P11207 - Feasibility Analysis

Range of the transmission for the different available frequencies with Low Power RF Protocols

Based on the fact that the Engineering Specification #3 requires an "Operation allowed without license", we will compare the 3 ISM Bands available on the market (433MHz; 915MHz; 2450MHz) for Low RF Power applications.

The objective of this analysis is to determine the maximum range reachable using these different frequencies and also which transmitter power configuration allows us to meet the 200m LOS range as required in Specification #2.

These calculations will be made using the link budget formula established by FRIIS for a Line Of Sight configuration.

ISM Band studied

- $f_1 = 433\ MHz$
- $f_2 = 915\ MHz$
- $f_3 = 2450\ MHz$

Friis' Formula

$$P_r = \frac{P_t \cdot G_t \cdot G_r \cdot \lambda^2}{(4\pi \cdot d)^\alpha}$$

$$P_{r\,dBm} = P_{t\,dBm} + G_{t\,dB} + G_{r\,dB} + 20\log\left(\frac{\lambda}{4\pi}\right) - 20\log(d)$$

$$\lambda = \frac{c}{f}$$

With:

- P_r: Received Power (mW)
- P_t: Transmitted Power (mW)
- G_t: Gain of the transmitting antenna (dB)
- G_r: Gain of the receiving antenna (dB)
- d: Distance between the transmitter and the receiver (m)
- λ: Wavelength (m)
- $c = 3x10^8\,\frac{m}{s}$: Speed of light
- f: Frequency (Hz)
- α: Parameter depending on the environment

We usually use: $\alpha = 2$ when we consider free space.

However in another kind of environment, this parameter can vary. For example when we consider propagation in an indoor environment with line of sight visibility it is common to have $\alpha < 2$ because of the reflections which contribute to a better reception.

For this case we will limit the study to a free space configuration, thus $\alpha = 2$.

Two parameters are directly related to the Transceiver:

- The received power P_r, which will be limited at its minimal value by the sensitivity of the transceiver. Typical transceivers offer a sensitivity of $P_{r_{min}} = -90dBm$ for the maximum data rate reachable.
- The transmitted power P_t, which is usually configurable in the typical range of [-30dBm; 0dBm]

The antenna used in the desired application will be an omnidirectional antenna, therefore it will have a low gain, set at $G_r = G_t = 0dBi$ for this analysis.

Scenario 1: Calculation of the required transmitted Power to reach 200m

- **Configuration:**
  - Sensitivity of the receiver: $P_{r_{dBm_{min}}} = -90 \text{ dBm}$
  - Gain of the antennas: $G_r = G_t = 0 \text{ dBi}$
  - Distance: $d = 200m$
- **Results:**

Frequency (MHz)	Required P_t (dBm)
$f_1 = 433$	-18.79
$f_2 = 915$	-12.31
$f_3 = 2450$	-3.76

- **Conclusion:**

Since the output Power Range on most of the transceivers sold on the market is from -30dBm to 0dBm, we can theoretically reach 200m with any frequency in a LOS (Line of sight) configuration.

The 2 lowest frequencies provide a sufficient theoretical margin to reach the desired distance of 200m. However since we are using a free space LOS representation, we need to be aware that the real transmission will slightly differ from this theoretical analysis because of the contribution of multiple paths.

For 200m, a visible difference of dB can be observed. Thus the highest frequency (2.45GHz) does not provide a sufficient margin (only 3.76dB) to be sure to reach 200m with this configuration. In this case an amplifier would be required.

Scenario 2: Calculation of the maximum range reachable at $P_t = 0dBm$ and receiver sensitivity of -90dBm

- **Configuration:**
  - Sensitivity of the receiver: $P_{r_{dBm_{min}}} = -90 \text{ dBm}$
  - Gain of the antennas: $G_r = G_t = 0 \text{ dBi}$
  - Transmitted Power: $P_t = 0 \ dBm$
- **Results:**

Frequency (MHz)	Maximum Distance TX/RX (m)
$f_1 = 433$	1739.5
$f_2 = 915$	825.1
$f_3 = 2450$	314.5

- **Conclusion:**

Using a lower frequency can be a good approach in terms of Power consumption because it will allow us to use a lower Transmit Power Level to reach the distance of 200m.

Scenario 3: Calculation of the maximum range reachable at $P_t = 0dBm$ by an existing Transceiver (CC2500) with sensitivity of -89dBm at 250kBaud

- **Transceiver: CC2500**
  - Maximum output power: $P_{t_{max}} = 1\ dBm$
  - Sensitivity of receiver: $P_{r_{min}} = -89\ dBm$
  - $f = 2450\ MHz$
  - $G_r = G_t = 0\ dBi$ (Omnidirectional antennas)
- **Result:**

$$d_{max} = 308.01\ m$$

Scenario 4: Calculation of the maximum range reachable at $P_t = 0dBm$ by an existing Transceiver (CC1111) with sensitivity of -94dBm at 250kBaud

- **Transceiver: CC1111**
  - Maximum output power: $P_{t_{max}} = 10\ dBm$
  - Sensitivity of receiver: $P_{r_{min}} = -94\ dBm$
  - $f = 915\ MHz$
  - $G_r = G_t = 0\ dBi$ (Omnidirectional antennas)
- **Result:**

$$d_{max} = 4136\ m$$

- **Conclusion:**

The latest transceivers available on the market theoretically give us the possibility to reach the target distance easily with the 915MHz frequency. With 2.4GHz, the results obtained with these calculations show that an amplifier is required to make sure that the range is reached safely.

However since the sensitivity depends on the data rate of the transmission, we can also expect that with a lower data rate we can have a better link budget.