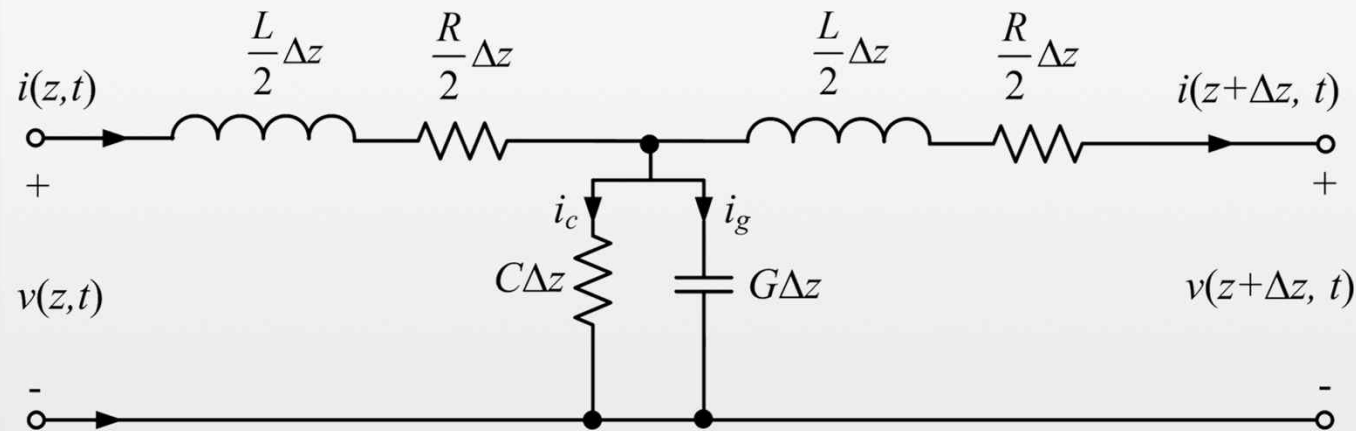


Chapter 2

Transmission Line

Prof. Jeong, Yongchae



Learning Objectives

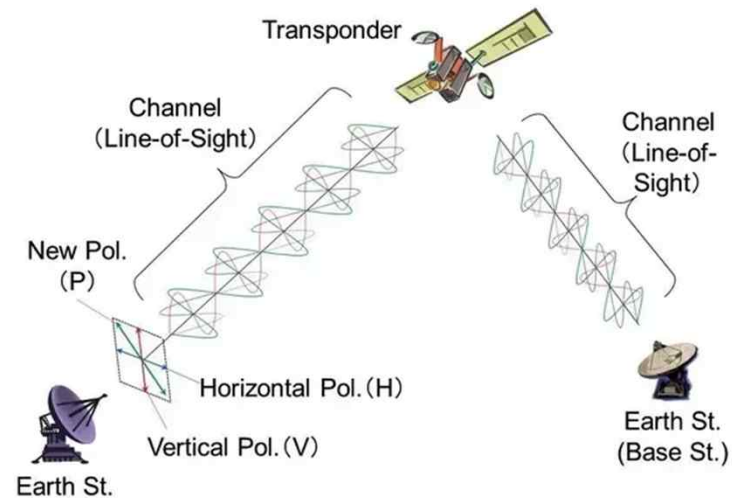
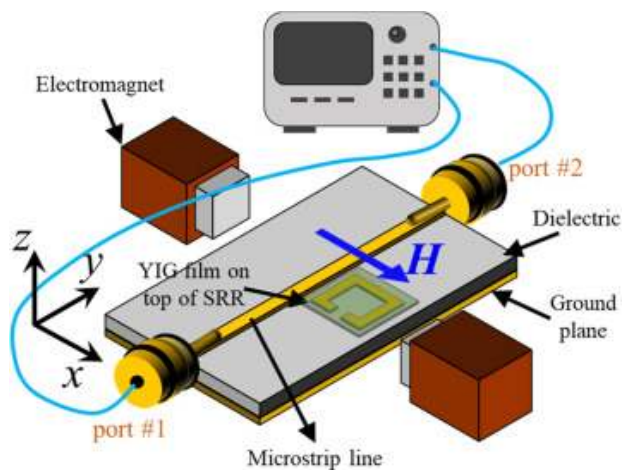
- Learn what is Microwave Engineering
- Learn concept and operation of transmission lines
- Understanding real transmission lines

Learning contents

- Introduction of Microwave Engineering
- What is a ‘Transmission Line’?
- Several types of transmission line

1 Introduction of Microwave Engineering?

- Field of electronic engineering that focus on study and application of electromagnetic waves in microwave frequencies
- Combining principles from electrical engineering and physics to design and develop systems on useful microwave frequency.
- Microwaves frequency range: 300 MHz to 300 GHz
- Explores the transmission, reception, and processing of microwave signals for wide array of applications

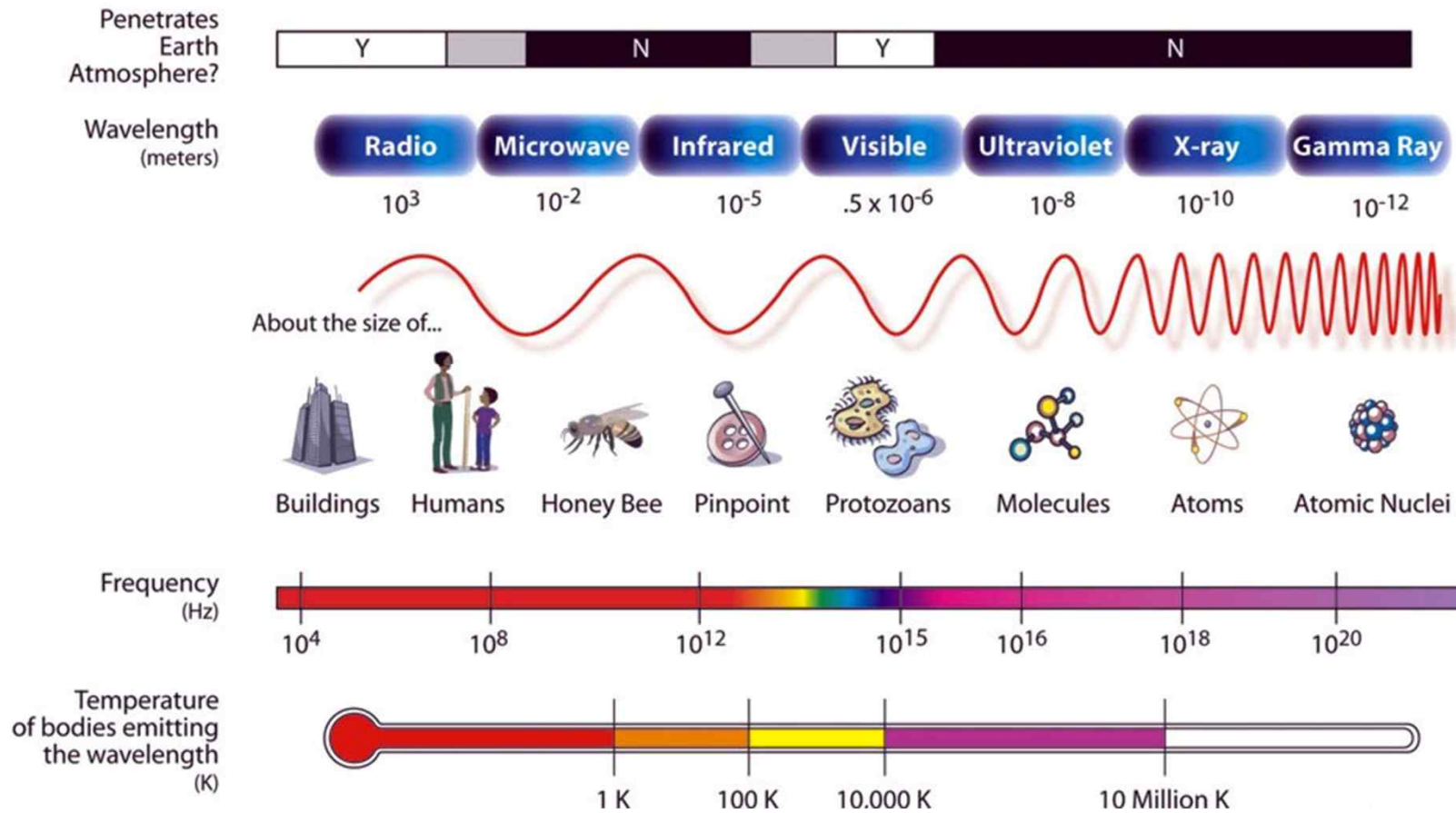


*<https://doi.org/10.1103/PhysRevB.99.134426>

*<https://ijari.org/assets/papers/7/3/IJARI-EE-19-09-104.pdf>

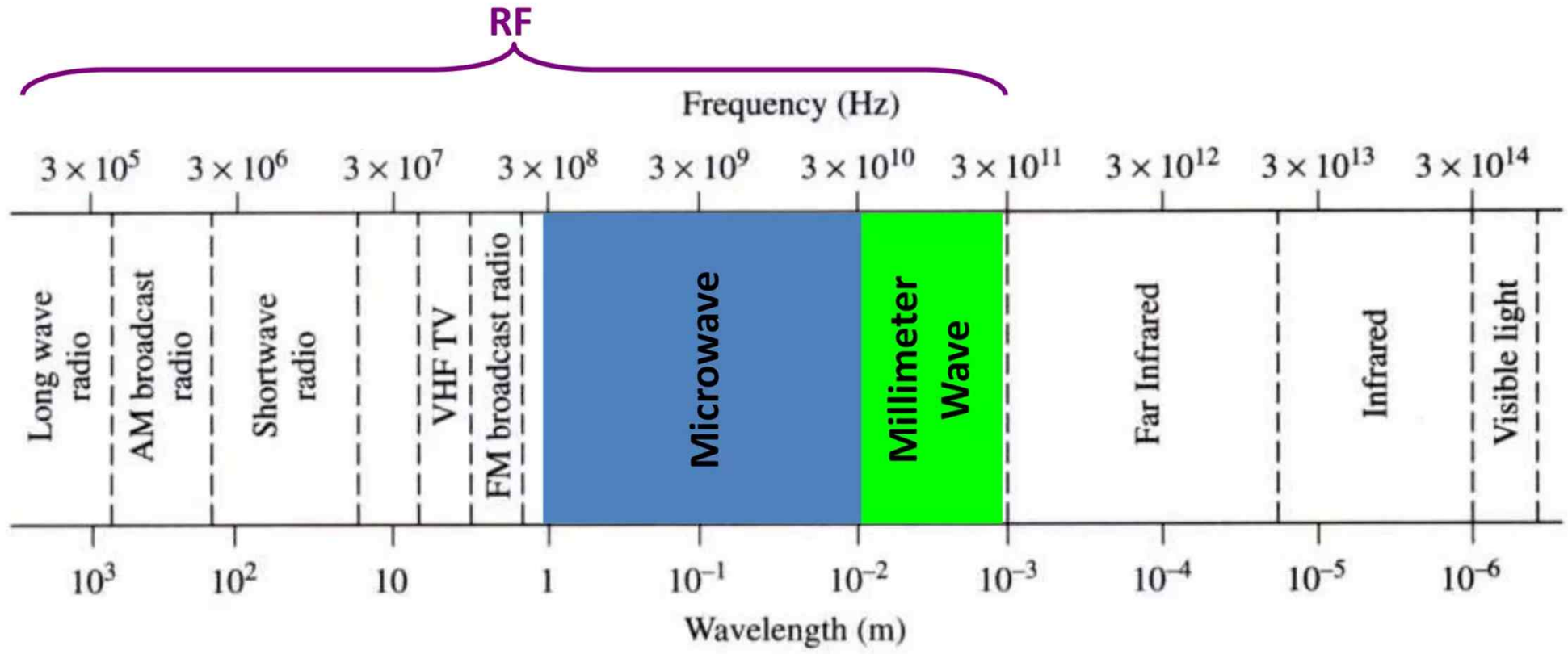
1.1 Electromagnetic spectrum

Electromagnetic Spectrum



*https://en.wikipedia.org/wiki/Electromagnetic_spectrum

1.1 Electromagnetic spectrum and frequency bands



*https://en.wikipedia.org/wiki/Electromagnetic_spectrum

1.1 Frequency bands

Frequency range	Wavelength range	ITU designation		IEEE bands ^[6]
		Full name	Abbreviation ^[7]	
Below 3 Hz	$>10^5$ km			—
3–30 Hz	10^5 – 10^4 km	Extremely low frequency	ELF	—
30–300 Hz	10^4 – 10^3 km	Super low frequency	SLF	—
300–3000 Hz	10^3 –100 km	Ultra low frequency	ULF	—
3–30 kHz	100–10 km	Very low frequency	VLF	—
30–300 kHz	10–1 km	Low frequency	LF	—
300 kHz – 3 MHz	1 km – 100 m	Medium frequency	MF	—
3–30 MHz	100–10 m	High frequency	HF	HF
30–300 MHz	10–1 m	Very high frequency	VHF	VHF
300 MHz – 3 GHz	1 m – 100 mm	Ultra high frequency	UHF	UHF, L, S
3–30 GHz	100–10 mm	Super high frequency	SHF	S, C, X, Ku, K, Ka
30–300 GHz	10–1 mm	Extremely high frequency	EHF	Ka, V, W, mm
300 GHz – 3 THz	1 mm – 0.1 mm	Tremendously high frequency	THF	—

- Microwave (or centimeter wave): 1 GHz ~ , Millimeter wave: 30 GHz ~ (due to wavelength)

1.2 Advantages and Limitations of Microwave

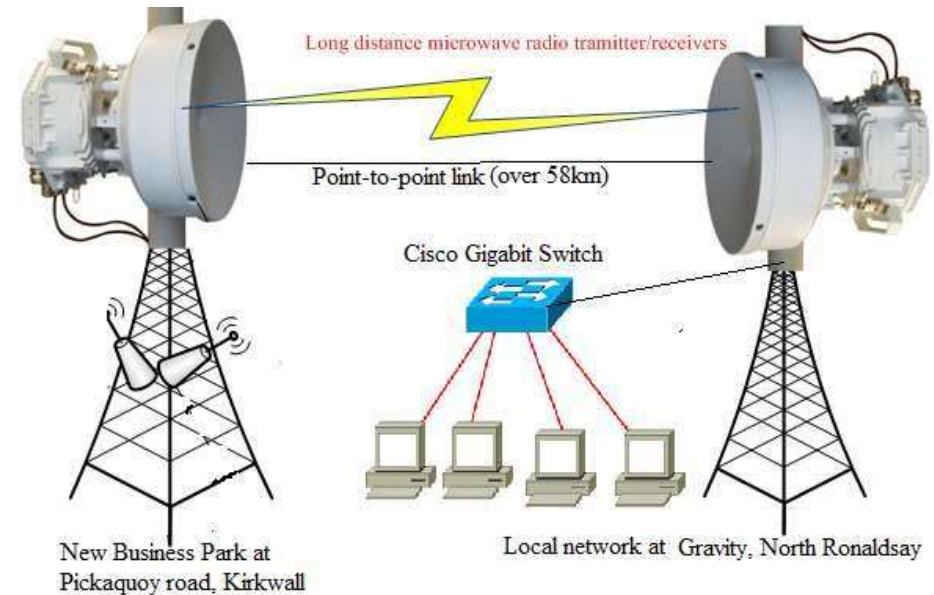
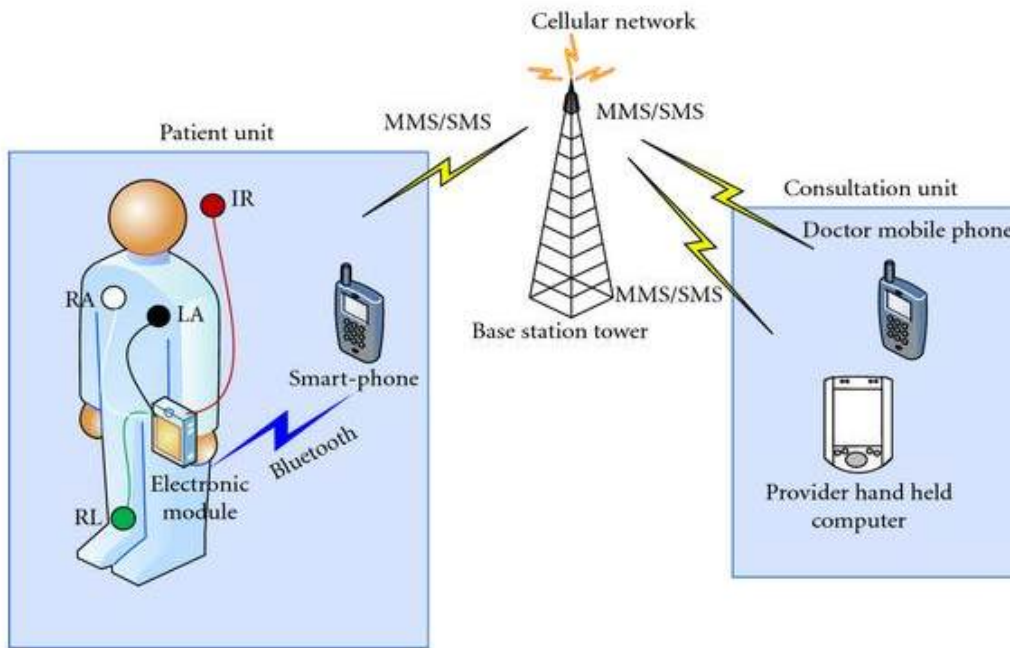
❑ Advantages of microwave

- ✓ Short wavelength monochromatic radiation results in high directivity and resolving power of microwave antennas
- ✓ Wide frequency spectrum available for communication
- ✓ High bandwidth because of large frequency range
- ✓ Higher speed of data transmission because of larger frequency bandwidths
- ✓ Penetration through atmosphere

1.3 Applications of Microwave Engineering

□ Applications of microwaves: Communication systems

- ✓ Mobile Communications
- ✓ Cellular communication
- ✓ Point-to-point microwave link
- ✓ WLAN



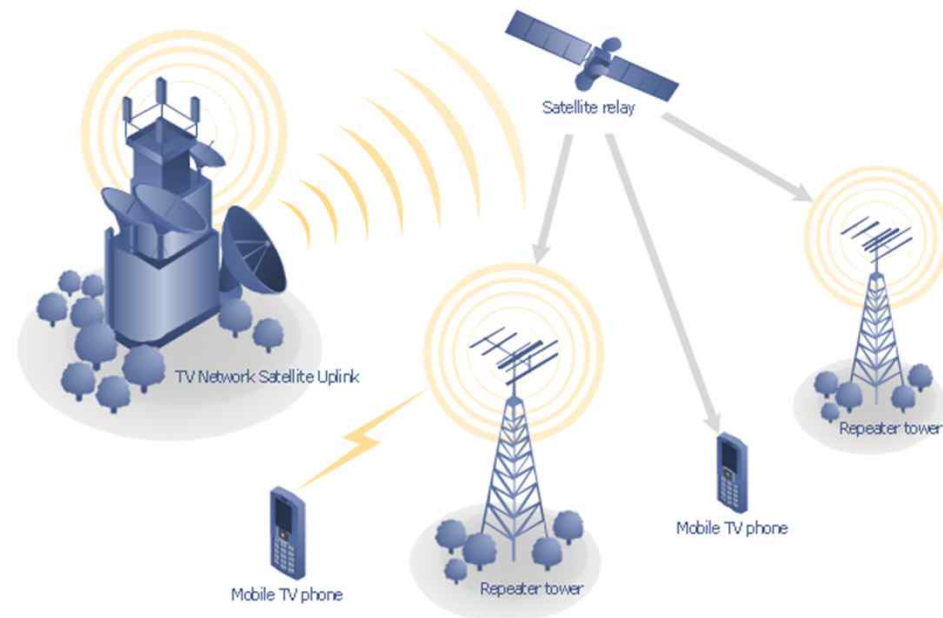
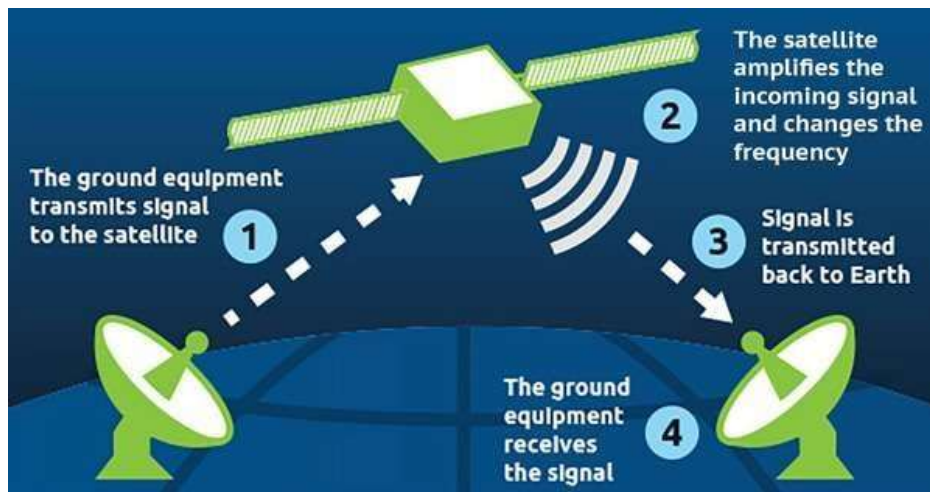
*<https://onlinelibrary.wiley.com/doi/10.1155/2009/859232>

*<https://www.sciencepublishinggroup.com/article/10.11648/j.cssp.20180701.12>

1.3 Applications of Microwave Engineering

☐ Applications of microwaves: Satellite communication

- ✓ Satellite communications enable long-distance communication
- ✓ Transmission of information between satellite and ground stations at microwave frequencies, particularly in C-band, Ku-band, Ka-band, and L-band

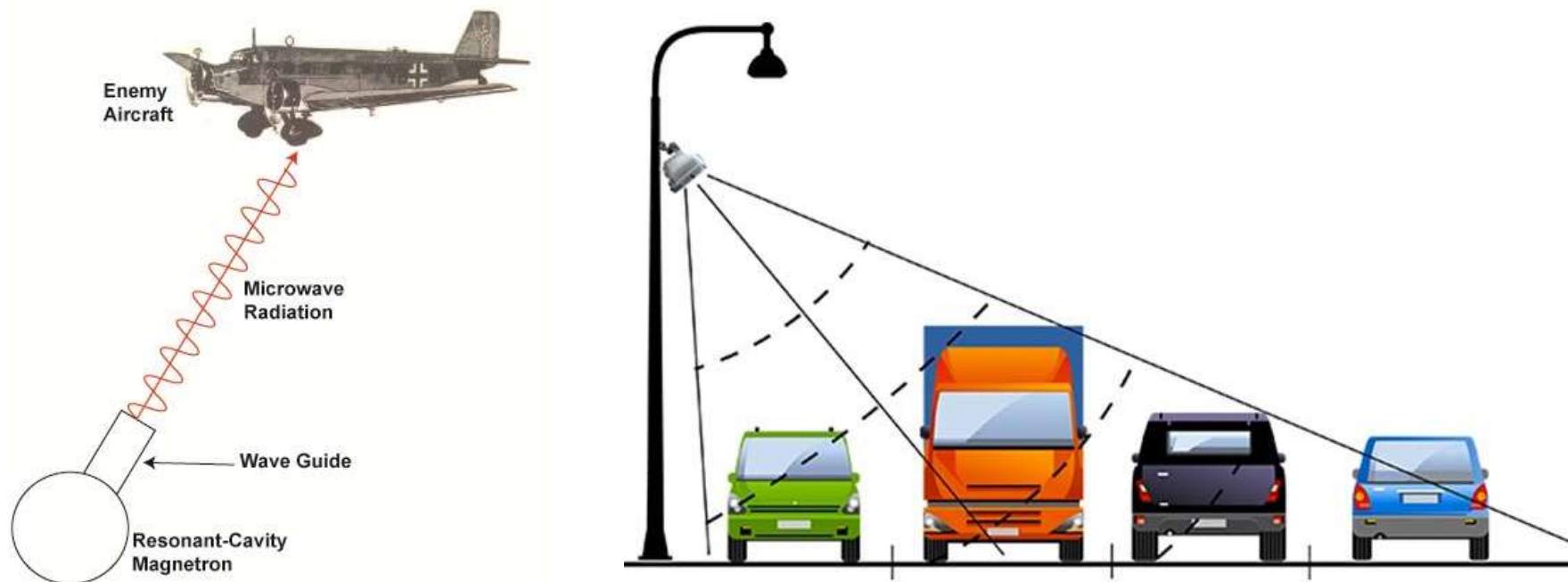


*<https://forum.huawei.com/enterprise/en/how-satellite-networks-transmit-data-from-space-to-earth/thread/700063387632943104-667213856692383744>

1.3 Applications of Microwave Engineering

□ Applications of microwaves: Radar

- ✓ Detection systems that uses radio waves to determine range, angle, or velocity of objects
- ✓ Traffic radar systems: detection and measurement of traffic on roadways



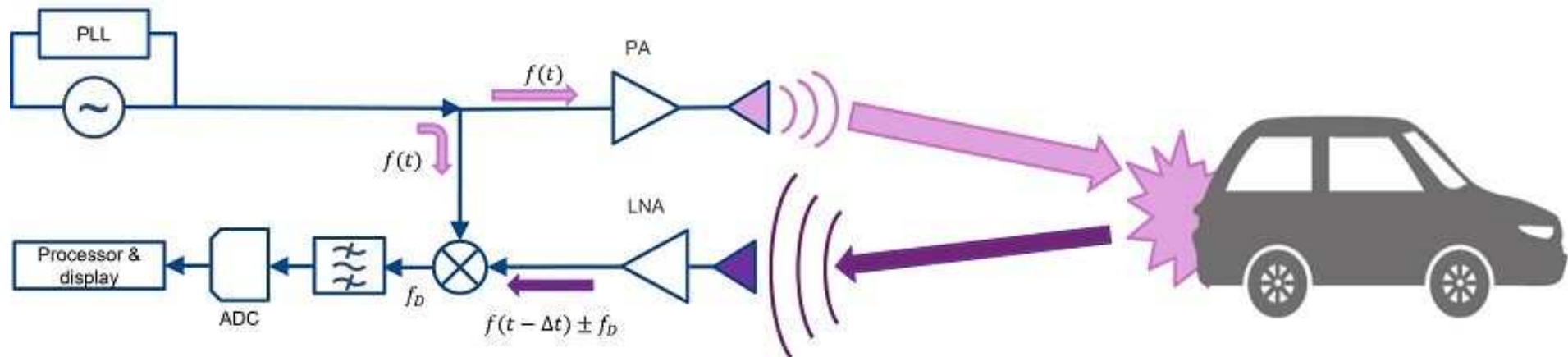
*<http://www.engineeringexpert.net/Engineering-Expert-Witness-Blog/tag/magnetron-tube>

*<https://www.scae.net/prodotti/sensore-traffico-rtms-sx-300/>

1.3 Applications of Microwave Engineering

□ Applications of microwaves: Radar for automotive

- ✓ Use radio waves with frequencies of 24 GHz, 77 GHz and 79 GHz
- ✓ Various types of radar for autonomous vehicular applications such as impulse radar and frequency-modulated continuous wave (FMCW) radar



*<https://www.renesas.com/us/en/blogs/basics-fmcw-radar>

1.3 Applications of Microwave Engineering

☐ Applications of microwaves: Defense radar

- ✓ Used for military purpose to detect, track, and identify aircraft, missiles, ships and other objects in air, ground, or at sea.



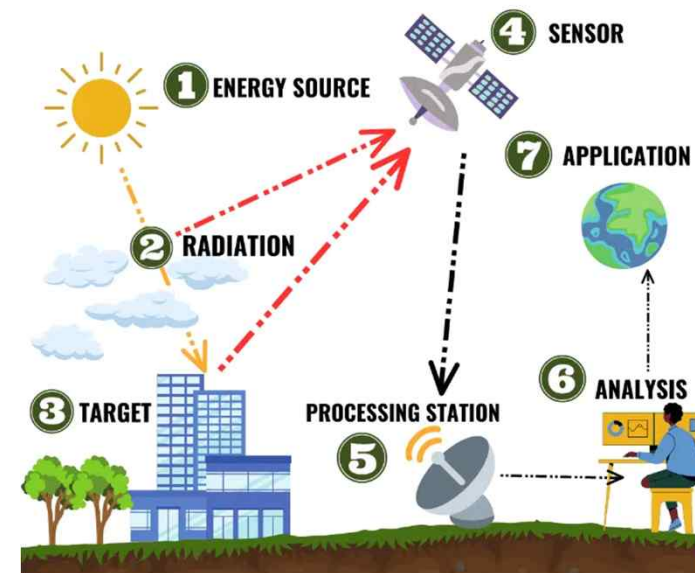
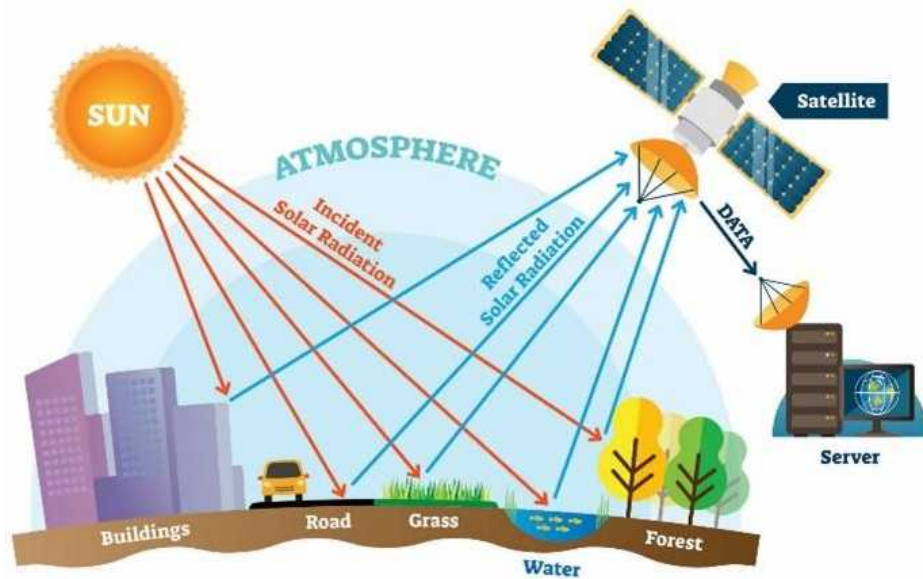
*<https://missiledefenseadvocacy.org/defense-systems/kalkan-air-defense-radar/>

*<https://www.alamy.com/stock-photo/radar-equipment-and-armor.html?sortBy=relevant>

1.3 Applications of Microwave Engineering

☐ Applications of microwaves: Remote sensing

- ✓ Acquisition of information about object or phenomenon without making physical contact with object
- ✓ Environmental monitoring: tracking changes in ecosystems,
- ✓ Meteorology: monitoring weather patterns, climate change and natural disasters



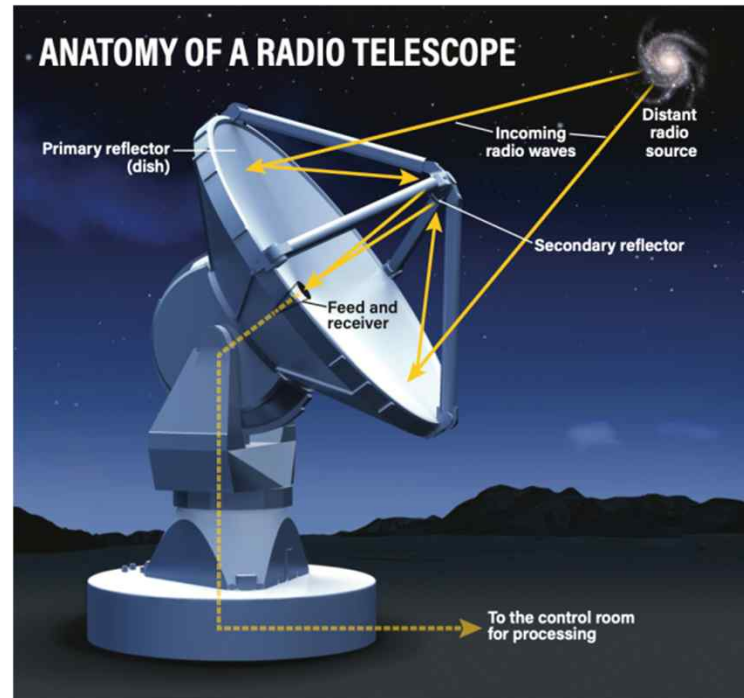
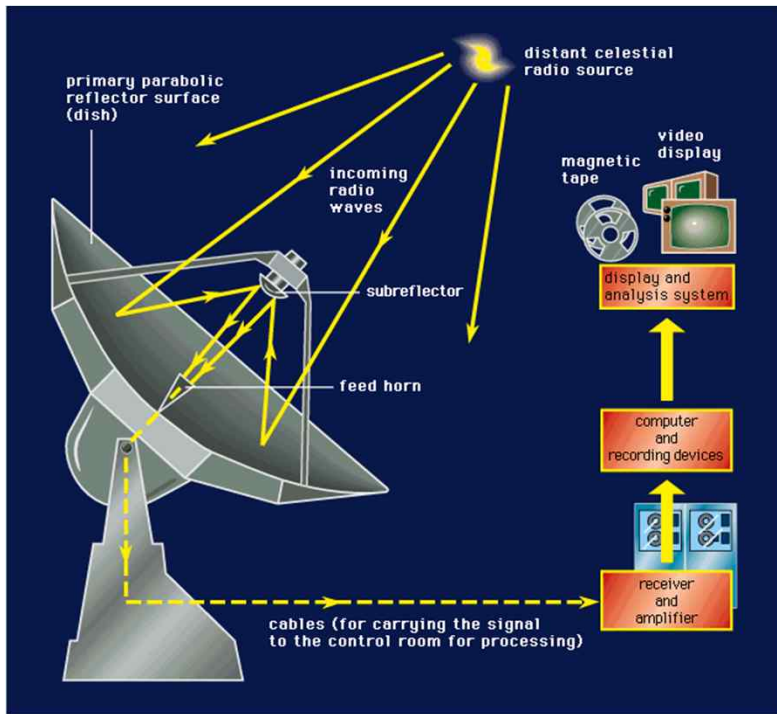
*<https://www.nist.gov/image/remote-sensing>

*<https://sigmaearth.com/basics-of-remote-sensing-and-gis/>

1.3 Applications of Microwave Engineering

☐ Applications of microwaves: Radio Astronomy

- ✓ Field of astronomy that studies celestial objects at radio frequencies



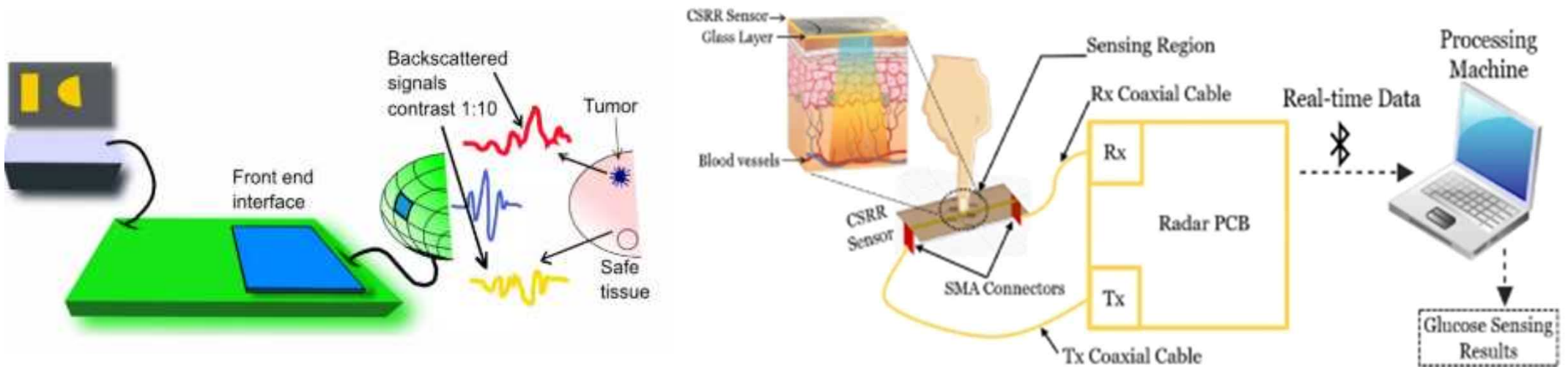
*<https://www.sciencedirect.com/science/article/pii/S0925231216314229>

*<https://www.astronomy.com/science/how-do-radio-telescopes-work/>

1.3 Applications of Microwave Engineering

□ Applications of microwaves: Medical applications

- ✓ Microwave imaging for medical purpose: detecting/locating technique to evaluate hidden or embedded objects using electromagnetic waves in microwave regime
- ✓ Microwave sensors can be used for non-invasive monitoring of various physiological parameters such as blood glucose levels.



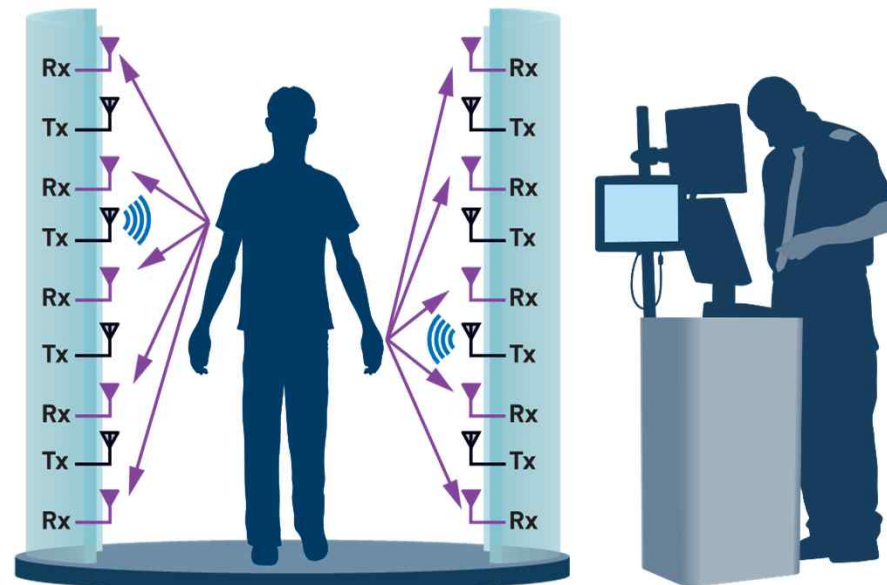
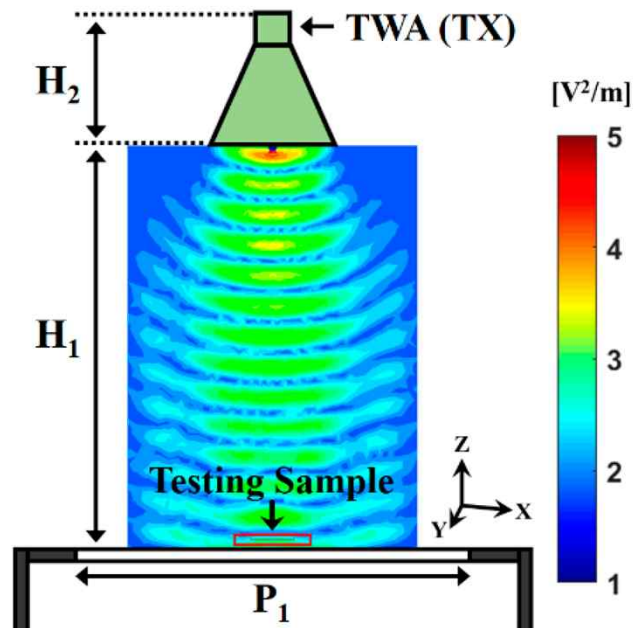
*<https://www.slideshare.net/slideshow/microwaveengineering/792497614229>

*<https://contest.techbriefs.com/2020/entries/medical/10764>

1.3 Applications of Microwave Engineering

□ Applications of microwaves

- ✓ Microwave imaging for food security
- ✓ Millimeter wave scanner are superior to traditional metal detectors because they can identify and locate both metallic and nonmetallic threats.



*<https://www.mdpi.com/1424-8220/20/3/699>

*<https://www.electronicdesign.com/technologies/analog/article/21276247/analog-devices-how-edge-processing-enables-next-gen-mmwave-scanners>

1.3 Applications of Microwave Engineering

❑ Industry applications of microwaves engineering

- ✓ Microwave oven
- ✓ Drying machines: textile, food, and paper industry for drying clothes, printed material etc
- ✓ Food processing industry: processing/cooking, pasteurization/sterility, roasting of food grains
- ✓ Rubber industry/plastic/chemical/forest product industries
- ✓ Drying inks/textiles

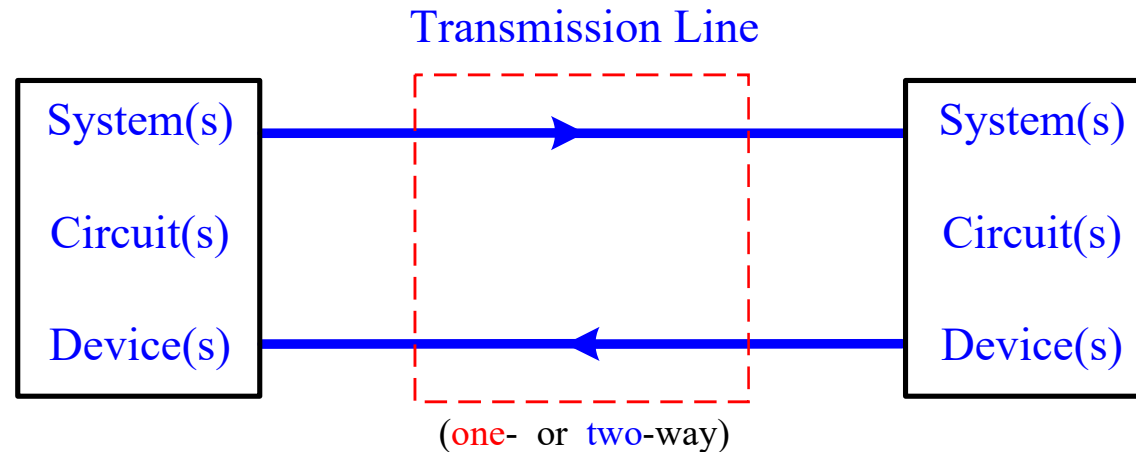


*<https://www.electrolux.co.th/en-th/blog/how-to-use-a-microwave-oven/>

*<https://ferriteinc.com/industrial-microwave-systems/materials-processing/>

2 What is a 'Transmission Line'?

- **Transmission line:** carrier to transmit electric energy, signals, data, and information from one point to another point with small insertion loss



Ex: Source

Hydroelectric generating plant

Audio system

Broadcasting system

Cable service provider

Comm. transmitter

Computer



Load

Factory, Home

Speaker

TV, Radio

TV

Comm. receiver

Computer

2 What is a 'Transmission Line'?

- **Lumped elements** (R , L , C , etc.) ignores a time delay to traverse the elements
→ Per-unit-distance basis

Distributed elements (transmission line) can't be ignored the time delay to traverse the elements
→ Over-unit-distance basis

- Analyzing approaches

1) Maxwell's equations: electromagnetic field method (complete & accurate)

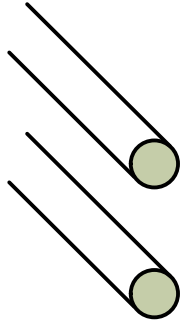
2) Circuit equations: equivalent voltage and current analysis method (intuitive & inaccurate)

Voltage wave ↔ **Electric field**

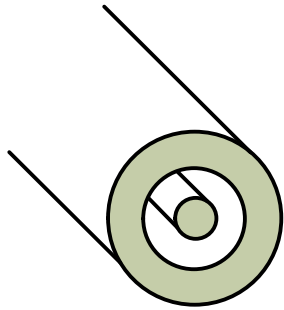
Current wave ↔ **Magnetic field**

** Reference Textbook: Microwave Engineering (4th edition, David M. Pozar, John Wiley & Sons, Inc.)*

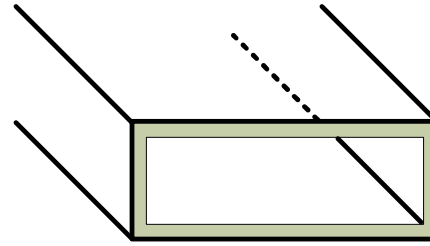
2.1 Several Types of Transmission Line



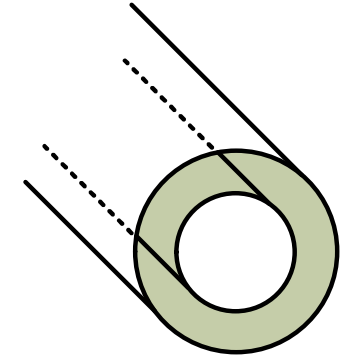
Two-wire line



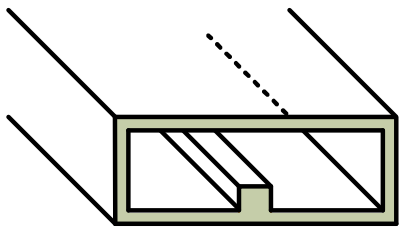
Coaxial cable



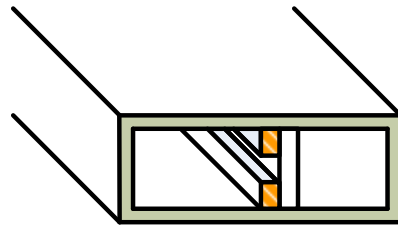
Rectangular waveguide



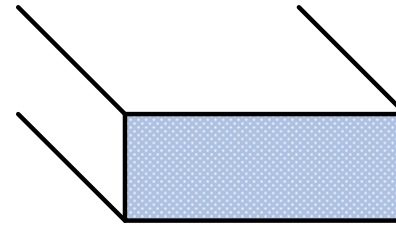
Circular waveguide



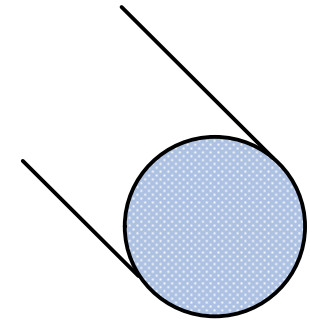
Ridge waveguide



Fin-line waveguide

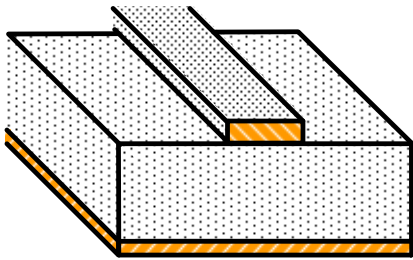


Rectangular dielectric waveguide

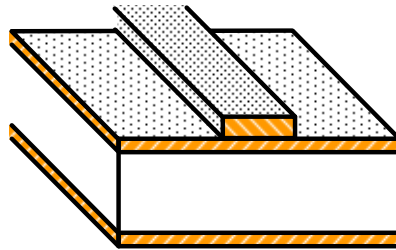


Circular dielectric waveguide

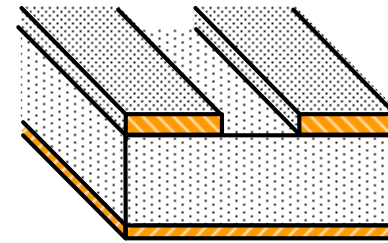
2.2 Several Types of Transmission Line



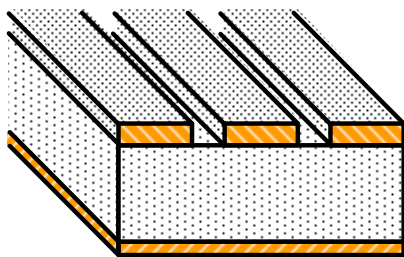
Microstrip line



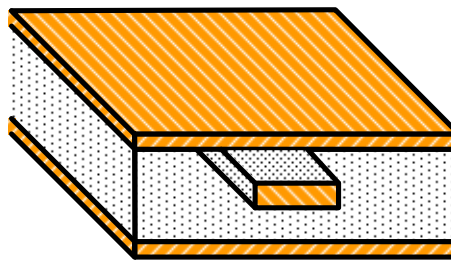
Suspended microstrip line



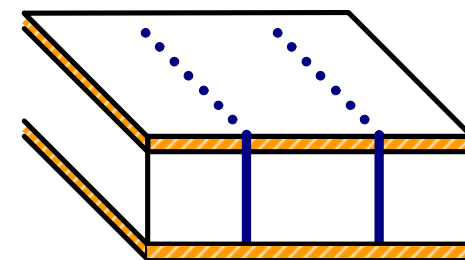
Slot line



Coplanar waveguide



Strip line



Substrate integrated
Waveguide (SIW)

3 Review

- Microwave engineering and its applications
- Transmission lines
 - Definition
 - Physical realizations