Manufacturing and Testing of Ka-band Communication Payload of COMS

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***Abstract*—Communication, Ocean and Meteorological Satellite (COMS) is the multi-purposed Korean geostationary satellite funded by Korean government ministry, and is to supply communication services, ocean and weather observation for 7 years. As part of Communication, Ocean and Meteorological Satellite, Ka-band communication payload is developed by Electronics and Telecommunications Research Institute. The purpose of Ka-band payload development in Communication, Ocean and Meteorological Satellite program is to acquire space proven technology of Ka-band payload and to exploit advanced multimedia communication services. The Communication, Ocean and Meteorological Satellite was launched at end of June 2010 at French Guiana. The Ka-band payload function and performance were verified by in-orbit test after launch. In this paper, we will review development and in-orbit test of Ka-band payload system in Communication, Ocean and Meteorological Satellite program.**

Keywords- Communication, Ocean and Meteorological Satellite; Ka-band payload; In orbit test

I. INTRODUCTION

Communication, Ocean and Meteorological Satellite (COMS) named Chunrian is the first geostationary satellite developed by local developers funded by Korean government Ministries including Ministry of Education and Technology, Korea Communication Commission, Ministry of Land, Transport and maritime Affairs, and Korea Meteorological Agency. COMS 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 program, is sponsored by Korea Communication Commission and developed by Electronics and Telecommunications Research Institute (ETRI) with Korean local companies [1][6].

The purpose of Ka-band Payload development is to acquire space proven technology of Ka-band equipment and system and to exploit advanced multimedia communication services. ETRI with domestic technologies successfully finished Ka-band payload equipments development and system integration and testing at ground facility [3][4][5]. After satellite launch, ETRI verified all Ka-band payload function and performance are normal state by In Orbit Test (IOT) [7].

Ka-band Payload of COMS 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 [1][6].

In this paper, we will review integration, manufacturing process and test validation status of Ka-band communication payload of COMS. COMS configuration will be reviewed in Section 2, followed by Ka-band payload configuration in Section 3. Manufacturing and ground test activities will be reviewed in Section 4. Finally, in orbit test results of Ka-band payload will be reviewed in Section 5. Section 6 will present the conclusion and future works.

II. THE COMS OVERVIEW

The COMS is a multipurpose hybrid geostationary satellite launched at the end of June 2010. Many of Korean research institutes and industries are participated in COMS program for first Korean hybrid satellite program success. COMS program has been led by Korea Aerospace Research Institute (KARI) with the collaboration with EADS Astrium. ETRI was involved in Ka-band payload development with cooperation with Korean industries.

The COMS is a geostationary three-axis body-stabilized platform, which can support more frequent observation of atmosphere and ocean. This feature enables the COMS system to provide large volume of source data with high quality for meteorological and ocean research organizations [1].

Three mission payloads consist of Meteorological Imager (MI), Geostationary Ocean Color Imager (GOCI) and Ka-band Communication Payload System (COPS).

The MI is a radiometer, which measures energy from Earth's surface and atmosphere, which has one visible channel with 1km spatial resolution and four infra-red channels with 4km spatial resolution. The MI can scan a scene as large as the full Earth disc every 30 minutes, or smaller area as 1000km×1000km in less than 60 seconds. Radiometric data collected with MI is useful for cloud and pollution detection, storm identification, cloud height measurement, water vapor wind vectors, surface and cloud top temperature, etc.

The GOCI is the first ocean observation instrument operating in a geostationary orbit. It has eight visible channels with a spatial resolution better than 0.5km at the center of imaging area. The GOCI imaging area is 2500km×2500km around Korean peninsula. The GOCI is a step-stare type instrument to get sufficient radiometric energy within limited imaging time.

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The Ka-band payload consists of transponder subsystem, antenna subsystem, and beacon assembly for the Ka-band fixed satellite service in the required service coverage. The Transponder subsystem includes all the necessary microwave hardware in order to receive, switch, amplify and transmit microwave signals. The antenna subsystem generates the three Ka-band beams for the South Korea, North Korea and Donbei region of China. The Beacon assembly generates Ka-band beacon signal for the rain attenuation experiment and antenna tracking. Figure 1 shows the COMS configuration in space [3][4][5][6][7].

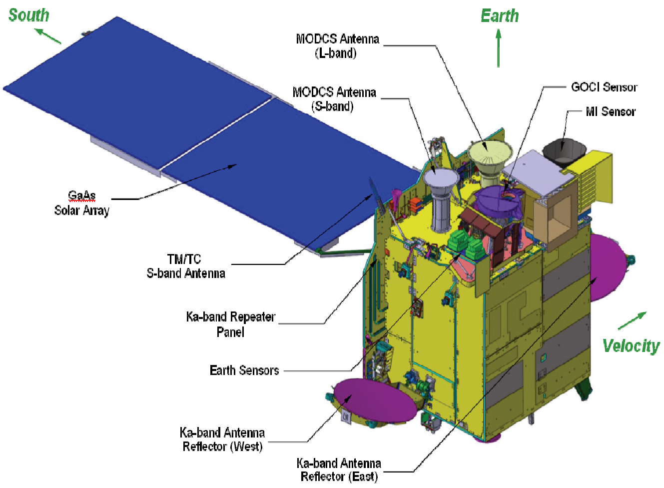

Figure 1. COMS configuration in space

III. KA-BAND PAYLOAD OVERVIEW

The Ka-band payload provides 100MHz wide four channels for fixed satellite service. Three channels are assigned for on-board switching for multi-beam connection and one channel is assigned for bent pipe connection. The uplink is frequency band is 30GHz and the downlink frequency band is 20GHz. The multi-beam switching is performed at 3.4GHz band. Channel allocation and frequency plan of Ka-band payload are shown in Figure 2.

The Ka-band payload will provide communication services for natural disaster such as its prediction, prevention, recovery service in the government communication network and high-speed multimedia services such as Internet via satellite, remote-medicine, and distance learning in the public communication network. The Ka-band payload was designed to meet link availability 99.7% during the service period at BER 10^{-6} quality.

As shown in Figure 3 service coverage for the Ka-band payload system is two regions named by beam 1, 2 and 3. Beam 1 was assigned to the South Korea for national disaster service network and satellite multimedia service network, while beam 2 and 3 will be assigned to the North Korea and North-east of China respectively.

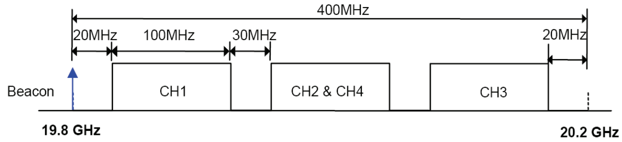

Figure 2. Ka-band payload frequency plan

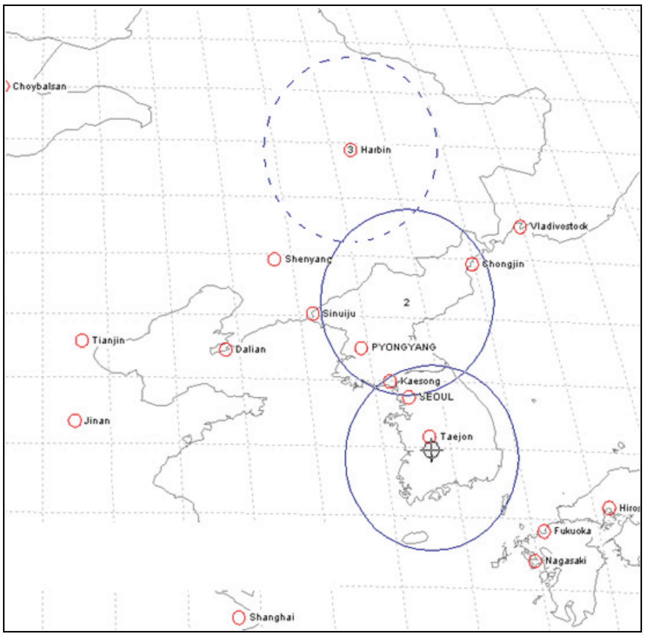

Figure 3. Ka-band payload beam coverage

The Ka-band payload consists of multi beam antenna and on-board switching transponder subsystem, which includes all the necessary microwave hardware in order to receive, switch, amplify and transmit microwave signals within the defined coverage area. The Ka-band payload system was designed to be capable of the communication service function among the individual beams [2][3][4].

The transponder subsystem supports beam switching function for high speed satellite multimedia services between each beams. To accomplish this mission 3.4GHz band Microwave Switch Matrix (MSM) was integrated in the transponder panel. The Figure 10, at end of this paper, shows the block diagram of Ka-band payload system. The antenna subsystem generates three Ka-band multi beams for the required coverage areas and simultaneously transmits and receives the microwave signal to and from the Earth station via beams, respectively. The China beam channel is reserved for standby channel for South Korea and North Korea channels. Table I shows the main specification of the Ka-band payload.

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TABLE I. MAIN SPECIFICATION OF KA-BAND PAYLOAD

Parameters	Specifications
G/T	13dB/K
EIRP	58dBW
Power	< 1.1KW
Mass	< 100Kg
Frequency	TX: 19.8 ~ 20.2GHz RX: 29.6 ~ 30.0GHz
Satellite Longitude	128.2°E
Polarization	Linear

IV. MANUFACTURING AND TESTING

The Spacecraft (S/C) structure was equipped and tested with the combined propulsion system by EADS Astrium and shipped to Korea Aerospace Research Institute (KARI) in Korea. Spacecraft Assemble, Integration and Test (AIT) activities were then started with structure preparation and bus harness installation, just before unit level mechanical and electrical integration. Then, Spacecraft Functional Test (SFT) was performed [5]. The Ka-band transponder integration was performed at ETRI, in parallel, on a wall provided by EADS Astrium, and verification tests were performed at equipment level and subassembly level. Then, the wall equipped with Ka-band was delivered to KARI for spacecraft level integration and system level testing. MI and GOCI were delivered to KARI and assembled, integrated and tested at subassembly level.

The S/C system level activities were started with the transfer and the electrical coupling of the Ka-band payload onto the bus. Then, MI and GOCI were mechanically installed and electrically integrated on the bus.

The test program was continued with the "integrated system test" to baseline the 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.

Before mechanical qualification, the spacecraft assembly was completed with the integration of antennas and solar array wing. At this stage, all the spacecraft alignments and all the release, deployment, and trimming tests of mechanisms were performed.

The fully assembled spacecraft was submitted to a first S/C health check test then to mechanical qualification tests (sine vibration, acoustic noise). At the end of the mechanical tests, the fully assembled spacecraft was submitted to a second S/C health check test in order to verify S/C integrity and to a launch vehicle adaptor fit-check. Release/deployment tests of mechanisms, alignment checks were performed to verify the system integrity and performances after mechanical exposures. After solar array wing and the deployable antennas were removed, the spacecraft was submitted to the thermal balance and thermal vacuum exposure. Functional and performance tests are performed for selected thermal conditions.

After thermal qualification, Chemical Propulsion System (CPS) performance test was performed to verify the system integrity. The deployable reflectors were re-integrated on the spacecraft, the release / deployment / trimming tests of the mechanisms and the alignments checks was performed in the RF compact range. With the reflectors deployed and clamped in the nominal flight position, the final SFT with the same hard-line connections than the previous ones, a ground segment compatibility and authentication test, the antennas performance tests and the RF compatibility was performed to complete the spacecraft integrity and performance verification. The spacecraft integration was achieved with the final integration of solar array. After external finishes, the spacecraft physical property was measured. The spacecraft was ready for storage or shipment to the launch site. The Figure-4 shows the Ka-band payload AIT flow.

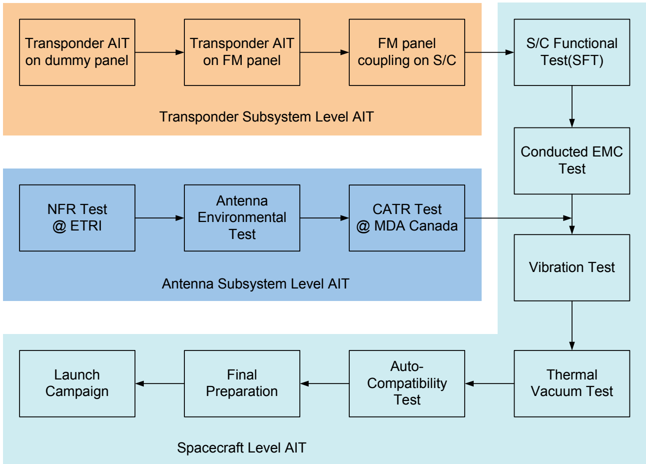

Figure 4. Ka-band payload AIT flow

V. IN ORBIT VALIDATION

After the successful launch of a satellite and verification that it has reached its geosynchronous orbit position, the spacecraft antennas have been deployed. This was followed by an intensive test program called In Orbit Test (IOT). The purpose of IOT is to determine whether the satellite and its subsystem have survived the launch, and whether subsystem performance is as expected. Hereinafter we will review IOT system configurations and review Ka-band payload IOT results.

A. IOT System

An integrated suite of microwave measurement equipment, computer hardware, and measurement software was designed, fabricated, and installed into a unified test facility for measuring the performance of Ka-band payload of COMS. IOT measurements are performed by transmitting test signals to spacecraft and comparing their power, frequency with the signals re-transmitted from the satellite. The major components of the Ka-band IOT facility are the IOT equipment, the Earth station equipment, and the large size reflector TX/RX antenna. The Earth station equipment receives uplink signal generated by the IOT hardware, perform frequency conversion from L band to Ka-band, amplifies them, and transmits them to the antenna system. It then receives downlink signal from the spacecraft, amplifies them, perform frequency conversion from Ka-band to L band, and transmits them to the IOT equipment for measurement. Table II shows the Ka-band IOT system equipment description and Figure 5 shows the IOT system diagram respectively.

TABLE II. IOT SYSTEM EQUIPMENT

	Equipment	Description
Earth station equipment	Antenna	Reflector size: 7 meters Gain: 63.5dB in 30GHz 60.4dB in 20GHz
	Up-converter	Frequency conversion from 1.2GHz to 30GHz
	HPA	Up to 175W output
	LNA	Gain: 50dB
	Down-converter	Frequency conversion from 20GHz to 1.2GHz
IOT equipment	Signal generator	Up to 3GHz
	Spectrum analyzer	Up to 3GHz
	Power meter	Up to 33GHz
	Frequency counter	Up to 40GHz
	IOT console	PC with windows-xp

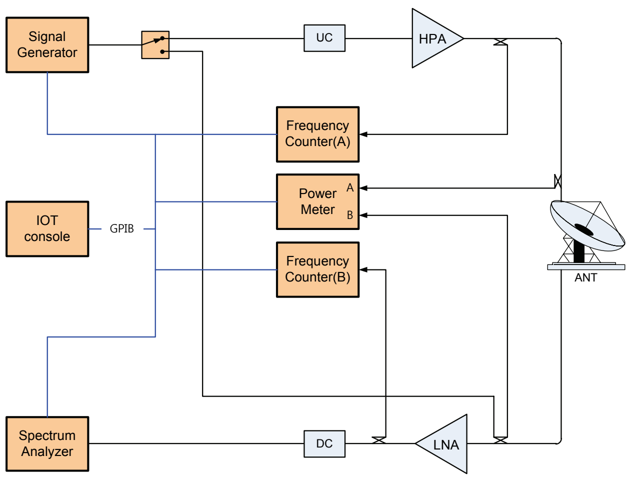

Figure 5. Ka-band IOT system diagram

B. *IOT Results*

Ka-band payload IOT was performed in two phases. The first phase is antenna pattern measurement and the second phase is payload RF performance measurements.

1) Antenna Pattern Measurements

The roles of the Antenna Pattern Measurements (APM) are to check that the satellite antennas were not damaged during the launch and to check that the antenna pointing alignment were not disturbed by the launch. For the APM, the spacecraft needs to be rotated during IOT station transmit test signal to satellite and receive returned signal from the satellite. The spacecraft was rotated $\pm 1^{o}$ from the beam center in azimuth angle and elevation angle respectively with 0.1^{o}/min. speed. The IOT station transmit CW signal to satellite and measure returned signal from the satellite to get relationship between signal strength vs. spacecraft rotation angle. During the APM, Channel Amplifier mode of Ka-band payload was selected to Fixed Gain Mode (FGM) and Automatic Level Control (ALC) respectively. The antenna Transmit (TX) pattern can be measured in ALC mode, whereas antenna Receive (RX) pattern can be derived from the measurements in ALC mode.

The antenna patterns measured during the IOT were compared with Compact Antenna Test Range (CATR) measurement results performed on ground facility. The APM of IOT and CATR are very similar and this confirms there was no antenna performance degradations by the vibration during the satellite launch. The Figure 6 and Figure 7 show APM results of IOT and compared with the CATR results performed in ground facility [4][7].

Figure 6 shows satellite antenna TX pattern of beam 1. The dotted line is APM results from IOT and solid red line is APM results from CATR measurement in ground. The two patterns similarity shows that satellite antenna performance was not degraded by the launch vibration. Figure 7 shows combined TX and RX pattern of beam 1.

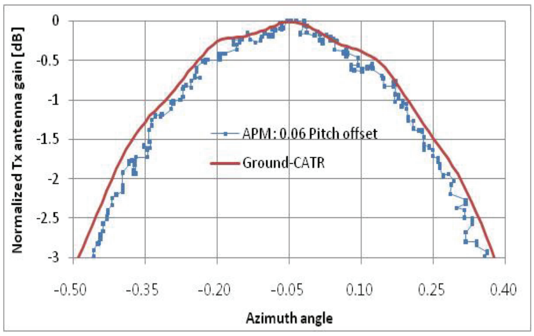

Figure 6. TX pattern of beam 1

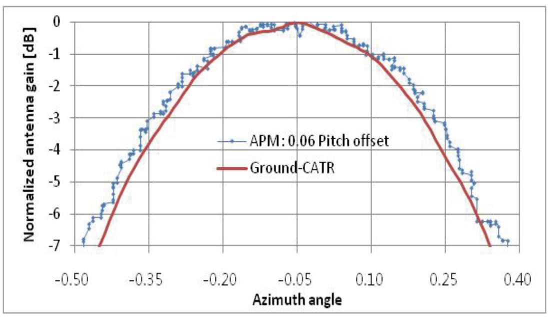

Figure 7. TX+RX pattern of beam 1

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2) *Payload RF Performance Tests*

The purpose of payload RF performance tests are to check Ka-band transponder was not damaged during the launch. The test parameters are as followings.

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

a) *IPS/EIRP Measurements*

IOT station generates CW carrier and transmit to the spacecraft. The returned CW signal from the spacecraft is monitored by the Spectrum Analyzer in the IOT station and compare with the transmission signal. The uplink CW carrier signal power was increase 1dB step until monitored downlink signal power was saturated. When the downlink signal power is in saturation, input power to the spacecraft transponder is called Input Power Saturation (IPS) and transponder output power is called saturation Effective Isotropic Radiation Power (EIRP). The measured IPS/EIRP of the Ka-band payload was similar with ground test results. Figure 8 shows the transponder input and output power transfer characteristics.

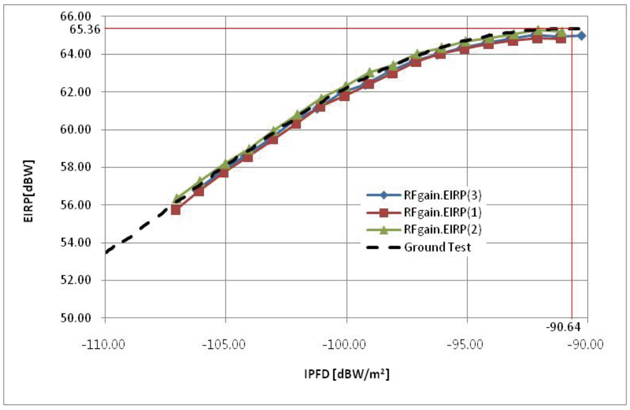

Figure 8. Transfer characteristics of channel 1

b) *Amplitude vs. Frequency Response Measurements*

The amplitude vs. frequency response measurement is to be performed when transponder in linear condition. The uplink signal is swept from starting frequency to stop frequency over the channel band with 2MHz steps. The downlink signal is measured by spectrum analyzer and compensate uplink path and downlink path frequency response to get satellite transponder frequency response. The measured amplitude vs. frequency response during the IOT was similar with ground test results. Figure 9 shows transponder amplitude vs. frequency response characteristic of the channel 4.

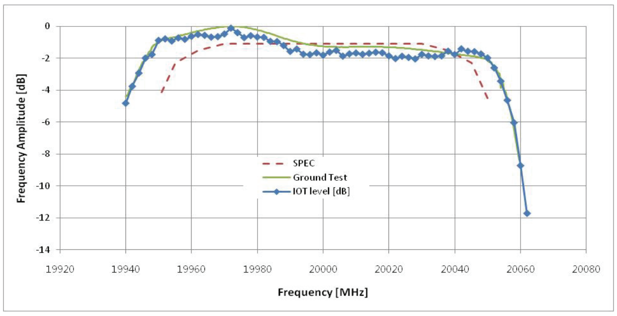

Figure 9. Amplitude vs. frequency response of channel 4

VI. CONCLUSION AND FUTURE WORKS

In this paper, we reviewed integration, manufacturing and test validation of Ka-band communication payload of COMS. The similarity between in-orbit test results and ground test results are confirms that Ka-band payload was well withstands launch environments and also performances are not degraded in space environments. At this moment, 3D-HDTV broadcasting and broadband VSAT communications are in trial service through Ka-band payload. The first made in Korea Ka-band telecommunication payload of Chunrian satellite will be used for satellite R&D experiments, test-bed for new satellite telecommunication technology verification test and public services test. The space proven technologies from the COMS program will be used for next telecommunication satellite development.

REFERENCES

[1] S.P. Lee, "Development of Satellite Communication System for COMS", Proceedings of APSCC 2004, pp. 71-96.

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

[3] J.S. Choi, Y.D. Lee, and S.P. Lee, "Development of Ka-band Multibeam Antenna", 13th Ka and Broadband Communications Conference, 2007, K000055.

[4] J.S. Choi, Y.D. Lee, and S.P. Lee, "CATR Test for Ka-band Multi-beam Antenna", 26th International Communications Satellite Systems Conference (ICSSC), June 2008, AIAA 2008-551.

[5] J.H. Jo, H.J. Woo, and S.P. Lee, "The Design and Implementation of Electrical Ground Support Equipment (EGSE) for COMS Ka-band Transponder Testing", 26th International Communications Satellite Systems Conference (ICSSC), June 2008, AIAA 2008-5436.

[6] S.P. Lee, J.H. Jo, M.H. You, J.S. Choi, and K.B. Ahn, "Ka-band Communication Payload System Technology of COMS", JC-SAT2010, October 2010, pp. 19~24.

[7] S.P. Lee, J.H. Jo, M.H. You, J.S. Choi, "Integration, Testing and In Orbit Validation of Ka-band Communication Payload of COMS", ICTC-2010, pp. 309~313.

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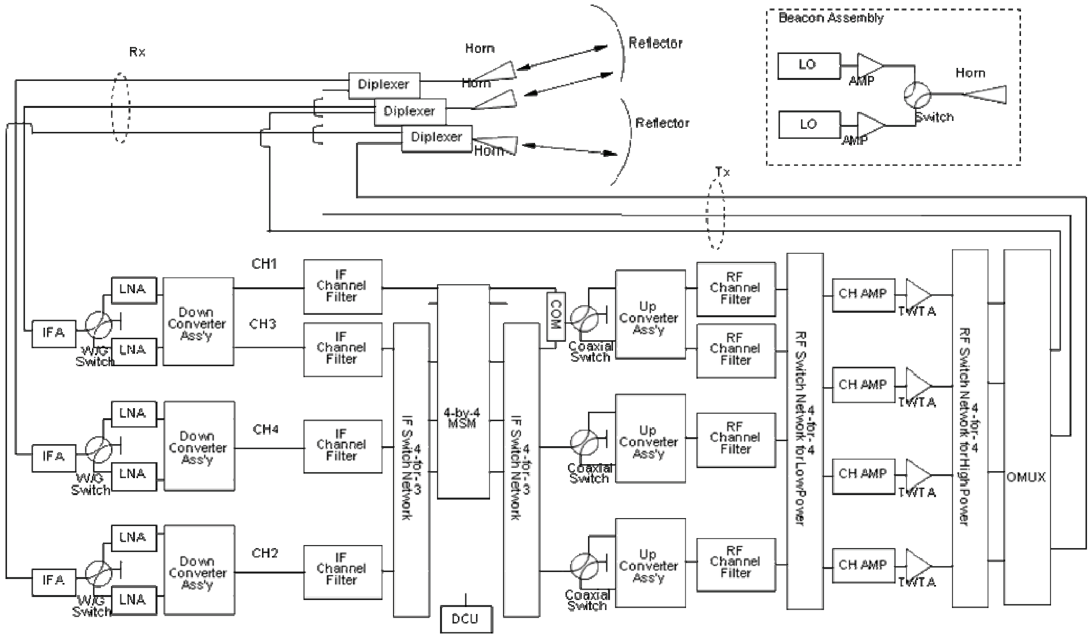

Figure 10. Block diagram of Ka-band payload system