LELEC2910 – Project

Introduction and Link Budget

Claude Oestges

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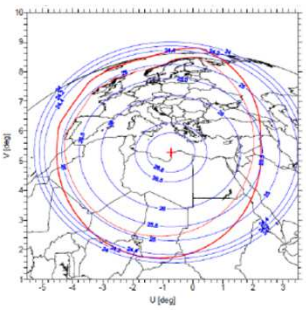
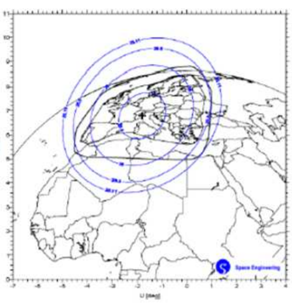
Satellite propagation measurements

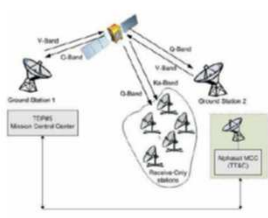
- Measurement of tropospheric effects
  - Alphasat (GEO) satellite: beacon in Ka and Q band



Ka beacon Antenna Radiation Pattern



Q beacon Antenna Radiation Pattern



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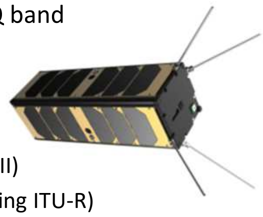
Project description

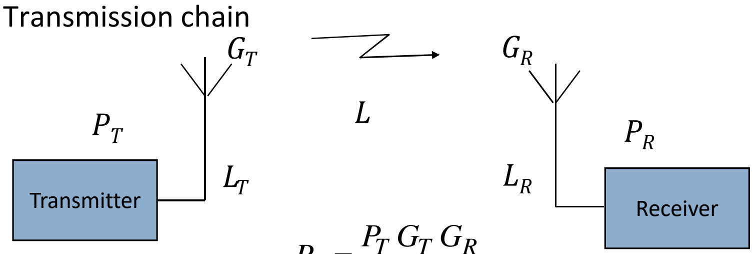
- Tropospheric effects on Q-band LEO satellite payload and design of future W band systems
  - Design of Alphasat payload: EIRP calculation in Q band
  - Design of a W band system



  - Report
    - Calculation of tropospheric effects (using RAPIDS II)
    - Including the effect of varying elevation angle (using ITU-R)
    - Comparison between
      - 2 Earth stations (per group)
      - 2 frequency bands (Q and W)
  - Tools
    - RAPIDS II software
    - ITU-R recommendations (on moodle) and python packages (e.g. SkyField)
    - Link budget analysis (cfr. this presentation)

Free space loss

- Transmission chain



$$P_R = \frac{P_T\, G_T\, G_R}{L\, L_T\, L_R}$$

  - where
    - P_R received power
    - P_T emitted power
    - G_T gain of the emitting antenna (dBi)
    - G_R gain of the receiving (dBi)
    - L free space losses
    - $L_{T,R}$ feeder losses (transmitter, receiver)

Free space loss

- Effective isotropic radiated power (EIRP)

$$EIRP = \frac{P_T G_T}{L_T} = P_{TI}$$

- Effective isotropic received power

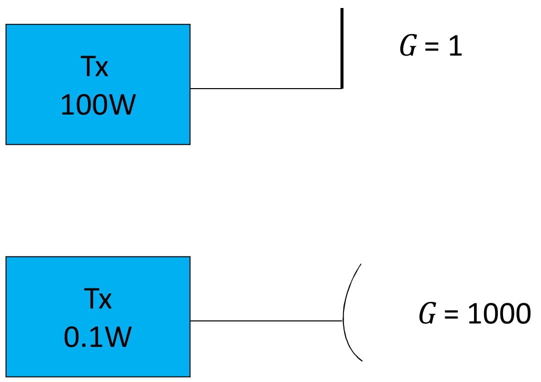
$$P_{RI} = \frac{P_R L_R}{G_R}$$

- Free space losses

$$L_{dB} = 10 \log\left(\frac{P_{TI}}{P_{RI}}\right)$$

Free space loss

- Example: identical EIRP produced by two different systems



Free space loss: from Tx to Rx

- Assuming two antennas with matched polarizations, the power density arriving at the receiving antenna is (taking $L_T = 1$)

$$S = \frac{P_T\, G_T}{4\pi r^2} \quad \left(W/m^2\right)$$

- Power received by Rx antenna (taking $L_R = 1$)

$$P_R = \frac{P_T G_T A_{eR}}{4\pi r^2} \quad (W)$$

  - where A_{eR} is the effective area of the receiving antenna

$$G_R = \frac{4\pi}{\lambda^2} A_{eR}$$

Free space loss: receive antenna

- Effective antenna area ≡ surface multiplied by the efficiency

$$A_{eR} = \eta\left(\frac{\pi D^2}{4}\right)$$

  - where η is the efficiency (typically 0.55 for a parabolic antenna and 0.75 for a horn) and D is the antenna diameter

- For a directive antenna, the gain and the received power depend on the direction (θ,φ) → directivity

$$D(\vartheta,\varphi) = \frac{P(\vartheta,\varphi)}{P_t/4\pi}$$

Free space loss vs. frequency

$$P_R = \frac{P_T G_T A_{eR}}{4\pi r^2}$$

$$P_R = \frac{P_T A_{eT} A_{eR}}{\lambda^2 r^2}$$

$$P_R = \frac{P_T A_{eT} G_R}{4\pi r^2}$$

$$P_R = \frac{P_T G_T G_R \lambda^2}{(4\pi r)^2}$$

- Assuming that the diameters of the antennas are fixed, A_{eT} and A_{eR} are the fixed variables
  - In that case, the second equation is used → the power increases as the square of frequency

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Free space loss

- Path-loss

$$L = \left(\frac{P_{TI}}{P_{RI}}\right) = \frac{P_T G_T}{\left(\frac{P_R}{G_R}\right)} = \frac{P_T G_T G_R}{P_R}$$

$$P_R = \frac{EIRP\ G_R \lambda^2}{(4\pi r)^2} = \frac{EIRP\ G_R}{L}$$

$$\boxed{L = \left(\frac{4\pi r}{\lambda}\right)^2}$$

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Link budget

- System design
  - For performance evaluation the signal-to-noise ratio (SNR) is on eof the most important metric

$$SNR = \frac{P_R}{N} = \frac{EIRP\ G_R}{NL}$$

  - Evaluation of signal level
    - Should account for all system gain/loss (antennas, amplifiers, cables, etc.)
    - Should include tropospheric degradations
    - EIRP is the design target parameter
  - Evaluation of noise power
    - Thermal noise (AWGN)

$$N = kTB \quad (W)$$

$$\frac{P_R}{N} = \frac{EIRP\ G_R}{BN_0L} = \frac{EIRP\ \boxed{G_R/T}}{BkL_{TOT}}$$

$$\frac{P_R}{N_0} = \frac{EIRP\ G_R/T}{kL_{TOT}}$$

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Link budget: reminder about noise

- Thermal noise

$$N = kTB \quad (W)$$

- Noise figure and temperature
  - Measures the SNR degradation by a quadripole

$$F = \frac{(S/N)_1}{(S/N)_2}$$

$$F - 1 = \frac{T}{T_0} \quad ; \quad T = T_0(F-1)$$

- Cascaded quadripoles

$$F_{12} = F_1 + \frac{F_2 - 1}{G_1}$$

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Link budget: SNR margin and service availability

- A security margin is generally added at link level in order to enable some degradation to occur before the link cuts off

$$\frac{P_R}{N_0} = M\left(\frac{P_R}{N_0}\right)_{req}$$

$$M(dB) = \left(\frac{P_R}{N_0}\right) - \left(\frac{P_R}{N_0}\right)_{req}$$

$$M = \frac{EIRP\ G_R/T}{(P_R/N_0)_{req}\, kL_{TOT}}$$

- Tropospheric degradations are random
  - Need to define the service availability to estimate the attenuation

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Link budget: example

Tx power	20	dBW
Tx circuit loss	2	dB
Antenna gain	51.6	dBi
EIRP ($P_T G_T$)	69.6	dBW
Free space loss	202.7	dB
Tropospheric loss (depending on availability)	4	dB
Micellaneous loss	6	dB
Received isotropic power	-143.1	dBW
Rx antenna gain	35.1	dB
Misalignment loss (antenna lobe)	2	dB
Received power P_R	-110	dBW
Rx noise factor F	11.5	dB
Rx noise temperature = 3806 K	35.8	dBK
Antenna temp. (sky noise) = 300K	24.8	dBK
System noise temp. = 4106K	36.1	dBK
Rx sensitivity G/T	-1	dB/K
$N_0 = kT$	-192.5	dBW/Hz
SNR = P_R/N_0	**82.5**	**dB (Hz)**

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Project schedule

November	Mon 8	3-4	Atmospheric Propagation and Satellite Systems: Introduction Extinction and Depolarization by Hydrometeors (1)
	Thu 11	7-8	- (Armistice day)
	Mon 15	3-4	Project: introduction and organisation
	Thu 18	7-8	Project: RAPIDS lab session
	Mon 22	3-4	Extinction and Depolarization by Hydrometeors (2)
	Thu 25	7-8	Project: RAPIDS lab session
	Mon 29	3-4	Gaseous Absorption and Tropospheric Radiometry
December	Thu 2	7-8	Tropospheric Scintillation, Refraction and Multipaths
	Mon 6	3-4	Project: RAPIDS lab session
	Thu 9	7-8	Ionospheric Propagation – Remote Sensing, SatCom and GNSS
	Mon 13	3-4	Project: preliminary presentation
	Thu 16	7-8	Project: preliminary presentation

Project practicalities

- Teaching assistant for propagation project
  - Mojtaba Razavian
- Project includes three lab sessions
  - Two supervised sessions with your own laptop
  - Third session is on request (consultancy)
- Project deliverables
  - Preliminary presentation (non-certificative) on Dec 13 or Dec 16, 2021
  - Final report on moodle by the ELEC2910 exam starting time in January
- Evaluation (reminder)
  - Propagation project accounts for 1/3 of the final LELEC2910 grade (6.7/20)
  - No exam on propagation part in January