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COMMUNICATION LINK MARGIN DESIGN FOR PICOSATELLITE OPERATING ON HAP

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ABSTRACT

This paper examines the testing of Picosatellites on High-altitude Platforms (HAPs), conducting experiments to collect data at stratosphere or near-space. This involves long-distance over hundreds of kilometers telecommunication between ground stations and HAP. This paper will suggest designing an appropriate link margin from ground to Picosatellites on HAPs, by utilizing data from actual experiments for analysis and presentation.

KEYWORDS

High-altitude platform

Radiosonde

Near-space

Link margin

Picosatellite

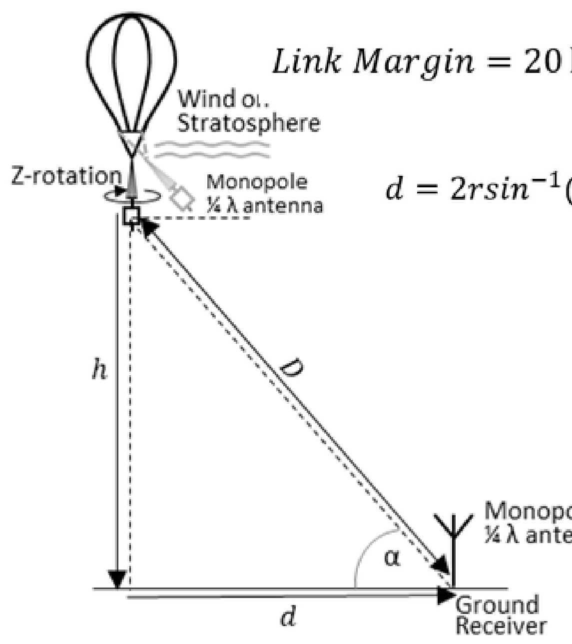
INTRODUCTION

High-altitude platform is a valuable method for conducting near-space experiments altitude ranging from 0 to 40 km ASL for various missions such as satellite component testing, capacity building, and other experiments. The platform can communicate to the ground receiver within line of sight, covering hundreds of kilometers. RF transmission systems must be well-designed to facilitate continuous communication throughout the mission while the transmission power must be kept at a minimum weight. Therefore, precise propagation calculations are essential for determining link margin and designing an appropriate radio wave transmission system.

This paper will report on the results of experiments by attaching signal transmitter on HAPs, with data collection on signal strength received from the picosatellite.

NUMERICAL DATA ON FLIGHT

This paper had gathered data for analysis including: Latitude, longitude, and altitude of picosatellite and Received Signal Strength Indicator (RSSI). To calculate the actual distance between the receiver and HAP can be computed by Haversine formula. And for the Link margin that can be estimated by path loss equation



$$Link\ Margin = 20\log(D) + 20\log(f) + 20\log\left(\frac{4\pi}{c}\right) - G_{Tx} - G_{Rx}$$

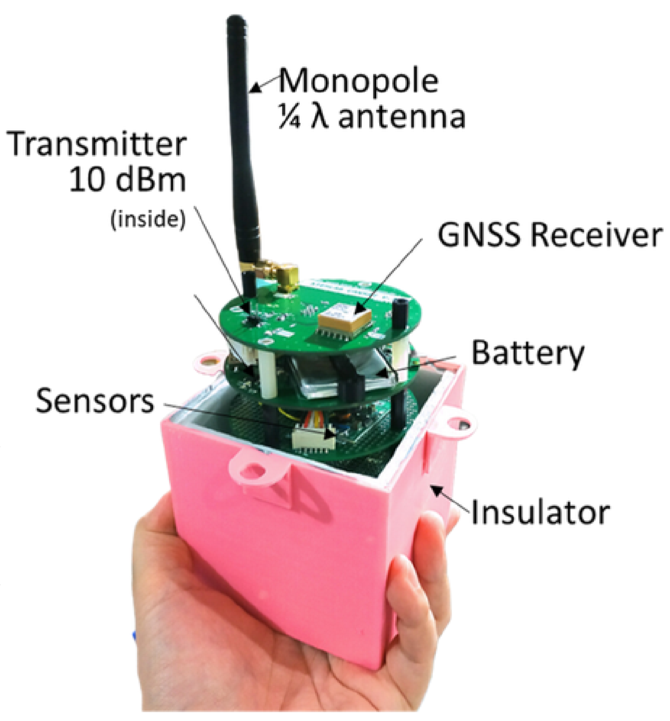
$$d = 2r\sin^{-1}\left(\sqrt{\sin^2\left(\frac{\Phi_2-\Phi_1}{2}\right)\cos(\Phi_1)\cos(\Phi_2)\sin^2\left(\frac{\lambda_2-\lambda_1}{2}\right)}\right)$$

$$D^2 = h^2 + d^2$$

$$\alpha = \tan^{-1}\left(\frac{h}{d}\right)$$

PICOSATELLITE ON HAP

In this experiment, the picosatellite will serve as the payload of the HAP. Due to weight restrictions, the payload should not exceed 100-200 grams to ensure safe descent and landing with a parachute.



- GNSS receiver: this sensor receives signals from GNSS satellites then converts them into coordinates, for reporting the picosatellite's position.
- GNSS receiver: this sensor receives signals from GNSS
- Microcontroller: Responsible for controlling operations on picosatellite, data link with sensors, manage telecommunication and managing electrical power.
- Transmitter: Designed to have transmission gain at a power of 10dBm ±1dBm from the Tx module.
- Monopole antenna: With a gain of 0 dB according to manufacturer's specifications.
- Sensors: Multiple sensors are installed for environmental monitoring throughout the mission.
- Insulator: Installed to protect electronic boards against extreme weather conditions in the upper atmosphere layer.

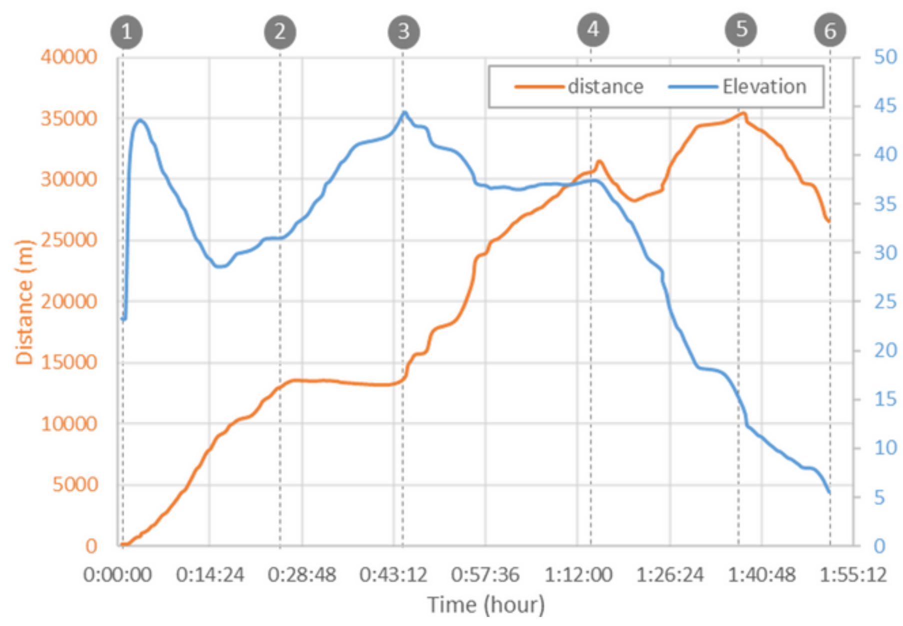
RESULT & CONCLUSION

PICOSATELLITE JOURNEY

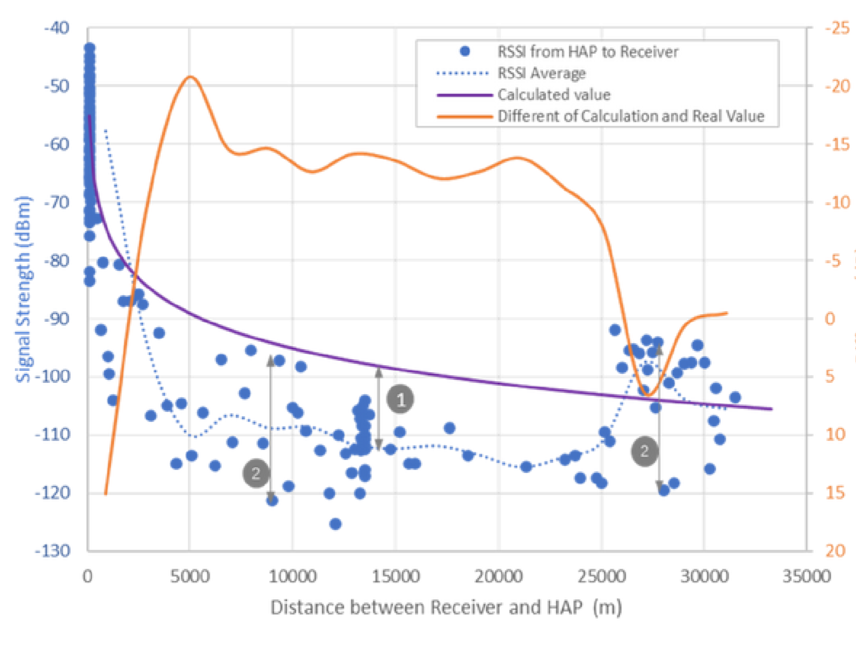
In this experiment, the payload operates in the sky for 2 hours, flying along the wind direction at various altitudes, correlated with the graph showing distance and elevation from the perspective of the ground receiver station to the HAP.

The journey of HAP depends on wind speed and direction on that altitude which is uncontrollable. It begins from its release point on the ground (number 1), where it is initially blown eastward by the wind until it reaches an altitude of 8.3 km ASL (number 2). Then, the HAP is blown westward until it returns closest to the release point (number 3). During the period between points 2 and 3, the elevation gradually increases while the distance remains relatively constant. Subsequently, the HAP continues to ascend and proceeds westward until the balloon bursts at an altitude of 23.9 km ASL (number 4). It then descends while still traveling westward, with a gradual decrease in elevation until it reaches an altitude of 8.8 km ASL (number 5). At this point, the wind changes direction to the east again, causing the distance between the HAP and the receiver to decrease. Finally, it lands in the sea at the endpoint (number 6). The maximum communication distance recorded during this journey is 35 kilometers (number 5).

DISTANCE AND ELEVATION



SIGNAL STRENGTH



When plotting the RSSI values from the ground receiver against the distance, it can be compared with the values calculated from the link margin. From the data, we can analyze and summarize as follows:

- The graph of the RSSI is consistently lower than the calculated values, especially when less than 25 km. On average, there is a significant difference of 15 dB between the calculated link margin and the RSSI values (number 1).
- The signal shows significant fluctuations at similar distances (number 2), indicating possible antenna rotation due to the wind, which affect the antenna pattern.
- Both the transmission on HAP and receiver on ground antennas are of the same type, quarter-wave monopole. They may not have a whole omni-directional pattern but rather exhibit directional characteristics to some degree or have a pattern resembling spikes or peaks.
- The polarization of the antennas may be uncertain, leading to mismatches in some elevation angles.

SUGGESTION

1. Antennas should have a 3 dB beamwidth in the range of 0-45 degrees of elevation, which is crucial for operation throughout the HAP.
2. It's important to measure the antenna pattern to ensure symmetry and avoid signal dropout's characteristic.
3. Receiver antennas should be circular polarization to compensate HAP rotation.
4. Transmitter antennas should have a pattern designed to push signals towards the ground, such as egg butter antenna pattern or cross dipole antenna pattern.
5. Communication system designs should include an additional 20 dB of link margin to compensate unforeseen factors.