Ripple: Communicating through Physical Vibrations

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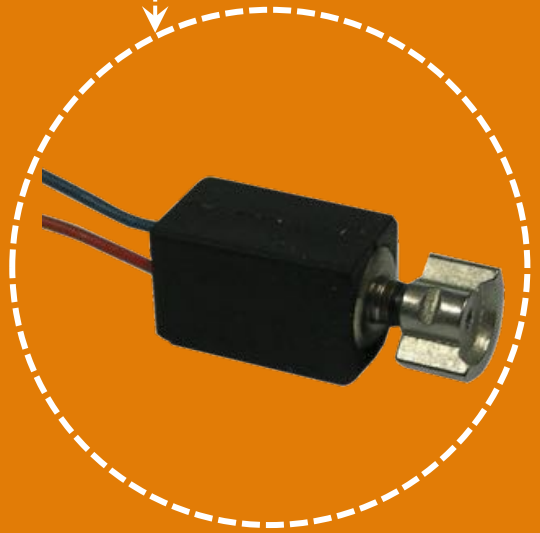
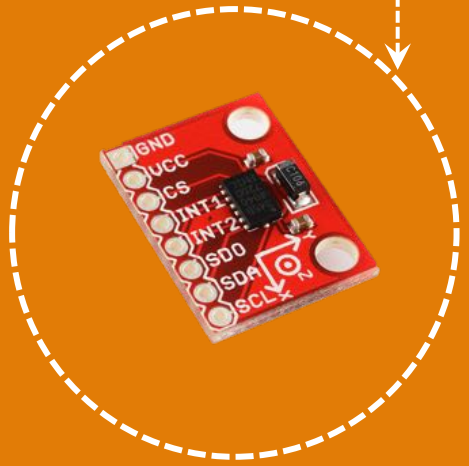
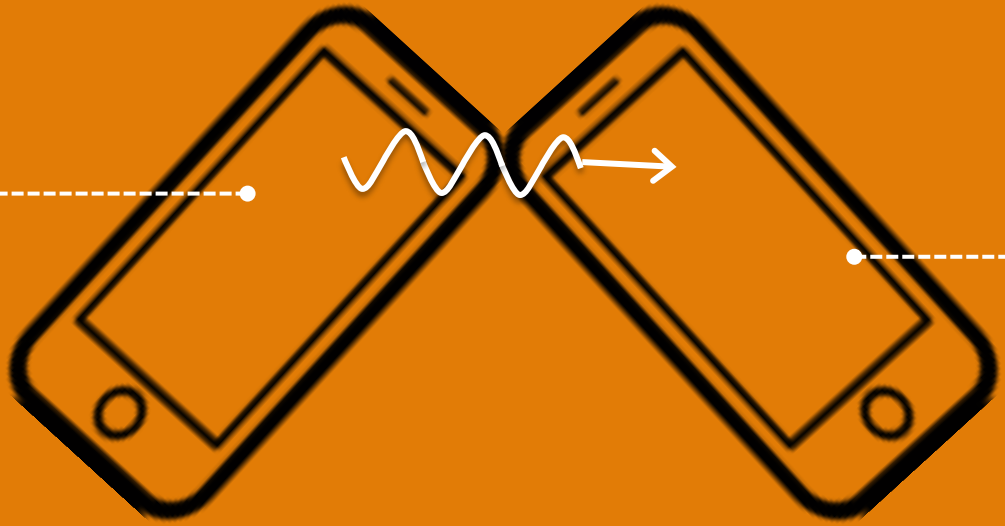
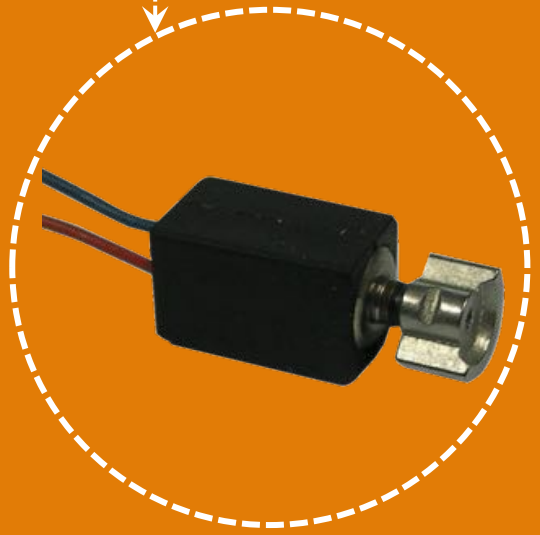


Vibration Motor

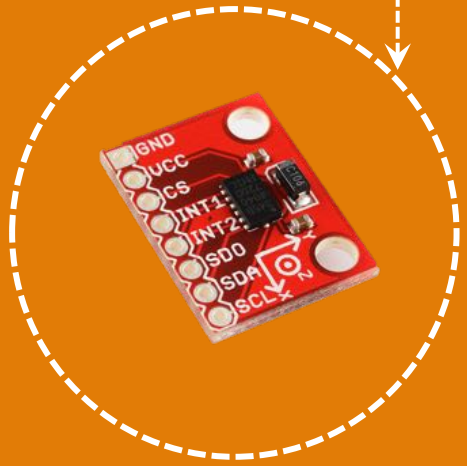


Accelerometer

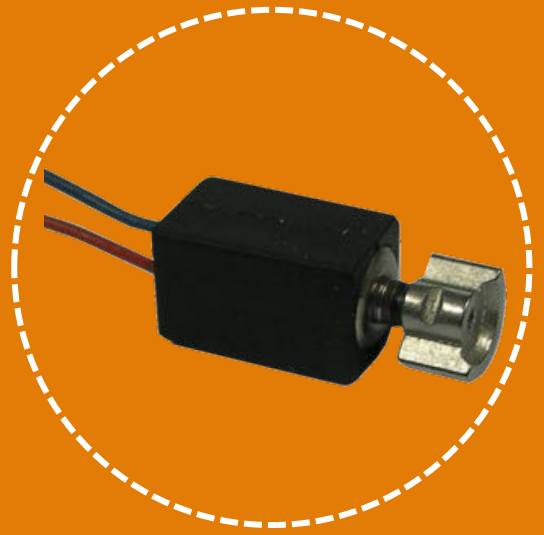




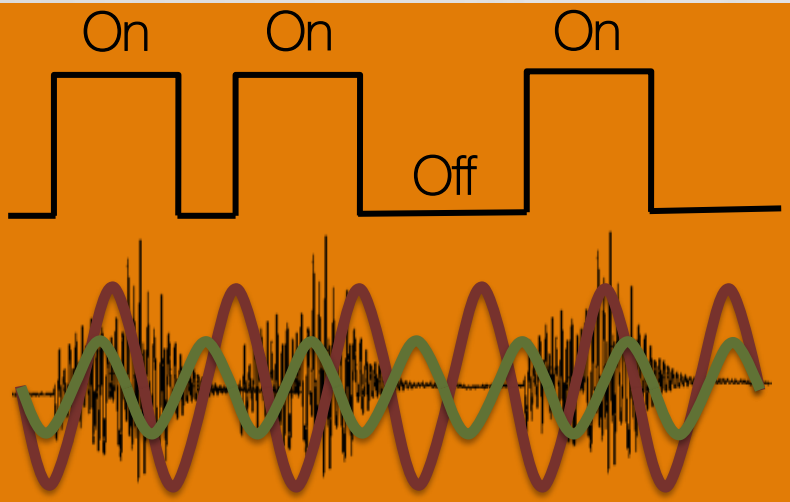
Vibration Motor



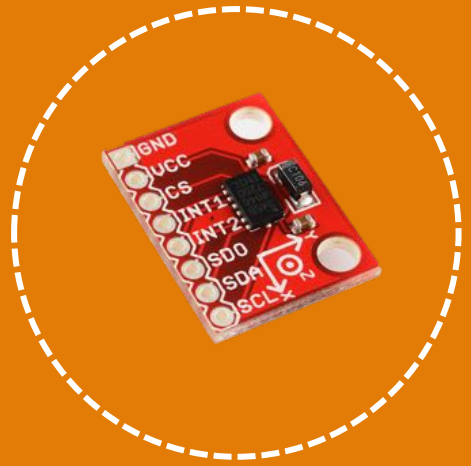
Accelerometer



Vibration Motor



Modulated vibration



Accelerometer

Radio-Frequency

Optical

Vibratory Communication through Solids

Acoustic

Magnetic

Radio-Frequency

Optical

Vibratory

Why do we care?

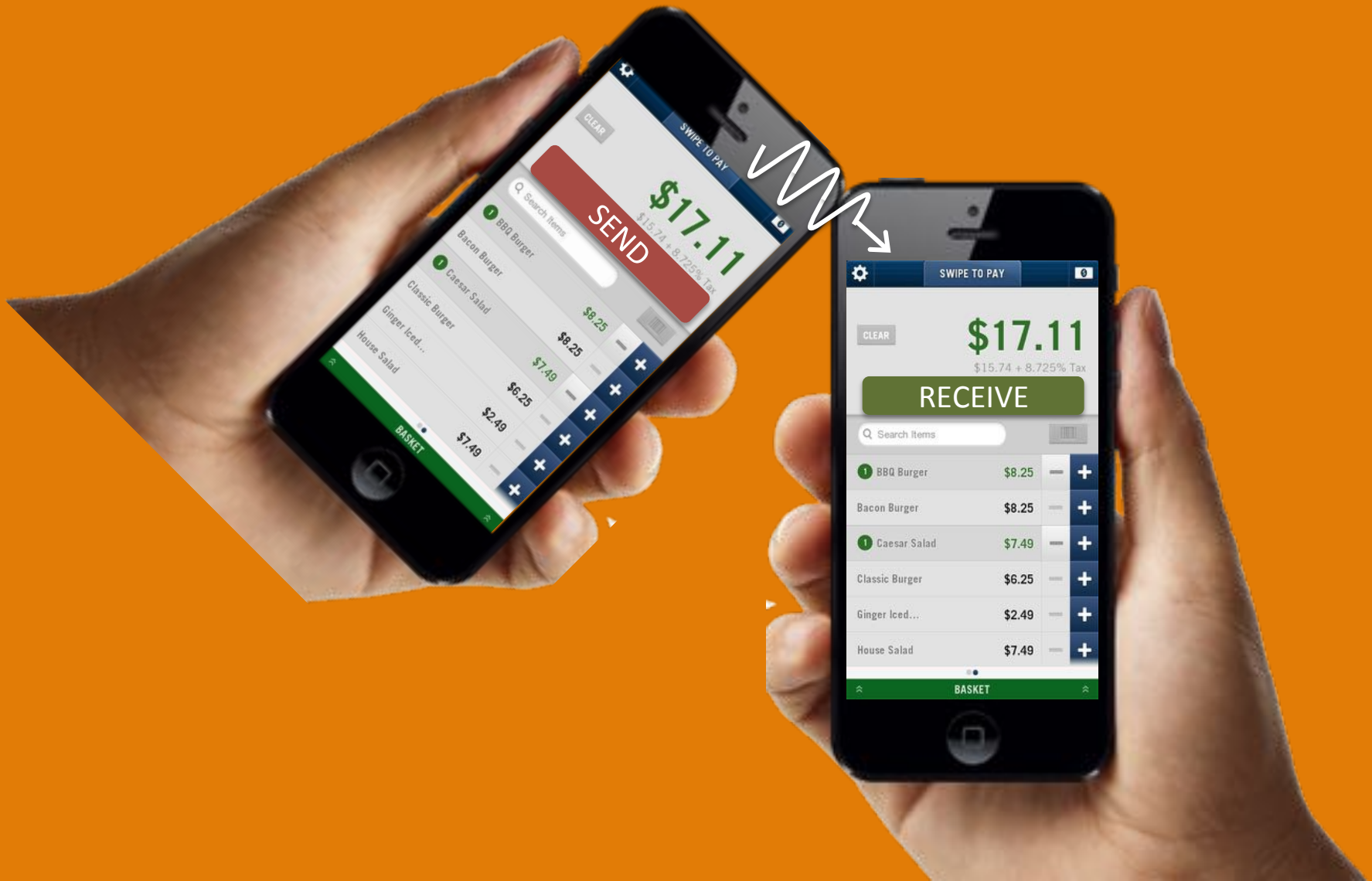
through Solids

Acoustic

Magnetic

Applications: Mobile Money Transfer

Applications: Mobile Money Transfer



Applications: Authentication with Ring

Applications: Authentication with Ring

Applications: Authentication with Ring

Applications: Body-Area Network

Again, we don't know the killer-app.

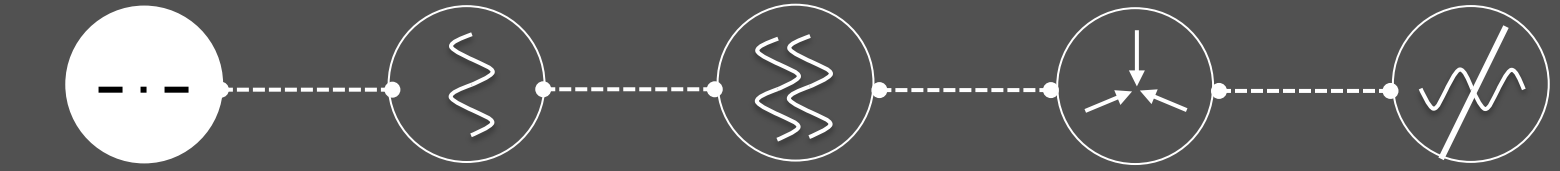
Application

Vibratory Radio

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

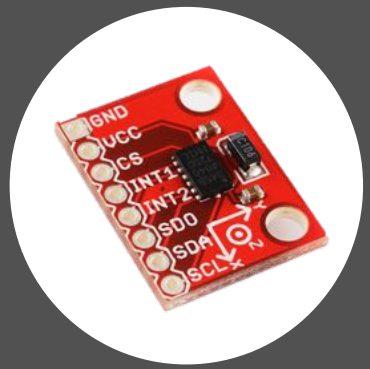
Hardware

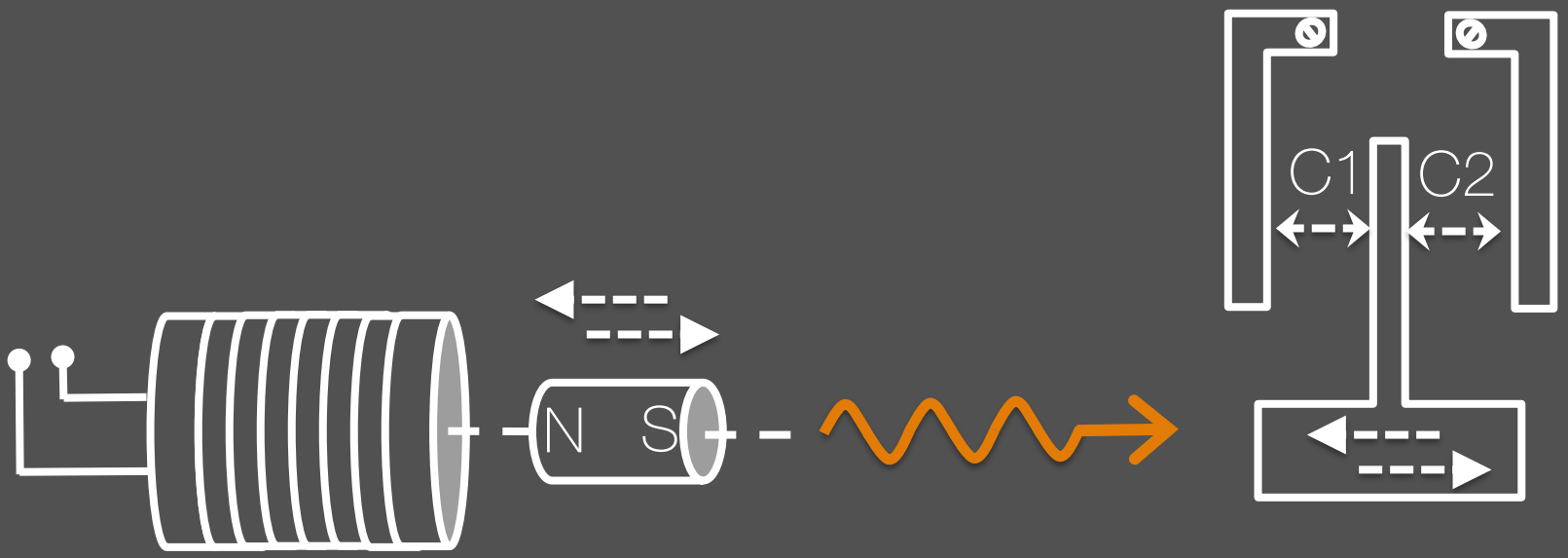
Morse-code	Single-Carrier	Multi-Carrier	Multi-dimension	Phy-Security
6 bps	80 bps	200 bps	400 bps	+secured

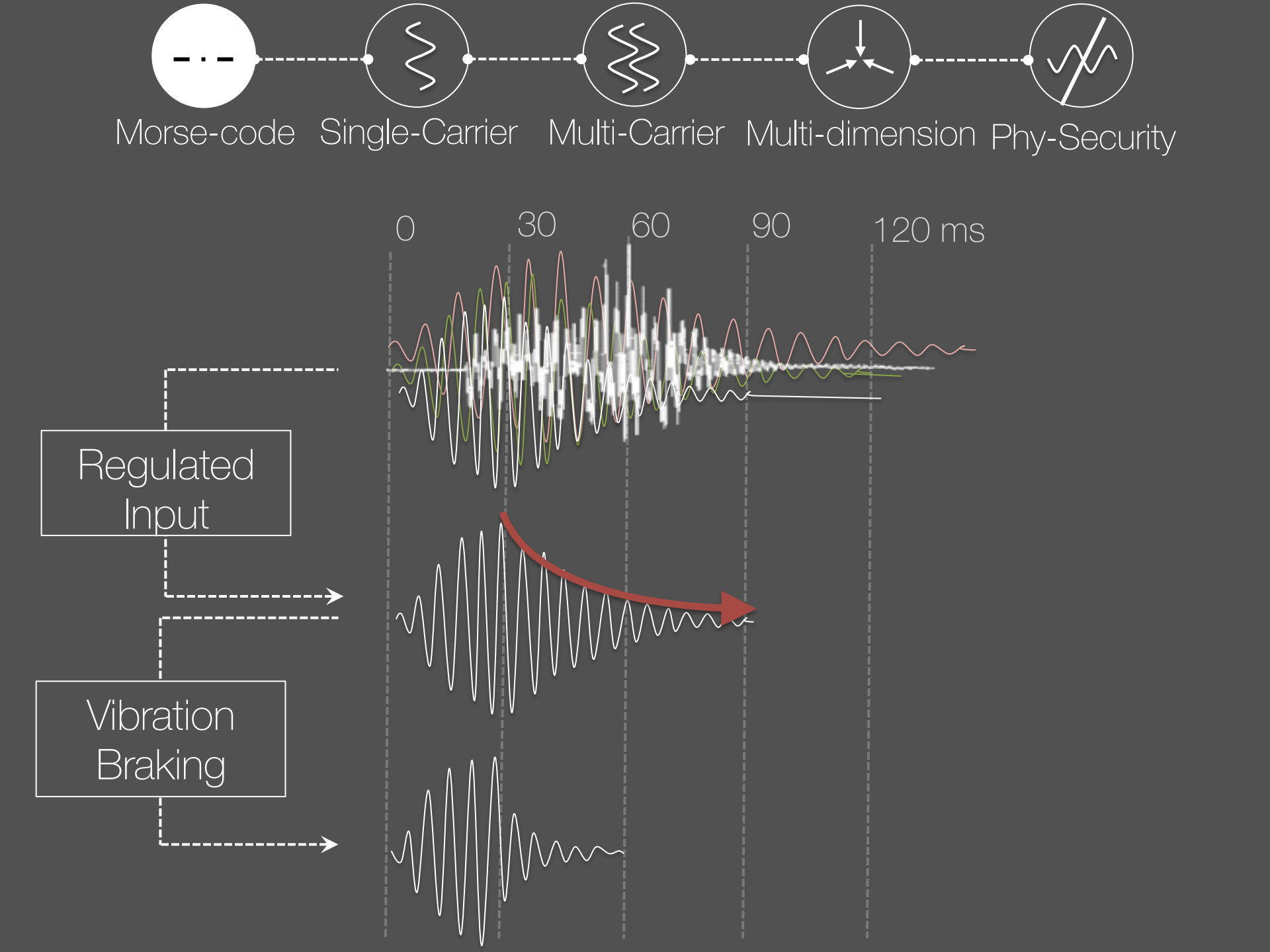


Vibration Motor

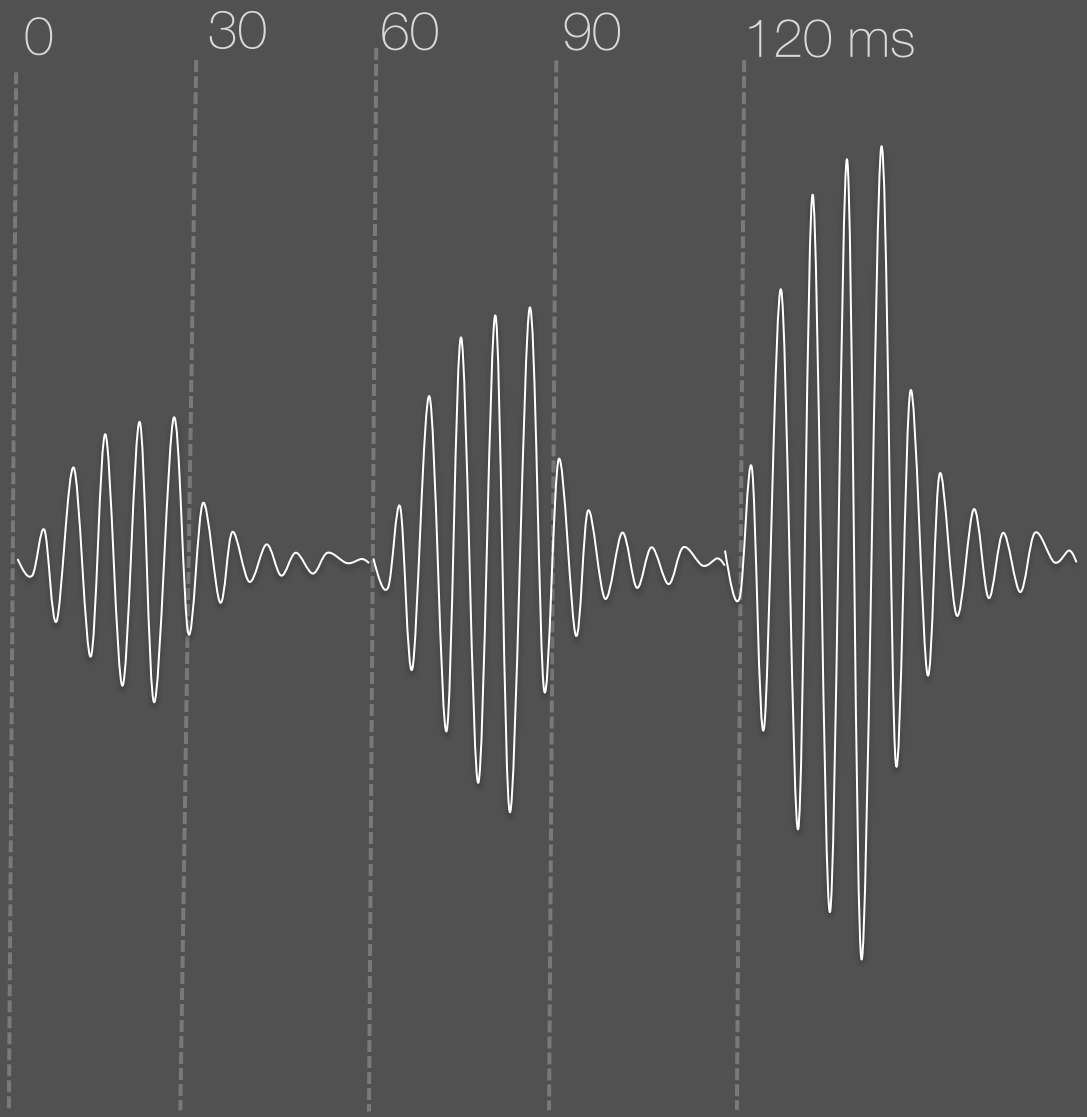
Accelerometer

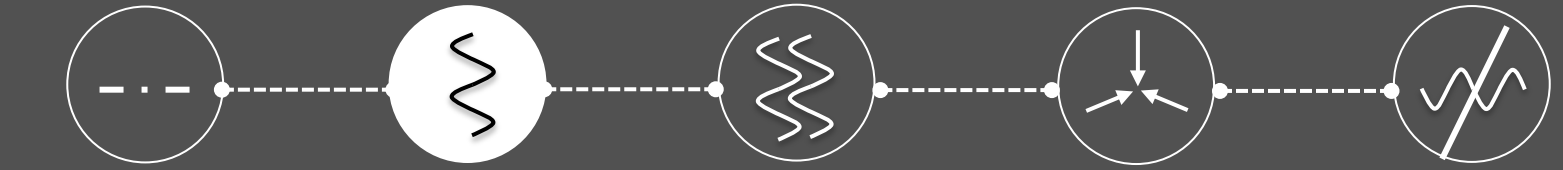


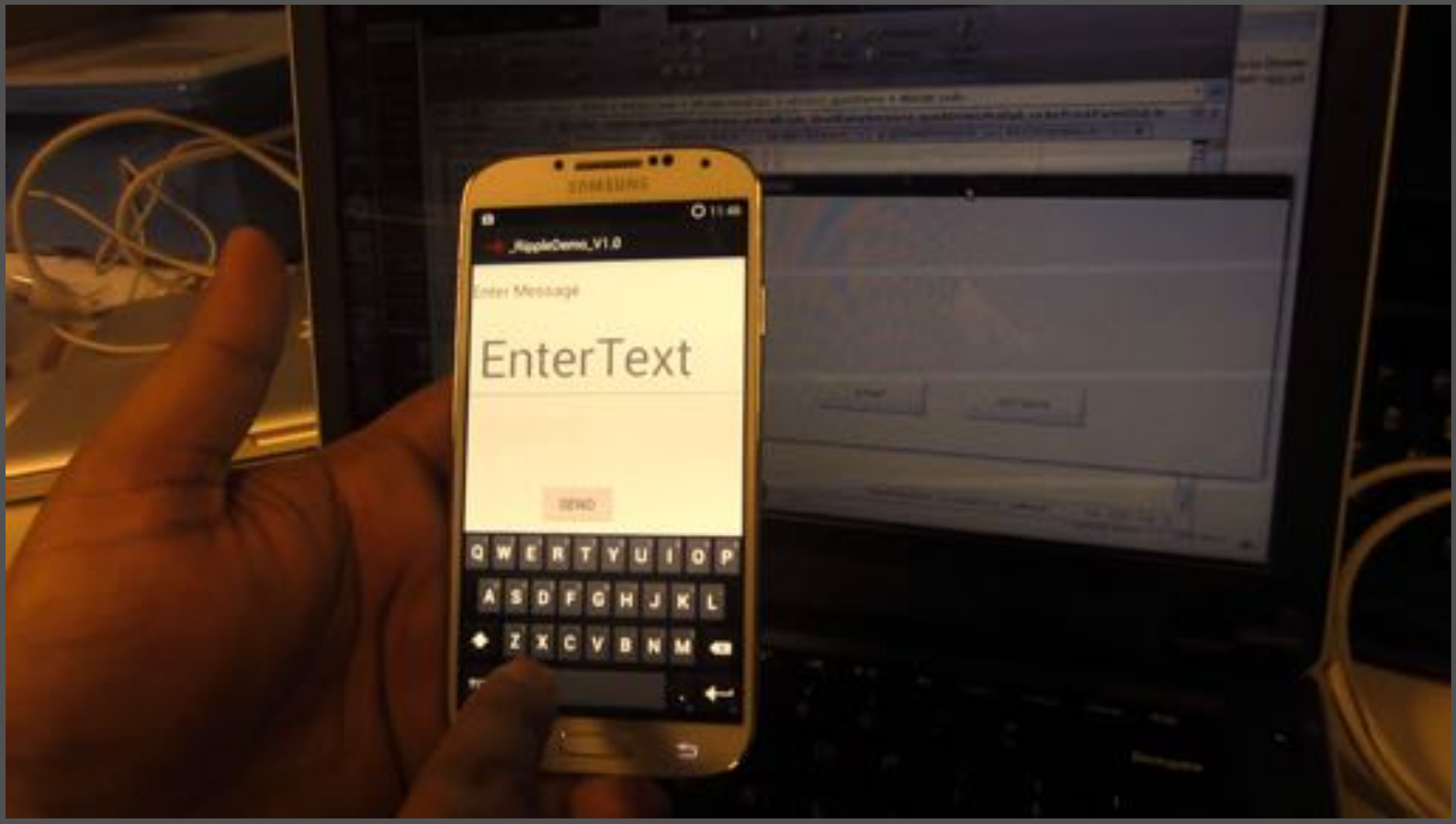


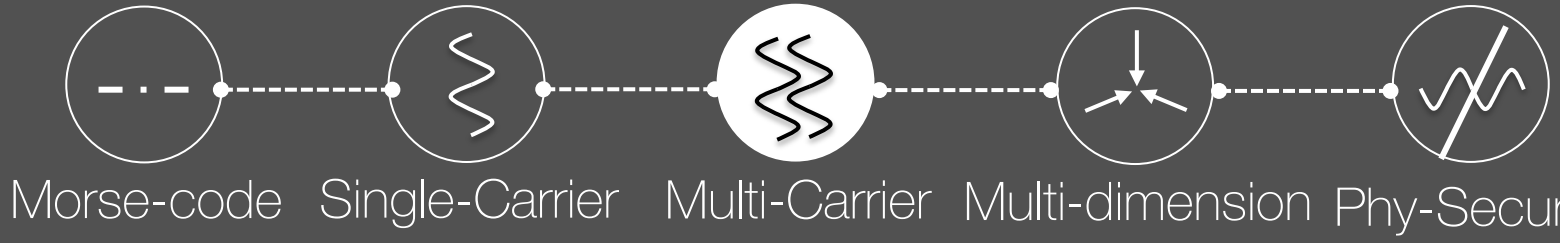

Morse-code
Single-Carrier
Multi-Carrier
Multi-dimension
Phy-Security
0
30
60
90
120 ms
Regulated Input
Vibration Braking

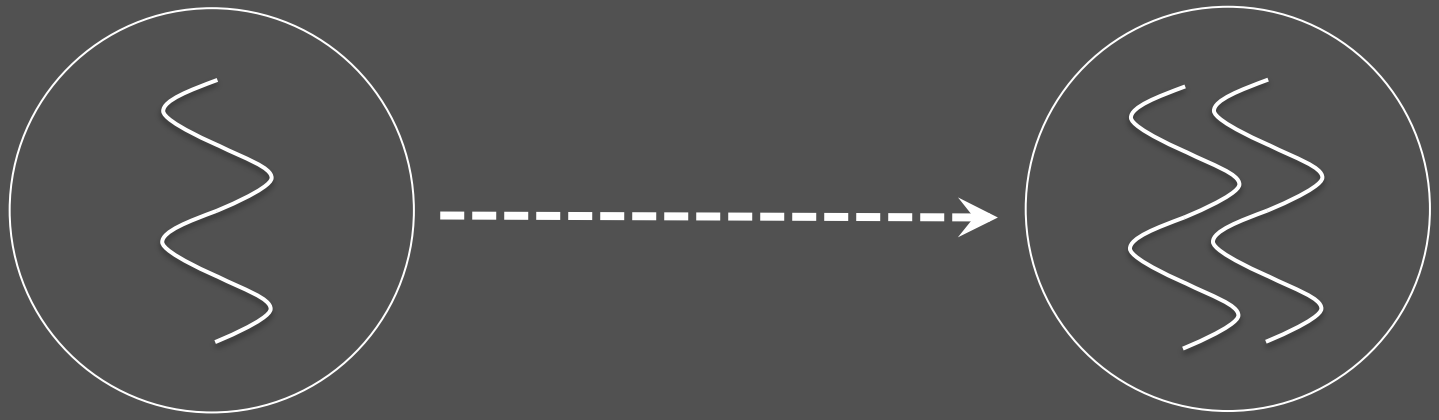
Morse-code
Single-Carrier
Multi-Carrier
Multi-dimension
Phy-Security


0
30
60
90
120 ms

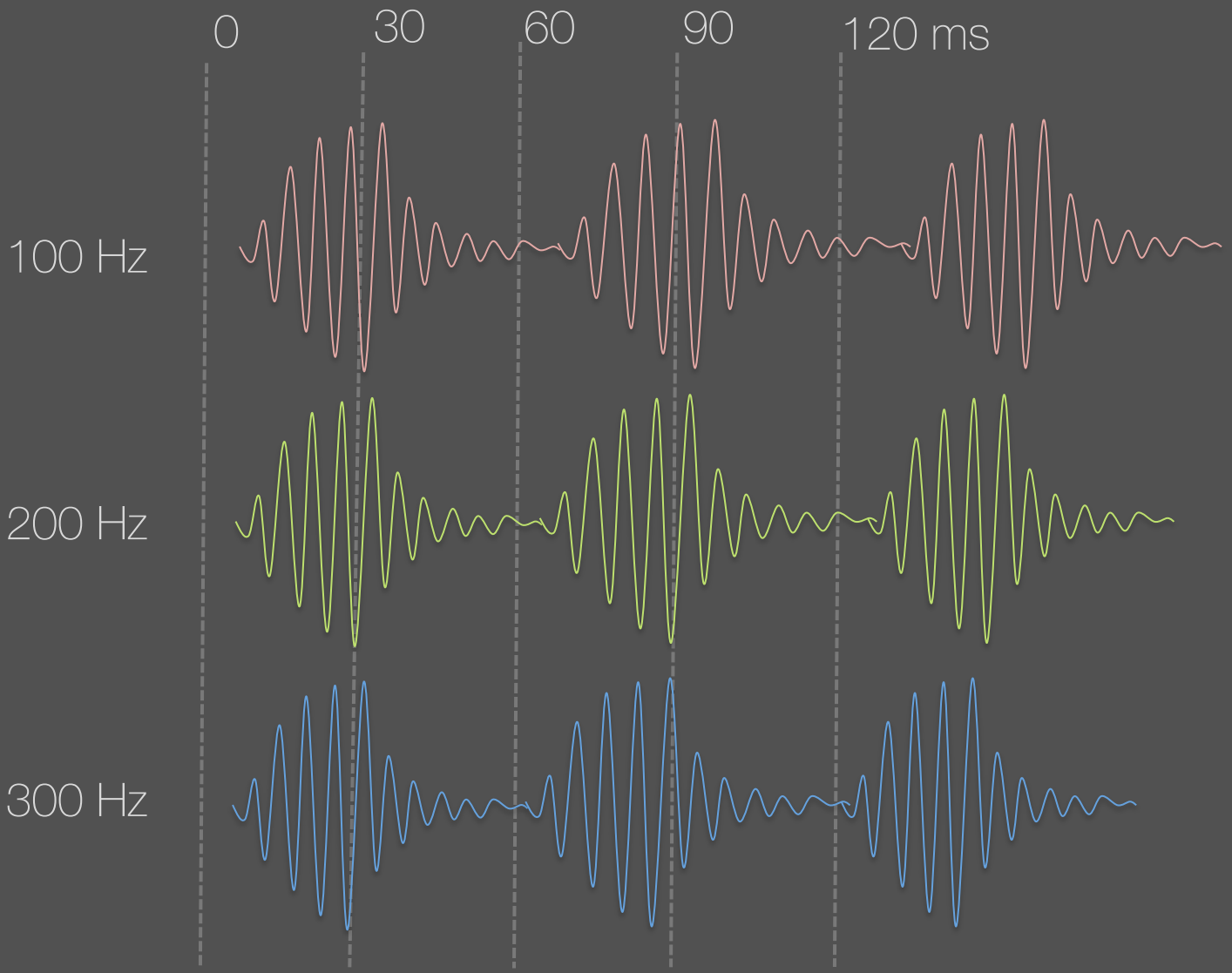

Morse-code
Single-Carrier
Multi-Carrier
Multi-dimension
Phy-Security

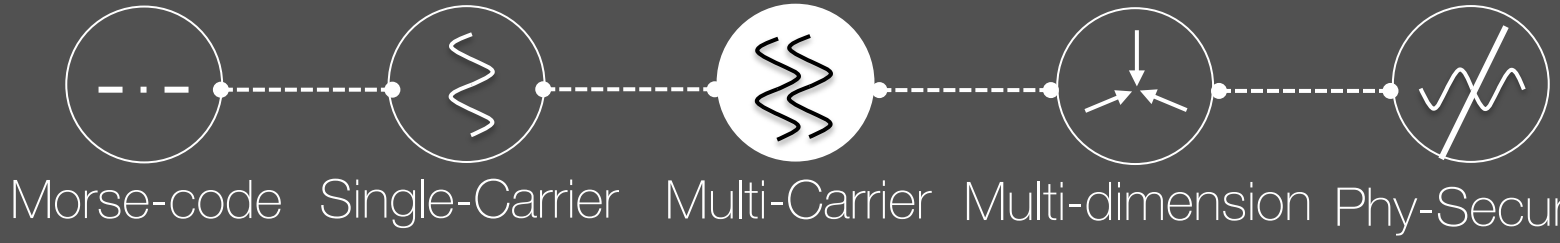

SAMSUNG
_RippleDemo_V1.0
Enter Message
EnterText
SEND
Q W E R T Y U I O P
A S D F G H J K L
Z X C V B N M

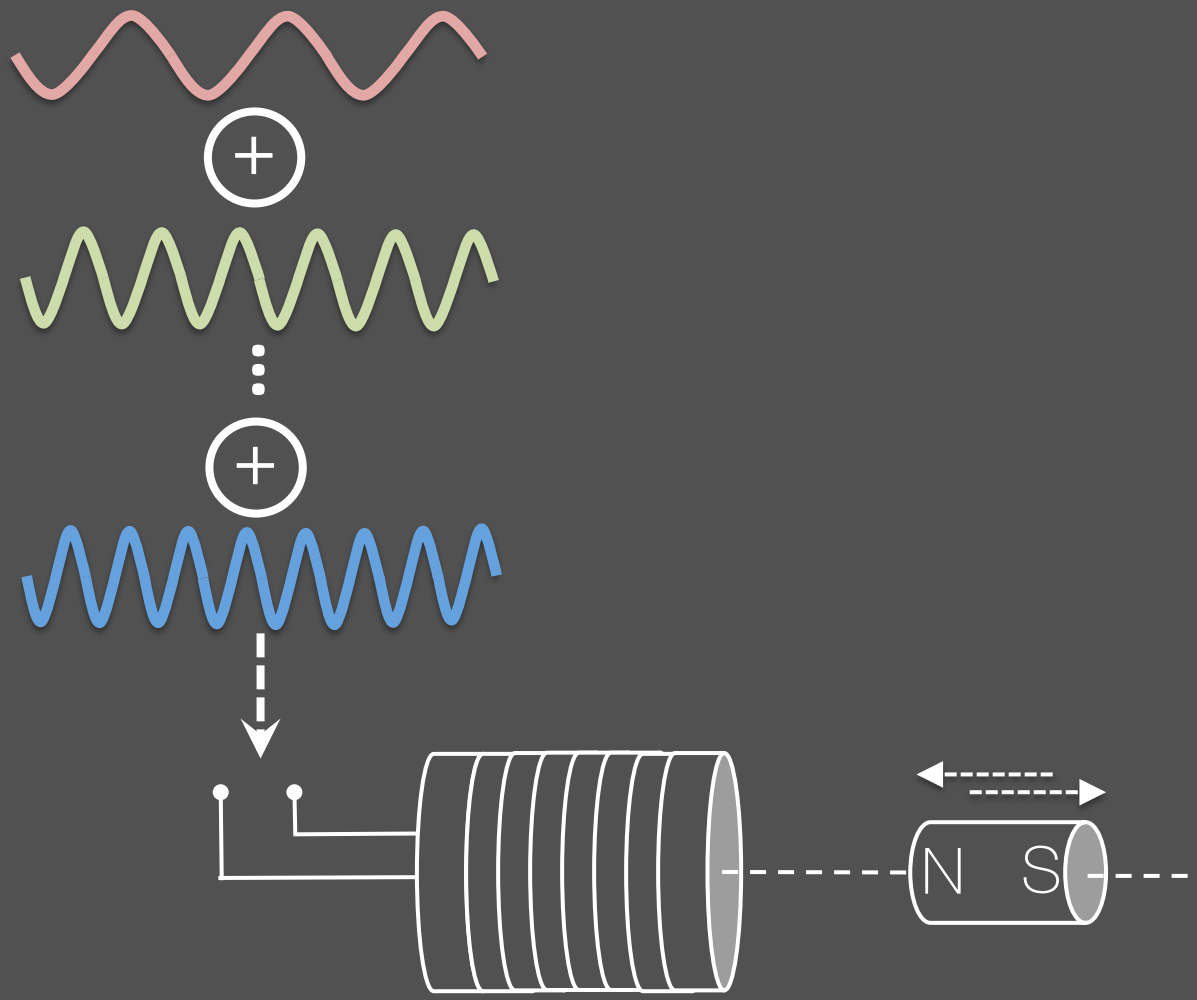

Morse-code
Single-Carrier
Multi-Carrier
Multi-dimension
Phy-Security

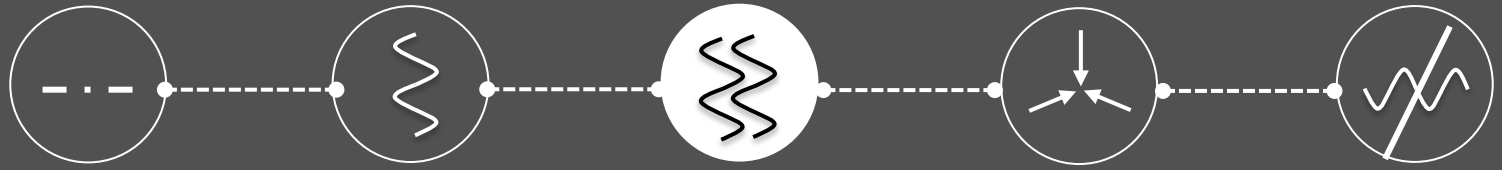

Single-Carrier
Multi-Carrier

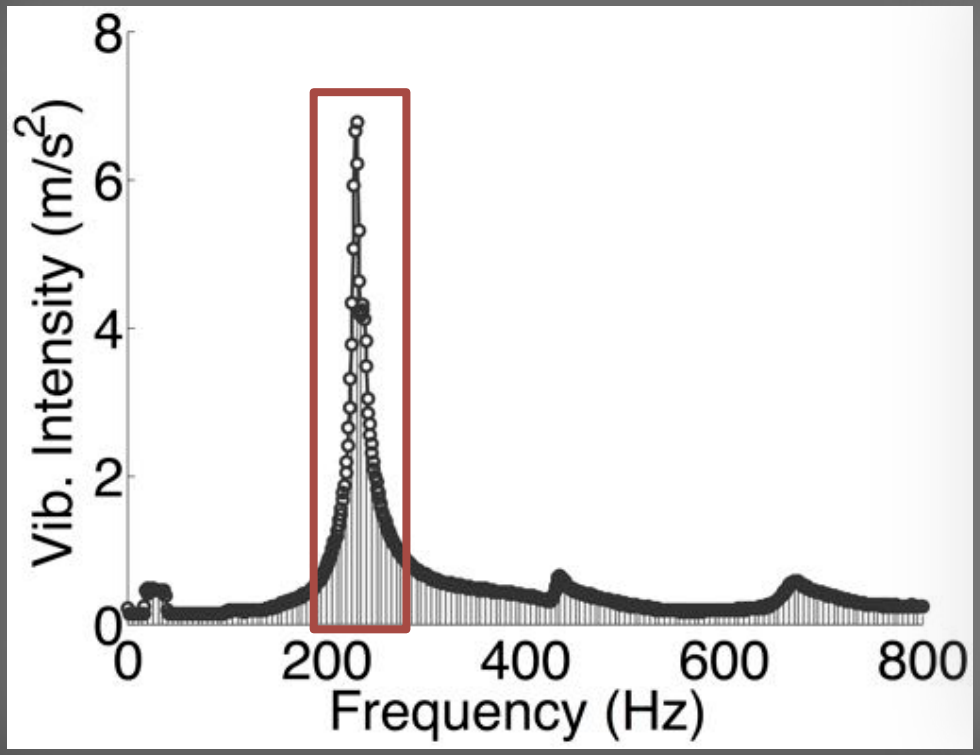
Morse-code
Single-Carrier
Multi-Carrier
Multi-dimension
Phy-Security

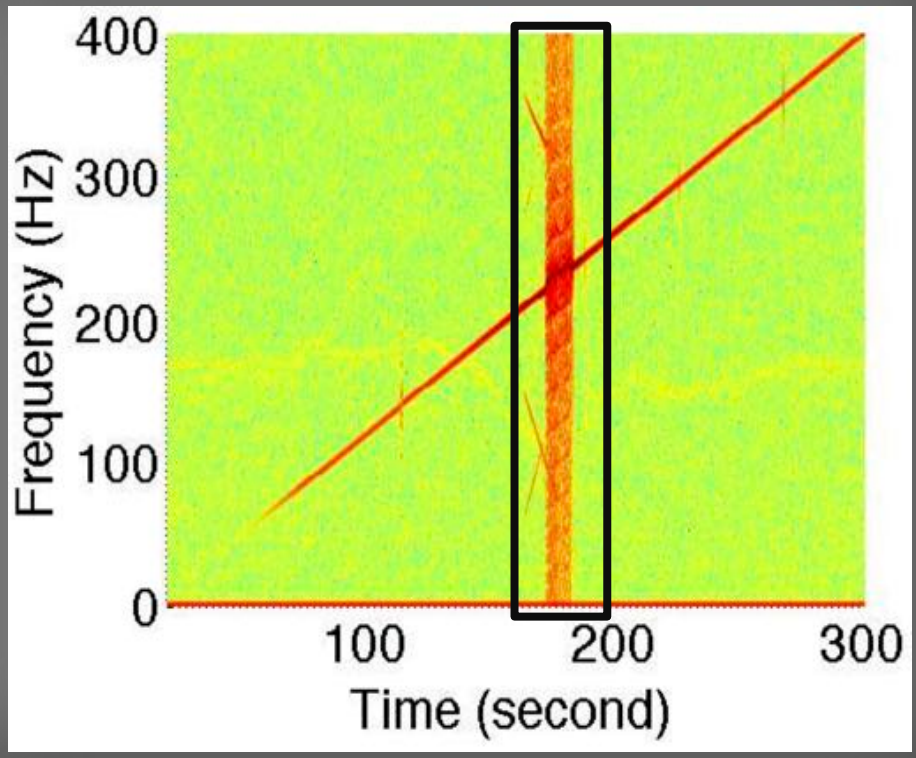

0
30
60
90
120 ms
100 Hz
200 Hz
300 Hz

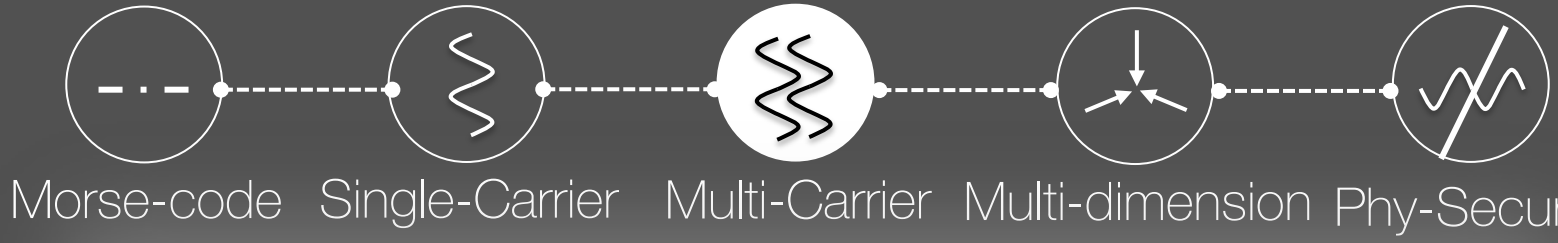

Morse-code
Single-Carrier
Multi-Carrier
Multi-dimension
Phy-Security

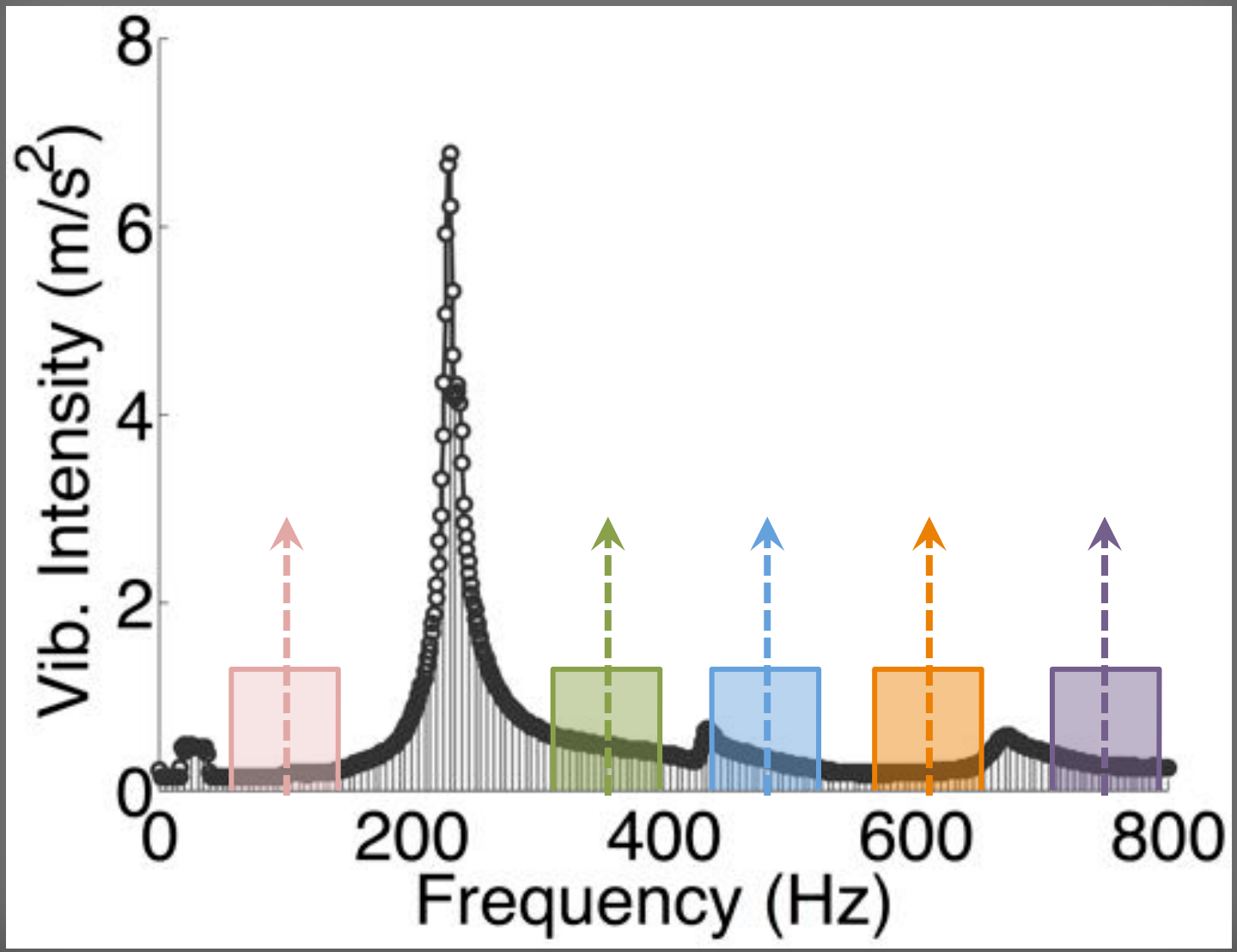

N
S

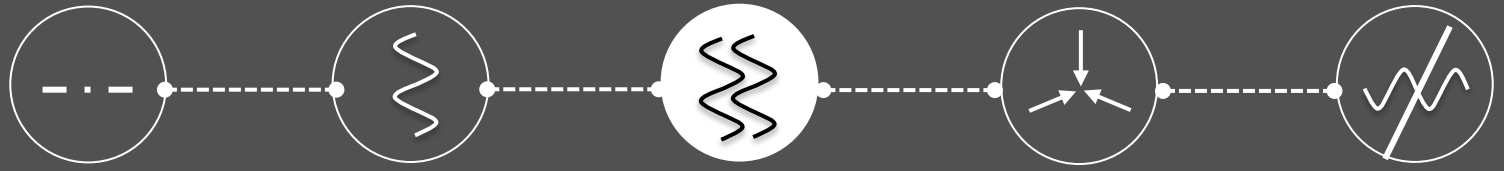

Morse-code
Single-Carrier
Multi-Carrier
Multi-dimension
Phy-Security

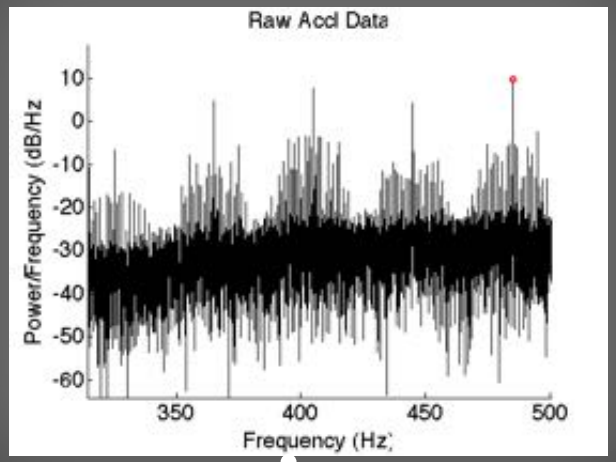

Vib. Intensity (m/s2)
0
2
4
6
8
0
200
400
600
800
Frequency (Hz)

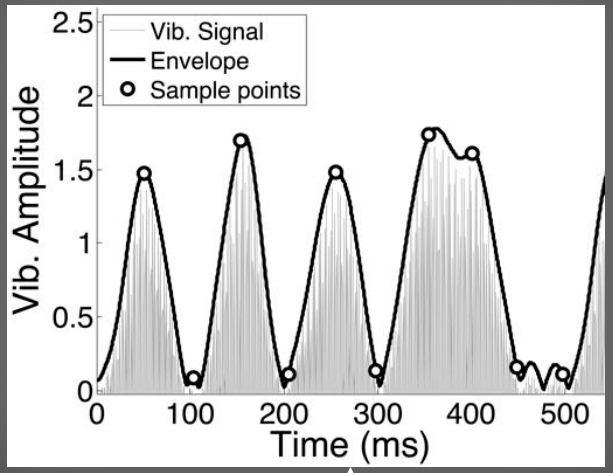

Frequency (Hz)
0
100
200
300
400
100
200
300
Time (second)


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

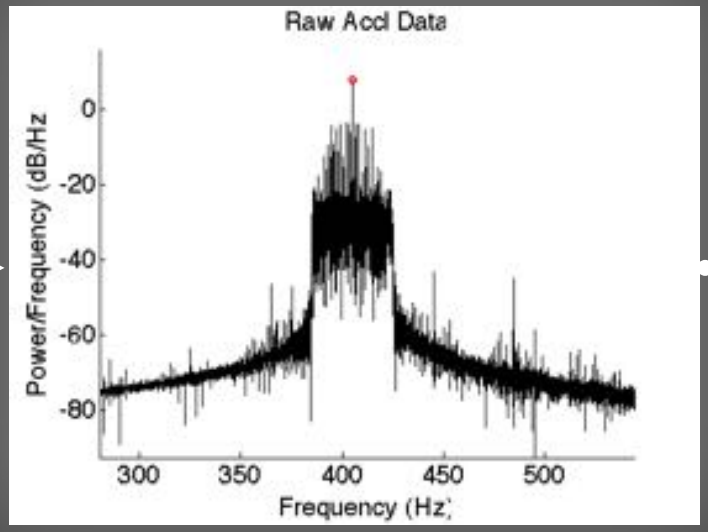

Vib. Intensity (m/s²)
0
2
4
6
8
0
200
400
600
800
Frequency (Hz)



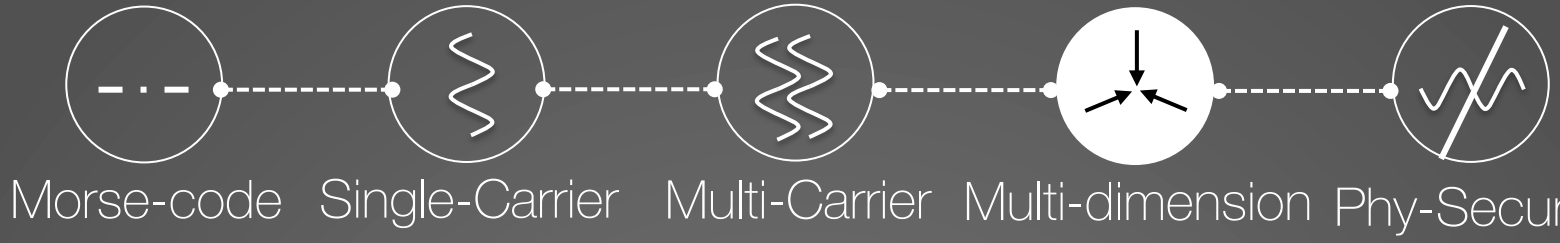


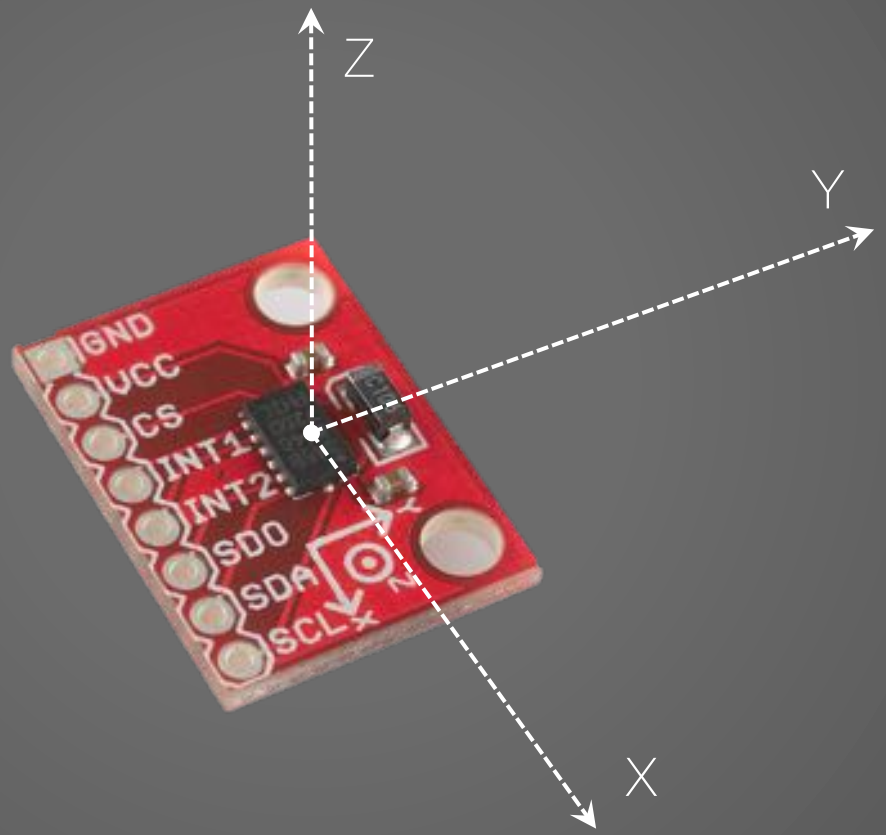


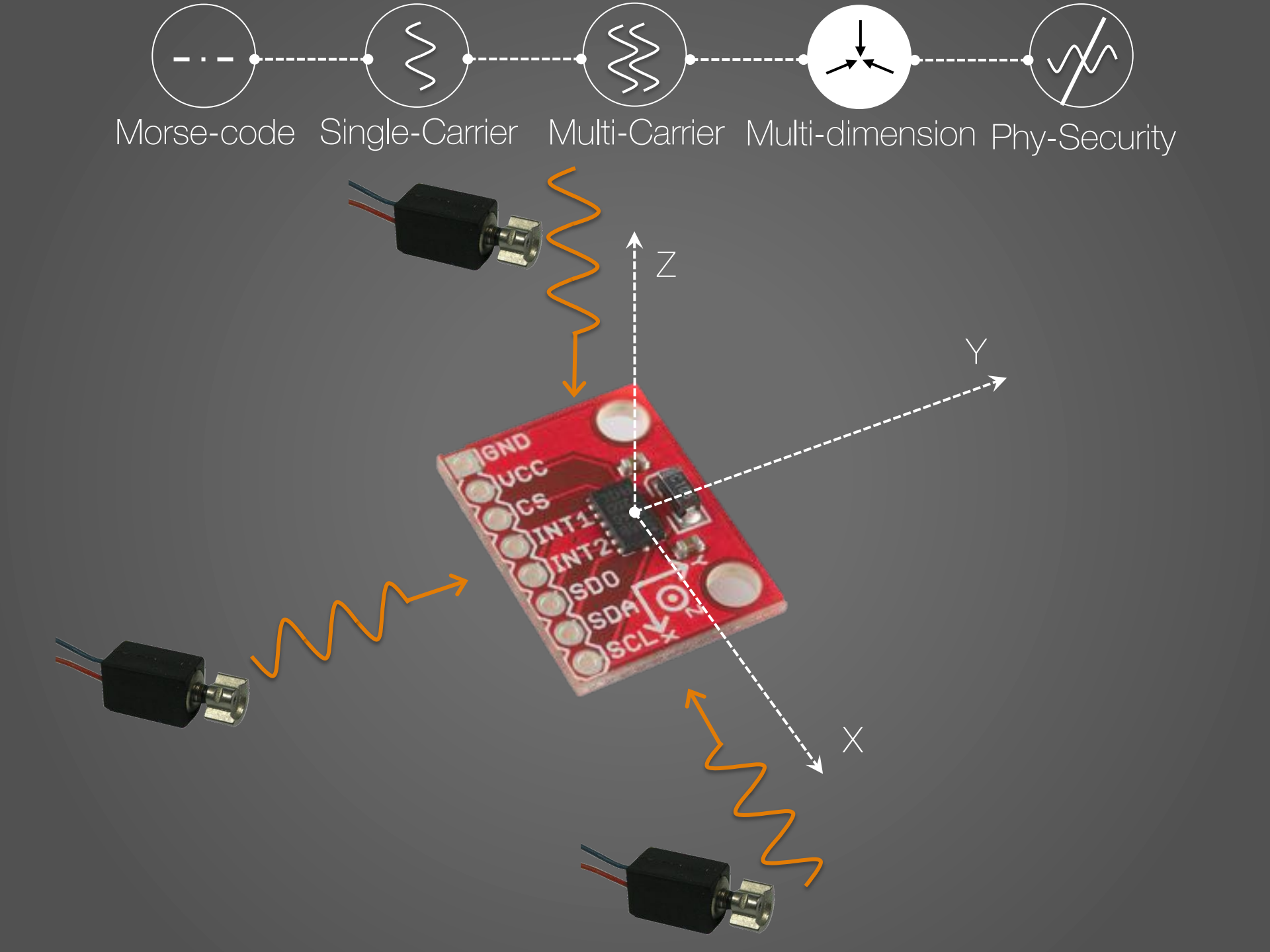
Filtering

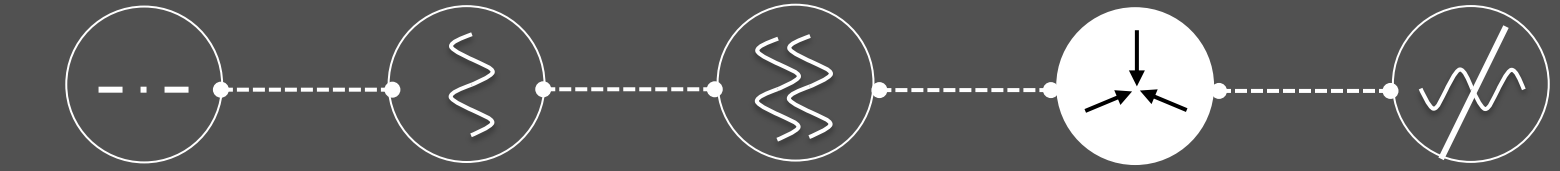


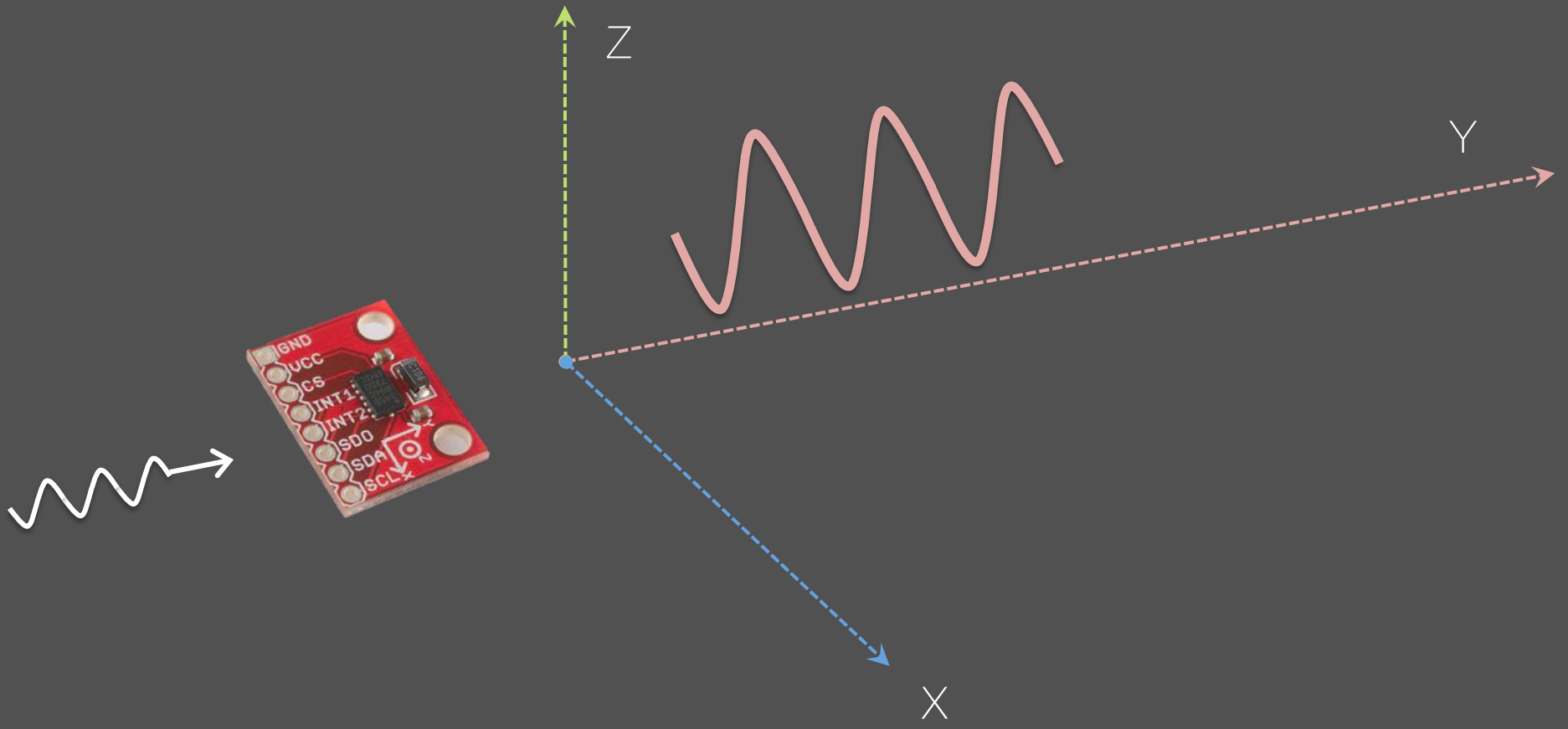
Envelope Detection


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

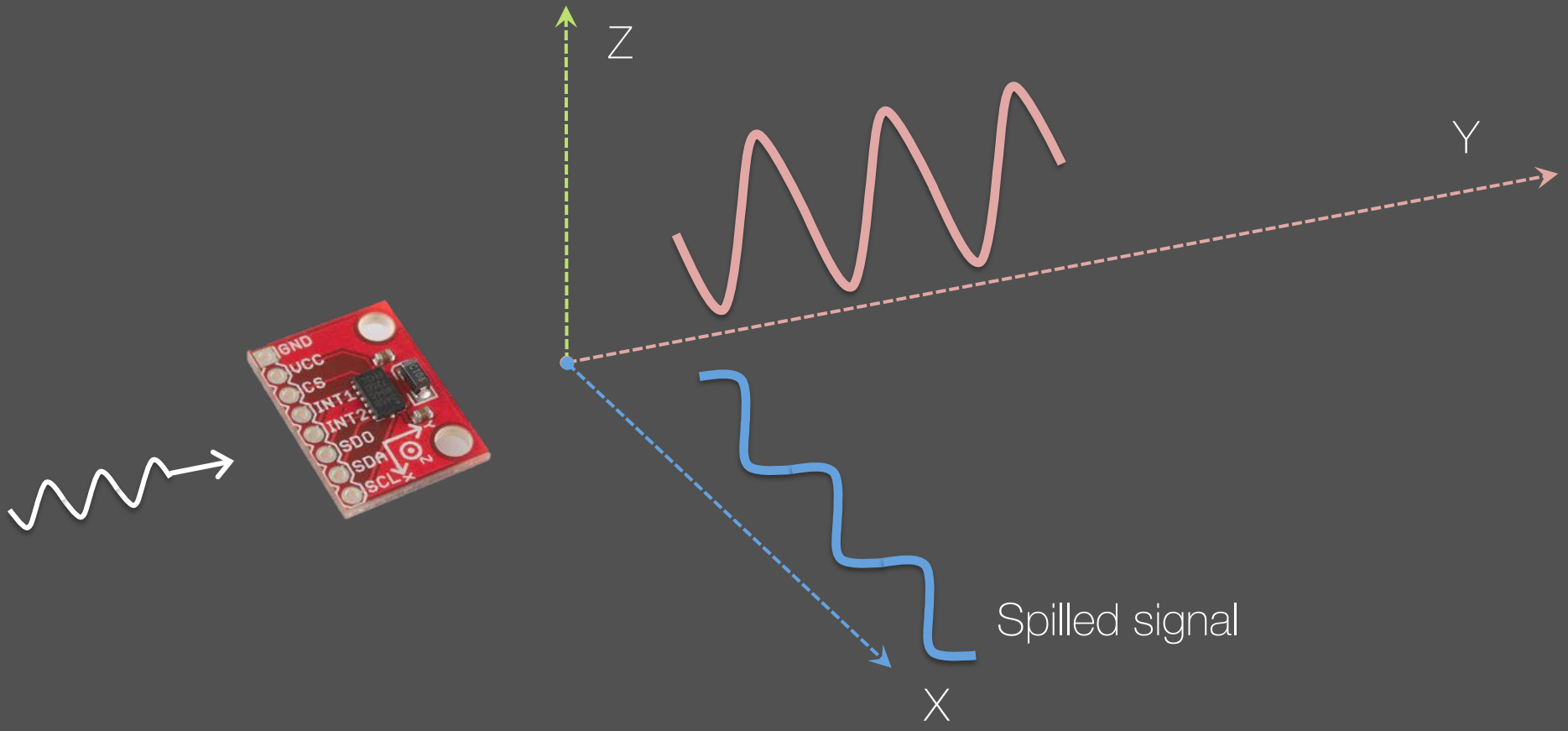

Z
Y
X
GND
VCC
CS
INT1
INT2
SDO
SDA
SCL


Morse-code
Single-Carrier
Multi-Carrier
Multi-dimension
Phy-Security
Z
Y
X
GND
VCC
CS
INT1
INT2
SDO
SDA
SCL

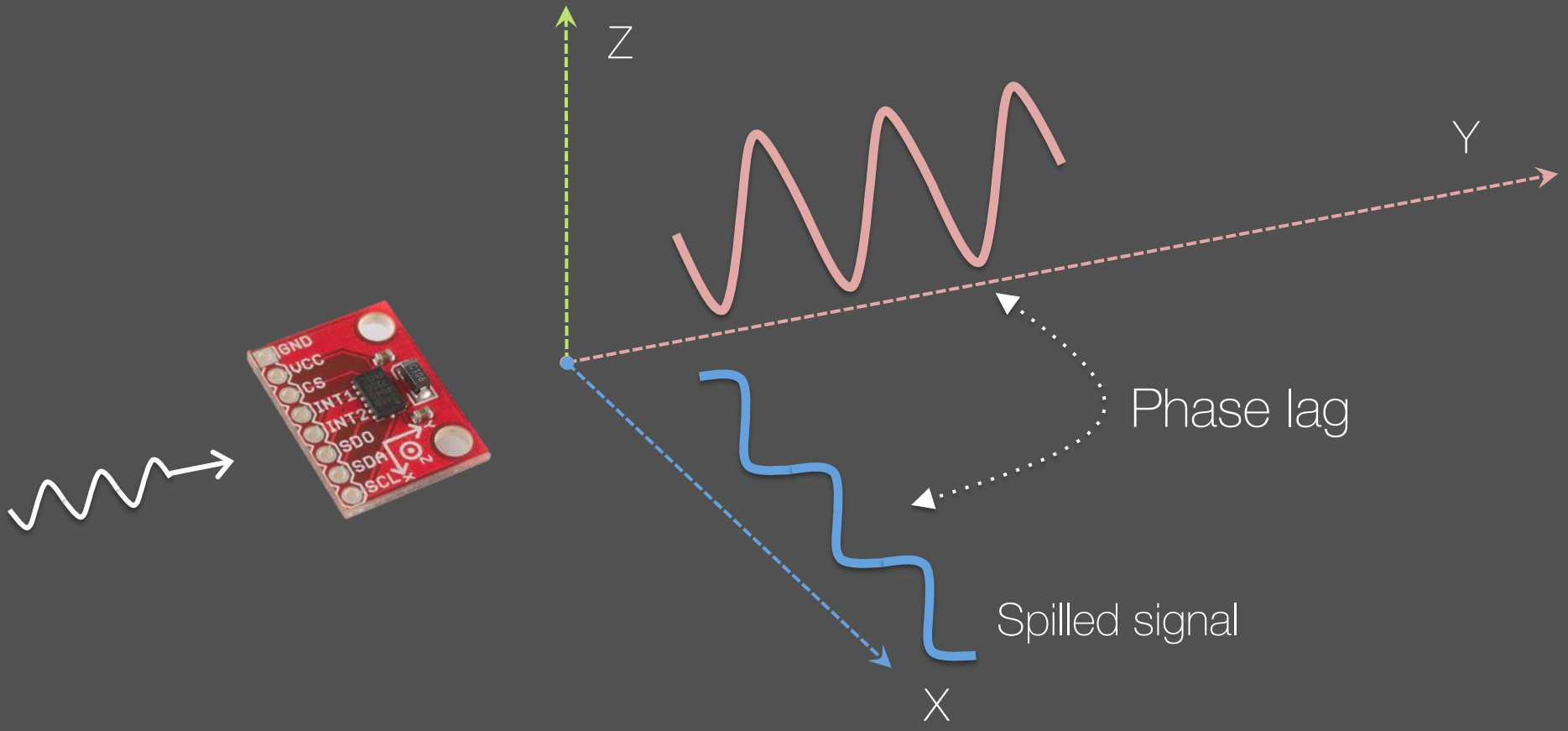

Morse-code
Single-Carrier
Multi-Carrier
Multi-dimension
Phy-Security


Z
Y
X
GND
VCC
CS
INT1
INT2
SDO
SDA
SCL

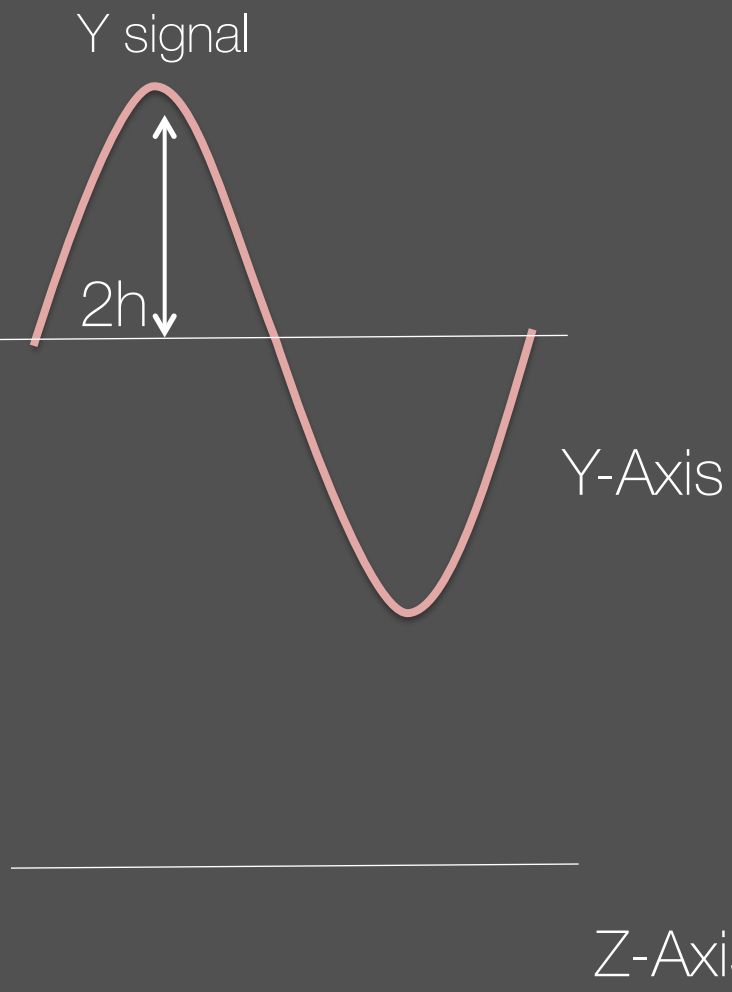
Morse-code
Single-Carrier
Multi-Carrier
Multi-dimension
Phy-Security


Z
Y
X
Spilled signal
GND
VCC
CS
INT1
INT2
SDO
SDA
SCL

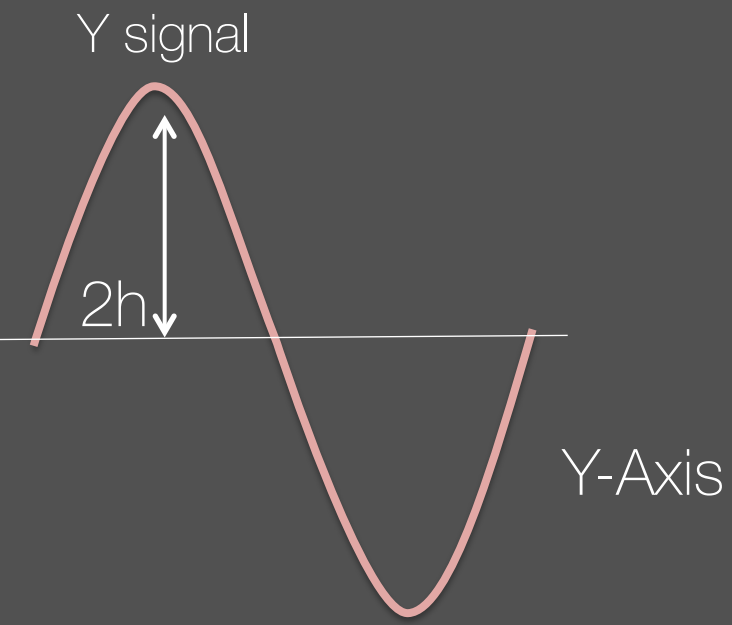
Morse-code
Single-Carrier
Multi-Carrier
Multi-dimension
Phy-Security

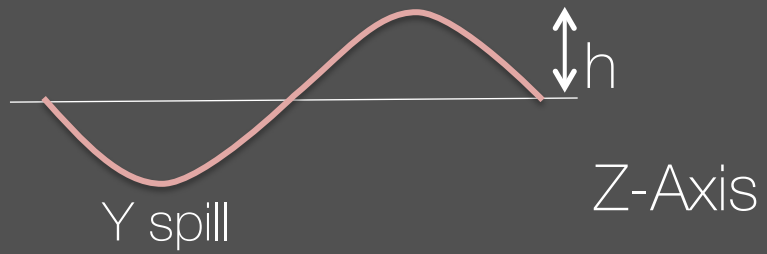

Z
Y
X
Phase lag
Spilled signal
GND
VCC
CS
INT1
INT2
SDO
SDA
SCL

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

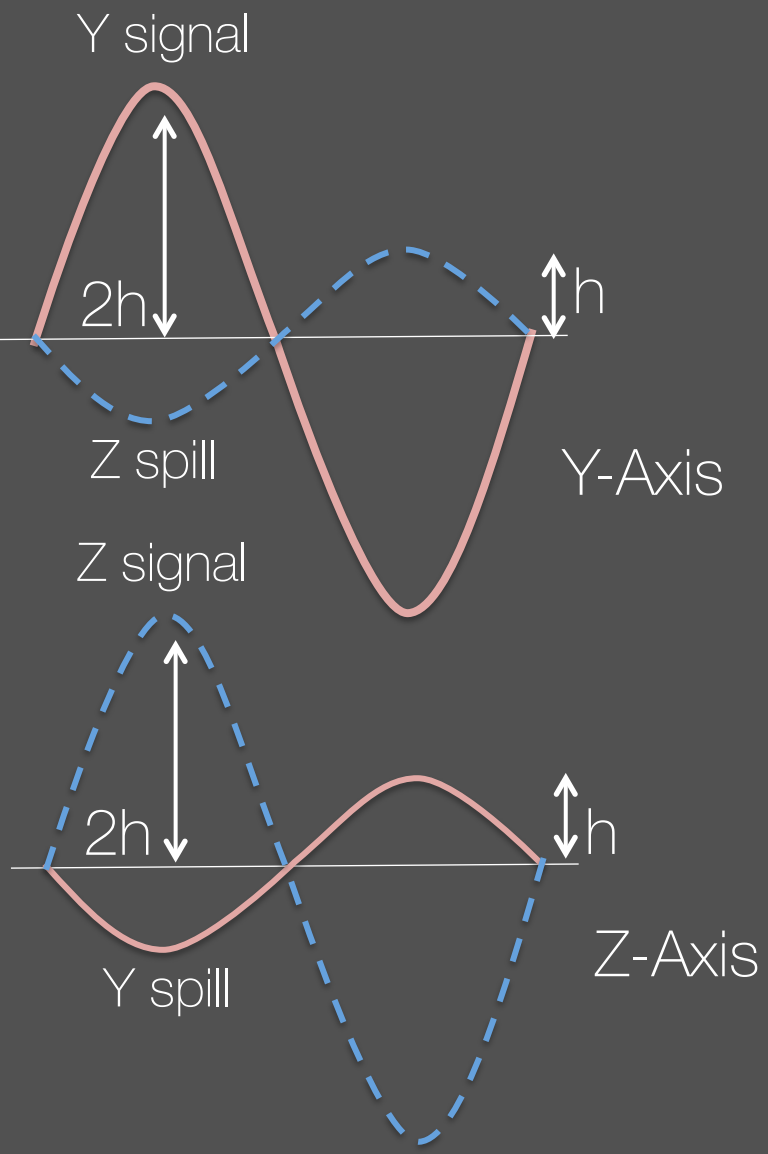

Y signal
2h
Y-Axis
Z-Axis

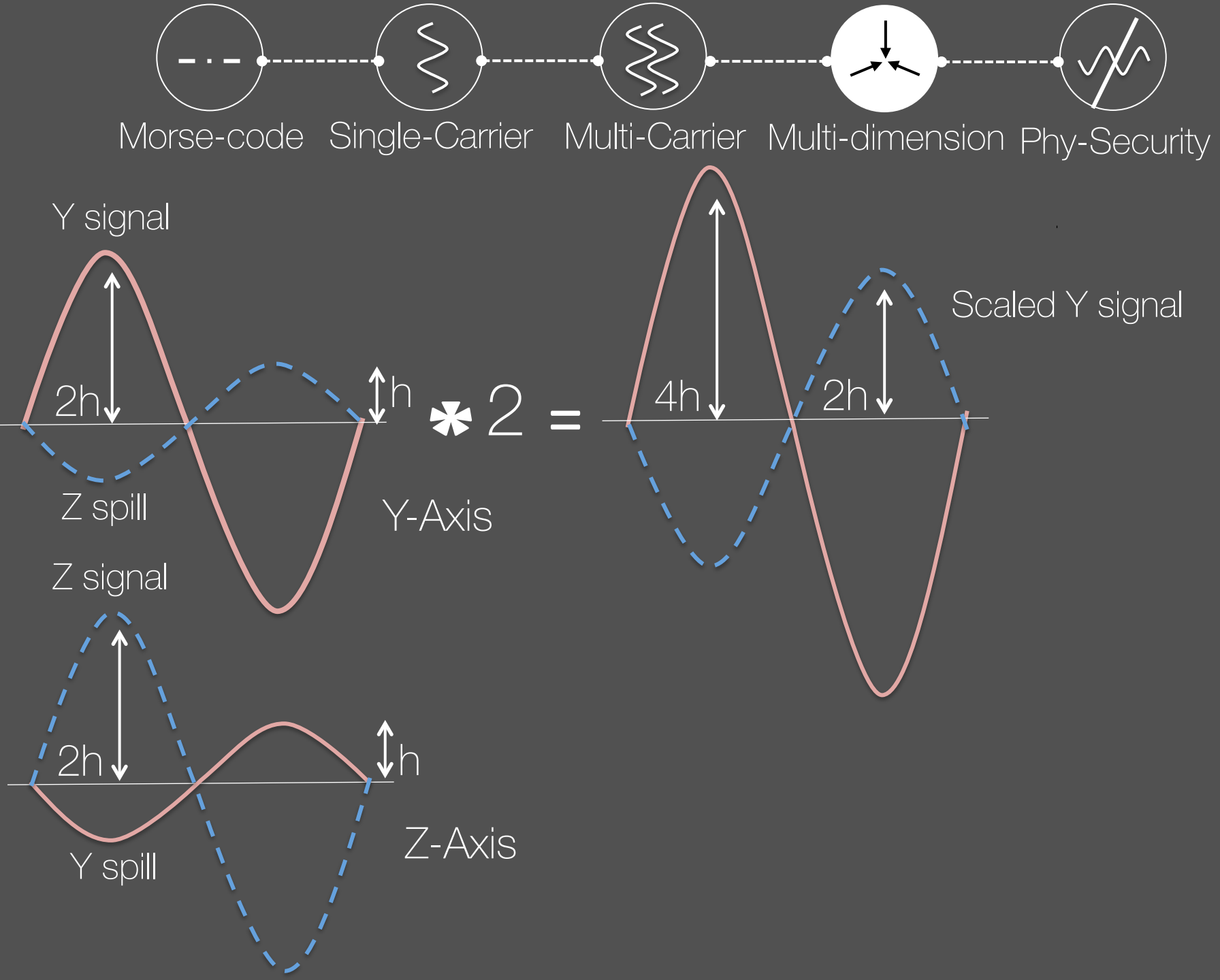
Morse-code
Single-Carrier
Multi-Carrier
Multi-dimension
Phy-Security

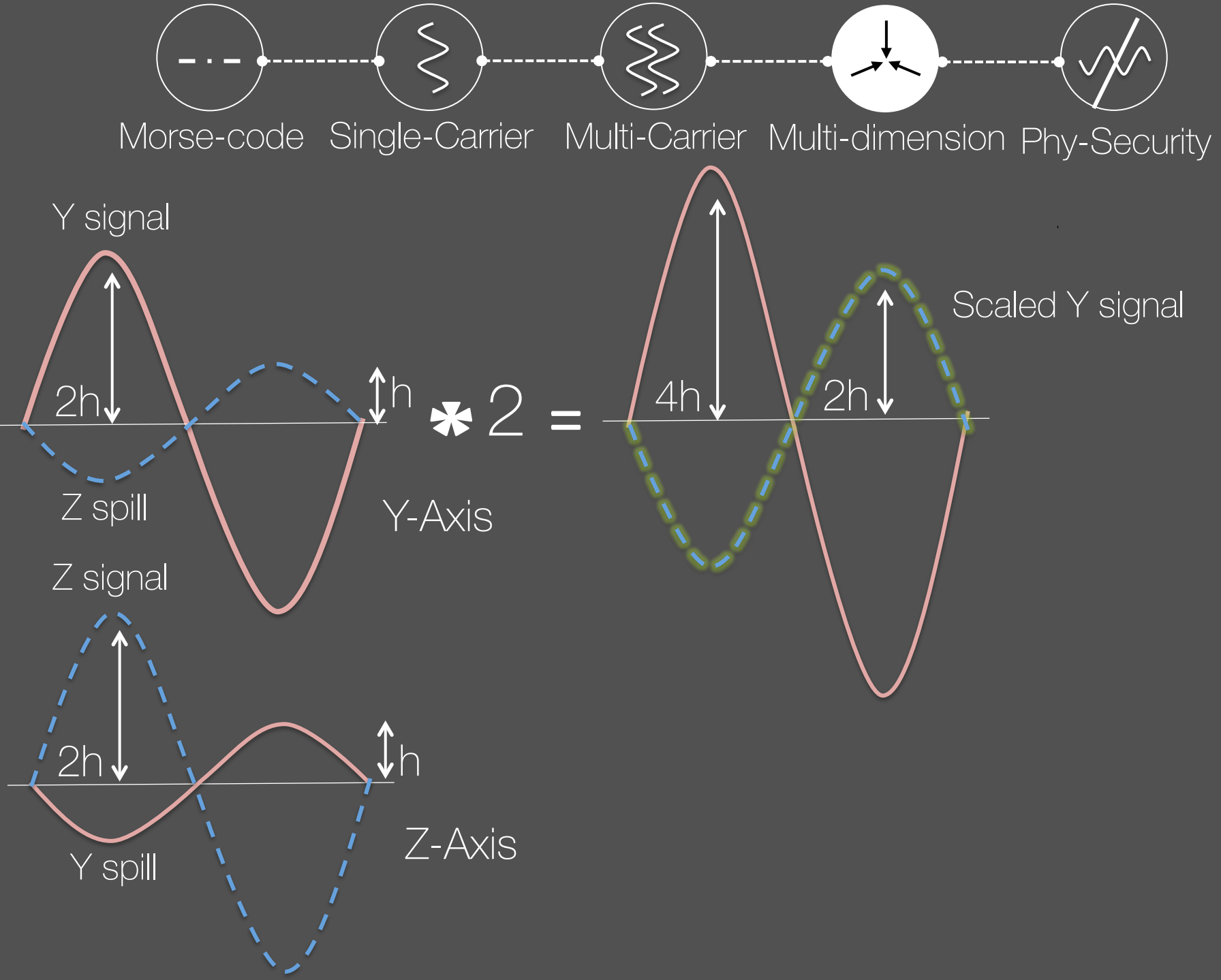

Y signal
2h
Y-Axis

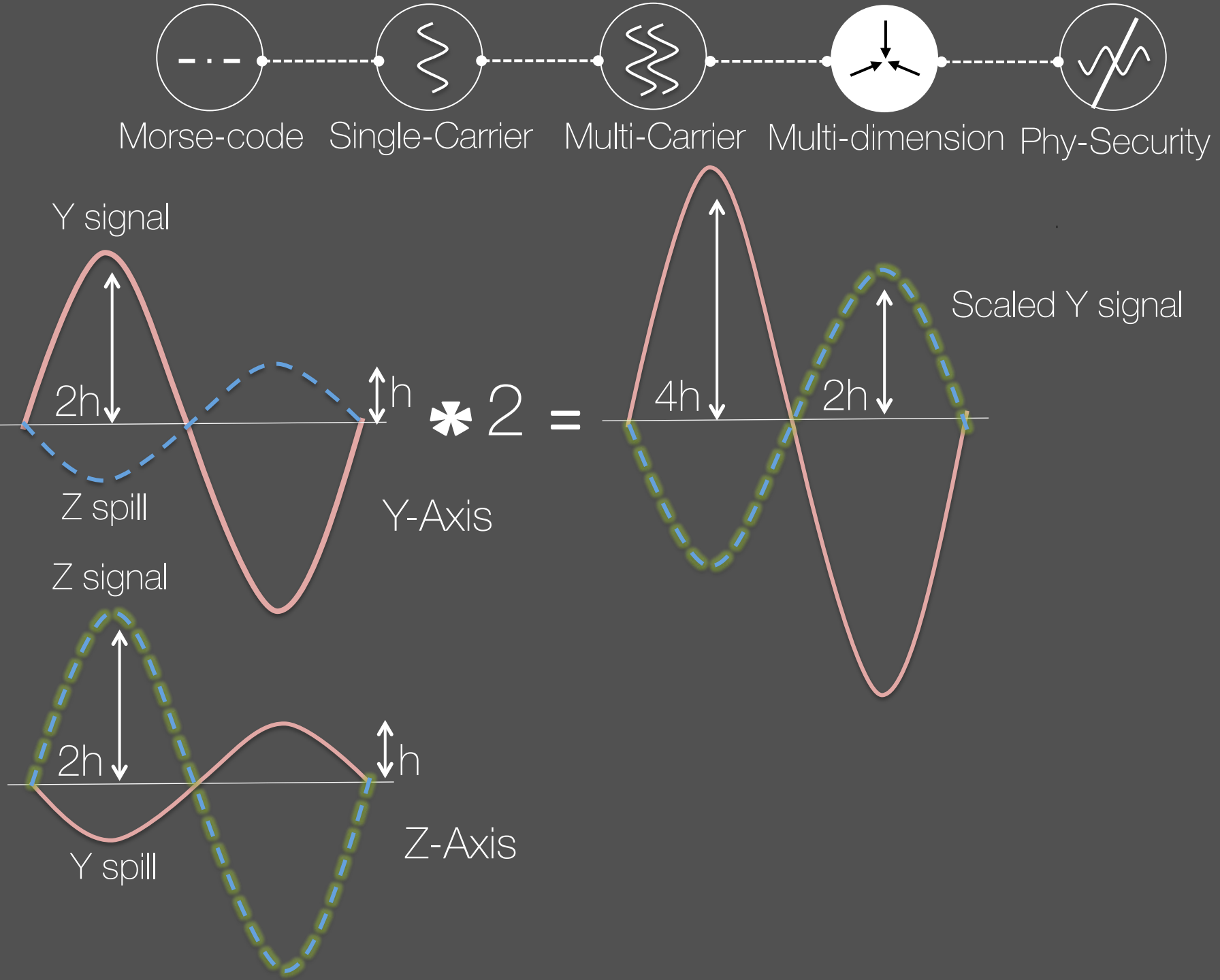

h
Z-Axis
Y spill

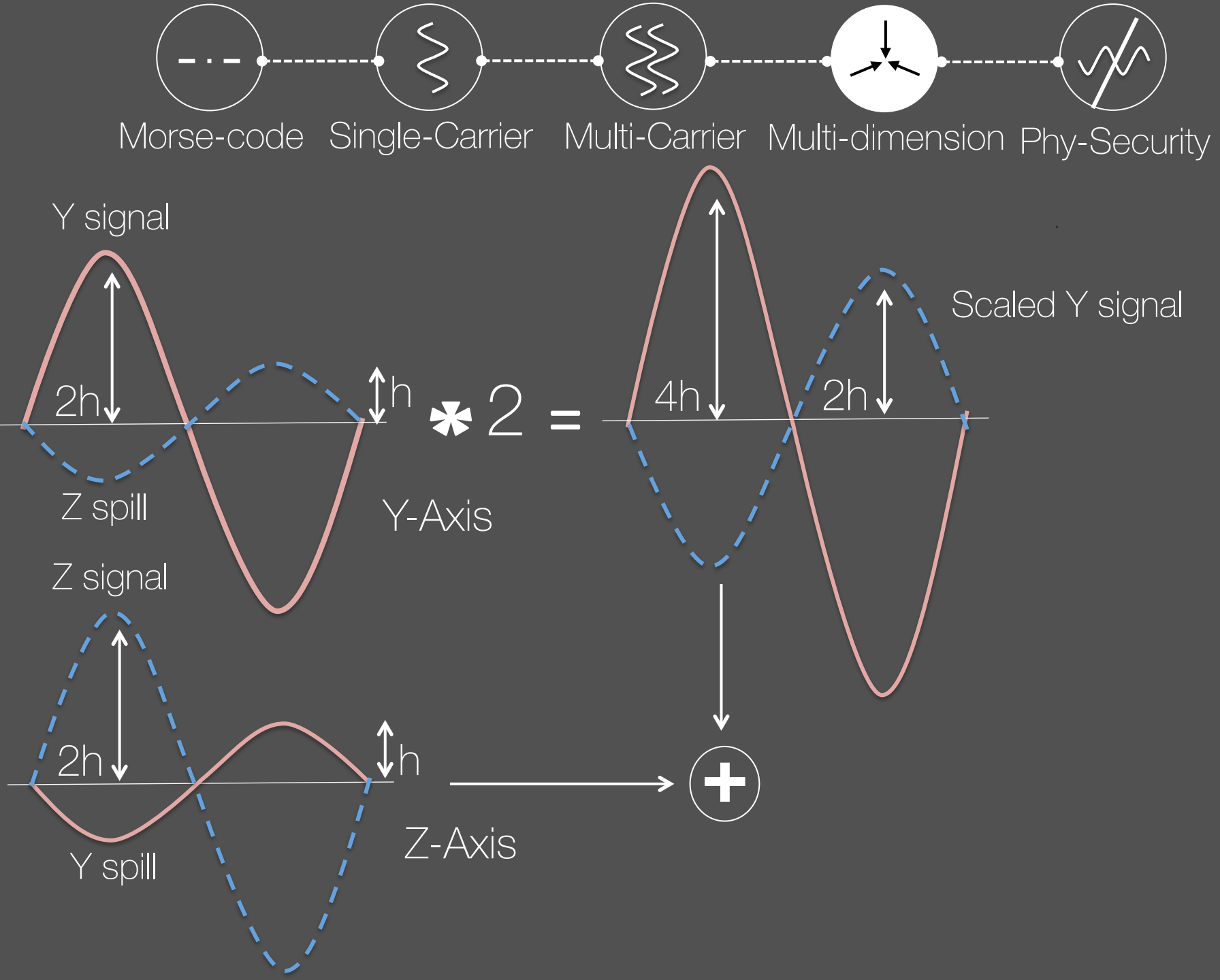
Morse-code
Single-Carrier
Multi-Carrier
Multi-dimension
Phy-Security

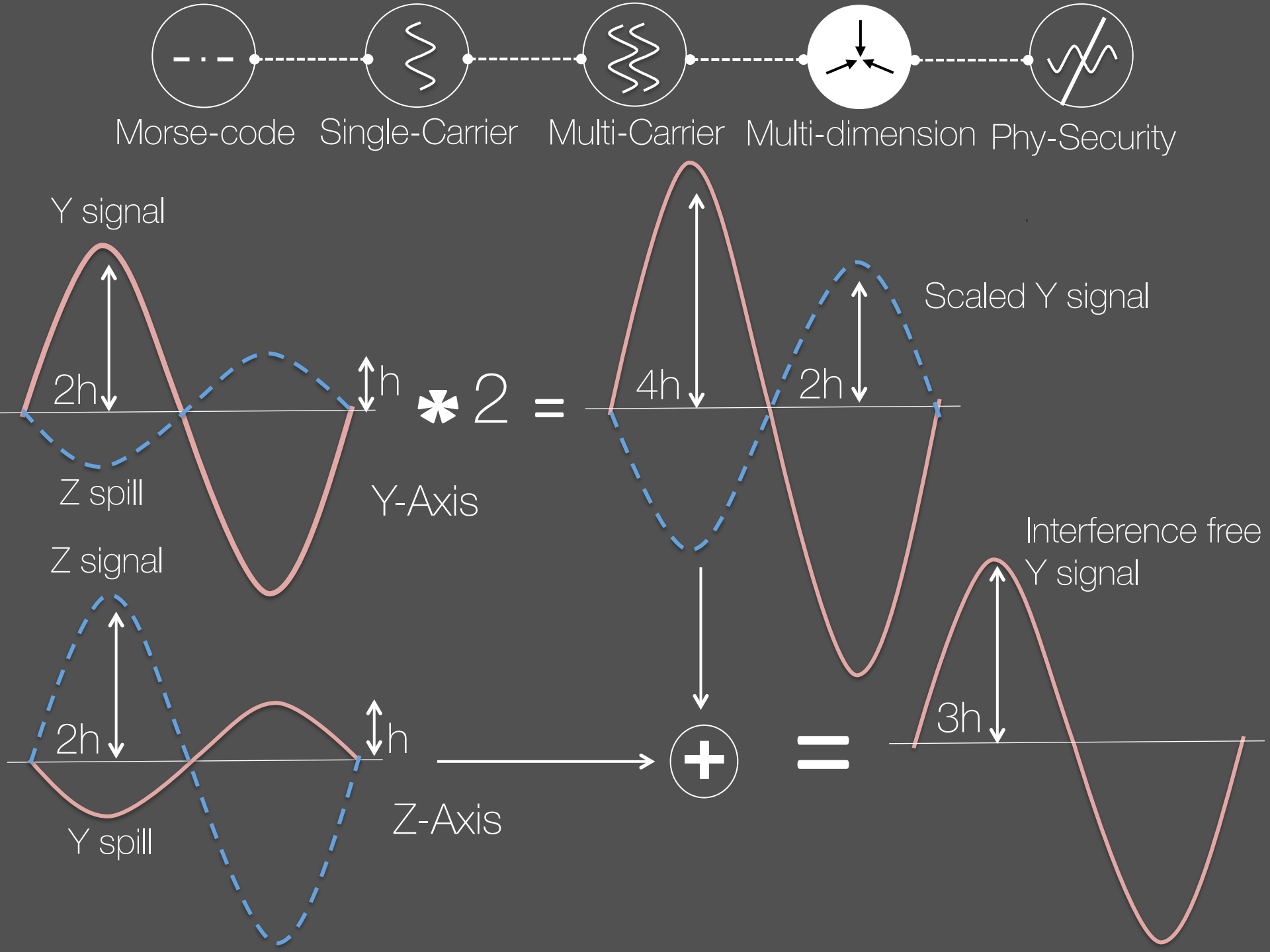

Y signal
2h
h
Z spill
Y-Axis
Z signal
2h
h
Y spill
Z-Axis

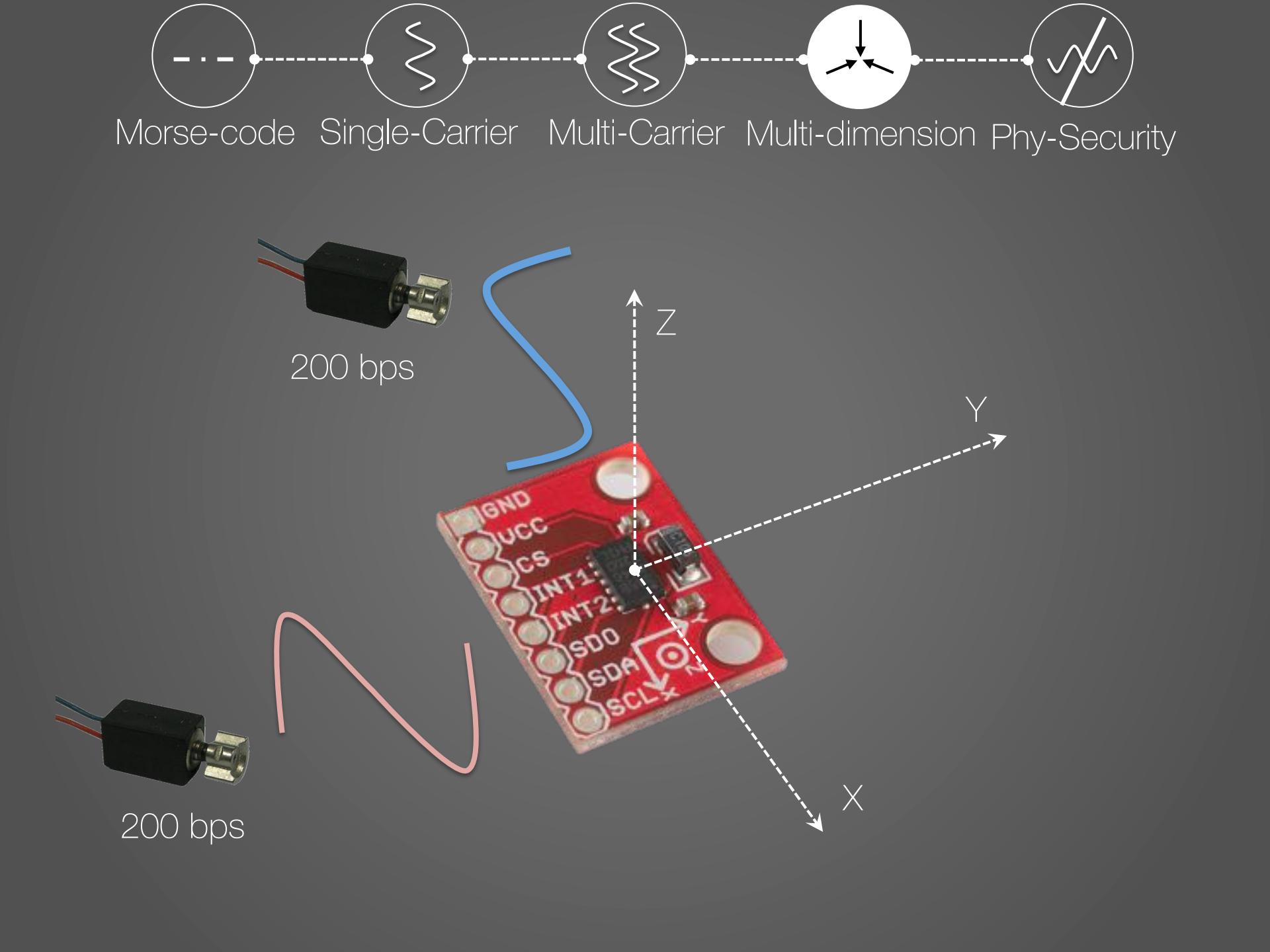

Morse-code
Single-Carrier
Multi-Carrier
Multi-dimension
Phy-Security
Y signal
2h
h
Z spill
Y-Axis
* 2 =
4h
2h
Scaled Y signal
Z signal
2h
h
Y spill
Z-Axis

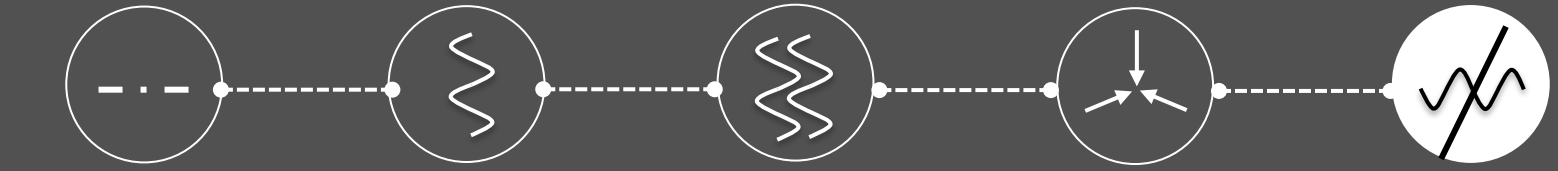

Morse-code
Single-Carrier
Multi-Carrier
Multi-dimension
Phy-Security
Y signal
2h
h
Z spill
Y-Axis
* 2 =
4h
2h
Scaled Y signal
Z signal
2h
h
Y spill
Z-Axis


Morse-code
Single-Carrier
Multi-Carrier
Multi-dimension
Phy-Security
Y signal
2h
h
Z spill
Y-Axis
* 2 =
4h
2h
Scaled Y signal
Z signal
2h
h
Y spill
Z-Axis


Morse-code
Single-Carrier
Multi-Carrier
Multi-dimension
Phy-Security
Y signal
2h
h
Z spill
Y-Axis
* 2 =
4h
2h
Scaled Y signal
Z signal
2h
h
Y spill
Z-Axis

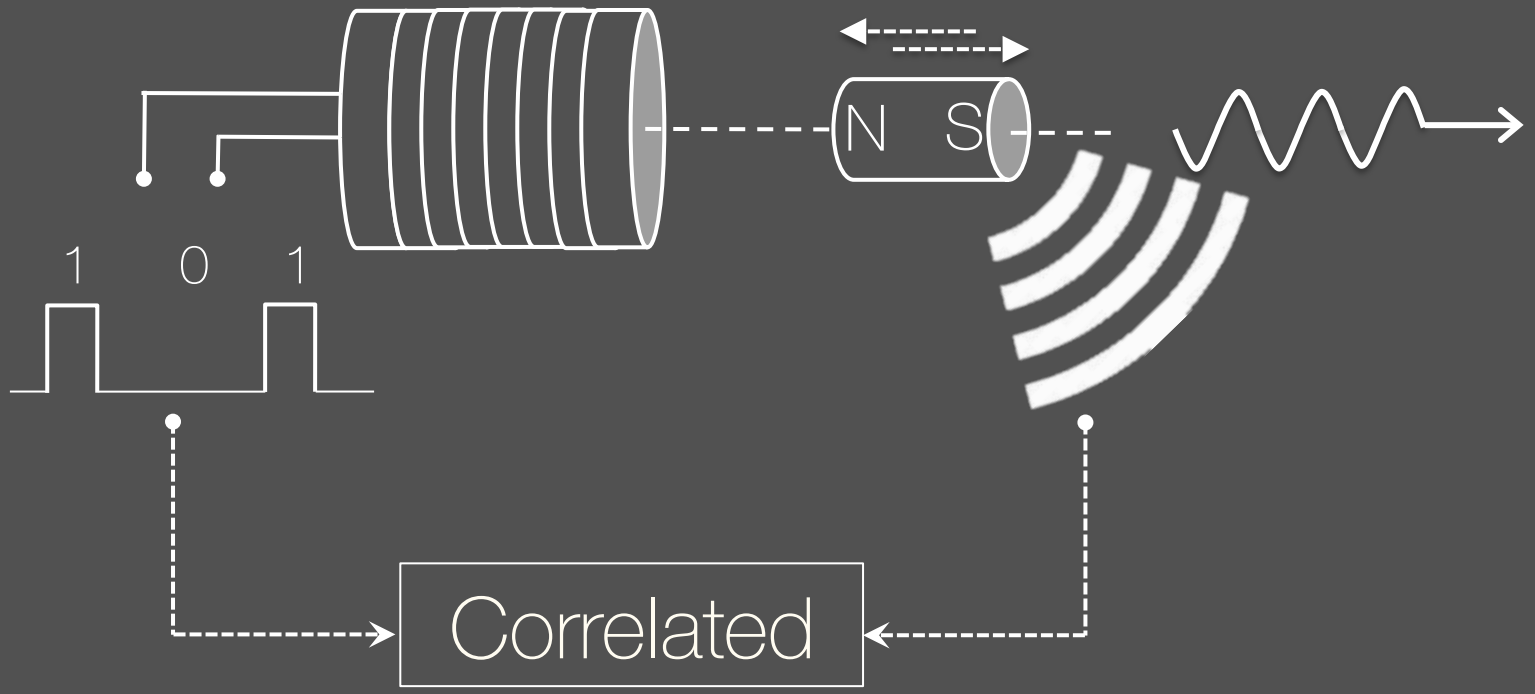

Morse-code
Single-Carrier
Multi-Carrier
Multi-dimension
Phy-Security
Y signal
2h
h
Z spill
Y-Axis
* 2 =
4h
2h
Scaled Y signal
Z signal
2h
h
Y spill
Z-Axis
+
=
Interference free
Y signal
3h


Morse-code
Single-Carrier
Multi-Carrier
Multi-dimension
Phy-Security
200 bps
Z
Y
X
GND
VCC
CS
INT1
INT2
SDO
SDA
SCL
200 bps

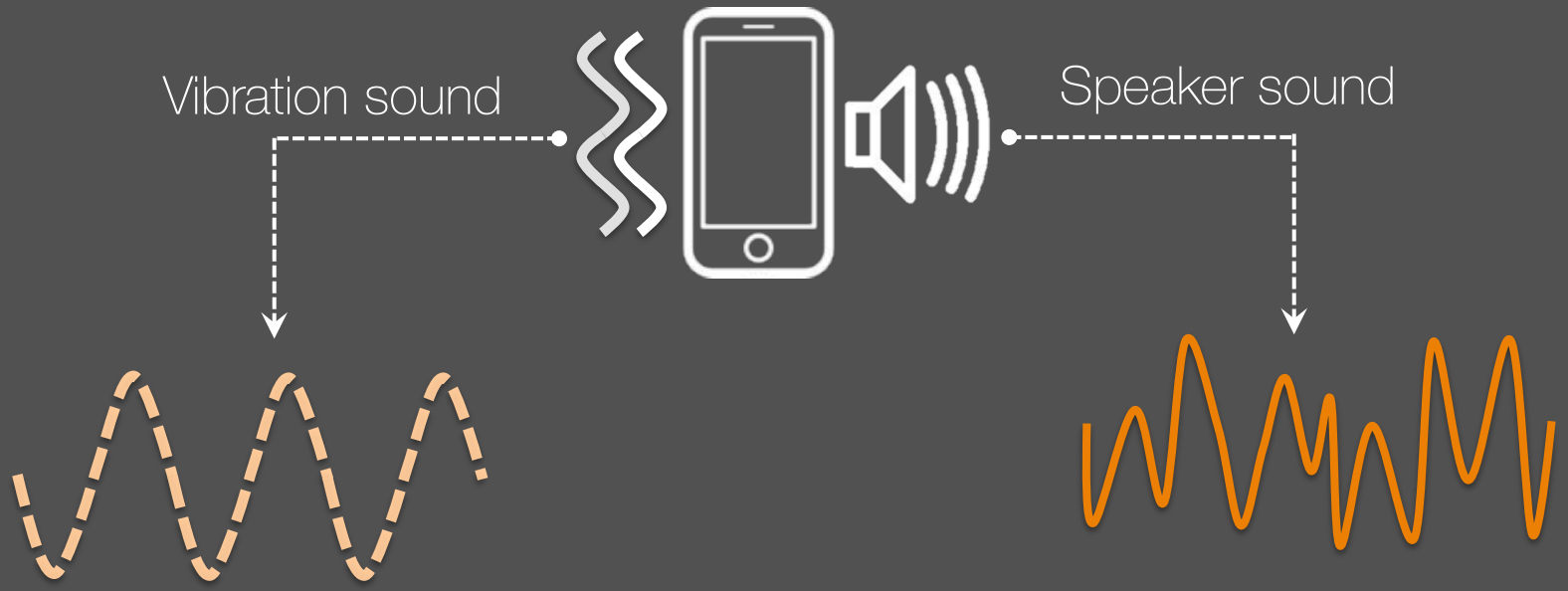


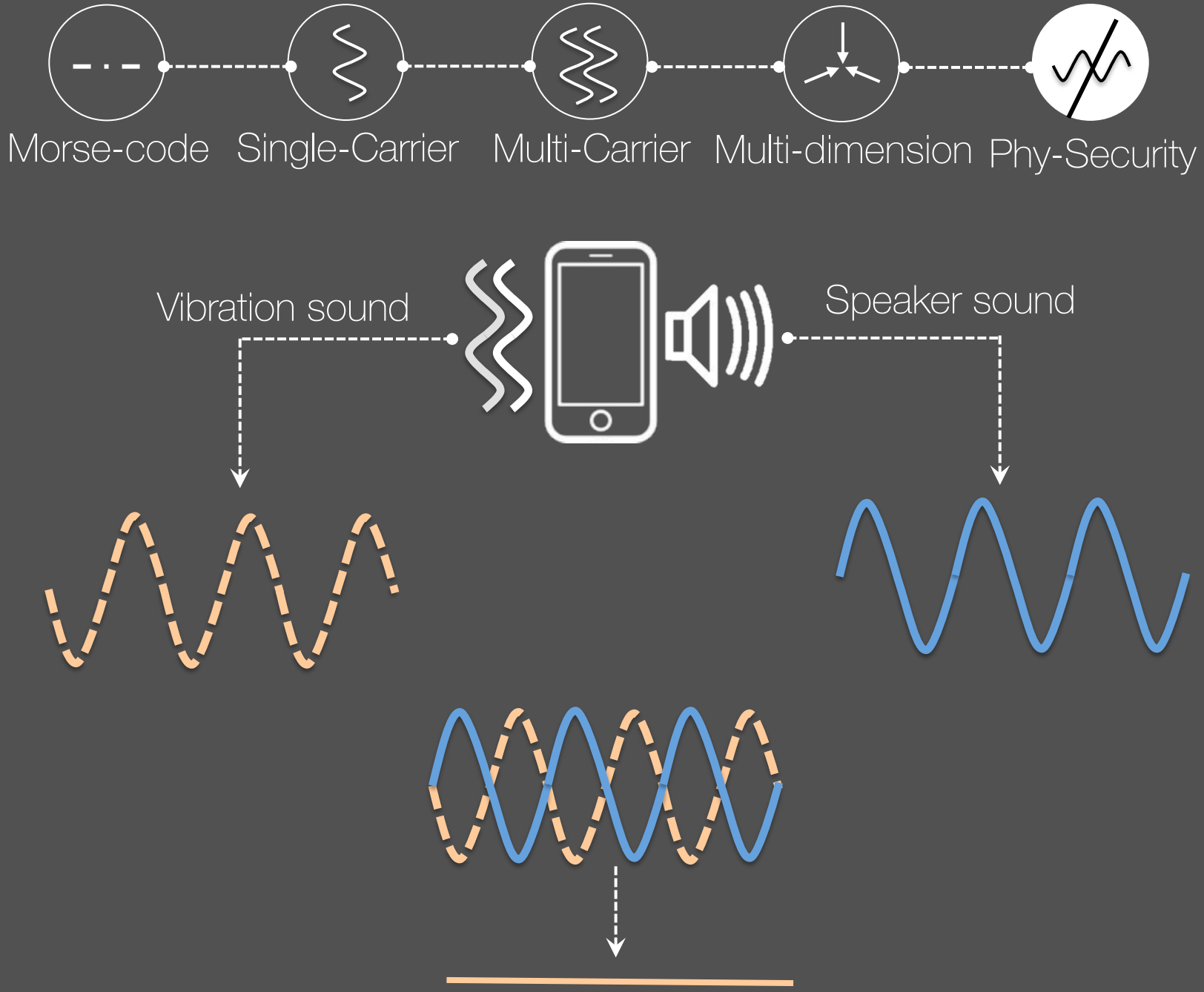
Physical Layer Security

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

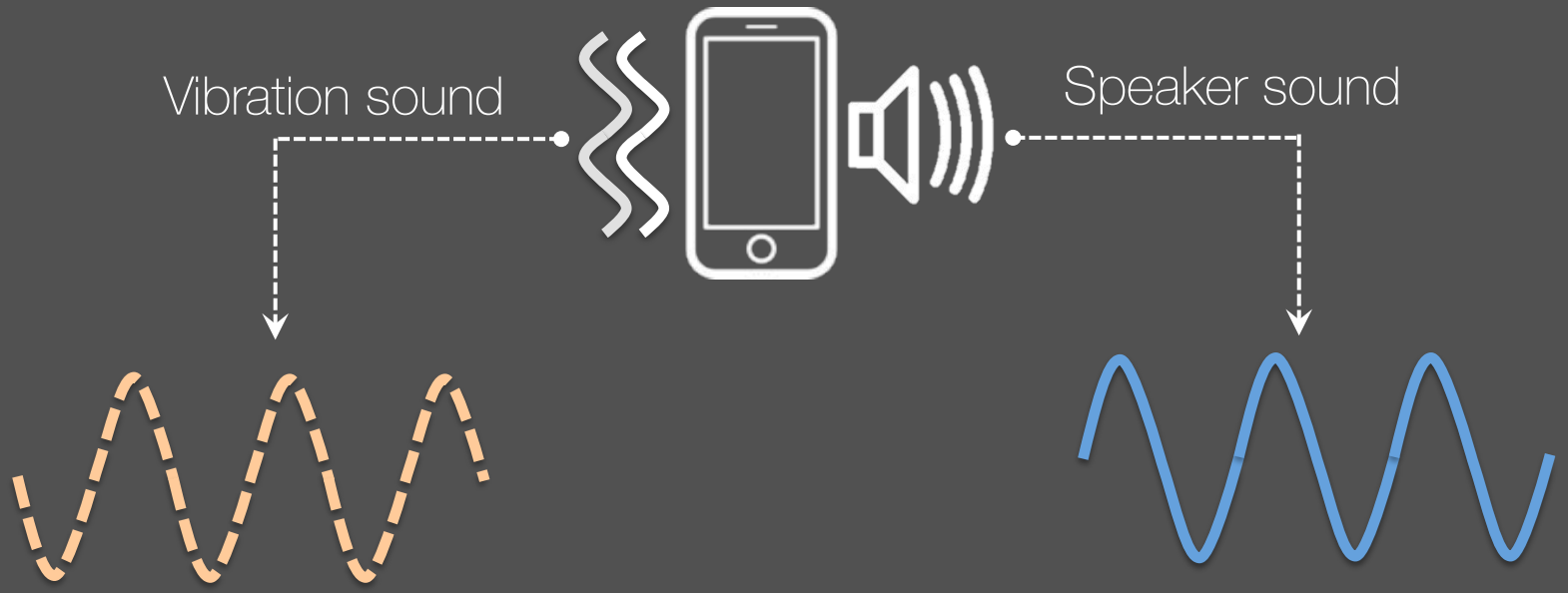

N
S
1
0
1
Correlated

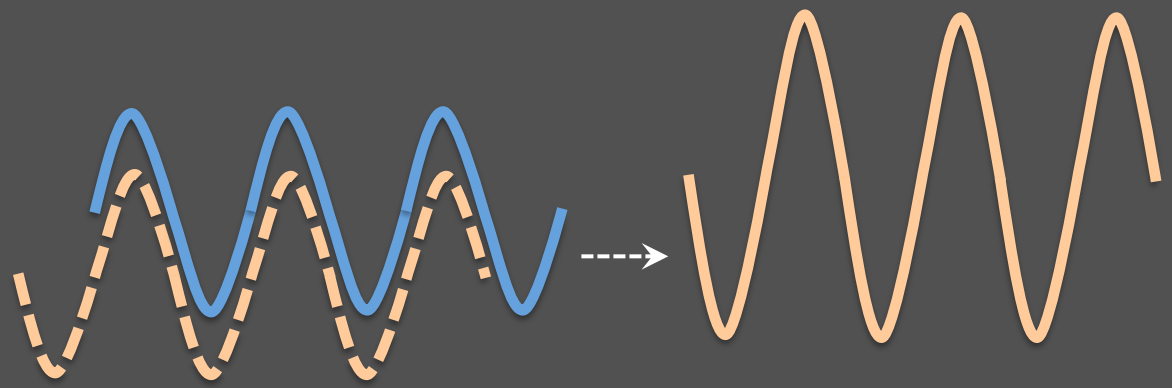
Morse-code
Single-Carrier
Multi-Carrier
Multi-dimension
Phy-Security


Vibration sound
Speaker sound

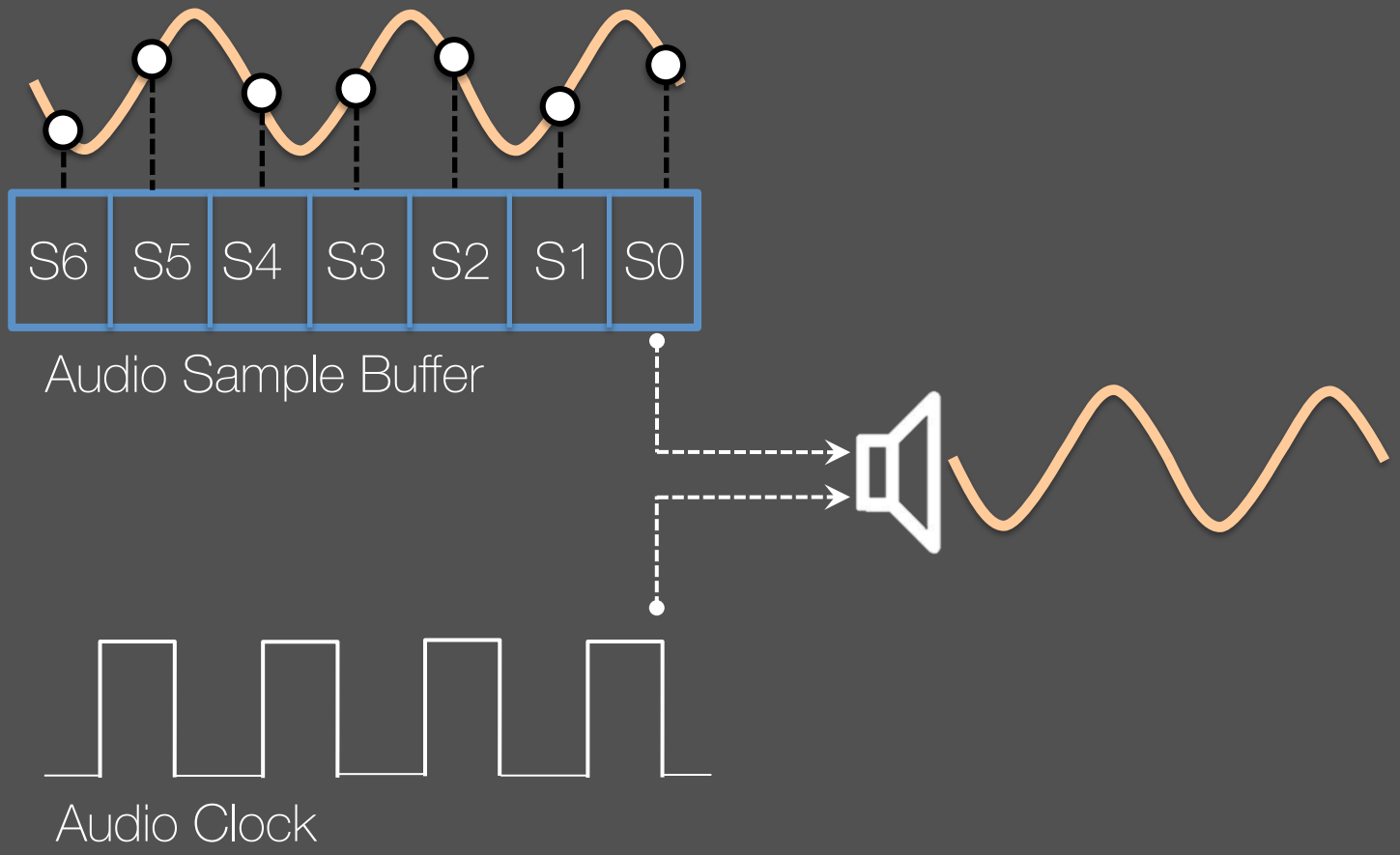

Morse-code
Single-Carrier
Multi-Carrier
Multi-dimension
Phy-Security
Vibration sound
Speaker sound

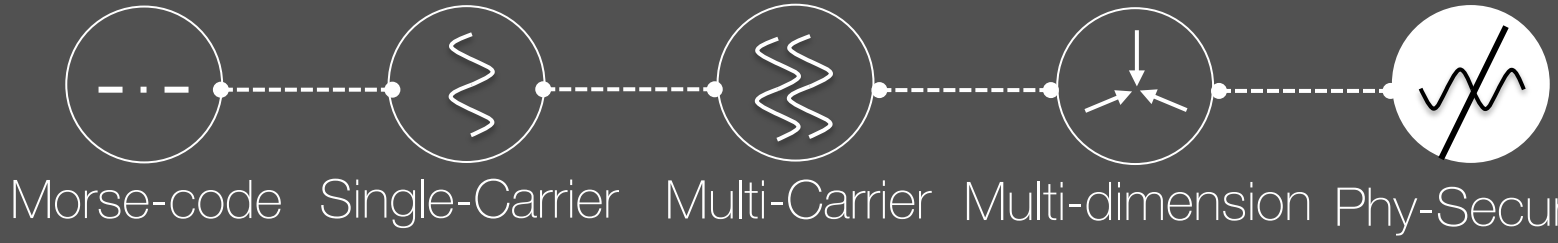
Morse-code
Single-Carrier
Multi-Carrier
Multi-dimension
Phy-Security

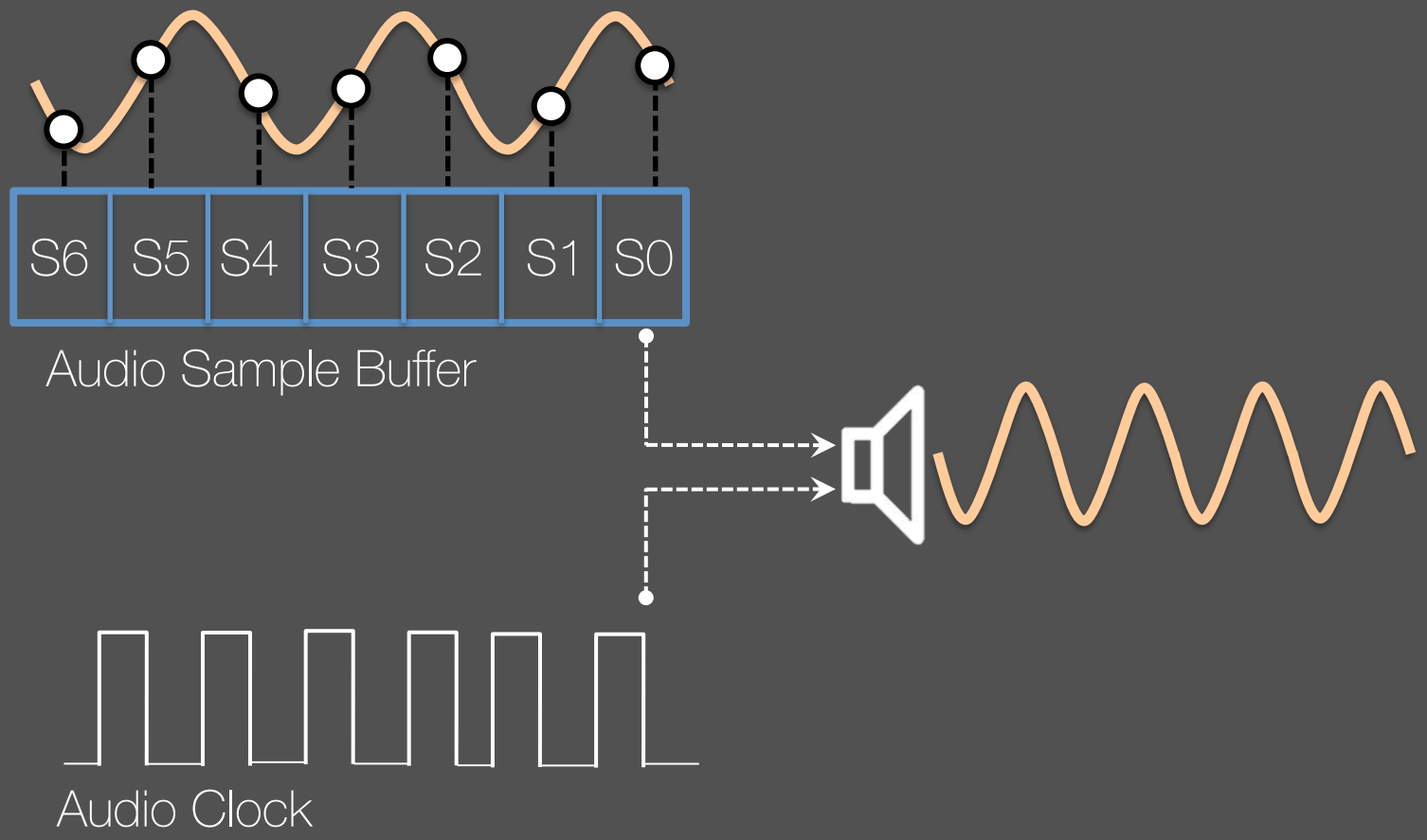

Vibration sound
Speaker sound



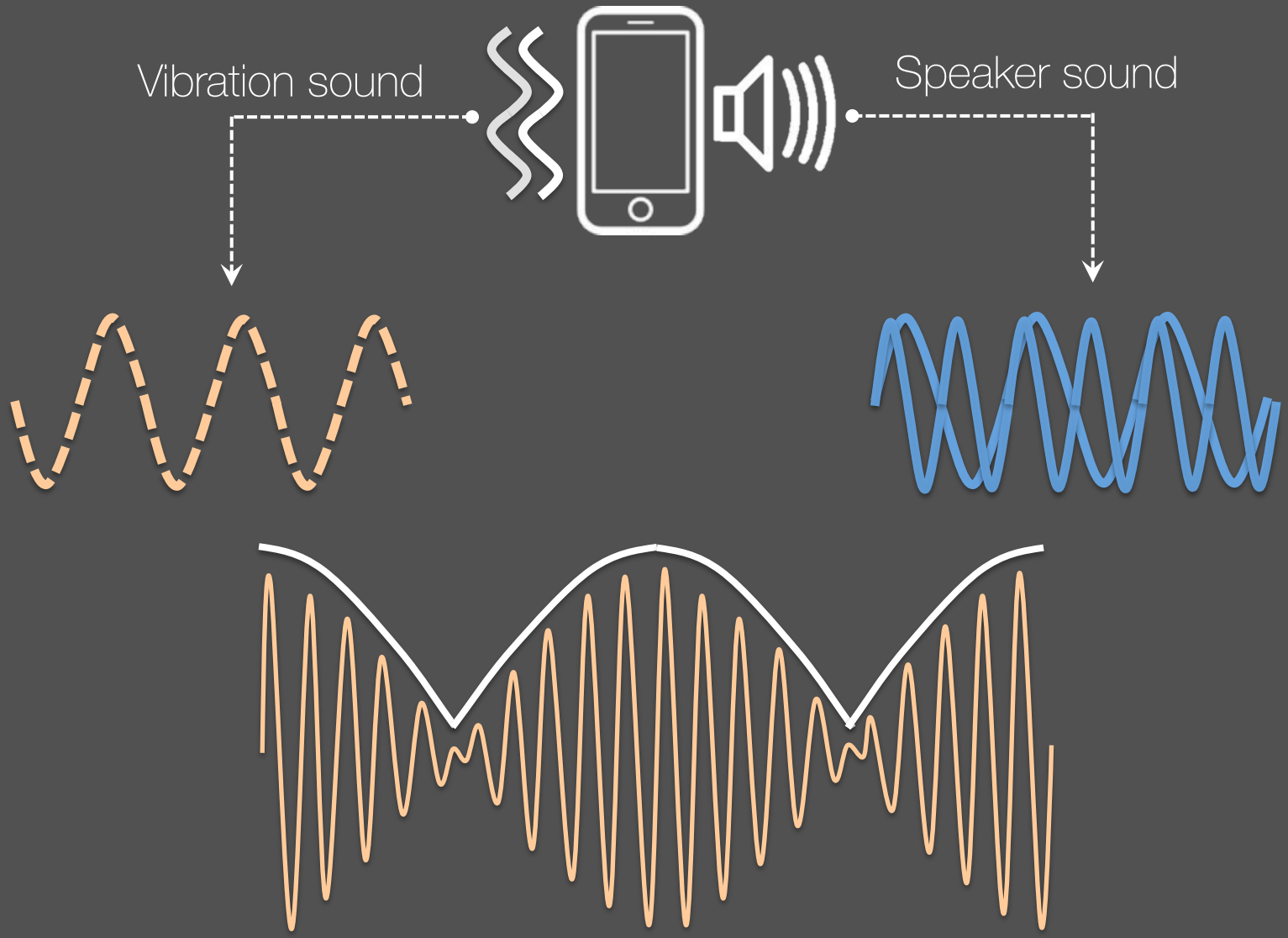
Morse-code
Single-Carrier
Multi-Carrier
Multi-dimension
Phy-Security


S6
S5
S4
S3
S2
S1
S0
Audio Sample Buffer
Audio Clock

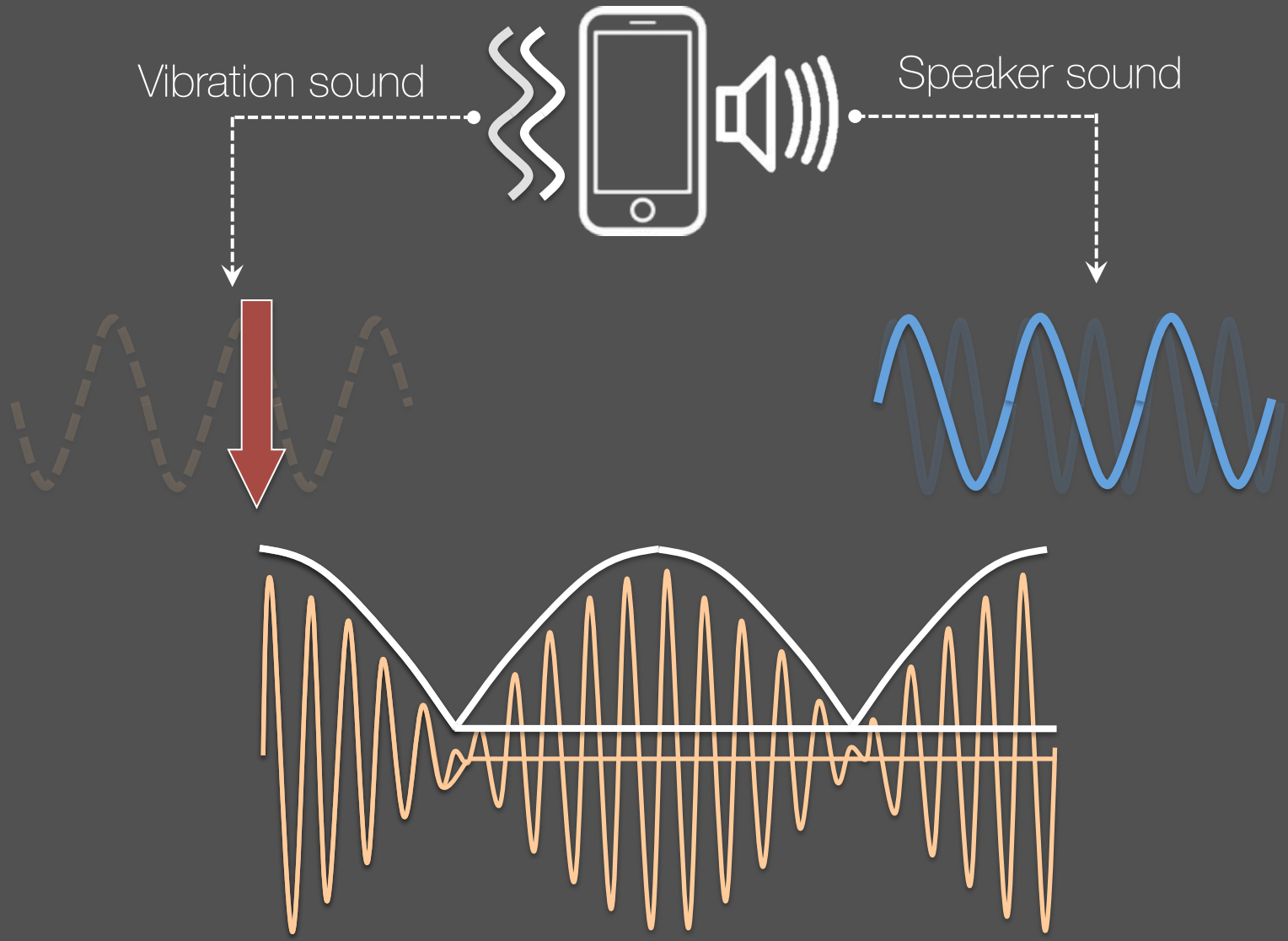

Morse-code
Single-Carrier
Multi-Carrier
Multi-dimension
Phy-Security

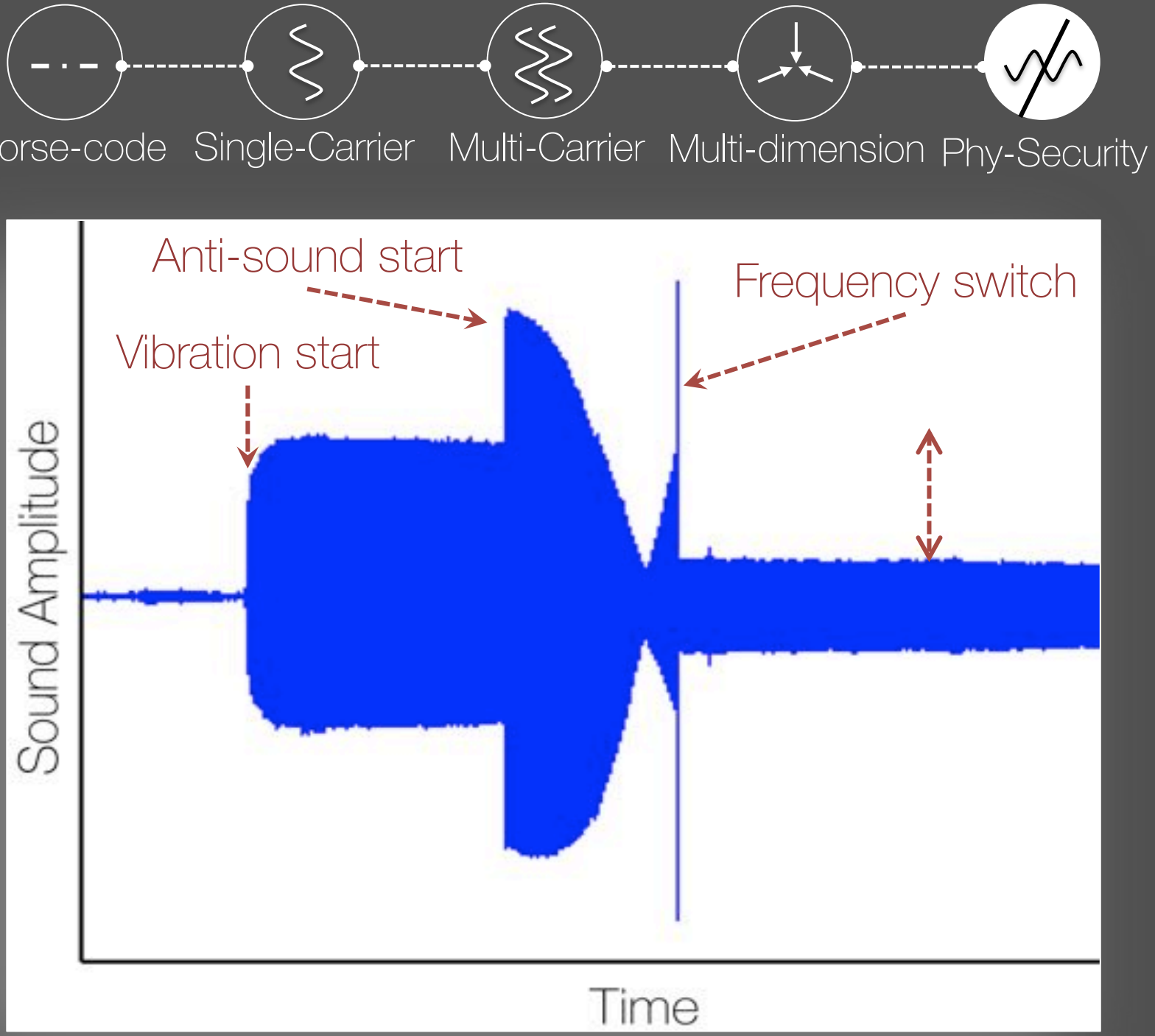

S6
S5
S4
S3
S2
S1
S0
Audio Sample Buffer
Audio Clock

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


Vibration sound
Speaker sound

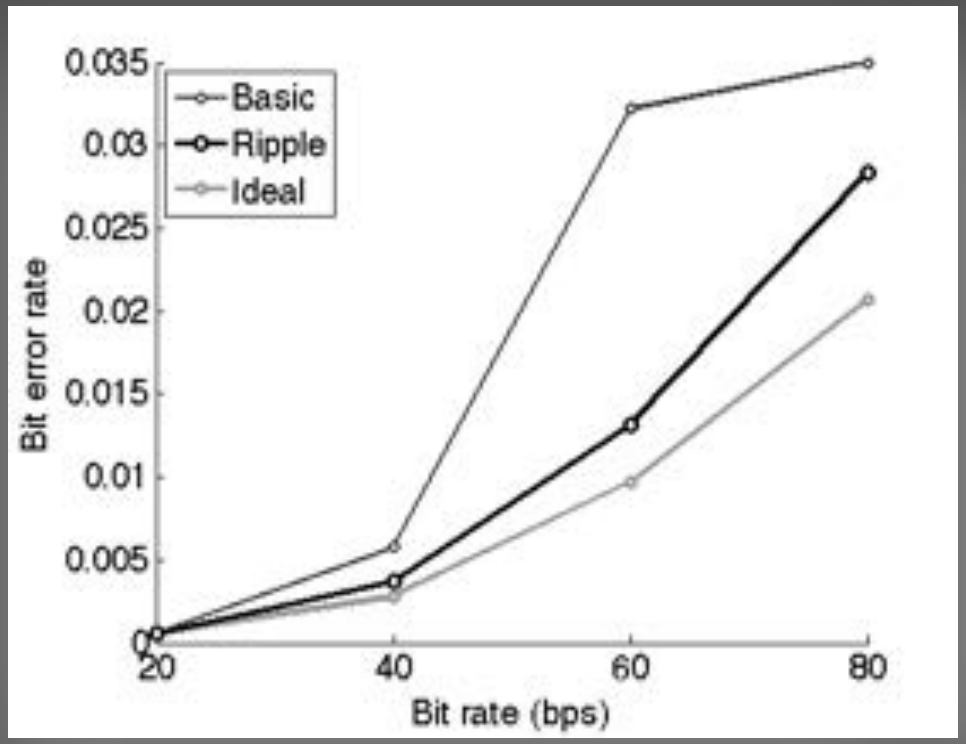
Morse-code
Single-Carrier
Multi-Carrier
Multi-dimension
Phy-Security

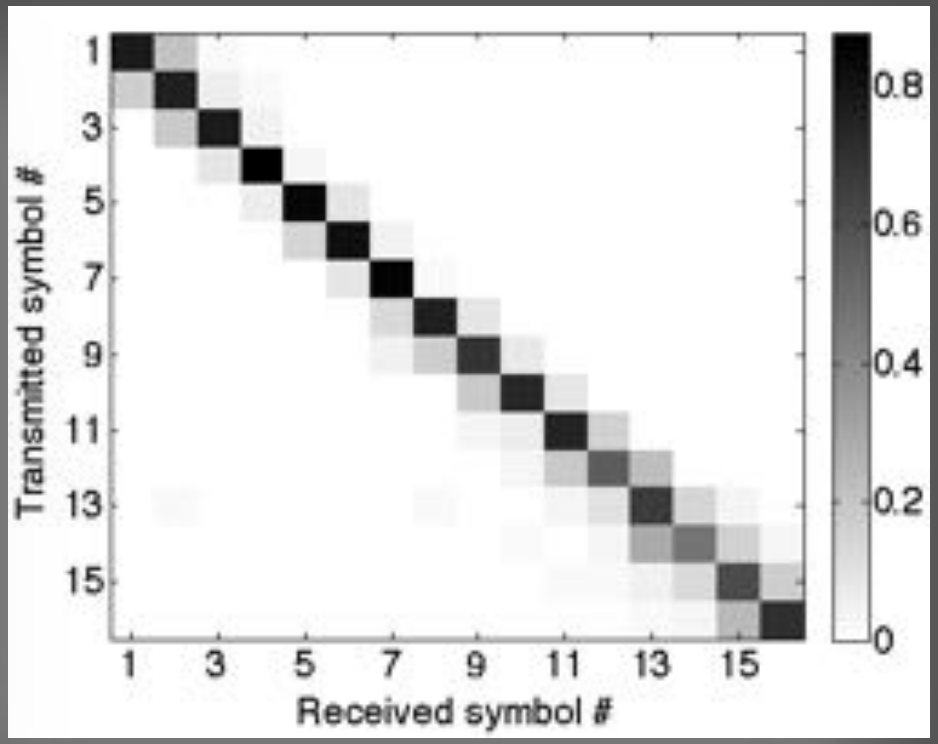

Vibration sound
Speaker sound


Morse-code
Single-Carrier
Multi-Carrier
Multi-dimension
Phy-Security
Anti-sound start
Frequency switch
Vibration start
Sound Amplitude
Time

Evaluation

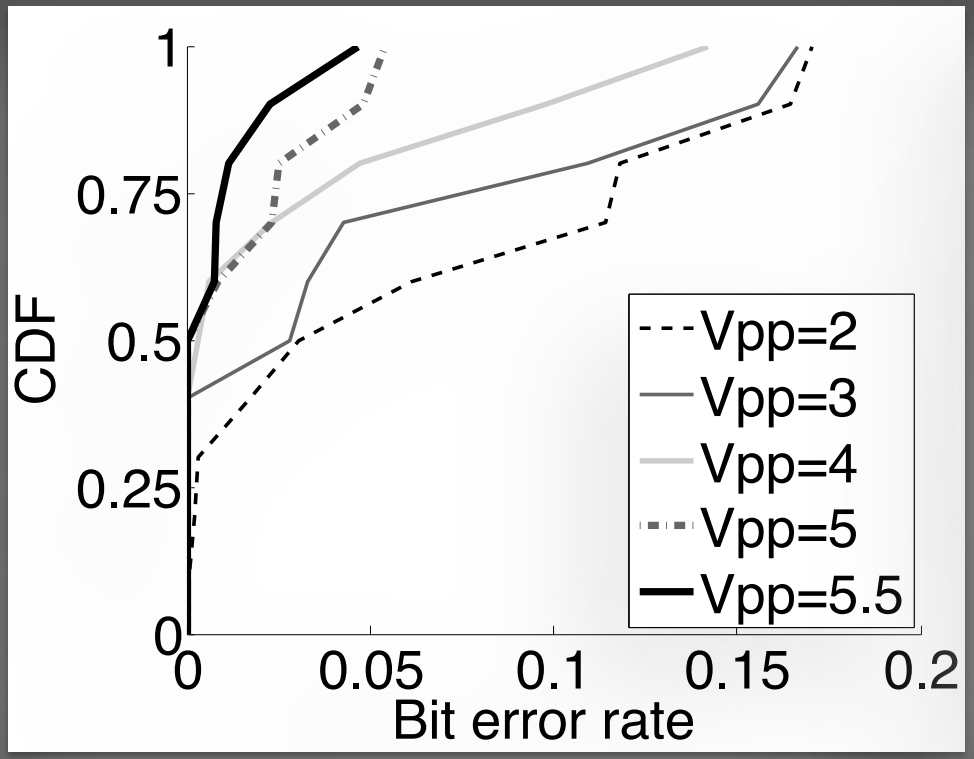
Single-carrier

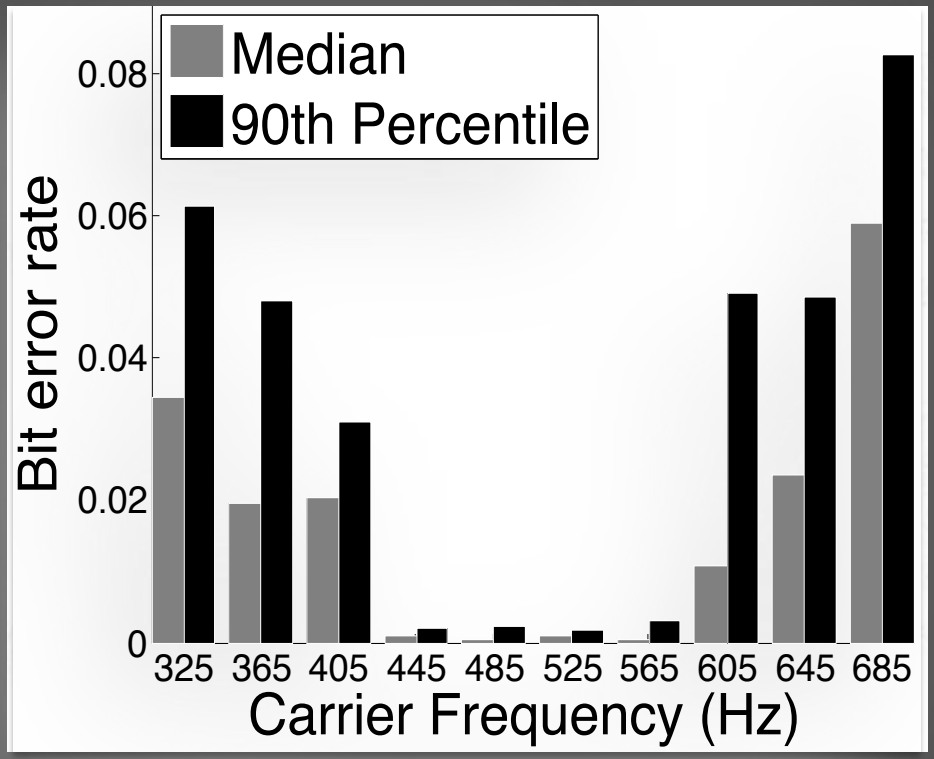




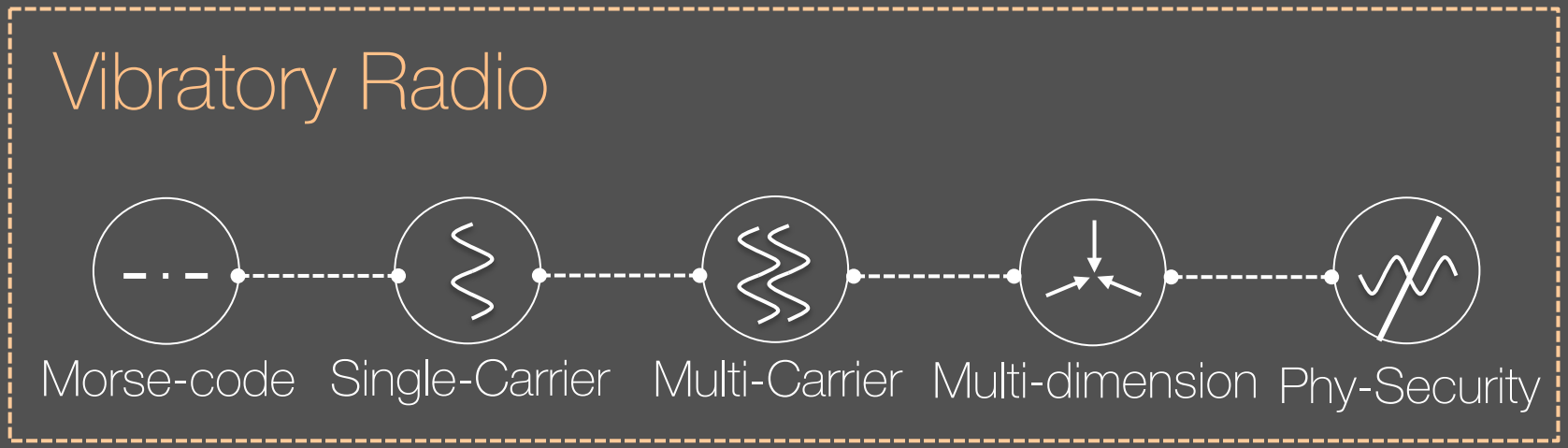
Evaluation

Multi-carrier





Summary


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

Thank You

(SyNRG Hardware Lab, UIUC)