

# Broadband satellite communications in Ka band: System approach and solutions

Template reference : 100182079N-EN

BS-SPI

September 2012

**THALES**

All rights reserved, 2007, Thales Alenia Space

## **Ku band satellites in Kazakhstan: KazSat2 and KazSat3**

### **Why Ka band:**

- Technical Opportunities of Ka-band: RF performance
- Regulatory Opportunities of Ka-band: Available spectrum resources
- Technical Opportunities of Ka-band: broadband satellite communications and networks

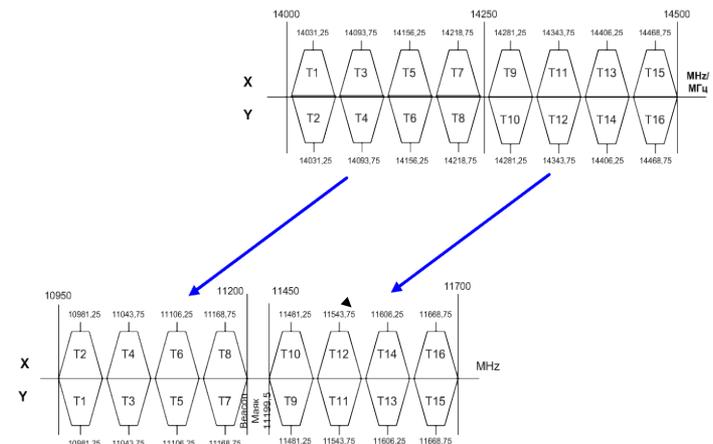
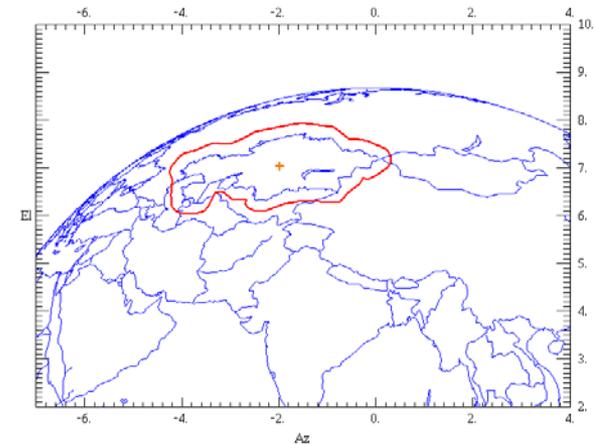
## **Fade Mitigation techniques for broadband satellite systems in Ka band**

## **Capacity optimization in High Throughput Ka band Satellite Systems**

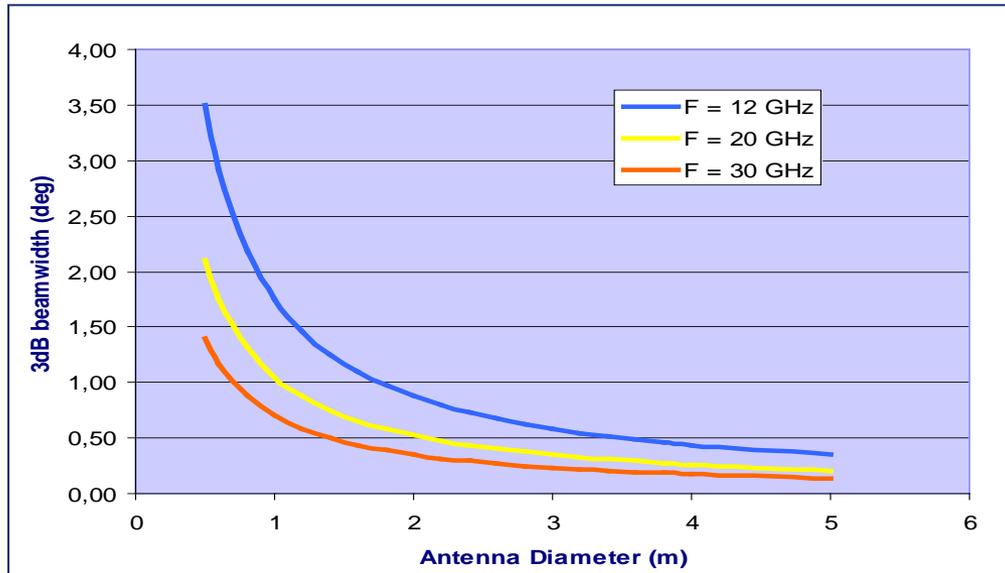
## **Concluding remarks**

## KazSat 2

- Launched in 2011
- Satellite in geostationary orbit at 86.5°E
- Payload: manufactured by TAS
  - 16 communications channels in Ku-band with useful bandwidth of 54 MHz
    - U/L: 14.00 ÷ 14.50 GHz
    - D/L: 10.95 ÷ 11.70 GHz
- Spacecraft: Express MD from KHRUNICEV



**Half-Power Beamwidth vs. Frequency, Antenna Size**



**Ka band antenna directivity is higher than that of comparably sized Ku band antennas.**

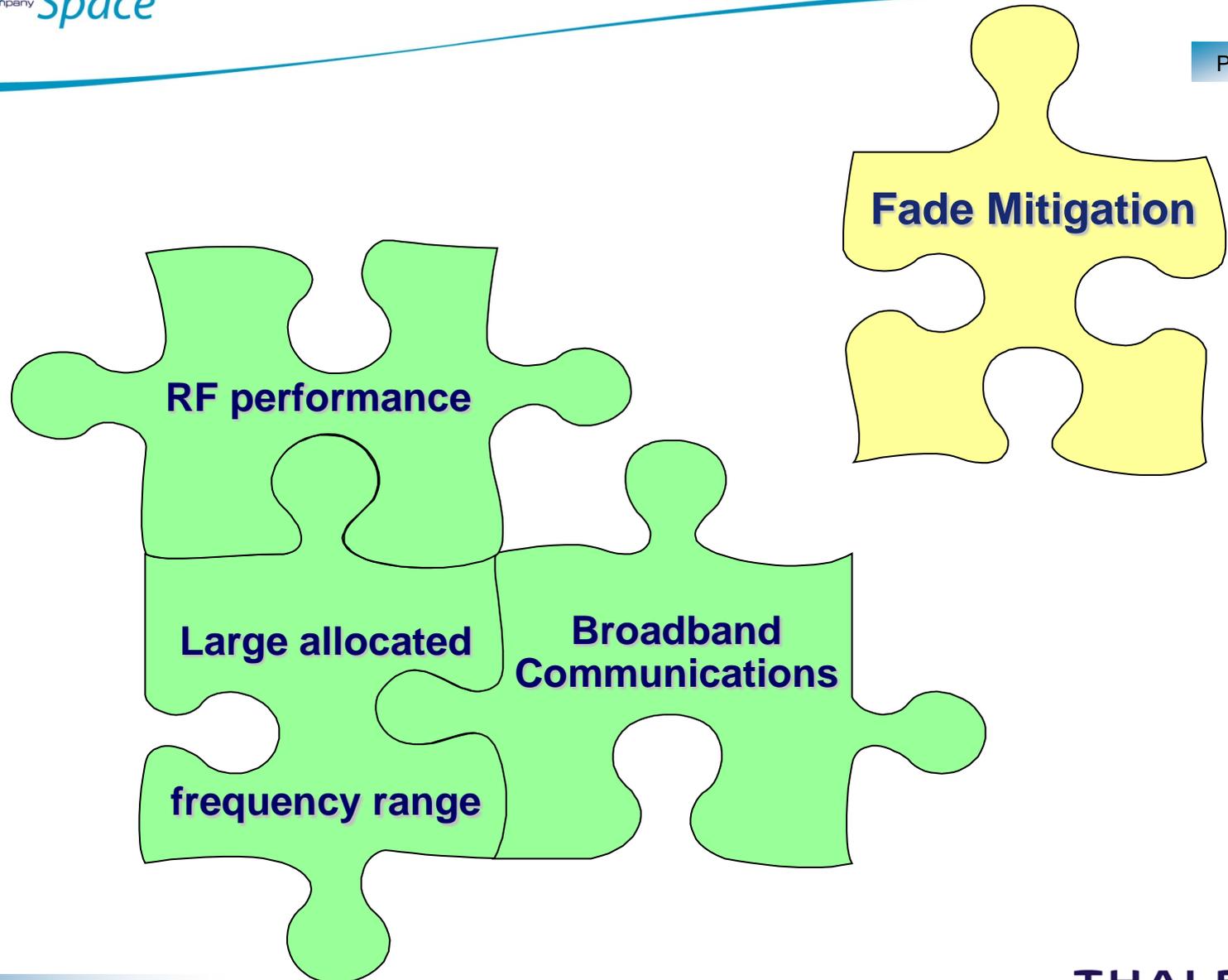
**Antenna directivity is a key performance to dimension the Satellite Communication System.**

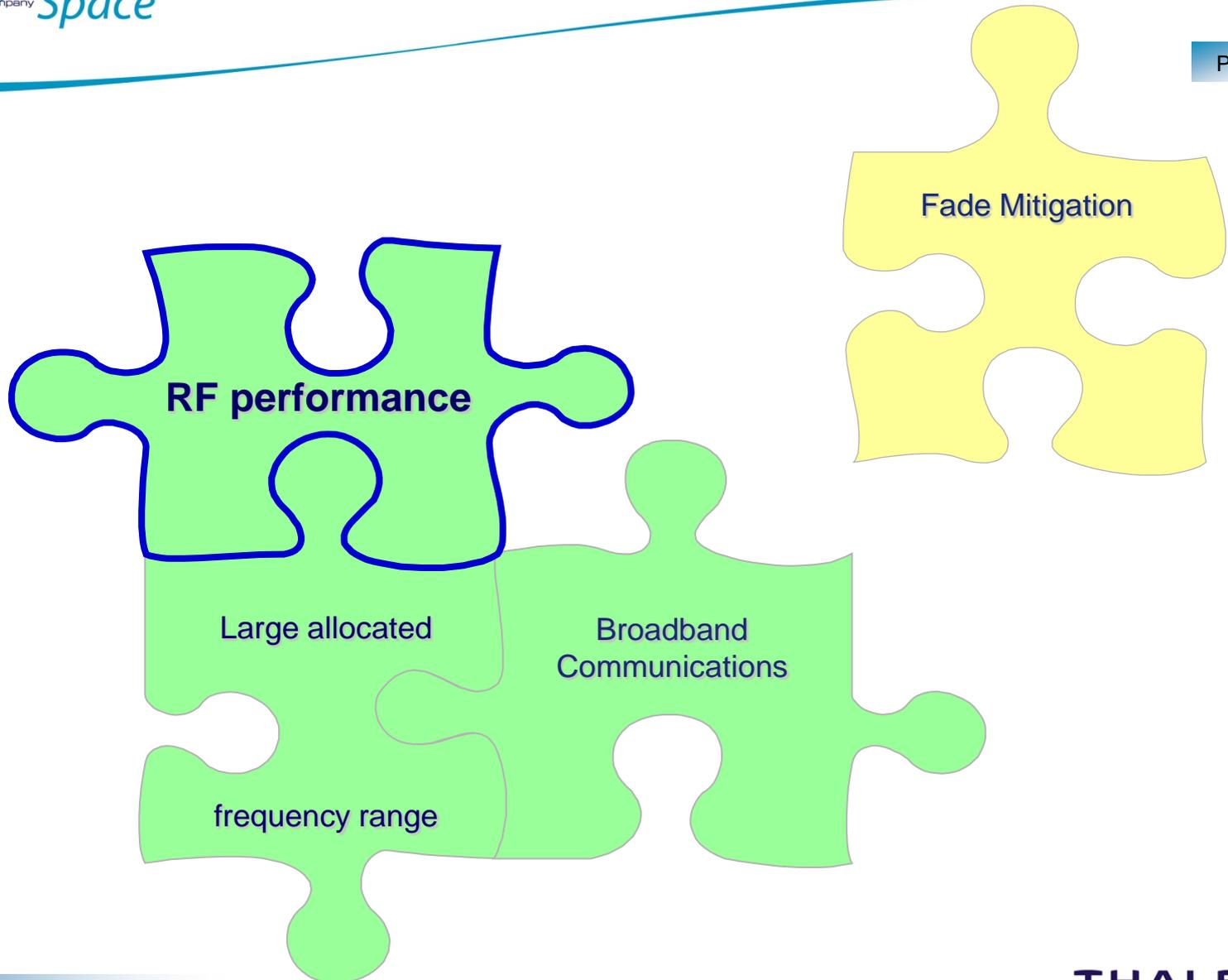
- $\theta_{3dB}$  (satellite RX)  $\Rightarrow$  Gain<sub>RX</sub>
- $\theta_{3dB}$  (satellite TX)  $\Rightarrow$  Gain<sub>TX</sub>

**BENEFITS**

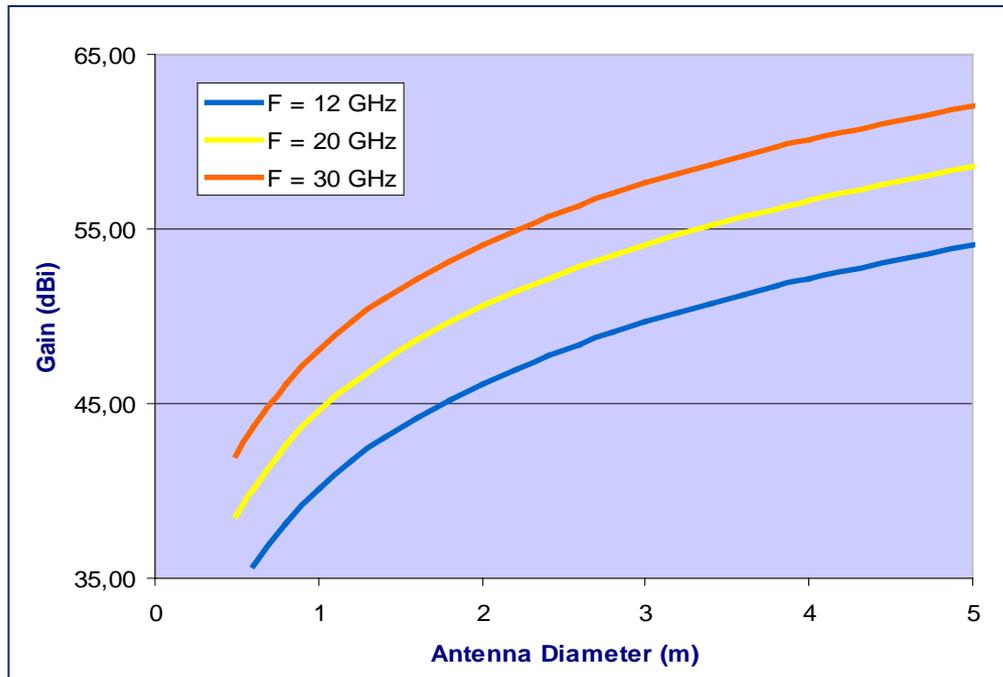
**Ka band well suits to multi-spot coverage, providing high satellite EIRP and G/T for Very High Throughput Satellite Systems.**

**Ka band improved directivity performance makes frequency coordination less critical, especially for small terminals ( $\varnothing < 1$  m) and small orbital separations.**





**Antenna Gain vs. Frequency, Antenna size**



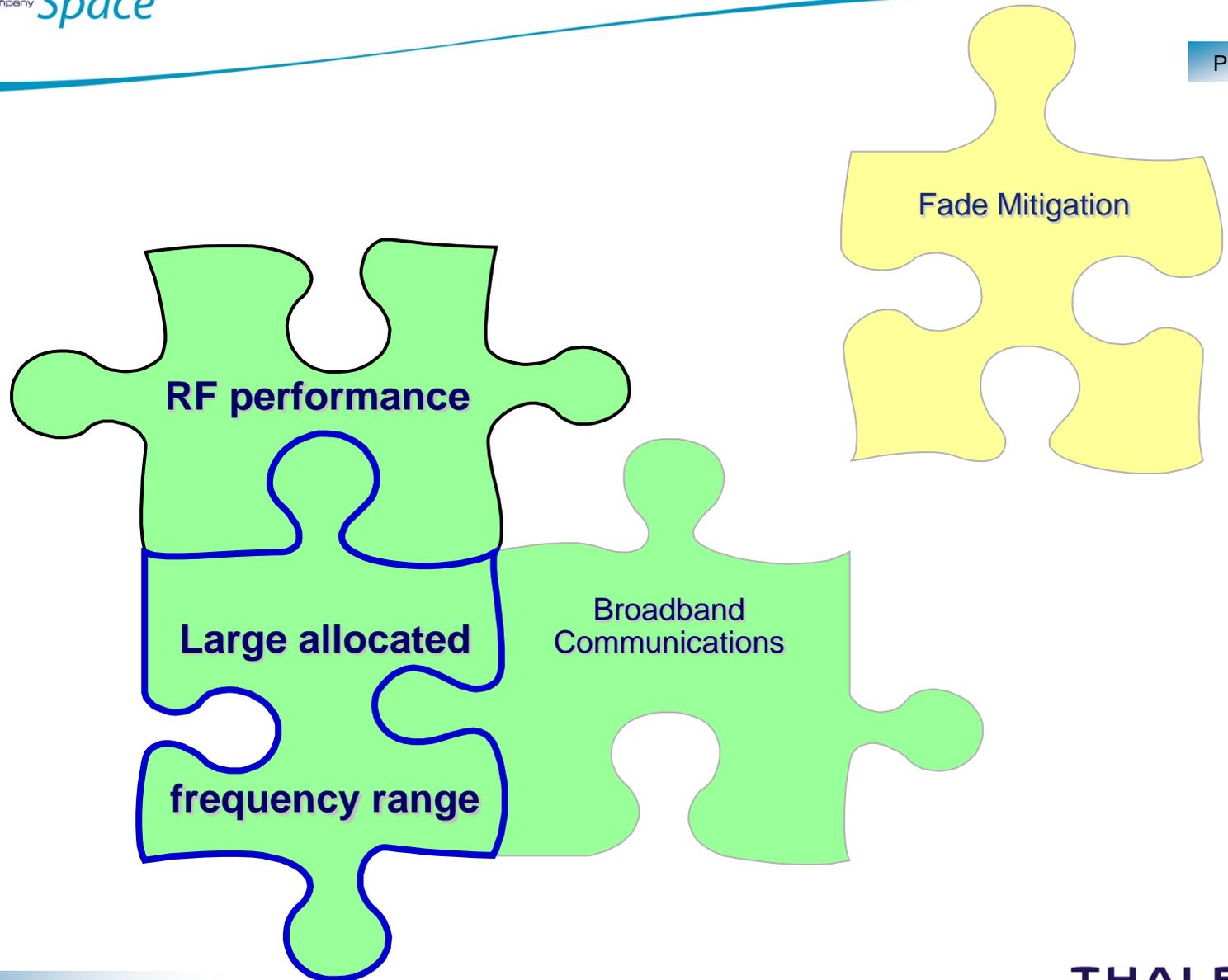
**Ka band antennas gain is higher than that of comparably sized Ku band antennas.**

**RX and TX antenna gains are key RF performance to dimension the Satellite Communication System:**

- Gain<sub>RX</sub> ⇒ G/T
- Gain<sub>TX</sub> ⇒ EIRP

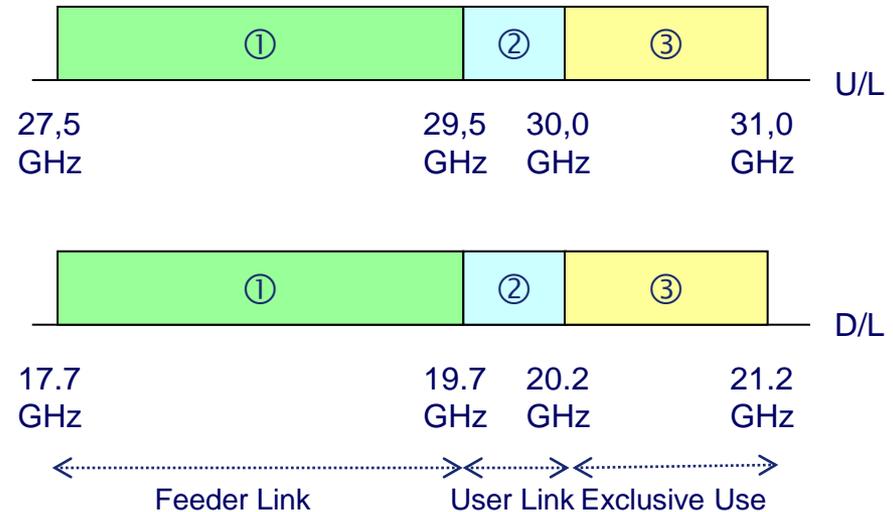
**BENEFIT**

**Ka band achievable satellite EIRP and G/T reduce the requirements on EIRP and G/T of ground traffic elements (gateway, satellite terminals)**



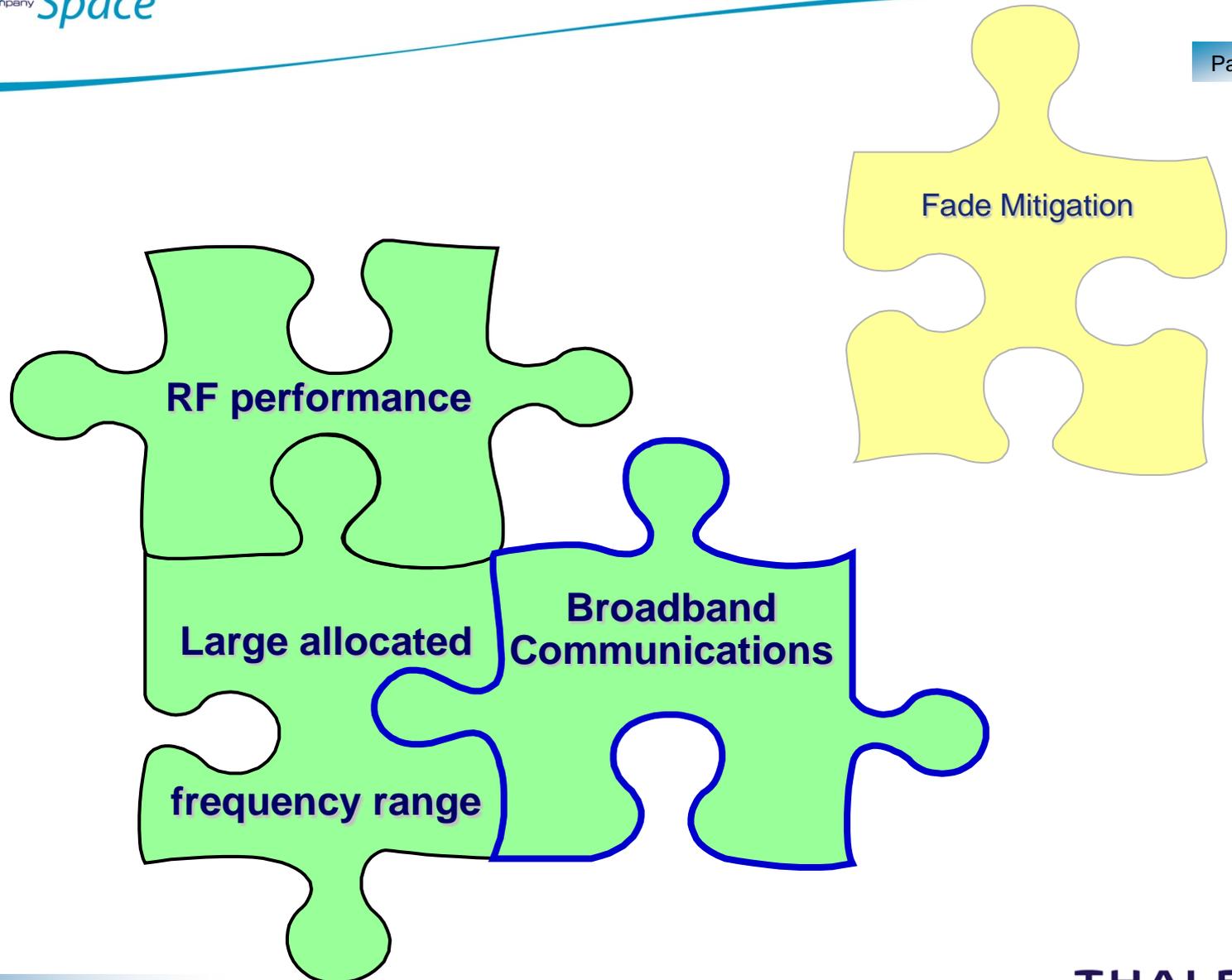
## The allocated Ka band Frequency Spectrum is wider than Ku band frequency spectrum allocated to FSS:

- ① 2 GHz allocated to coordinated services (e.g. Feeder Link, TX, RX):
  - [27.5 - 29.5] GHz, RX by satellite
  - [17.7 - 19.7] GHz, TX by satellite
- ② 500 MHz allocated to high EIRP satellite terminals (HEST) with exemption from individual licensing if using an EIRP not exceeding 60 dBW:
  - [29.5 - 30.0] GHz, RX by satellite
  - [19.7 - 20,2] GHz, TX by satellite
- ③ 1 GHz allocated for exclusive use to satellite services:
  - [30.0 - 31.0] GHz, RX by satellite
  - [20,2 - 21.2] GHz, TX by satellite



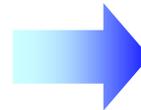
### BENEFITS

An overall range of 3,5 GHz, which largely increases by exploiting multi-spot coverage with frequency reuse and polarization discrimination.





- Broadband Internet Access
- Virtual Private Network and Critical Network Infrastructures for secure data exchange
- Video-Surveillance for monitoring and security purposes
- Emergency Communication Networks
- Distance learning
- Distance healthcare

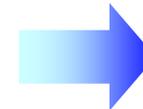


- Governmental Institutions
- Hospitals, Medical Centers
- Schools, Universities

## Professional Data Network



- Professional Internet Access
- Intranet and VPN for secure data exchange
- Site interconnection
- Machine to Machine Supervisory Control And Data Acquisition
- Internet Backhauling
- Backup and Emergency Networks

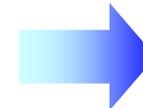


- Enterprises
- SoHo

## Satellite News Gathering



- Satellite News Gathering
- Data Gathering

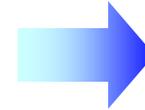


- News agencies
- Enterprises

## Two-Way Broadband



- High throughput Internet



- Consumers

## Broadcasting and Content Delivery



- IPTV with push VoD
- IP Multicast and Push platform
- IP streaming/webcasting
- Direct-To-Home TV
- Digital Radio Broadcasting
- CD quality audio
- Store-and-forward
- Video-on demand
- Web-casting



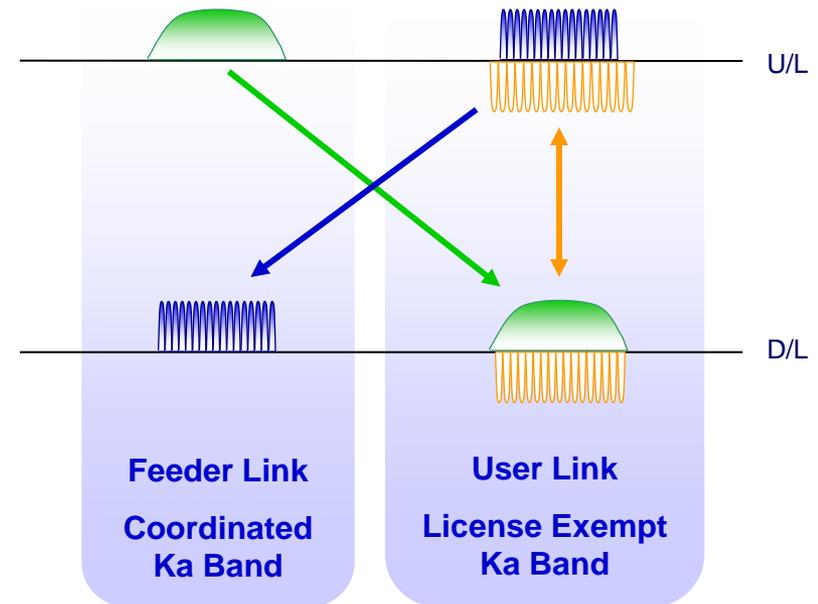
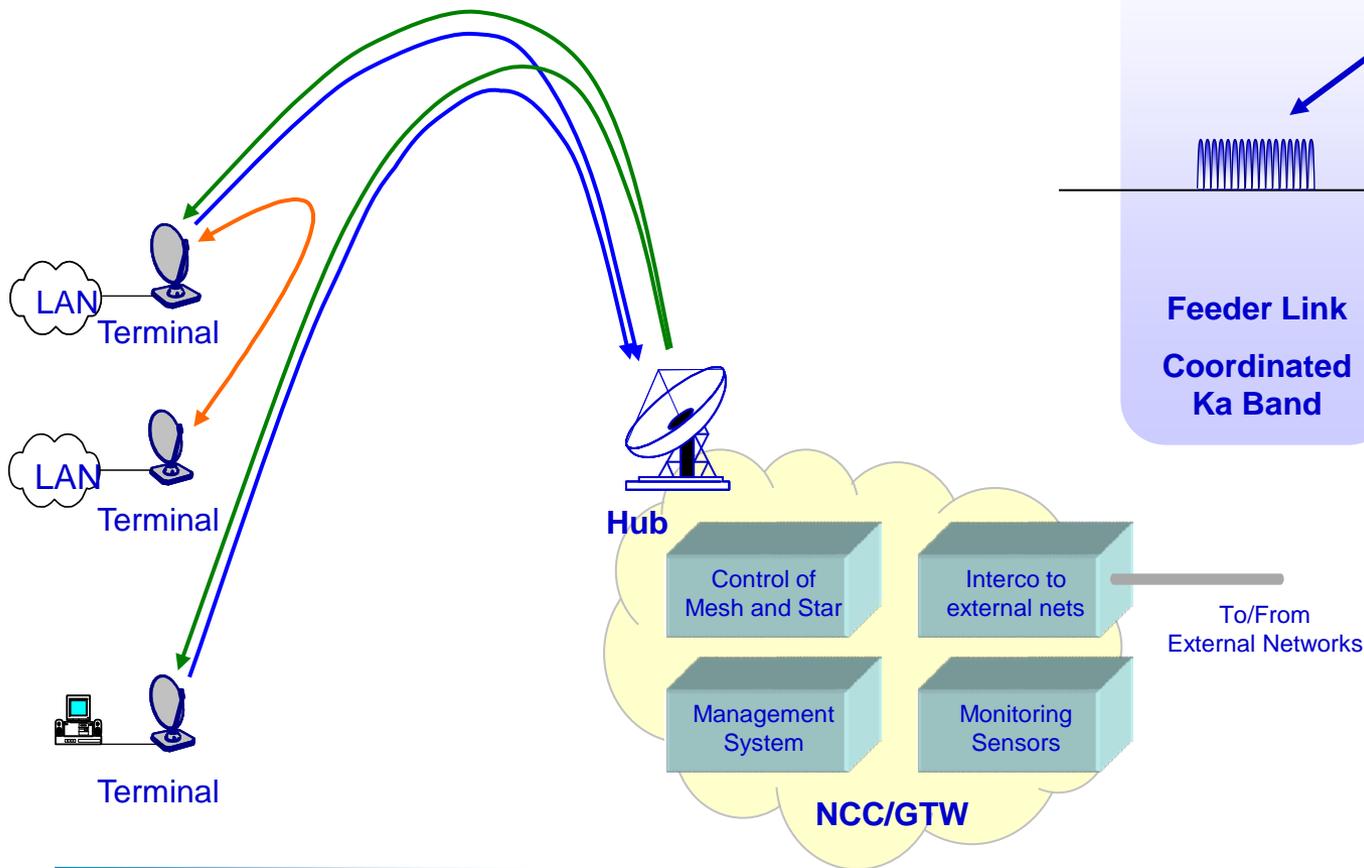
- Consumers

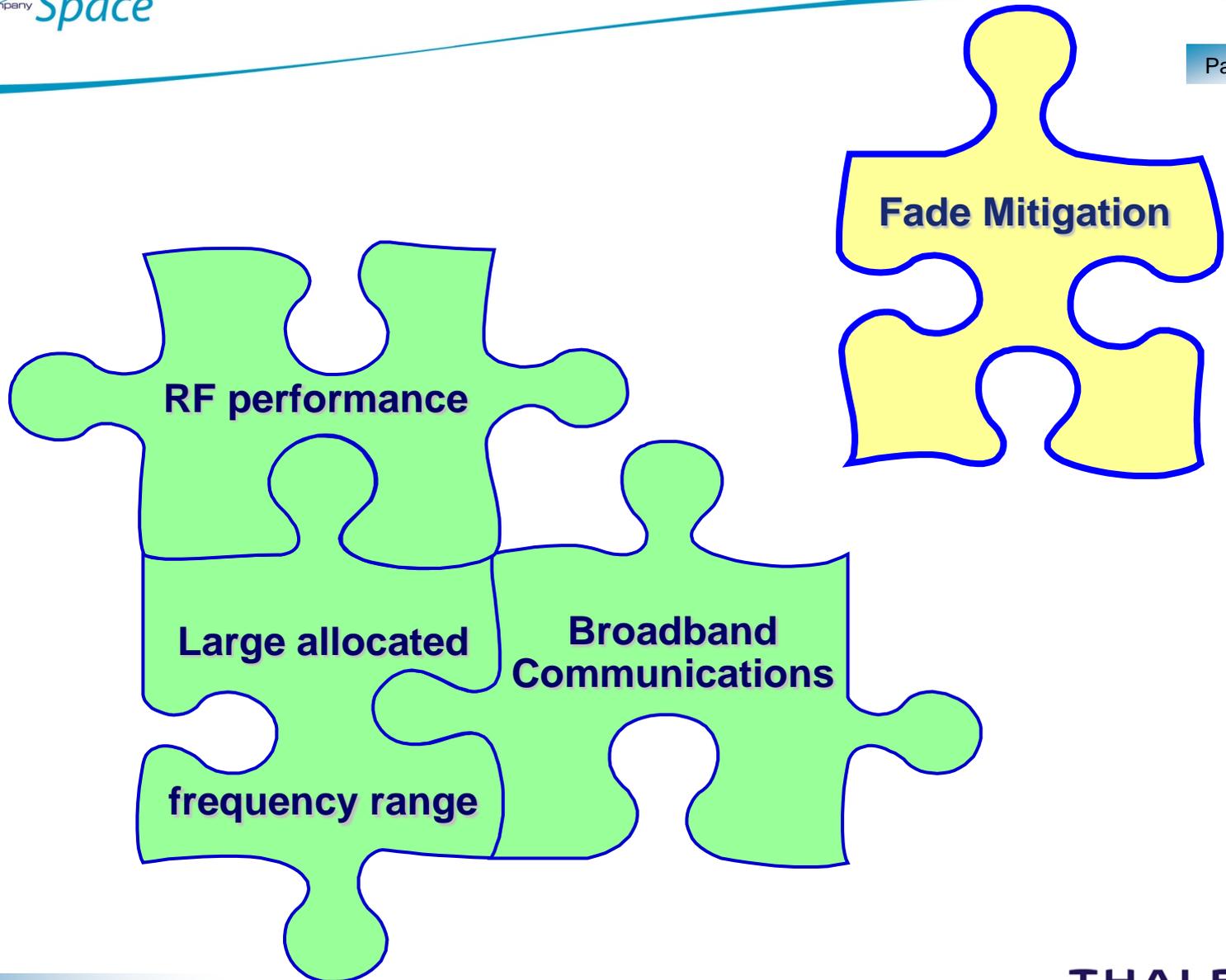
User Family	Communication Services Applications	Communication Connectivity
<b>Consumer</b>	Internet Access	Star
	Webcasting and Streaming	Star
	IPTV with push VoD	Star
	IP Multicast and Push platform	Star
	Direct-To-Home Television service	Star
	High quality audio	Star
	Video-on demand	Star
<b>Corporate, Business</b>	Broadband Internet Access	Star
	Site Interconnection	Mesh
	Intranet and VPN with secure data exchange	Mesh
	Machine to Machine Supervisory Control / Data	Mesh
	Satellite News Gathering	Star
<b>Governmental, Institutions</b>	Broadband Internet Access	Star
	VPN and CNI with secure data exchange	Mesh
	Emergency Communication Networks	Star / Mesh
	Back up and Disaster Recovery Networks	Star
	Distance learning	Mesh
	Distance Healthcare	Star / Mesh

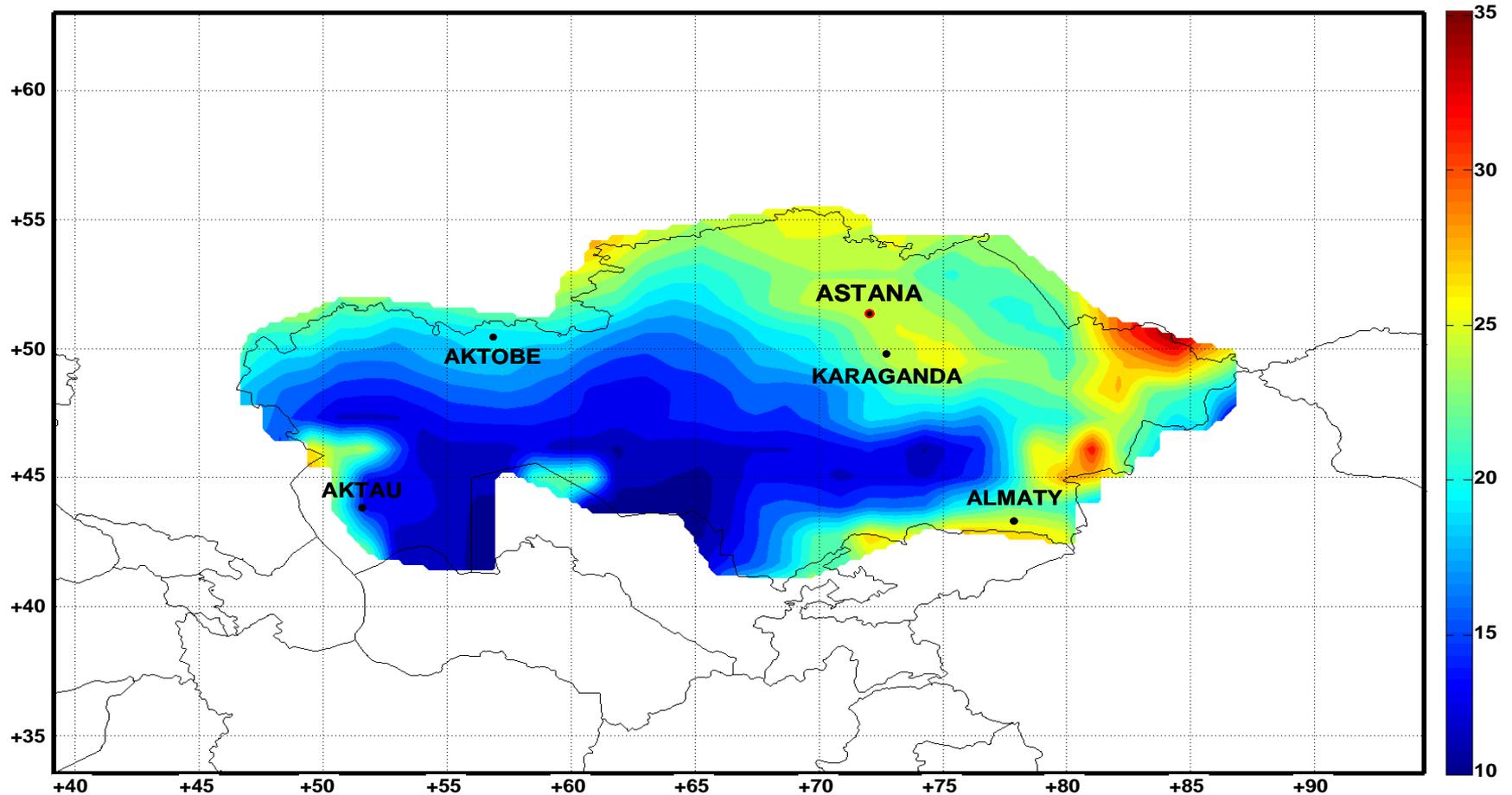
Communication Needs



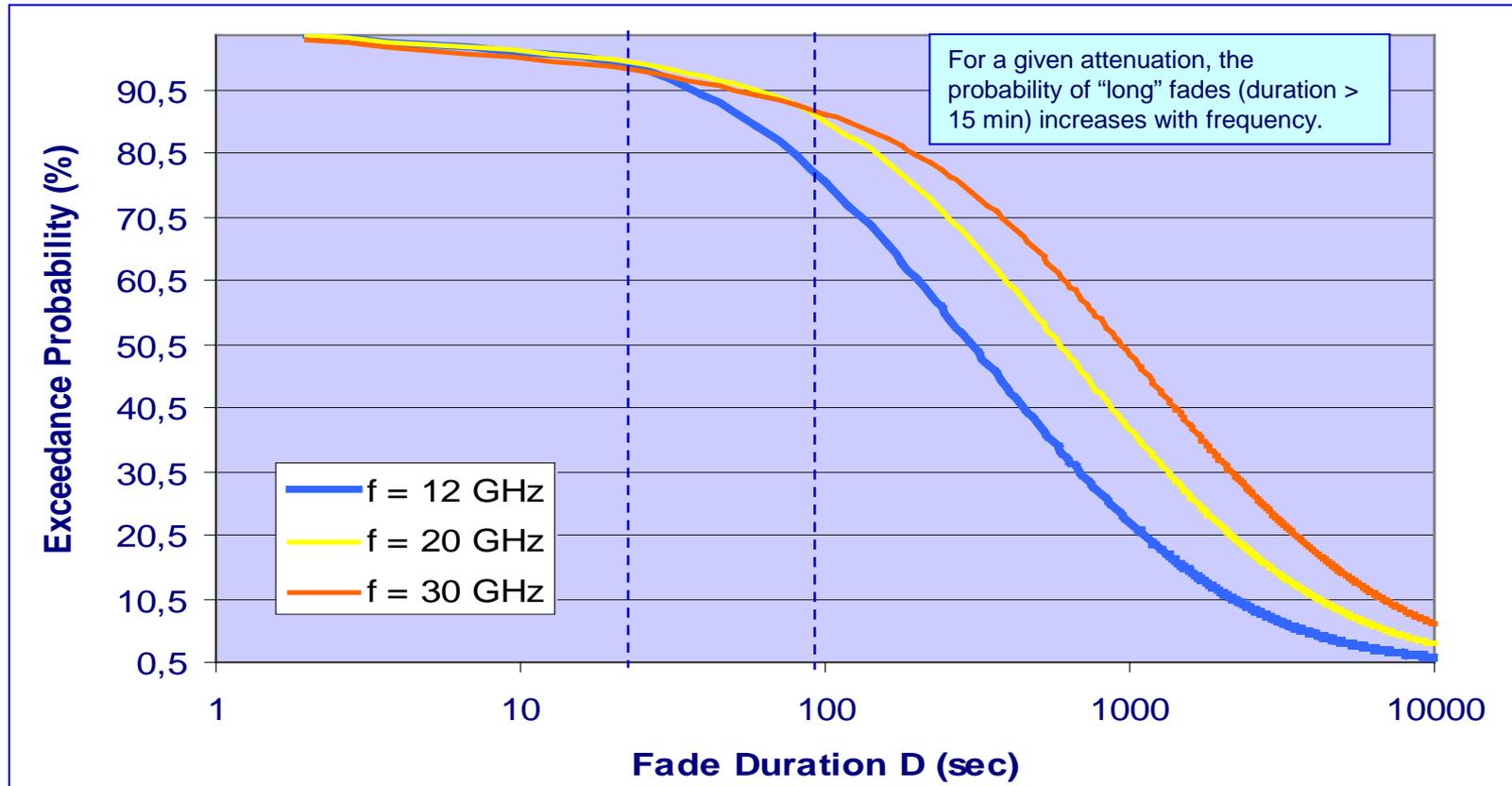
Communication Connectivity







Rain Intensity (mm/h) exceeded during 0.01% (~ 52 min.) of an average year



CDF of total fraction of fade time due to fades of duration longer than D  
(example for elevation = 25°, fade attenuation > 8 dB)

**Fade Mitigation Techniques aim at adapting the operating conditions (modulation, coding and power level) of the ground segment traffic elements (gateways, satellite terminals), so that the System performance is no longer dominated by the worst-case link conditions, but rather by the average link conditions of the system.**

**Thus, deep fading events have a lower impact on the overall system capacity and cause the reduction of the individual link peak data rates only.**

**Ka band Broadband Satellite Systems take advantage of a combination of the following Fade Mitigation Techniques:**

- Adaptive Coding And Modulation (ACM);
- Adaptive Coding (AC);
- Dynamic Rate Adaptation (DRA);
- Uplink Power Control (UPC).

## Uplink Power Control (UPC):

- The terminals and gateways increase the transmit power, with mitigation capability ranging from few to several dBs.
- UPC applicable to compensate for uplink fades only.

## Adaptive Coding And Modulation (ACM):

- the MODCODE, i.e. the combination of modulation type and forward error correction code, of each terminal is adaptively tuned to meet the current terminal requirements, determined by channel conditions.
- The goal of adaptation is to give each terminal the highest possible data rate that the link may support, while preserving operating margin enough to compensate short term fluctuations.
- Terminals in the same beam may use different MODCODE values, because rain fades tend to be highly localized.

## Adaptive Coding (AC):

- the CODE, i.e. the forward error correction code rate, of each terminal is adaptively tuned keeping constant the modulation type, to meet the current terminal requirements, determined by channel conditions changes.
- The goal of adaptation is to give each terminal the highest possible data rate that the link may support, while preserving operating margin enough to compensate short term fluctuations.
- Terminals in the same beam may use different CODE values, because rain fades tend to be highly localized.

## Dynamic Rate Adaptation (DRA):

- the Symbol Rate of each terminal is adaptively tuned to meet the current terminal requirements, determined by channel conditions changes.
- The goal of adaptation is to give each terminal the highest possible Symbol Rate that the link may support, while preserving operating margin enough to compensate short term fluctuations.
- Terminals in the same beam may use different Symbol Rate values, because rain fades tend to be highly localized in space.

## **ACM and UPC aim at counteracting the link fading by adapting the data rate and TX power as follows:**

- UPC increases the TX power to mitigate/compensate the fade attenuation and bring the SNR back to a level that possibly keeps the MODCOD unchanged and, so, the data rate;
- when the maximum UPC compensation range is reached, the residual SNR reduction due to fading is counteracted by means of ACM, which changes the MODCOD to reduce the data rate down to the level that matches the link conditions;
- ACM and UPC do not change the communication symbol rate.

## **AC+DRA counteract link fades by adapting the data rate and the symbol rate as follows:**

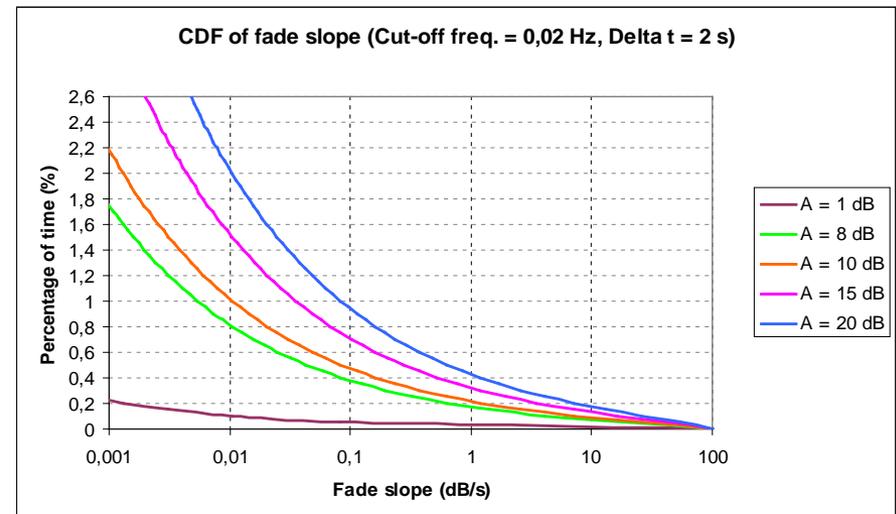
- AC reduces the TX data rate to mitigate/compensate the fade attenuation and bring the SNR back to a level that possibly keeps the MODCOD unchanged and, so, the data rate;
- AC does not change the symbol rate;
- when the maximum AC compensation range is reached, the residual SNR reduction due to fading is counteracted by means of DRA, which reduces the communication symbol rate;
- Accordingly, the terminal “moves” to a smaller carrier.

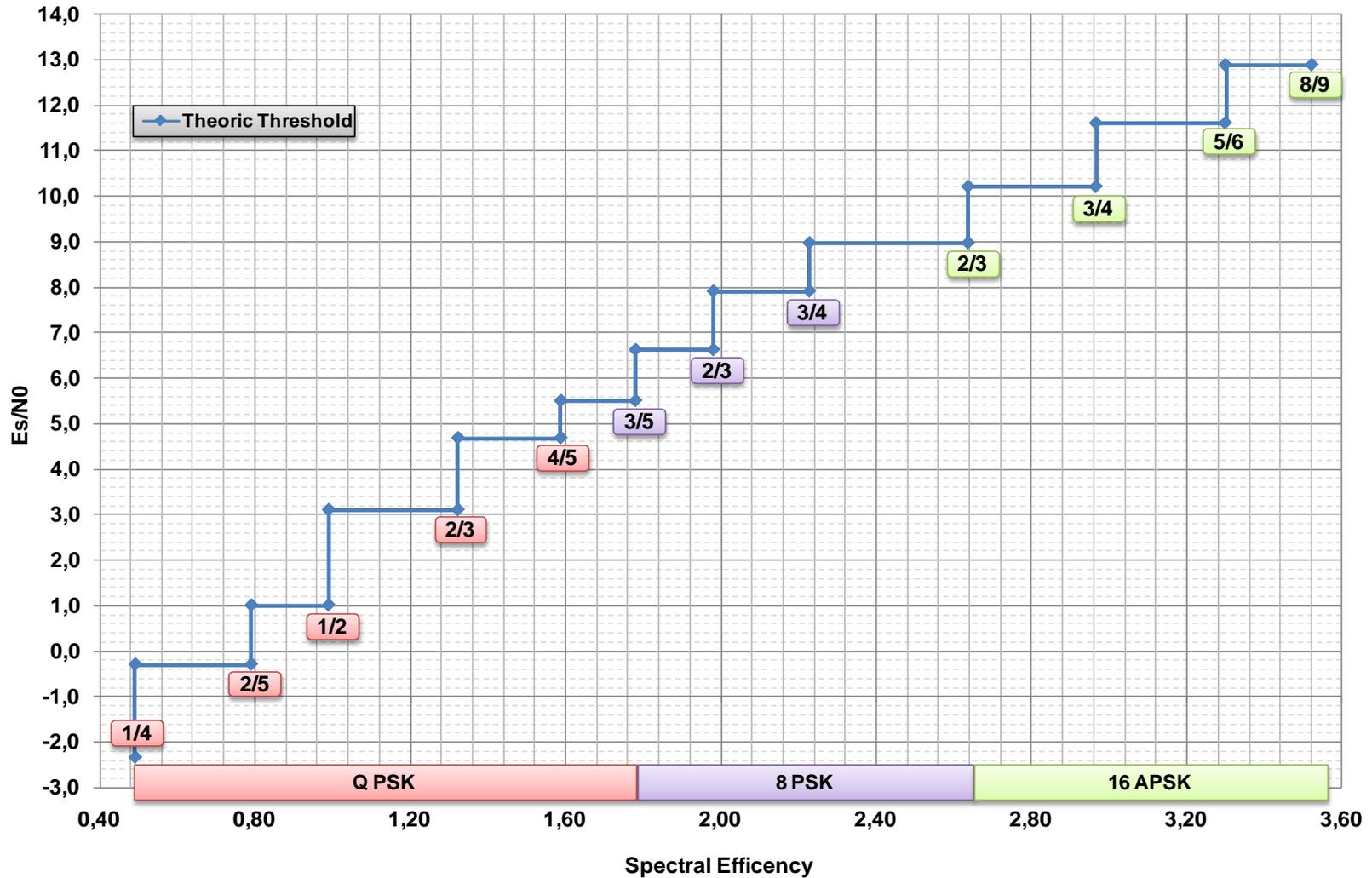
ACM, as DRA and AC, is a threshold based mechanism for the decision of the MODCOD to be used, given a fading condition in a communication configuration characterized by system specific target data rate and RF performance of space segment and ground traffic segment elements.

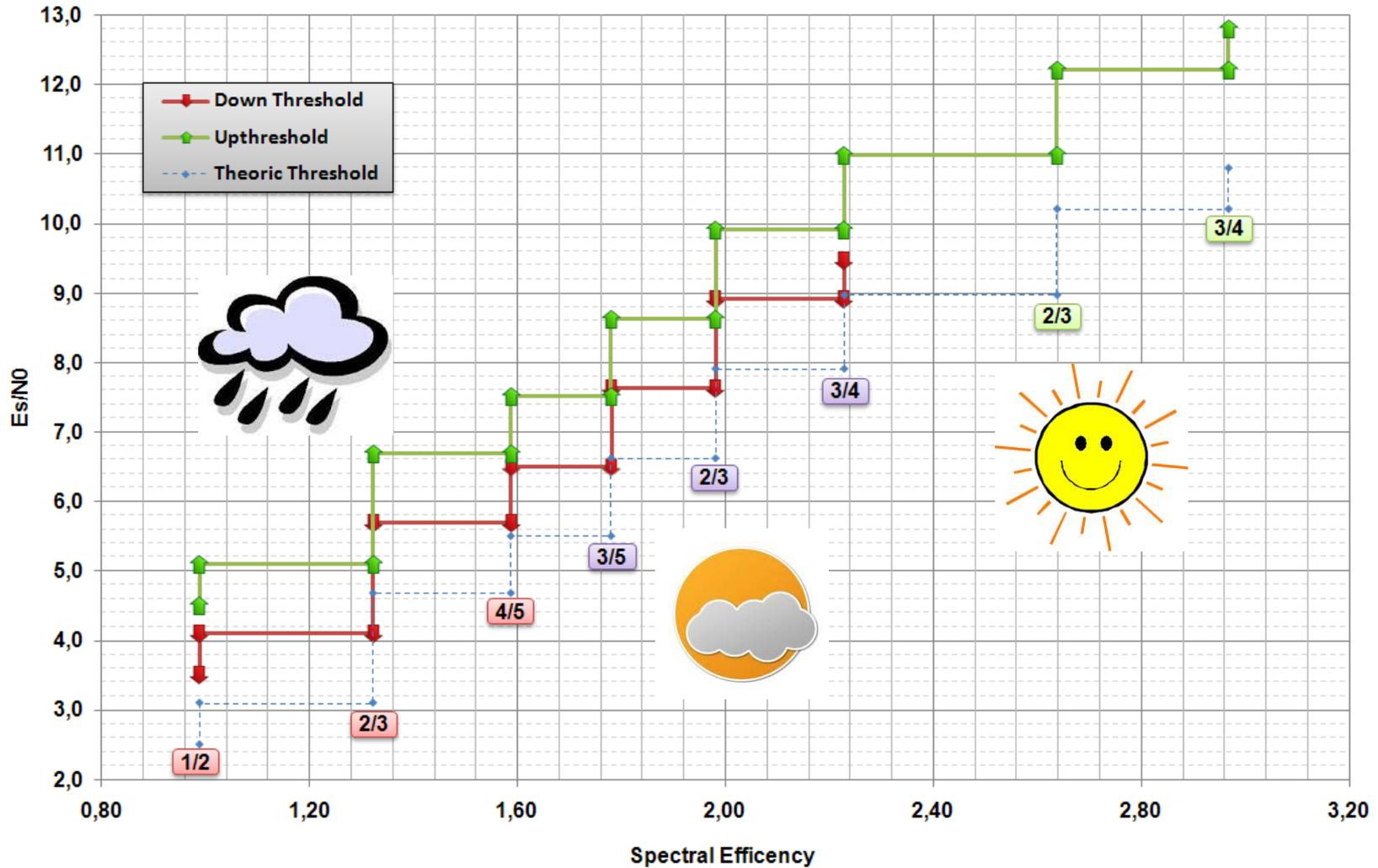
Thresholds are defined based on the Satellite System operational scenario (link budgets) and on the performance of ground traffic elements.

The “Down Threshold” and the “Up Threshold” are defined considering:

- an ACM margin due to the system loop delay and latency:
  - loop delay counts for the overall end to end control process, including signaling transmission, propagation and processing; on the average it is in the order of 2 s;
  - rain fade slope in the range of 0.5÷1 dB/s for typical availability performance;
  - the resulting ACM margin is in the range of 1÷2 dB.
- modem implementation losses;
- hysteresis margin, defined to avoid transitions when the fading fluctuates around a threshold point.



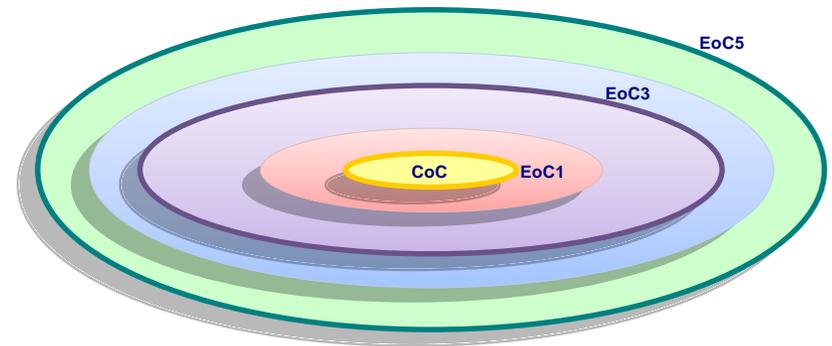




A “wedding cake” model well represents the allocation of MODCOD over a service area.

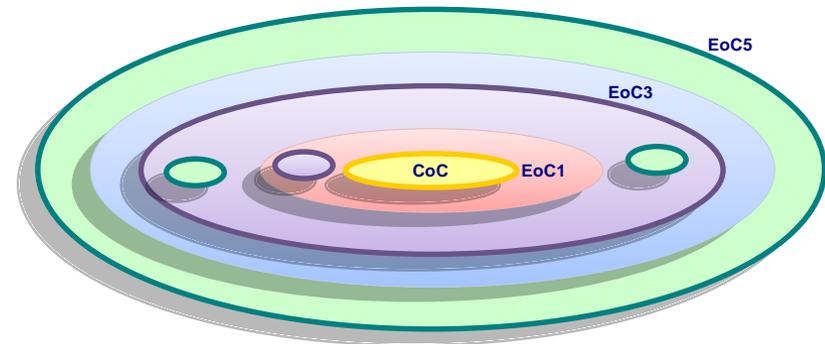
**Under uniform weather, terminal type and traffic targets over a service area:**

- A set of MODCOD values are used over the overall service area;
- Each MODCOD value suits to an area over which the range of System RF performance (EIRP, G/T) determines a signal to noise ratio that is best satisfied by the selected MODCOD; as an example:
  - MODCOD1: from CoC to EoC1;
  - MODCOD2: from EoC1 to EoC3;
  - MODCOD3: from EoC3 to EoC5.



**Non-uniform MODCOD allocations in a sector of a satellite beam result from:**

- Co-existence of terminals with different RF performance and data rate targets, requiring specific and different MODCOD values;
- Effects of localised fades, requiring different MODCOD values even for same terminal types in different areas.



## BENEFIT

**This optimizes Capacity and Availability over the service area.**

## Ka band Systems are a win-win solution for High Throughput Satellite Communications:

- Improved RF performance vs. lower band FSS satellite systems
- Larger frequency spectrum available
- Excellent suitability to broadband communications, covering the needs of all end user types, from residential to Institutions and Governmental Bodies.
- Consolidated base of space and ground segment products:
  - large portfolio of high performance and flexible repeater equipments and satellite antennas;
  - large portfolio of End-User terminal types, covering all market segments and featuring small sizes, high performance, installation easiness and high reliability
  - solutions for ground mission products, including: Payload Traffic Manager, Communication Spectrum Monitoring, Station Monitoring & Control for complete management of space and ground elements.
- High immunity to the effects of atmospheric conditions, thanks to fade mitigation techniques, already implemented by ground traffic element manufacturers and available for System exploitation towards optimal performance in terms of traffic capacity and communication availability.

