Lect7: Wave Propagation Paths

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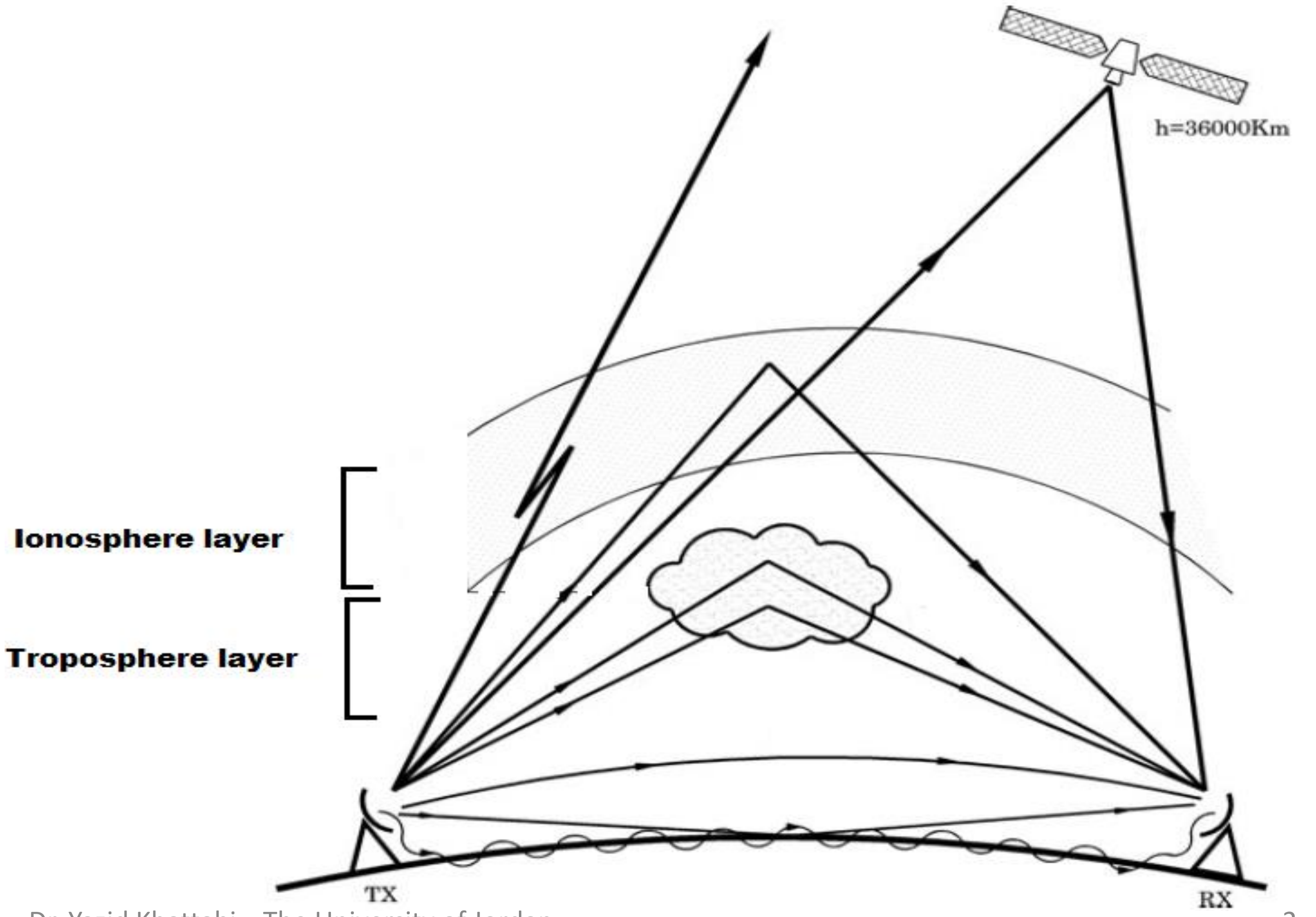
Wave propagation paths

❑The three basic paths that a radio signal can take through space

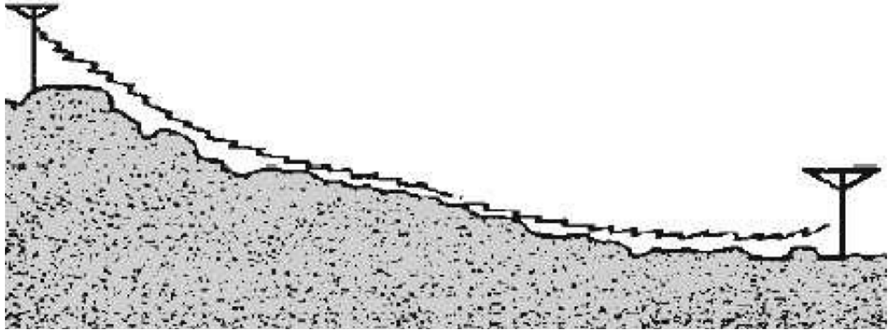
- The ground (surface) wave,
- The sky wave.
- The space (direct) wave.

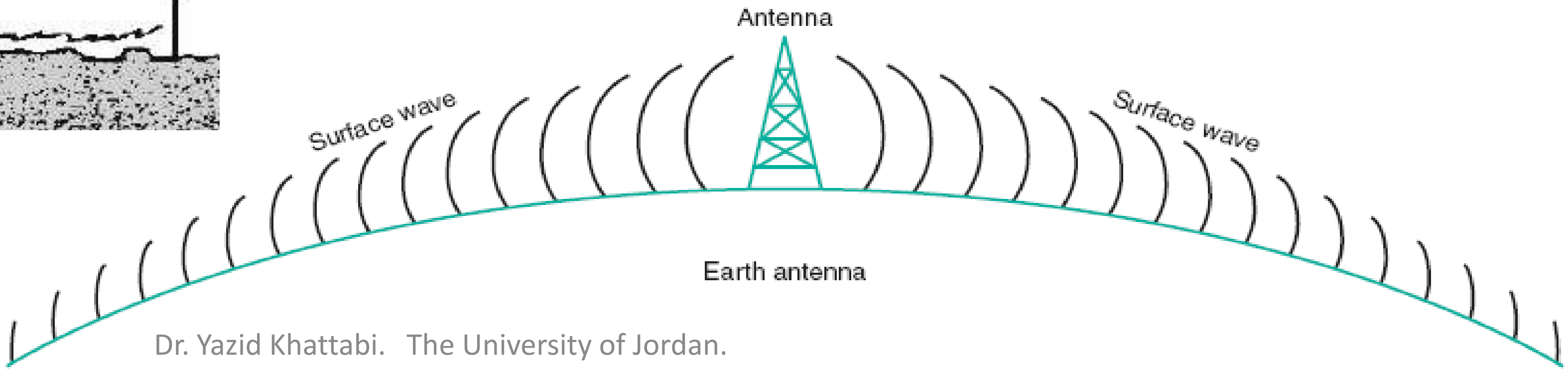


Wave propagation paths

❑The ground wave:

- Leaves an antenna and remains close (parallel) to the earth.
- Follows the curvature of the earth and can, therefore, travel at distances beyond the horizon.
- Must have vertical polarization. Horizontally polarized waves are absorbed or shorted by the earth.

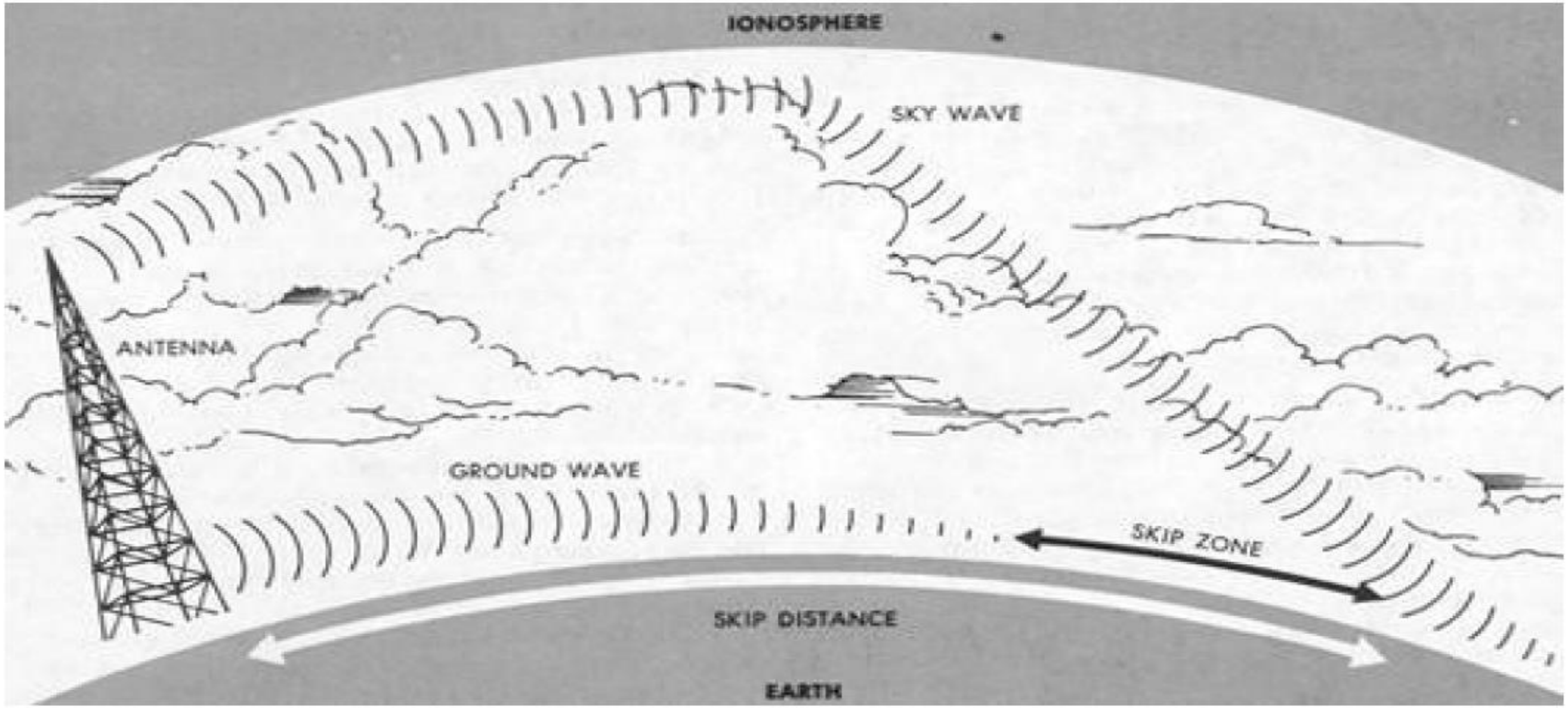




Wave propagation paths

❑The ground wave:

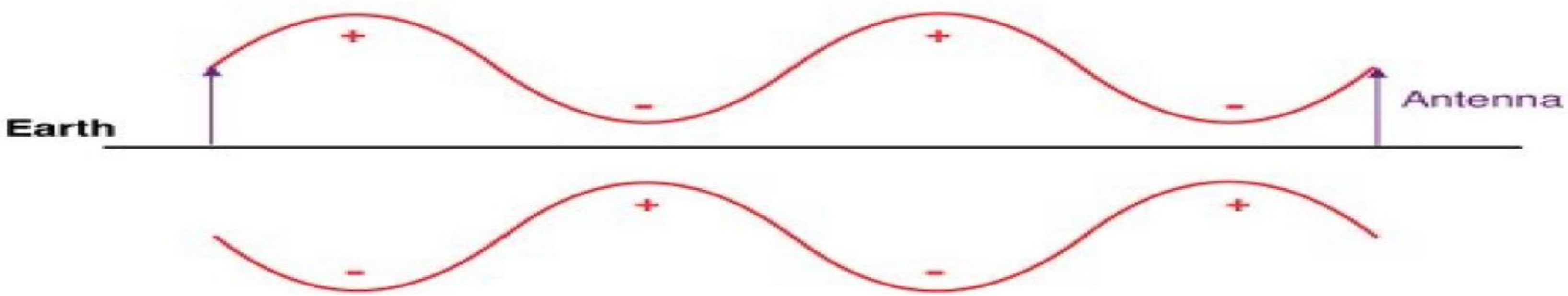
- As compared to sky wave, used for short wave communication.



Wave propagation paths

❑The ground wave:

- Induced wave in ground attenuates the original wave (short circuit chances leakage energy).



- High frequency waves attenuate faster (s.c chances higher). So, ground wave are more efficient in in low & medium frequencies: 30KHz~3MHz.
- Can propagate for 100s and sometimes 1000s of miles at these low frequencies.
- Unlike high frequencies, ground waves at these frequencies can bend (diffract) around large obstacles.
- Ex: AM broadcasting during the day (by sky waves at nigh) + police & military communications

Wave propagation paths

❑The ground wave:

- The conductivity of the earth determines how well ground waves are propagated.
- The better the conductivity, the less the attenuation and the greater the distance the waves can travel.
- Compare salt water with dry areas like deserts?
- At frequencies beyond 3 MHz, the earth begins to attenuate radio signals. Objects on the earth and features of the terrain become the same order of magnitude in size as the wavelength of the signal and thus absorb or adversely affect the signal.
- For this reason, the ground wave propagation of signals above 3 MHz is insignificant except within several miles of the transmitting antenna.

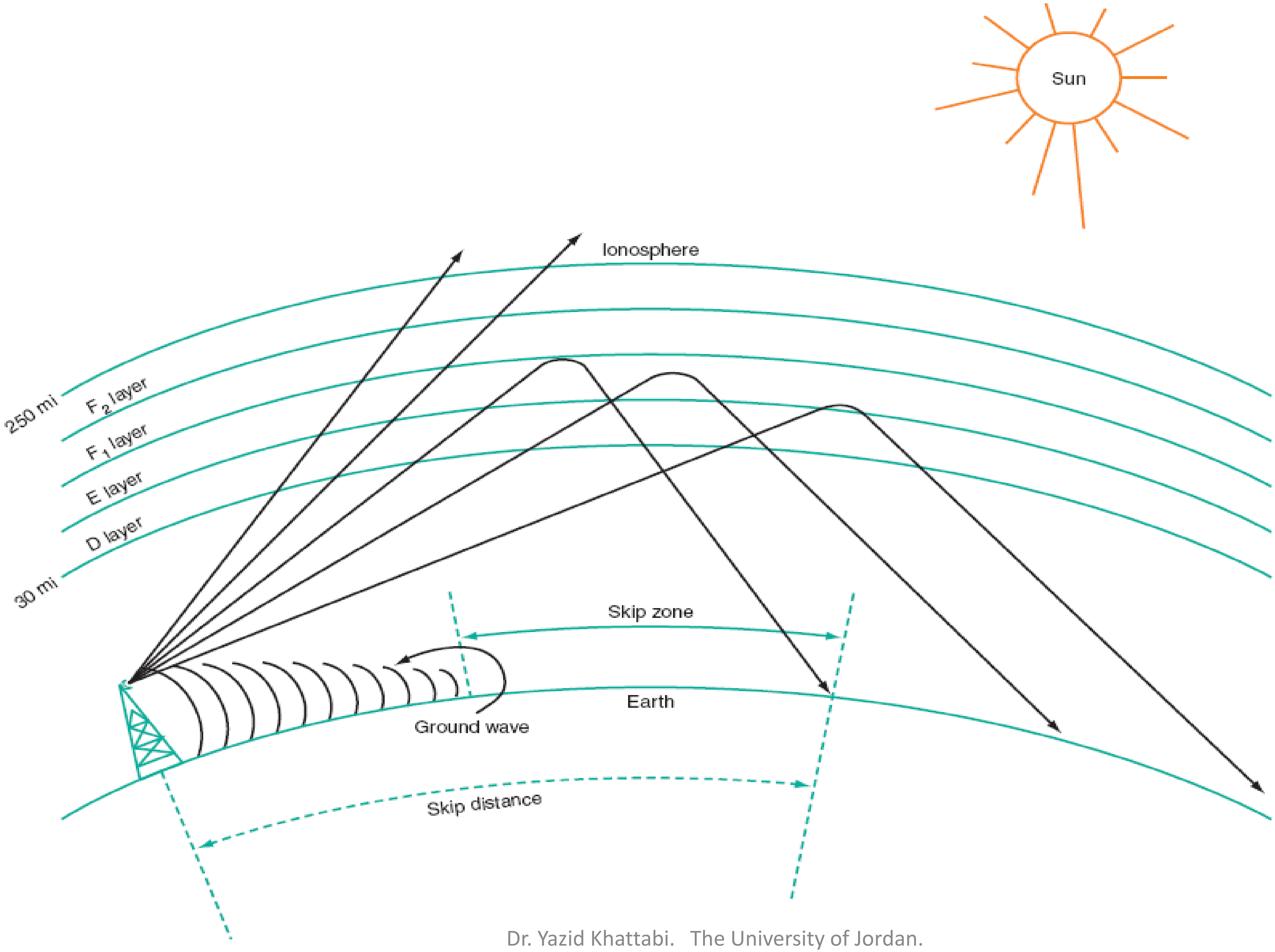
Wave propagation paths

❑The sky wave:

- Radiated by the antenna into the upper atmosphere, where they are bent back to earth. 3- to 30-MHz or shortwave range.

- This bending is caused by reflection or refraction by the ionosphere (a region of the upper atmosphere).

- Sent back to earth with minimum loss. So propagated over an extremely long distance.


Sun
Ionosphere
250 mi
F2 layer
F1 layer
E layer
D layer
30 mi
Skip zone
Earth
Ground wave
Skip distance

Wave propagation paths

❑The sky wave: [2]

- The upper atmosphere is ionized (electrically charged) by the sun ultraviolet radiation.
- The atoms take on or lose electrons, becoming positive or negative ions. Free electrons are also present.
- The ionosphere is ~ 30 mi (50 km) above the earth and extends as far as 250 mi (400 km) from the earth.
- The ionosphere divided into three layers:

➢ The D layer,

➢ The E layer, and

➢ The F layer: F1 & F2 layers.

- The D & E layers are weakly ionized and exist only during daylight hours
- MF range (300 kHz to 3 MHz) waves are absorbed by D & E layers (so sky-wave is not efficient at day time).

Wave propagation paths

❑The sky wave:

- The different levels of ionization cause the radio waves to be gradually bent.

- The direction of bending depends on:

➢The different degrees of ionization of the layers (Snell's law).

➢ The angle at which the radio wave enters the ionosphere. (see the figure) (critical angle?).

➢The signal frequency:

- higher frequency waves can resist the ionosphere and pass through it. To refract high frequencies reduce the angle. Refraction of frequencies above 50 MHz is seldom regardless of the angle. VHF, UHF, and microwave signals usually pass through the ionosphere without bending

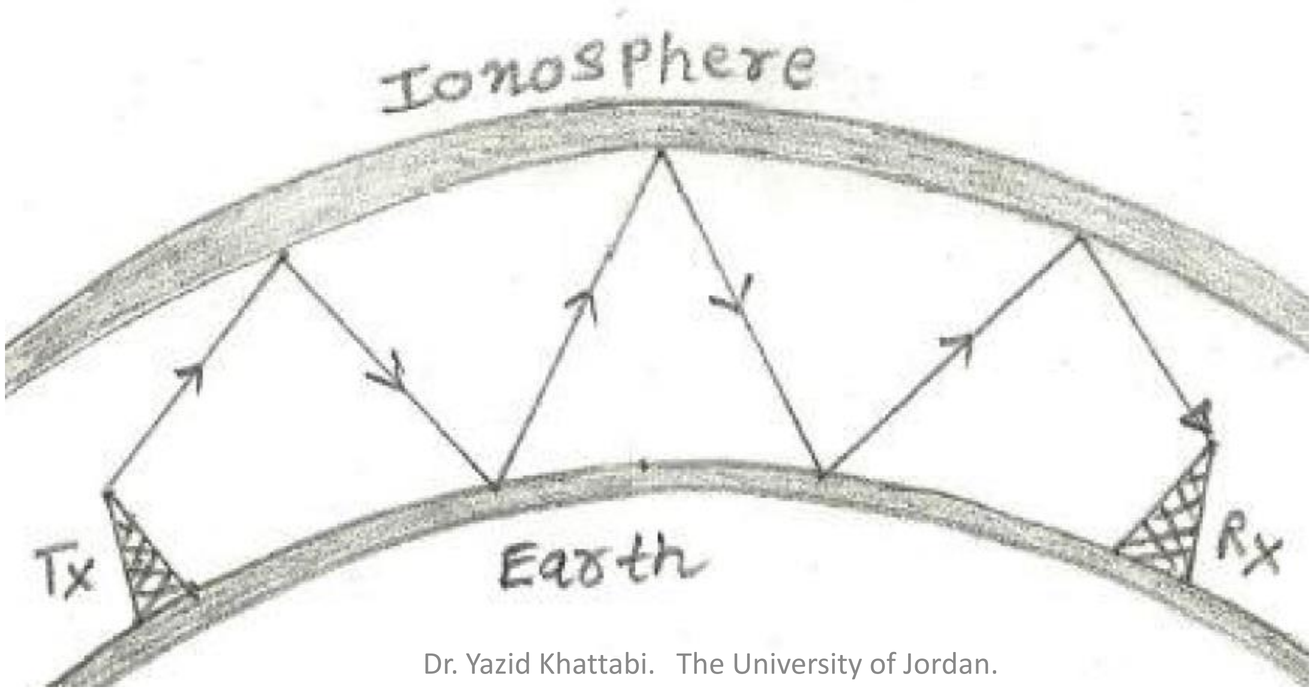
Wave propagation paths

❑The sky wave:

- Multiple-skip or multiple-hop transmission

➢As many as 20 hops are possible

➢The maximum distance of a single hop ~ 2000 mi. With multiple hops, transmissions all the way around the world are possible.

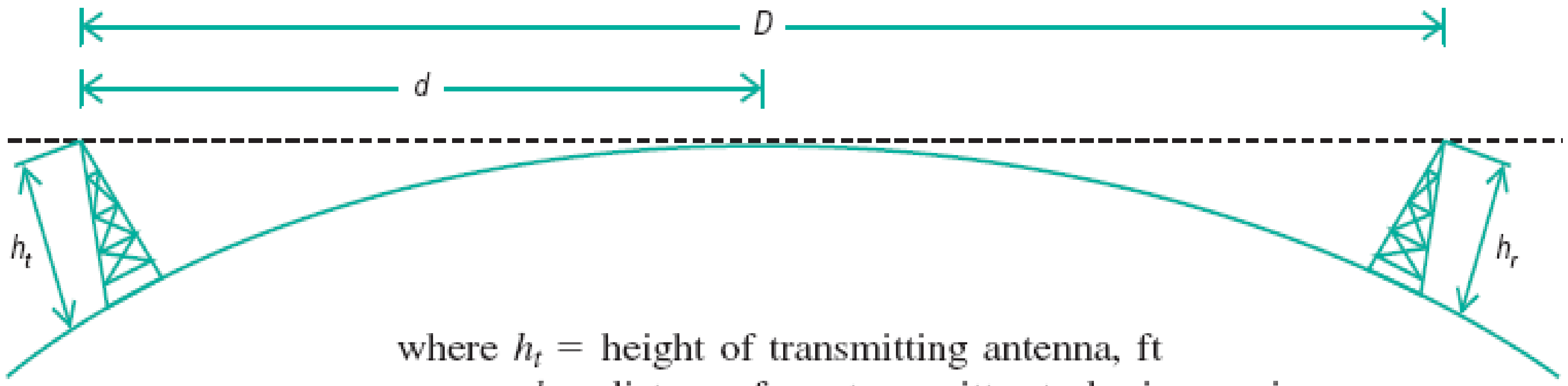


Wave propagation paths

❑The space wave:

- Travels in a straight line directly from the Tx antenna to the Rx antenna.
- Often referred to as LOS_ communication.
- Not refracted, nor do they follow the curvature of the earth.

$$d = \sqrt{2h_t}$$
$$D = \sqrt{2h_t} + \sqrt{2h_r}$$



where h_t = height of transmitting antenna, ft
d = distance from transmitter to horizon, mi

d is called the radio horizon.

Wave propagation paths

- Transmitting antenna is 350 ft high. Receiving antenna is 25 ft high, the longest practical transmission distance is?

$$D = \sqrt{2(350)} + \sqrt{2(25)} = \sqrt{700} + \sqrt{50} = 26.46 + 7.07 = 33.53 \text{ mi}$$

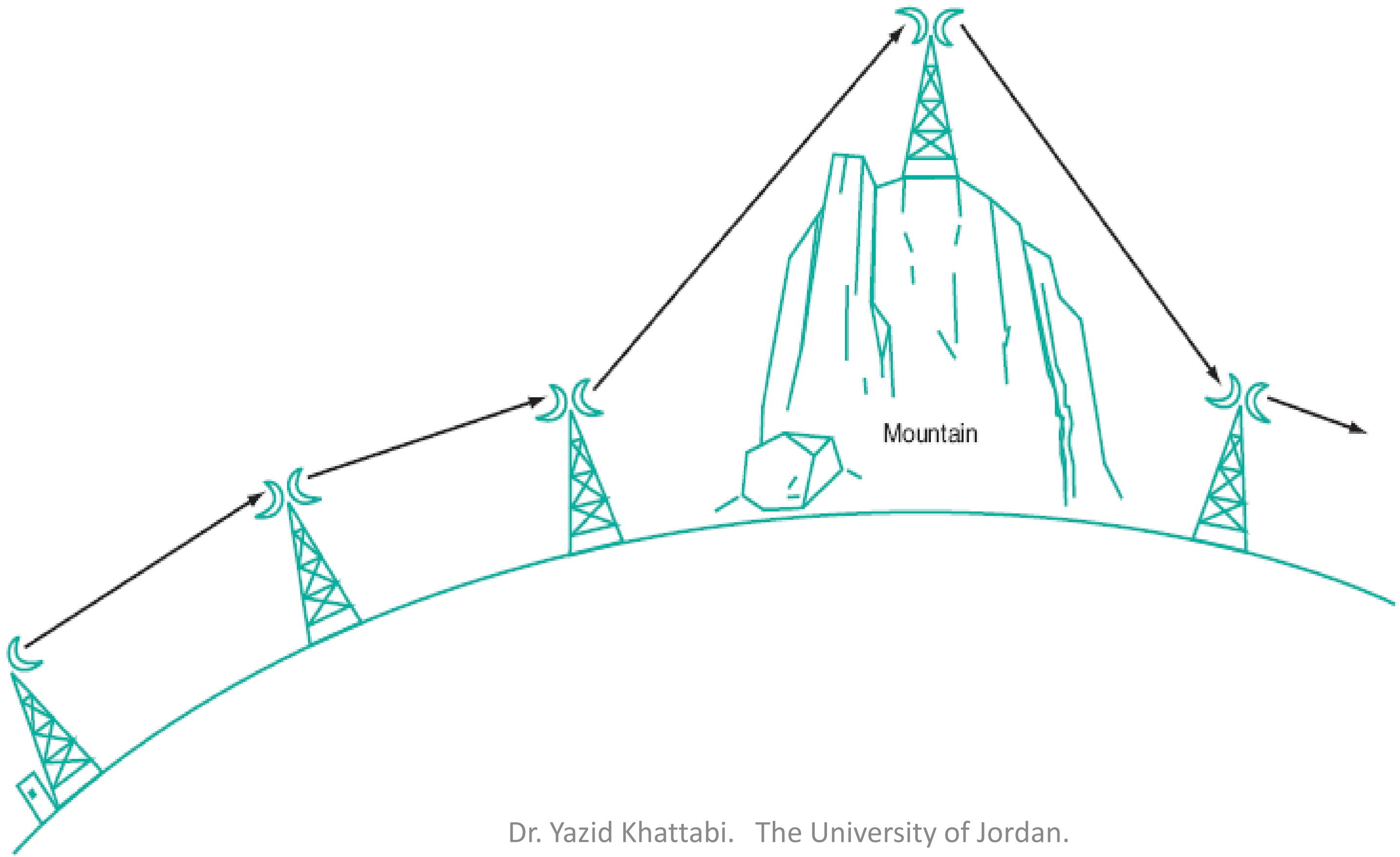
- Line-of-sight communication: radio signals with a frequency above ~ 30 MHz (VHF, UHF, and microwave signals).
- They pass through the ionosphere and are not bent.
- Their transmission distances are extremely limited, and it is obvious why very high transmitting antennas must be used for FM and TV broadcasts.

- To increase the range and guarantee LOS: The antennas are typically located on top of tall buildings or on mountains.

Wave propagation paths

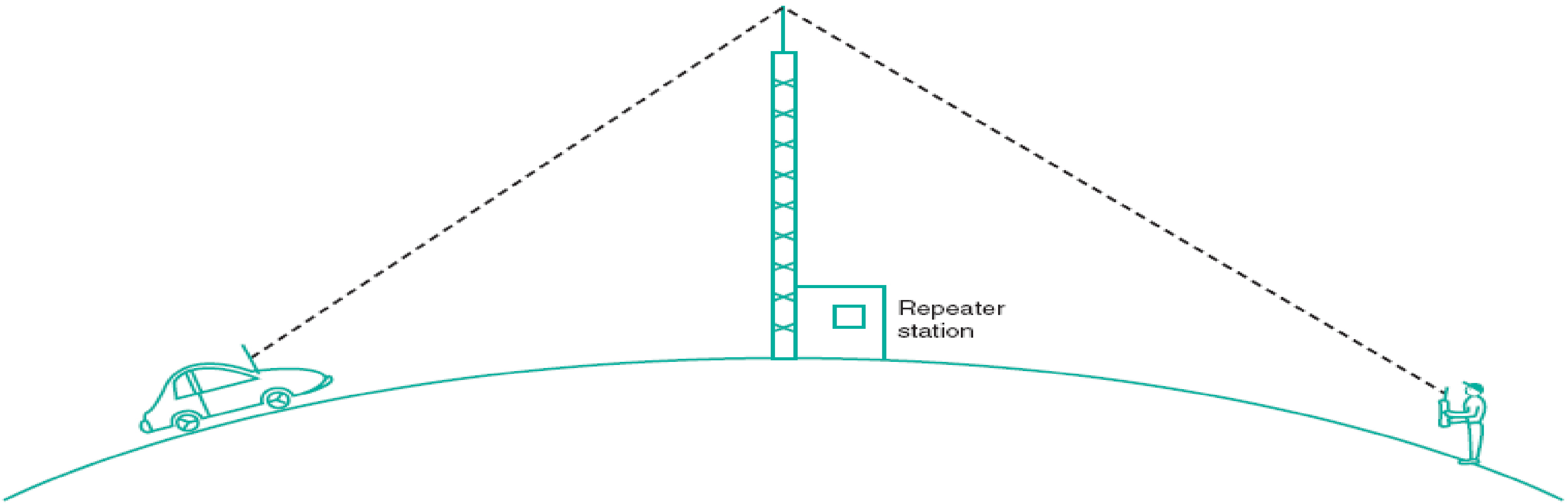
- To increase the range and guarantee LOS: The antennas are typically located on top of tall buildings or on mountains.

Using repeater stations to increase communication distances at microwave frequencies.



Wave propagation paths

- To increase the range: use a repeater stations. The repeater picks up a signal from a remote transmitter, amplifies it, and retransmits it (on another frequency) to a remote receiver.



Thank you