Basics of satellites

propagation impairments and mitigation techniques

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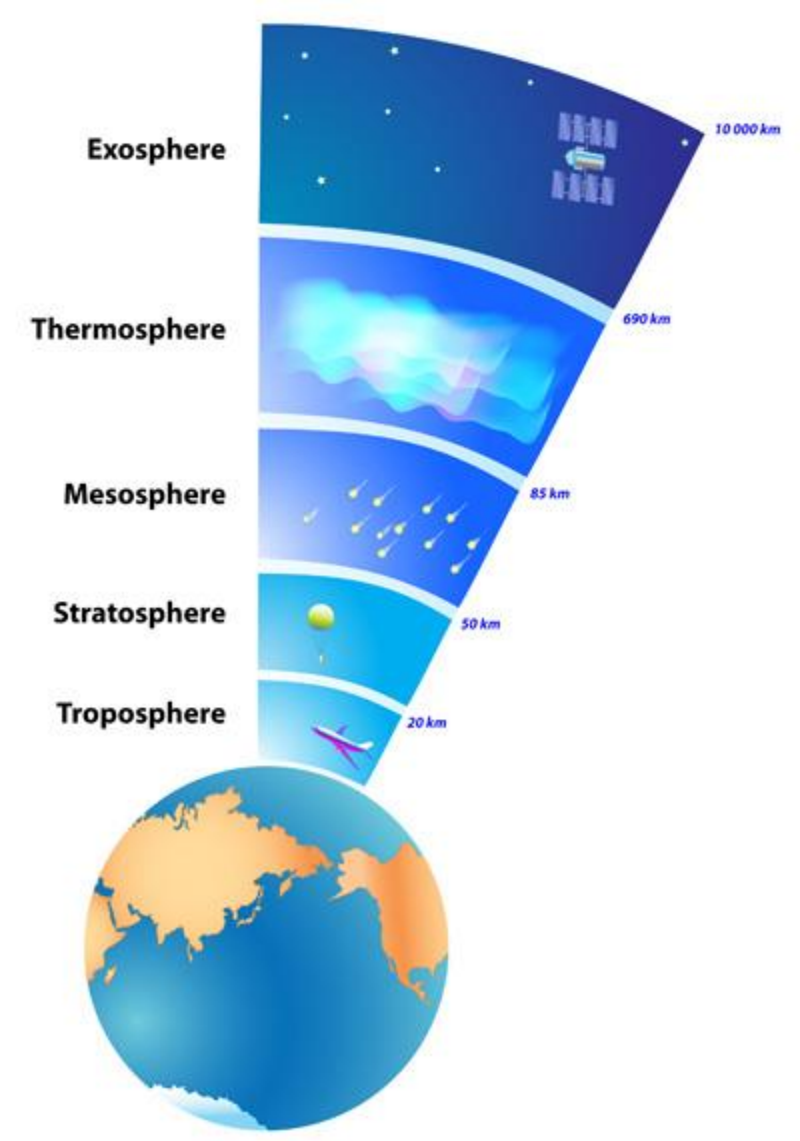
Basics about satellites

- Frequency range: Usually more than 500Mhz
- L(1-2GHZ)
- S(2-4GHZ)
- C(4-6GHZ)

Need more capacity↑ ➔ increase frequency ↑

- Ku band (12-14GHZ)
- Ka band (20-30GHZ)
- V band (40-50GHZ)

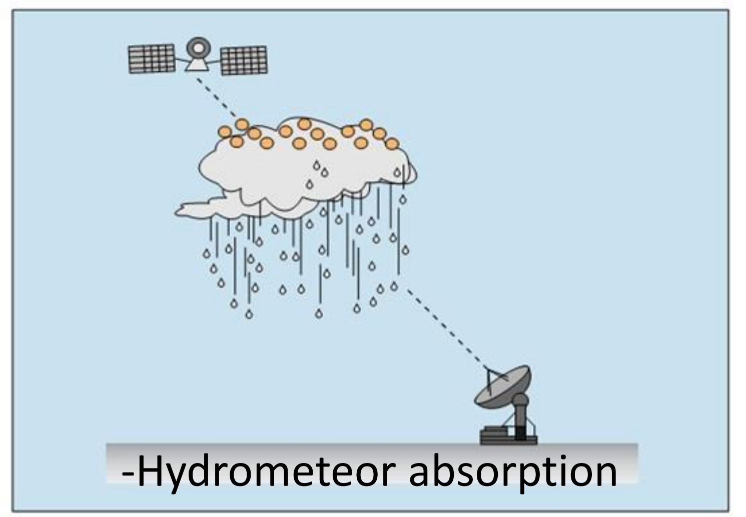
Earth-Space layers



Ionosphere layer consist of Mesosphere, Thermosphere and Exosphere

Ionosphere layer effects on signals lower than **3GHZ**↓
Tropospheric layer effects on signals upper than **3GHZ**↑

If the satellite works above 10GHZ we only have Tropospheric effects
Tropospheric effects:
-Hydrometeor absorption
-Gaseous absorption
-Signal depolarization
-Tropospheric scintillations

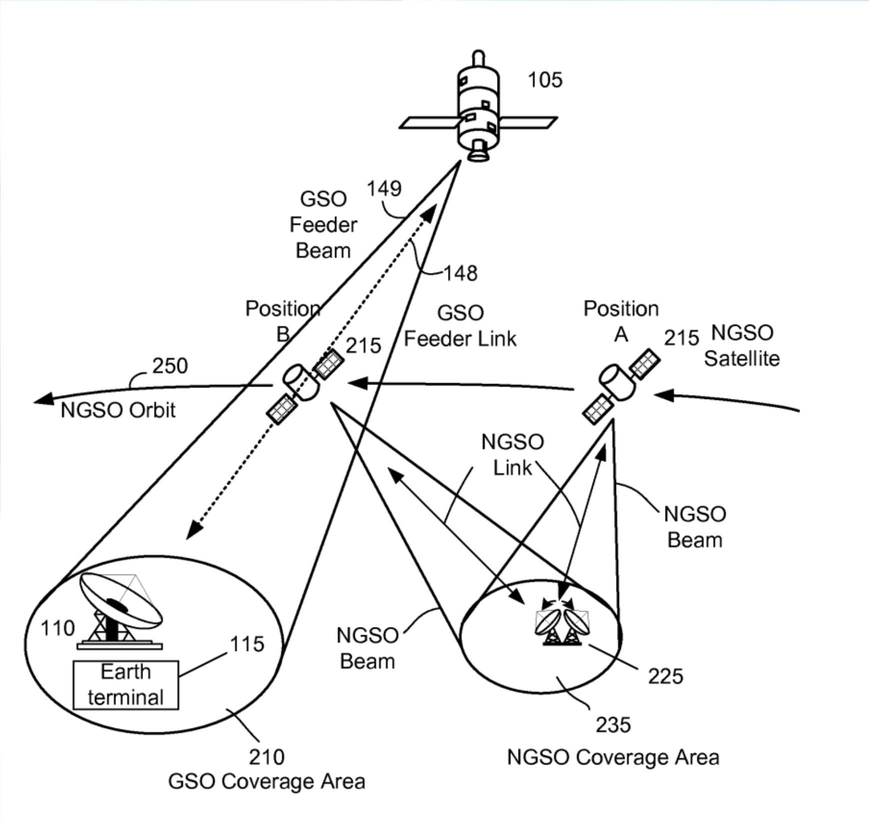


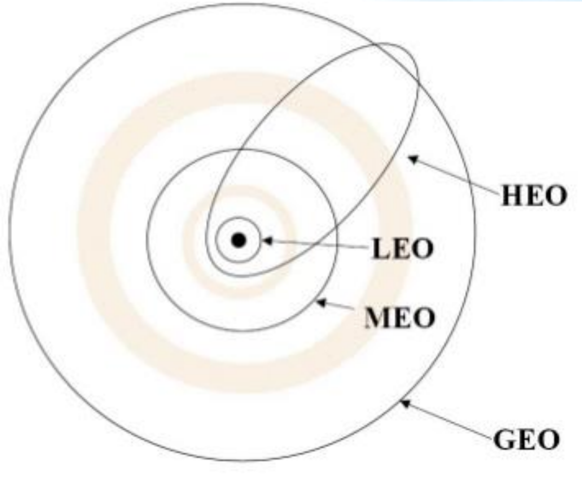
GSO vs NGSO satellites

A geosynchronous orbit (sometimes abbreviated GSO) is an orbit around the Earth with an orbital period of one sidereal day, intentionally matching the Earth's sidereal rotation period

A non geosynchronous orbit (sometimes abbreviated NGSO) is always orbit closer to the earth than GSO satellites and with different speed depending on their height
Can consist into :

LEO(Low Earth Orbit)
MEO(Medium Earth Orbit)
HEO(Highly Earth Orbit)





Satellite basic concepts

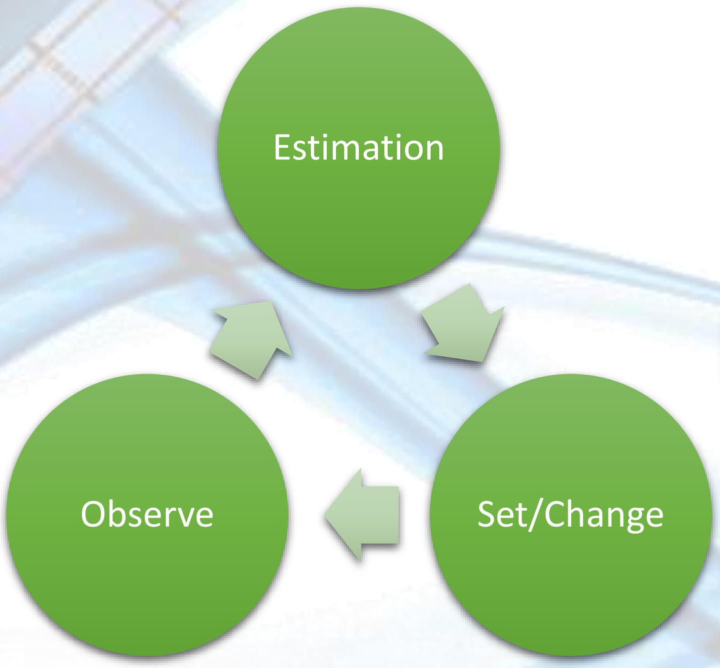
- Availability: time percentage in a year BER<ξ (threshold about 10^{-7}BER in QPSK correspond to 0.06% of the year 315.4 min/year)

- Fade margin = $A_{precipation}^{db} - A_{clear\ sky}^{db}$

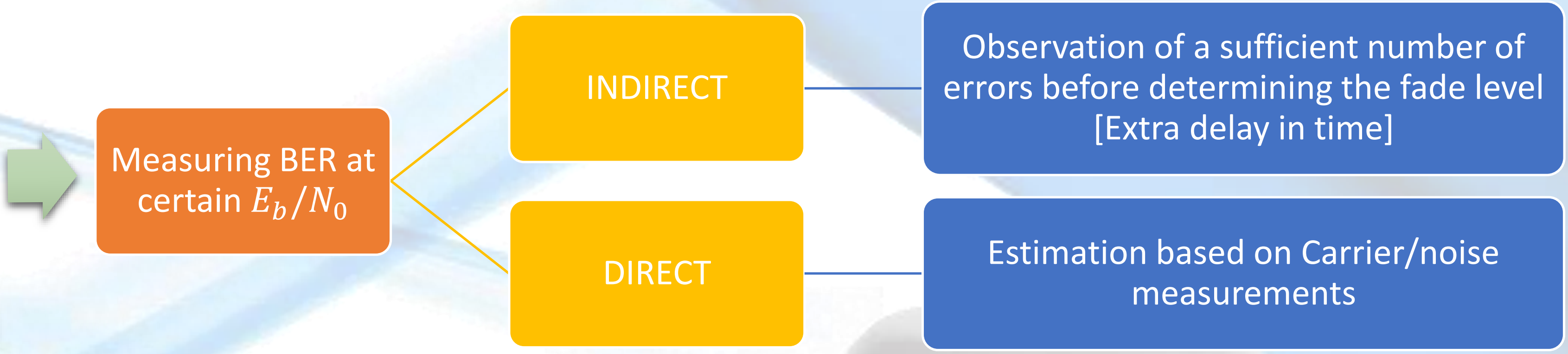
- To satisfy availability and QOS ➔ system gain↑ ➔ fade margin↑

FMT techniques

- Fade Mitigation Techniques (FMT) $\begin{cases} EIRP\ control \\ Adaptive\ transmission \\ Diversity\ protection\ scheme \end{cases}$

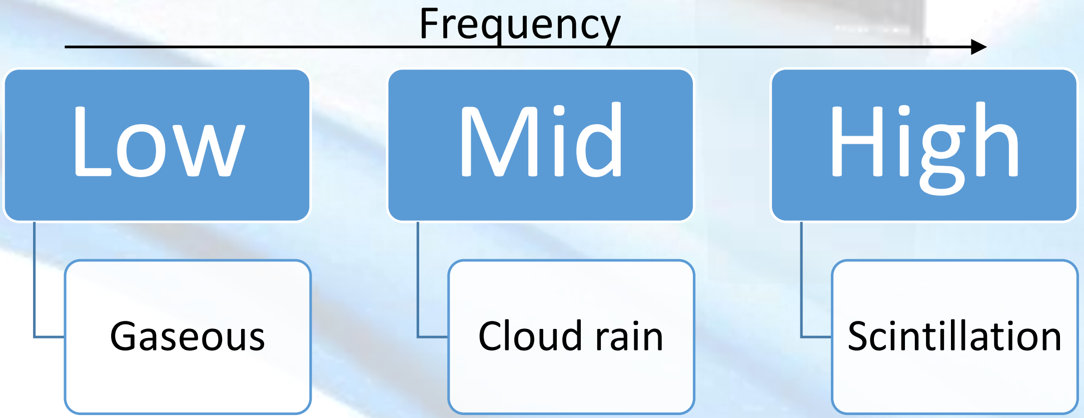


Fade mitigation techniques circle

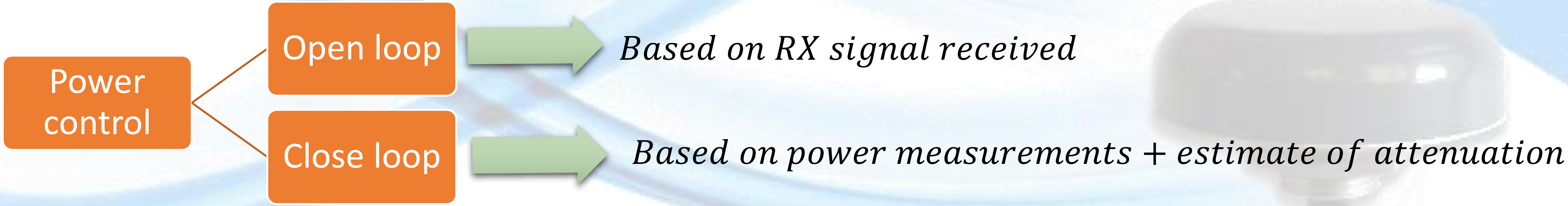


Estimation of fades in control loop using frequency scaling

- Frequency decomposition:



$EIRP\ control(Effective\ Isotropic\ Radiated\ Power)$: Can be implemented in 2 way
-Carrier power → both station (sat&earth)
-Antenna gain → only on sat by spot beam shaping

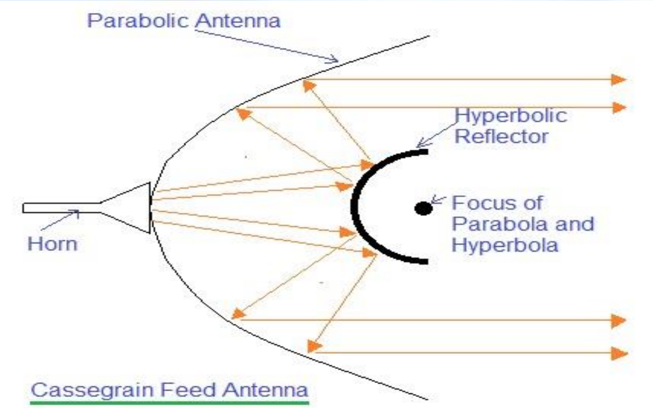


Power control in fade mitigation

ULPC(Uplink Power Control)	**Adjusting HPA of earth station based on attenuation measurements** ***problem=adjacent satellite interference → when part of signal energy falls into adjacent channel**
DLPC(Downlink Power Control)	Adjusting HPA of sat station based on attenuation measurements *Problem= Intermodulation interference Single carrier per transponder TDMA $\underset{better}{>}$ FDMA
SBS(Spot Beam Shaping)	In GSO sat's In a certain geographical region where coverage provided by spot beams Higher EIRP↑ → lower beam width↓ → higher gain↑

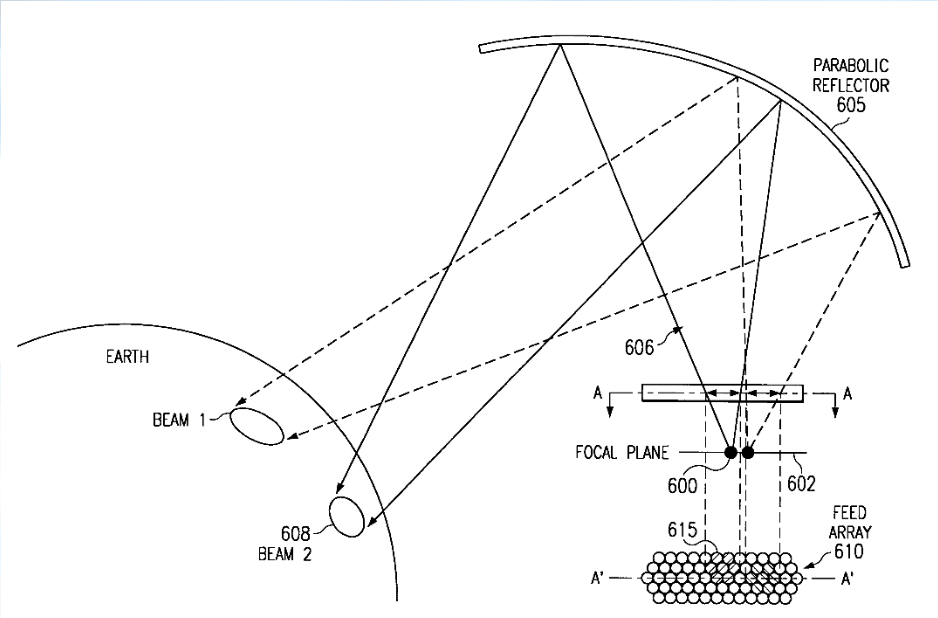
SBS(Spot Beam Shaping)

- For implementing this type of power control there are 2 ways:
- Cassegrain antenna(1feed)



Cassegrain antenna

- Multifeed with beamforming network (Better)



Multifeed with beamforming network

SBS(Spot Beam Shaping)

- Advantages:

1.real time estimates of attenuation not needed(important parameter in FMT control loop) why? Because compensation carried out on entire coverage not single site

2.Compensation for rain attenuation achieved by shaping the antenna pattern and not by reducing output back-off of amplifiers → no intermodulation interference

Future: OBP →ON BOARD PROCESSING MULTICASTING

Adaptive transmission techniques

- Concept: modifying the manner signals are processed by nodes
- Hierarchical Coding(HC)
- Hierarchical Modulation(HM)
- Data Rate Reduction(DRR)

HC= why coding? Because: better detection & correction of bit errors by adding redundancy to information signal

General law behind different techniques

HC

- Forward Error Coding(FEC): The central idea is the sender encodes the message in a redundant way by using an error-correcting code
- FEC: At RX without having to resort to any feedback from TX
- Automatic Repeat Request(AQR): Error detection and correction achieved by retransmitting the erroneous block of bits [Usually in sat’s e.g. Vsat&Usat]
- Error coding designed to counter termal noise(random errors)
- But Above 10GHZ we have errors caused by bursts!
- Countering Burst: 1.Interleaving method 2.Concatenated method

Countering bursts

- 1.Interleaving method: Spreading each message in time ➔ apply coding to the columns of a shift register arranged as matrix & then transmit the coded word row wise [Good for scintillation problem]

- 2. Concatenated codes: combat error bursts In coding theory, concatenated codes form a class of error-correcting codes that are derived by combining an inner code and an outer code.

- Combination of Interleaving + Concatenated codes = Turbo codes

Turbo codes are used in 3G/4G mobile communications (e.g. in UMTS and LTE) and in (deep space) satellite communications as well as other applications where designers seek to achieve reliable information transfer over bandwidth- or latency-constrained communication links in the presence of data-corrupting noise

HM

- HM techniques exchange spectral efficiency for power requirement during heavy rainfalls.
- Satellite system modulation : PSK
- Spectral efficiency: transmit more bit/sec with specific RF bandwidth
- Higher ↑ M in M-PSK or M-QAM ➔ more spectral efficiency↑
- Higher ↑ order of modulation M ➔ higher ↑ susceptible to errors (BER ↑) WHY ? Because separation between consecutive amplitude or phase states is reduced
- So we reduce the order of modulation e.g.
- Clear sky = 64 PSK -256 QAM
- Rain = BPSK – QPSK
- HM performed in closed loop FMT (good for Vsat)

DRR

- Control system monitor next channel state in deep fade➔data rate reduced
- DRR in framework called “OLYMPUS”(Ka band video conference Vsat)
- BER & Bandwidth is constant at RX by combining information data rate reduction with a pseudorandom data spreading

- Advantage VS HC&HM : equally distribute sat resources(BW & burst) to every user

Diversity protection schemes

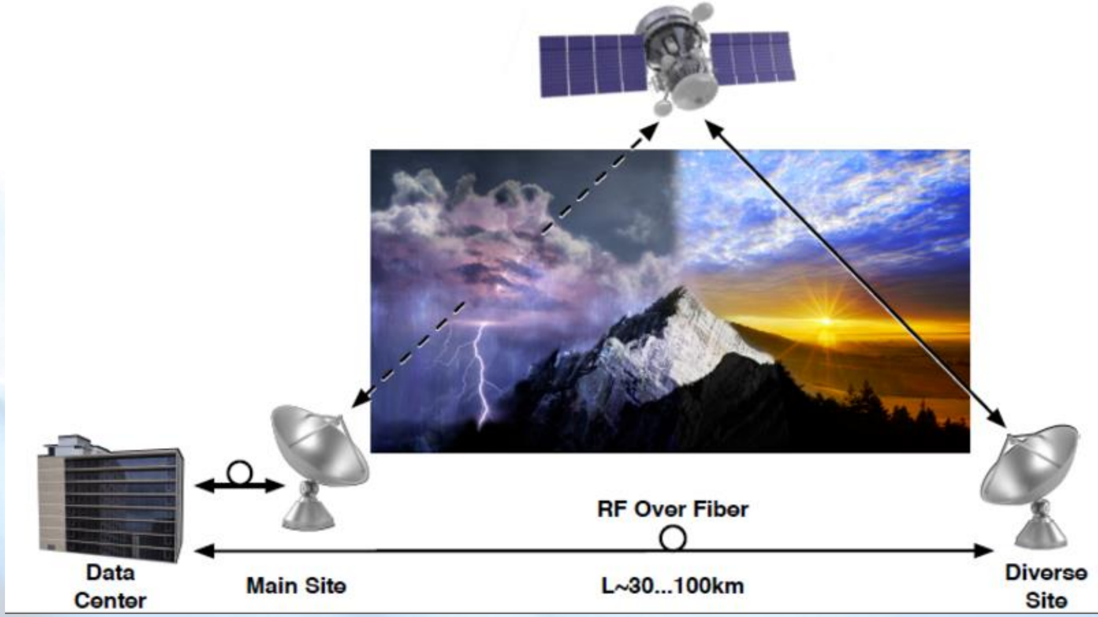
- Usually works for rain fades

Site Diversity(SD)
Orbital Diversity(OB)
} Take advantages of spatial structure

Frequency Diversity(FD)
Time Diversity(TD)
} Based on spectral & temporal dependence

Site Diversity(SD)

- Stratiform rain or convective form

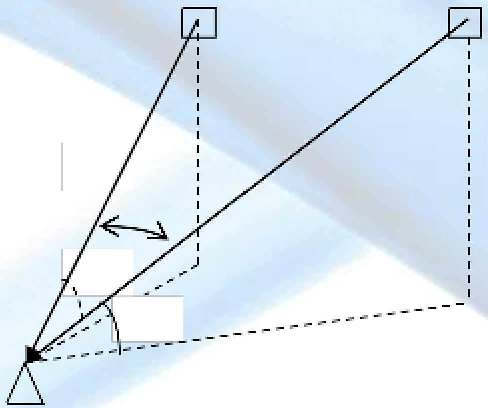


- Main concept behind SD: if the signal received via different paths it is quite likely that a deep fade will occur only on one of them & leaving others less affected.
- SD takes advantage of this characteristic of convective rain by 2-3 site diversity earth stations. The received signal at each earth station are sent to master station to improve C/N ratio.
- If D be separation distance between two station :

D ↑➔ GAIN↑(Highest gain by any FMT)

Orbital Diversity

- Choosing between multiple satellites
- Adv: It has lower cost Disadva: separation of alternative path is smaller



- SIRIO → Ku band GSO
- OLYMPUS [ITALSAT] → Ka band

Frequency Diversity

- Employs the use of high frequency bands (Ka&EHF) during normal operation & switches over to spare channel at lower freq bands(Ku)
- Drawback: capacity allocation why? At large freq↑ → BW ↑ at Lowfreq↓→BW↓

Time Diversity

- Only service that can tolerate delays based on retransmission of data corrupted by fading
- TD VS ARQ (Difference): TD duration is based on estimation of fade interval duration
- Video on demand, multimedia and data applications can tolerate time delay

Mixed FMT's

- 1.Multi Frequency TDMA(MF-TDMA): -Very/Ultra small aperture terminal(Vsat/Usat) –Return Channel Satellite Terminal(RCST)
- How It works? Reserving a pool of time slots within the frame shared among all earth terminals during high attenuation.
- These slots needed to offer lower coding rate & Lower modulation scheme which gives additional fade margin
- Adaptive TDMA →Advanced communication technology satellite(ACTS)

Clear region	Fade region

ACTS downlink TDMA

Thank you

References:

A. D. Panagopoulos, P. D. M. Arapoglou and P. G. Cottis, "Satellite communications at KU, KA, and V bands: Propagation impairments and mitigation techniques," in *IEEE Communications Surveys & Tutorials*, vol. 6, no. 3, pp. 2-14, Third Quarter 2004.
doi: 10.1109/COMST.2004.5342290