CSE 162 Mobile Computing

Lecture 13: Distance Estimation Technologies, GPS

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Distance Estimation Technologies

Distance Estimation

- Multiply the radio signal velocity and the travel time
  - Time of arrival (TOA)
  - Time difference of arrival (TDOA)

- Compute the attenuation of the emitted signal strength
  - RSSI

- Problem: Multipath fading

Distance Estimation: TOA

- Distance
  - Based on one signal’s travelling time from target to measuring unit
  - $d = v_{radio} * t_{radio}$
- Requirement
  - Transmitters and receivers should be precisely synchronized
  - Timestamp must be labeled in the transmitting signal

Distance Estimation: TDOA

- The transmitter sends a radio and a sound
- Receiver measurements: receiving time t1 and t2
- Known parameter: vr and vs
- How to estimate the distance?

Distance Estimation: TDOA

Let the transmission time be denoted t0. We have

d = (t1-t0)*vr

d = (t2-t0)*vs

Therefore : $\frac{d}{v_s} - \frac{d}{v_r} = t_2 - t_1$

Finally we get: $d = (t_2 - t_1) * v_r * v_s / (v_r - v_s)$

Distance Estimation: RSSI

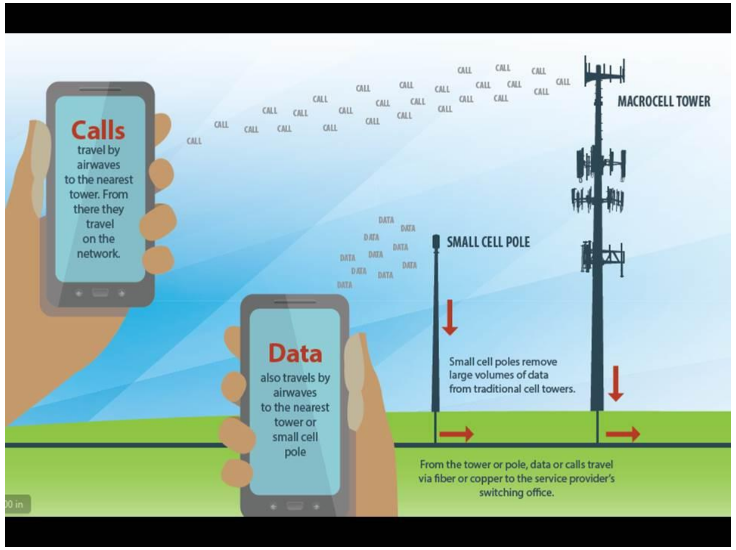
- Distance
  - Based on radio propagation model

$$P(d) = P(d_0) - \eta 10 \log\left(\frac{d}{d_0}\right) + X_\sigma$$

- Requirement
  - Path loss exponent η for a given environment is known

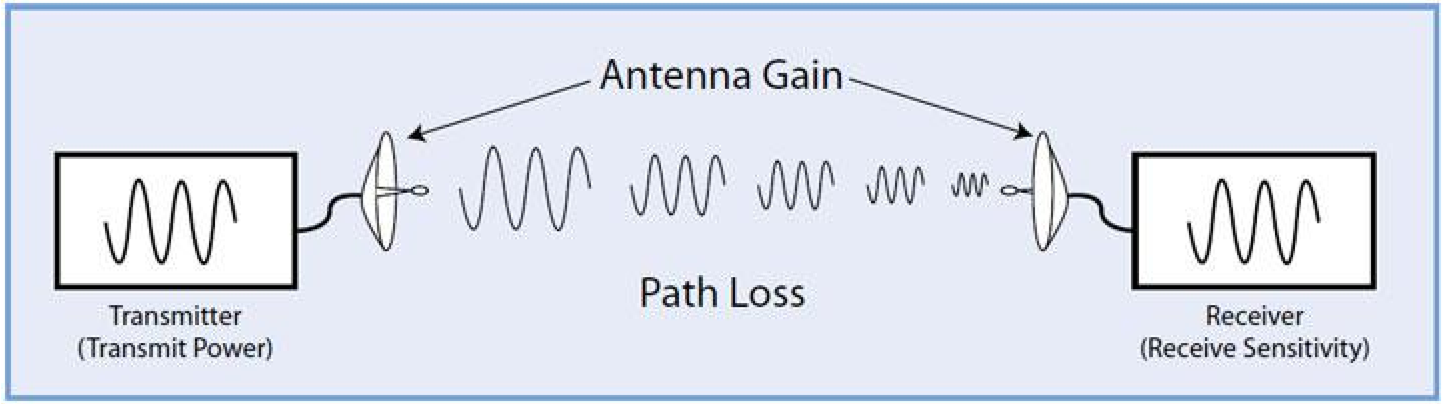
RSSI based distance estimation

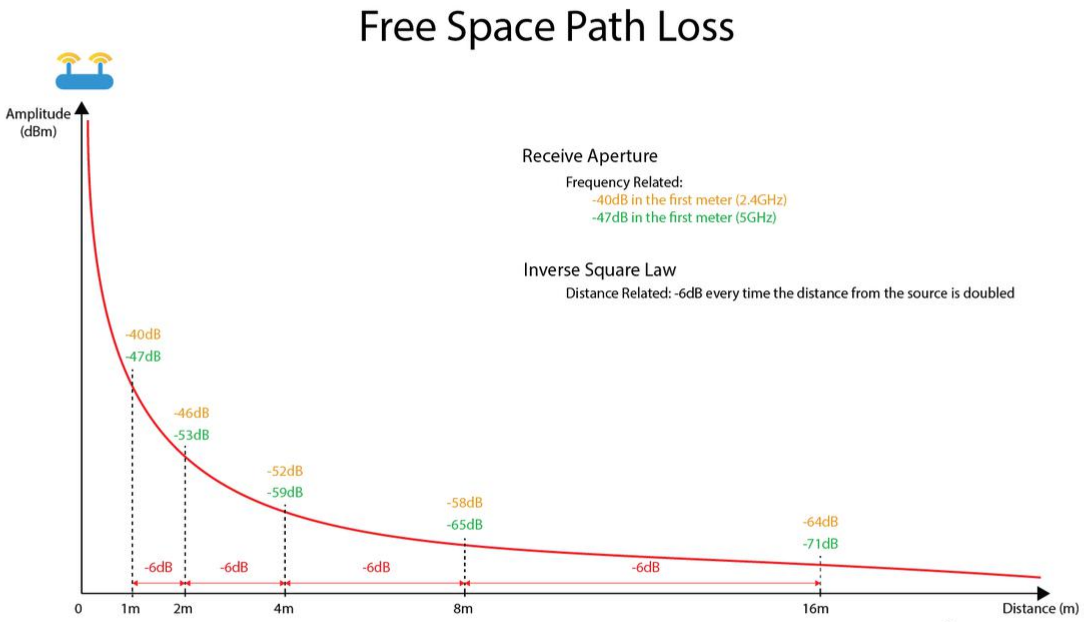
- Signal strength attenuates as distance increases



RSSI based distance estimation

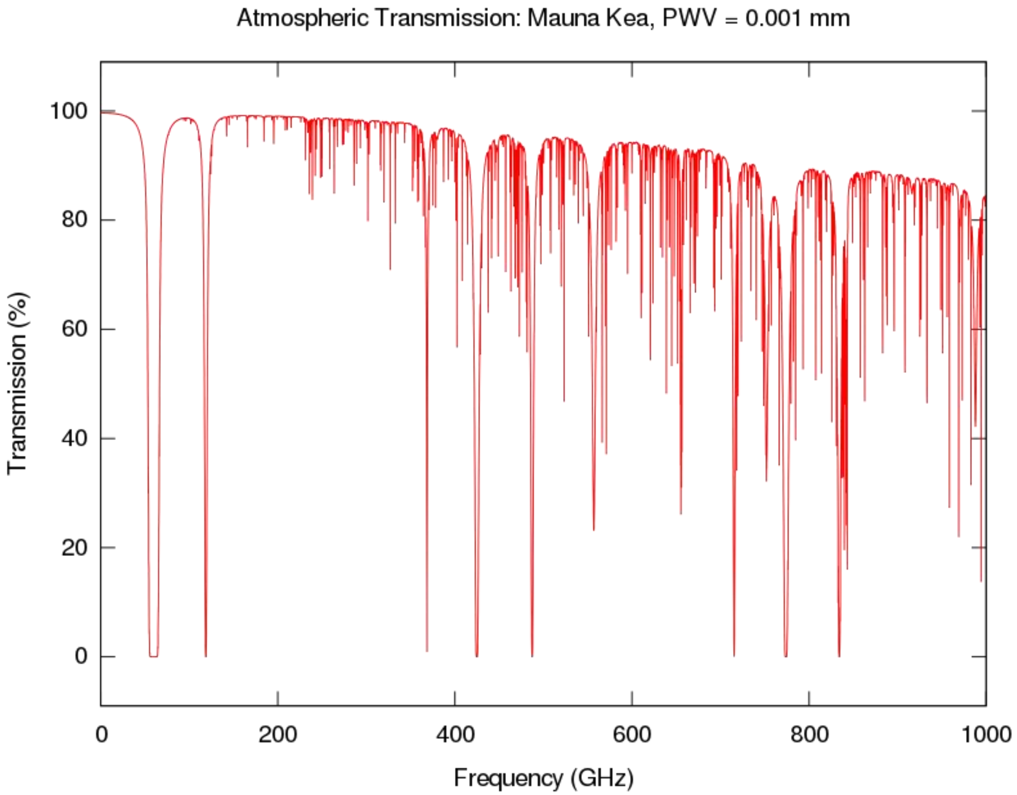
- Theoretical model



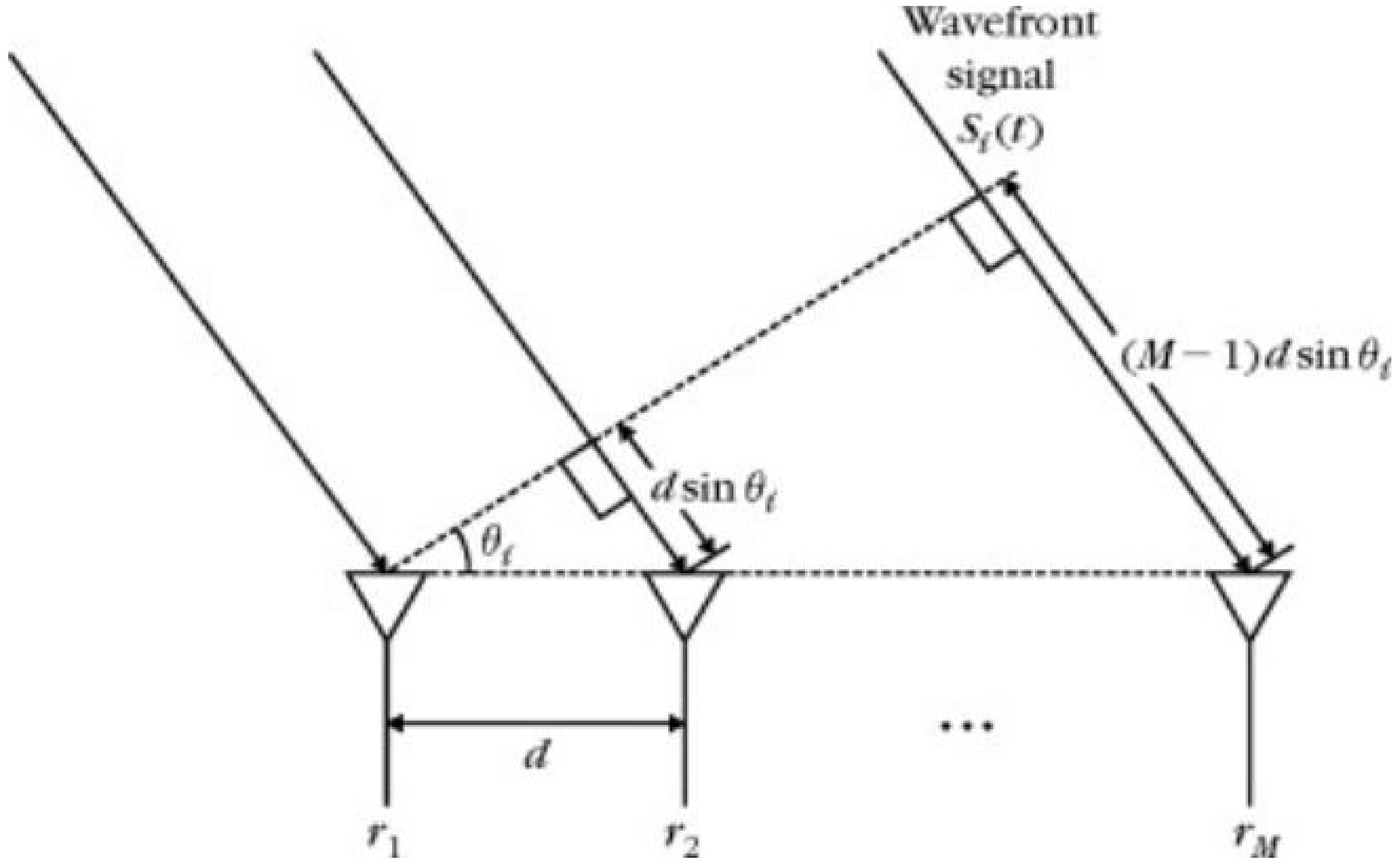


Limitation: Actual rssi is very noisy

- The RSSI and distance are correlated, but can significantly fluctuate



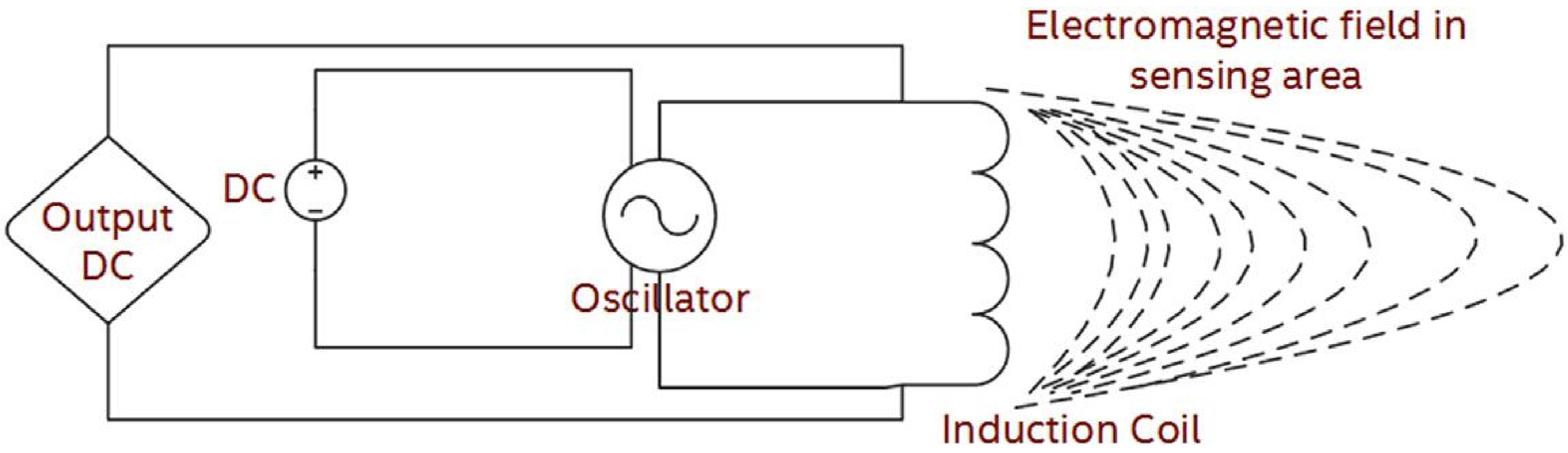
Estimating Angle of Arrival: beamforming

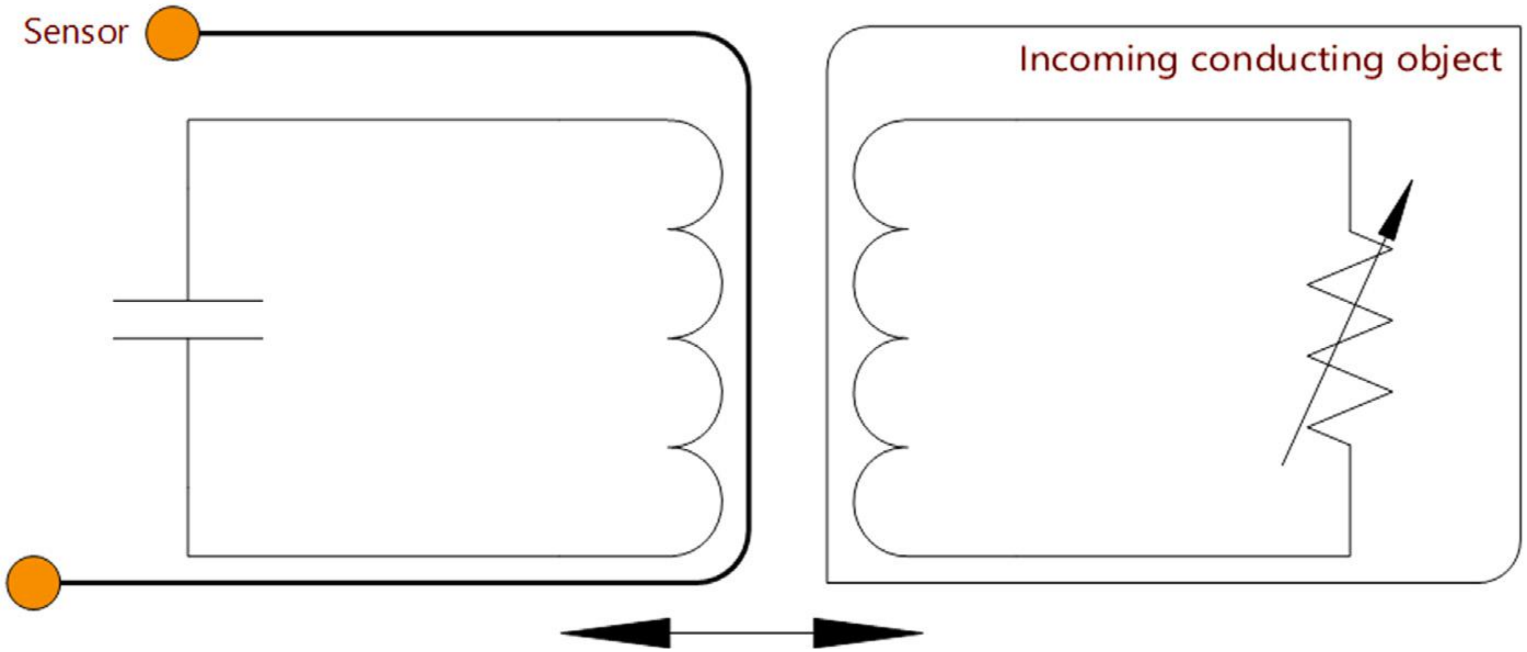


Distance Sensors

Inductive Sensor

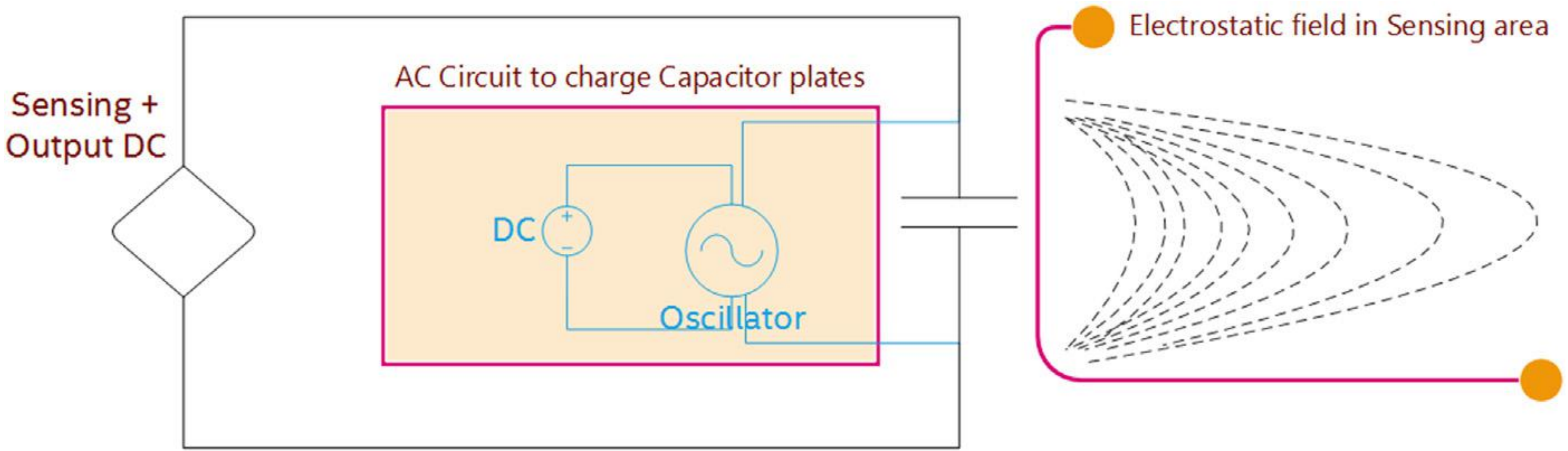
- An inductive proximity sensor mainly consists of a coil, an electronic oscillator, a detection circuit, an output circuit, and an energy source to provide electrical stimulation.
- Working Principle:
  - oscillator generates a changing alternating current
  - the induction coil, it generates a changing electromagnetic field
  - metal object generates a change in impedance due to eddy currents, changing the detection circuit measurements


Electromagnetic field in
sensing area
Output
DC
DC
Oscillator
Induction Coil


Sensor
Incoming conducting object

Capacitive Proximity Sensor

- Use electrostatic field, instead of magnetic field, for detection.
  - Thus, non metallic objects can be sensed.



Distance and Ranging: Infrared Sensors

- Contain an infrared emitter, and an infrared detector
- Works by emitting a certain amount of infrared light, and seeing how much it gets back
- Why infrared?
  - There are not many other infrared sources in everyday life that would interfere with this sensor
  - If visible light were used, light bulbs, computer screens, cellphone screens, etc, would all interfere with the depth reading

Distance and Ranging: Infrared Sensors

- Great at measuring shorter distances (2” –30”)
- Where do you see these?
  - Touchless Switches (toilets, faucets, etc)
  - Roomba vacuums
  - Kinect
- Related: Passive Infrared (PIR) Sensors
  - No IR emitter, just detects ambient IR.
  - Detects some normal state (like a wall’s IR emissions) and when something moves in front, it detects a change
  - Great for detecting motion (motion sensors for security systems)

Distance and Ranging: Speed detector

- e.g. police radar guns
  - Microwave radars use the Doppler effect (the return echo from a moving object will be frequency shifted).
  - The greater the target speed, the greater the frequency (Doppler) shift

Ultrasonic Sensors

- Contain a high frequency speaker , and a microphone
- Works just like a sonar, emitting a sound, and listening for the echo to determine range
- Why is it called ultrasonic?
  - Very high frequency sound, it is barely at the edge of what humans can hear.
  - This is nice since it is not as annoying to use
- Pros: More accurate than IR sensors at slightly longer distance (typically up to several feet)
- Cons: Almost twice the price

Lidar

- LIDAR — Light Detection and Ranging
- How it works?
  - send pulses of light, and determine the difference in reflection time between consecutive pulses to determine speed
- Application:
  - automobile
  - Indoor mapping robot