Antenna pattern ~~loss~~

↳ They describe directional radition characteristics of an antenna. ideally we max gain direction is assumed as boresight, but in physical world the alignment also causes some small amount of losses in propagation of signals. for example parabolic dish antenna the perfect pattern have high gain but sidelobes can introduces Interference esle they reduce gain, the pattern losses can add upto 3 dB

polarization mismatch:

↳ orientation of Electromagnetic waves "electric field"

→ mismatch b/w transmitter and reciever polarization cause power loss.

$L_{pol} = 20 \log_{10}|\cos\psi|$, ψ is angle b/w polarization, the loss can Vary for lineal or circular, horizontal fields. losses upto 3 dB

→ we can use same polarization type for Antenna to reduce losses

pointing losses:-

→ arise from inaccurate in alining the antenna beam towards transmitter/reciever

The results in reduction of effective gain upto 1–5 dB depending on inaccuracy. the natural causes like wind, thermal distortion/mechanical Errors creates losses here

Atmospheric losses:-

→ Atmosphere effects attenuate signal through absorption, scattering and refraction, valying by frequency, weather/path.

- Tropospheric losses:- at lower atmosphere (0–10 km), absorption by gasses. The loss increases with frequency (significantly)
- Inospheric losses:- random fluctuation due to irregularity in ionsphere, more at lower fuquecies.

Ground Clutter:- signal blockage from obstacle near ground station or reflection that cause multi-path fading. Solution is to locate ground station in area where minimal nearby structures

Marginal Allocation:-

link margin is the extra power above minimum required.

$M = P_{req} - P_{min}$

Allocation strategy. is process of deciding how much margin to add based on system uncertainity Notmaually varies from 3 dB to 10 dB.

- margin also covers all the losses mentioned earlier.

fade statistics:-

→ its describation of probability and duration signal loss.

its specially for high frequency bands, rainfall data of ground station is used to determine the fade level exceedition.

we also have other fadings like multipath fading, Rain fade. Racianfade.

modulation and coding selection:-

it depends directly on calc link margin and Data rate

→ modulation converts Digital Data stream into an analog wave form.

High order modulations require higher SNR (signal to noise ratio) but offer higher throughput. coding adds multiple records of error at cost of rate

Coding (FEC → Forward Error correction)

→ it adds redudancy to data allow receiver to correct error without retransmission

FEC improves link by providing coding gain; reduces Prequired given by BER (Bit Error Rate)

→ convolution coding is chosen when link margin is low / Low BER Required.

UHF, S band & X-band downlinks for different mission type

→ These are frequency bands.

① UHF (Ultra High Frequency) → (~400-500) MHz

→ Primarily for Telemetry Tracking and commanding, have low Data rate

→ Low Lfs (Loss in Free space) at low frequecies / high to tolerance to pointing losses

→ Lower cost, less sophisticated (ADCS) – machine is simple

→ Cons:- Low Data Rates : limited bandwidth / Large antenna size lead low Data rates.

② S-band (2-4 GHz)

→ stable performance and good penetration through atmospheric conditions

→ medium rate Data ; commanding and Telemetry

Pros:- Balanced performance

→ commonly used for both uplink and downlinking

Con: → insufficient for large volume ~~data~~ data (HD images)

③ X - Band Downlinks. 8-12 GHz

Highly stabled

→ High Data Rate

→ Smaller ~~att~~ antennas → high gain smaller ~~atte~~ antennas on both cubesat and ground station

Cons:- complexity increased and power consumption (↑)

→ more susceptible for signal degradation due to atmospheric rain fade, tropospheric losses, required higher link margin

$\therefore$ we know that $10\log_{10}(x) = x^{dB}$ then

$$10\log_{10}(P_r) = 10\log_{10}(P_t) + 10\log_{10}G_r + 10\log_{10}(G_t) + 20\log\left(\frac{\lambda}{4\pi D}\right)$$

$$P_r^{dB} = P_t^{dB} + G_r^{dB} + G_t^{dB} + 20\left(\log\lambda - \log(4\pi D)\right)$$

By observing the equation also $\lambda << 4\pi D$ then

→ $\underline{\log(\lambda)} - \underline{\log(4\pi D)}$ is < 0

$$L_{fs} = 20\log_{10}\left(\frac{4\pi D}{\lambda}\right)$$; free space path loss.

L_{fs} → loss of signal strength occurs as electromagnetic waves spreads out in frees space. even with no obstacles power density (↓) with distance

L_{misc} → miscellenous losses

↳ group of all additional system losses account for real world imperfections. non ideal situation.

typically small decible (dB) (1-5)dB

$$\boxed{P_r^{dB} = P_t^{dB} + G_r^{dB} + G_t^{dB} - L_{fs} - L_{misc}}$$

$$P_r = P_t + G_r + G_t - L_{fs} - L_{misc}$$

$10\log(x^2)(dB) = 20\log(x)(dB)$