통신해양기상위성 기상해양데이터통신계의 예비 성능 해석

김 중 표*, 양 군 호*

A Preliminary Performance Analysis of the Meteorological and Ocean Data Communication Subsystem in COMS

Joong Pyo Kim*, Koon Ho Yang*

요 약

기상, 해양 및 Ka-대역 통신 탑재체를 탑재하고 정지궤도에서 기상 및 해양 감시 임무 및 통신 서비스를 수행하는 통신해양기상위성은 기상 및 해양 탑재체에서 관측된 원시 데이터의 지상국 전송 및 지상국에서 처리된 기상 데이터의 최종 사용자국에게 중계 전송을 기상해양데이터통신 서브시스템이 있다. 기상해양데이터통신 서브시스템은 기상 및 해양 탑재체에서 수집된 원시 데이터를 받아 CCSDS 권고안에 준하여 포맷하고 증폭기를 거쳐 지상국에 전송하는 SD 채널과 지상국에서 처리된 기상 데이터를 CGMS 권고안에 따라 LRIT/HRIT 포맷팅된 신호를 최종 사용자국에 중계하는 기능을 제공하는 MPDR 채널로 구성된다. 본 논문은 관측 데이터 전송 및 중계를 위해 구성된 기상해양데이터통신 서브시스템을 구성하고 서브시스템 예비 성능 해석을 통해 주요 요구 성능 파라미터의 만족 여부를 확인하는데 있다.

키워드 : 위성, 데이터 통신, 성능 해석, 지상국, 정지궤도

ABSTRACT

The COMS (Communication, Ocean, and Meteorological Satellite) performing meteorological and ocean monitoring and providing communication service with meteorological, ocean and Ka-band payload in the geostationary orbit includes 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 comprises of two channels: SD channel which formats the raw data according to CCSDS recommendation, amplifies and transmits its signal to the ground station; MPDR channel which relays to the end-user stations the ground-processed meteorological data in the data format of LRIT/HRIT recommended by CGMS. This paper constructs the architecture of MODCS for transmitting and relaying the observed data, and investigates that the key performance parameters have the required margin through the preliminary performance analyses.

Key Words : satellite, data communications, performance analysis, ground station, geostationary orbit

* COMS System Department, Korea Aerospace Research Institute 45 Eoeun-dong, Youseong-gu, Daejeon, KOREA 305-333
Email: joongpyo@gmail.com, khyang@jdtcoms.completel.fr

Ⅰ. Introduction

In the situation that every year a lot of severe storm and typhoon are happening in the Korean peninsula, it is very important to perform the meteorological monitoring and forecast the precise weather conditions. To this end, the COMS (Communication, Ocean, and Meteorological Satellite) performing meteorological and ocean monitoring and providing communication service with meteorological, ocean and Ka-band payload in the geostationary is being developed. 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. This paper is to build up the architecture of MODCS for transmitting and relaying the observed data and shows that the main performance requirements specified are accomplished through the preliminary performance analyses.

2. MODCS Design

2.1. Configuration and Interface

MODCS consists of two channels: one channel for SD (Sensor Data) signal which formats the raw data 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]. Figure 1 shows the MODCS block diagram.

The SD data coming from MI and GOCI payload are CCSDS formatted and QPSK modulated. The QPSK modulator includes the CCSDS formatting function and pulse shaping function which are implemented by FPGA (Field Programmable Gate Array) inside the modulator. The modulator has a 2-for-1 redundancy. The MPDR i.e., LRIT/HRIT signals received by the S-band antenna are first filtered by the input filter. The signals are then amplified and down-converted from S-band frequency to L-band frequency within the S-band receiver. After the receiver the LRIT/HRIT signals are filtered by a so-called noise rejection filter to reject the noise generated by the receiver which falls into the frequency band used for the SD signal. The signals coming from the modulator and the receiver are combined. The combined signal is then amplified by a single HPA (High Power Amplifier) taking into account that a certain OBO (Output Back-Off) has to be provided due to three carrier operation. A 2-for-1 redundancy was selected for the HPAs. The amplified signal is filtered by an output filter and then transmitted via the L-band antenna. In order to facilitate testing couplers before the input filter and after the output filter are included.

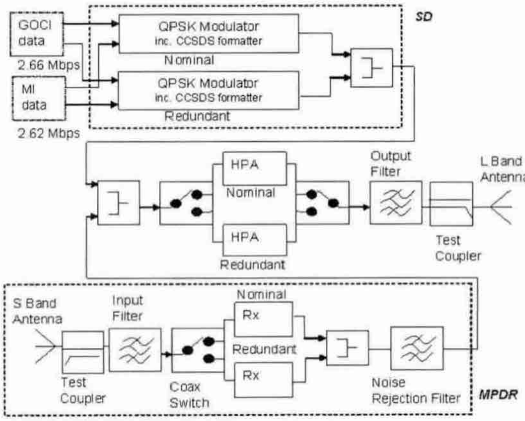


Figure 1: MODCS Block Diagram

Figure 2 shows the interface between COMS satellite and ground stations. The raw data taken by MI and GOCI from a geosynchronous orbit will be transmitted to the MSC and KOSC. At the MSC (Meteorological Satellite Center) and KOSC (Korean Ocean Satellite Center), raw data will be calibrated geometrically and radiometrically and be converted to the processed data. The certain part of processed MI data in the form of LRIT/HRIT will be sent back to COMS satellite for the dissemination service to end users. The spacecraft operation and monitoring will be performed at the satellite operation center (SOC). SOC will have hot backup processing against any emergency at MSC and KOSC. The CTES (Communication Test Earth Center)will monitor RF signals to check the status of Ka-Band communication system. The SOC and the MSC/KOSC will be connected through dedicated line network for data exchange.

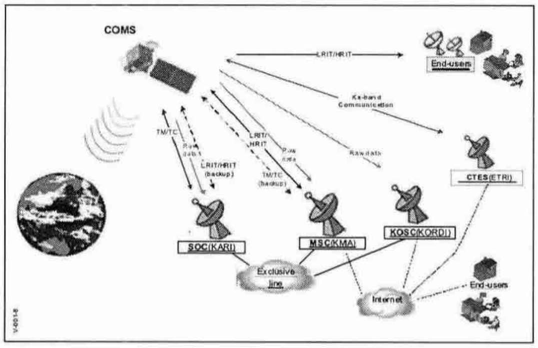


Figure 2: I/F between COMS and Ground Stations

2.2. Frequency Plans

For the registration of COMS satellite network on ITU (International Telecommunication Union), two cases of COMS frequency plans are made and submitted to ITU. The two candidate orbits under the coordinating processes are E116.2 and E128.2 Longitude. Figure 3 and Figure 4 show the frequency plans of uplink and downlink, respectively. It is crucial to choose the best frequency combination in order to ease the coordination processes with other satellite networks and alleviate the design constraints which can be imposed on MODCS.

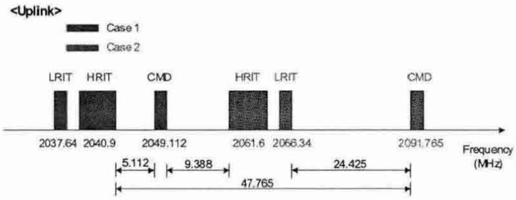


Figure 3: Uplink Frequency plans

From the viewpoint of design, the critical point for the uplinkis the frequency gap between MPDR and CMD. Indeed, the proximity of these two input signals forces MODCS receiving system to implement a complex filter to reject CMD signal without degrading MODCS MPDR signal. Obviously, the more space they are between CMD signal and MPDR signal, the better the performances of MODCS will be. Indeed, having a complex filter will lead to more sensible unit with respect to space environment (such as temperature and ageing) and to more lossy equipment, so the overall performances of the HRIT/LRIT path will be degraded. Consequently, the best choiceis case 1 for MPDR (LRIT= 2037.64 MHz; HRIT=2040.9 MHz) and case 2 for CMD (2091.765 MHz).

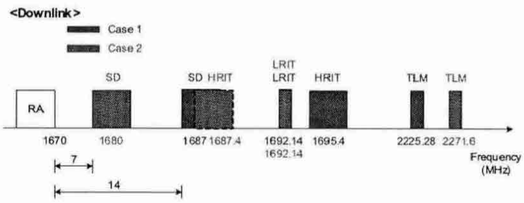


Figure 4: Downlink Frequency Plans

The critical point for the downlink is the frequency gap between RA and SD. If SD signal goes closer to the RA band which should be protected, the output filter needs bigger size which leads to increasing its mass and insertion loss. The best output filter will be realized with an SD signal as far as possible from the RA band. Consequently, the best solution is case 1 for SD (SD=1687 MHz). In summary, the best frequencies of uplink and downlink of MODCS are case 1 while CMD and TLM are case 2. These frequencies are selected as a baseline for MODCS design.

2.3. SD Generation

As shown in Figure 1, the modulator has CCSDS formatter generating SD data in accordance with CCSDS AOS standard. This formatter including FPGA receives the raw data from MI and GOCI, formats and encodes the input data streams into a CADU (Channel Access Data Unit) frame according to CCSDS standard, and then generates the I & Q baseband signals with pulse shaping in order to avoid the Inter Symbol Interference (ISI) and to enforce needed RF spectrum control. Figure 5 shows the CADU format of SD generated by the CCSDS formatter in the modulator.

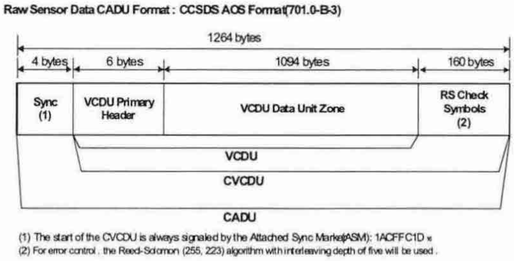


Figure 5: CADU Frame of SD

The LRIT/HRIT data being specific to COMS mission will be generated by the ground station according to CGMS recommendation.

2.4. Main Communication Link Parameters

Since the MODCS directly interfaces with the ground stations, the performance of MODCS is also affected by the parameters of the ground stations. Through the optimizing processes regarding the many constraints of MODCS itself as well as the ground station including cost, service area, interference with the other satellite networks and performance margins, the main communication link parameters were defined. Table 1 summarizes the main communication link parameters of the MODCS.

Table 1: Main Link Parameters

	SD	HRIT	LRIT
Uplink frequency (MHz)	N/A	2040.9	2037.64
Downlink frequency (MHz)	1687	1690.2	1696.4
Bandwidth (MHz)	≤6	≤5.2	≤1
Information data rate	≤6 Mbps	3 Mbps	256 kbps
Minimum received PFD	N/A	-106.5 dBW/m^2	-106.5 dBW/m^2
FEC coding	RS (255,223,5)	Conv(1/2,k=7) +RS(255,223,4)	Conv(1/2,k=7) +RS(255,223,4)
Minimum G/T (dB/K)	19	11.1	1.9
Minimum Elevation angle	46.37	10	10
Required BER	$1X10^{-8}$	$1X10^{-8}$	$1X10^{-8}$
Polarization	Linear	RHCP(Uplink)/ Linear(Downlink)	RHCP(Uplink)/ Linear(Downlink)
Modulation method	NRZ-L/QPSK	NRZ-L/QPSK	NRZ-L/BPSK
Required IMD (dBc)	15	16	16
Required link margin (dB)	3	3	3
Minimum EIRP (dBm)	52	55	55

3. Preliminary Performance Analysis

Based on the main parameters given in Table 1, first of all, the link budget analyses were performed for the uplink and downlink, respectively. As to the uplink link budget, the ground station shall transmit the uplink power to meet the minimum power flux density (PFD) of -106.5 dBW/m^2 in front of the S-band receive antenna. The S-band antenna gain given by the antenna manufacturer at the elevation angle of 46.37 was 16.0 dBi.

Table 2: Preliminary Uplink Budgets

Uplink budget	Units	LRIT	HRIT
minimum density flux	dBW/m	-106,5	-106,5
Isotropic Area	dBW/m	-27,63	-27,65
S/C Antenna Gain	dBi	16	16
S/C Antenna Gain Degradation	dB	0,5	0,5
Systme Noise Temperature	dBK	30,27	30,27
Satellite G/T	dB/K	-14,77	-14,77
Uplink C/No	**dBHz**	**79,70**	**79,68**
Uplink C/N	**dB**	**19,70**	**12,52**
Uplink IMP C/I	**dB**	**25,00**	**25,00**
Total Uplink C/(N+I)	**dB**	**18,58**	**12,28**
Total Uplink C/(N+I)o	**dBHz**	**78,58**	**79,45**

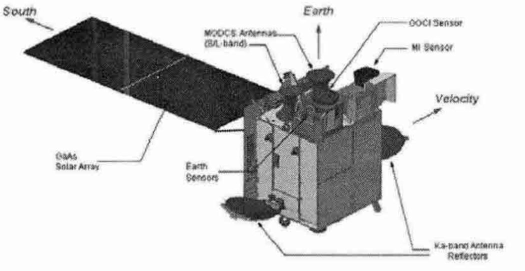


Figure 6: MODCS Antennas Location

As shown in Figure 6, the S-band and L-band antenna are located near both MI and GOCI on the top floor. So both of the antennas is necessary to consider the influence occurred by MI and GOCI payloads as well as the other structures. In order to include the antenna gain degradation by electromagnetic interactions with the neighboring structures, the GTD (Geometry Theory of Diffraction) analysis was performed. The antenna gain degradation obtained was less than 0.5 dB. For the calculation of noise figure and G/T of the receiver, a gain/level allocation plan was generated for each of LRIT/HRIT. The equivalent noise figure and G/T are 5.64 dB and -14.77 dB/K, respectively. In the uplink budget, the uplink IMP C/I given by the third intermodulation products of the ground station HPA operating two carriers was included.

Table 3: Preliminary Downlink Budgets

Downlink budget	Units	LRIT	HRIT	SD
HPA RF power	W	18,74	18,74	17,00
On-board losses	dB	-2,53	-2,53	-2,53
Antenna gain	dBi	15,30	15,30	16,20
S/C Antenna Gain Degradation	dB	0,5	0,5	0,50
Satellite EIRP	dBW	25,00	25,00	25,47
Required minimum EIRP(TBD)	dBW	25,00	25,00	22,00
Maximum EIRP in ITU Filing	dBW	32,50	32,50	29,50
Elevation angle	°	10	10	**46,37**
G/S to satellite distance	km	40586	40586	37317
Free space loss	dB	-189,18	-189.19	-188,42
Atmospheric loss	dB	-0,50	-0,50	-0,50
Ground station G/T	dB/K	**1,90**	11,10	19,00
Depolarization loss	dB	-1,00	-1,00	-1,00
Downlink C/No	**dBHz**	**64,82**	**74,00**	**83,15**
Downlink C/N	**dB**	**4,82**	**6,84**	**16,48**
Coupled C/N	**dB**			**28,42**
Downlink C/I	**dB**	**16,00**	**16,00**	**15,00**
Total Downlink C/(N+I)	**dB**	**4,50**	**6,35**	**12,55**
Total Downlink C/(N+I)o	**dBHz**	**64,50**	**73,51**	**79,23**
Total C/(N+I)o	**dBHz**	**64,33**	**72,52**	**79,23**
Implementation losses	dB	-1,50	-1,50	-1,50
Data rate	dB/Hz	54,08	64,77	67,23
Calculated Eb/No	dB	**8,75**	**6,25**	**10,49**
Required Eb/No	dB	3,20	3,20	7,00
Eb/No Margin	**dB**	**5,55**	**3,05**	**3,49**
Required Margin	**dB**	**3,00**	**3,00**	**3,00**
Calculated PFD in 4kHz Band	dBW/m?4kHz	-161,05	-168,21	-168,35
Required PFD in 4kHz band	dBW/m?4kHz	-154	-154	-154

Table 3 shows the results of the downlink budget. The main driver of the downlink budget is the minimum required EIRP (Equivalent Isotropic Radiated Power). The minimum required EIRP value is not frozen, and will be finally decided depending on the results of COMS satellite network coordination. For ITU filing, the maximum EIRP value for LRIT/HRIT carrier is 32.5 dBW. In case of LRIT and HRIT, the HPA output power required to meet the minimum required EIRP of 25 dBW was defined with regard to the onboard losses, antenna gain and gain degradation. In the same way as the uplink case, the L-band antenna gain degradation occurred by nearby structures was also included in the downlink budget. The antenna gain was obtained regarding the end of beam coverage defined at the elevation angle of 10. In case of SD, the required minimum EIRP was 22 dBW, the maximum EIRP value of SD carrier filed on ITU is 29.5 dBW. The HPA output power of SD was increased up to 25.47 dBW to meet the 3 dB link margin. The used antenna gain for the SD was defined at the elevation angle of 46.37. As can be seen from the block diagram, the receiver signals and the modulator signals are combined. The noise generated within the receiver path can be coupled into the modulator path. To reduce the impact of the injected noise the noise rejection filter was introduced. The resulting C/N of 25.5 dB affected by the receiver path with noise rejection filter was included in Table 3.

As shown in Figure 1, the single HPA amplifies three signals. In case of multi-carrier operation in a single HPA, as is often the case, the linearized HPA shall be used to minimize the level of third intermodulation and spectral regrowth. With respect to the third intermodulation product [3], the requirement value is -16 dBc against each signal when both LRIT and HRIT are amplified with a common amplifier. According to the required minimum EIRP, the EIRP of SD is 3 dB lower than those of LRIT/HRIT, in that case, the C/I of SD signal is more degraded compared to those of LRIT/HRIT and therefore defined as 15 dBc. In order to see if the requirement of 16 dBc for the LRIT/HRIT and 15 dBc for the SD can be met, simulations were performed to find the appropriate OBO level of the HPA. The results of the simulations are given in Figure 7.

In Figure 7, CH 2 is the amplified output signal at 2 dB OBO, and CH 1 is the amplified signal at 0 dB OBO, i.e., the saturation. At 0 dB OBO, the obtained IMD is about 10 dBc, it does not meat the requirement of 16 dBc. With 2 dB OBO, the IMD level of 16 dBc can be obtained. At least 2 dB OBO is needed to meet the requirement. As mentioned before, in real design, the EIRP of SD was almost the same as those of LRIT/HRIT. The results of simulation with same power level for the three channels are shown in Figure 8. In that case, the obtained IMD levels for each of 2 dB and 0 dB OBO were improved up to around 18 dBc and 12 dBc, respectively. With the same power level of three channels, the IMD of 2 dB was improved, compared to the case of Figure 7. The final conclusion is that at least 2 dB OBO is necessary to meet the IMD requirement.

As indicated in Table 3, the final obtained Eb/Nos for three channels have more than 3 dB, and meet the required margin of 3 dB. Finally it is shown that the PFDs of three channels can meet the required PFD of ITU [4].

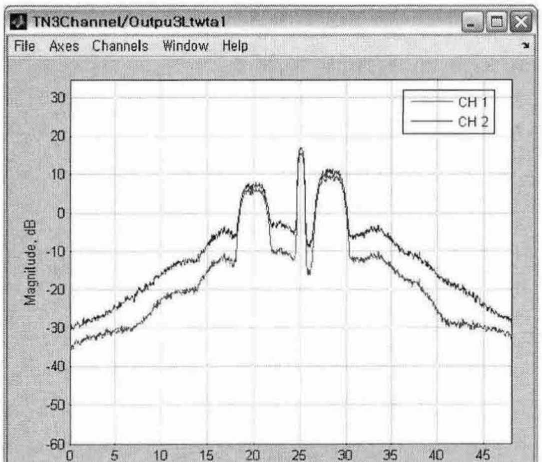


Figure 7: Simulation results at 2dB and 0 dB OBO

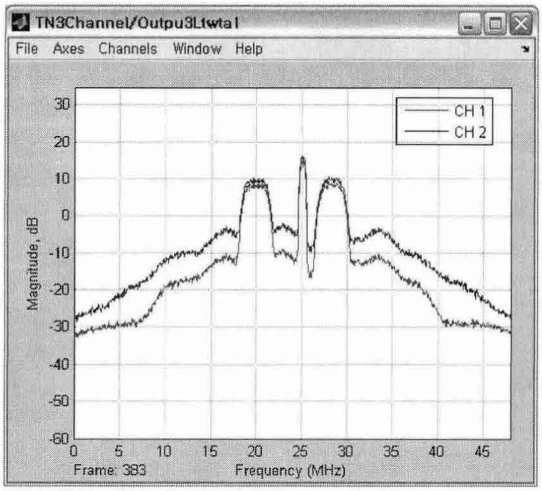


Figure 8: Simulation results at 2 dB and 0 dB OBO

Besides the link budget analyses, the other performances including the gain/loss budget, noise figure and G/T, transmission signal suppression in the receive chain, gain variation versus frequency, group delay variation versus frequency, group delay stability, AM/PM conversion, in-band spurious output, out-of-band spurious outputs including the RA (Radio Astronomy) band protection [5], overdrive capability are analyzed to see if their defined requirements can be met. All of these performances are found to meet their own requirements. Owing to limited space, their results are omitted.

5. Conclusions

The configuration of MODCS having the function of transmitting the observed raw data transferred from MI and GOCI payloads to the ground station and relaying the processed meteorological data to the end-users was introduced with the block diagram, and its main function and its interface with the ground stations are briefly described. The best frequency combinations were selected regarding the design constraints of MODCS for two candidate frequency plans submitted to ITU. In conjunction with the link parameters of ground station, the main communication link parameters are defined to accomplish the given function of MODCS. Based on these parameters, the link budget analyses are performed, and the required margin of 3 dB are met for three signals. It was also shown by simulation that the EIRP should be increased to meet the margin of 3 dB for SD, and 2 dB OBO are at least needed to meet the IMD requirement. In the very near future, based on this preliminary analyses performed, detailed design, implementation and test of MODCS will be performed.

Reference

[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.

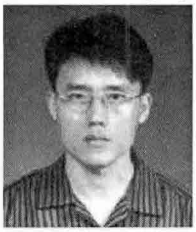
[3] G. Maral, M. Bousquet, "Satellite Communications System", 1998.

[4] ITU Article S21 of the ITU Radio Regulations RR-S21, "ITU Regulations for Power Flux Density", 2001.

[5] ITU-R RA 769-1, "ITU Regulations for Radio Astronomy", 1998.

저 자

김 중 표(Joong-Pyo Kim)



1991년 2월 : 경북대학교 전자공학과 졸업

1993년 2월 : 경북대학교 전자공학과 석사

2000년 2월 : 경북대학교 전자공학과 박사

2000년 3월~현재 한국항공우주연구원 통신해양기상위성사업단 통해기체계팀 선임연구원

<관심분야> 전자공학, 초고주파공학, 안테나공학, 위성 통신시스템 설계

양 군 호(Koon-Ho Yang)

1985년 2월 : 서울대학교 기계공학과 졸업

1987년 2월 : 한국과학기술원 기계공학과 석사

1987년 3월~1990년8월 : LG 전자 연구소 근무

1996년 2월 : 한국과학기술원 기계공학과 박사

1996년 3월~현재 한국항공우주연구원 통신해양기상위성사업단 통해기체계팀장

<관심분야> 진동 및 동역학, 제어공학, 위성 시스템 설계