# MLI-Integrated Compact High Gain Antenna for mmWave Satellite Communication Systems


Ye-Bon Kim
*Satellite Navigation Research Section*
*Electronics and Telecommunications Research Institute*
Daejeon, South of Korea
ybk1m@etri.re.kr

Seunghwa Jung
*Satellite Navigation Research Section*
*Electronics and Telecommunications Research Institute*
Daejeon, South of Korea
shjung@etri.re.kr

Sanguk Lee
*Satellite Navigation Research Section*
*Electronics and Telecommunications Research Institute*
Daejeon, South of Korea
slee@etri.re.kr

Yoola Hwang
*Satellite Navigation Research Section*
*Electronics and Telecommunications Research Institute*
Daejeon, South of Korea
ylhwang@etri.re.kr



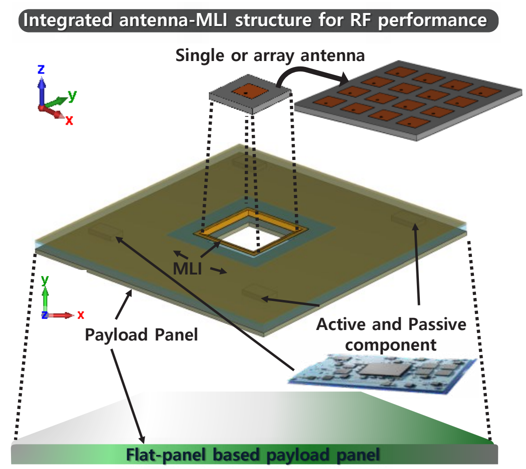
***Abstract*—This paper proposes a novel compact high-gain mmWave antenna design that integrates MLI into a flat-panel patch antenna structure to improve the performance of LEO satellite communication systems. As demand for higher data transmission rates drives the move toward higher frequency bands, there is a growing need for compact, low-cost, and easily integrable antenna solutions. Conventional satellite antennas often rely on large patch arrays and complex beamforming networks, which increase system complexity, size, and cost. To overcome these challenges, the proposed design leverages the structural influence of MLI to enhance the gain of a single patch antenna, reducing the need for large arrays while maintaining high-performance communication capabilities.**



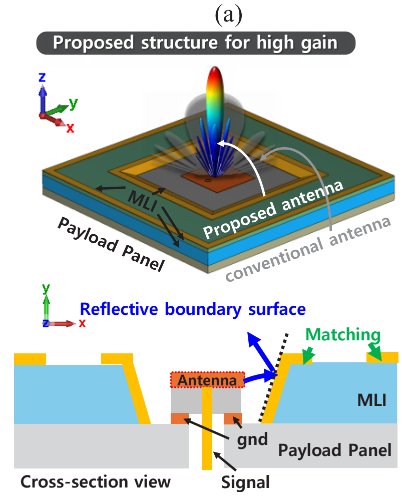
***Keywords*—mmWave LEO satellite communication, MLI, Compact antenna, Beamforming antenna, High gain antenna**


## I. INTRODUCTION

With the emergence of next-generation satellite communication systems such as Low Earth Orbit (LEO) satellites, the refinement of beamforming antenna technologies is rapidly progressing to meet new commercial demands. In particular, in high-frequency bands like millimeter waves (mmWave), patch antennas are widely used due to their flat-panel structure and ease of integration. However, they suffer from a fundamental limitation of low gain [1]. To overcome this, large antenna arrays are typically employed, which in turn increases system complexity and module size. If sufficient gain can be achieved with a single patch antenna, the number of array elements can be reduced, enabling simpler and more compact system designs. This approach not only reduces design complexity but also minimizes manufacturing costs and system volume—key advantages in spaceborne applications. Meanwhile, Multilayer Insulation (MLI) is extensively used in satellite systems for thermal management and protection against harsh environments. In particular, MLI plays a critical role in thermal control and electromagnetic interference (EMI) reduction around antennas and RF active/passive components [2]. As shown in Fig. 1(a), MLI has traditionally been regarded as a passive thermal shielding structure. However, its electromagnetic influence on antenna radiation its



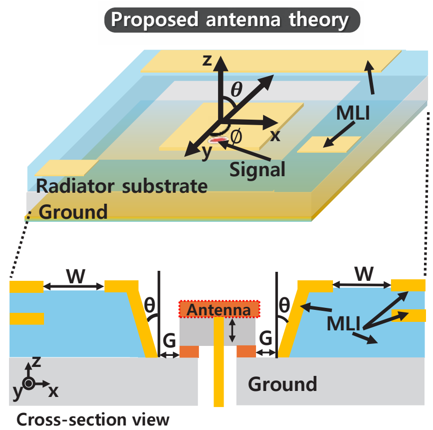

(a)



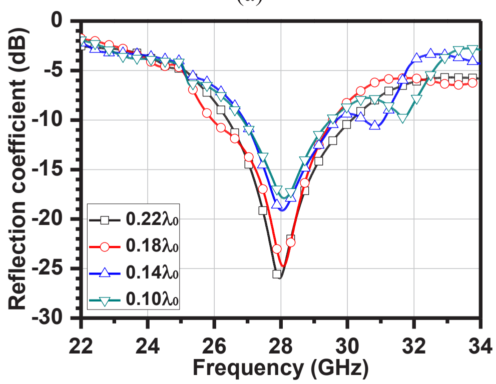

(b)

Fig. 1. Integrated antenna-MLI structure for RF performance: (a) Overall configuration, and (b) proposed antenna concept

characteristics has not been fully explored. A novel antenna design approach is introduced in this paper, which actively leverages the structural effects of MLI on radiation performance, as illustrated in Fig. 1(b), to enhance the gain of




(a)




(b)

Fig. 2. Simulated results of the proposed MLI-integrated high gain antenna: (a) Antenna configurations, and (b) spacing between the antenna and MLI to ensure RF performance.

a flat-panel antenna suitable for integration on satellite panels.

## II. PROPOSED ANTENNA DESIGN AND ANALYSIS

Fig. 2(a) illustrates the proposed MLI-based sharp-beam antenna structure applied to a flat-panel patch antenna, which is compatible with conventional satellite panel installations. In this configuration, MLI is formed around the antenna radiator, and electromagnetic fields are reflected through the inclined surfaces and the open conductor gaps of the MLI, thereby producing a highly directive radiation pattern. The dielectric properties of the MLI can influence the distribution of the electromagnetic field. In particular, by spacing the outermost conductive layer of the MLI from the antenna, both radiation performance and thermal characteristics can be improved. The key design parameters considered include the gap G between the radiator and the outermost MLI conductor, the inclination angle θ of the MLI's outer slope, and the spacing W between the MLI outer conductors. Increasing the length of the inclined surface allows reflected fields to be focused more effectively, thereby enhancing antenna gain. The dielectric materials of the antenna radiator and the MLI may be either the same or different. The open region in the outermost MLI layer can vary in shape and position depending on the radiation characteristics of the antenna, and may be configured differently according to specific design requirements. In this paper, the antenna is designed for the

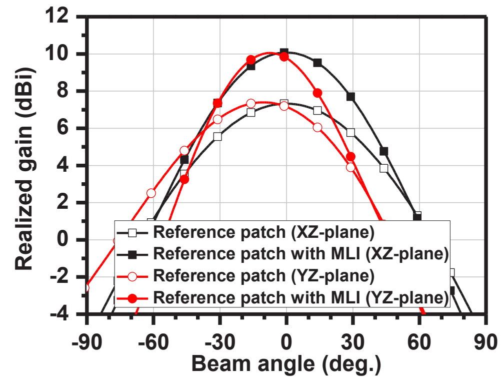



Fig. 3. Simulated radiation patterns of the MLI-based conventional patch and the proposed antenna at 28 GHz.

mmWave 28 GHz band, using a Taconic TLY-5 substrate. The MLI material is selected based on a dielectric constant of 3, which is commonly used in thermal insulation applications. Fig. 2(b) shows the reflection characteristics of the antenna as a function of the spacing W of the outermost MLI conductor. Simulation results confirm that W= 0.18 $\lambda_0$, provides an optimal trade-off between reflection loss and thermal protection performance. Figure 3 compares the gain performance of a conventional patch antenna and the proposed MLI-based patch antenna structure under the optimized condition. Based on the 2D beam pattern in the xz- and yz-planes, the gain improved from approximately 7 dBi to 10.5 dBi, showing an enhancement of about 3.5 dBi. These results indicate that the proposed antenna structure enables high-gain performance even with a reduced number of antenna elements when expanded into an array configuration.

## III. CONCLUSION

This paper proposes a novel technique that enhances the gain of compact antenna beam patterns by utilizing a flat-panel antenna suitable for mmWave satellite communication platforms, in conjunction with MLI, which is widely used for thermal management. By modifying the structure and application method of the MLI, the antenna beam pattern can be optimized. This approach enables the optimization of system-level performance metrics such as effective isotropic radiated power (EIRP) or gain-to-noise-temperature (G/T), allowing for a more efficient hardware configuration. Therefore, the proposed integrated structure of MLI and antenna is expected to significantly improve satellite communication performance.

## ACKNOWLEDGMENT

This work was supported by the Korea Agency for Infrastructure Technology Advancement (KAIA) Development (RS-2022-00198024, SBAS Payload Development) funded By the Ministry of Land, Infrastructure and Transport (MOLIT, Korea)

## REFERENCES

[1] F. S. Prol *et al.*, "Position, Navigation, and Timing (PNT) Through Low Earth Orbit (LEO) Satellites: A Survey on Current Status, Challenges, and Opportunities," *IEEE Access*, vol. 10, pp. 83971-84002, 2022.

[2] A. Mazzinghi, M. Sabbadini, and A. Freni, "Enhanced RF behavior multi-layer thermal insulation," Scienfitic Reports, vol. 8, 2018.