
# Link Availability for LEO Constellations

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# Outline

- **Introduction**
- **Telesat GEO Satellites**
  - Static Link Analysis
  - Atmospheric Fading and Link Availability
  - Adaptive Mechanisms
- **Telesat LEO Constellation**
  - Dynamic Link Analysis
  - Atmospheric Fading and Link Availability in LEO
  - Adaptive Mechanisms in LEO
- **Q & A**

Introduction

- About Telesat
  - Established in 1969
  - One of the largest satellite operators in the world
  - Corporate headquarters in downtown Ottawa
  - Launched the first commercial domestic communications satellite in geostationary orbit – Anik A1
  - Launched first commercial Ku-band satellite offering first direct-to-home (DTH) television service
  - First satellite operator to provide Internet access to ISPs over satellite

# Telesat GEO Satellites

# Telesat GEO Satellites

Back to Satellite Selection

## Telstar 19 VANTAGE 63° WL

New HTS co-located with Telstar 14R supporting mobility and enterprise broadband across the Americas and Atlantic

Select Coverage Area

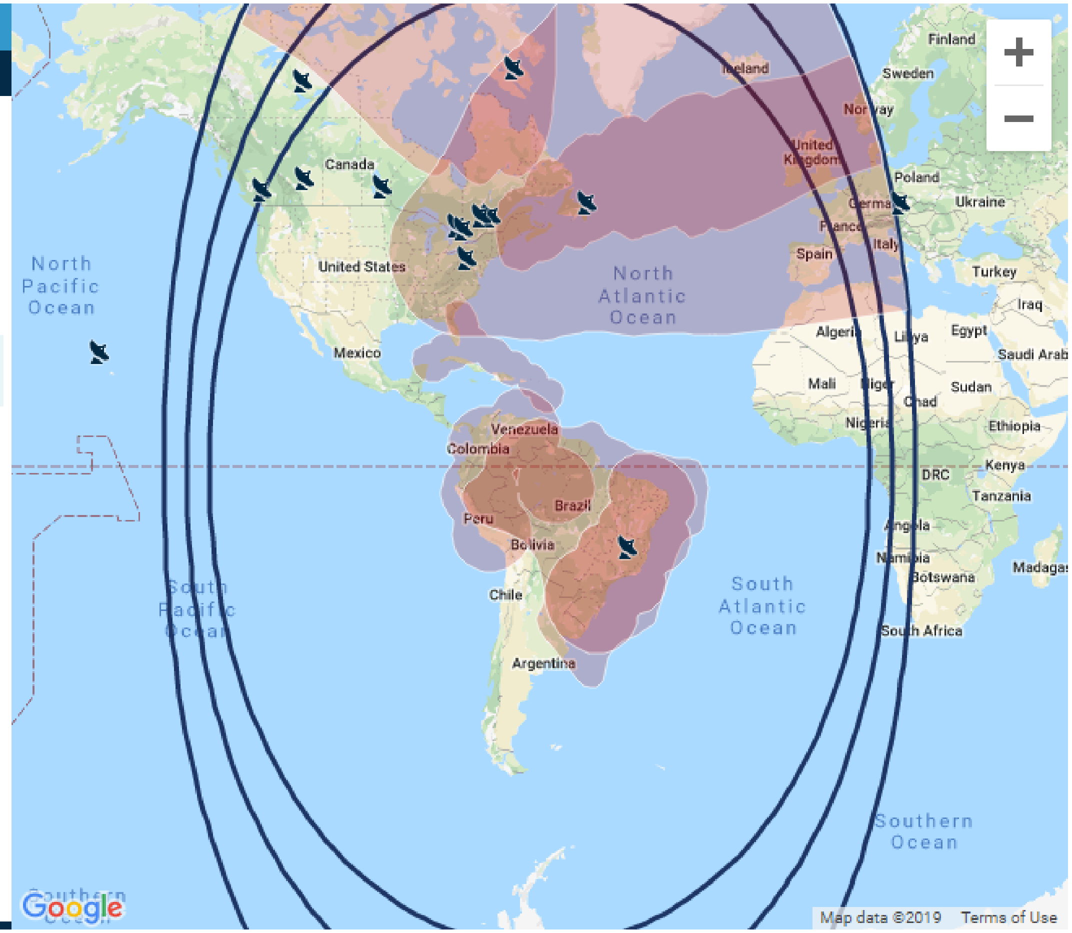
Satellite Overview ▾

Learn about iDirect, VNO, co-location and teleport services available for this satellite

| Manufacturer | Vehicle |
|---|---|
| Space Systems/Loral | SpaceX Falcon 9 |
| **In Service Date** | **Launch Date** |
| August 2018 | July 2018 |
| **Type** | **Weight** |
| SSL 1300 | 7080kg |

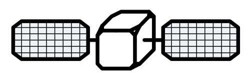
### Downloads

- Footprint Brochure (Letter, PDF)
- Footprint Brochure (A4, PDF)



# Telesat GEO Satellites

# Static Link Analysis



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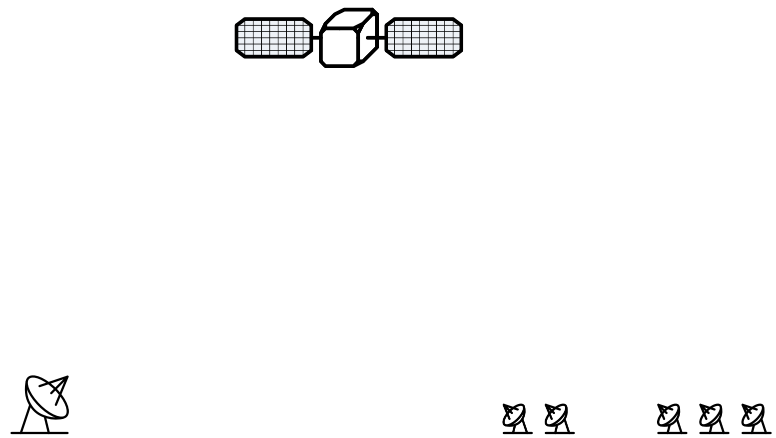

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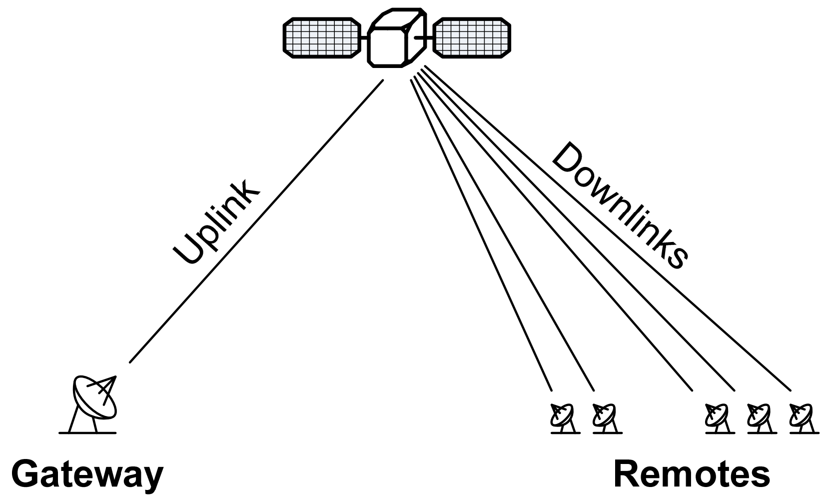

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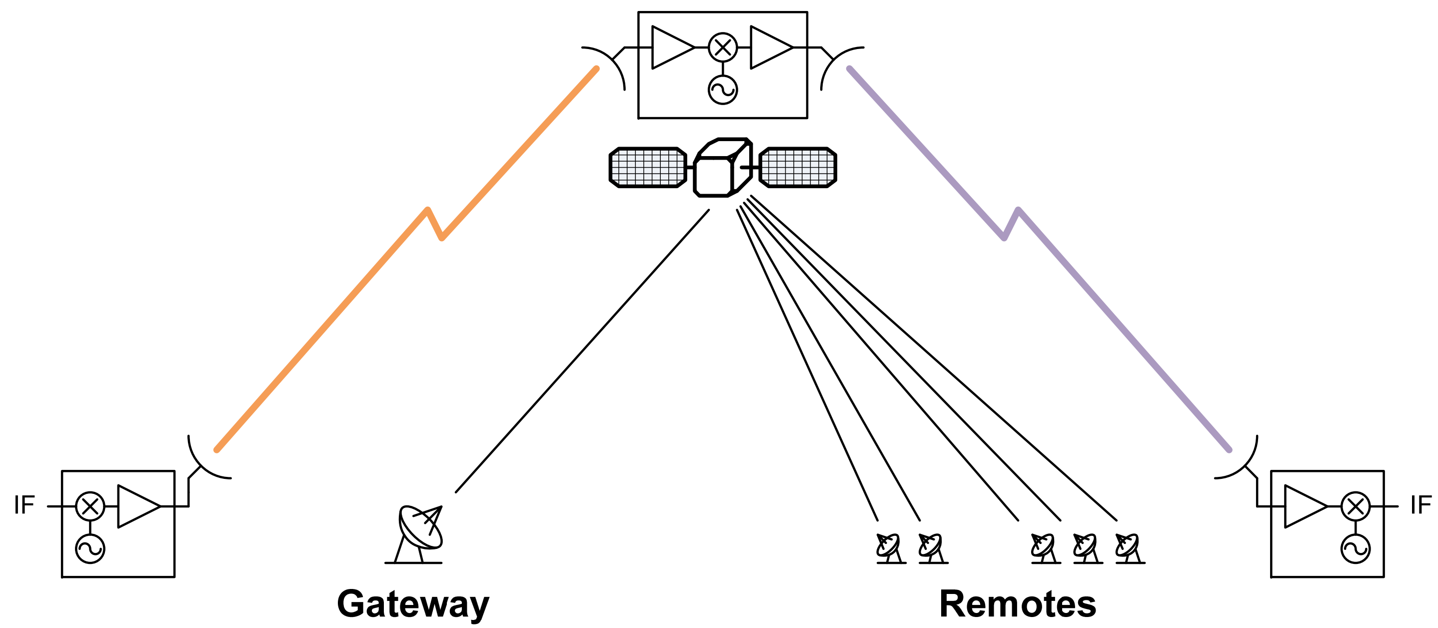

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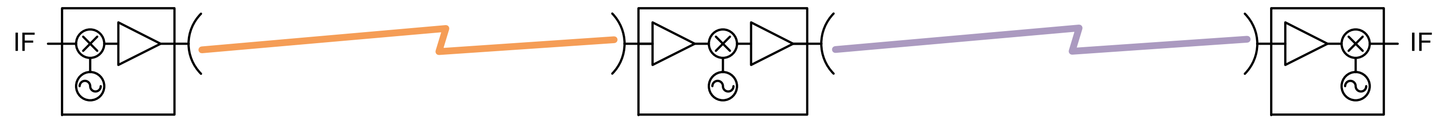

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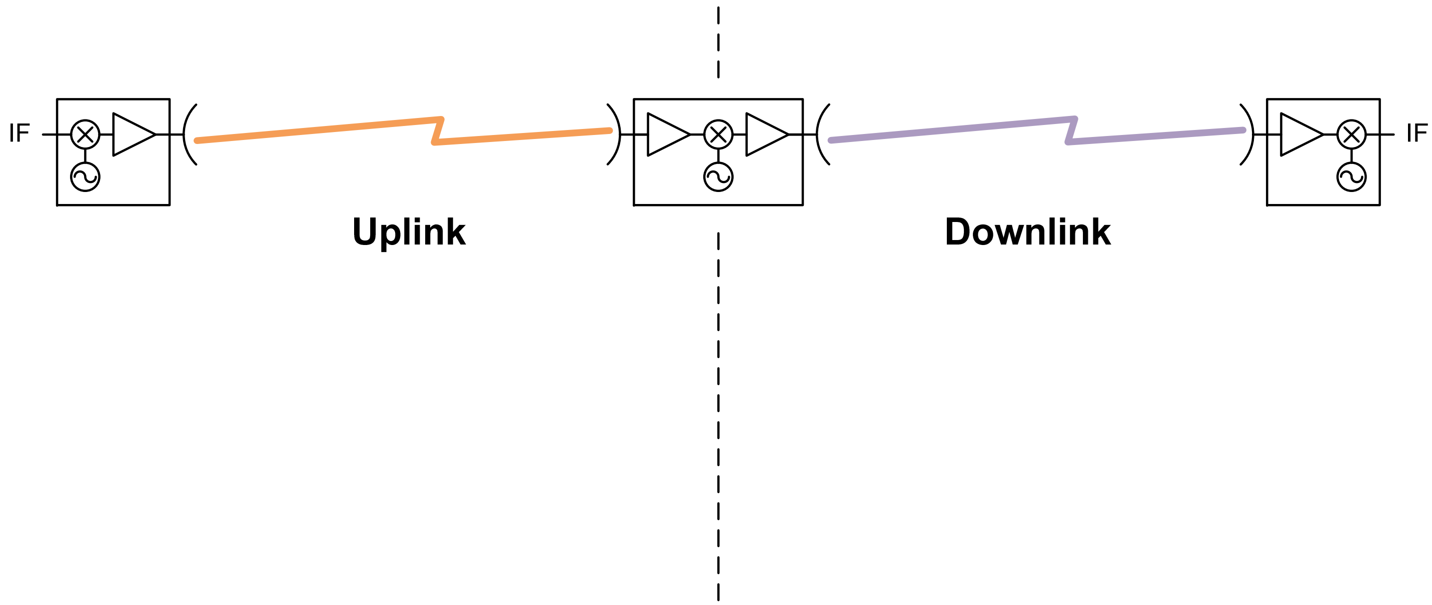

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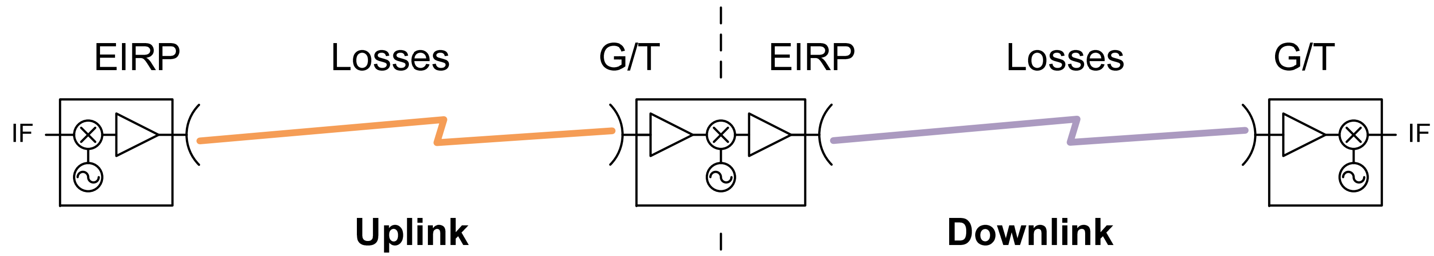
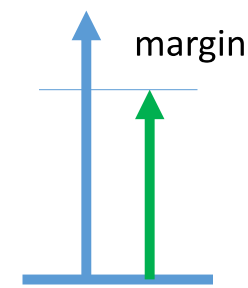



$$\left(\frac{C}{N}\right)_U = EIRP_U + \left(\frac{G}{T}\right)_U - Losses_U - k - B$$

$$\left(\frac{C}{N}\right)_D = EIRP_D + \left(\frac{G}{T}\right)_D - Losses_D - k - B$$

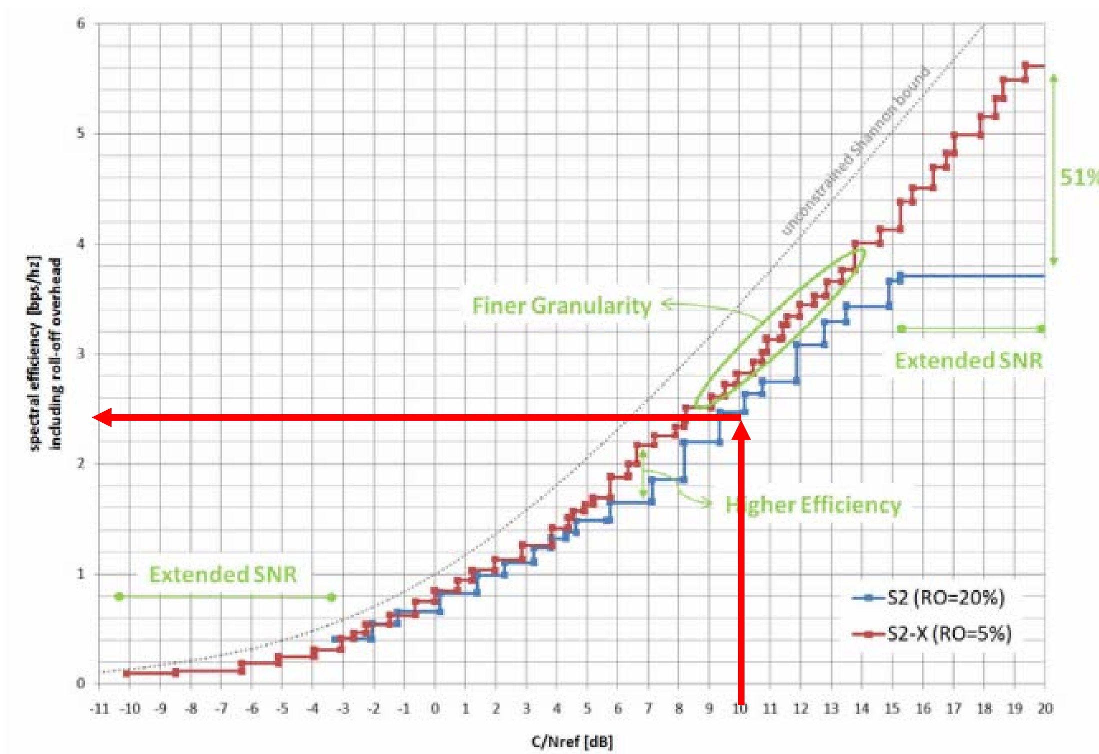
$$\left(\frac{C}{N}\right)_T^{-1} = \left(\frac{C}{N}\right)_U^{-1} + \left(\frac{C}{N}\right)_D^{-1}$$



# Converting C/N to Data Rate

- To convert a C/N to a data rate, you use the spectral efficiency of the modulation coding scheme being applied
- Spectral efficiency is a measure of how effectively the link is passing information relative to the spectrum it is occupying

$$DataRate = spec.eff \times bandwidth$$

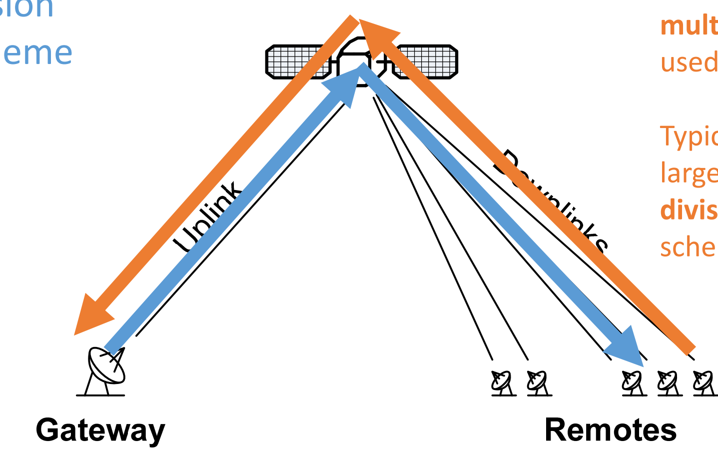



# Forward and Return Link Sharing

## Forward Link
## - Gateway to Remote

One transmitter to many receivers requires a **multiplexing** scheme

Typically, in large satellite networks – a time-division multiplexing (TDM) scheme is used




## Return Link
## - Remote to Gateway

One receiver from many transmitters requires a **multiple access** scheme

Typically, for a large number of small remotes – a **time-division multiple access (TDMA)** scheme is used

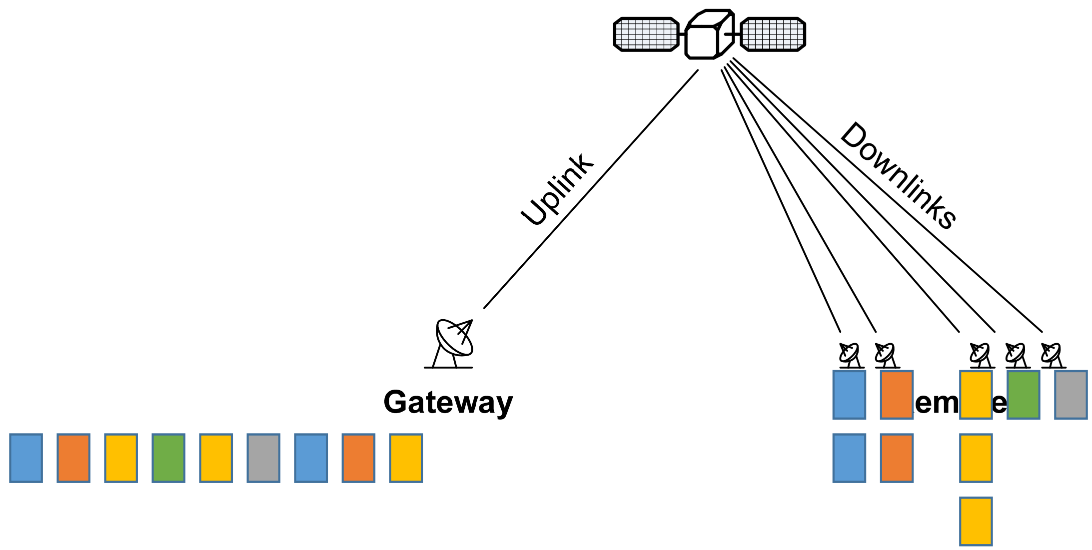
Typically, for a small number of large remotes – a **frequency division multiple access (FDMA)** scheme is used

Notes:

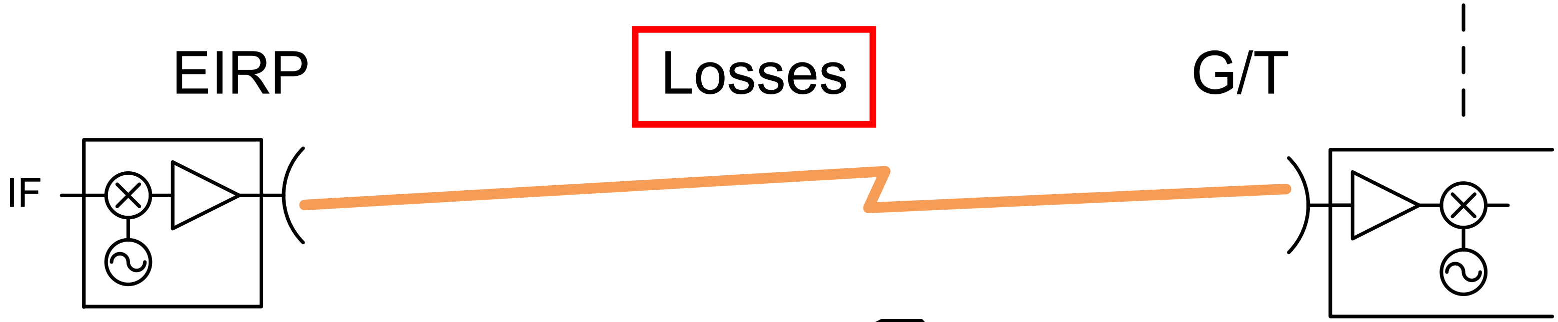
- FDMA is often referred to as SCPC for "Single Channel per Carrier")
- Most TDMA systems use multiple return carriers – referred to as Multiple Frequency – Time Division Multiple Access (MF-TDMA)

- Time-Division schemes share data rate among many remotes using schedulers
- Forward scheduling is arrival based
- Return scheduling is request based

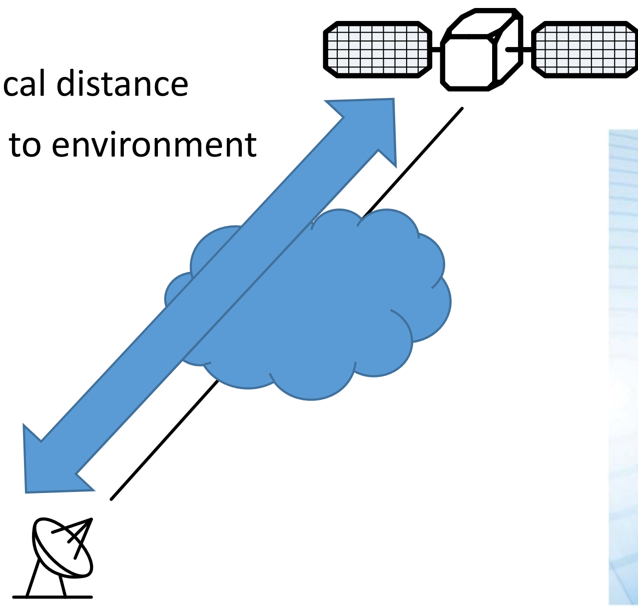
$$EffectiveDataRate = DataRate \times \frac{time\ slots\ assigned}{time\ slots\ available}$$

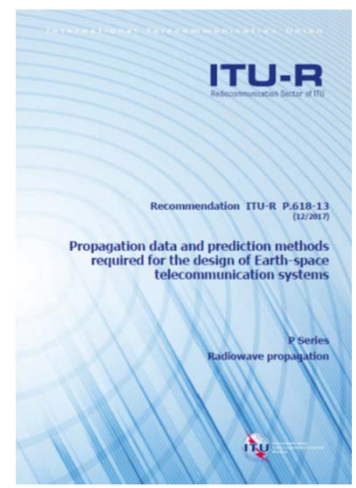


# Atmospheric Fading and Link Availability




- Path Loss is due to physical distance
- Atmospheric Loss is due to environment





# Atmospheric Fading and Link Availability

The propagation loss on an Earth-space path, relative to the free-space loss, is the sum of different contributions as follows:

– attenuation by atmospheric gases;

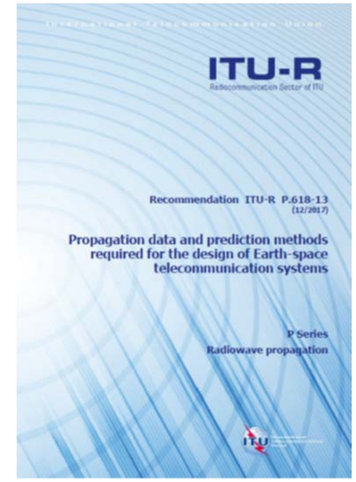
– attenuation by rain, other precipitation and clouds;

– focusing and defocusing;

– decrease in antenna gain due to wave-front incoherence;

– scintillation and multipath effects;

– attenuation by sand and dust storms.

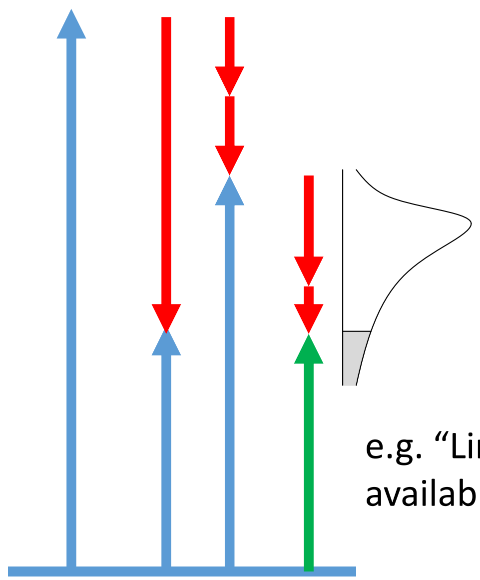



Each of these contributions has its own characteristics as a function of frequency, geographic location and elevation angle. *As a rule, at elevation angles above 10°, only gaseous attenuation, rain and cloud attenuation and possibly scintillation will be significant*, depending on propagation conditions.”

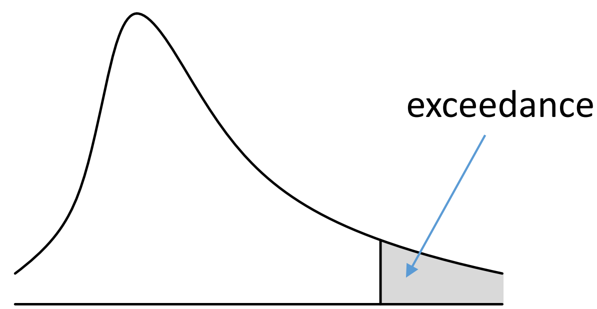
# Atmospheric Fading and Link Availability

$$\left(\frac{C}{N}\right)_U = EIRP_U + \left(\frac{G}{T}\right)_U - Losses_U - \mathrm{k} - \mathrm{B}$$

- Free Space Path Loss
- Gaseous Attenuation
- Rain and Cloud Attenuation
- Scintillation

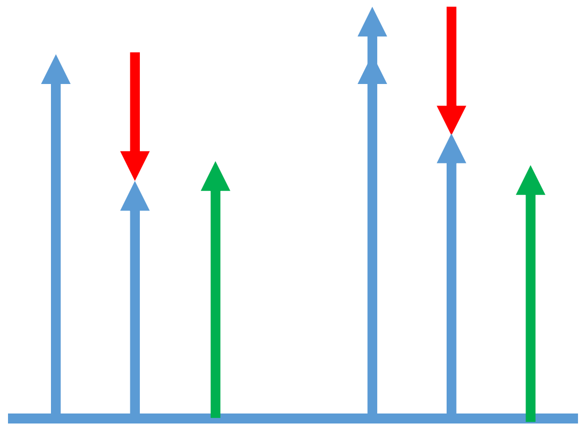


e.g. “Link is available 99.5%”



Adaptive Mechanisms

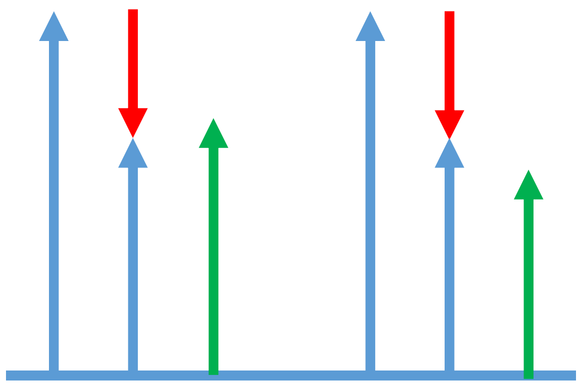
- Uplink Power Control
  - Linearity
  - Cost



$$\left(\frac{C}{N}\right)_U = EIRP_U + \left(\frac{G}{T}\right)_U - Losses_U - k - B$$

# Adaptive Mechanisms

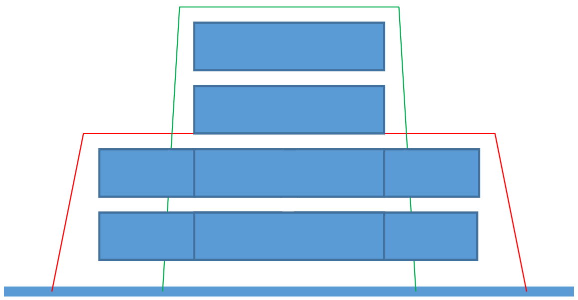
- Adaptive Coding and Modulation
  - Throughput
  - Cost



$$\left(\frac{C}{N}\right)_U = EIRP_U + \left(\frac{G}{T}\right)_U - Losses_U - k - B$$

Adaptive Mechanisms

- Dynamic Rate Allocation
  - Throughput
  - Cost



$$\left(\frac{C}{N}\right)_U = EIRP_U + \left(\frac{G}{T}\right)_U - Losses_U - k - B$$

# Static Link Adaptation Summary

- Summary
  - Earth-space communications links are susceptible to variation in channel performance
  - The predominant contribution to variable channel losses are **rain and cloud attenuations** that change significantly over short time horizons
  - There are **four** methods to improve link reliability
    - build **fade margin** in the link design
      - simplest solution
      - inefficient use of satellite resources
    - use **uplink power control**
      - most efficient solution
      - costly for very small terminals
    - use **adaptive coding and modulation (ACM)**
      - highest dynamic range
      - reduced data rate during fading events
    - use **dynamic rate adaptation**
      - used with other solutions to increase dynamic range
      - reduced data rate during fade events

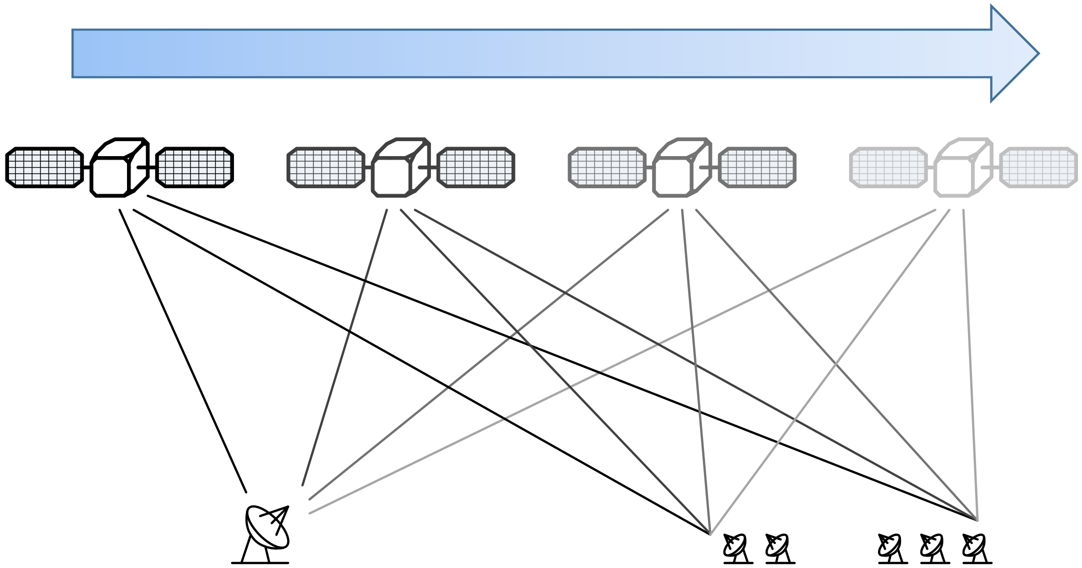
# Telesat LEO Constellation

# Telesat LEO Constellation

Next-Generation Satellite Constellation

- Key Technologies
  - On-board Processing
    - De-couples uplink and downlink RF performance
  - Beam-Hopping
    - Improves total coverage without degrading link RF performance
  - Direct-Radiating Arrays
    - Allows flexible coverage and pointing
  - Inter-Satellite Links
    - Establishes orbital mesh network for flexible connectivity

# Dynamic Link Analysis



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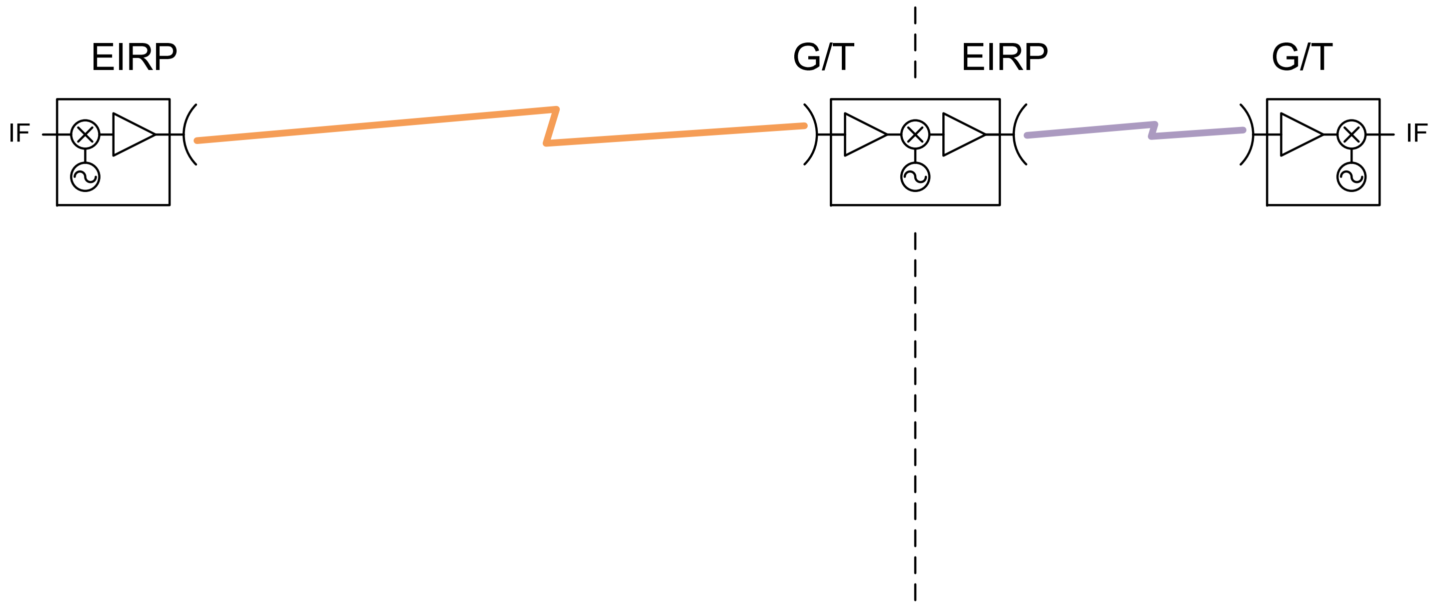


# Dynamic Link Analysis

$$\left(\frac{C}{N}\right)_U = EIRP_U + \left(\frac{G}{T}\right)_U - Losses_U - k - B$$

$$\left(\frac{C}{N}\right)_U(t) = EIRP_U(t) + \left(\frac{G}{T}\right)_U(t) - Losses_U(t) - k - B$$

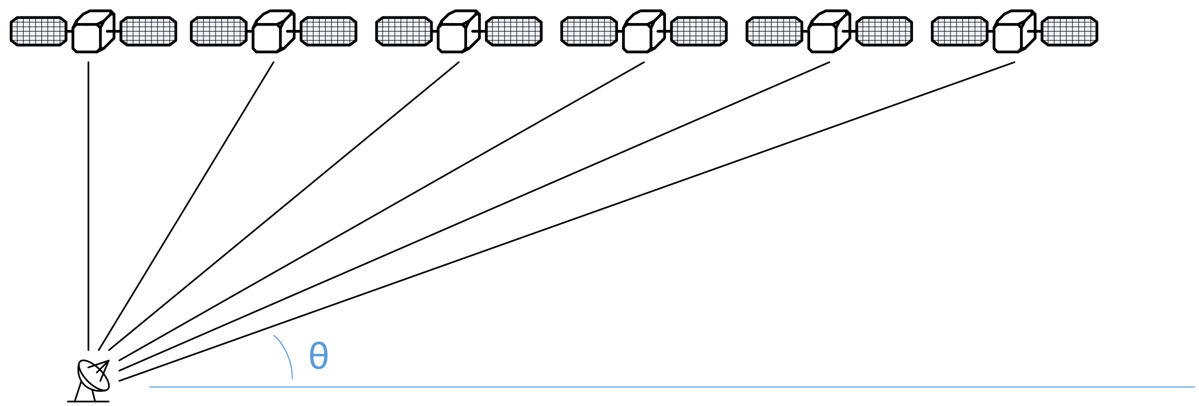
Dynamic Geometry

Terminal Phased Array

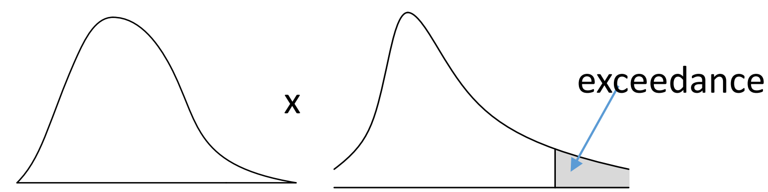
Satellite Phased Array

# Predicting Fade Variation in LEO

- Solving the dynamic fade likelihood

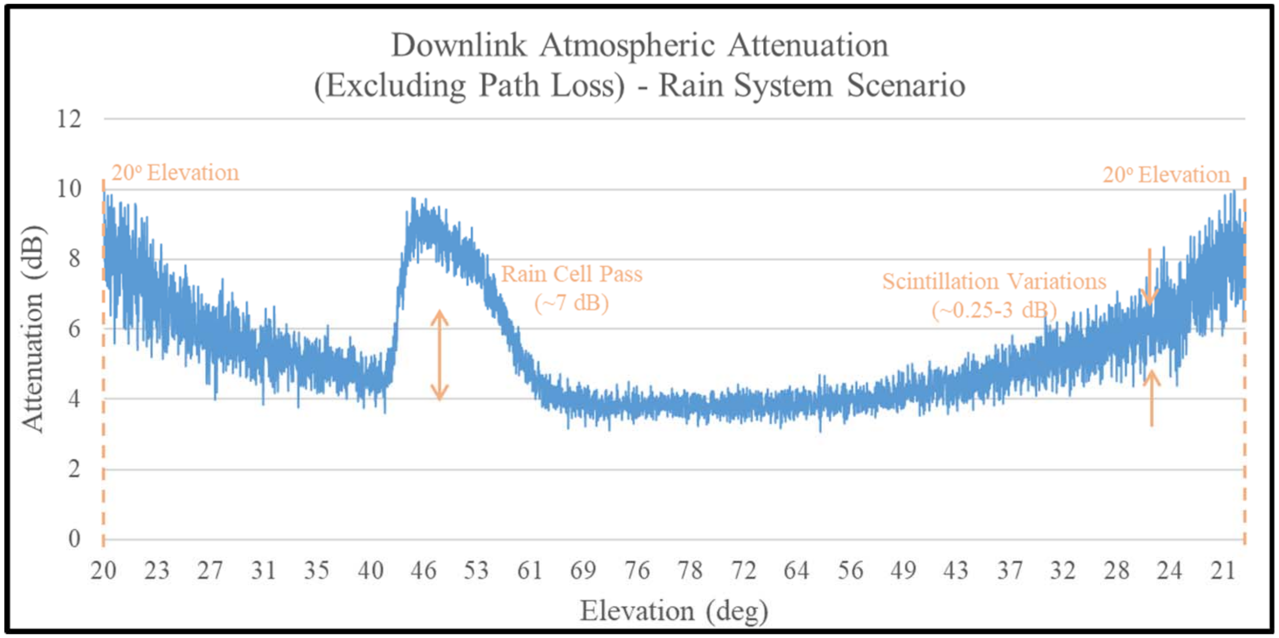



- We need to consider both
  - the likelihood of being in the fade condition
  - the likelihood that it is occurring along a particular geometry




$$p(Fade < x) = \sum_{\theta=0}^{90} p(Fade(\theta) < x) \times p(\theta)$$

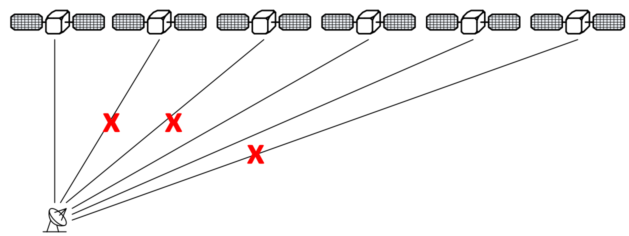
# Fading is more dynamic for LEO




- We need "all hands on deck" for this nonsense
  - Uplink Power Control
  - Adaptive Coding and Modulation
  - Dynamic Rate Adaptation

# Adaptive Mechanisms in LEO

- In LEO, we have a couple more tools in the toolbox
  - Diversity
  - Beam Hopping (next slide)
- Diversity allows us to pick a different satellite with a more advantageous link performance



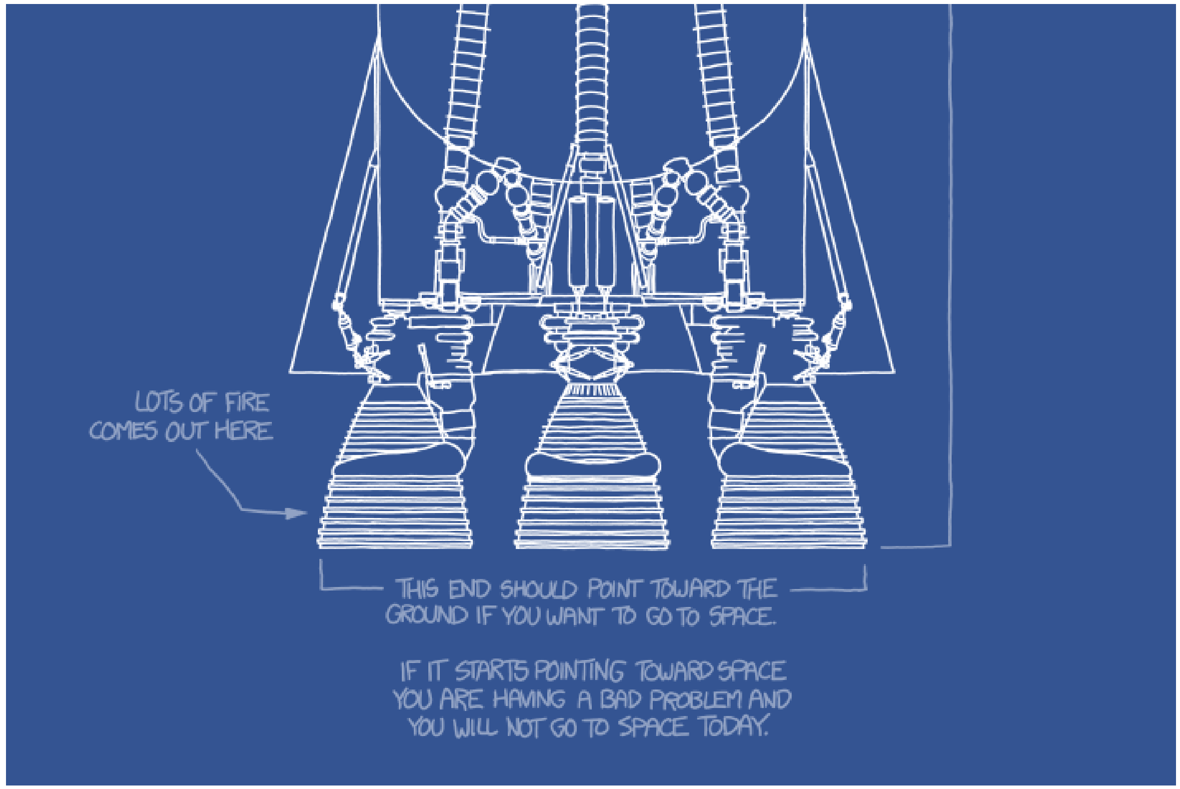
- Challenge with diversity is that the geometries are not always available due to
  - Regulatory constriants (non-interference requirements)
  - Local elevation blockages
  - Rain clouds are big

- Beam Hopping
  - A form of time-division sharing
  - TDM and TDMA are constrained to a particular "hop slot" during which the beam is illuminating that particular area on the Earth
  - Extends to time-division data rate scaling equation as follows

$$EffectiveDataRate = DataRate \times \frac{time\ slots\ assigned}{time\ slots\ available} \times \frac{hop\ slots\ assigned}{hop\ slots\ available}$$

$$spec.eff \times bandwidth$$

- **Questions?**


LOTS OF FIRE COMES OUT HERE
THIS END SHOULD POINT TOWARD THE GROUND IF YOU WANT TO GO TO SPACE.
IF IT STARTS POINTING TOWARD SPACE YOU ARE HAVING A BAD PROBLEM AND YOU WILL NOT GO TO SPACE TODAY.