



Link budget Course

SWE-DISH SATELLITE SYSTEMS



# AGENDA

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**Link Budgets**

**Transmit Power Budget**

**Questions**



# LINK BUDGET

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## What is a link budget?

A link budget is a relatively simple addition and subtraction of gains and losses within an RF link.

When these gains and losses of various components are determined and summed, the result is an estimation of end-to-end system performance in the real world.



# LINK BUDGET

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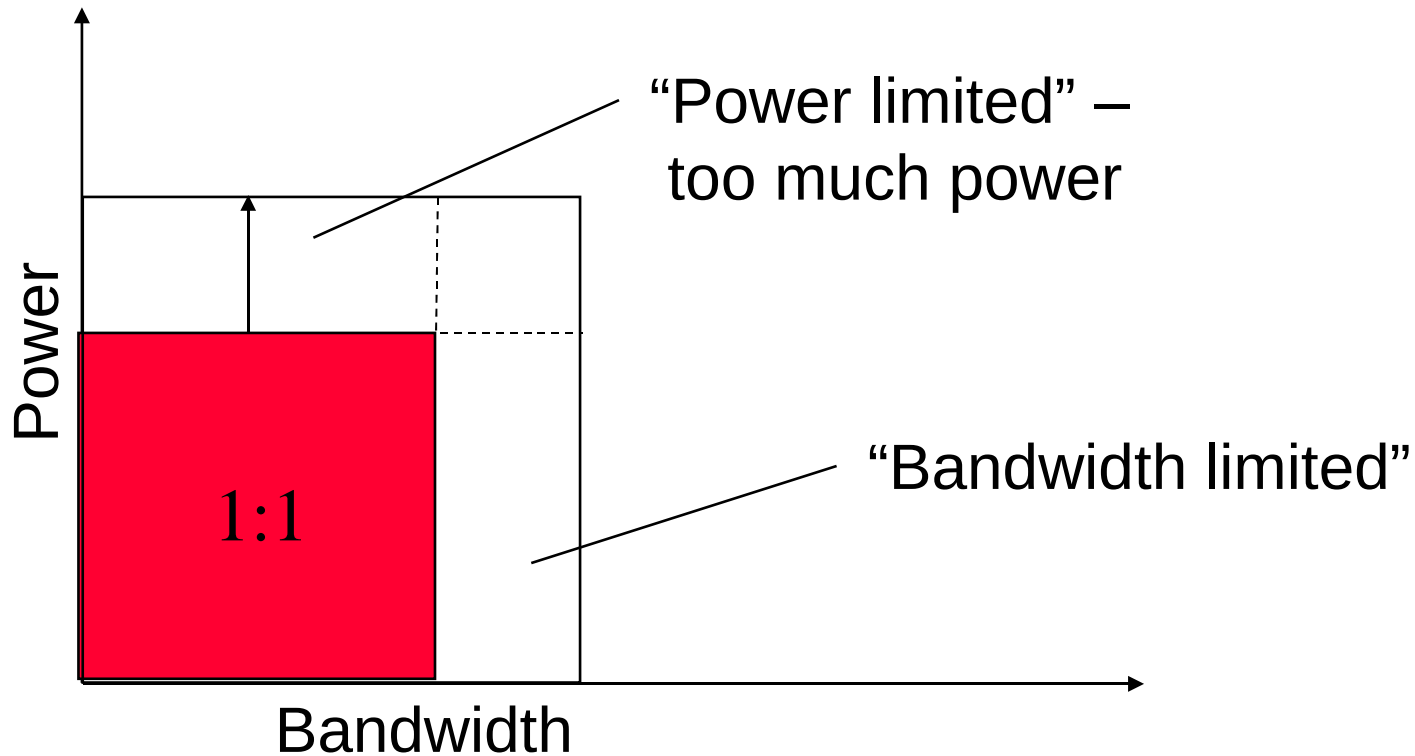
## Why do I need a link budget?

- Minimize Lease Bandwidth
- Maximize Satellite EIRP
- Minimize Earth Station Size



# LINK BUDGET

## Minimize Lease Bandwidth

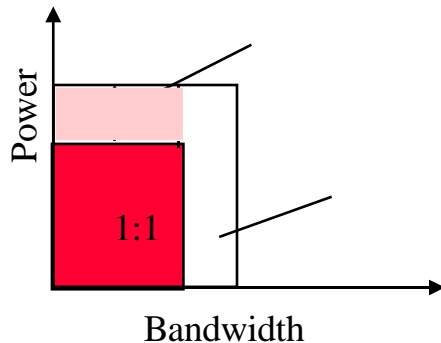


# LINK BUDGET

## Minimize Lease Bandwidth

“Power limited”

**What to do?**



- Increase receiving antenna size
- Change the FEC rate (7/8 to 3/4 FEC)
- Introduce Reed Solomon coding
- Change the modulation technique (8-PSK to QPSK)
- Manipulate the link availability
- Sensibly reduce additional margins

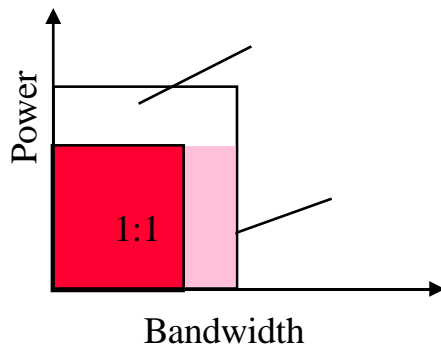


# LINK BUDGET

## Minimize Lease Bandwidth

“Bandwidth limited”

### What to do?



- Change the FEC rate (3/4 to 7/8 FEC)
- Change the modulation technique (QPSK to 8-PSK)



# LINK BUDGET

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## Maximize Satellite EIRP

### How?

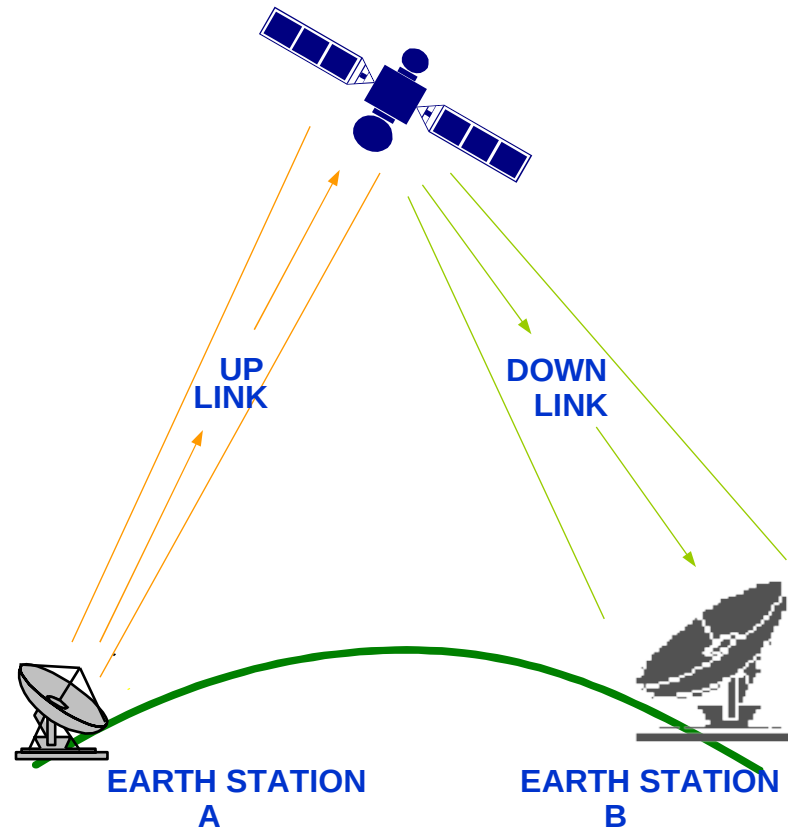
- By selecting the optimum satellite and transponder connectivity



# LINK BUDGET

## The Satellite Link

- Space Segment Parameters
- Carrier Parameters
- Earth Segment Parameters





# LINK BUDGET

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## Space Segment Parameters

### Transponder Parameters

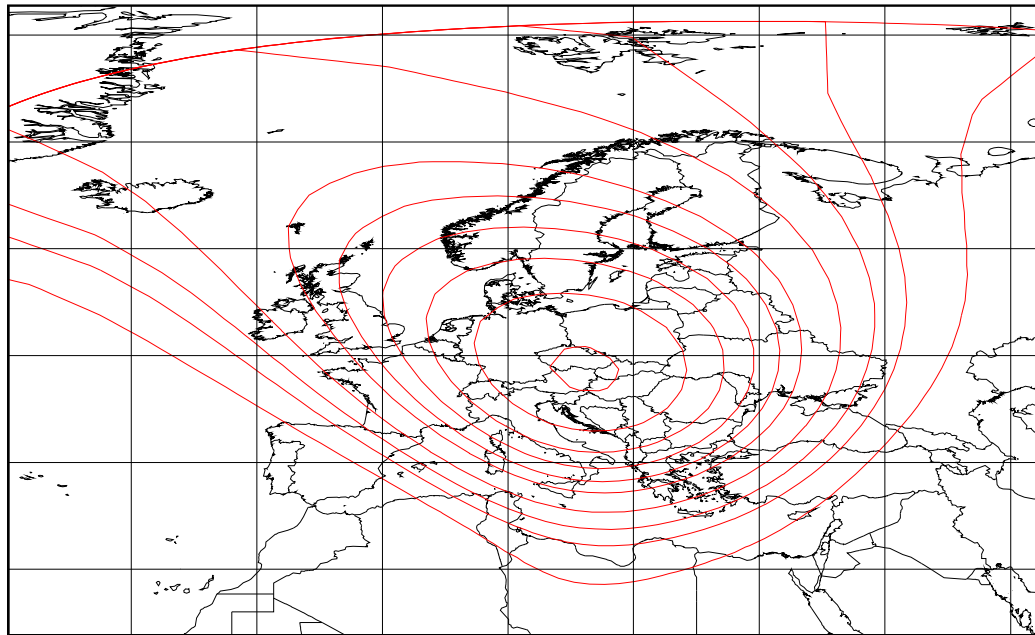
- G/T Receive [dB/K]
- Saturation Flux Density (SFD) [dBW/m<sup>2</sup>]
- EIRP (Saturation) [dBW]
- Transponder Bandwidth [MHz]
- Transponder IBO (Input Back-off) [dB]
- Transponder OBO (Output back-off) [dB]
- Transponder Intermodulation Interference (C/IM) [dB]



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## Space Segment Parameters

G/T



Uplink coverage for F transponders of EUROBIRD™ at 28.5° East  
(-4, 0, +2, +4, +6, +7, +8, +9, +10 & +11 dB/K, Steerable 2 beamcentre = 16.7°E & 48.8°N)



# LINK BUDGET

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## Space Segment Parameters

### Saturation Flux Density

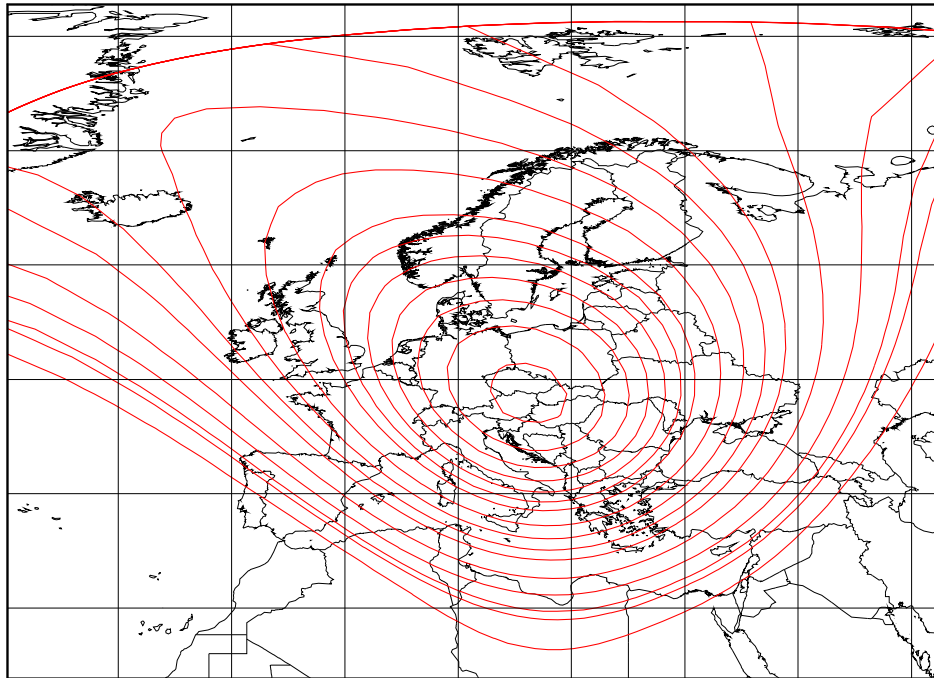
- Is the power density from the earth station required to achieve saturation of the transponder on the satellite.
- Is dependent on the  $G/T$  contour of the footprint.



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## Space Segment Parameters

EIRP



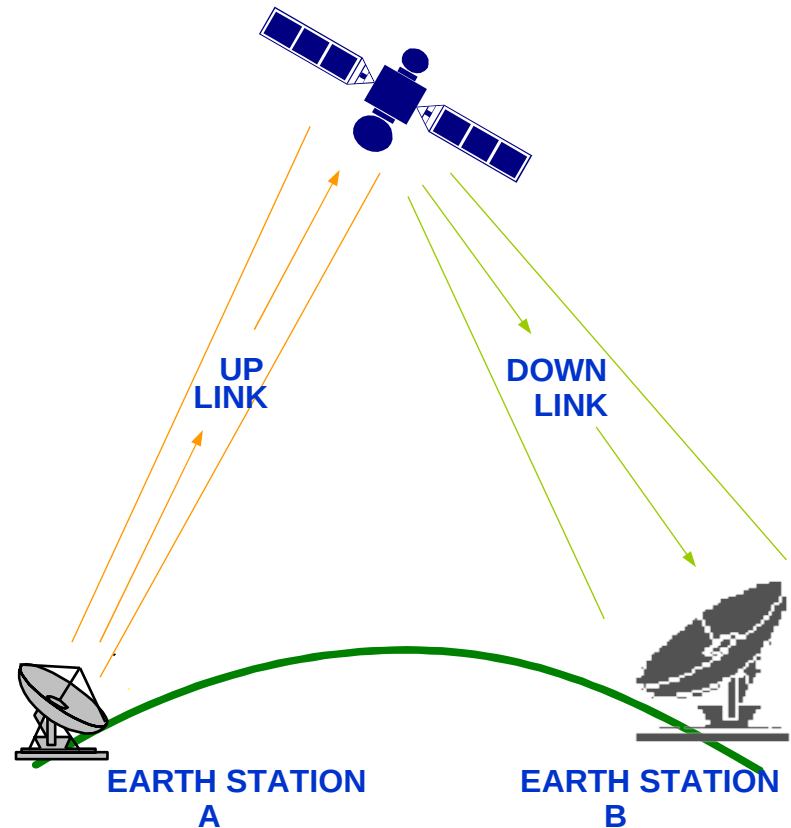
Downlink coverage for F transponders of EUROBIRD™ at 28.5° East (end-of-life & worst path EIRP)  
(38, 41, 42, 44, 46, 48, 49, 50, 51, 52, 52.5, 53, 53.5, 54, 54.5 & 55 dBW, Steerable 2 beamcentre = 16.7°E & 48.8°N)



# LINK BUDGET

## The Satellite Link

- Space Segment Parameters
- **Carrier Parameters**
- Earth Segment Parameters





# LINK BUDGET

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## Carrier Parameters

- Modulation Technique [BPSK/QPSK]
- Data Rate [bps]
- Forward Error Correction Rate (FEC)
- Reed Solomon Coding Rate (R-S)
- Turbo Coding (TPC)

➤ [Allocated Bandwidth](#)



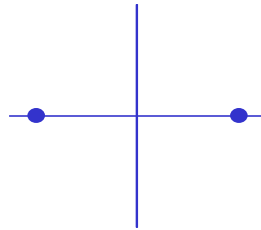
# LINK BUDGET

## Carrier Parameters - Modulation Schemes

BPSK:

Binary Phase Shift Keying

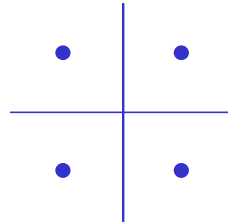
- 2 Phases
- 1 Bit (1, 0)



QPSK:

Quadrature Phase Shift Keying

- 4 Phases
- 2 Bits (00, 01, 11, 10)





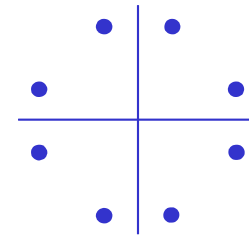
# LINK BUDGET

## Carrier Parameters - Modulation Schemes

8-PSK:

8 Phase Shift Keying

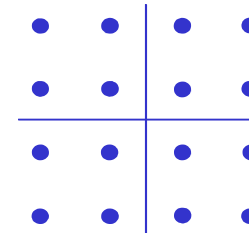
- 8 Phases
- 3 Bit (000, 001, 010, 011, 111, 110, 101, 100)



16 QAM:

16 Quadrature Amplitude Modulation

- 16 Amplitudes
- 4 Bit (0000, ....., 1111)





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## Carrier Parameters

### Carrier Allocated Bandwidth

- BPSK:  $BW = TR * 1.4 / 1$
- QPSK:  $BW = TR * 1.4 / 2$
- 8-PSK:  $BW = TR * 1.4 / 3$
- 16 QAM:  $BW = TR * 1.4 / 4$

Note: TR (Transmit Rate) = Information Bit Rate incl. Error Correction Bits

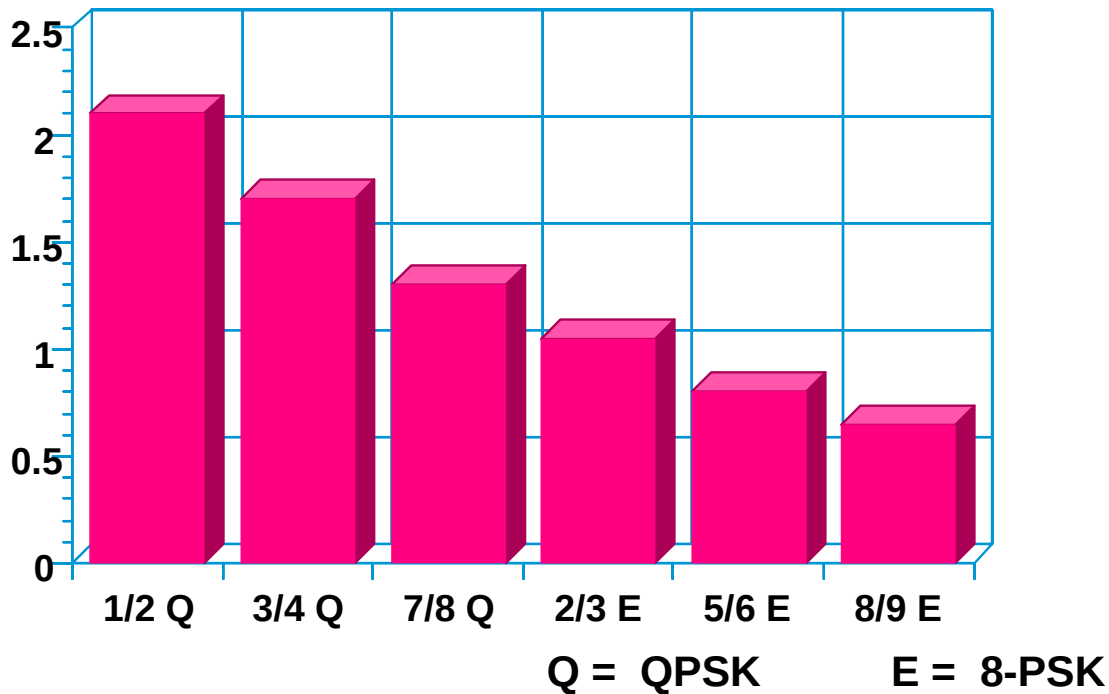
Carrier Occupied Bandwidth =  $TR * 1.2 / 1$  (BPSK)



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## Carrier Parameters

### Bandwidth Comparison





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## Carrier Parameters

### Forward Error Correction (FEC)

- Why?
  - To improve the signal quality
- How?
  - By allowing automatic error correction
  - By providing redundancy in original transmission
  - By increasing the number of bit sent
- Why not?
  - By introducing FEC, the effective data rate is reduced



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## Carrier Parameters

### Forward Error Correction (FEC)

1/2 FEC:



3/4 FEC :



7/8 FEC :



Data Bit



Extra Bit



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## Carrier Parameters

### Forward Error Correction (FEC)

- Typical FEC Rates:
  - QPSK: 1/2 FEC, 3/4 FEC, 7/8 FEC
  - 8-PSK: 2/3 FEC, 5/6 FEC, 8/9 FEC
- Optimal FEC Rates:
  - Why?
    - To achieve optimum use of power and bandwidth
    - To provide best possible availability within system limitations

$$\text{Transmission Rate} = \text{Data Rate} * 1/\text{FEC}$$



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## Carrier Parameters

### Reed Solomon (R-S)

- Why?
  - How?
  - Why not?
- To improve the signal quality
  - By increasing the carrier allocated bandwidth
  - R-S has an undesired effect when calculations are bandwidth limited

Turbo Coding is another coding technique with similar performance.



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## Carrier Parameters

### Reed Solomon (R-S)

- Commonly used RS Codes:
  - ~ 2Mbps: (204,188) or factor 0.922
  - also: (126,112) or factor 0.889
  - (225, 205) or factor 0.911
  - (219, 201) or factor 0.918
  - (194,178) or factor 0.918
  - (208,192) or factor 0.923

Transmission Rate = Data Rate \* 1/FEC \* 1/RS



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## Carrier Parameters

- Eb/No Threshold
- Bit Error Rate (BER)
- Rain Attenuation

➤ Power Resources



# LINK BUDGET

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## Carrier Parameters

- Eb/No Threshold
  - Why?
    - To represent the minimum carrier performance before link failure
  - What?
    - Eb/No is the strength of the carrier divided by the bit rate
    - Eb/No is directly related to the carrier-to-noise ratio (C/N)
  - $E_b/N_0 = C/N + 10 \log (\text{noise BW}) - 10 \log (DR)$



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## Carrier Parameters

- Bit Error Rate (BER)
  - Why?
    - To represent the amount of errors occurring in a transmission
    - To express the link quality
  - What?
    - BER is an equipment characteristic
    - BER is directly related to  $E_b/N_0$
    - BER improves as the  $E_b/N_0$  gets larger



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## Carrier Parameters

- Bit Error Rate (BER)

Performance:

– Typical Eb/No values for different FEC Rates and QPSK.

6.5	7.1	7.6	9.9
Eb/No for FEC 1/2 (dB)	Eb/No for FEC 3/4 (dB)	Eb/No for FEC 7/8 (dB)	BER
6.5	8.0	9.1	$10^{-6}$
7.1	8.7	9.7	$10^{-7}$
7.6	9.2	10.4	$10^{-8}$
9.9	11.0	12.1	$10^{-10}$



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## Carrier Parameters

- Rain Attenuation

Performance:

- Availability
  - Rain Margins
    - Typically 99.6 % for Ku-Band
    - Typically 99.96 % for C-Band
- Additional Margins
  - Adjacent Satellite Interference (ASI)
  - Interference Margins



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## Carrier Parameters

- Rain Attenuation

### Elevation Angle

- Path Length

### Frequency

- Generic:
  - Ku-Band: 3-8 dB
  - C-Band: 1-2 dB

### Antenna Location

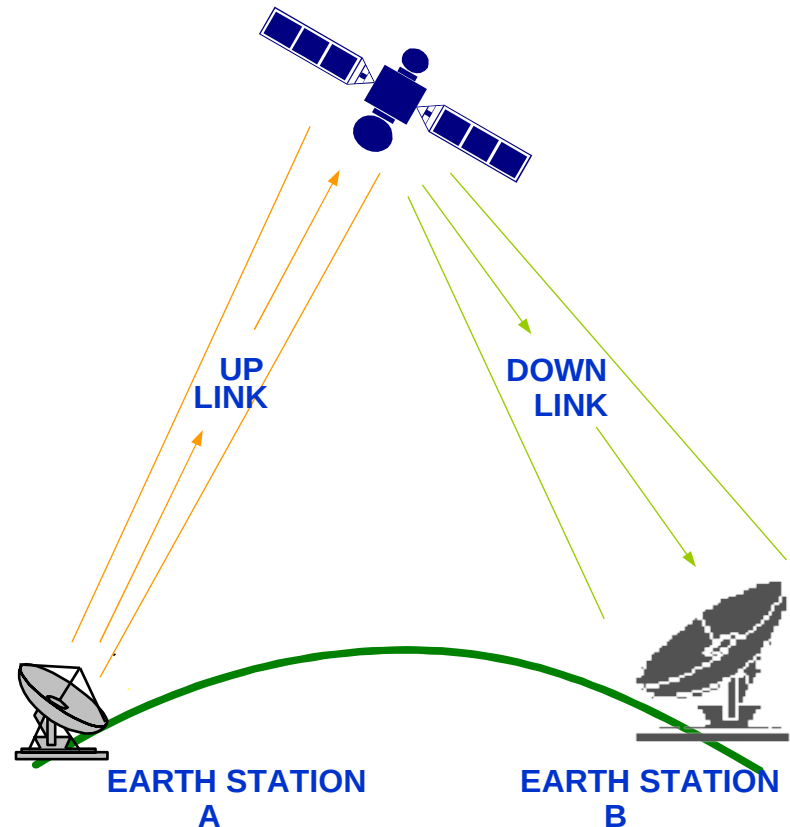
- Rain Zone
  - Annual Rain Fall
  - Thunderstorm Factor



# LINK BUDGET

## The Satellite Link

- Space Segment Parameters
- Carrier Parameters
- Earth Segment Parameters





# LINK BUDGET

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## Earth Segment Parameters

- Antenna Size
- HPA size
- Receive Antenna G/T
- Location



# LINK BUDGET

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## Earth Segment Parameters

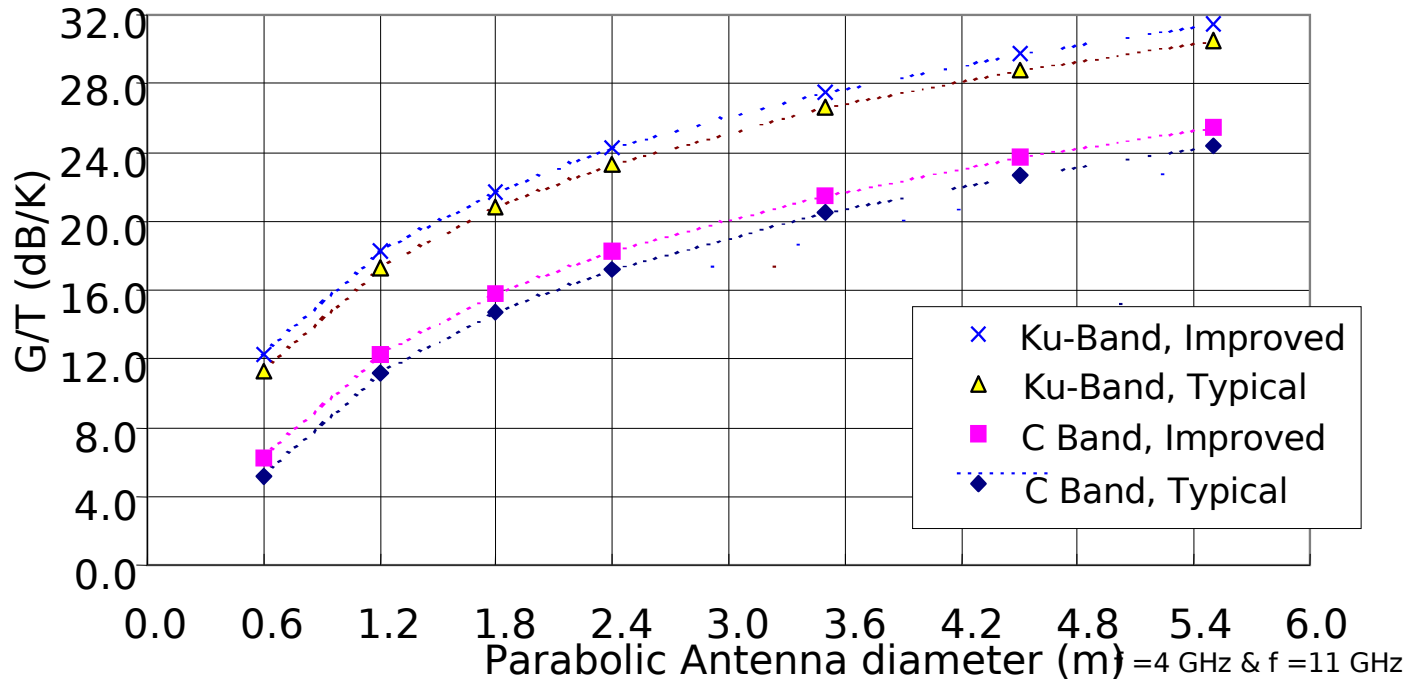
- Antenna Size
  - What?
    - Diameter
    - Efficiency
  - Impact?
    - The larger the antenna diameter, the higher the antenna gain
    - The larger the antenna diameter, the better the antenna G/T



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## Earth Segment Parameters

### G/T versus Antenna Diameter





# LINK BUDGET

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## Earth Segment Parameters

- HPA Size
  - What?
    - To amplify the carrier signal
  - Depends on?
    - The carrier size
    - The carrier performance
    - The sensitivity of the transponder



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## Earth Segment Parameters

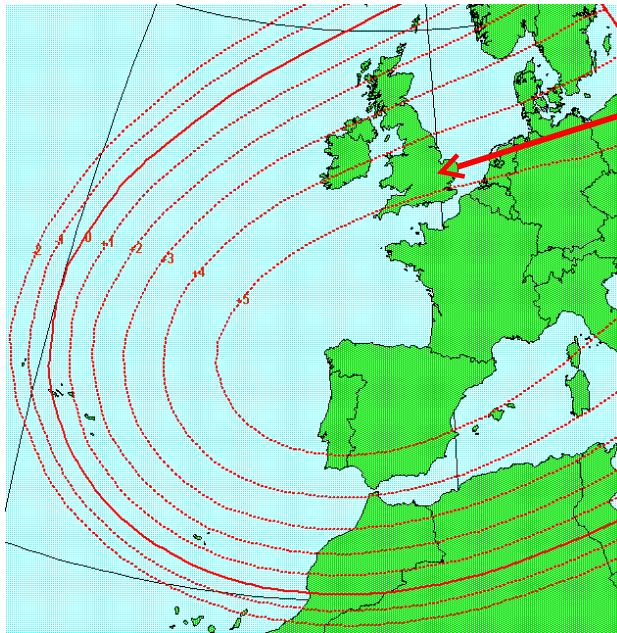
- HPA Size, Example

EIRP Carrier 1 (EIRP <sub>1</sub> ) - 128 kb/s		45,6	dBW
EIRP Carrier 2 (EIRP <sub>2</sub> ) - 64 kb/s		42,6	dBW
EIRP Total through HPA (EIRP <sub>t</sub> )	$=10 \cdot \text{LOG}(10^{(EIRP_1/10)} + 10^{(EIRP_2/10)})$	47,4	dBW
Antenna Gain (G <sub>ant</sub> ) - 2.4 mC-Band		41,6	dB
Feed Losses (L <sub>f</sub> )		1,0	dB
Power required at HPA output (P <sub>req</sub> )	$=EIRP_t - G_{ant} + L_f$	6,8	dBW
HPA Back-off (PA <sub>OBO</sub> )		2,0	dB
Saturated HPA output power (P <sub>s</sub> )	$=P_{req} + PA_{OBO}$	8,8	dBW
<b>HPA Size</b>	<b><math>=10^{(P_s/10)}</math></b>	<b>7,5</b>	<b>W</b>

# LINK BUDGET

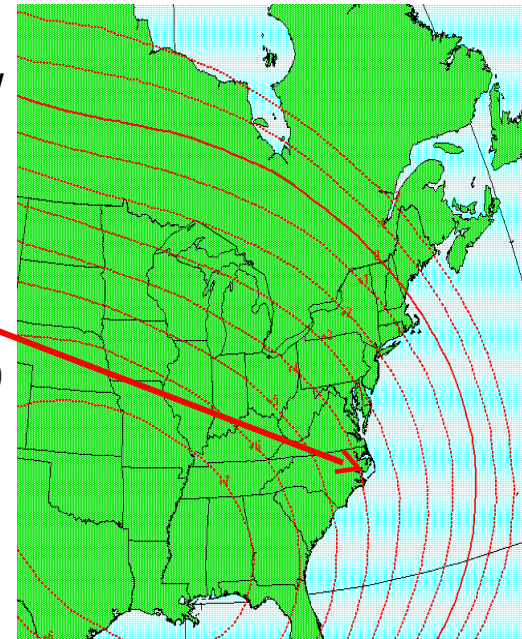
## Earth Segment Parameters

- Location - Appropriate Contours, Example



London:  
 $G/T = +4.5$  dB/  
K

Washington,  
DC:  
EIRP = 48.0  
dBW

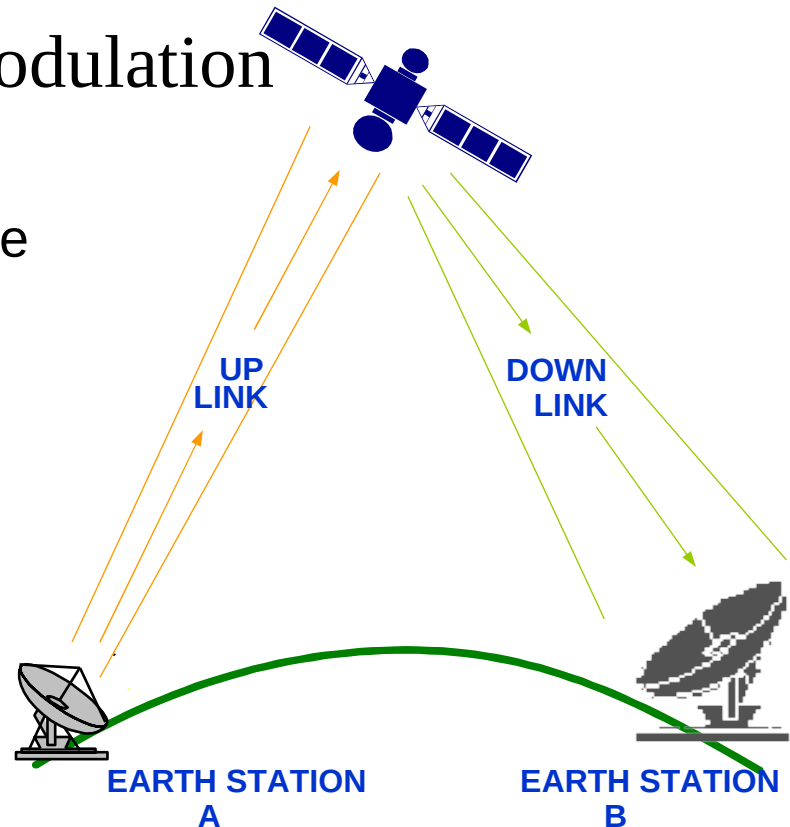




# LINK BUDGET

## Losses/Interference/Intermodulation

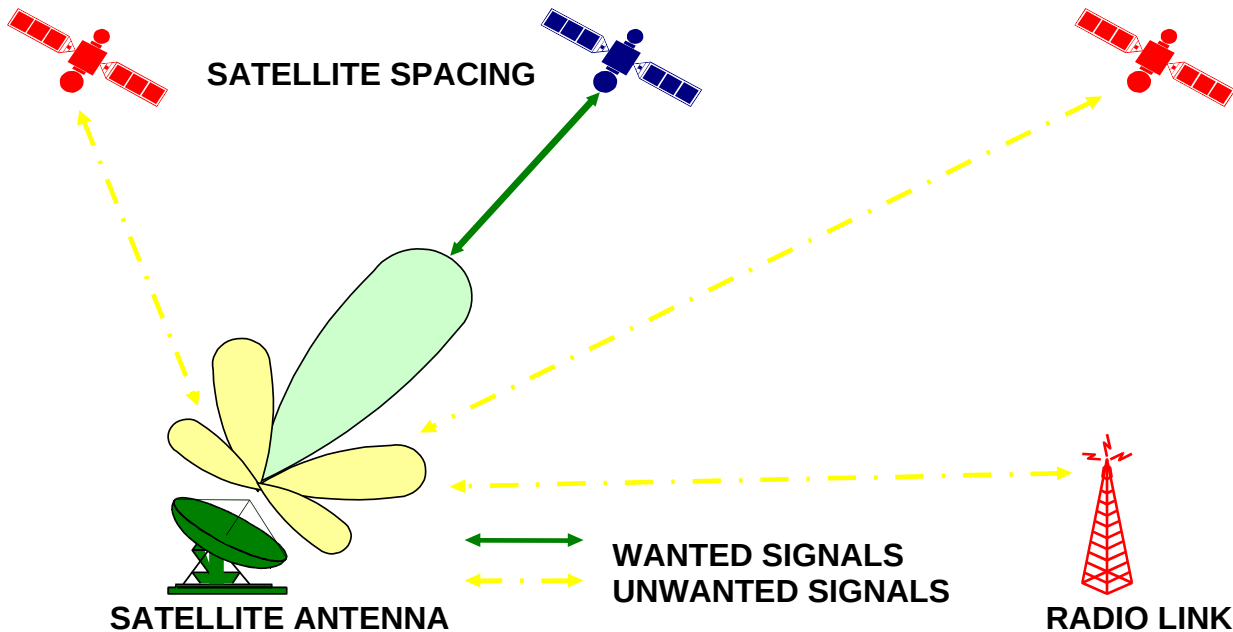
- Satellite
  - Co-Channel Interference
  - TWTA IM
- Path Losses
  - C/T uplink, thermal
  - C/T downlink, thermal
- Earth Station
  - HPA IM



# LINK BUDGET

## Losses/Interference/Intermodulation

- Co-Channel Interference  
Adjacent Satellite Interference (ASI)



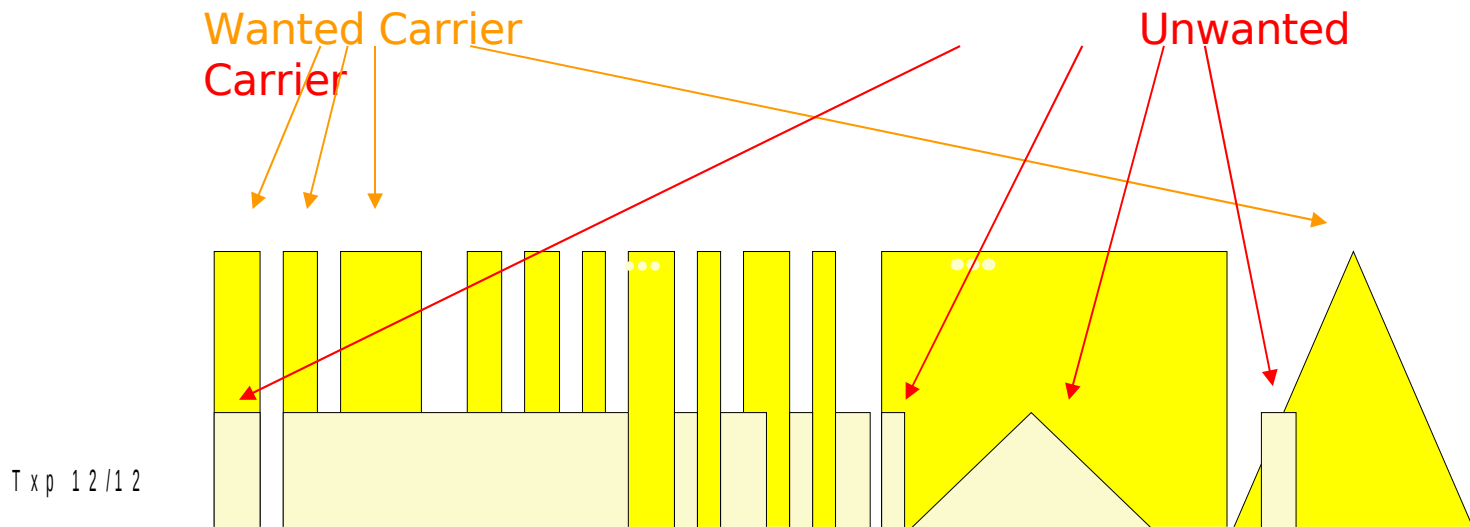


# LINK BUDGET

## Losses/Interference/Intermodulation

- TWTA Intermodulation

Different signals are sent simultaneously





# LINK BUDGET

## THE LINK EQUATION

- The link equation defines the relationship between the noise level at the receiver (in terms of carrier to noise ratio), the radiated transmitter power (EIRP), the loss in the link (space loss) and the noise performance of the receiver itself (receiver quality factor, G/T).

$$\left(\frac{C}{N_o}\right) = EIRP - L_s + \left(\frac{G_R}{T_s}\right) + K$$



# LINK BUDGET

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## Key Input Data:

- Satellite Parameters

- Orbital Location
- Band
- Beam
- Transponder

- Carrier Parameters

- Modulation Technique
- Data Rate
- Forward Error Correction (FEC)
- Reed Solomon (RS)

- E/S Parameters

- Standard
- Location

- Carrier Performance Parameters

- Threshold  $E_b/N_0$
- Required Rain Margins
- Additional Margins



# LINK BUDGET

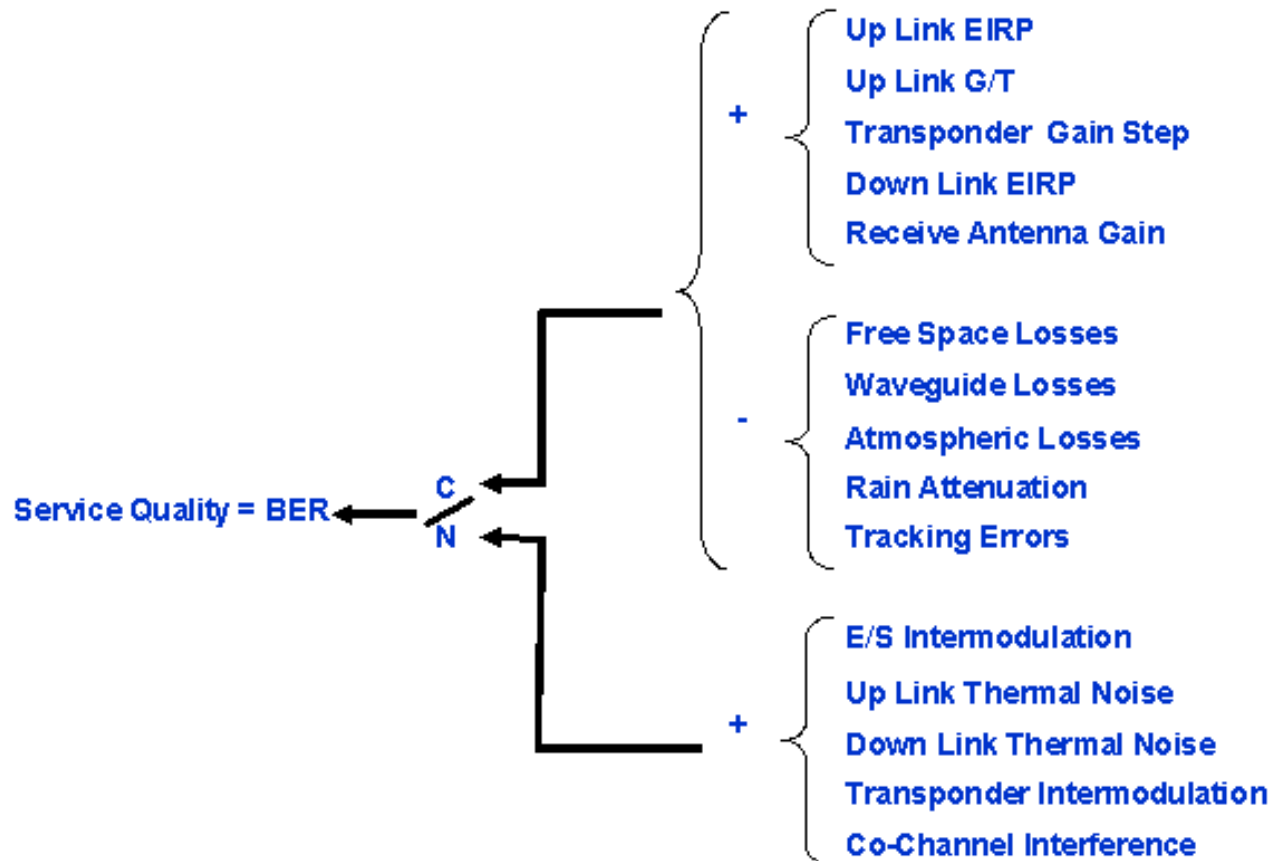
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## Key Output Data:

- Satellite Resources
  - Down link EIRP
  - Allocated Bandwidth per Carrier
- E/S Requirements
  - Diameter
  - HPA size
- Carrier Performance
  - Eb/No; BER



# LINK BUDGET

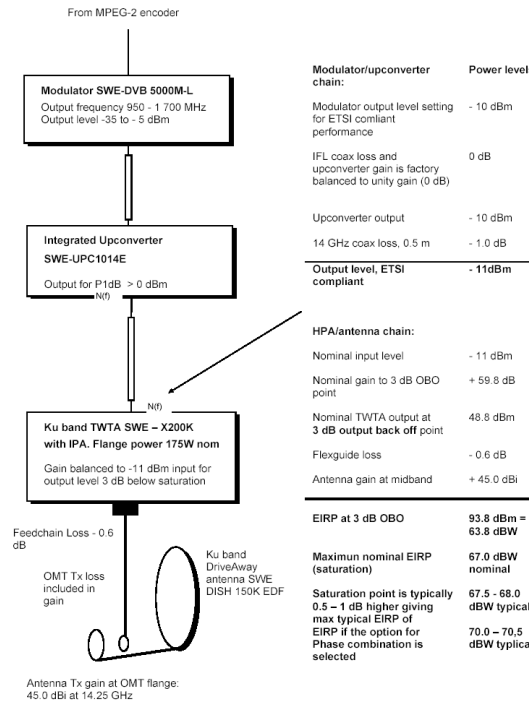






# Transmit Power Budget

## Transmit Power Budget - Calculation examples...

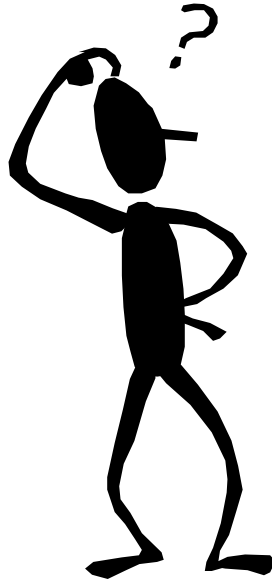


Modulator/upconverter chain:	Power levels
Modulator output level setting for ETSI compliant performance	- 10 dBm
IFL coax loss and upconverter gain is factory balanced to unity gain (0 dB)	0 dB
Upconverter output	- 10 dBm
14 GHz coax loss, 0.5 m	- 1.0 dB
<b>Output level, ETSI compliant</b>	<b>- 11dBm</b>
<b>HPA/antenna chain:</b>	
Nominal input level	- 11 dBm
Nominal gain to 3 dB OBO point	+ 59.8 dB
Nominal TWTA output at 3 dB output back off point	48.8 dBm
Flexguide loss	- 0.6 dB
Antenna gain at midband	+ 45.0 dBi
<b>EIRP at 3 dB OBO</b>	<b>93.8 dBm = 63.8 dBW</b>
<b>Maximum nominal EIRP (saturation)</b>	<b>67.0 dBW nominal</b>
<b>Saturation point is typically 0.5 – 1 dB higher giving max typical EIRP of</b>	<b>67.5 - 68.0 dBW typical</b>
<b>EIRP if the option for Phase combination is selected</b>	<b>70.0 – 70.5 dBW typical</b>



# QUESTIONS

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