Module Eight

Henrik Frank, hefra13@student.sdu.dk
Christian Arentsen, chare13@student.sdu.dk
Vasileios Karvouniaris, vakar15@student.sdu.dk
Asbjørn Schou Müller, asmul10@student.sdu.dk

I. Exercises

I. Radio link budget

The objective of this exercise is to learn about radio link budgets and how they may be applied when designing radio communication systems for drones.

I.1 Unit conversion mW and dbm

What is the unit conversion between power expressed in mW and dBm? What is the value in dBm for 100mW, 500mW and 1W?

Result 1mW is relative to 1dBm. Rule of thumb; double the power = 3dBm increase, half the power = 3dBm decrease

$$dB = 10 * log_10 \frac{P_1}{P_2}$$

100 mW	20 dBm
500 mW	27 dBm
1W	30 dBm

I.2 Free-space basic transmission loss

The *free-space basic transmission loss* (attenuation) L_{bf} expressed in dB in equation 3 where P_r is the power received by an isotropic antenna, P_t is the power transmitted by an isotropic antenna, f is the frequency in MHz, d is the distance in meter between transmitter and receiver [1].

$$\frac{P_t}{P_r} = \left(\frac{4\pi f d}{300}\right)^2 \tag{1}$$

$$L_{bf} = 10\,log_{10}\left(\frac{4\pi f d}{300}\right)^2 = 20\,log_{10}\left(\frac{4\pi f d}{300}\right) \tag{2}$$

$$\approx -27.55 + 20\,log_{10}(f) + 20\,log_{10}(d) \tag{3}$$

Please explain in words what is free-space basic transmission loss and what physical properties contributes to this?

[1] RECOMMENDATION ITU-R P.525-2

Free-space basic transmission loss (FSPL) is the power loss that would occur on a line-of-sight path through space, without being affected by reflection or refraction. Usually expressed in dB, although the IEEE standard does not say that.[1] The main properties of FSPL are the transmission distance and the frequency of the signal.

I.3 Radio link budget

A radio link budget contains the following factors listed below expressed in decibels. Optionally the calculation may include Bit Error Rate (BER) for digital links.

1. The transmitted power level
2. Signal loss as it travels to the receiver (free-space)
3. Frequency band background noise level (what is the minimum SNR that will allow the receiver to extract a usable signal).
4. How the transmitting and receiving antenna systems shape the signal
5. Receiver sensitivity

Please create (and document) a radio link budget for a a 2.4 GHz C2 link, a 433 MHz telemetry link and a 5.8 GHz video downlink respectively. This is not a trivial task, and you may want to search the web for examples of radio link budgets. The course materials for this module contains a few references as well.

Results Please refer to the spreadsheet included in the handin folder, thank you.

II. Near field absorption and Fresnel zones

The objective of this exercise is to learn about near field absorption and Fresnel zones and how they relate to drone technology.

II.1 Near field absorptions

Please explain what is *near field absorption* and to the extent possible based on information available on the web please quantify the signal attenuation.

II.2 Fresnel zones

Please explain in details using a sketch or an image from the web what is a Fresnel zone (equation 4) and how does it relate to drone C2 and telemetry links?

$$F_n = \sqrt{\frac{n\,\lambda\,(d_1\,d_2)}{d_1 + d_2}} \tag{4}$$

Fresnel zones are a series of prolate ellipsoidal regions of space between and around a transmitting antenna and a receiving antenna system.[2]. The equation above4 is used for calculating the Fresnel zone radius at any point P in between the transmitting and the receiving antennas. F_n is the radius of the zone, d_1 is the distance of P from one end-point, d_2 and λ is the wavelength of the transmitted signal.

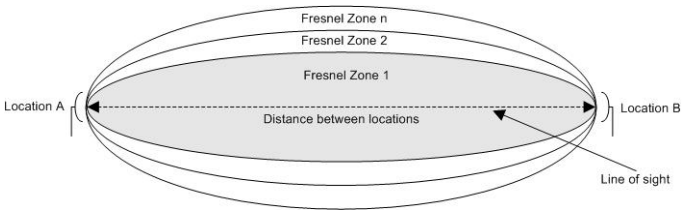

Figure 1: Graph of Fresnel zones

II.3 Plotting Fresnel zones

Using Python please plot the Fresnel zones for a 2.4 GHz C2 link, a 433 MHz telemetry link and a 5.8 GHz video downlink respectively.

II.4 Fresnel zone loss

Assuming that the greatest Fresnel zone losses occur when a diffracting object blocks about 40% of the 1st Fresnel zone. Please calculate and discuss what this means to a drone at a height of 50m with respect to the ground at 400m distance from an operator sitting on the ground holding the TX at an approx height of 0.5m.

Please consider another situation where a standing drone operator controls a drone at 200m distance. The drone is visible just above the ride line of the metal roof of a building at a distance of 30 meter. How much visual clearance must there be between the direct line of sight and the ridge line to ensure that the first Fresnel zone is clear for a 2.4 GHz C2 link, a 433 MHz telemetry link and a 5.8 GHz video downlink respectively?

III. Path loss model based on terrain contours

Use the VHF/UHF Area Prediction Tool to model path loss influenced by the terrain contours. Is the result comparable to the free space loss estimated in exercuse I.2 if you select HCA Airport as location (N55.47036, E010.32967)? What if you select Svanninge Bakker (N55.12518, E010.25419)?

References

[1] Free-Space Path Loss. `https://en.wikipedia.org/wiki/Free-space_path_loss`, Feb 2002. [Online].

[2] Fresnel zone. `https://en.wikipedia.org/wiki/Fresnel_zone`, Feb 2002. [Online].