OSCW 2019

Dynamic Open-source Satlink Analyzer (DOSA)

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Presented on
14/10/2019

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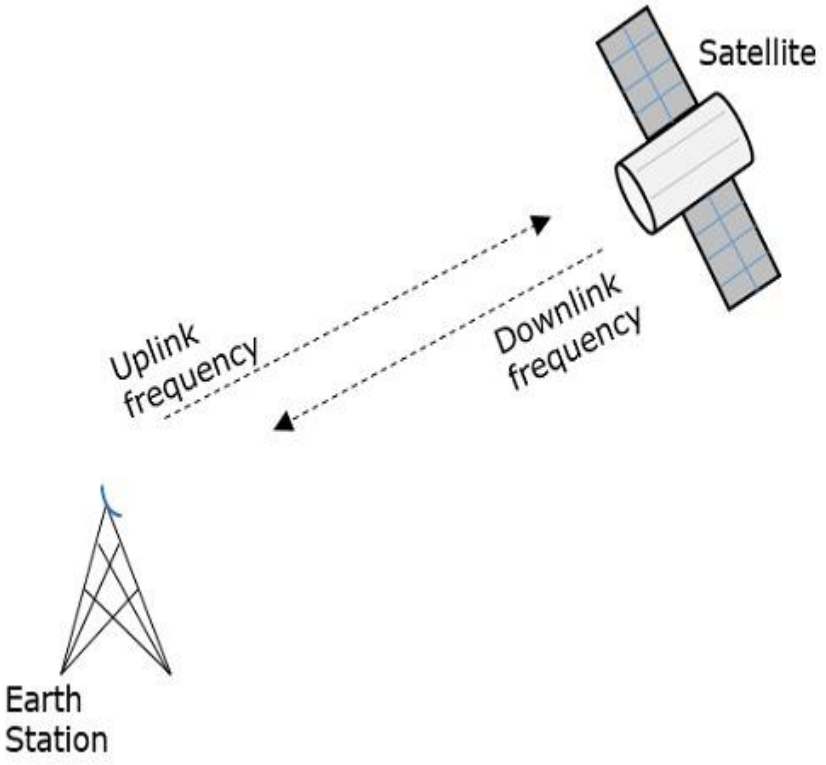
What is a Link Budget?



[Transmitted Power]

+

[Gains]

–

[Losses]

=

[Received Power]

More Received Power* ➡ More Received Data

*Carrier Signal to Noise Power Spectral Density Ratio

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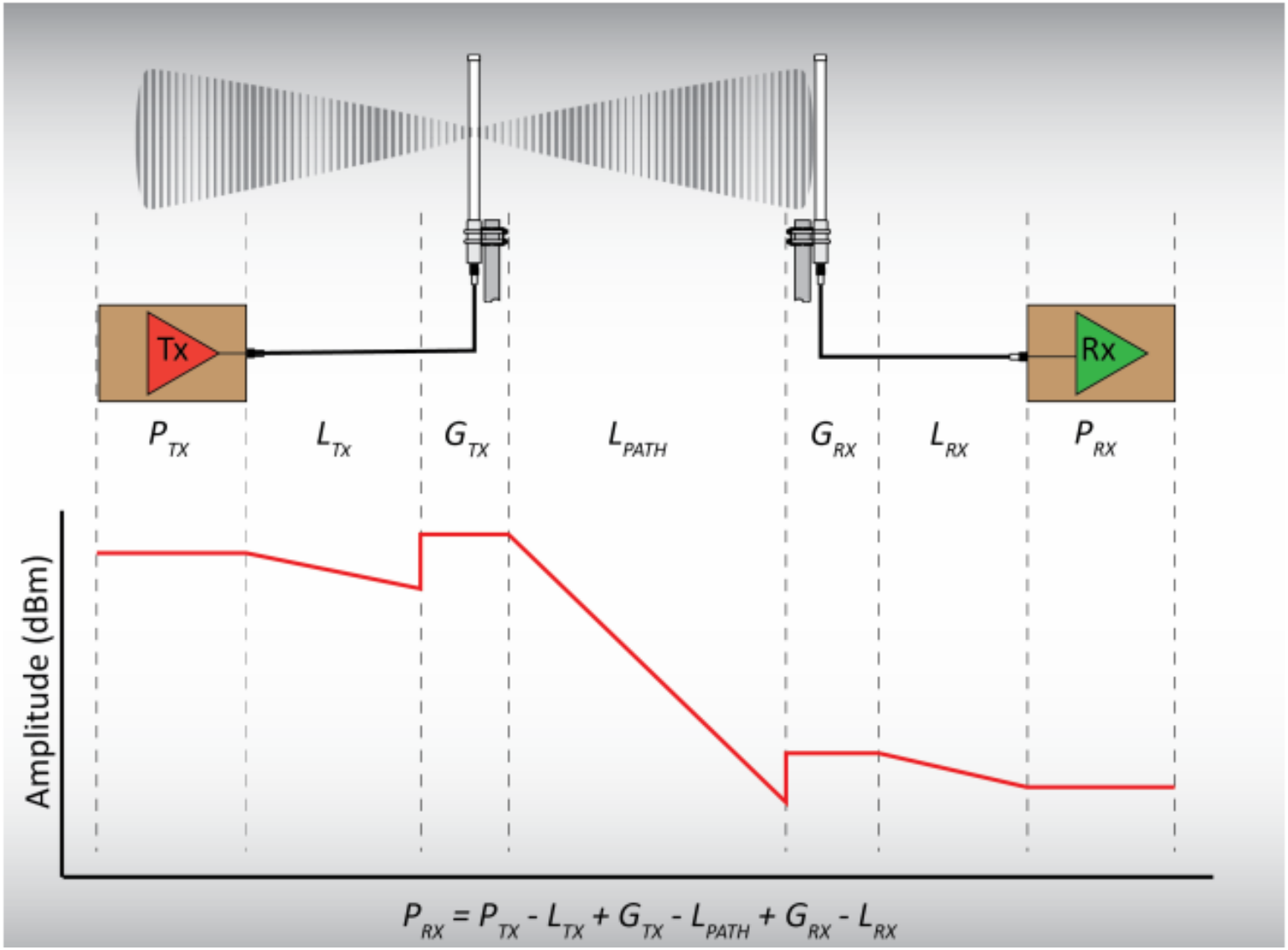
Signal Gain Loss Profile



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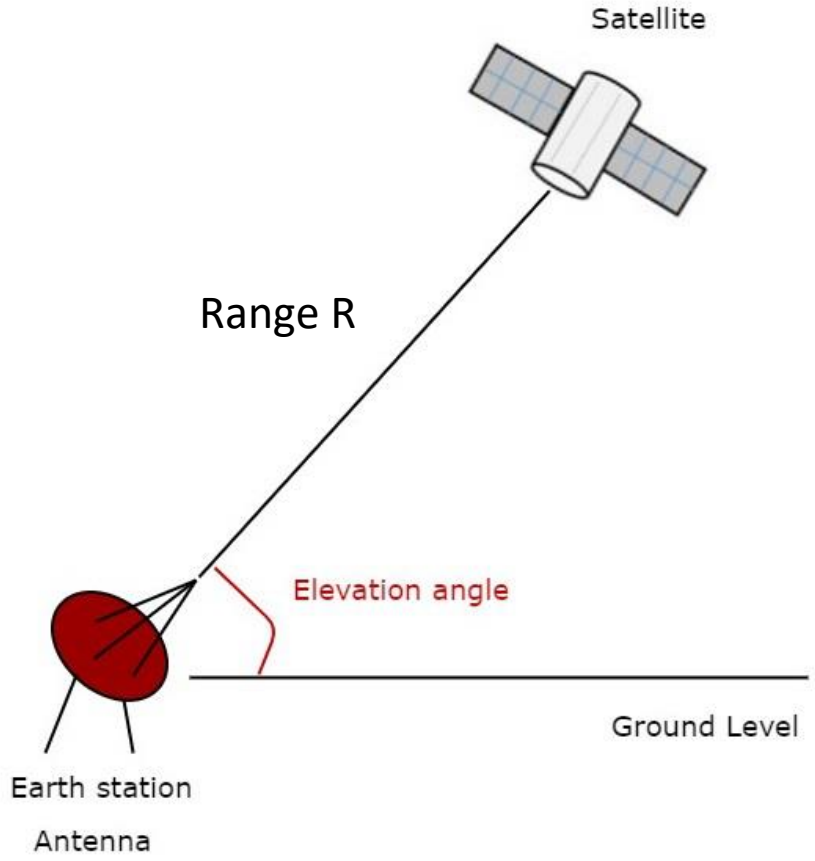
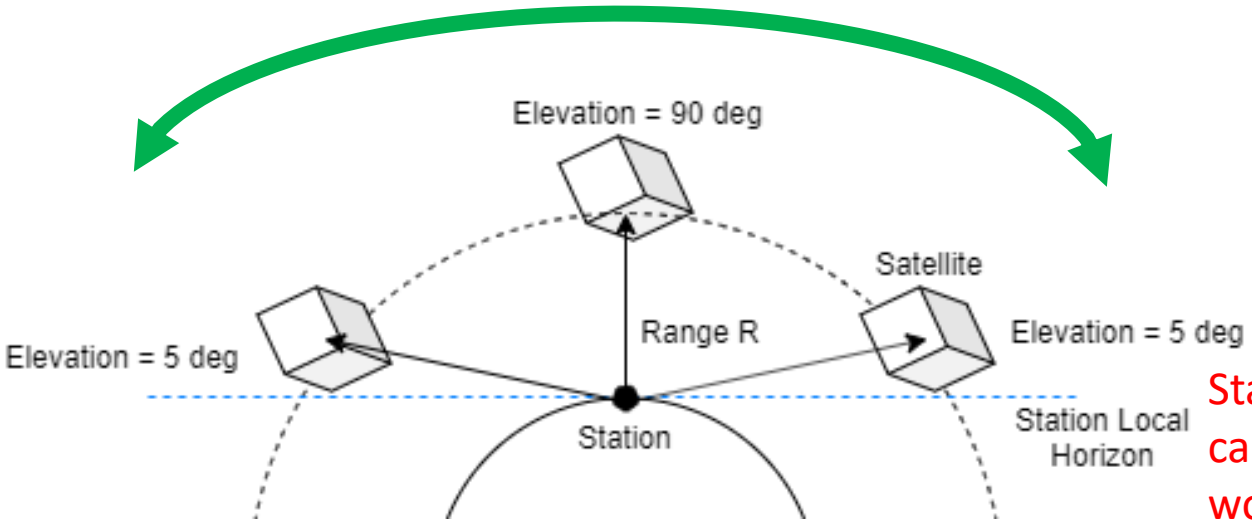
Range and Elevation Angle



Static Vs Dynamic Link Budget

Dynamic link budget calculates as a function of time over entire pass



Static Link Budget calculates at only worst case of 5-10 degrees

State of the Art

STK®

Telecom Forecaster Predictor (TFP)

- High dependency on restricted software or database for orbit propagation
- Tools are NOT open source

AMSAT®

IARU Link Model by Jan A. King

- Useful but calculates only Static Link Budget
- Can be complex to use

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DOSA

Repository:
https://sourceforge.isae.fr/projects/dosa_link_budget_analysis

- Calculates dynamic link budget
- Enables to select best passes
- Visualisation of available margins

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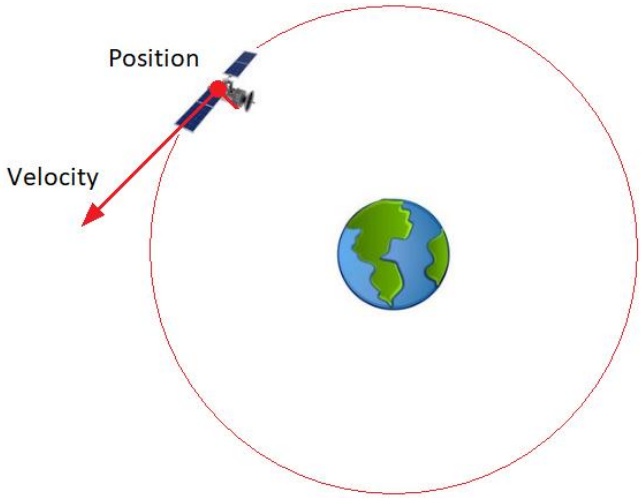
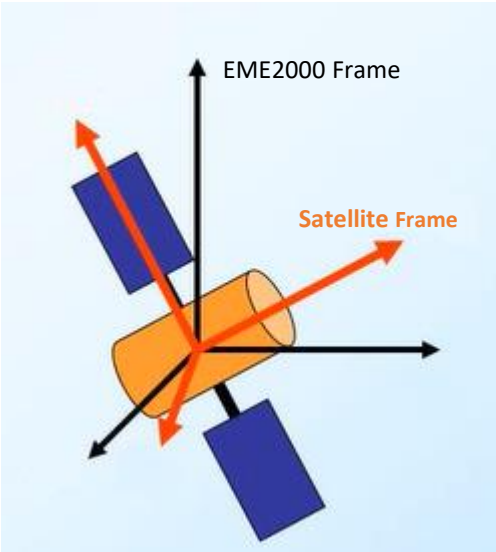
OEM and AEM Files in CCSDS format



Orbit Ephemeris Message (OEM) – *"An OEM specifies the **position** and **velocity** of a single object at multiple epochs contained within a specified time range."*



Attitude Ephemeris Message (AEM) – *"An AEM specifies the **attitude state** of a single object at multiple epochs, contained within a specified time range. "*

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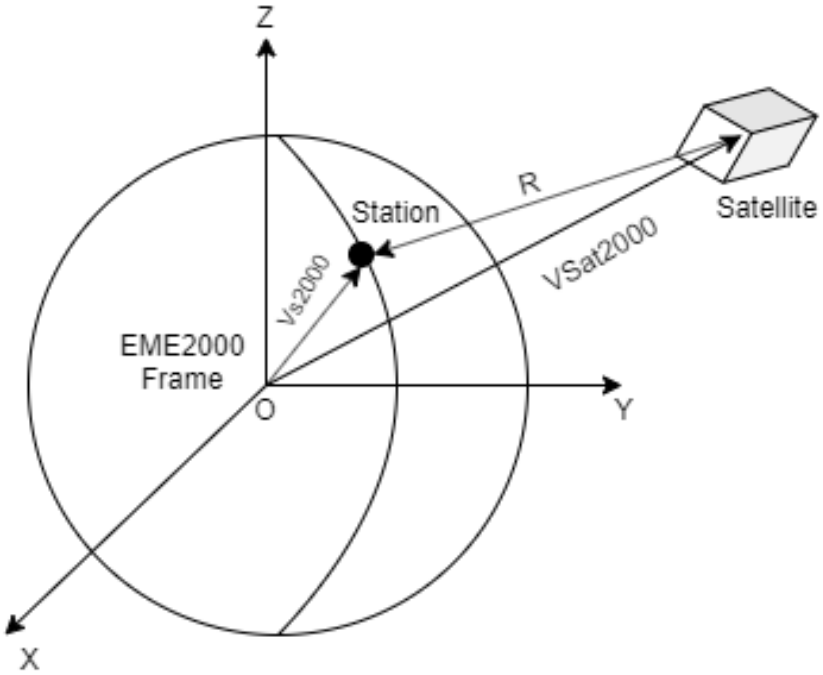
Free Space Loss

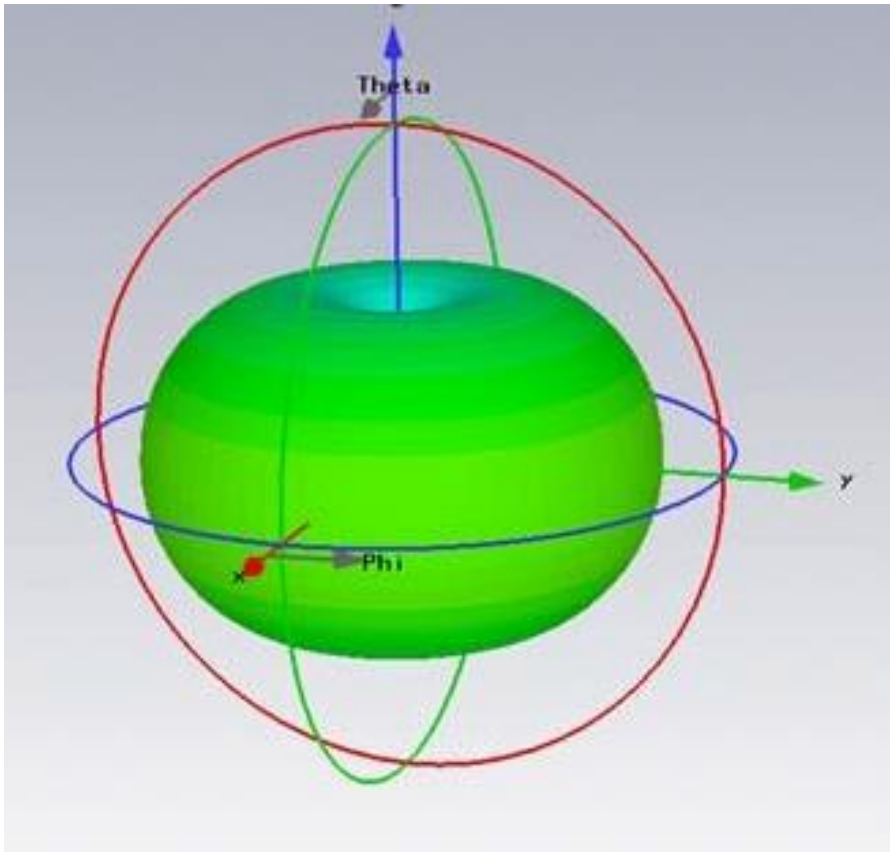


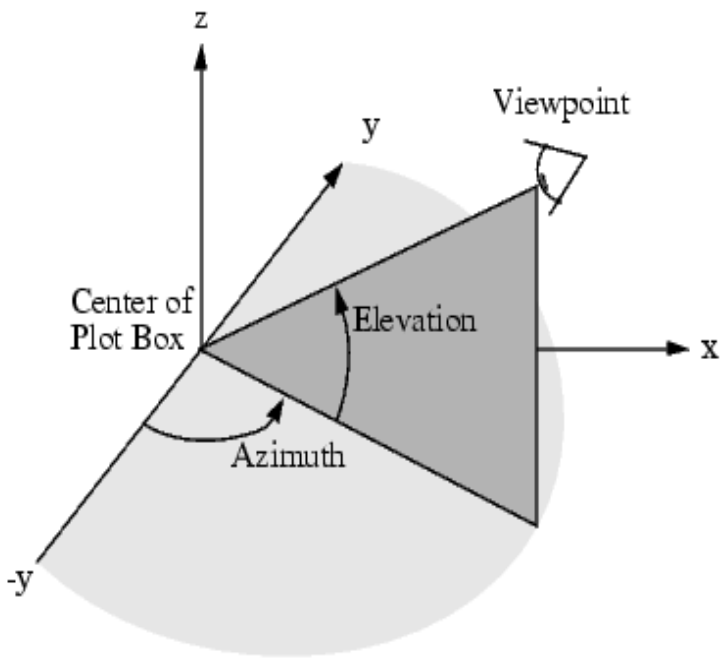
$$L_{FSL} = \frac{4\pi R f_c}{c}$$

$$R = V_{S2000} - V_{Sat2000}$$

Loss varies as per satellite-station distance R over the orbit

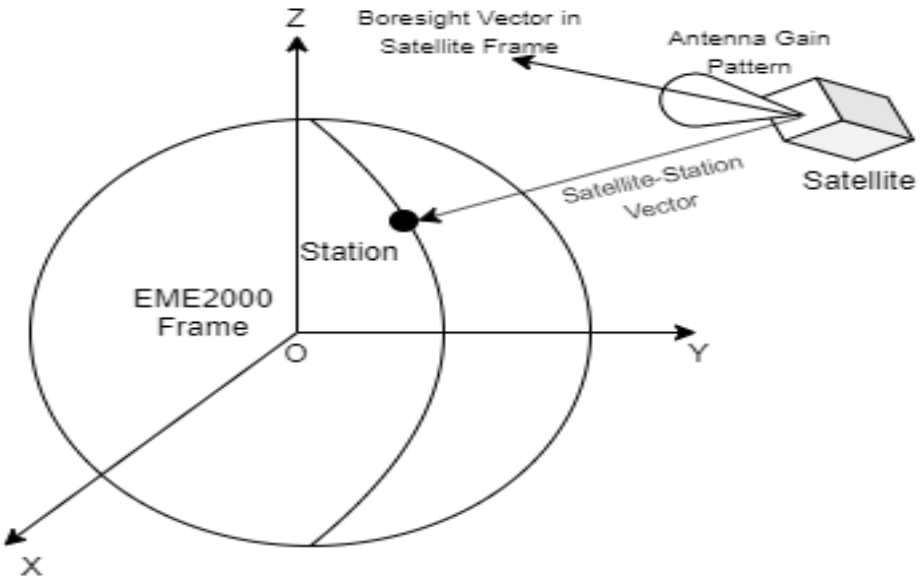
Antenna Gain Pattern

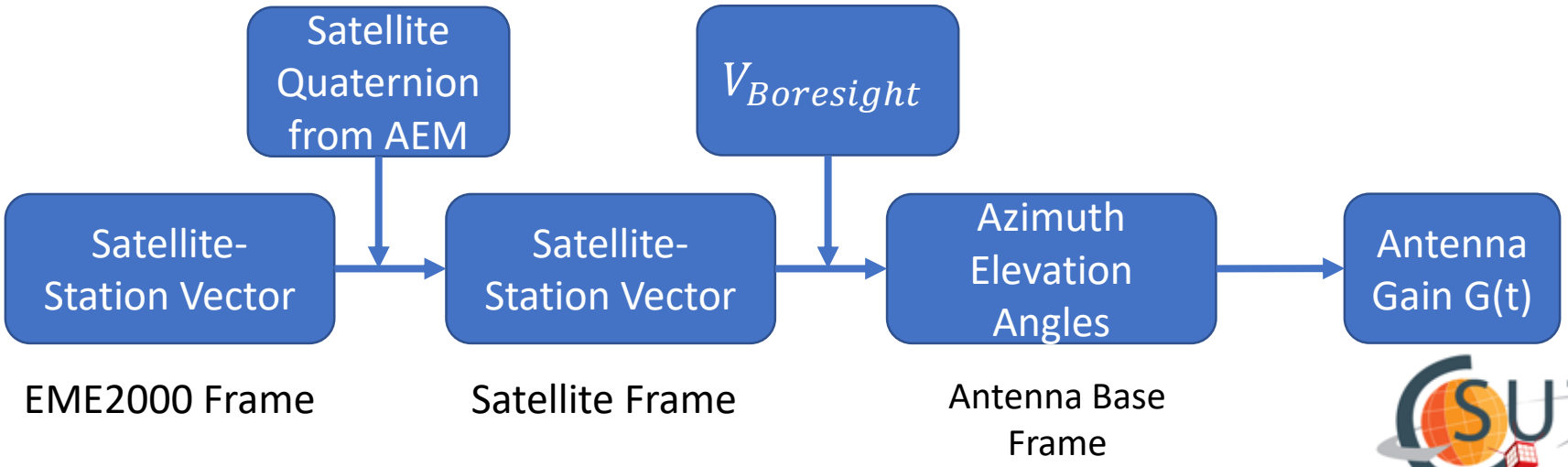




Antenna Gain is function of Azimuth and Elevation angles in the Antenna Base Frame

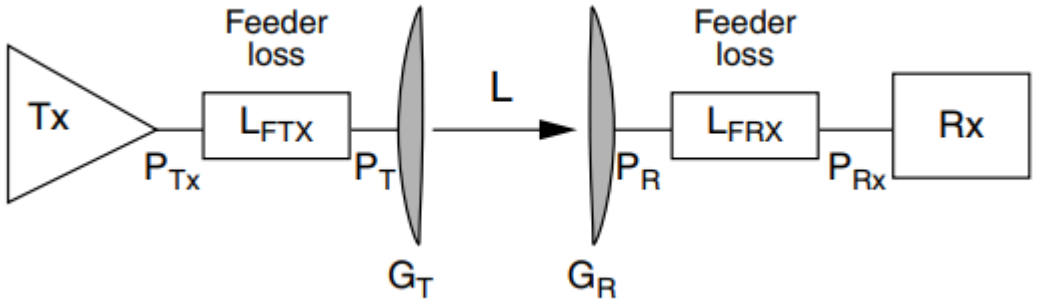
Pointing Loss





Link Budget Equation

General Link Architecture



$$\left[\frac{C}{N_0}\right] = [P_{Tx}] + [G_T] - [L_T + L_{PTx}] - [L_{FSL} + L_{Atm}] + [G_R] - [T_N] - [k]$$

- $\left[\frac{C}{N_0}\right]$: Received Signal to Noise Power Spectral Density
- $[P_{Tx}]$: Transmitter Power
- $[G_T]$: Transmitter Antenna Gain
- $[L_T + L_{PTx}]$: Transmitter Losses
- $[L_{FSL}]$: Free Space Loss
- L_{Atm}: Other atmospheric Losses
- $[G_R]$: Receiver Antenna Gain
- $[T_N]$: Receiver Noise Temperature
- $[k]$: Boltzmann constant

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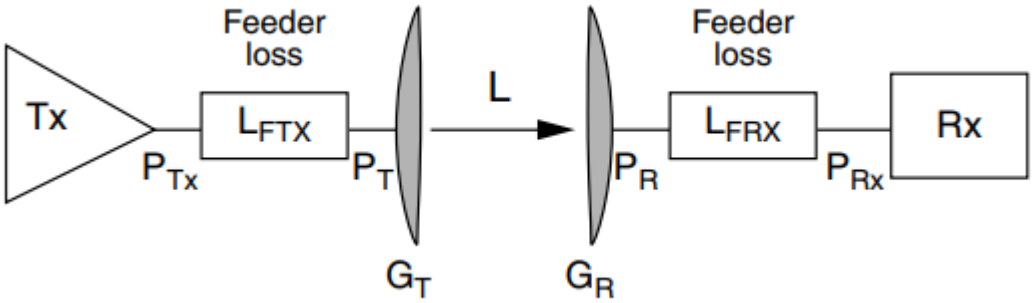
Link Budget Equation

General Link Architecture



$$\left[\frac{E_b}{N_0}\right] = \left[\frac{C}{N_0}\right] - [R_b]$$

Bit Energy to Noise Power Spectral Density

Received Signal to Noise Power Spectral Density

Bit Rate

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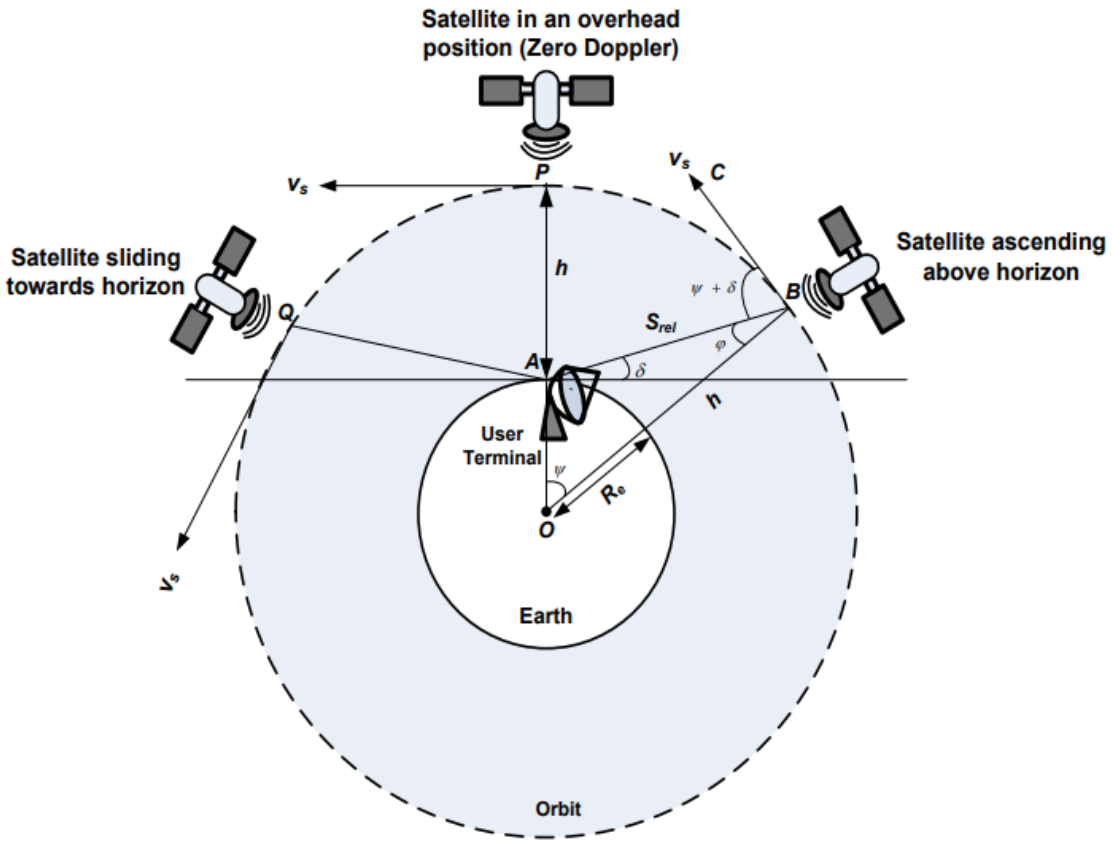
Doppler Effect



$$Doppler\ Shift\ (f_d) = \frac{f_c v_s}{c}$$

$$v_s = \frac{d}{dt}(distance_{satellite-station})$$

$$Doppler\ Rate = \dot{f}_d$$

Doppler Shift varies as per satellite velocity relative to station

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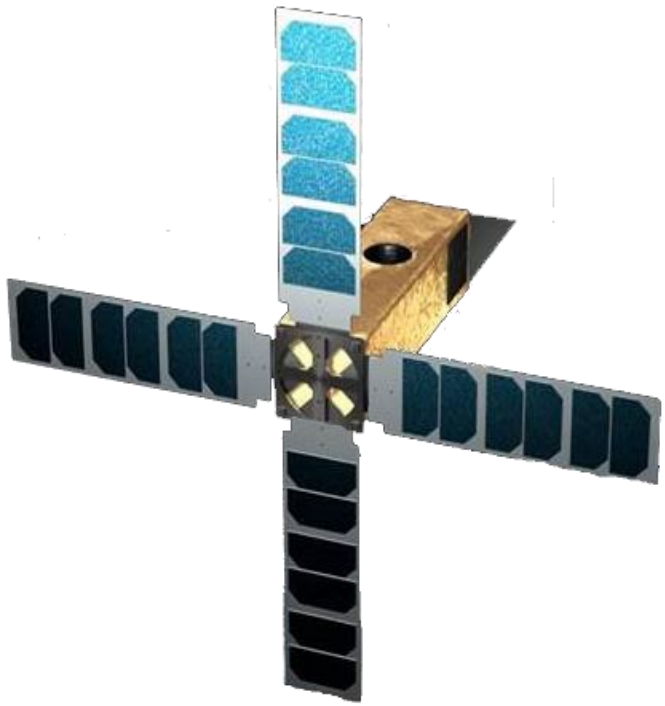
Case Study - EyeSat

Orbit Parameters

Semi-major axis	=	**6872.3 (km)**
Eccentricity	=	0.00026
Inclination	=	97.4 (deg)
Argument of perigee	=	222.62 (deg)
Longitude of ascending node	=	111.15925 (deg)
Mean anomaly at epoch	=	333.2539 (deg)

Link Parameters

Downlink frequency	=	**2210 (MHz)**
Minimum station elevation	=	10 (deg)
Data rate after channel coding	=	234000 (b/s)
Transmitter Power	=	3 (dBW)



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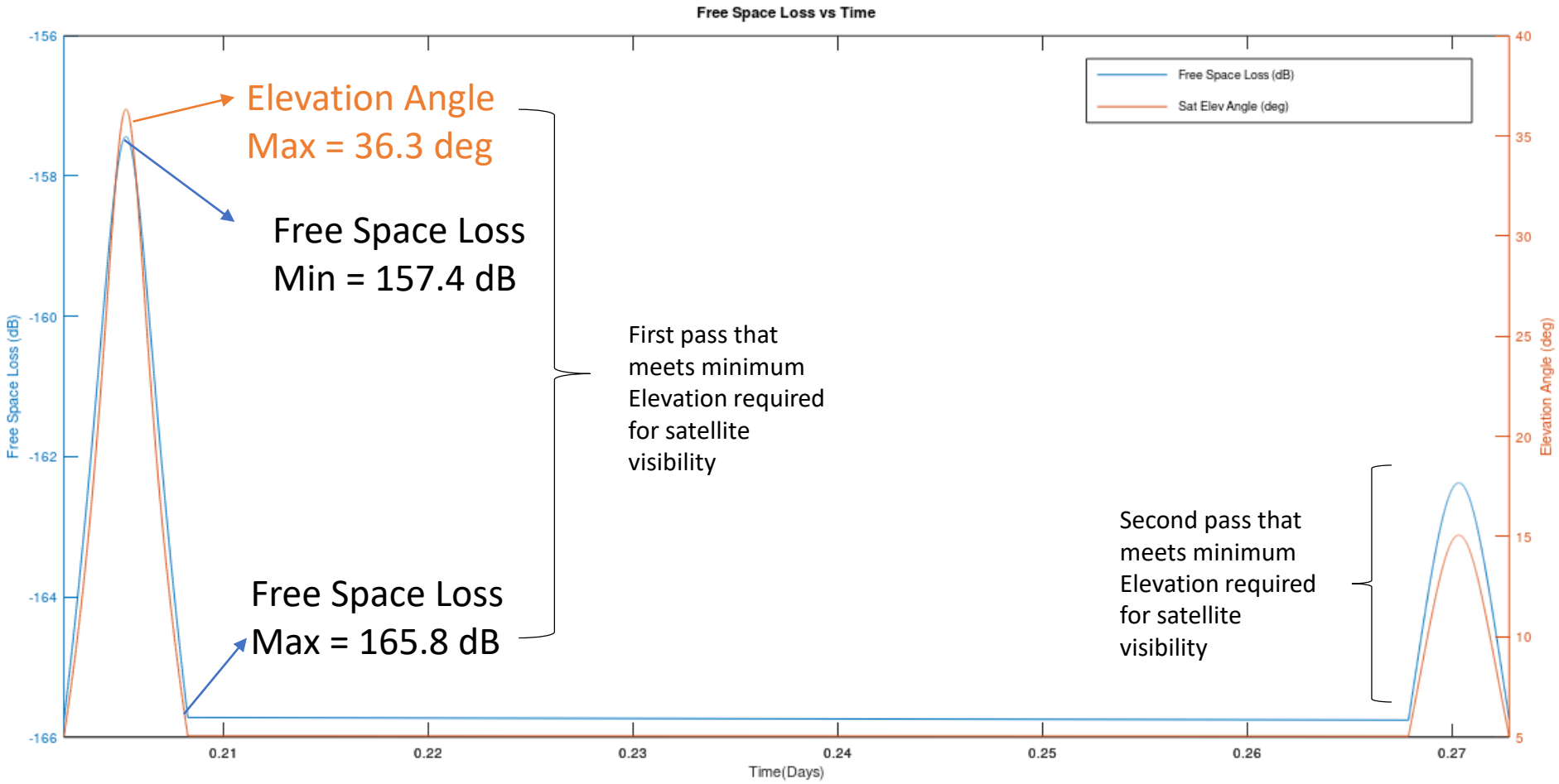
Free Space Loss and Elevation Angle



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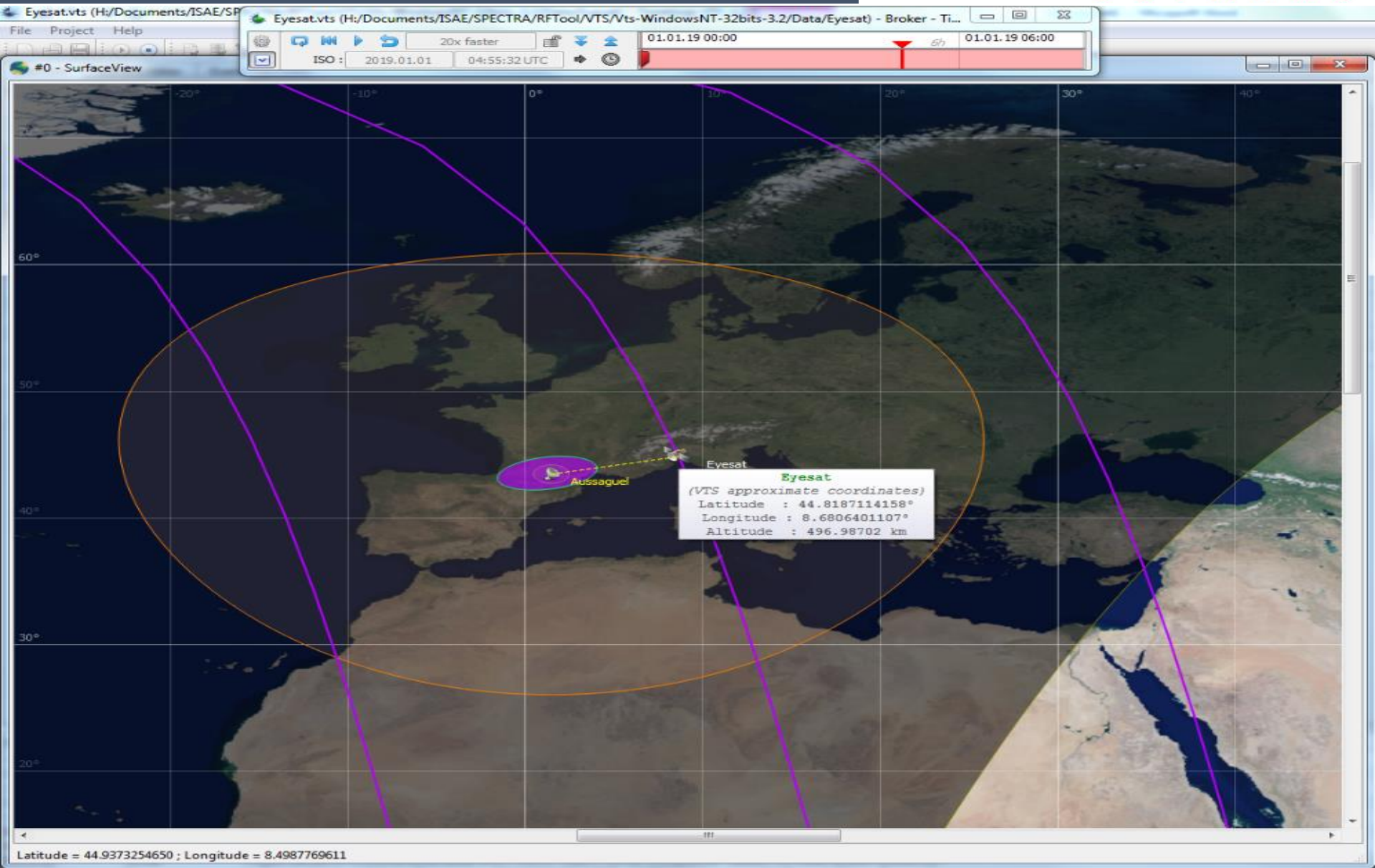
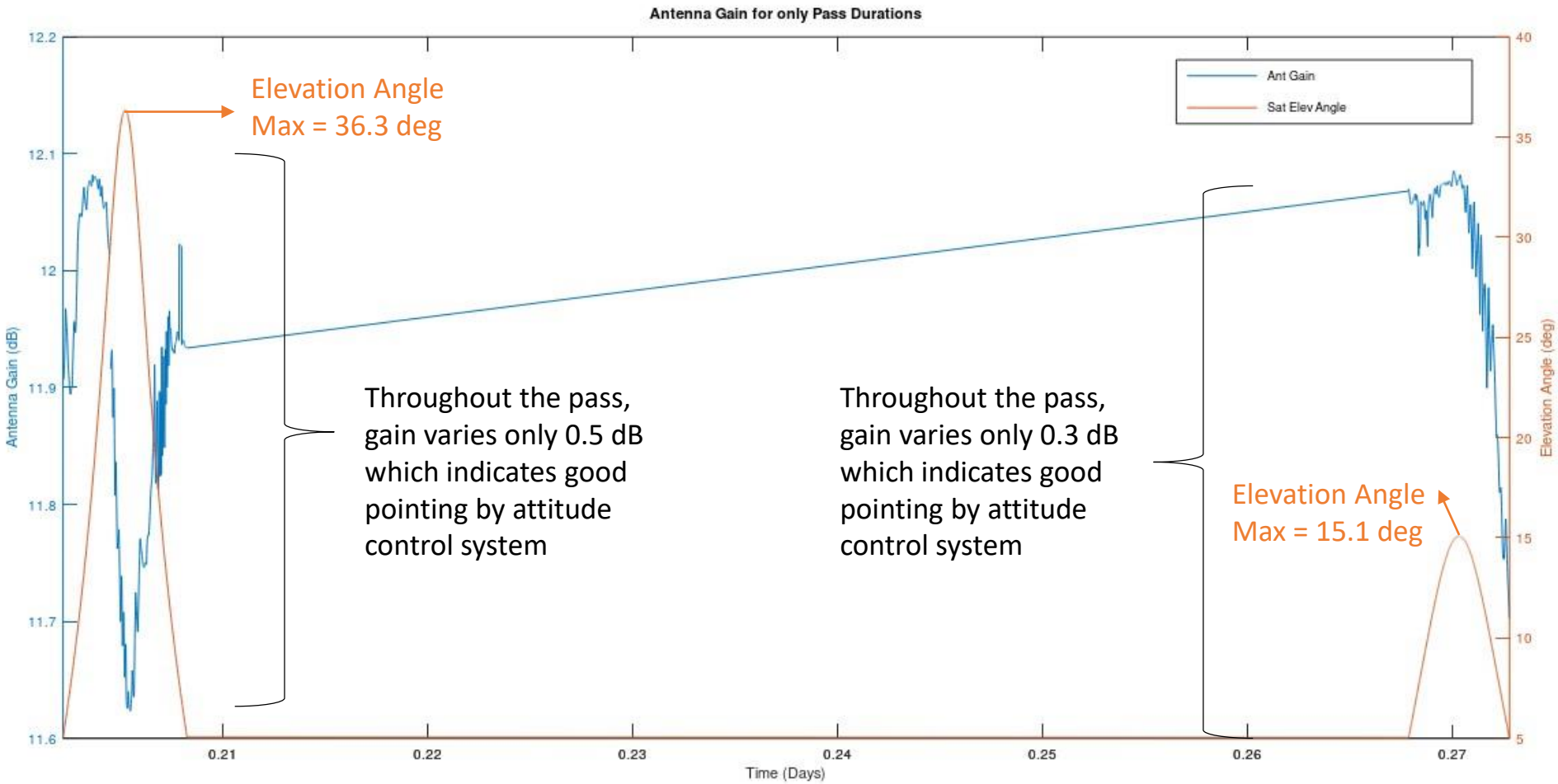
VTS Simulation



Antenna Gain variations



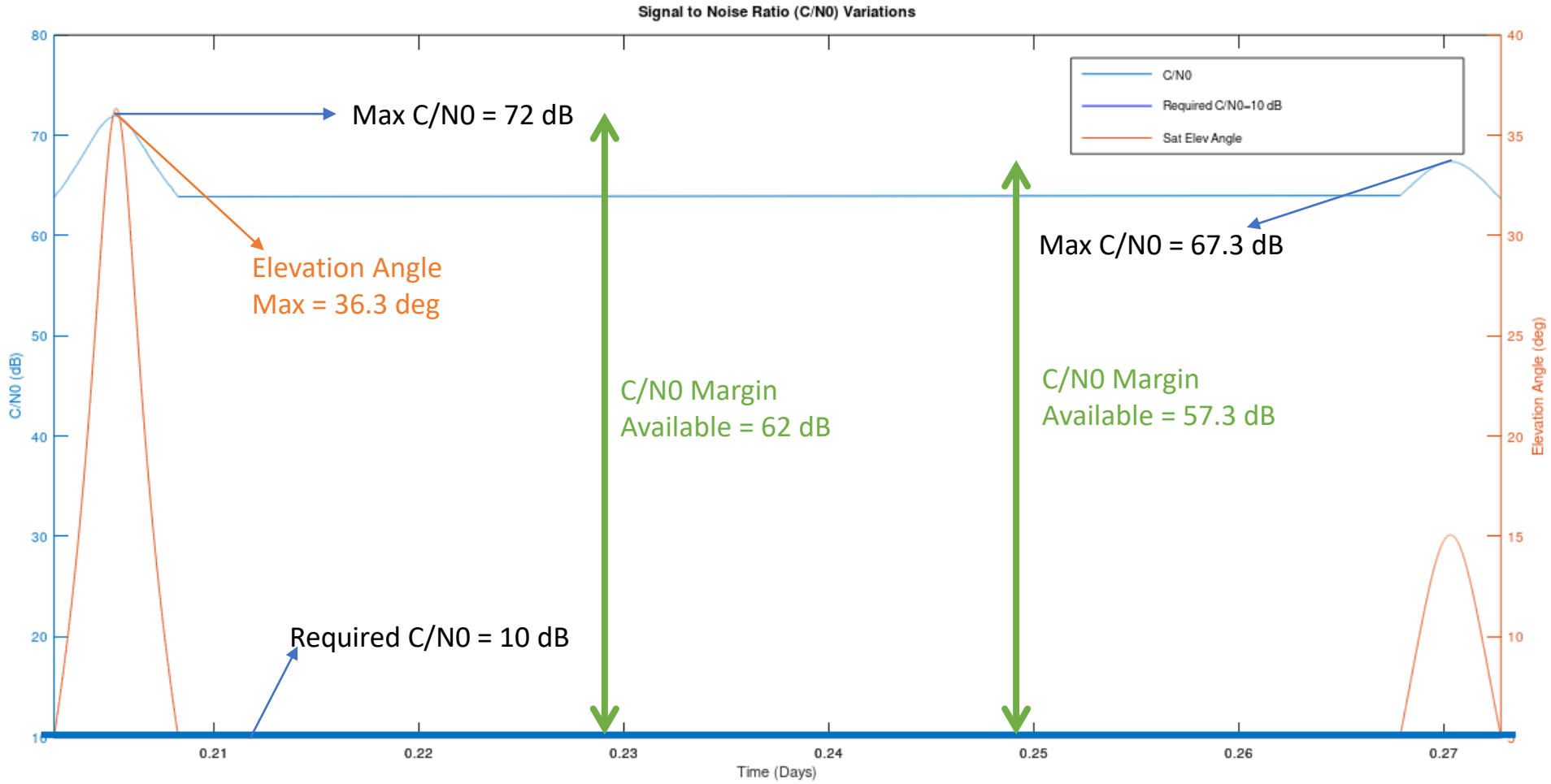
Elevation Angle
Max = 36.3 deg

Throughout the pass, gain varies only 0.5 dB which indicates good pointing by attitude control system

Throughout the pass, gain varies only 0.3 dB which indicates good pointing by attitude control system

Elevation Angle
Max = 15.1 deg

C/N0 Variations and Elevation Angle



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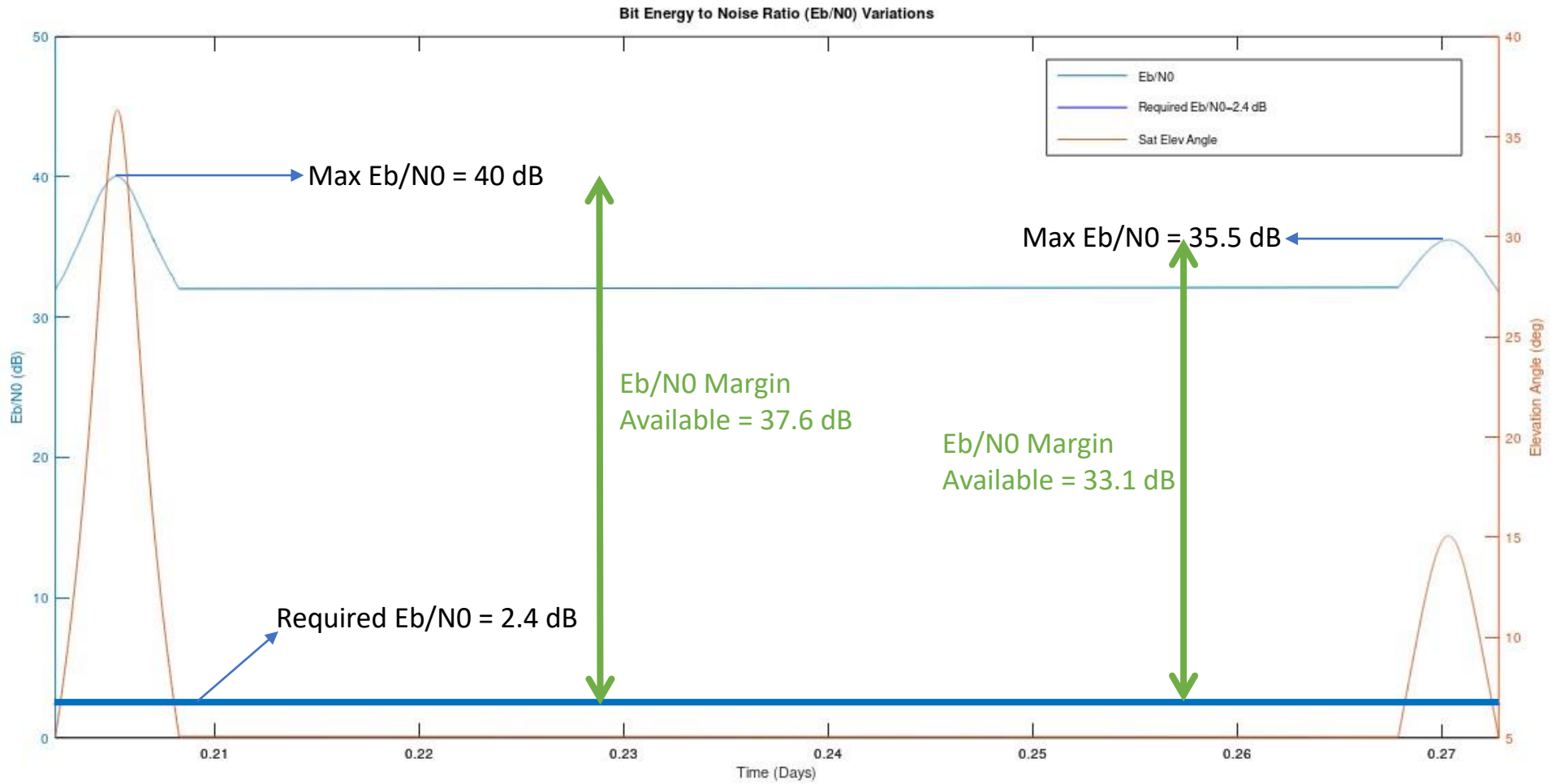
Eb/N0 variations and Elevation Angle



Future Work

- Provide Celestlab code for OEM, AEM generation
- Standardise Antenna Gain measurement
- Develop GUI for user inputs

UserInputs.m

```
28
29  %% General Data for Link Budget Calculations
30  c = 299792458; % speed of light m/s
31  boltz = 1.38064852E-23; %% Boltzman Constant
32  earth_rad = 6378.45e3;  % meters
33  sat_alt = 493e3; %% [km] --> satellite altitude
34  freq_Tx = 2210e6; %% [Hz]
35  data_rate = .117E+06; %datarate bit/s
36  code_rate = 1/2;
37  mod_sym = 4; % modulation symbols
38  bandwidth_chan = 350E6; %Channel Bandwidth in Hz
39  min_elev = 5; % Satellite minimum elevation from station [deg]
40  graph_pass_only = true;
41  %% Transmitter Data
42
43  power_Tx = 3.0; % dBW Satellite TX Power
44  loss_cable_Tx = -0.5; % dB Cable loss
45  loss_feeder_Tx = -3; %dB Coupler loss
46  loss_point_Tx = 0.0; % dB Transmitter antenna pointing loss
47  antG_Tx = -6; % dBi Transmitter Antenna Gain
48
49  %% Propagation Losses
50
51  loss_pol = -1.1; % dB Polarisation Loss
52  loss_atm = -0.5; % dB Atmospheric gas attenuation
53  loss_scin = 0.0; % dB Scintillation loss
54  loss_rain = 0.0; % dB Rain attenuation
55  loss_clouds = 0.0; % dB Clouds attenuation
56  loss_si = 0.0; % dB Snow and Ice attenuation
57
58  %% Receiver Data
```

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DOSA

Repository:
https://sourceforge.isae.fr/projects/dosa_link_budget_analysis

- Calculates dynamic link budget
- Enables to identify best passes
- Visualisation of available margins*

*Modenini, Andrea. “Tutorial - Dynamic Link Budget Optimisation for Telemetry Links”. This paper provides algorithms for choosing optimal bitrate in a dynamic link budget to maximise amount of data downloaded.

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Thank You for your attention

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