Course notes, week 11

Radio communication theory

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1 Agenda

1. Practical information
2. Presentation of week 7 lab exercises by team 2.
3. Presentation of week 8 lab exercises by team 3.
4. Introduction to the module theory and exercises.
5. Exercises.

2 Theory presented in class

This module contains most of the basic theoretical elements of radio communication that you need to know. The two subsequent modules will include work on Telemetry links and Command and Control (C2) links respectively.

1. Radio wave propagation
2. Radio frequency spectrum
3. Antennas, gain, reciprocity
   - isotropic
   - half wave dipole
   - quater wave ground-plane
   - yagi-uda
4. Feed lines and connector attenuation
5. Path loss, inverse square law, near field obstacles, Fresnel zones, polarization
6. Radio link budget

3 Exercises

3.1 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.

3.1.1 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?

3.1.2 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 and perhaps using a sketch, what is free-space basic transmission loss and what physical properties contributes to this?

3.1.3 Radio link budget

A radio link budget contains essentially the below factors expressed in decibels.

1. Transmitted power
2. Path loss (as the transmitted signal travels to the receiver, free-space)
3. Receiver required power
4. Margin (Transmitted power - Path loss - Receiver sensibility)

The factors may be described in more details: The Transmitted power may be divided into transmitter output power, transmission line loss, antenna gain; The Receiver required power may be divided into antenna gain, transmission line loss, receiver sensibility.

Please create in a spreadsheet 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. Please notice that the course materials for this module contains some references on this.

3.2 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.

3.2.1 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.

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

3.2.2 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?

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

3.2.3 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.

3.2.4 Fresnel zone loss

Assuming that the greatest Fresnel zone losses occur when a diffracting object blocks 40% or more 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 ridge line of the metal roof of a building at a distance of 100 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?

3.3 Simulation of path loss based on terrain contours

The purpose of this exercise is for you to get an idea about the terrain influence on radio signal propagation.

Use the Radio Mobile Online[2] to model the Link and Coverage influenced by the terrain contours and properties. Do the results align quantitatively with the free space loss estimated in exercise 3.1.2 and your radio link budget developed in 3.1.3 when using the same input data?

I suggest that you select HCA Airport as location (N55.47182, E010.32581) and also Svanninge Bakker (N55.12518, E010.25419) as an example of a more hilly location.

Please spend some time working with Radio Mobile, looking into the functionality and possible information output etc. as this may become a valuable tool to you.

[2] ,