Design of Future W-Band and Q-band LEO Satellite Earth Observation Systems: Payload Estimation

Introduction

European Space Agency (ESA) has launched a project for the design, fabrication and launch of a W-band Cubesat at 76 GHz. Indeed, future Communication Satellites and Earth Observation satellites will use this frequency band in order to increase the bandwidth that can generally be considered as a fraction (about 10%) of the centre frequency. The current MetOp (A, B, and C) Second Generation meteorological satellite[1] will download the data in the 26 GHz band and the future generation foresee to use the next window in the attenuation spectrum, located between 76 and 90 GHz.

If the total amount of data (called “data throughput”) increases at 75 GHz, the degradation due to tropospheric gases, clouds, and rain becomes important. The atmospheric channel-propagation-models available from the ITU are known to be accurate up to about 50 GHz. Therefore, new measurement campaigns are needed to characterize the atmospheric propagation channel at W-band where the models proposed by ITU-R have not been validated.

Cubesats are non-geostationary and there are nearly no propagation measurements available for non-geostationary satellites. Therefore, the combination of 75 GHz and non-GEO orbits will be difficult to handle. In order to reduce the uncertainties, a second frequency of 37.5 GHz will be used for the verification of the non-GEO models.

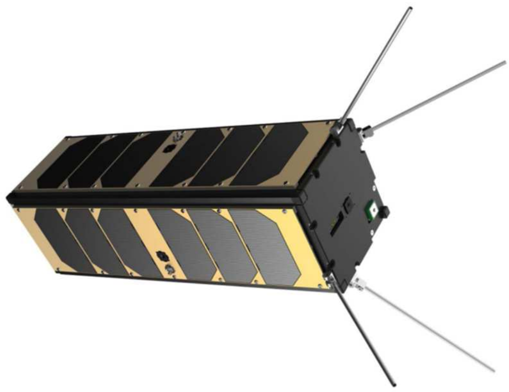

Figure 1: Example of a 2 Units cubesat (Reaktor Space, Finland)

UCLouvain takes part in the project for the propagation campaign definition and the extraction of the effects of the troposphere from the measurements.

The purpose of the present project is to calculate the link budget in order to evaluate the power on-board the satellite (EIRP), for both Q-band and future W-band systems.

[1] https://www.eumetsat.int/website/home/Satellites/CurrentSatellites/Metop/index.html

Location of Receiving Earth Stations

The link budget will be calculated for various receiving stations in different climates[2].

Location	Latitude	Longitude	Above mean see level	Group
UK Chilbolton	51.15°N	1.43°W	100 m	1
Argentina Malargüe				
Austria Graz	47.07°N	15.44°E	353 m	2
Norway Isfjord radio				
Spain Vigo	42.170°N	8.688°W	447 m	3
ACT, Australia Canberra				
Portugal Aveiro	40.612°N	8.662°W	12 m	4
WA, Australia New Norcia				
Cyprus Kofinou	34.859°N	33.384°E	120 m	5
Antartica McMurdo				
Greece Athens	37.975°N	23.785°E	210 m	6
VA, USA Wallops Islands				
Singapore Bukit Timah	1.353°S	103.791°E	164 m	7
Sweden Esrange				
CA, USA Goldstone Observatory	35.28°N	116.78°W	900 m	8
Belgium Redu				
UK Madley	52.03°N	2.84°W	118 m	9
Spain Madrid				
South Africa Hartebeesthoek	25.89°S	27.68E	1276 m	10
Germany Düsseldorf				
CA, USA Jamesburgh	36.4°N	121.64°W	525 m	11
France Toulouse				

[2] One station per group is fully characterized.

Location	Latitude	Longitude	Above mean see level	Group
Japan Usuda	36.07°N	138.21°E	1456 m	12
Sweden Kiruna				
HI, USA Kaena	21.33°N	158.14°W	460 m	13
Hungary Budapest				
Belgium Louvain-la-Neuve	50.668°N	4.615°E	160 m	14
Kenya Malindi				
Greece Lavrion	37.72°N	24.048°E	20 m	15
Slovania Ljubljana	46.04°N			
Czech Republic Prague	50.04°N	14.48°E	274 m	16
Ghana Kuntunse	5.75°N			

Table 1: Geographical coordinates of Earth receiving sites

The parameters of use for the link budget are given in Table 2.

Evaluation of Tropospheric Effects

The purpose of this project is to calculate the effects of the troposphere on both beacons, using the RAPIDS II version Pastel propagation tool, in single site mode, for various elevation angles:

- enter "New calculation" and "Effects - Expert mode": chose "troposphere" "single site mode";
- enter your stations if they are not available yet;
- request the calculation of various attenuation effects as well as their combination.

Important note

You need to derive a proper method to account for the LEO orbit and the varying elevation angle (the RAPIDS tool will not do it for you). Indeed, RAPIDS II provides the troposphere impairments for GEO satellites. The final attenuation should be corrected for non-GEO satellites using a conditional probability:

$$P(A > A_{th}) = \sum P\,(A > A_{th}|\theta_i)P(\theta_i)$$

where $\theta_i$is the elevation angle in any bin i and $P(\theta_i)$is the probability occurrence of the non-GSO satellite in elevation angle θ_i. Further information can be found in ITU-R recommendations[3], as well as on additional documents available on moodle. Every group is free to choose a given LEO orbit (e.g. MetOp A/B/C, or COMS, etc.).

[3] https://www.itu.int/rec/R-REC-P.618/en, https://www.itu.int/rec/R-REC-S.1257/en

Earth-satellite mean distance: 2800 km	
W band	
Frequency	75 GHz
Polarization	Dual polarization (RHCP* and LHCP*)
Antenna boresight	Nadir
EIRP	?? dBW
Receive antenna gain	51 dBi
Antenna efficiency	57%
LNA noise temperature	500K
Receiver bandwidth	50 Hz
Min C/N for detection	10 dB
Q band	
Frequency	37.5 GHz
Q Band Polarization	Dual polarization (RHCP* and LHCP*)
Boresight	Nadir
EIRP	?? dBW
Receive antenna gain	To be evaluated, same antenna as for W band
Antenna efficiency	60%
LNA noise temperature	450K
Receiver bandwidth	50 Hz
Min C/N for detection	10 dB

Table 2: Main characteristics of W- and Q-band beacons

(* RHCP=Right Hand Circular Polarization – LHCP= Left Hand Circular Polarization)

Deliverable

A brief report, **to be uploaded on Moodle by January 18**, will contain

- the total attenuation as well as the attenuation for various components (rain, gases, clouds, scintillation);
- their analysis (discuss/comment the importance of the various effects in function of the frequency, assuming an availability of the station of 99.0, 99.5, 99.9 and 99.99% of the time) and the comparison between both stations;
- the link budget for both frequencies and the proposed EIRP.

A **formative** discussion about the preliminary results (10 minutes for presentation + 5 minutes for feedback) will take place on 13/12 at 10:45 or 16/12 at 16:15 (depending on the groups).