# COMS L-대역 송신 안테나 합성 이득 해석

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# Combined Gain Analysis of L-band Transmit Antenna in COMS

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요 약

통신해양기상위성(COMS)은 통신, 해양, 기상 탑재체를 장착하고 3개의 임무를 수행하는 복합 정지궤도 위성이다. COMS는 기상 탑재체 MI와 해양 탑재체 GOCI가 관측 후 전송하는 원시 데이터를 지상국에 전송하고 지상국에서 처리된 기상 데이터를 최종 사용자국에 중계하는 기능을 갖는 기상해양자료송수신계(MODCS)가 있다. 여기서 시스템 관점에서 관측 데이터 SD 신호와 중계 신호를 전송하는 L-대역 송신 안테나는 MI 탑재체와 기상탑재체와 함께 COMS 위성의 지구패널에 장착시 안테나 합성 이득을 예측하도록 요구되어진다. 우선 주어진 요구 사항에 대해 L-대역 송신 안테나 설계 및 해석이 수행된다. 설계된 안테나를 지구패널에 장착 후 3가지 다른 해석 방법을 사용하여 합성이득 해석이 수행된다. 얻어진 안테나 이득들은 3가지 다른 해석 방법 사이에 매우 유사한 결과를 제공하는 것을 확인하였으며 최종적으로 0.5 dB 이하의 안테나 이득 열화가 추정되어진다.

Key Words : geostationary satellites; payloads; large structure; transmit antennas; combined gain.

ABSTRACT

The COMS (Communication Ocean Meteorological Satellite) is a hybrid geostationary satellite including communication, ocean, and meteorological payloads. The COMS includes the MODCS (Meteorological and Ocean Data Communication Subsystem) which provides transmitting the raw data collected by meteorological payload called MI (Meteorological Imager) and ocean payload named GOCI (Geostationary Ocean Color Imager) to the ground station, and relaying the meteorological data processed on the ground to the end-user stations. Here, for the L-band transmit antenna transmitting SD (Sensor Data) signal and the processed signal, from the system point of view, it is required to estimate the combined antenna gain when the L-band transmit is placed with MI and GOCI payloads on the earth panel of COMS. First of all, the L-band transmit horn is designed and analyzed for the requirements given, and then after placing it on the earth panel, the combined gain analysis is performed using three different analysis methods. It's shown that the obtained gain patterns are very similar among three different analysis methods. Finally the antenna gain degradation of less than 0.5 dB is estimated.

## I. Introduction

The COMS (Communication Ocean Meteorological Satellite) is a hybrid satellite including communication, ocean, and meteorological payloads. The main missions of COMS are the weather and ocean monitoring and satellite communication. The COMS includes the MODCS (Meteorological and Ocean Data Communication Subsystem) which provides transmitting the raw data collected by meteorological payload called MI (Meteorological Imager) and ocean payload named GOCI (Geostationary Ocean Color Imager) to the ground station, and relaying the meteorological data processed on the ground to the end-user stations. MODCS consists of two channels: one channel for SD (Sensor Data) signal which formats the raw data

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according to CCSDS (Consultative Committee for Space Data Systems) recommendation [1], QPSK modulates, amplifies and transmits its signal to the ground station; the other channel for MPDR (Meteorological Processed Data Relay) signal which relays to the end-user stations the ground-processed meteorological data in the data format of LRIT/HRIT (Low Rate Information Transmission/High Rate Information Transmission) recommended by CGMS (Coordination Group for Meteorological Satellite) [2]. The L-band transmit antenna transmitting SD signal and LRIT/HRIT signal is needed to have an antenna with a global beam pattern and relatively high gain. The L-band transmit antenna is installed on the earth panel along with MI payload and GOCI payload. In this case, the L-band antenna gain is combined with the interference beam scattered by the neighboring structures, mainly MI and GOCI payloads. As a result, the stand-alone L-band transmit antenna gain is degraded to some extent. This degradation should be included in the system link budget. To estimate this antenna gain degradation, first of all, we model and design the L-band transmit antenna with the L-band antenna specification given. Using the L-band transmit antenna pattern obtained, the combined gain patterns reflecting the gain degradation by structures using three different analysis methods are presented. The obtained gain patterns are very similar among three different analysis methods. Finally the antenna gain degradation is estimated.

## Ⅱ. Design of L-band Transmit Antenna

### 1. Key Requirements of L-band Transmit Antenna

As the L-band transmit antenna is installed on the same earth panel with MI and GOCI payloads which have relatively high height, the L-band antenna structure is required to have the similar height as those of MI and GOCI payload. The finally selected antenna type is a circular horn which provides a high level of mechanical stability, and also has many of satellite heritages.

The key requirements of L-band transmit antenna are presented in Table 1. The polarization is specified as linear, the center frequency operated is 1691 MHz which corresponds to the center of three transmitting signals. The occupied bandwidth is 14 MHz, and the beamwidth is defined as 17.4° to cover the service area including the user station having elevation angle of 10°. The gain of 15.3dBi is derived as a minimum so that the link margin of 3 dB is ensured, and the reflection loss is more than 21 dB. Lastly, to minimize the effect of cross-polarization, the cross-polarization discrimination (XPD) is defined more than 30 dB.

Table 1. Key requirements

| Item | Requirements |
|---|---|
| Polarization | Linear |
| Operating requency (Bandwidth) | 1684-1698MHz (14 MHz) |
| Beamwidth | 17.4° |
| Gain | >15.3 dBi |
| Reflection loss | >21 dB |
| XPD | >30 dB |

### 2. L-band Transmit Antenna Design and Analysis

The antenna was designed to meet the design parameters specified in Table 1. The horn antenna configuration obtained is shown in Figure 1. The detailed design method is well described in [3]. The commercial tool used is FEKO [6]. The antenna largely consists of conical type of horn section, rectangular-to-circular waveguide transition section, feeding probe section.

As shown in Figure 2, the reflection loss higher than the specification of 21 dB is obtained over the bandwidth of 40 MHz which is bigger than the specified bandwidth of 14 MHz.

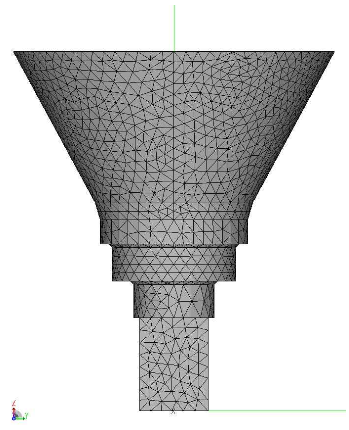

Figure 1. Antenna configuration

Figure 3 shows the gain radiation pattern obtained in the polar coordinate for the phi of 0°, 45°, 90° at the center frequency of 1691 MHz. The max gain is 17.4 dBi.

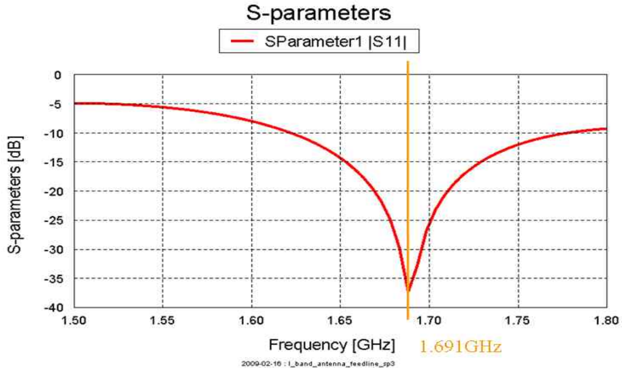


Figure 2. Reflection loss

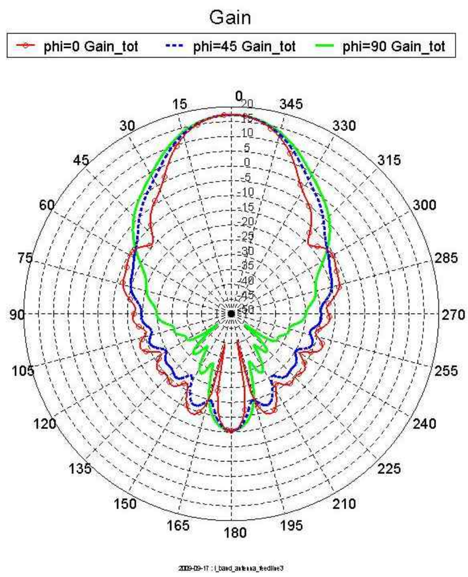


Figure 3. Radiation pattern in polar coordinate

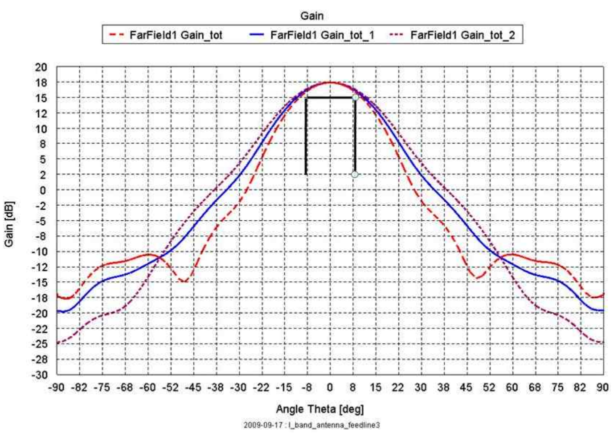


Figure 4. Radiation pattern in rectangular coordinate

Figure 4 shows the gain pattern from -90° to 90° in rectangular coordinate. It is found that the beamwidth obtained well meets the required one, 17.4°. It also shows that the radiation pattern has good axial symmetry. This pattern will be used as a source to estimate the gain reduction introduced by placing the horn antenna on the earth panel of the satellite.

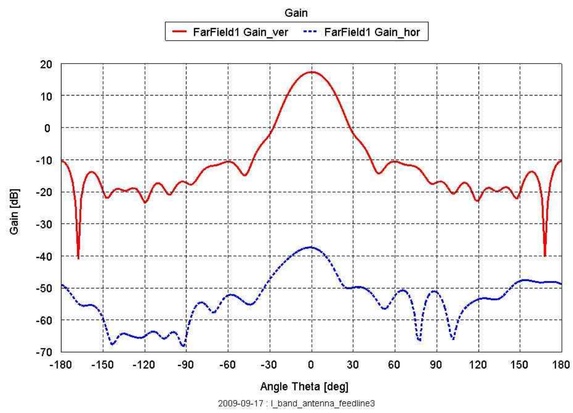


Figure 5. Cross-polarization discrimination

Lastly, Figure 5 shows the result of the cross-polarization discrimination. It is shown that the XPD requirement of more than 30 dB is well met.

## Ⅲ. Combined Antenna Gain Analysis

The L-band transmit antenna installed on COMS satellite providing the global beam service has relatively high level of gain of more than 15.3 dBi over the bandwidth, and also has low level of back radiation. When considering this kind of beam characteristics, the solar array attached to the COMS satellite can be removed to reduce the simulation time. The final satellite model to be analyzed is shown in Figure 6.

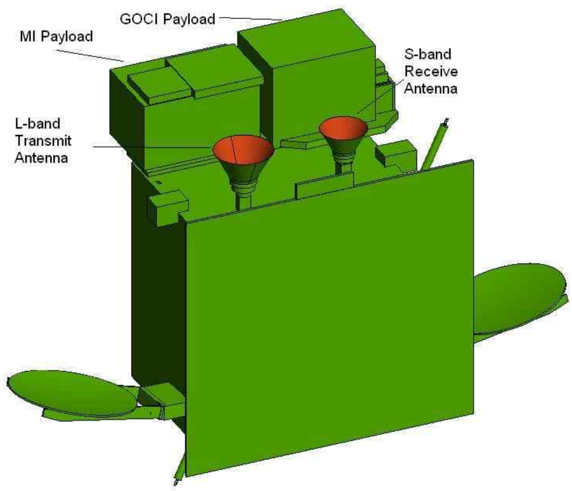


Figure 6. Satellite model to be analyzed

The left one on the earth panel is the L-band horn antenna to be analyzed, the right one is the S-band receive horn antenna which is used to receive the uplink signal from the ground station. As shown in Figure 6, the L-band horn is very close to both MI payload and GOCI payload which can be the main disturbance against the original L-band horn antenna radiation. There are several numerical methods to efficiently deal with the electrically large structures such as the aircrafts, ships, and satellites. To verify that the results are almost similar to each other, three different methods such as UTD (uniform geometrical theory of diffraction), PO (Physical Optics) and MLFMM (Multilevel Fast Multipole Method) are adopted [4], [5].

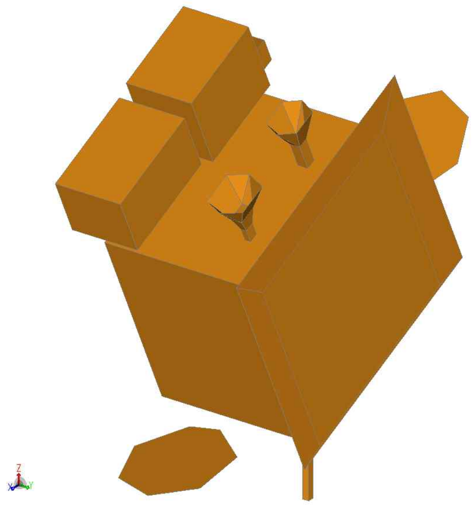

Figure 7. Reshaped satellite model for UTD method

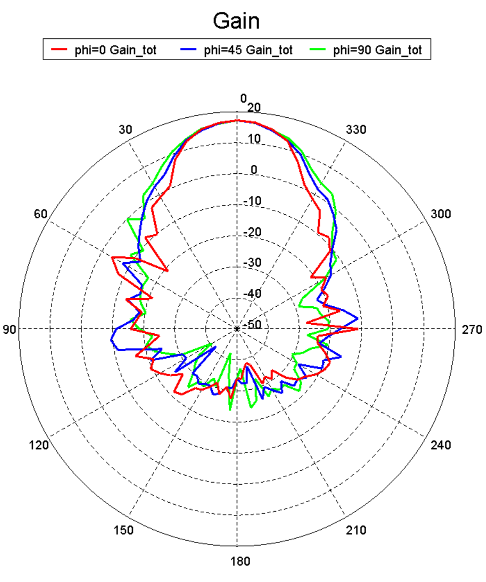


Figure 8. Combined gain pattern by UTD method

Firstly, the UTD method is applied. The original satellite model shown in Figure 6 directly can't be used because the UTD method requires the polygonal shape. The electrically small part of the original satellite model is trimmed. The reshaped satellite model for UTD is shown in Figure 7. The L-band antenna structure is removed from the UTD satellite model, and then the obtained far-field pattern in Figure 3 is applied on that place.

Figure 8 shows the gain radiation pattern obtained by use of UTD in the polar coordinate for the phi of 0°, 45°, 90° at the center frequency of 1691 MHz.

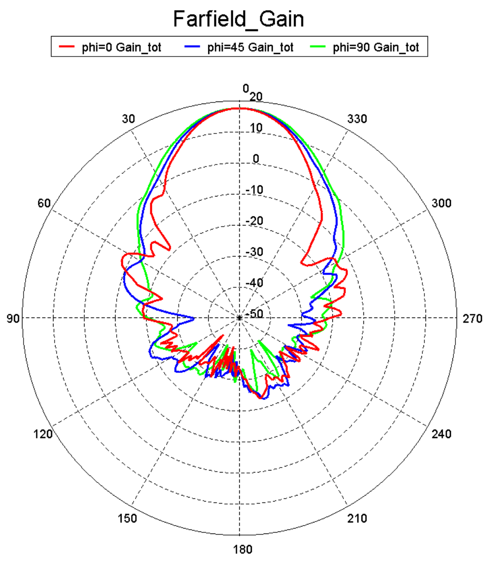


Figure 9. Combined gain pattern by MLFMM method

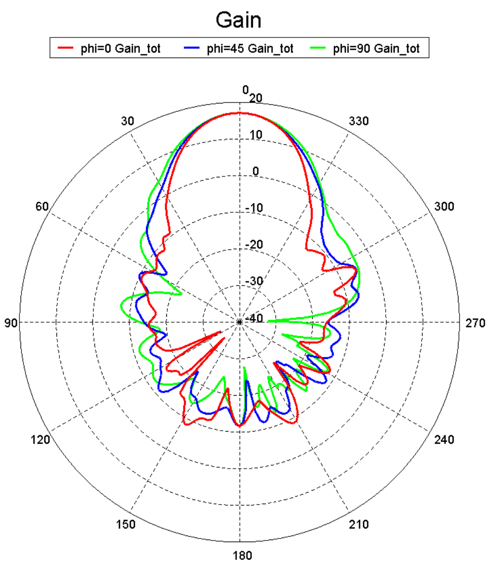


Figure 10. Combined gain pattern by PO method

The next method called MLFMM is applied to the satellite model of Figure 6. There is no need to reshape and trim the satellite model. Figure 9 shows the gain radiation pattern obtained in the polar coordinate for the phi of 0°, 45°, 90° at the center frequency of 1691 MHz.

Lastly the PO method is applied to Figure 6. In the same way as UTD, the L-band antenna structure is removed from the satellite model, and then the obtained far-field pattern in Figure 3 is used as a radiation source. Figure 10 shows the gain radiation pattern obtained by use of PO method in the polar coordinate for the phi of 0°, 45°, 90° at the center frequency of 1691 MHz.

It is shown in Figure 11 that the results of three methods are very similar to each other. The shapes of the main beams obtained with three different methods are almost the same as one of the stand-alone antenna main beam over the beamwidth of 17.4°. The variation of the combined gain in comparison to the stand-alone antenna gain over the the beamwidth of 17.4° is less than 0.5 dB. As already expected due to the directional beam characteristics of the L-band horn antenna, the gain degradation by the mechanical structures of MI and GOCI payloads was found to be small.

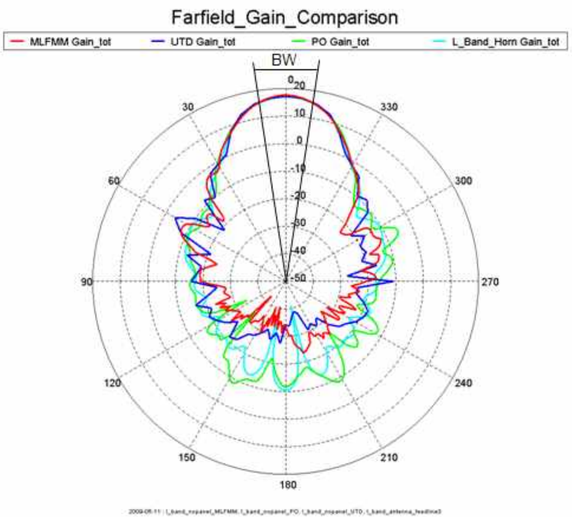


Figure 11. Comparison of three combined gain patterns

The computational platform used for three analysis methods is two quad-core Intel Xeon CPU E5430 2.66 GHz. The computation time and the used memory is shown in Table 2. As expected, the full-wave simulation method MLFMM requires much higher computation time and computer RAM memory than the PO and UTD methods. From the viewpoint of accuracy, the MLFMM is the best, but the more computation resources are needed compared to the PO and UTD methods.

Table 2. Computation time and the used memory

| Item | Computation time | Used memory |
|---|---|---|
| MLFMM | 5.04 hour | 8.35 GByte |
| PO | 0.48 hour | 114.13 MByte |
| UTD | 1.83 hour | 2.30 MByte |

In conclusion, the gain degradation of 0.5 dB through the combined antenna gain analysis using three different analysis methods was included to consider the worst case of the system communication link budget.

## Ⅳ. Conclusions

Since the L-band transmit antenna transmitting SD signal and LRIT/HRIT signal is installed on the earth panel along with MI payload and GOCI payload, the L-band antenna gain is combined with the interference beam scattered by the neighboring structures, mainly MI and GOCI payloads. Thus, the stand-alone L-band transmit antenna gain is degraded to some degree. Firstly with the L-band antenna specification given, the L-band transmit antenna pattern was obtained, and then the combined gain patterns including the gain degradation by structures using three different analysis methods were presented. The obtained combined gain patterns are very similar among three different analysis methods. Finally the antenna gain degradation was estimated to be less than 0.5 dB which was used in the system link budget. The methods applied here will be utilized for the optimized antenna placement on the follow-on satellites

## References

[1] CCSDS 701.0-B-3, “Advanced Orbiting Systems, Networks and Data Links: Architectural Specification”, June 2001.

[2] EUMETSAT, “LRIT/HRIT Global Specification”, August 1999.

[3] P. D. Potter, “A new horn antenna with

suppressed side lobes and equal beamwidths," Microw. J., pp. 71-78, Jun. 1963.
[4] D. McNamara, C. Pistorius, and J. Malherbe, Introduction to the Uniorm and Geometrical Theory of Diffraction, Artech House, Boston
[5] J. Yuan, Y. Qiu, J. L. Guo, Y. L. Zou, and Q. Z. Liu, "Fast analysis of antenna mounted on electrically large composite objects," PIER 80, pp. 29-44, 2008.
[6] FEKO Suite 5.4, [Online]. Available: http://www.feko.info

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