Auto-compatibility Analysis for Ka-band payload of COMS

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요 약

2009년 발사예정인 우리나라가 개발한 최초의 정지궤도위성 COMS에는 기상센서, 해양센서 및 Ka대역 통신탑재체등 세 개의 탑재체가 실리며 해양센서 및 기상센서의 측정데이타를 전송하기위한 L대역 통신중계기가 있다. 또한 S대역의 원격측정 및 원격명령서브시스템과 Ka대역 비콘등이 있다. Ka대역 통신탑재체는 스위칭 중계기로서 부품의 우주인증 및 재난통신서비스에 활용될 전망이다. 또한 Ka대역 비콘은 지상국 안테나의 포인팅 및 강우감쇠 실험을 포함한 Ka대역 전송실험에 활용될 예정이다. 본 논문은 L대역 센서데이타 전송용 중계기 및 S 대역 원격명령/측정 서브시스템의 RF 복사가 Ka 대역 중계기 및 비콘에 어떤 영향을 주며, Ka밴드 비콘이 L 대역 및 S 대역 중계기에 어떤 영향을 주는지 조사하였다. 중계기들의 상향/하향 링크시 출력, 안테나들의 기하학적 위치 및 거리 및 중계기들에 포함되어 있는 필터들의 rejection 그리고 편파에 의한 degradation factor등을 포함하여 coupling factor를 고려하여 상호 호환성을 고려하였다. 분석결과 L대역 및 S대역 중계기에 의한 Ka대역 탑재체에 대한 영향은 미미한 것으로 계산되었으며, Ka대역 비콘의 영향도 무시할 정도임을 밝혔다.

키워드: 통신해양 통신해양기상위성, Ka 대역 통신탑재체, 복사 상호 호환성

ABSTRACT

The first geostationary satellite made by Korea, COMS, has the three different payload ; Meteorological sensor, Oceanographic sensor and Ka-band communication payload. There are Meteorological & Ocean Data Communication Subsystem(MODCS) and Telemetry, Command and Ranging Subsystem(TC&R) as other RF radiation sources. MODCS transmits and receives Meteo and Ocean measurement data from/to earth using L-band and TC&R using S-band. The Ka-band communication payload will provide high-speed multimedia services and communication services for natural disaster such as prediction, prevention, and recovery services in the government communications network. Ka-band beacon is for the earth antenna pointing and the experiment of rain fading.

This paper gives the analysis results about the mutual radiation effect on Ka-band communication payload, Ka-band beacon, MODCS and TC&R. Up/Down link power and coupling factor including the geometrical position and distance of antenna, filter rejection and degradation factor due to the different polarization are considered. The results show MODCS and TC&R are compatible for Ka-band communication payload and Ka-band beacon does not interfere with MODCS and TC&R normal operation.

Key Words : COMS, Ka-band communication payload, Radiation auto-compatibility

I. Introduction

COMS is the one of the most complicated geostationary spacecraft over the world. There are three different payloads for various missions, multimedia communication, meteorological and oceanic monitoring.

Auto-compatibility means the RF compatibility among the radiating sources. There are several RF radiating source in COMS including Ka-band communication antenna and feeder, Ka-band beacon transmitter, Telemetry & Telecommand subsystem(TC&R) and Image data communication subsystem(MODCS). In this paper the RF compatibility analysis among the following sources are shown;

— Ka-band Communication Payload and COMS subsystem(TCR & MODCS)

— Ka-band Beacon Transmitter and COMS subsystem(TCR & MODCS)

II. COMS Configuration and RF Compatibility

The top floor layout which needs to be considered is given Figure 1.

Generally auto-compatibility analyses for COMS to be considered are summarized in Table 1.

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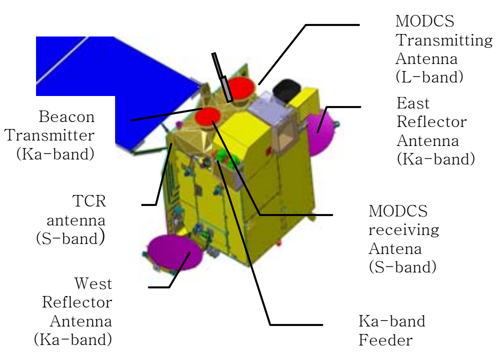

Figure 1. Outside RF environment of COMS

Table 1. Summary of Auto-compatibility for COMS

	Ka-band receiver	TCR receiver (S-band)	MODCS receiver (S-band)
Ka-band uplink	N/A	○	○
Ka-band downlink	PIM analysis	○	○
TCR uplink (S-band, TC)	○	N/A	○
TC&R downlink (S-band, TM)	○	○	○
MODCS uplink(S-band)	○	○	N/A
MODCS downlink(L-band)	○	○	○
Beacon downlink(Ka-band)	○	○	○

Here the effects on Ka-band receiver of other sources and the effects on TC&R and MODCS of Ka-band beacon are only considered.

III. RF Auto-compatibility Analysis

3.1 Ka-band Payload Rx Compatibility with TC uplink signal

TCR ground station EIRP is estimated to 70dBW. With free space loss(-189.6 dB) and Ka-band antenna maximum gain(~48dBi), TCR signal at Ka-band antenna will be -71.6dBW. Moreover with considering input loss to receiver and injection by input filter this is sufficiently compatible with Ka-band receiver.

3.2 Ka-band Payload Rx Compatibility with TM downlink signal

This section is dedicated to verifying that Ka-band receiver is compatible with TCR S-band downlink signal. According to the layout West reflector can be affected by +Z TM antenna. Figure 2 shows the geometry between TC&R antenna and west reflector.

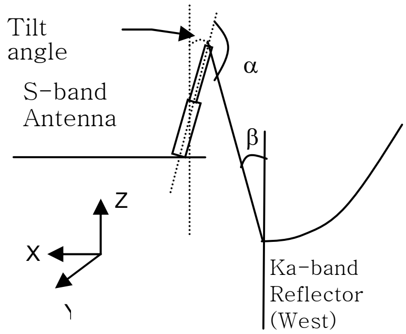

Figure 2. Geometry between TCR antenna and Ka-band Reflector(West)

The coordinates of two antenna, distance between two antennas and angle of view can be found in Table 2.

Table 2. Geometry parameters of TCR antenna and Ka-band reflector

Items	Parameters	Values
S/C Coordinates	TCR antenna	X(m) = -1.203 Y(m) = 0.866 Z(m) = 3.084
	Ka-band reflector(West)	X(m) = -1.512 Y(m) = 0.303 Z(m) = 0.753
Tilt angle of TCR antenna		25 deg
Distance(D)		2.4 m
Angle of view	TCR to Ka (α)	148 deg
	Ka to TC&R (β)	8 deg

Before calculating the coupling factor, the basic data for two antennas are summarized in Table 3. Antenna gains according to angle of view are obtained from Figure 3. Ka-band antenna can be considered to have same pattern in west and east side antenna.

Table 3. Characteristics of TM antenna and West Ka-band reflector

Item	TCR(TM)	Ka-band
Frequency(GHz)	2.29	20.2
Wave length (λ in m)	0.1310	0.01485
Number of channels	1	4
Output power(dBW)	7(=37dBm)	26.3

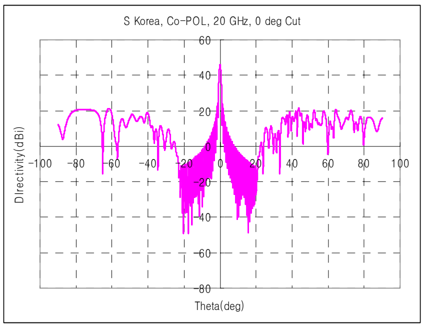

Figure 3 Ka-band Antenna Pattern

The coupling factor(CF) between two antennas is estimated by the formula (1) and the result is evaluated in Table 4.

$$CF = G_{TC}(\alpha) + G_{Ka}(\beta) - 20*\log(4\pi D/\lambda) - DF \quad (1)$$

G means gain and DF is degradation factor due to different polarization scheme between two systems. 3dB is for the linear to circular polarization transformation as minimum value which is applied to the others as worst case.

Table 4 Coupling Factor for TCR to Ka-band

Item	Value
$G_{TM}(148°)$	-13dBi
$G_{Ka}(8°)$	- 3 dBi
Free space loss : $20*\log(4\pi D/\lambda)$	47dB
DF	3dB
Coupling Factor(CF)	-66 dB

Minimum input loss of Ka-band payload which is consist of cable loss between diplexer and IFA(Input Filter Assembly) and filter injection of IFA is about -96 dB. Finally total power at Ka-band receiver will be -152 dB. This is under of specification (-30dBW). So, Ka-band payload is compatible with TM downlink signal of TC&R subsystem.

3.3 Ka-band Payload Rx Compatibility with MODCS uplink signal

MODCS ground station EIRP is estimated to 57dBW. With free space loss (-189.6 dB) and Ka-band antenna maximum gain(~48dBi) MODCS signal at Ka-band antenna will be -84.6dBW. Moreover with considering input loss to receiver and injection by input filter this is sufficiently compatible with Ka-band receiver.

3.4 Ka-band Payload receiver Compatibility with MODCS downlink signal

This section is dedicated to verifying that Ka-band receiver is compatible with MODCS L-band downlink signal. Figure 4 shows the geometry between L-band antenna and east reflector.

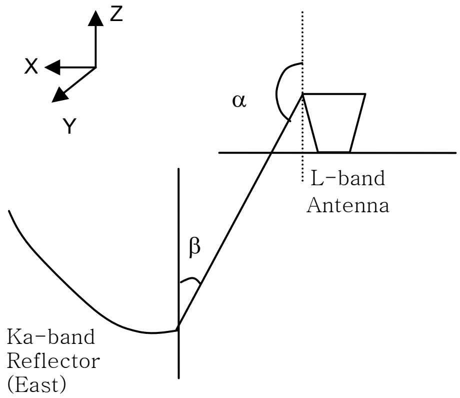

Figure 4 Geometry between L-band MODCS antenna and Ka-band Reflector(East)

The coordinates of two antenna, distance between two antennas and angle of view can be found in Table 5.

Table 5 Geometry parameters of MODCS antenna and Ka-band reflector (East)

Items	Parameters	Values
S/C Coordinates	L-band MODCS antenna	X(mm) = 0.204 Y(mm) = 0.373 Z (mm) = 2.984
	Ka-band reflector(East)	X(mm) = 1.512 Y(mm) = 0.303 Z (mm) = 0.753
Distance(D)		2.6 m
Angle of view	MODCS to Ka (α)	149 deg
	Ka to MODCS (β)	30 deg

Before calculating the coupling factor, the basic data for two antennas are summarized in Table 6. Antenna gains of two antennas according to angle of view are obtained from Figure 3 and Figure 5 respectively.

Table 6. Characteristics of TM antenna and Ka-band reflector (East)

Item	MODCS	Ka-band
Frequency(GHz)	1.7	20.2
Wave length (λ in m)	0.1765	0.01485
Number of chnnels	1	4
Output power(dBW)	8.2	26.3

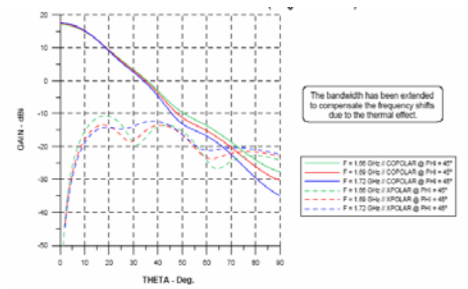

Figure 5. L-band MODCS antenna Pattern

The coupling factor(CF) between two antennas is estimated by the formula (1) and the result is evaluated in Table 7.

Table 7. Coupling Factor for MODCS to Ka-band

Item	Value
$G_{MODCS}(149°)$*	<-35dBi (=G(90°))
$G_{Ka}(30°)$	10dBi
Free space loss : 20*log(4πD/λ)	46dB
DF	3dB
Coupling Factor	-74dB

Minimum input loss of Ka-band payload which is consist of cable loss between diplexer and IFA and filter injection of IFA is about -96 dB. Finally total power at Ka-band receiver will be -162 dB. This is under of specification (-30dBW). So, Ka-band payload is compatible with L-band MODCS downlink signal.

3.5 Ka-band payload receiver compatibility with Beacon signal

This section is verifying that Ka-band beacon transmitting signal is compatible with Ka-band communication payload. According to the layout West reflector can be affected by beacon antenna. Figure 6 shows the geometry between Beacon antenna and West reflector.

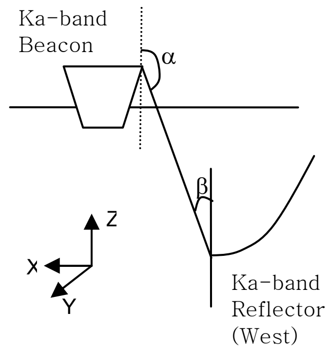

Figure 6. Geometry between Ka-band Beacon antenna and Ka-band Reflector(West)

The coordinates of two antenna, distance between two antennas and angle of view can be found in Table 8.

Table 8. Geometry parameters of Beacon antenna and Ka-band reflector (West)

Items	Parameters	Values
S/C Coordinates	Beacon antenna	X(mm) = -0.873 Y(mm) = 0.800 Z (mm) = 2.875
	Ka-band reflector (West)	X(mm) = -1.512 Y(mm) = 0.303 Z (mm) = 0.753
Distance(D)		2.3 m
Angle of view	Beacon to Ka (α)	163deg
	Ka to Beacon(β)	17 deg

Before calculating the coupling factor, the basic data for two antennas are summarized in Table 9. Antenna gains of two antennas according to angle of view are obtained from Figure 3 and Figure 7 respectively.

Table 9. Characteristics of Beacon antenna and Ka-band reflector (West)

Item	Beacon	Ka-band
Frequency(GHz)	19.8	20.2
Wave length (λ in m)	0.01515	0.01485
Number of chnnels	1	4
Output power(dBW)	22	26.3

The coupling factor(CF) between two antennas is estimated by the formula (1) and the result is evaluated in Table 10.

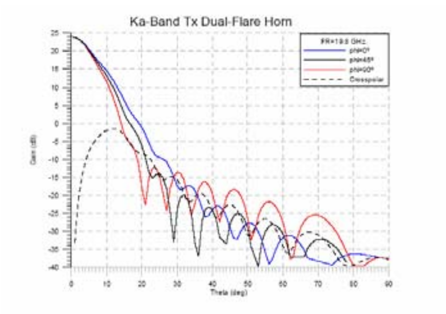

Figure 7. Beacon antenna Pattern

Table 10. Coupling Factor for Beacon to Ka-band

Item	Value
$G_{beacon}(163°)$	<-35dBi =G(90°)
$G_{Ka}(16°)$	0 dBi
Free space loss : 20*log(4πD/λ)	66dB
DF	3dB
Coupling Factor	-104 dB

Minimum input loss of Ka-band payload which is consist of cable loss between diplexer and IFA and filter injection of IFA is about -96 dB. Finally total power at Ka-band receiver will be -177 dB. This is under of specification (-30dBW). So, Ka-band payload is compatible with Beacon transmitting signal.

3.6 TCR receiver Compatibility with Beacon signal

This section is verifying that Ka-band beacon transmitting signal is compatible with TCR receiver. Figure 8 shows the geometry between TCR antenna and Beacon antenna.

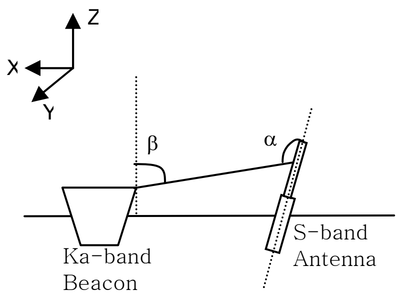

Figure 8. Geometry between Ka-band Beacon antenna and TCR antenna

The coordinates of two antenna, distance between two antennas and angle of view can be found in Table 11.

Before calculating the coupling factor, the basic data for two antennas are summarized in Table 12. Antenna gains of two antennas according to angle of view are obtained from Figure 4 and Figure 9 respectively.

Table 11. Geometry parameters of Ka-band Beacon antenna and TCR antenna

Items	Parameters	Values
S/C Coordinates	Beacon antenna	X(mm) = -0.873 Y(mm) = 0.800 Z (mm) = 2.875
	S-band TCR antenna	X(mm) = -1.203 Y(mm) = 0.866 Z (mm) = 3.084
Distance(D)		0.40 m
Angle of view	Beacon to TCR (α)	58 deg
	TCR to Beacon(β)	57 deg

Table 12. Characteristics of Ka-band Beacon antenna and TCR antenna

Item	Beacon	TCR
Frequency(GHz)	19.8	2.29
Wave length (λ in m)	0.01515	0.1310
Number of chnnels	1	1
Output power(dBW)	22	7(=37dBm)

The coupling factor(CF) between two antennas is estimated by the formula (1) and the result is evaluated in Table 13.

Table 13. Coupling Factor for Beacon to TCR

Item	Value
$G_{beacon}(58°)$	<3dBi (maximum gain)
$G_{TCR}(57°)$	-22 dBi
Free space loss:20*log(4πD/λ)	50 dB
DF	3dB
Coupling Factor	-72dB

Minimum input loss of TCR is about -4.6 dB which is the case in the L-band. However in case of Ka-band this will be larger. So this value is considered as worst case. Finally total power at TCR receiver will be -55 dB. This is under of specification (-30dBW). So, TCR receiver is compatible with Beacon transmitting signal.

3.7 MODCS receiver Compatibility with Beacon signal

This section is verifying that Ka-band beacon transmitting signal is compatible with MODCS receiver. Figure 9 shows the geometry between MODCS receive antenna and Beacon antenna.

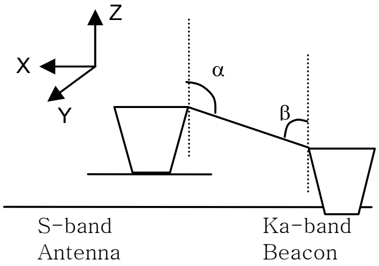

Figure 9. Geometry between Ka-band Beacon antenna and MODCS antenna

The coordinates of two antenna, distance between two antennas and angle of view can be found in Table 14.

Tableau 14 Geometry parameters of MODCS antenna and Beacon antenna

Items	Parameters	Values
S/C Coordinates	Beacon antenna	X(mm) = -0.873 Y(mm) = 0.800 Z (mm) = 2.875
	S-band MODCS antenna	X(mm) = -0.204 Y(mm) = 0.373 Z (mm) = 2.984
Distance(D)		0.8 m
Angle of view	Beacon to MODCS (α)	80 deg
	MODCS to Beacon(β)	99 deg

Before calculating the coupling factor, the basic data for two antennas are summarized in Table 15. Antenna gains of beacon antennas according to angle of view are obtained from Figure 7.

Table 15. Characteristics of MODCS antenna and Beacon antenna

Item	Beacon	MODCS (S-band)
Frequency(GHz)	19.8	2.0
Wave length (λ in m)	0.01515	0.15
Number of channels	1	1
Output power(dBW)	22	-

The coupling factor(CF) between two antennas is estimated by the formula (1) and the result is evaluated in Table 16.

Minimum input loss of MODCS is about -20 dB which is the case in the S-band. However in case of Ka-band this will be larger. So this value is considered as worst case. Finally total power at MODCS receiver will be -78 dB. This is under of specification (-30dBW). So, MODCS receiver is compatible with Beacon transmitting signal.

Table 16 Coupling Factor for Beacon to MODCS

Item	Value
$G_{beacon}(80°)$	-35 dBi
$G_{MODCS}(99°)$	<16dBi (=nominal gain)
Free space loss:20*log($4\pi D/\lambda$)	56 dB
DF	3dB
Coupling Factor	-76 dB

IV. Conclusion

So far the effect of RF sources in COMS including TCR and MODCS on Ka-band communication payload is analyzed. Uplink and downlink RF powers of each source are investigated and are transformed based on their distance and geometry in spacecraft. Lastly coupling factors between two radiating sources are calculated and the power losses of input section are considered.

In the result Ka-band payload is compatible with all radiating equipment such as TCR, MODCS and Beacon in COMS. Moreover TCR and MODCS are compatible with Ka-band beacon transmitter.

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