Namaste Link Budget
Geosynchronous Satellite
W5NYV, KB5MU

The GEO Orbit allows the link model operator to select a GEO Orbit Slot and the location of two satellite users (one for the uplink and one for the downlink). Then the slant range to each user as well as the azimuth and elevation bearing to the satellite from each user are calculated. As an additional output the Earth central angle from the sub-satellite point to the user location is also provided. The slant range results are used int the computation of the link path loss.

Path length to User Terminal from Spacecraft assumes the following constants.

$Geostationary\_Altitude := 35786.019 \cdot km$ Height above ground.

$Equitorial\_Radius\_of\_Earth := 6378.137 \cdot km$

$Geostationary\_semi\_major\_axis := 42164.156 \cdot km$

$Typical\_Path\_Length := 37410 \cdot km$ User at typical longitudinal difference.

$Shortest\_Path\_Length := 35786.019 \cdot km$ User at same longitude of spacecraft.

$Longest\_Path\_Length := 41678.957 \cdot km$ User at maximum difference in longitude. 0 degrees elevation.

You provide the following values

$Uplink\_User\_Latitude := 40 \cdot deg$ Positive for North Latitude, negative for South.

$Uplink\_User\_Longitude := -110 \cdot deg$ Positive for East Longitude, negative for West.

$Spacecraft\_Slot\_Longitude := -116 \cdot deg$ Slot position in degrees longitude.

$Downlink\_User\_Latitude := 40 \cdot deg$ Positive for North Latitude, negative for South.

$Downlink\_User\_Longitude := -120 \cdot deg$ Positive for East Longitude, negative for West.

Intermediate Uplink calculations.

$$\text{Uplink\_Longitude\_Delta} := \text{Uplink\_User\_Longitude} - \text{Spacecraft\_Slot\_Longitude}$$

$$\text{Uplink\_Earth\_Central\_Angle} := \text{acos}(\cos(\text{Uplink\_User\_Latitude}) \cdot \cos(\text{Uplink\_Longitude\_Delta})$$

$$\text{Uplink\_Earth\_Central\_Angle} = 40.373 \cdot \text{deg}$$

$$\text{Uplink\_Slant\_Range} := \sqrt{\text{Geostationary\_semi\_major\_axis}^2 + \text{Equitorial\_Radius\_of\_Earth}^2 - 2 \cdot}$$

$$\text{Uplink\_Slant\_Range} = 37.533 \times 10^3 \cdot \text{km}$$

$$\text{Uplink\_Elevation\_Angle} := \text{atan}\left[\frac{\left[\cos(\text{Uplink\_Earth\_Central\_Angle}) - \left(\frac{\text{Equitorial\_Radius\_c}}{\text{Geostationary\_semi\_n}}\right.\right.}{\sin(\text{Uplink\_Earth\_Central\_Angle})}\right.$$

$$\text{Uplink\_Elevation\_Angle} = 43.308 \cdot \text{deg}$$

Intermediate Downlink calculations.

$$\text{Downlink\_Longitude\_Delta} := \text{Downlink\_User\_Longitude} - \text{Spacecraft\_Slot\_Longitude}$$

$$\text{Downlink\_Earth\_Central\_Angle} := \text{acos}(\cos(\text{Downlink\_User\_Latitude}) \cdot \cos(\text{Downlink\_Longitu}$$

$$\text{Downlink\_Earth\_Central\_Angle} = 40.166 \cdot \text{deg}$$

$$\text{Downlink\_Slant\_Range} := \sqrt{\text{Geostationary\_semi\_major\_axis}^2 + \text{Equitorial\_Radius\_of\_Earth}^2 -}$$

$$\text{Downlink\_Slant\_Range} = 37.516 \times 10^3 \cdot \text{km}$$

$$\text{Downlink\_Elevation\_Angle} := \text{atan}\left[\frac{\left[\cos(\text{Downlink\_Earth\_Central\_Angle}) - \left(\frac{\text{Equitorial\_Ra}}{\text{Geostationary\_s}}\right.\right.}{\sin(\text{Downlink\_Earth\_Central\_Angle})}\right.$$

$Downlink\_Elevation\_Angle = 43.538 \cdot deg$

Azimuth Calculations Within a Quadrant

$$Uplink\_QDAV := \begin{cases} (-90deg) & \text{if } Uplink\_User\_Latitude = 0 \cdot deg \\ atan\left[\dfrac{\sin(Uplink\_Longitude\_Delta)}{((-\sin(Uplink\_User\_Latitude) \cdot \cos(Uplink\_Longitude\_Delta)))}\right] & \text{otherwise} \end{cases}$$

$Uplink\_QDAV = -9.286\,deg$

$$Downlink\_QDAV := \begin{cases} (-90deg) & \text{if } Downlink\_User\_Latitude = 0 \cdot deg \\ atan\left[\dfrac{\sin(Downlink\_Longitude\_Delta)}{((-\sin(Downlink\_User\_Latitude) \cdot \cos(Downlink\_Longitude\_Delta)))}\right] & \text{othe} \end{cases}$$

$Downlink\_QDAV = 6.209\,deg$

1 is North, 0 is South. 1 is East of Satellite, 0 is West of Satellite.

$$Uplink\_N\_or\_S\_Hemisphere := \begin{cases} 1 & \text{if } Uplink\_User\_Latitude > 0 \\ 0 & \text{otherwise} \end{cases}$$

$Uplink\_N\_or\_S\_Hemisphere = 1$

$$\text{Uplink\_E\_or\_W\_of\_Satellite} := \begin{cases} 1 & \text{if Uplink\_Longitude\_Delta} > 0 \\ 0 & \text{otherwise} \end{cases}$$

Uplink_E_or_W_of_Satellite = 1

$$\text{Downlink\_N\_or\_S\_Hemisphere} := \begin{cases} 1 & \text{if Downlink\_User\_Latitude} > 0 \\ 0 & \text{otherwise} \end{cases}$$

Downlink_N_or_S_Hemisphere = 1

$$\text{Downlink\_E\_or\_W\_of\_Satellite} := \begin{cases} 1 & \text{if Downlink\_Longitude\_Delta} > 0 \\ 0 & \text{otherwise} \end{cases}$$

Downlink_E_or_W_of_Satellite = 0

Determine which quadrant the satellite is in relative to the uplink.

$$\text{Uplink\_Quadrant\_NE} := \begin{cases} 1 & \text{if } \neg\text{Uplink\_N\_or\_S\_Hemisphere}\cdot\neg\text{Uplink\_E\_or\_W\_of\_Satellite} \\ 0 & \text{otherwise} \end{cases}$$

Uplink_Quadrant_NE = 0

$$\text{Uplink\_Quadrant\_SE} := \begin{cases} 1 & \text{if Uplink\_N\_or\_S\_Hemisphere}\cdot\neg\text{Uplink\_E\_or\_W\_of\_Satellite} \\ 0 & \text{otherwise} \end{cases}$$

Uplink_Quadrant_SE = 0

$$\text{Uplink\_Quadrant\_SW} := \begin{cases} 1 & \text{if Uplink\_N\_or\_S\_Hemisphere}\cdot\text{Uplink\_E\_or\_W\_of\_Satellite} \\ 0 & \text{otherwise} \end{cases}$$

Uplink_Quadrant_SW = 1

$$\text{Uplink\_Quadrant\_NW} := \begin{cases} 1 & \text{if } \neg\text{Uplink\_N\_or\_S\_Hemisphere}\cdot\text{Uplink\_E\_or\_W\_of\_Satellite} \\ 0 & \text{otherwise} \end{cases}$$

$$\text{Uplink\_Quadrant\_NW} = 0$$

Determine which quadrant the satellite is in relative to the downlink.

$$\text{Downlink\_Quadrant\_NE} := \begin{cases} 1 & \text{if } \neg\text{Downlink\_N\_or\_S\_Hemisphere}\cdot\neg\text{Downlink\_E\_or\_W\_of\_Sa} \\ 0 & \text{otherwise} \end{cases}$$

$$\text{Downlink\_Quadrant\_NE} = 0$$

$$\text{Downlink\_Quadrant\_SE} := \begin{cases} 1 & \text{if } \text{Downlink\_N\_or\_S\_Hemisphere}\cdot\neg\text{Downlink\_E\_or\_W\_of\_Sate} \\ 0 & \text{otherwise} \end{cases}$$

$$\text{Downlink\_Quadrant\_SE} = 1$$

$$\text{Downlink\_Quadrant\_SW} := \begin{cases} 1 & \text{if } \text{Downlink\_N\_or\_S\_Hemisphere}\cdot\text{Downlink\_E\_or\_W\_of\_Satell} \\ 0 & \text{otherwise} \end{cases}$$

$$\text{Downlink\_Quadrant\_SW} = 0$$

$$\text{Downlink\_Quadrant\_NW} := \begin{cases} 1 & \text{if } \neg\text{Downlink\_N\_or\_S\_Hemisphere}\cdot\text{Downlink\_E\_or\_W\_of\_Sat} \\ 0 & \text{otherwise} \end{cases}$$

$$\text{Downlink\_Quadrant\_NW} = 0$$

Calculate the Azimuth Result

$Uplink\_Azimuth := (Uplink\_Quadrant\_NE \cdot -Uplink\_QDAV) + [Uplink\_Quadrant\_SE \cdot (180deg -$

$Uplink\_Azimuth = 189.286\,deg$

$Downlink\_Azimuth := (Downlink\_Quadrant\_NE \cdot -Downlink\_QDAV) + [Downlink\_Quadrant\_SE$

$Downlink\_Azimuth = 173.791\,deg$

Ground station

$TransmitPower\_Watts := 1$

$AntennaGain\_dBi := 2.15$

$ImplementationLoss\_dB := 1$

$DishDiameter\_Meters := 1$

$GroundEIRP\_dBW := (10\log(TransmitPower\_Watts) + AntennaGain\_dBi - ImplementationLoss\_dI$

$GroundEIRP\_dBW = 1.15$

Uplink Path Loss

$Range\_Meters := 40000000$

$Frequency\_Hz := 3400000000$

$$\text{Wavelength\_Meters} := \frac{299792458}{\text{Frequency\_Hz}}$$

$$\text{UplinkPathLoss\_dB} := 20\log\left[\frac{(4\pi\ \text{Range\_Meters})}{\text{Wavelength\_Meters}}\right]$$

$$\text{UplinkPathLoss\_dB} = 195.119$$

Friis Equation

"The antenna gains are with respect to isotropic (and not in decibels), and the wavelength and distance units must be the same." -wikipedia

$$\text{PowerReceived\_Watts} := \text{PowerTransmitted\_Watts}\cdot\text{TransmitterAntennaGain}\cdot\text{ReceiverAntennaGain}\cdot\left(\frac{\text{Wa}}{4\cdot\pi}\right.$$

"Information in the transmitted signal is seldom concentrated at a single frequency, so the path loss will actually be different for every frequency component in the signal. Fortunately, the ratio of the bandwidth to center frequency is usually small enough to not matter. Still, a signal that is transmitted with a constant power across some bandwidth will appear at the receiver with a power slope that decreases at the upper end of the band." http://www.rfcafe.com/references/electrical/path_loss.htm

The gain of a parabolic antenna of effective diameter D at wavelength Lambda and efficiency mu can be can calculated as follows. Efficiency ranges between 55% and 65%

depending on antenna diamter and geometry.

$$DishEfficiency := .55$$

$$DishGain := DishEfficiency \cdot \left(\pi \cdot \frac{DishDiameter\_Meters}{Wavelength\_Meters}\right)^2$$

$$DishGain\_dB := 10 \cdot \log(DishGain)$$

$$DishGain\_dB = 28.44$$

A satellite link has two parts, the uplink and the downlink.

Uplink
The ground station transmits the signal up to the satellite. This is a filtered BPSK signal

C/N uplink = earth station EIRP - path loss + satellite G/T - bandwidth + 228.6 dB?

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Geostationary_semi_major_axis·Equitorial_Radius_of_Earth·cos(Uplink_Earth_Central_Angle)

of_Earth

major_axis

de_Delta))

- 2·Geostationary_semi_major_axis·Equitorial_Radius_of_Earth·cos(Downlink_Earth_Central_Angle)

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Uplink_QDAV)] + [Uplink_Quadrant_SW·(180deg − Uplink_QDAV)] + [Uplink_Quadrant_NW·(360deg −

·(180deg − Downlink_QDAV)] + [Downlink_Quadrant_SW·(180deg − Downlink_QDAV)] + [Downlink_Qu

3)

$$\left(\frac{\text{velength\_Meters}}{\cdot\text{Range\_Meters}}\right)^2$$

Uplink_QDAV)]

ıadrant_NW·(360deg − Downlink_QDAV)]