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RF COMPATIBILITY TEST BETWEEN KOMPSAT AND TTC STATION

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ABSTRACT

Results of RF compatibility test between KOMPSAT(Korea Multi-Purpose SATellite) and TTC(Tracking, Telemetry, and Command) station are described. S/C(Spacecraft) RF Test, telemetry test, command test, ranging test, and tracking receiver test were performed with respect to pass/fail criteria. To provide physical RF interface between KOMPSAT and TTC equipment, direct low loss cable and antenna-to-antenna interface were implemented. Through RF compatibility tests, it was fully demonstrated that KOMPSAT and TTC equipment are functionally workable.

1. OVERVIEW

The objective of the RF compatibility test is to demonstrate the design compatibility between the satellite and ground station at the RF levels of the telemetry and command signals. For this purpose tests were performed between FM(Flight Model) KOMPSAT satellite and TTC equipment of MCE(Mission Control Element). The FM satellite was located in KARI AI&T(Assembly, Integration, and Test) High-bay and interfaced to MCE equipment via coaxial cables (hard wired) to reduce the RF interference from outside. Testing was planned to begin mid Dec. 1998(3 working days). Nominally, 8 hours of testing was planned for each day. 1 week before test period, preparatory test was performed. Test criteria was derived from KOMPSAT Space-Ground ICD(Interface Control Document), KOMPSAT TC&R(Telemetry Command and Ranging) Subsystem Specification and test telemetry and command were selected from documents titled "KOMPSAT Telemetry Allocation Document", "KOMPSAT Command Allocation Document." To ensure reliable test and prevent any damage to S/C and TTC equipment, engineers and manager were allocated to all related functional area, including overall management of test, managing the S/C and EGSE(Electrical Ground Support Equipment), safe operation of KOMPSAT, and test conduct and operation of TTC equipment.

Principal real-time support personnel were planned to be located in the MCE H/W room, MCE control center (SOS: Satellite operation Subsystem), and I&T control room at KARI. Support personnel participating in the test from KARI, ETRI and TRW were TC(Test Conductor), TTC operator, SOS operator, AIT S/C operator, and QA(Quality Assurance) All personnel maintained surveillance for conditions, which may endanger flight hardware, or the personnel involved and reported any

hazard to the test conductor. Electrical connectors to the spacecraft were not mated or demated when spacecraft or the source power was ON for safety. For ESD(Electro Static Discharge) precautions, personnel handling units or harness/connectors wore wrist straps in direct skin contact at ground potential prior to contact with the hardware. Wrist straps were tested prior to each use by an approved commercial wrist strap tester. During test, MCE TTC antenna had not been pointed toward any KARI facility unless antenna feed input power is less than - 40dBW to help prevent any harmful RF radiation to human beings.

2. TEST CONFIGURATION

Two interface methods were selected between FM KOMPSAT and MCE TTC Station. Direct coaxial cable interface and antenna-to-antenna interface were used to provide RF signal path between spacecraft and TTC station. Direct coaxial cable interface is shown in Figure 1. FM KOMPSAT and MCE TTC hardware were about 1,000 m apart. FM KOMPSAT, EGSE, and 3dB power divider were located in AIT High-Bay while diplexer, step attenuators, couplers were located in TTC hardware room. Both S-Band antennas in spacecraft were demated for test. FM KOMPSAT was connected to EGSE through GSE(Ground Support Equipment) hard-line with OBC(On Board Computer). Nadir antenna port was connected with diplexer through low loss cable and 3dB power divider. Diplexer in TTC hardware room was used to provide simultaneous command and telemetry using one cable. Step attenuators were used to adjust and simulate various signal environments. Power meter, frequency counter, and spectrum analyzer were connected to 10dB coupler. Every test items in S-Band compatibility test were tested with direct cable interface except for spacecraft-MCE antenna functional test. Through cable interface, both MCE and EGSE could send command and receive telemetry.

Limited command and telemetry test was performed through antenna-to-antenna interface. Antenna-to-antenna interface is shown in Figure 2. Functional communication test was achieved even though signal interference caused by ground reflection was expected due to relative short distance, about 650m apart, between both antennas. This antenna-to-antenna test interface didn't aim to test electrical antenna performance but provided only signal path for command and telemetry. MCE antenna was positioned to point roof-top antenna in AIT high-bay with G/S(Ground Station) EIRP(Electrical Isotropic Radiated Power) of less than 3dBW. Roof-top antenna provided omni-directional pattern and interfaced by cable with antenna test cap, which covers nadir S-Band antenna of FM KOMPSAT.

Link margin analysis was performed to each test configuration to ensure that each configuration could provide the signal strength environments expected during normal operation

3. TEST RESULTS

[S/C RF Test] Uplink and downlink carrier frequency stability test was performed to verify both ends provide fully workable frequency stability. Excessive instability of downlink frequency might require the readjustment of TTC equipment. Both S/C transponders and TTC up-converters were tested in coherent and non-coherent mode configurations. Through 10 times of measurements, it was

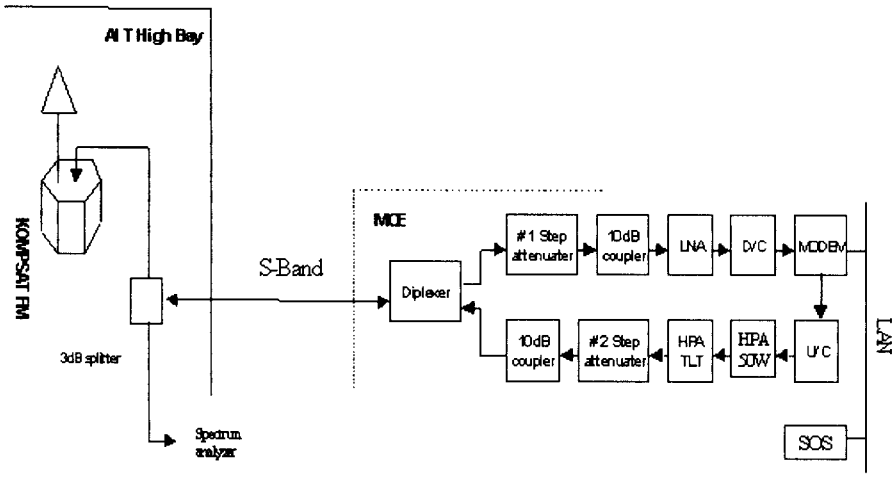

Figure 1. Compatibility Test Configuration, Cable Interface

found that both S/C transponders and TTC uplink equipment meet frequency stability requirement in both non-coherent and coherent mode. Table 1 shows detail frequency stability measurements. PPM(Parts Per Million) was used as a unit

To ensure that the KOMPSAT's receiver and MCE's transmitter can be operated over the required mission parameter range, RF carrier acquisition threshold level of KOMPSAT on-board receiver was tested. Through measurements, threshold levels of both transponders were found to be fully workable in normal operations, expected as around 20dB attenuation in step attenuator #2. Table 2 shows detail measurements of acquisition threshold of both transponders to various uplink power. It was found that at least 30dB of margin is provided for the HPA power of 200W in MCE.

In order to verify that the KOMPSAT receiver has the capability to track an uplink carrier frequency with a specified offset and at a specified rate, tracking frequency range and rate of S-Band transponder was tested. To simulate worst case expected in normal operation, 30kHz offset uplink frequency was used and lock time was measured. Through measurement, it was verified that both transponders were successfully locked and maintained lock status during uplink carrier swept with range of +/-140kHz, offset frequency of 30kHz, and rate of 32kHz/sec and it was taken 6-7 sec to lock to swept uplink carrier. Through test, it was ensured that KOMPSAT's both receivers and MCE's transmitter can be operated over the required mission parameter range. Table 3 shows brief test

Table 1. Uplink and Downlink Carrier Frequency Stability Test.

	U/L Frequency	D/L Frequency Non-Coh mode	D/L Frequency Coherent mode	Criteria
Worst case deviation	0 PPM	1.86 PPM	0.35 PPM	25PPM

Table 2. Transponder Lock/unlock vs. uplink carrier.

Step attenuator value in step attenuator #2, dB	Transponder-A (Lock: o, Unlock: ×)	Transponder-B (Lock: o, Unlock: ×)
20	o	o
30	o (-94.6981 dBm)	o (-97.165 dBm)
40	o (-103.233 dBm)	o (-107.630 dBm)
41	o (-104.996 dBm)	o (-108.771 dBm)
42	o (-106.269 dBm)	o (-111.757 dBm)
43	o (-107.323 dBm)	o (-110.308 dBm)
44	o (-107.937 dBm)	o (-114.083 dBm)
45	o (-109.430 dBm)	o (-123.029 dBm)
46	o (- 110.220 dBm)	o (-123.029 dBm)
47	o (-114.522 dBm)	o (-123.027 dBm)
48	o (-115.124 dBm)	o (-123.027 dBm)
49	o (-116.405 dBm)	o (-123.027 dBm)
50	o (-123.029 dBm)	o (-123.027 dBm)
51	o	o
52	o	o
53	o	o
54	o	×, o
55	o	×
56	o	×
57	o	×
58	×	×
59	×	×

result for tracking range and rate of spacecraft transponders. Both transponders showed successful tracking capacity for normal operation environment.

[Telemetry Test] To determine the threshold sensitivity of the MCE's telemetry receiver to a telemetry signal from KOMPSAT, the threshold level of telemetry data was measured in case of real-time and playback, respectively, for both S/C transponders. This test items ensures that the RF carrier loop of MCE's receiver is compatible with the KOMPSAT telemetry signal at a specified threshold power levels. Through test, it was verified that TTC MODEM/BB(Modulation Demodulation Baseband) equipment fully satisfied the requirement and provides around 20dB margin for real-time telemetry and 17dB margin for playback telemetry. Table 4 is the test result when 300Hz of PLL BW is used in demodulator for test.

Test of uplink carrier margin effects on telemetry was performed by measuring the power level of subcarrier in downlink signal in coherent mode. Different power level of uplink signal was used

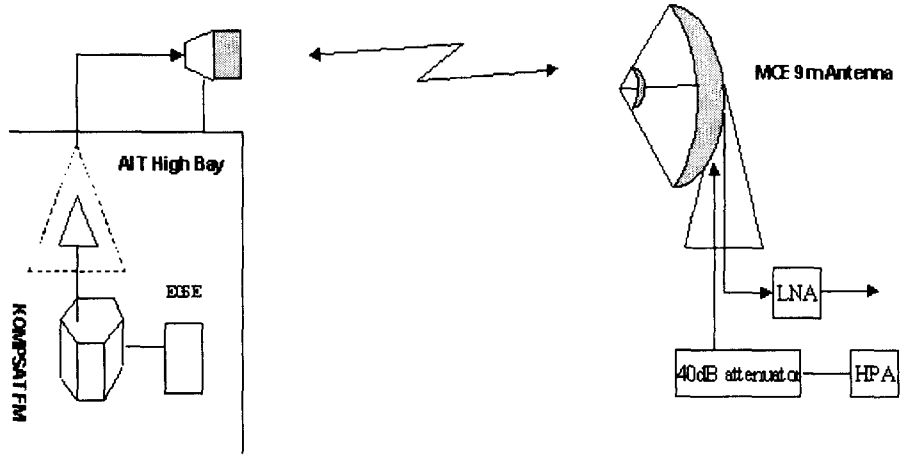

Figure 2. Compatibility Test Configuration, Antenna-to-Antenna Interface.

in test for real-time and playback telemetry. Through measurements, it was found that telemetry power in real-time and playback mode is independent of uplink power by TTC in both on-board transponders (see Table 5).

[Command Tests] Combined test for S/C receiver command threshold measurement and command phase modulation sensitivity measurement was performed to verify that the threshold values for KOMPSAT receiver's command subcarrier and RF carrier loops are correct and also to verify proper command performance at a specified minimum power level. Expected command MI(Modulation Index) variation is 1.0 rad +/-10%. Attenuation value of 18dB in step attenuator #2 was assumed as the weakest command power expected at 10 degree elevation environment during normal operation. Through the test, it was ensured that KOMPSAT's RF carrier and command subcarrier loops are compatible with the MCE's transmitted uplink signal expected during normal operations. NOOP(No-Operation) command was used for test command and command counter was monitored and recorded with EGSE and SOS as shown in Table 6.

[Ranging Tests] Turnaround ranging delay was measured to verify that both ranging system of spacecraft and TTC equipment are fully workable. Both transponder delay and MCE delay were calibrated before test. GSTDN(Ground Space Tracking and Data Network) tone ranging method for both transponders was used for test with respect to different uplink power levels and

Table 3. offset uplink freq.: FD-30kHz, sweeping range: +/-140kHz, sweeping range: 32kHz/s.

	Lock/In-lock Status
Transponder-A	Lock
Transponder-B	Lock

Table 4. Telemetry Receiver Threshold Test, Transponder-B.

	Real-time Telemetry Case		Playback Telemetry Case	
	step att. #1		step att. #1	
	39dB	Good telemetry	36dB	Good telemetry
	40dB	Frame Check error	37dB	Frame check error
1_{st} drop lock	52dB	PLL unlock	46dB	PLL unlock
1_{st} re-lock	51dB	PLL re-lock	44dB	PLL re-lock
2_{nd} drop lock	53dB		46dB	
2_{nd} re-lock	52dB		45dB	

Table 5. Subcarrier TLM power in real-time telemetry (Transponder-A, Real-time mode).

	Real-Time Mode	Playback Mode
Att. value in step att. #2 (dB)	Subcarrier power in dBm	TLM power in dBm
7dB, Non-coherent mode	Carrier: -30.67 Subcarrier: -34.67	TLM power: -23.33 Unwanted Spectra power: -23.17
7dB, Coherent mode	Subcarrier: -34.83	TLM power: -23.33 Unwanted Spectra power: -23.17
13dB, Coherent mode	Subcarrier: -34.83	TLM power: -23.33 Unwanted Spectra power: -23.17
18dB, Coherent mode	Subcarrier: -34.83	TLM power: -23.33 Unwanted Spectra power: -23.17

ranging modulation index, expected during normal operation. Through tests, it was found that both transponders and MCE equipment provide constant ranging delay results with maximum difference of 8ns. Table 7 shows ranging delay and distance between spacecraft and TTC equipment. Distance of around 15km came from 1000m cable, which has more propagation delay than free space.

[MCE Tracking Receiver Carrier Threshold Test] Threshold level of tracking sum channel was measured to determine the threshold sensitivity of the MCE's antenna pointing/tracking system to a signal input from the KOMPSAT. Both real-time telemetry and playback telemetry were used for source of tracking receiver. Through test, it was ensured that the RF carrier loop of the MCE's antenna pointing/tracking system is compatible with the KOMPSAT's telemetry signal at specified threshold power levels. MCE tracking receiver had the threshold level of 40.33dB and 34 dB in step attenuator #1, which was assumed to be 20.33dB and 14 dB less than the weakest telemetry signal power, respectively for real-time and playback telemetry, expected during normal operation environment. Table 8 shows test measurements.

[Antenna-to-Antenna Test] The functional test of command and telemetry via antenna interface as shown in Figure 2 was performed to demonstrate that KOMPSAT and MCE are workable as a

Table 6. Command test measurements.

	Att. Value in atteunator #2(dB)	CMD MI = 1.1 rad		CMD MI = 1.0 rad		CMD MI = 0.9 rad	
		RCVR's Lock status	CMD Counter (EGSE/SOS)	RCVR's Lock status	CMD Counter (EGSE/SOS)	RCVR's Lock status	CMD Counter (EGSE/SOS)
Xpdr-A	7	Lock	30/30->35/35	Lock	35/35->40/40	Lock	40/40->45/45
	13	Lock	51/51->56/56	Lock	58/58->63/63	Lock	63/63->68/68
	18	Lock	71/71->76/76	Lock	76/76->81/81	Lock	81/81->86/86
	25	Lock	86/86->91/91	Lock	91/91->96/96	Lock	96/96->101/101
Xpdr-B	7	Lock	106/106->111/111	Lock	111/111 -> 116/116	Lock	116/116 -> 121/121
	13	Lock	125/125 -> 130/130	Lock	130/130 -> 135/135	Lock	135/135 -> 140/140
	18	Lock	140/140 -> 145/145	Lock	145/145 -> 150/150	Lock	150/150 -> 155/155
	25	Lock	155/155 > 160/160	Lock	160/160 -> 165/165	Lock	165/165 -> 170/170

Table 7. Turnaround Ranging Delay Measurement.

Att. #2	Uplink RNG MI	Transponder-A (RNG delay results)	Transponder-B (RNG delay results)
7dB	0.4 rad	14.055 km, 46883 ns	14.0643 km, 46913.5 ns
	0.412 rad	14.057 km, 46892 ns	14.064 km, 46912.5 ns
	0.388 rad	14.056 km, 46888 ns	14.064 km, 46912.5 ns
13dB	0.4 rad	14.0559 km, 46885.5 ns	14.06355 km, 46911 ns
	0.412 rad	14.05695 km, 46889 ns	14.06415 km, 46913 ns
	0.388 rad	14.0565 km, 46887.5 ns	14.06415 km, 46913 ns
18dB	0.4 rad	14.0574 km, 46890.5 ns	14.0646 km, 46914.5 ns
	0.412 rad	14.0577 km, 46891.5 ns	14.0637 km, 46911.5 ns
	0.388 rad	14.0565 km, 46887.5 ns	14.0643 km, 46913.5 ns
25dB	0.4 rad	14.0571 km, 46889.5 ns	14.06445 km, 46914 ns
	0.412 rad	14.0577 km, 46891.5 ns	14.06475 km, 46915 ns
	0.388 rad	14.05635 km, 46887 ns	14.0643 km, 46913.5 ns

system. Real KOMPSAT operation was conducted solely by MCE. Several essential commands for downlink mode change, antenna selection, playback operations were uploaded and verified with command counter and verifier (dedicated telemetry to uploaded command). Through this test, it was successfully demonstrated that KOMPSAT and MCE can function as a real system. Table 9 is a N2 chart showing one of test results for mode change from real-time to playback and vice versa. 8 seconds was taken to get real-time telemetry displayed on MCE console after uploading command CXMTRAON while 11 seconds was taken to get playback telemetry displayed after uploading RTCS(Relative Timed Command Sequence) CPBELP.

4. CONCLUSIONS

Core RF compatibility test results was described in this paper. S/C radio frequency test, telemetry

Table 8. Tracking receiver threshold level in real-time and playback mode, Xpdr-A and -B.

		Attenuation level in step attenuator #1 (dB)			
		Transponder-A		Transponder-B	
		Unlock level (Xpdr-A)	Lock level (Xpdr-A)	Unlock level (Xpdr-B)	Lock level (Xpdr-B)
Real-time TLM case	1_{st} measure	42	41	41	39
	2_{nd} measure	42	40	41	40
	3_{rd} measure	41	40	41	40
	Average	41		40.33	
Playback TLM case	1_{st} measure	36	35	35	34
	2_{nd} measure	36	35	35	33
	3_{rd} measure	36	35	34	33

Table 9. N2 chart for time to get TLM mode transition in transponder-A.

No TLM	8 sec after CXMTRAON	
	R/T TLM	11 sec after RTCS cmd CPBELP
	10 sec after RTCS cmd CPBSTOP	Playback TLM

test, command test, ranging test, earth station tracking receiver threshold test, antenna-to-antenna functional test results were briefly described. Through RF compatibility test, both compatibility and workability between the KOMPSAT and MCE at the RF levels of the telemetry and command signals were fully demonstrated.

Acknowledgement

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REFERENCES

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