Antenna and Pathloss

Wireless Communications lecture series

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Free space and Pathloss

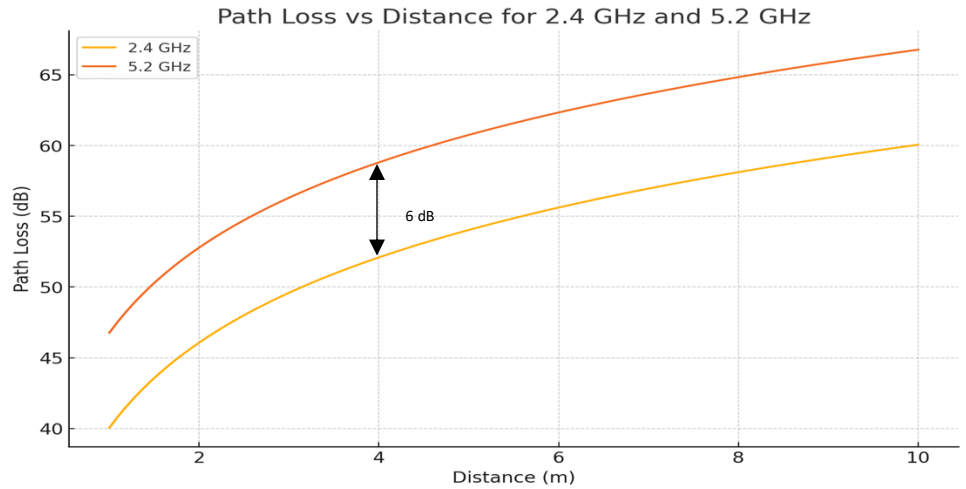
Friis equation shows the inverse relationship between received power and and distance.

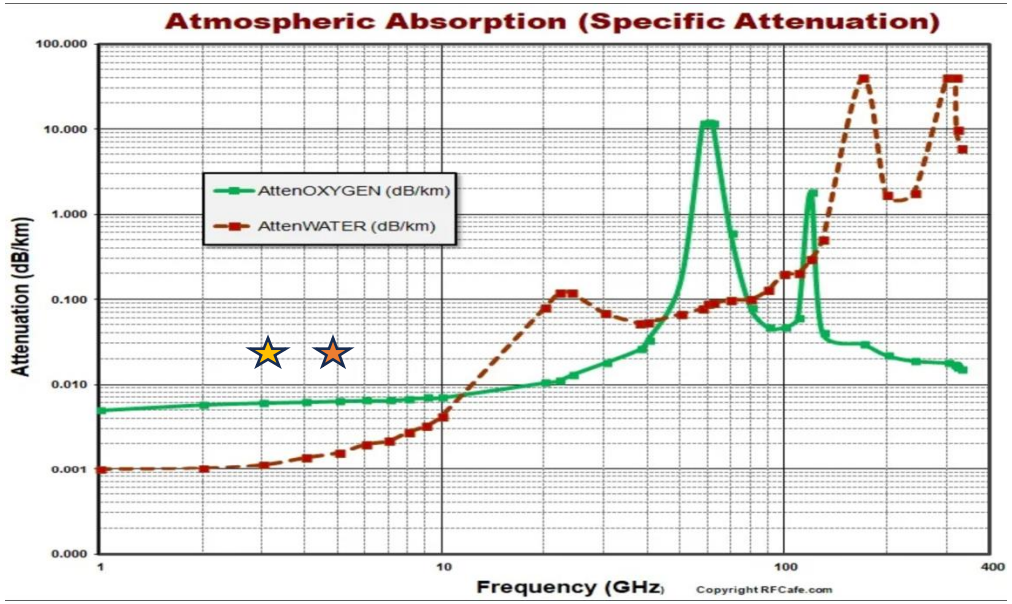
$$P_r = P_t \cdot G_t \cdot G_r \cdot \left(\frac{\lambda}{4\pi R}\right)^2$$ ← Pathloss

Does a transmitter dissipate RF energy while propagating through free space?

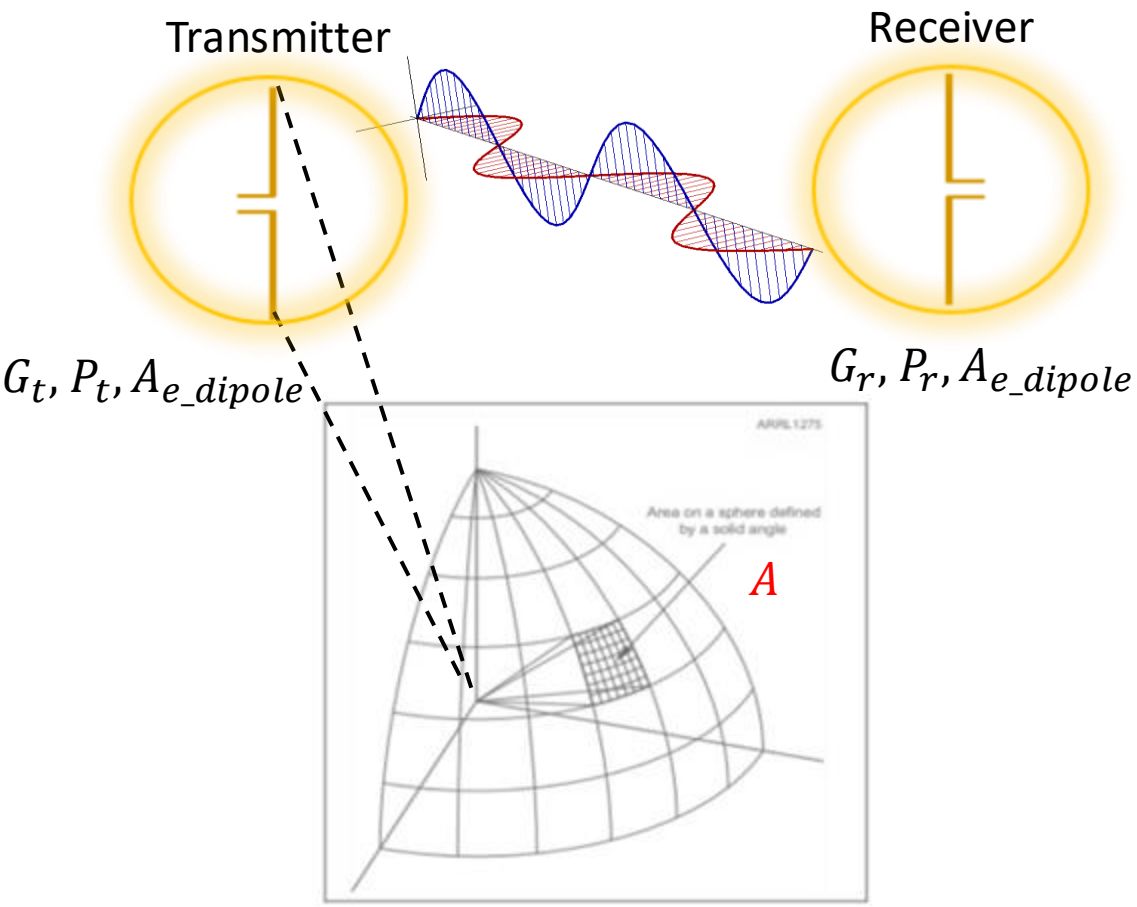
- EM waves are absorbed by the H_2O and O_2 in atmosphere
  - Oxygen absopriton is same at 2.4GHz and 5GHz band
  - H_20 absoprtion increases by 0.001 dB/km

So what causes the a 6 dB difference in pathloss between 2.4GHz and 5GHz Wi-Fi bands?





Antenna aperture



Antenna aperture is an equivalent area over which an antenna extracts energy from a passive radio wave. [J.D Kraus]

- Received Power

$$P_r = P_t \frac{\boldsymbol{A}}{4\pi D^2}$$

- For an imgainary isotropic antenna

$$G_t = G_R = 1 \qquad A_{e\_iso} = \frac{\lambda^2}{4\pi}$$

$$P_r = P_t \frac{\frac{\lambda^2}{4\pi}}{4\pi D^2} \qquad P_r = P_t\left(\frac{\lambda}{4\pi D}\right)^2$$

- For a real $\frac{\lambda}{2}$ Dipole antenna

$$G_t = G_R = 1.64 \qquad A_{e\_dipole} = \frac{1.64\lambda^2}{4\pi}$$

$$P_r = 2.69 * P_t\left(\frac{\lambda}{4\pi D}\right)^2 \qquad P_r = P_t \cdot G_t \cdot G_r \cdot \left(\frac{\lambda}{4\pi R}\right)^2$$

Antenna aperture is smaller at higher frequencies.
Wi-Fi 5GHz antennas capture less RF energy compared to 2.4 GHz antennas

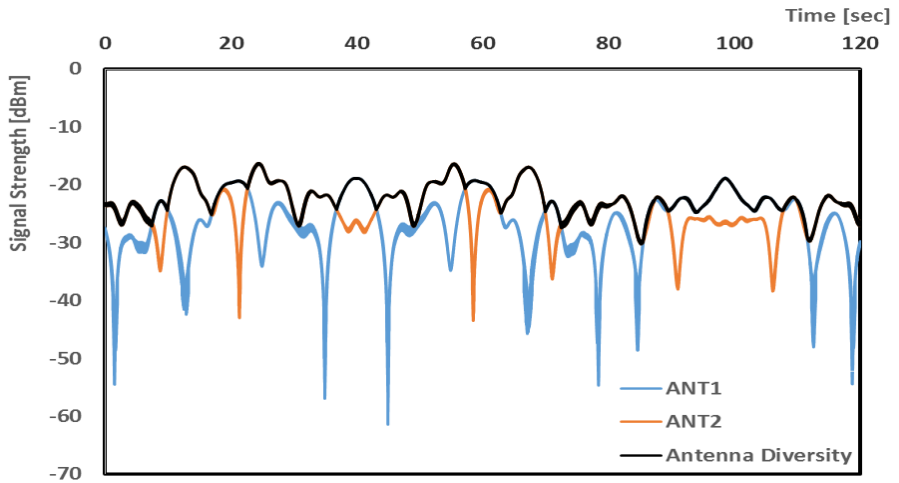
Real world pathloss

Why Wi-Fi users experience better coverage in the 2.4 GHz band as compared to the 5GHz and 6GHz band?

- Friis equation is applicable only to free space communication, i.e. the Transmitter and Receiver have direct line of sight.
- Wi-Fi signals have to pass through obstacles such as concrete floors, brick walls, wooden and plasters walls, etc whose attenuation increases with frequencies.
- Wi-Fi signals specially in residential and enterprise environment undergo attenuation due to Rayliegh fading, caused by reflection, scattering and diffraction of Wi-Fi signals which also increase with frequency.

Along with the smaller antenna aperture size, channel properties and enviroment have a significant contribution to the Pathloss.

How can we account for these channel impairements?



References

- **Kieth Parsons on 6GHz Wi-Fi (The inspirer!)**

https://www.youtube.com/watch?v=yPlY-Q5lS2A

- Atmospheric absorption:

https://www.rfcafe.com/references/electrical/images2/atmospheric-absorption-electromagnetic-energy.jpg

- There is no Loss in Free Space Path Loss. And it doesn't change with frequency

https://hexandflex.com/2021/07/25/the-freespace-pathloss-myth/

- Antenna aperture

https://coppermountaintech.com/wp-content/uploads/2021/05/Introduction-to-Antenna-Aperture-Webinar-Handout.pdf

- Antenna by John D Kraus

https://durenberger.com/wp-content/uploads/2019/11/Kraus_antennas.pdf

- Isotropic antenna aperture derivation

https://phys.libretexts.org/Bookshelves/Electricity_and_Magnetism/Electromagnetics_II_(Ellingson)/10%3A_Antennas/10.13%3A_Effective_Aperture