Breadboarding of Innovative Space Surveillance and Tracking Concept

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Abstract

Following a successful feasibility study of a novel concept by UKLSL to identify and track space objects at **low cost**, this project aims to continue the development of the concept by selecting and testing key components for the system. Simulations are performed to inform the energy requirements of the space segment and to calculate link budgets. Also, the RF range of the selected components is tested along with code developed for **attitude acquisition**.

1. Objectives

- Develop an understanding of **Space Surveillance and Tracking (SST)** services in general and of UKLSL's "BEAP" concept in particular
- Identify technical elements of the system relevant for a **breadboard prototype** of the beacon
- Simulate mission requirements and develop and test a prototype for the breadboard

2. Component Selection

The key components of the **space segment** proof-of-concept prototype were identified as follows:

- Microcontroller with RF capabilities
- Power source and storage
- Attitude and rate determination
- Antenna

As it was not economically feasible (nor necessary at this stage of development in the project) to purchase radiation hardened components, **commercial off-the-shelf (COTS)** products were purchased to develop the proof-of-concept prototype.

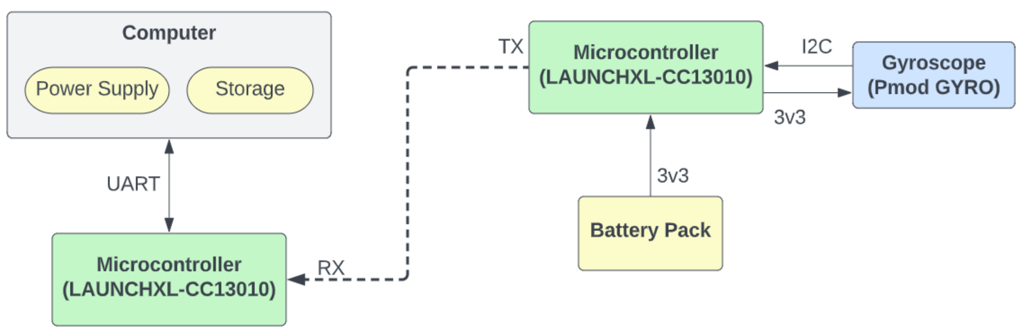

Figure 1: Block diagram illustrating communication protocol and power supply to components for the prototype

3. Simulations

A "worst-case" orbit was simulated in GMAT to plot the device's **beta angle** to the Sun, as this informs the amount of solar power available to provide energy to the components, and thus validates the selection of components. The simulated orbit was then utilised to calculate the **eclipse period** i.e., the duration of the orbit where no solar power can be generated.

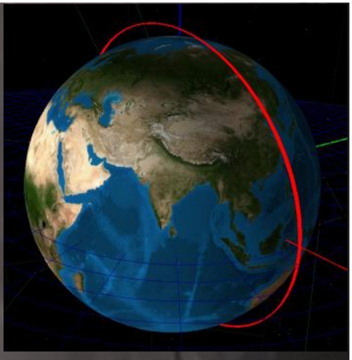

Figure 2: GMAT simulation of a satellite in a polar SSO at 600 km (red)

3.1 Energy Budget

The average Sun beta angle (73.3°) was used to generate a model for the solar power generation, considering a satellite **tumbling rate of 3°/s** (EOL).

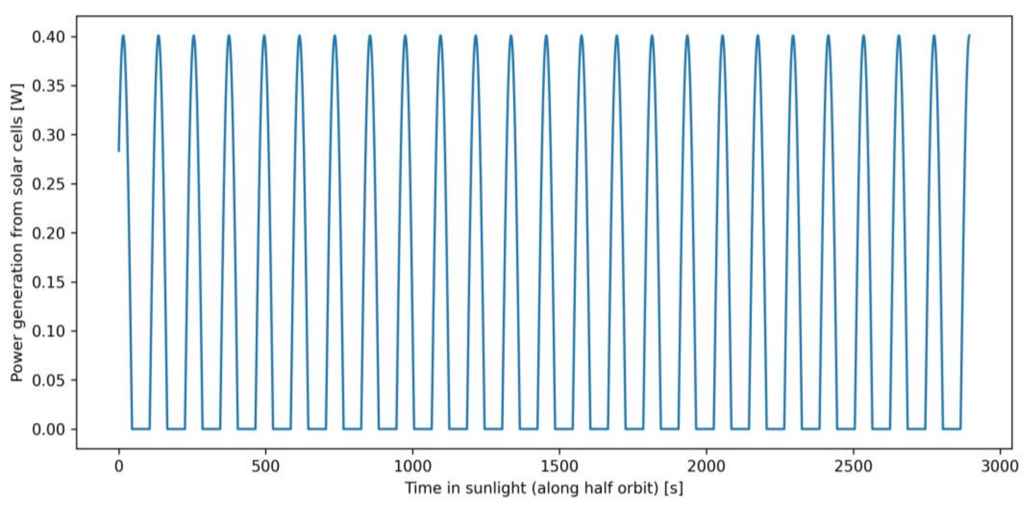

Figure 3: Theoretical solar power generation at stated tumbling rate

The **solar power model** was integrated to produce an energy generation plot. This was then validated against an energy budget calculated specifically for the simulated orbit, using MEMS versions of the selected COTS components.

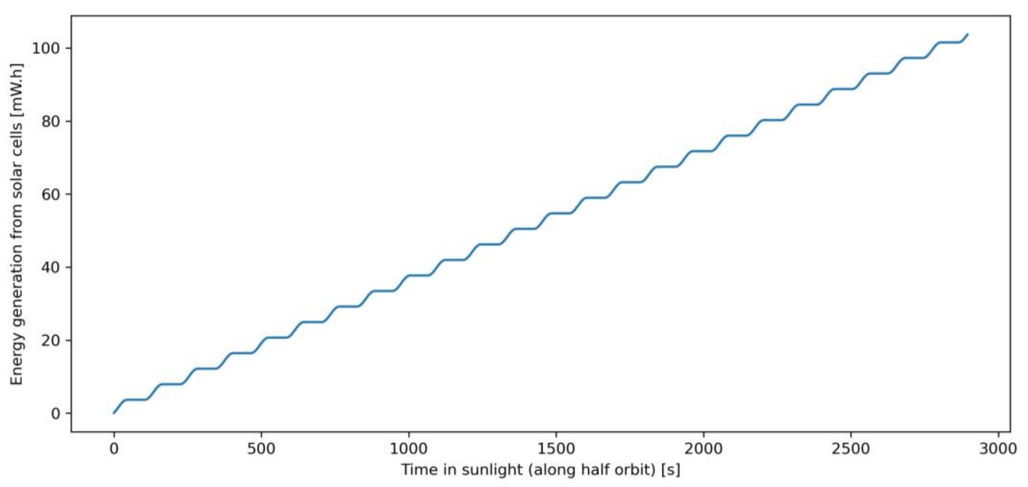

Figure 4: Theoretical energy generation from solar power model

3.2 Link Budget

The **Friis equation** was used to calculate the link margin for the utilised orbit and frequency (868 MHz), also considering losses within the transmission system (applied for various elevation angles to the ground station). The results, demonstrating a positive **link margin**, are displayed in the table to the right.

Elevation [deg]	Link Margin [dB]
5	0.92616
10	2.54568
15	4.04341
20	5.393039
30	7.63765
45	10.04267
70	12.21035
90 *(nadir)*	12.70280

4. Testing

The RF link between the TX and RX microcontrollers was tested by sending packets and checking the error rate. Also, the change in quality of continuous TX/RX link was observed by gradually increasing the distance between the two. The results indicate a sufficient link margin for prototype testing as minimal downlink speed and data size will be required for BEAP. Additionally, external antennae can also be connected to the microcontrollers to further improve **RF performance**.

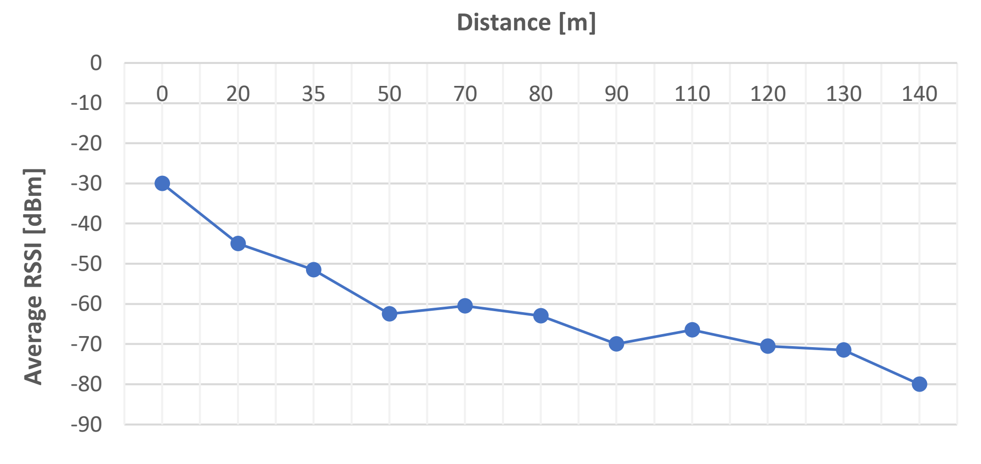

Figure 5: MCU continuous RX-TX range field test

5. Conclusions

- Comparing the energy budget against the developed solar power model indicates that the energy generated on board the space segment should be sufficient for BEAP functionality
- Link budget calculations demonstrate a positive link margin for the space segment at a **downlink** rate of 100 bps
- TX/RX range tests demonstrate a **sufficient RF link** for prototype testing

6. Future Work

- Determine the exact solution for power generation and storage on board the space segment
- Test and validate the **final prototype**