ENCE606029

Wireless Technology

Lecture 1: Introduction

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Faculty of Engineering
Universitas Indonesia

Course Learning Objectives (CLO)

- Learn the basics of wireless technologies including how it works, techniques, and standardizing on wireless network and mobile.
- Able to explain the basics of wireless technology, techniques in wireless networks, wireless communication standard IEEE 802.11, 802.15 and cellular, and capable of analyzing projections of future wireless technologies.

Contents

- Wireless fundamentals
  - Channel properties, fading, diversity, …
- Techniques, Design, Engineering
  - Telephony/cellular, computer networks, device’s networks
  - RC toys, TV, radio, satellite, maritime, aerospace
- Standards Evolution
  - IEEE 802.11 families
  - 1G, 2G, 3G, 4G, 5G

About the lecture

Prerequisites:

- Computer Networks + Lab.
- Telecommunication Network & Lab.

Online Course: at Emas.ui.ac.id

Assessment

40% Assignments 30% Mid-term exam 30% Final-term exam	**OR**	30% Assignments 30% Mid-term exam 40% Programming task

- Cheating = score penalty 50-100%
- Late submission = no submission
- Corrupted file submission = no submission

Suggestions

- Be active (bonus points)
- English difficulty? Ask!
- Sufficient attendance
- Manage your time!
- Be self-motivated, responsible, respectful, honest

About Lecturer

- Undergraduate: Computer Engineering 2007
- Master: UI+NTUST
- Doctoral: NTUST
- Related certifications:
  - IEEE Wireless Engineering Professional
  - Huawei Certified Associate Instructor

- Office: Networking Lab., DTE 2nd floor
- Email: ruki.h@ui.ac.id

References

- Rappaport, "Wireless Communication Principles and Practice", 2nd Ed., Prentice Hall, 2002
- Walke et. al., "IEEE 802 Wireless Systems", Wiley, England, 2006
- Iti Saha Misra, “Wireless Communications and Networks – 3G And Beyond”, 2nd Ed., McGraw Hill Edu., India, 2013
- Kurose and Ross, “Computer Networking – A Top Down Approach”, 5th Ed., Pearson, 2010

Class Rep.?

Chat group?

WIRELESS TECHNOLOGY

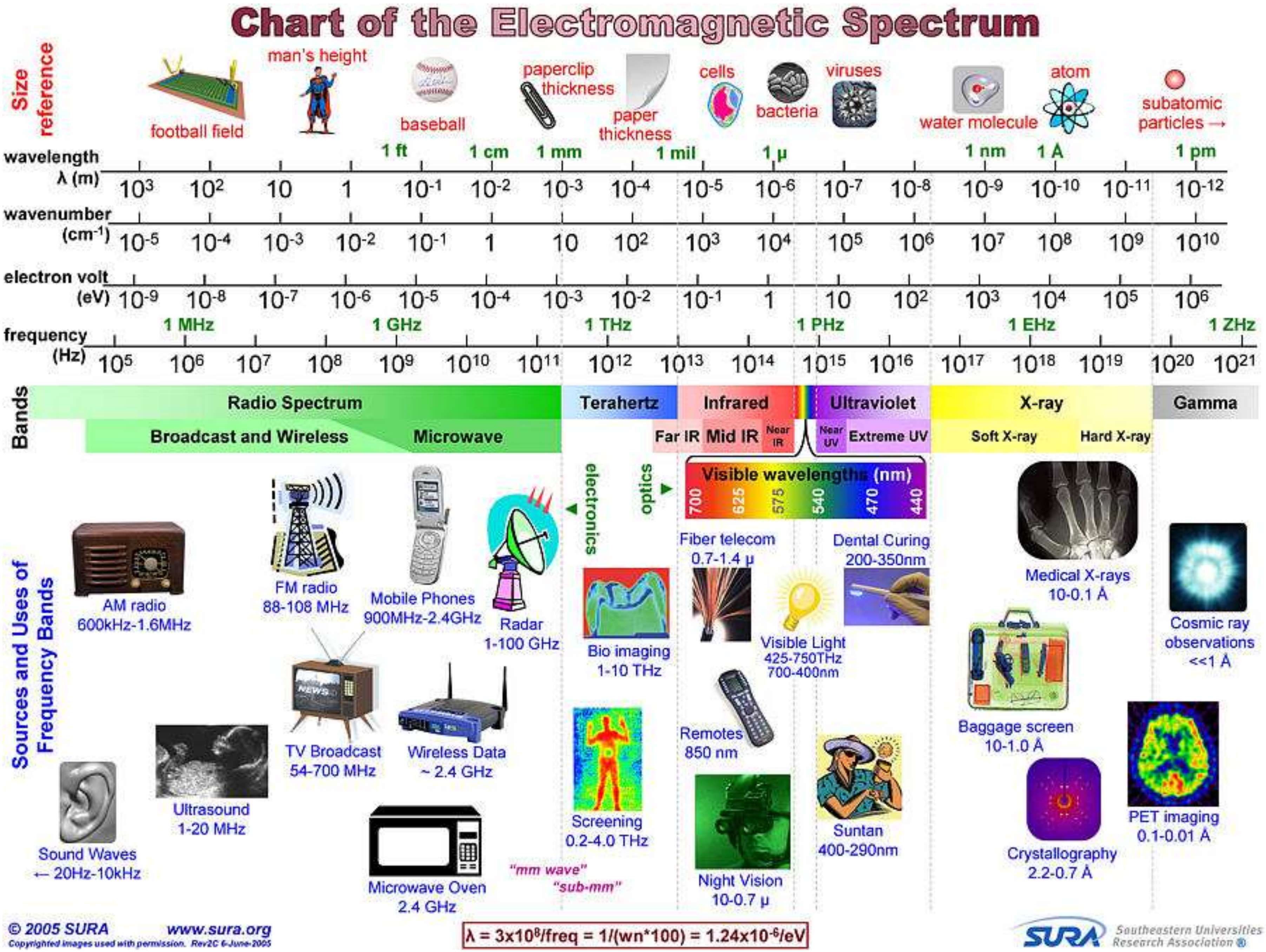
Chart of the Electromagnetic Spectrum
Size reference
football field
man's height
baseball
paperclip thickness
paper thickness
cells
bacteria
viruses
water molecule
atom
subatomic particles →
wavelength λ (m)
1 ft
1 cm
1 mm
1 mil
1 μ
1 nm
1 Å
1 pm
10^3 10^2 10 1 10^-1 10^-2 10^-3 10^-4 10^-5 10^-6 10^-7 10^-8 10^-9 10^-10 10^-11 10^-12
wavenumber (cm^-1)
10^-5 10^-4 10^-3 10^-2 10^-1 1 10 10^2 10^3 10^4 10^5 10^6 10^7 10^8 10^9 10^10
electron volt (eV)
10^-9 10^-8 10^-7 10^-6 10^-5 10^-4 10^-3 10^-2 10^-1 1 10 10^2 10^3 10^4 10^5 10^6
frequency (Hz)
1 MHz
1 GHz
1 THz
1 PHz
1 EHz
1 ZHz
10^5 10^6 10^7 10^8 10^9 10^10 10^11 10^12 10^13 10^14 10^15 10^16 10^17 10^18 10^19 10^20 10^21
Bands
Radio Spectrum
Terahertz
Infrared
Ultraviolet
X-ray
Gamma
Broadcast and Wireless
Microwave
Far IR
Mid IR
Near IR
Near UV
Extreme UV
Soft X-ray
Hard X-ray
electronics
optics
Visible wavelengths (nm)
700 625 575 540 470 440
Sources and Uses of Frequency Bands
AM radio 600kHz-1.6MHz
FM radio 88-108 MHz
Mobile Phones 900MHz-2.4GHz
Radar 1-100 GHz
Bio imaging 1-10 THz
Fiber telecom 0.7-1.4 μ
Dental Curing 200-350nm
Medical X-rays 10-0.1 Å
Cosmic ray observations <<1 Å
Visible Light 425-750THz 700-400nm
TV Broadcast 54-700 MHz
Wireless Data ~ 2.4 GHz
Remotes 850 nm
Baggage screen 10-1.0 Å
Ultrasound 1-20 MHz
Screening 0.2-4.0 THz
Suntan 400-290nm
PET imaging 0.1-0.01 Å
Sound Waves ← 20Hz-10kHz
Microwave Oven 2.4 GHz
"mm wave"
"sub-mm"
Night Vision 10-0.7 μ
Crystallography 2.2-0.7 Å
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λ = 3x10^8/freq = 1/(wn*100) = 1.24x10^-6/eV
SURA Southeastern Universities Research Association ®

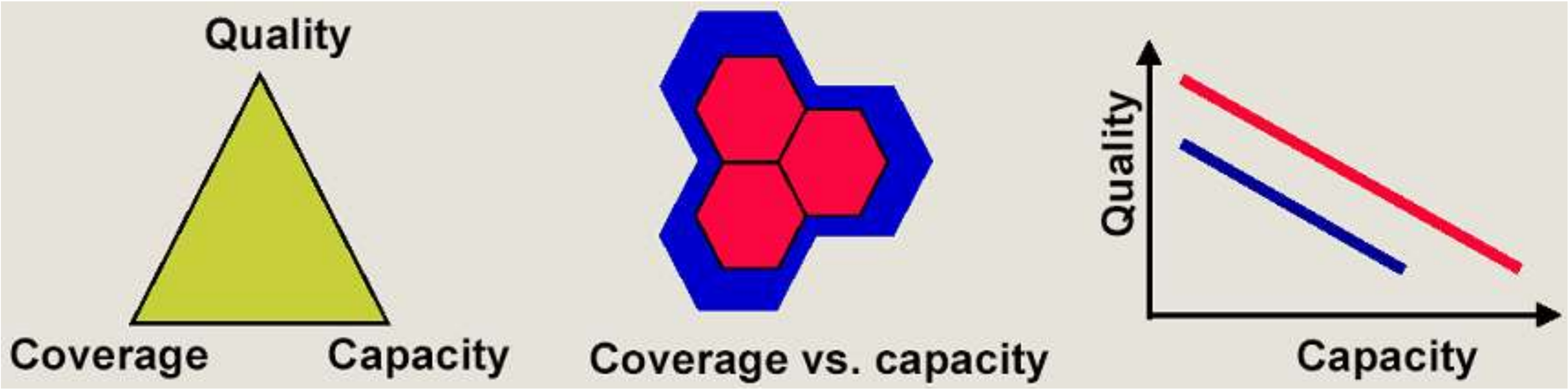
Networking Options

Wired	Wireless
Not flexible	Flexible
Expensive labor	Easy installation
Unfriendly to interior	Friendly to interiors
Cheap price	Higher price
~~Low profit~~ Opportunity	~~Good profit~~ another opportunity

Bolt Bangkrut

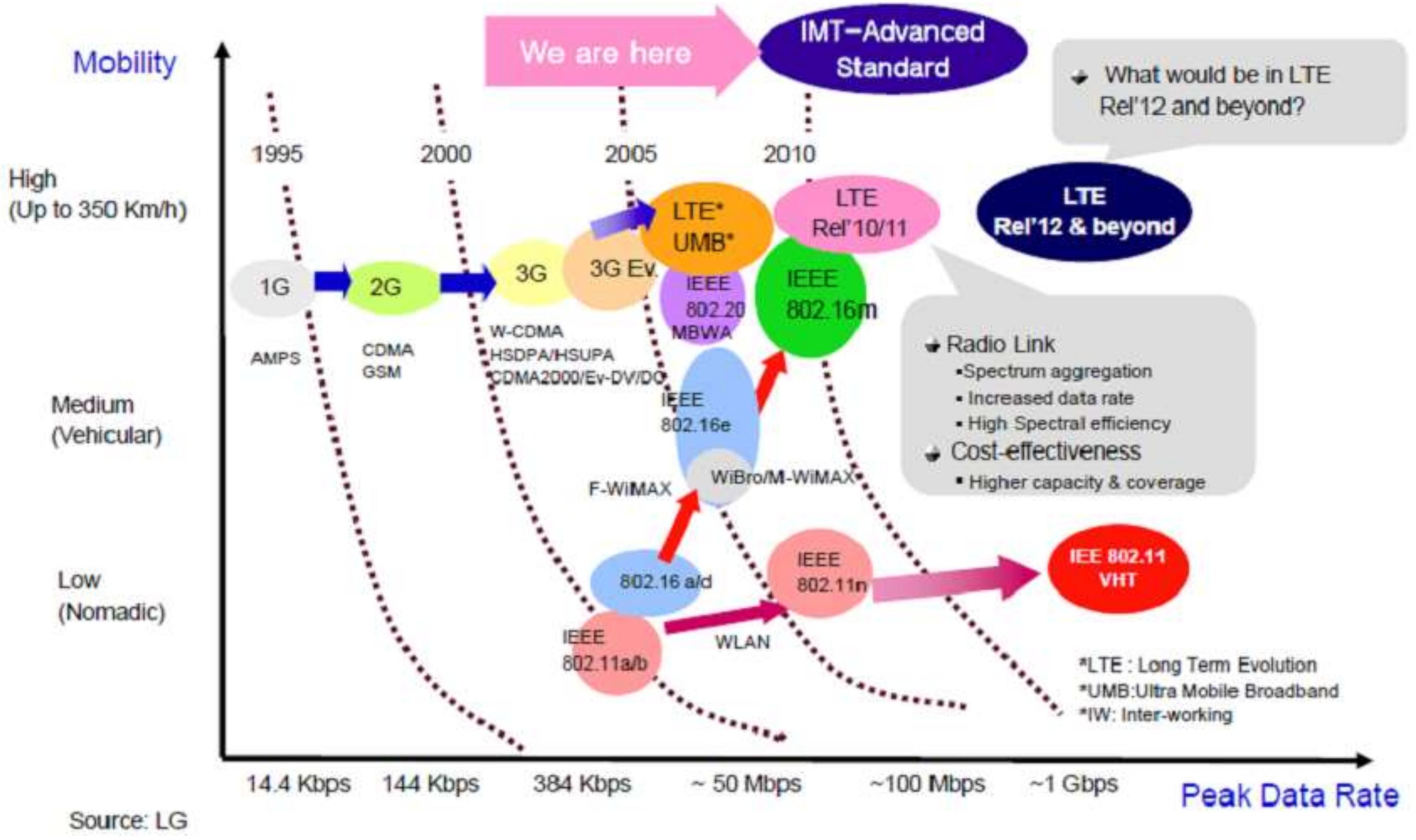
Wireless Tech. Limitations

"Performance" of wireless network: CCQ

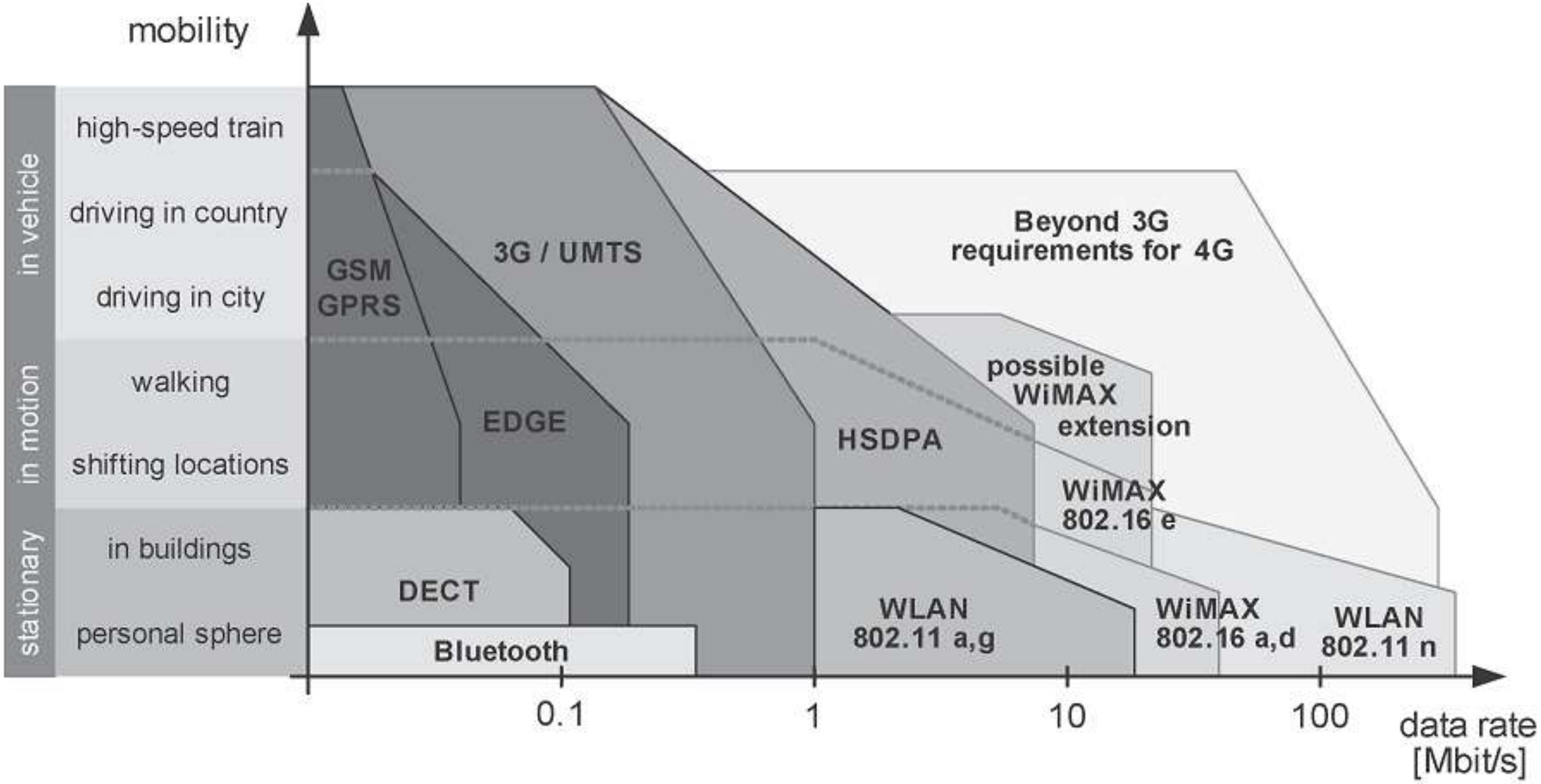
- 

- Coverage: radius, mobility
- Capacity: data rate
- Quality: error rate

Communication Standard Evolution

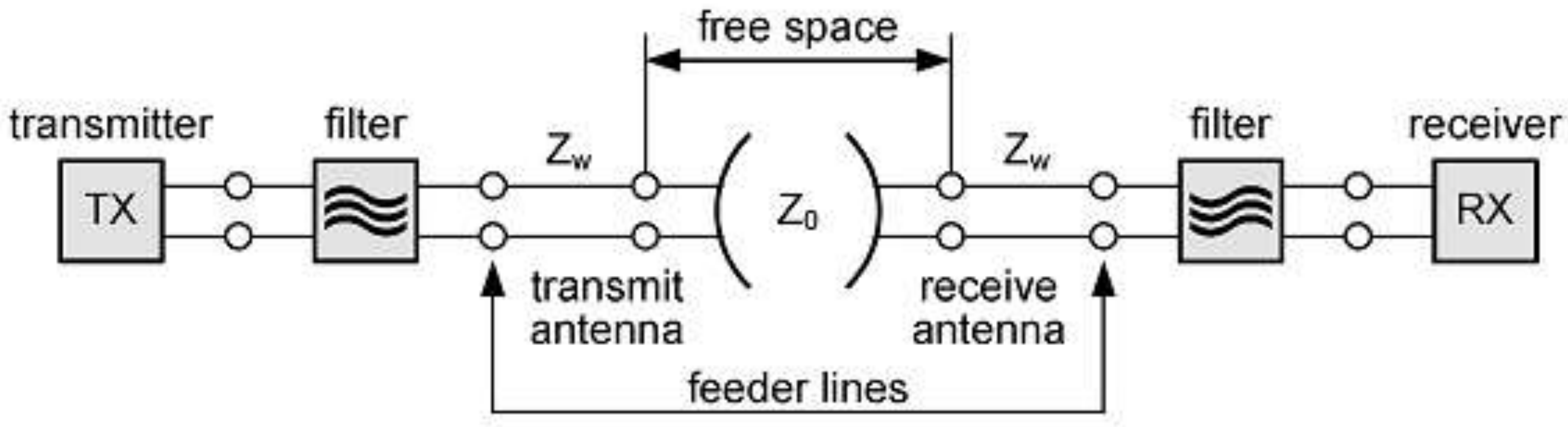


Communication Standard Evolution

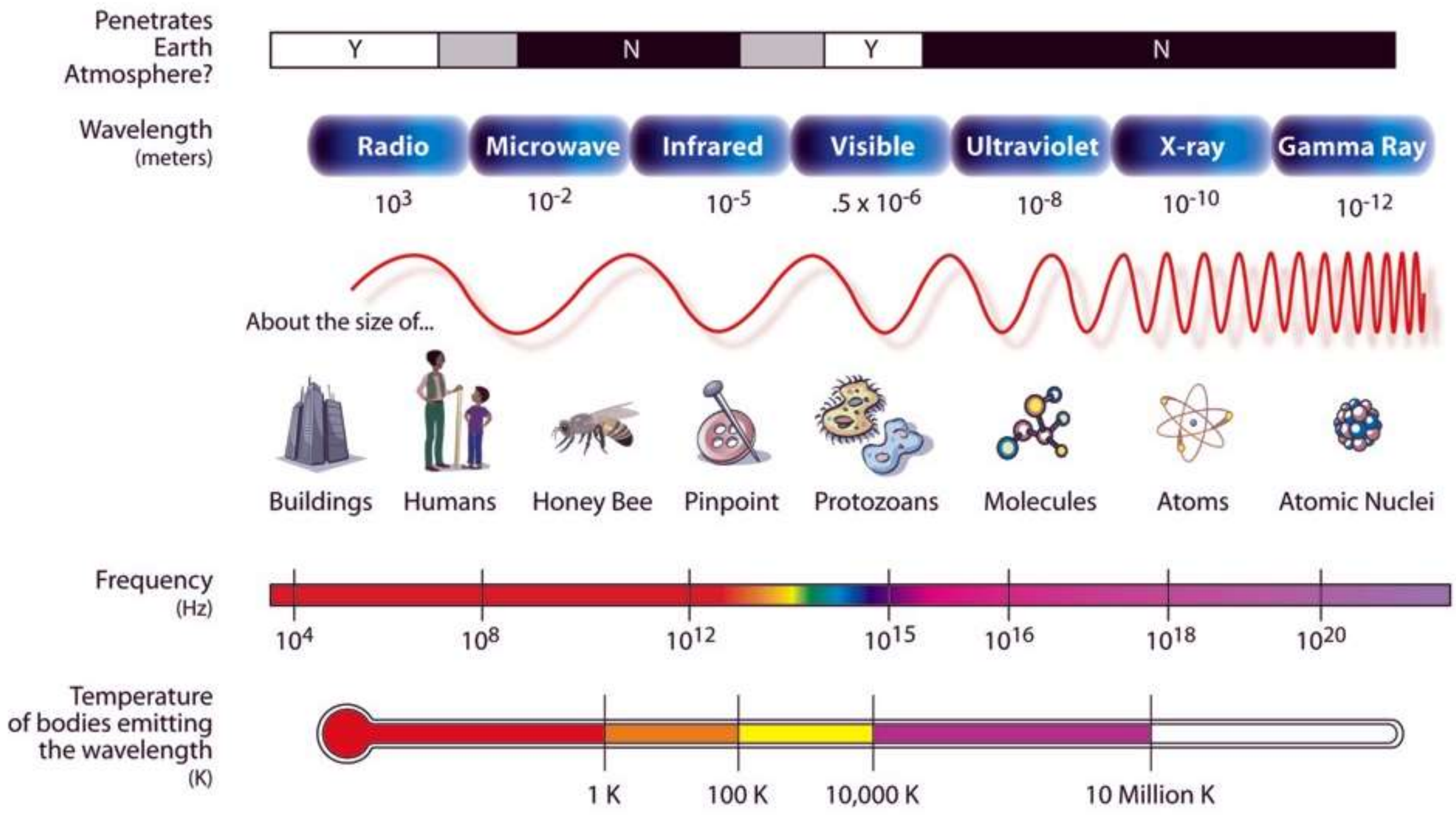


Radio Spectrum

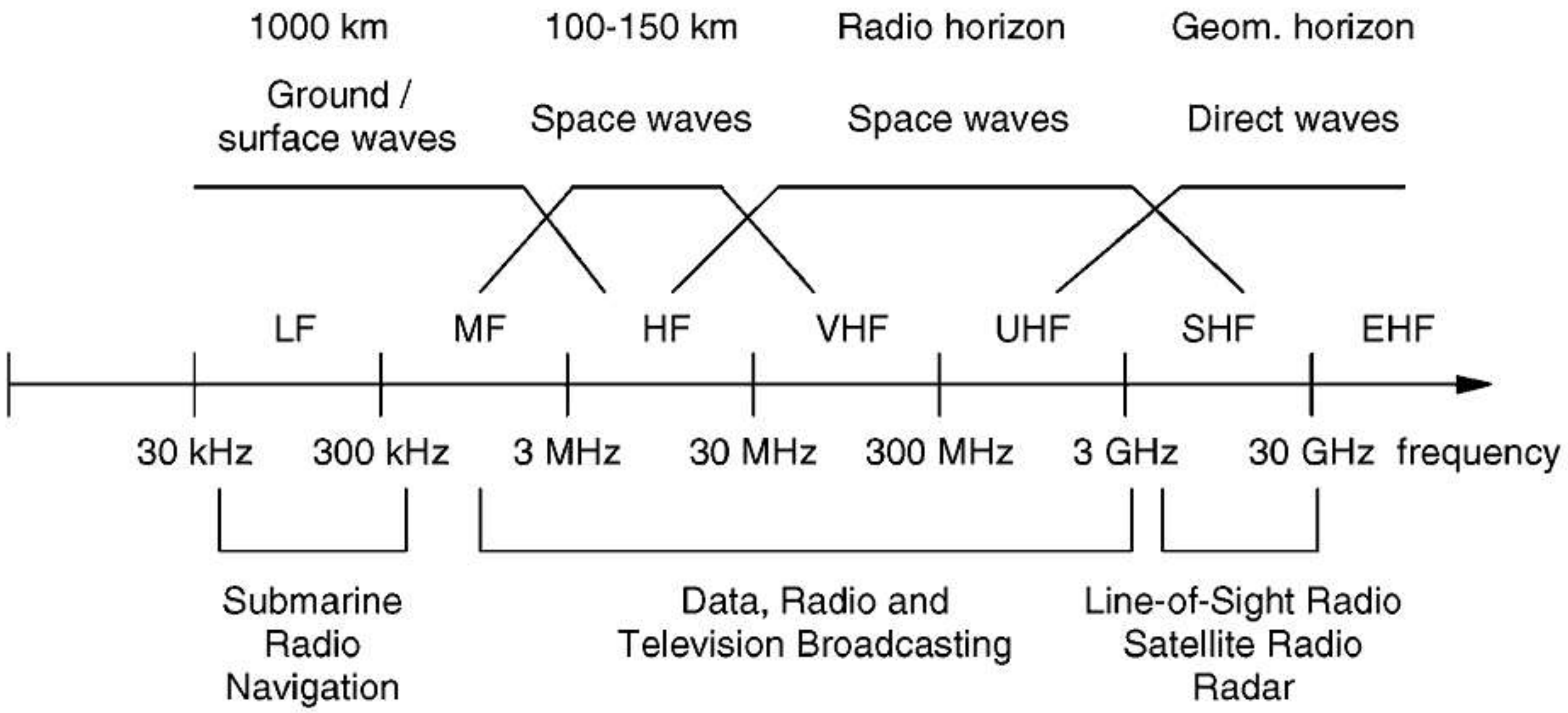
Radio Transmission



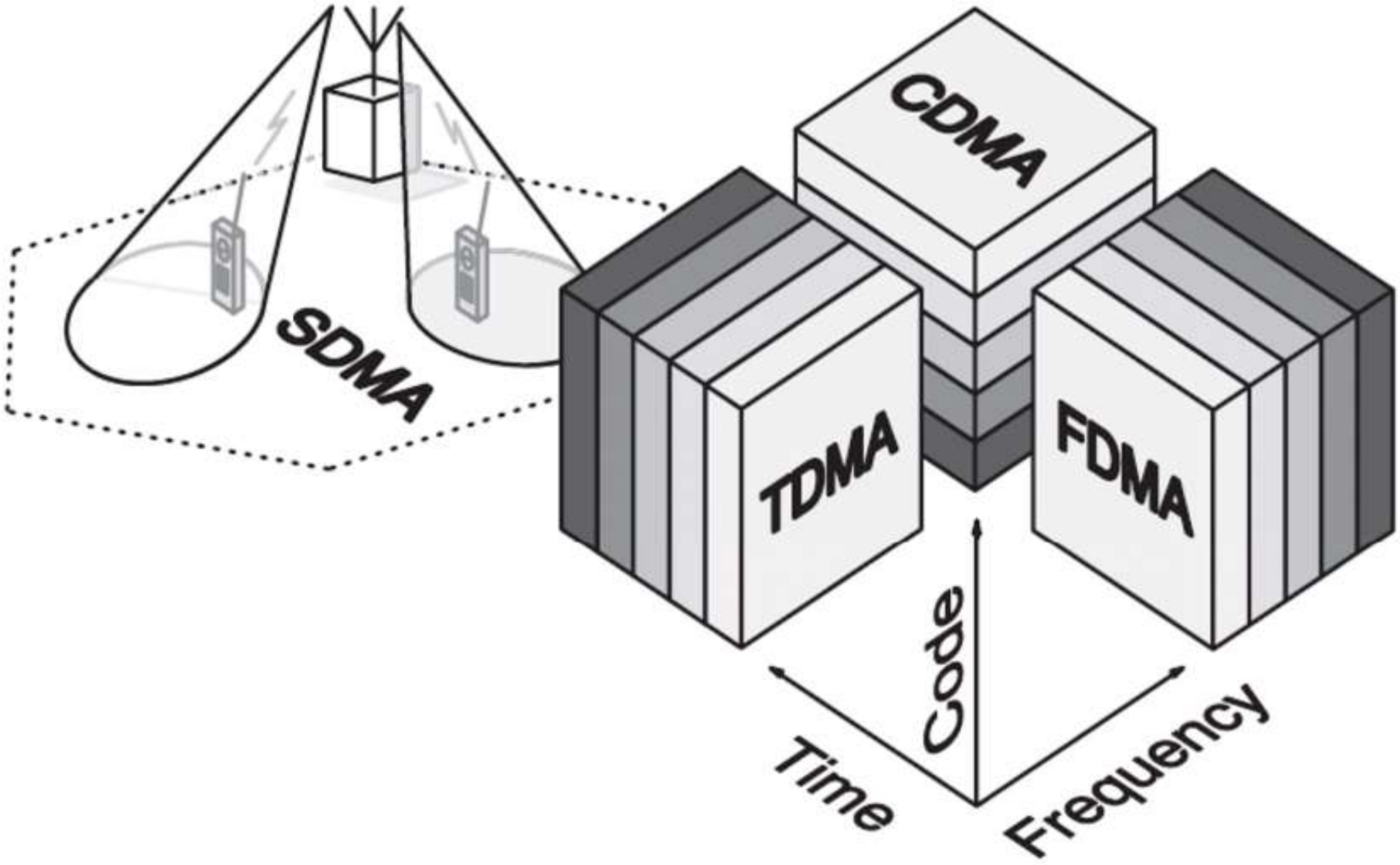
Radio Spectrum



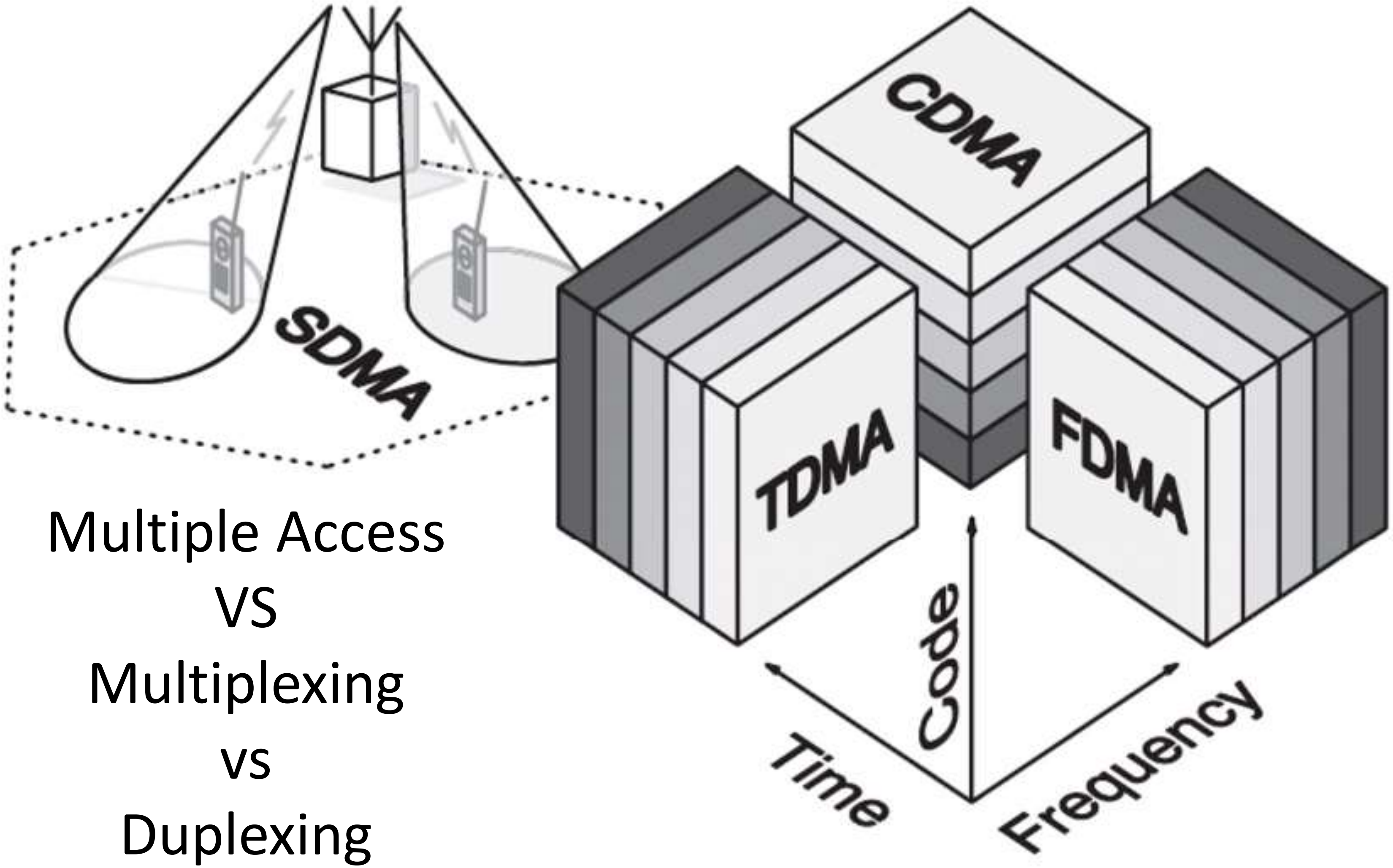
Radio Spectrum



Multi-Access Technology

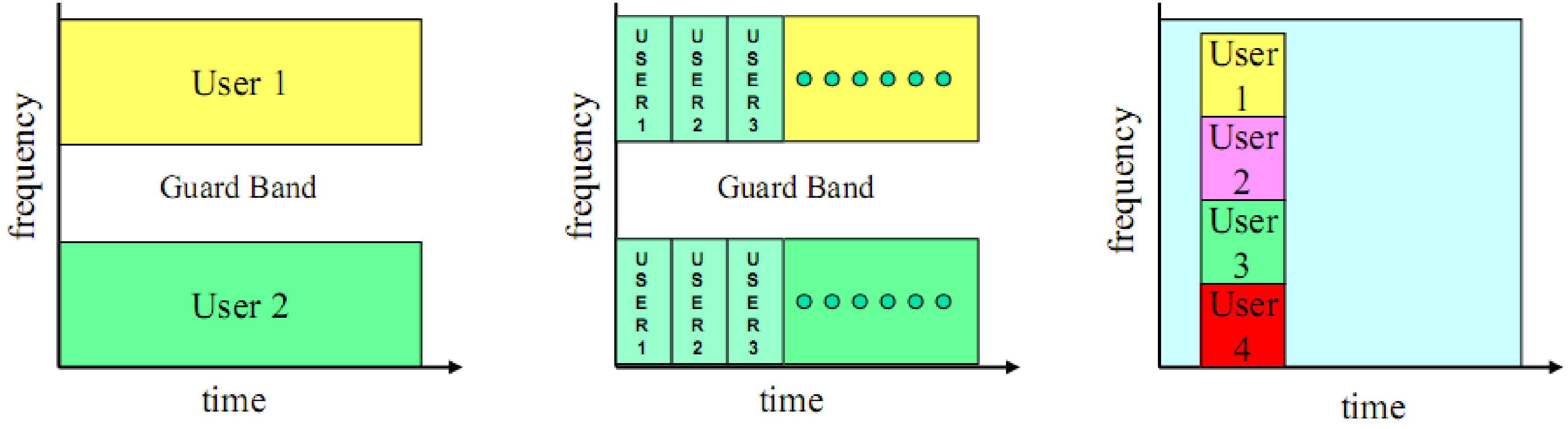


Multi-Access Technology



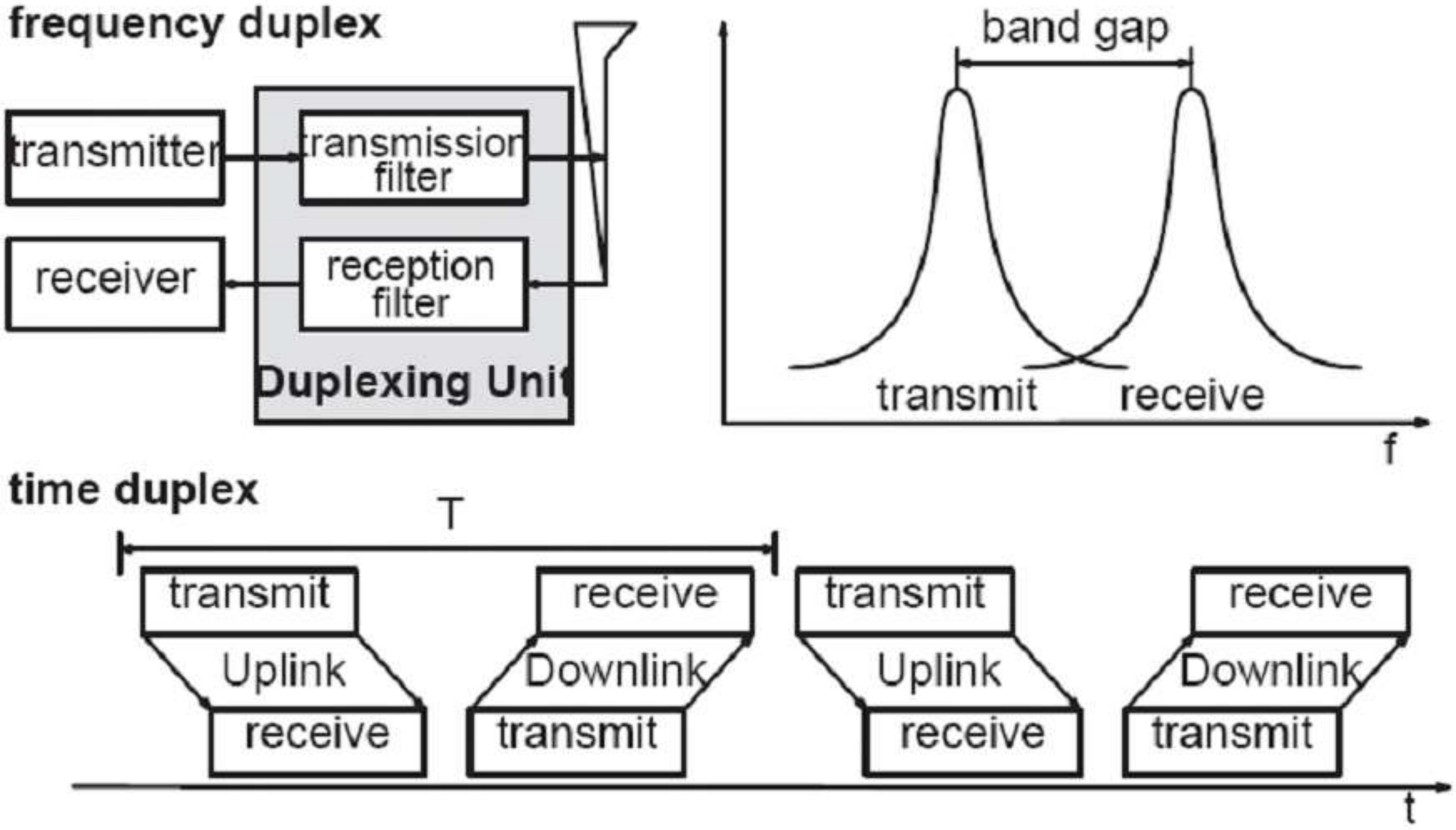
Multiple Access
VS
Multiplexing
vs
Duplexing
?

Multi-Access Technology

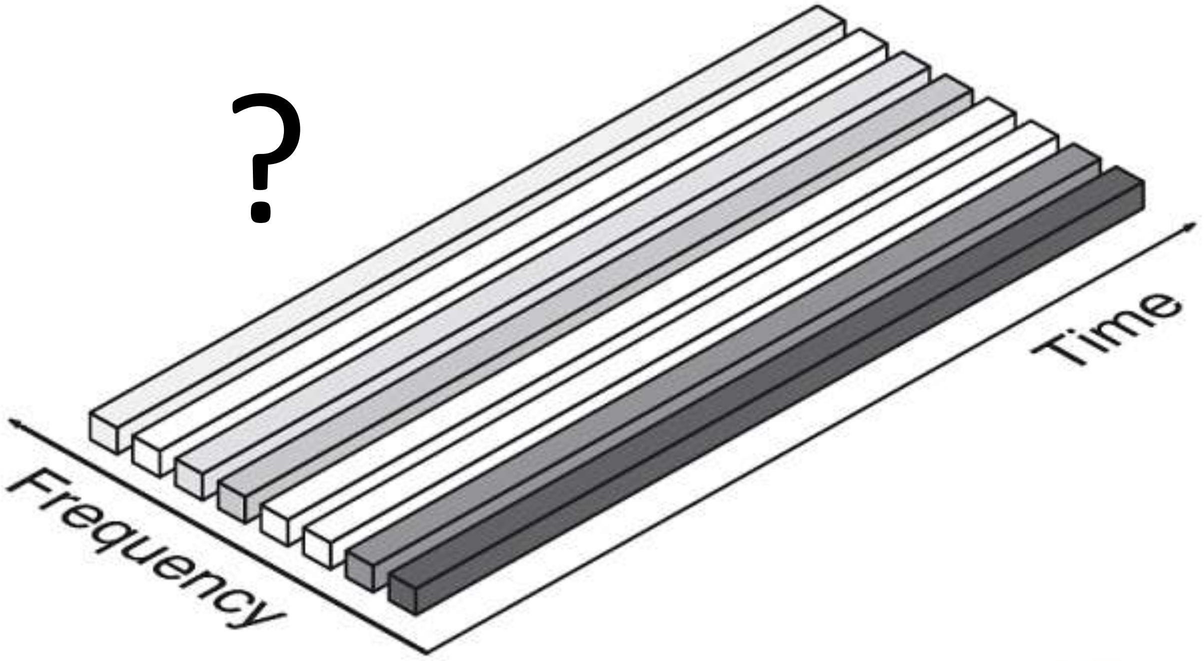


FDMA (example AMPS)	TDMA (example GSM, US IS-136)	CDMA (DS)
Mostly used in 1G	Mostly used in 2G Proposed for 3G	Used in 2G and 3G

Multi-Access Technology

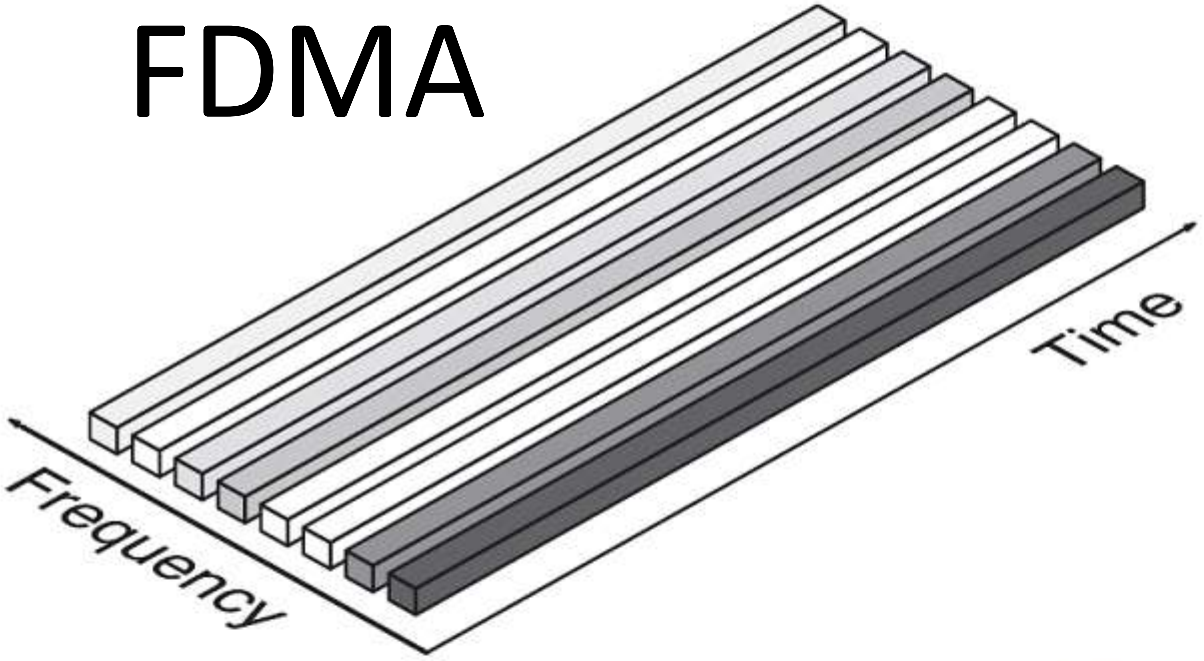


Multi-Access Technology



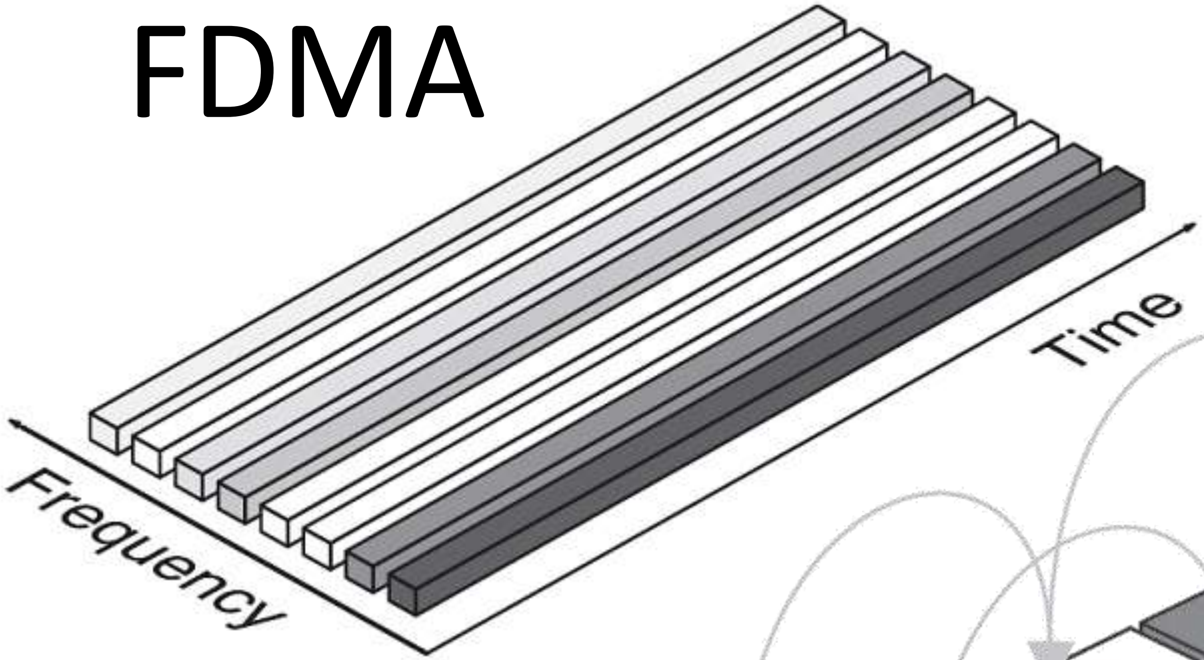
Multi-Access Technology

FDMA

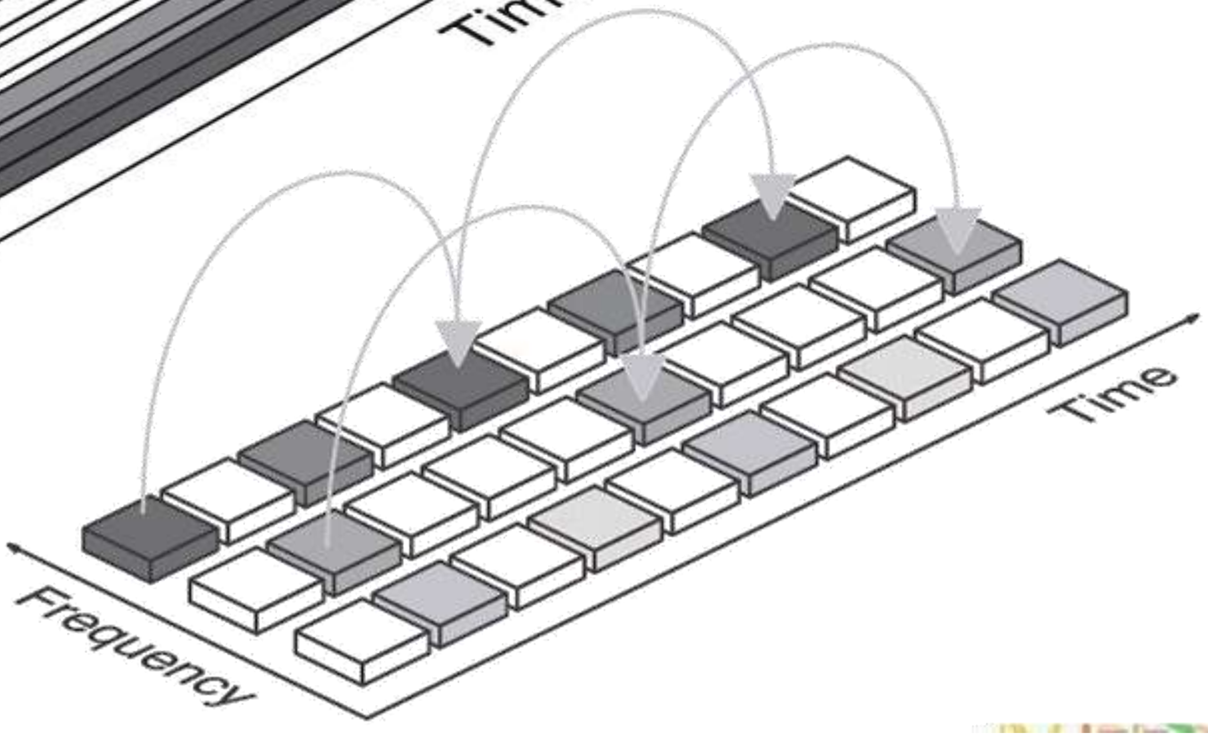


Multi-Access Technology

FDMA

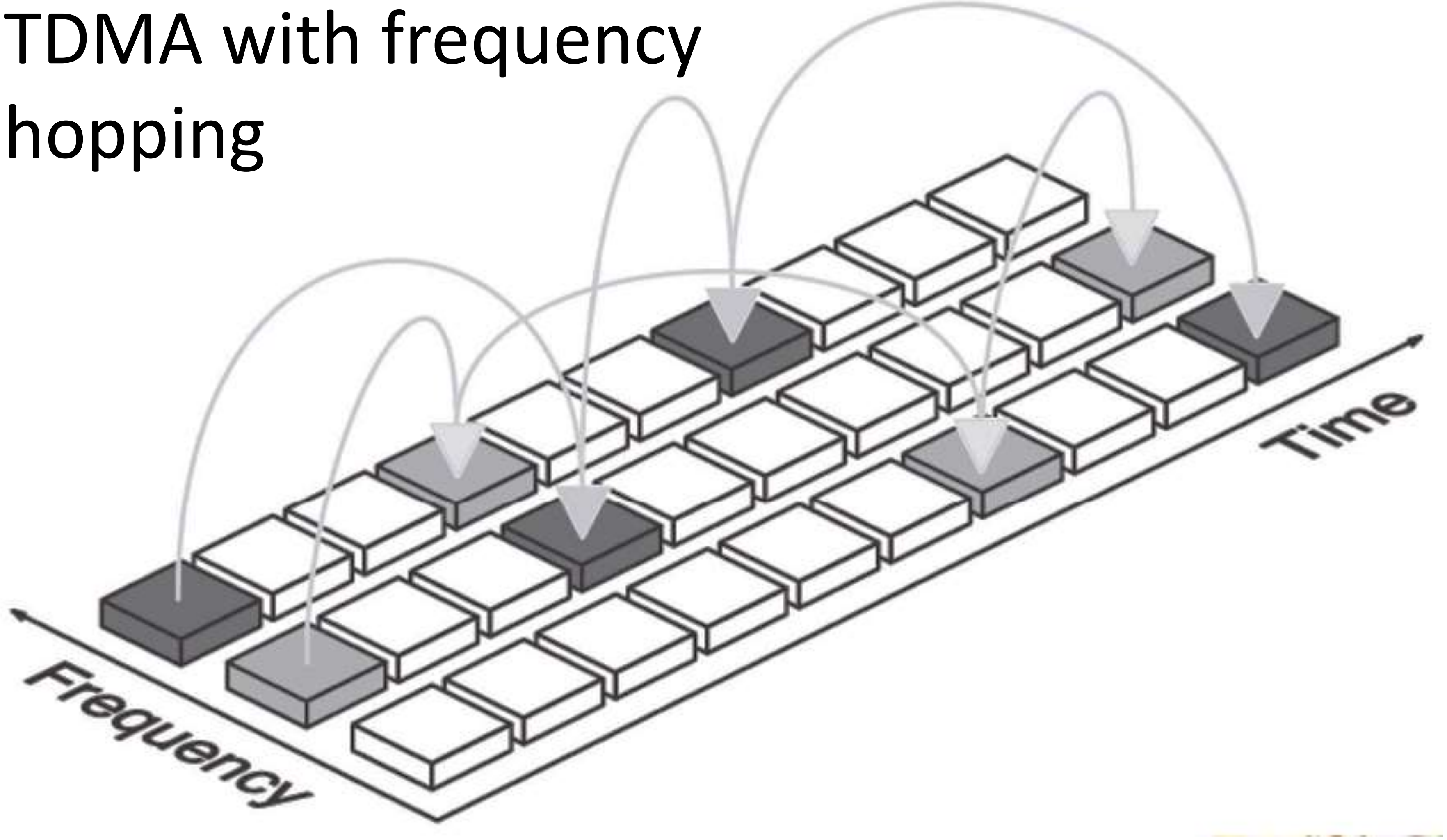


TDMA on multi-carrier freq.



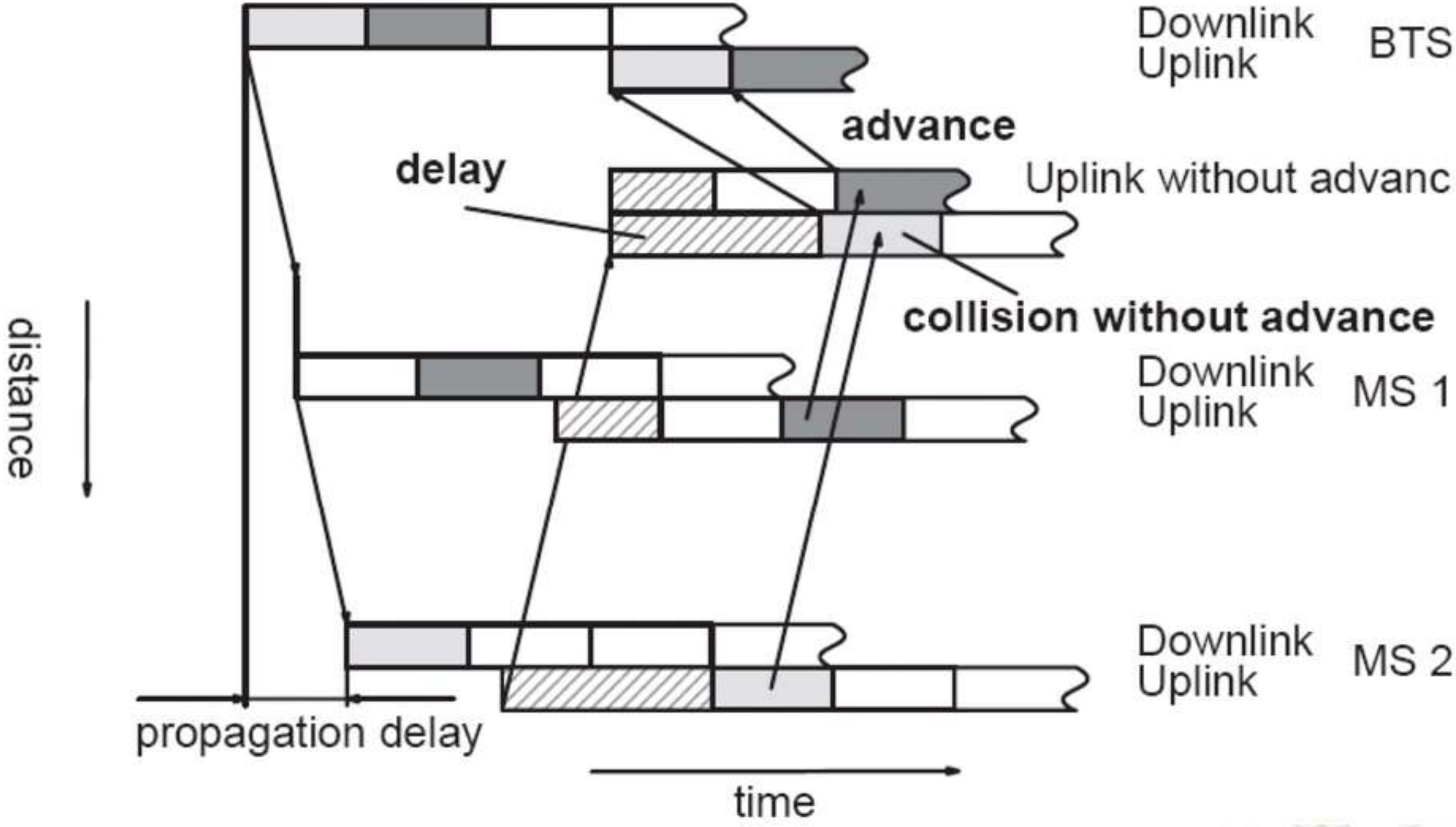
Multi-Access Technology

TDMA with frequency hopping



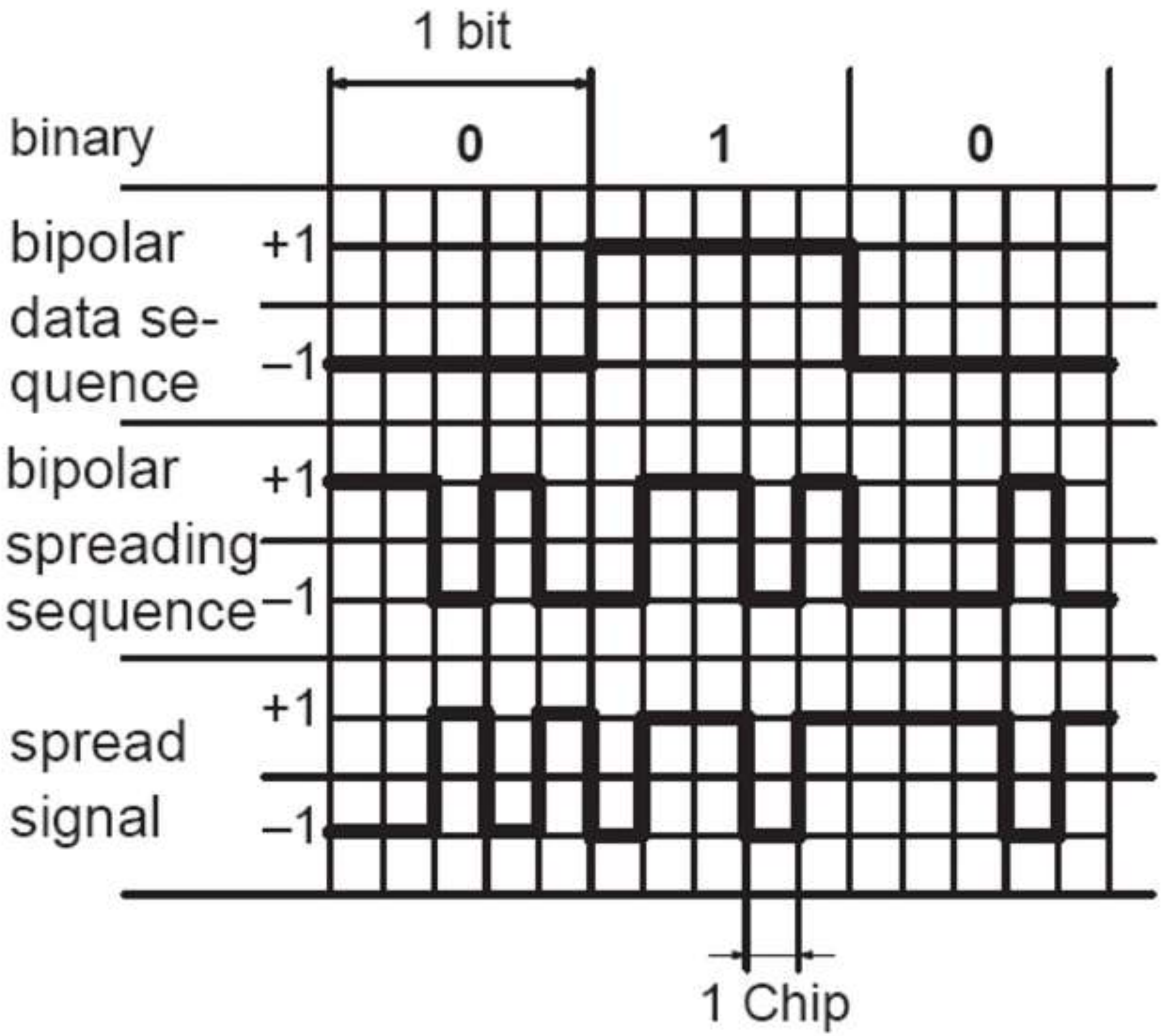
Tricking The Propagation Delay

TDMA



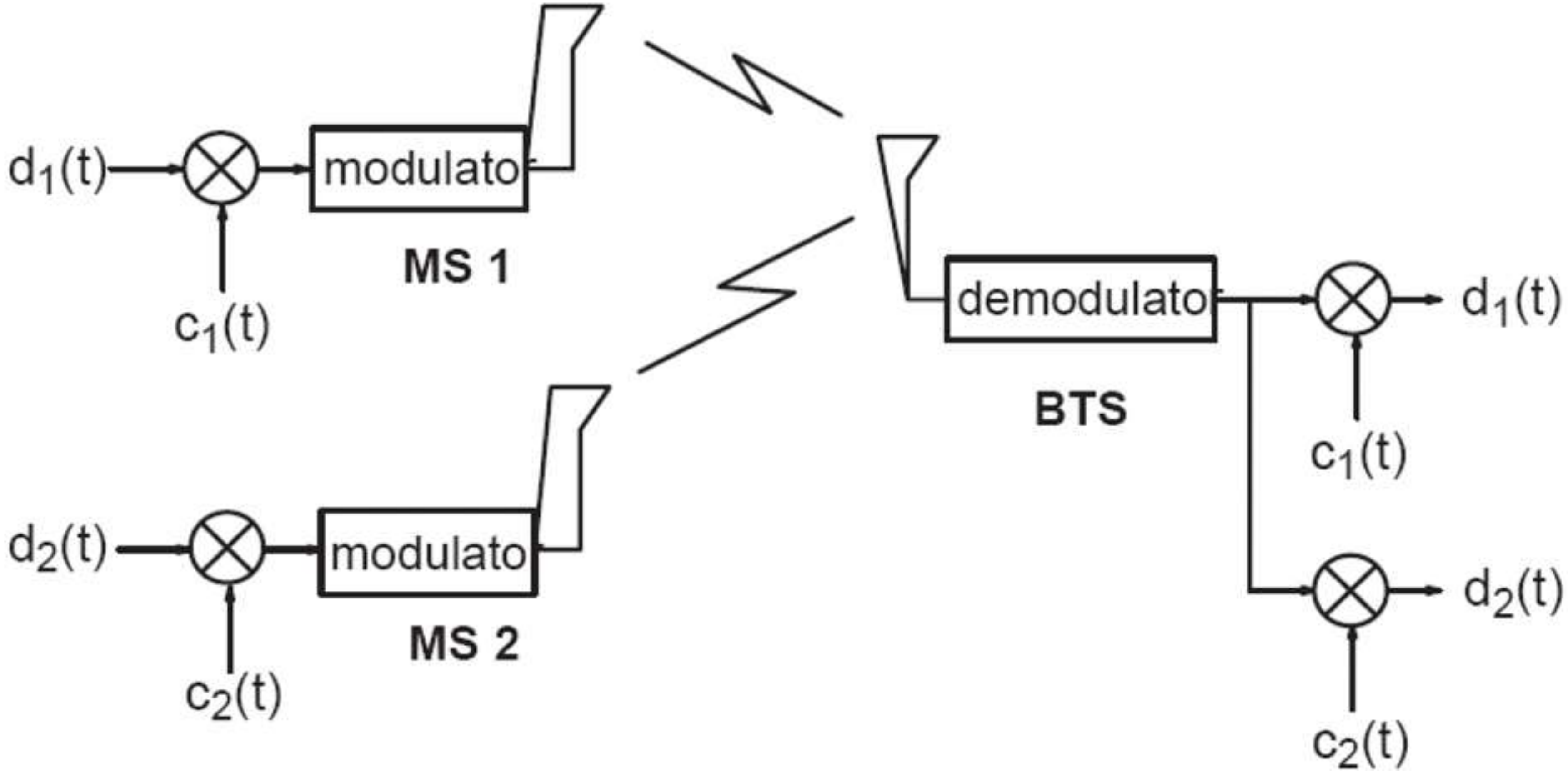
Multi-Access Technology

CDMA



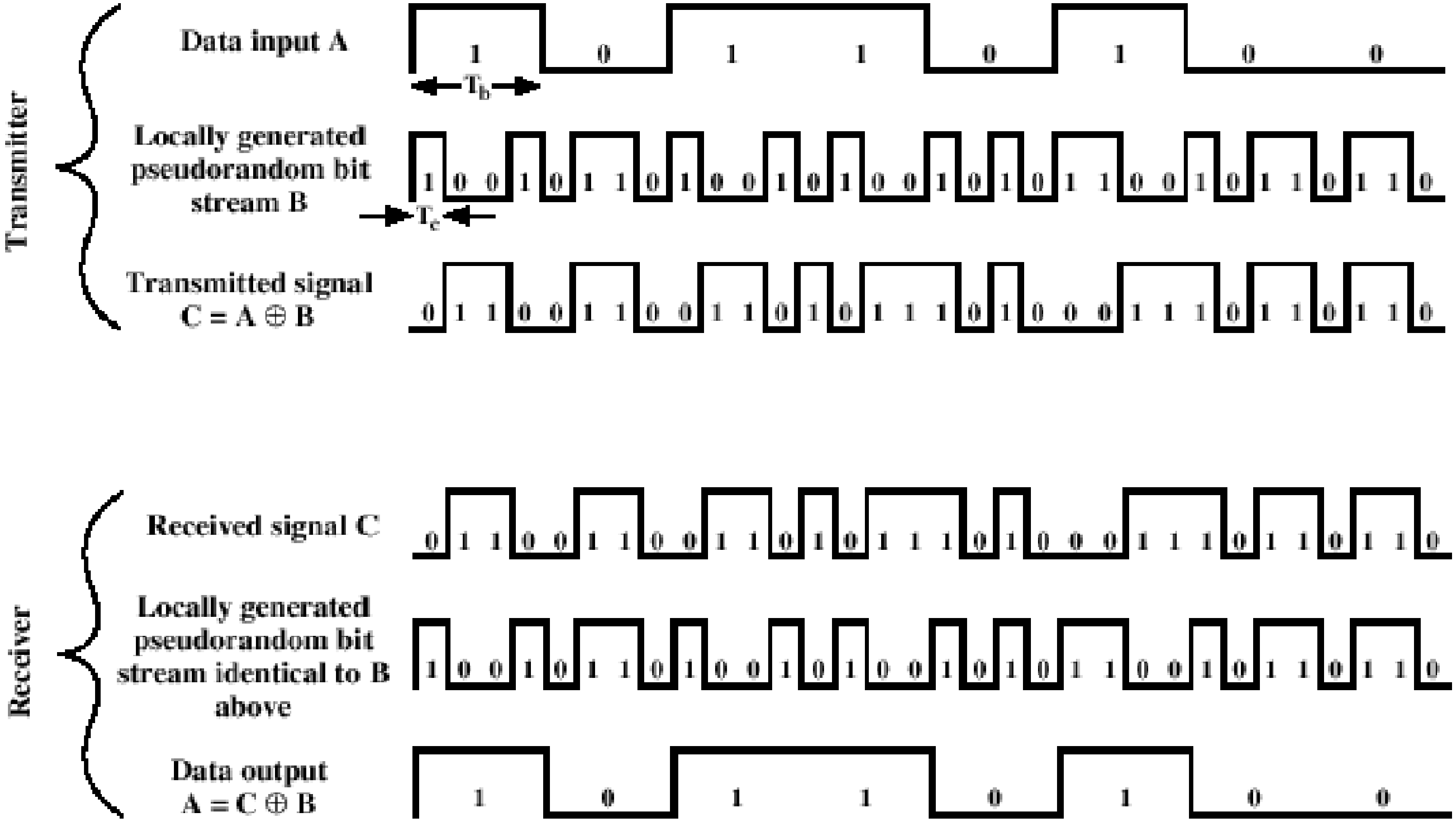
Multi-Access Technology

CDMA

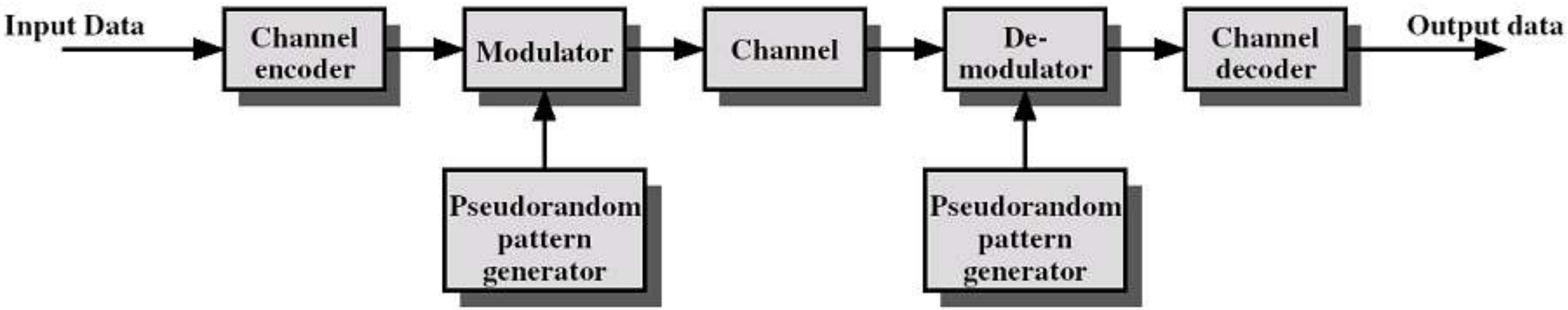


Multi-Access Technology

CDMA

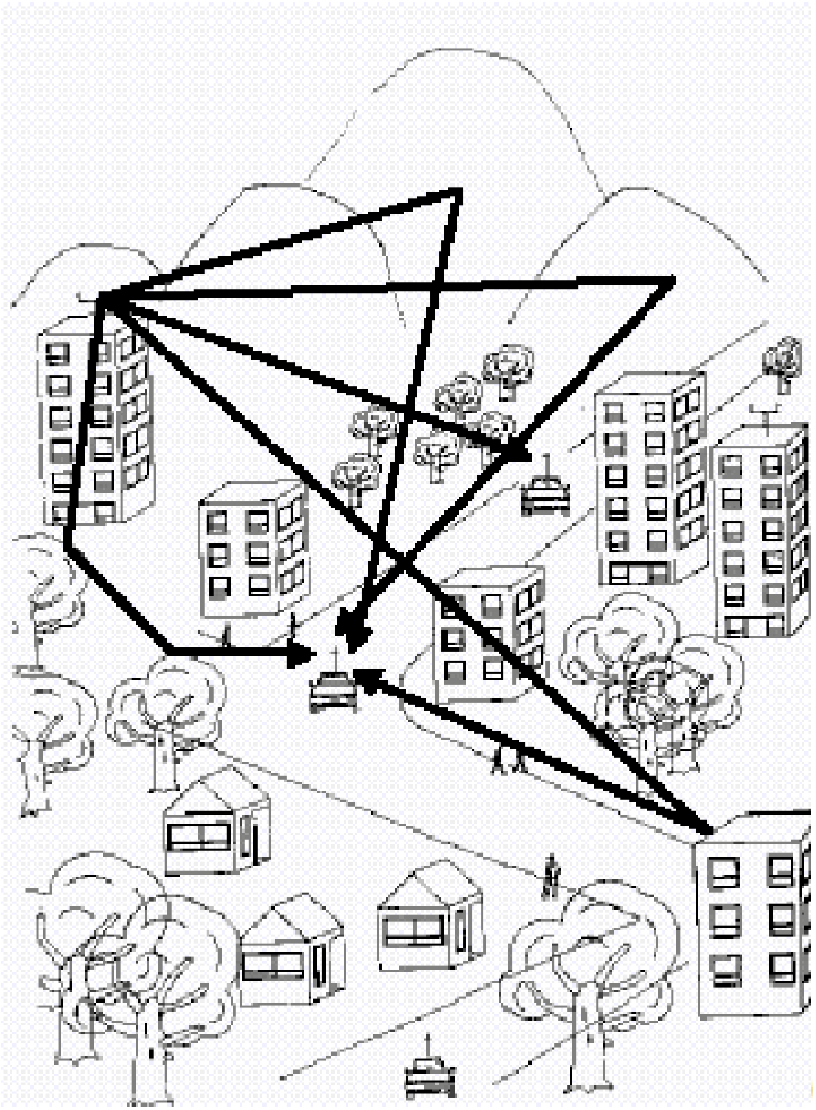


Digital Communication System



- Why digital?
- 2 main steps in converting analog signal to digital signal?

Radio Propagation



CONVENTION OF POWER UNIT

dB, dBm, dBW, dBi

- **decibel** (dB) is a unit of measurement used to express the *ratio* of one magnitude to another on a logarithmic scale.
- **dBm** (sometimes $\mathbf{dB_{mW}}$ or decibel-milliwatts) is *unit of level* used to indicate that a power ratio is expressed in decibels (dB) with reference to one milliwatt (mW).
- **dBW** is like dBm but the reference is one watt.
- **dBi** is a measure of *gain*, referenced to isotropic antenna.

dBm

The power in decibel-milliwatts ($P_{(dBm)}$) is equal to 10 times base 10 logarithm of the power in milliwatts ($P_{(mW)}$):

$$P_{(dBm)} = 10 \cdot \log_{10}(P_{(mW)} \;/\; 1mW)$$

The power in milliwatts ($P_{(mW)}$) is equal to 1mW times 10 raised by the power in decibel-milliwatts ($P_{(dBm)}$) divided by 10:

$$P_{(mW)} = 1mW \cdot 10^{(P_{(dBm)} \;/\; 10)}$$

1 milliwatt is equal to 0 dBm:

$$1mW = 0dBm$$

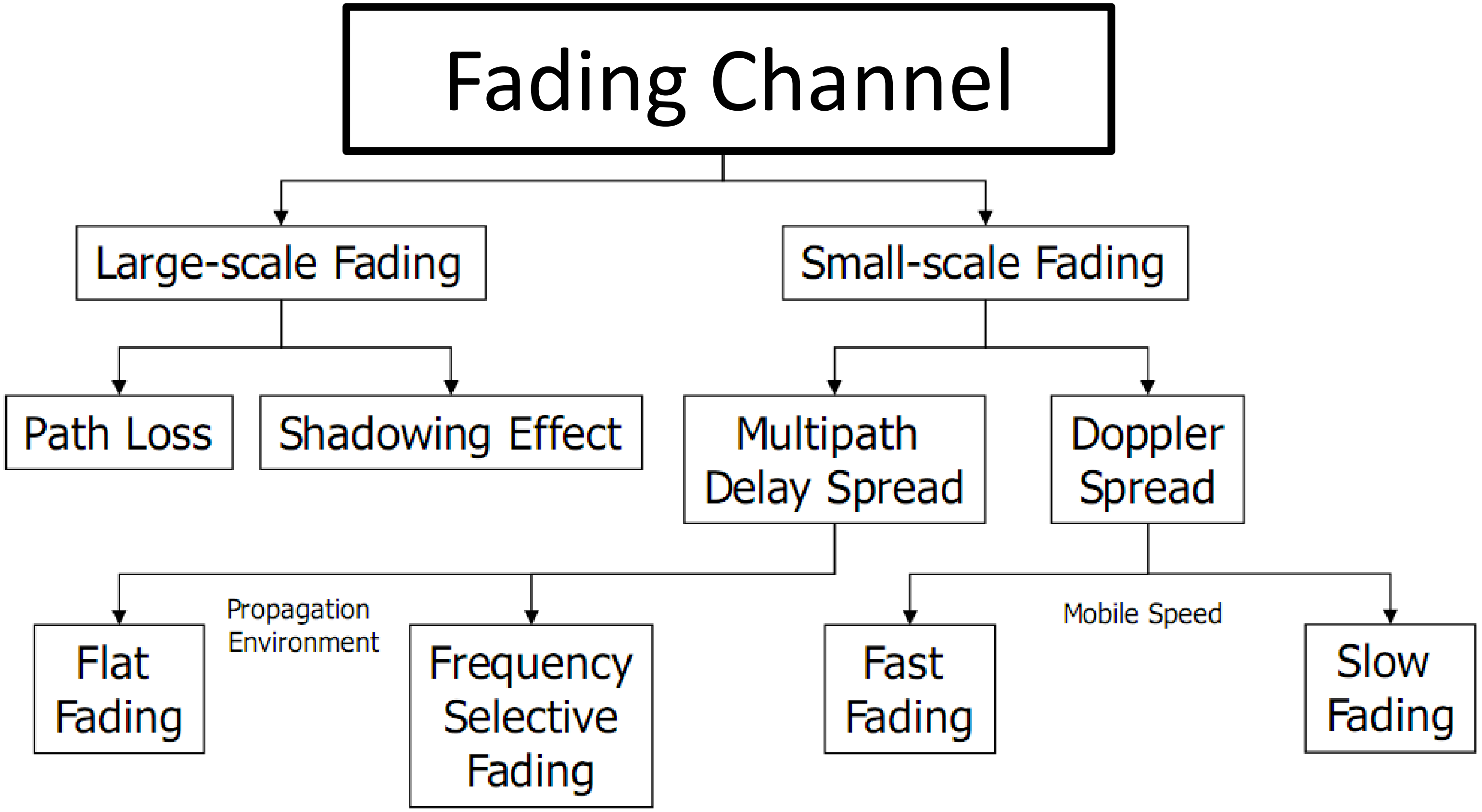
1 watt is equal to 30dBm:

$$1W = 1000mW = 30dBm$$

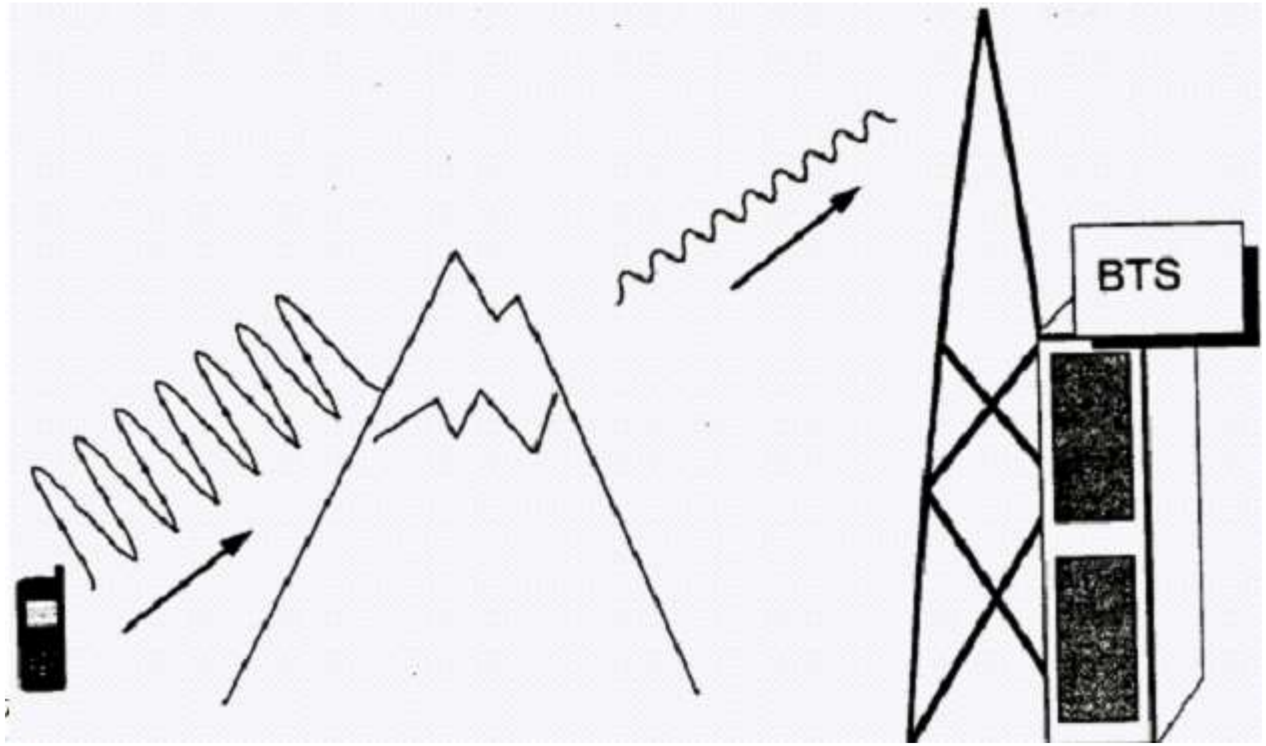
Wireless Communication Environment

- Time-varying transmission channel
- Path loss/shadowing
- Multipath fading
- Doppler effect
- Propagation delay
- Security issue

Radio Propagation



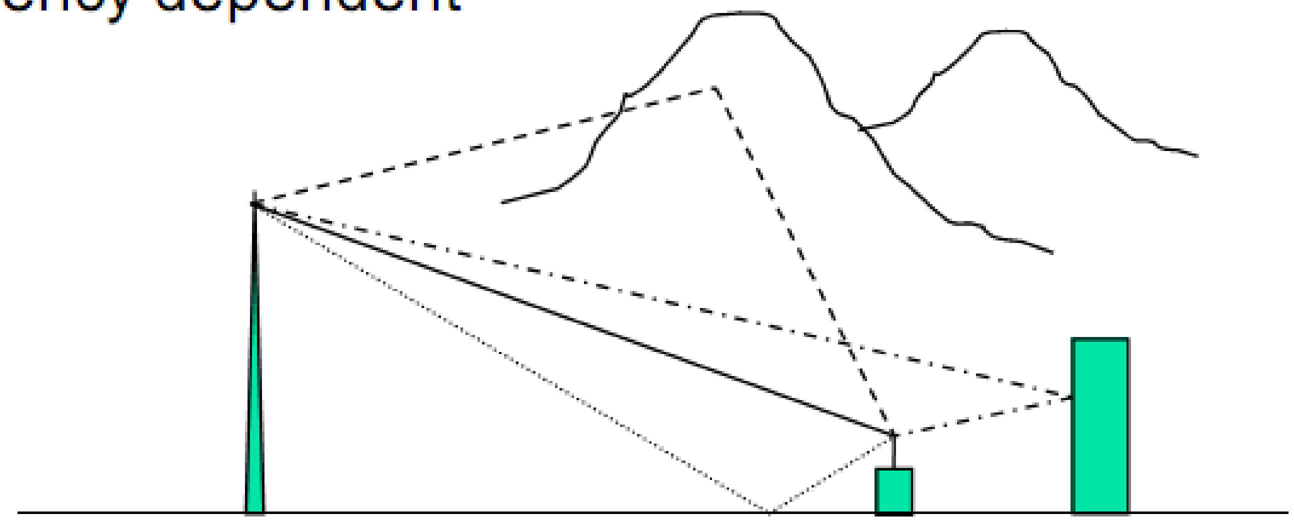
Path Loss & Shadowing



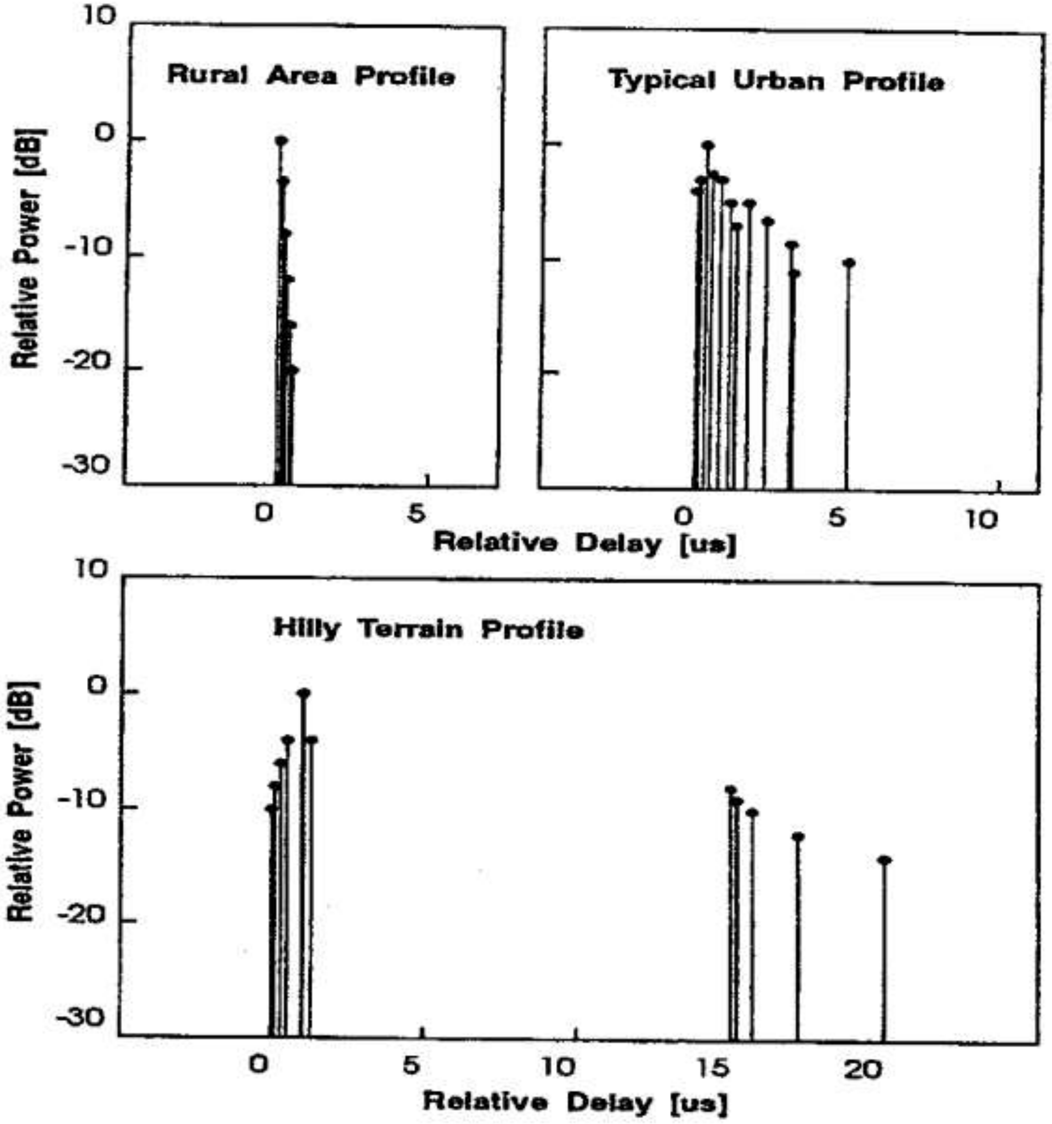
→ Adjust transmitter power or receiver gain

Multipath Fading

- The result of multipath propagation
- Constructive and destructive interference
- Location dependent
- Time dependent
- Frequency dependent

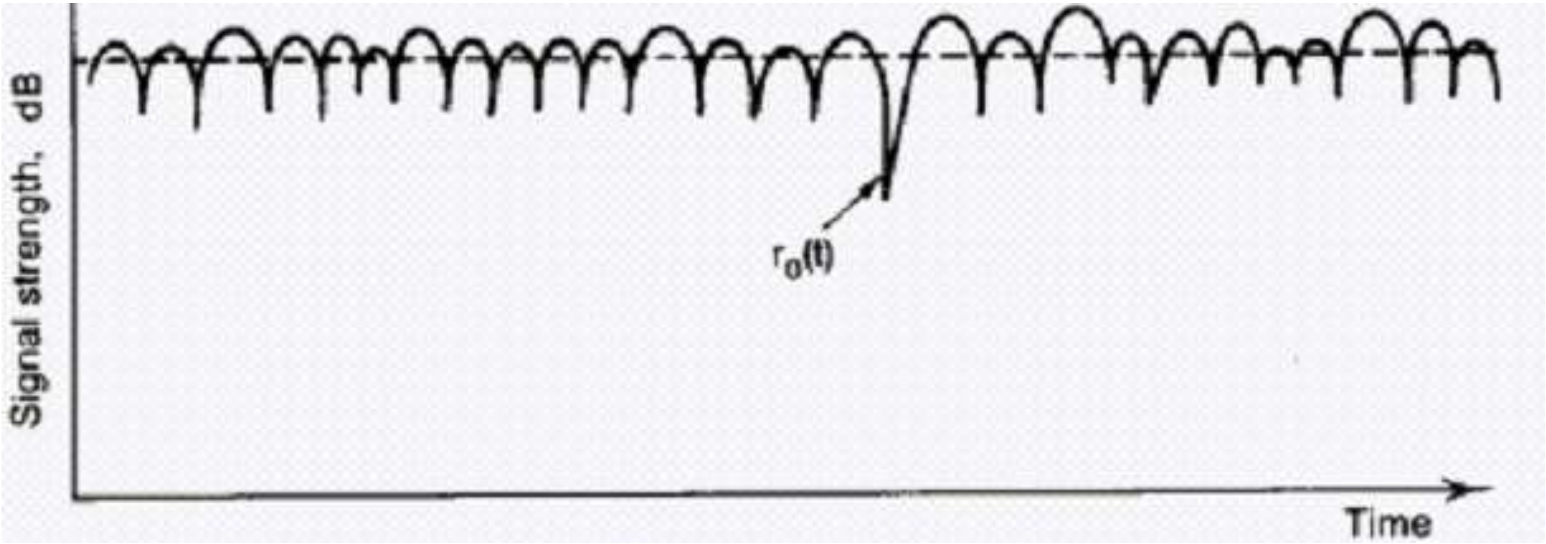


Multi-path Propagation



Multipath Fading

Received signal



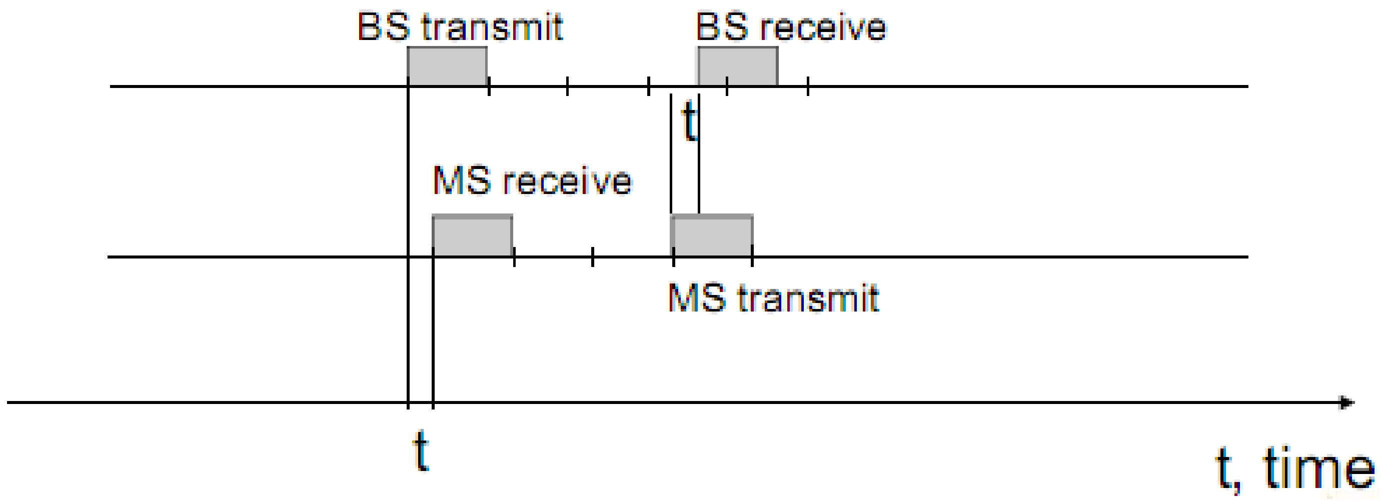
Doppler Effect

- MS movement
- Environmental change
- Fast fading
- Slow fading

Propagation Delay

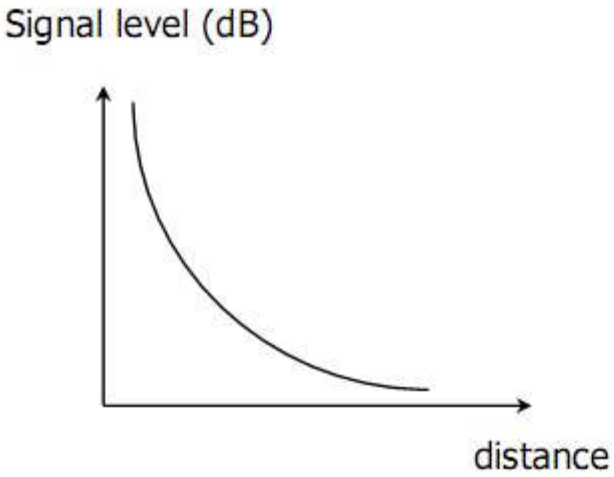
- How BS & MS can have synchronized clock?

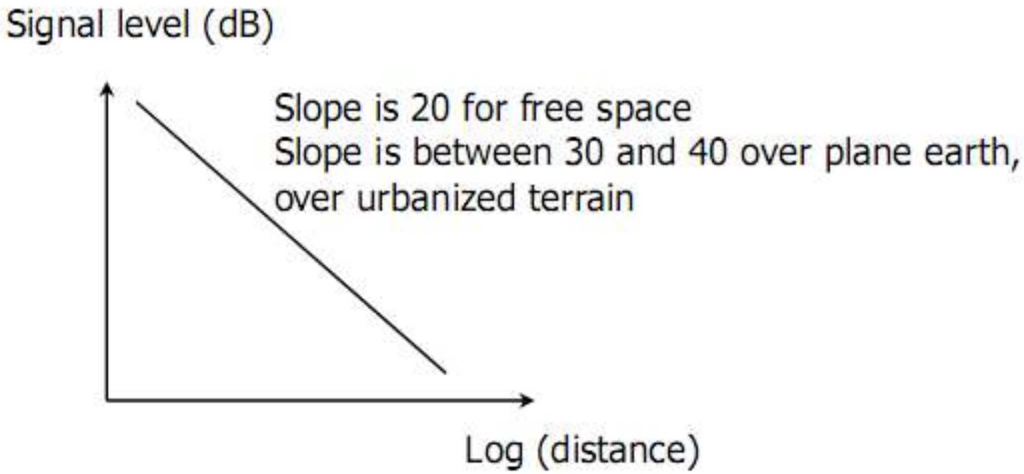
  - Timing advance: BS timing is respected



Path Loss

- Path attenuation is usually proportional to the logarithm of the mobile to base station distance (if there is no terrain obstacles)



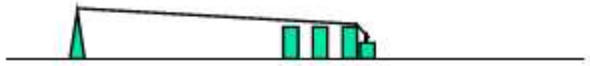


Path Loss

Radio propagation scenarios

No reflections or obstructions -
free space, slope=20

Ground reflection and line of sight -
plane earth, slope=40



Diffraction over many building tops -
multi-screen diffraction, slope=38

Path Loss

- For other environments (suburban, rural-quasi-open), the path loss per decade remains the same, but the unit loss is reduced by a certain amount.
- The smaller the cells, the more important are the details of e.g. the building structure within the cell.

Path Loss

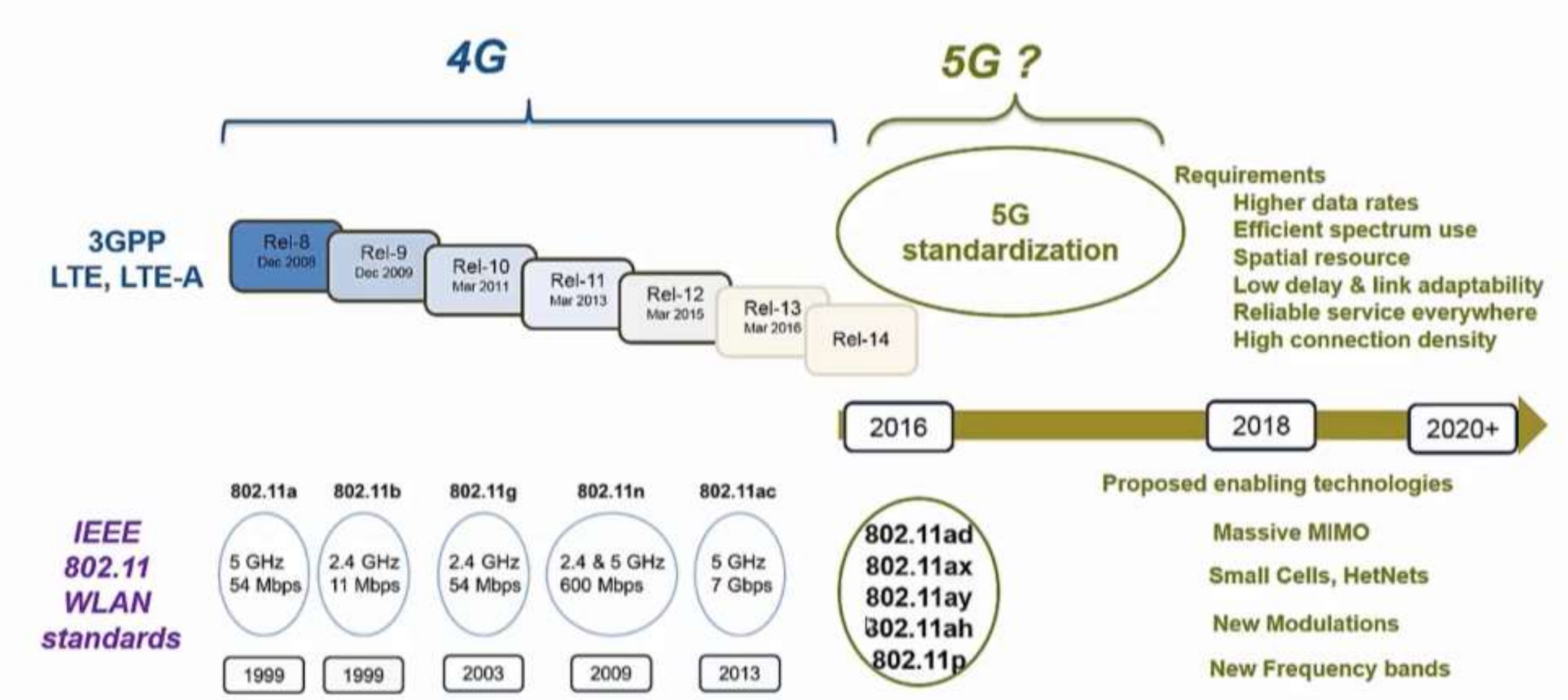
Free space propagation rarely occurs in reality, due to:

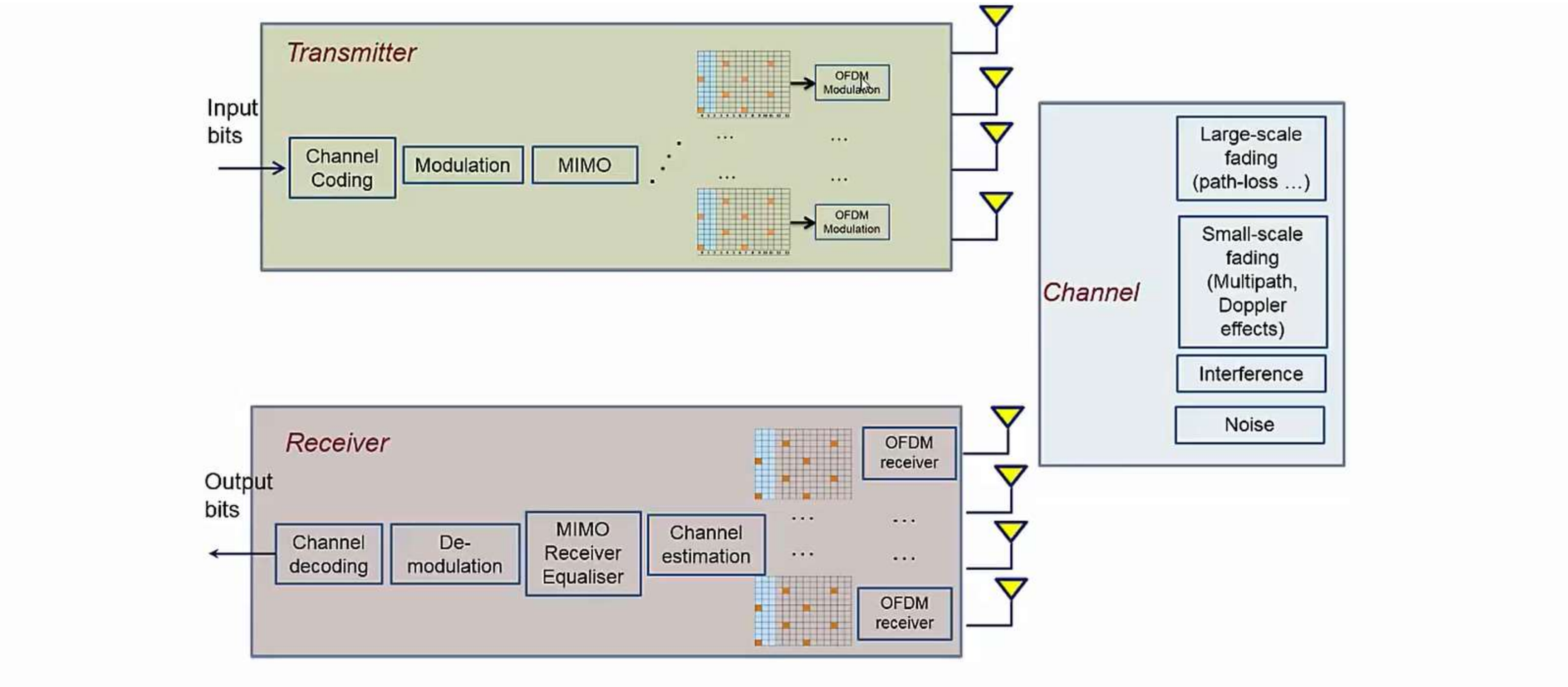
- Obstructions in the propagation path.
  - This is particularly frequent in the case of mobile propagation because of the low height of the mobile antenna.
- Obstructions in the first Fresnel zone.
  - Since the mobile station is so low, the first Fresnel zone is almost always interrupted by the ground, even if line of sight conditions apply.
- Reflections from the ground and other objects.
  - Reflections combine in and out of phase to vary the signal received.

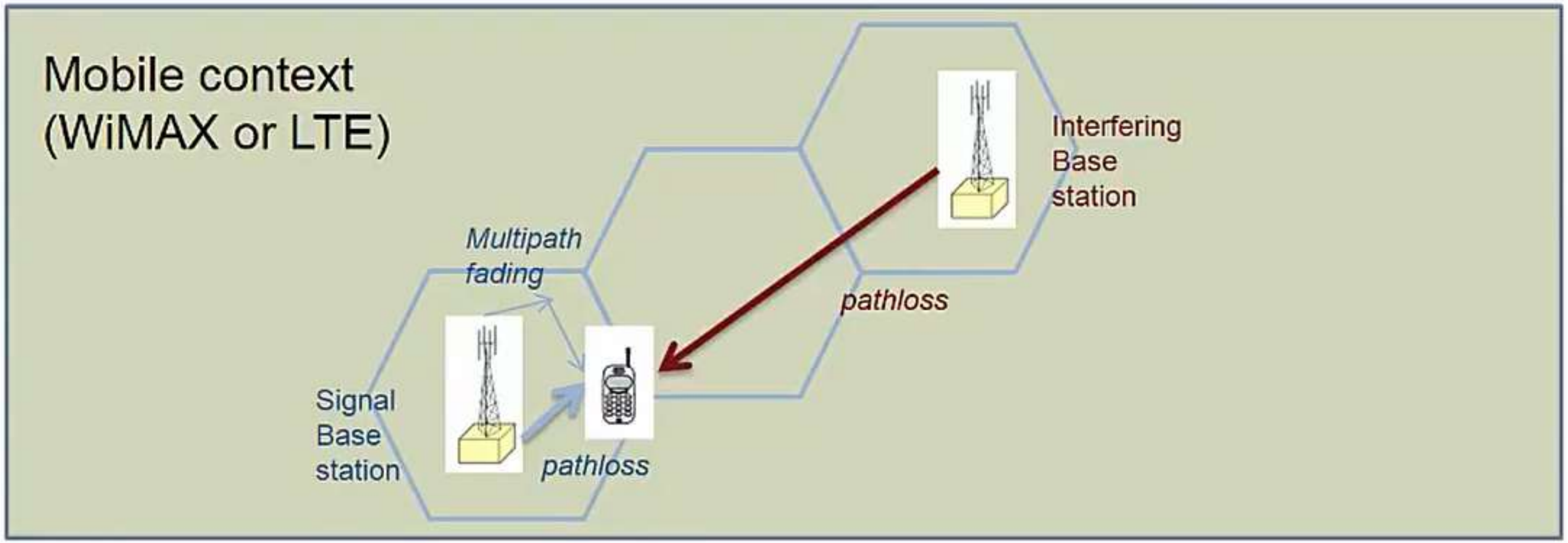
Security

Security issue

- Preventing eavesdropping
- User authentication
- Data encryption

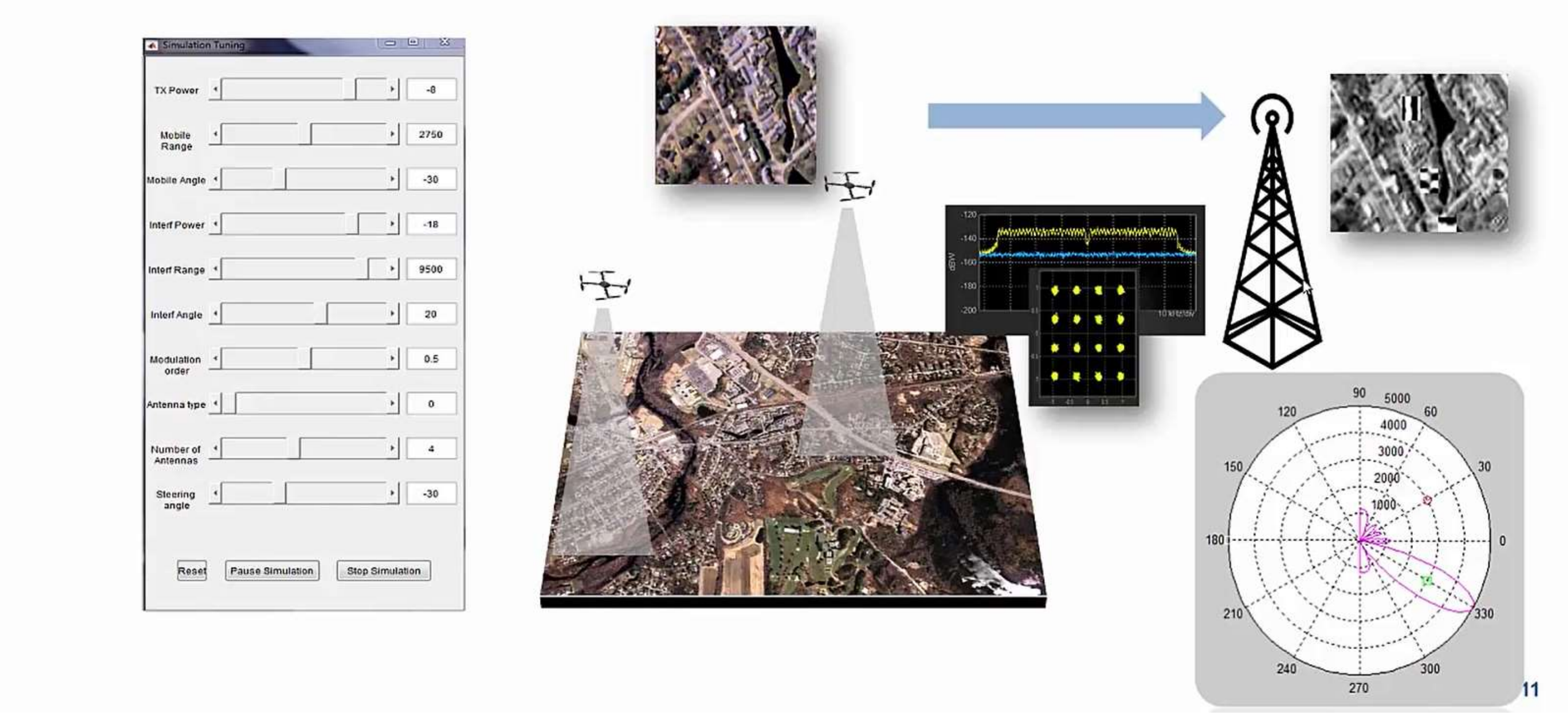

4G
5G ?
3GPP
LTE, LTE-A
Rel-8
Dec 2008
Rel-9
Dec 2009
Rel-10
Mar 2011
Rel-11
Mar 2013
Rel-12
Mar 2015
Rel-13
Mar 2016
Rel-14
5G
standardization
Requirements
Higher data rates
Efficient spectrum use
Spatial resource
Low delay & link adaptability
Reliable service everywhere
High connection density
2016
2018
2020+
Proposed enabling technologies
Massive MIMO
Small Cells, HetNets
New Modulations
New Frequency bands
IEEE
802.11
WLAN
standards
802.11a
5 GHz
54 Mbps
1999
802.11b
2.4 GHz
11 Mbps
1999
802.11g
2.4 GHz
54 Mbps
2003
802.11n
2.4 & 5 GHz
600 Mbps
2009
802.11ac
5 GHz
7 Gbps
2013
802.11ad
802.11ax
802.11ay
802.11ah
802.11p


Transmitter
Input bits
Channel Coding
Modulation
MIMO
OFDM Modulation
OFDM Modulation
Channel
Large-scale fading (path-loss …)
Small-scale fading (Multipath, Doppler effects)
Interference
Noise
Receiver
Output bits
Channel decoding
De-modulation
MIMO Receiver Equaliser
Channel estimation
OFDM receiver
OFDM receiver


Mobile context
(WiMAX or LTE)
Interfering
Base
station
Multipath
fading
pathloss
Signal
Base
station
pathloss

Challenge in designing wireless communication system

- Performance evaluation with realistic channel models
- Transceiver system responding to dynamic channel conditions
- Evaluating the combined effects of
  - Fading channels
  - Interfering signals
  - Non-linearity of front-end receivers
  - Phase noise, Frequency offset, Timing mismatch, IQ imbalance
  - Channel estimation & Equalization
  - Antenna arrays & directional propagation
  - Beamforming & beam steering
  - …


Simulation Tuning
TX Power
-8
Mobile Range
2750
Mobile Angle
-30
Interf Power
-18
Interf Range
9500
Interf Angle
20
Modulation order
0.5
Antenna type
0
Number of Antennas
4
Steering angle
-30
Reset
Pause Simulation
Stop Simulation
90
120
60
150
30
180
0
210
330
240
300
270
5000
4000
3000
2000
1000

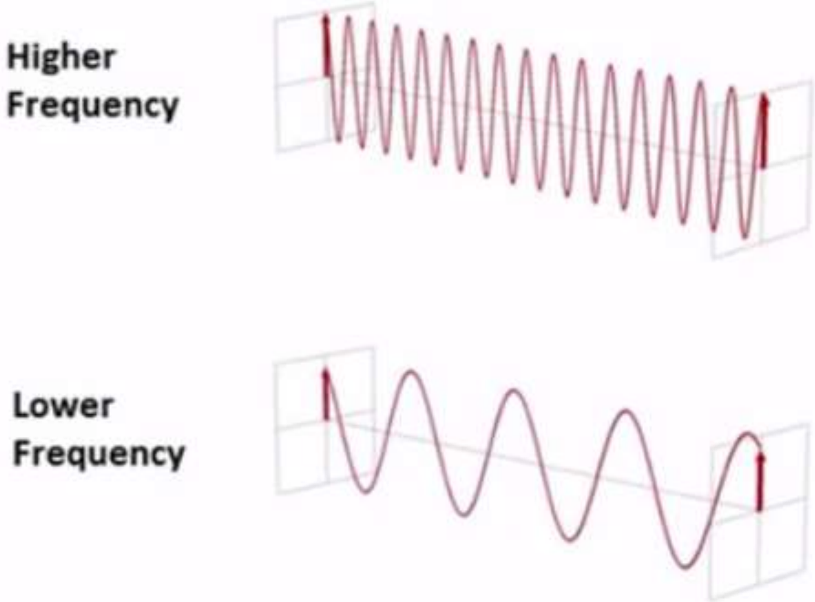

Chanalyzer
File View Wi-Spy Wi-Fi CleanAir® Report Builder Tools Help
Register
Buy
Wi-Spy DBx
TIMESPAN 5:37
Full 2.4 GHz Band
Edimax AC1200 Wireless LAN USB Adapter
Learn
Interferers
Channels Table
Physical
FILTERS
MAC Address
ESSID
AP Alias
Channels
FLUKE networks.
AirMagnet Spectrum Adapter
wi-spy DBx

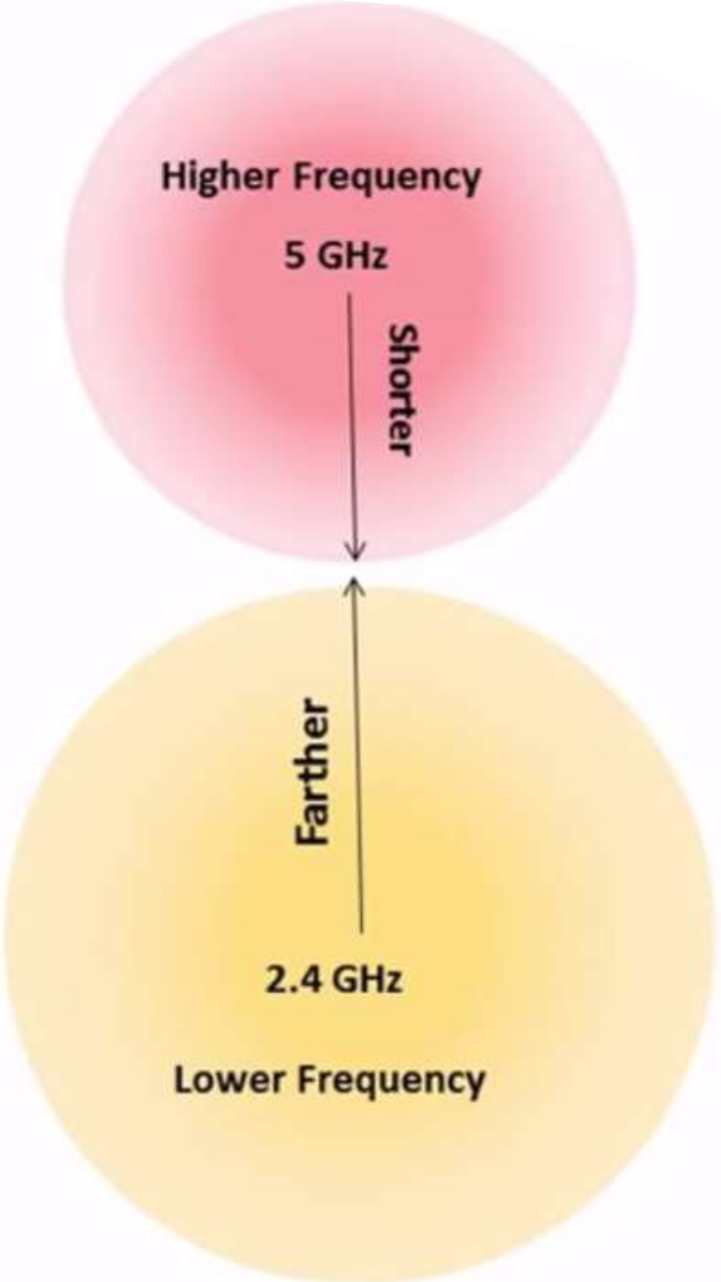
SOME BASICS IN WIRELESS COMMUNICATION SYSTEM

Frequencies

Frequency: How often an RF wave cycles per second.

Examples:
- 20 Hz = 20 cycles/second
- 900 MHz = 900 million cycles/second
- 2.4 GHz = 2.4 billion cycles/second





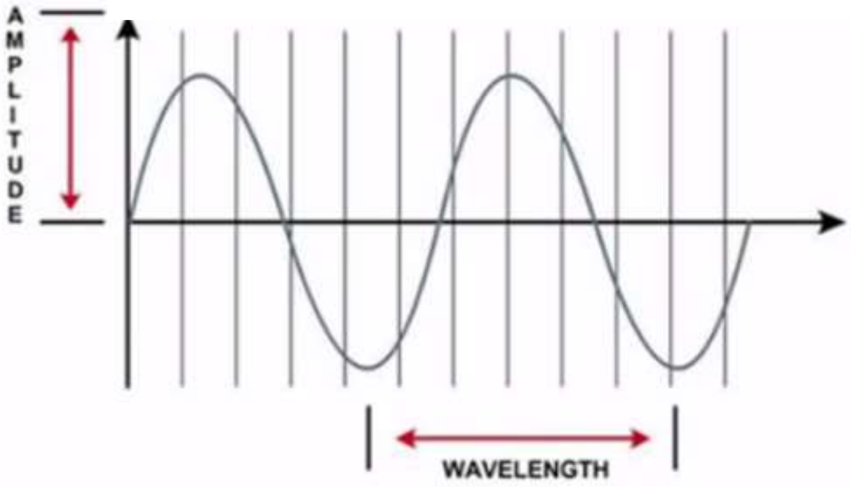
Waves

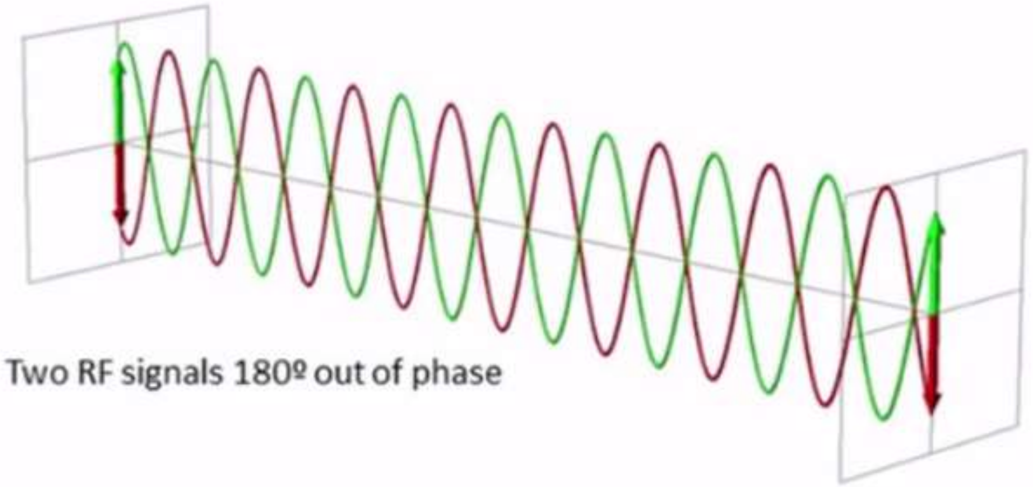
Wavelength: 360º movement of an RF wave, called a Hertz (Hz)

Amplitude: Power level of an RF wave. In Wi-Fi, typically measured in milliwatts (mW) or decibels relative to 1 mW (0 dBm)

Period: The distance between two identical points on an RF wave

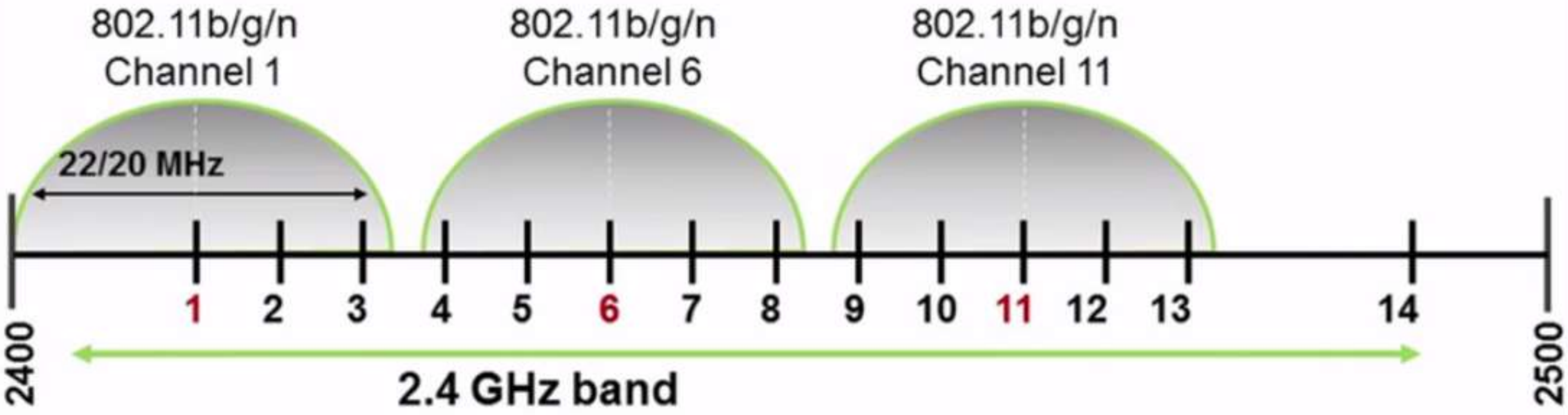
Phase: the relationship between ***two*** signals based on ***when*** their alternative current levels are rising and falling





Two RF signals 180º out of phase

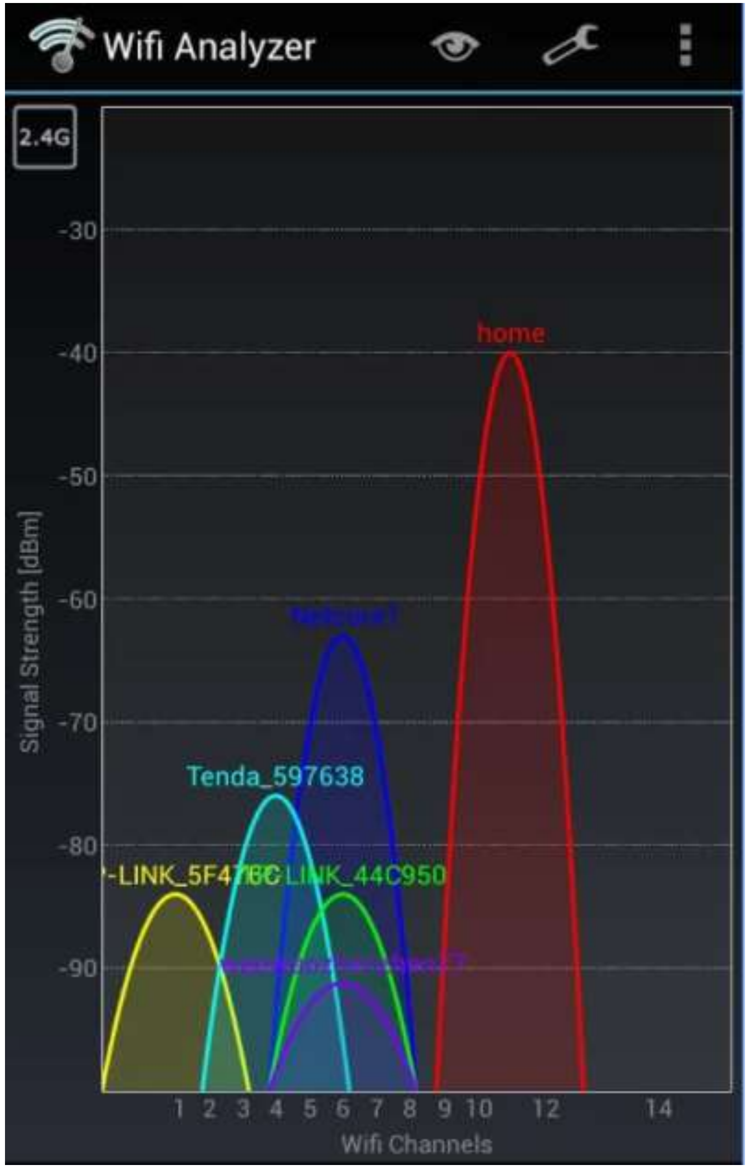
Channels (2.4 GHz)

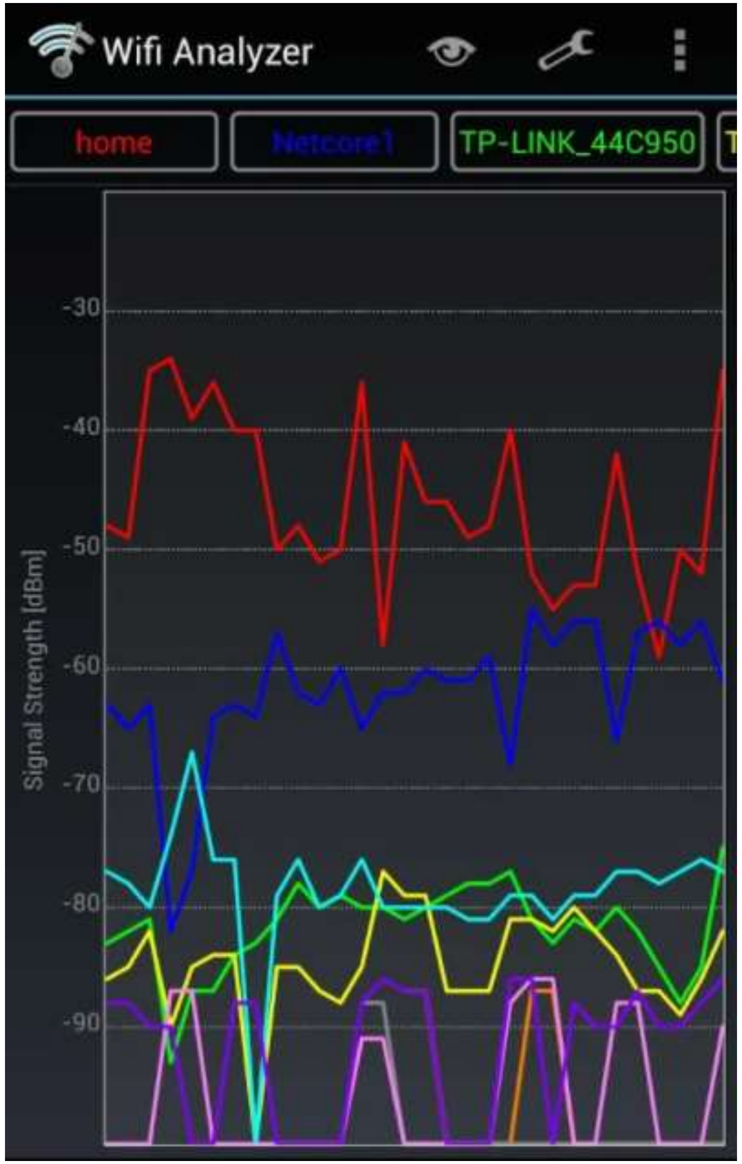


Channel	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Center Frequency (MHz)	2412	2417	2422	2427	2432	2437	2442	2447	2452	2457	2462	2467	2472	2484

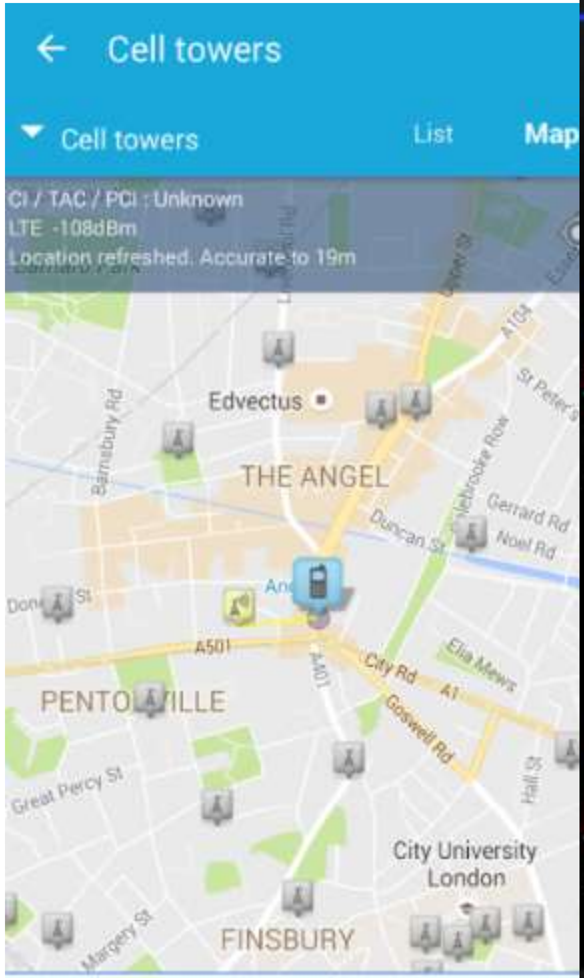
- 14 total channels worldwide (not available everywhere)
- Channels are separated by 5 MHz based on center frequency
- Active Wi-Fi signals are 20-22 MHz wide

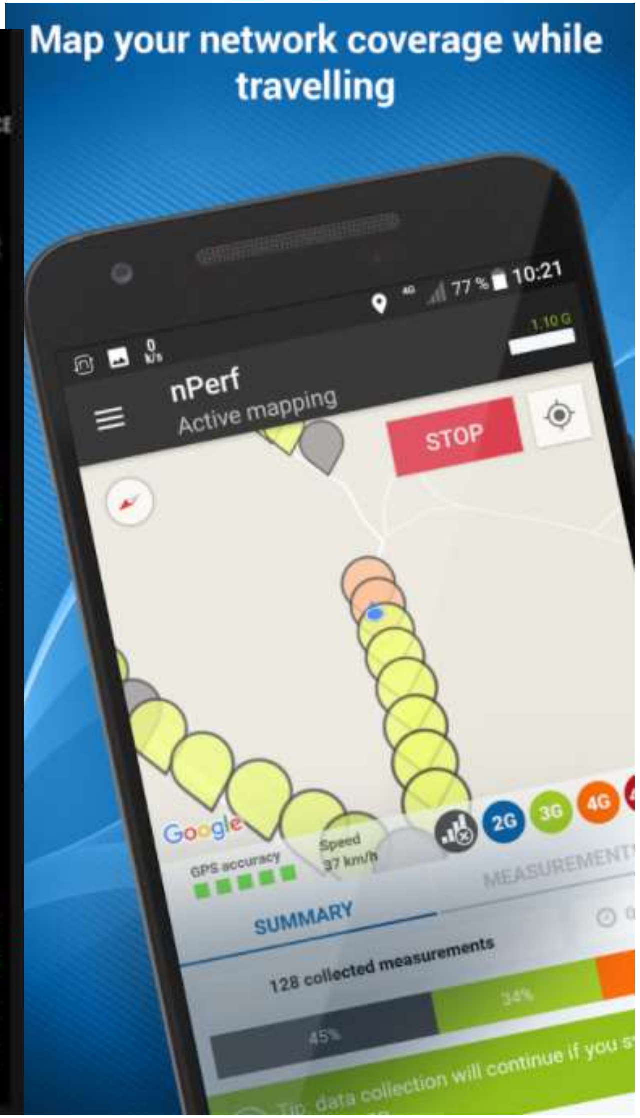
WiFi Analyzer





Cellular Analyzer





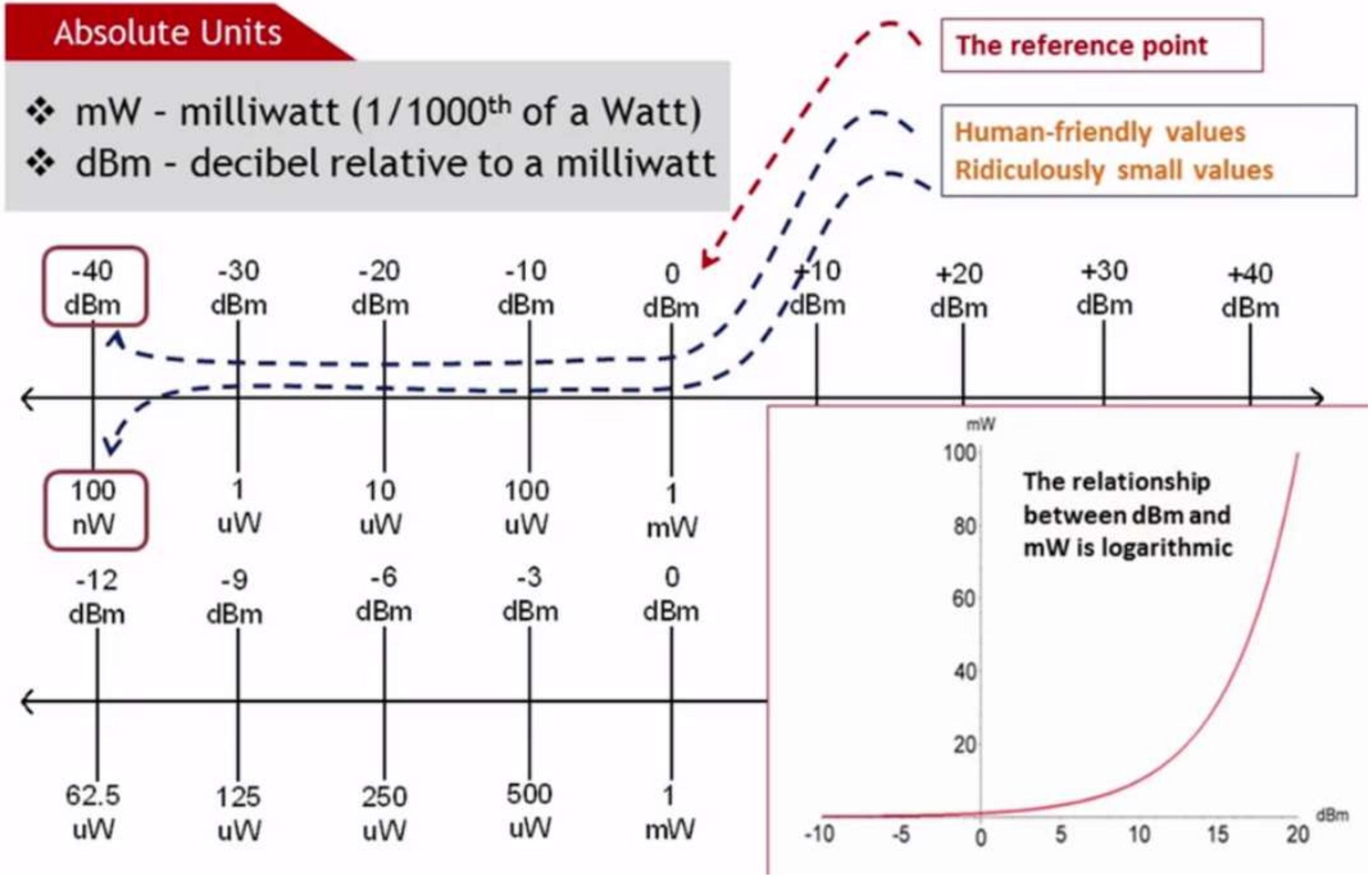
Tugas: Install dan coba:

- WiFi analyzer
- Network Cell Info Lite

RF Measurements

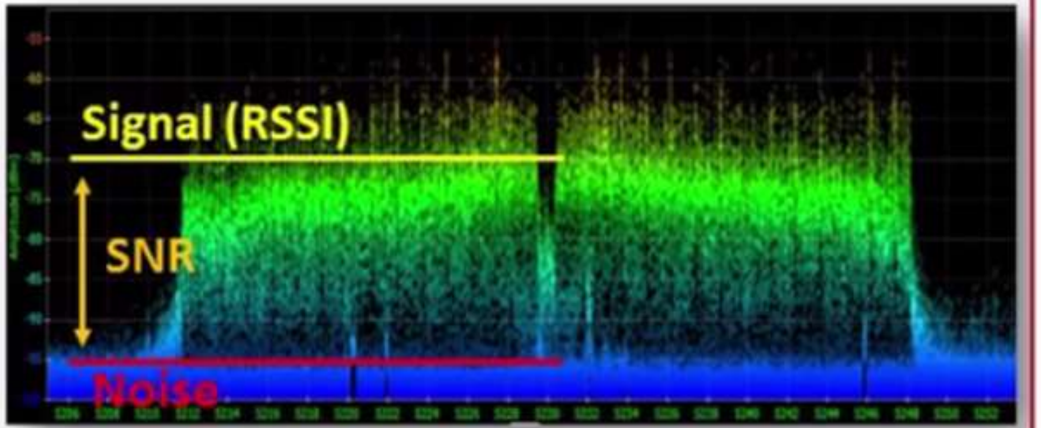
Absolute Units

- mW - milliwatt (1/1000th of a Watt)
- dBm - decibel relative to a milliwatt



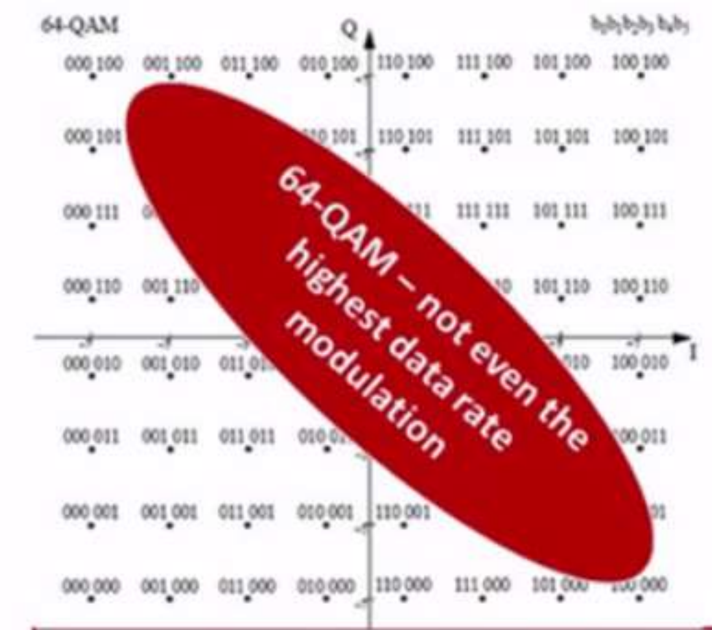
- RSSI
- Noise Floor
- SNR

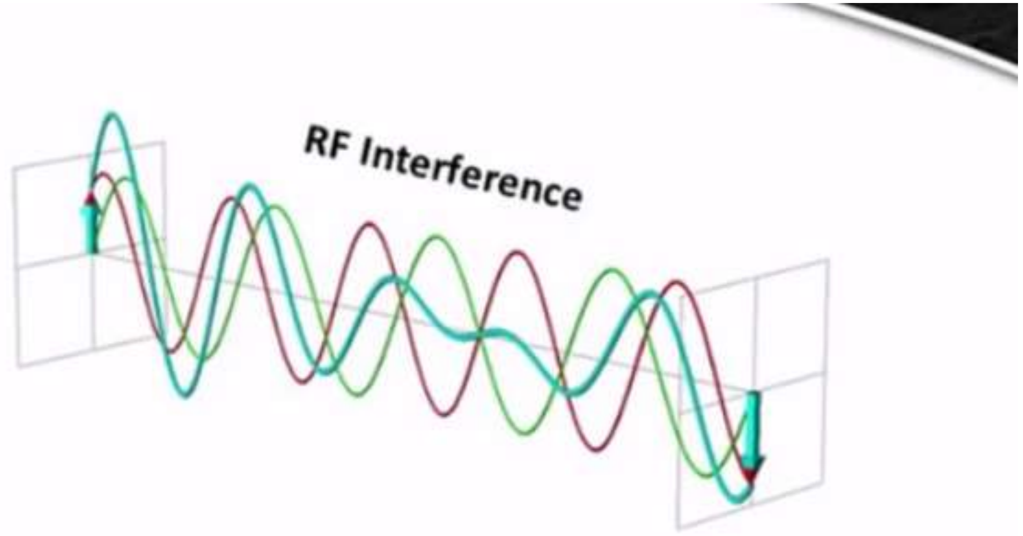
1 mW = 0 dBm	1 mW = 0 dBm
10 mW = 10 dBm	2 mW = 3 dBm
100 mW = 20 dBm	4 mW = 6 dBm
1W = 1000 mW = 30 dBm	8 mW = 9 dBm



- **Relative Power Measurement**
  - Measured in gain or loss
  - Measured in decibels (dB)
- **Gain/Loss Examples**:
  - -3 = 1/2 the original power
  - +3 = 2 times the original power
  - -10 = 1/10th the original power
  - +10 = 10 times the orinal power
- **Component Examples**:
  - Antennas & amplifiers introduce gain
  - Connectors & cables introduce loss

Interference





- **RF Interference** – When an external modulated (data-carrying) or unmodulated (non data-carrying) RF influence affects the ability of an RF receiver to interpret a data signal
  - Higher data rates use more complex waveforms, which are more susceptible to error
  - Low signal strength and external RF interference sources are problematic for high data rates
- Interference happens at the receiver
- Low duty cycle interference can often be tolerated
- High duty cycle interference can wreak havoc on a channel