PERFORMANCE ESTIMATION METHODS OF AN ON-BOARD ANTENNA DRIVE CONTROL SYSTEM

Hiroshi TANAKA and Yoichi KAWAKAMI
NTT Radio Communication Systems Laboratories
1-2356,Take, Yokosuka-shi,Kanagawa,238-03,Japan

1. Introduction

Because of narrow beam-width, accurate antenna pointing is required in multi-beam satellite communication systems. To meet this requirement, new on-board antenna pointing control systems are being investigated.[1] At present, NTT plans to make field experiments on multi-beam communications with the sixth Japanese Engineering Test Satellite(ETS-VI). The antenna pointing control system on the ETS-VI consists of a conventional satellite attitude control system and an antenna drive control system to keep the pointing accuracy to within 0.015 deg.

The antenna drive control system operates precisely in orbit environments, zero gravity, vacuum and wide thermal circumstances. Therefore, ground side simulation of the orbit environments and accurate angle measurement are necessary both to conduct the performance tests and to estimate control characteristics.

In this paper, simulation methods and test equipments are studied. It is shown that on-board control characteristics can be gained from the data of ground side testing.

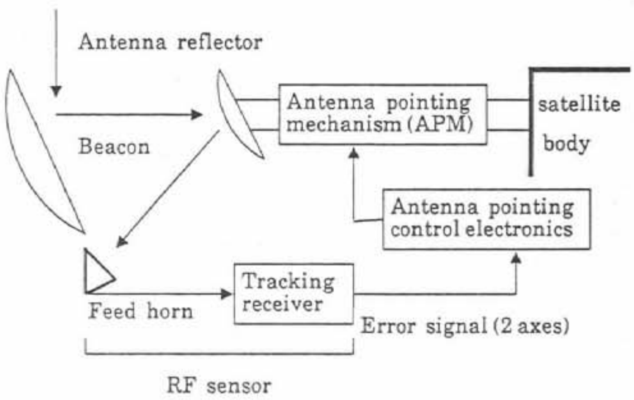

Fig. 1 Antenna drive control system

2. Ground test system

2.1 Antenna drive control system[2]

Figure 1 shows the configuration of the ETS-VI antenna drive control system. It consists of an RF sensor, an antenna pointing mechanism (APM) and antenna pointing control electronics (APE). The sub-reflector is rotated by the APM around two orthogonal axes. The APM is controlled by the APE corresponding to a pointing error detected by the RF sensor. Figure 2 shows an antenna pointing error budget.[2] Errors due to an antenna system and attitude control system exceed 0.1 deg. To compensate

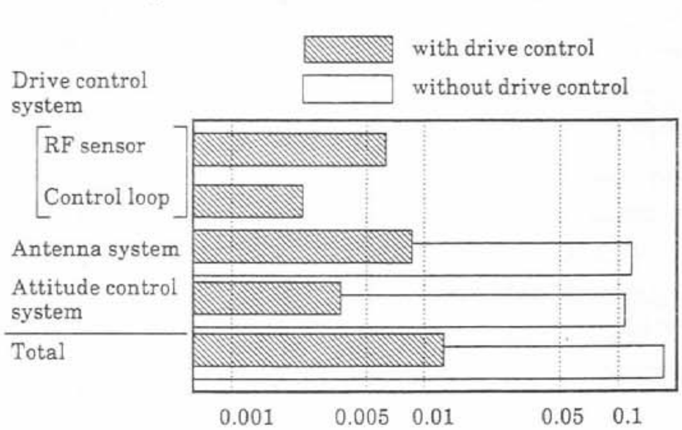

Fig. 2 Antenna pointing error budget

these erors to within 0.015 deg. with this antenna drive control system, the control loop accuracy about 0.002 deg. is required.

2.2 Ground test configuration

The following items must be taken into consideration in the ground tests.

(1) Simulating thermal vacuum environments in orbit

(2) Realizing zero gravity conditions in orbit

(3) Precise measurement of the APM rotation angles

Major requirements for the ground tests are shown in Table 1. The affection of gravity must be eliminate not to disturb the APM rotation. The requirements for the angle measurement were decided considering the APM drive angle range and the control loop accuracy. And sampling period was determined to keep stability of the ground test system.

Table 1 Requirments for the ground tests

Items	values
Increase of stiffness by gravity	<0.03Nm/rad
Measurement range	>2deg
Measurement stability	<0.001deg
Sampling period	<50msec

Figure 3 shows the configuration of the ground test system. This system is composed of three on-board components and seven test equipments. The orbit environments are created in a vacuum chamber. The temperature of the chamber shroud (ϕ 2.4m) is about -190°C. On-board thermal environments are simulated with this shroud, heaters and multi layer insulation. The zero gravity conditions were simulated through suspending the APM's rotor and an inertia dummy by one wire.

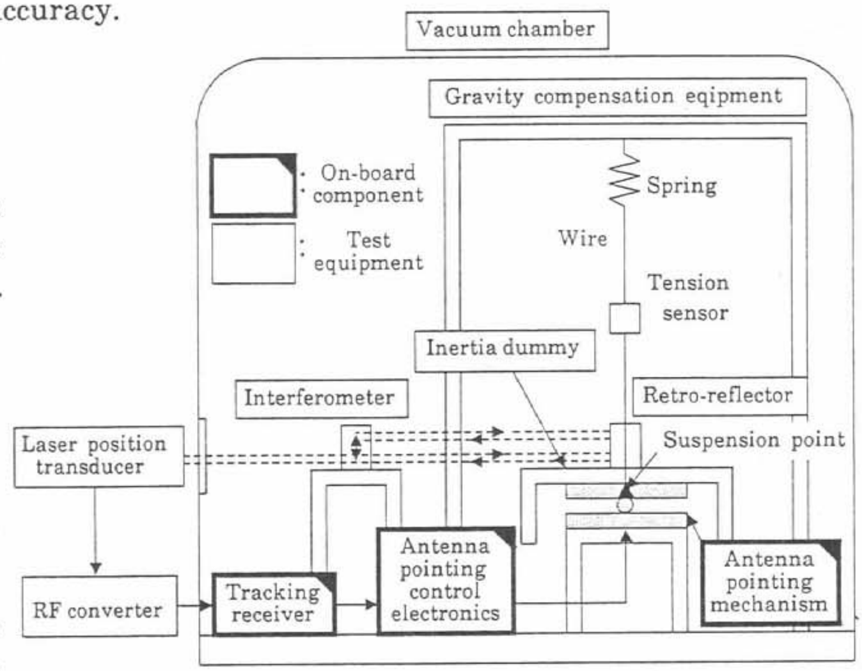

Fig. 3 Configuration of the ground test system

A laser angle measurement system is used to measure the APM rotation angles. The RF sensor cannot be used because of small room in the chamber. An RF converter[3] was developed in order to feed the results back into the tracking receiver in the test system.

3.Characteristics of the test system

The temperatures of the interferometer and the retro-reflector in the chamber are kept at about 20°C with heaters and multi-layer insulation to maintain measurement stability. Angle measurement histories of the measurement system are shown in Fig.4. Thermal control is necessary to suppress output drift. By subsequent study, it was confirmed that angular variations of ±0.001 deg. could be reduced to less than ±0.0005 deg. through isolating the chamber from vacuum pumps.

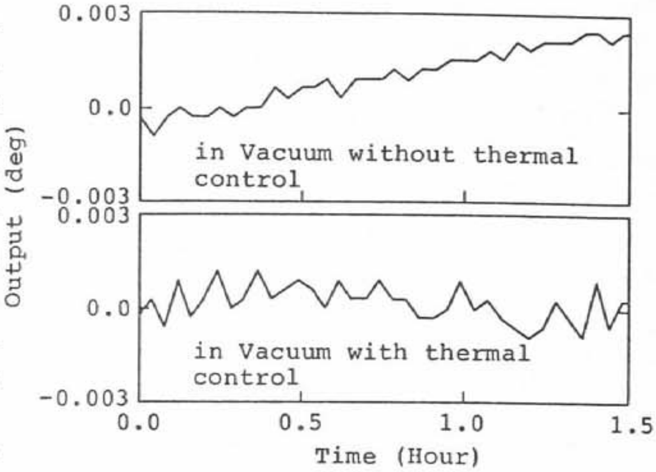

Fig. 4 Output of the angle measurement system

For a study on gravity compensation applied to the APM, a rotation stiffness on ground is considered. The rotation stiffness K is derived based on balance of the moment forces around the rotation center of the APM

$$K = (F - W)Z + F\Delta Z + k \qquad (1)$$

where, F : tension force of the wire, W : weight of the rotating part, Z : distance between the rotation center of the APM and the center of gravity of the rotating part, ΔZ : distance between the suspension point location and the center of gravity of the rotating part, k : the stiffness of the APM's bearings

To simulate the zero gravity condition of $K = k$, the tension force of F is adjusted to equal to W and the suspension point location is selected so that $\Delta Z = 0$. Figure 5 shows the relation between ΔZ and the rotation stiffness. The rotation stiffness K can be set to the nominal value of 0.34 Nm/rad ± about 0.03 Nm/rad by adjusting ΔZ to within 0.1mm.

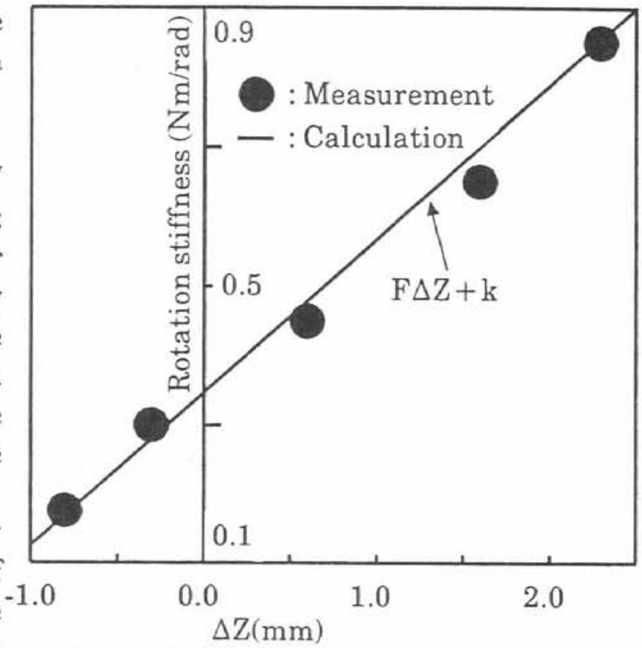

Fig. 5 Relation between ΔZ and the rotation stiffness

The configuration of the RF converter is shown in Fig.6. This equipment converts digital signals to RF signals. A sampling rate of a preliminary converter was 110 msec to control attenuators and shifters. To ensure stability of the test system,

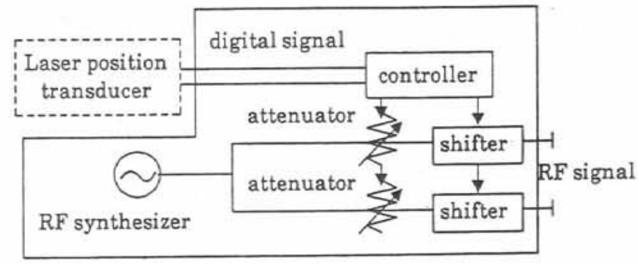

Fig. 6 Configuration of the RF converter

the I/O of the developed converter was improved and the sampling rate has been reduced to 23 mcec.

Frequency response of the whole test system was measured by input of a sweep-sine signal to the APE, the results are shown in Fig.7. The dotted line is the measurement result, and the solid line is the estimated on-board performance taken ground test errors into consideration. It is clarified that the gain difference between two lines is within 1dB near the cross-over frequency, and the on-board control characteristics can be estimated from the data of ground tests.

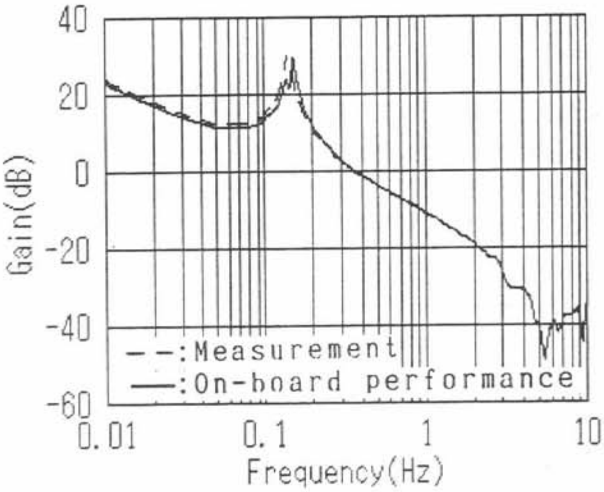

Fig 7 Frequency response of the test system

4.Conclusion

Performance estimation methods for the antenna drive control system on the ETS-VI have been studied. Major results are as follows.

(1) The ground test system with gravity compensation in a vacuum chamber can simulate orbit environments.

(2) It is verified that the output stability of the measurement system can be suppressed to within 0.001 deg. by thermal control.

(3) It is clarified that the gain variation due to ground tests is within 1dB near the cross-over frequency, and the on-board control characteristics can be estimated from the data of ground tests.

Acknowledgements

The authors would like to acknowledge the continuing guidance of Drs. Heiichi Yamamoto, the Executive Manager of the Communication Satellite Technology Laboratory and Isao Ohtomo, the Research Group Leader of the same laboratory.

References

(1) I. Ohtomo and H. Kumazawa : 18th European Microwave Conf., pp. 61-69, 1988.

(2) Y. Kawakami, H. Hojo and M. Ueba : AIAA/AAS, Astrodynamics Conf., pp. 689 - 694, 1988.

(3) E. Hattori and K. Ueno : Nat. Conv. IEICE. Japan, p. 260, 1988. (in Japanese)