EarthCARE
Cloud Profiling Radar (CPR)

Instrument Budgets

概要 Overview
This document presents the instrument budgets of EarthCARE Cloud Profiling Radar (CPR).

キーワード Key words					
情報の区分	□一般	□B 情報	☑B 情報（関係者限定）	□A 情報	□AA 情報
開示制限解除年月		年　月			
個人情報の種類（該当する場合のみ）	□B 個人情報		□A 個人情報		

配付先 Distribution List	欧州宇宙機関（ESA）
配付種類	正
部数	1

関連	承認 Approved by	点検 Checked by	作成 Prepared by	技術資料番号 Document No.	改訂符号 Revision
	E Tomita 2014.12.25	2014.12.25	2014.12.12	SEC-080011	D
				EarthCARE/CPR Project Team	

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改訂記録
Change record

符号 Revision	承認年月日 Date	承認 Approved by	点検 Checked by	作成 Prepared by	改訂箇所 Changed Section	改訂内容、理由等 Description of Change
NC	28 November 2008	T.Kimura	H.Nakatsuka	H.Horie	N/A	初版制定 First Issue
A	27 Feb. 2009	T.Kimura	H.Nakatsuka	H.Horie		3.4 Update Pointing Budget
B	24August 2009	T.Kimura	H.Nakatsuka	K.Sato		3.1 Update Mass budget 3.4 Update pointing budget
C	4 April 2014	E.Tomita	H.Nakatsuka	H.Nakatsuka		3.1 Update Mass budget 3.2 Update Power budget 3.3 Update Datarate budget 3.4 Update Pointing budget
D		表紙参照 See Cover page			 Chapter 3.3.3 Chapter 3.3.4 Chapter 3.3.5 Chapter 3.3.6 Chapter 3.3.7 Chapter 3.4.4 Chapter 3.4.6.2	**Updates according to EC-ASD-CPR-CDR RIDs:** **SY-7(PK-07)** TC budget is added. **SY-75(ESA-MS-31)** Memory budget is added. SPU start-up time is added. SEU is added **SY-163(PR-21)** Timing Budget is added. **SY-159(ME-07)** Update -- Contents inappropriate to Budget document removed (ref EC-ASD-CPR-CDR SY-167(JL-17))

EarthCARE
Cloud Profiling Radar (CPR)

Instrument Budgets

Japan Aerospace Exploration Agency
(JAXA)

Table of Contents

1. INTRODUCTION

1.1 Scope

This document presents the instrument budgets of EarthCARE Cloud Profiling Radar (CPR).

2. DOCUMENTS

2.1 Applicable Documents

NONE

2.2 Reference Documents

1) EC.ICD.ASD.CPR.00001	CPR Interface Control Document
2) SEC-080001	CPR Instrument Technical Description
3) SEC-080010	CPR Mechanical, Thermal and Electrical ICDs

3. INSTRUMENT BUDGETS

3.1 Mass Budget

The mass budget of CPR is shown in Table 3.1-1.
The mass meets the requirement (270 kg maximum).
Regarding mass, NEC has issued NECS-RFW-0042. The requirement of ESA/ICD is that the mass of the CPR shall be less than 245.3kg. NEC required that the mass of CPR is changed or less 270kg by NECS-RFW-0042.

Table 3.1-1 CPR mass budgets

		Nominal		Maximum	
CPR System	MREF	34.7		35.0	
	DPM	3.8		3.8	
	HRM	5.8		5.8	
	SPU	29.0		31.9	
	HSW	2.1		2.3	
	INT	17.2		18.2	
	STR	49.5		50.1	
	STR(platform)	44.0		44.0	
	Sub Total		186.1		191.0
TRS		51.5		55.2	
QOF		18.5		22.8	
Total		256.2		269.0	
Requirement				270kg or less	

(Unit: kg)

3.2 Power Budget

The power budget of CPR is shown in Table 3.2-1 and Table 3.2-2. Regarding power consumption, NEC has issued NECS-RFW-0063, NECS-RFW-0095 and NECS-RFW-0096.

Table 3.2-1 Power Consumption of Survival Heater

Heater Margin= 18%

Survival Heater

S/C position is stabilized.

140.9W=119.4W(thermal analysis result)+21.5W(margin18%)

No.	CPR MODE	average *1,*3	peak	
			@Lower voltage*2	@34V
1	All Off	0.0	0.0	0.0
2	Safety	140.9	196.0	386.9
3	INIT	88.3	196.0	386.9
4	Standby	0.0	0.0	0.0
5	IDLE/ silent state	0.0	0.0	0.0
6	Observation	0.0	0.0	0.0
7	Contingency Observation	0.0	0.0	0.0
8	Internal Calibration	0.0	0.0	0.0
9	External Calibration	0.0	0.0	0.0
10	Sea Surface Calibration	0.0	0.0	0.0
11	Standby Refuse	0.0	0.0	0.0
12	Idel Refuse	0.0	0.0	0.0

*1:28V　*2:24.2V

*3: Orbit Average

Heater Margin= 0%

Survival Heater(Including temperature margin)

For 45min > 207.7W =161.4W (thermal analysis result)+46.3W (analytical uncertainty)
For 60min > 207.7W =160.5W (thermal analysis result)+47.2W (analytical uncertainty)
For 63min > 207.7W =146.7W (thermal analysis result)+61.0W (analytical uncertainty)
To be repeated for 20 orbit > 158.5W=134.3W (thermal analysis result)+24.2W(margin18%)
Thermal analysis condition is below.
>MREF Deployed

No.	S/C MODE	average *1	peak	
			@Lower voltage*2	@34V
1	(168min)e (105min)	**207.7**	166.1	327.9

*1:28V　*2:24.2V

Table 3.2-2 CPR Power consumption

Including temperature margin HPT=8.1degreeC,Others=15degreeC

Operational mode(Nominal operation mode : HPT duty = 2.0%)

No	CPR MODE	Operational Heater				SPU*5	HSW*6	TRS/QOF*7 (except HPT)	HPT*7	BOL			EOL		
		average	*2 *3	peak @Lower voltage*1	peak @34V					average *2,3	peak @Lower voltage*1	peak @34V	average *2,3	peak @Lower voltage*1	peak @34V
1	All Off	0.0		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	Safety	0.0		0.0	0.0	0.2	0.2	0.6	0.5	1.5	1.5	1.5	1.5	1.5	1.5
3	INIT	0.0		0.0	0.0	54.0	0.2	0.6	0.5	55.3	55.3	55.3	55.3	55.3	55.3
3a	INIT-Standby	184.3	*4	155.6	307.1	54.0	2.0	64.9	0.5	305.7	277.0	428.5	305.7	277.0	428.5
4	Standby	184.3	*4	155.6	307.1	54.0	2.0	64.9	0.5	305.7	277.0	428.5	305.7	277.0	428.5
5	IDLE/silent state	135.9	*4	155.6	307.1	54.0	2.0	64.9	25.0	281.8	301.5	453.0	281.8	301.5	453.0
		182.4	*4	155.6	307.1	48.0	6.4	45.8	15.0	297.6	270.8	422.3	297.6	270.8	422.3
6	Observation*8	22.0	*4	37.3	73.7	54.0	0.5	64.9	181.0	$\boxed{322.4}$	337.7	374.1	322.4	337.7	374.1
		59.5	*4	88.3	174.3	48.0	1.0	45.8	136.6	290.9	319.7	405.7	290.9	319.7	405.7
7	Contingency Observation	Same as Observation mode								Same as Observation mode					
8	Internal Calibration	135.9	*4	155.6	307.1	54.0	2.0	64.9	25.0	281.8	301.5	453.0	281.8	301.5	453.0
		182.4	*4	155.6	307.1	48.0	6.4	45.8	15.0	297.6	270.8	422.3	297.6	270.8	422.3
9	External Calibration	Same as Observation mode								Same as Observation mode					
10	Sea Surface Calibration*8 (410sec)	53.7	*4	37.3	73.7	54.0	1.0	64.9	181.0	$\boxed{354.6}$	338.2	374.6	354.6	338.2	374.6
		69.7	*4	132.4	261.3	48.0	1.5	45.8	136.6	301.6	364.3	493.2	301.6	364.3	493.2
11	Standby Refuse	184.3	*4	155.6	307.1	54.0	2.0	64.9	0.5	305.7	277.0	428.5	305.7	277.0	428.5
12	Idle Refuse	135.9	*4	155.6	307.1	54.0	2.0	64.9	25.0	281.8	301.5	453.0	281.8	301.5	453.0
		182.4	*4	155.6	307.1	48.0	6.4	45.8	15.0	297.6	270.8	422.3	297.6	270.8	422.3

Other possible operation modes(Nominal operation mode : HPT duty = 2.2%)

No	CPR MODE	Operational Heater				SPU*5	HSW*6	TRS/QOF*7 (except HPT)	HPT*7	BOL			EOL		
		average	*2 *3	peak @Lower voltage*1	peak @34V					average *2,3	peak @Lower voltage*1	peak @34V	average *2,3	peak @Lower voltage*1	peak @34V
1	All Off	0.0		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	Safety	0.0		0.0	0.0	0.2	0.2	0.6	0.5	1.5	1.5	1.5	1.5	1.5	1.5
3	INIT	0.0		0.0	0.0	54.0	0.2	0.6	0.5	55.3	55.3	55.3	55.3	55.3	55.3
3a	INIT-Standby	184.3	*4	155.6	307.1	54.0	0.2	64.9	0.5	303.9	275.2	426.7	303.9	275.2	426.7
4	Standby	184.3	*4	155.6	307.1	54.0	2.0	64.9	0.5	305.7	277.0	428.5	305.7	277.0	428.5
5	IDLE/silent state*8	135.9	*4	155.6	307.1	54.0	2.0	64.9	25.0	281.8	301.5	453.0	281.8	301.5	453.0
		182.4	*4	155.6	307.1	48.0	6.4	45.8	15.0	297.6	270.8	422.3	297.6	270.8	422.3
6	Observation*8	22.0	*4	37.3	73.7	54.0	0.5	64.9	198.0	$\boxed{339.4}$	354.7	391.1	339.4	354.7	391.1
		59.5	*4	88.3	174.3	48.0	1.0	45.8	136.6	290.9	319.7	405.7	290.9	319.7	405.7
7	Contingency Observation	Same as Observation mode								Same as Observation mode					
8	Internal Calibration*8	135.9	*4	155.6	307.1	54.0	2.0	64.9	25.0	281.8	301.5	453.0	281.8	301.5	453.0
		182.4	*4	155.6	307.1	48.0	6.4	45.8	15.0	297.6	270.8	422.3	297.6	270.8	422.3
9	External Calibration	Same as Observation mode								Same as Observation mode					
10	Sea Surface Calibration*8 (410sec)	53.7	*4	37.3	73.7	54.0	1.0	64.9	198.0	$\boxed{371.6}$	355.2	391.6	371.6	355.2	391.6
		69.7	*4	132.4	261.3	48.0	1.5	45.8	136.6	301.6	364.3	493.2	301.6	364.3	493.2
11	Standby Refuse	184.3	*4	155.6	307.1	54.0	2.0	64.9	0.5	305.7	277.0	428.5	305.7	277.0	428.5
12	Idle Refuse*8	135.9	*4	155.6	307.1	54.0	2.0	64.9	25.0	281.8	301.5	453.0	281.8	301.5	453.0
		182.4	*4	155.6	307.1	48.0	6.4	45.8	15.0	297.6	270.8	422.3	297.6	270.8	422.3

*1 : 24.2V
*2 : 29.0V
*3: Orbit average except Sea Surface CAL. Sea Surface CAL: average for 410 sec.
*4 : Cold Case
*5 : ICD-0S9459rev.2、*6 : ICD-0S9903rev.4
*7 : TRS and HPT max power is based on IDS-ECA-169929-001、QOF:JX-ESPC-100594C
*8:Upper=Unit Dissipation is maximum case. Lower=Unit Dissipation is minimum case.

3.3 Datarate Budget

3.3.1 Housekeeping Telemetry Datarate

There are two telemetries of housekeeping telemetry.
One is HK telemetry via RIU, the other is HK telemetry via MIL-bus.

3.3.1.1 Housekeeping Telemetry Data rate

Data Rate of HK telemetry via MIL-1553B: 656bps (less than 700bps)

3.3.1.2 Housekeeping Telemetry Formats

HK telemetry via MIL-BUS is designed in accordance with PUS.

3.3.2 Science Telemetry

(1) Science Telemetry Data rate

Data rate of science telemetry is less than 270kbps.

The Science Telemetry data rate detail is shown Table 3.3.2-1.

Table 3.3.2-1 Science Telemetry

TM(240.1)	Byte	TM(240.2)	Byte	TM(240.3)	Byte
Packet Header Data Field Header Private Science Data Header Source Data CRC	6 12 10 208 2	Packet Header Data Field Header Private Science Data Header Source Data CRC	6 12 10 2340 2	Packet Header Data Field Header Private Science Data Header Source Data CRC	6 12 10 1234 2
Total Data Size (Byte)	238	Total Data Size (Byte)	2370	Total Data Size (Byte)	1264

TM(240.4)	Byte	TM(240.5)	Byte
Packet Header Data Field Header Private Science Data Header Source Data CRC	6 12 10 186 2	Packet Header Data Field Header Private Science Data Header Source Data CRC	6 12 10 2172 2
Total Data Size (Byte)	216	Total Data Size (Byte)	2202

Observation/Sea CAL/Ext CAL	@1sec	Contingency	@1sec	Internal Cal	@1sec
TM(240.1)×1packet (Byte) TM(240.2)×14packet (Byte)	238 33180	TM(240.1)×1packet (Byte) TM(240.3)×14packet (Byte)	238 17696	TM(240.4)×1packet (Byte) TM(240.5)×7packet (Byte)	212 15414
Total Data Size (Byte)	33414	Total Data Size (Byte)	17930	Total Data Size (Byte)	15626
Total Data Size (kbps)	267	Total Data Size (kbps)	143	Total Data Size (kbps)	125

(2) Science Telemetry Formats

Header and Temperature Data are stored once per second, and observation data is stored 14 times per second. The packet structure of science telemetry is designed in accordance with PUS.

In CPR, five packets are defined.

i) TM(240.1)

This packet format output once per second in Observation / Sea CAL / External CAL / Contingency mode.

TM(240.1) Format				
Packet Header	Data Field Header	Private Science Data Header	Source Date > Science Status1 + Science Status2 <	Packet CRC
6 byte	12 byte	10 byte		2 byte

Private Science Data Header		
S/C State Vector Quality	ISPS Version Number	Ancillary data
4 byte	2 byte	4 byte

ii)TM(240.2)

This packet format output 14 times per second in Observation / Sea CAL / External CAL mode.

TM(240.2) Format				
Packet Header	Data Field Header	Private Science Data Header	Source Date > Science Data <	Packet CRC
6 byte	12 byte	10 byte		2 byte

Private Science Data Header		
S/C State Vector Quality	ISPS Version Number	Ancillary data
4 byte	2 byte	4 byte

iii) TM(240.3)

This packet format output 14 times per second in Contingency mode.

TM(240.3) Format				
Packet Header	Data Field Header	Private Science Data Header	Source Date > Science Data <	Packet CRC
6 byte	12 byte	10 byte		2 byte

Private Science Data Header		
S/C State Vector Quality	ISPS Version Number	Ancillary data
4 byte	2 byte	4 byte

iv) TM(240.4)

This packet format output once per second in Internal CAL mode.

TM(240.4) Format				
Packet Header	Data Field Header	Private Science Data Header	Source Date > Science Status1 + Science Status2 <	Packet CRC
6 byte	12 byte	10 byte		2 byte

Private Science Data Header		
S/C State Vector Quality	ISPS Version Number	Ancillary data
4 byte	2 byte	4 byte

v) TM(240.5)

This packet format output 7 times per second in Internal CAL mode.

TM(240.5) Format				
Packet Header	Data Field Header	Private Science Data Header	Source Date ＞ Science Data ＜	Packet CRC
6 byte	12 byte	10 byte		2 byte

Private Science Data Header		
S/C State Vector Quality	ISPS Version Number	Ancillary data
4 byte	2 byte	4 byte

D

3.3.3 TC budget

Number of CMDs and CMD-ID and size of the CMD

1) Typical orbit (consider CAL/VAL and for Nominal operations)
   In normal operation, we send mode transition commands to CPR.
   Send SPU ON command. This is the RIU interface command.
   After that, we send the following mode transition commands to CPR. The sizes and frequency are shown in Table 3.3.3-1.
   All mode transition command sizes are the same.
   CCSDS Primary Header: 6byte
   Data Field Header : 4byte
   Function ID : 1byte
   Reserve : 1byte
   Operational mode : 2byte
   Sub mode : 2byte
   CRC : 2byte
   Total 18byte

Table 3.3.3-1 Mode transition commands size and frequency (Nominal operation)

No.	command	size	frequency	remarks
1	Standby mode transition	18byte	1 time after SPU-INI mode transition completion.	
2	IDLE mode transition	18byte	1 time after Standby mode transition completion.	
3	NOM mode transition	18byte	1 time after IDLE mode transition completion	

Mode transition time is shown in Table 3.3.3-2. The frequency to send the above commands is very low. After mode transition to NOM completion, we don’t send commands to CPR. Then the command sending frequency is very low.

D

Table 3.3.3-2 Mode transition time

To \ From	All-off	Safety	SPU INI	Standby	IDLE	Observation	Int. CAL	Ext CAL	Sea CAL	Contin-gency	Standby refuse	IDLE refuse
All-off	—	1	—	—	—	—	—	—	—	—	—	—
Safety	1		1									
SPU-INI	—	50	—	1	1	1	1	1	1	1	1	1
Standby	—	—	12[1]	—	1	—	—	—	—	—	1	1
IDLE	—		—	305[2]	—	1	1	1	1	1	—	1
Observation	—		—	—	1	—	1	1	1	1	—	—
Int. CAL	—		—	—	1	1	—	1	1	1	—	—
Ext CAL	—		—	—	1	1	1	—	1	1	—	—
Sea CAL	—		—	—	1	1	1	1	—	1	—	—
Contingency	—		—	—	1	1	1	1	1	—	—	—
Standby refuse	—		—	1	1	1	1	1	1	1	—	1
IDLE refuse	—		—	—	1	1	1	1	1	1	—	—

Unit: Second

*1 Depend on the equipment temperature. When equipment in CPR temperature is in the turn-on range, it takes 10 seconds.

*2 Depend on HPT temperature and HPT startup time. When HPT temperature is in the turn-on range, it takes 300 seconds. And Software processing time for this mode transition is 5 sec. In this case, the waiting time for equipment turn on is zero.

— : Impossible to transfer

Next, in CAL/VAL phase, CPR transfers to the following calibration modes. D

a) Internal calibration
b) External calibration
c) Sea surface calibration

The necessary commands are shown in Table 3.3.3-3. Then the command sending frequency is very low.

Table 3.3.3-3 Cal. mode transition commands size and frequency (Nominal operation)

No.	command	size	frequency	remarks
	Internal calibration mode transition	18byte	CAL/VAL phase: 1 time. Nom. Operation: 2 times per month.	
	External calibration mode transition	18byte	CAL/VAL phase: 1 time Nom. Operation: 1 time per month.	
	Sea surface calibration mode transition	18byte	CAL/VAL phase: 1 time Nom. Operation: 1 time per month.	

2) Typical day (consider CAL/VAL and for Nominal operations)

Although in CAL/VAL phase, CPR usually continues observation. Then basically we don't send commands. According to the above 1), we send commands. Then the command sending frequency is very low.

3) 5 Day autonomous operation period (consider CAL/VAL and for Nominal operations)

As the same above, CPR usually continues observation. Then basically we don't send commands. When we need calibration data of CPR, we send mode transition commands.

3.3.4 Memory budget

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Memory Budget
PROM (Version 0xF0)
Total capacity :128KB
Used amount
IPL/SPL/Monitor : 26,159byte (20.0%)
Vector : 320byte (0.0%)
OS & Application: 70,888byte (54.1%)
Sum total : 97,367byte(74.3%)
Remaining capacity :33,705 byte(25.7%)

EEPROM (Version 0x62)
Total capacity :1MB
Used amount :
Vector : 472byte (0.0%)
PROM->RAM copy table : 112byte (0.0%)
OS : 64,912byte (0.1%)
Application : 519,584byte (49.6%)
Table & log : 146,228byte (13.9%)
Sum total : 731,308byte(69.7%)
Remaining capacity :317,268byte (30.2%)

There is enough remaining capacity on both PROM and EEPROM.

3.3.5 SPU start-up time

Watch dog Timer Timeout is 25.6 seconds when SPU starts-up.

The time from Power ON to PROM start-up (MIL-BUS communication start) is for 15 seconds.
And from Restart caused by SPU S/W Restart to EEPROM start-up is for 16.4 seconds.
For each case, there is about 10-second-margin. Therefore WDT Timeout does not occur at start-up.

WDT Timeout is for 3 seconds during CPR operation.
WDT Timer is reset once a second.
Unit of SPUFS internal process is decided on the integral frame (about 56ms~70ms) which is CPR internal processing.
The time for integral frame processing with its maximum load is approximately for 10ms, therefore there is enough time to process.
The process of MIL-BUS communication is about for 6ms at MF0 where processing is concentrated. It has enough time compared to 1MF (50ms).

3.3.6 SEU

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We confirmed SPU memory scrubbing rate and SEU phenomenon. And it is confirmed that CPR memory scrubbing rate is much faster than the occurrence rate of SEU. The details are shown in EC-N-T-13083

3.3.7 Timing budget

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When CPR is synchronized to 1PPS, the time stamp includes about 4 clocks time error. The one clock is 1/48MHz = 20.8ns. Then the error is 83.2ns.
On the other hand, Lo oscillator short term stability in CPR is around 100us. Then this Lo oscillator short term stability determines the accuracy of CPR time stamp.

CPR provides time stamp as Course time + Fine time. Fine time is determined inside CPR. This Fine time accuracy is around 100ns according to the Lo oscillator short term stability.

Then CPR time stamp error is around 100us.

3.4 ビーム指向精度 Antenna beam pointing accuracy

3.4.1 概要 Outline

アンテナビーム指向精度とアンテナビーム指向決定精度は表 3.4.1-1に示すように要求を満足する。

Antenna beam pointing accuracy and antenna beam pointing accuracy of unknown meet the requirement, as shown in table 3.4.1-1.

表 3.4.1-1　アンテナビーム指向精度とアンテナビーム指向決定精度の要求と結果

Table 3.4.1-1 The requirement and result of Antenna beam pointing accuracy and antenna beam pointing accuracy of unknown

	Cross-track (RX)		Along-track (RY)	
	pointing accuracy	Pointing accuracy of unknown	pointing accuracy	Pointing accuracy of unknown
CPR (without QOF)	3.17E-03	1.92E-03	8.90E-03	1.50E-03
QOF	2.51E-03	1.23E-03	1.80E-03	9.15E-04
RSS of CPR and QOF	4.04E-03	2.28E-03	9.08E-03	1.76E-03
Requirement	<1.5E-2(1σ)	<2.5E-3(1σ)	<1.5E-2(1σ)	<2.5E-3(1σ)

*QOF のアンテナビーム指向精度とアンテナビーム指向決定精度は QOF　PDR で CPR が提示した配分値を使用した

* Antenna beam pointing accuracy and antenna beam pointing accuracy of unknown of QOF use distribution value which CPR system provided by QOF PDR.

3.4.2 アンテナビーム指向精度とアンテナビーム指向決定精度 Antenna beam pointing accuracy and antenna beam pointing accuracy of unknown

アンテナビーム指向精度とアンテナビーム指向決定精度の定義を以下に示す。

アンテナビーム指向精度：理想的なアンテナビーム指向方向に対する誤差
常に一定の誤差を要する Bias 成分、時間（長周期）と共にビーム方向が変動する Harmonic 成分及び時間に関係なく変動する Random 成分の合計

アンテナビーム指向決定精度：理想的なアンテナビーム指向方向に対する誤差のうち既知分を取り除いた unknown 成分

The definition of antenna beam pointing accuracy and antenna beam pointing accuracy of unknown are shown below.

Antenna beam pointing accuracy: The error over the ideal antenna beam pointing direction
The antenna beam pointing accuracy is sum total of the bias value which always requires a fixed error, the random value changed regardless and the Harmonic value for

which the direction of a beam is changed with time (long cycle), and time

Antenna beam pointing accuracy of unknown: The unknown component which removed a part for known among the errors over the ideal antenna beam inclination direction

3.4.3 アンテナビーム指向精度誤差要因 The error Factor of antenna beam pointing accuracy

各誤差要因の個別説明を以下に示す。

The explanation of each error factor is shown below.

(a) Fabrication Error

アンテナ指向軸方向は NFM で測定されるが、アンテナビーム指向方向ノミナル値と測定値の差。軌道上で変動しないため Bias 成分のみである。
測定結果ノミナル値とアンテナビーム指向方向ノミナル値の差が known 分、測定誤差が unknown 分となる。

Antenna pointing direction are the differences of the antenna beam pointing direction nominal value and measured value, although measured by NFM.
Since it does not change on an orbit, it is only a Bias value.
The difference of a measurement result nominal value and the antenna beam pointing direction design value is the known value, and an error of measurement is the unknown value.

(b) Thermal Distortion

軌道上での熱変形による誤差。熱変形解析によって算出される。時間（長周期）により変動するので Harmonic 成分のみである。解析結果が known 分となり、解析誤差が unknown 分となる。

The error is the thermal deformation on orbit. It is calculated by thermal deformation analysis. Since it changes by time (long cycle), it is only a Harmonic value.
An analysis result is the known value and an analysis error is unknown value.

(c) Gravity Release

地上でのアライメント測定の１G 変形による誤差。軌道上で変動しないため Bias 成分のみである。
解析結果が known 分となり、解析誤差が unknown 分となる。１G 変形及び主反射鏡支持治具による主反射鏡の矯正分の切り分けをして更に精度を上げる為に、図

3.4.3-1に示す方法で主反射鏡支持治具なしの状態でCPRの角度を変えてアライメント測定を実施する。

The error is 1G modification of alignment measurement in the ground. Since it does not change on an orbit, it is only a Bias value. The analysis result is known value and the analysis error is unknown value.
In order to improve accuracy of alignment measurement, alignment measurement is carried out by the configuration shown in a figure 3.4.3-1.

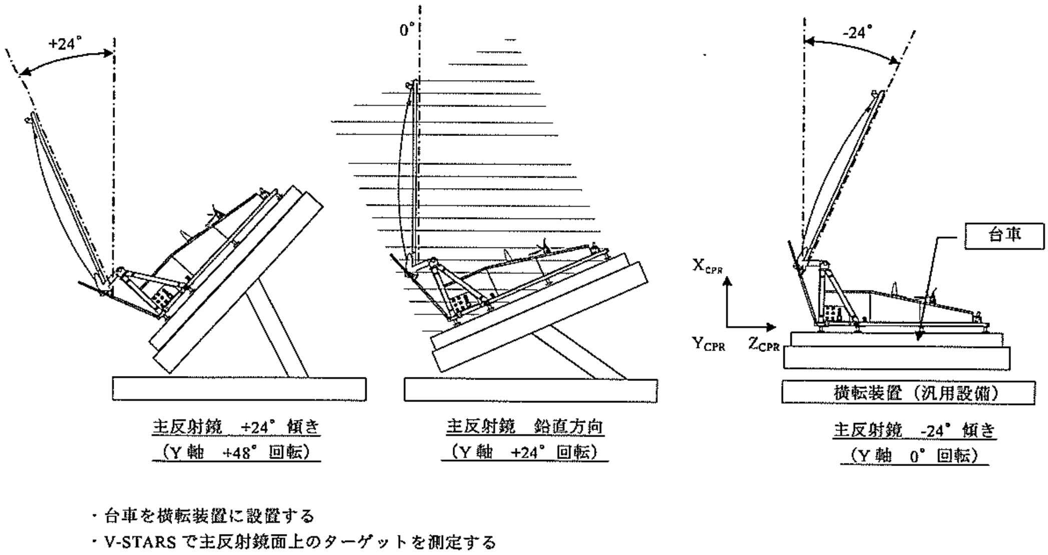


図 3.4.3-1　１G 変形測定コンフィギュレーション Alignment measurement configuration

(d) Moisture Desorption

CFRP等の吸湿素材の排湿変形による誤差。軌道上で変動しないためBias成分のみである。解析結果がknown分となり、解析誤差がunknown分となる。

The error is the moisture desorption modification of moisture absorption materials, such as CFRP. Since it does not change on an orbit, it is only a bias value.
the analysis result is known value and the analysis error is unknown value.

(e) Launch Shift

耐機械環境に対するヒステリシス誤差。軌道上で変動しないためBias成分のみである。予測ができないためunknown分のみである。機械環境試験前後で測定した、CPRに取り付けてある2個のキューブミラー（CPR１：CPR機械座標系原点付近の衛星I/Fの近くに取り付けた、CPR2：MREF　ARMに取り付けた）の相対角度の変動量を取り込んだ。キューブミラーによる測定は衛星I/FからMREF　ARMまでのヒステリシスが保証され、その先のMREFについては外観検査及びpre/post LLS比較にて健全性を確認している。高弾性CFRP製サンドイッチパネルのMREFはその特性上脆性が低く塑性変形するより先に破損するため、外観検査とpre/post　LLS比較で変形がないことを確認することが可能である。

The error is the hysteresis error by the mechanical environment. Since it does not change on an orbit, it is only a Bias value. Since prediction is impossible, it is only unknown value.
The amount of change of the relative angle of two cube mirrors attached to CPR measured before and after the mechanical environmental test was taken in. The hysteresis from satellite I/F to MREF ARM has guaranteed by measurement by a cube mirror. MREF is checked by a visual examination and pre/post LLS comparison.

(f) Development Repeatability

展開機構の展開再現性による誤差。軌道上で変動しないため Bias 成分のみである。
予測ができないため unknown 分のみである。今回は展開試験の結果の値を入れている。仕様値は 5.0E-4 度。

The error is the deployment reproducibility of a deployment mechanism. Since it does not change on an orbit, it is only a Bias value. Since prediction is impossible, it is unknown value. The value as a result of a deployment test is put in this time. The specification value is 5.0E-4 degree.

(g) Micro vibration

軌道上で衛星の発するマイクロバイブレーションによって生じる変形誤差であるが、短周期であるために、ドップラー速度変動誤差内で影響を評価することにした為、アンテナビーム指向変動誤差には積算しないことになった(3.4.6)

This error is a modification error which arises by the micro vibration which a satellite emits on orbit. Since it was a short cycle and decided to evaluate influence within the Doppler velocity fluctuation error, it will not calculate for an antenna beam pointing error (See Section 3.4.6).

(h) Compensation of bias error

Bias 成分のうち known 分については衛星に搭載する際にシム調で補正を行い取り除く（よって known 分は０となる）。Compensation of bias error はシム補正時に生じるシムの最少厚さによる調整代の限界、シム厚の公差等による誤差である。本誤差は Bias 成分の unknown 分に分類される。

When CPR carried in a satellite, the bias value of the beam pointing error is removed by the Shim adjustment (therefore, set to 0 by the amount of known). Compensation of bias error is an error by the limit of the adjustment by the minimum thickness of Shim which produces at the time of the Shim compensation and the common difference of the Shim thickness. This error is unknown of a Bias value.

3.4.4 算出方法 Calculation Method

CPR アンテナビーム指向精度とアンテナビーム指向決定精度の算出方法を表 3.4.4-1 に示す。また gravity release, moisture distortion,の各誤差要因の unknown 分の算出結果を表 3.4.4-2 に示す。Fabrication error の算出結果を表 3.4.4-3 に示す。

既知の値は定量的に予測可能なビーム指向精度で、次の値を含む：fabrication errors の計測値, deformation by gravity release の解析値, deformation by moisture desorption の解析値、および thermal distortion の解析値 D

Unknown 分の値は一定範囲の値を取る不確実な値であり、次の値を含む： fabrication errors の計測誤差, deformation by gravity release の解析誤差, deformation by moisture desorption の解析誤差, thermal distortion の解析誤差, deformation by launch shift の解析誤差, 展開再現性、および the compensation of bias error.

本文書中で用いている用語で、“Pointing accuracy” と “ Pointing accuracy of unknown”はそれぞれ” Absolute Pointing Error (APE)”と”Absolute Measurement Error (AME)”に相当する。

The calculation method of CPR antenna beam pointing accuracy and antenna beam pointing accuracy of unknown is shown in Table 3.4.4-1. The calculation result for unknown value of error factor of gravity release and moisture distortion is shown in Table 3.4.4-2.

The calculation result of Fabrication error is shown in Table 3.4.4-3.

The known value are the value that the beam pointing accuracy can predict with numerical value. The following items are included; the measurement value of fabrication errors, the analysis value of deformation by gravity release, the analysis value of deformation by moisture desorption and the analysis value of thermal distortion. D

The unknown value is the uncertain numerical value that is predicted in certain range. The following items are included; the measurement error of fabrication errors, the analysis error of deformation by gravity release, the analysis error of deformation by moisture desorption, the analysis error of thermal distortion, the analysis error of deformation by launch shift, the deployment repeatability and the compensation of bias error.

The terms “Pointing accuracy” and “ Pointing accuracy of unknown” used in this document are equivalent to so called Absolute Pointing Error (APE) and Absolute Measurement Error (AME) respectively. AME is calculated by RSS of (Bau, Bck, Bcu, Bdk, Bdu, Beu, Bfu, Bhu, Hbk, Hbu).

表 3.4.4-1　アンテナビーム指向精度とアンテナビーム指向決定精度の算出方法

Table 3.4.4-1 The calculation method of CPR antenna beam pointing accuracy and antenna beam pointing accuracy of unknown

		Cross-track (RX)						
		pointing accuracy						Pointing accuracy of unknown
		Bias		Harmonic		Random		
		known	Unknown	known	Unknown	known	Unknown	
a	Fabrication Error	Bak	Bau	------------	--------------	------------	------------	=Bau
b	Thermal Distortion(*1	------------	--------------	Hbk	Hbu=Hbk*30%/3	------------	------------	=Hbu
c	Gravity Release	Bck(*2	Bcu=Bc*16%/3	------------	--------------	------------	------------	=Bcu
d	Moisture Desorption	Bdk(*3	Bdu=Bd*21%/3	------------	--------------	------------	------------	=Bdu
e	Launch Shift	------------	Beu	------------	--------------	------------	------------	=Beu
f	Deployment Repeatability	------------	Bfu	------------	--------------	------------	------------	=Bfu
g	micro vibration	------------	--------------	------------	--------------	------------	------------	------------
h	compensation of bias error	------------	Bhu(*5	------------	--------------	------------	------------	=Bhu
	RSS of Bias(*6	=RSS of (Bau,Bcu,Bdu,Beu,Bfu,Bhu)		--------------		--------------		------------
	RSS of harmonic			=Hbk + Hbu		--------------		------------
	RSS of Random	--------------		--------------		Rgu		------------
	pointing accuracy	=RSS of (RSS of Bias, RSS of Harmonic, RSS of Random)						------------
	Pointing accuracy of unknown	--------------						RSS of 指向決定精度
	Requirement	<1.5E-2(1σ)						<2.5E-3(1σ)

		Along-track (RY)						
		pointing accuracy						Pointing accuracy of unknown
		Bias		Harmonic		Random		
		known	Unknown	known	Unknown	known	Unknown	
a	Fabrication Error	Bak	Bau	------------	--------------	------------	------------	=Bau
b	Thermal Distortion	------------	------------	Hbk(*1	Hbu=Hbk*30%/3	------------	------------	=Hbu
c	Gravity Release	Bck(*2	Bcu=Bc*16%/3	------------	--------------	------------	------------	=Bcu
d	Moisture Desorption	Bdk(*3	Bdu=Bd*21%/3	------------	--------------	------------	------------	=Bdu
e	Launch Shift	------------	Beu	------------	--------------	------------	------------	=Beu
f	Deployment Repeatability	------------	Bfu	------------	--------------	------------	------------	=Bfu
g	micro vibration	------------	------------	------------	--------------	------------	------------	------------
h	compensation of bias error	------------	Bhu(*5	------------	--------------	------------	------------	=Bhu
	RSS of Bias	=RSS of (Bau,Bcu,Bdu,Beu,Bfu,Bhu)		--------------		--------------		------------
	RSS of harmonic			=Hbk + Hbu		--------------		------------
	RSS of Random	--------------		--------------		Rgu		------------
	pointing accuracy	=RSS of (RSS of Bias, RSS of Harmonic, RSS of Random)						------------
	Pointing accuracy of unknown	--------------						RSS of (Bau, Hbu, Bcu, Bdu, Beu , Bfu, Rgu, Bhu)
	Requirement	<1.5E-2(1σ)						<2.5E-3(1σ)

注
＊1　既知分は軌道上熱変形による指向軸変動の解析ﾉﾐﾅﾙ値。軌道上で本値を使用してビーム指向軸変動の補正をする。
　unknownの算出方法については8章を参照
＊2　1G変形による指向軸変動のﾉﾐﾅﾙ値（解析値）。
＊3　吸湿変形による指向軸変動のﾉﾐﾅﾙ値（解析値）。
＊4　欠
＊5　シムによるバイアス補正で残ってしまう誤差
＊6　Bak, Bck, Bdkはシムによるバイアス補正により補正するので、積算しない。また計算式は以下による

$$RSS\cdot of\cdot(Bau, Bcu, Bdu, Beu, Bfu, Bhu) = \sqrt{Bau^2 + Bcu^2 + Bdu^2 + Beu^2 + Bfu^2 + Bhu^2}$$

Note

*1 The known value is the analysis nominal value of the antenna beam pointing direction change by thermal deformation on orbit. The antenna beam pointing change is rectified on an orbit using this value.

*2 This value is the nominal value by Gravity Release analysis.

*3 This value is the nominal value by moisture desorption analysis.

*4 The missing number

*5 The error which remains by adjustment by Shim

*6 Since B_{ak}, B_{ck}, and B_{dk} are removed as bias correction by Shim, they does not integrate. A formula is shown below.

$$RSS \cdot of \cdot (Bau, Bcu, Bdu, Beu, Bfu, Bhu) = \sqrt{Bau^2 + Bcu^2 + Bdu^2 + Beu^2 + Bfu^2 + Bhu^2}$$

表 3.4.4-2　各誤差要因の unknown 分の算出結果(3σ)

Predictive accuracy of the gravity release				
Factor of error			個別予測精度	備考
Structure	Analysis	The prediction error of distribution of mass	5%	The prediction error of distribution of mass and the error of distribution to a model
		The error by modeling (Stiffeness)	15%	The tolerance of the characteristics of each component, and the error by rigid imitation
Predictive accuracy（RSS）			16%	

Predictive accuracy of the moisture desorption				
誤差要因			個別予測精度	備考
Structure	Analysis	CME	15%	The tolerance of CME of each component, and the diffence of moisture desorption configuration
		The error by modeling (Stiffeness)	15%	The tolerance of the characteristics of each component, and the error by rigid imitation
Predictive accuracy（RSS）			21%	

表　3.4.4-3　Fabrication error unknown 分の算出結果(3σ)

		Along-track(RY)		Cross-track(RX)	
MGSE of integration		Along-track(RY)		Cross-track(RX)	
	Coaxiality of alignment pin			2.50E-04	
	Assembly reproducibility	4.50E-06		6.20E-04	
	measurement error og cube	1.22E-03		1.94E-03	
	measurement error of alignment			1.94E-03	
	measurement error of level	4.40E-04			
	RSS		1.30E-03		2.83E-03
measurement error between MGSE cube and CPR cube		Along-track(RY)		Cross-track(RX)	
	measurement error og MGSE cube	1.22E-03		1.94E-03	
	measurement error og CPR cube	1.22E-03		1.94E-03	
	measurement error of alignment			1.94E-03	
	RSS		1.73E-03		3.37E-03
Measurement of a NEF measurement coordinate system		Along-track(RY)		Cross-track(RX)	
	measurement of probe coordinate system	1.11E-05		1.78E-04	
	measurement error og CPR cube	1.22E-03		1.94E-03	
	measurement error of alignment			1.94E-03	
	RSS		1.22E-03		2.76E-03
error of NFM measurement *)		Along-track(RY)		Cross-track(RX)	
			3.00E-04		3.00E-04
Error which remains by ajustment by sShim		Along-track(RY)		Cross-track(RX)	
			5.70E-04		5.70E-04
		Along-track(RY)		Cross-track(RX)	
合計			2.57E-03		5.23E-03

＊）アンテナパターンを測定する近傍界測定装置（Near-Field Measurement System; NFM）自身が持っている角度測定誤差は、0.3E-4deg 以下であり、十分小さい。

　これは、NFM 自身が持っている位相変動誤差が W 帯において 2deg 以下であり、これを 3.5m 四方のスキャンを行う際に一軸方向に発生する(最悪ケース)場合に起こる誤差である。

概要；

　94.05GHz の波長は 3.19mm。位相差 2deg は 1.77E-2mm に対応する。3.5m スキャンで 1.77E-2mm の誤差を考えると、tan-1(1.77E-2／3500)＝0.0003deg となる。

*)The angle measurement error which Near-Field Measurement System itself has is less than 0.3E-4deg, and is small enough. The phase fluctuation error which the NFM itself has is 2 or less degree in W band. This error occurs, when scanning 3.5 m around and generating in one axis (the worst case).
Outline;

The wavelength of 94.05 GHz is 3.19 mm. Phase difference 2degree corresponds to 1.77E-2mm. It will be set to tan-1(1.77E-2 / 3500)=0.0003deg if a 1.77E-2mm error is considered with a 3.5-m scan.

3.4.5 アンテナビーム指向精度及びアンテナビーム指向決定精度計算結果 Calculation result of antenna beam pointing accuracy and antenna beam pointing accuracy of unknown

解析結果及び誤差の積み上げ結果より算出した、アンテナビーム指向精度及びアンテナビーム指向決定精度の配分値を表 6.7.5-1 に示す。アンテナビーム指向精度の要求　0.015degree 以下に対して 0.00682degree（RX）、0.00961degree（RY）、アンテナビーム指向決定精度の要求 0.0025degree 以下の要求に対して 0.00232degree（RX）、0.00177degree（RY）と要求を満足する。

The calculation result of antenna beam pointing accuracy and antenna beam pointing accuracy of unknown is shown in table 6.7.5-1. The specification value of antenna beam pointing accuracy is 0.015 or less degree, and results are 0.00682degree (RX) and 0.00961degree (RY), and meet the specification. The specification value of antenna beam pointing accuracy of unknown is 0.0025 or less degree, and results are 0.00232degree (RX) and 0.00177degree (RY), and meet the specification.

表 3.4.5-1　アンテナビーム指向精度及びアンテナビーム指向決定精度計算結果(1/2)　　Table 3.4.5-1 Calculation result of antenna beam pointing accuracy and antenna beam pointing accuracy of unknown

(a)　Cross-track

CPR (without QOF) (Unit: degree)

		Cross-track (RX)						
		pointing accuracy						Pointing accuracy of unknown
		Bias		Harmonic		Random		
		known	Unknown	known	Unknown	known	Unknown	
a	Fabrication Error	measured value	1.74E-03	------------	------------	------------	------------	1.74E-03
b	Thermal Distortion	------------	------------	2.30E-03	2.30E-04	------------	------------	2.30E-04
c	Gravity Release	5.00E-05	2.64E-06	------------	------------	------------	------------	2.64E-06
d	Moisture Desorption	5.00E-05	3.54E-06	------------	------------	------------	------------	3.54E-06
e	Launch Shift	------------	6.48E-04	------------	------------	------------	------------	6.48E-04
f	Deployment Repeatability	------------	3.10E-04	------------	------------	------------	------------	3.10E-04
g	micro vibration	------------	------------	------------	------------	------------	------------	------------
h	compensation of bias error	------------	2.58E-04	------------	------------	------------	------------	2.58E-04
	RSS of Bias	1.90E-03		--------------		--------------		------------
	RSS of harmonic	------------		2.53E-03		--------------		------------
	RSS of Random	--------------		--------------				------------
	pointing accuracy	3.17E-03						------------
	Pointing accuracy of unknown	--------------						1.92E-03

QOF (Unit: degree)

		Cross-track (RX)						
		pointing accuracy						Pointing accuracy of unknown
		Bias		Harmonic		Random		
		known	Unknown	known	Unknown	known	Unknown	
a	Fabrication Error	0.0E+00	9.0E-03	------------	------------	------------	------------	9.0E-03
b	Thermal Distortion	------------	------------	6.1E-04	6.0E-05	------------	------------	3.0E-05
c	Gravity Release	1.1E-03	1.1E-04	------------	------------	------------	------------	1.1E-04
d	Moisture Desorption	1.1E-03	1.1E-04	------------	------------	------------	------------	1.1E-04
e	Launch Shift	------------	1.2E-03	------------	------------	------------	------------	1.2E-03
f	Deployment Repeatability	1.1E-03	1.1E-04	------------	------------	------------	------------	1.1E-04
g	micro vibration	------------	------------	------------	------------	------------	------------	------------
h	compensation of bias error	------------	------------	------------	------------	------------	------------	------------
	RSS of Bias	2.4E-03		--------------		--------------		------------
	RSS of harmonic	------------		6.7E-04		--------------		------------
	RSS of Random	--------------		--------------		--------------		------------
	pointing accuracy	2.5E-03						------------
	Pointing accuracy of unknown	--------------						1.2E-03

(unit: degree)

(注)　QOF の表は QOF　PDR で CPR が QOF に提示した配分値。Fabrication　error は CPR の NFM 測定時に同時に測定されるため積算しない。

Note
The table of QOF is the distribution value which CPR showed to QOF by QOF PDR.
Since it is simultaneously measured at the time of NFM measurement of CPR, Fabrication error is not integrated.

表 3.4.5-1　アンテナビーム指向精度及びアンテナビーム指向決定精度計算結果(2/2)

Table 3.4.5-1 Calculation result of antenna beam pointing accuracy and antenna beam pointing accuracy of unknown

(b)　Along-track

CPR (without QOF) (Unit: degree)

		Along-track (RY)						
		pointing accuracy						Pointing accuracy of unknown
		Bias		Harmonic		Random		
		known	Unknown	known	Unknown	known	Unknown	
a	Fabrication Error	measured value	8.55E-04	------------	------------	------------	------------	8.55E-04
b	Thermal Distortion	------------	------------	8.00E-03	8.06E-04	------------	------------	8.06E-04
c	Gravity Release	3.00E-04	1.58E-05	------------	------------	------------	------------	1.58E-05
d	Moisture Desorption	4.00E-03	2.83E-04	------------	------------	------------	------------	2.83E-04
e	Launch Shift	------------	6.48E-04	------------	------------	------------	------------	6.48E-04
f	Deployment Repeatability	------------	3.10E-04	------------	------------	------------	------------	3.10E-04
g	micro vibration	------------	------------	------------	------------	------------	------------	------------
h	compensation of bias error	------------	5.16E-04	------------	------------	------------	------------	5.16E-04
	RSS of Bias	1.26E-03		--------------		--------------		------------
	RSS of harmonic	------------		8.81E-03		--------------		------------
	RSS of Random	--------------		--------------		------------		------------
	pointing accuracy	8.90E-03						------------
	Pointing accuracy of unknown	--------------						1.50E-03

QOF (Unit: degree)

		Along-track (RY)						
		pointing accuracy						Pointing accuracy of unknown
		Bias		Harmonic		Random		
		known	Unknown	known	Unknown	known	Unknown	
a	Fabrication Error	0.0E+00	9.0E-03	------------	------------	------------	------------	9.0E-03
b	Thermal Distortion	------------	------------	9.4E-04	9.0E-05	------------	------------	9.0E-05
c	Gravity Release	8.2E-04	8.0E-05	------------	------------	------------	------------	8.0E-05
d	Moisture Desorption	8.2E-04	8.0E-05	------------	------------	------------	------------	8.0E-05
e	Launch Shift	------------	9.0E-04	------------	------------	------------	------------	9.0E-04
f	Deployment Repeatability	8.2E-04	8.0E-05	------------	------------	------------	------------	8.0E-05
g	micro vibration	------------	------------	------------	------------	------------	------------	------------
h	compensation of bias error	------------	------------	------------	------------	------------	------------	------------
	RSS of Bias	1.8E-03		--------------		--------------		------------
	RSS of harmonic	------------		9.0E-05		--------------		------------
	RSS of Random	--------------		--------------		------------		------------
	pointing accuracy	1.8E-03						------------
	Pointing accuracy of unknown	--------------						9.2E-04

(unit: degree)

(注)　QOF の表は QOF　PDR で CPR が QOF に提示した配分値。Fabrication　error は CPR の NFM に測定時に同時に測定されるため積算しない。

Note

The table of QOF is the distribution value which CPR showed to QOF by QOF PDR.

Since it is simultaneously measured at the time of NFM measurement of CPR, Fabrication error is not integrated.

(c)CPR と QOF の積算 SUM of CPR and QOF

	Cross-track (RX)		Along-track (RY)	
	pointing accuracy	Pointing accuracy of unknown	pointing accuracy	Pointing accuracy of unknown
CPR (without QOF)	3.17E-03	1.92E-03	8.90E-03	1.50E-03
QOF	2.51E-03	1.23E-03	1.80E-03	9.15E-04
RSS of CPR and QOF	4.04E-03	2.28E-03	9.08E-03	1.76E-03
Requirement	<1.5E-2(1σ)	<2.5E-3(1σ)	<1.5E-2(1σ)	<2.5E-3(1σ)

(unit: degree)

(注)　アンテナビーム指向決定精度は作業分界を簡略化するため known と unknown の合計値を RSS した（すなわち QOF の既知分での bias 補正は行わない）。

Note

The antenna beam pointing accuracy of unknown of QOF is the RSS of known and unknown value in order to simplify the work demarcation.

PDR 以降、衛星側に要求していたアンテナビーム指向決定精度が満足できないことが判明した。そこで ARC 補正にて Bias 分誤差を補正することにした。

It became clear after PDR that the specification of antenna beam pointing accuracy of unknown being demanded of the satellite side was unsatisfying. Then, it decided to correct a Bias part error by ARC compensation. It is shown in Chapter 6.1 for details.

3.4.6 ドップラ位相変動　Doppler Phase Fluctuation

3.4.6.1 QOF へのマイクロバイブレーション条件　Micro-Vibration environment of QOF

　マイクロバイブレーションによるビームずれについてアンテナビーム指向精度、アンテナビーム指向決定精度要求に対して QOF の設計結果が満足しない。そこでマイクロバイブレーションによるビームずれをアンテナビーム指向精度、アンテナビーム指向決定精度のバジェットから除いて、ドップラ速度誤差バジェットで管理することにした。しかし、QOF の設計値に対して 70%以下にビームずれを低減させせなければドップラ速度誤差バジェットも要求を満足しない。

　そこで QOF へのマイクロバイブレーションレベルの低減検討を実施した。

　結果、QOF のマイクロバイブレーションによるビームずれが 70%以下にすることができ、ドップラ速度誤差バジェットが要求を満足できることを確認した。

The design consequence of QOF is not met to the antenna beam pointing accuracy and the antenna beam pointing accuracy of unknown demand by micro vibration. Then, it decided to manage by a Doppler speed error budget and removing from the budget of antenna beam pointing accuracy and antenna beam pointing accuracy of unknown. However, if a beam change is not reduced to 70% or less to the design value of QOF, a Doppler speed error budget does not satisfy a demand, either. Then, reduction examination of the micro vibration level to QOF was carried out. The beam change by the micro vibration of QOF could make it to 70% or less, and it checked that a Doppler speed error budget could satisfy a demand.

衛星から提示された CPR へのマイクロバイブレーションレベル及び SEC-070014 Environment Condition Design Requirements で QOF に提示したマイクロバイブレーションレベル、EM 開発試験結果から低減したマイクロバイブレーションレベルを表 3.4.6-1に示す。QOF へのマイクロバイブレーション条件の低減は EM 正弦波振動試験、展開時モーダル試験の結果から検討したレベルである。それぞれの試験結果を図 3.4.6-1から図 3.4.6-3に示す。また QOF　SUB-REF の応答解析の結果を図 3.4.6-5に示す。また QOF 取り付け部の収納時と展開時の応答解析結果の比較を図 3.4.6-6に示す。QOF 取付部の 500Hz までの応答に関して展開/収納で大きな差異はありません。よって 300Hz までの結果は収納時コンフィギュレーションで試験した正弦波振動試験結果を用いても問題は無い。マイクロバイブレーションによる QOF のビームずれには SUN-REF の挙動が支配的である。QOF　SUB-REF の振動モードは 150Hz 以上にあり、200-500Hz はマイクロバイブレーションレベルを一律 1/3 に低減した。また 150-200Hz の QOF の応答は X 軸応答：Y 軸応答：Z 軸応答＝1:1:4 である。マイクロバイブレーションレベルを印加した時に現 QOF レベルから低減 QOF レベルの差は振動エネルギー比より 50%程度ビームずれも低減される。

The micro vibration level from a satellite to shown CPR, the micro vibration level which QOF was shown by SEC-070014 Environment Condition Design Requirements, and the micro vibration level reduced from EM development test result is shown in table 3.4.6-1. Reduction of the micro vibration conditions to QOF is EM sine wave vibration test and the level examined from the result of the modal examination at the time of deployment. each test result are shown in figure 3.4.3-1 to figure 3.4.3-3. the result of the response analysis of QOF SUB-REFis shown in figure 3.4.3-5. The result of response analysis of deployed configuration and stowed configyuration are shown in Figura 3.4.3-6. There is no big difference by deployed/stowed about the response up to 500 Hz of a QOF interface. Therefore, it is satisfactory even if it uses the sine vibration test result of having tsted the result up to 300 Hz by the configuration at the stowed configuration. The responce of SUN-REF is dominant in a beam change of QOF by micro vibration. Since the natural frequency of QOF SUB-REF was in 150 Hz or more, 200 to 500 Hz reduced the micro vibration level to one third uniformly. moreover, the response resio of QOF of 150 to 200 Hz is “X-axis response: Y-axis response: Z-axis response =1:1:4. From the difference of the vibrational energy of the QOF level and a reduction QOF level when a micro vibration level is inputed, a beam change is reduced about 50%.

$$R_{M-biv} = \frac{0.075\frac{1}{1+1+4} + 0.05\frac{1}{1+1+4} + 0.025\frac{4}{1+1+4}}{0.075} = 50\%$$

よって 150-200Hz は 50%低減、200-500Hz で 33.3%低減であり、トータルで見て低減マイクロバイブレーションレベルでは少なくとも QOF のビームずれは 70%程度までは低減できることを確認した。

the beam change by 150 to 200 Hz is 50% reduction, and the beam change by 200 to 500 Hz is 33.3% reduction. Therefore, beam change of QOF can be reduced to about at least 70%.

表 3.4.6-1 マイクロバイブレーションレベル　The micro-vibration level

Frequincy	CPR level	QOF level	Reduse QOF level		
			X_{CPR} axis	Y_{CPR} axis	Z_{CPR} axis
0.1-7Hz	0.098m/S^2 (0.01G)	0.098m/S^2 (0.01G)	0.098m/S^2 (0.01G)	0.098m/S^2 (0.01G)	0.098m/S^2 (0.01G)
7-10Hz	0.0098 m/S^2 (0.001G)	0.0098 m/S^2 (0.001G)	0.0098 m/S^2 (0.001G)	0.0098 m/S^2 (0.001G)	0.0098 m/S^2 (0.001G)
10-50Hz	0.098m/S^2 (0.01G)	0.098m/S^2 (0.01G)	0.098m/S^2 (0.01G)	0.098m/S^2 (0.01G)	0.098m/S^2 (0.01G)
50-100Hz	0.098m/S^2 (0.01G)	0.29m/S^2 (0.03G)	0.29m/S^2 (0.03G)	0.29m/S^2 (0.03G)	0.29m/S^2 (0.03G)
100-150Hz	0.25m/S^2 (0.025G)	0.74m/S^2 (0.075G)	0.74m/S^2 (0.075G)	0.49m/S^2 (0.05G)	0.74m/S^2 (0.075G)
150-200Hz	0.25m/S^2 (0.025G)	0.74m/S^2 (0.075G)	0.74m/S^2 (0.075G)	0.49m/S^2 (0.05G)	0.25m/S^2 (0.025G)
200-500Hz	0.49m/S^2 (0.05G)	1.47m/S^2 (0.15G)	0.98m/S^2 (0.1G)	0.98m/S^2 (0.1G)	0.98m/S^2 (0.1G)

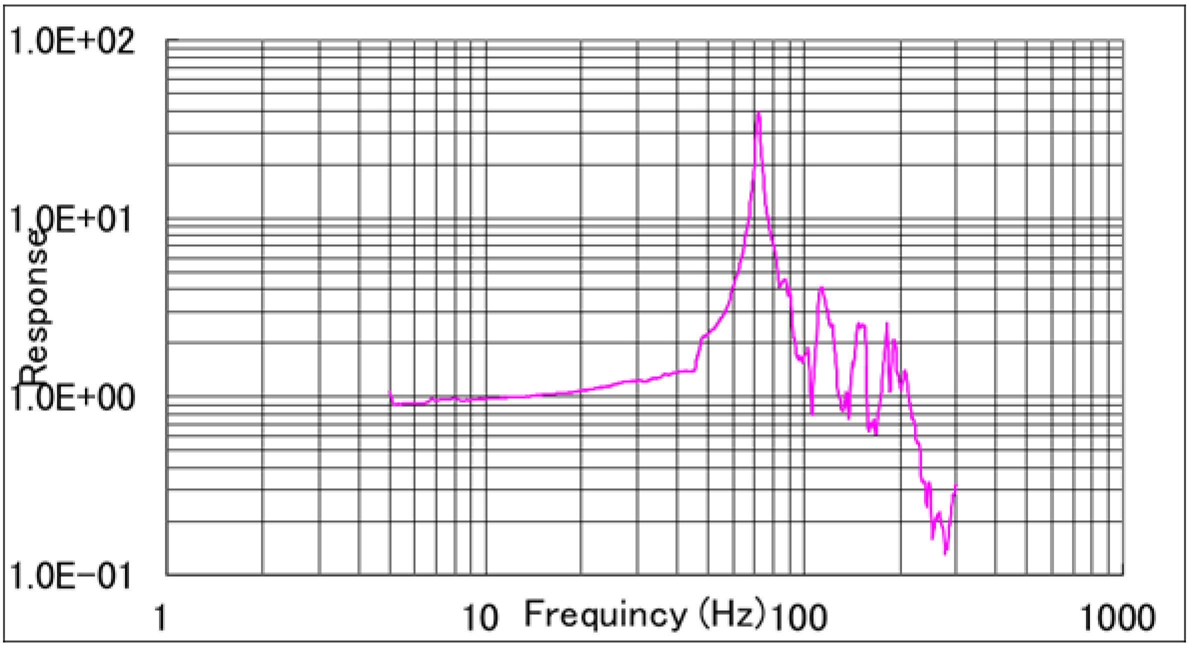


図 3.4.6-1　正弦波振動試験 X 加振　QOF 応答 Sine-vibration test X-axis vibration response of QOF

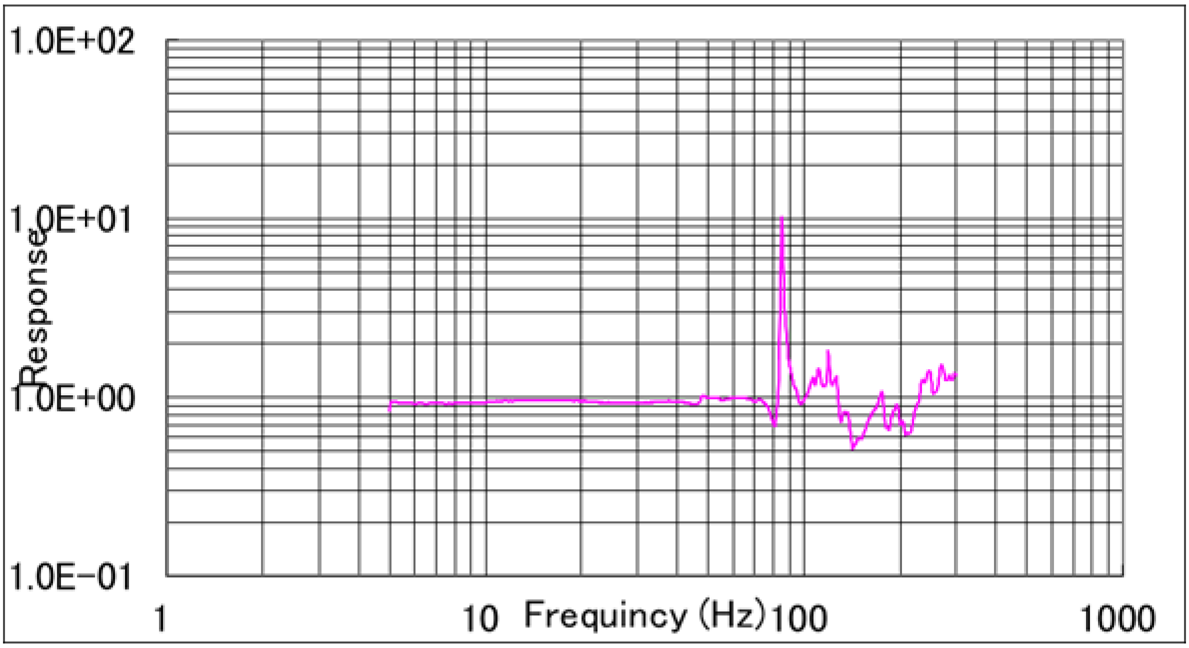


図 3.4.6-2　正弦波振動試験 Y 加振　QOF 応答 Sine-vibration test Y-axis vibration response of QOF

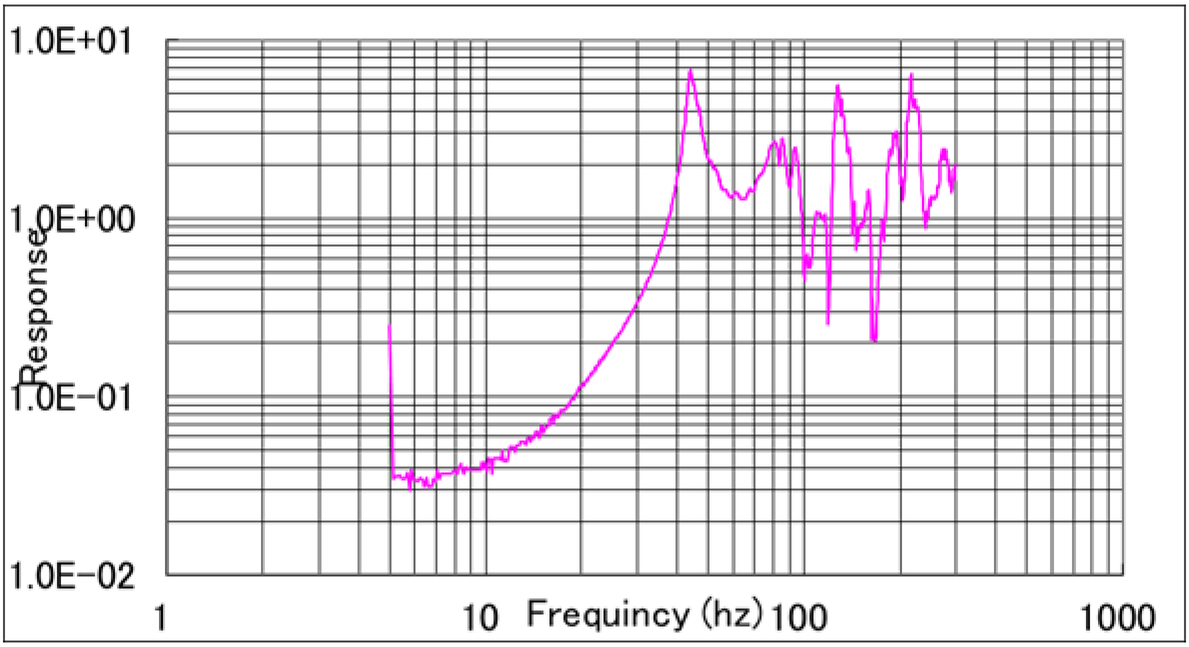


図 3.4.6-3　正弦波振動試験 Z 加振　QOF 応答 Sine-vibration test Z-axis vibration response of QOF

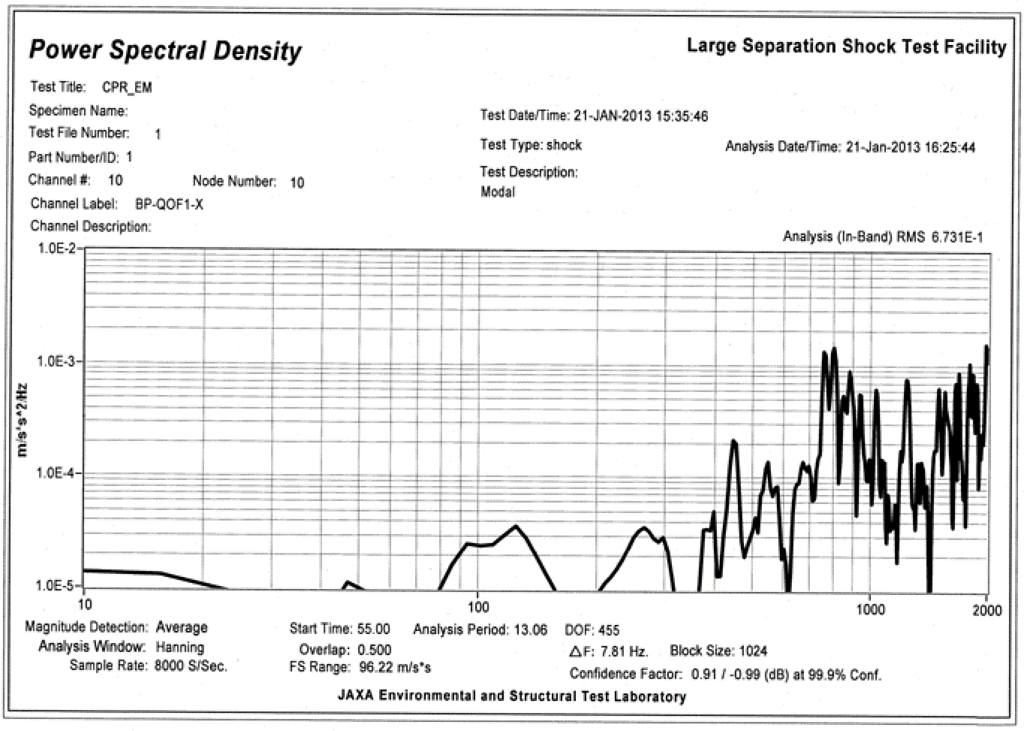


図 3.4.6-4　展開時モーダル　QOF　ハンマリング応答

Modal test deployed configuration (hammering test) response of QOF

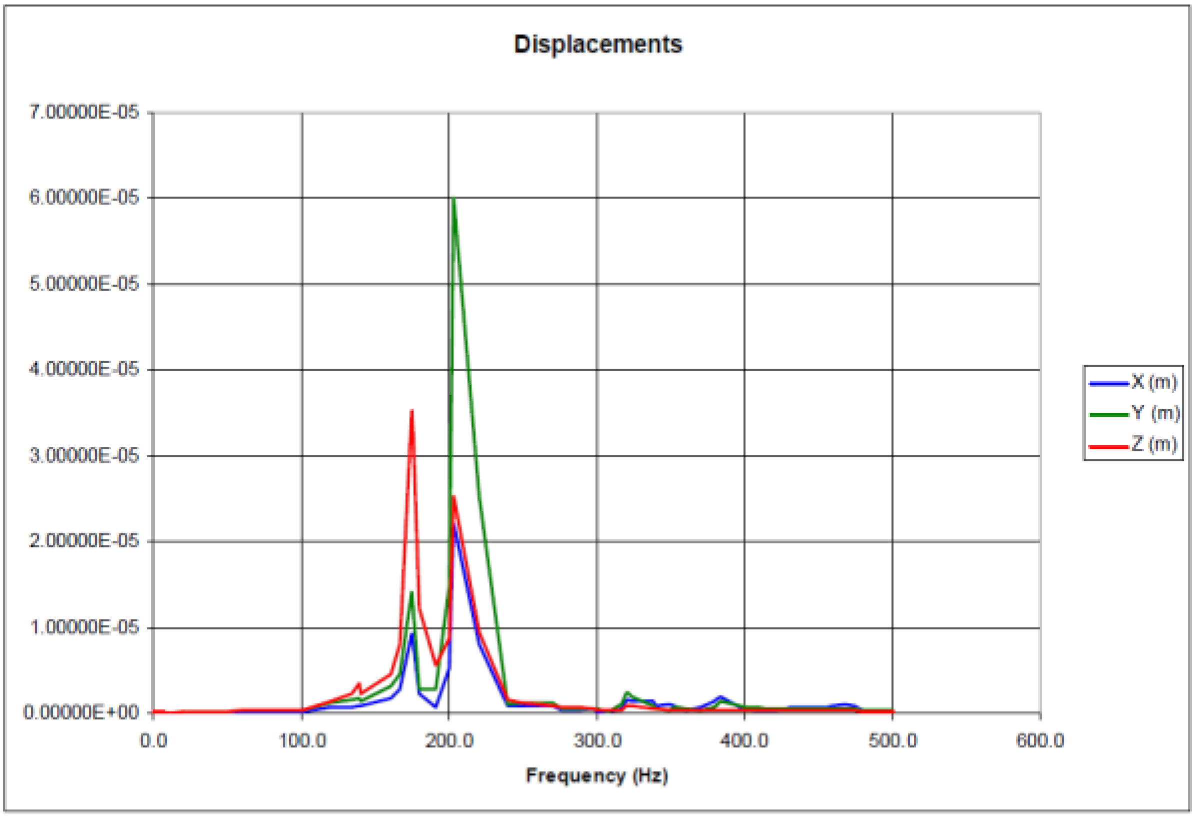
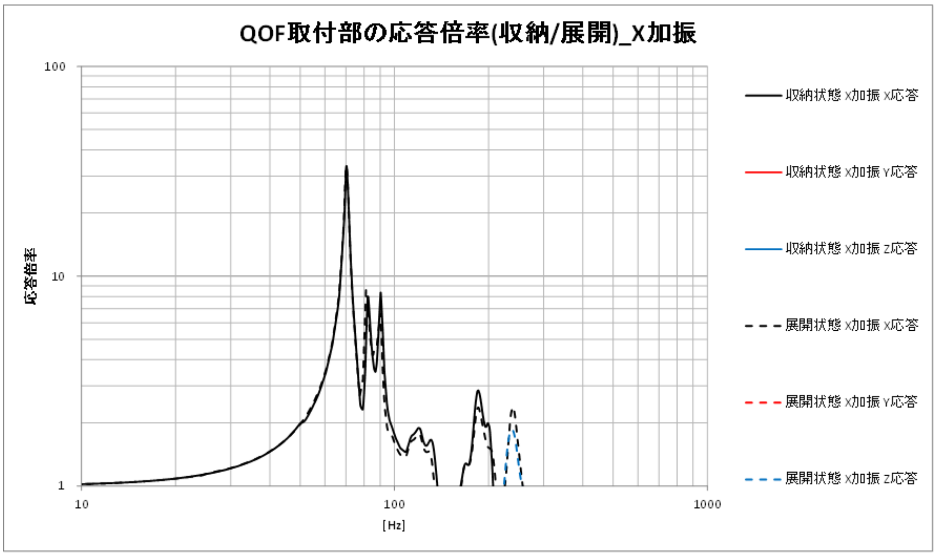


図 3.4.6-5　QOF　SUB-REF の応答 Response of QOF SUB-REF


QOF取付部の応答倍率(収納/展開)_X加振
100
10
1
応答倍率
10
100
1000
[Hz]
収納状態 X加振 X応答
収納状態 X加振 Y応答
収納状態 X加振 Z応答
展開状態 X加振 X応答
展開状態 X加振 Y応答
展開状態 X加振 Z応答

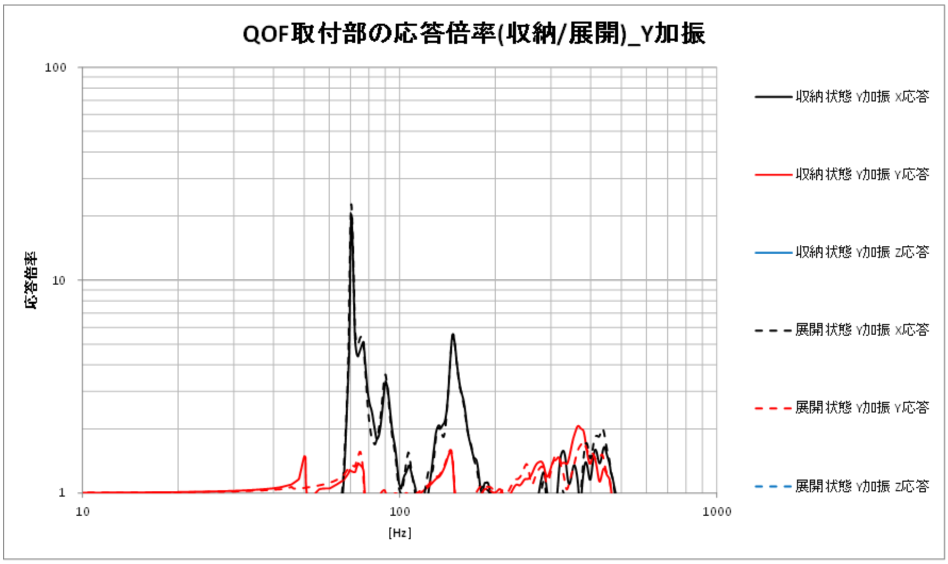
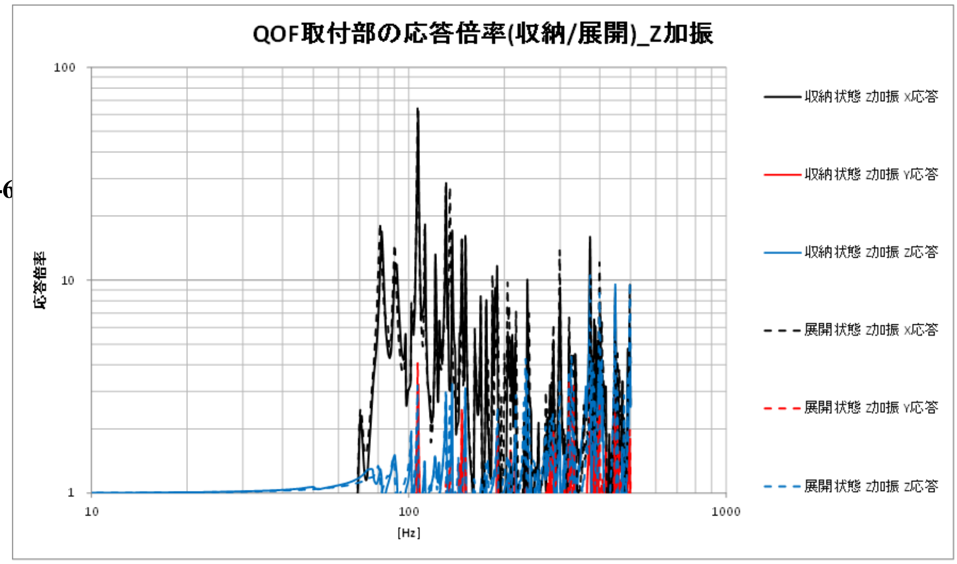

QOF取付部の応答倍率(収納/展開)_Y加振
100
10
1
応答倍率
10
100
1000
[Hz]
収納状態 Y加振 X応答
収納状態 Y加振 Y応答
収納状態 Y加振 Z応答
展開状態 Y加振 X応答
展開状態 Y加振 Y応答
展開状態 Y加振 Z応答

図 3.4.6-6


QOF取付部の応答倍率(収納/展開)_Z加振
100
10
1
応答倍率
10
100
1000
[Hz]
収納状態 Z加振 X応答
収納状態 Z加振 Y応答
収納状態 Z加振 Z応答
展開状態 Z加振 X応答
展開状態 Z加振 Y応答
展開状態 Z加振 Z応答

3.4.6.2 (Deleted)

D

3.5 Timing budget

When CPR is synchronized to 1PPS, the time stamp includes about 4 clocks time error. The one clock is 1/48MHz = 20.8ns. Then the error is 83.2ns.
On the other hand, Lo oscillator short term stability in CPR is around 100us. Then this Lo oscillator short term stability determines the accuracy of CPR time stamp.

CPR provides time stamp as Course time + Fine time. Fine time is determined inside CPR. This Fine time accuracy is around 100ns according to the Lo oscillator short term stability.

Then CPR time stamp error is around 100us.