Designing a Lightweight Multilayer EMI Shield for Protecting CubSat Electronics in 1-8GHz Range

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Abstract

Electromagnetic Interference (EMI) poses a significant challenge for CubeSats due to the high density of internal electronics. This project focuses on designing a lightweight, multi-layered shield, providing a robust advantage by protecting components without adding excessive weight to the satellite. During the structural development phase, we implemented a shielding design that integrates aluminum, copper, foam, and carbon fiber to block electromagnetic waves through both absorption and reflection mechanisms. The design was simulated using CST Studio Suite, and the experimental results were validated using ESP32 modules. The findings demonstrate that a 0.45 mm thick shield successfully reduced signal strength from -53 dBm to -97 dBm at a frequency of 2.4 GHz. These results prove that multi-layered shielding is an effective and optimal solution for weight-sensitive applications, ensuring the protection of electronics in space environments.

Introduction / Background

The rapid advancement of high-density electronic packaging in modern CubeSats operating in the 1–8 GHz range has significantly heightened their susceptibility to Electromagnetic Interference (EMI), which poses severe risks to signal integrity and mission reliability. Although conventional thick metal enclosures offer effective shielding, their substantial weight imposes costly payload penalties for space launches. To overcome this challenge, modern aerospace engineering relies on lightweight multilayer shielding concepts. This scientific approach combines highly conductive metals—which primarily block electromagnetic waves through reflection—with advanced carbon-based fabrics. Carbon fabric plays a critical role in this synergy; due to its unique structural properties, it acts as an absorption medium that attenuates and dissipates trapped signals through internal multiple reflections. Utilizing this collaborative multilayer mechanism provides a vital pathway to achieving exceptional Shielding Effectiveness (SE) while maintaining the ultra-lightweight profile essential for space missions.

System Model / Methodology

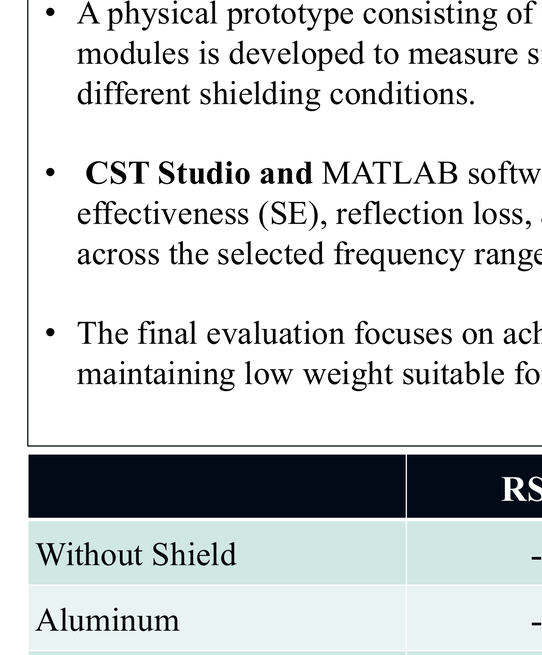
- The proposed system is designed to protect **CubeSat** electronics from electromagnetic interference (EMI) within the **1–8 GHz** frequency range using a lightweight multilayer shielding structure.
- The methodology includes comparing **three shielding configurations:**

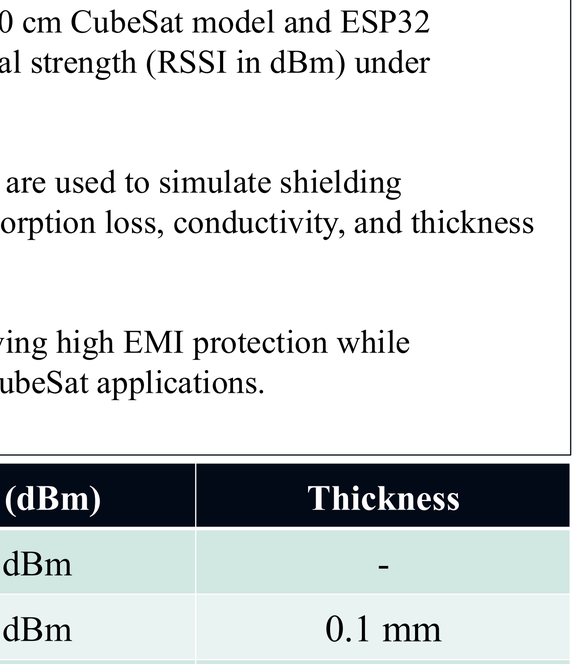
1. Without shielding 2.Single-layer shielding 3.Multilayer shielding

- Different materials such as copper, aluminum, and carbon fabric are used to evaluate shielding effectiveness and weight performance.
- A physical prototype consisting of a 20 cm CubeSat model and ESP32 modules is developed to measure signal strength (RSSI in dBm) under different shielding conditions.
- **CST Studio and** MATLAB software are used to simulate shielding effectiveness (SE), reflection loss, absorption loss, conductivity, and thickness across the selected frequency range.
- The final evaluation focuses on achieving high EMI protection while maintaining low weight suitable for CubeSat applications.

	RSSI (dBm)	Thickness
Without Shield	-53 dBm	-
Aluminum	-60 dBm	0.1 mm
Copper Only	-64 dBm	0.1 mm
Carbon Fabric Only	-76 dBm	0.25 mm
Proposed Multilayer Shield	-97 dBm	0.45 mm

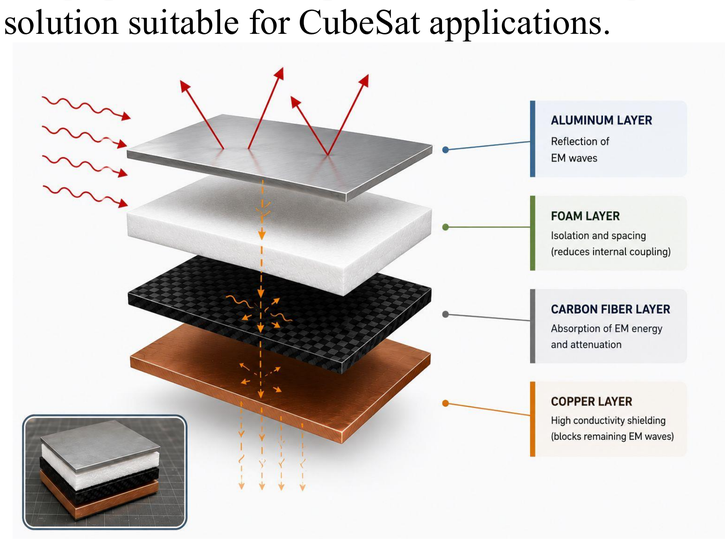
Table 1. RSSI Measurements at 2.4 GHz





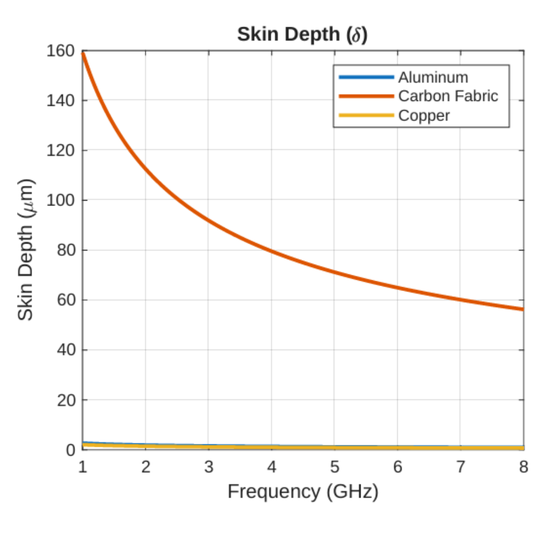
Proposed Solution / Main Idea

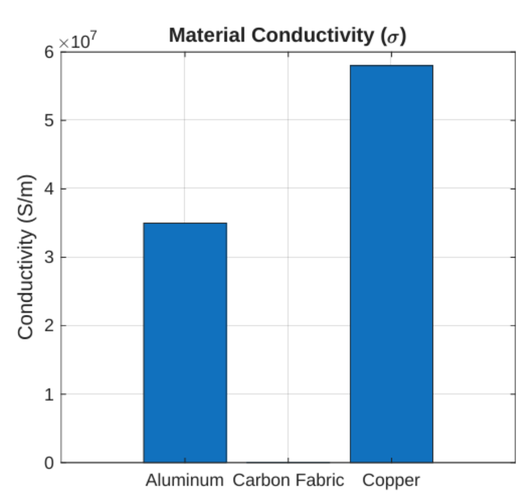
- A lightweight multilayer EMI shielding structure was developed to protect CubeSat electronics operating in the 1-8 GHz frequency range.
- The proposed design combines aluminium, foam, carbon fibre, and copper layers to improve electromagnetic wave attenuation through reflection and absorption mechanisms.
- Aluminium and cover layers enhance conductivity and wave reflection, while carbon fibre contributes to lightweight absorption performance. The foam layer reduces internal coupling affects and provides structural spacing.
- Experimental testing using ESP32 modules and RSSI measurements was conducted to evaluate shielding performance for individual layers and complete multilayer structure.
- MATLAB analysis, experimental RSSI measurements, and CST Studio simulations were utilized to evaluate shielding effectiveness and electromagnetic behavior across the selected frequency range.
- The final design provides a compact, low-cost, and lightweight shielding solution suitable for CubeSat applications.

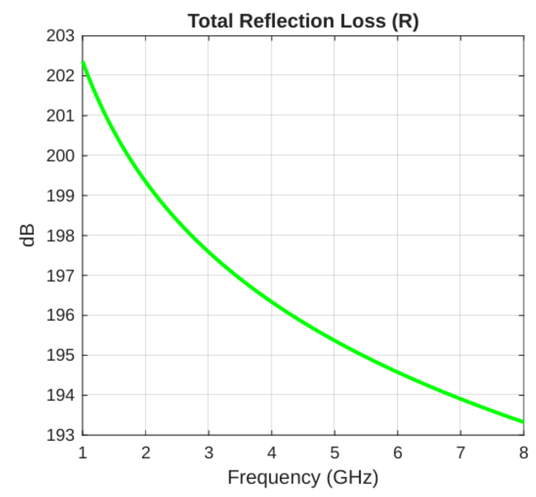


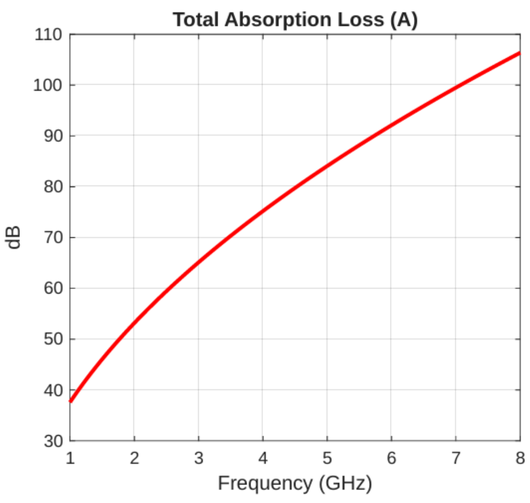
Results / Simulation / Discussion

The effectiveness of the proposed multilayer shield was evaluated by measuring the Received Signal Strength Indicator (RSSI) at 2.4 GHz and comparing it against single-material baselines.
Copper exhibits the highest conductivity 5.8×10^7 S/m followed by Aluminum, providing a strong reflective barrier, while the Carbon Fabric enhances absorption.
Simulation vs. Hardware: Measured SE at 2.4 GHz was ~45 dB, closely matching the CST simulation trend. **Frequency Performance (1-8 GHz):** Simulation shows that Absorption Loss (A) is the dominant mechanism at higher frequencies, exceeding 100 dB at 8 GHz**. Design Validation:** The correlation between the -97 dBm (measured) and -87 dBm (simulated) confirms the reliability of the multilayer design.









Conclusions

This project developed a lightweight multilayer EMI shield for CubeSat electronics operating in the 1–8 GHz range. By combining aluminum, copper, carbon fabric, and foam layers, the proposed design improved shielding performance through reflection and absorption while maintaining low weight. Simulation and experimental RSSI results confirmed that the multilayer structure provides more effective EMI protection than single-layer shielding. Future work may focus on optimizing materials, thickness, and testing under real space conditions.

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