

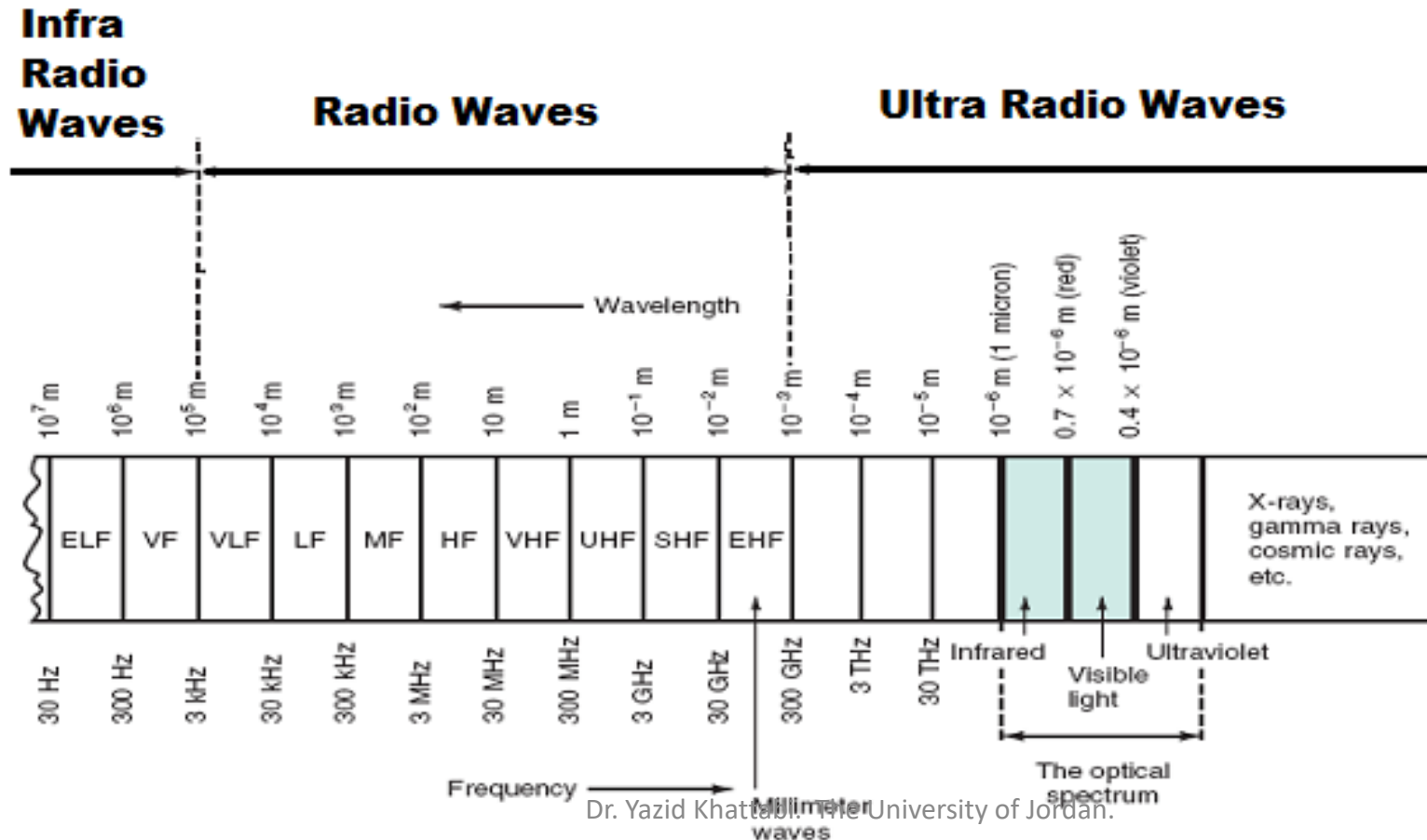
# Lect3: The Electromagnetic (EM) Spectrum

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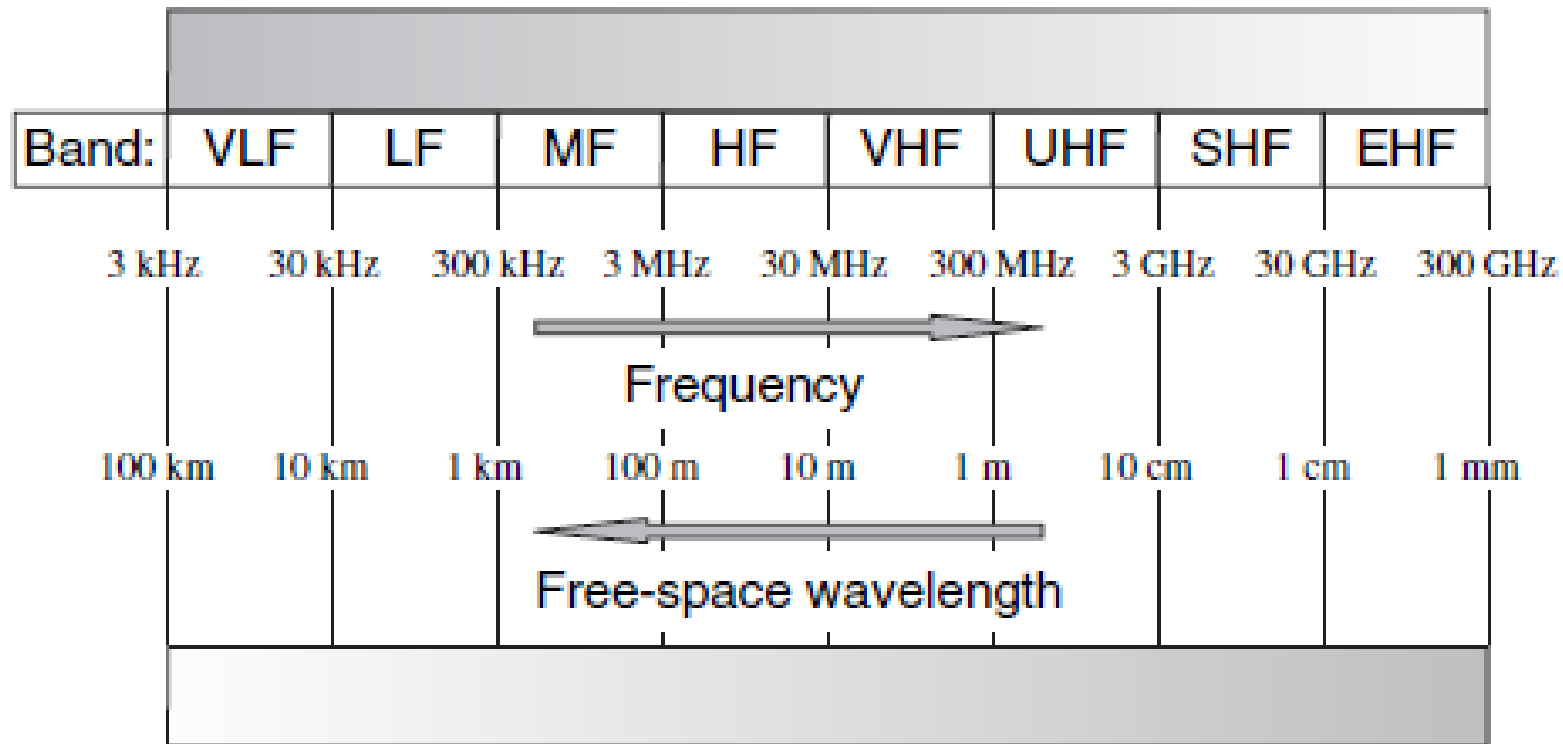
# The Electromagnetic spectrum

- It is the basic resource in wireless communication systems.
- It is the range of electromagnetic signals encompassing all frequencies.
- EM, radio waves, and antennas basics will be discussed in Lect3.



# The Electromagnetic spectrum

□ Radio wave spectrum:



# The Electromagnetic spectrum

- Two conventional ways of dividing the spectrum into frequency bands:

Name	Frequency	Wavelength
Extremely low frequencies (ELFs)	30–300 Hz	$10^7$ – $10^6$ m
Voice frequencies (VFs)	300–3000 Hz	$10^6$ – $10^5$ m
Very low frequencies (VLFs)	3–30 kHz	$10^5$ – $10^4$ m
Low frequencies (LFs)	30–300 kHz	$10^4$ – $10^3$ m
Medium frequencies (MFs)	300 kHz–3 MHz	$10^3$ – $10^2$ m
High frequencies (HF)	3–30 MHz	$10^2$ – $10^1$ m
Very high frequencies (VHF)	30–300 MHz	$10^1$ –1 m
Ultra high frequencies (UHF)	300 MHz–3 GHz	1– $10^{-1}$ m
Super high frequencies (SHF)	3–30 GHz	$10^{-1}$ – $10^{-2}$ m
Extremely high frequencies (EHF)	30–300 GHz	$10^{-2}$ – $10^{-3}$ m
Infrared	—	0.7–10 $\mu$ m
The visible spectrum (light)	—	0.4–0.8 $\mu$ m

Band name	Frequency range [GHz]
L band	1–2
S band	2–4
C band	4–8
X band	8–12
Ku band	12–18
K band	18–26
Ka band	26–40
V band	40–75
W band	75–111

# The Electromagnetic spectrum

## □ Some Applications of EM- Spectrum:

- **ELF (30-300 Hz):** include ac power line frequencies (50 and 60 Hz are common) and the low end of the human audio range.
- **VF (300-3000 Hz):** human speech. Although human hearing extends from approximately 20 to 20,000 Hz, most intelligible (clear) sound occurs in the VF range.
- **VLF (3-30 KHz):** military communications (VLF radio transmission is used by the navy to communicate with submarines).
- **LF (30-300K):** aeronautical and marine navigation.
- **MF (300K-3M):** AM broadcasting (535 to 1605 kHz). Marine.
- **HF (3-30M) (called short waves):** simplex broadcasting and half duplex two-way radio communication. Aviation communication, weather stations, public safety (police and fire), diplomatic communication between embassies.

# The Electromagnetic spectrum

## □ Some Applications of EM- Spectrum:

- **VHF (30-300M)** : FM radio broadcasting (88 to 108 MHz), and VHF TV.
- **UHF (300M-3G)**: UHF TV, cellular telephones, radar.
- **SHF (3-30G) *microwaves***: microwave ovens usually operate at 2.45 GHz, satellite communication, radar, WLANs, and many cellular telephone systems.
- **EHF (30-300G)**: called *millimeter waves*. Complex and expensive equipments used for these waves. There is growing use of this range for satellite communication telephony, cellular networks, and some specialized radar.

# The Electromagnetic spectrum

## □ Some Applications of EM- Spectrum:

- **Between 300 GHz and the Optical Spectrum:** virtually uninhabited. Lack of hardware and components limits its use.
- **The Optical Spectrum:**
  - **Infrared:** associated with heat sources. TV remote-control. Fiber-optic
  - **The Visible Spectrum (light: red to violet):** glass-optics, laser communications.
  - **Ultraviolet light (UV):** generated by the sun (causes sunburn), fluorescent lamps. not used for communication; its primary use is medical.

# The Electromagnetic spectrum

□ Note:

- EM waves with frequencies less than 9KHz are not employed due to the following reasons:
  - Limited bandwidth resulting in low traffic capacity.
  - Very large antennas because of long wavelengths.
  
- Also, frequency bands higher than 100GHz are not usually employed for the time being due to the following reasons:
  - High free space loss.
  - High atmospheric attenuation.
  - Limitations in RF component manufacturing.



# The Electromagnetic spectrum

- ❑ Spectrum is a valuable and finite natural resource.
- ❑ *Spectrum-management & regulatory bodies* are needed nationally & internationally.
- ❑ Role: allocate spectrum space, issue licenses, set standards,....
- ❑ In US: Federal Communications Commission (FCC) & National Telecommunications and Information Administration (NTIA).
- ❑ International Telecommunications Union (ITU): brings countries together to discuss how the frequency spectrum is to be divided up and shared:
  - Short distances spectrum: countries can use simultaneously.
  - Long distances spectrum: countries must negotiate to coordinate to prevent interference.

# The Electromagnetic spectrum

## □Standards:

- Set and followed so that when equipment is designed and built, compatibility is ensured.
- Interoperability : the ability of equipment from one manufacturer to work compatibly with that of another.
- Standards for: *long-distance telephone transmission, digital cell phones, LANs, and computer modems, ..*
- Telecommunication Standard organizations: **ANSI, EIA, ETSI, IEEE, ITU, IETF, IF, TIA**

# Thank you