

# 천리안 위성 Ka 대역 통신탑재체시스템 기술

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## Ka band Communication Payload System Technology of COMS

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### 요 약

통신해양기상위성은 4개 정부부처 공동사업으로, 통신서비스, 해양기상 관측서비스를 7년간 제공하게 된다. 위성 스위칭 중계기와 다중빔 안테나로 구성된 Ka 통신탑재체 개발은 방송통신위원회 출연으로 ETRI 주관으로 개발하였으며, 통신탑재체 개발목적은 우주인증 기술확보와 차세대 멀티미디어 위성서비스 개발이다.

본 논문 목적은 통해기 통신탑재체 국산 개발사업의 전 과정을 통한, ETRI 의 Ka대역 통신탑재체 개발기술 연구이며, 또한 통신탑재체 응용 기술에 대해 다루고자 한다.

Key Words : Ka Communication Payload, Geostationary satellite, switching transponder, multi-beam antenna.

### ABSTRACT

COMS (Communication, Ocean and Meteorological Satellite) is the multi-purposed Korean geostationary satellite funded by four Korean government ministries, and is to supply communication services, ocean and weather observation for 7 years. As part of COMS, development of Ka band communication payload composed of microwave switching transponder and multi-horn antenna is sponsored by KCC (Korea Communications Commission) and developed by ETRI (Electronics and Telecommunications Research Institute). The purpose of Ka Payload development is to acquire space proven technology of Ka payload and to exploit advanced multimedia communication services.

This paper aims to study development technology of Ka payload system through whole process of ETRI project. Also application of Ka payload will be dealt in this paper.

### I. Introduction

Chunrian satellite (COMS : Communication, Ocean and Meteorological Satellite) is the first geostationary satellite developed by local developers funded by four Korean government Ministries including Ministry of Education and Technology, Korea Communication Commission, Ministry of Land, Transport and maritime Affairs, and Korea Meteorological Agency, and will be used for multi-purposes such as communication services,

ocean and weather observation for 7 years . Ka band communication payload development, as a part of COMS project, is sponsored by Korea Communication Commission and developed by Electronics and Telecommunications Research Institute with local companies (SaTREC-I, KoSpace, M&M Lynx, Korean Air Line and ART).

The purpose of Ka Payload development is to acquire space proven technology of Ka equipment and system and to exploit advanced multimedia communication services. ETRI with domestic technologies successfully developed Ka payload equipments and system throughout

design, manufacturing and test. ETRI completed IOT (In Orbit Test) of Ka Payload and verified the final status of the Payload located at GEO in 128.2 E. IOT test result of Ka Payload is compliant with specification and same as that of Thermal Vacuum Test done at ground test.

Ka Payload developed by ETRI will be applied for R&D experiment, Test-bed for new technology verification and Public services test. Domestic developed technology of Ka communication payload will be contributed to exploit new multi-media services.

## II. Ka Payload System Design

The payload system will provide high-speed multimedia services such as Internet via satellite, remote-medicine, and distance learning in the public communication network and communication services for natural disaster such as prediction, prevention, and recovery services in the government communications network. The main feature of the Ka-band communication payload is shown in Table 1.

Table 1: Main feature of the Ka-band payload system

Parameters	Features
Service area	Korean peninsula
Relevant frequency band	29.6~30.0GHz(uplink) 19.8~20.2GHz(downlink)
Orbit and position	Geostationary at 128.2°E
Service Life	7.7 years

The service coverage of the COMS Ka-band payload system is South Korea and North Korea via individual satellite beams for communication services. The individual regions will be covered by separate single beam. The beam width of each beam has 0.7 degree including 0.1 degree pointing error.

The payload architecture utilizes Ka-band on-board switching transponder and multi-beam antenna designs. The payload block diagram shown in Figure 1 illustrates that the Ka-band transponder provides four channels including one redundancy, two antennas and a beacon assembly.

Ka Payload performance in the final design phase is fully compliant with the required system specifications.

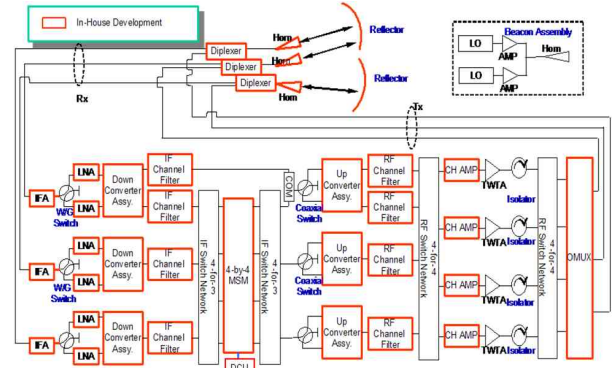


Figure 1: Ka-Band payload functional block diagram

## III. Ka Payload System Manufacturing, Integration and Test

### 1. Equipment and Transponder Manufacture

Around 80 % of all equipments of Ka Payload system were designed and manufactured by ETRI and local companies, and the other 20% were procured from oversea manufactured.

All the developed equipments were manufactured, in the phases of EM and EQM, tested and verified confirming space environment requirement. In the phase of FM, all equipments of Ka Payload met the requirement of space environment and interface supplied by COMS spacecraft from Astrium. The FM equipments were integrated into Transponder panel supplied by Astrium, and conformed RF performance as well as interface to BUS in the point of electrical and mechanical. All interface aspects was checked and confirmed working well.

After that, test was performed at the level of "integrated system" to verify satellite electrical performance prior to environmental exposures: complementary functional tests to check the integrity of both bus and payloads and to cover modified hardware and interfaces during payloads/bus mating; a conducted EMC was performed to measure the spacecraft performances.

### 2. Transponder Subsystem Integration and Test

Ka-band payload AIT was successfully conducted in terms of the mechanical activities, thermal preparation, waveguide and cable routing and integration, and electrical interface test. Interface issues between Bus and the Ka transponder have been reviewed and confirmed.

Ka-band payload AIT was conducted in two steps.

The first is to perform using the dummy panel to avoid schedule problem and troubleshoot as shown in Figure-6, and second is to perform on the FM panel.

All Ka equipments were integrated on the +Y axes of FM panel after the preparation such as thermostat bonding, mass measurement, and flatness check. The resistance between the equipment and panel was controlled within the required value using the ground strap. After that, the waveguide, coaxial cable, and harness were integrated.

Sniff & spray test was performed to check RF leakage after panel integration, and RF performance tests and the electrical interface tests with the bus system were performed successfully.

The environment test of the Ka-band payload in the system level was performed with the full spacecraft system. The sine vibration, acoustic, pyro separation tests, and EMI/EMC test were successfully performed. The thermal vacuum test is performed successfully. After thermal vacuum testing, auto-compatibility testing was performed to check radiated EMC interference between payloads and S/C. Ka Payload AIT flow is shown in Figure 2.

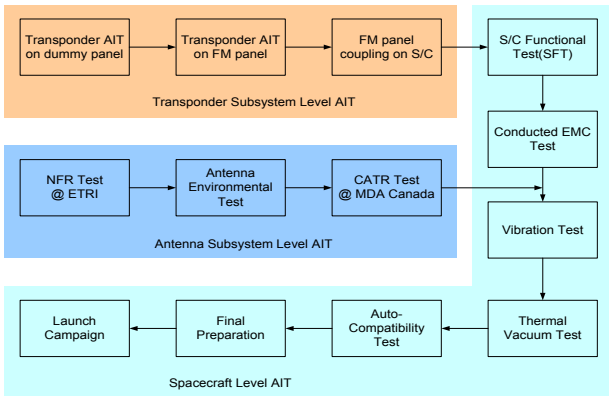


Figure 2: Ka-band Payload AIT flow

### 3. Antenna Subsystem Integration and Test

#### 3.1 Antenna Integration

The antenna is installed to provide the beam coverage to South Korea and North Korea from a geostationary orbit of 128.2°East longitude. The antenna consists of two(2) single offset reflector configuration. The antenna structure consists of reflector with backing rib structure and brackets to accommodate deployment mechanism and hold down and release mechanism.

The feed assembly is composed of horn,

wave-guide run, diplexer, and supporting brackets. The feed assembly was installed onto the earth panel of the spacecraft.

#### 3.2 Antenna Near Field Test (NFR)

The purpose of the antenna near field measurement is to verify the electrical RF alignment of the antenna beams with respect to the spacecraft reference coordinate system at ETRI facility. The antenna range test is conducted to measure radiation performance of antenna, such as patterns, polarization, gain, cross-polarization, side-lobes etc. in the ETRI Near-Field Range (NFR) facility. The measured Tx & Rx beam patterns are shown in Figure 3.

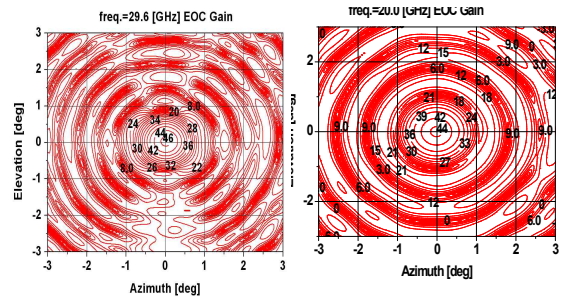


Figure 3: Co-pol. Contour at 29.6 GHz, at 20 GHz

#### 3.3 Antenna CATR (Compact Antenna Test Range)

The purpose of CATR measurement is to verify the RF alignment of the antenna beams with respect to the spacecraft reference coordinate system at spacecraft level. Gain pattern measurements were performed base on the gain comparison method by using standard gain horn. The Tx & Rx co-pol patterns of the East and West antennas show that the beams are pointing in the required direction and are relatively well centered on their respective coverage. CATR test configuration and radiation pattern are shown in Figure 4.

The source horn polarization alignment accuracy is better than 0.1°. The antenna spacecraft coordinates polarization alignment in the compact range was better than 0.055°. The cross-polarization discrimination meets the specification over coverage for both East and West antennas for Tx and Rx by a margin of at least 2.46 dB including the 0.1° pointing error.

The CATR test result is compliant to Spec and NFR test result, which implies antenna alignment result is perfect as shown in Table 2 and Table 3.

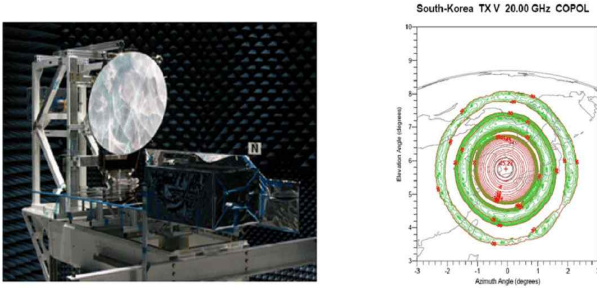


Figure 4: CATR Test Configuration and Radiation pattern

Table 2: CATR test result at Tx

	Gain [dBi], Spec. >40.9 [dBi]				
Frequency [GHz]	19.80	19.87	20.00	20.13	20.19
S-Korea	44.10	44.16	43.99	44.15	44.47
S-Korea 0.1 deg Pointing error	43.03	43.11	42.93	43.16	43.50

Table 3: CATR test result at Rx

	Gain [dBi], Spec. >42.8 [dBi]				
Frequency [GHz]	29.6	29.67	29.80	29.93	30.00
S-Korea	46.43	46.33	46.23	46.45	46.29
S-Korea 0.1 deg Pointing error	44.40	44.32	44.25	44.46	44.31

### 3.4 Ka Payload Environment Test

#### 3.4.1 Vibration Test of Ka band payload

The sine vibration test was conducted in x, y and z-axes with the flight level. A low level vibration survey was conducted to measure natural frequency. Accelerometers were attached on the Ka band payload to measure dynamic response. The maximum deviations of the natural frequency between pre and post low-level sine survey are within 5% in all axes. The vibration test results show that no structural degradation or fracture occurs during test.

#### 3.4.2 Acoustic Test of Ka band payload

Acoustic test was conducted to simulate launch load condition. Low level acoustic surveys were conducted before and after test to detect any structural failure or degradation of Ka band payload. There is no frequency difference between pre and post low-level results. The acoustic test results show that the Ka band payload(reflector) has enough design margin to withstand the applied acoustic vibration loads.

### 3.4.3 Thermal Vacuum Test

#### 3.4.3.1 Test parameter and procedure

Thermal Balance (TB) and Thermal Vacuum (TV) test was performed in KARI facility. The Ka-band EGSE was installed outside of chamber and long waveguide were connected between EGSE and Ka-band Transponder for RF performance measurements during the thermal cycling. Thermal profile is as follows.

Phase	Activities / Testing
Open door	Setup TB/TV test Initial ambient reference test
Pumping	De-pressurization of S/C
Cold down & out gassing	S/C out gassing
TB hot	S/C hot balance test to check thermal model
Transition	Transponders gain variation monitor
TB cold	S/C cold balance test to check thermal model
Eclipse simulation	S/C eclipse simulation test
Transfer, survival mode	Check S/C in transfer orbit or survival conditions
TV cold (SFT-2)	Transponder testing in cold case
Transition	Transponders gain variation monitor
TV hot (SFT-3)	Transponder testing in hot case
Return to ambient	Recover to ambient condition
Open door (SFT-4)	Final ambient reference test



Figure 5: Thermal Vacuum Test of COMS

#### 3.4.3.2 Test result of TV

Thermal Vacuum test for transponder RF performance (SFT-2, SFT-3, and SFT-4) was

performed successfully. The test results are summarized in Figure 6.

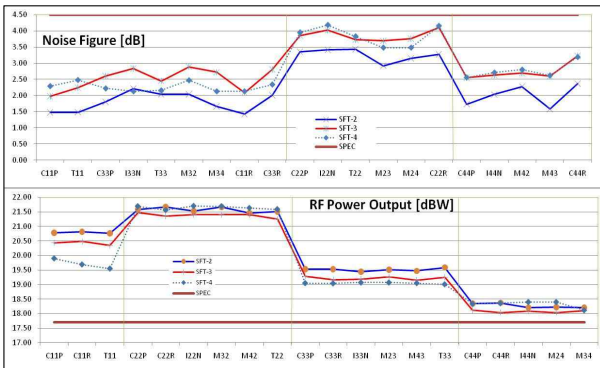


Figure 6: Thermal Vacuum Test Results for Main Parameters of Each Transponder Channel

### 3.4.4 EMI/EMC Compatibility Test

The RF auto-compatibility test was performed in large EMC chamber at Intespace in Toulouse. The purpose of the test is to check RF interference level between payloads in COMS in normal operation condition. The threshold level was  $-65\text{dBc}$  as in-band spurious specification. The result shows no spurious level over  $-65\text{dBc}$  when TCR and MODCS were powered on. After RF auto-compatibility test, two test carriers were injected on the Ka-band transponder to measure 55th PIM level. The result shows no PIM signal on 55th and the other order PIMs also. As a result, auto-compatibility test and PIM test were successfully completed. The test setup for RF auto-compatibility and PIM test is shown in Figure 7.

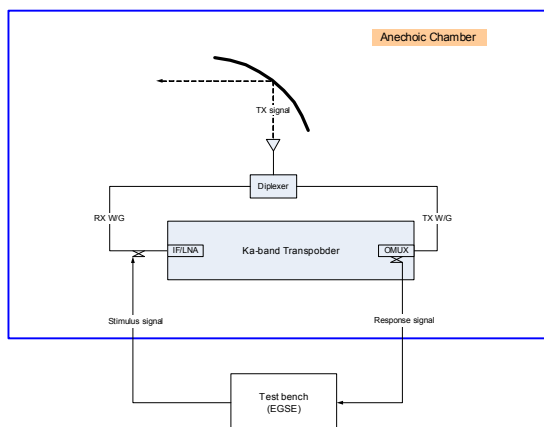


Figure 7: RF auto-compatibility and PIM test setup

During the launch campaign, Ka-band payload health check was performed as a final TM/TC functional checking. All Ka-band TM/TC functions were verified. The health check parameters are as

following.

- o Discrete TM/TC check
  - RF switch position TM/TC functional checking
  - Active equipment on/off TM/TC and analog TM (current, voltage, temp.) display checking
- o LSSB TM/TC check
  - Channel Amp modes(FGM/ALC), output level (Gain/Level) functional checking
  - MSM TM/TC functional checking

## IV. In Orbit Test

### 1 Launch

COMS on board Ka Payload was successfully launched at Kourou in French Guyane at 27th Jun. 2010. (Korean Time). It was stationed at GEO 128.2E.

### 2 Ka Payload IOT

#### 2.1 Test parameter and procedure

Ka-band Payload IOT was performed in two parts, Antenna Pattern Measurements (APM) and payload RF Performance Measurements. Ka payload configuration change was done by KARI SOC (Satellite Operation Center) according to ETRI request and Ka-band telemetry was forwarded to IOT operation center at ETRI. The overall Ka Payload IOT configuration is shown in Figure 8.

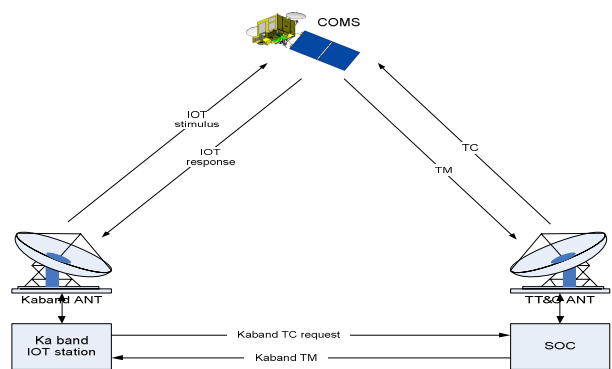


Figure 8: Ka-band IOT configuration

□ APM (Antenna Pattern Measuremet)

Three Ka-band antenna beam patterns were measured at the first phase of IOT. When S/C was slewing, each beam Antenna Pattern was measured at IOT station. The APM information is as follows.

- o APM beams: SK/NK and China beams

- o Cross cuts for each beams:  $\pm 1^\circ$  range
- o Ch. Amp modes
  - ALC mode for TX pattern
  - FGM mode for RX pattern
- o S/C slewing speed:  $0.2^\circ$  /min.
- o Time synchronization between IOT station and SOC

□ Payload RF Performance Measurement

After completing APM, RF performance measurements for Transponder channels are performed. The Test parameters of P/L IOT are as following.

- o IPFD/EIRP (Transfer characteristics)
- o Amplitude vs. Frequency Response (AFR)
- o Frequency conversion characteristics
- o Payload G/T
- o FGM function
- o ALC function

2.2 Test Result

Table 4 shows the APM results for the South Korea beam and the North Korea beam. The de-pointing angles are within acceptable range and no ADTM adjustments are necessary.

Table 4: APM test results

Parameter		Spec. Value	De-pointing Value
S. Korea beam center	Azimuth	-0.09	-0.02
	Elevation	5.75	0.06
N. Korea beam center	Azimuth	-0.19	-0.06
	Elevation	6.20	-0.03

Figure 9 shows the major RF performance of Ka band payload evaluated from IOT measurement results. IOT measurement for RF performance of the South Korea channels and the North Korea channels are performed successfully and all performance are consistent with the ground test results.

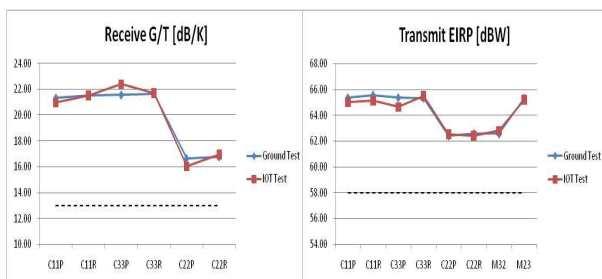


Figure 9: IOT RF performance results

V. Applications

As completing IOT and verifying excellent status of Ka Payload, it is to apply the various areas. It is to use Ka frequency transmission experiment including rain attenuation and modeling study, and RF performance verification over lifetime of domestic built Ka Payload system. It is also to apply Test-bed for new developed technology such as VSAT terminal and service including UHDTV and 3DTV transmission by domestic University, Industry and Institutes. It is to apply for public services such as natural disaster prevention / recovery services.

VI. Conclusion

Ka payload composed of on board switching transponder and multi-horn antenna was developed successfully by ETRI in cooperation with local companies.

Around 80 % of Ka payload equipments was designed, manufactured and tested by ETRI and domestic companies, and integration & test of transponder and antenna was successfully completed by local technology. Local technology of Ka Payload development was perfectly verified as a result of in orbit test which shows compliant to ground test result.

Ka Payload developed by ETRI is to operate normally, and to apply several areas including public services.

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