#BluetoothAsia2019#

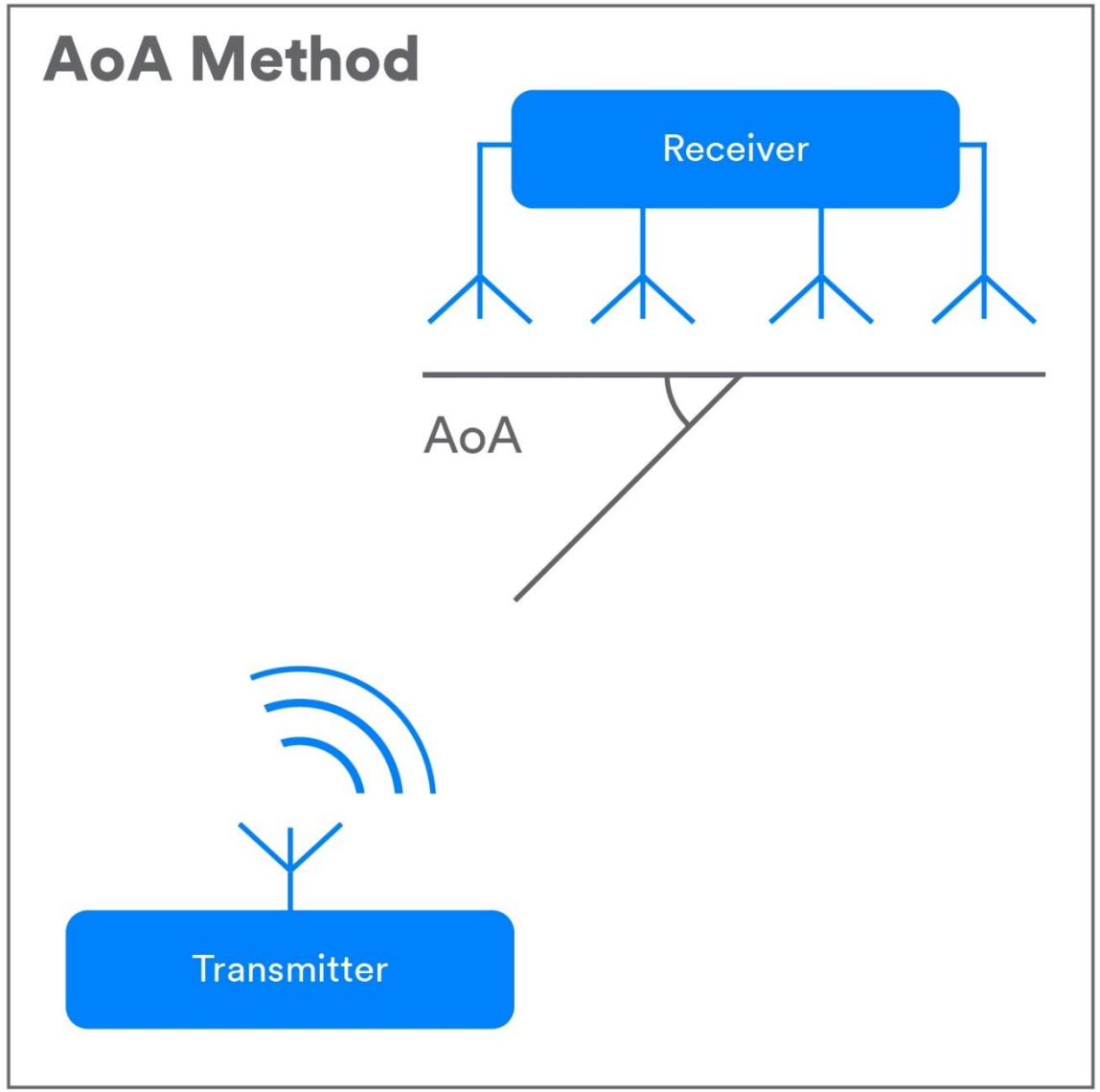
BluetoothAsia
探索、创新、开拓

Bluetooth Direction Finding Feature and the Latest Specification Enhancements

Kai Ren, Senior Developer Relations Manager, Bluetooth SIG

微信

Direction Finding

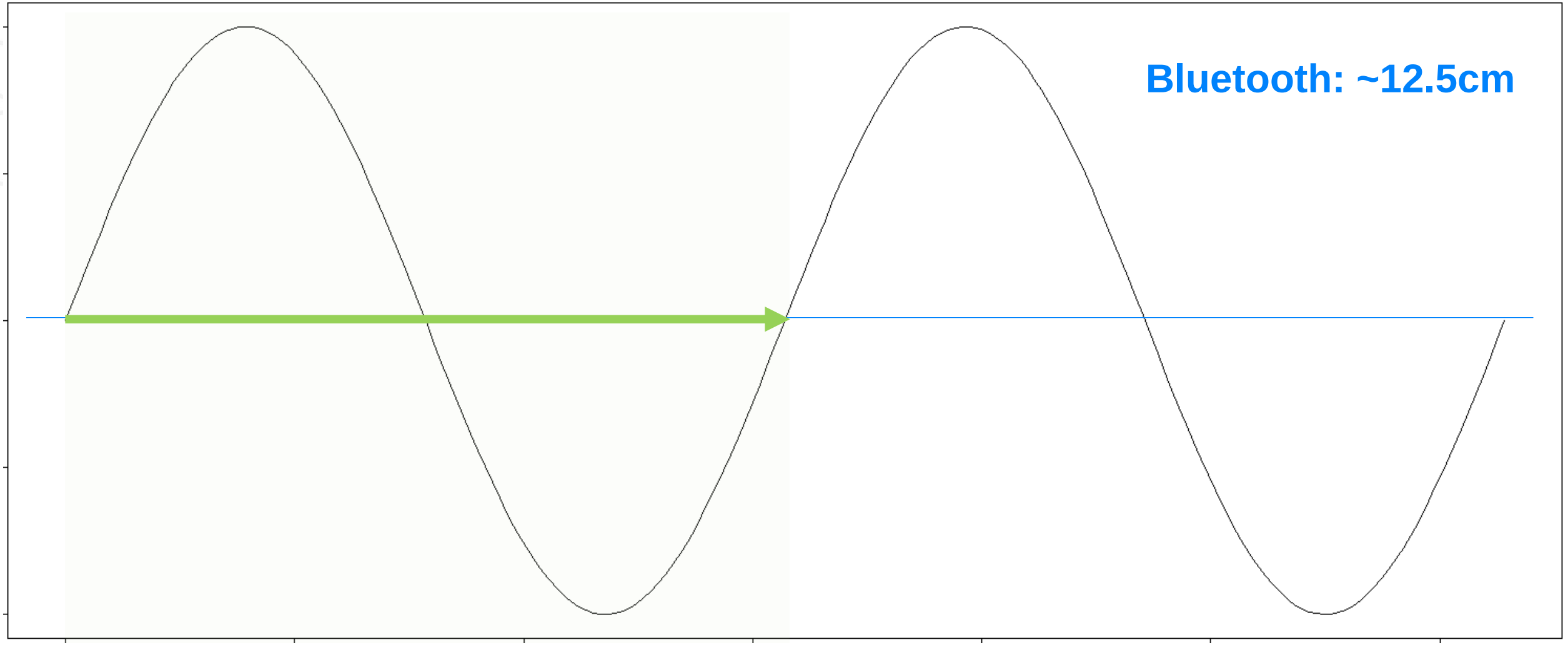


Angle of Arrival

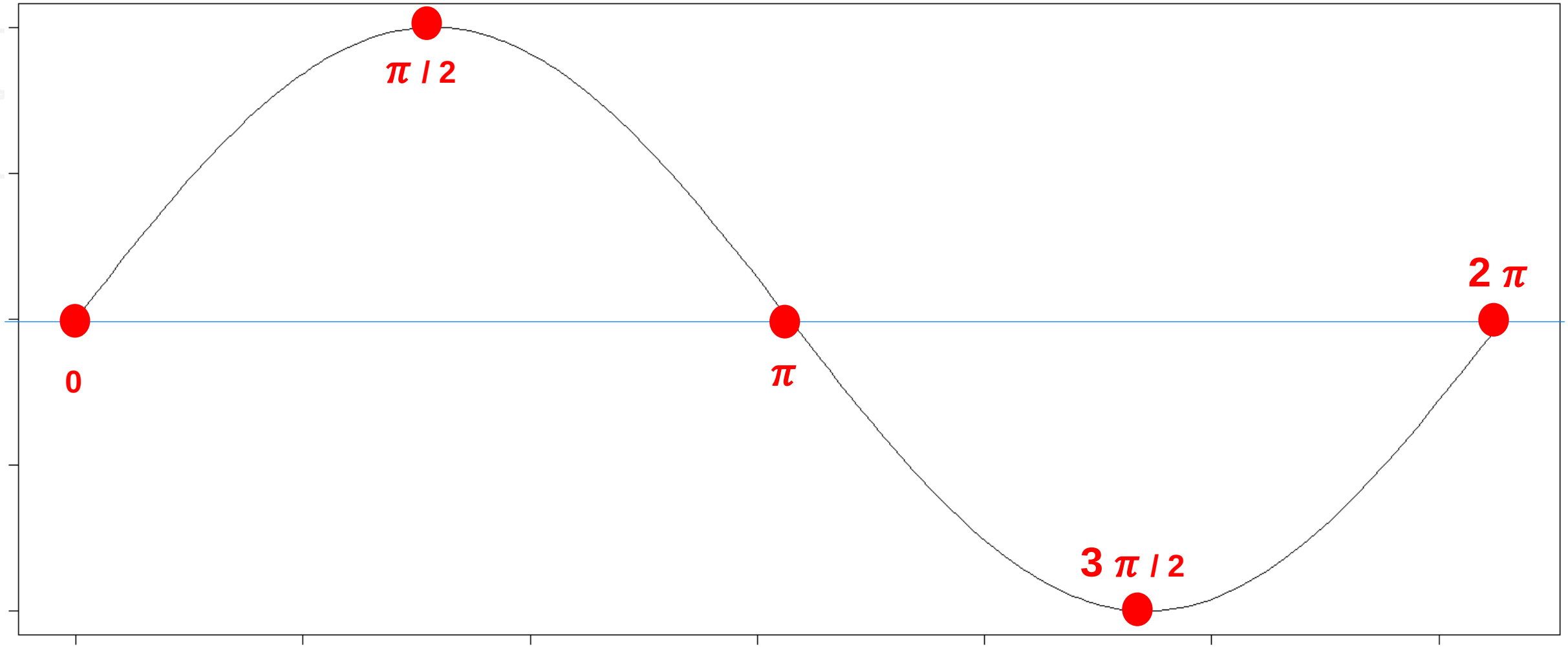
- **Transmitter**
  - sends special packets using a single antenna
- **Receiver**
  - has multiple antenna arranged in an array
  - antennas see received signal phase difference because of different distances to the transmitter
  - takes IQ samples from received signal while switching between active antenna
  - relative signal direction calculated using sampled data

For RTLS, item finding, and PoI

RF Fundamentals - Wavelength



RF Fundamentals - Phase



What is IQ?

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Intelligence Quotient?

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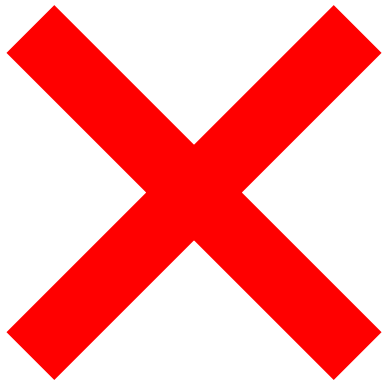

What is IQ?

In-phase/Quadrature

RF Fundamentals - IQ Sampling

HCI commands use IQ format to report the RF signal phase.

Host can use these commands to ask Controller to report RF signal’s phase.

RF Fundamentals - IQ Sampling

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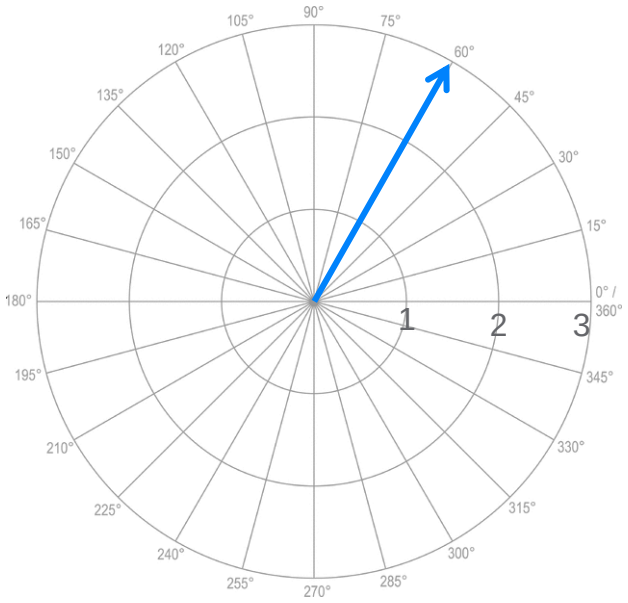

Polar coordinates
phase angle = 60˚, amplitude = 3

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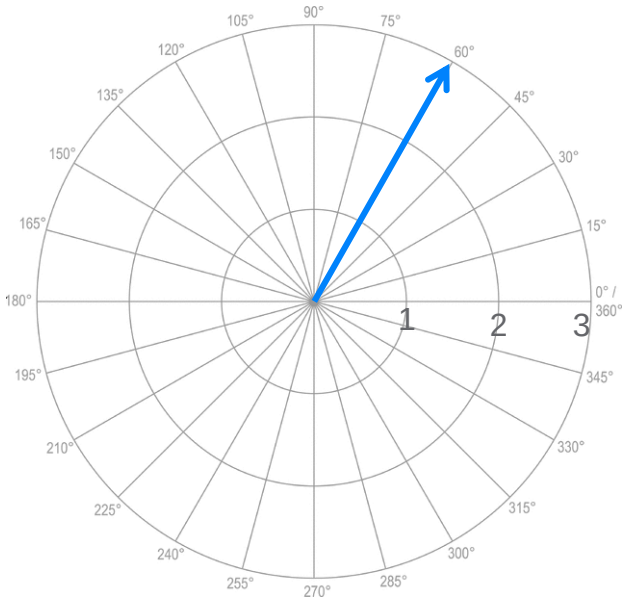

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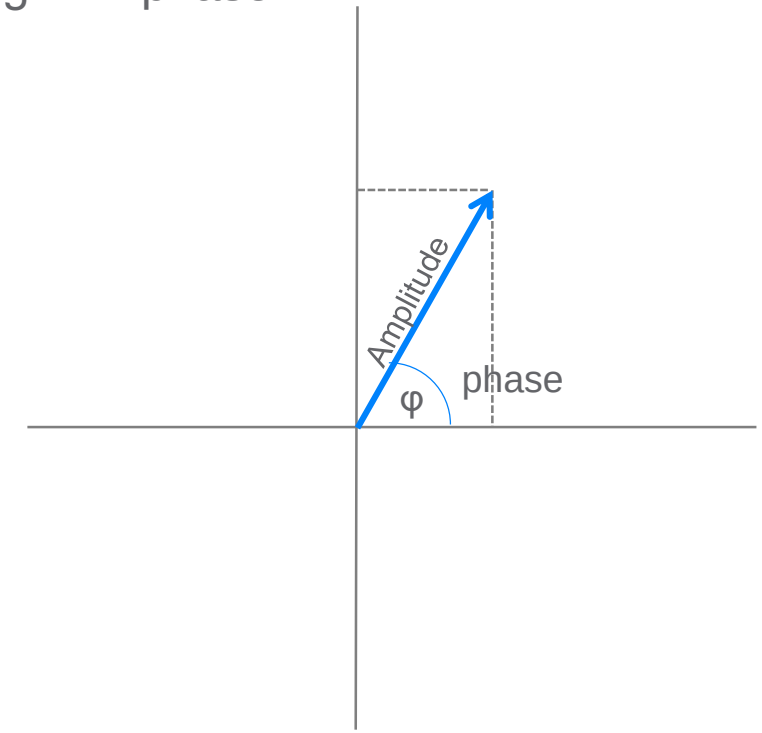

Cartesian with I and Q coordinates

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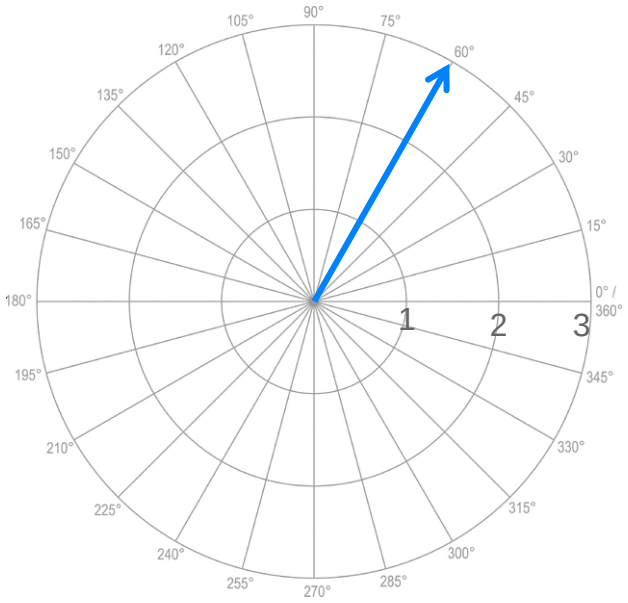

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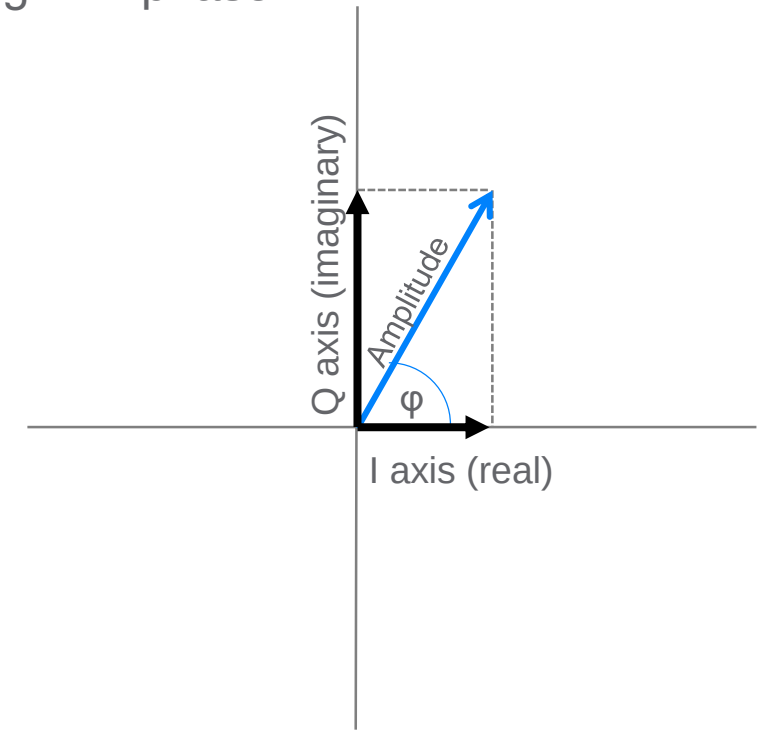

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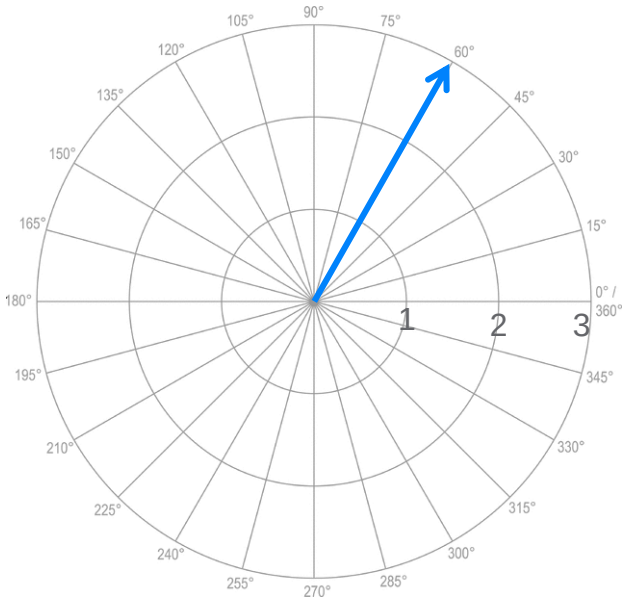

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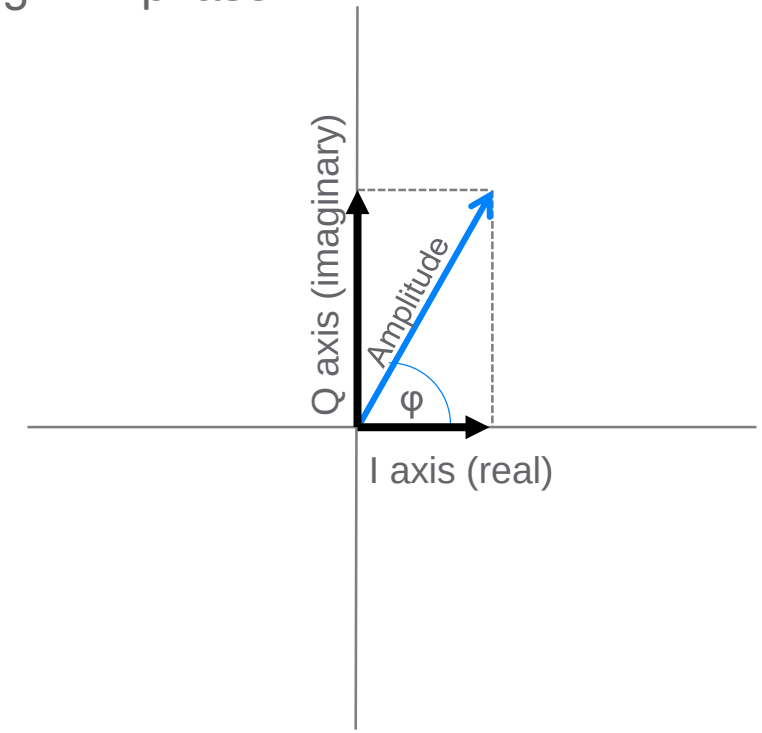

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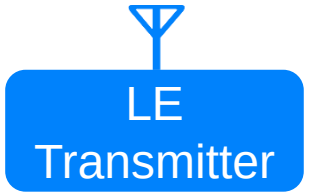
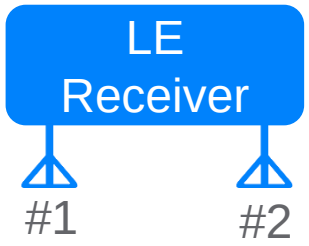
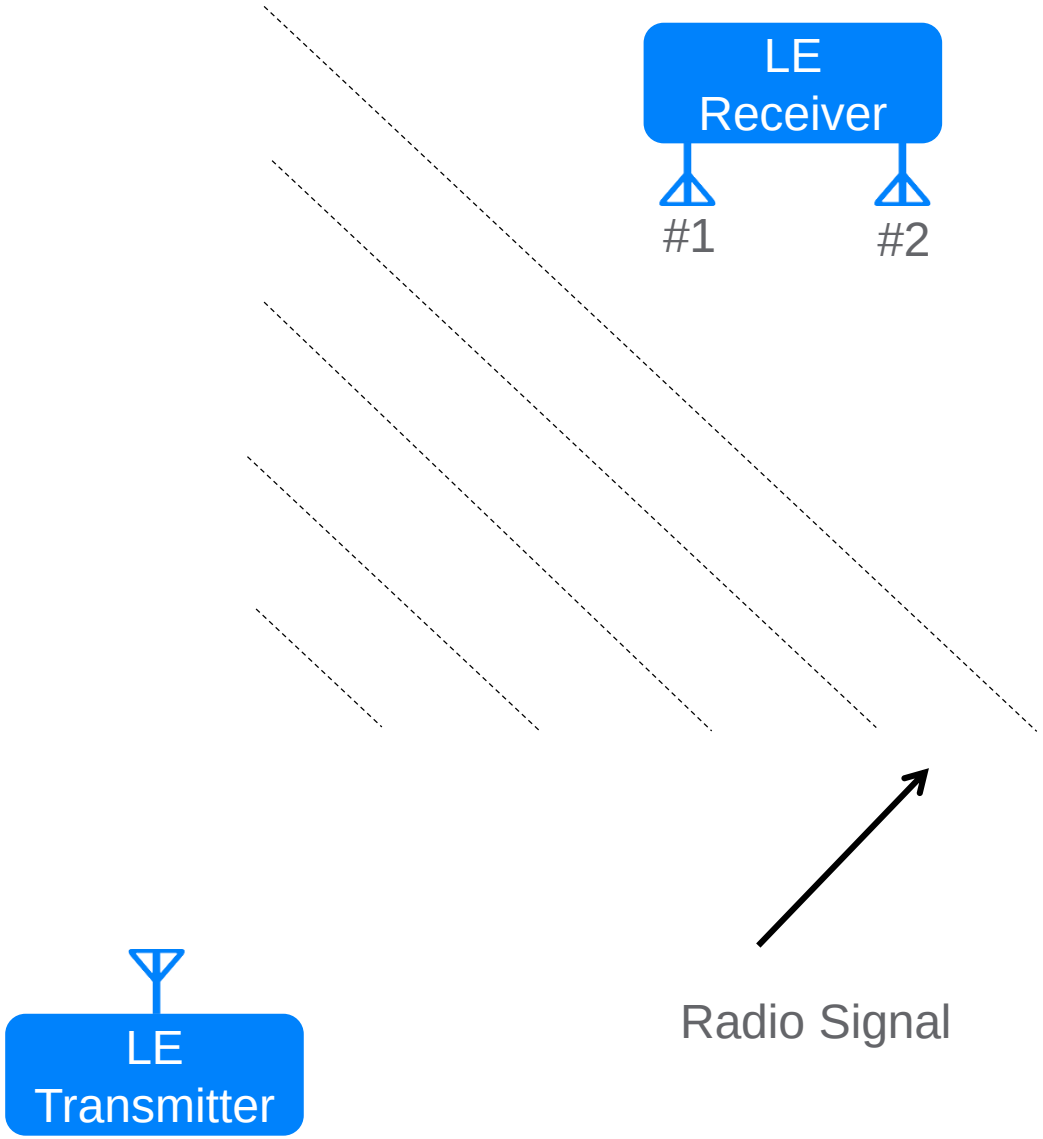




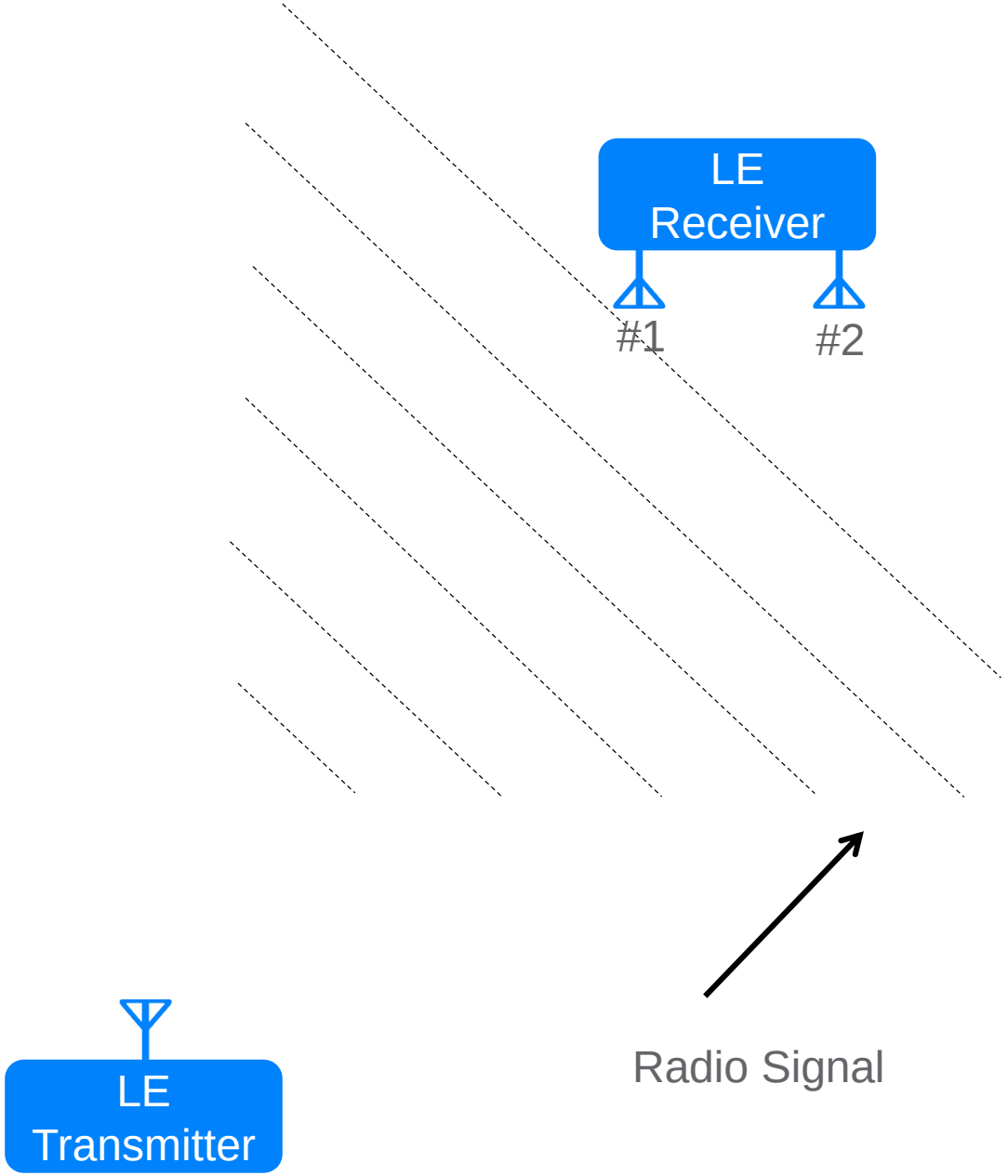
Angle of Arrival, AoA

- Multiple antennas, #1 and #2



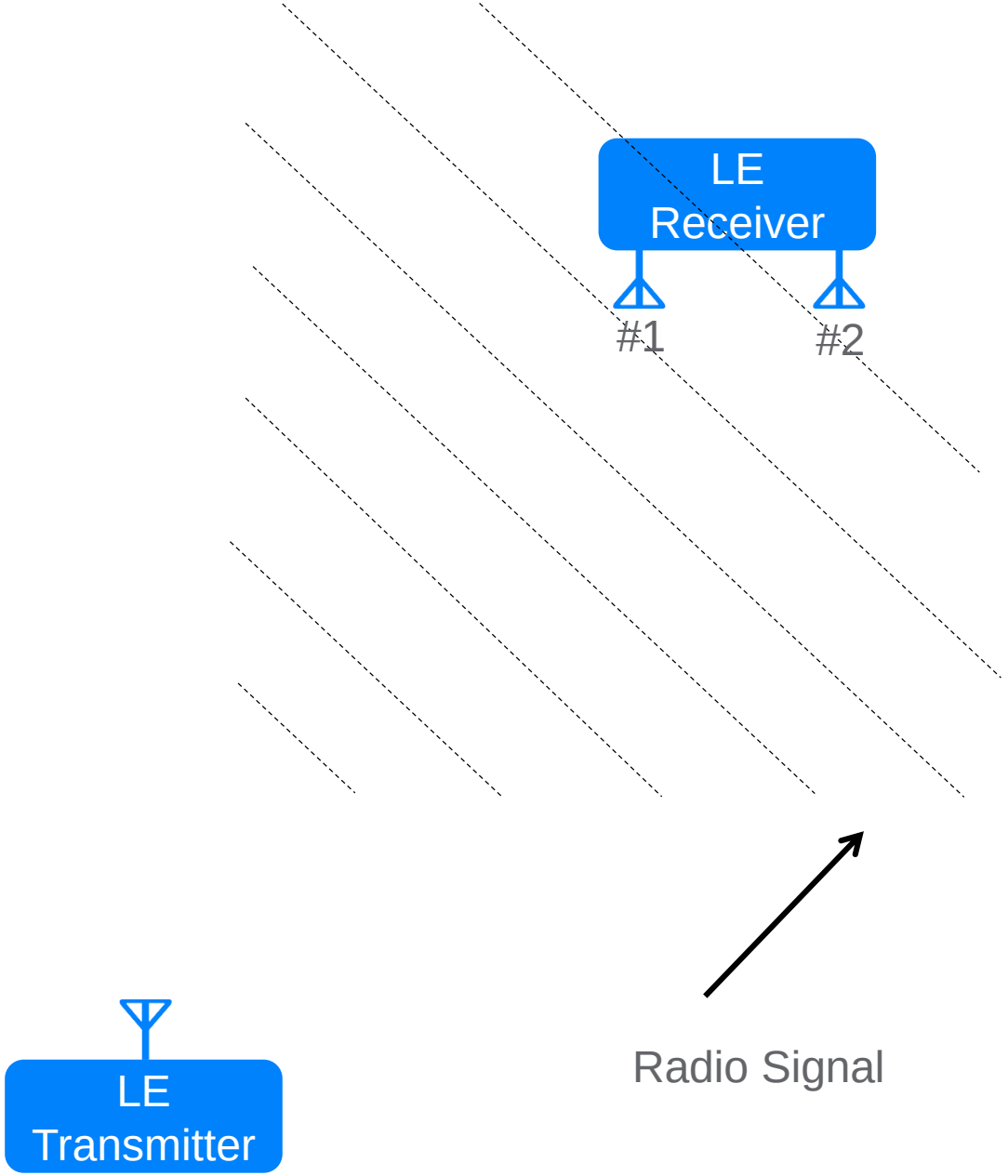
Angle of Arrival, AoA

- Multiple antennas, #1 and #2
- LE transmitter sends special Direction Finding message out periodically



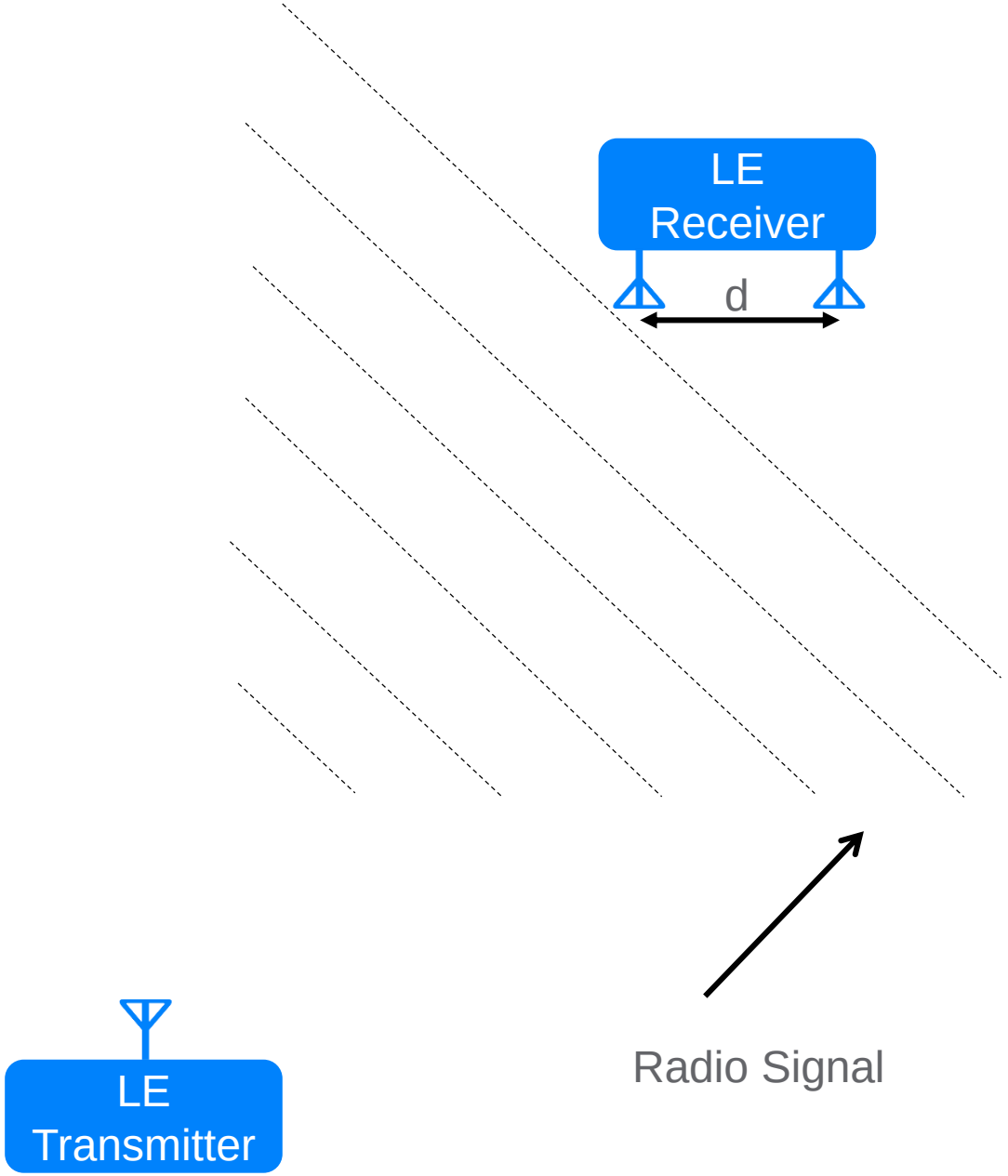
Angle of Arrival, AoA

- Multiple antennas, #1 and #2
- LE transmitter sends special Direction Finding message out periodically
- RF signal arrives at antenna #1 -- phase #1, timestamp #1



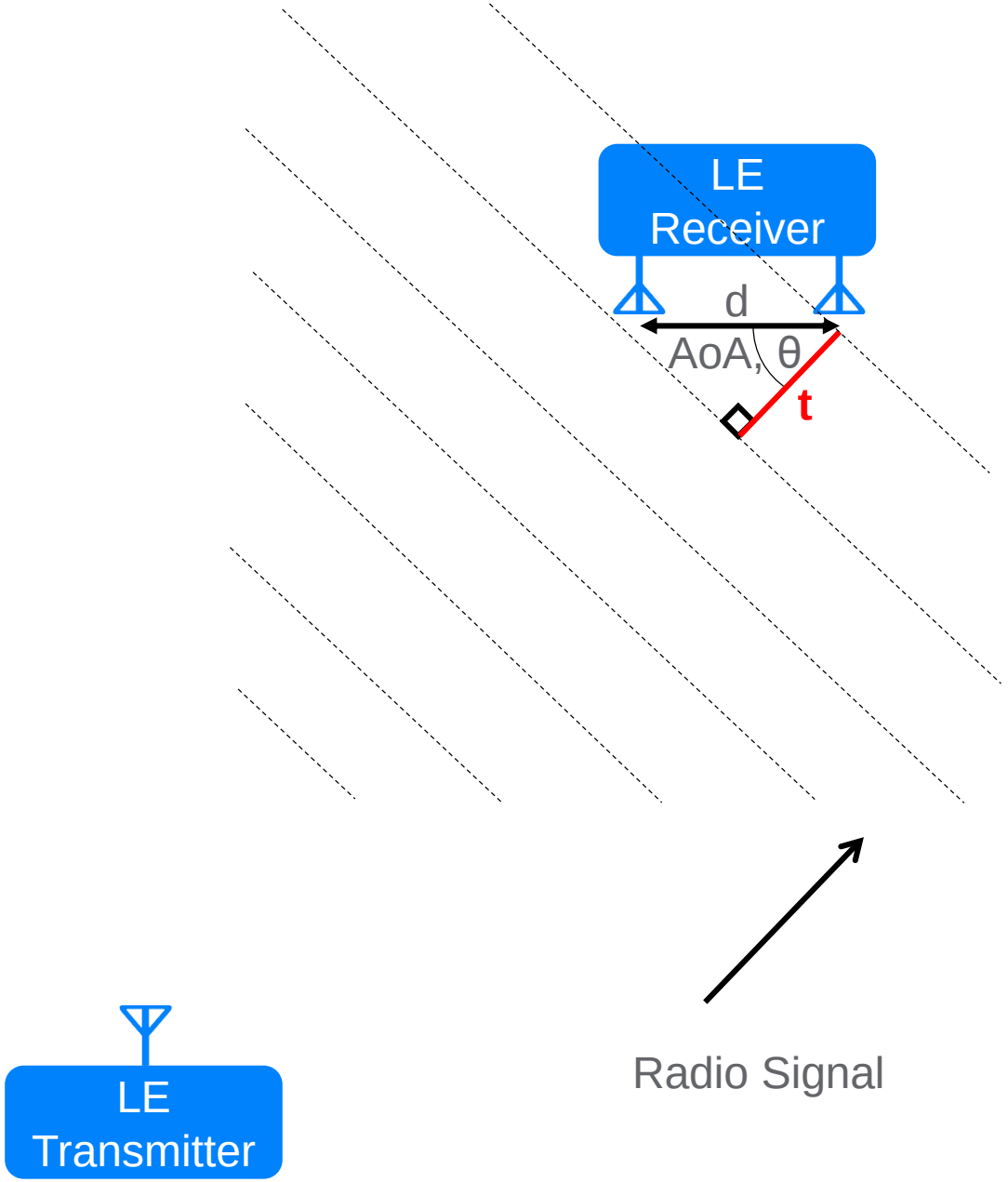
Angle of Arrival, AoA

- Multiple antennas, #1 and #2
- LE transmitter sends special Direction Finding message out periodically
- RF signal arrives at antenna #1 -- phase #1, timestamp #1
- RF signal arrives at antenna #2 -- phase #2, timestamp #2



Angle of Arrival, AoA

- d is known



Angle of Arrival, AoA

- d is known
- θ is Angle of Arrival
- t = (φ / 2π)· λ, φ is phase difference, λ is wavelength, about 0.125m
- θ = arccos(t/d) = arccos((φ·λ)/(2π·d))

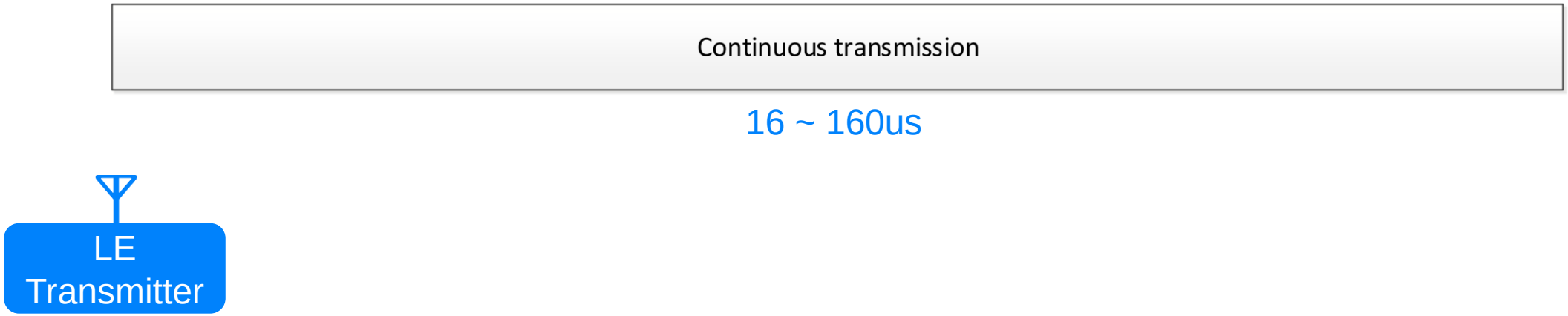
Constant Tone Extension, CTE

Constant Tone Extension, CTE

Constant Tone Extension, CTE

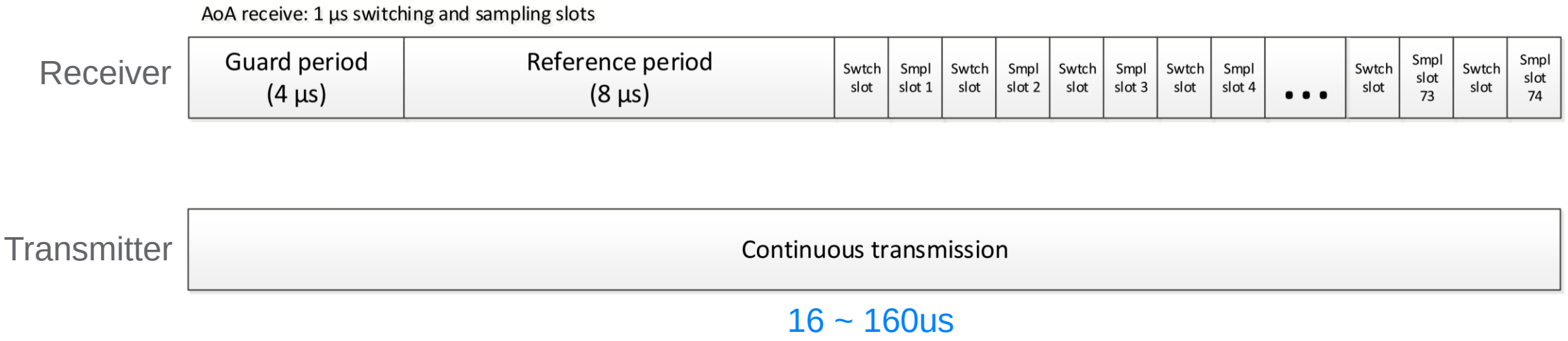
- Shall be at least 16us, not longer than 160us
- The contents are a constantly modulated series of 1s
- No whitening shall be applied
- Switch slot and sample slot, each either 1us or 2us long

AoA

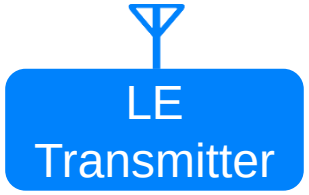


AoA

LE
Receiver

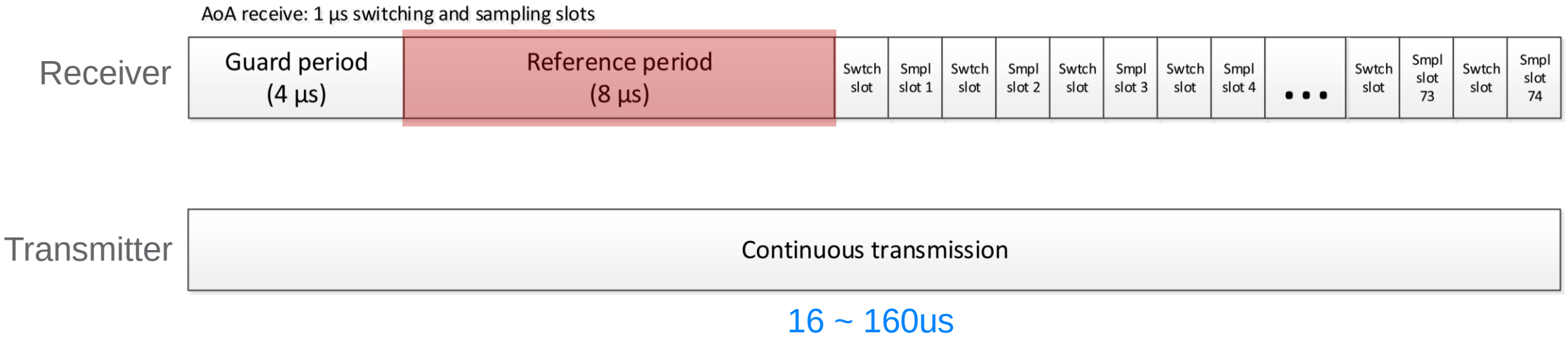

AoA receive: 1 µs switching and sampling slots
Receiver
Guard period (4 µs)
Reference period (8 µs)
Swtch slot
Smpl slot 1
Swtch slot
Smpl slot 2
Swtch slot
Smpl slot 3
Swtch slot
Smpl slot 4
• • •
Swtch slot
Smpl slot 73
Swtch slot
Smpl slot 74
Transmitter
Continuous transmission

16 ~ 160us


LE
Transmitter

AoA

LE
Receiver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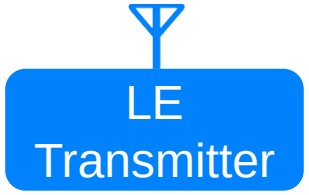
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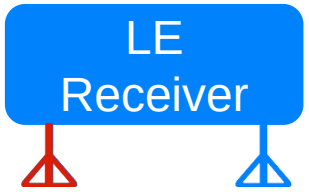

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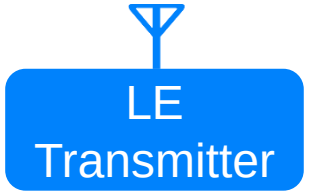

AoA

AoA receive: 1 µs switching and sampling slots

Receiver

Guard period (4 µs)	Reference period (8 µs)	Swtch slot	Smpl slot 1	Swtch slot	Smpl slot 2	Swtch slot	Smpl slot 3	Swtch slot	Smpl slot 4	• • •	Swtch slot	Smpl slot 73	Swtch slot	Smpl slot 74

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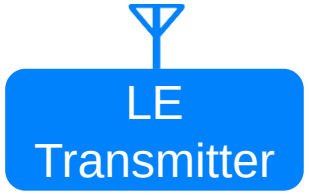

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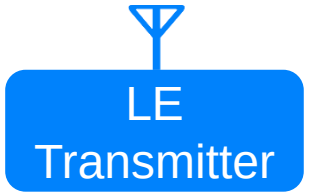

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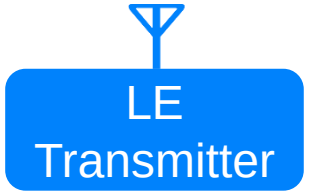

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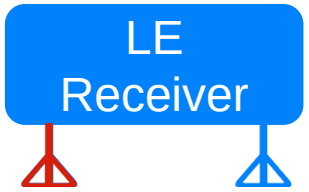

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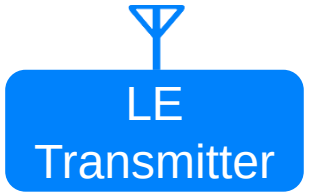

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Transmitter

Continuous transmission

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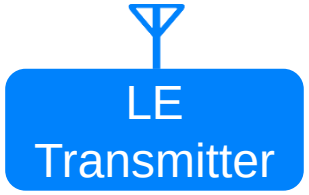


AoA

AoA receive: 2 µs switching and sampling slots

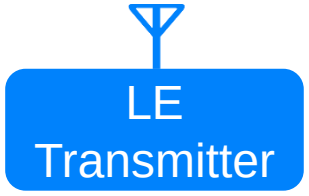
Receiver

Guard period (4 µs)	Reference period (8 µs)	Switch slot	Sample slot 1	Switch slot	Sample slot 2	. . .	Switch slot	Sample slot 37

Transmitter

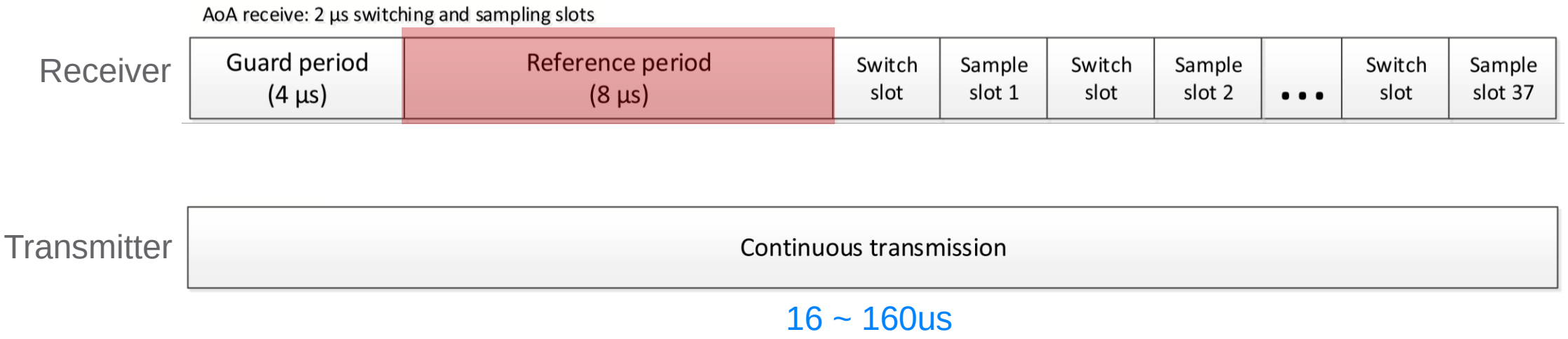
Continuous transmission

16 ~ 160us



AoA

LE
Receiver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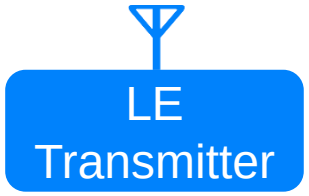
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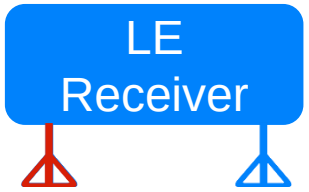
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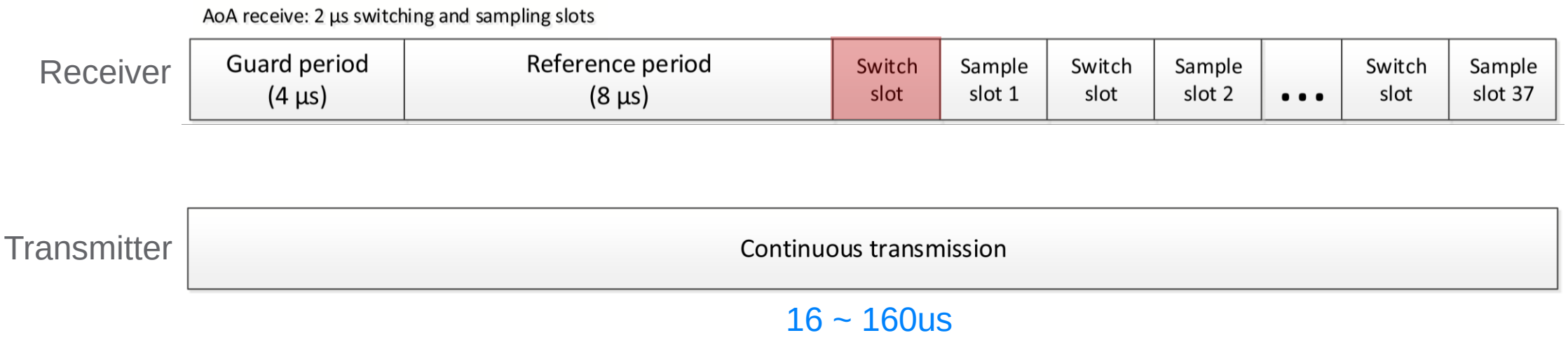
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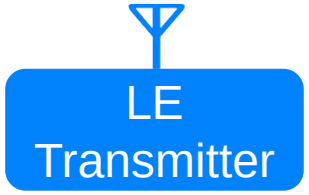
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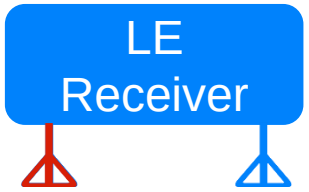
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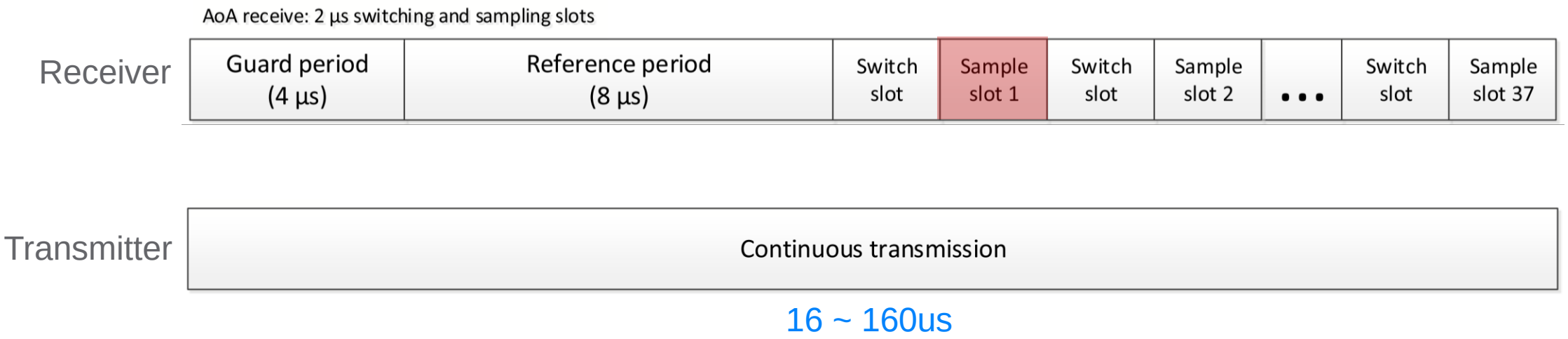
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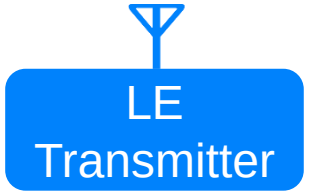
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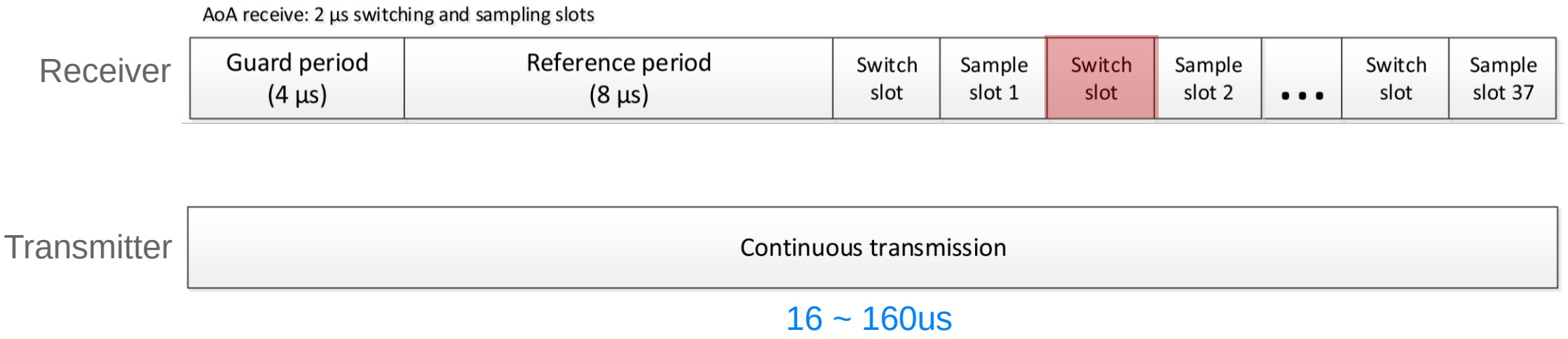
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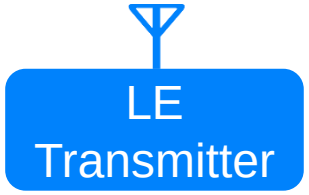
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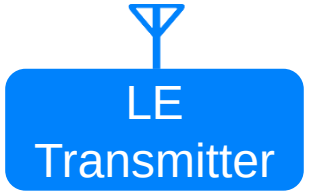
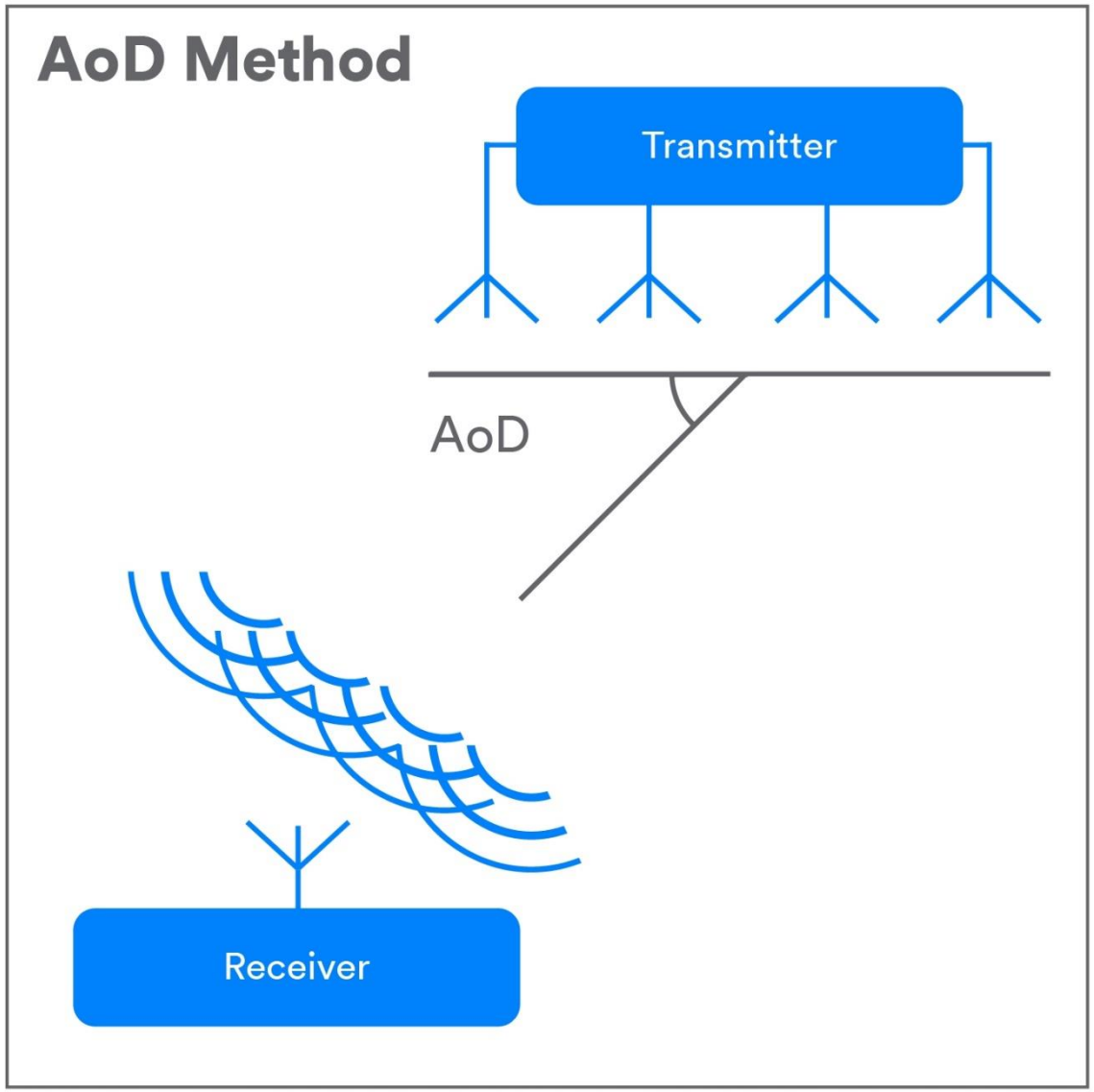
Transmitter

Continuous transmission

16 ~ 160us



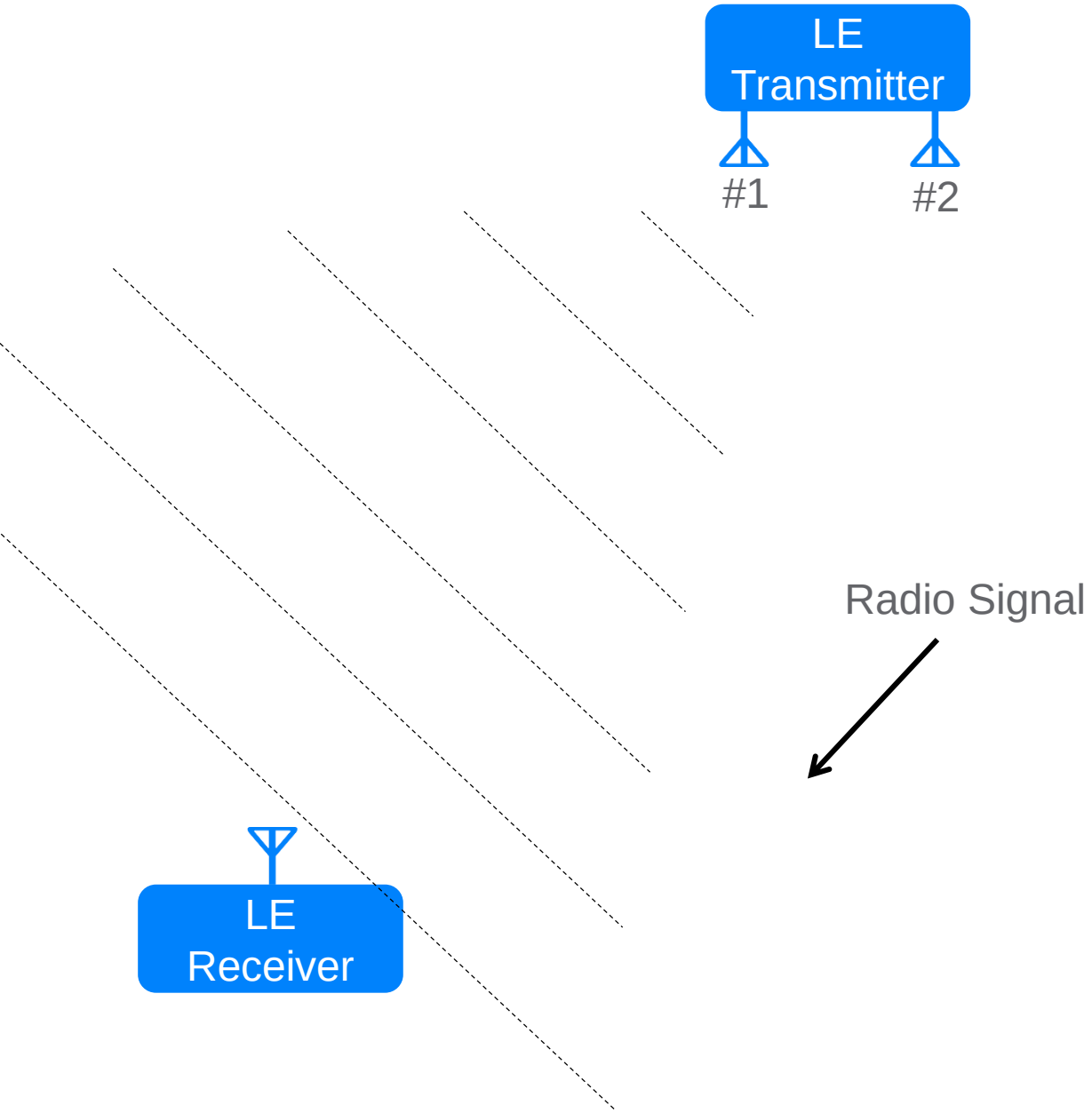


- **Angle of Departure**

- **Transmitter**
  - sends special packets while switching between active antenna arranged in an array

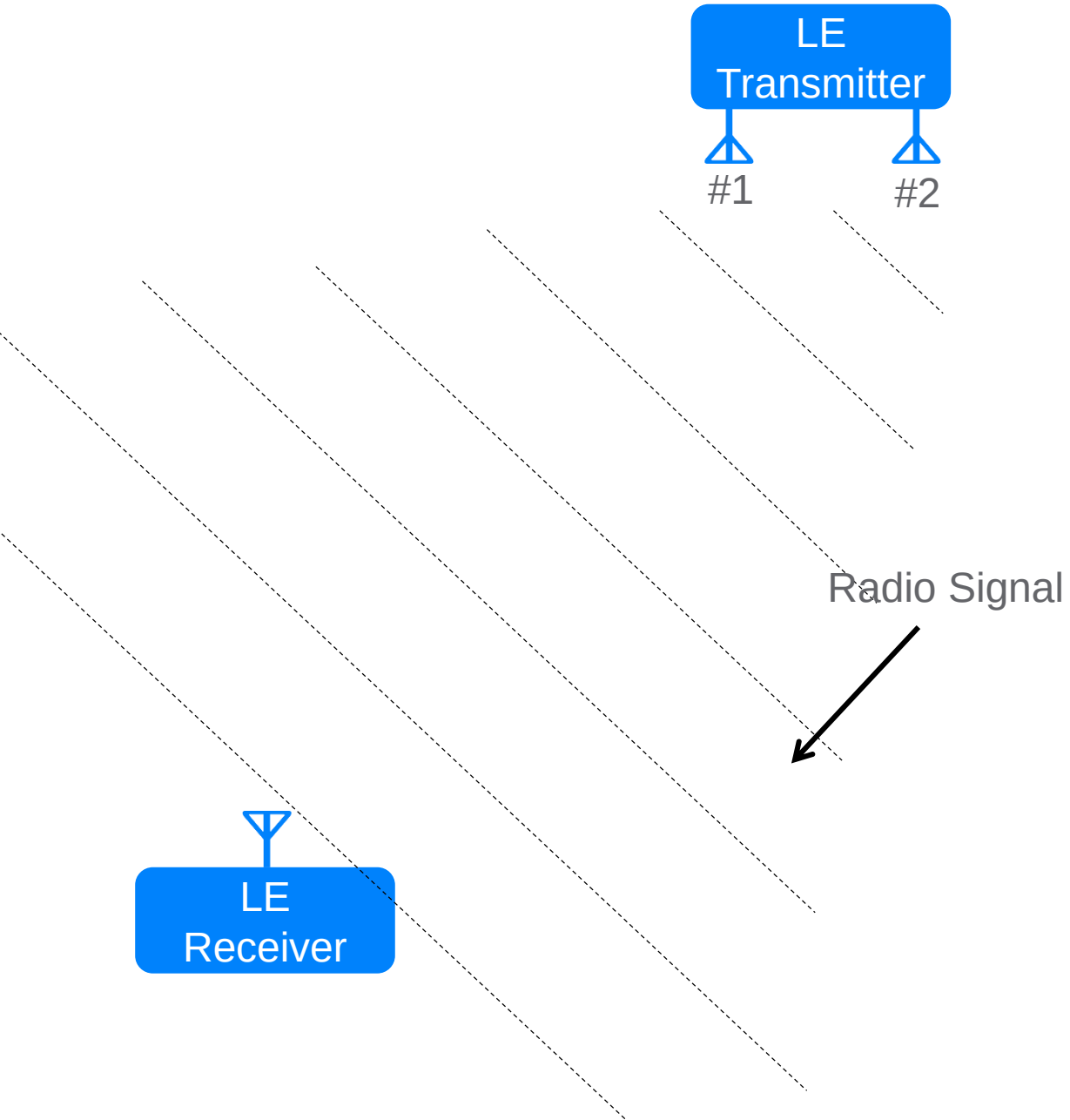
- **Receiver**
  - receives signals using single antenna
  - has knowledge of antenna layout within transmitter
  - takes IQ samples from received signals
  - relative signal direction calculated using sampled data

For indoor positioning systems (IPS)



Angle of Departure, AoD

- Multiple antennas, #1 and #2 in transmitter side
- LE transmitter sending by antenna#1

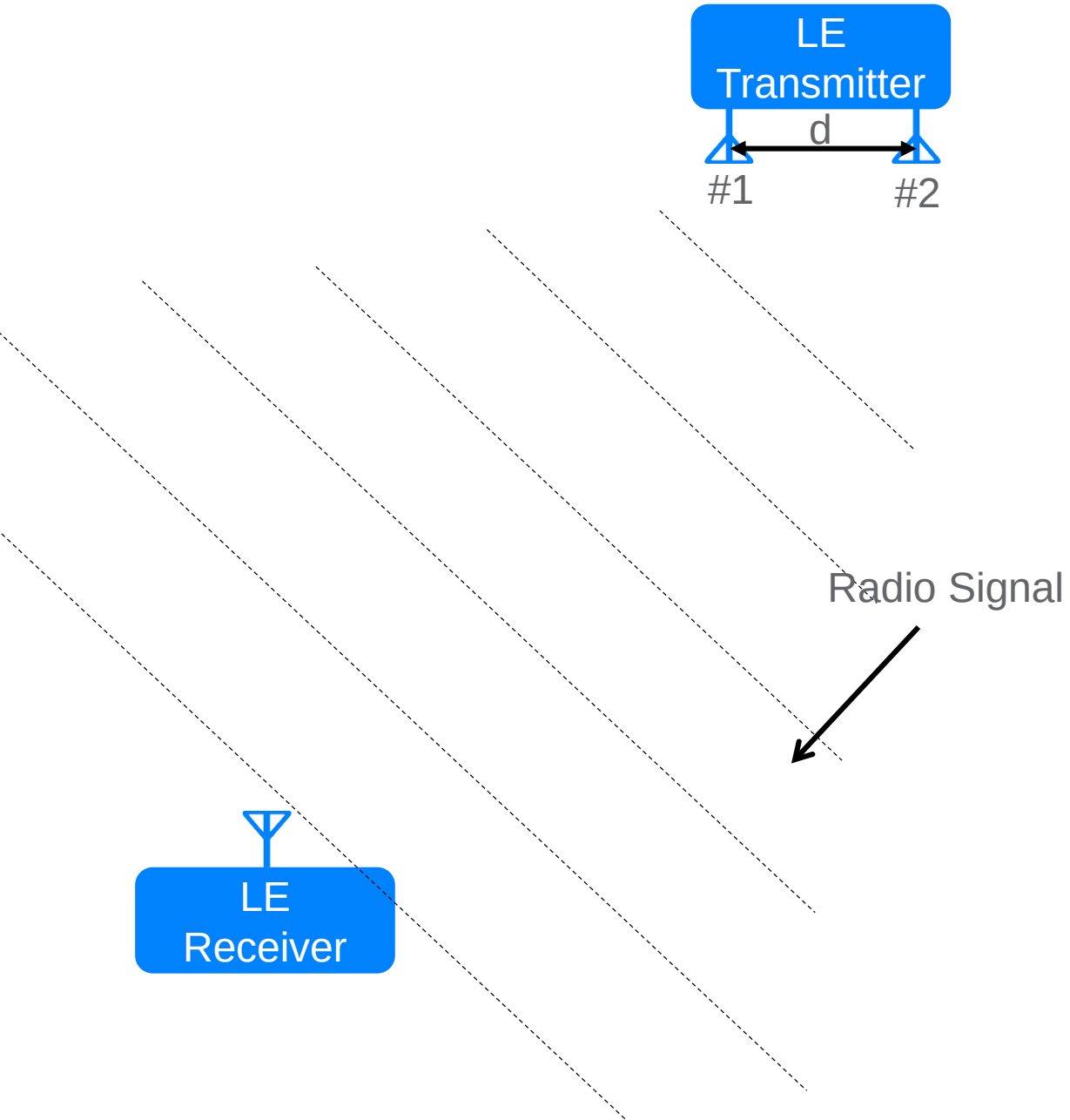


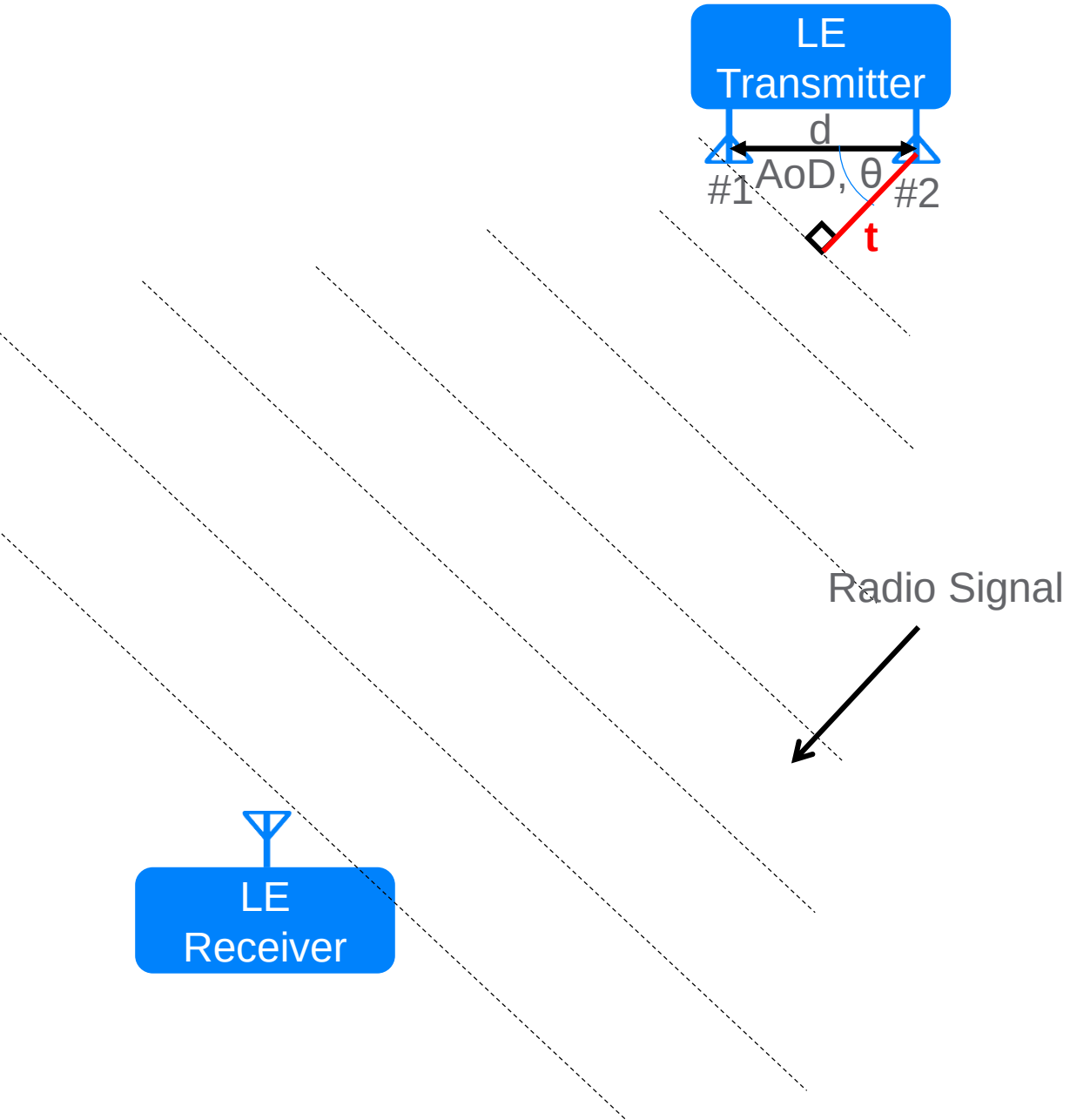
Angle of Departure, AoD

- Multiple antennas, #1 and #2 in transmitter side
- LE transmitter sending by antenna#1
- LE transmitter sending by antenna#2

Angle of Departure, AoD

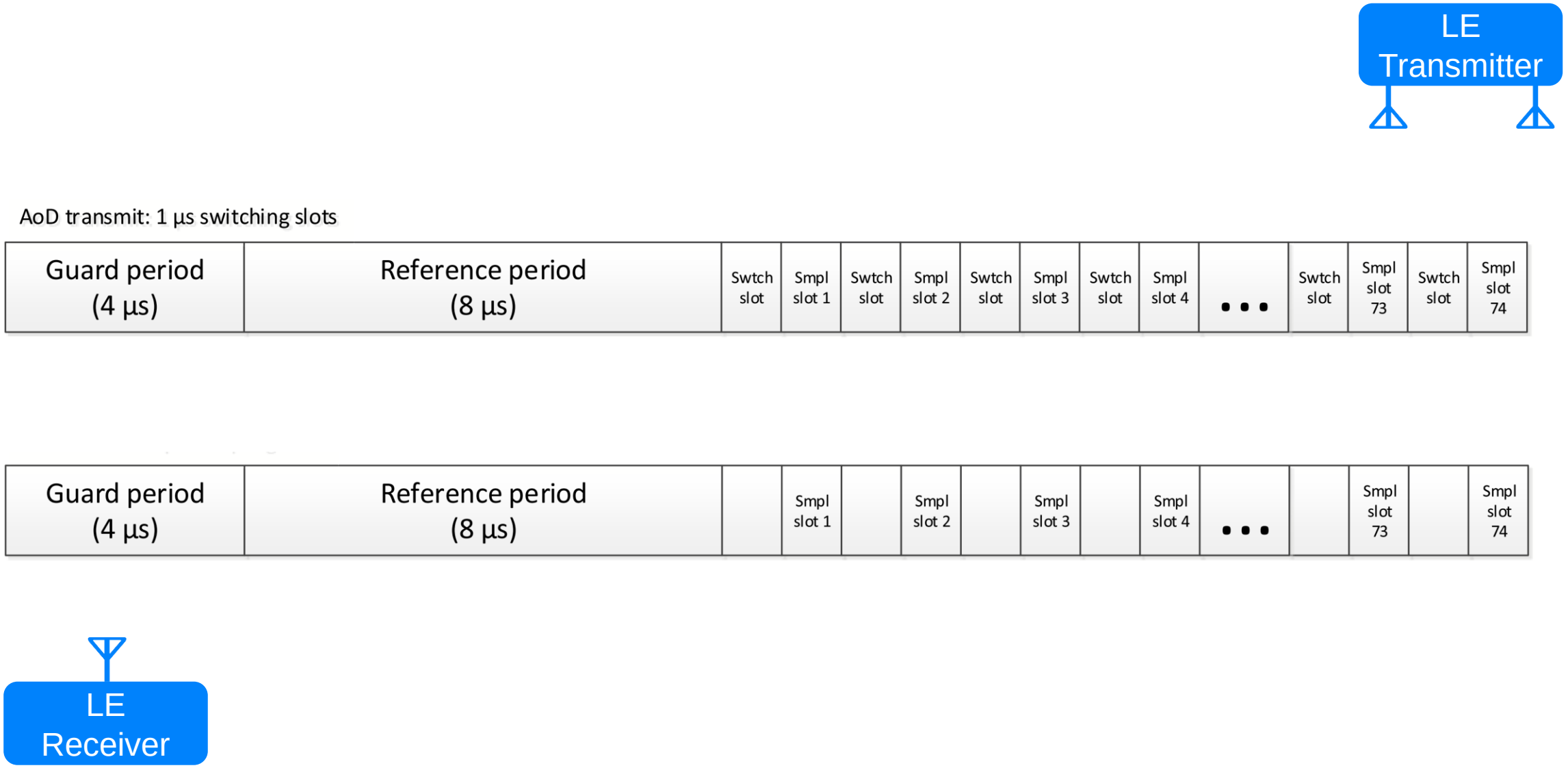
- d is known

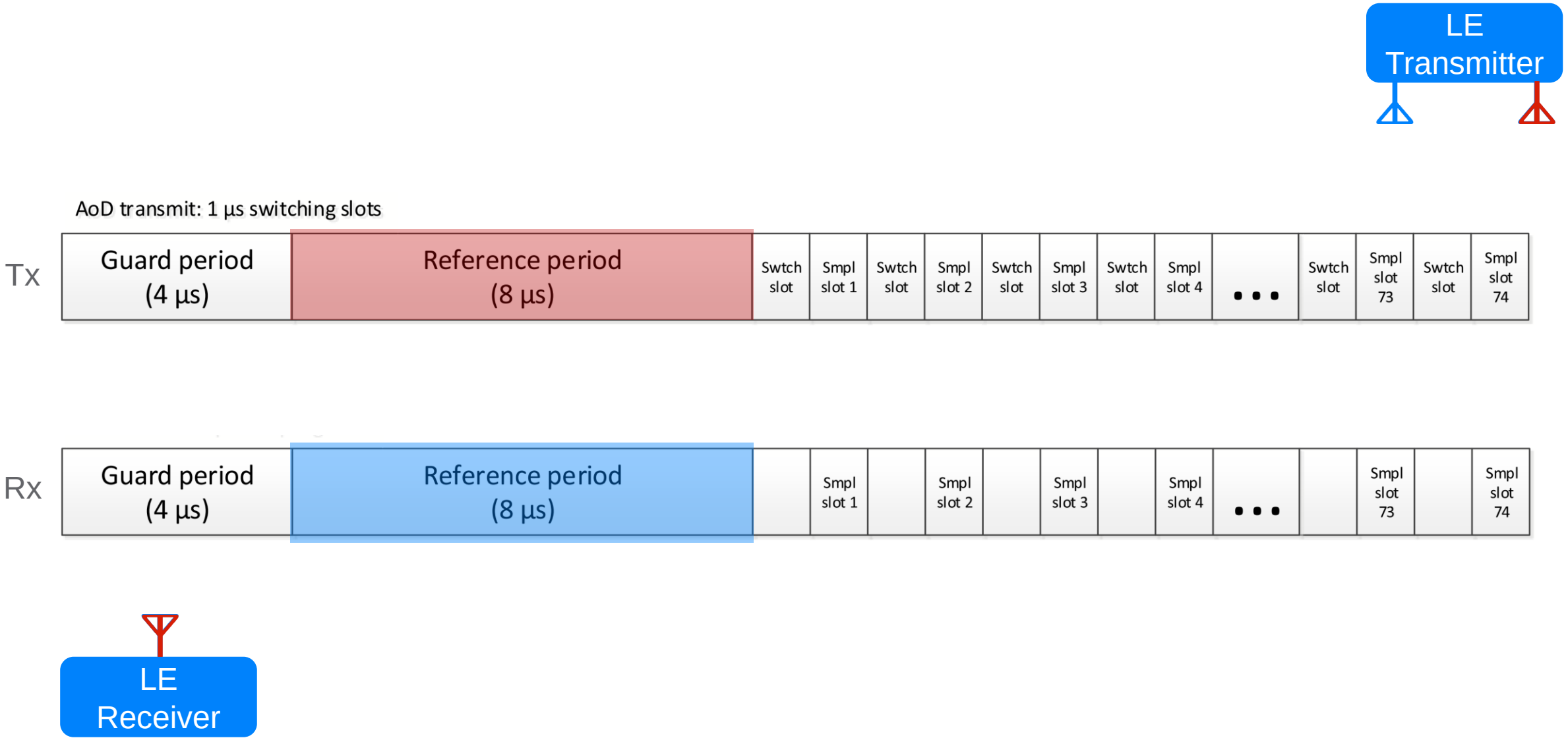




Angle of Departure, AoD

- d is known
- θ is Angle of Arrival
- t = (φ / 2π)· λ, φ is phase difference, λ is wavelength, about 0.125m
- θ = arccos(t/d) = arccos((φ·λ)/(2π·d))


LE Transmitter
AoD transmit: 1 µs switching slots
Tx
Guard period (4 µs)
Reference period (8 µs)
Swtch slot
Smpl slot 1
Swtch slot
Smpl slot 2
Swtch slot
Smpl slot 3
Swtch slot
Smpl slot 4
• • •
Swtch slot
Smpl slot 73
Swtch slot
Smpl slot 74
Rx
Guard period (4 µs)
Reference period (8 µs)
Smpl slot 1
Smpl slot 2
Smpl slot 3
Smpl slot 4
• • •
Smpl slot 73
Smpl slot 74
LE Receiver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Reference period (8 µs)
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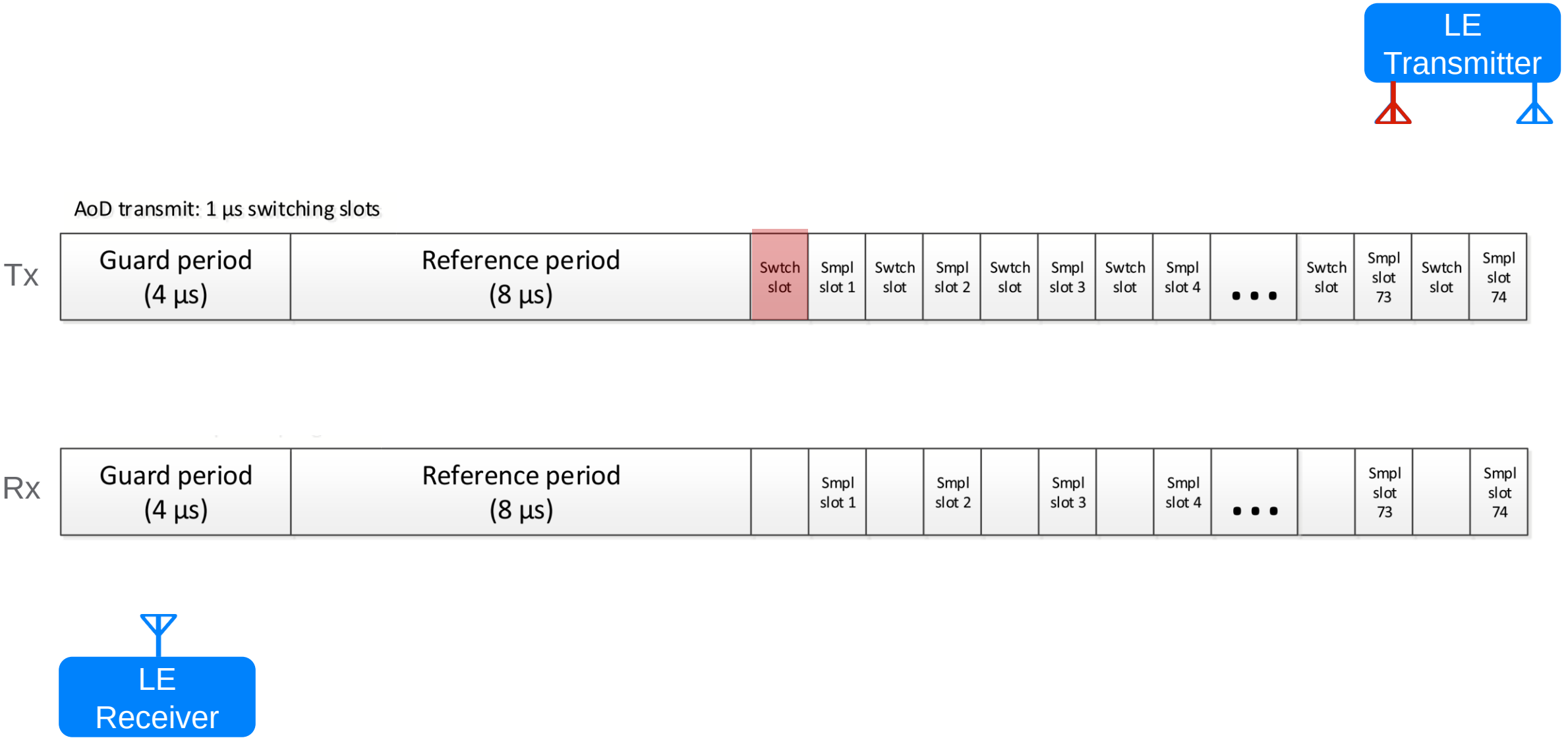
Smpl slot 3
Swtch slot
Smpl slot 4
• • •
Swtch slot
Smpl slot 73
Swtch slot
Smpl slot 74
Rx
Guard period (4 µs)
Reference period (8 µs)
Smpl slot 1
Smpl slot 2
Smpl slot 3
Smpl slot 4
• • •
Smpl slot 73
Smpl slot 74
LE Receiver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Smpl slot 2
Smpl slot 3
Smpl slot 4
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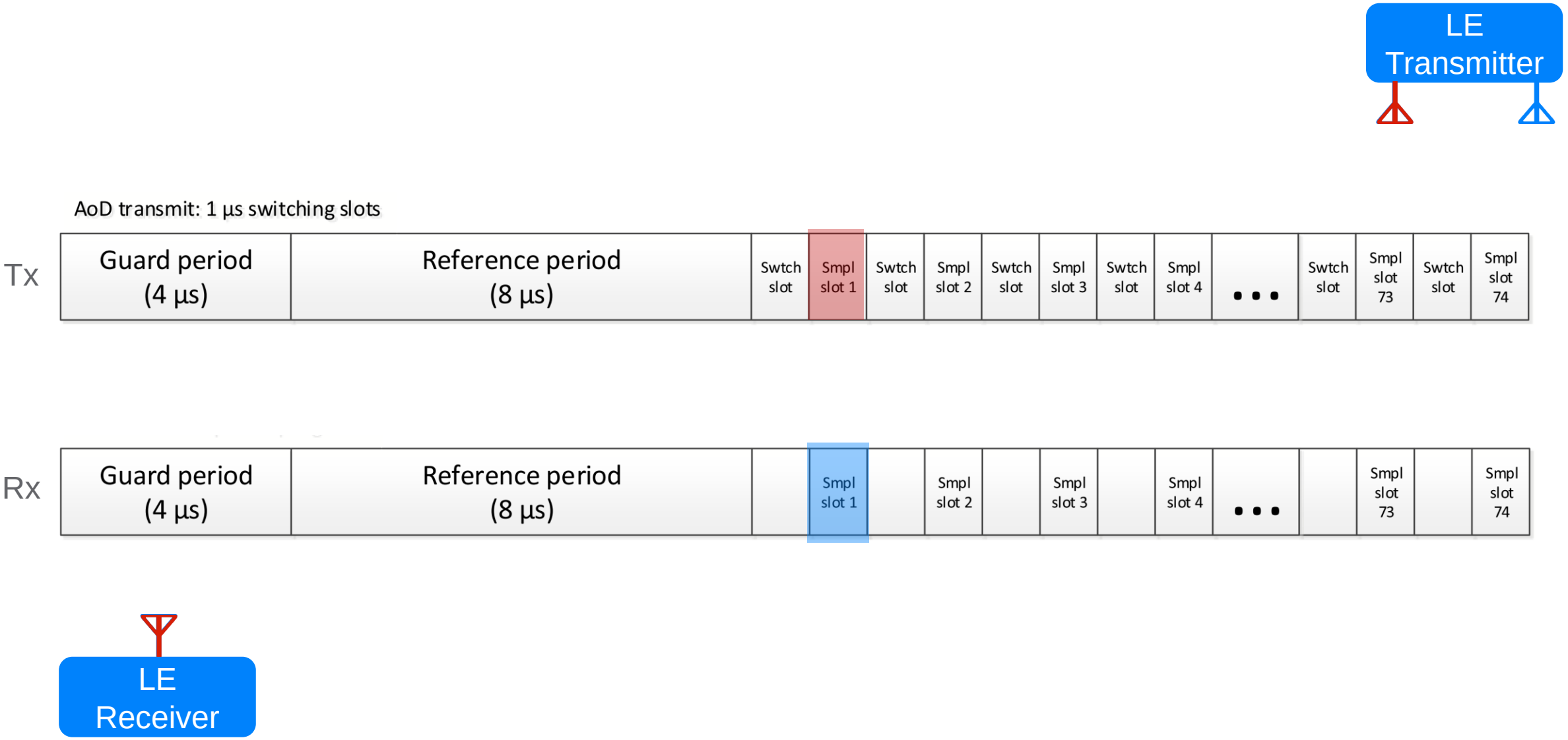
Smpl slot 73
Smpl slot 74
LE Receiver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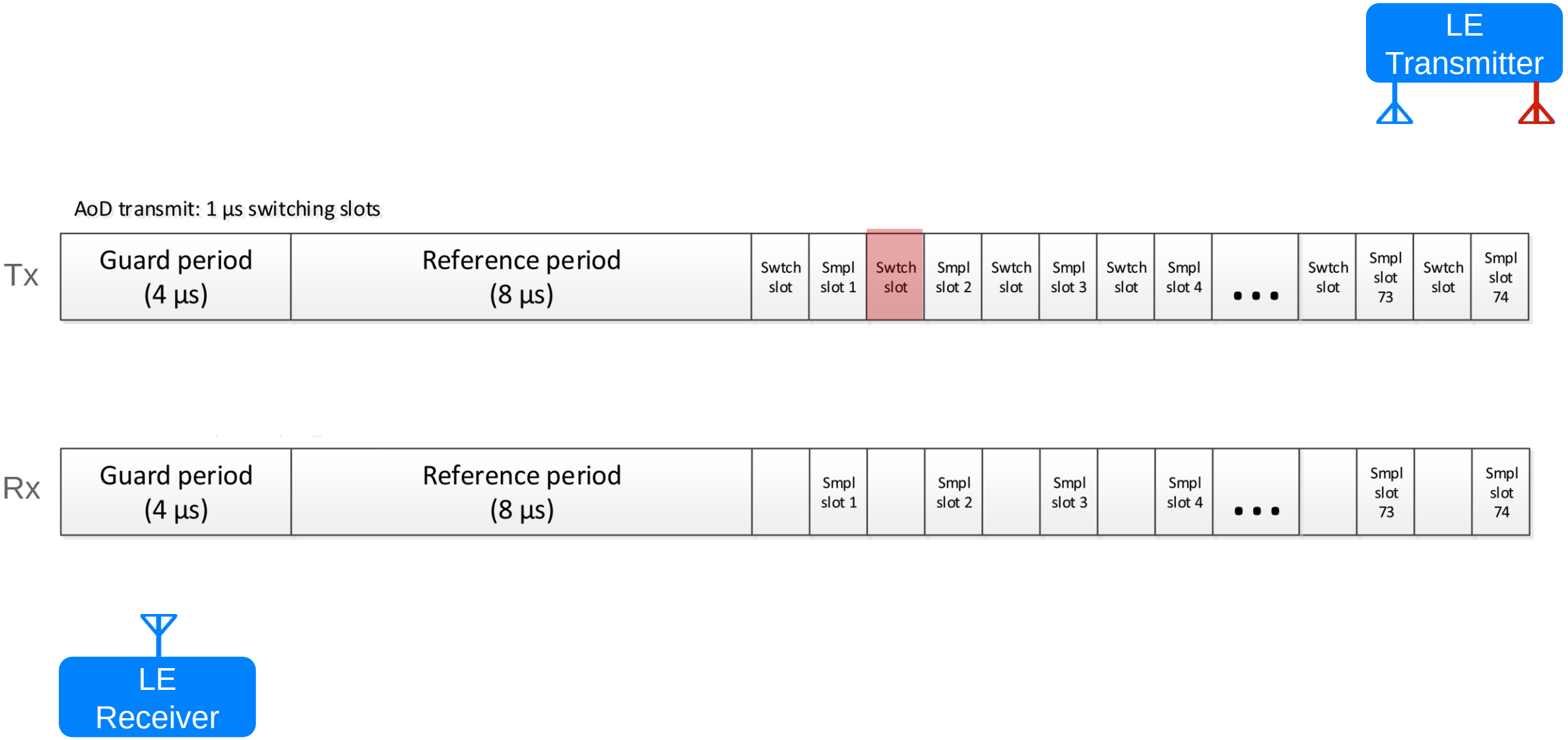
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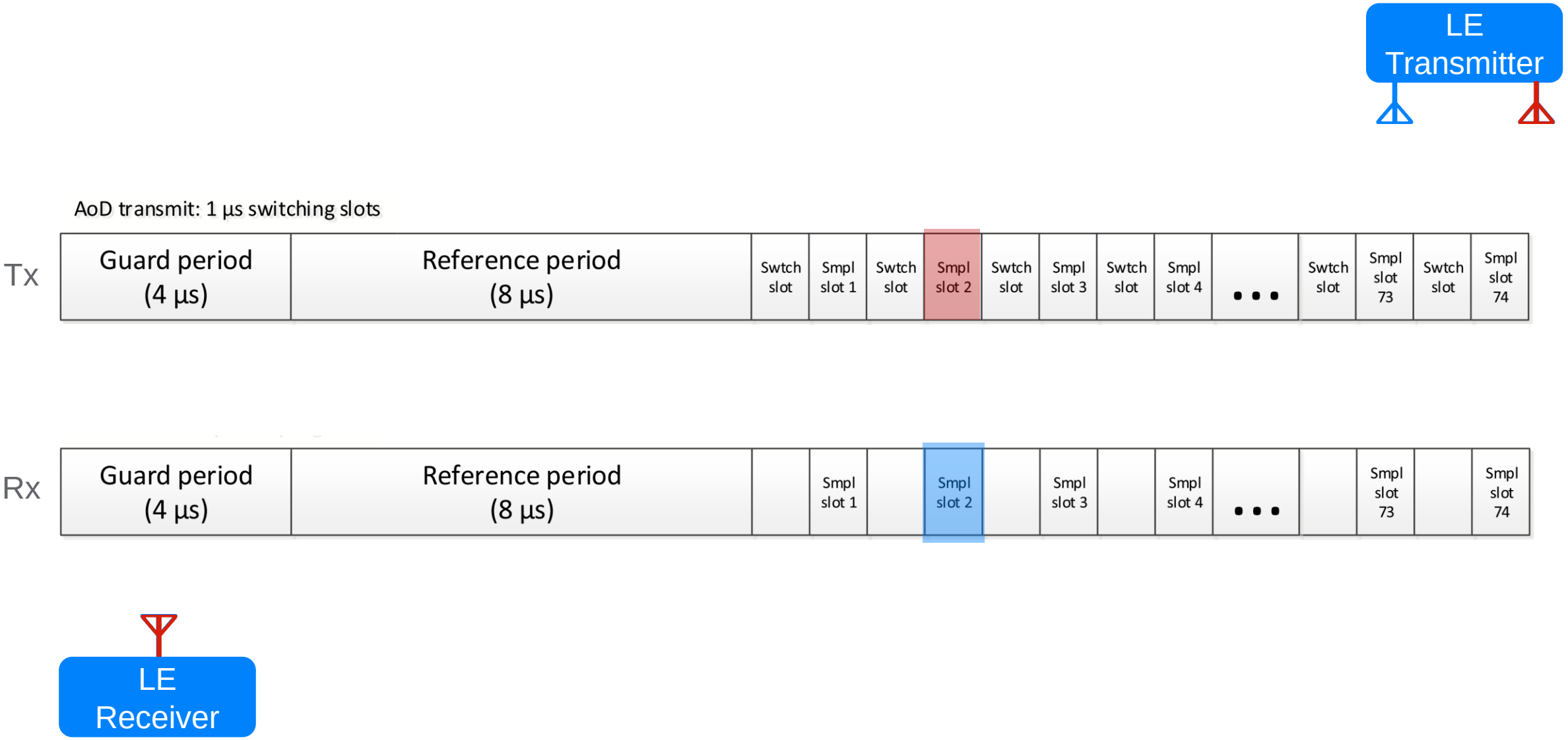
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Reference period (8 µs)
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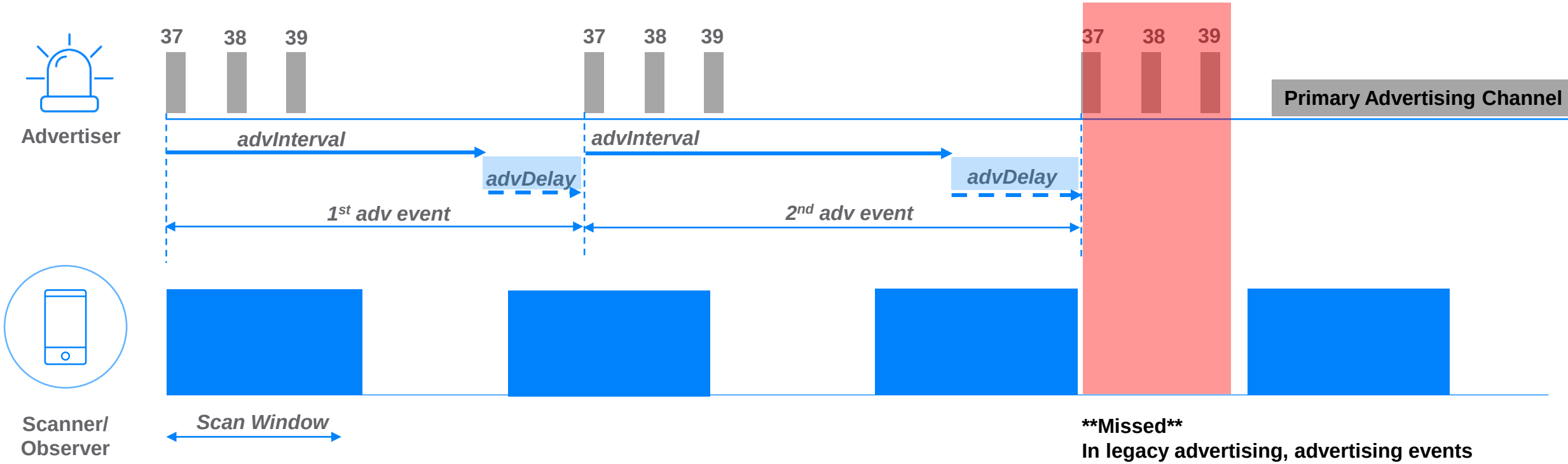
Smpl slot 2
Smpl slot 3
Smpl slot 4
• • •
Smpl slot 73
Smpl slot 74
LE Receiver

Periodical Advertising Sync Transfer, PAST

Legacy Advertising



Missed
In legacy advertising, advertising events have a random delay to prevent persistent collisions
It is hard for a scanner to follow the advertiser.

* Periodical advertising is one of the adv features in Core Spec v5.0.

Periodical Advertising

Advertiser

37 38 39

ADV_EXT_IND ADV_EXT_IND ADV_EXT_IND

- Which channel used
- Offset of AUX_ADV_IND
- Which PHY used

Primary Advertising Channel

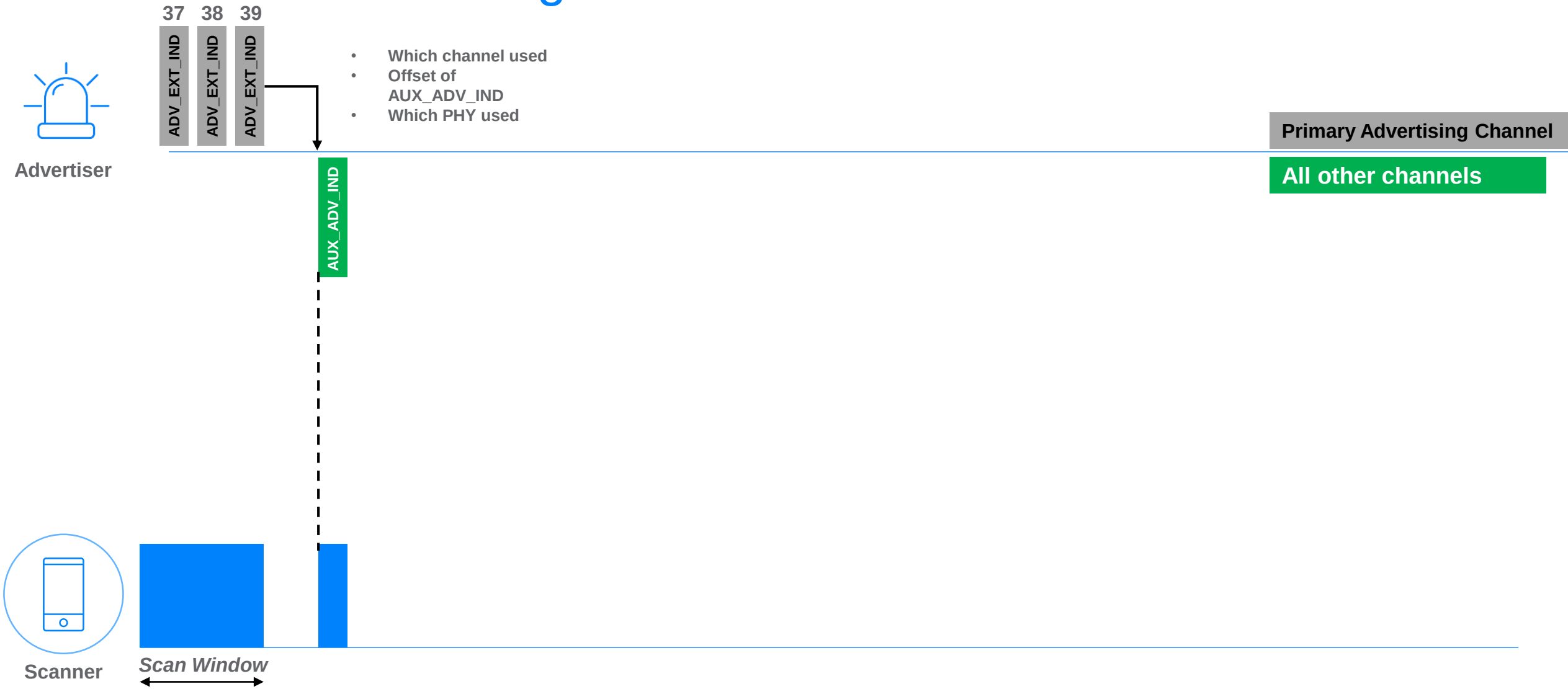
All other channels

Scanner

Scan Window

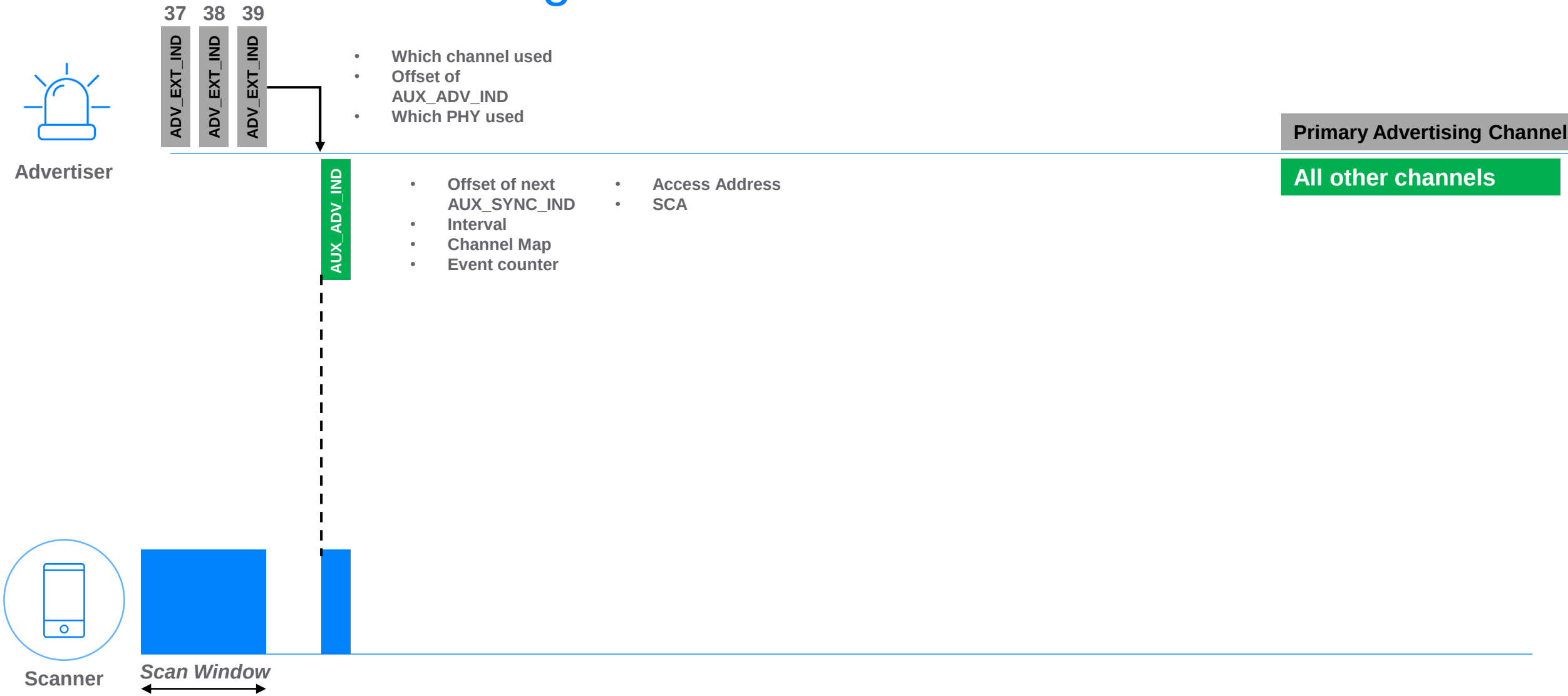
* Periodical advertising is one of the adv features in Core Spec v5.0.

Periodical Advertising



* Periodical advertising is one of the adv features in Core Spec v5.0.

Periodical Advertising



* Periodical advertising is one of the adv features in Core Spec v5.0.

Periodical Advertising

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Periodical Advertising

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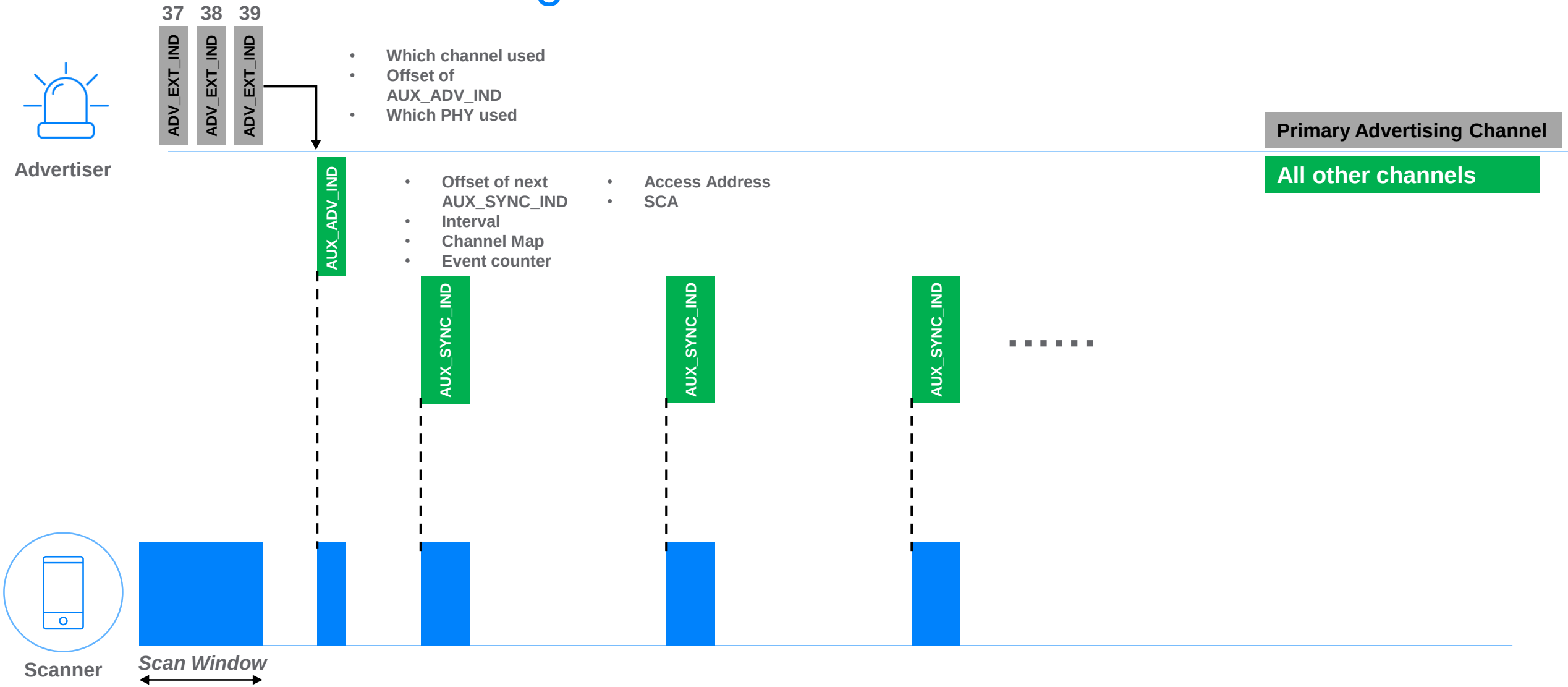
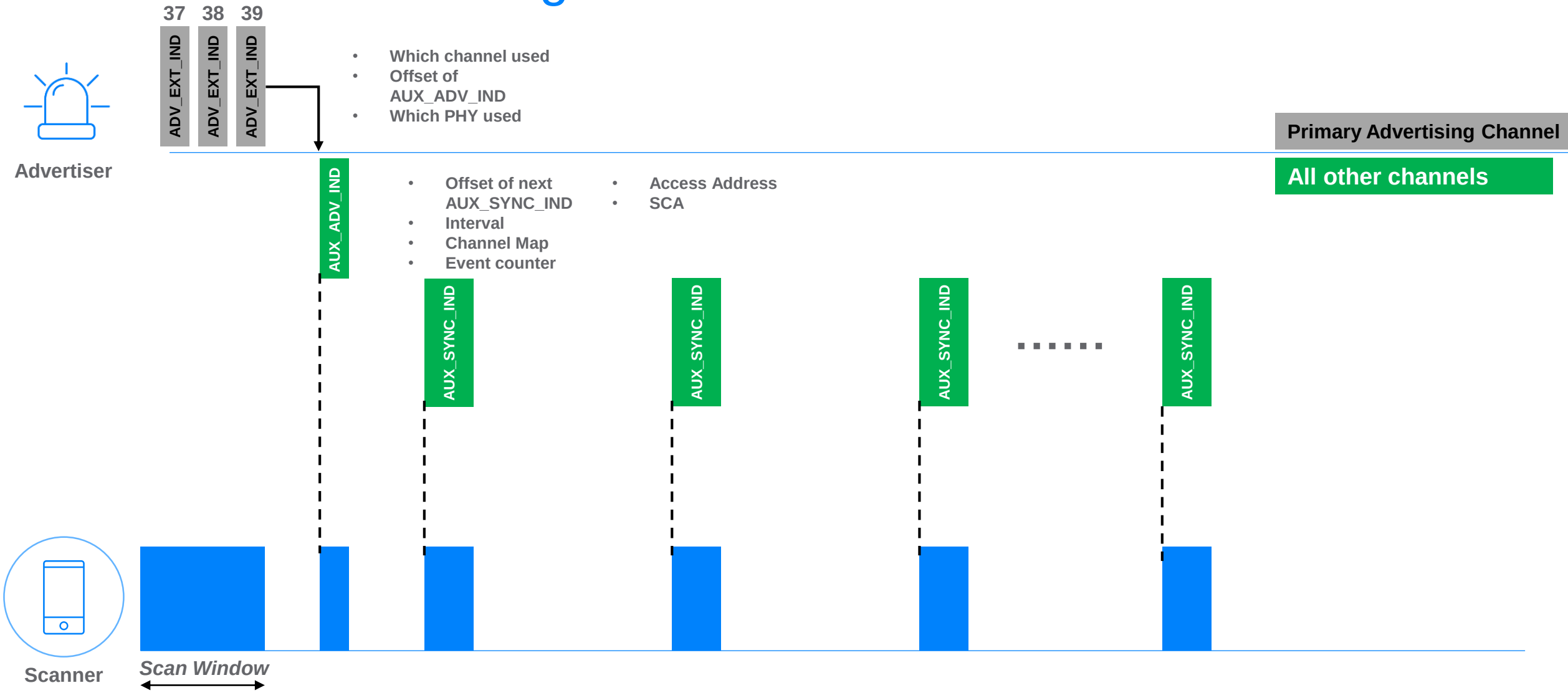
Periodical Advertising



* Periodical advertising is one of the adv features in Core Spec v5.0.

Periodical Advertising



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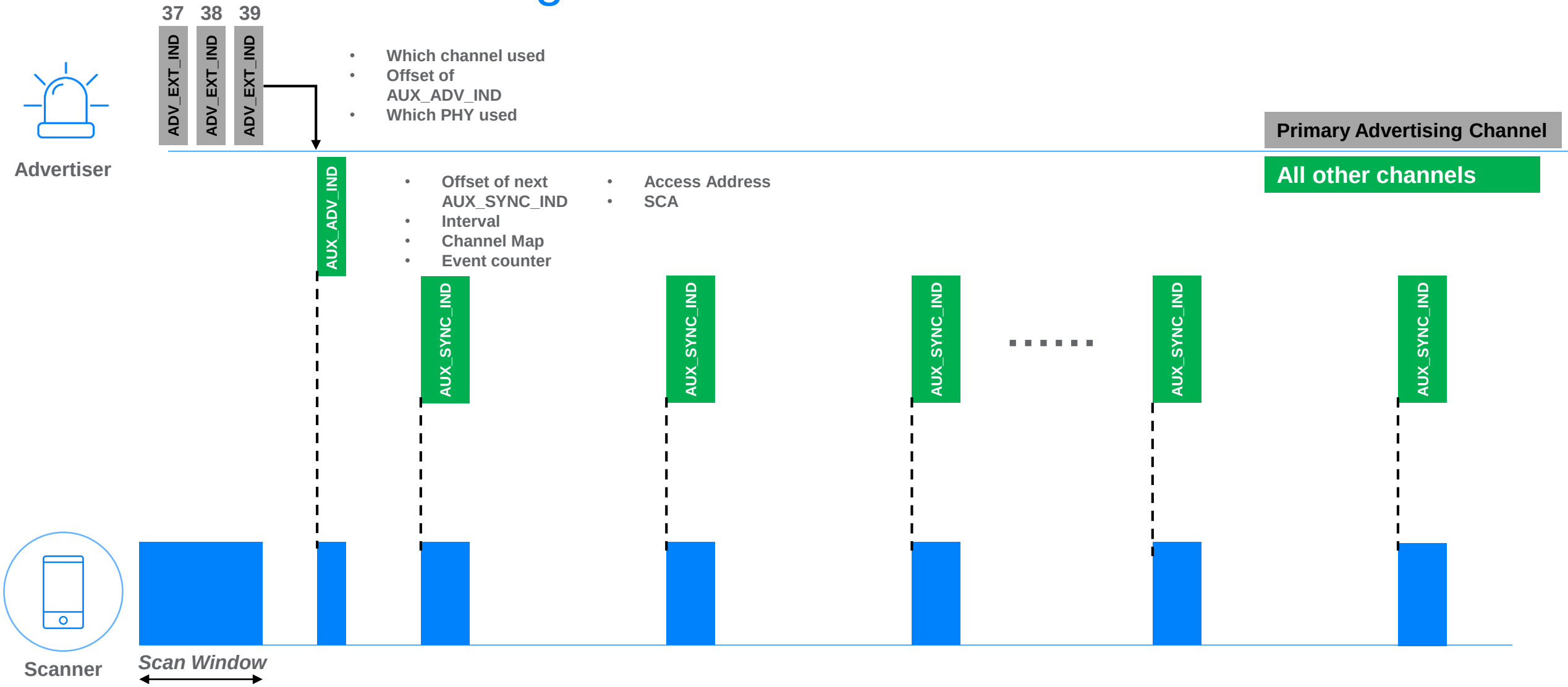
Periodical Advertising



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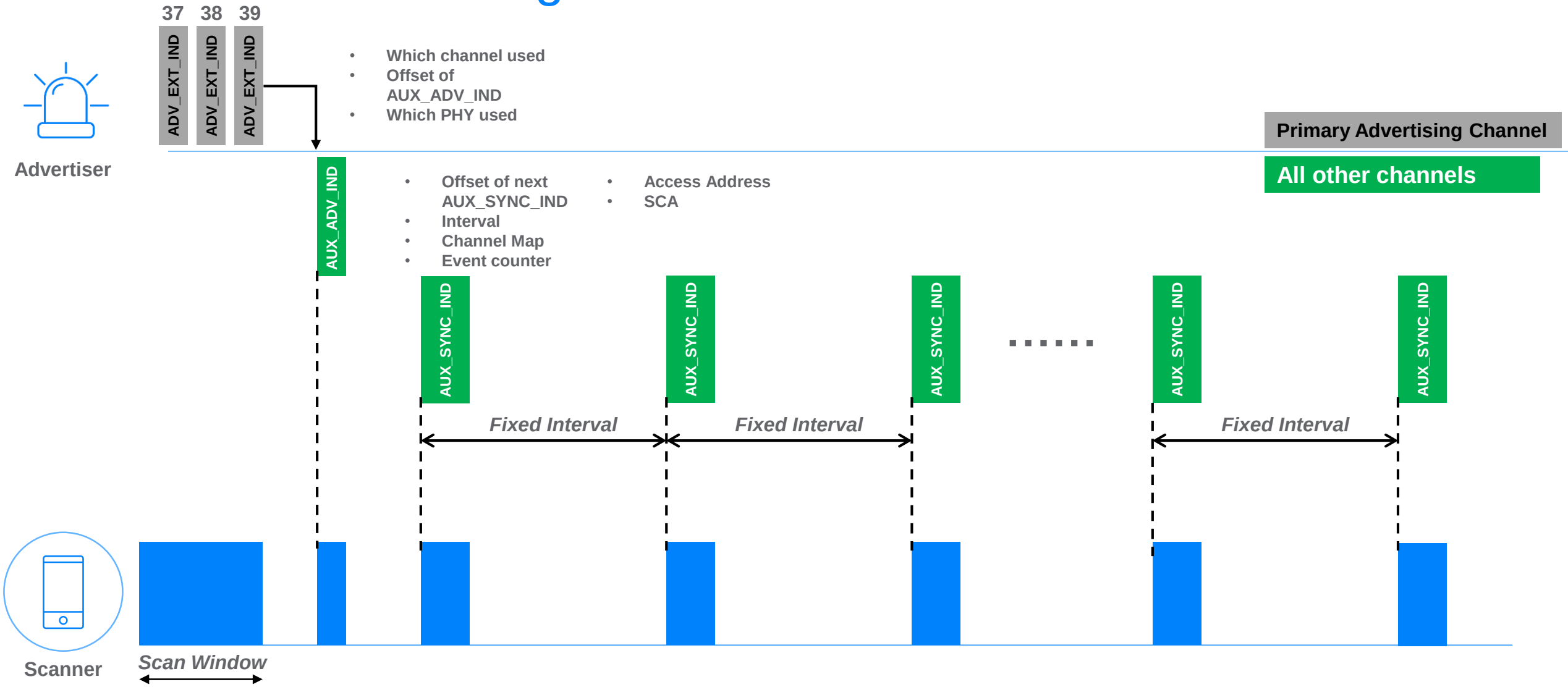
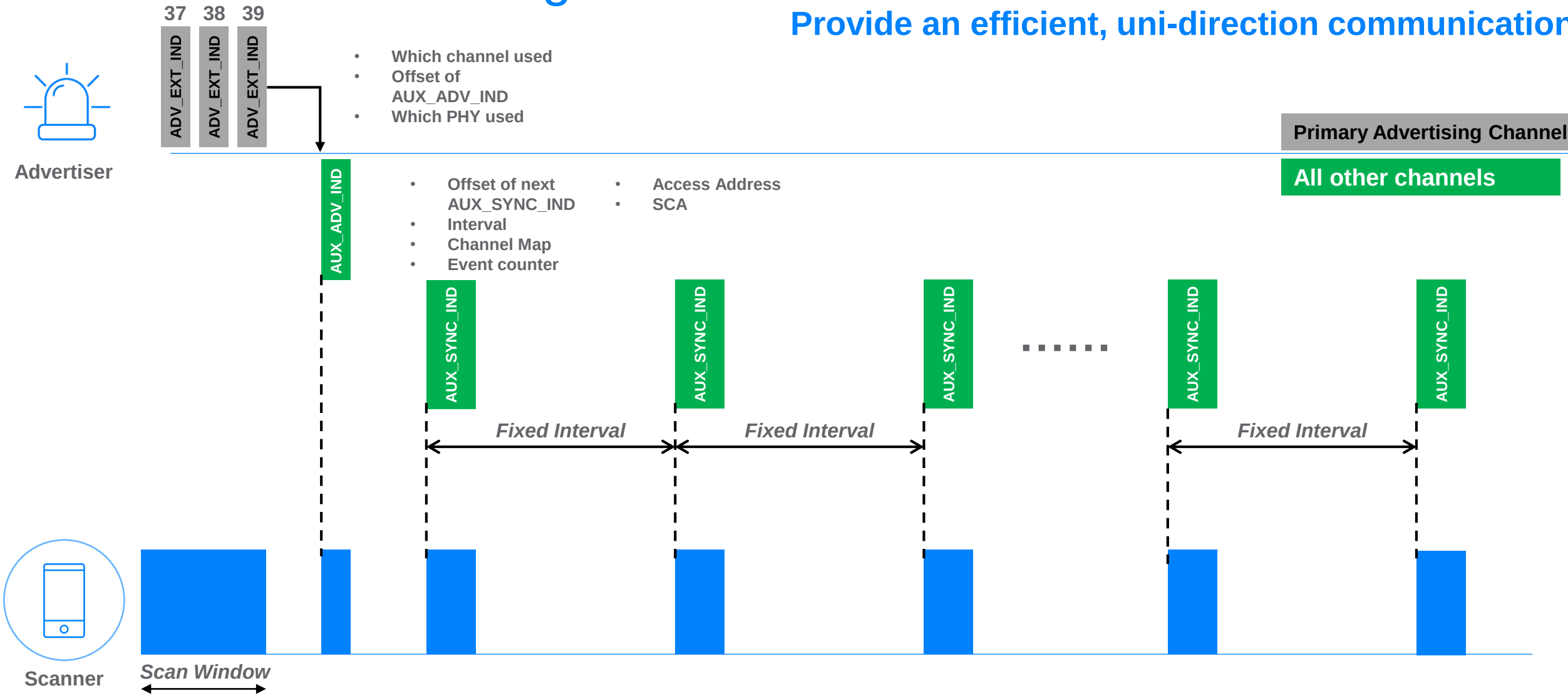
Periodical Advertising



* Periodical advertising is one of the adv features in Core Spec v5.0.

Periodical Advertising

Provide an efficient, uni-direction communication.

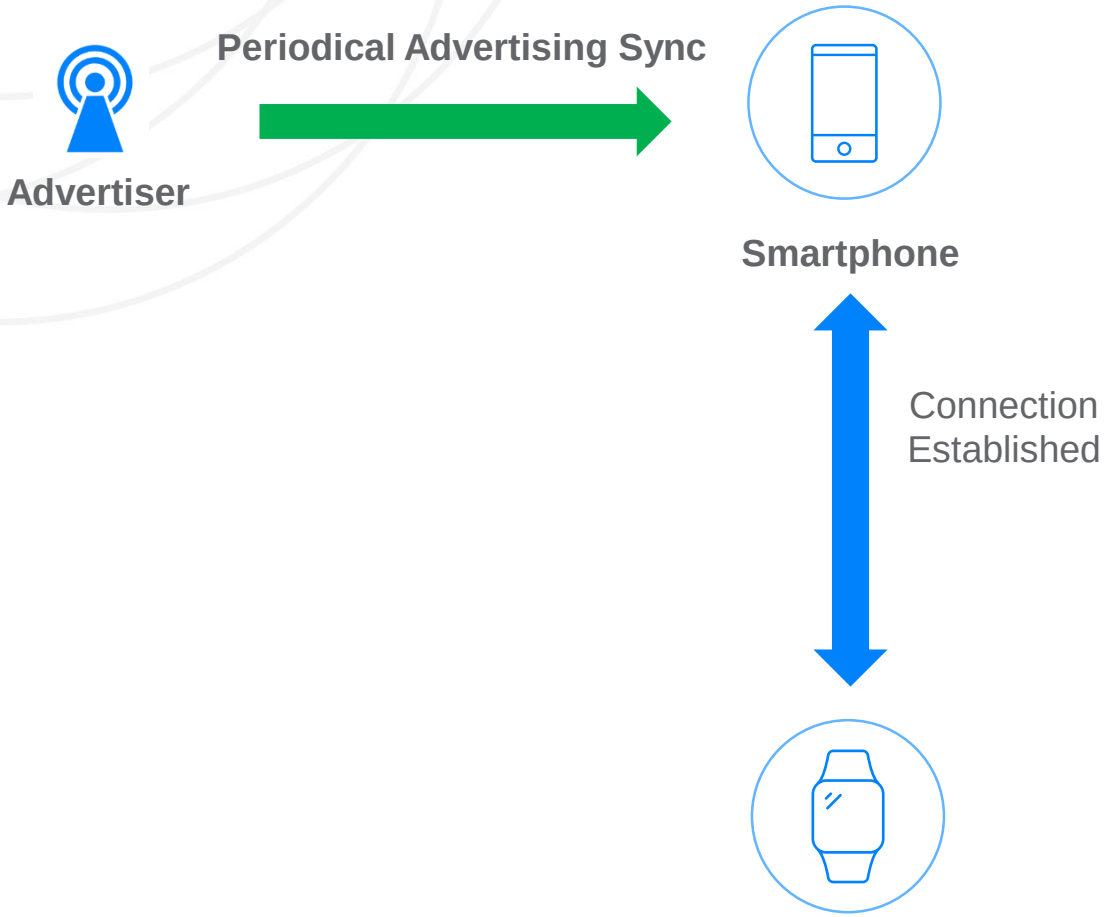


Without PAST

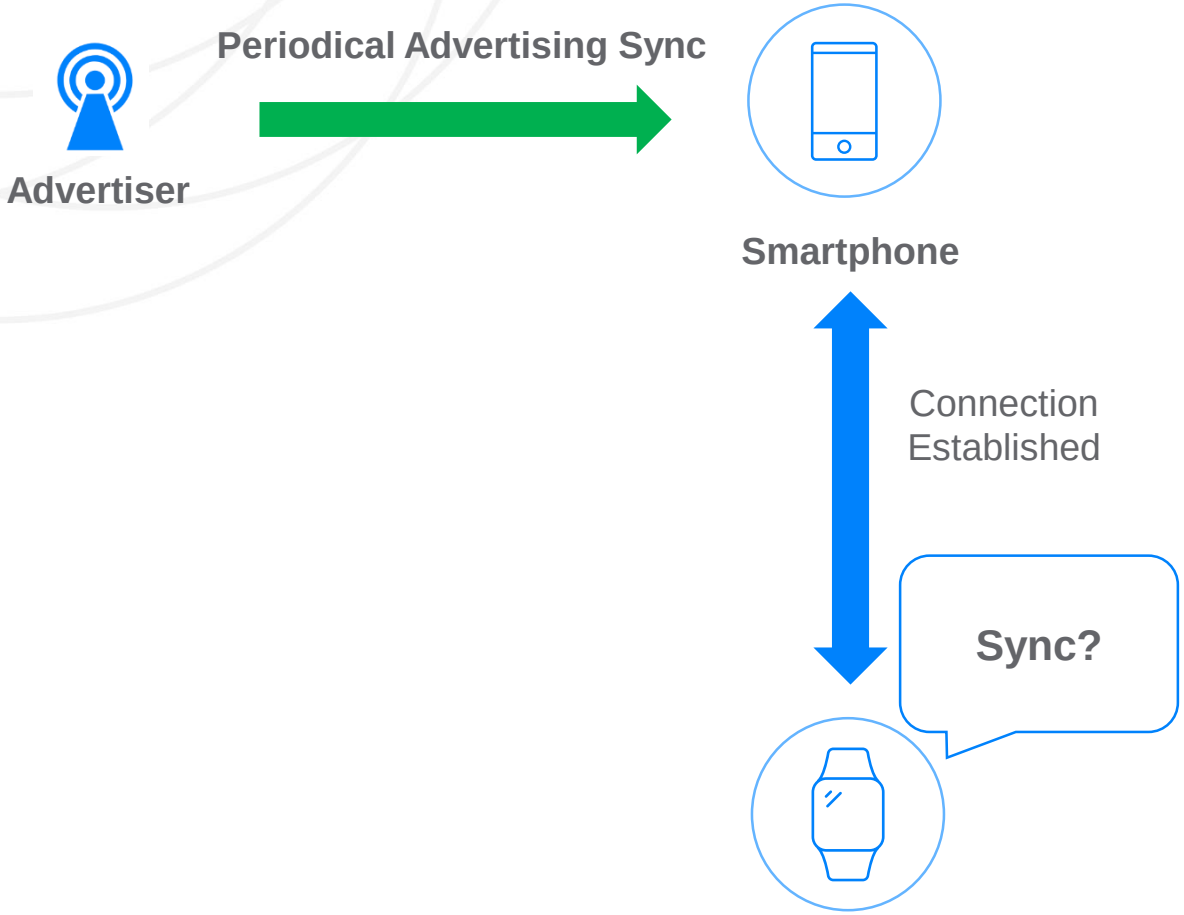
Advertiser

Smartphone

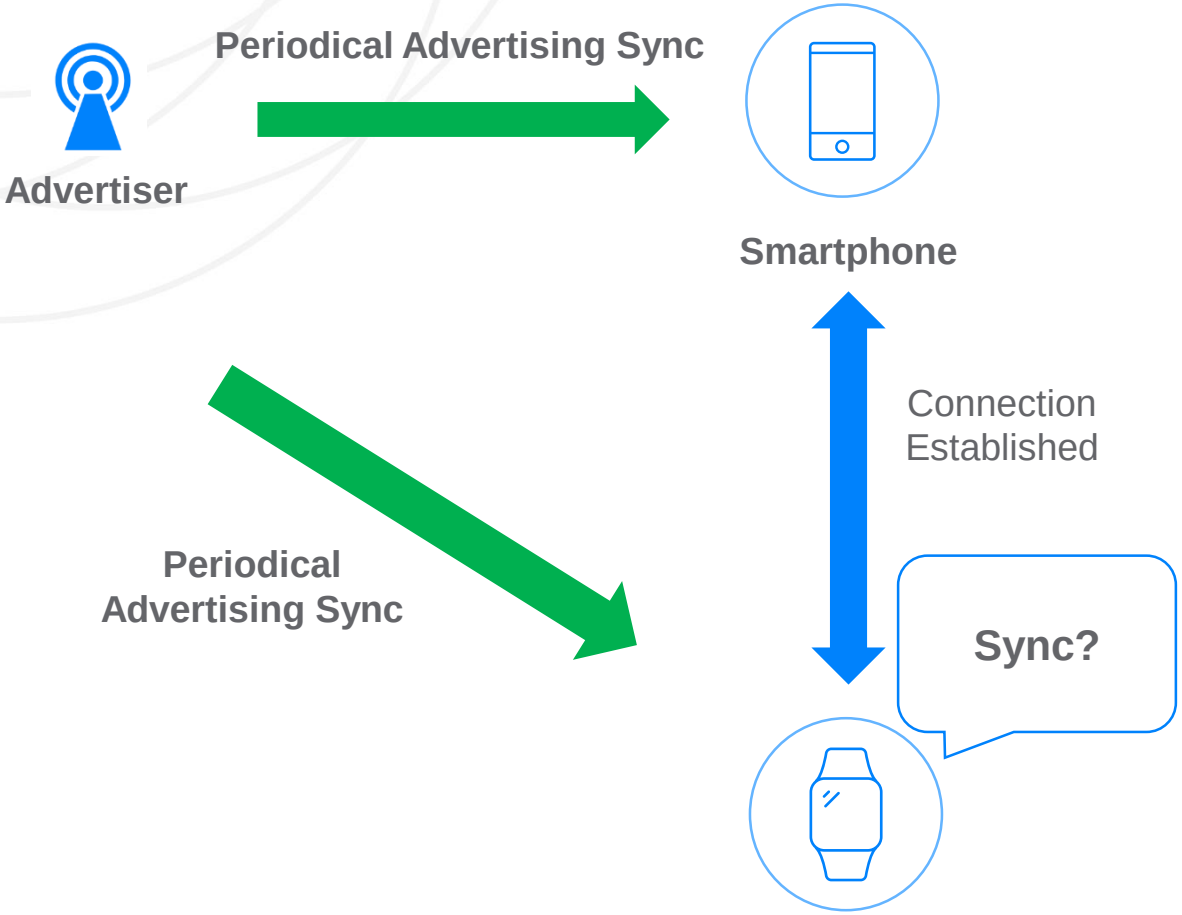
Without PAST



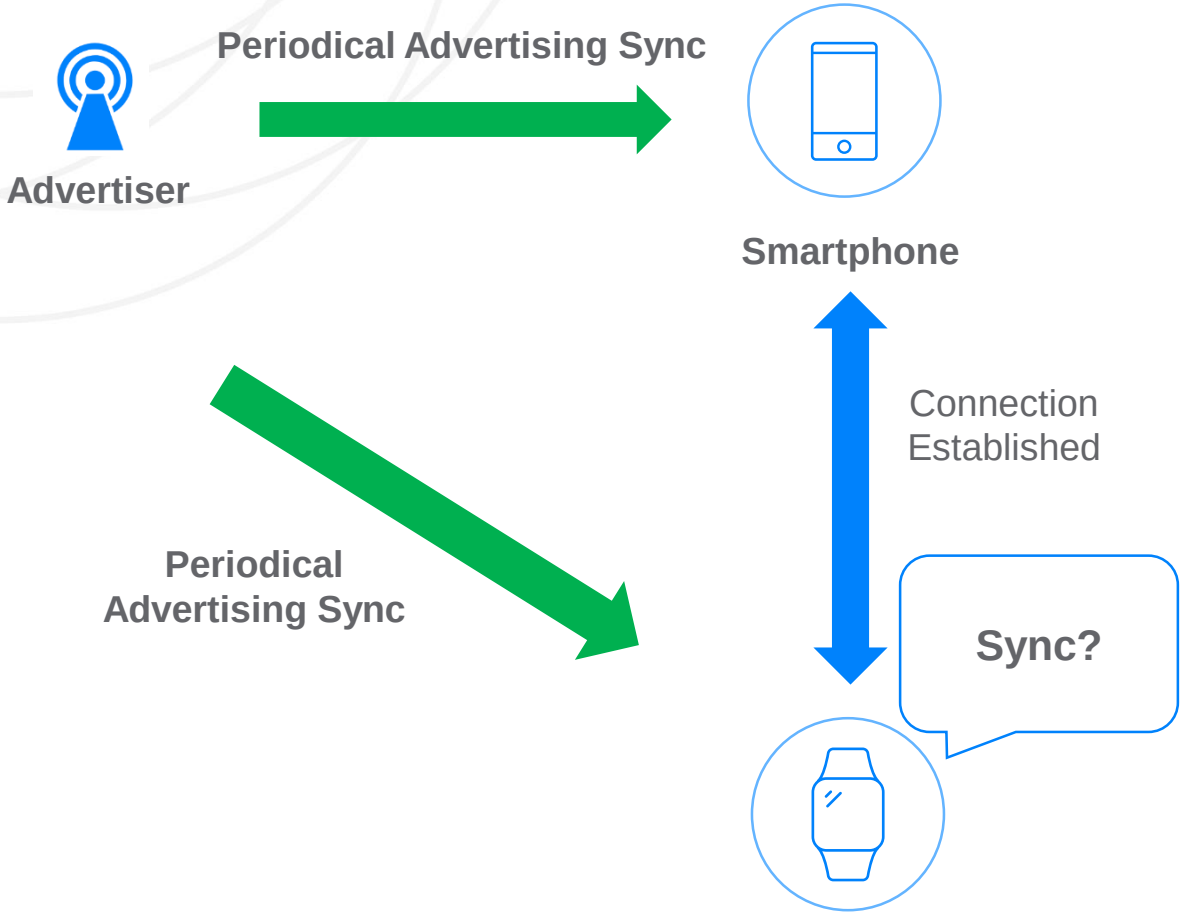
Without PAST



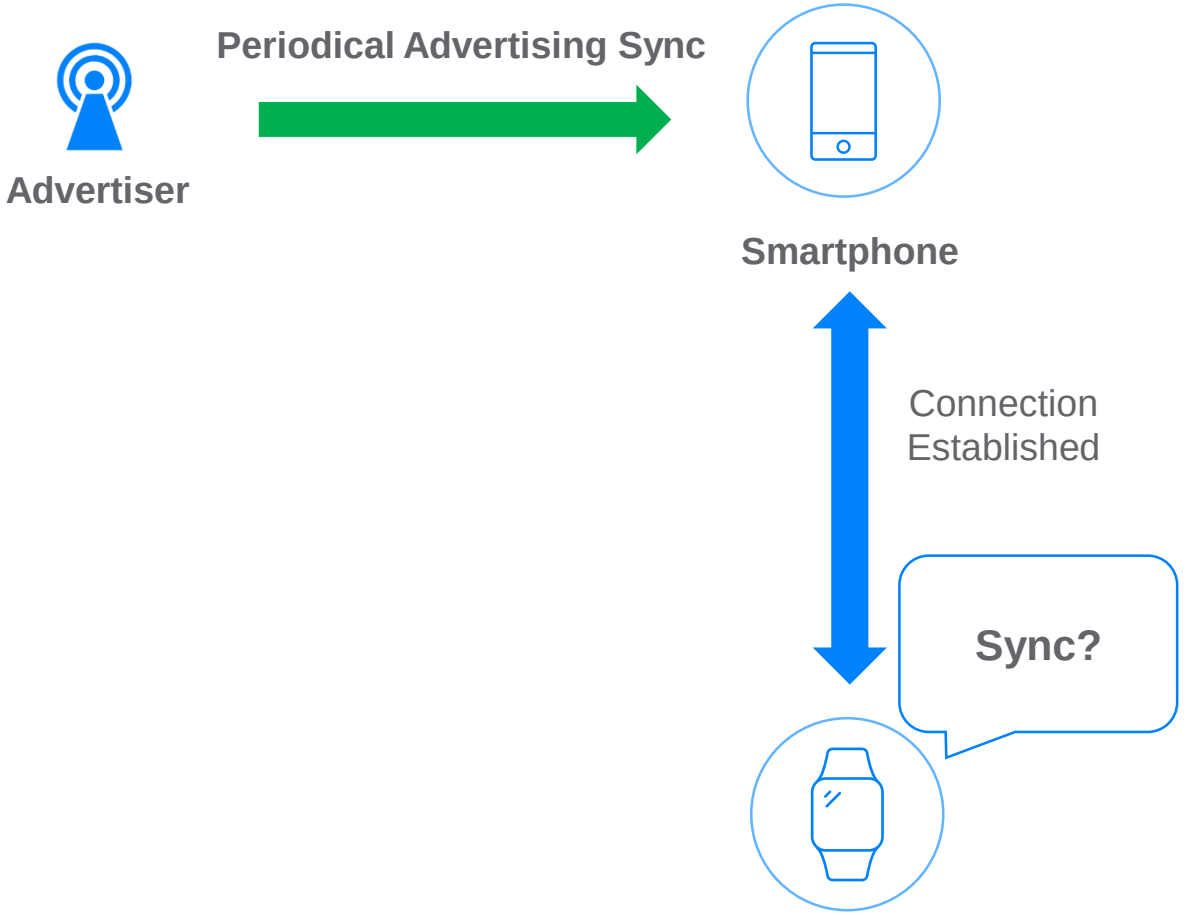
Without PAST



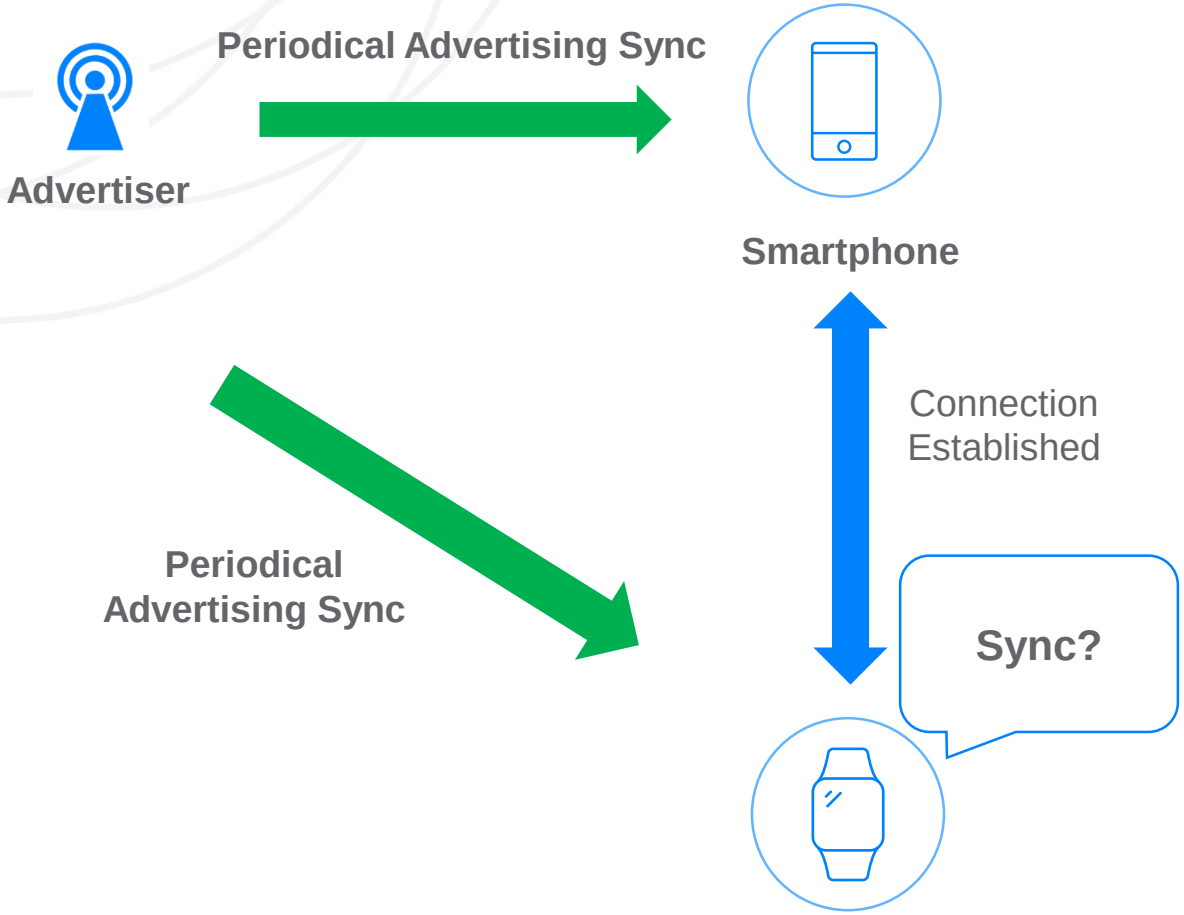
Without PAST



With PAST



Without PAST



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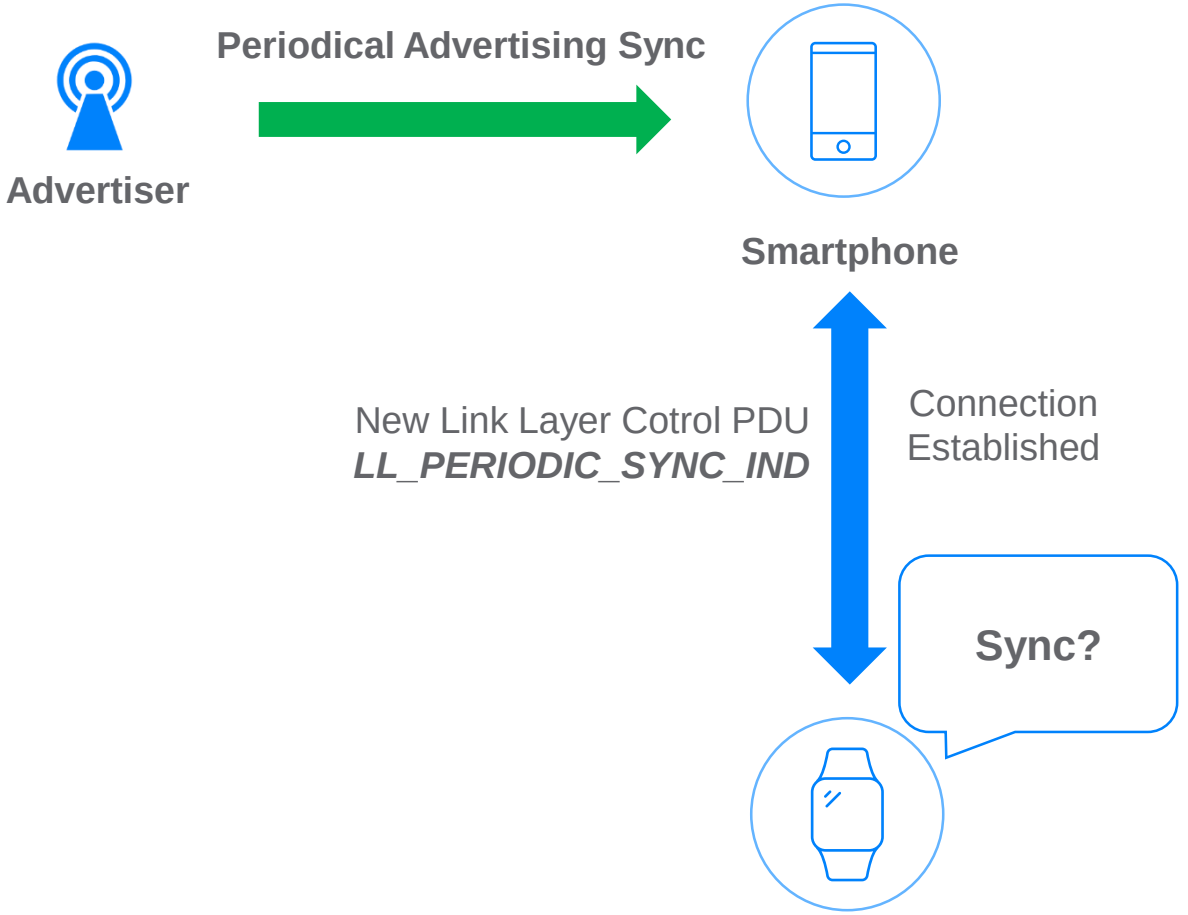
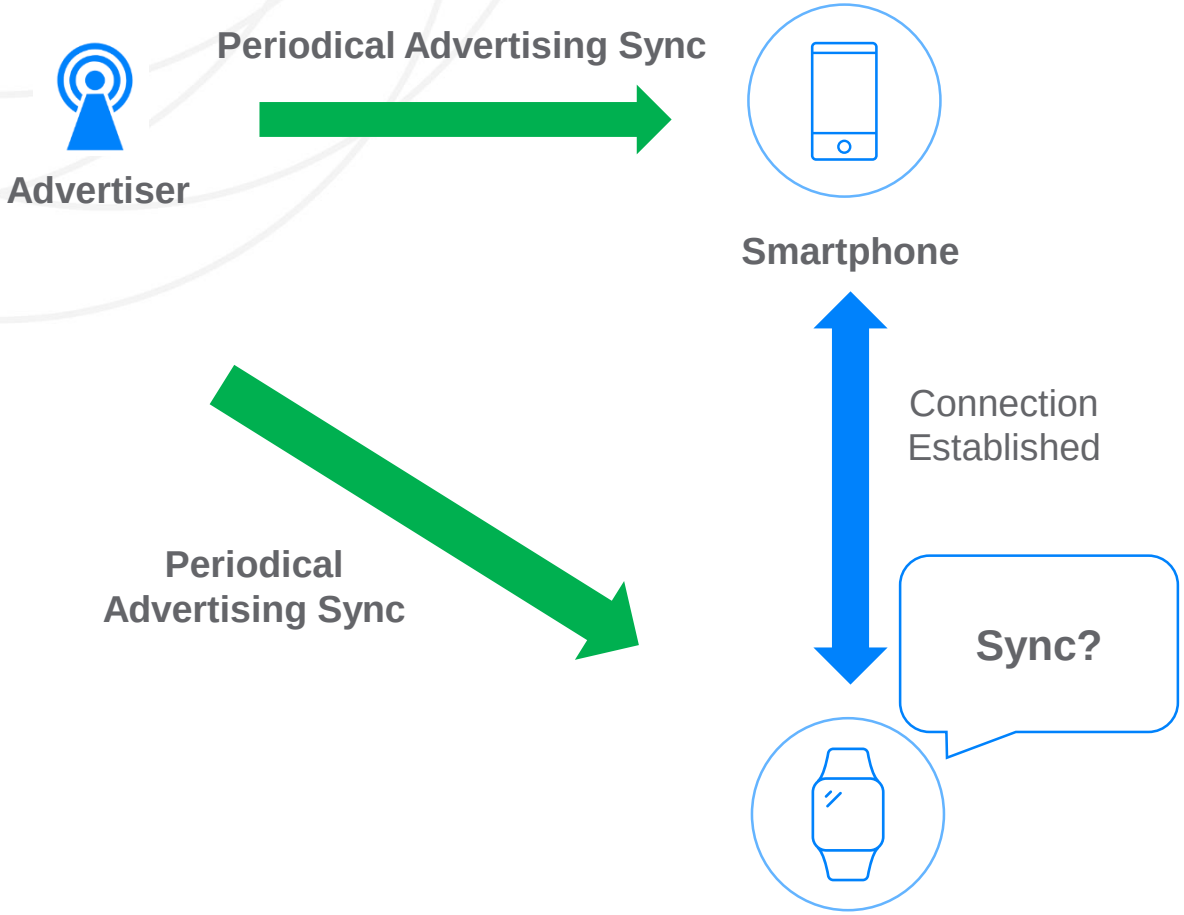
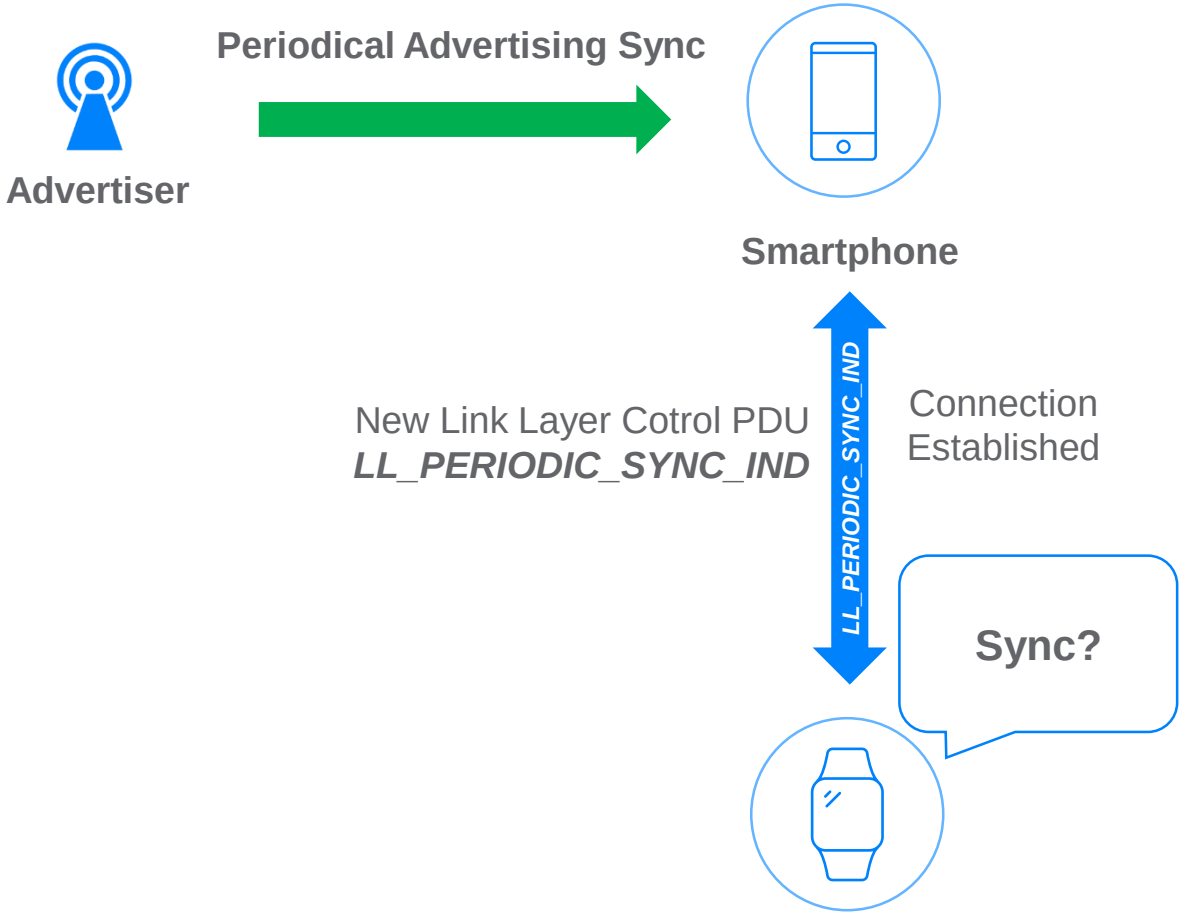


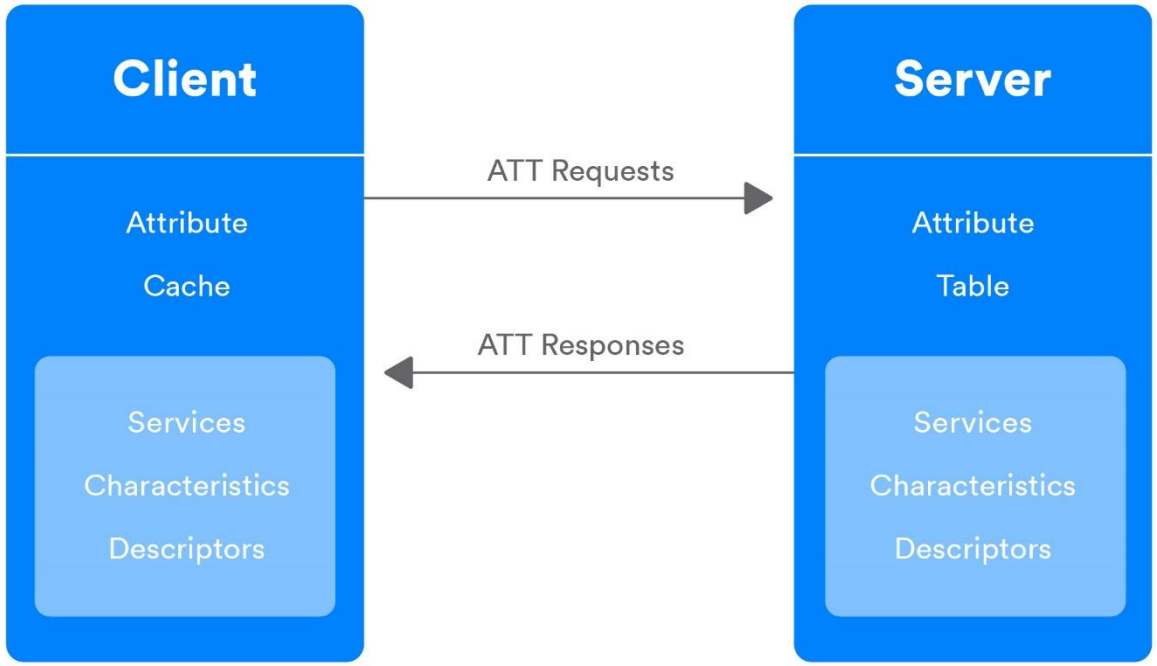
Without PAST



With PAST



GATT Caching



GATT caching enhancement

GATT devices contain a database known as the *attribute table*

GATT clients must perform a procedure known as *service discovery* to acquire details of the attribute table on the remote GATT server device

Previously, clients and servers that were not bonded were required to perform service discovery every time they connect

Service discovery takes time and consumes energy

Previously, attribute table synchronisation was controlled by the server using the *Service Changed* characteristic. Possible race condition.

GATT caching enhancement

- Allows unbonded clients to cache the attribute table
  - Avoids unnecessary service discoveries
  - Lower power usage and faster connect time

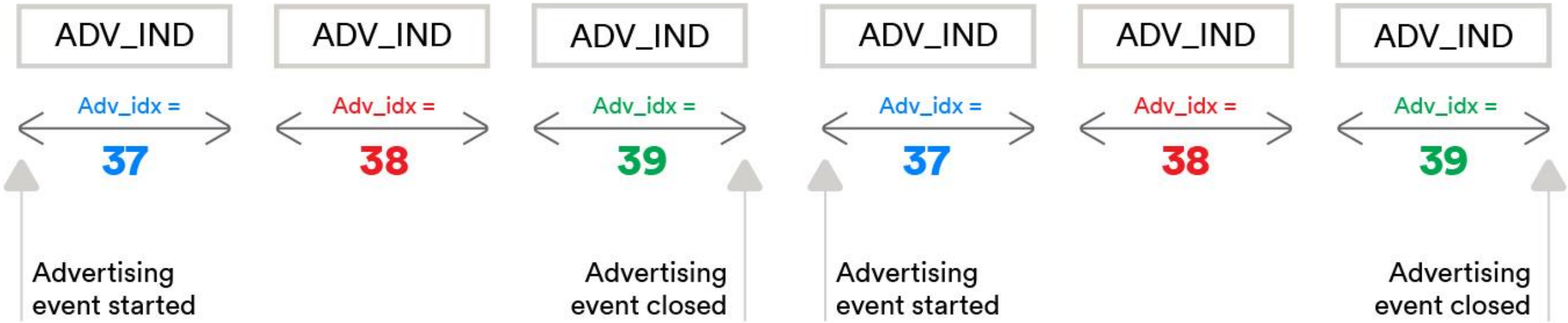
- New Database Hash characteristic puts the client in control of attribute table cache synchronization

- Energy saving
- User experience improvement

- *Can allow devices of the same type to be identified and avoid unnecessary service discovery operations*

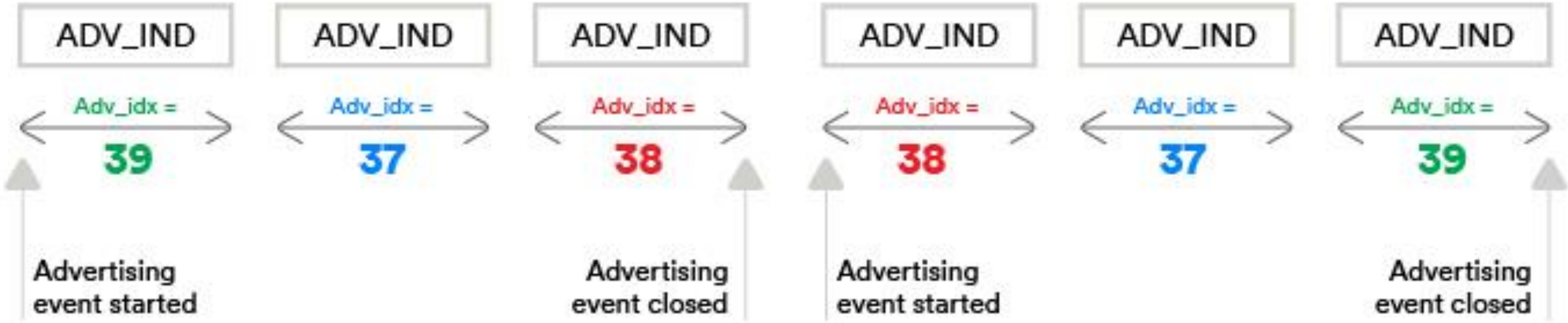
Randomized Advertising Channel Indexing

Advertising channel index randomisation



Before: fixed channel index sequence 37 -> 38 -> 39

Advertising channel index randomisation



5.1: random channel index sequence

Reduced probability of collisions

Greater reliability and scalability in connectionless communication

#BluetoothAsia2019#

BluetoothAsia
探索、创新、开拓

谢谢

Thank you!