통신해양기상위성 Ka 대역 인증모델 멀티플렉서에 대한 연구

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A Study on Ka band Qualification Model Multiplexers for Communication, Ocean and Meteorological Satellite (COMS) Payload

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요 약

본 논문에서 2008년에 발사될 통신해양기상 위성탑재용 Ka 대역 멀티플렉서의 인증모델 결과를 보였다. 이들은 위성통신에서 주파수 자원을 효율적으로 사용하기 위한 위성중계기용 입력 및 출력 멀티플렉서와 반사판 안테나를 송수신 대역에서 공용으로 사용하기 위한 급전용 다이플렉서이다. 4개의 주파수채널을 지닌 중계기 입력부에서 사용되는 입력 멀티플렉서는 높은 주파수 선택도 특성을 지닌 협대역 8차 타원형 필터와 2차 군지연등화기를 갖는 독립 채널 필터들로 이루어져 있다. 출력 멀티플렉서는 저손실 특성을 갖고, 무게 및 부피가 적은 매니폴드 형태가 이용되었다. 급전부에 사용되는 다이플렉서의 송수신 포트는 E 평면 T 접합부를 이용하여 분기되었고, 수신부 필터는 튜닝이 용이하도록 비대칭 유도성 아이리스를 이용한 필터가 적용되었다. 제작된 인증모델 멀티플렉서들은 요구 규격에 맞도록 전기적 성능시험, 진동시험, 기계적 충격시험, 열진공 시험, EMC 시험 등이 실시되었고, 시험결과 비행모델에 적용 가능한 성능을 보였다.

Key Words : Communication Satellite; Channel filter; Waveguide filter, Multiplexer

ABSTRACT

This paper presents the test results of Ka band qualification model multiplexers for COMS Payload to be launched in 2008. These are the input and output multiplexers of the satellite transponder to use available frequency resources effectively and the diplexer of the satellite antenna to use the same reflector for both transmitting and receiving frequency bands, respectively. The input multiplexer with four frequency channels has four(4) independent channel filters which consist of an 8-pole elliptic band-pass filter for high frequency selectivity and a 2-pole equalizer for group delay equalization. For low insertion loss, mass and volume reduction, manifold type is employed for output multiplexer. E-plane T-junction is used for either splitting or combining a frequency band into two sub-bands. Asymmetric inductive irises are used to tune the receiving filter easily. The electrical performance and environmental test such as vibration test, mechanical shock test, thermal vacuum test and EMC test are performed and the results of all qualification model multiplexers are compliant to the requirement of each multiplexer. Followed by this qualification, the flight model equipment will be developed.

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Ⅰ. Introduction

After establishing the development plan of Koreasat in the beginning of 1990, transponder systems, antenna systems and RF components for communication satellites began to be developed in Korea. Based on the national long-term space plan established by Korea government[1], Electronics and Telecommunications Research Institute (ETRI) has developed the engineering qualification model (EQM) payload system and its core technologies for the communication and broadcasting satellite from 2000 to 2003. After successfully developing the CBS project, ETRI has been developing the payload system and its core technologies for Communication, Ocean and Meteorological Satellite (COMS) to be launched in 2008[2].

In satellite communication systems, the channelization of frequency band is required to use the available frequency spectrum effectively. Therefore input and output multiplexers with high frequency selectivity are constantly demanded in satellite transponders[3]. Furthermore, a diplexer, for either splitting or combining a frequency band into two sub-bands (transmitting and receiving band), is widely used because it permits the use of the same reflector antenna for the different frequency bands. Now, ETRI has been developing flight model multiplexers and accumulating the key development technologies.

This paper presents the test results of Ka band qualification model (QM) multiplexers such as the input multiplexer, the output multiplexer and the diplexer for COMS Payload. The design target was determined by the heritage[4-5] of former project and to meet the transponder system requirement. The design of the multiplexers was finalized through several design reviews. They were manufactured according to the process approved by Quality Assurance personnel. The electrical performance and environmental test such as vibration test, mechanical shock test, thermal vacuum test and EMC test were carried out. The results of all qualification model multiplexers are compliant to the requirement of each multiplexer.

Ⅱ. Input Multiplexer

The main function of input multiplexer is to divide the input low power signals from up-converter into individual channel signals. The input multiplexer in the COMS transponder with four frequency channels has four(4) independent channel filters which consist of a narrow 8-pole elliptic band-pass filter for high frequency selectivity and a 2-pole equalizer for group delay equalization[2]. Table 1shows the design target of RF channel filters. In this paper, one channel (channel no. 2) of RF channel filter is presented since each channel has almost same performance.

Table 1. Design target of RF channel filters

Parameter	Target
Center Frequency	CH 1 : 19.87GHz CH 2 & 4 : 20.00GHz CH 3 : 20.13GHz
Bandwidth	100MHz
Insertion Loss	< 4.5dB @ fc
Return Loss	> 20.8dB
Amplitude variation	< 1.3dB (fc±50MHz)
Group delay variation	< 22.5ns (fc±50MHz)
Rejection	> 48.0dB (fc±80MHz)
Temperature Range	-20 ~ 55°C

As shown Fig. 1, the individual channel band-pass filter was realized by iris coupled cylindrical waveguide cavities using the TE_{113} orthogonal degenerate modes. Each open ended cylindrical cavity was machined from Solid Invar 36, a thermal low expansion alloy which provides a stable RF performance over the specified temperature range. To improve electrical contact between rectangular waveguide and circular waveguide, irises including a short rectangular waveguide line were used for source-first cavity and last cavity-load coupling. However, the irises for inter-cavity coupling were made from a thin sheet of Invar 36. According to appropriate work instructions, the cavities, irises, and tuning screws are finished with silver plating to minimize the insertion loss. The channel filter and the external group delay equalizer are tuned individually and then RF channel filter is adjusted to flat the variation of amplitude and group delay.

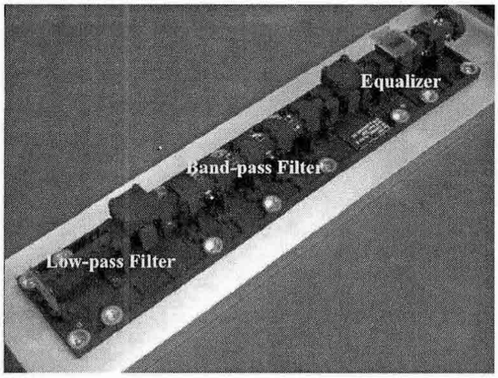
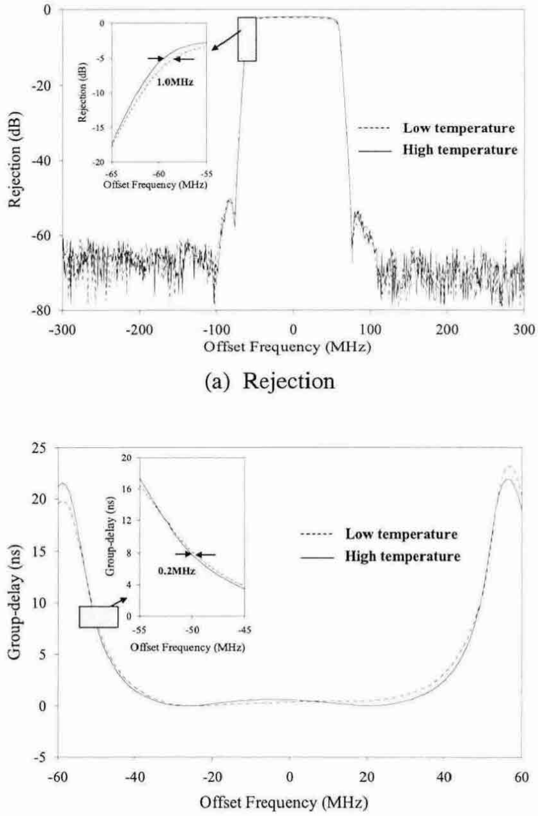


Fig. 1 Fabricated RF channel filter.

The fabricated RF channel filter was measured through approved QM test flow. First, initial performance test was carried out over the qualification temperature range. Fig. 2 shows the near band rejection and group-delay result of RF channel filter over the specified temperature range. The measured frequency shift is only 1MHz at the near edge of bandwidth. All the test results are in compliance with the design target. Through thermal vacuum test, we confirmed about 0.03% of center frequency shift under the pressure of below 10^{-5}Torr.

EMC test such as radiated emission (RE) and radiated susceptibility (RS) test was performed in an anechoic-chamber to verify the RF channel filter. For RE test, when the maximum input power level is -11.81dBm, the measured field level is 29.14 dBμV/m. It is very low level compared with the permissible field strength of 96dBμV/m. For RS test, the measured spurious signal is less than -83dBm with respect to the outside field of 25V/m.

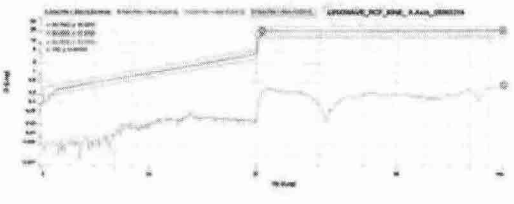


(a) Rejection

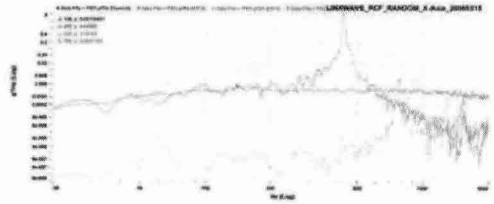
(b) Group delay

Fig. 2 Measured electrical performance of the RF channel filter.

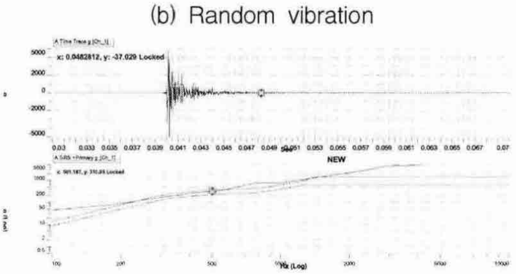
The channel filter went through vibration tests and a mechanical shock test. Vibration tests consist of a sine vibration in a range of 50~100Hz, a random vibration of 12.8g_{RMS} in a range of 20~2000Hz during 3 minutes, and low-level random vibration surveys performed before and after sine and random vibrations. Vibration test was carried out along three perpendicular axes. Natural frequency drift after sine or random vibration was less than 5%. The first natural frequency is 1,543Hz and grater than the specified value of 100Hz. Mechanical shock test was performed with an impact hammer along three perpendicular axes. There is no degradation of electrical performance after the mechanical shock test.



(a) Sine vibration



(b) Random vibration



(C) Mechanical Shock

Fig. 3 Measured results of vibration and mechanical shock.

Ⅲ. Output Multiplexer

The multiplexing of the frequency band from a number of RF channels is required because of the practical constraints of non-linearity in high power amplifiers. Multiplexing equipment requires the lowest insertion loss to obtain the optimal efficiency with the limited dc power and the lowest mass due to the high launch cost of the payload[6].

The output multiplexer for COMS payload system consists of two channel filters (ch. #1 & #3) with manifold and two channel filters (ch. #2 & #4) without manifold. Although the channel filters of ch. #2 and #4 can be designed independently, those of ch. #1 and #3 have to be designed considering the particular degradation of the response relative to the manifold application. Therefore, channel filter design for the manifold multiplexer requires optimization process to meet the design target as shown in Table 2[2].

Table 2. Design target of Output multiplexer

Parameter	Target
Center Frequency	CH 1 : 19.87GHz CH 2 & 4 : 20.00GHz CH 3 : 20.13GHz
Bandwidth	100MHz
Insertion Loss	< 1.2dB @ fc
Return Loss	> 20.8dB
Amplitude variation	< 1.3dB (fc±50MHz)
Group delay variation	< 22.5ns (fc±50MHz)
Rejection	> 8.5dB (fc±80MHz) > 20dB (fc±130MHz)
Temperature Range	0 ~ 80°C

The manifold of output multiplexer as shown in Fig. 4 was constructed out of thin-wall aluminum, which could yield the best compromise among electrical, thermal, and mechanical performance. To minimize the electrical performance degradation in the required temperature range, all the cavities were manufactured from thin-wall INVAR similar with RF channel filter. The cavity surface was silver-plated to minimize the losses.

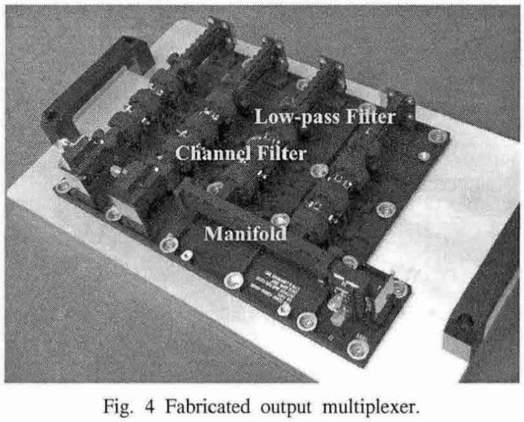
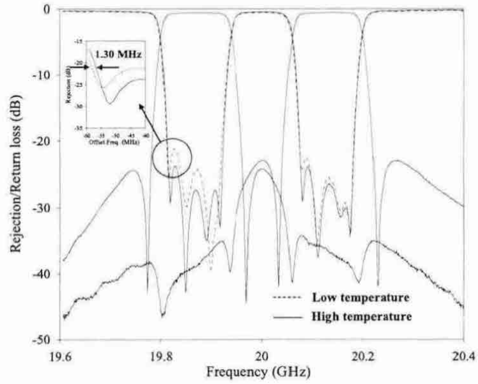
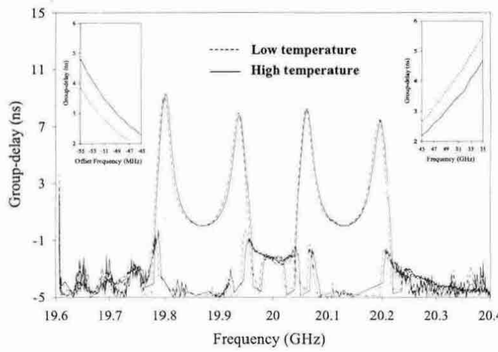


Fig. 4 Fabricated output multiplexer.

The OMUX was tested in consideration of self heating effect. If 48.8dBm of input signal is injected into OMUX, there can be 20°C of self heat. The condition of high temperature is changed from 80°C to 100°C. The measured maximum frequency shift over the temperature range is only 1.3 MHz. The output multiplexer was measured through the same flow chart of RF channel filter. First, initial performance test was carried out over temperature range. Fig. 5 shows the near band rejection, return loss, and group-delay test result of OMUX over the temperature range (0~100°C). All the test results are in compliance with the design target.



(a) Rejection and Return loss

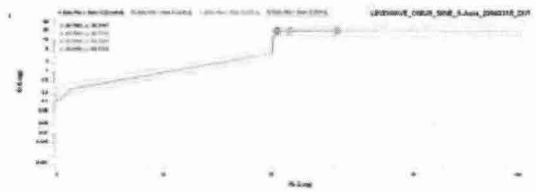


(b) Group delay

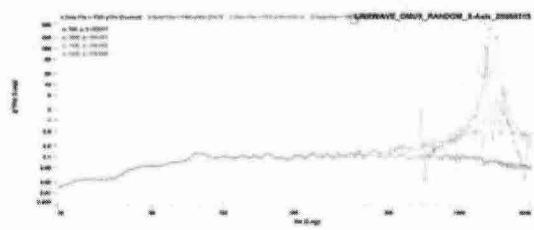
Fig. 5 Measured electrical performance of OMUX.

For RE test, when the maximum input power level of OMUX is 48.8dBm, the measured RE field level is 87.3dBμV/m. It is compliant to the permissible field strength of 96dBμV/m. For RS test, when the outside radiated field is 25 V/m, the measured spurious signal level inside the filter is -66.8dBm. It is less than the filter's minimum input signal level of 48.8dBm by 111.6dB.

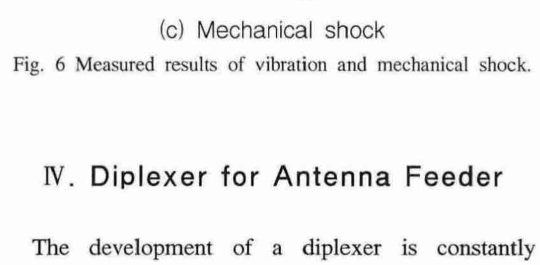
The output multiplexer went through the same vibration and mechanical shock tests as those of the RF channel filter. Natural frequency drift after sine or random vibration was less than 5% and the output multiplexer passed the vibration test. The first natural frequency was found to be 590Hz. There is no degradation of RF performance after the mechanical shock test.



(a) Sine Vibration



(b) Random vibration



(c) Mechanical shock

Fig. 6 Measured results of vibration and mechanical shock.

Ⅳ. Diplexer for Antenna Feeder

The development of a diplexer is constantly demanded to reduce mass and volume of satellite antenna. To meet the design target shown in Table 3, the COMS diplexer which consists of a corrugated low pass filter for transmitting frequency band, an asymmetric inductive iris band pass filter for receiving frequency band and a manifold to combine two filters was chosen. Two filters and T-junction that were optimally designed in advance were plugged in to the diplexer. Even if filters and a T-junction each were designed well, the RF performance of whole diplexer hardly ever achieves the wanted value simultaneously in both pass bands. This is mainly due to the variation of the phase of reflection coefficient from filters and the higher order mode. Therefore, the whole diplexer needs to be effectively re-optimized. The optimization was performed on the equivalent circuit and checked by 3D FEM field simulator[7].

Table 3. Design target of Output multiplexer

Parameter	Target
Frequency	Tx : 19.8~20.2 GHz Rx : 29.6~30.0 GHz
Insertion Loss	< 0.2 dB
Return Loss	> 22.0 dB
Isolation	> 40.0 @TX band
Temperature Range	-110~ 130°C

The designed diplexer was manufactured in two halves, as shown in Fig. 7. The low level of PIMP can be expected because the split in each unit of filters was along the broad wall of the filters and manifold. These were plated with silver to minimize the insertion loss and bolted together with proper torque. The leakage at waveguide to waveguide junctions and tuning screws was tested in EMC chamber. The low leakage values of -149dBc at transmitting frequency and -124dBc at receiving frequency were obtained, respectively.

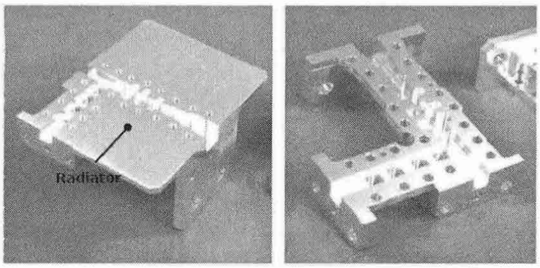
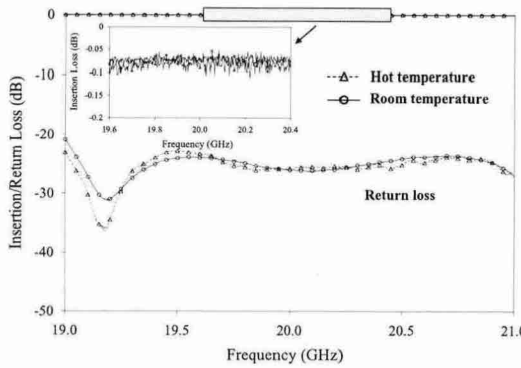
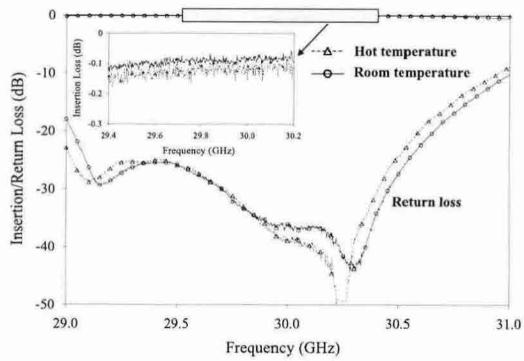


Fig. 7 Fabricated diplexer.



(a) TX frequency



(b) RX frequency

Fig. 8 Measured results of diplexer.

Fig. 8 shows the measured results at the room and hot (130°C) temperature. Even though it is a high temperature, there are few changes for the return loss and the insertion loss over transmitting frequency band. The performance of 80MHz down-shifted return loss and 0.02dB better insertion loss was observed over receiving frequency band. All the test results are in compliance with the design target.

V. Conclusion

This paper described the results of COMS qualification model multiplexer such as input multiplexer, output multiplexer and diplexer. Design targets of each equipment were determined by the heritage of the former project and to meet the system performance for transponder and antenna system. Good agreement between test results and simulation results is confirmed during the performance test. Test results are also compliant to the requirements.

Based on the development plan, flight model passive equipment will be developed for COMS system.

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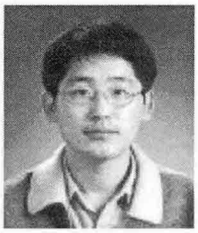

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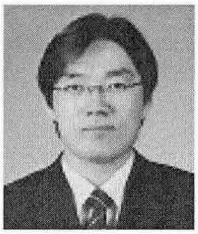

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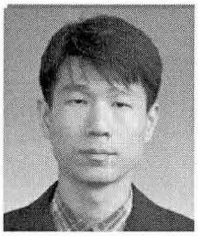

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