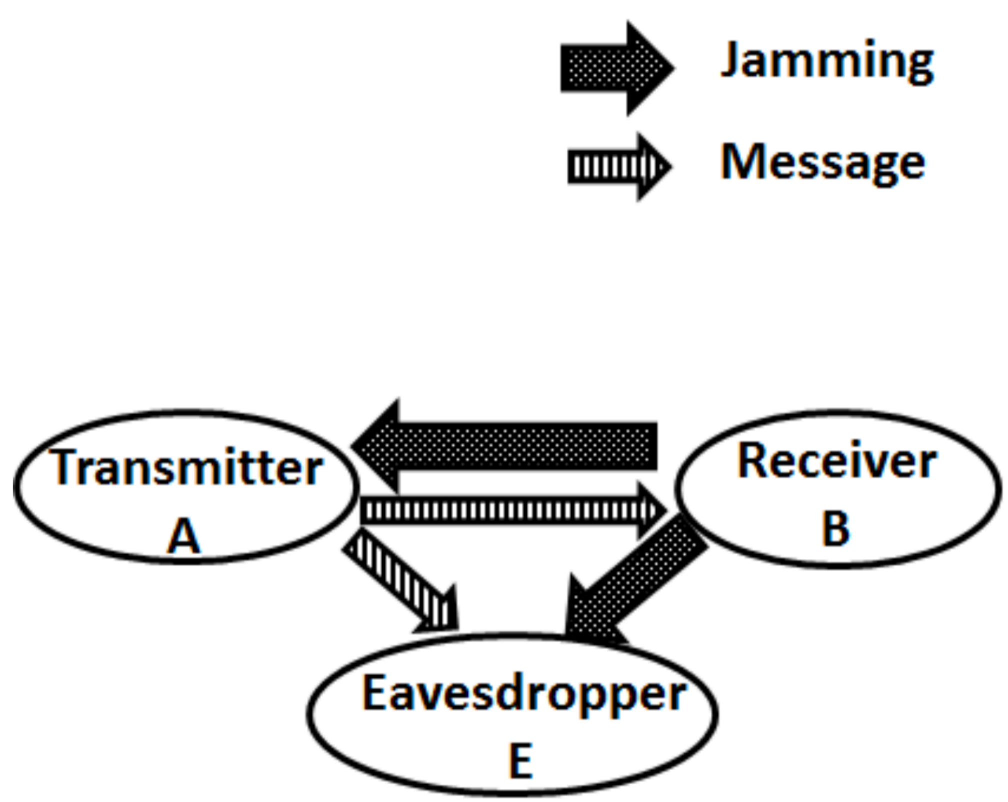


Image: Dhwani - Nandakumar et al.

Results

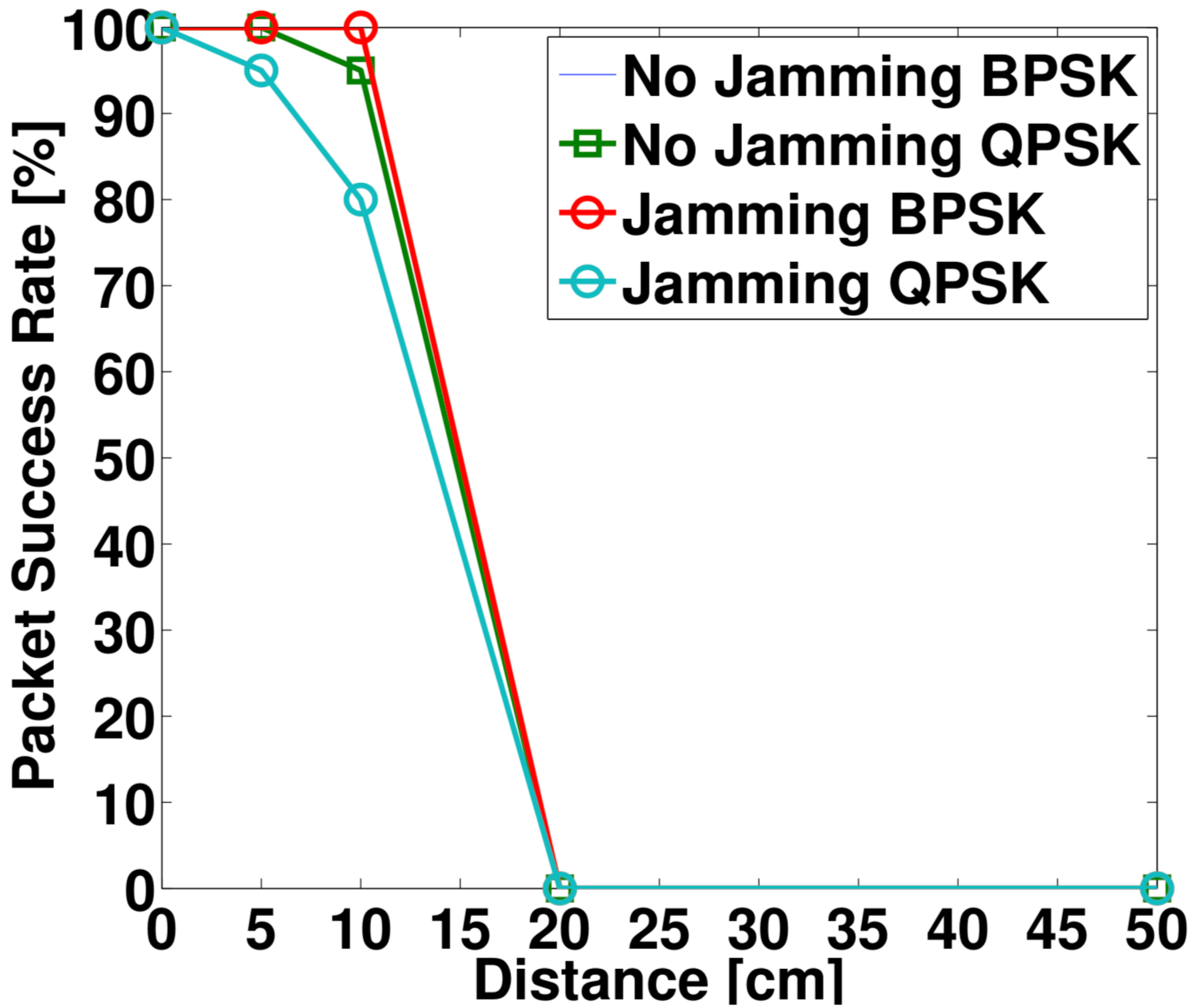


Image: Dhwani - Nandakumar et al.

Attacks

Prevents

- Man-in-the-Middle
- Placement Attacks

Affected by

- DOS
- Shielding

Conclusions

	Dolphin	Backdoor	Dhwani
Description	Hide Data in Audible Range	Non-Linearities High Frequencies	Acoustic NFC
Receiver	Smartphone Microphone	Smartphone Microphone	Smartphone Microphone & Speaker
Sender	Speaker	2 Ultrasound Speakers	Smartphone Microphone & Speaker
Throughput	500bps (at 1m)	4kbps	2.4kbps
Range	up to 10m	1m	20cm
Operating Frequencies	8-20kHz	40 & 50kHz	6-7kHz
Inaudible	Yes, but requires Sound	Yes	No (up to 1.5m)