

### Project Description:

In some scenarios, such as terrestrial communication infrastructure failure due to a disaster or a temporary high demand (like in big and crowded events), unmanned aerial vehicles (UAV) can be deployed to support the network thanks to their low cost, flexibility, and favorable propagation channels.

Typically, a UAV serves as a relay between the available ground base station (BS) and another end point that might be another BS or a user. In this project, we are interested to study the point-to-point (P2P) link between the UAV and the ground BS as shown in Figure 1.

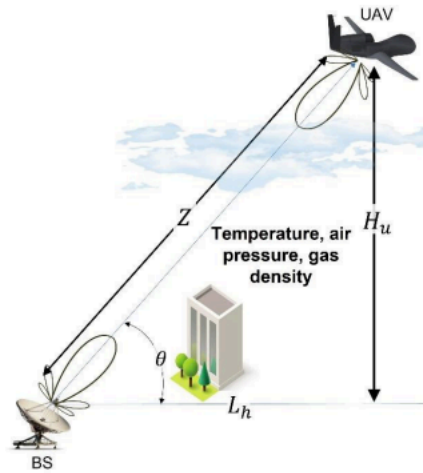


Figure 1: System Model

One can easily verify that the larger the elevation angle  $\theta$  the higher is the line-of-sight (LOS) probability (knowing that the BS is surrounded by buildings) and hence a better performance. Therefore, we would prefer to deploy the UAV at the highest possible elevation. However, as we will verify, due to path losses and atmospheric conditions there is a trade-off between elevation (probability of LOS), frequency and link quality.

The questions to be answered by this project, for a specific network setup:

1. What will be the best elevation of UAV to obtain the best link quality?
2. What is the effect of the antenna radiation pattern (or directivity gain) on the link quality?
3. What is the effect of the used frequency band?

In specific, you need to follow the below steps

- 1- You need to construct the following models:
  - a. Pathloss model for the channel (using the ITU report with focus on the slant channel and approximate model introduced).
  - b. Antenna gain model (for both transmitter and receiver with focus on linear array models).
- 2- Performance Metrics:
  - a. Outage probability definition and model.
  - b. Channel capacity definition and model.
- 3- Parameters to study:
  - a. UAV Height.
  - b. Frequency used.
  - c. Elevation angle.

Project Report:

The project report should have a brief introduction, the system and channel models, and the numerical results outlining the effects of the different parameters. In particular, you need to highlight the following:

1. How to decide on the right angle, right frequency, and right size of antenna to achieve a certain quality of service.
2. How the antenna model is derived using propagation of EM signals as outlined in the reference. Moreover, you need to summarize the laws of gas absorptions to RF waves as outlined by the ITU report.
3. How the performance metrics are calculated, i.e. the calculations of outage probability, signal-to-noise ratios, and other metrics in absolute and dB scales.

**Project Requirement:**

The project report should follow a single column free format, and should include the below sections:

1. Introduction: Summarizing the need of using UAVs in communications (e.g. in disaster situations, big events, rural areas with no coverage, ...)
2. System and Channel Models: Here you need to have subsections emphasizing your understanding of both the used antenna pattern and the model of the channel. You need to mention all parameters that affect the derived mathematical models.
3. Performance Metrics: Here you need also to have subsections explaining the definition of SNR, outage probability and capacity. Here you also derive those metrics using the specific channel and antenna patterns you have in the previous section.
4. Numerical results: In this section you need to plot different figures showing the effects of height, frequency and elevation angle. You should use log-log scale in all figures. A discussion of the resulting behavior is expected.

There is no specific length required, you just need to make sure that you covered the above sections. Make sure to cite references appropriately when needed.

The project will be used in the evaluation of ABET Student Outcome 1 (SO (1)).

**Student Outcome (SO (1)):**

An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.

**Performance Indicators (PI's)**

1. Identify and formulate a complex engineering problem.
2. Solve a complex engineering problem by applying principles of engineering.
3. Solve a complex engineering problem by applying principles of science.
- Solve a complex engineering problem by applying the principles of mathematics.

**Project parts that can be used to assess the PI's are**

- 1- Identifying and formulating complex engineering problem will be assessed from motivation of developing the communication link characterization (by formulating the pathloss model and antenna gain models) between a base station and a flying UAV.
- 2- Principles of engineering can be assessed from deciding on the right angle, right frequency, and right size of antenna to achieve a certain quality of service.
- 3- Principles of science can be assessed from propagation of EM signals, the laws of gas absorptions to RF waves.
- 4- Principles of math will be assessed from the calculations of outage probability, signal-to-noise ratios, and other metrics in absolute and dB scales.