# Fundamental Link Budget Analysis for Low Earth Orbit Satellite Downlink Communications

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***Abstract*—This paper demonstrates the link budget of low Earth orbit (LEO) system under 3GPP parameters, providing results as a benchmark for future research. Furthermore, downlink communications, i.e., data deliverye from LEO satellites to ground stateions, are considered which is generally considered in many applications.**

## I. Introduction

In modern beyond 5G or 6G research, low Earth orbit (LEO) satellites such as non-territorial networks (NTN) have been actively and widely considered for various applications such as synthetic-aperture radar (SAR) delivery [1]. In order to utilize the LEO satellite communications, it is essentially required to estimate how much data can be fundamentally delivered. Based on these requirements, this paper presents the link budget analysis of LEO satellite communications. Moreover, this paper especially considers downlink situations which is generally considered in many satellite applications, e.g., SAR image delivery from LEO satellites to ground stateions for surveillance applications.

## II. Link Budget Calculations

### A. Theorical Link Budget

The theoretical data rate between a transmitter and a receiver can be ascertained as follows,

$$C = B \log_2 \left( 1 + \frac{S}{N} \right), \tag{1}$$

where $B$ represents the bandwidth of the channel, and $S/N$ denotes the signal-to-noise ratio of the communication channel at the receiver, which can be computed in a dB scale as follows,

$$\frac{S}{N} = EIRP - PL_F + \frac{G}{T} - k_B - B, \tag{2}$$

where $EIRP$, $PL_F$, $G/T$, and $k_B$ are the effective isotropic radiated power (EIRP), free space path loss, antenna gain-to-noise-temperature ratio (13.1 dB/K), and Boltzmann constant (228.6 dBW/K/Hz), respectively. Table I presents the essential parameters for the calculation. In a bandwidth of 100 MHz, the EIRP is determined to be 35.9 dBW. Given the satellite's altitude at 888 km, a path loss of 182.3 dB arises when the distance between the satellite and the user equipment (UE) spans 1391 km. Therefore, the SNR is derived to be 15.3 dB. After obtaining the given SNR from the link budget analysis and taking into account the bandwidth used for transmission, the maximum achievable capacity, $C_{max}$, is determined to be 512 Mbps, as derived from the Shannon-Hartley theorem.

TABLE I: Parameters for the numerical evaluation.

| Parameter | Value |
|---|---|
| Downlink frequency band | 20 GHz |
| EIRP | 35.9 dBW |
| Channel bandwidth | 100 MHz |
| Mean altitude | 888 km |
| Antenna elevation angle | 35 deg |

### B. Expected Link Budget Range

According to the 3GPP specification, orthogonal frequency division multiple access (OFDMA) is applied in the downlink. A resource block (RB) comprises 12 consecutive subcarriers, and the duration of one RB is 0.5 ms, corresponding to 7 consecutive OFDM symbols. With a 120 kHz subcarrier spacing (SCS), each frame comprises 80 slots. Given the assumed 100 MHz bandwidth, it contains 66 RBs. Therefore, the total number of resource elements (RE) per frame can be computed as 11,088 REs. If we exclude control resources such as demodulation reference signals (DMRS) and physical downlink control channel (PDCCH), we estimate a total of 9,108 REs. Ultimately, in an environment with an SNR of 15.3 dB, using the 64 QAM modulation scheme and assuming a code rate of 0.702, the expected transmission rate can be calculated as 306 Mbps (with control overhead) and 373 Mbps (without control overhead).

## III. Conclusion

In this study, we examine the link budget computation for NTN systems operating in the Ka-band. When assuming a scenario with a SNR of 15.3 dB and adhering to the modulation scheme and resource grid structure prescribed by the 3GPP standard, the achievable transmission rate excluding the signaling overhead which can be 373 Mbps. Including the overhead, the transmission rate can be approximated as 306 Mbps.

## References

[1] K. Kim, J.-H. Lee, S. Jung, J. Kim, and J.-H. Kim, "Stabilized detection accuracy maximization using adaptive SAR image processing in LEO networks," *IEEE Transactions on Vehicular Technology*, vol. 71, no. 5, pp. 5661–5665, May 2022.