Location Services and Direction Finding with Bluetooth

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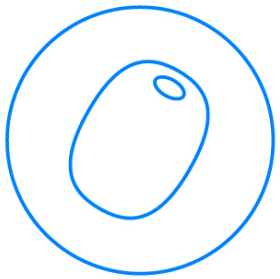
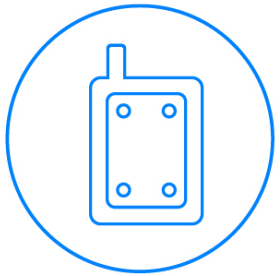
Bluetooth location services



item finding solutions
(e.g. personal property tags)

point of interest information solutions
(e.g. proximity marketing)

proximity solutions

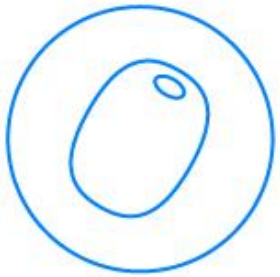


real time locating systems (RTLS)
(e.g. asset tracking)

indoor positioning systems (IPS)
(e.g. wayfinding)

positioning systems

Bluetooth location services



item finding solutions
(e.g. personal property tags)

Proximity Profile

Find Me Profile

point of interest
information solutions
(e.g. proximity marketing)

real time locating
systems (RTLS)
(e.g. asset tracking)

Bluetooth beacons
(iBeacon, Eddystone)

indoor positioning
systems (IPS)
(e.g. wayfinding)

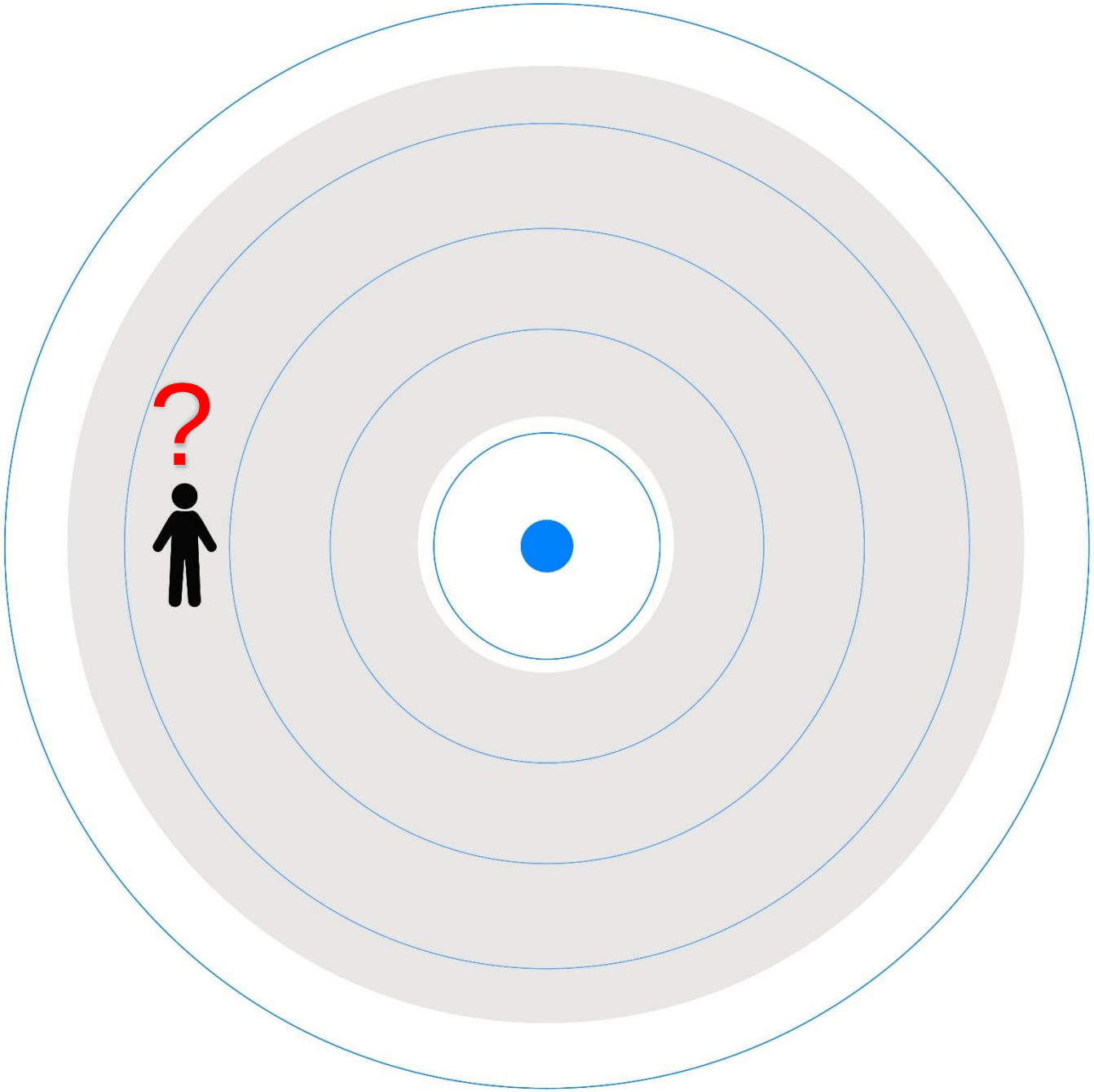
Indoor Positioning
Profile

Positioning Without Direction

Person is in range of the beacon

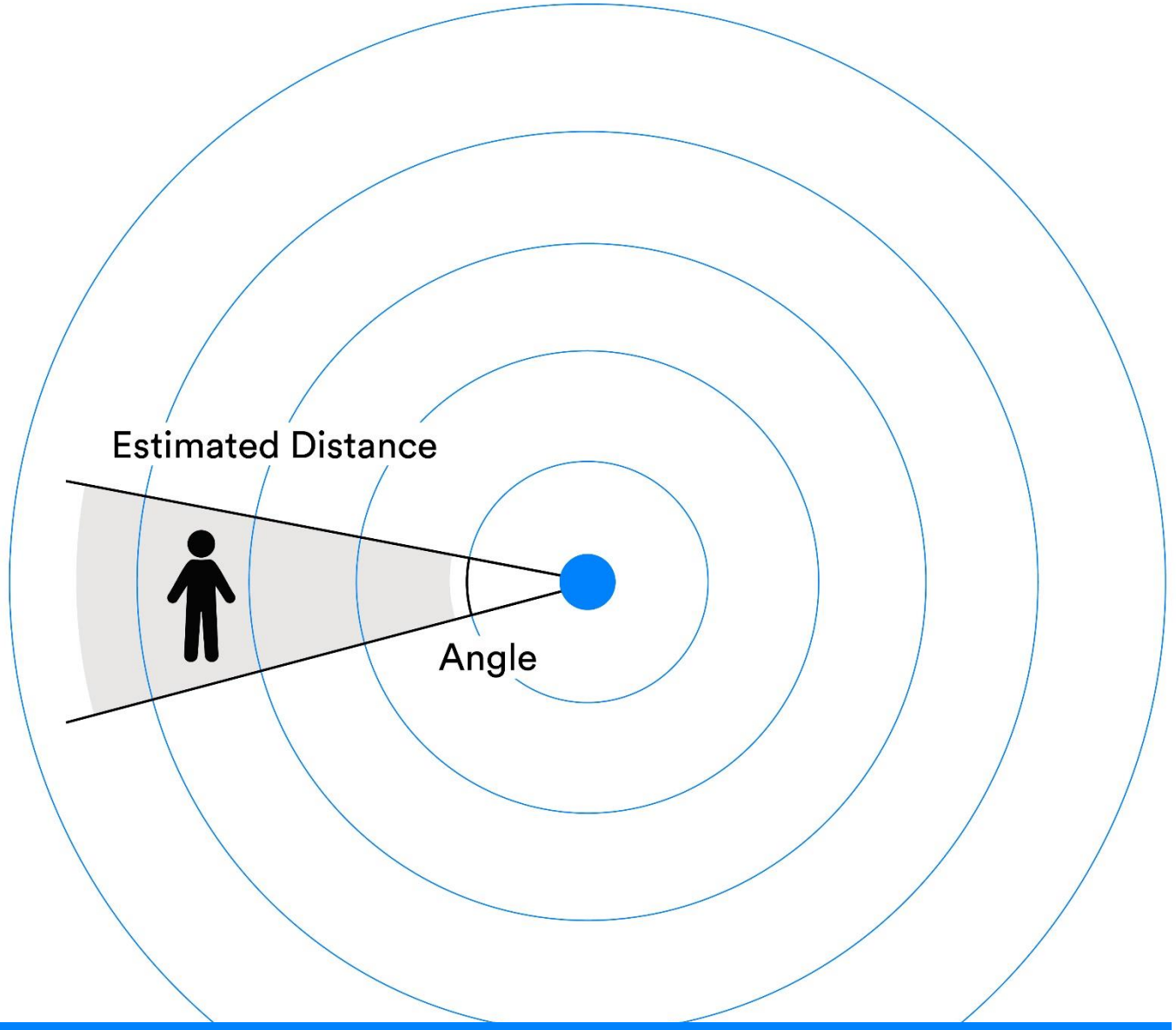
Signal strength tells us ***roughly*** how far away they are

We have no idea what direction one is from the other



Positioning with Direction Finding

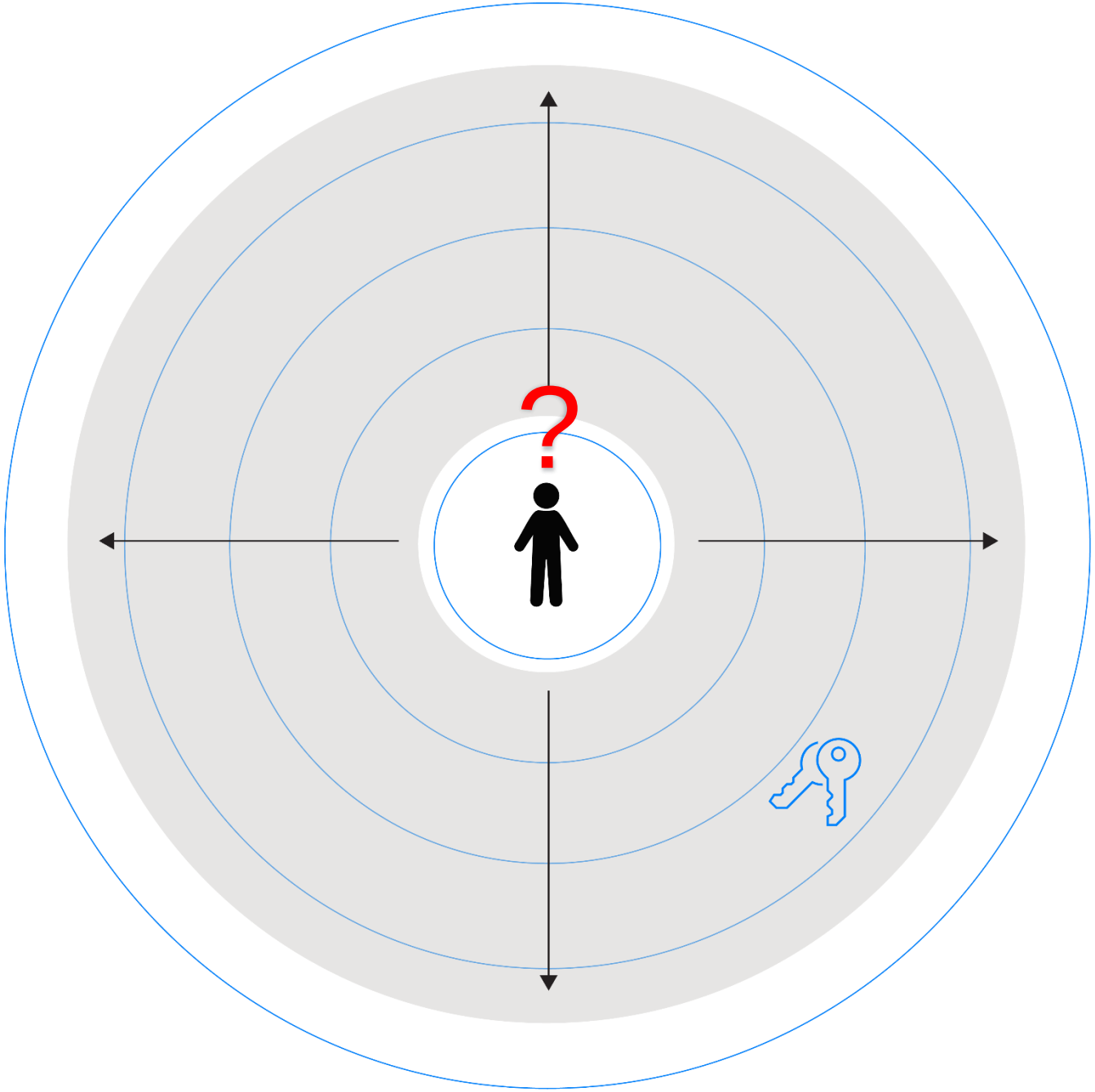
Knowing direction, dramatically improves location accuracy



Bluetooth Direction Finding – new in 5.1

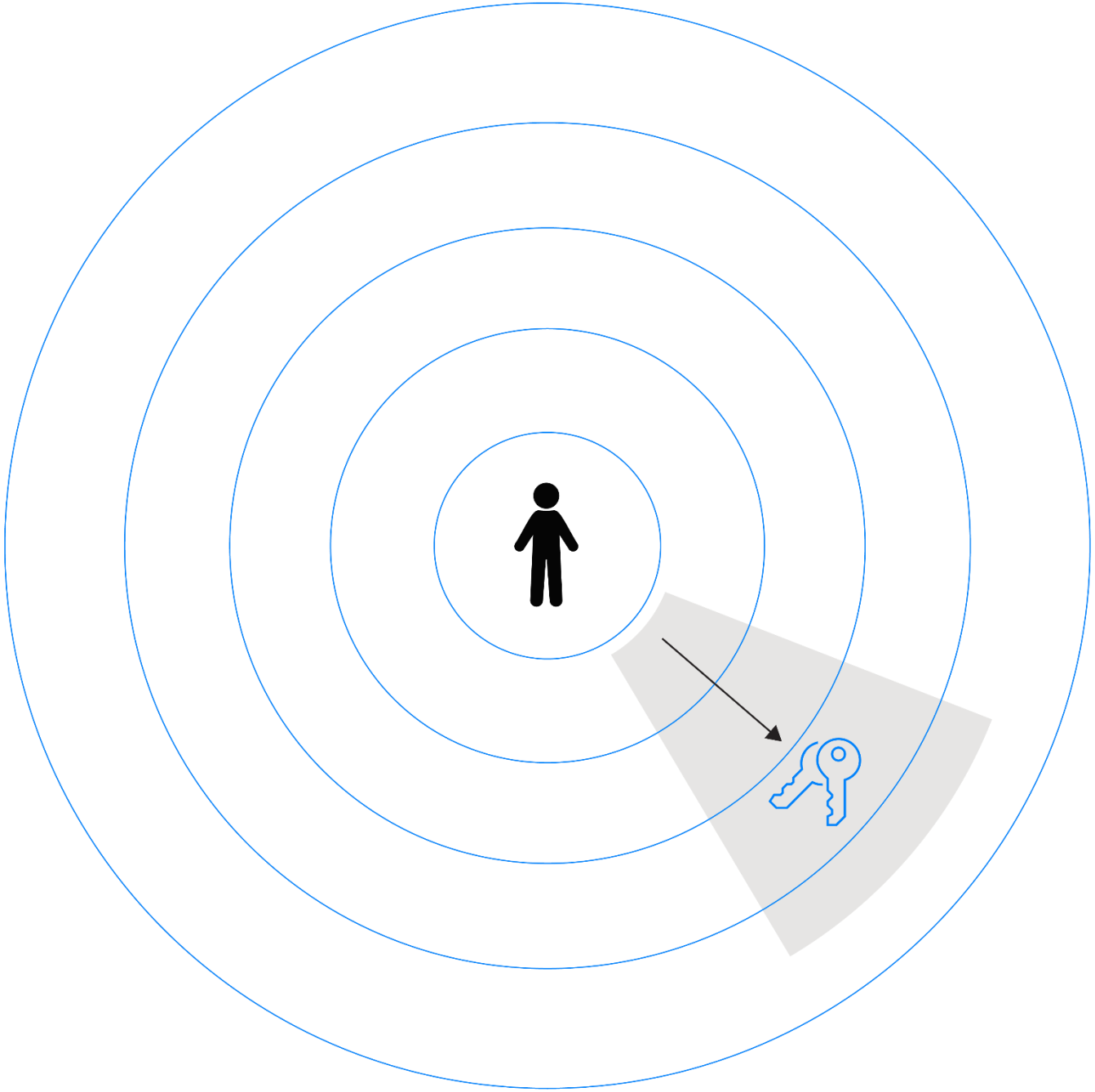
Item Finding Without Direction

Item finding requires an experimental approach when we don’t know the direction of the lost item!



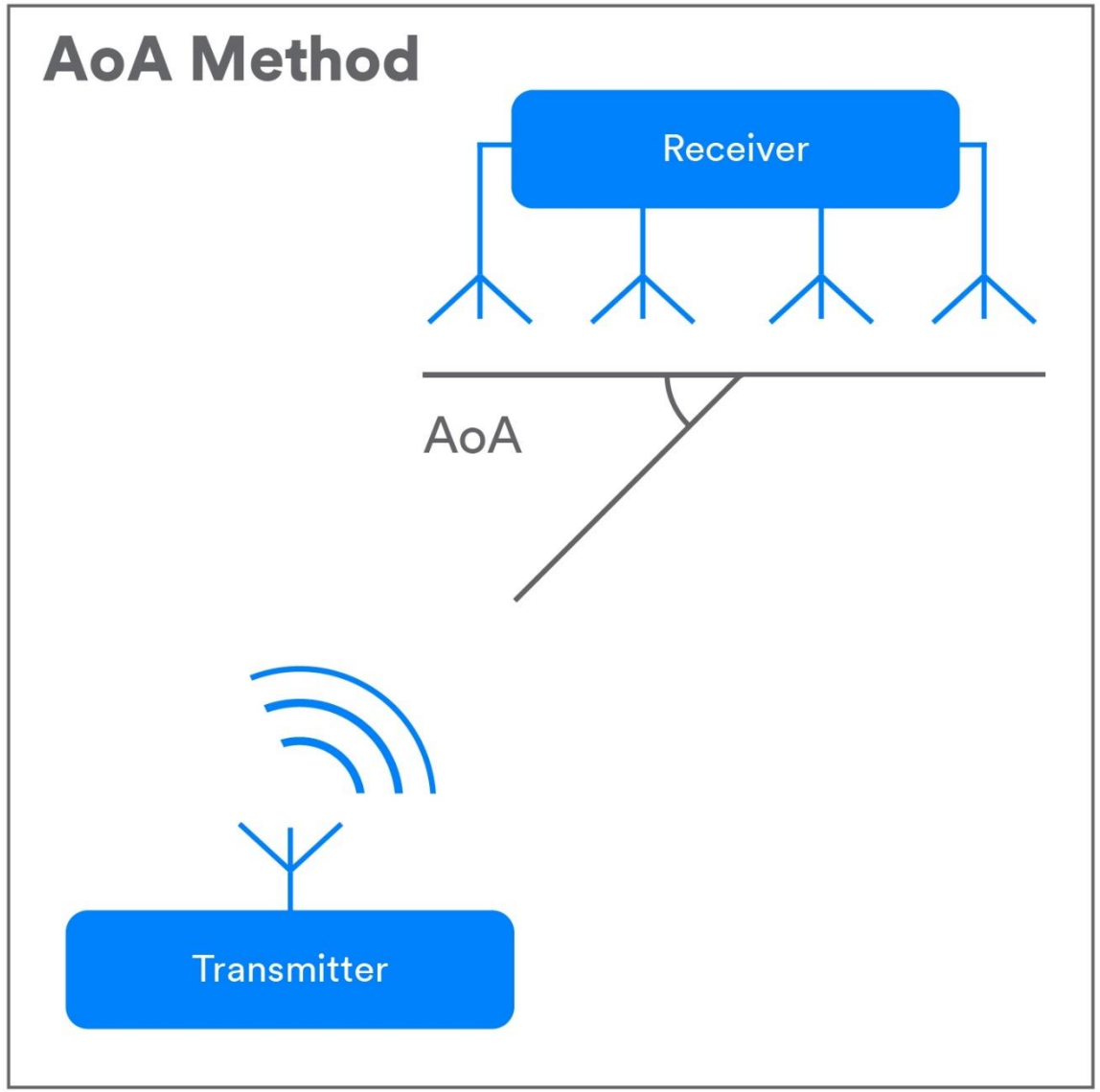
Item Finding With Direction

The user experience is considerably better when we can indicate the direction to walk in!




New - Directional Discovery

About Bluetooth Direction Finding



Angle of Arrival

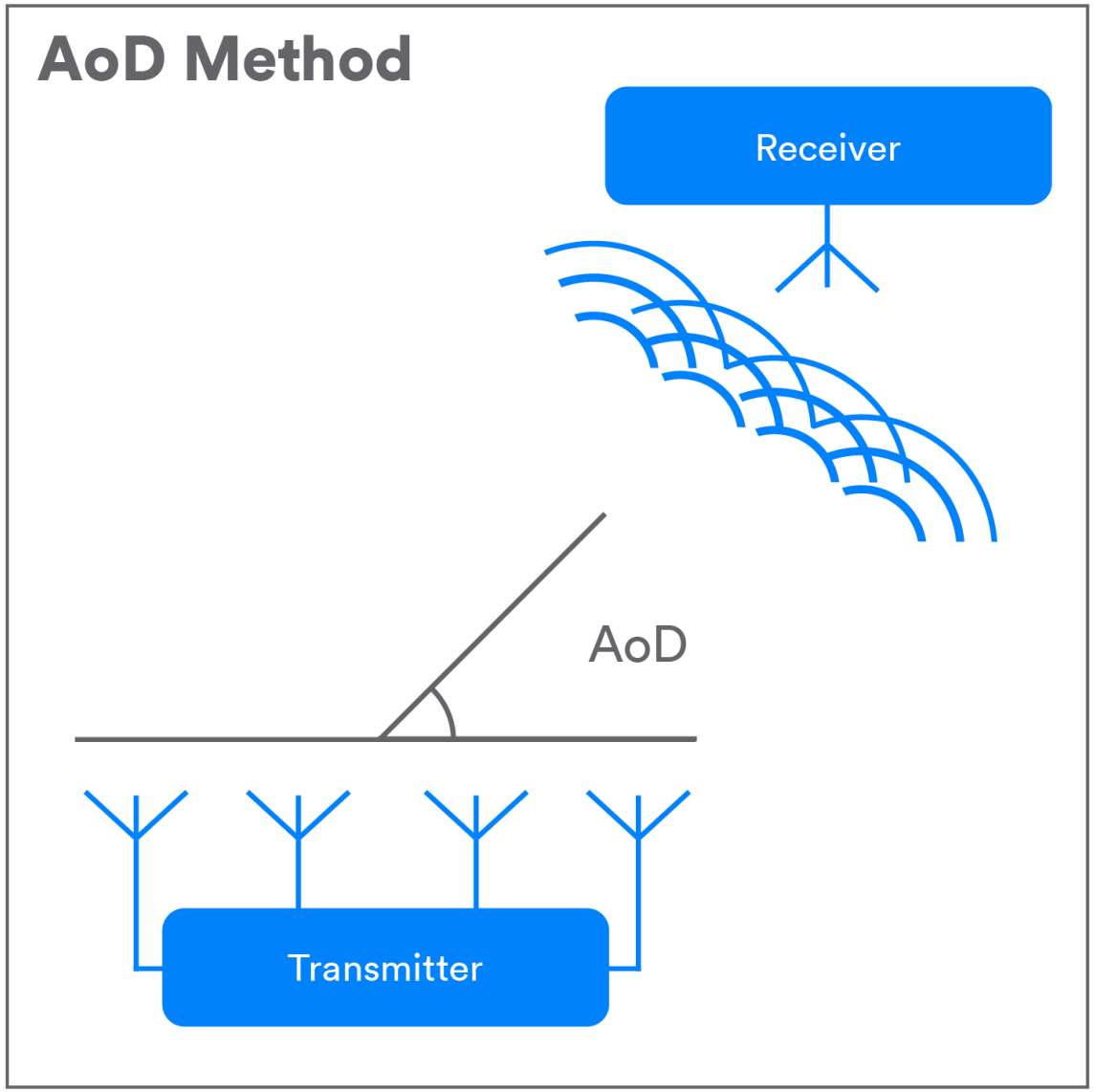
Transmitter

- 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



Angle of Departure

Transmitter

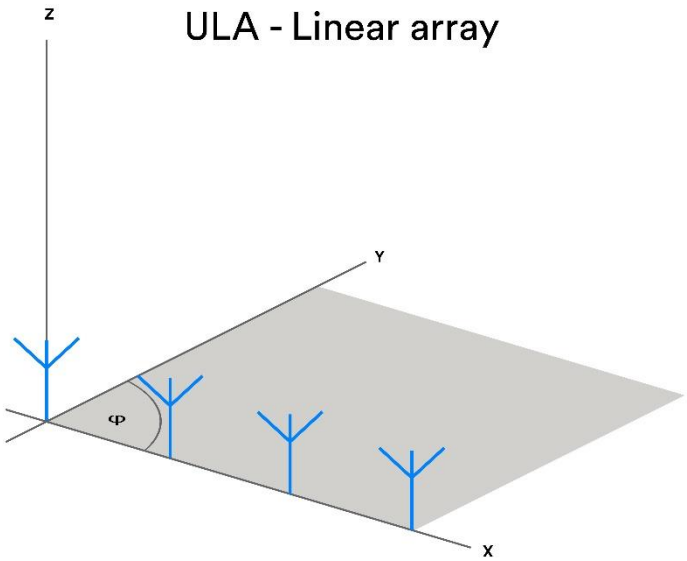
- sends special packets while switching between active antenna arranged in an array

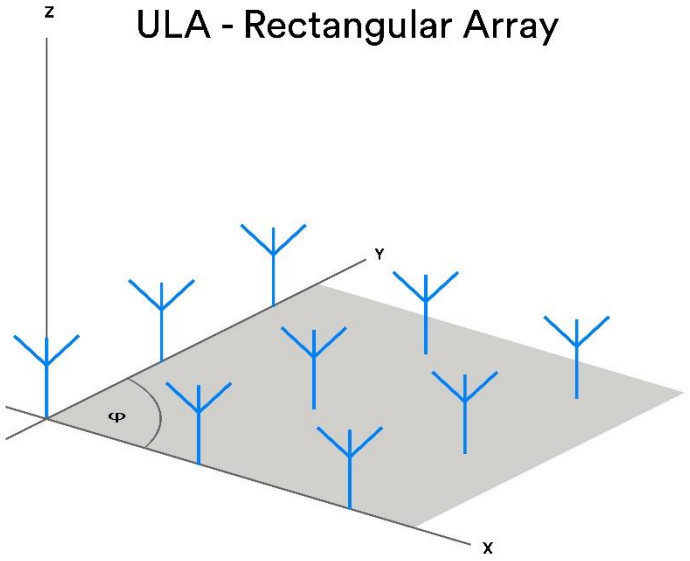
Receiver

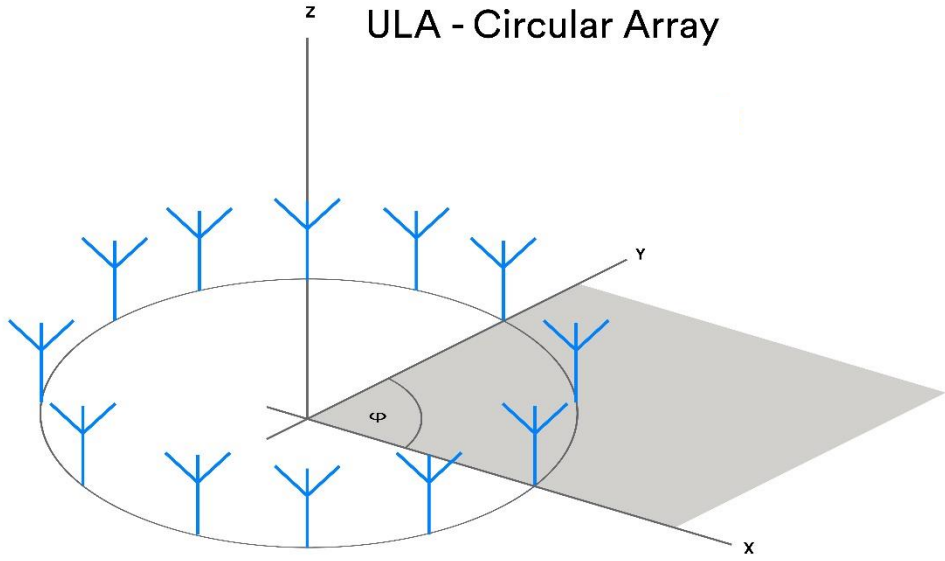
- receives signals using single antenna
- has knowledge of antenna layout within transmitter
- takes IQ samples from received signals
- relative signal direction calculated using sampled data

For indoor positioning systems (IPS)

Antenna Arrays

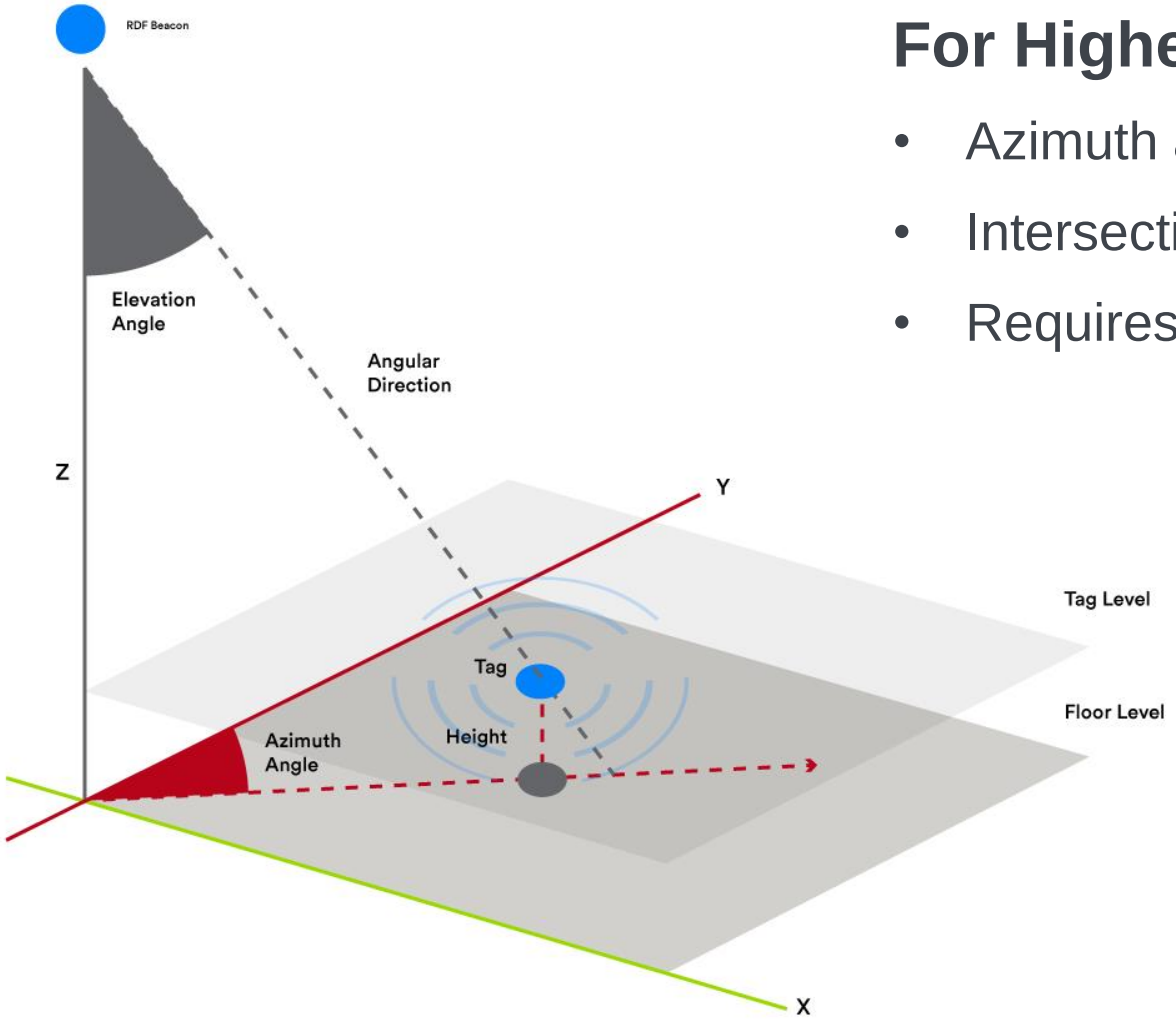






A variety of antenna array designs are possible and they affect the maths and parameters into the maths

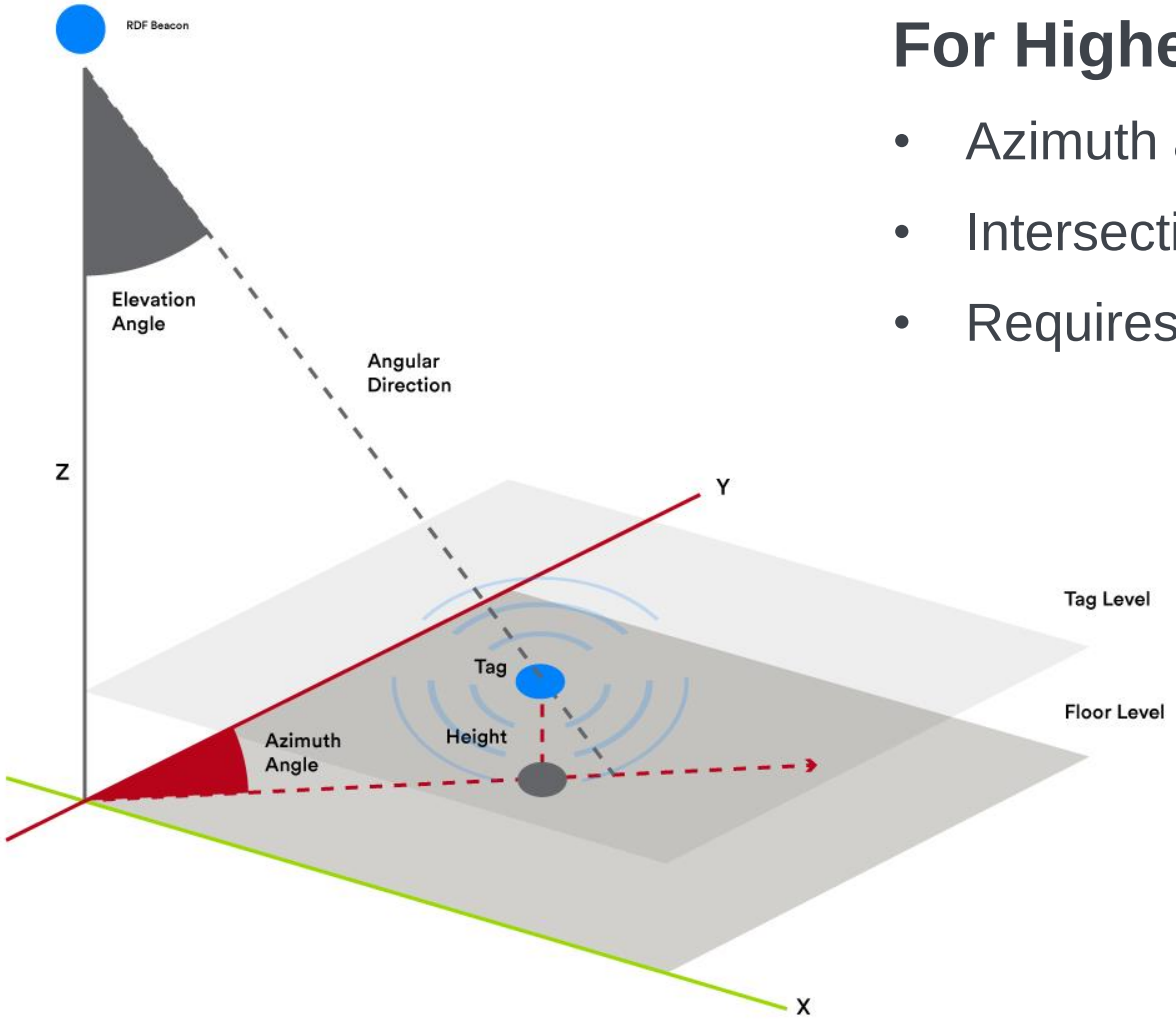
High Accuracy Location Potential



For Highest Accuracy Calculate 2 angles

- Azimuth and Elevation are commonly measured
- Intersection provides accurate location determination
- Requires suitable antenna array

High Accuracy Location Potential



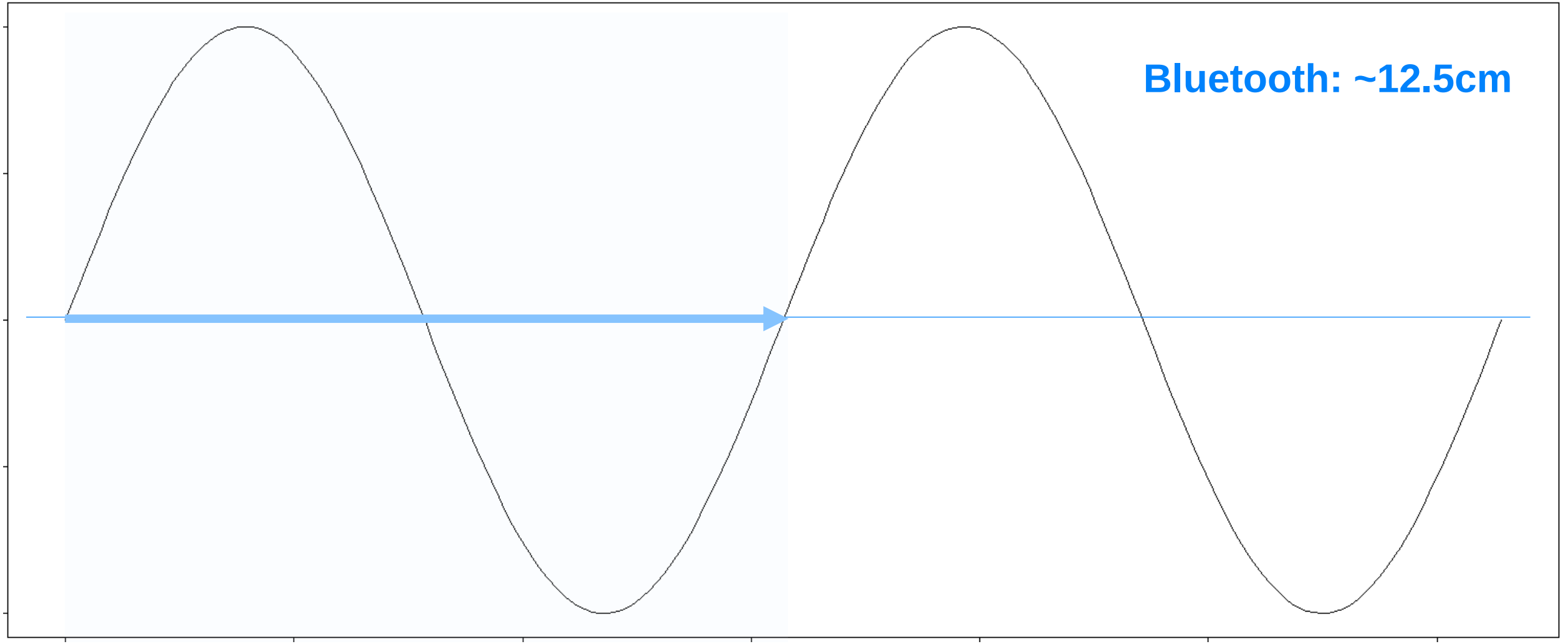
For Highest Accuracy Calculate 2 angles

- Azimuth and Elevation are commonly measured
- Intersection provides accurate location determination
- Requires suitable antenna array

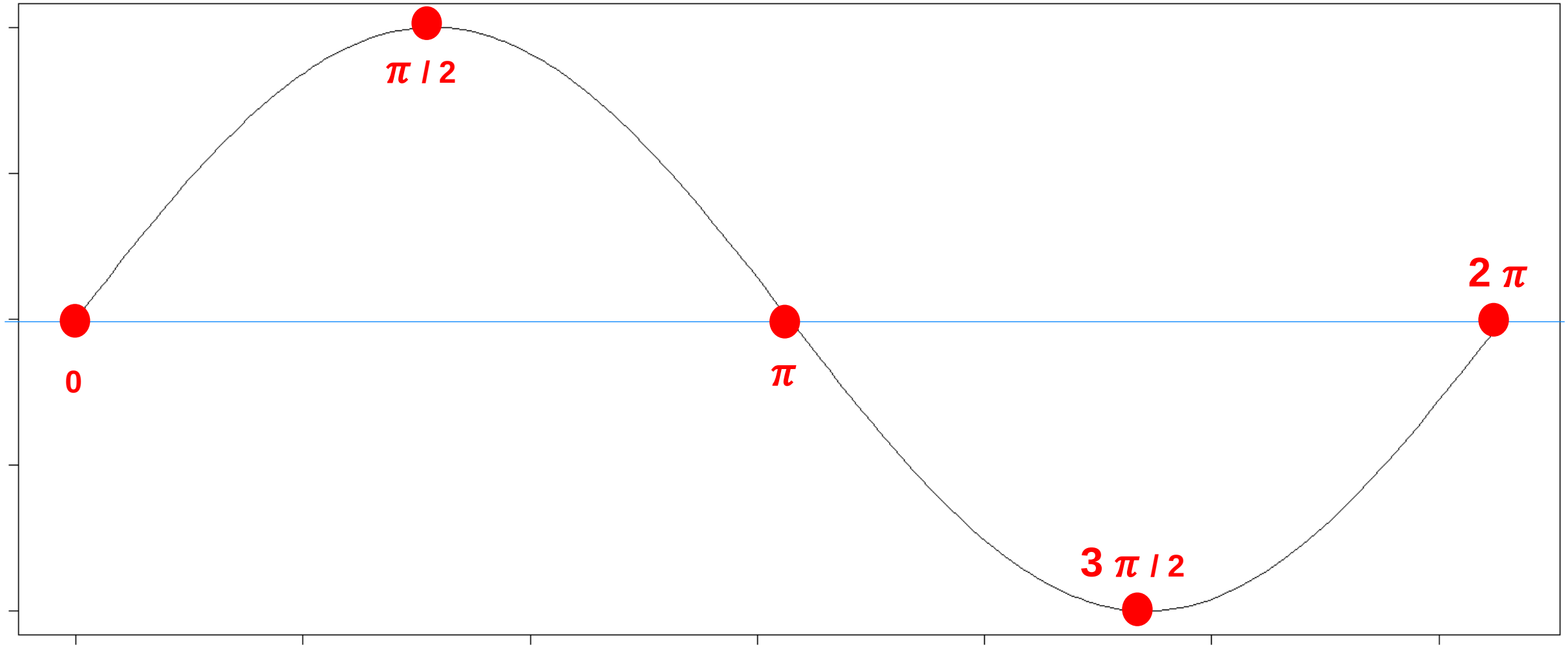
Location accuracy to within 10cm becomes possible

Direction Finding Theory

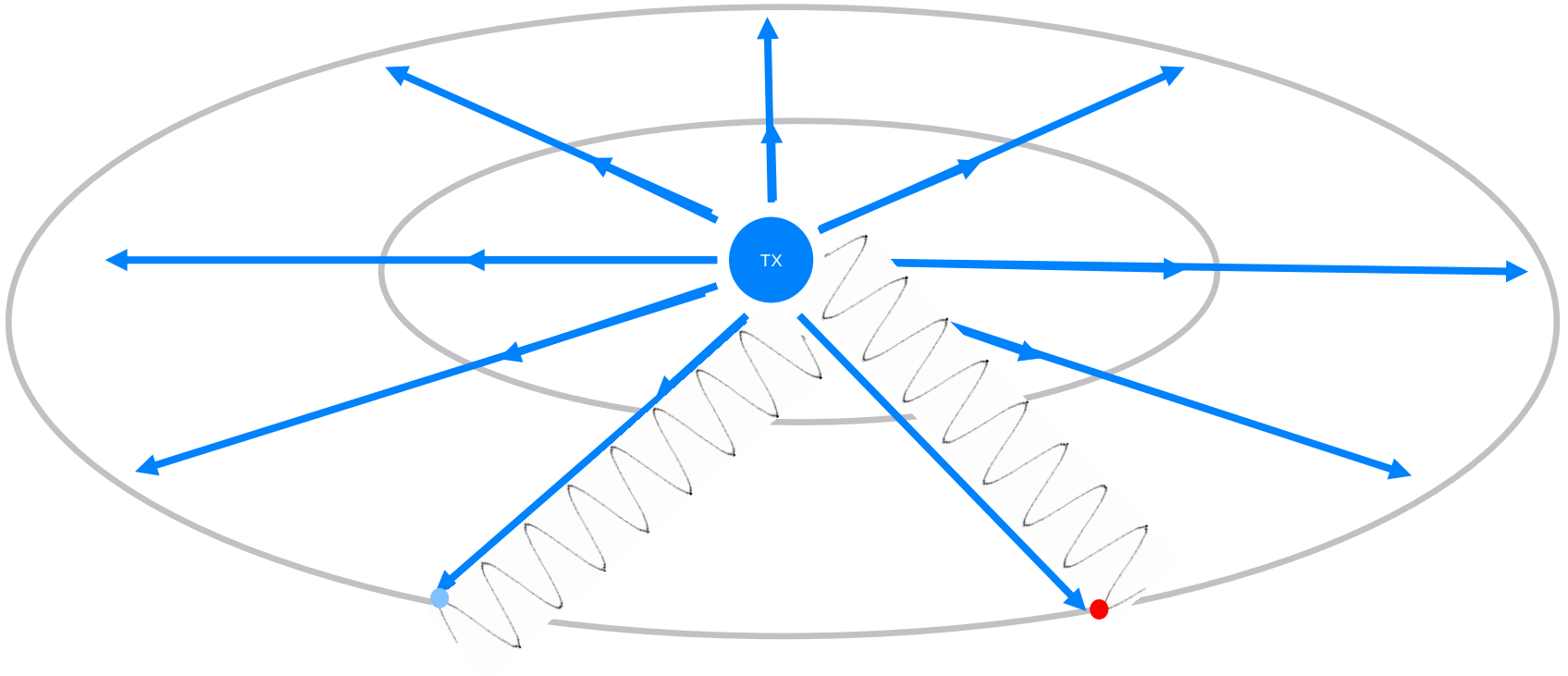
RF Fundamentals - Wavelength



RF Fundamentals - Phase



Phase and Distance from a Transmitter



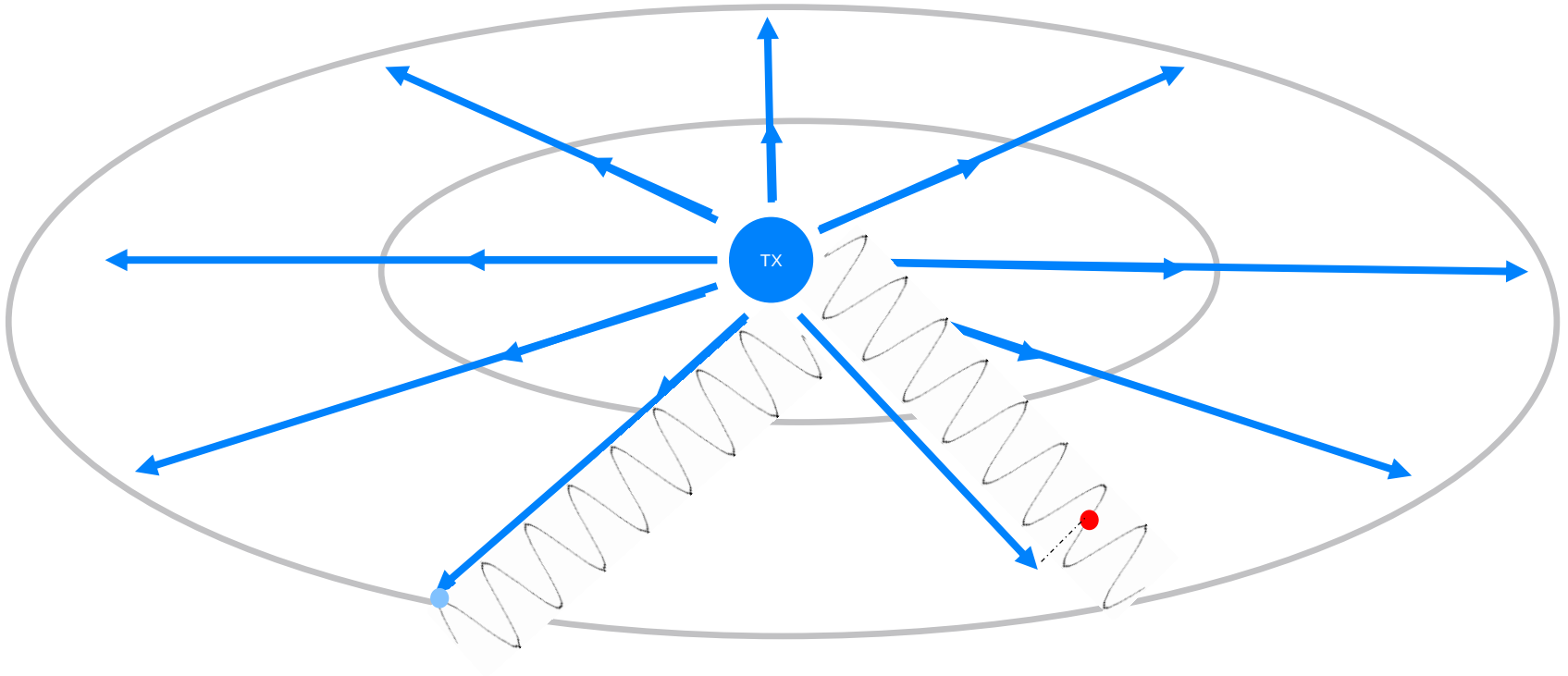
2 antennae at the same distance from the transmitter

Same signal

Same frequency and so same wave length

Phase is the same at both antennae at a given point in time

Phase and Distance from a Transmitter

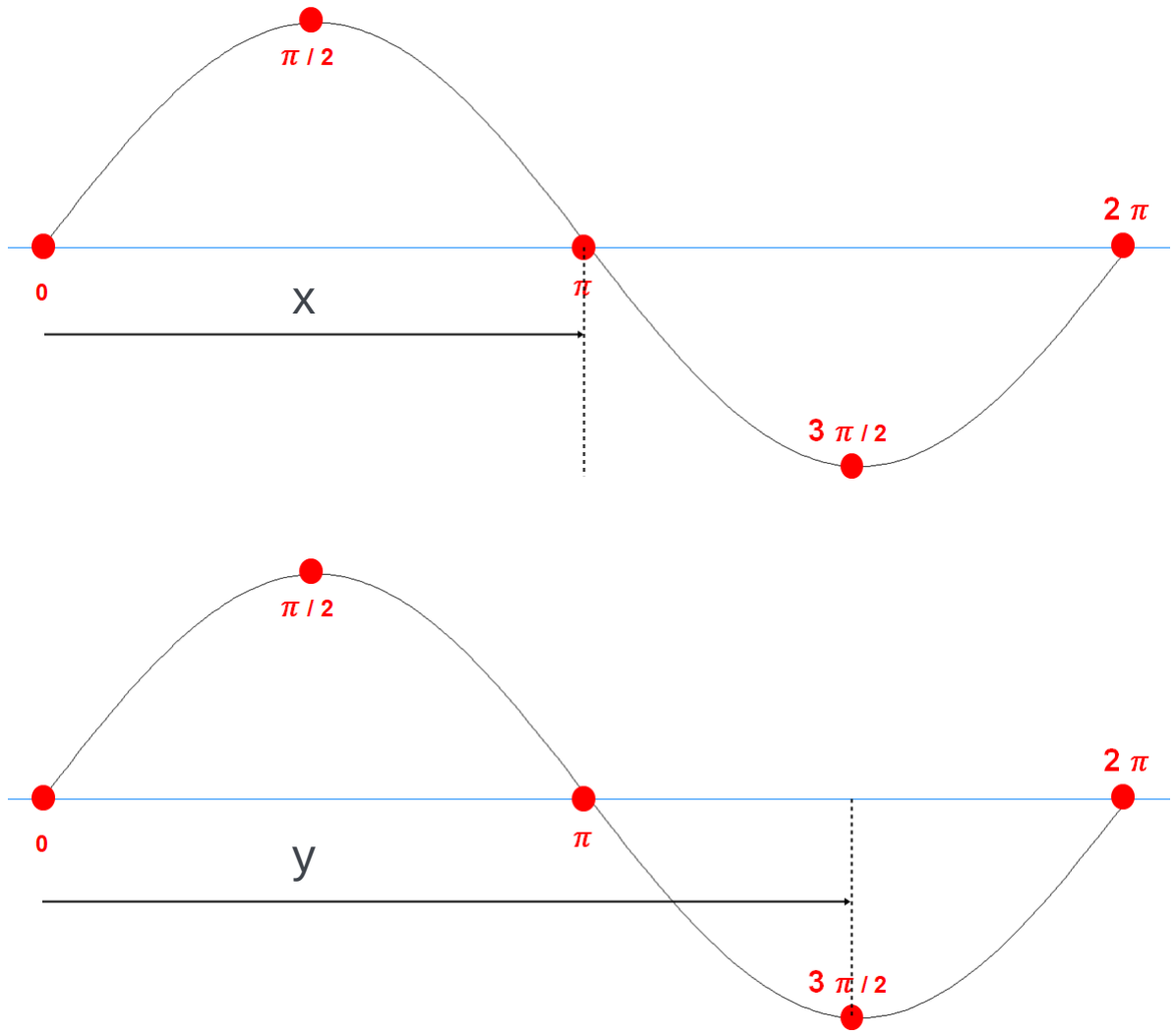


But with 2 antennae at different distances from the transmitter

And the difference between the two antenna distances is not a multiple of the wave length

Phase is **NOT** the same at both antennae at a given point in time

Phase and Distance from a Transmitter



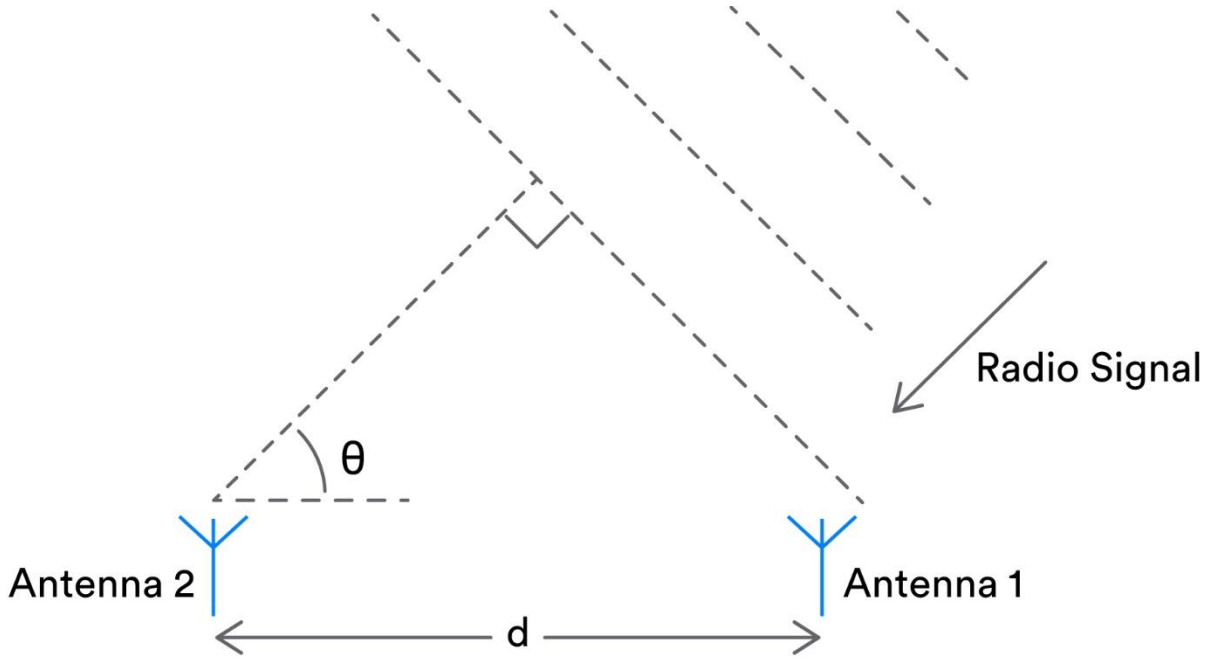
Direction Finding from phase difference and antenna details

$\theta = \arccos((\psi\lambda)/(2\pi d))$

ψ is the phase difference

λ is the wave length

d is the distance between adjacent antennae



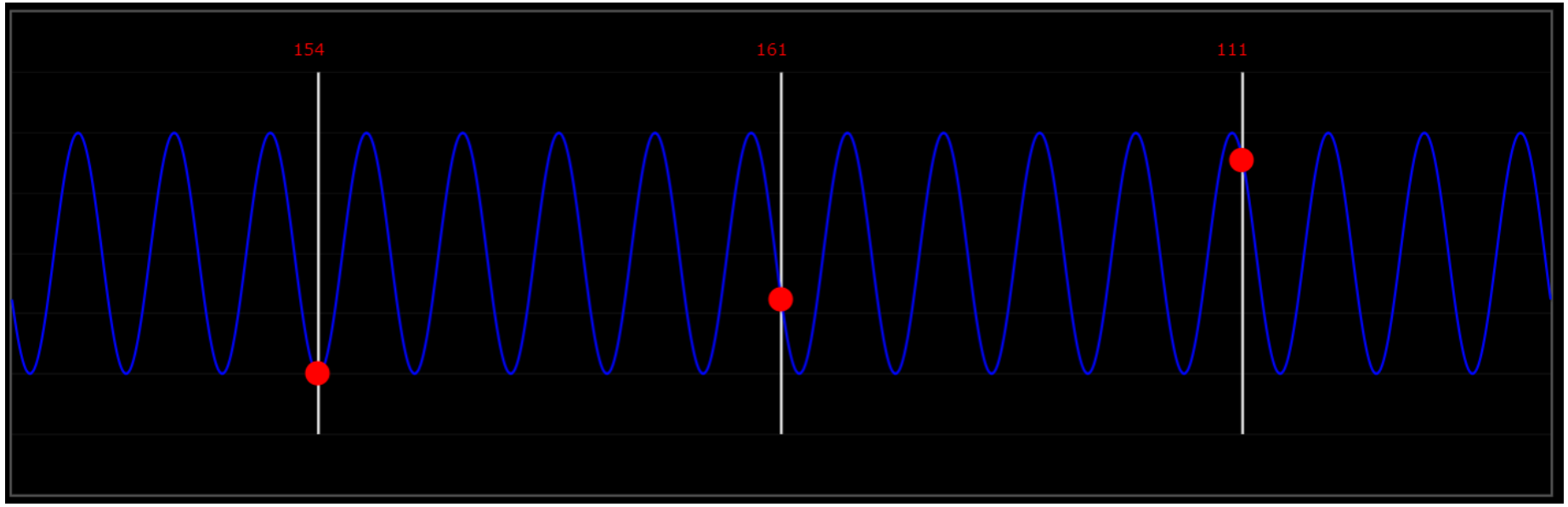
RF Fundamentals - IQ Sampling

IQ data is sampled at strict time intervals. With AoA, we sample from one antenna at a time, moving from antenna to antenna in a given sequence

A different phase angle means this antenna is at a different distance from the receiver compared to another antennae

The IQ samples can be used to calculate the phase difference in the radio signal received using different elements of the antenna array, which in turn can be used to estimate the angle of arrival (AoA)

We have to know details of the antenna array and get our sample timing right



Seeing this in motion is much easier to appreciate

Frequency Deviation

Analogue symbols represent digital 0s and 1s

Within a radio channel two frequencies are used, one to represent 0 and one for 1

Therefore two wavelengths are used within a channel

This complicates direction calculations since wavelength is a part of the formula

And phase angle sampling would need different timing for the different frequencies

So… we don’t sample everything and restrict sampling to something….*special*

Direction Finding Signals

DF signals are standard Bluetooth packets with an extra field called the **Constant Tone Extension (CTE)**

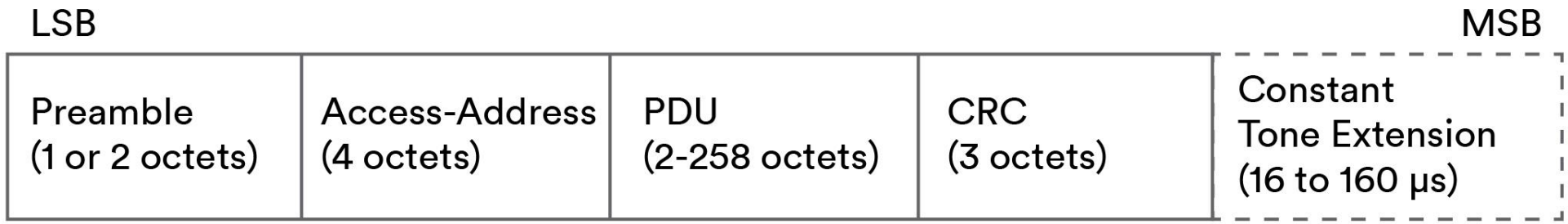
CTE appears after the CRC and is not included in the CRC calculation

CTE consists of a series of 1 symbols and is therefore a constant frequency for a given channel

Its length is requested by the host

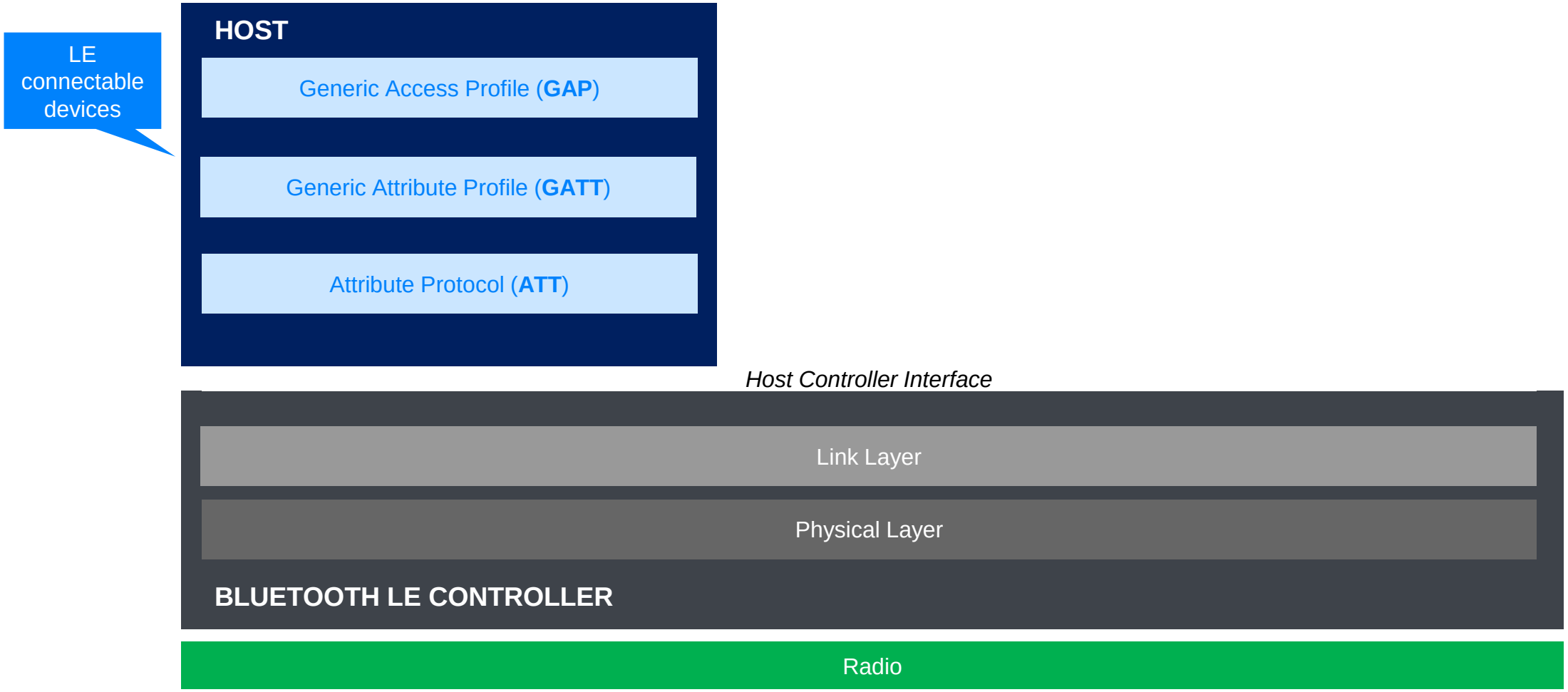
CTE is not subjected to the whitening process

It is the CTE which is IQ sampled and from which phase differences are determined



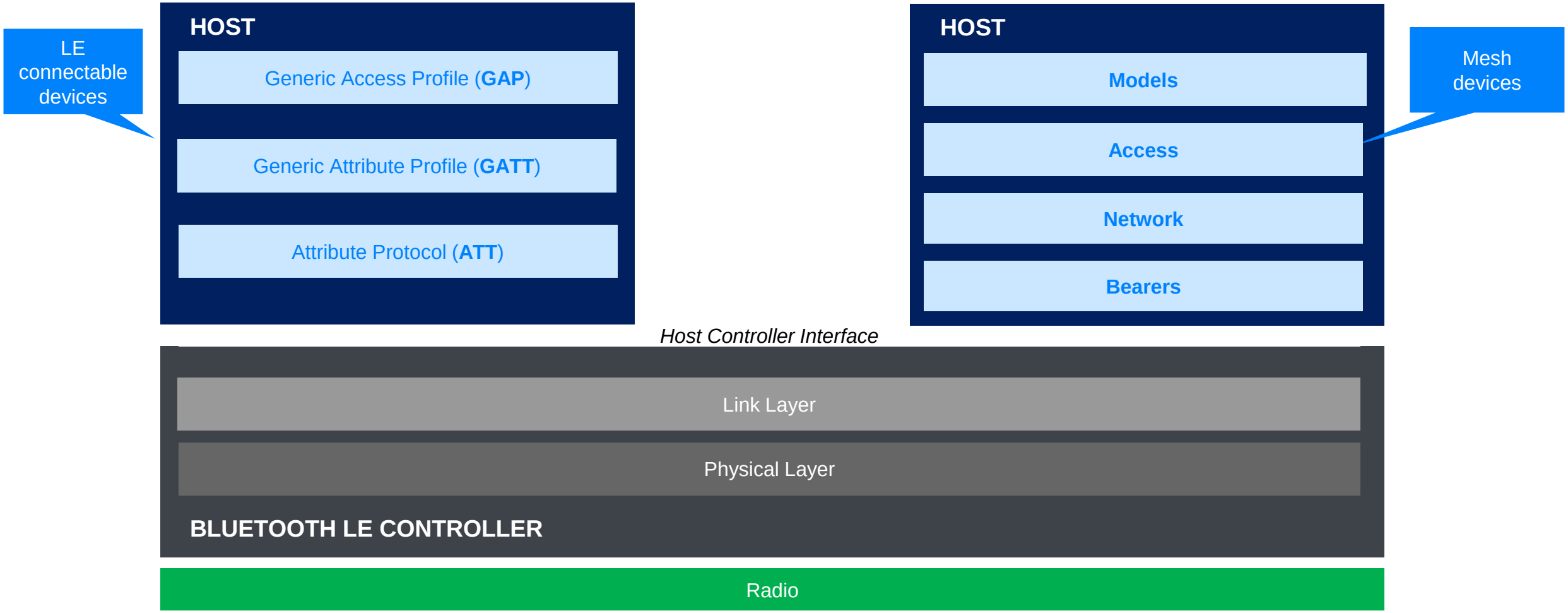
Direction Finding and the Bluetooth stack

Stack Configurations



NB: stack diagram has been simplified

Stack Configurations



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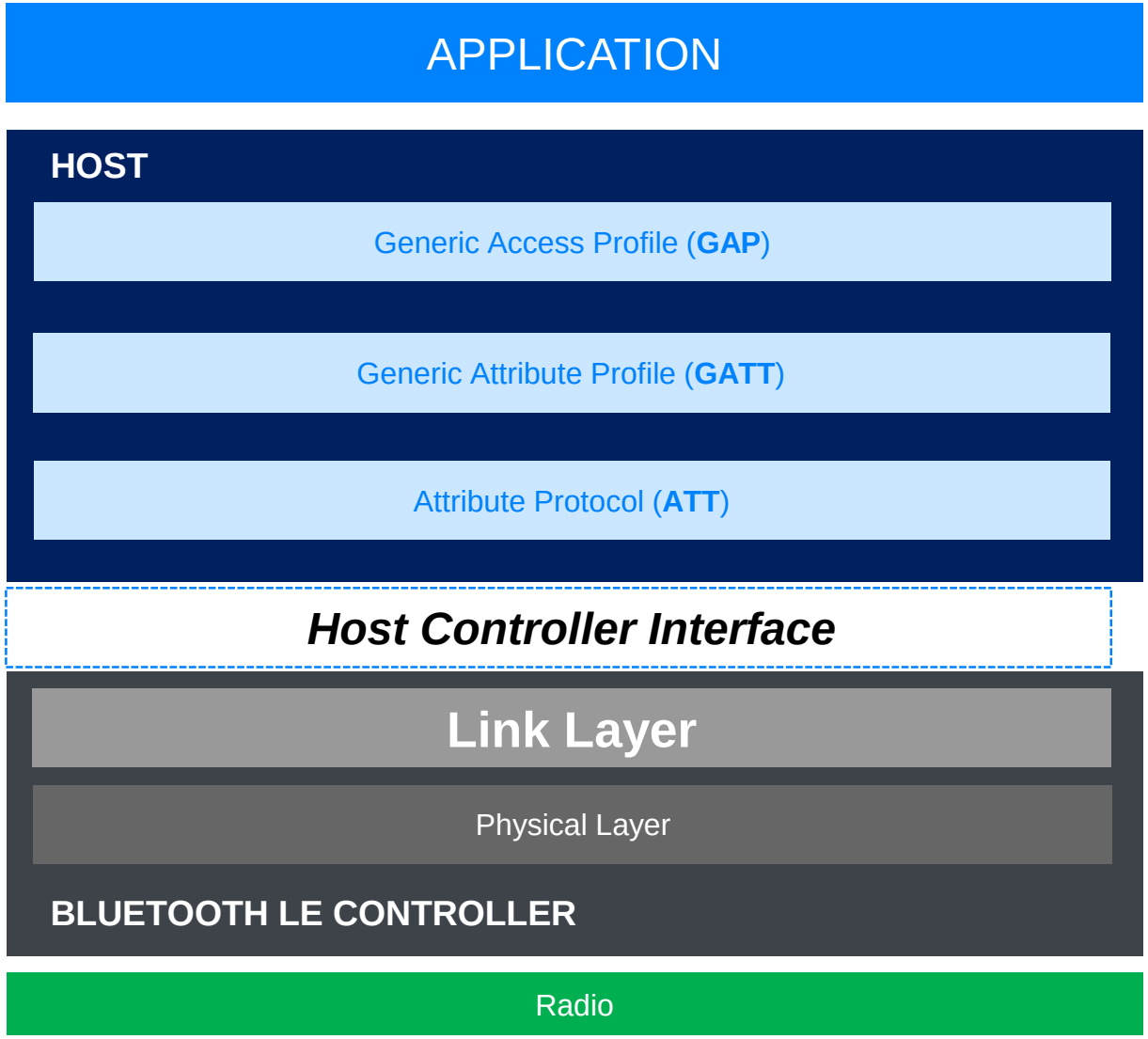


All the action takes place in the controller

The HCI allows the host to configure, enable and disable IQ sampling and CTE details

Both connection-oriented and connectionless communication scenarios are supported

The **application** has plenty of work to do

IQ sampling enablement and configuration

CTE enablement and configuration

NB: stack diagram has been simplified

Connection-Oriented AoA/AoD

Host A and B are connected

New HCI commands lets **Host A** set CTE receive parameters and then enable CTE request sending

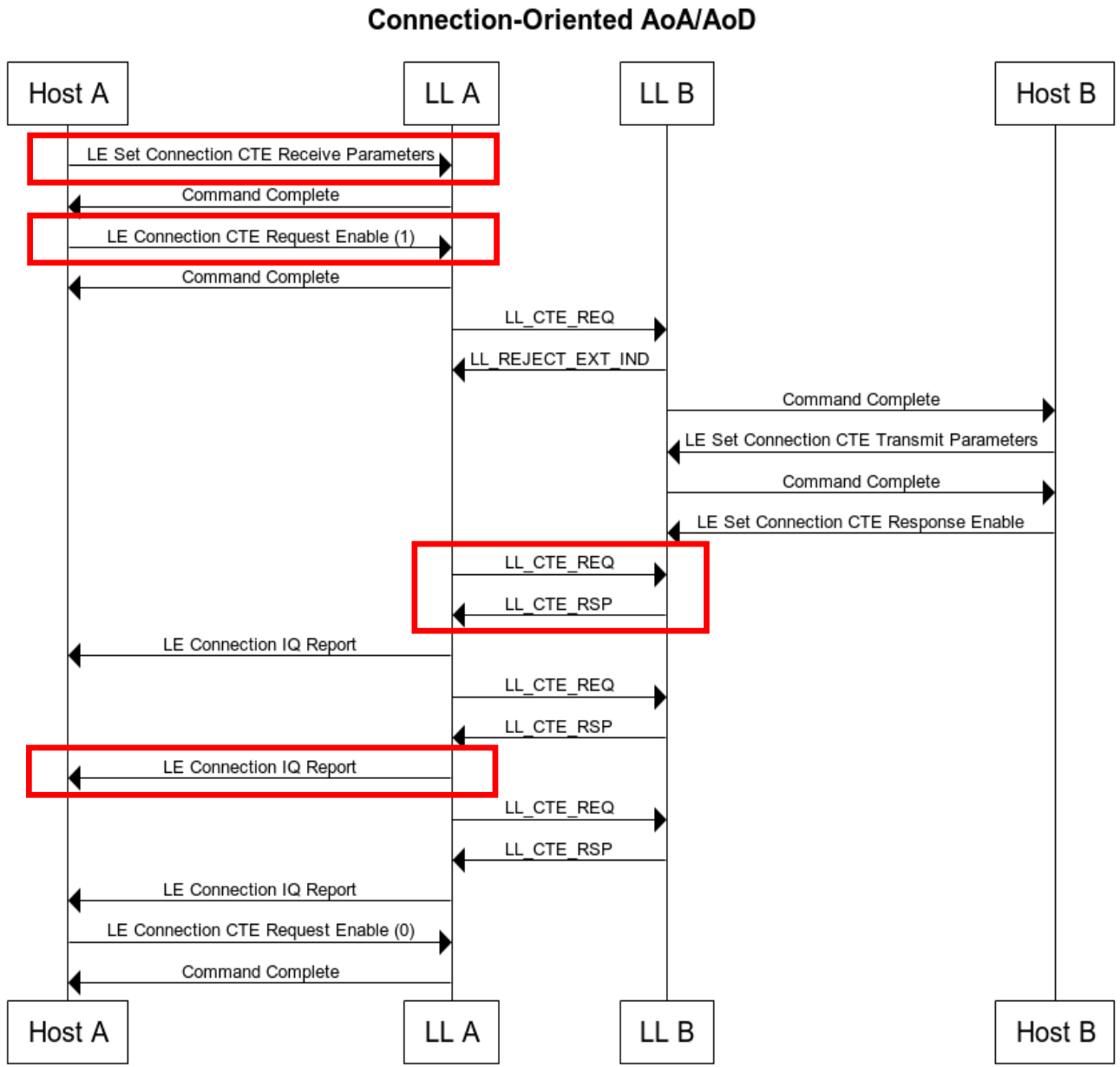
LE Set Connection CTE Receive Parameters

LE Set Connection CTE Request Enable

New HCI commands lets **Host B** set CTE transmit parameters and then enable CTE response sending

Host A sends new LL_CTE_REQ
Host B replies with LL_CTE_RSP

Until CTE requests are disabled by Host A



Bluetooth Direction Finding

Where next?

Bluetooth SIG Resources – Reading Material

Core Specifications

The *Bluetooth*® Core Specification defines the technology building blocks that developers use to create the interoperable devices that make up the thriving Bluetooth ecosystem. The Bluetooth specification is overseen by the Bluetooth Special Interest Group (SIG) and is regularly updated and enhanced by Bluetooth SIG Working Groups to meet evolving technology and market needs.

Specification		Version	Status	Adoption Date
CS	Core Specification	5.1	Active	21 Jan 2019
CSS	Core Specification Supplement	8	Active	21 Jan 2019

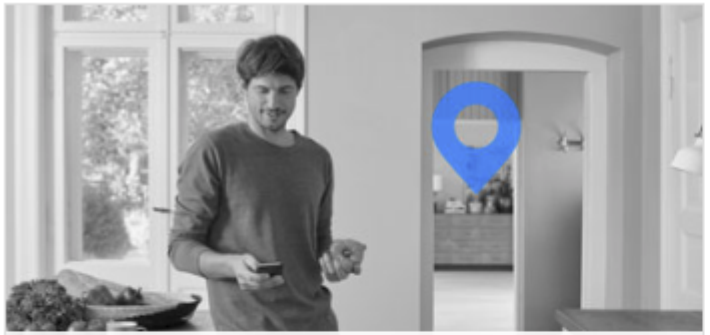
Bluetooth SIG Resources – Reading Material

Paper

Bluetooth Direction Finding: A Technical Overview

This comprehensive overview examines how two new Bluetooth direction finding methods can enable location services solutions that support high-accuracy.

LEARN MORE

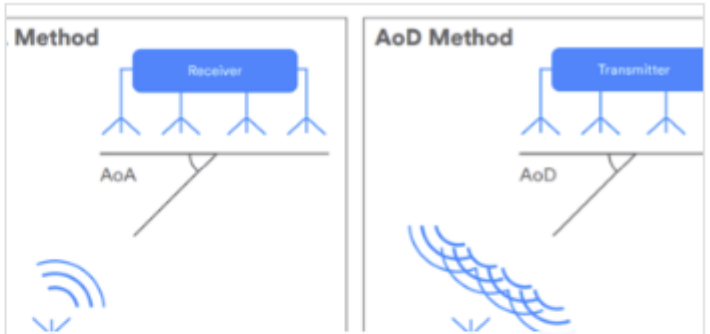


Paper

Enhancing Bluetooth Location Services with Direction Finding

See how the new direction finding feature will enhance the performance of Bluetooth location services solutions

LEARN MORE



Paper

Bluetooth Angle Estimation for Real-Time Locationing

In this paper, Silicon Labs explains the basics of Bluetooth Angle of Arrival (AoA) and Angle of Departure (AoD) technologies, and give some theory for estimating direction of arrival.

LEARN MORE

SIG Member

questions?

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