*DarkSide Logistics  Lunar Spaceport Initiative*

# Communications: Power Analysis

## Earth-Lander Link

### *Carrier to Noise*

- Rate 2/3 turbo code can achieve a C/N within 2 dB of Shannon Channel Capacity.
- C/N at Shannon Channel Capacity:
  $CNR = 2^{\frac{C}{B}} - 1 = 0.85175\,dB$ (at the Shannon Limit)
- C/N needed to achieve BER of $10^{-6}$: 2.85175 dB
- For our link budget calculations, we will add an addition C/N buffer and increase it to 4dB.

### *Path Loss*

- Pathloss = $20\log_{10}\left(\frac{4\pi}{\lambda}R\right)$ dB
- R = 405,500 km (distance from earth to moon at apogee)
- Uplink Pathloss ($\lambda$ =0.04m) = 222.103 dB
- Downlink Pathloss ($\lambda$ =0.0375m) = 222.663 dB

### *Downlink Budget*

- $P_T = {C}/{N} + P_N - G_R - G_T + Pathloss$
- $P_N = kT_{sys}B_N$= 129.106 x $10^{-15}$ (linear) = -128.433 dB
  - $T_{sys}$ = 44K
  - $B_N$ = 5.625 MHz
  - k = 1.38 x $10^{-23}$
  - Multiply by 42 (number of elements in Allen Telescope Array)
- $G_R = h_A\left(\frac{pD}{\lambda}\right)^2 = 6.68543 \times 10^6 (linear) = 68.2518\,dBi$ (for all 42 elements)
  - $\lambda$=0.0375 m
  - $\eta$=0.63
  - D=6m
  - 42 Elements
- $G_T$ = 44.4 dBi
- C/N = 4 dB
- Pathloss = 222.663

- Link Budget Calculation: $P_T$ = -14.4218 dBW = 32.1263 mW

### *Uplink Budget*

- $P_T = {}^{C}\!/_{N} + P_N - G_R - G_T + Pathloss$
- $P_N = kT_{sys}B_N$= 23.2875 x $10^{-18}$ (linear) = -166.329 dB
    - $T_{sys}$ = 50K
    - $B_N$ = 33.75 kHz
    - k = 1.38 x $10^{-23}$
- $G_R$ = 37.4 dBi
- $G_T$ = 44.4 dBi
- C/N = 4 dB
- Pathloss = 222.103
- Link Budget Calculation: $P_T$ = -22.026 dBW = 6.27 mW

## Lander-Rover Link

- In our link budget equations, we will assume a C/N of 20 dB to ensure near-errorless transmission
- Maximum gain of a half-wave dipole antenna is 2.15dB, so we will assume a worst-case gain of 1 dB for both transmit and receive antennas for the link budget.

### *Path Loss*

- To allow the rover to travel long distances from the lander but still communicate with it, we will assume a maximum communication distance of 10km.
- Uplink (Lander to Rover):
    - Carrier Frequency: 1 GHz
    - Pathloss = 112.442
- Downlink (Rover to Lander):
    - Carrier Frequency: 900 MHz
    - Pathloss = 111.527

### *Noise Power*

- Taking into account the device nosie temperatures from the oscillators, mixers, amplifiers, and other RF devices in the link, we will assume a worst case $T_{sys}$ of 400K.
    - Uplink (Lander to Rover):
        - $B_N$=22.5 kHz
        - $P_N$=124.2 x $10^{-18}$ (linear) = -159.059dB
    - Downlink (Rover to Lander):
        - $B_N$ =3.75 MHz

- $P_N$=20.7x$10^{-15}$ (linear) = -136.84dB

## *Transmit Power*

- Uplink (Lander to Rover) = -28.617 dBW = 1.375 mW
- Downlink (Rover to Lander) = -7.313 dBW = 185.652 mW