



**LUND**  
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# **EITP30 Modern Wireless Systems - 5G and Beyond**

## **Lecture 14– Exam Info**

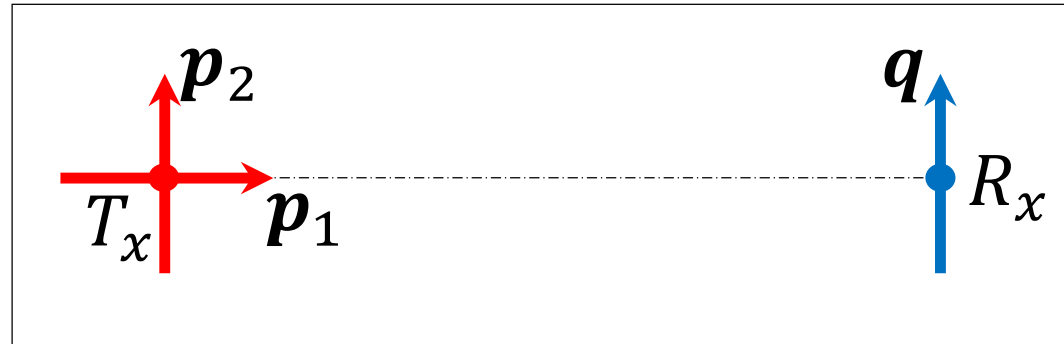
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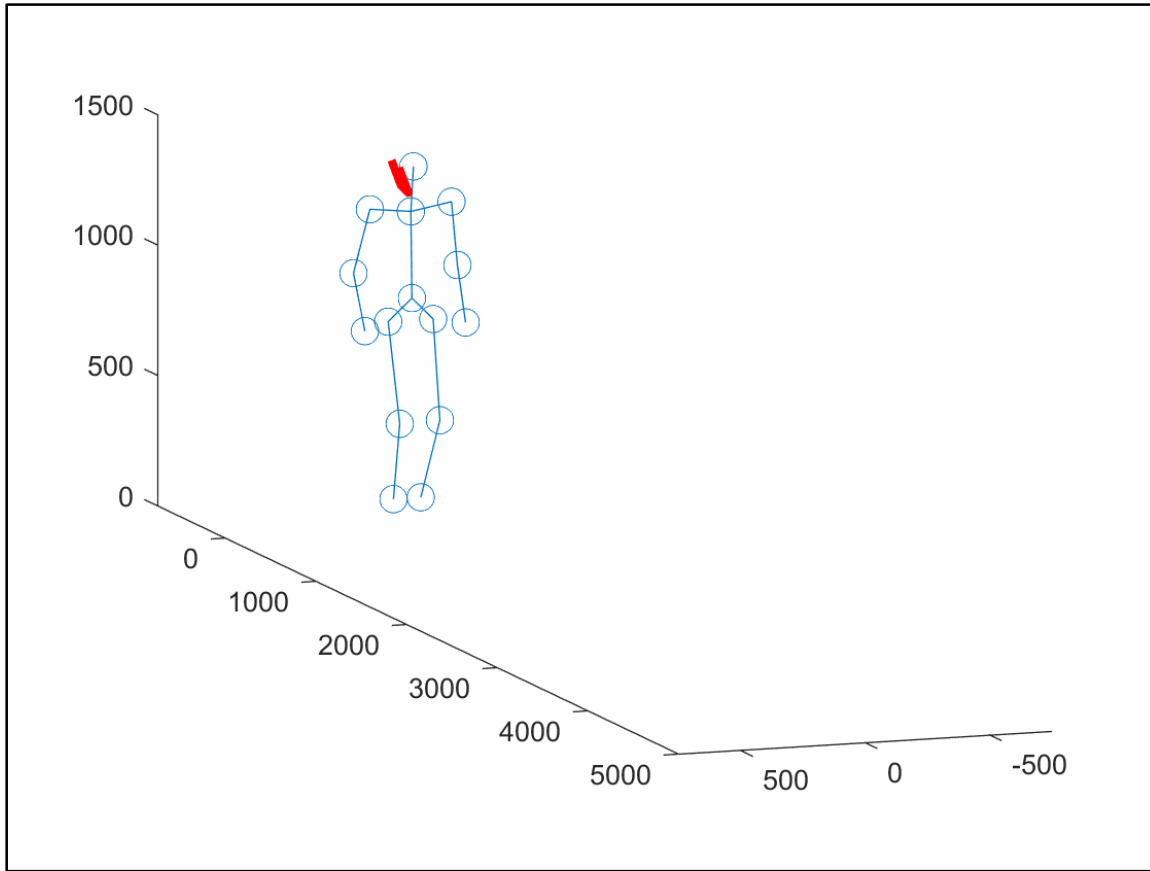
# The Taste of Channel Modeling

# A Simple Observation

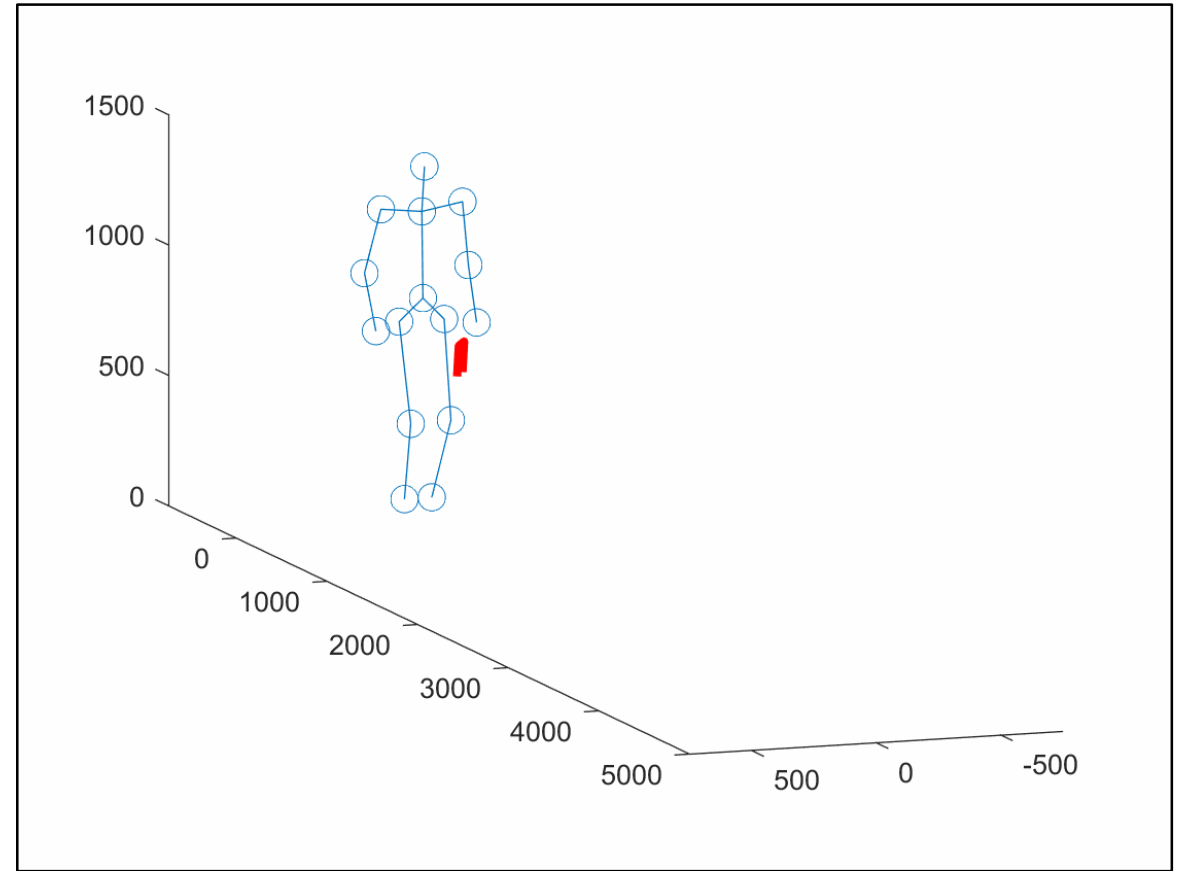


Minimum reception for  $p_1$  and maximum for  $p_2$

# The Smartphone's Orientation Change

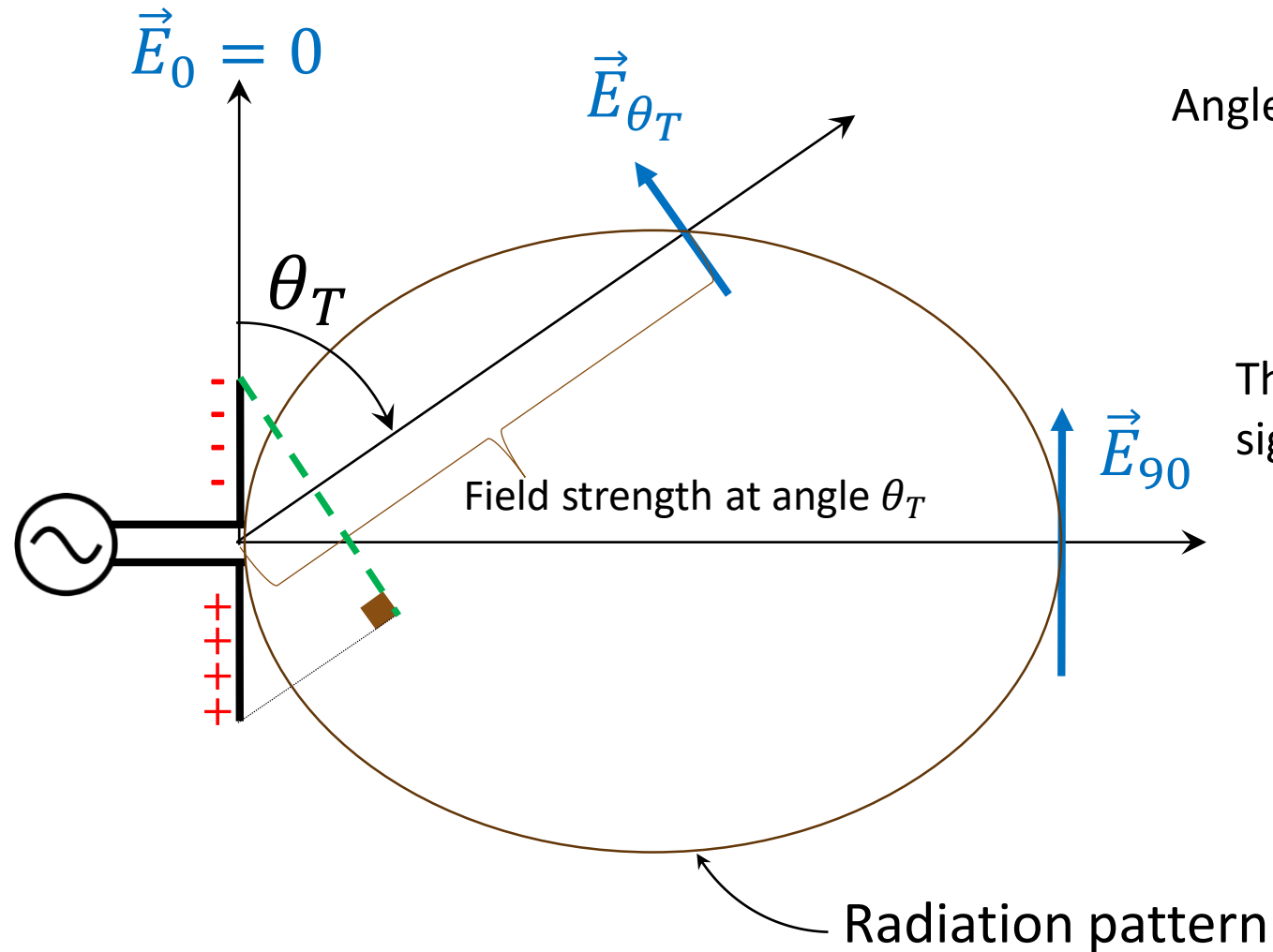


The Smartphone is near the human's head



The Smartphone is in the human's hand

# Antenna Polarization



Angle dependent attenuation coefficient:

$$k(\theta_T) = \sin \theta_T$$

The amplitude of the transmitted signal decreases with this factor

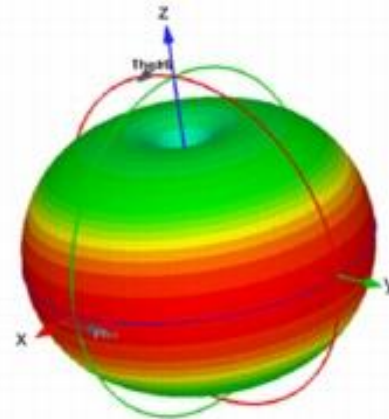
$$s(\theta_T, t) = k(\theta_T) s(t)$$



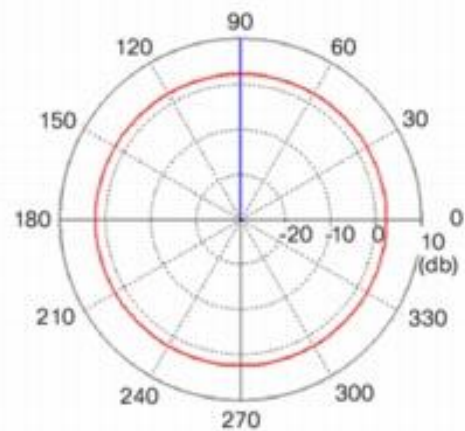
# Antenna Radiation Pattern



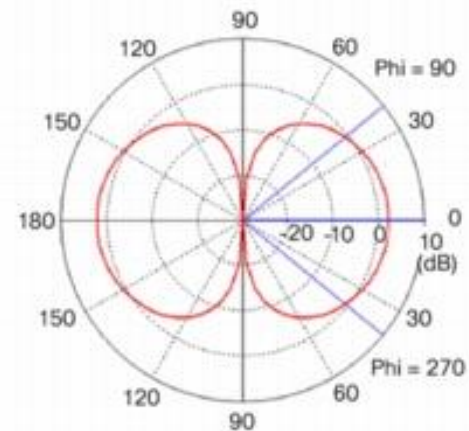
(a) Dipole Antenna Model



(b) Dipole 3D Radiation Pattern



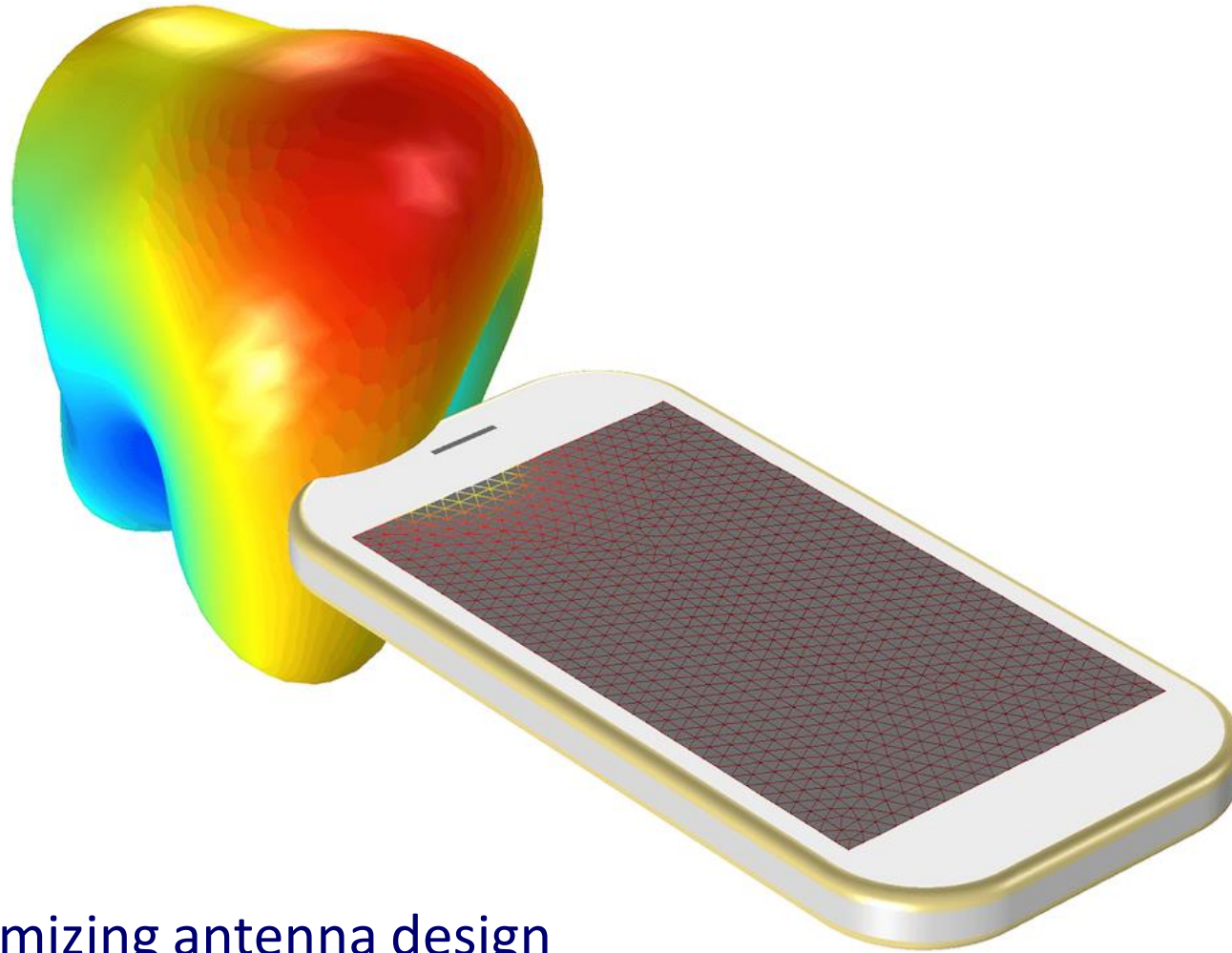
(c) Dipole Azimuth Plane Pattern



(d) Dipole Elevation Plane Pattern

[Link to Cisco site](#)

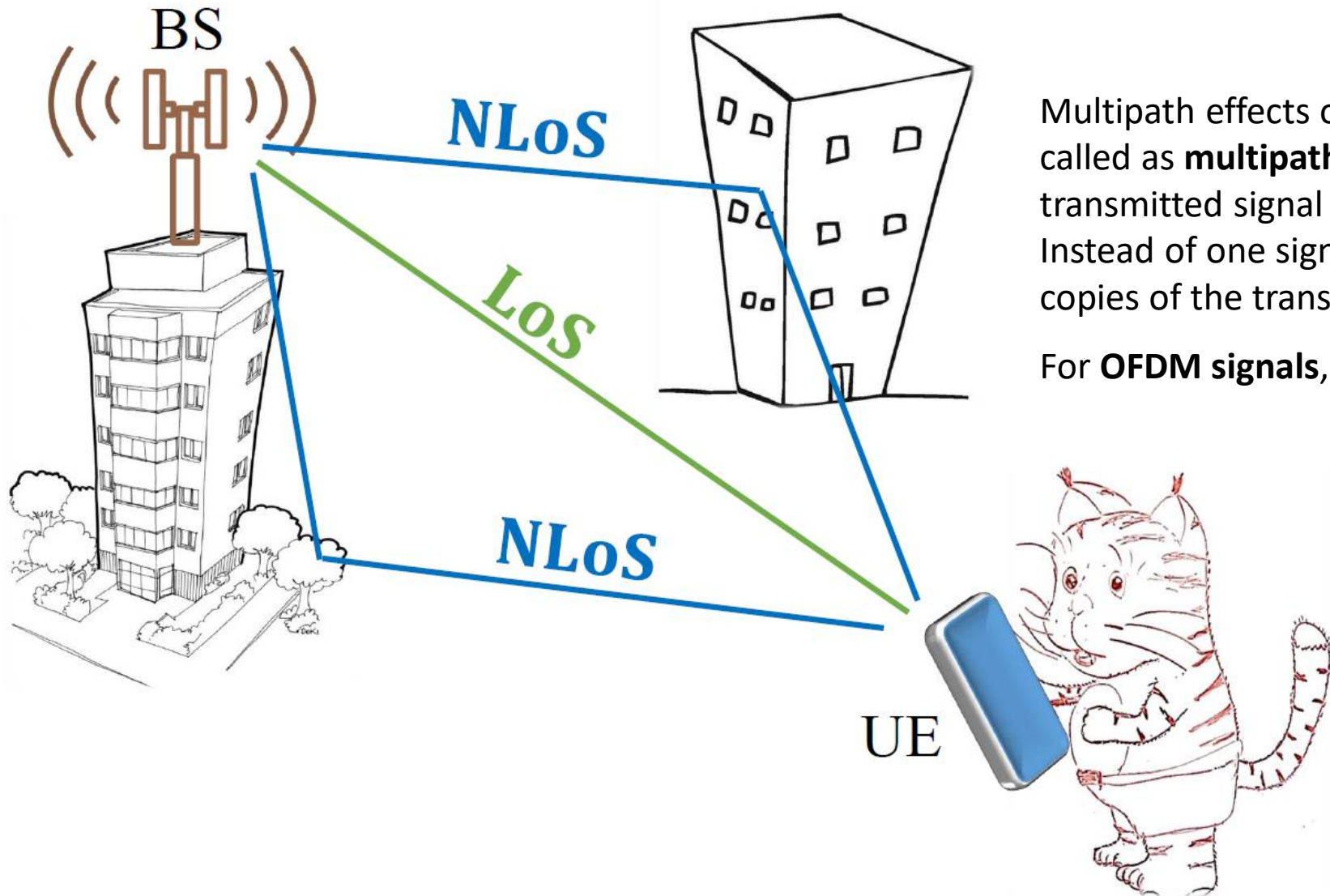
# An Example for a Smartphone



Optimizing antenna design

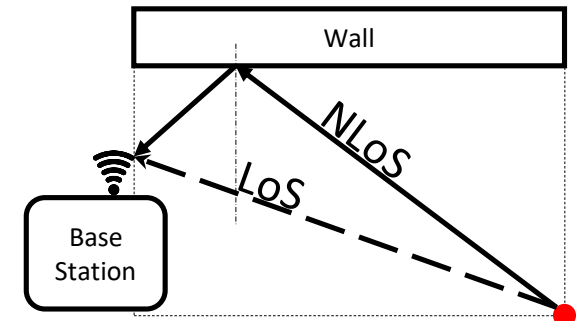


# Multipath propagation

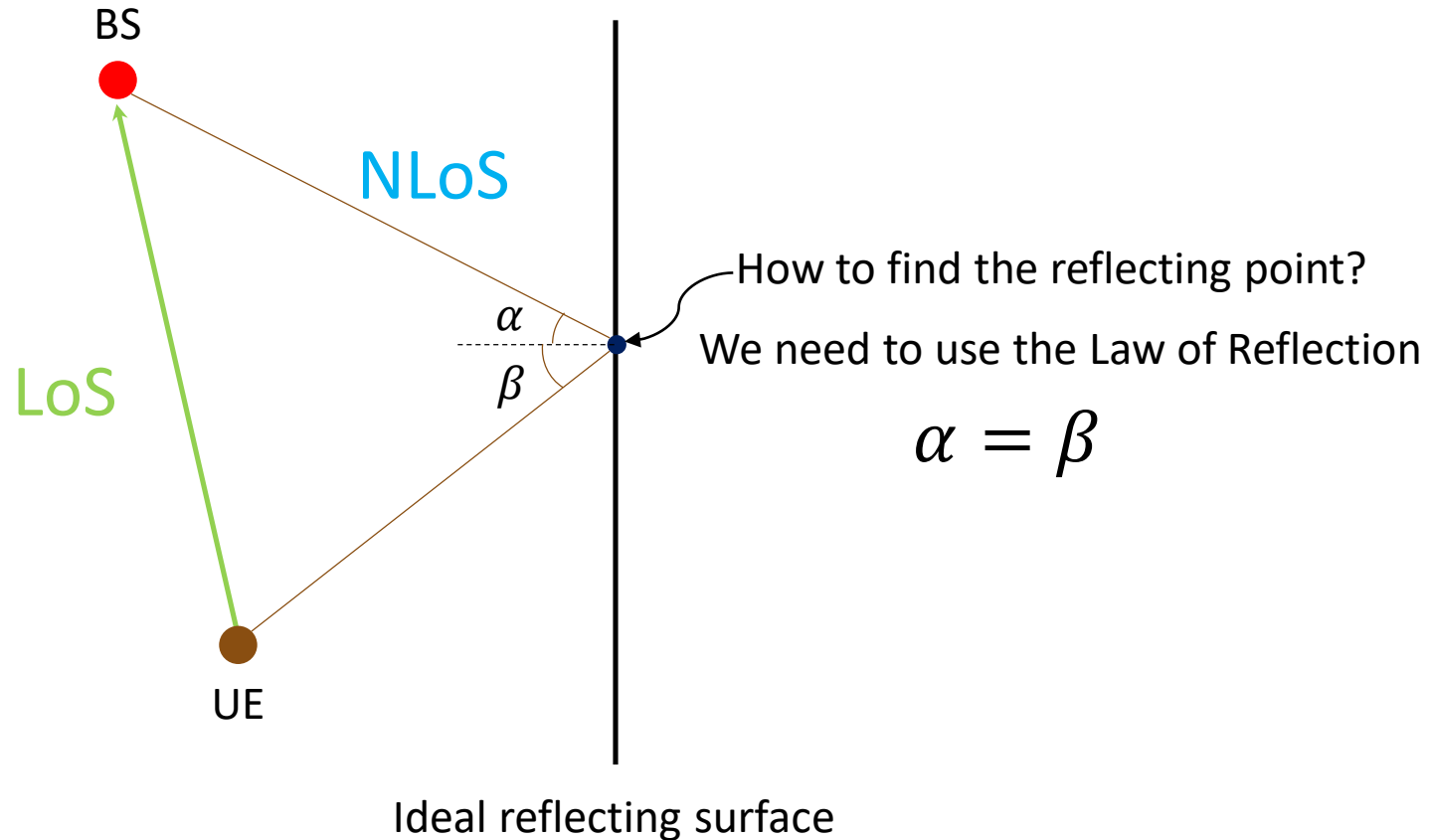


Multipath effects occur in a wireless channel, which is called as **multipath propagation** channel, where a transmitted signal reflects from different obstacles. Instead of one signal, the receiver receives several copies of the transmitted signal.

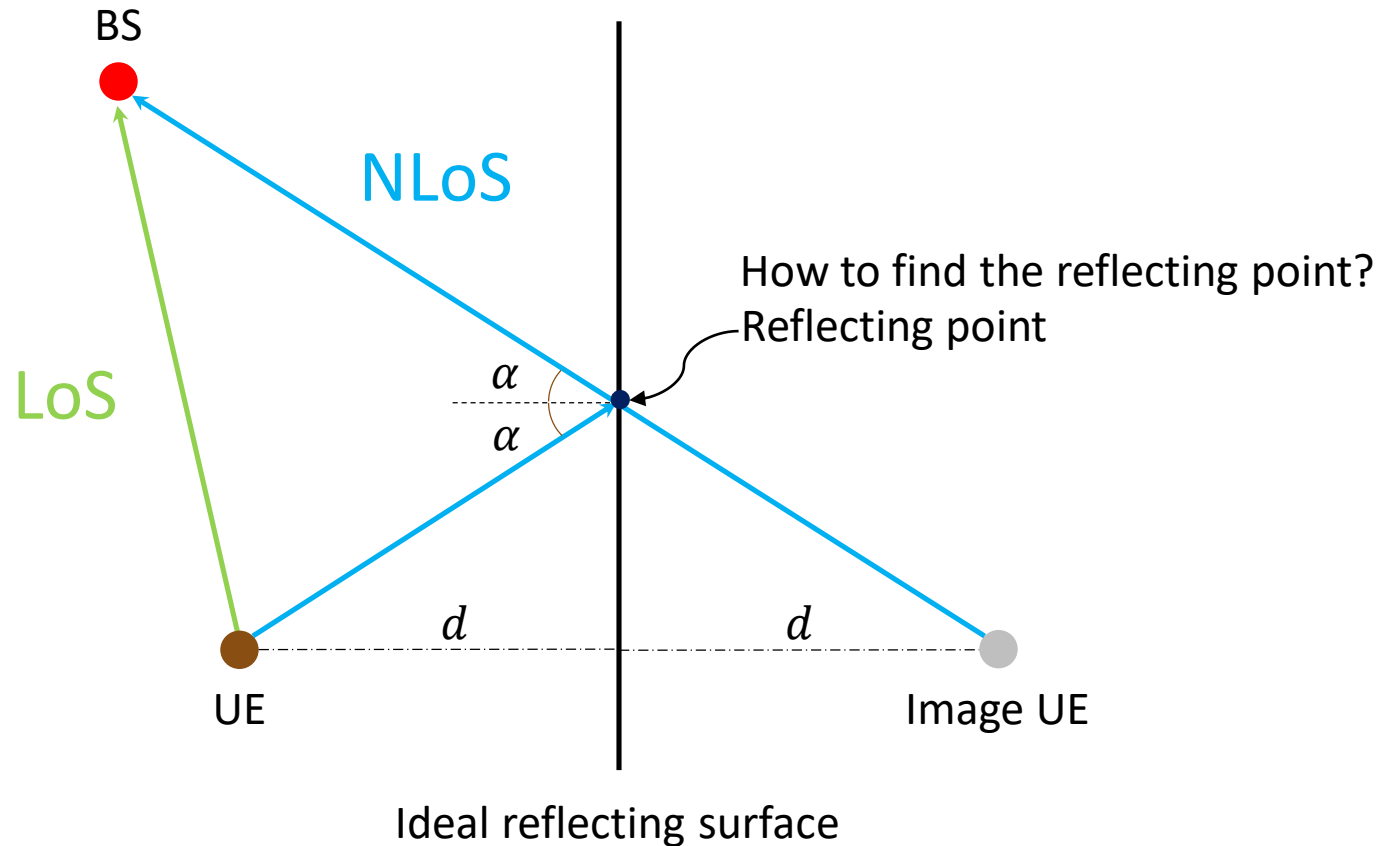
For **OFDM signals**, this becomes frequency-selective!



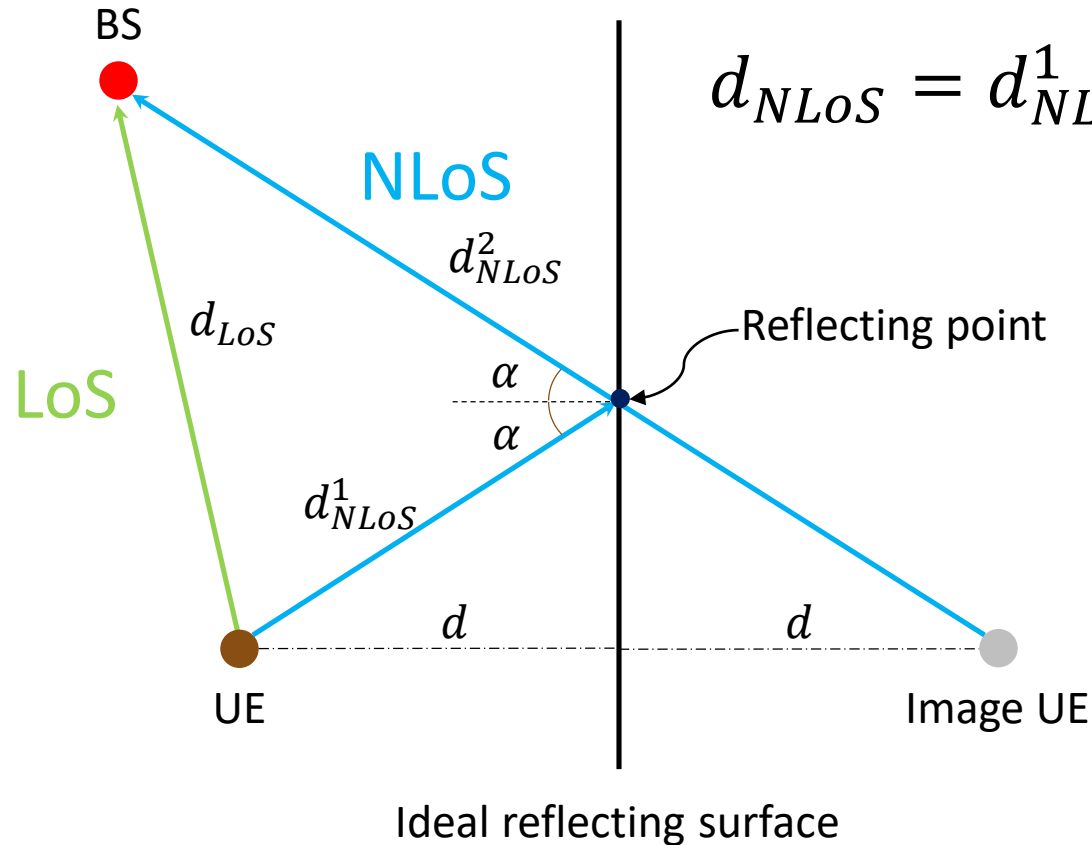
# How to Find Paths in a Generic Environment?



# How to Find Paths in a Generic Environment?



# Frequency Selective Channel

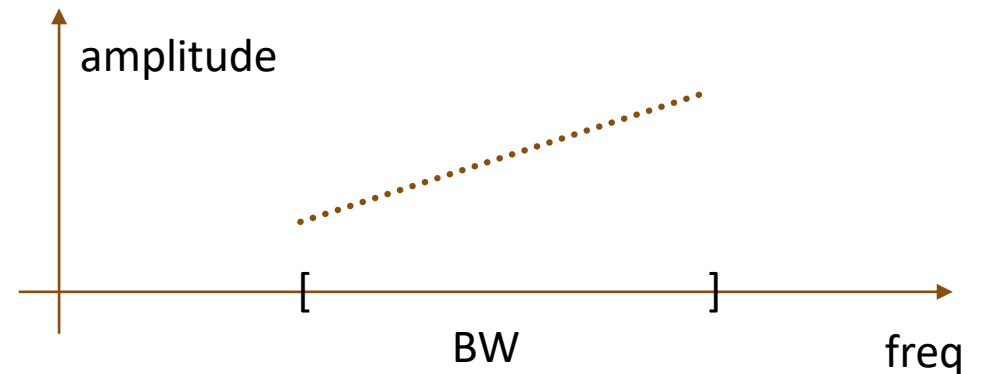


$$d_{NLoS} = d_{NLoS}^1 + d_{NLoS}^2,$$

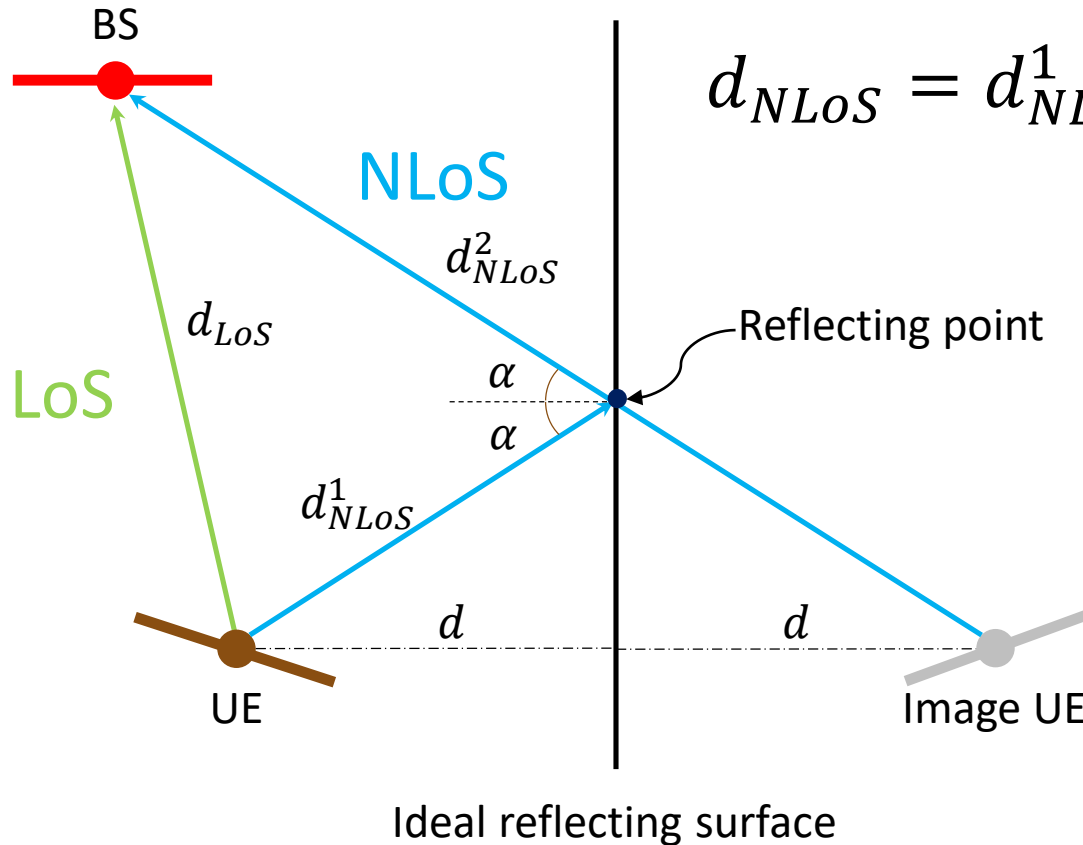
$$\tau = \frac{d_{NLoS} - d_{LoS}}{c}$$

For **OFDM signals**, this becomes frequency-selective!

$$\begin{aligned} \sin(\omega_1 t) + \sin(\omega_1 t + \omega_1 \tau) &= B_1 \sin(\omega_1 t + \psi_1) \\ \sin(\omega_2 t) + \sin(\omega_2 t + \omega_2 \tau) &= B_2 \sin(\omega_2 t + \psi_2) \\ \sin(\omega_3 t) + \sin(\omega_3 t + \omega_3 \tau) &= B_3 \sin(\omega_3 t + \psi_3) \\ \sin(\omega_4 t) + \sin(\omega_4 t + \omega_4 \tau) &= B_4 \sin(\omega_4 t + \psi_4) \end{aligned}$$



# Frequency Selective Channel

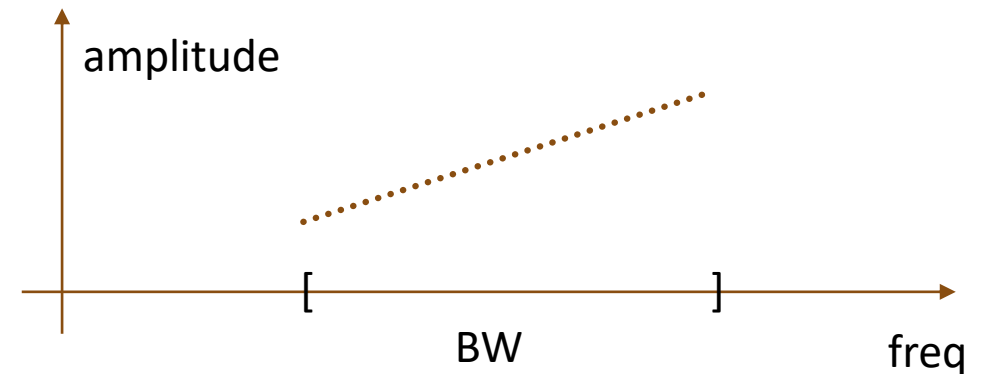


$$d_{NLoS} = d^1_{NLoS} + d^2_{NLoS},$$

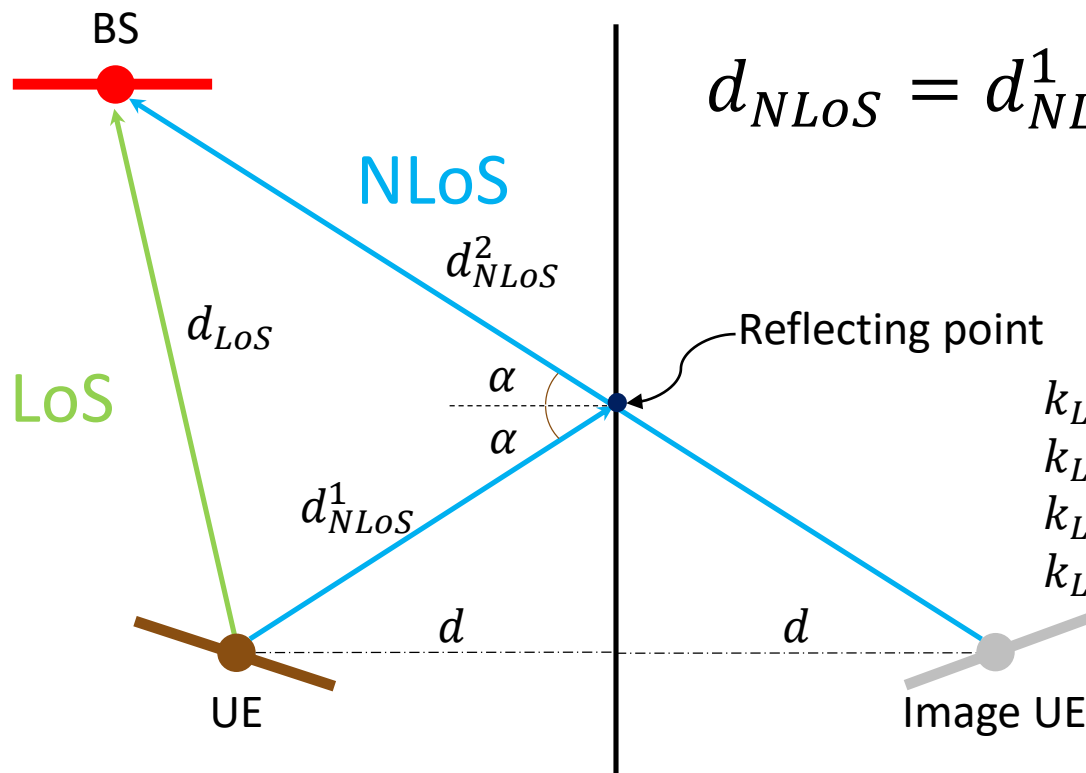
$$\tau = \frac{d_{NLoS} - d_{LoS}}{c}$$

For **OFDM signals**, this becomes frequency-selective!

$$\begin{aligned} \sin(\omega_1 t) + \sin(\omega_1 t + \omega_1 \tau) &= B_1 \sin(\omega_1 t + \psi_1) \\ \sin(\omega_2 t) + \sin(\omega_2 t + \omega_2 \tau) &= B_2 \sin(\omega_2 t + \psi_2) \\ \sin(\omega_3 t) + \sin(\omega_3 t + \omega_3 \tau) &= B_3 \sin(\omega_3 t + \psi_3) \\ \sin(\omega_4 t) + \sin(\omega_4 t + \omega_4 \tau) &= B_4 \sin(\omega_4 t + \psi_4) \end{aligned}$$



# Frequency Selective Channel and Polarization



$$d_{NLoS} = d_{NLoS}^1 + d_{NLoS}^2,$$

$$\tau = \frac{d_{NLoS} - d_{LoS}}{c}$$

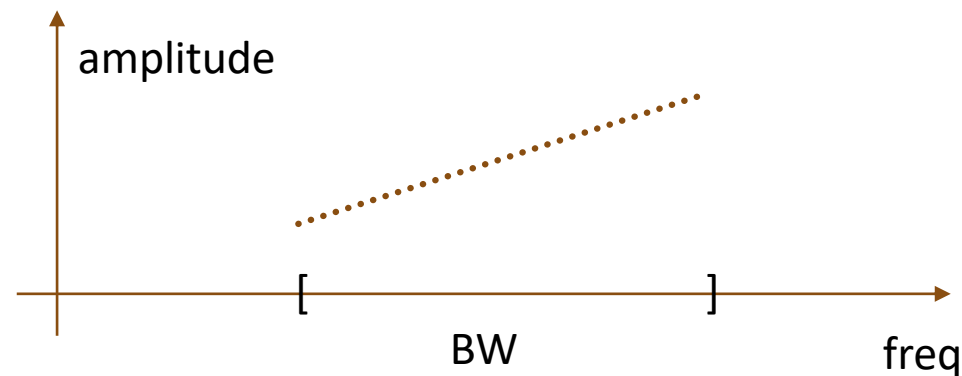
For **OFDM signals**, this becomes frequency-selective!

$$k_{LoS} \cdot \sin(\omega_1 t) + k_{NLoS} \cdot \sin(\omega_1 t + \omega_1 \tau) = C_1 \sin(\omega_1 t + \psi_1)$$

$$k_{LoS} \cdot \sin(\omega_2 t) + k_{NLoS} \cdot \sin(\omega_2 t + \omega_2 \tau) = C_2 \sin(\omega_2 t + \psi_2)$$

$$k_{LoS} \cdot \sin(\omega_3 t) + k_{NLoS} \cdot \sin(\omega_3 t + \omega_3 \tau) = C_3 \sin(\omega_3 t + \psi_3)$$

$$k_{LoS} \cdot \sin(\omega_4 t) + k_{NLoS} \cdot \sin(\omega_4 t + \omega_4 \tau) = C_4 \sin(\omega_4 t + \psi_4)$$



Ideal reflecting surface

$$FSL = \frac{\lambda^2}{(4\pi d)^2}$$

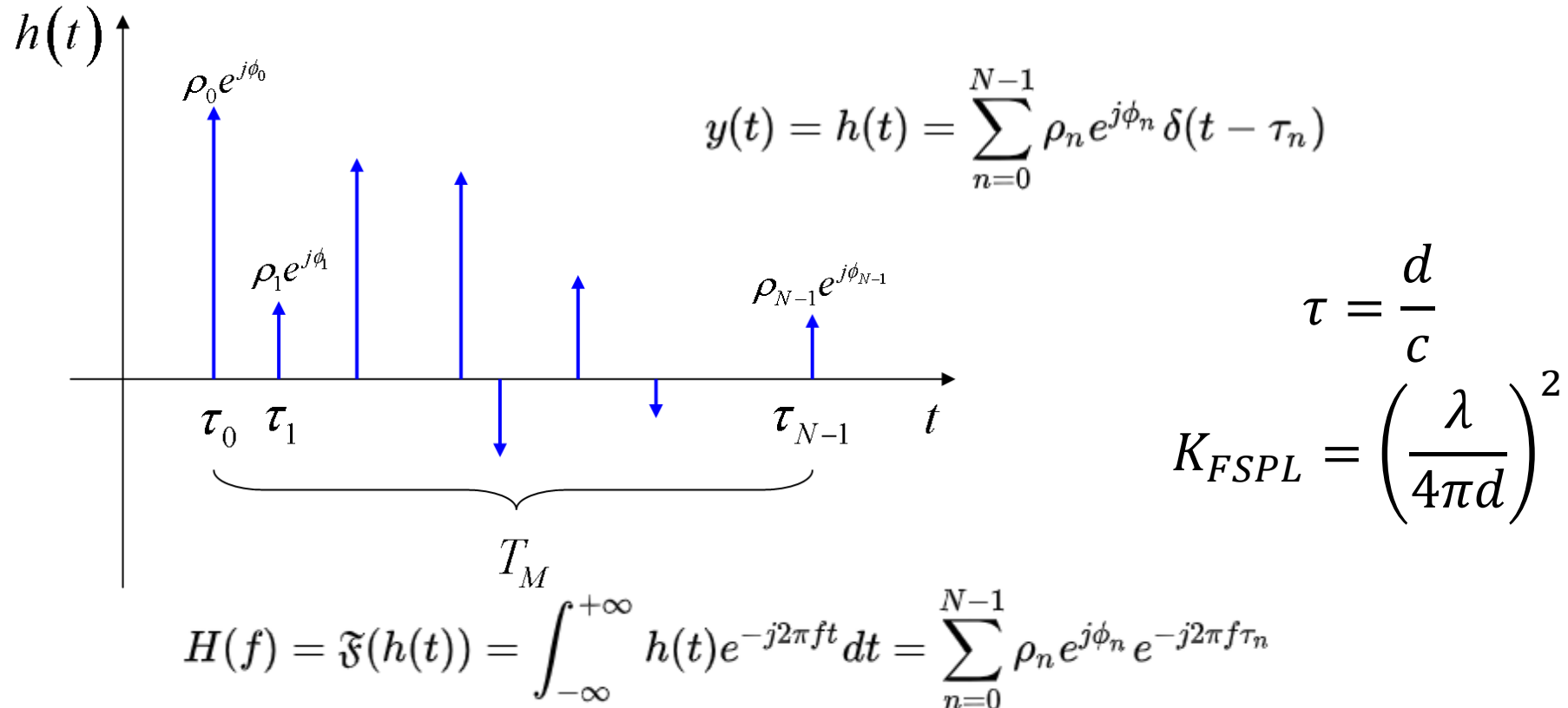
$$RC * FSL = K * \frac{\lambda^2}{(4\pi d)^2}$$

D LoS => SNR max

D NLoS Reflection Coeff => SNR min

# Higher Frequency Communication Issues

- The following is a classical multipath channel model



- The time delay dispersion does not depend on the frequency that we use
  - Hence, shorter CP leads to a complicated receive

# Exam Questions Example

- **Problem 1: Multiple Choice Questions (3p)**

In FDD, why is it important to send uplink Sounding Reference Signals (SRS)?

- a. Because the base station needs to know the downlink channel state information to choose the correct downlink transmission scheme.
- b. Because SRS provides reference symbols to enable coherent demodulation of uplink transmissions.
- c. Because SRS enables cell selection for a UE by informing its channel state information to surrounding base stations.
- d. Because the base station can obtain the uplink channel state information, which can be used for uplink resource scheduling, beam management, and power control.
- e. None of the above options is correct.

- **Problem 2: Short Answer Questions (6p)**

3. When you turn on your cellphone, the very first signal transmitted from your cellphone is Random Access Channel (RACH) preamble. (1p)

(True, before sending RACH, a device can only listen and search for PSS and SSS)

- **Problem 3: Discussion Questions (10p)**

The flexible numerology of NR allows supporting a wide range of deployment scenarios, from large cells with sub-1 GHz carrier frequency up to mm-wave deployments with very wide spectrum allocations.

- a. Due to flexible numerology, the initial access procedures in NR differ from LTE's procedures. Please, list several major differences and highlight possible pros and cons of the NR's the initial access procedures? (5p)  
(In NR, a device needs to search for an SS block on the sparser synchronization raster; SS block periodicity from 5ms to 160 ms; a devices can assume the SS block is repeated at least once every 20 ms while 5ms in LTE, SS burst set in NR; (2p)  
PSS is no longer ZC sequence; (1p)  
Cons: a device can spend too long time for searching for an SS block; PSS is M-sequence based, which leads to orthogonality lose in the time domain; ... (2p))



# Exam Task Example 1

## Problem 1 – Cell Search

For the sake of simplicity, in exam tasks, we are using 3<sup>rd</sup> order M-sequences. In the following figure, a Primary Synchronization Signal (PSS) generating scheme is given:

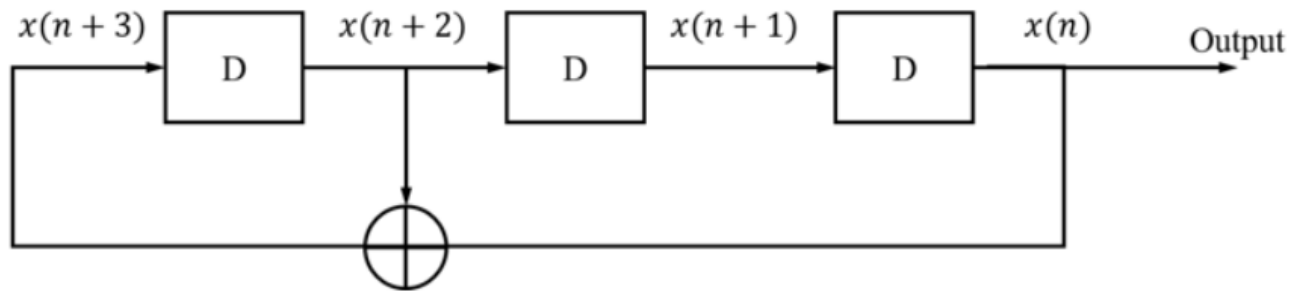


Figure 1. Generation of basic M-sequence:  $x(k) = x(k - 1) \oplus x(k - 3)$ .

Initial sequences for the scheme are determined as follows:

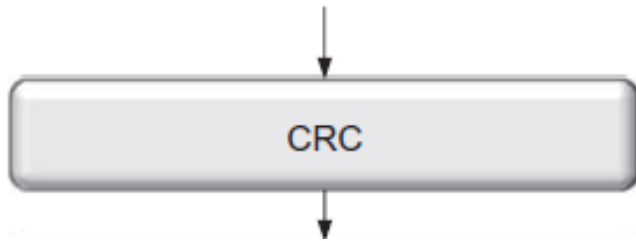
- PSS = 0 has initial sequence  $[x(2), x(1), x(0)] = [0 \ 1 \ 1]$ ;
- PSS = 1 has initial sequence  $[x(2), x(1), x(0)] = [0 \ 1 \ 0]$ ;
- PSS = 2 has initial sequence  $[x(2), x(1), x(0)] = [1 \ 0 \ 0]$ .

You will define numerology,  
BW allocation, and etc.

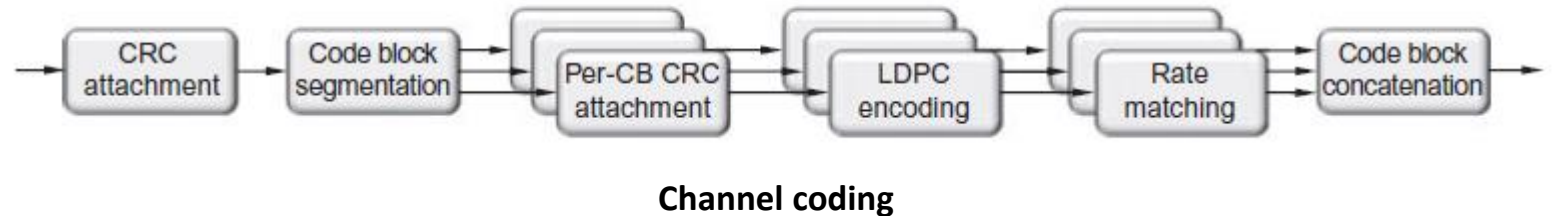
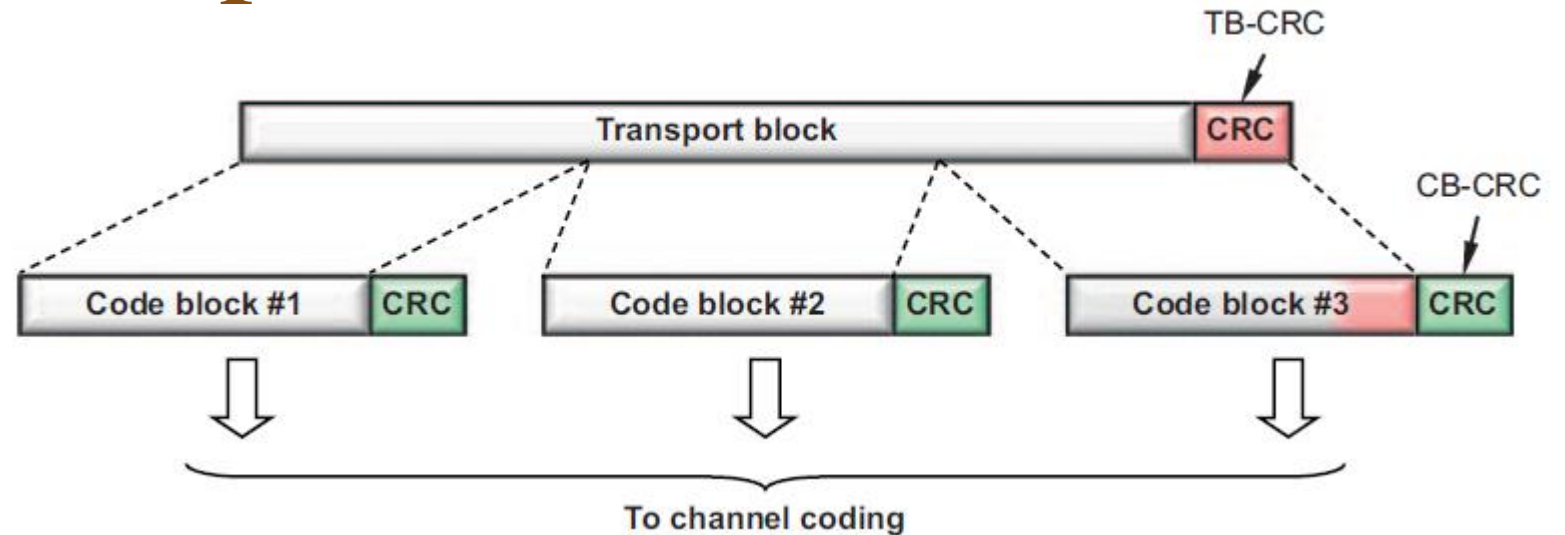
After a UE is switched on, it starts the procedure of cell search. During the synchronization phase it detects a PSS sequence  $[1 \ 1 \ 1 \ 0 \ 0 \ 0]$ . Assume that one value of the received sequence is detected incorrectly (either 0 or 1) due to the channel influence.

# Exam Task Example 2

One (or two) transport block(s) of dynamic size delivered from the MAC layer



1. TB CRC is calculated and attached
  - a. If TB > 3824, then 24-bit CRC;
  - b. Otherwise, 16-bit CRC.
2. Code-block segmentation
  - a. Code-block size is defined by LDPC coder;
  - b. 8424 bits for base graph 1, 3840 bits for base graph 2;
  - c. CB CRC has 24 bits
3. CB CRC is calculated and attached



# Exam Task Example 2

```
11010011101100 000 <--- input right padded by 3 bits
1011 <--- divisor
01100011101100 000 <--- result (note the first four bits are the XOR with the divisor
beneath, the rest of the bits are unchanged)
 1011 <--- divisor ...
00111011101100 000
 1011
00010111101100 000
 1011
00000001101100 000 <--- note that the divisor moves over to align with the next 1 in the
dividend (since quotient for that step was zero)
 1011 (in other words, it doesn't necessarily move one bit per
iteration)
00000000110100 000
 1011
00000000011000 000
 1011
00000000001110 000
 1011
00000000000101 000
 101 1
-----
00000000000000 100 <--- remainder (3 bits). Division algorithm stops here as dividend is
equal to zero.
11010011101100 100 <--- input with check value
1011 <--- divisor
```

# Exam Task Example 3

## Problem 2 – Resource Allocation

A very basic OFDM transmitter chain intended for 5G NR is shown in the figure below:

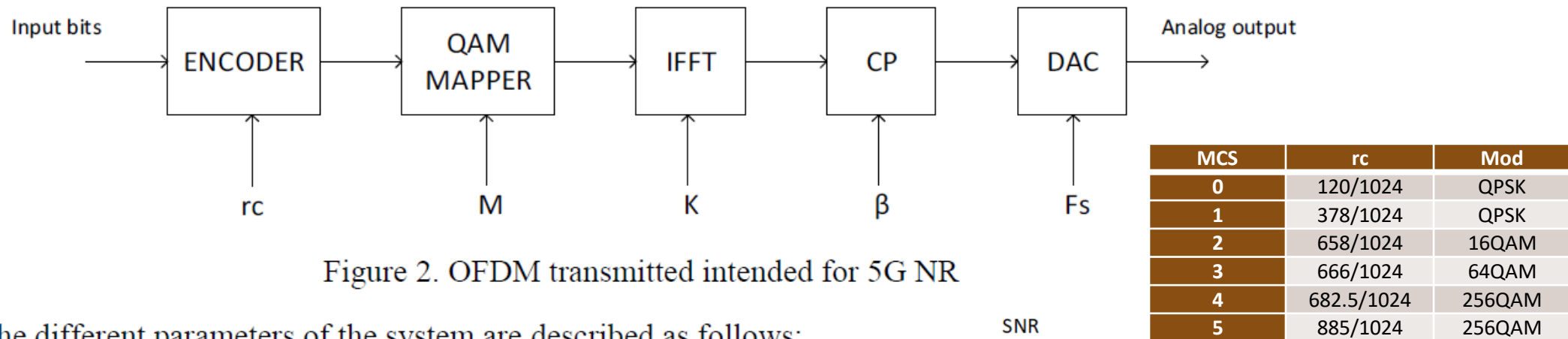


Figure 2. OFDM transmitted intended for 5G NR

The different parameters of the system are described as follows:

- $rc$ : Coding rate.
- $K$ : Number of subcarriers.
- $M$ : Modulation order.
- $T_{cp}$ : Cyclic prefix duration.
- $T_u$ : Useful part of OFDM symbol duration.
- $\beta$ :  $T_{cp}/T_u$ . CP overhead.
- $F_s$ : Sampling rate.

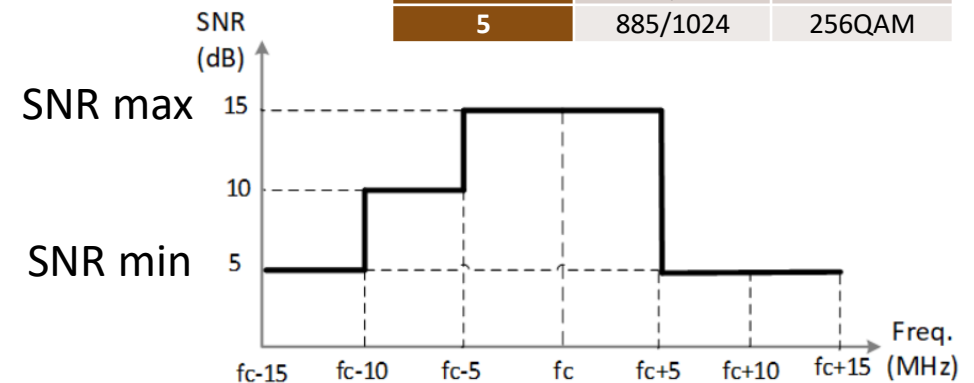


Figure 3: SNR per subcarrier vs frequency in the receiver.



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