Link Budget Design For Free Space Optical Communication

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INTRODUCTION

Free space optical (FSO) communication is an innovative wireless technology that employs light to transmit data through the air. Unlike traditional radio frequency communication, FSO systems offer high bandwidth, low interference, and secure data transmission. However, designing an effective link budget for FSO communication is crucial to ensure reliable performance across various scenarios. This includes accounting for factors such as atmospheric conditions, distance, and optical components.

In this work, we will provide an overview of the link budget design for different scenarios, including ground-to-ground links and up/down links. By examining these scenarios, we aim to highlight the key parameters and considerations essential for optimizing FSO communication. Our goal is to offer comprehensive insights into achieving efficient and robust FSO communication under diverse conditions.

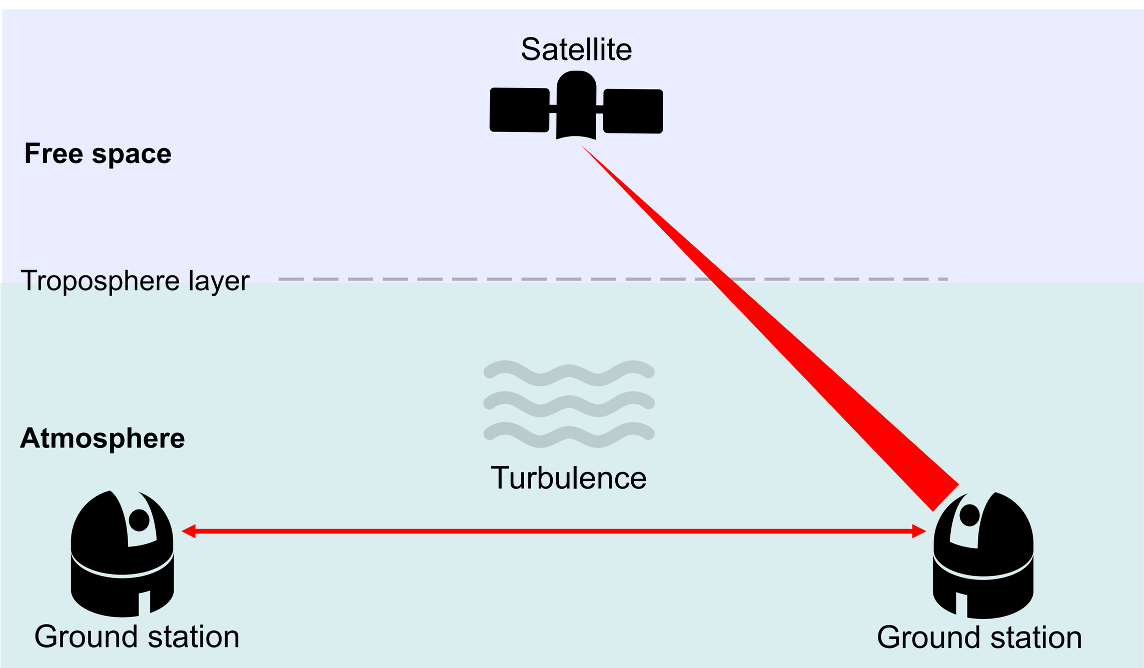

Fig 1: Schemtic of Uplink, Downlink and Ground to Ground scenarios

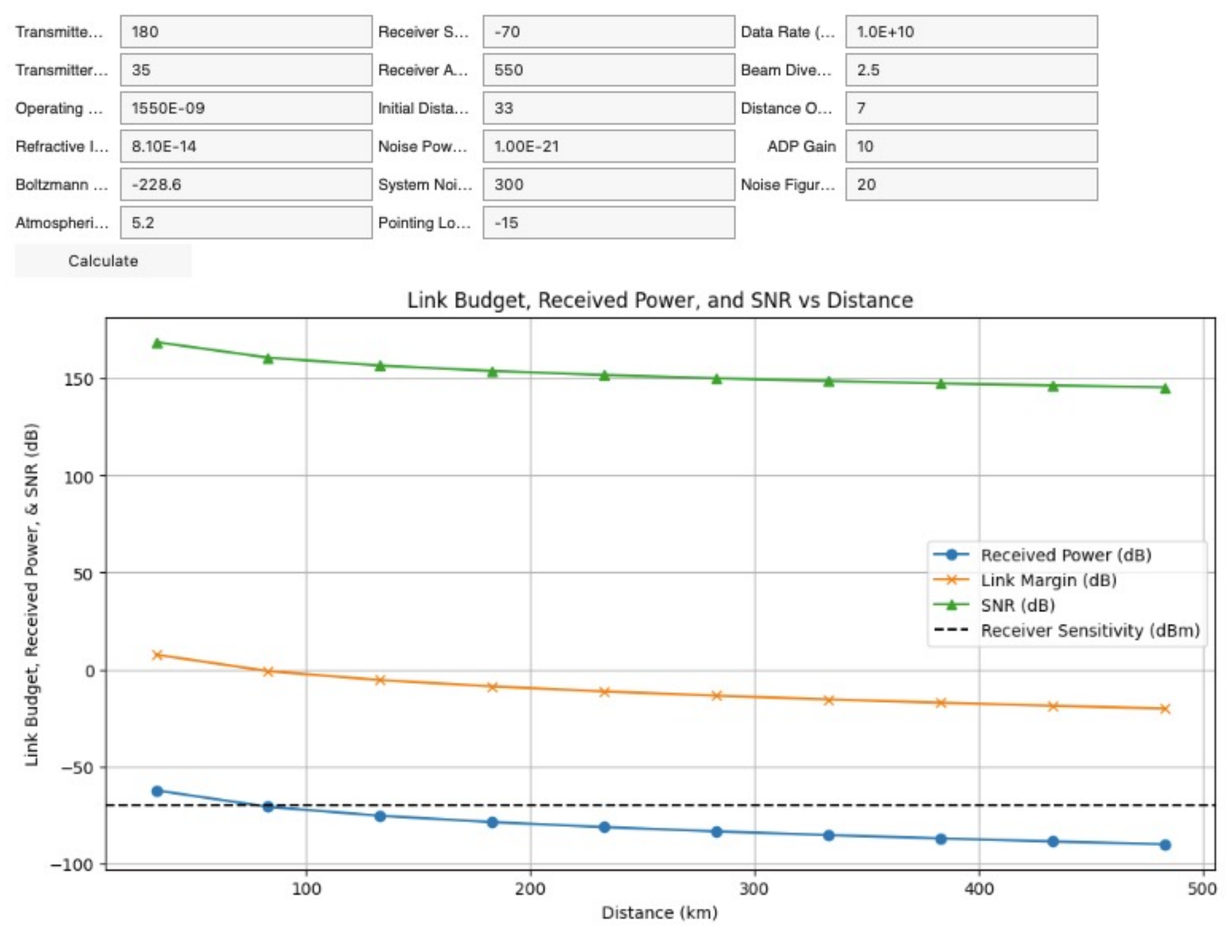

Fig.2 Design interface

CHALLENGES & METHODOLOGY

Challenges in Designing FSO Communication Systems

Designing Free Space Optics (FSO) communication systems involves significant challenges. Atmospheric loss (absorption and scattering) and turbulence affect ground-to-ground links. For uplink and downlink communication, free space loss due to vast distances leads to beam divergence. Minimizing optical component inefficiencies and pointing errors is crucial. Theoretical challenges include modeling atmospheric conditions and turbulence, developing precise beam tracking algorithms, and optimizing trade-offs between link distance, data rate, and reliability.

Design and Methodology

To address these challenges, we used data collected on turbulence and atmospheric conditions in the UAE. Our study also incorporated various system specifications for testing. Accurate data and robust design principles are essential for reliable FSO communication.

Parameter	Ground to ground	Satellite to ground
Power transmitted, mW	1	400
Travel Distance, Km	5 ~ 29	33 ~ 983
Transmitter gain, dBi	77.5	84.2
Beam divergence, mrad	2.5	2.5
Aperture size, mm	35	35-600
Receiver gain, dBi	76	102.8
Turbulence & Atmospheric losses, dB	29	27.2
Pointing loss, dB	12	30
Free space loss, dB	0.5	251
Receiver sensitivity, dBm	-20	-70
Link margin, dB	40	-5.1

Table 1: Comparative Link Budget for G-G and S-G Communication

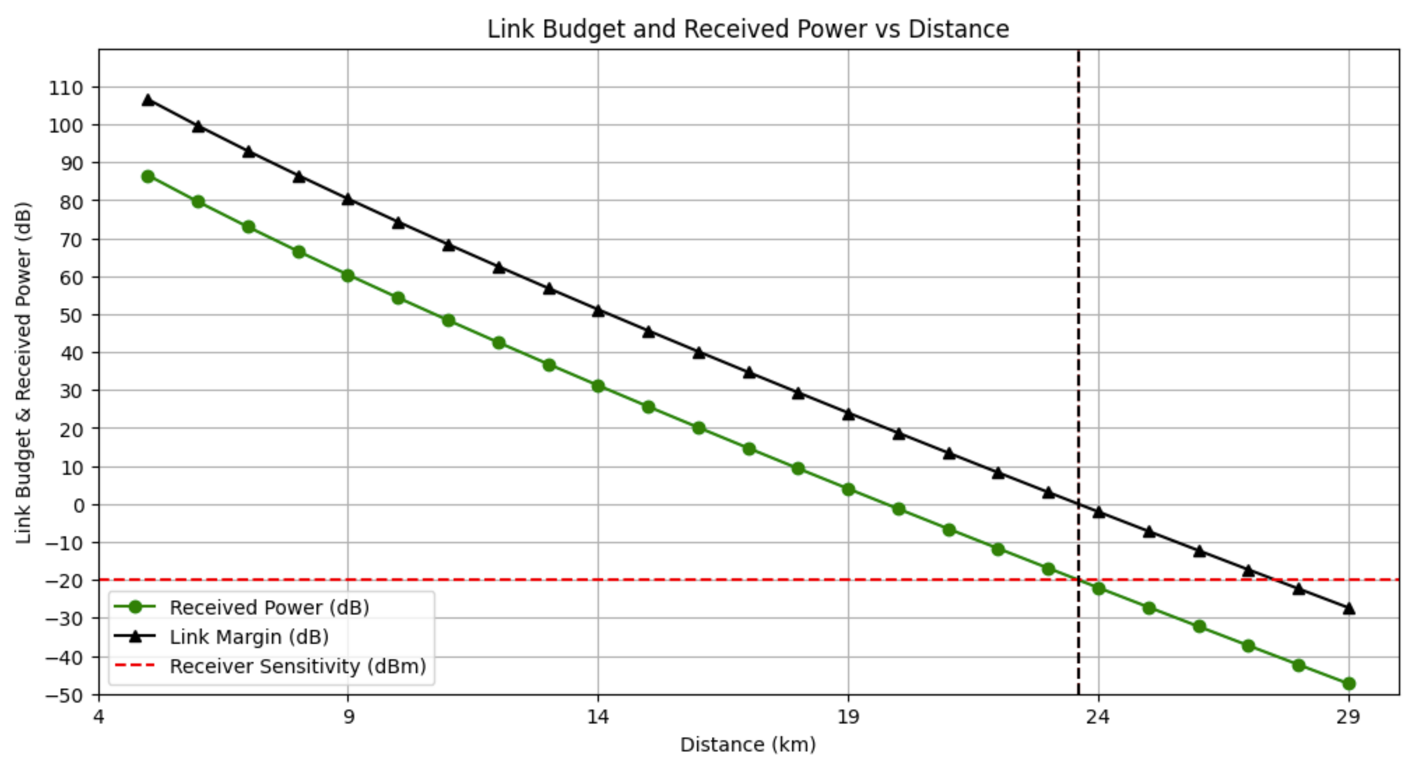

Fig.3: G-G Link margin, Received power vs Distance

RESULTS

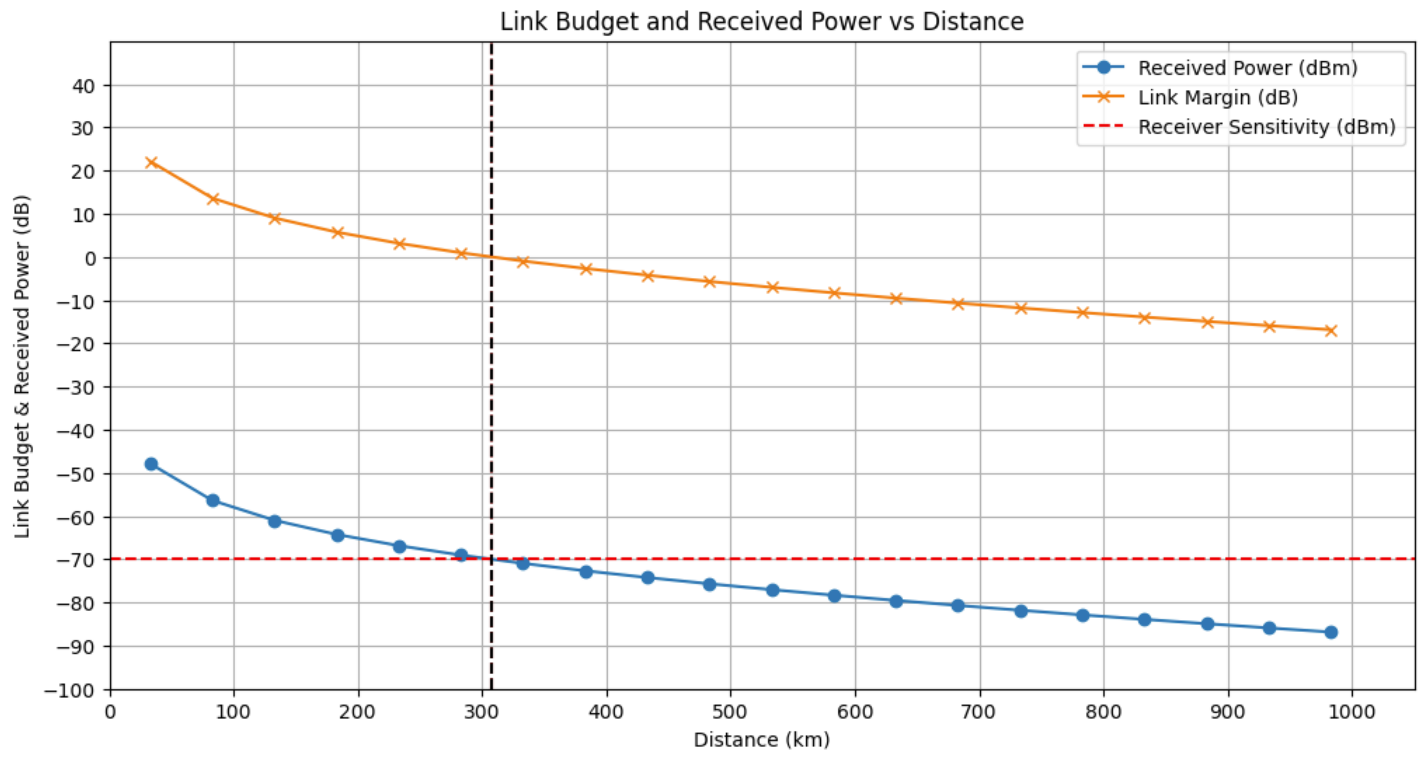

Fig.4: S-G Link margin, Received power vs Distance

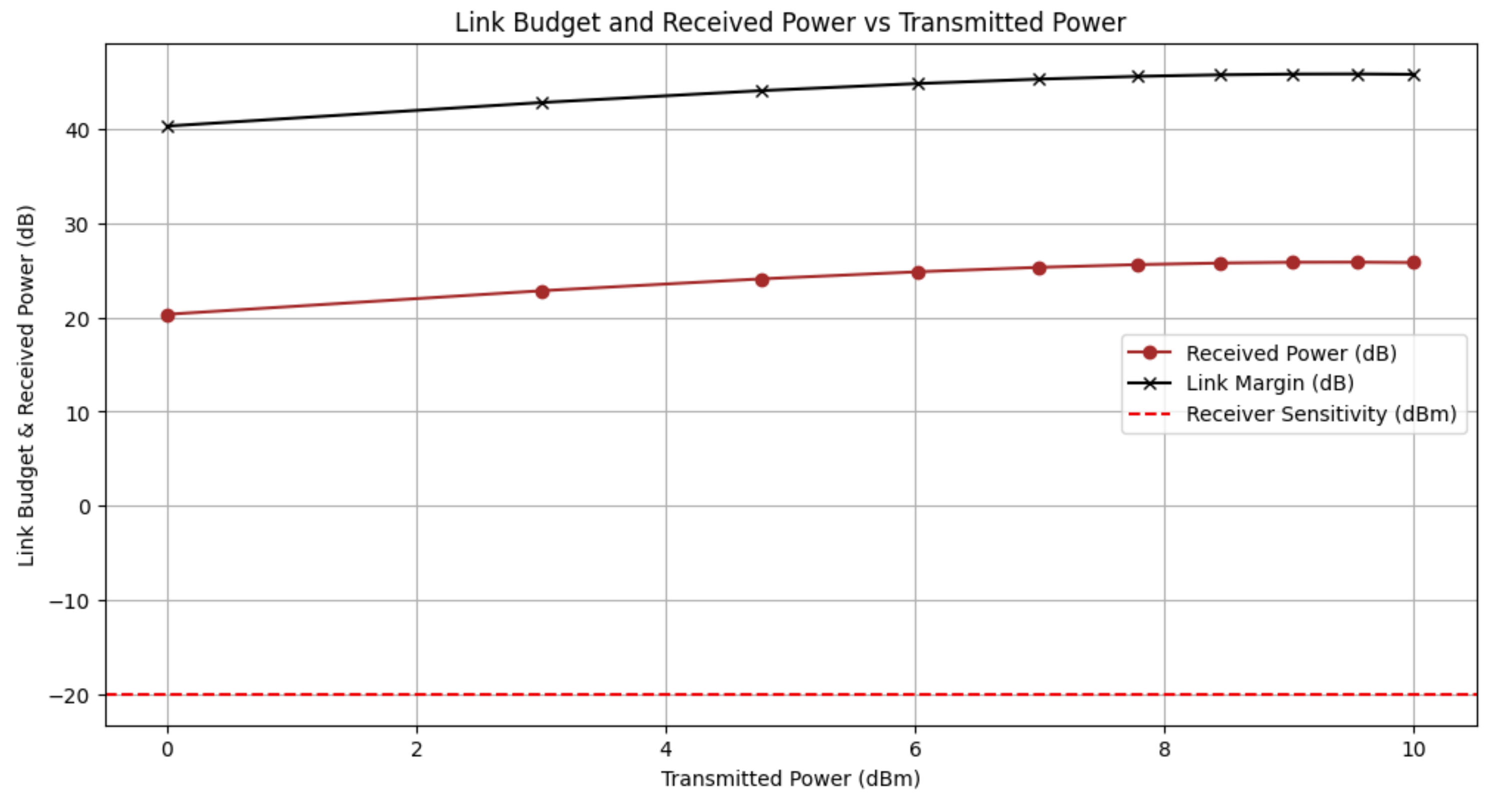

Fig.5: G-G Link margin, Received power vs Transmitted power

DATA ANALYSIS & CONCLUSIONS

In ground-to-ground communication, a link can be maintained up to 24 km, beyond which received power falls below the receiver sensitivity threshold, risking link failure. At a fixed distance, increasing transmitted power improves received power and link margin, though benefits diminish beyond certain power levels.

For satellite-to-ground communication, significant path loss occurs over large distances, with reliable communication feasible up to 300 km. It's crucial to consider the rapid decrease in received power with distance and design the system to optimize link budget components, considering atmospheric conditions.

When the parameters such as transmitted power, receiver sensitivity, antenna gain, and beam divergence are improved by 10%, the communication range could be extended up to 900 km. To extend communication ranges and improve system performance, it is essential to enhance transmitted power, improve receiver sensitivity, use larger optics apertures (if the design allows it), and optimize beam divergence.