# EBG Cloaking for Antenna Transparency in Compact Satellite-Based Systems

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***Abstract*—Electromagnetic scattering from metallic VHF monopoles placed near higher–frequency apertures is a recurrent integration issue in compact LEO spacecraft. A thin, sleeve–type electromagnetic–bandgap (EBG) cloak, replicated only along the monopole axis, is introduced to preserve the VHF function while suppressing its visibility to the higher–frequency antenna. Compared with conventional two– or three–dimensional EBG skins, the one–dimensional replication simplifies geometry and fabrication. Full–wave results indicate that the array pattern with the cloaked monopole is practically indistinguishable from the monopole–free baseline, while the $\sim$2 dB realized–gain loss induced by the bare monopole is recovered. The approach enables lightweight, fabrication–friendly electromagnetic coexistence in tightly packed satellite payloads.**

***Index Terms*—antenna cloaking, CubeSat integration, electromagnetic bandgap (EBG), interference mitigation, satellite antennas.**

## I. Introduction

In recent years, the rapid growth of Low Earth Orbit (LEO) satellite constellations [1] has driven the demand for compact, lightweight, and cost-efficient spacecraft. To achieve this, manufacturers minimize mass and volume by integrating multiple subsystems within constrained physical dimensions. However, such high levels of integration can lead to undesired electromagnetic interactions, whereby structural or functional components interfere with the radiation characteristics of on-board antennas. These interactions can degrade antenna performance, distort radiation patterns, and ultimately compromise communication or navigation capabilities.

This study focuses on closely spaced antennas within small satellites. In CubeSats, VHF antennas are typically implemented as monopoles protruding from the satellite surface [2], [3], [4], [5]. Within the iTEAM research group, designs of this type have been developed, such as the one illustrated in Fig. 1. In this configuration, the metallic elements of the VHF monopole may align with the main propagation direction of a higher-frequency patch antenna mounted on one of the satellite faces, such as those presented in [6], [7], [8], thereby obstructing and scattering the electromagnetic field. As a result, the radiation pattern of the higher-frequency antenna can be distorted, even when both systems operate independently.

To mitigate scattering produced by metallic elements, several solutions based on electromagnetic bandgap (EBG) technologies have been proposed [9], [10], [11], [12], [13], [14]. Following this line, a thin-layer EBG-based structure is considered that can be placed around the metallic parts of the VHF antenna. The structure enables efficient radiation at the VHF operating frequency while attenuating or suppressing higher-frequency components, effectively rendering the metallic elements electromagnetically "invisible" to the higher-frequency signals. Unlike conventional EBG implementations, the design requires replication in a single dimension along the monopole, which simplifies geometry and potential manufacturing. For clarity, a specific scenario is analyzed: a $2 \times 2$ patch antenna array with a metal wire inclined at $45°$ crossing the antenna radiation region at a distance of 100 mm, as shown in Fig. 2.

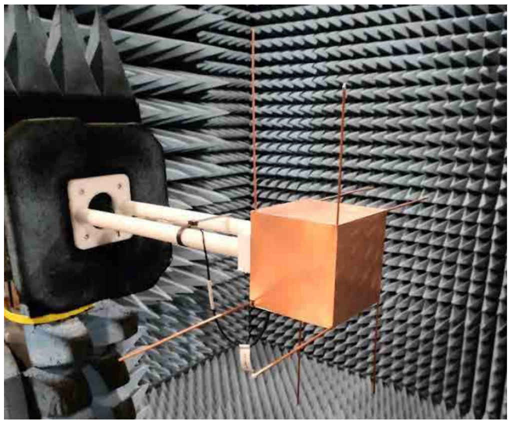


Fig. 1. VHF antenna integrated in a CubeSat structure [5].

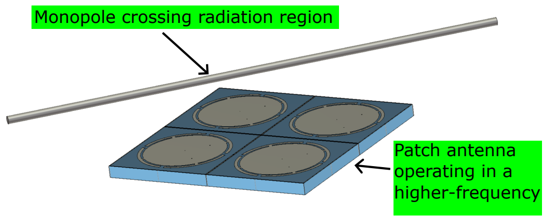
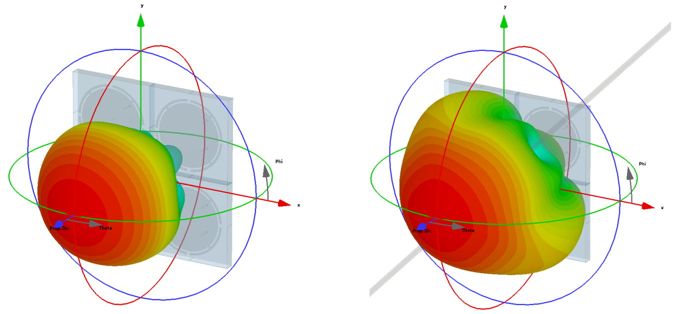



Fig. 2. Simplified scenario considered in this paper, showing a $\lambda \times \lambda$ patch antenna with a monopole crossing its radiation region at a distance of 100 mm.

Section II presents a baseline mitigation approach based on monopole segmentation. Section III introduces the practical EBG cloak and assesses its performance. Section IV summarizes the conclusions and outlines directions for future work.



(a) (b)

Fig. 3. 3D radiation pattern of the patch array (a) without the monopole and (b) with the monopole in the radiation region.

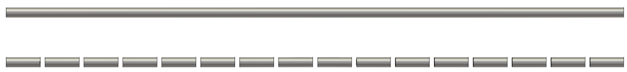


Fig. 4. Segmentation of the monopole to reduces the scattering.

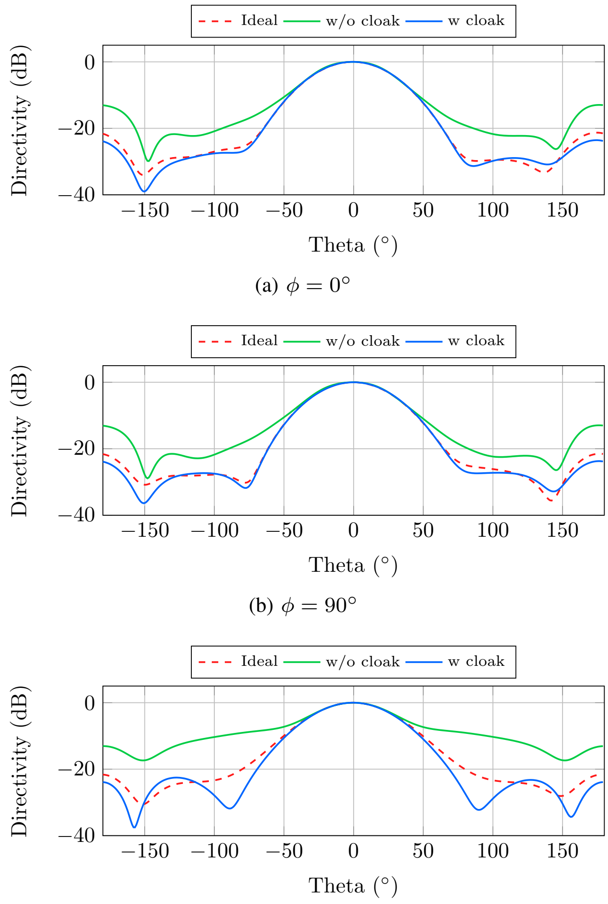
## II. Initial Approach for Monopole Interference Mitigation

When a metallic wire is placed in front of the antenna, the radiation pattern is evidently degraded, as shown in Fig. 3. It can also be observed that the most affected plane corresponds to the direction perpendicular to the monopole orientation, $\phi = 135°$ in this case.

The initial approach to mitigate this interference consists of dividing the monopole into smaller segments, as shown in Fig. 4. This segmentation effectively reduces the electrical length of the wire with respect to the higher frequency. As shown in Fig. 5, this segmentation helps reduce the scattering effect, resulting in a radiation pattern that closely resembles the one obtained without the monopole in front of the antenna.

To better understand the interaction mechanism between the monopole and the patch antenna, the surface current distribution was analyzed. As shown in Fig. 6, the continuous monopole exhibits a sinusoidal current profile, with minima at the edges and a maximum at the center. When segmented, this overall behavior is preserved, although each section develops its own local sinusoidal distribution, with higher current levels concentrated in the central segments.

There is a trade-off between reducing the scattering of the monopole and maintaining a practical structural design, as reducing the unit length increases the number of required segments. To evaluate this balance, a small parametric study was conducted to analyze the effect of decreasing the unit length. As shown in Fig. 7, although a $\lambda/4$ unit delivers an acceptable result, in the $\phi = 135°$ plane the sidelobe level is 10 dB worse than without segmentation. From $\lambda/8$ onward, the resulting radiation pattern closely matches the reference case across all cuts, representing an optimal compromise between electromagnetic performance and implementation complexity.




(a) $\phi = 0°$

(b) $\phi = 90°$

(c) $\phi = 135°$

Fig. 5. Comparison of the radiation patterns of the antenna in three configurations: without monopole, with monopole, and with segmented monopole.$\phi = 0°$ (a), $\phi = 90°$ (b) and $\phi = 90°$ (c).

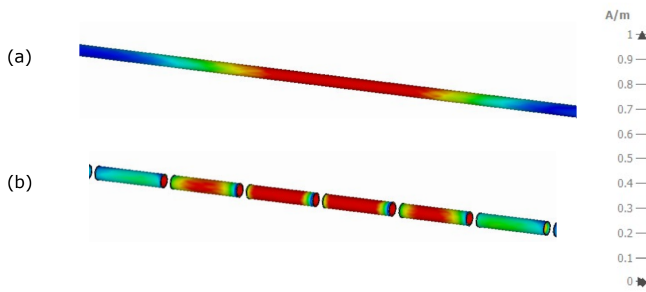
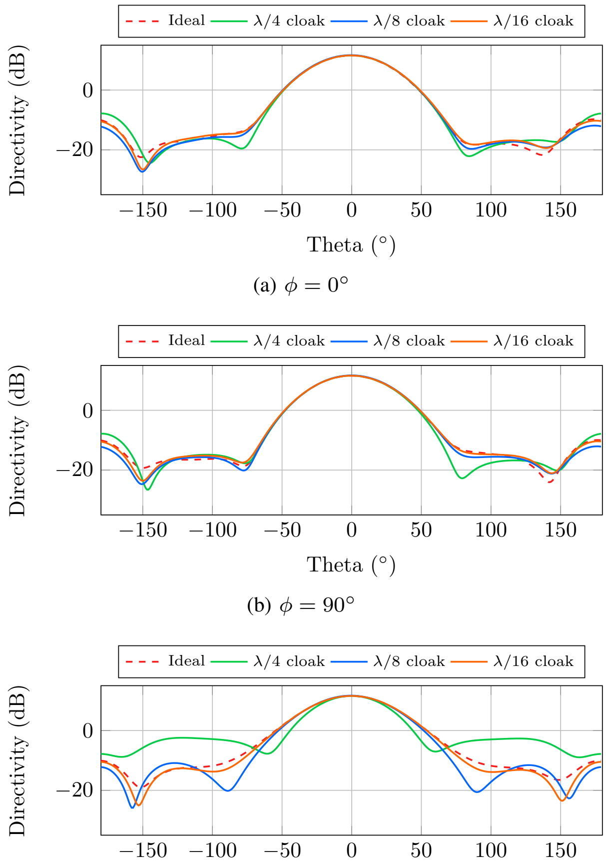



Fig. 6. Surface currents on the monopole (a) and on the monopole segmented (b).

## III. Design and Performance of the EBG Cloak

Although the segmented monopole demonstrates promising results, it is not suitable for practical implementation. To translate this concept into a realizable design, an EBG-based cloak was developed to enclose the monopole. The cloak consists of a conducting tube short-circuited at one end, as shown in Fig. 8. These tubes behave as transmission-line sections; to replicate the behavior of the segmented wire, each unit must exhibit an open-circuit condition at its input impedance.




(a) $\phi = 0°$

(b) $\phi = 90°$

(c) $\phi = 135°$

Fig. 7. Radiation patterns for the segmented monopole, showing the effect of varying the unit length of the EBG structure at $\phi = 0°$ (a) and $\phi = 90°$ (b).

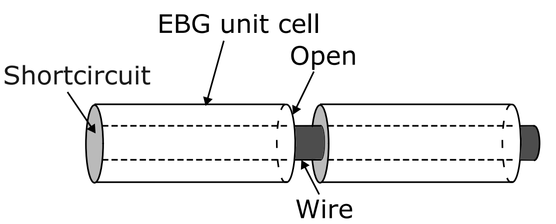
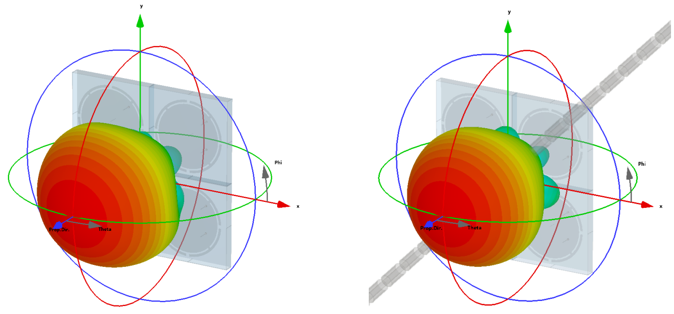



Fig. 8. EBG cloak unit cell configuration.

Equation (1) allows calculating the input impedance of each sleeve, where a high-impedance condition is achieved when $l = \lambda_g/4$, where $\lambda_g = \lambda_0/\sqrt{\varepsilon_r}$, with $\lambda_0$ being the wavelength in free space and $\varepsilon_r$ the substrate relative permittivity. For this preliminary simulation, a dielectric with $\varepsilon_r = 4$ was used, resulting in a unit length of $\lambda_0/8$. These units are periodically replicated along the entire VHF monopole, forming the complete cloak structure. This configuration introduces a bandgap around the desired frequency, effectively suppressing unwanted coupling and preserving the radiation characteristics of the higher-frequency antenna.

$$Z_{in} = jZ_0 \tan(k_g l) \tag{1}$$



(a) (b)

Fig. 9. 3D radiation pattern of the patch array (a) without the monopole and (b) with the monopole cloaked.

TABLE I
COMPARISON OF DIRECTIVITY AND EFFICIENCY WITH AND WITHOUT THE EBG CLOAK.

| | Ideal | Without cloak | With cloak |
|---|---|---|---|
| Directivity (dBi) | 11.85 | 10.32 | 11.65 |
| Efficiency (dB) | -0.73 | -1.46 | -0.59 |

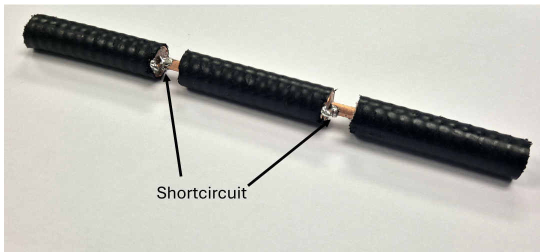



Fig. 10. In-house prototype of the EBG cloak based with a coaxial cable

As shown in Fig. 9, the proposed EBG cloak successfully restores the radiation pattern of the patch antenna, effectively mitigating the scattering introduced by the presence of the wire. Furthermore, placing the VHF antenna in front of the patch originally caused a gain degradation of approximately 2 dB, due to reduced directivity and efficiency. This loss is fully recovered after implementing the EBG cloak, as summarized in Table I.

An in-house prototype was fabricated using a rigid-core coaxial cable, where sections of the outer conductor and dielectric were periodically removed to emulate the unit cells of the proposed EBG cloak, as shown in Fig. 10.

## IV. Conclusion

A one-dimensionally replicated, sleeve-type EBG cloak has been demonstrated to restore the radiation pattern and realized gain of a high-frequency array in the presence of a co-located VHF monopole. The proposed concept achieves near-ideal transparency while preserving the functionality of the low-frequency antenna, offering a lightweight and fabrication-friendly solution for small spacecraft. While the current study is simulation-based, the results are highly encouraging. Future work will focus on prototyping, experimental characterization, and integration into CubeSat platforms.

## V. Acknowledgment

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