Astro 331X Lab 3: Radio Communication

Lt Col Jordan Firth

2023-06

Overview

You will use an XBee radio on FlatSat to communicate with another XBee radio connected to the laptop (acting as your ground station). You will develop a model (equations) to predict the performance of FlatSAT's communication link during ground test and in orbit. Both radios (ground station and FlatSAT) will use an external stick antenna (see PulseLARSEN datasheet in appendix).

During the lab you will capture the RSSI value (received signal strength indicator) from the radio at various distances (500 mm–5 m) to validate your model and ensure that the radio will meet performance requirements on-orbit.

Content

For each distance, calculate your predictions for received signal strength, which can be calculated using a simplified version of the link budget equation. Assume free space path loss is the only loss term.

Link margin is a simplified version of the E_b/N_0 equation we used in class—a positive value (in dB) is good.

Calculate the performance of this communications subsystem if the FlatSat were launched into a circular orbit with a 500 km altitude.

If the link margin you calculate at 500 km is less than 9 dB, describe and calculate at least two possible design changes you could make to the design bring the link margin up to 9 dB.

Math

Decibel conversion

$$x \text{ dB} = 10 \log_{10} x \tag{1}$$

$$x = 10^{(x \text{ dB}/10)} \tag{2}$$

Received signal strength (dB):

$$RSSI = P + G_t + G_r + L_s \tag{3}$$

Free space path loss (unitless):

$$L_s = \left(\frac{\lambda}{4\pi S}\right)^2 \tag{4}$$

Remember to convert free space path loss to decibels before using it in the equation for RSSI.

Link Margin (dB):

$$LinkMargin = RSSI - ReceiverSensitivity \tag{5}$$

Receiver Sensitivity indicates the capability of the receiver to extract information from a weak signal, quantified as the lowest signal that is able to be received. Use the attached data to find the radio transmission frequency, transmitter power, gain of the transmitter and receiver (same antenna for both), and receiver sensitivity.

Complete Table 1 with your predictions. After collecting data, compare your measurements to your predictions.

Table 1 Link Values

	predicted RSSI (dB)	predicted margin (dB)	measured RSSI (dB)	measured margin (dB)
0.5 m				
1 m				
2 m				
5 m				
max tested (indicate distance)				
500 km				

Appendix A: Specifications

Use the performance specifications for the XBee 3 (not 3-PRO).

Note: dBm corresponds to power in mW (you will need to convert dBm to dB)

IEEE 802.15.4-specific specifications *Performance specifications*

Performance specifications

The following table describes the performance specifications for the devices.

Specification	XBee 3	XBee 3-PRO
Indoor/urban range	Up to 60 m (200 ft)	Up to 90 m (300 ft)
Outdoor RF line-of-sight range	Up to 1200 m (4000 ft)	Up to 3200 m (2 mi)
RF Transmit power output (maximum)	6.3 mW (+8 dBm)	79 mW (+19 dBm)
BLE power output	6.3 mW (+8 dBm)	6.3 mW (+8 dBm)
RF data rate	250,000 b/s	
Receiver sensitivity	-103 dBm	

Note Range figure estimates are based on free-air terrain with limited sources of interference. Actual range will vary based on transmitting power, orientation of transmitter and receiver, height of transmitting antenna, height of receiving antenna, weather conditions, interference sources in the area, and terrain between receiver and transmitter, including indoor and outdoor structures such as walls, trees, buildings, hills, and mountains.

Part number	Type (description)	Gain (dBi)
Integral antennas		
29000294	Integral PCB antenna (through-hole only)	-0.5 dBi

TECHNICAL DATA SHEET

Series: Stick Antenna

Description: Wireless External Antenna for 2.4 GHz Applications

PART NUMBER: W1038x

Features:

- High gain performance, 3.8dBi
- For WLAN devices using WiFi (802.11b/g), Bluetooth® and ZigBeeTM
- Omni-directional radiation pattern provides broad 360° coverage
- One-quarter wavelength dipole configuration, length 196.2mm
- Connection and color options easily integrate with OEM designs
- **W1038** Black; **W1038W** White; **W1038G** Gray

Applications:

- Omni-directional antennas provide a uniform, donut-shaped, 360° radiation pattern. The omni-directional pattern is suitable for point-to-multipoint broadcasting in all directions. The antenna is primarily used for WLAN applications. However, it can also be used for a variety of other applications within the specified frequency range. When used as an access point, the antenna is ideally located at the center of the coverage

Issue: 1821

For more information:

Pulse Worldwide Headquarters	Pulse/Larsen Antennas	Europe Headquarters	Pulse (Suzhou) Wireless Products Co, Inc.
15255 Innovation Drive #100	18110 SE 34th St Bldg 2 Suite 250	Pulse GmbH & Do, KG	99 Huo Ju Road(#29 Bldg,4th Phase
San Diego, CA 92128	Vancouver, WA 98683	Zeppelinstrasse 15	Suzhou New District
USA	USA	Herrenberg, Germany	Jiangsu Province, Suzhou 215009 PR China
Tel:1-858-674-8100	Tel: 1-360-944-7551	Tel: 49 7032 7806 0	Tel: 86 512 6807 9998

Note: dBi indicates that the gain is isotropic. It is equivalent to dB.