|  |  |  |
| --- | --- | --- |
| Spacecraft | | |
| Transmit power | 1.76 | dBW |
| Transmitter gain | 0 | dBi |
| Transmitter line losses | -1.93 | dB |
| Transmitter antenna pointing loss | -3 | dB |
| EIRP | -3.17 | dBW |
| Link | | |
| Frequency | 435 | MHz |
| Bandwidth (max achievable) | 158.5 | kHz |
| Path length (409 km altitude, 15° elevation) | 1196.622 | km |
| Free space path loss | -146.777 | dB |
| Other losses (atmospheric, polarisation, …) | -4.6 | dB |
| Ground Station | | |
| RIP | -154.61 | dBW |
| Receiver gain | 12 | dB |
| Receiver line losses | -2.4 | dB |
| Receiver system noise temperature | 249.3 | K |
| Receiver sensitivity | -11.97 | dB-K |
| Implementation loss | -2 | dB |
| Received CN0R | 62.03 | dB |
| Received CNR | 12.025 | dB |
| Required CNR | -10 | dB |
| Link Margin | 2.025 | dB |

The given **transmitter power** is based on the ESA’s FYS! requirements. The requirements limit the transmitting power of the satellite’s antenna to 1.5W. STRATHcube’s selected antenna for downlink communication, the ISIS deployable antenna, has a max power output of 2W.

The **transmitter gain** is based on the downlink antenna specification, which specifies the antenna as having 0dBi gain.

The **transmitter line losses** number is an estimate on the expected losses that will be incurred to the signal while on-board STRATHcube. This can be caused by components such as connectors, coaxial cables, (possibly) bandpass filters. AMSAT / IARU Annotated Link Model System was used to find this estimate. It is expected that a system with lower losses can be achieved.

The **transmitter antenna pointing loss** is an estimate on the expected loss that will be incurred from potential pointing inaccuracies while downlinking. This number is based on AcubeSAT’s numbers for downlink pointing loss. They specify it with two different values in their CDR link budget: 2 dB and 3.44 dB. To derive an estimate for STRATHcube an analysis on the downlink antennas directivity and radiation pattern would need to be performed, as well as an ADCS analysis of the STRATHcube’s pointing accuracy when downlinking.

AcubeSAT CDR link budget: <https://gitlab.com/acubesat/documentation/cdr-public/-/blob/master/DDJF/DDJF_LINK_ARPT.pdf?ref_type=heads>

Effective Isotropic Radiated Power (**EIRP**) is a critical measure of performance of an RF system. It represents an estimate of the maximum radiated power of the transmitter antenna in its pointing direction. The number found in the link budget above included the transmitter antenna pointing loss, after reviewing resources, this shouldn’t have been included in the EIRP calculation. This doesn’t affect any of the other calculations. The corrected EIRP can be found below.

STRATHcube’s downlink will be using the **frequency** 435 MHz.

The maximum **bandwidth** is the highest bandwidth the link can achieve given the conditions given in the link budget table. These conditions are based on the worst-case scenario, i.e. longest distance from ground station, low elevation angle, and high path losses incurred. The number is based on the achieved performance of the link, i.e. the carrier-to-noise-density-ratio (CN0R). The formula for calculating the bandwidth is given below.

The **path length** is the slant range from the 409 km of altitude (the altitude where STRATHcube deploys) to the James Weir Ground Station (JWGS) at 41 m of altitude with a 15-degree elevation angle between them (the minimum expected angle to establish a reliable link).

The **free-space path loss** is the loss that is incurred to the signal power due to distance. It is calculated given the formula below.

The **other losses** are path losses incurred from the atmosphere (1.1dB), ionosphere (0.4dB), scintillation (0.16dB), etc. these have been estimated using the AMSAT / IARU Annotated Link Model System and numbers from ITU. The polarisation mismatch between a horizontally aligned antenna and a circularly aligned antenna results in a loss of -3dB, as the polarisation configuration of the downlink antenna and JWGS is unknown, this has been included to account for a worst-case scenario.

Received Isotropic Power (**RIP**) is a measure of the transmitted signals power when it is received by the GS. It is given by the formula below.

As JWGS is currently out-of-operation, a GS with performance measures expected to be similar to what a potential “renovation” to JWGS could offer, was found to derive a representative link budget. AcubeSAT’s GS was the selected GS used as reference. The performance measure of their GS for numbers such as **receiver gain, line losses** and **system noise temperature** can be found in their GS and link budget CDR reports linked below

AcubeSAT CDR GS: <https://gitlab.com/acubesat/documentation/cdr-public/-/blob/master/DDJF/DDJF_GS.pdf?ref_type=heads>

AcubeSAT CDR link budget: <https://gitlab.com/acubesat/documentation/cdr-public/-/blob/master/DDJF/DDJF_LINK_ARPT.pdf?ref_type=heads>

**Receiver sensitivity** (also known as G/T) is a critical measure of performance of the GS. It denotes the antenna’s ability to capture the downlink signal among the other noise present in the system. It is given by the formula below.

The **Implementation loss** is an estimate of the loss incurred from the difference between the theoretical AWGN Eb/N0 and the measured Eb/N0 of the signal. It is expected to be between 1 and 2 dB for lower coding rates.

Source for implementation loss: <https://ntrs.nasa.gov/api/citations/20190028945/downloads/20190028945.pdf>

The carrier-to-noise-density-ratio (**CN0R**) is a critical measure of performance. It denotes the power of the signal relative to the noise of the path and system. The formula for CN0R is given below, where is the Boltzmann constant.

The carrier-to-noise-ratio (**CNR**) is a critical measure of performance. It denotes the power of the signal relative to the noise of the path and system for a specified bandwidth. The formula for CNR is given below, where is the Boltzmann constant.

The **required CNR** is the minimum required CNR to establish a reliable link between STRATHcube and the GS. This number is based on the requirements of the suite of modulation and encoding schemes within DVB-S2.

See figure H.2: <https://www.etsi.org/deliver/etsi_en/302300_302399/302307/01.03.01_20/en_302307v010301a.pdf>

The **link margin** is a critical measure of performance. It denotes the link’s tolerance to noise factors that might impact the system. It is given by the formula below.