# Ka 대역 안테나 서브시스템 포인팅 에러 분석

이 용 덕*, 최 장 섭*, 박 재 우*, 이 성 팔*

# Ka-band Antenna Subsystem Pointing Variation Analysis

Yong Deuk Lee*, Jang Sup Choi*, Jae Woo Park*, Seong Pal Lee*

요 약

한국전자통신연구원은 2008년 말에 발사될 예정인 통신해양기상위성에 탑재될 Ka대역 안테나서브시스템을 개발하고 있다. Ka대역 통신용 안테나 서브시스템은 위성체의 동,서 판넬에 각각 하나씩 구성되어 있다. 이를 추진하기 위하여 한국전자통신연구원은 현재 대한항공㈜과 공동으로 통신위성 안테나 서브시스템을 설계하고 있다.

본 논문은 이득 변화 등과 같은 안테나 서브시스템 성능 규격을 검증하기 위하여 Ka 대역 반사판 포인팅 에러 분석에 대하여 기술한다. 수행된 분석은 열변형에 의한 반사판 표면 변형 데이터 이며 이를 Ticra로 빔패턴의 변화를 확인하였다.

**키워드 :** Ka대역 안테나 서브시스템, 포인팅 에러, 열변형, 빔패턴

ABSTRACT

ETRI has been developing the Ka-band Antenna subsystem for COMS(Communications, Ocean, and Meteorological Satellite) which will be launched at the end of 2008. The antenna subsystem employs the two parts: East Panel and West panel of spacecraft. ETRI in cooperation with domestic companies are under design phase for the antenna subsystem development.

This paper focuses on the Ka-band reflector pointing error analysis to verify the antenna subsystem performance specification, especially EOC gain variation etc. The analysis performed is that induced by reflector surface deformation as a result of thermo elastic distortion. Beam pattern variations are verified by the use of TICRA

**Key Words** : Ka-band antenna subsystem, Pointing error, Thermo elastic distortion, Beam pattern

## 1. Introduction

The Ka-band communication payload consists of satellite switching transponder and multibeam antenna subsystem. The Ka-band communications payload will provide high-speed multimedia services such as Internet via satellite, remote-medicine, and distance learning in the public communications network and communication services for natural disaster such as prediction, prevention, and recovery services in the government communications network. [1]The service lifetime of the Ka-band payload system will be at least 7 years to achieve two main missions described above[1]. The payload system will be operated in the geostationary orbit of 128.2°E longitudes. [1], [2] In this paper the antenna subsystem pointing analysis for Ka-band Communications Payload System(COPS) for Satellite Communication System(SATCOM) are presented.

* Global Area Wireless Technology Research Group, ETRI Yusong P.O. Box 106, Taejon 305-600, Korea
E-mail: ydlee@etri.re.kr, chaos@etri.re.kr, pjw@etri.re.kr, spallee@etri.re.kr

## 2. Antenna Configuration and RF Design

Figure 1 shows the configuration of the antenna subsystem. The antenna subsystem consists of two single offset reflector. The reflector antennas are mounted to the west panel for N Korea beam, and to the east of spacecraft panel for S Korea. The projected aperture diameter of the S Korea reflector is 1100mm. The focal lengths are 1760mm. [2] The reflectors are constructed of graphite composite that exhibits excellent electrical performance and provides thermally and mechanically stable structures. The antenna is bore-sight angle of 0.091 in azimuth and 5.75 in elevation from the orbital plane. The cross-polarization isolation is more than 30 dB for frequency re-use. [3]

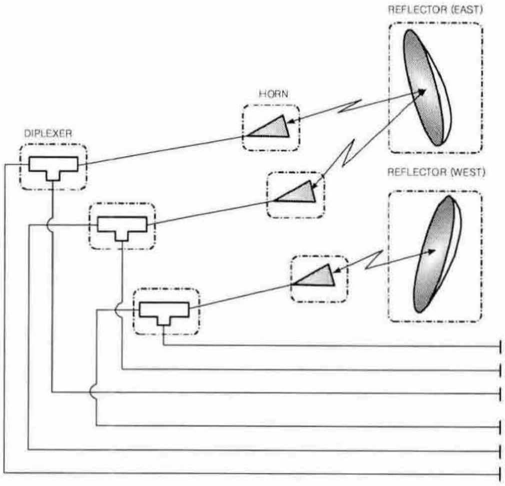



Figure 1. Configuration of antenna sybsystem

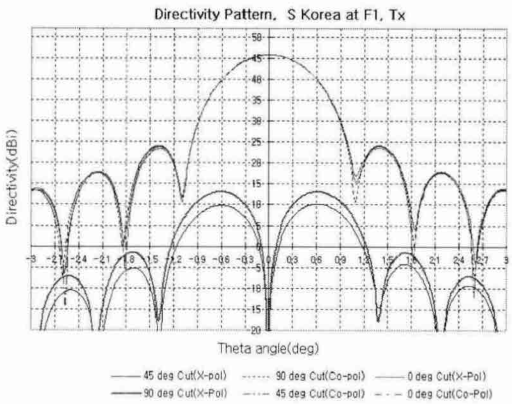



Figure 2. Tx CO-POL/X-POL Directivity Pattern

The cross-polarization discrimination of horn to meet cross-polarization isolation of 30 dB in antenna system should be more than 30dB at the edge taper angle of 16.82 degree as shown in Figure 2.

## 3. Reflector Thermal Anaysis

The reflector is honeycomb sandwich structure with graphite/epoxy facesheets and non-perforated flex 5056 core and backing ribs are honeycomb sandwich structure with graphite/epoxy face sheets and aluminum hexagonal core. The surface of reflector is a section of paraboloid. Thermal Interface is assumed that heat dissipation is generated from inside the bus and the heat is transferred to antenna structure through antenna mount brackets. Also, radiative heat transfer is assemed to be accomplished through external surface of bus structure. The temperatures of external bus surface are changed for each sun location, thermal dissipation in bus and spacecraft attitude.[2]

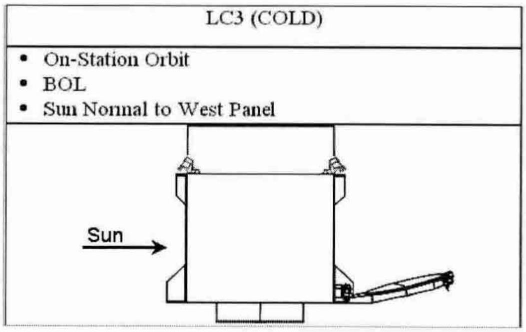



Figure 3. LC3 Geometry for Worst Case

For the on-station orbit case was performed for each season(March Equinox, June Solstice and December Solstice). The heat flux calculatios and temperature predictions were performed at every fifteen minute(900sec.). Figure 3 shows the sun dirction for worst load case. Minimum temperature, -154.5 ℃, occurs at 8 hour of LC3.Figure 4 show the temperature contour for minimum temperature case. The thermal deformation analysis was performed with the results of thermal analysis using MSC/NASTRAN. Maximum deformation value(0.276 mm) at minimum temperature case is shown in Figure 5. Figure 6 shows the temperature profile for worst load case.

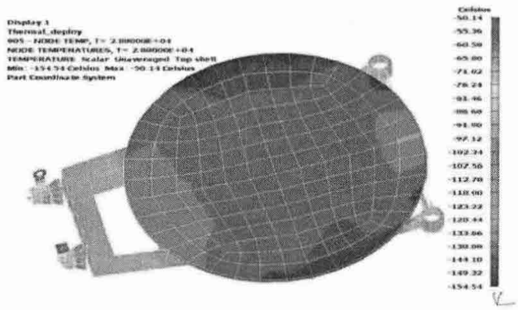


Figure 4. Reflector Temperature Contour for Minimum Temperature Case (Tmin = -154.5 °C at LC3, March, 8hr)

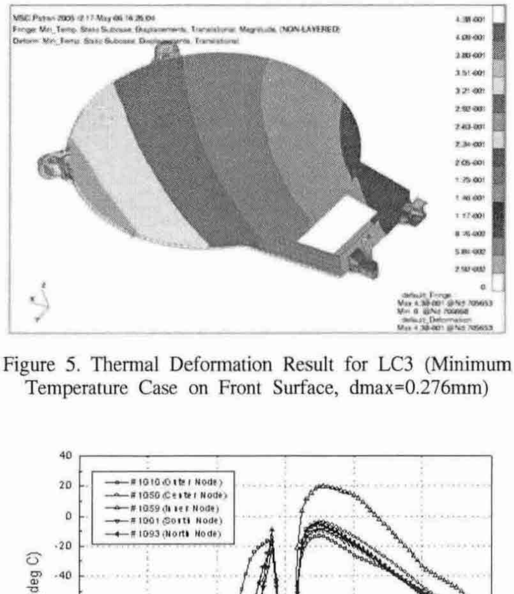


Figure 5. Thermal Deformation Result for LC3 (Minimum Temperature Case on Front Surface, dmax=0.276mm)

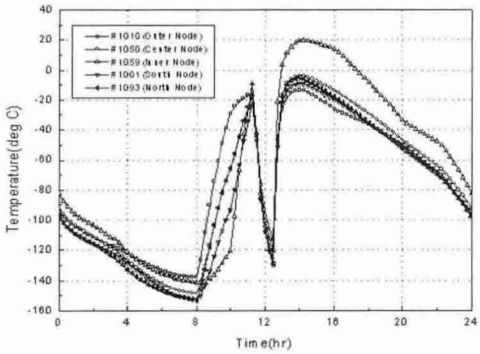



Figure 6. Reflector Temperature Profile for LC3

## 4. Pointing Error Calculation Methods and Beam Pattern Variations

ETRI tried to estimate the equivalent beam pointing error due to the antenna reflector thermal distortion. There are two cases: symmetric distortion and asymmetric distortion.

The sysmetric distortion defocuses the reflector, which reduces the peak gain and to a lesser extent the (Edge Of Coverage)EOC gain. Physically, the beam becomes broader and the sidelobes increase. At the EOC, the broadening of the beam somewhat compensates for the loss of peak gain, since the beam slope is reduced.

The symmetric reflctor distortion case is defined by the following equation

$$PE\ (equiv) = gain\ loss\ /\ gain\ slope \qquad (a)$$

The use of distorted reflector data to re-compute the pattern is the general approach to computing the loss due to distortion. However, since the data describes only a symmetric distortion case, the computed loss is only due to a defocusing of the reflector. If the reflector distortion is asymmetric, but with a similar distortion magnitude, the impact would be, as follows:

a) A loss in the peak gain of the beam, which translates into a loss of the EOC gain, with some compensation due to beam broadening same effect as symmetric case.

b) A further loss of EOC gain due to the asymmetric distortion of the beam, which results in a further loss of EOC gain at certain points around the edge of the service area.

The above equivalent PE computation from analysis of the symmetrical reflector, therefore, would likely give an optimistic result for the distorted case.

As follows, it tries to describe about the method for calculating the pointing error.

**a) Best method to compute EOC loss and equivalent PE:**

1. Obtain the correct prediction for the asymmetric reflector distortion from thermal analysis.
2. Re-compute the antenna pattern with the distorted reflector profile as input (using Ticra-Grasp or equivalent software) and determine the worst case loss in EOC gain with respect to the service area specification.
3. Compute the equivalent PE using the formula(a).

**b) Approximate method, if asymmetric distortion data is not available from thermal analysis:**

1. Convert the symmetric distortion formula to an asymmetric formula
2. Include the distorted reflector profile as input to Ticra-Grasp or equivalent pattern computation software
3. Compute the worst case loss in EOC gain
4. Compute the equivalent PE using the formula (a).
   Asymmetric distortion formula:

$$DZ = DZmax\ (r/rmax)^2 \sin(\phi) \qquad (b)$$

The modified reflector surface profile from this formula will cause beam de-pointing in the Y-Z plane ($\phi = 90°$) as well as a loss in peak gain.

**c) Alternate, approximate calculation method for asymmetric case:**

We compute the loss due to the quasi-random surface error and the loss due to de-pointing of the beam.

1. Compute loss due to the reflector surface error (DG1).

**Alternative approach:**

Use the symmetric or asymmetric distortion formula to compute the distortion at each point on the reflector and compute the loss due to the rms surface error. (We assume the surface errors are quasi-random.)

$$\Delta G1\ (\text{rms surface error}) = -10 \log 10 \{Exp((4\pi\ Erms/\lambda)^2)\} \qquad (c)$$

**Where:**

$Erms = sqrt[\Sigma\phi\ \Sigma r\ (\Delta Z \times W)^2 / n]$

$\lambda$ = wavelength

$\Delta Z = \Delta Zmax\ (r/rmax)^2 \sin(\phi)$ or $\Delta Zmax\ (r/rmax)^2 \cos(2\phi)$

$\phi = 0$ to $2\pi$, $r = 0$ to rmax, equal increments in $\Delta\phi$ and $\Delta r$ ($\Delta r$ and $r\ \Delta\phi <= 0.5\ \lambda$)

$W$ = area weighting $= r\ \Delta r\ \Delta\phi\ /\ (rmax\ \Delta r\ \Delta\phi) = r\ /\ rmax$

2. Compute the loss due to de-pointing of the beam

With asymmetric distortion, we have an effective rotation of the reflector and an associated displacement of the fixed feed from the design focal point since the reflector axis has been rotated.

$$PE\ \text{degrees (plane of asymmetry)} = 2 \arctan(2\ \Delta Zmax/D)\ 180/\pi = 4\ \Delta max/D\ 180/\pi \qquad (d)$$

**Where:**

The first factor of 2 accounts for the feed displacement effect.

D = reflector diameter

$\Delta G2$ de-pointing (dB) = -PE x gain slope

3. Compute the equivalent PE

$$PE\ (equiv) = (\Delta G1 + \Delta G2)\ /\ \text{gain slope} \qquad (e)$$

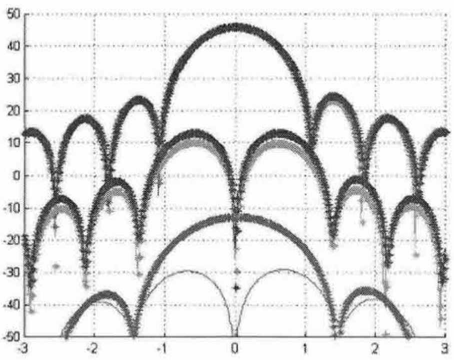



Figure 7. Beam Pattern with thermal distortion

Antenna beam pattern at the transmission(20 GHz) with consideration of thermal distortion of reflector is recomputed by using TICRA as shown in figure 7, 8 and table 1. Maximum degradation in EOC directivity is 0.136 dB at theta=+0.025degree which is one edge of the EOC

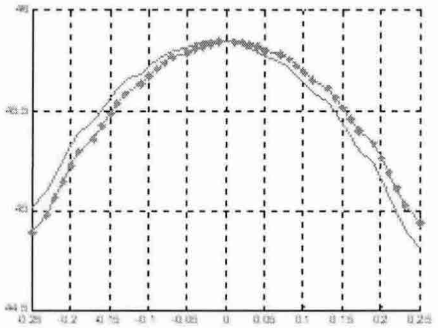


Figure 8. 45 degree cut Beam Pattern

Equivalent pointing error due to directivity degradation can be calculated with gain slope of edge(~11.05 dB/degree for Tx) as worst case; Pointing error(degree) = gain loss/gain slope = 0.136 / 11.05 = 0.0123 degree.

Table 1. Directivity Degradation according to cut angle

Theta: - 0.25 Degree

| Cut Deg. | EOC directivity without distortion(dB) | EOC directivity with distortion(dB) | Difference(dB) |
|---|---|---|---|
| 0 | 44.907 | 44.954 | 0.047 ↑ |
| 45 | 44.894 | 45.02 | 0.126 ↑ |
| 90 | 44.896 | 45.026 | 0.130 ↑ |

Theta: + 0.25 Degree

| Cut Deg. | EOC directivity without distortion(dB) | EOC directivity with distortion(dB) | Difference(dB) |
|---|---|---|---|
| 0 (Roll axis) | 44.931 | 44.879 | 0.052 ↓ |
| 45 | 44.945 | 44.813 | 0.132 ↓ |
| 90 (Pitch axis) | 44.943 | 44.807 | 0.136 ↓ |

## 5. Conclusions

The pointing error analysis for the Ka-band antenna subsystem were performed. As the worst case the reflector thermal distortion caused the de-pointing of 0.0123degree. This is a little greater than the requirement (0.01 peak-to-peak) which was given by COMS prime contractor. There is no way to improve the performance due tothe thermal distortion of reflector. Prime contractor will combine this error with bus system errors in terms of each spacecraft axis(roll, yaw and pitch)and then total error will be calculated.

## References

[1] S.P. Lee, "Development of Satellite Communication System for COMS", APSCC 2004, Sept 2004, pp71-96.

[2] J.H. Lee, J.H. Kim, S.P. Lee, H.J. Lee," Multi-Beam Satellite Antenna Design", IEEE Int'l Symposium on Antennas and Propagation and USNC/URSI National Radio Science Meeting, July 2004, Session 84.

[3] Y.M.Lee, J.W.Eun, S.P.Lee, "Comceptual Design of the Ka-Band Communication Payload for COMS", The International Conference on Advanced Communication Technology, Phoenix Park, Feb. 2004, pp. 84-85.

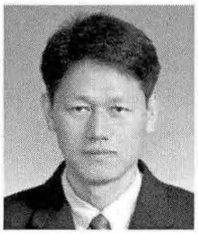
## 저 자

이 용 덕(Yong Deuk Lee) 정회원

2003년 8월 : 광운대학교 박사
2003년 9월 : BK 21 사업 MPM 연구 박사후 과정
2004년 4월~현재 : 한국전자통신연구원 통신위성시스템연구팀 선임연구원

<관심분야> 위성 안테나 설계 분석, PLVCO

최 장 섭(Jang Sup Choi) 정회원



1991년 3월 ~ : 한국항공우주연구원 선임연구원
1996년 3월~ : 현대전자 위성사업단 책임연구원
2000년 10월~현재 : 한국전자통신연구원 통신위성시스템연구팀 책임연구원

<관심분야> 위성체 시스템설계, 위성체 AI

박 재 우(Jae Woo Park) 정회원

1990년 2월 : 한국전자통신연구소 위성관제시스템 연구원
1997년 7월 : 러시아 과학 아카데미 우주연구소 박사
2000년 4월~현재 : 한국전자통신연구원 통신위성시스템연구팀 책임연구원

<관심분야> 위성임무분석, 위성체시스템 설계

이 성 팔 (Seong Pal Lee) 정회원