<u>**Link budget Calculation**</u>
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The following document is composed of simple calculations demonstrating the feasibility of using a 100mw Lo-Ra sx1278 aboard a LEO picosatellite (Low Earth Orbit) in order to communicate with it using simple low cost equipment.

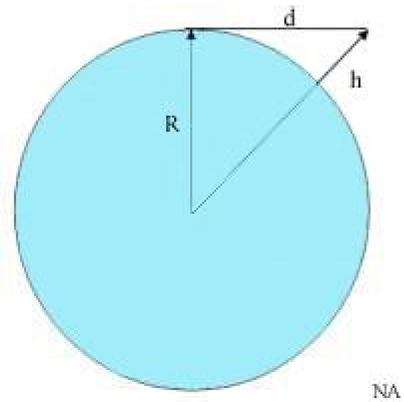
Taking in consideration a transmission power of 17dB using an SX1278 and its respective sensitivity, the link budget for downlink is as follows.

Power: 17dBm
Tx antenna gain (approximation for half wave dipole): 1.2dBi
Free Space loss (2550 km, 433MHz): 153.3 dB
We are using this distance as it is the estimated line of sight horizon of our satellite and its nominal orbit of 500 km
The estimated calculation for distance is simply done using the following formula where d (distance) is given by the pythagorean theorem. (This calculation does not consider the irregularities of earth's surface)*

$$d^2 = (R+h)^2 - R^2 = 2 \cdot R \cdot h + h^2$$

Thus If height is given in meters and distance in kilometers the simplified version would be:

$$d \approx 3.57 \cdot \sqrt{h}$$



Substituting into this formula with our orbit of 500km we get a distance of 2.425km.

Now we have the distance we can use the free space path loss formula to determine the loss of the RF distance over that distance.

$$FSPL = 20\ log_{10}(d) + 20\ log_{10}(f) + \ 20 log_{10}\left(\frac{4\pi}{c}\right)$$

Where -

d = Distance between the antennas.

f = Frequency

c = Speed of light in vacuum (Meters per Second)

Substituting in this formula gives us a free space path loss of 153.30dB, once again this does not account for external factors such as obstacles, reflections or the difference in atmospheric density throughout the path.

Rx Antenna Gain (approximation for half wave dipole): 1.2dBi
Therefore, 17dBm + 1.2 - 153.3 + 1.2 = -133.9dBm

Using an equivalent SX1278 as a receiver at a spreading factor of 11 the receiver sensitivity would be -135.5dBm leaving us with 1.6dB of margin for fading and external factors
When using a spreading factor of 12 the receiver sensitivity increases to -138dBm giving us a margin of 4.1 dB for fading and external factors.

Therefore the communication of our satellite with its equivalent <4$ module on earth is theoretically accomplishable with a relative margin for external factors.
These calculations are carried out taking in consideration an output power of 17dBm at 125KHz (Our estimated settings for the satellite), Power restrictions, Frequency allocation approval, battery power available and the maximum frequency offset tolerable by the SX1278's will ultimately decide the settings used.
Theoretically with the current 10 PPM +- Crystal at a bandwidth of 62.5 and a maximum output power of 20dBm we could reach a margin of 10.1 dB with the use of simple dipoles, a yagi directional antenna could nearly double this margin for a 20$ increase in cost.

Additionally non license radio operators could transmit in the ISM band **<u>(Depending on their region)</u>** at a limited 10dBm using the exact same equipment, for example at a distance to achieve a fading margin of about 1.5dB using the current monopole antennas it would be necessary to be at a distance of 1555 km, not exactly radio horizon but still a considerable range for most passes. Once again a cheap homemade yagi antenna would drastically increase this range.