5ft S-Band TT&C Antenna Test

Sang-il Ahn, Dong-Chul Park
Satellite Mission Operation Dept., Korea Aerospace Research Institute
P.O. Box 113, Yuseong, Daejeon, Korea
siahn@kari.re.kr
Dept. of Radio Science and Engineering, Chung-Nam National University
Yuseong, Daejeon, Korea
dcpark@cnu.ac.kr

Abstract: In early 2004, KARI developed 5ft S-Band TT&C antenna for especially KOMPSAT-2 operation in LEOP phase. This paper shows system features of 5ft S-Band antenna and its test result with KOMPSAT-1. Tracking test, command uplink test and telemetry downlink test were performed. Through tests, 5ft antenna was verified to be operational in uplink and downlink with KOMPSAT series. Due to its inherent wide 3dB beam-width of about 7deg at S-Band, this antenna system can be used very effectively even though orbital information is less accurate like LEOP and spacecraft safe mode.
Key words: TT&C, 3dB, S-Band, 5FT ANTENNA

1. Introduction

KARI had experienced totally unsuccessful S-band communication link between KOMPSAT-1 and ground station during 1^{st} 14hrs since 1 successful link at McMurdo station just after launch on 21 Dec. 1999 due to inaccurate separation vector for orbital information.

This made KARI look for solution or risk mitigation method to have more reliable communication link and tracking data like ranging and Doppler measurement as soon as possible for quick orbit determination even though inaccurate orbit information is available like LEOP.

Based on operation experience for KOMPSAT-1, KARI reached a belief that current 9m and 13m antenna capability is far beyond normal specification required for KOMPSAT-1 operation. Therefore KARI derived more realistic antenna specification based on nominal and real link parameter instead of worst case value and roughly assumed value in link analysis.

In general, only if reliable link of BER value of 1×10^{-5} is met, excessive margin is not significant in data communication link itself.

Initial calculation showed somewhat promising result that about 6.5dB/K in G/T can provide reliable telemetry link above EL angle of 10deg in both low-rate (2kbps) and high-rate mode (1.5Mbps) and only 40dBW of EIRP can warrant reliable command link for 2kbps.

Through several calculations, KARI found small size antenna can fully function required for KOMPSAT operations.

KARI decided to implement parabolic antenna system due to its simplicity instead of dual reflector system. Antenna reflector size was decided to be 5ft after tradeoff study for antenna size, diplexer size, diplexer location, interface cable length and its thickness under meeting G/T value of 6.5dB/K.

For fully compatible operational interface between spacecraft control center and antenna system, ground data exchange format and RF/IF hardware were decided to be developed identically to current system as much as possible.

This paper shows requirement of 5ft antenna system, link analysis, and test results between antenna system and KOMPSAT-1.

2. System Design

System design verification was done mainly by link analysis. General antenna system requirements are shown in Table 1.

Table 1. Key System Requirements

Parameter	Value	Remark
EIRP	40dBW	2025MHz
G/T	6.5dB	2200MHz
Polarization	RHCP	
Tracking accuracy	0.1deg	
Uplink CMD Modulation	PCM/BPSK/PM	
Downlink TLM Modulation	PCM/BPSK/PM	low-rate
	BPSK	high-rate
Uplink frequency	2025~2120MHz	
Downlink frequency	2200~2300MHz	

Based on G/T value of 6.5dB/K, feed, diplexer, LNA requirement was derived and system G/T analysis is shown in Fig 1.

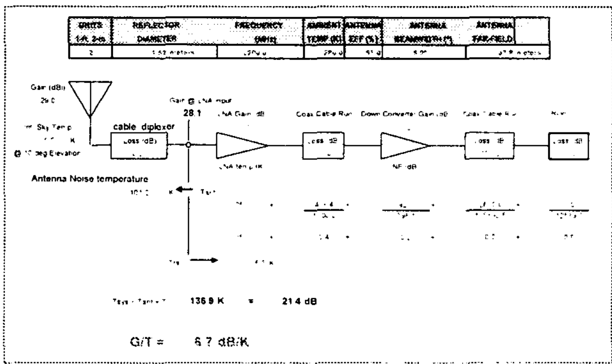

Fig. 1. System G/T Calculation

Communication link margin calculation was done based on system requirement in Table 1and KOMPSAT-2 nominal link parameter to verify how reliable link can be established.

For telemetry case, 2kbps low-rate and 1.5Mbps high-rate mode were considered.

Table 2. Telemetry Link Analysis

No.	Parameter	Value	Units
1	EL Angle	10.00	deg
2	Spacecraft EIRP	0.00	dBW
3	Space Loss	-165.83	dB
4	Atmospheric & Rain Loss	-0.25	dB
5	Gnd Station Axial Ratio	3.00	dB
6	Received Power	-166.96	dBW
7	Ground Station G/T	6.50	dB/K
8	GS antena pointing loss	-0.25	dB
8	Boltzmann's Constant	-228.60	dBW/Hz-K
9	Received S/No	67.89	dB-Hz
	Residual Carrier Received Power (low-rate)		
10	Modulation Index	1.00	radians
11	Carrier Modulation Loss	-2.32	dB
12	Carrier Noise Bandwidth	20.00	dB-Hz
13	Received Carrier SNR	45.57	dB
14	Required Carrier SNR	15.00	dB
16	Carrier Margin	30.57	dB
	Telemetry Data Received Power (low-rate)		
17	Modulation Index	1.00	radians
18	TLM Modulation Loss	-4.12	dB
19	Data Rate	2.048	Kbps
20	Modulation Rate	33.11	dB-Hz
21	System/Implementation Loss	-1.00	dB
22	Net Telemetry Eb/No	29.66	dB
23	Required Telemetry Eb/No	9.60	dB
24	Coding Gain (255,223) RS Code	4.50	dB
25	**Low-rate Telemetry Margin**	**24.56**	dB
	Telemetry Data Received Power (high-rate)		
29	Modulation Index	6.50	radians
26	TLM Modulation Loss	0.00	dB
28	Modulation Rate	61.76	dB-Hz
29	System/Implementation Loss	-1.00	dB
30	Net Telemetry Eb/No	5.13	dB
31	Required Telemetry Eb/No	9.60	dB
32	Coding Gain (255,223) RS Code	4.50	dB
33	**High-rate Telemetry Margin**	**0.03**	dB

From Table 2, 5ft antenna can provide 24dB and 0.03dB margins above link quality of 1×10^{-5} BER for 2kbps mode and 1.5Mbps mode, respectively, above EL angle of 10 deg.

For real-time telemetry, modulation loss for carrier and telemetry data was calculated to be 2.32dB, 4.12dB according to PM modulation index of 1.0 radian while there is no telemetry data modulation loss in high-rate due to usage of PM modulation index value of 1.57radian.

In link calculation, ground antenna pointing loss of 0.25dB was considered. Beam-width of 0.25dB at S-Band is about 1.7deg, which is relatively wide, even though tracking accuracy in Table 1 is just 0.1deg.

In KOMPSAT operation, high-rate mode is normal operation concept but in emergency case like LEOP and safe mode, low-rate is baseline. This means just 5ft antenna can be served as key antenna in LEOP due to its wide 3dB beam-width of about 6deg.

Table 3. Command Link Analysis

No.	Parameter	Value	Units
1	Look Angle	10.00	deg
2	EIRP	40.27	dBW
	- Antenna Gain	27.50	dBi
	- SSPA power	14.77	dBW
	- Passive loss from PA to Feed	-2.00	dB
3	Space Loss	-166.67	dB
4	Atmospheric & Rain Loss	-0.25	dB
5	Polarization Loss	-0.88	dB
6	Spacecraft G/T	-38.75	dB/K
7	Boltzmann's Constant	-228.60	dBW/Hz-K
8	S/C Noise Spectral Density	-160.85	dBm/Hz
9	GS antenna pointing loss	-0.25	dB
10	S/C Total Noise Spectral Density	-160.80	dBm/Hz
11	**Received S/No**	**62.02**	**dB-Hz**
	Residual Carrier Received Power		
12	Modulation Index (Max)	1.00	radians
13	Carrier Modulation Loss, max	-2.32	dB
14	Carrier Noise Bandwidth	29.03	dB-Hz
15	Required Carrier SNR	15.00	dB
16	Additional Margin Required	0.00	dB
17	**Carrier Margin**	**15.66**	**dB**
	Command Received Power		
18	Modulation Index	1.00	radians
19	Command Modulation Loss, max	-4.12	dB
20	Data Rate	33.01	dB-Hz
21	Receiver/Demodulation Loss	-1.00	dB
22	Required Command Eb/No	10.80	dB
23	Additional Margin Required	0.00	dB
24	**Command Margin**	**13.09**	**dB**

Table 3 is command link analysis results for 40dBW of EIRP in ground with KOMPSAT-2 and reveals EIRP of 40dBW can provide 13dB margins above link quality of 1×10^{-6} BER for 2kbps command data rate above EL angle of 10 deg..

KOMPSAT-2 has G/T value of -38.75dB/K, which is almost same with that of KOMPSAT-1. For command link, link margin has little degradation even though spacecraft's attitude is instable in safe mode and sun-pointing mode in LEOP because command receiver has 3dB coupler connected to nadir and zenith antenna in general, which warrants successful command signal reception only if uplink signal reaches spacecraft while there is link degradation according to attitude of spacecraft in telemetry link because only one telemetry transmitter is used unless ground command to enable 2 transmitters is uploaded.

13dB margin for command is really sufficient considering 2 antenna power combining concepts in spacecraft side. We can recognize that 13dB margin for 0.25dB pointing loss is identical to 3dB margin for 10dB pointing loss, meaning 12 deg of pointing loss. In other words, only if spacecraft is located within 10dB beam-width circle, command link is guaranteed to have link quality of 1×10^{-6} BER with additional 3dB margin.

Due to its wide beam-width, simple EL/AZ 2-axis program tracking system is selected instead of auto-tracking system for its simplicity.

Program track has a capability to generate spacecraft position based on NASA/NORAD TLE for tracking. Also pre-loaded table track table can be used for tracking. Considering schedule and cost effectiveness, 2-axis positioning system with DD mechanism without reduction gear was newly developed by Korean supplier named MTG [1].

3. System Integration & Test

Far-field antenna pattern measurement was performed just after integration of reflector and feed system using near-field measurement system at MTG facility.

Fig. 2 shows measured far-field pattern of 5ft reflector system at 2210MHz.

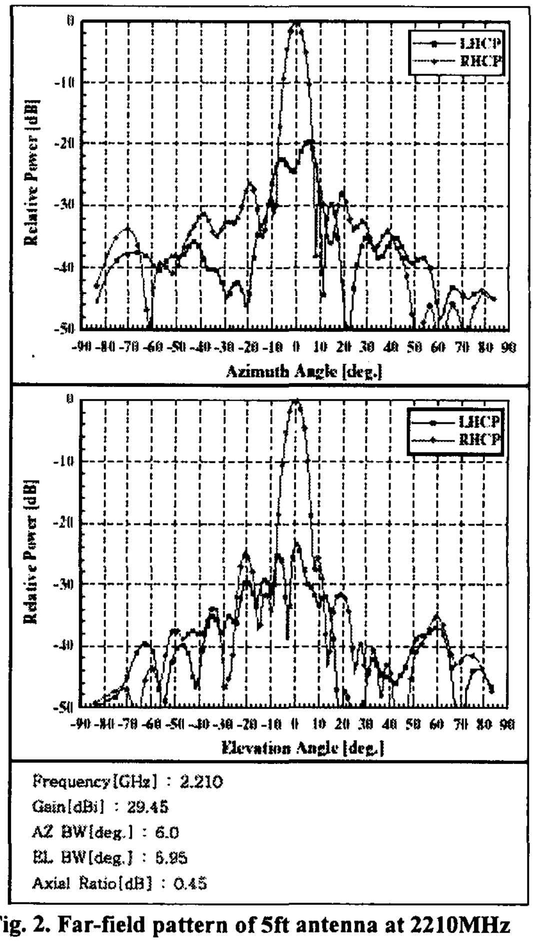

Fig. 2. Far-field pattern of 5ft antenna at 2210MHz

From measurements, antenna pattern is symmetrical in each axis and low side-lobe level of less than 20dB. Minimum polarization isolation is 20dB. Measured axial ratio is 0.45dB.

Antenna gain was measured to be 29.45dB within 0.5dB measuring error boundary.

Fig. 3 shows side view of fully integrated 5ft 2-axis positioning system at KARI.

Fig. 3. Integrated 5ft S-band antenna system

Integrated antenna system was fully tested per system acceptance test procedure and finally tested in conjunction with operational KOMPSAT-1, which is almost identical to KOMPSAT-2 in S-Band link characteristics except for just frequencies.

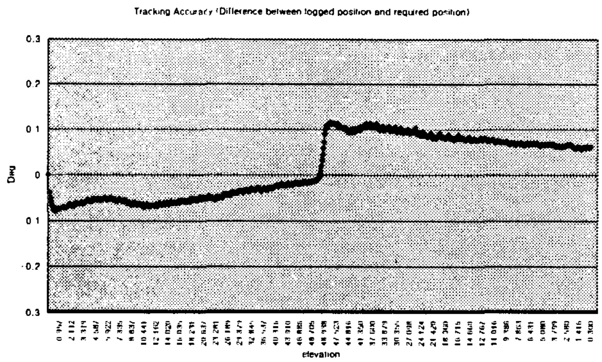

Fig. 4. Tracking accuracy test

Fig. 4 is plot for angle difference between real position logged and desired position, revealing there is maximum 0.1deg of pointing error during contact with KOMPSAT-1. This pointing error is expected to reduced when tracking software is updated to enforce offset angle in downward direction case in EL angle.

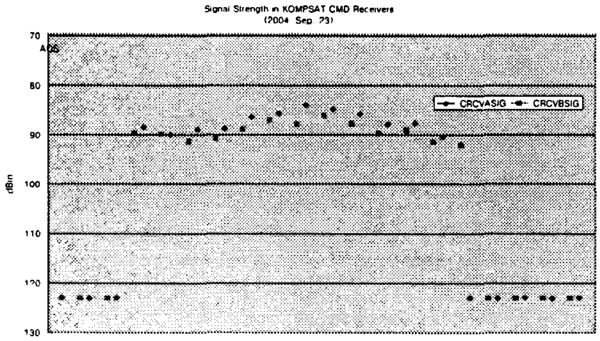

Fig. 5. Uplink command test

Fig. 5 shows both command receivers in KOMPSAT-1 were successfully locked during 5ft antenna system's HPA was on during 10 to 10 deg angle of elevation.

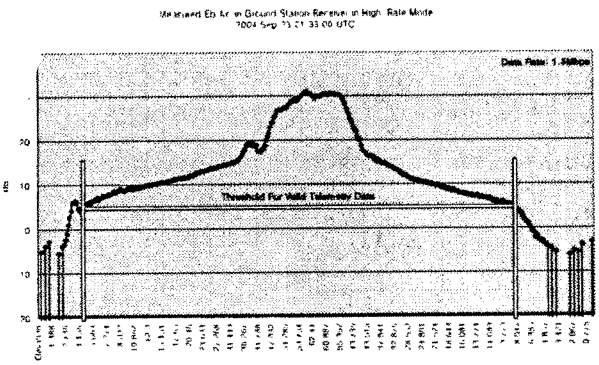

Fig. 6. Downlink TLM test in 1.5Mbps

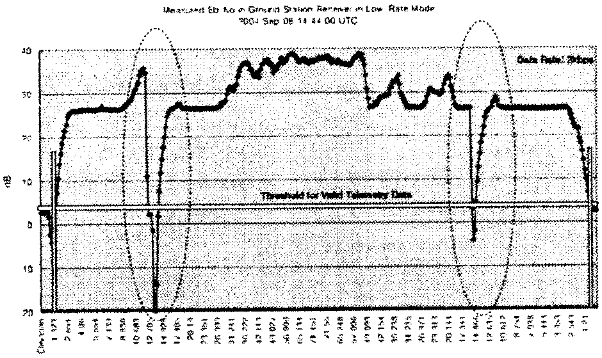

Fig. 7. Downlink TLM test in 2kbps

Fig. 6 and 7 shows plot for Eb/No measured at ground telemetry receiver in high-rate mode and low-rate mode, respectively.

When Eb/No value reaches 5dB, error-corrected valid telemetry is available. Fig. 6 shows 5ft antenna can provide reliable telemetry link above 10 deg of EL in high-rate mode. Fig.7 shows horizon to horizon telemetry link is available in low-rate mode. There are 2 dashed circles in Fig. 7, which shows short duration of link closure which was caused by uplink carrier sweeping when spacecraft downlink mode was configured to be coherent mode by previous uploaded ground commands.

4. Conclusion

System design, system test of 5ft S-Band antenna for KOMPSAT-2 operation in LEOP and emergency case were described.

Integrated 2-axis 5ft antenna system showed fully acceptable performance in operational tests with KOMPSAT-1 for tracking, command uplink, low-rate and high-rate telemetry downlink modes

KARI believes this 5ft antenna can be used effectively during KOMPSAT-2 LEOP phase.

References

[1] URL: http://www.mtginc.co.kr/