Design of 2-axis Gimbal Spaceborne X-band Antenna for High Data Rate Payload Transmission

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***Abstract* — The space borne X-band 2-axis gimbal antenna needs frequency re-uses techniques by dual circular polarization for the very high data transmission. The gimbal antenna consists of 2-axis driving mechanism, high efficient horn antenna, very low loss non-contact type RF transmission line of coaxial type rotary joint. This paper designed high efficient horn antenna and very low loss non-contact type RF transmission line of coaxial type rotary joint and 2-axis driving mechanism.**

***Index Terms* — gimbal antenna, rotary joint, X-band, low jitter, horn antenna, dual circular polarization.**

I. INTRODUCTION

The design of space borne payload antenna has two requirements : high data rate, even giga-bit data rate, and very low jitter when driving the mechanical actuator to track the ground station in order to download payload data. To get high resolution images from remote sensing satellites, it is important to increase the amount of data to be transmitted in real time.

To transmit payload data, a 2-axis gimbal X-band antenna is generally used on commercial satellites. For the Korea multipurpose satellite (KOMSAT) case, an Omni antenna was used to transmit data of 45 Mbps on KOMSAT-1, a planar antenna and corrugate antenna were used to transmit 320 Mbps, 640 Mbps on KOMSAT-2 and 3, respectively.

Fig. 1 shows the general structure of a 2-axis gimbal antenna. The next generation of optical cameras produces more high resolution images and it requires higher data rate of Giga-bit transmission. Thus the jitter reduction of satellite motion is a critical technical issue on the payload transmission of the gimbal antenna.

The techniques being considered for handling higher data rates along with implications in implementing the new techniques are frequency re-use techniques to enhance the data transmitting capability in the already allocated frequency bandwidth. One method for obtaining frequency reuse is to transmit two signals on the same frequency band (co-channel) by placing each on orthogonal polarizations like RHCP, LHCP; thereby doubling the information capacity carried by the satellite. A fundamental requirement of dual polarized transmission is to maintain a good level of isolation between two polarizations so that the co-channel interference is acceptable. Since remote sensing data can be received globally, compatibility of ground stations will be a major consideration in choosing the frequency band and polarization.

In this paper, we describe the design and implementation of a 2-axis gimbal antenna structure and the key RF components. Also it shows the analyzed antenna mechanical structure stability of the designed 2-axis gimbal antenna for space application. The modal analysis shows that the designed gimbal antenna structure is very stable.

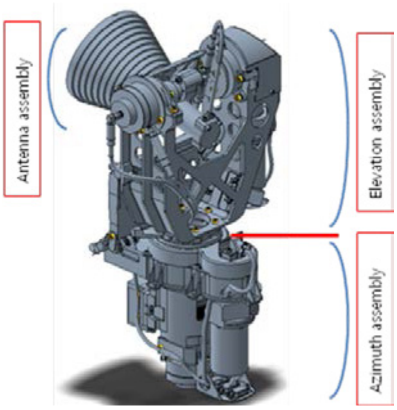

Fig. 1. Designed 2-axis gimbal antenna with antenna at X-band

II. DESIGN OF GIMBAL ANTENNA

Till now, many remote sensing satellites have used a fixed gimbal antenna to transmit payload data to the ground station at either the S-band or X-band with RHC polarization. To meet the demand for more high data rate transmission, we have considered the frequency re-use techniques using RHCP and/or LHCP on one antenna with septum. In this section, the mechanical structure of 2-axis gimbal antenna, and the key RF components of high efficiency, low insertion loss antenna and dual polarized circuit septum are described.

The 2-axis gimbal consists of azimuth and elevation driving step motors with FPGA based controller, horn antenna with dual circular polarized circuit septum, rotary joint of non-

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contact type RF transmission line in dual channel, and slip ring. In this paper, we will describe only the RF components of the antenna with septum polarizer and the rotary joint as the key components. And we will describe the total mechanical structure shortly to help the reader's understanding.

A. Corrugated Horn Antenna with RHCP/LHCP

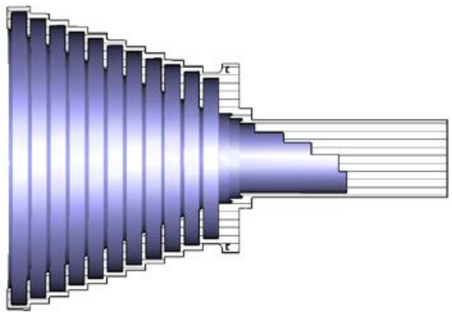


Fig. 2. Designed horn antenna with septum.

Fig. 3 shows the designed antenna. The designed antenna is the dual circular polarized corrugated horn type to reuse same X-band frequency. The antenna has the radiation capability of two independent RHCP and/or LHCP signals by using one horn antenna. The RH and LH polarization is generated by the septum which is integrated in the antenna feed line. In the septum design, the isolation of RHCP and LHCP is a critical parameter. The antenna is a corrugated horn type and the septum is matched to a 50 ohm coaxial input port and to a circular wave guide to antenna port. In our design, we have designed for a frequency of 600 MHz which is very wideband and it can use a worldwide ground station. After basic design of the corrugated horn and septum polarizer, it is optimized by the commercial tool(CST). The simulated maximum gain is 16.8 dBi, and the insertion loss is 0.035 dB including the septum at 8.2 GHz. In our design, the low insertion loss is a very critical design goal to keep the total antenna link budget. The antenna radiation pattern on RHCP and LHCP are identical beam pattern and the simulated cross polarizations of RHCP and LHCP are better than -43 dB.

B. Dual Channel Rotary Joint

The rotary joint is a component of RF transmission line with a 360° rotation mechanism. In our design, two RF channel in one rotary joint is required to increase the transmission of data rate. Two channels have the same frequency at the X-band and the bandwidth is at a minimum 600 MHz the technical difficulty is the small insertion loss of secondary channel less than 0.4 dB. Also, the rotary joint should have very robust mechanical structure to warranty more than 30,000 hour life time in its operation. Fig. 3 shows the insertion loss of the designed rotary joint for two channels. Ch1 is the contact type RF straight transmission line and it shows very low insertion loss less than 0.08 dB over band width of 1 GHz independent on the rotation angle. But for the Ch2 case, the insertion loss is changed by rotation angle and operation frequency. The typical insertion of Ch2 is less than 0.2 dB over full the bandwidth, but the performance is affected by the rotation angle, because the mechanical coupling of non-contact type transmission line has a different performance depending on the angle. Probably, this different coupling can be improved by the changing the coupling structure in next upgraded version.

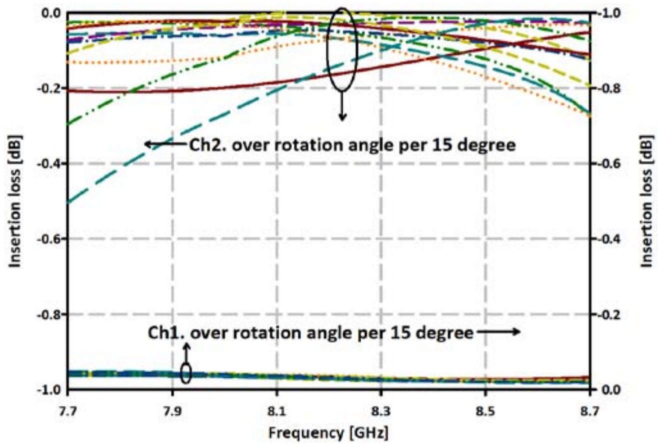
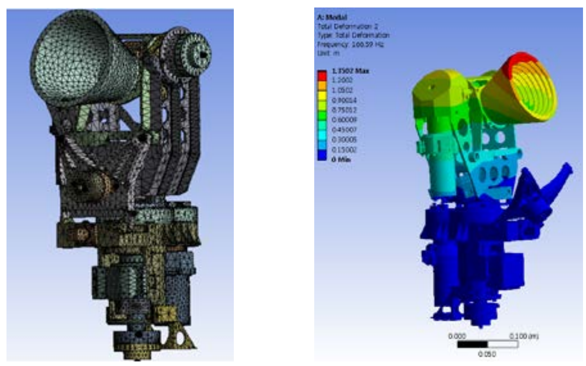


Fig. 3. Simulation result of insertion loss of rotary joint for RF channel1 and RF channel 2 depending on rotation angle at X-band.

C. Mechanical Structure of 2-axis Gimbal Antenna



(a) FE model (b) Result of model analysis

Fig. 4. Mesh model of 2-axis gimbal antenna and designed mechanical structure.

Due to its metallic construction the satellite antenna should be robust to radiation, thermal excursions, aging, vibration, etc. The design of mechanical structure focuses on two technical issues. First is the reduction of jitter in the gimbal driving mechanism which disturbs the image data quality during imagery collection. In general, the jitter caused by mechanical driving should be less than the satellite jitter which is 3 x 10^{-4} deg/sec. This requirement leads to a challenge in the mechanism design. The mechanism of gimbal consists of a mechanical housing, bearing assembly, brushless

DC motors for elevation-azimuth control, slip ring, gear, HRM and dual channel non-contact type RF Rotary joint for RF transmission in RHCP and LHCP. The elevation drive module drives the antenna by 180° □whi
module drives the elevation module together with antenna by 360°. The driving maximal speed of 10°/second is required to tracking the ground station by satellite flight.

Fig. 4(a) shows the mechanical structure in mesh model with nodes of 936108 and element of 484489. Fig. 4(b) shows the simulated structure analysis result of mesh model in 1st Mode is shown. The first frequency is 149.81 MHz and we analyzed to 30th modes to ensure the structure stability.

III. EXPERIMENT RESULTS

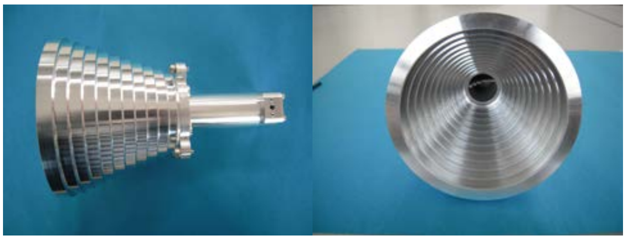


Fig. 5. Manufactured horn antenna with septum.

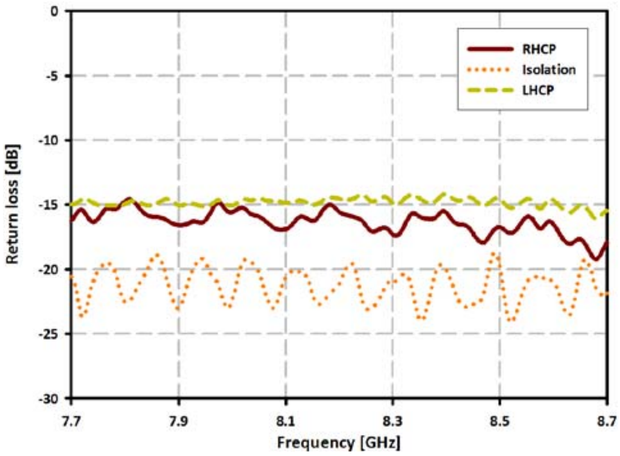


Fig. 6. Measured return loss and isolation for corrugated horn antenna with septum.

We manufactured the corrugated horn antenna with the septum. In this section, we show the experimental results of the antenna. Fig. 5 is the manufactured corrugated horn antenna with septum. The antenna was made of aluminum 6061. The antenna's total mass is 420 g including bolts and SMA connectors which are lighter than commercial space born antenna. Fig. 6 is the measured return loss and isolation of RHCP and LHCP. The measured return loss is below -14 dB and the isolation is -18 dB. Fig. 7 is measured radiation pattern of RHCP, LHCP and RHXP, LHXP. The measured gain is 17.35 dBi at 8.2GHz and the cross polarizations of RHCP and LHCP are better than -31 dB.

The dual channel rotary joint is in progress of manufacture.

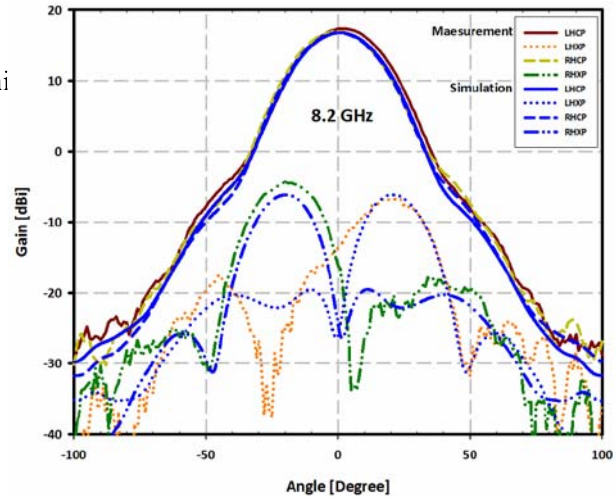


Fig. 7. Measured result for corrugated horn antenna with septum on LHCP, RHCP and on LHXP, RHXP at X-band.

VI. CONCLUSIONS AND FURTHER WORK

In this paper, we designed a 2-axial gimbal antenna for space application and it is the first to be produced in Korea. After design optimizations on the of engineering model, it will be space qualified and tested in space environment. After the final test, qualification, the developed gimbal antenna will be used for next generation medium-sized satellites in Korea.

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REFERENCES

[1] Y.H.Kim, T.H.Kim, S.H.S.Jung, S.G.Lee, "*XGA SRR Report*," GIST, Korea, Jan., 2013.
[2] C. Granet and G. L. James, "Design of corrugated horns: a primer," *IEEE Antennas and Propagation Magazine*, vol. 47, No.2, 2005, pp.76-84.
[3] M. Schmid, S. S. Yong, and S. G. Lee "Extremely compact tow-axis X-band antenna assembly," *Proc. 13th European Space Mechanisms and Tribology Symposium 2009*, Vienna, Austria.
[4] M. Ferris, and N. Phillips "The use and advancement of an affordable, adaptable antenna pointing mechanism," *Proc. 14th European Space Mechanisms and Tribology Symposium 2011*, Constance, Germany, pp.227-234