< Band 6 Cartridge 003 >

PAI Test Report

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Change Record

Version	Date	Affected Section(s)	Change Request #	Reason/Initiation/Remarks
A01	2008-02-29	All	–	dfs: Initial draft
A02	2008-03-04	All	–	dfs: updated data
B	2008-04-07	RDs	–	jee: Removed RFW references to "Unverified Specs" and "Vacuum" Note – original word file was lost, had to rebuild version A!

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1. Introduction

1.1. Purpose

This document contains test data to verify performance of this Band 6 Cartridge against requirements in the Band 6 Cartridge Specifications [AD 01]. The test data herein was measured according to individual test procedures given in Table 2 and in the Band 6 Cartridge Acceptance Test Plans [RD 04].

1.2. Scope

This document applies to the work-package for the Band 6 cartridge described by the statement of work in [RD 01].

1.3. Applicable documents

Documents listed in Table 1 are part of this document to the extent specified herein. If not explicitly stated otherwise, the latest issue of the document is valid.

Table 1: Applicable Document List

Reference	Document Title	ALMA Doc. Number
[AD 01]	Band 6 Cartridge – Technical Specifications	FEND-40.02.06.00-001-A-SPE
[AD 02]	Procedures for In-Plant and On-Site Acceptance of Band 6 Cartridge	FEND-40.02.06.00-104-A-PRO
[AD 03]	Data formats for cartridge operating parameters	FEND-40.02.00.00-016-A-STD
[AD 04]	Front End Integration Center Database Design Description	FEND-40.09.03.00-007-A-DSN

1.4. Reference documents

Table 2 below is the reference document list containing additional information.

Table 2: Reference Document List

Reference	Document Title	ALMA Doc. Number
[RD 01]	Band 6 Cartridge – Statement of Work	FEND-40.02.06.00-002-A-SOW
[RD 02]	Band 6 Cartridge – Management Plan	FEND-40.02.06.00-027-B-PLA
[RD 03]	PAI & PAS Procedures for the ALMA Band 6 Cartridge	FEND-40.02.06.00-104-A-PRO
[RD 04]	Band 6 Cartridge Acceptance Test Plan	FEND-40.02.06.00-072-B-PLA
[RD 05]	Band 6 Cartridge Test Procedure: Gain Saturation	FEND-40.02.06.00-078-B-PRO
[RD 06]	Band 6 Cartridge 001 Compression Measurement Test Report	FEND-40.02.06.00-102-A-TDR
[RD 07]	Band 6 Cartridge Test Procedure: Phase Drift Measurement	FEND-40.02.06.00-084-A-PRO
[RD 08]	ICD Interface Between Band 6 Cartridge and IF Switch Subsystem	FEND-40.02.06.00-40.08.01.00-A-ICD
[RD 09]	Band 6 Cartridge Power Density Slope Correction Using Warm IF Amps	FEND-40.02.06.00-098-A-DSN
[RD 10]	"Gain Stability Measurements of Band 6 Cartridge SN002," NRAO Memo dated 2005-12-08	Available at: http://www.cv.nrao.edu/~jeffland/GainStability2005-11-29.pdf
[RD 11]	Front End Optics Design Report	FEND-40.02.00.00-035-B-REP
[RD 12]	Band 6 Cartridge Test Procedure: Vibration, Shock, and Natural Frequency Testing	FEND-40.02.06.00-083-A-PRO
[RD 13]	Band 6 Cold Cartridge SN001 Vibration Test Report	FEND-40.02.06.00-110-A-TDR
[RD 14]	Band 6 Cartridge Test Procedure: Spurious Response	FEND-40.02.06.00-085-B-PRO
[RD 15]	Band 6 Cartridge Test Procedure: Polarization Alignment and Accuracy	FEND-40.02.06.01-021-B-PRO
[RD 16]	Band 6 Cartridge Test Procedure: RF Beam Pattern Measurement	FEND-40.02.06.01-035-A-PRO
[RD 17]	Beam Pattern Measurements of Band 6 Cartridge using Gunn Oscillator as Source	FEND-40.02.06.01-019-A-TDR
[RD 18]	Comparison of Calculated and Measured Data for Mirrors used in ALMA Band 6 Cartridges	FEND-40.02.06.01-022-A-REP

Table 2: Reference Document List		
Reference	**Document Title**	**ALMA Doc. Number**
[RD 19]	ALMA Band 6 antenna measurements at IRAM, 2005-08-26 (Preliminary Report)	FEND-40.02.06.01-023-A-REP
[RD 20]	Investigation into the sidelobe levels of the ALMA band 6 cartridge	FEND-40.02.06.01-024-A-REP
[RD 21]	Band 6 Cartridge 001 Beam Pattern Measurements	FEND-40.02.06.01-026-A-TDR
[RD 22]	Procedure to Measure Center of Mass of Band 6 Cartridge	FEND-40.02.06.08-003-A-PRO
[RD 23]	ICD between Band 6 Cartridge and Dewar	FEND-40.02.06.00-40.03.01.00-A-ICD
[RD 24]	Band 6 Leak Test Procedures for Waveguide Windows	FEND-40.02.06.02-009-A-PRO
[RD 25]	Band 6 Cartridge Test Procedure: Mechanical Inspection to Confirm Cold Plate Alignment	FEND-40.02.06.08-009-A-PRO
[RD 26]	Band 6 Cartridge Test Procedure: IF Output Power	FEND-40.02.06.00-082-B-PRO
[RD 27]	Band 6 Cartridge Test Procedure: Stabilization Time	FEND-40.02.06.00-135-A-PRO
[RD 28]	Band 6 Sidelobe Measurements Using a Room Temperature Receiver	FEND-40.02.06.01-038-A-REP
[RD 29]	Relaxation Of The 1st Mixer Sideband Ratio Specification For Single Sideband And Single Sideband (separating) Down Conversion Schemes	ALMA-80.04.00.00-014-A-CRE
[RD 30]	Band 6 Cartridge Test Procedures: Room Temperature Tests	FEND-40.02.06.00-124-B-PRO
[RD 31]	Imperial Dimensions Used In Band 6 Cartridges	FEND-40.02.06.00-063-A-MEM
[RD 32]	Cryostat Technical Specifications	FEND-40.03.00.00-002-C-SPE
[RD 33]	Band 6 Cartridge 007 Shock and Vibration Test Report	FEND-40.02.06.00-161-A-TDR
[RD 34]	Band 6 Cartridge Technical Design Document	FEND-40.02.06.00-060-E-DSN
[RD 35]	ICD From Band 6 Cartridge To Cartridge Bias Module	FEND-40.02.06.00-40.04.02.00-A-ICD
[RD 36]	FE IPT Documentation Approval Plan	FEND-40.00.00.00-100-A-PLA
[RD 37]	Waiver, Band 6 Cartridge: Metric Hardware	FEND-40.02.06.00-183-A-RFW

Table 2: Reference Document List		
Reference	**Document Title**	**ALMA Doc. Number**
[RD 38]	Waiver, Band 6 Cartridge SN 003: Noise Temperature 125% Limit	FEND-40.02.06.00-216-A-RFW
[RD 39]	Waiver, Band 6 Cartridge: Mass	FEND-40.02.06.00-123-A-RFW
[RD 40]	Waiver, Band 6 Cartridge SN 003: Cross-Pol Isolation	FEND-40.02.06.00-215-A-RFW
[RD 41]	Front-End Sub-System for the 12 m-Antenna Array Technical Specifications	ALMA-40.00.00.00-001-A-SPE
[RD 42]	Waiver, Band 6 Cartridges: Beam Edge Taper	FEND-40.02.06.01-046-C-RFW
[RD 43]	Waiver, Band 6 Cartridge SN 003: Power Density Slope	FEND-40.02.06.00-217-A-RFW
[RD 44]	Waiver, Band 6 Cartridge SN 003: Signal Path Phase Stability	FEND-40.02.06.00-218-A-RFW
[RD 45]	ALMA Front End Cryostat Leak Rate Budget	FEND-40.03.00.00-045-A-GEN

1.5. Acronyms

A list of the acronyms used in this document is given in Table 3.

Table 3: Acronyms	
Acronym	**Meaning**
A	Test verification method is by Analysis (Compliance Table)
ALMA	Atacama Large Millimeter Array
C	Compliant with specifications (Compliance Table)
CDR	Critical Design Review
D	Test verification method is by review of Design (Compliance Table)
FE	Front End
FEIC	Front End Integration Center
I	Test verification method is by Inspection
IR	Image Rejection
ICD	Interface Control Document
IF	Intermediate Frequency
IPT	Integrated Product Team

Table 3: Acronyms

Acronym	Meaning
LO	Local Oscillator
NC	Not Compliant with specifications (Compliance Table)
NRAO	National Radio Astronomy Observatory
NT	No Testing Planned for PAI (Compliance Table)
PAI	Preliminary Acceptance In-house
PAS	Provisional Acceptance On-Site (at FEIC)
PC	Partially Compliant with specifications (Compliance Table)
PDR	Preliminary Design Review
R	Test verification method is by Review of design
RF	Radio Frequency
T	Test verification method is by Testing (Compliance Table)
WCA	Warm Cartridge Assembly

2. Room Temperature Test Data

Room temperature test data is collected using the procedures described in [RD 30]. Table 4 provides values to be entered and read back on the monitor computer when the cartridge is at room temperature.

Table 5 lists the functional tests that confirm operation of cartridge devices that can't be monitored by the computer screen.

Table 4: Cartridge 6.003 DC Bias Test Data
< WCA:6.008 Bias Box: C2.021 Warm IF Plate: 6.204 Date: 2007-10-12 >

Pol	Item		Value Entered on Control Screen		Value Observed on Monitor Screen					
Cold Preamplifiers										
	HEMT Preamps		**V_d (V)**	**I_d (mA)**	**V_d (V)**	**Nominal (V)**	**I_d (mA)**	**Nominal (mA)**	**V_g (V)**	**Nominal (V)**
0	LNA 1	Stage 1	0.70	4.0	0.70	0.65-0.75	4.00	3.8-4.2	0.0	-0.3-+0.3
		Stage 2	0.70	4.0	0.70	0.65-0.75	4.01	3.8-4.2	-0.01	-0.3-+0.3
		Stage 3	0.70	3.0	0.70	0.65-0.75	3.02	2.8-3.2	-0.19	-0.3-+0.3
	LNA 2	Stage 1	0.70	4.0	0.70	0.65-0.75	4.03	3.8-4.2	0.01	-0.3-+0.3
		Stage 2	0.70	4.0	0.70	0.65-0.75	4.02	3.8-4.2	-0.02	-0.3-+0.3
		Stage 3	0.70	3.0	0.70	0.65-0.75	3.01	2.8-3.2	-0.12	-0.3-+0.3
1	LNA 1	Stage 1	0.70	4.0	0.70	0.65-0.75	4.02	3.8-4.2	-0.02	-0.3-+0.3
		Stage 2	0.70	4.0	0.70	0.65-0.75	4.03	3.8-4.2	-0.03	-0.3-+0.3
		Stage 3	0.70	3.0	0.70	0.65-0.75	3.02	2.8-3.2	-0.15	-0.3-+0.3
	LNA 2	Stage 1	0.70	4.0	0.70	0.65-0.75	4.02	3.8-4.2	-0.02	-0.3-+0.3
		Stage 2	0.70	4.0	0.70	0.65-0.75	4.05	3.8-4.2	-0.04	-0.3-+0.3
		Stage 3	0.70	3.0	0.70	0.65-0.75	3.04	2.8-3.2	-0.13	-0.3-+0.3

Table 4: Cartridge 6.003 DC Bias Test Data
< WCA:6.008 Bias Box: C2.021 Warm IF Plate: 6.204 Date: 2007-10-12 >

Pol	Item	Value Entered on Control Screen	Value Observed on Monitor Screen

SIS Mixers

Pol	SIS Junctions	Junction Bias Voltage (mV)	Bias voltage (mV)	Nominal (mV)	Bias Current (μA)	Nominal (μA)
0	Mixer 1	-9.00	-9.06	-9.0±1.0	-100	100±30
	Mixer2	9.00	8.94	9.0±1.0	108	100±30
1	Mixer 1	-9.00	-9.07	-9.0±1.0	-103	100±30
	Mixer 2	9.00	8.93	9.0±1.0	104	100±30

Magnet Coils

Pol	Magnet Current	Magnet Current (mA)	Magnet Voltage (V)	Nominal (V)	Magnet Current (mA)	Nominal (mA)
0	Magnet 1	10	4.06	3.5 – 4.5	9.2	7.75 – 12.25
1	Magnet 1	10	4.06	3.5 – 4.5	8.8	7.75 – 12.25

Temperature Sensors

Pol	Temperature Sensors	N/A	Temperature (K)
0	Temp 1 (4K Stage)	-	293.81
	Temp 2 (110K Stage)	-	294.37
	Temp 3 (Pol 0 Mixer)	-	294.02
1	Temp 1 (Pol 1 Temp 1)	-	Not Used
	Temp 2 (15K Stage)	-	292.72
	Temp 3 (Pol 1 Mixer)	-	293.17

Deflux Heaters

Pol	Deflux Heaters	Enabled	Heater Current (mA)	Nominal (mA)
0	Heater for Pol 0	Yes	78.91	75.0 – 95.0
1	Heater for Pol 1	Yes	80.36	75.0 – 95.0

Table 5: Cartridge 6.003 Room Temperature Functional Tests

< WCA:6.008 Bias Box: C2.021 Warm IF Plate: 6.204 Date: 2007-10-12 >

Pol	Item	Value Entered on Control Screen	Confirmation
0	2 amps on Mixer-preamp with 3 LED's on each HEMT preamplifier	Enabled	☑ -All 6 LED's illuminated
1	2 amps on Mixer-preamp with 3 LED's on each HEMT preamplifier	Enabled	☑ -All 6 LED's illuminated

3. Cold Test Data

3.1. Noise Performance and Image Band Rejection (FEND-40.02.06.00-00180-00/T) (FEND-40.02.06.00-00190-00/T)

3.1.1. 6-10 GHz IF

Noise temperature data for the 6-10 GHz IF bandwidth covered by the specifications is summarized in Table 7 and image rejection is summarized in Table 8. Graphs for this IF band are tabulated in Table 6:

Table 6: Graph Summary (IF = 6-10 GHz)

Graph	Pol	Sideband	Figure
Noise Temperature	0	Both	Figure 1
	1	Both	Figure 2
Noise Temperature Histograms	0	LSB	Figure 3
		USB	Figure 4
	1	LSB	Figure 5
		USB	Figure 6
Image Rejection	0	Both	Figure 7
	1	Both	Figure 8
Image Rejection Histograms	0	LSB	Figure 9
		USB	Figure 10
	1	LSB	Figure 11
		USB	Figure 12
Cartridge Gain	0	Both	Figure 13
	1	Both	Figure 14

Table 7: Noise Temperature Summary (IF = 6-10 GHz)

	Pol 0		Pol 1		
	USB	LSB	USB	LSB	Requirement
Total Measurements	485	483	488	488	≥ 400
Fraction > 83K	3.3%	0.6%	0.0%	0.0%	≤ 20%
Fraction > 136K	0%	0%	0%	0%	0%
Mean Noise Temp (K)	55	50	38	34	--
Fraction > 1.25 times mean	13.6%	3.7%	12.7%	2.3%	0%
\\cvfiler.nrao.edu\cv-cdl-sis\CartTstData\Cart6.003productionTSTdata\Cart6.003_Noise.xls Sheet: "HistNT 6-10					

Table 8: Image Rejection Summary (IF = 6-10 GHz)

	Pol 0		Pol 1		Requirement
	USB	LSB	USB	LSB	
Total Measurements	485	485	488	488	> 400
Measurements ≥ 10 dB	483	476	488	484	
Measurements < 10 dB	0	0	0	0	
Fraction < 10 dB	0.0%	0.0%	0.0%	0.0%	< 10%
Measurements < 7 dB	0	0	0	0	0
\\cvfiler.nrao.edu\cv-cdl-sis\CartTstData\Cart6.003productionTSTdata\Cart6.003_Noise.xls" Sheet: HistIR 6-10					

3.1.2. 4–12 GHz IF

Band 6 Cartridges operate with decreased performance over the entire 4-12 GHz IF. Noise temperature data for this expanded band is summarized in Table 10 and image rejection is summarized in Table 11. Percentages in these tables are obtained from overlapping sky frequencies as well as frequencies outside the specified RF band. That is, the statistics in the tables are calculated from all the points shown in the noise temperature graphs of Figure 15 and Figure 16 and image rejection graphs of Figure 21 and Figure 22, including overlapping frequencies and frequencies below 211 GHz and above 275 GHz. Histograms for this expanded IF band are also created with overlapping frequencies. However, it is felt that these statistics are still meaningful because noise temperature and image rejection is a function of LO frequency as well as sky frequencies.

Graphs for this IF band are tabulated in Table 9:

Table 9: Graph Summary (IF = 4-12 GHz)

Graph	Pol	Sideband	Figure
Noise Temperature	0	Both	Figure 15
	1	Both	Figure 16
Noise Temperature Histograms	0	LSB	Figure 17
		USB	Figure 18
	1	LSB	Figure 19
		USB	Figure 20
Image Rejection	0	Both	Figure 21
	1	Both	Figure 22
Image Rejection Histograms	0	LSB	Figure 23
		USB	Figure 24
	1	LSB	Figure 25
		USB	Figure 26
Cartridge Gain	0	Both	Figure 27
	1	Both	Figure 28

Table 10: Noise Temperature Summary (IF = 4-12 GHz)

	Pol 0		Pol 1		
	USB	LSB	USB	LSB	Requirement
Total Measurements	945	944	959	959	
Fraction > 83K	19.9%	14.6%	8.0%	3.3%	
Fraction > 136K	5%	3%	0%	0%	
Mean Noise Temp (K)	71	64	50	44	
Fraction > 1.25 times mean	15.8%	15.9%	18.1%	17.5%	
\\cvfiler.nrao.edu\cv-cdl-sis\CartTstData\Cart6.003productionTSTdata\Cart6.003_Noise.xls Sheet: HistNT 4-12					

Table 11: Image Rejection Summary (IF = 4-12 GHz)

	Pol 0		Pol 1		Requirement
	USB	LSB	USB	LSB	
Total Measurements	945	945	964	964	
Measurements ≥ 10 dB	939	929	962	957	
Measurements < 10 dB	0	0	0	0	
Fraction < 10 dB	0.0%	0.0%	0.0%	0.0%	
Measurements < 7 dB	0	0	0	0	
\\cvfiler.nrao.edu\cv-cdl-sis\CartTstData\Cart6.003productionTSTdata\Cart6.003_Noise.xls Sheet: HistIR 4-12					

Figure 1: Noise Temperature, Pol 0, IF = 6-10 GHz

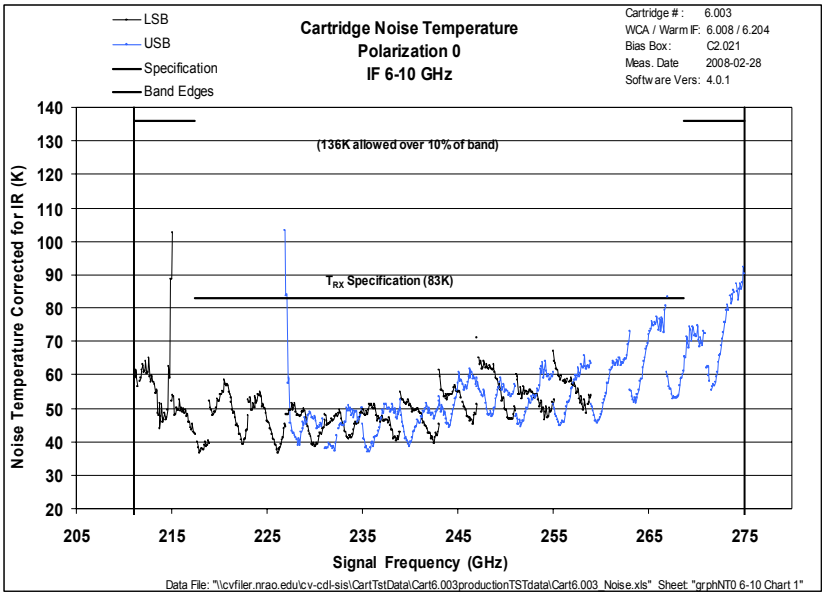


Figure 2: Noise Temperature, Pol 1, IF = 6-10 GHz

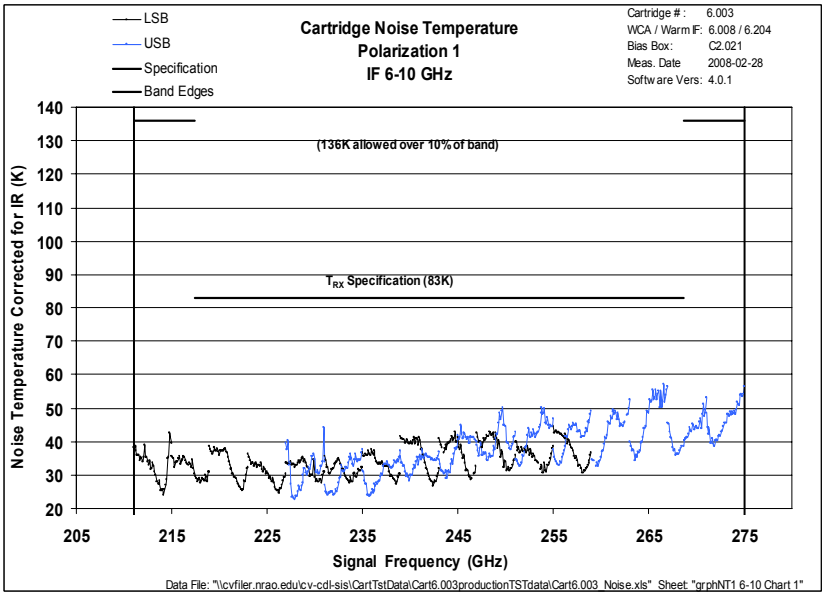


Figure 3: Pol 0 LSB Noise Temperature Histogram (6-10 GHz)

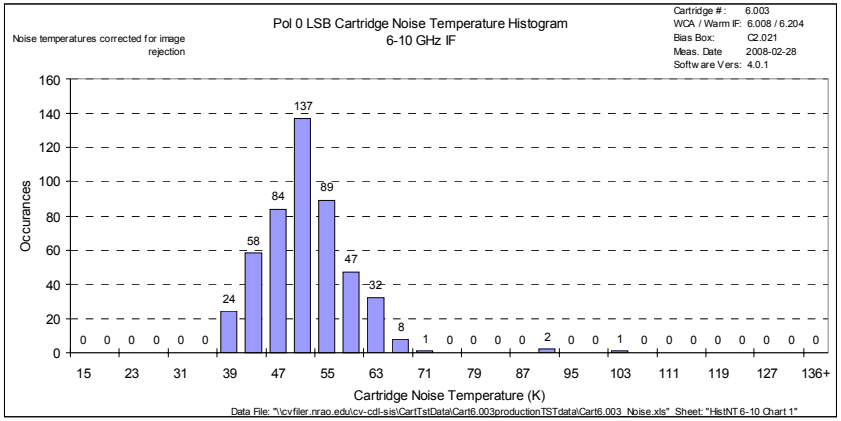


Figure 4: Pol 0 USB Noise Temperature Histogram (6-10 GHz)

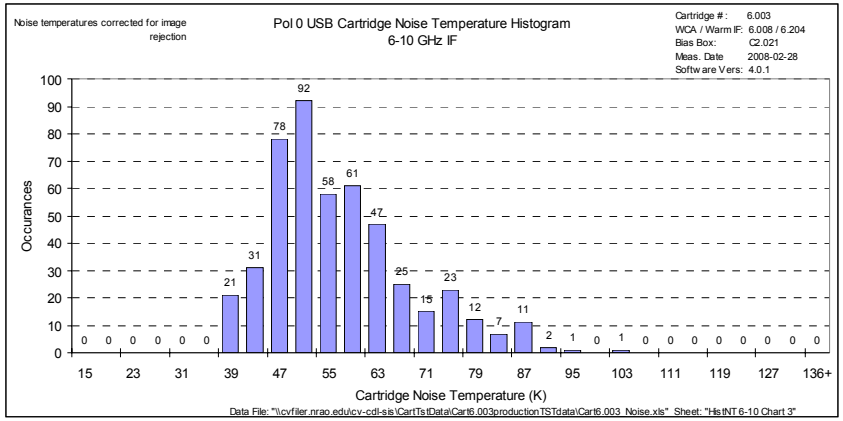


Figure 5: Pol 1 LSB Noise Temperature Histogram (6-10 GHz)

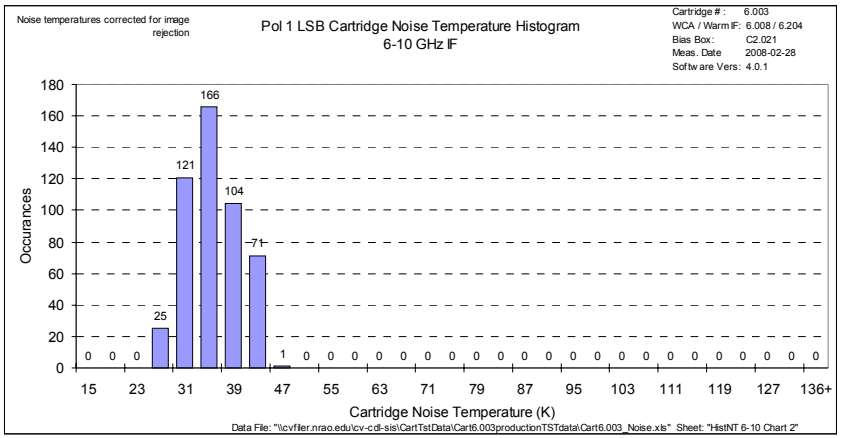


Figure 6: Pol 1 USB Noise Temperature Histogram (6-10 GHz)

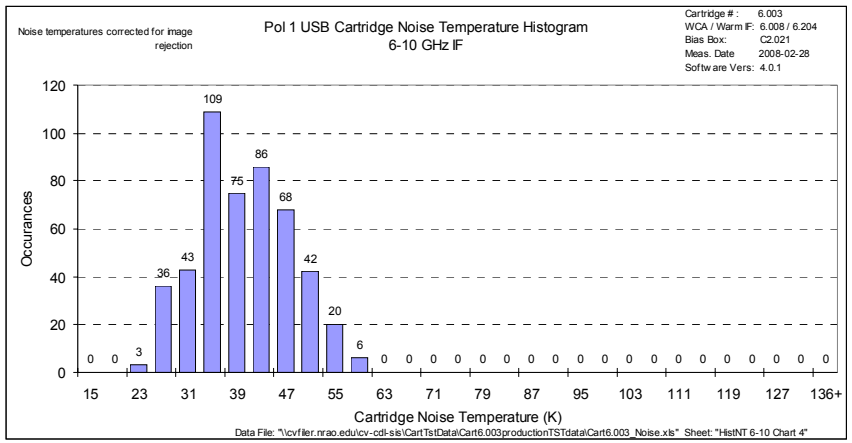


Figure 7: Image Rejection, Pol 0, IF = 6-10 GHz

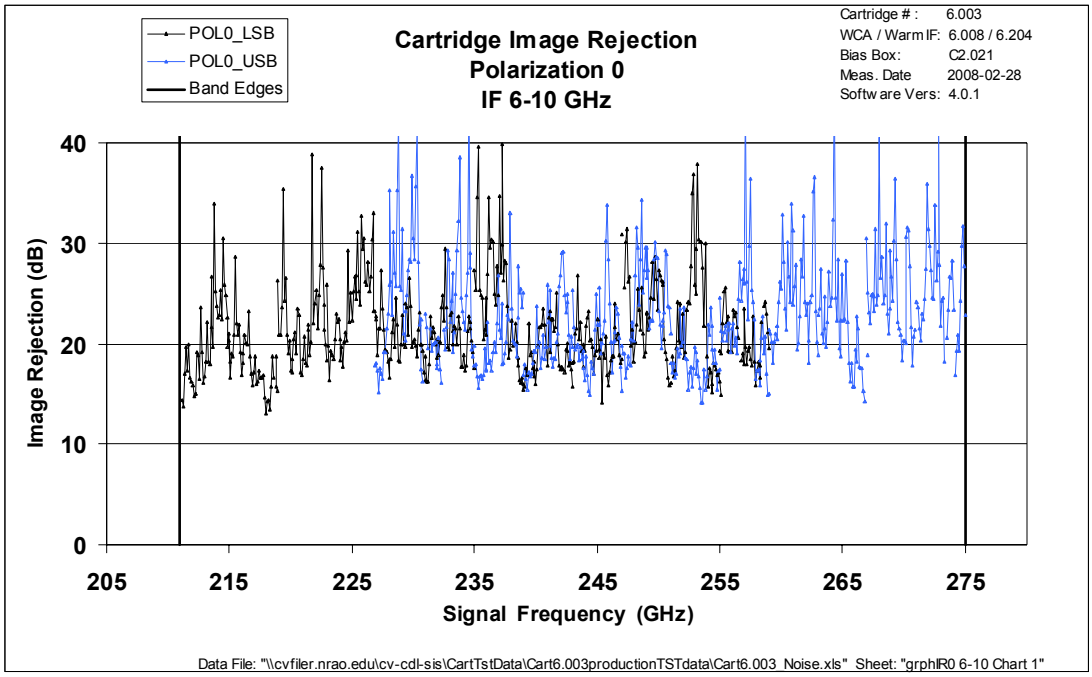


Figure 8: Image Rejection, Pol 1, IF = 6-10 GHz

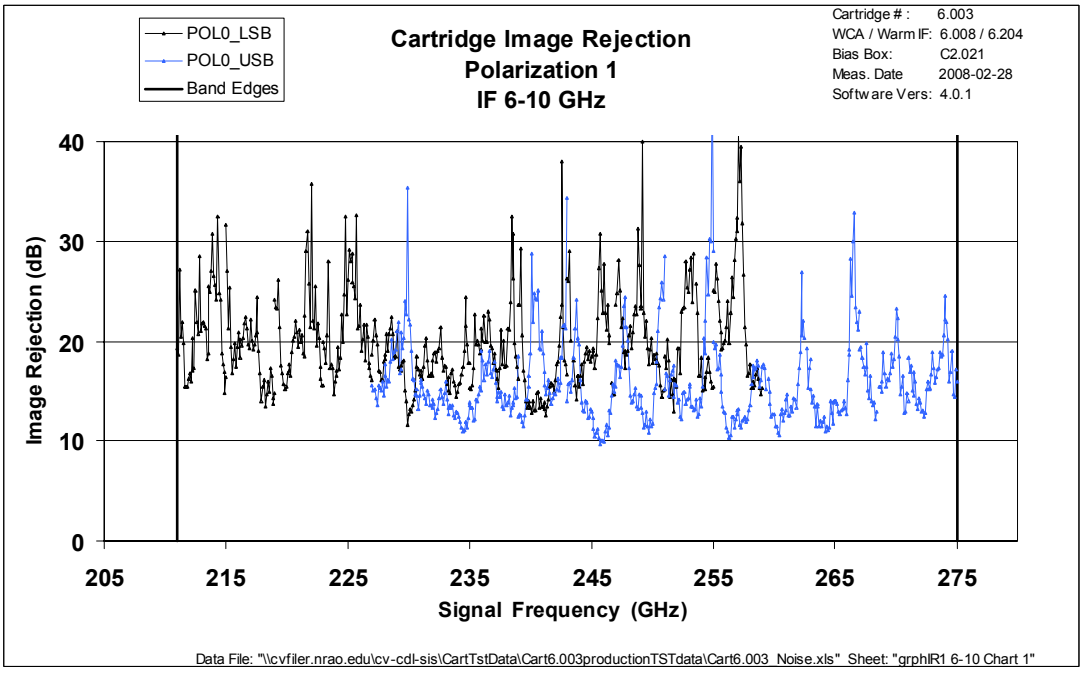


Figure 9: Pol 0 LSB Image Rejection Histogram (6-10 GHz)

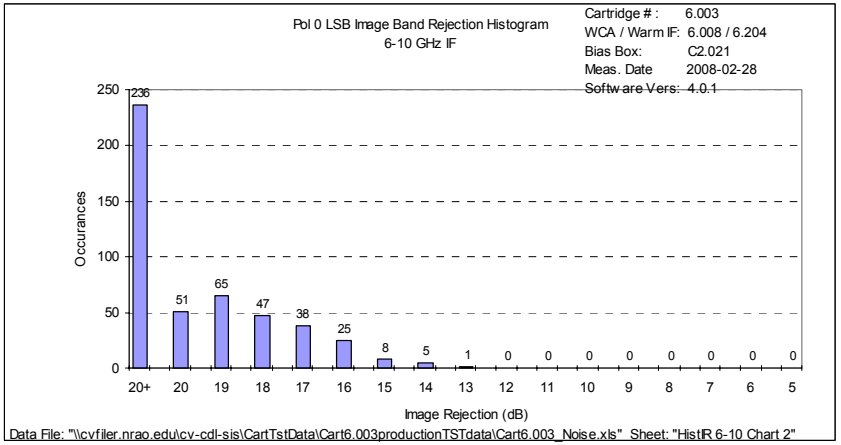


Figure 10: Pol 0 USB Image Rejection Histogram (6-10 GHz)

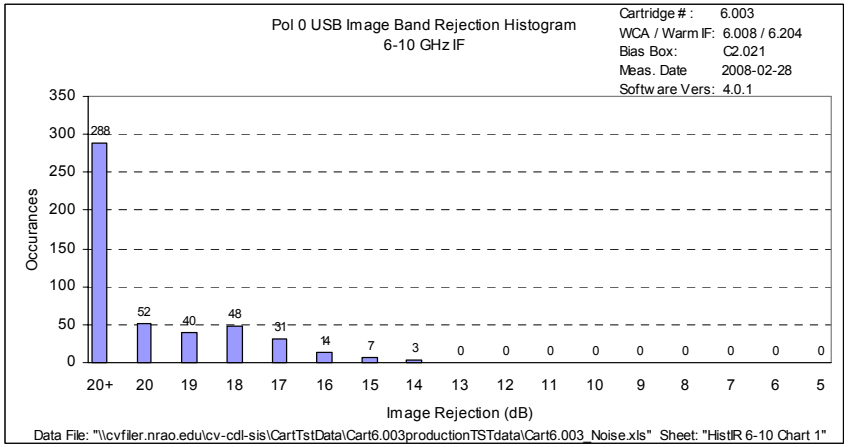


Figure 11: Pol 1 LSB Image Rejection Histogram (6-10 GHz)

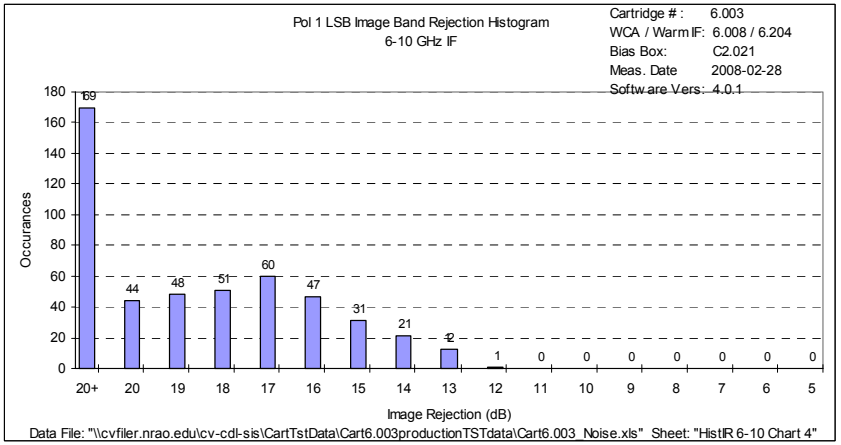


Figure 12: Pol 1 USB Image Rejection Histogram (6-10 GHz)

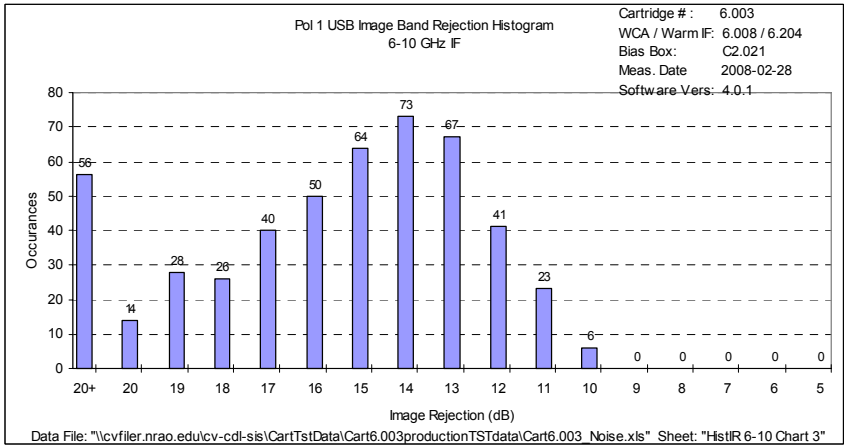


Figure 13: Cartridge Gain, Pol 0, IF=6-10 GHz

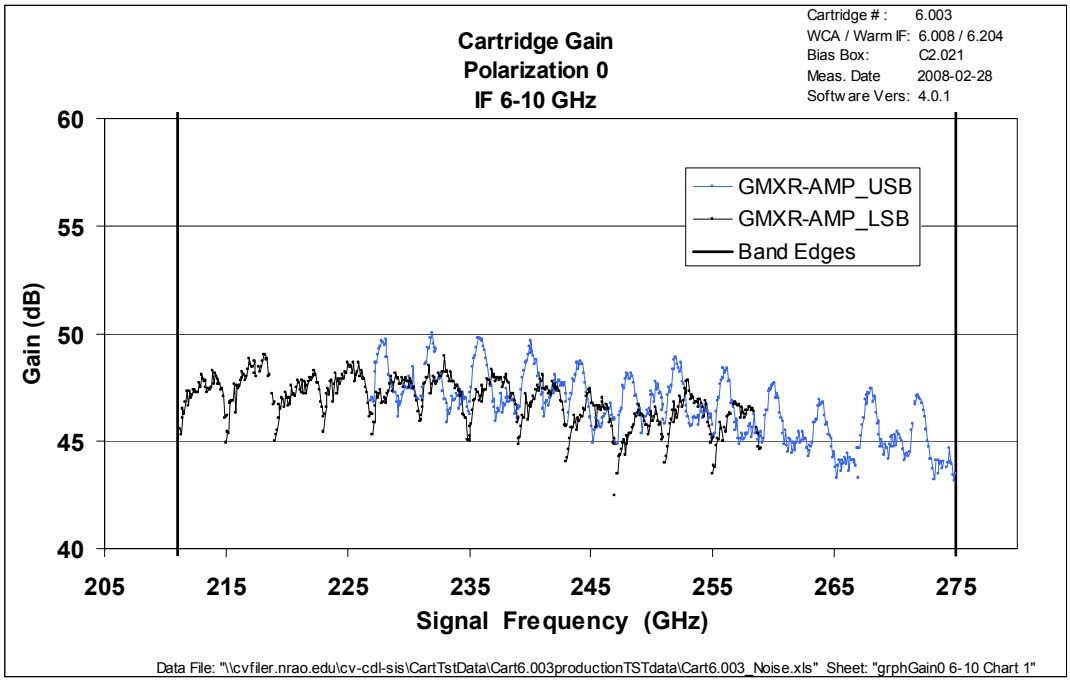


Figure 14: Cartridge Gain, Pol 1, IF= 6-10 GHz

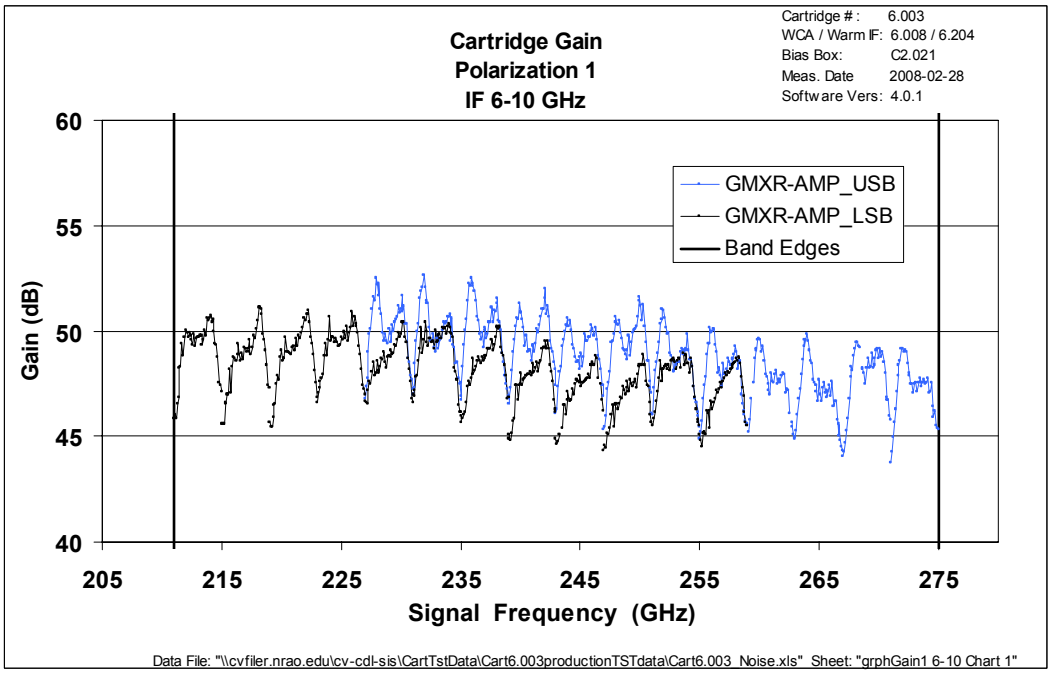


Figure 15: Noise Temperature, Pol 0, IF = 4-12 GHz

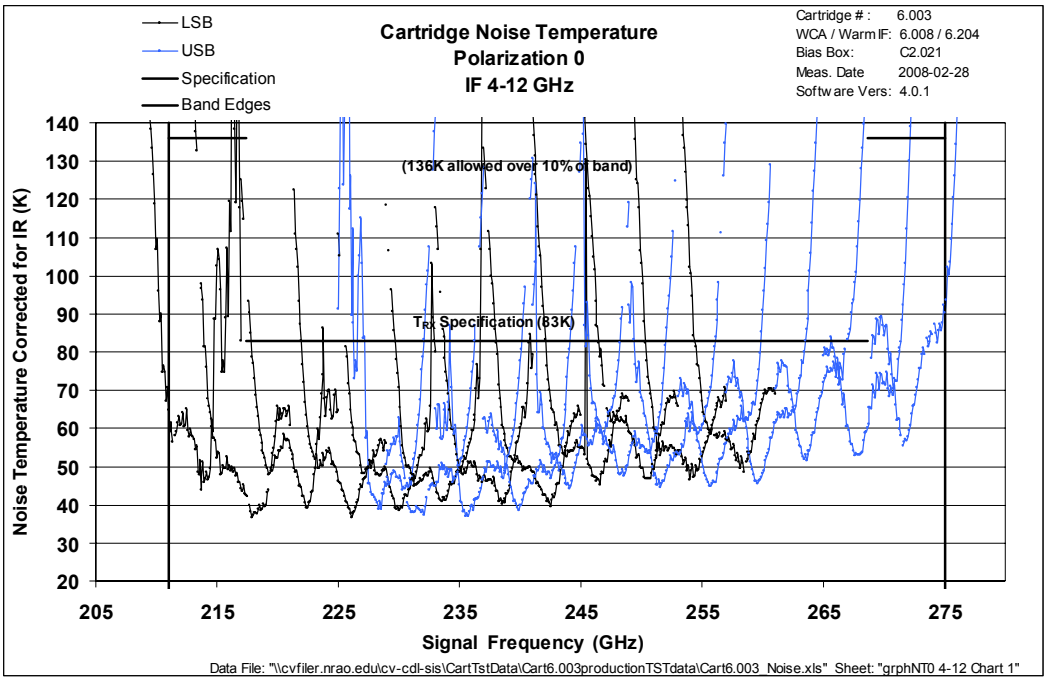


Figure 16: Noise Temperature, Pol 1, IF = 4-12 GHz

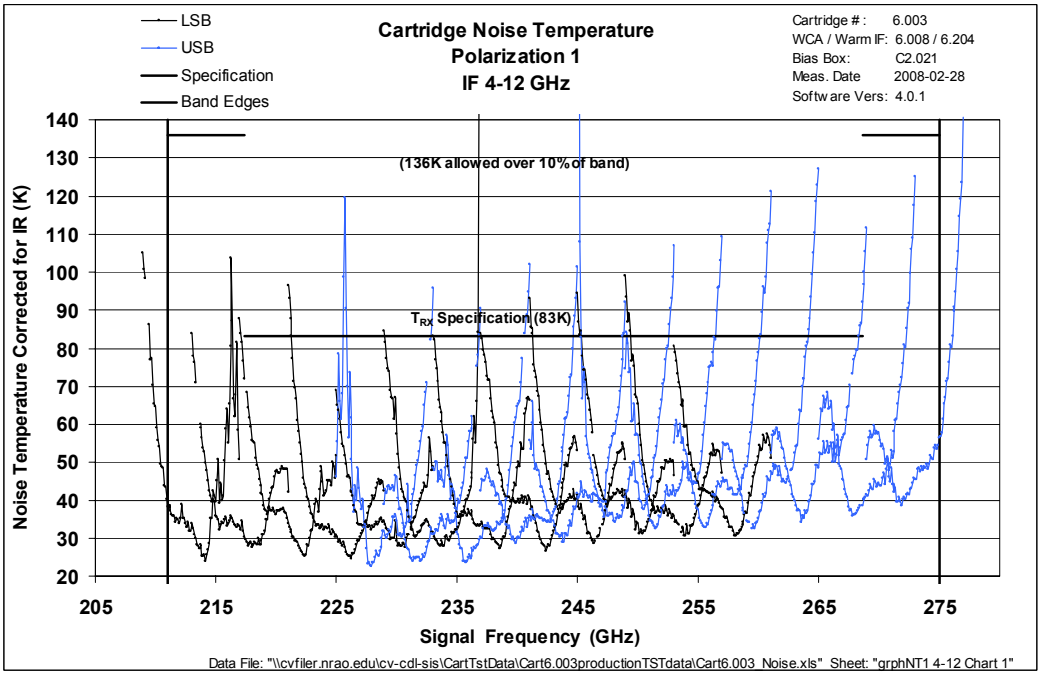


Figure 17: Pol 0 LSB Noise Temperature Histogram (4-12 GHz IF)

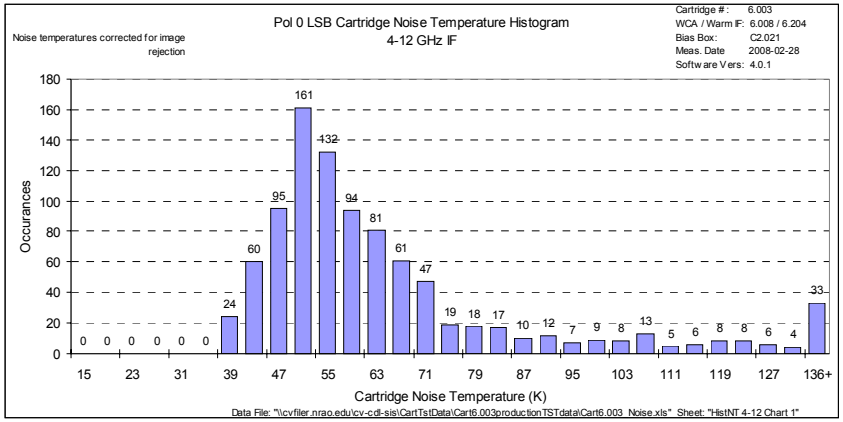


Figure 18: Pol 0 USB Noise Temperature Histogram (4-12 GHz IF)

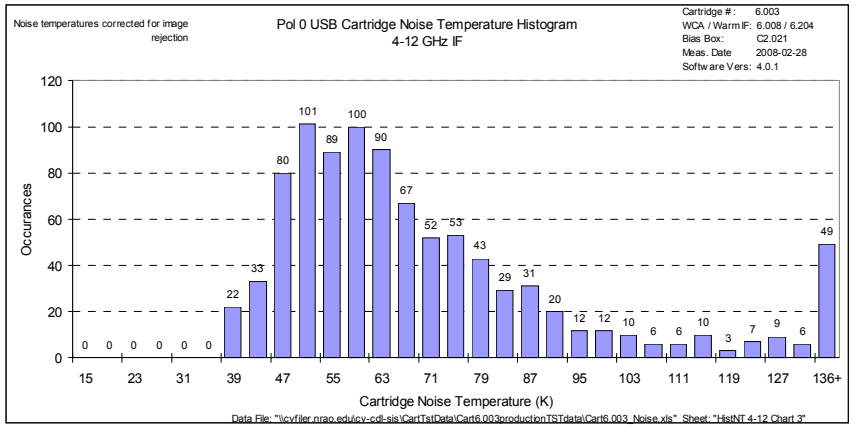


Figure 19: Pol 1 LSB Noise Temperature Histogram (4-12 GHz IF)

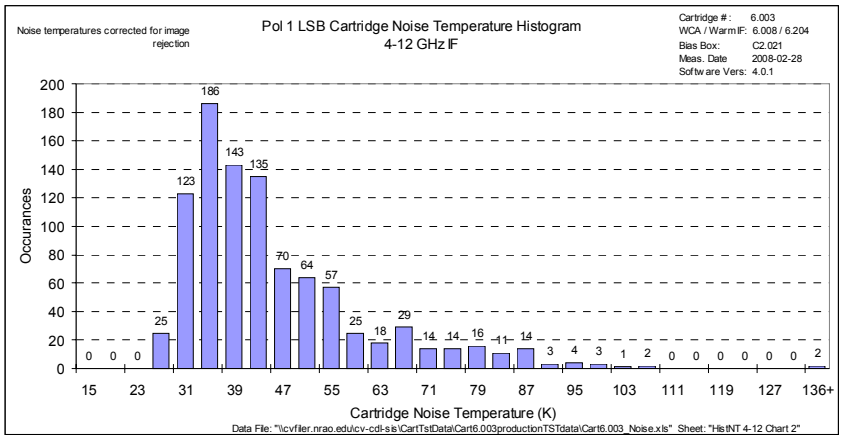


Figure 20: Pol 1 USB Noise Temperature Histogram (4-12 GHz IF)

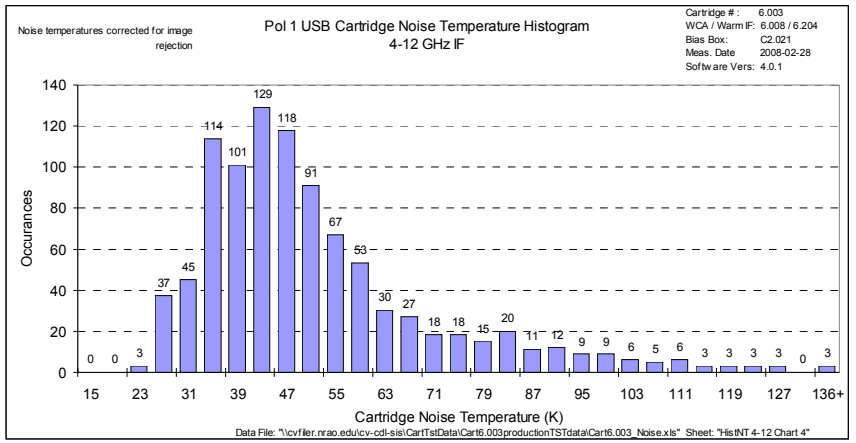


Figure 21: Image Rejection, Pol 0, IF = 4-12 GHz

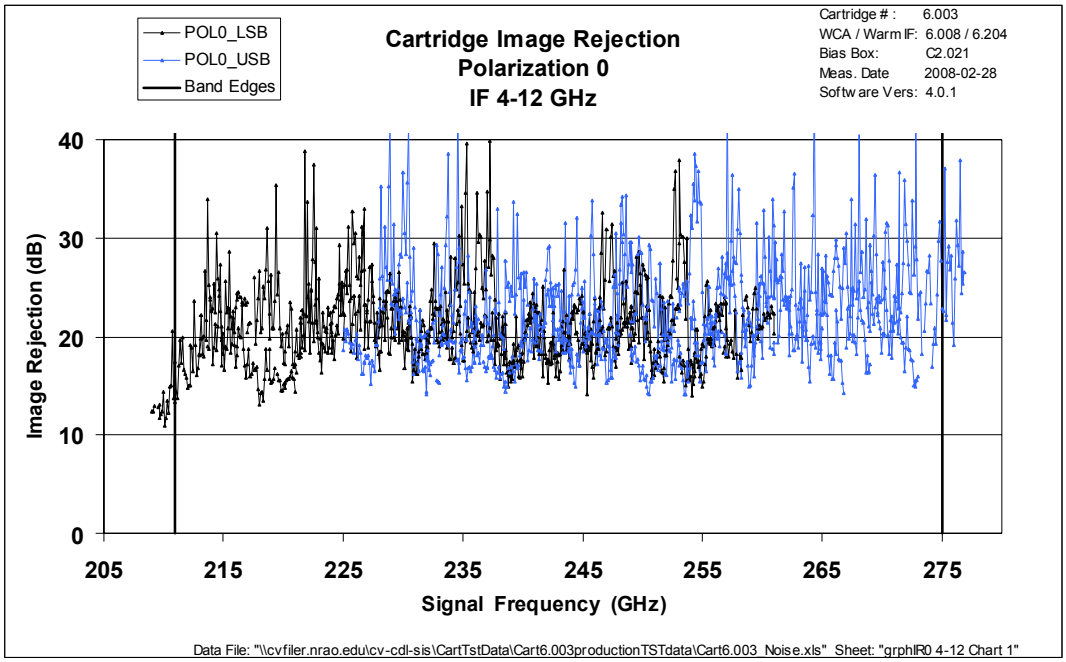


Figure 22: Image Rejection, Pol 1, IF = 4-12 GHz

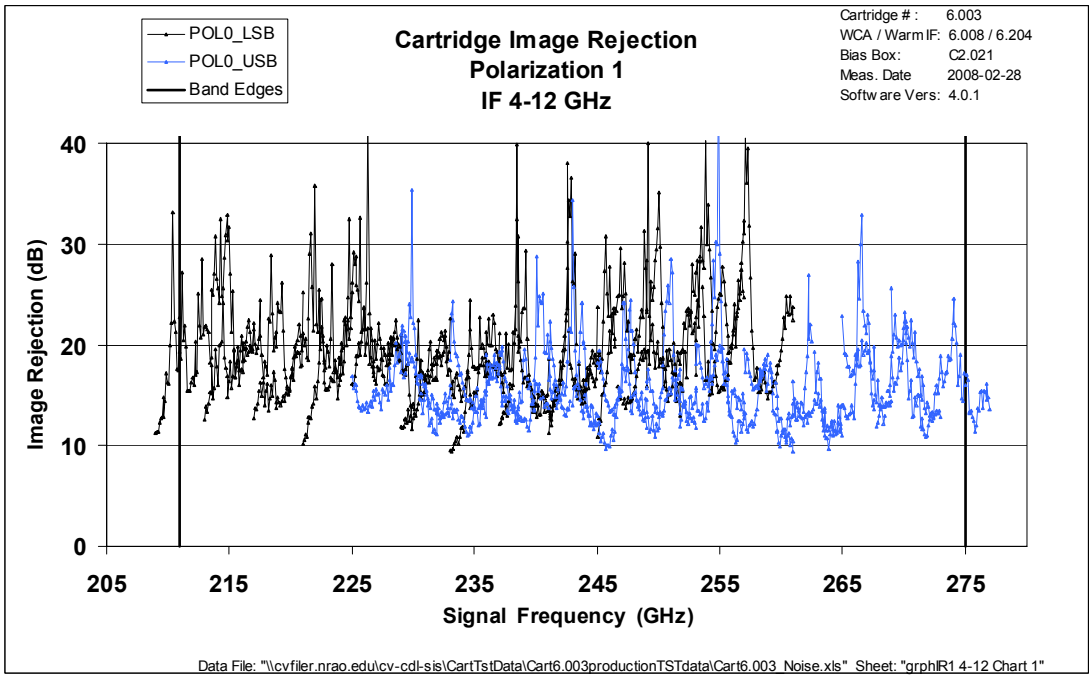


Figure 23: Pol 0 LSB Image Rejection Histogram (4-12 GHz IF)

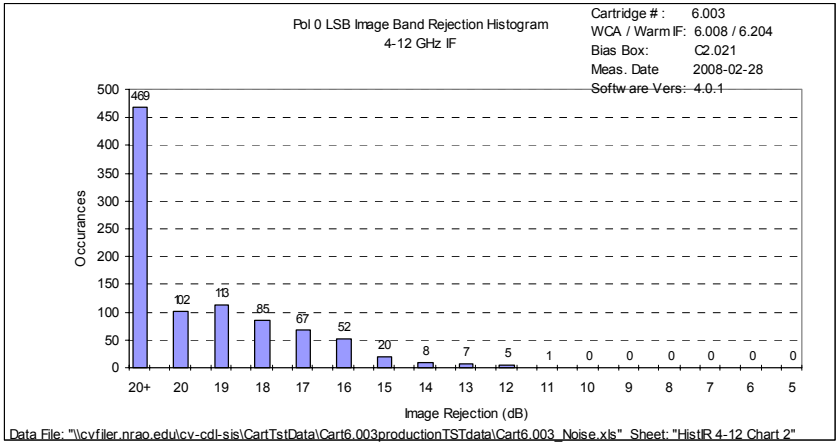


Figure 24: Pol 0 USB Image Rejection Histogram (4-12 GHz IF)

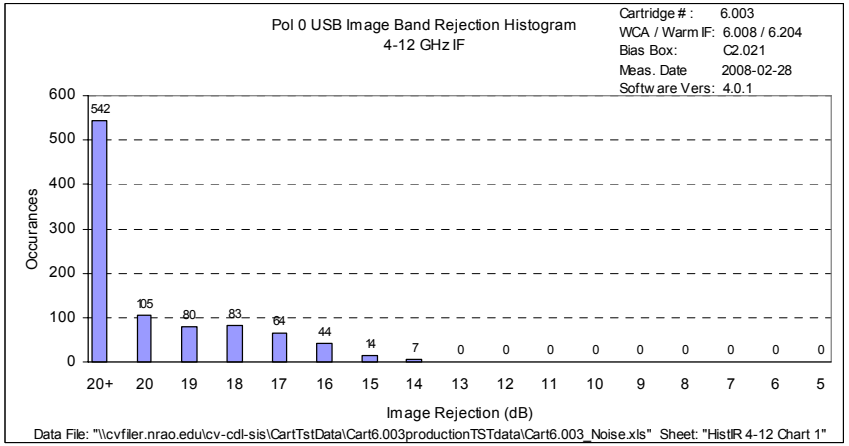


Figure 25: Pol 1 LSB Image Rejection Histogram (4-12 GHz IF)

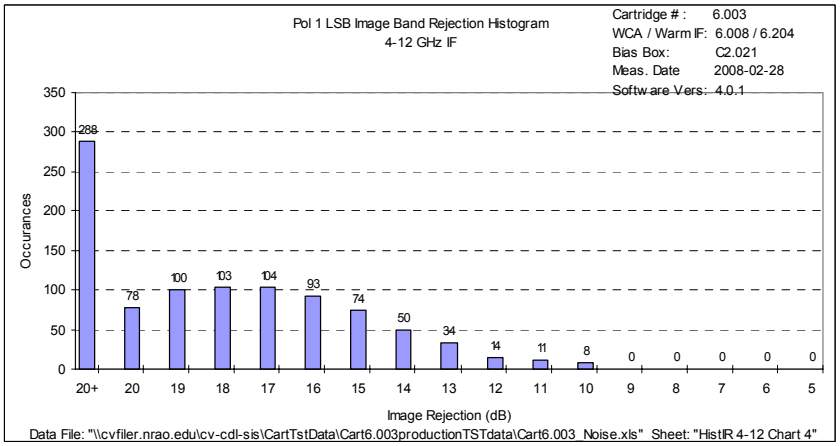


Figure 26: Pol 1 USB Image Rejection Histogram (4-12 GHz IF)

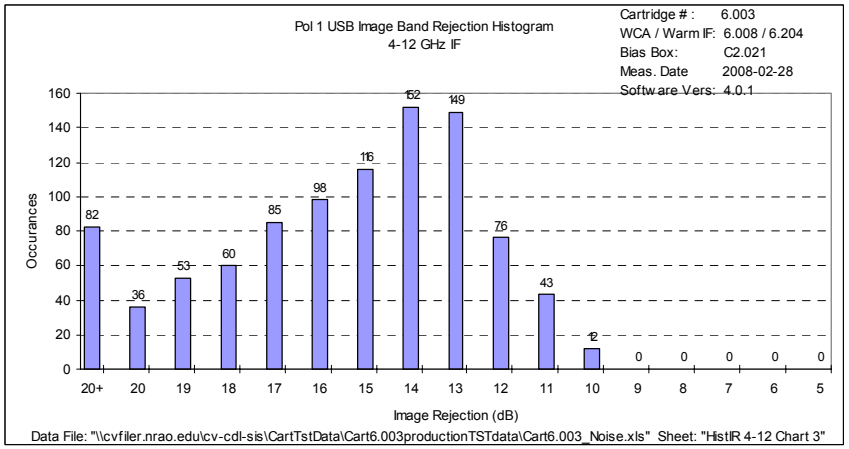


Figure 27: Cartridge Gain, Pol 0, IF = 4-12 GHz

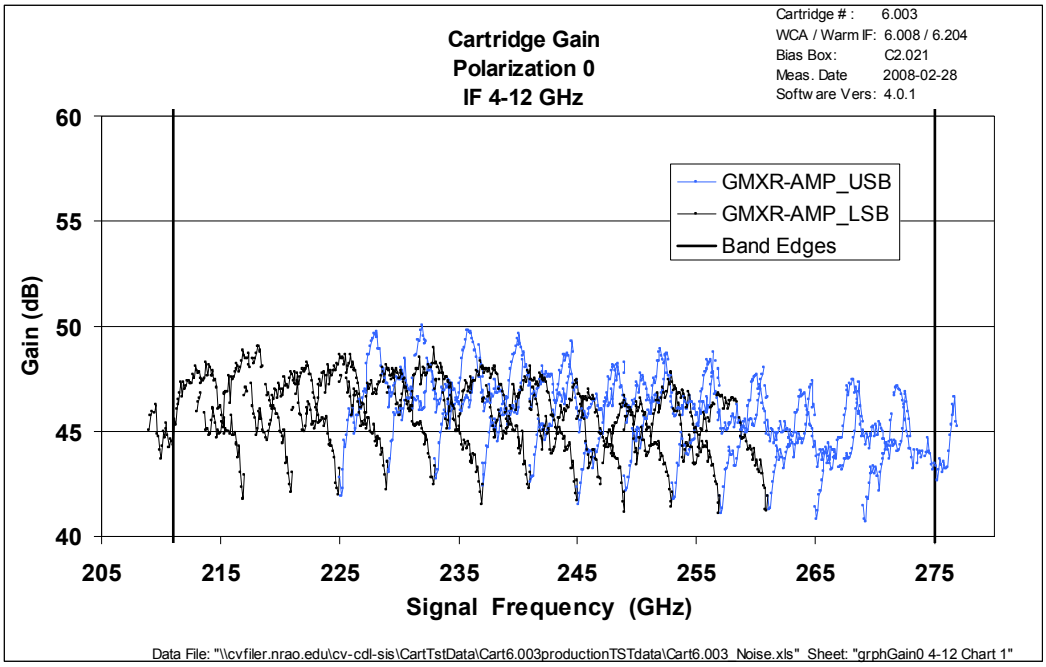
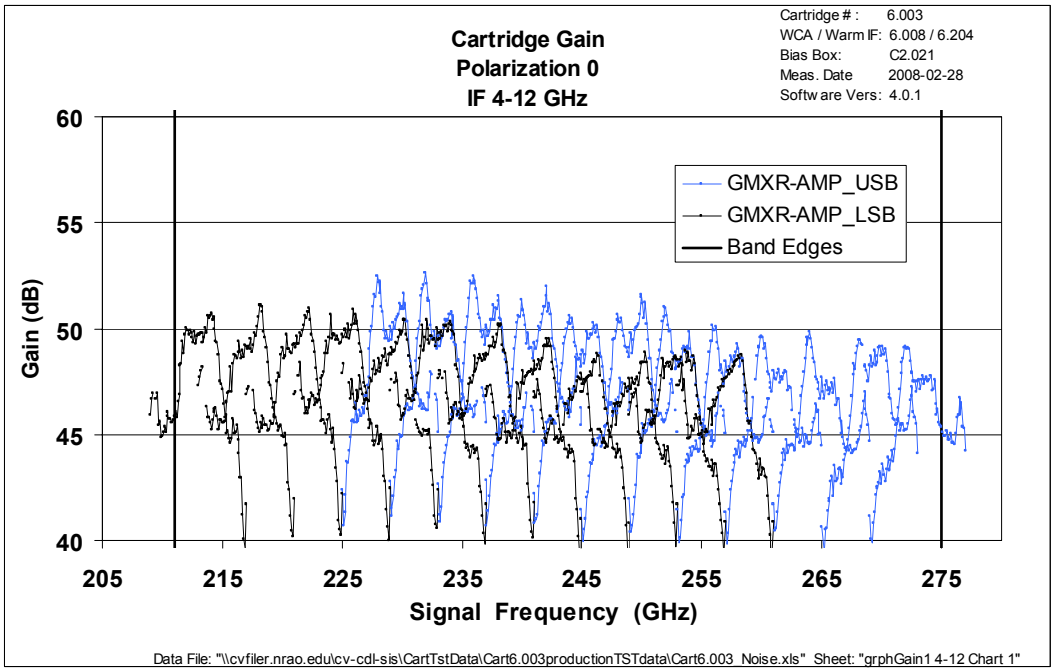


Figure 28: Cartridge Gain, Pol 1, IF = 4-12 GHz



3.2. Output Power and Power Density Slope (FEND-40.02.06.00-00200-00/T) (FEND-40.02.06.00-00210-00/T)

Power density slope requirements are specified in [AD 01] and output power requirements are given in the ICD between the cartridge and IF switch in [RD 08] . Output power is measured according to the procedures shown in [RD 26].

Power density for each polarization is plotted *vs*. IF for all measured LO's in Figure 29 and Figure 30 and shows that the 12 dB linear equalization in the warm IF amplifiers optimally compensates the net gain slopes from other cartridge components. That is, given that the equalizers are linear and can't compensate for higher order slopes, the linear part of the slope is essentially zero for the entire cartridge cascade.

The triangle and square points shown for each polarization in Figure 31 and Figure 32 are power density slopes averaged over the 4-GHz bandwidth from 6 to 10 GHz, which is the specified bandwidth. The solid lines are power density slopes averaged in a sliding 4 GHz bandwidth over the expanded 4 to 12 GHz IF band. This 4-GHz bandwidth has a center frequency that slides from 6 to 10 GHz so the band edges slide over the expanded band from 4 to 12 GHz.

Similarly, Figure 33 and Figure 34 are power density slopes measured over a 2 GHz bandwidth. In this case, the darker lines correspond to the 2-GHz bandwidth with a center frequency that slides from 7 to 9 GHz to cover the specified 6 to 10 GHz band. The lighter lines are power density slopes encompassing the expanded band from 4 to 12 GHz.

Total power measurements over the conventional and expanded IF band are graphed in Figure 35 and Figure 36. Total power measured from 10 MHz to 18 GHz is shown in Figure 37.

Figure 29: Output Power Density, Pol 0

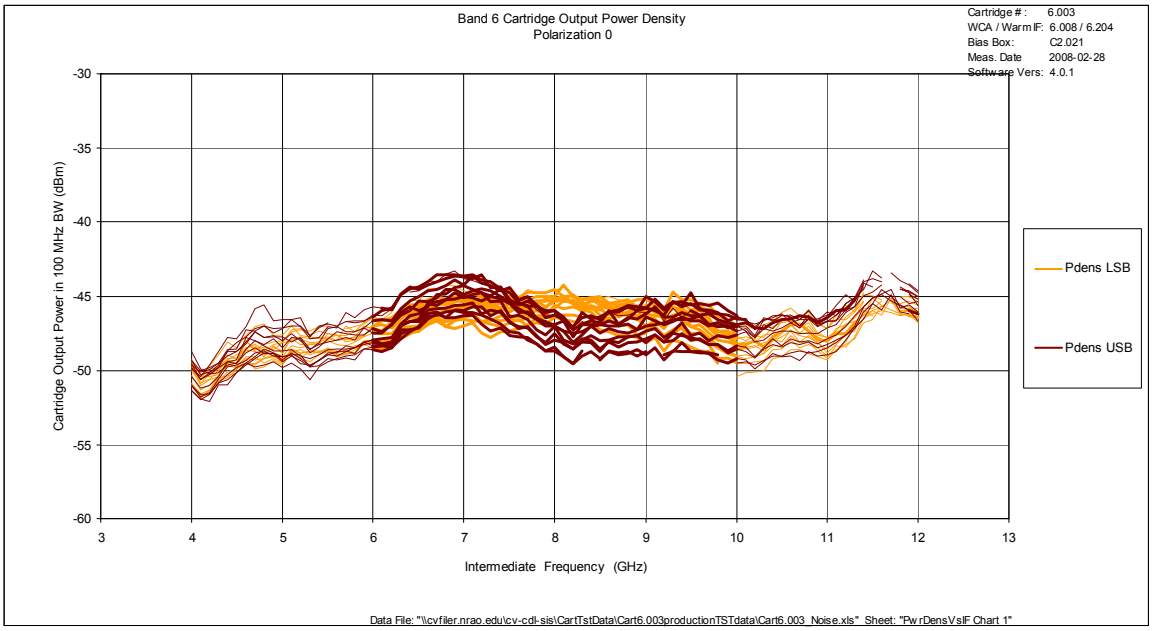


Figure 30: Output Power Density, Pol 1

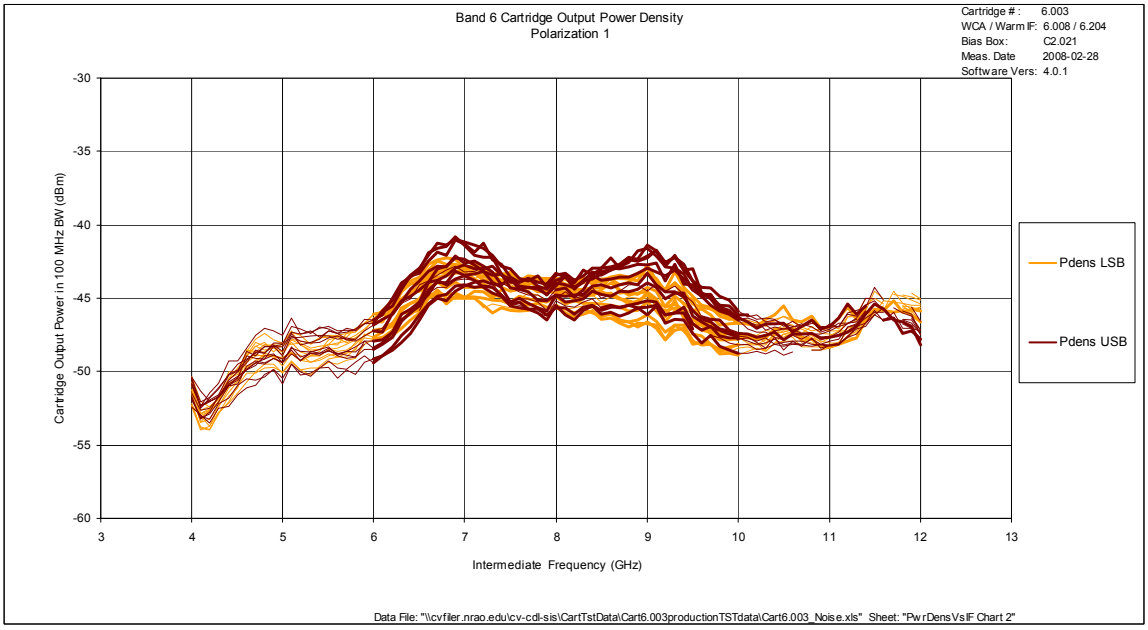


Figure 31: Power Density Slope Results, 4 GHz Bandwidth, Polarization 0

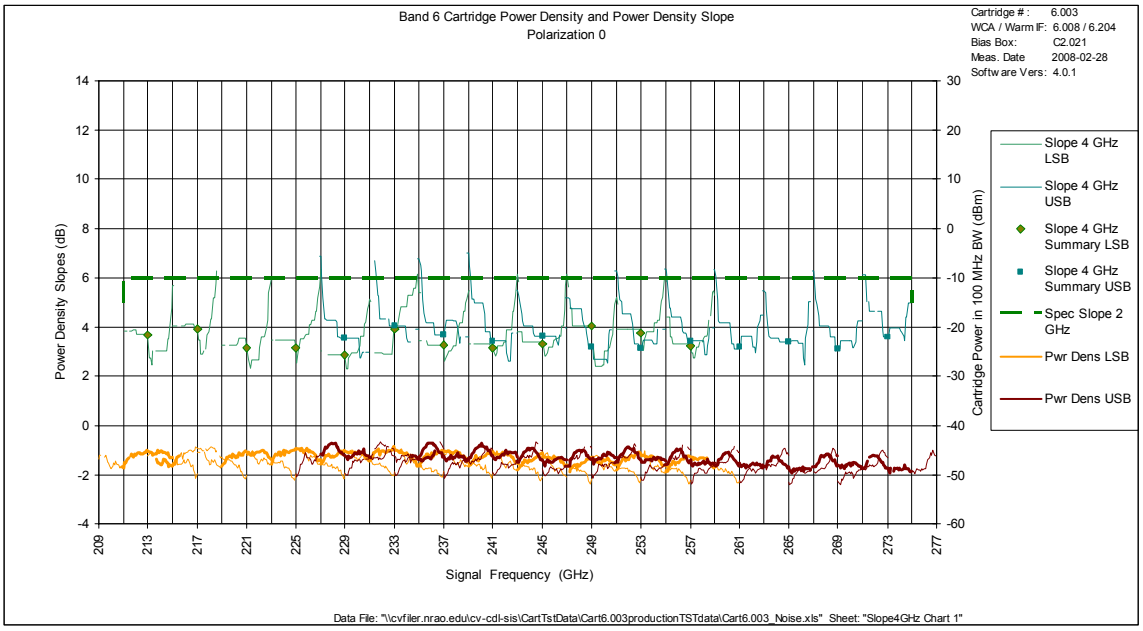


Figure 32: Power Density Slope Results, 4 GHz Bandwidth, Polarization 1

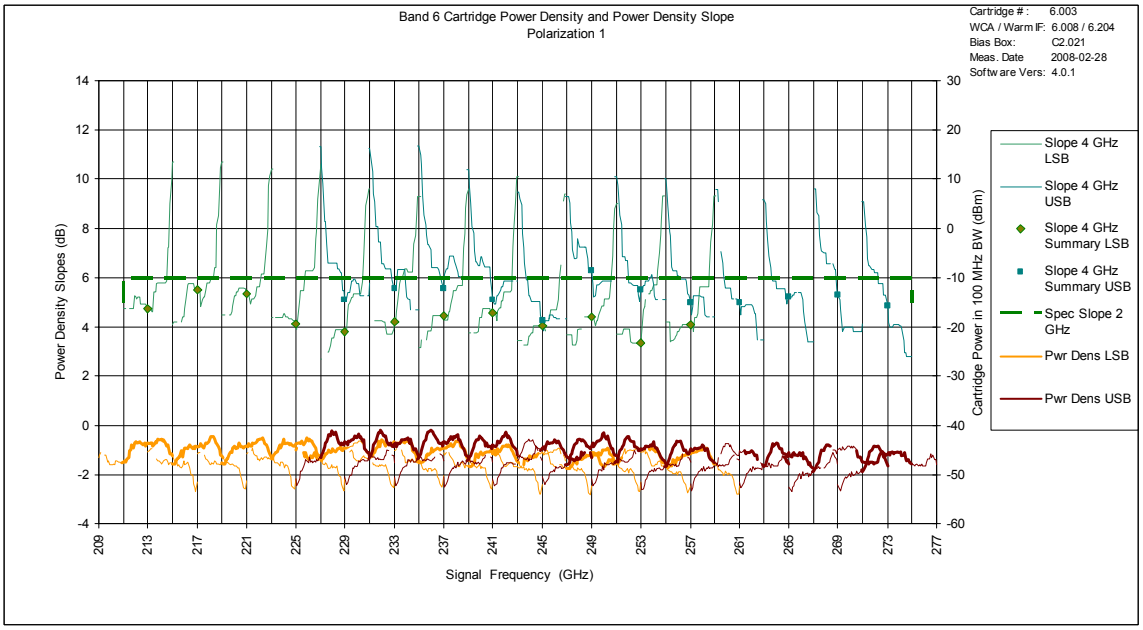


Figure 33: Power Density Slope Results, 2 GHz Bandwidth, Pol 0

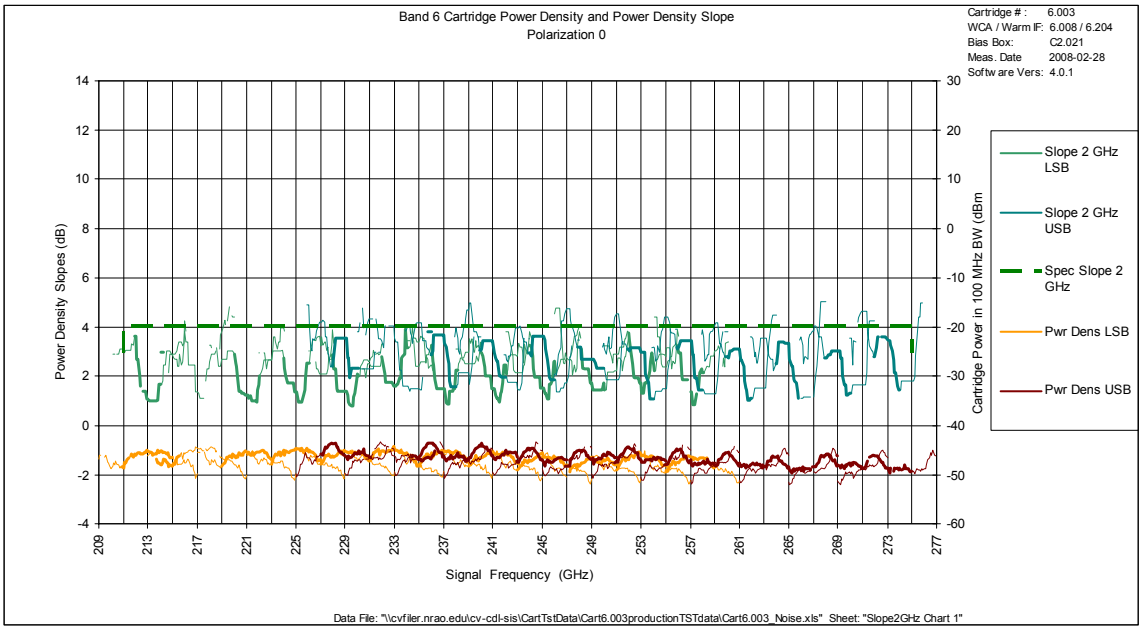


Figure 34: Power Density Slope Results, 2 GHz Bandwidth, Pol 1

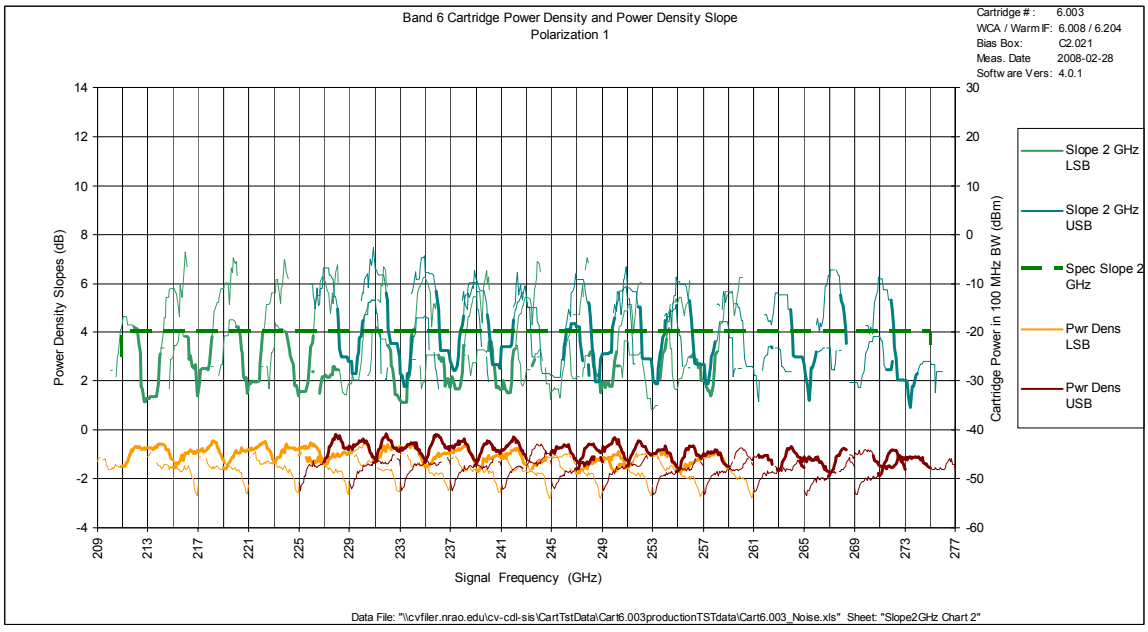


Figure 35: Total Power (6-10 and 4-12 GHz) for Polarization 0

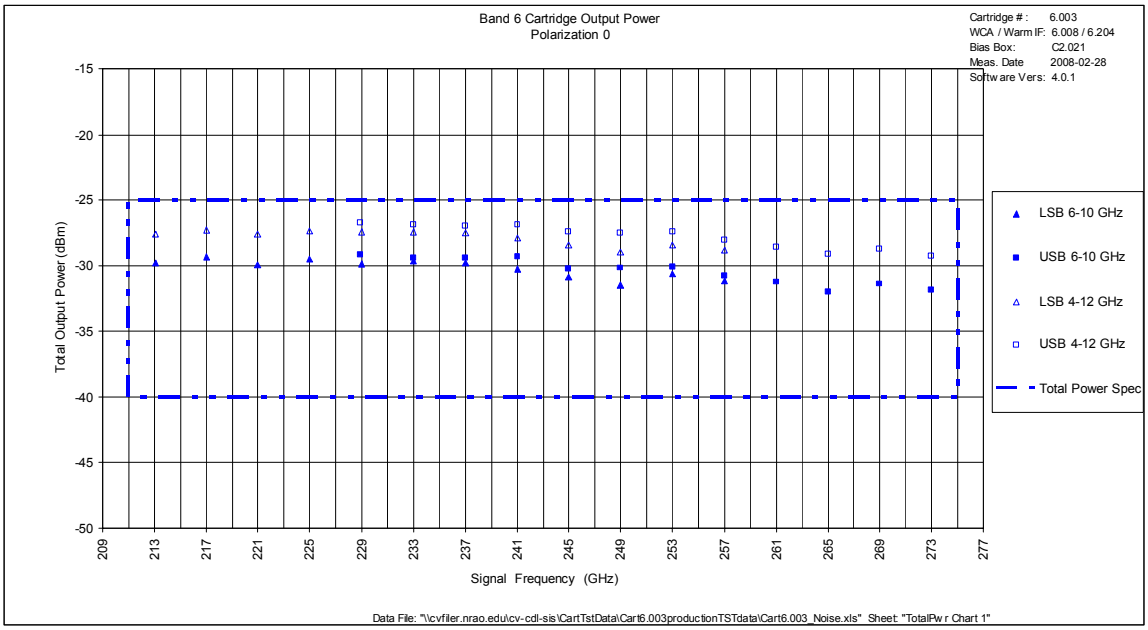


Figure 36: Total Power (6-10 and 4-12 GHz) for Polarization 1

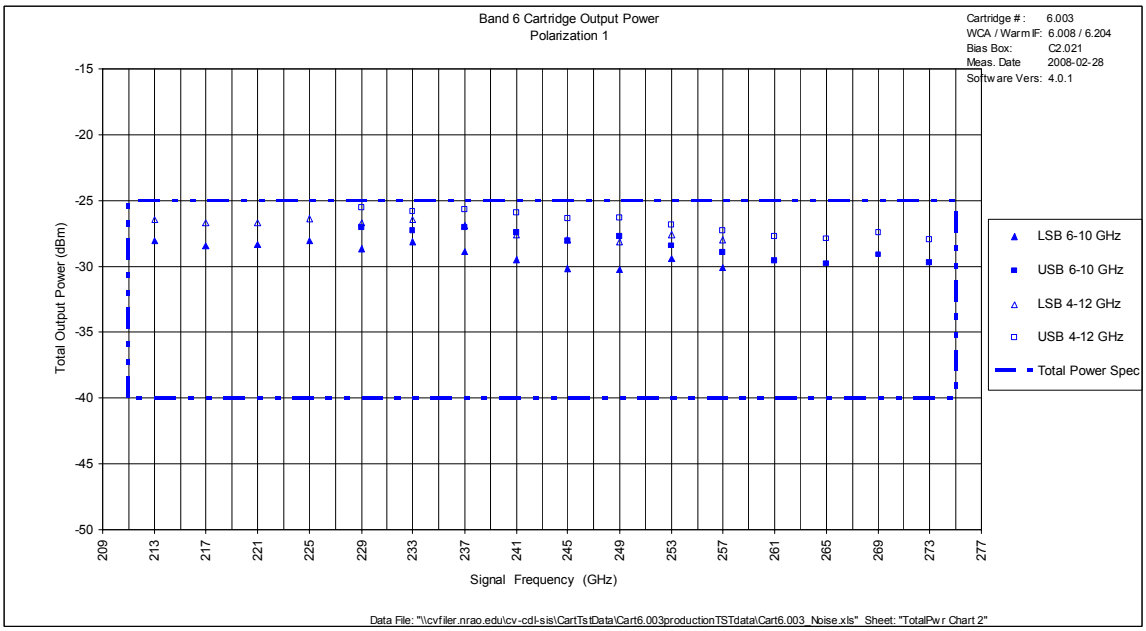
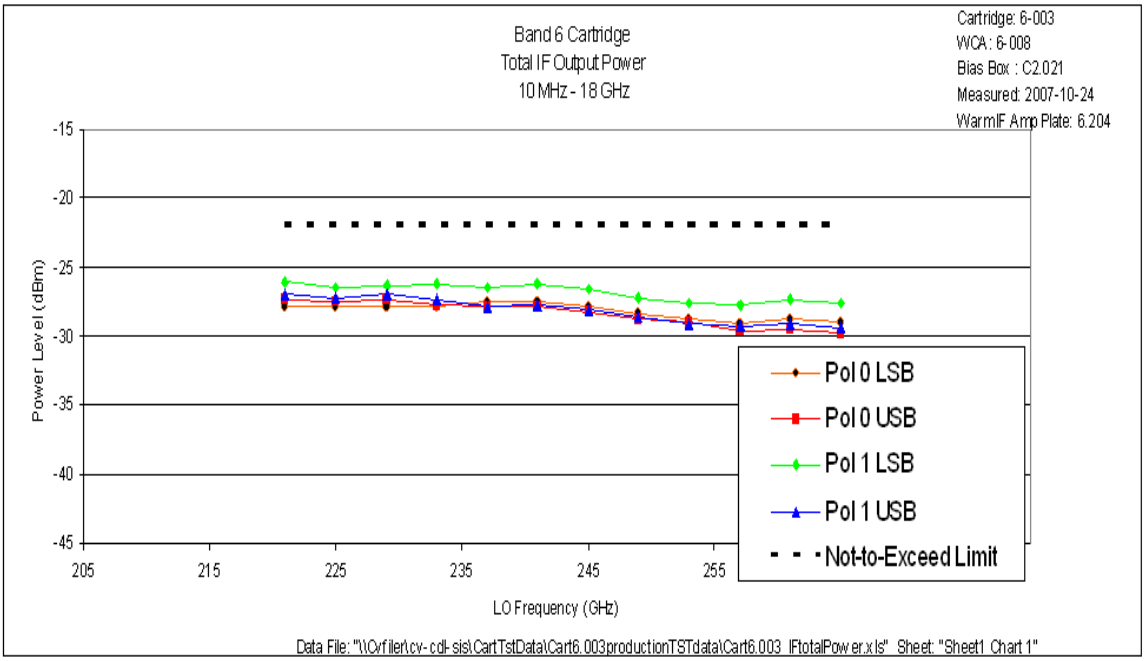


Figure 37: Total Output Power (10 MHz - 18 GHz)



3.3. Gain Compression (FEND-40.02.06.00-00230-00/T)

Gain compression was measured using the technique documented in [RD 05] and a detailed test report is given in [RD 06].

As shown in Figure 38, gain compression of the cartridge is 2% which is well within the 5% specification. The lines represent the maximum and minimum compression level measured in a 10 minute time span, whereas the dots represent the average. Non-cartridge components contribute about 0.2%, as shown in Figure 39.

Figure 38: Gain Compression Results

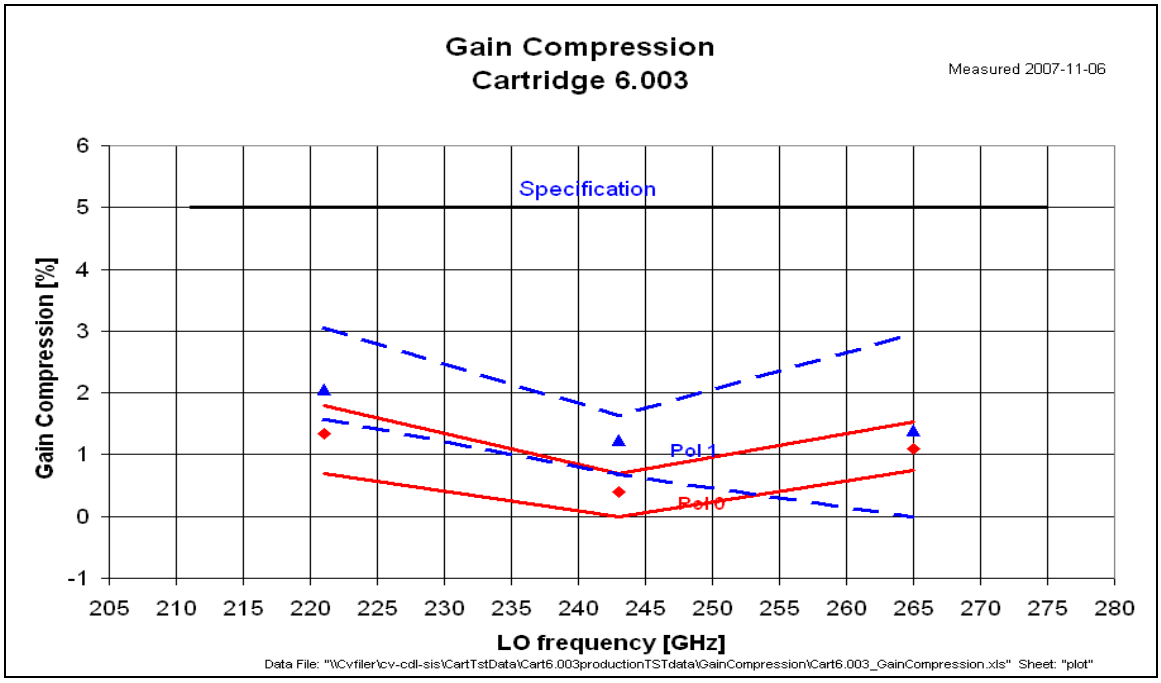
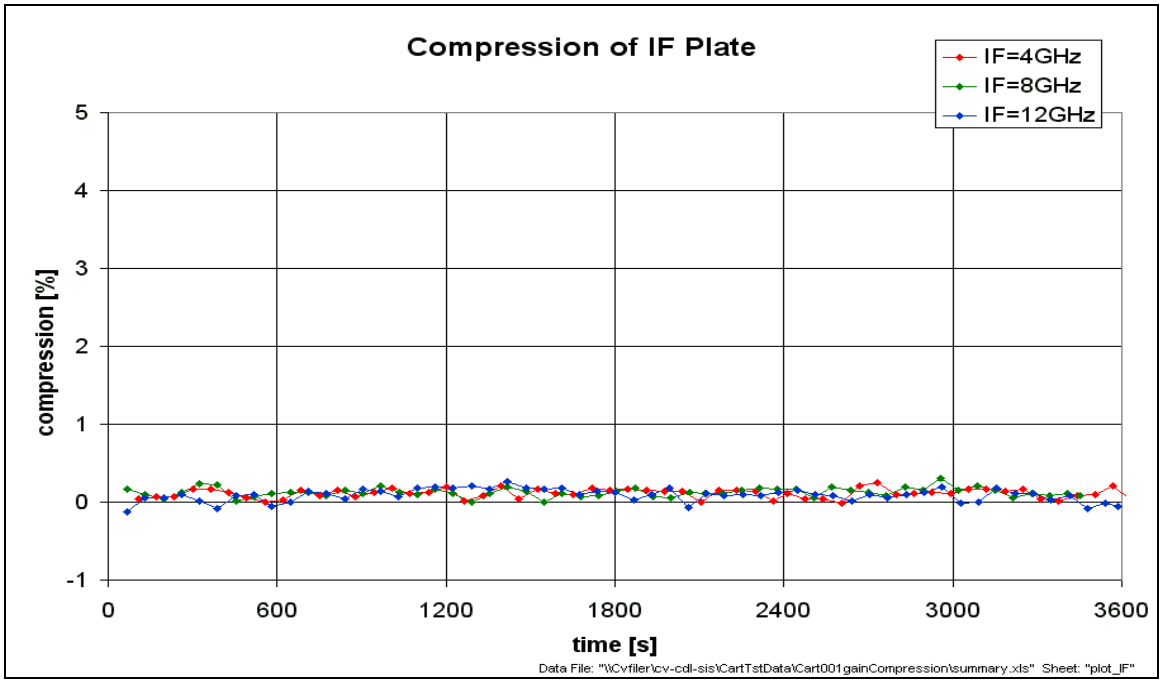


Figure 39: Typical Measured Compression Level of the Warm IF Plate



3.4. Amplitude Stability (FEND-40.02.06.00-00240-00/T)

Amplitude stability was measured with a Rev. C2 bias box, and both polarizations meet specifications, Figure 40 and Figure 41.

Figure 40: Amplitude Stability, Pol 0

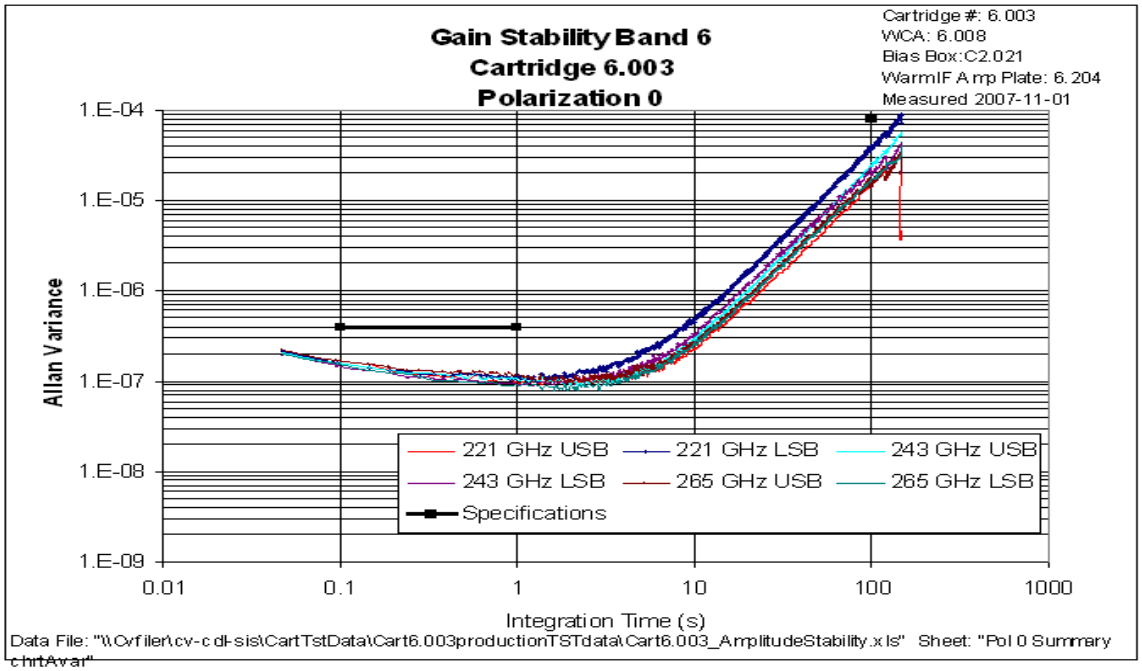
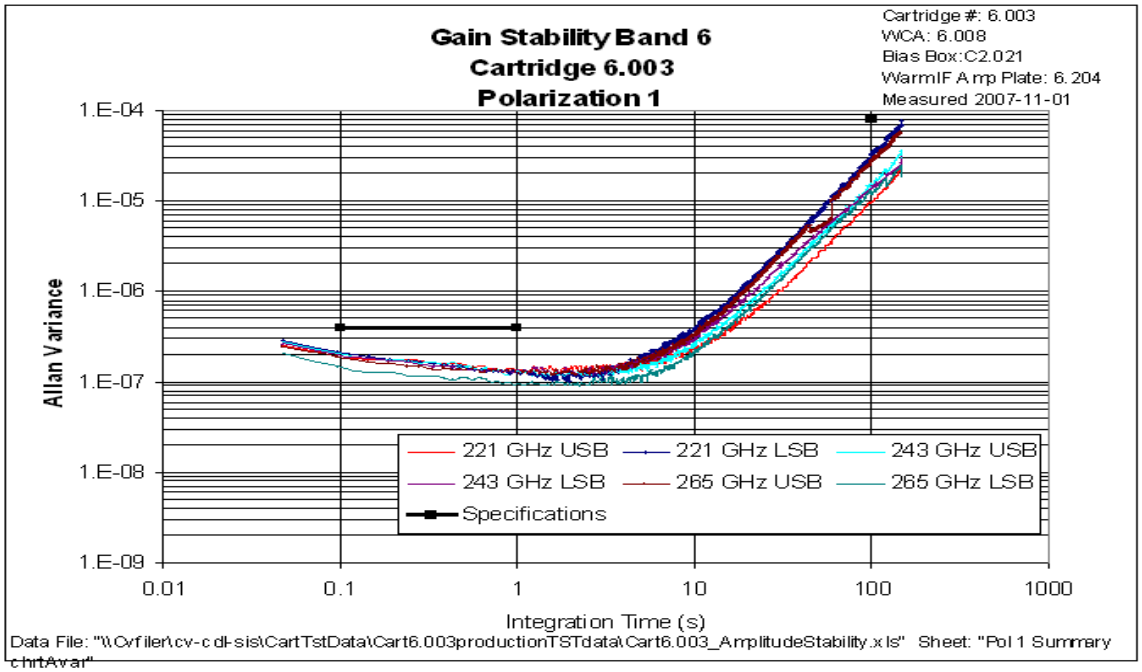


Figure 41: Amplitude Stability, Pol 1



3.5. Signal Path Phase Stability (FEND-40.02.06.00-00250-00/T)

Current Rev A phase drift specifications state that phase shall remain stable to within 0.5° on timescales up to 300 seconds. Rev B of the System Specifications requires the data be presented in the form of a 2-Point Allan Standard Deviation with a fixed averaging time of 10 seconds and intervals of 20 and 300 seconds.

Procedures for measuring phase drift are given in [RD 07]. The phase drift is shown in Figure 42 through Figure 43 is the time sequence data converted to Allan Variance.

Figure 42: Phase Stability 221 GHz, Pol 0

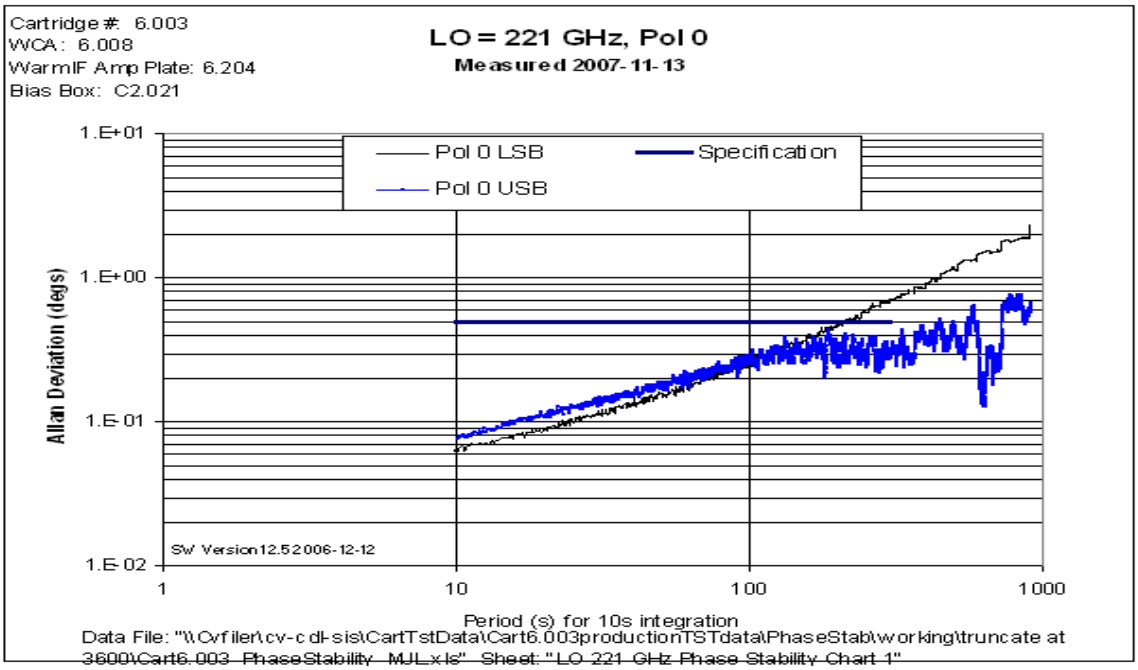


Figure 43: Phase Stability 221 GHz, Pol 1

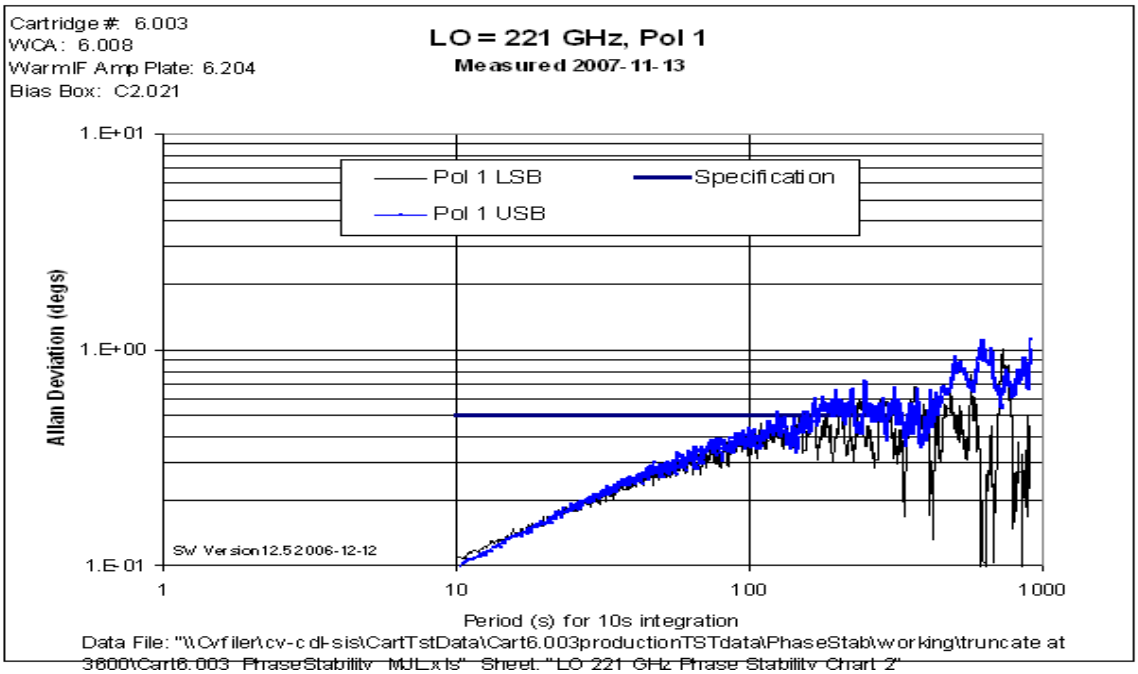


Figure 44: Phase Stability 245 GHz, Pol 0

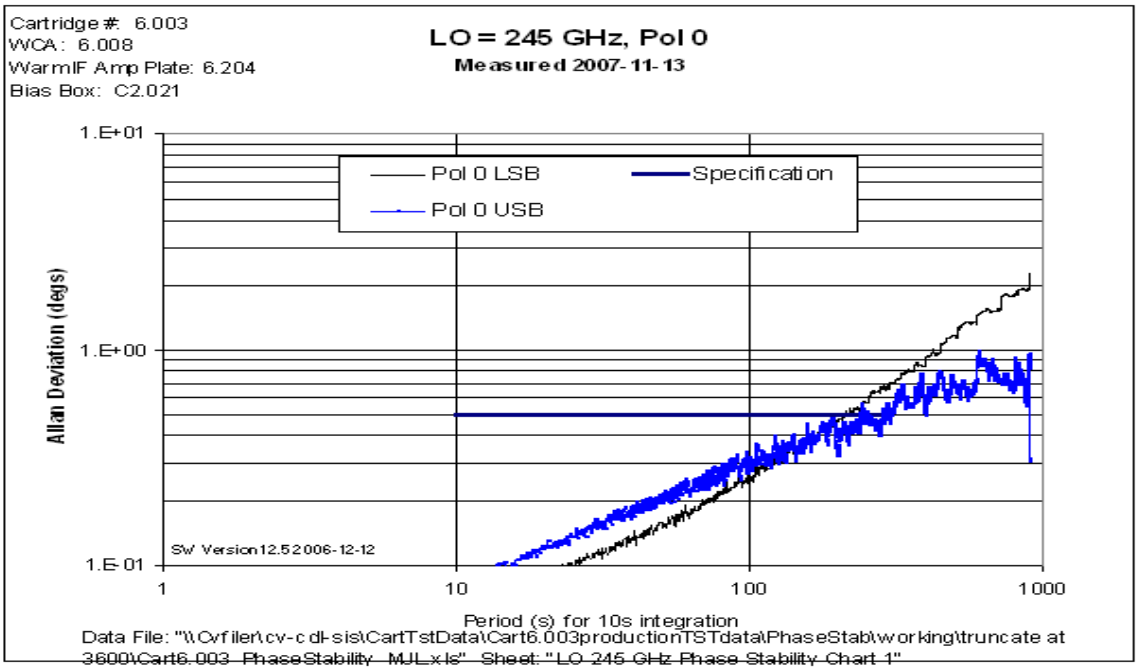


Figure 45: Phase Stability 245 GHz, Pol 1

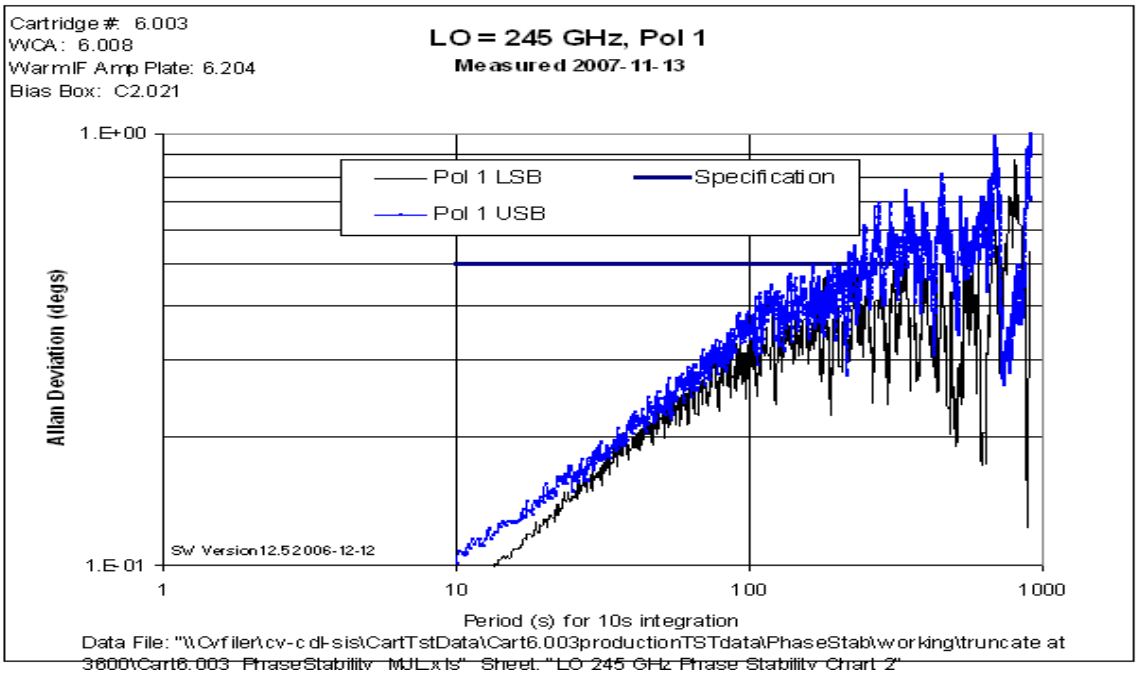


Figure 46: Phase Stability 265 GHz, Pol 0

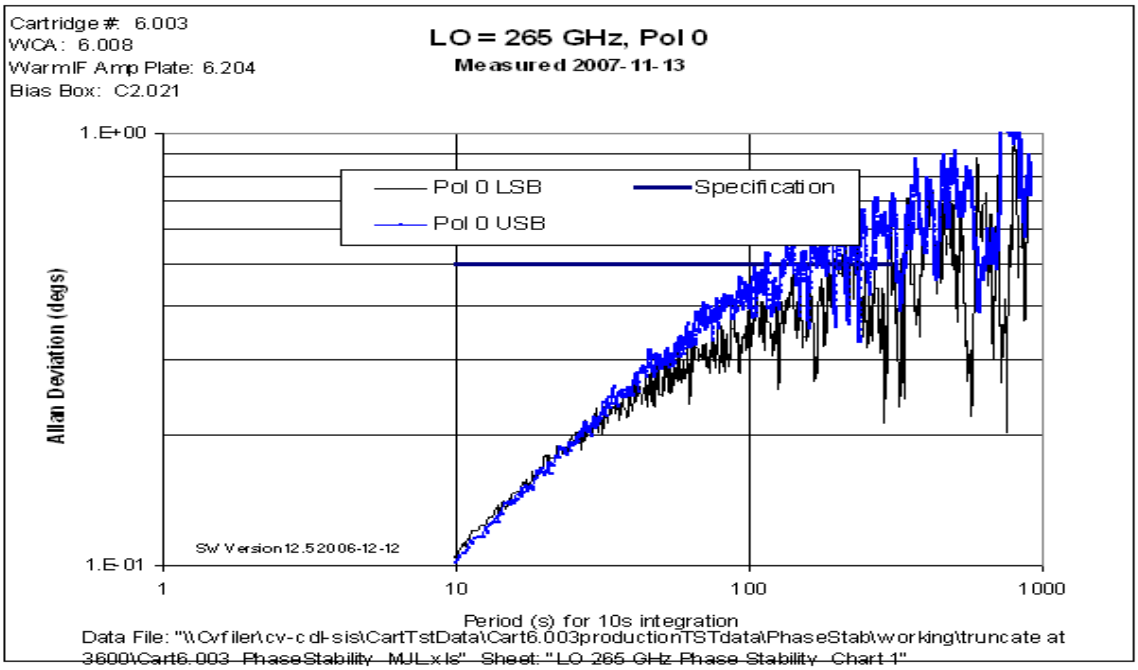
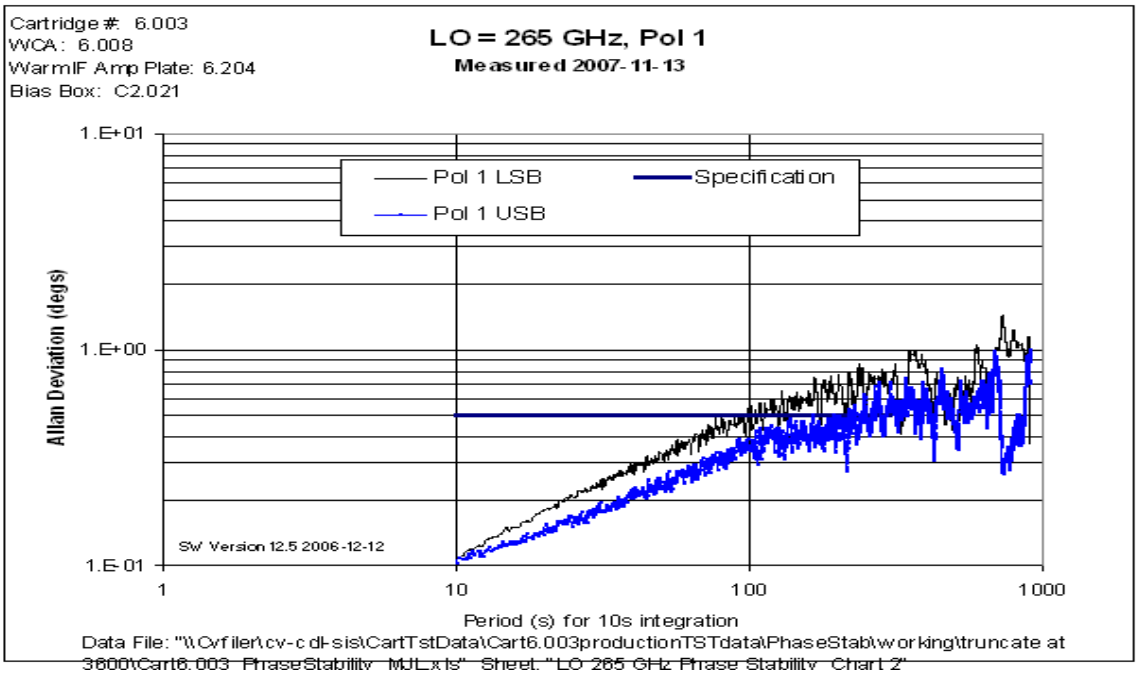


Figure 47: Phase Stability 265 GHz, Pol 1



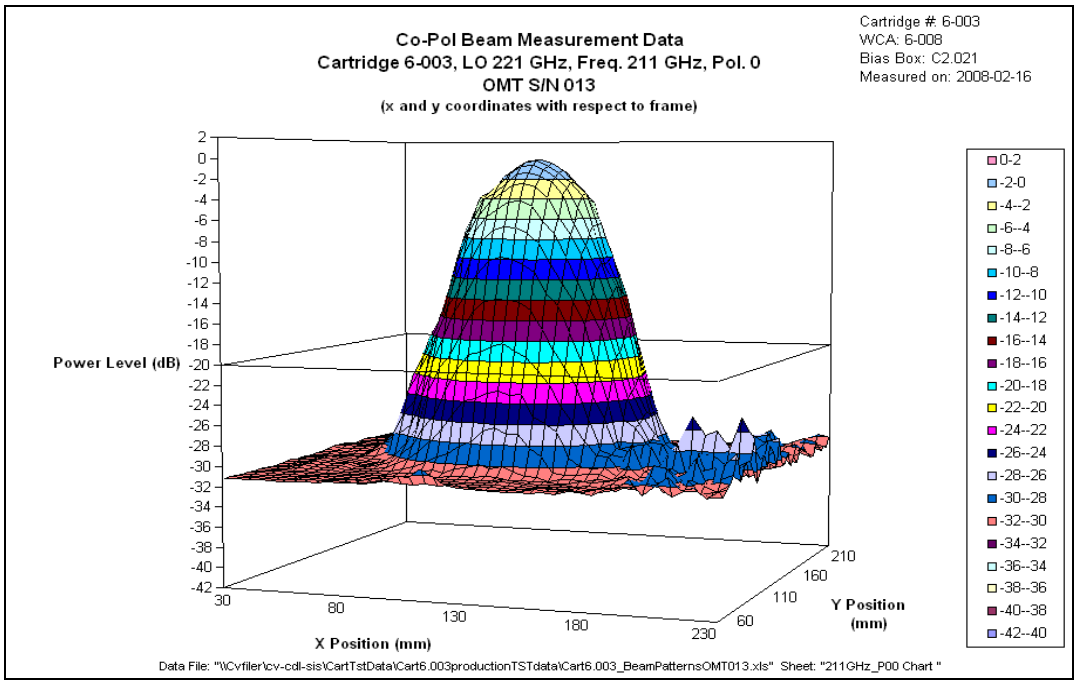
3.6. Beam Efficiency (FEND-40.02.06.00-00260-00/T)

Beam pattern measurements [RD 16] and [RD 20], with the chamfered feed horn, are presented in Figure 48 to Figure 53.

Figure 54 shows the measured beam efficiency as a function of frequency. The specification states the beam efficiency shall be greater than 90%, but the additional 2% above this spec accounts for scattering and pointing losses. Details (should be) given in [RD 11].

The specified edge taper is 10.5 dB at the sub reflector, but that can't be confirmed until completion of the cartridge test system near-field beam scanner. The North American Front End Integration Center measures 10 dB at 239 GHz.

Figure 48: Beam Patterns, 211 GHz, Pol 0



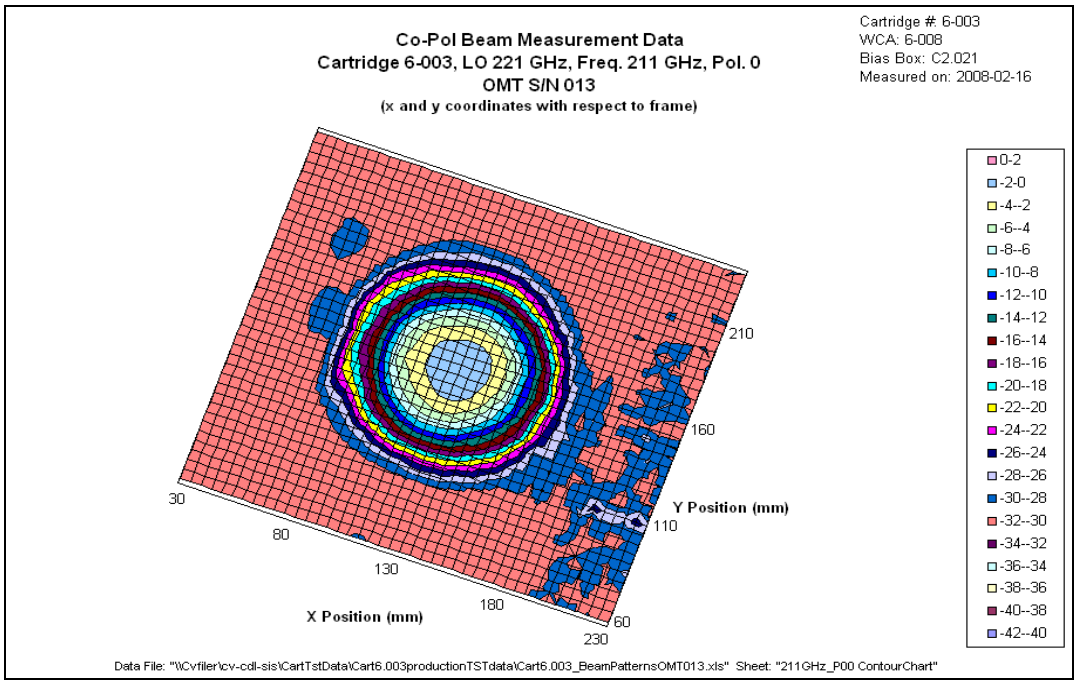
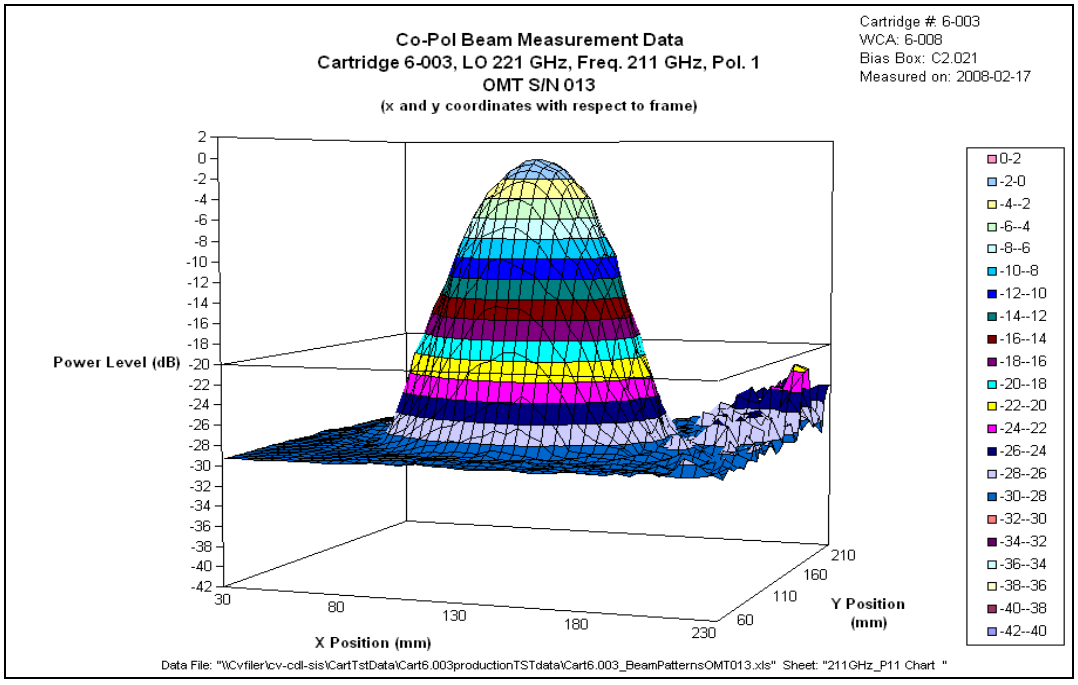


Figure 49: Beam Patterns, 211 GHz, Pol 1



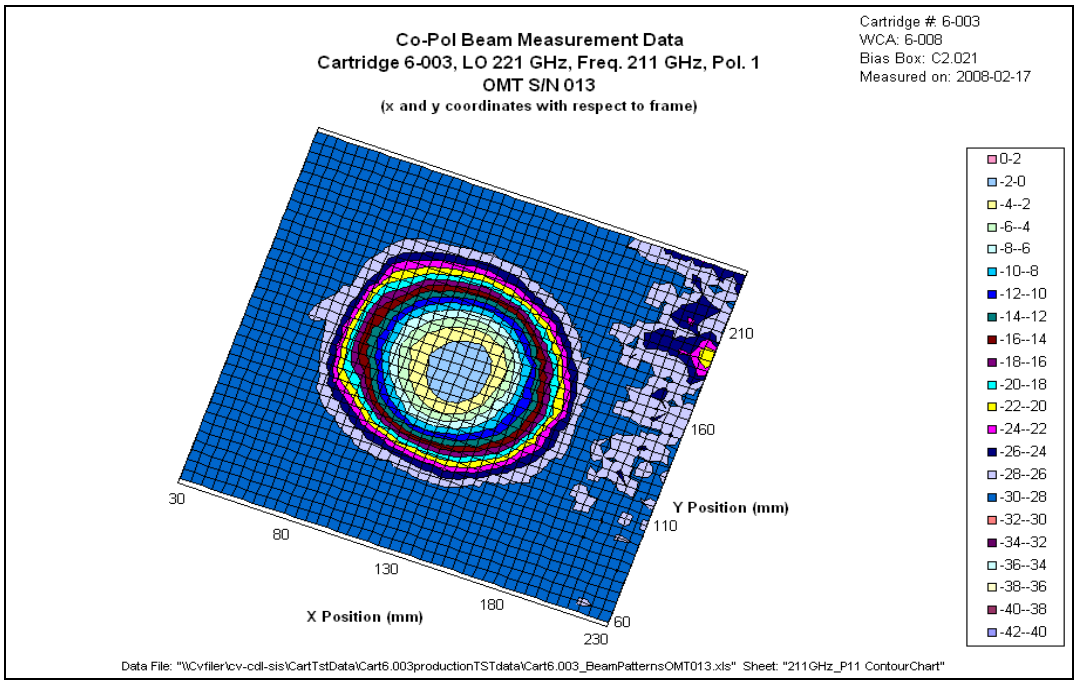
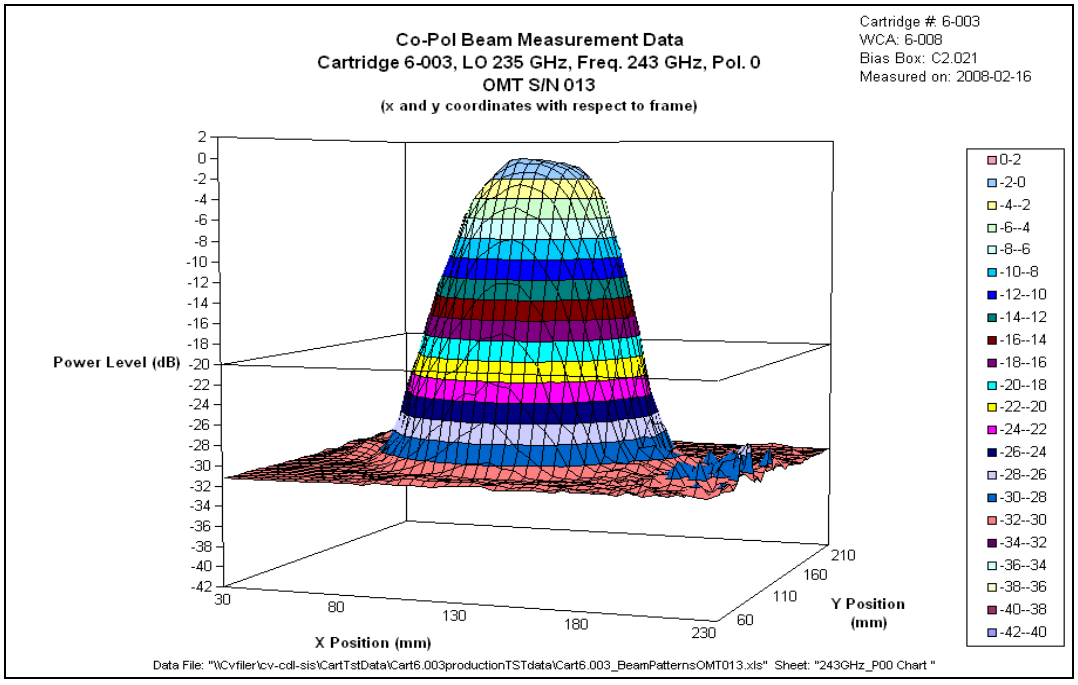


Figure 50: Beam Patterns, 243 GHz, Pol 0



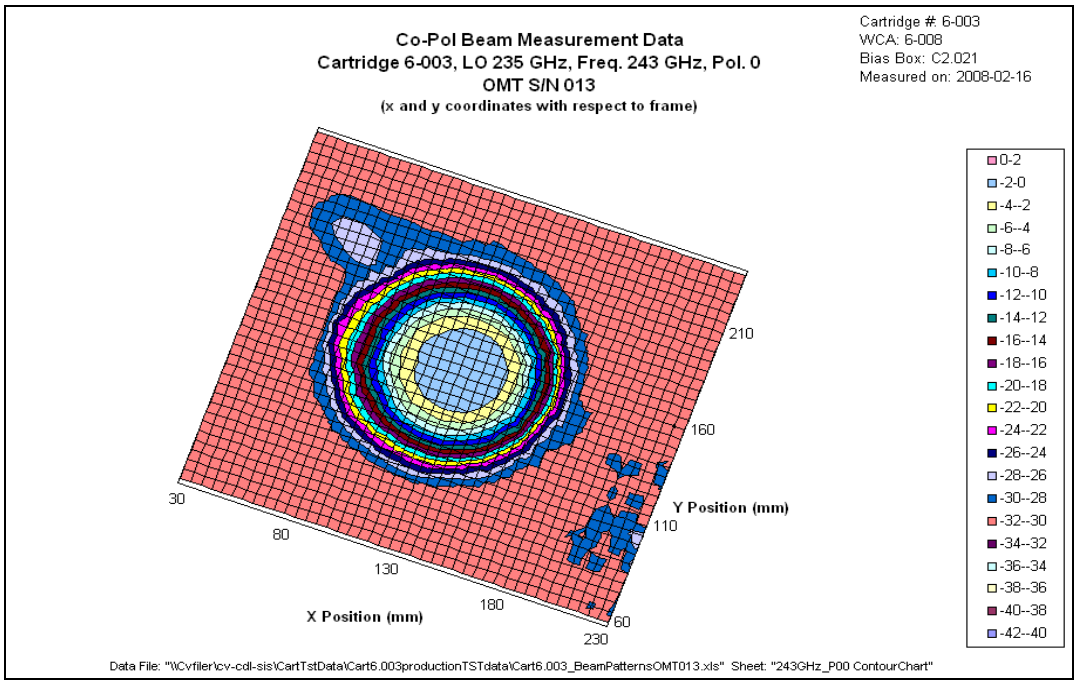
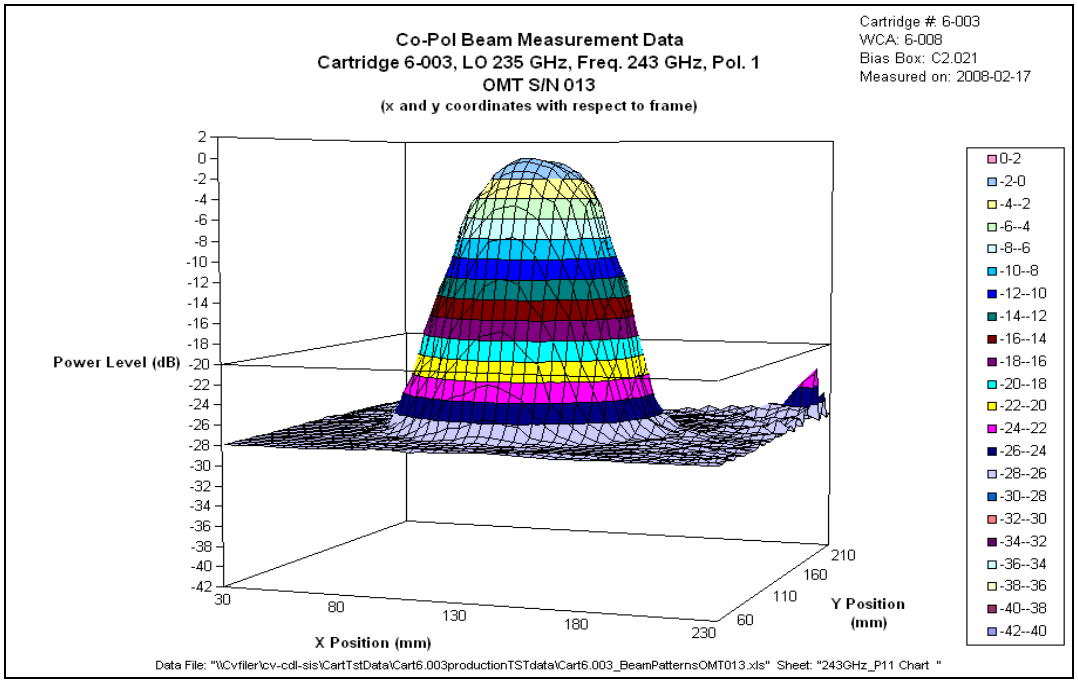


Figure 51: Beam Patterns, 243 GHz, Pol 1



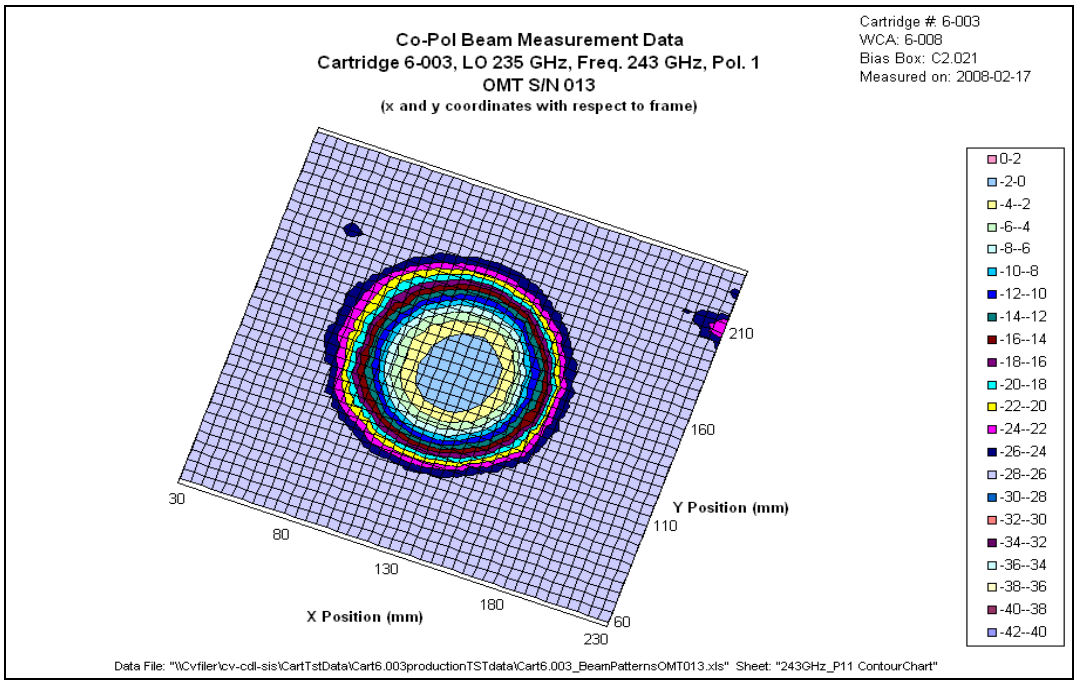
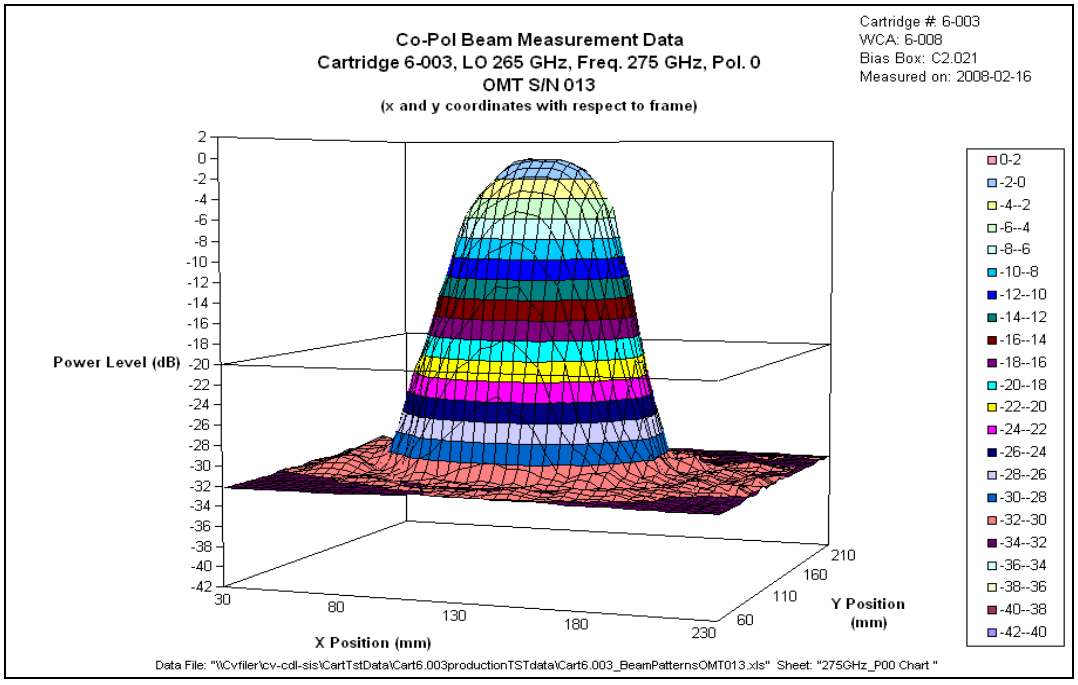


Figure 52: Beam Patterns, 275 GHz, Pol 0



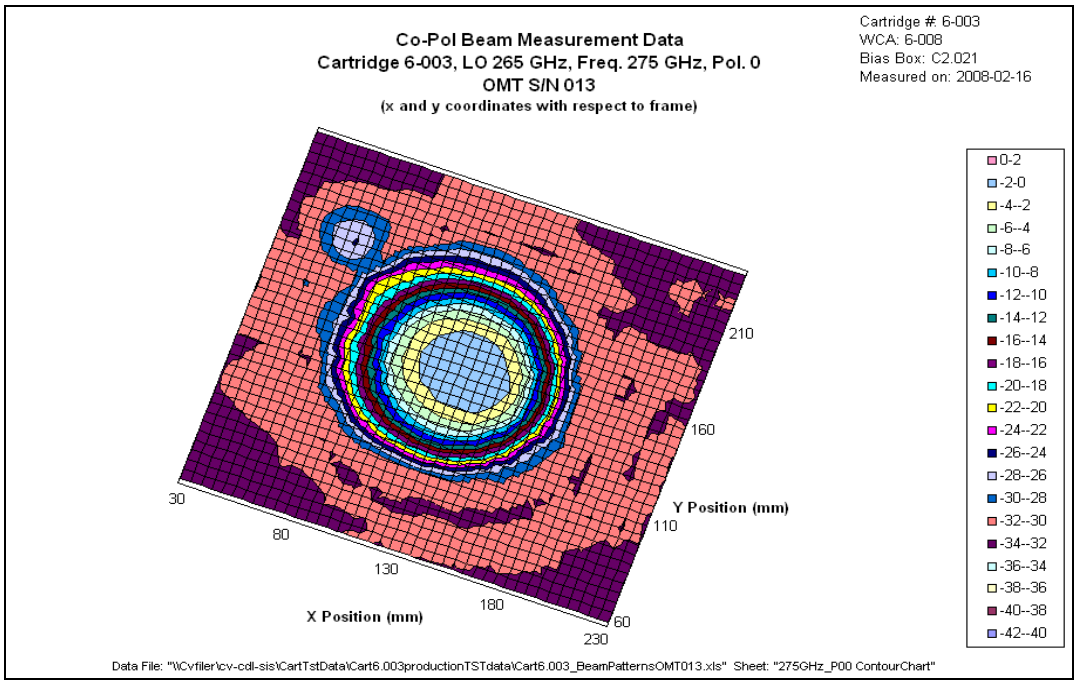
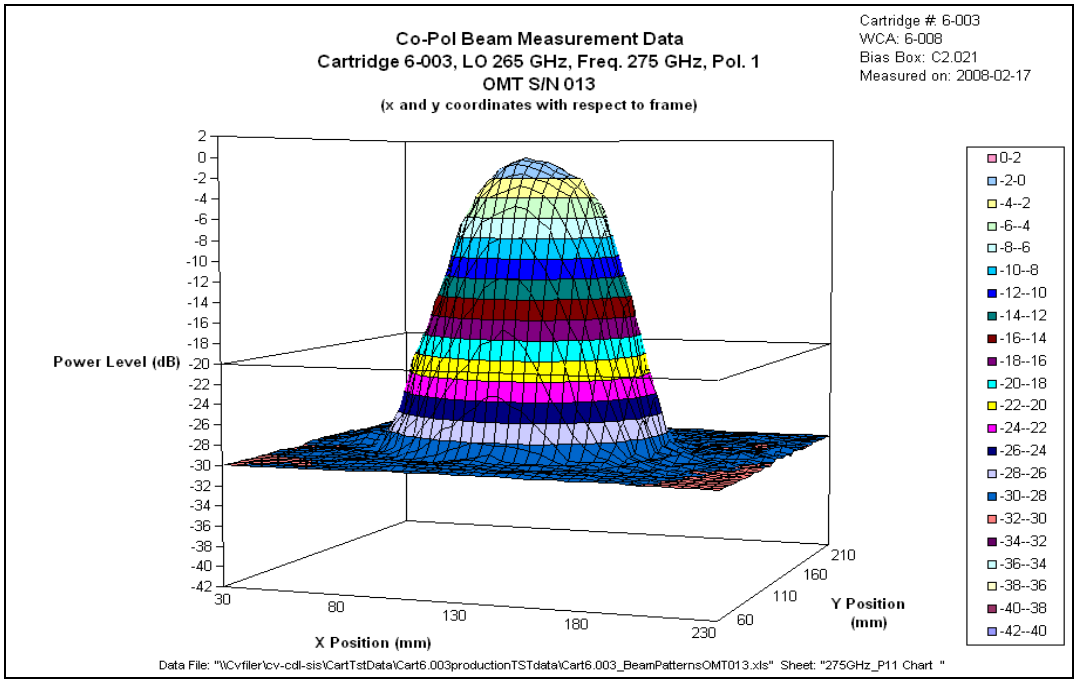


Figure 53: Beam Patterns, 275 GHz, Pol 1



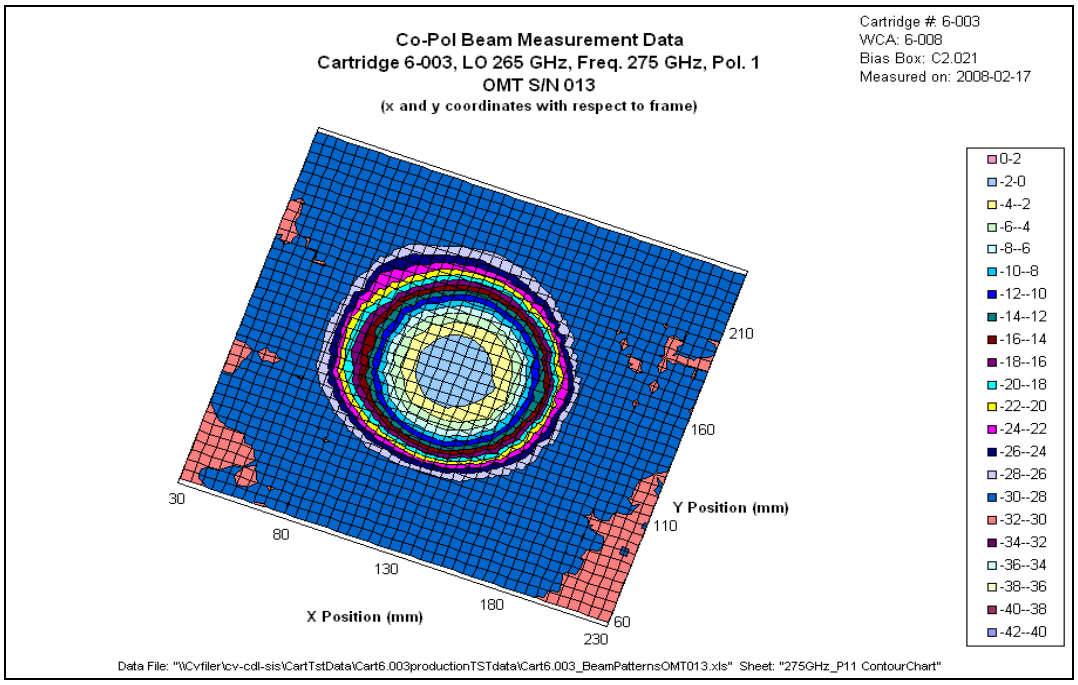
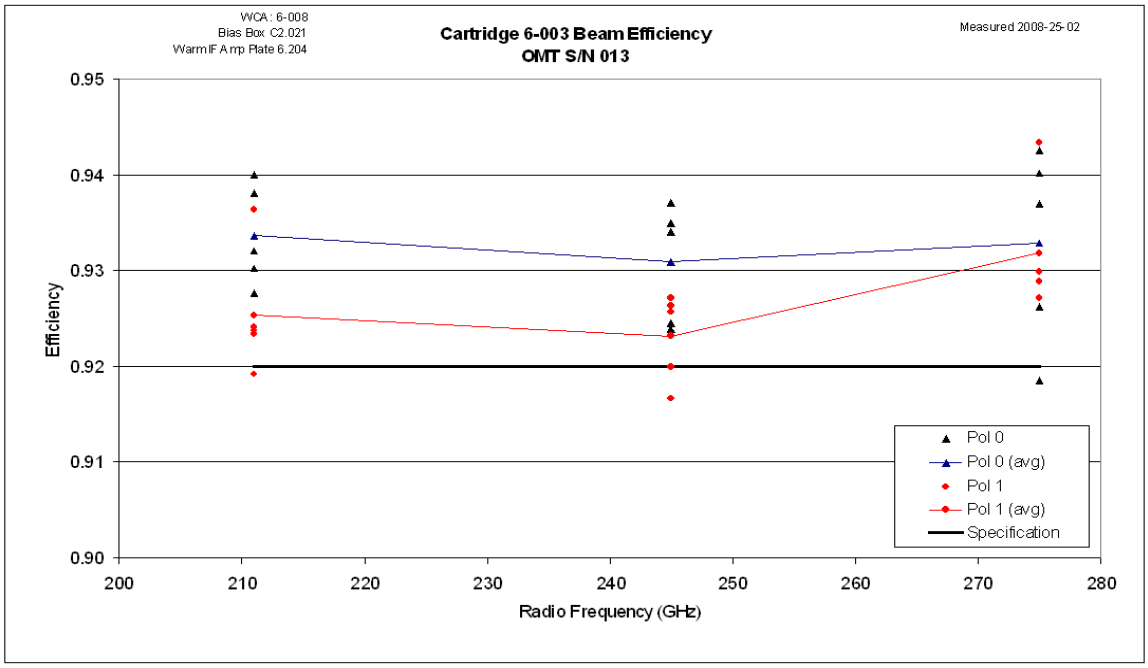

Co-Pol Beam Measurement Data
Cartridge 6-003, LO 265 GHz, Freq. 275 GHz, Pol. 1
OMT S/N 013
(x and y coordinates with respect to frame)
Cartridge #: 6-003
WCA: 6-008
Bias Box: C2.021
Measured on: 2008-02-17
0-2
-2-0
-4--2
-6--4
-8--6
-10--8
-12--10
-14--12
-16--14
-18--16
-20--18
-22--20
-24--22
-26--24
-28--26
-30--28
-32--30
-34--32
-36--34
-38--36
-40--38
-42--40
30
80
130
180
230
X Position (mm)
60
110
160
210
Y Position (mm)
Data File: "\\Cvfiler\cv-cdl-sis\CartTstData\Cart6.003productionTSTdata\Cart6.003_BeamPatternsOMT013.xls" Sheet: "275GHz_P11 ContourChart"

Figure 54: Measured Beam Efficiency



3.7. Polarization Alignment (FEND-40.02.06.00-00270-00/T)

Polarization alignment was confirmed using the test procedures given in [RD 15] and the results are shown in Table 12.

Table 12: Power Output from Polarization Alignment Confirmation Tests

	Sideband source polarization aligned with radial direction		Sideband source polarization orthogonal to radial direction	
LO Frequency (GHz)	**Port 0 USB**	**Port 1 USB**	**Port 1 USB**	**Port 0 USB**
245	-4.95 dBm	-32.77 dBm	-4.91 dBm	-33.15 dBm

3.8. Polarization Alignment Accuracy (FEND-40.02.06.00-00280-00/T)

Polarization alignment was measured according to the procedures given in [RD 15]. Figure 55 and Figure 56 show total power level near the cross-polarization null as a function of alignment angle for each polarization. The relative polarization alignment angle is plotted versus frequency in Figure 57.

Figure 55: Polarization Alignment Accuracy, Pol 0

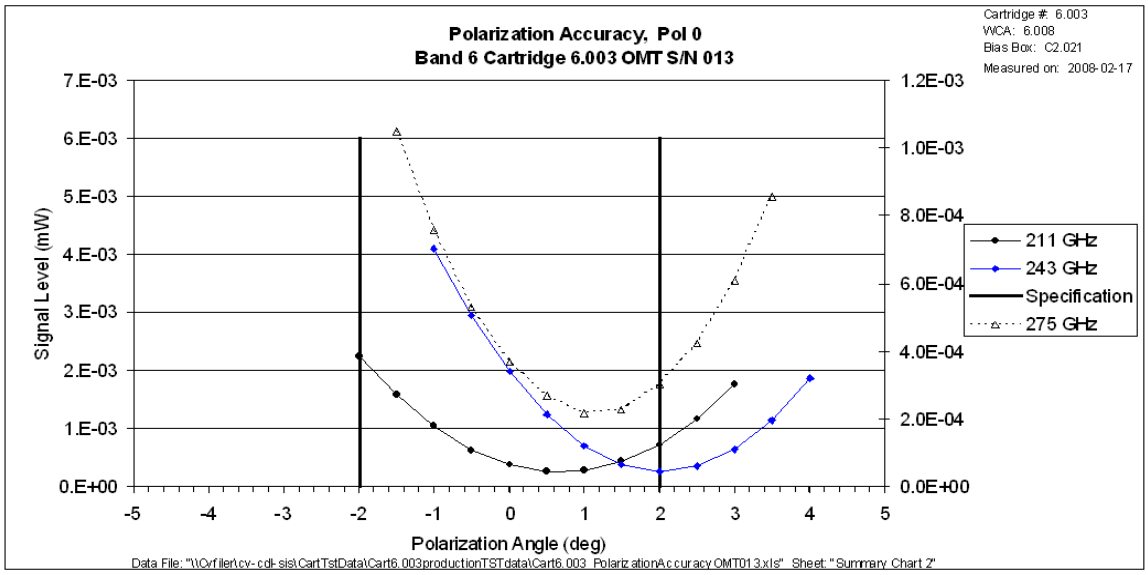


Figure 56: Polarization Alignment Accuracy, Pol 1

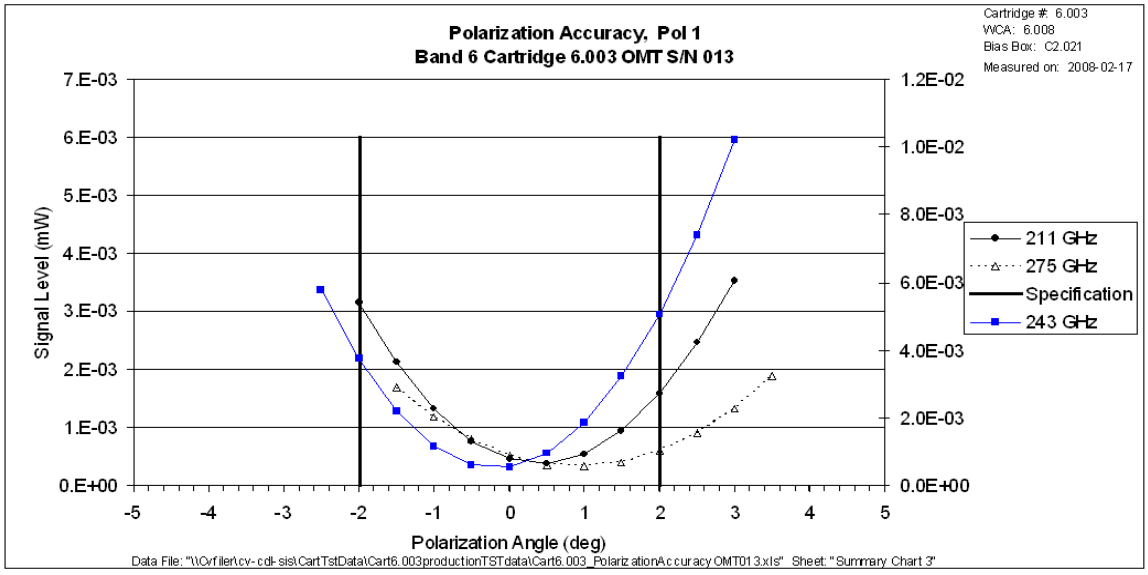
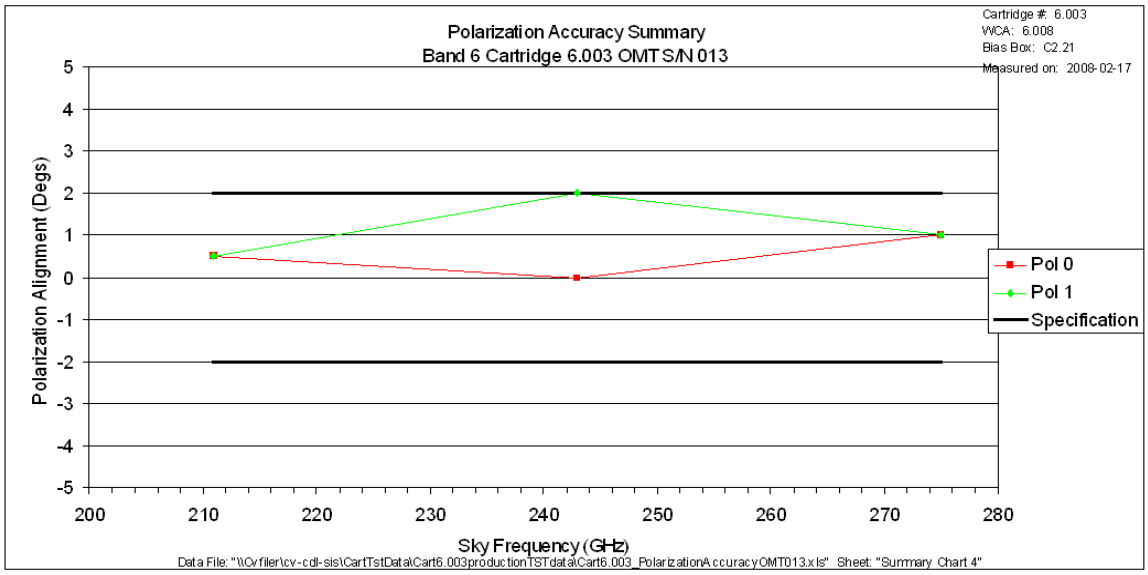


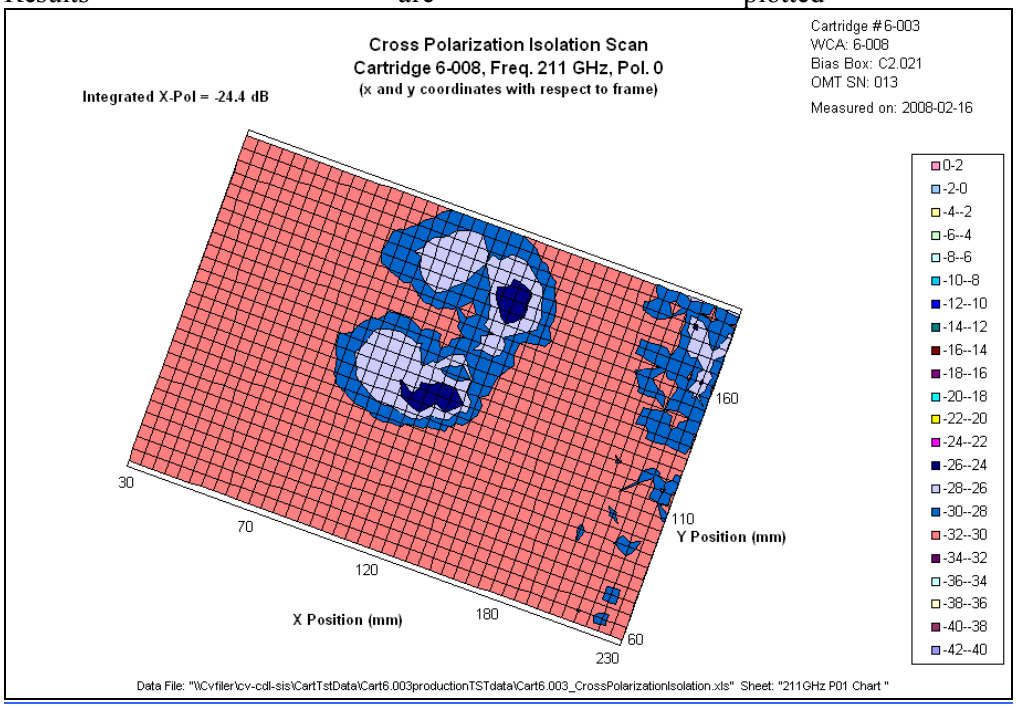
Figure 57: Polarization Alignment Accuracy Summary



3.9. Polarization Isolation (FEND-40.02.06.00-00290-00/T)

Cross-polarization isolation was measured according to the procedures in [RD 16].

Results are plotted in

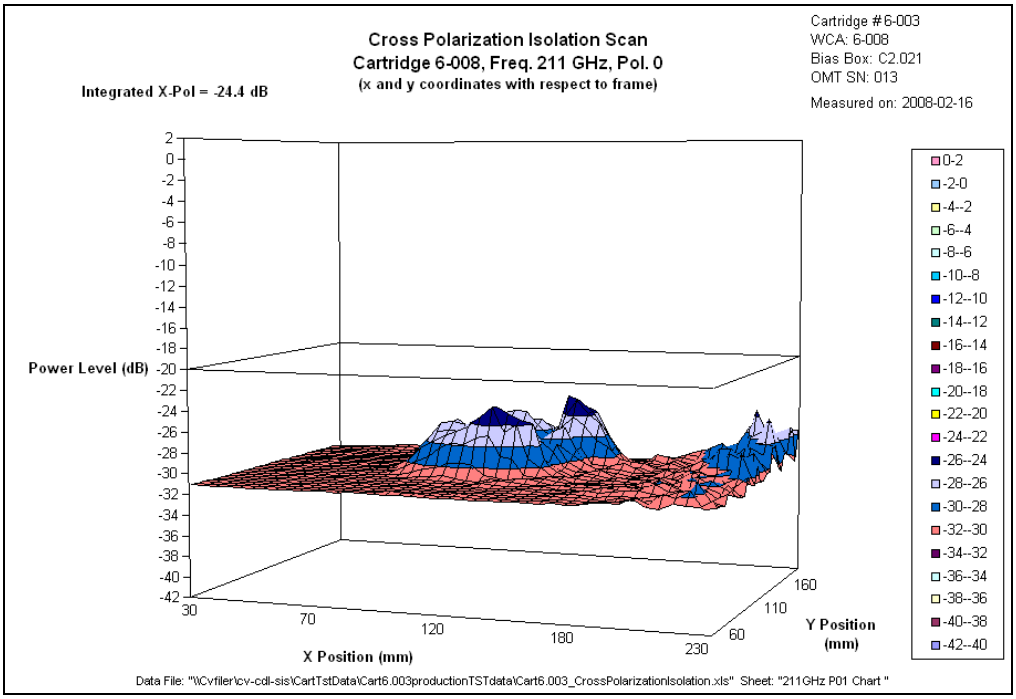


through Figure 63. Table 13 summarizes and compares cross-pol isolation peaks from the patterns to the values integrated over the extent of the subreflector.

Table 13: Worst-Case Cross Pol Isolation Peaks and Integrated Results

Freq. (GHz)	Pol.	Level from Co-Pol Peak (dB)	
		Worst-case Peak	Integrated
211	0	-24.2	-24.4
211	1	-22.4	-22.7
243	0	-22.3	-23.4
243	1	-23.4	-23.3
275	0	-18.0	-19.7
275	1	-20.0	-21.1

Figure 58: Cross-Polarization Isolation, RF=211 GHz, Pol 0



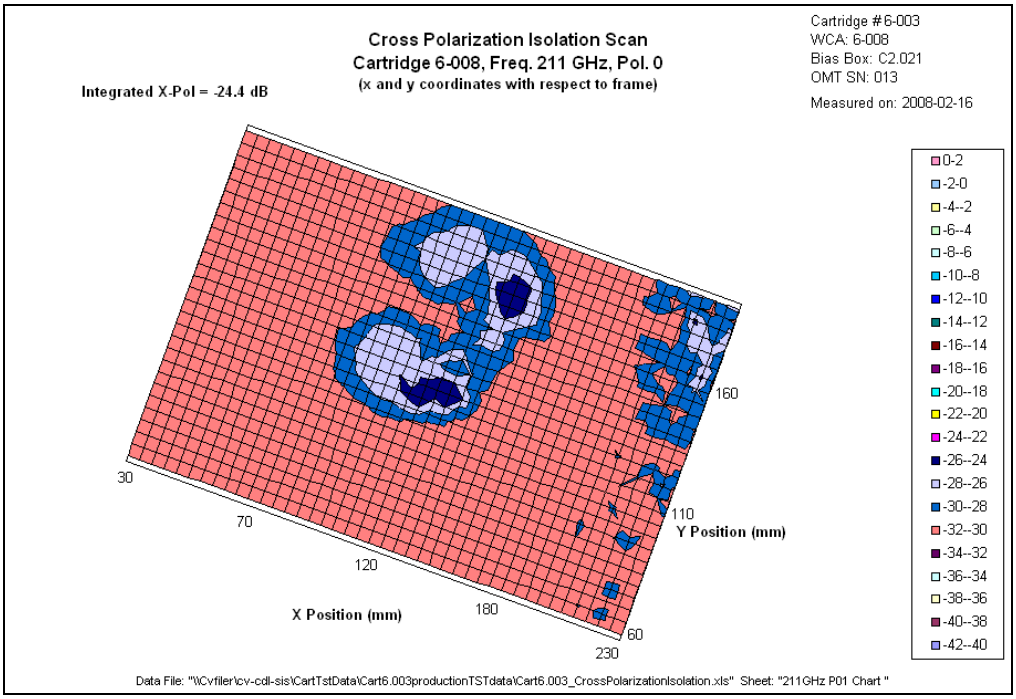
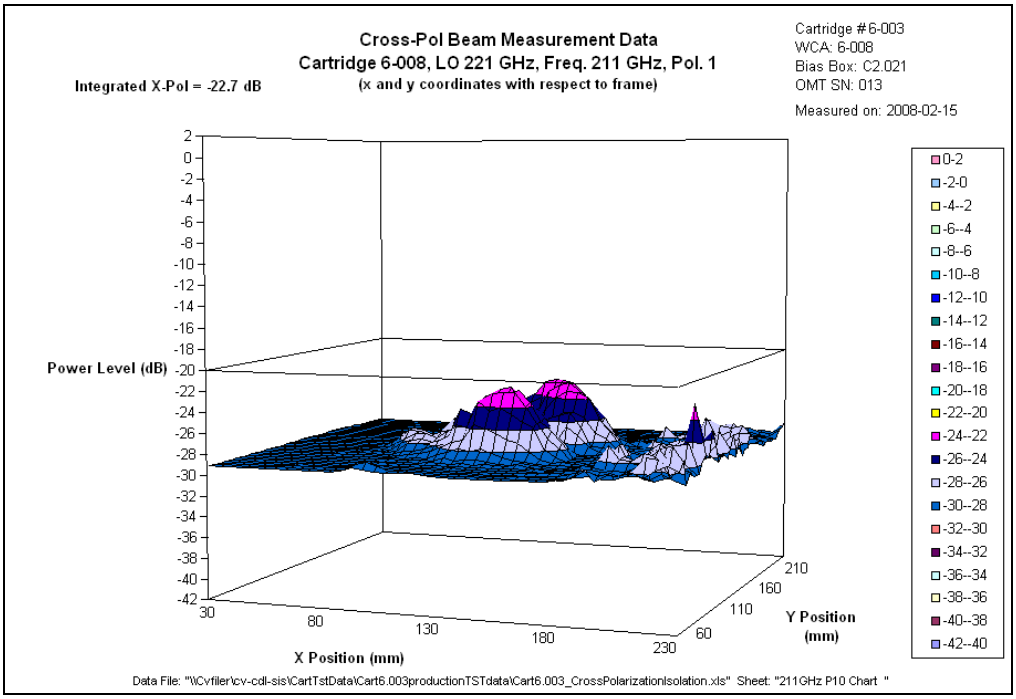


Figure 59: Cross-Polarization Isolation, RF = 211 GHz, Pol 1



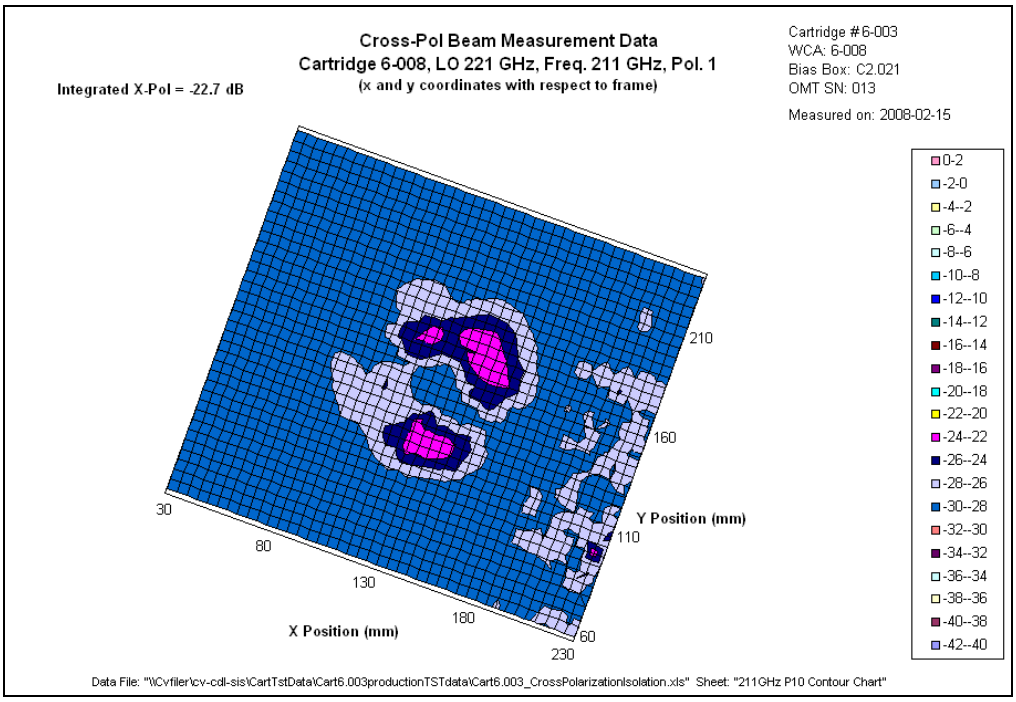
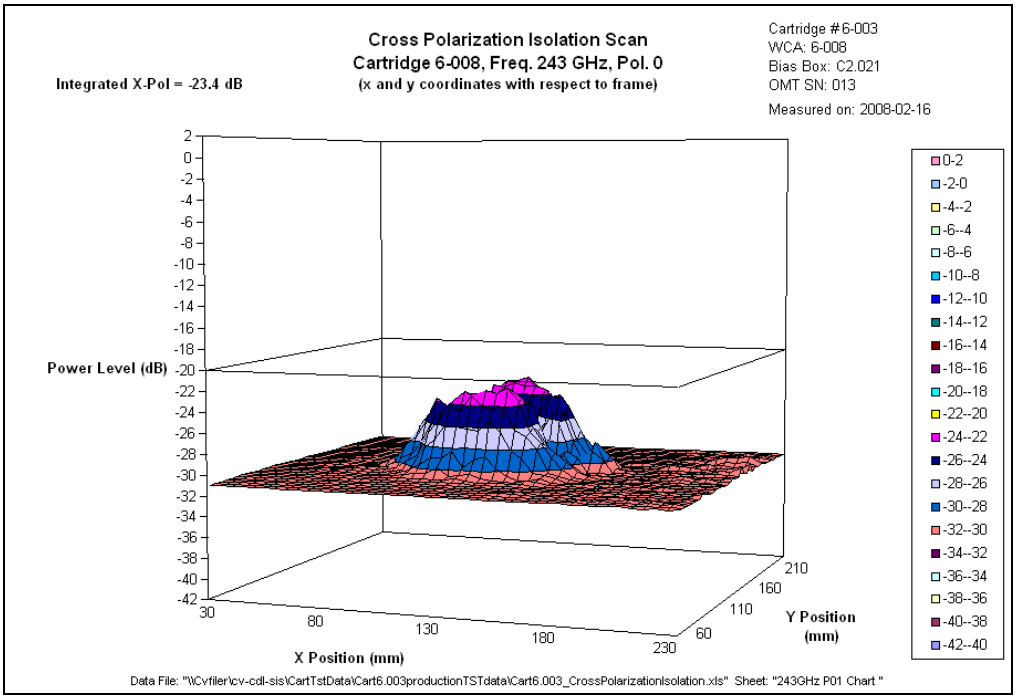


Figure 60: Cross-Polarization Isolation, RF=243 GHz, Pol 0



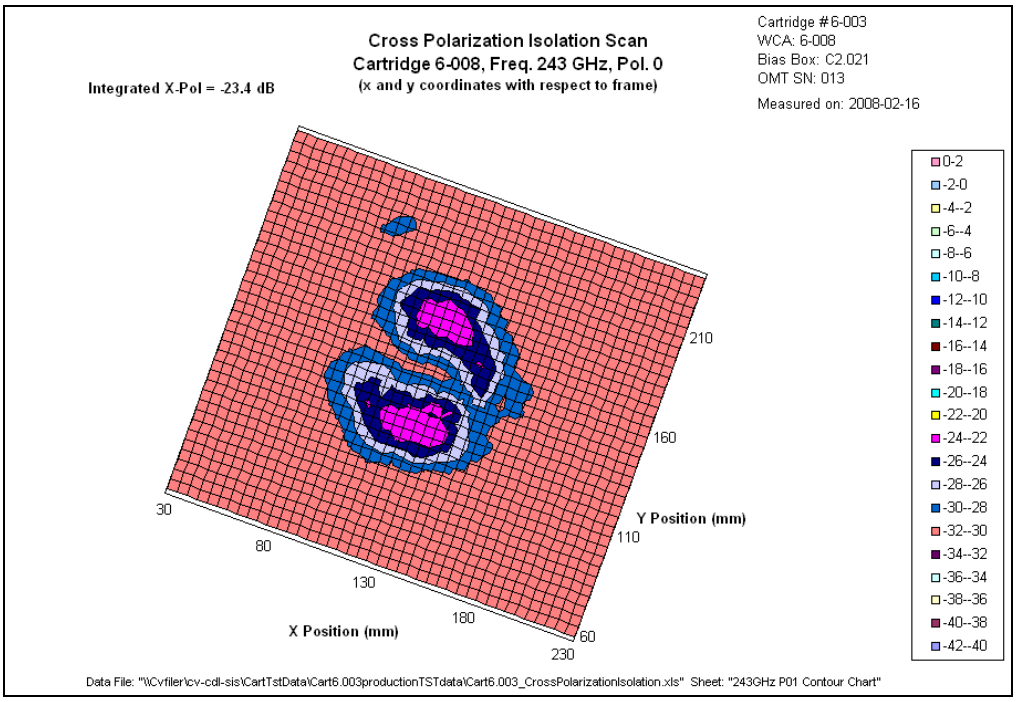
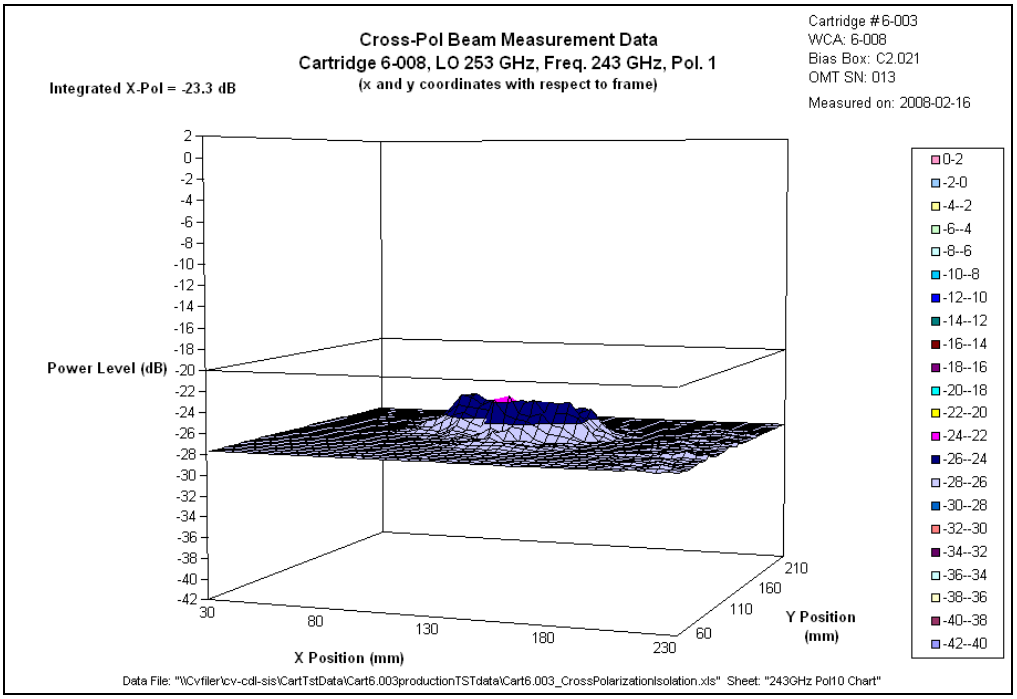


Figure 61: Cross-Polarization Isolation, RF=243 GHz, Pol 1



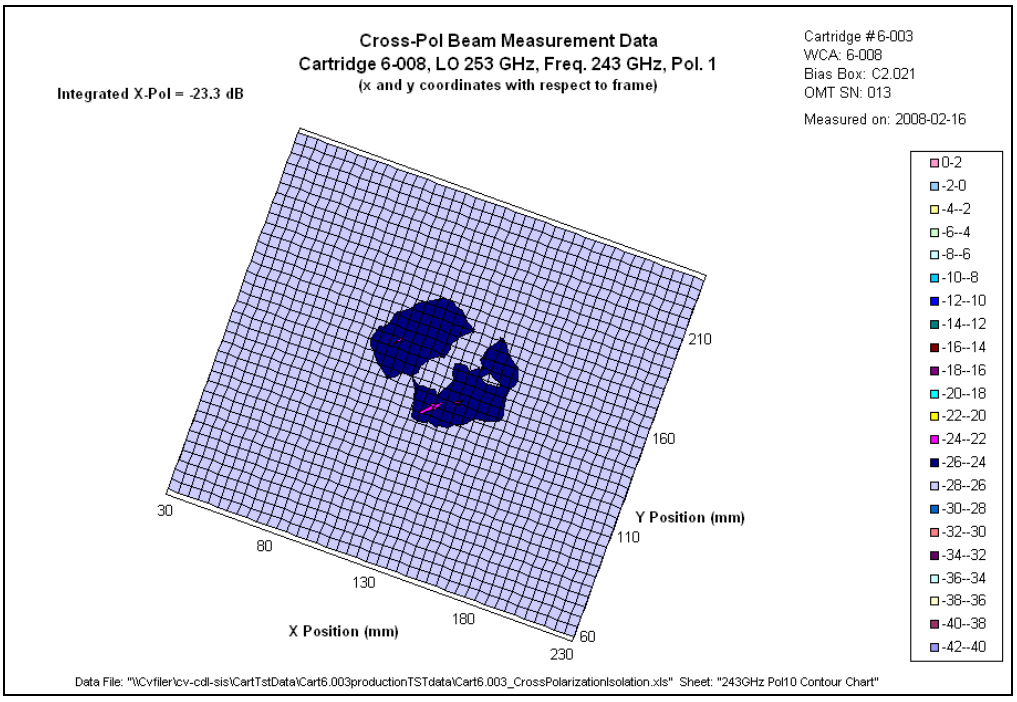
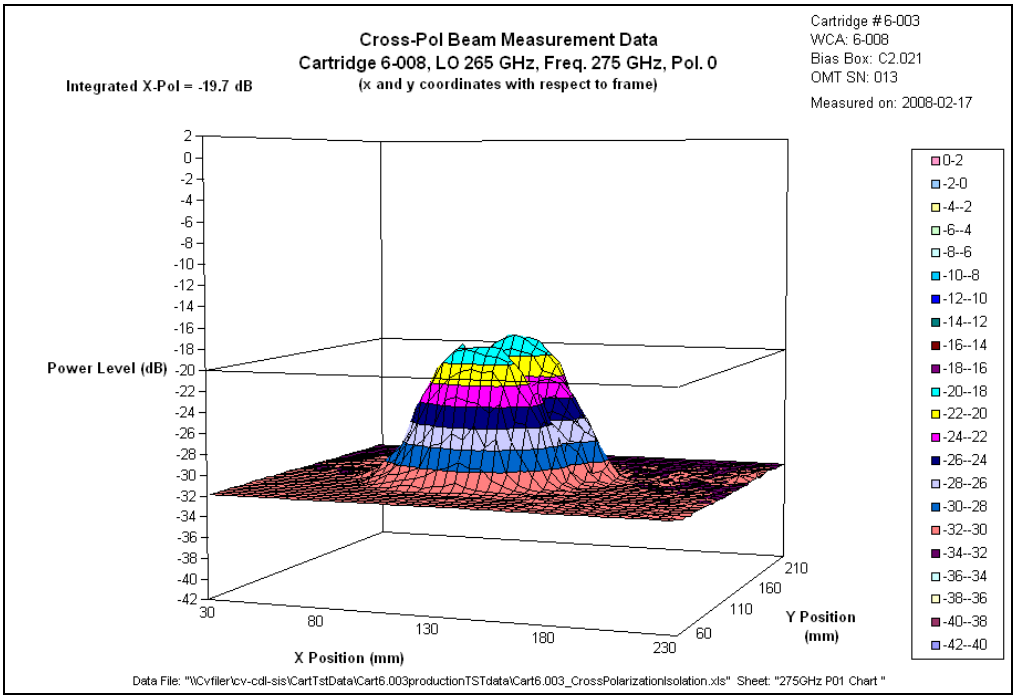


Figure 62: Cross-Polarization Isolation, RF=275 GHz, Pol 0



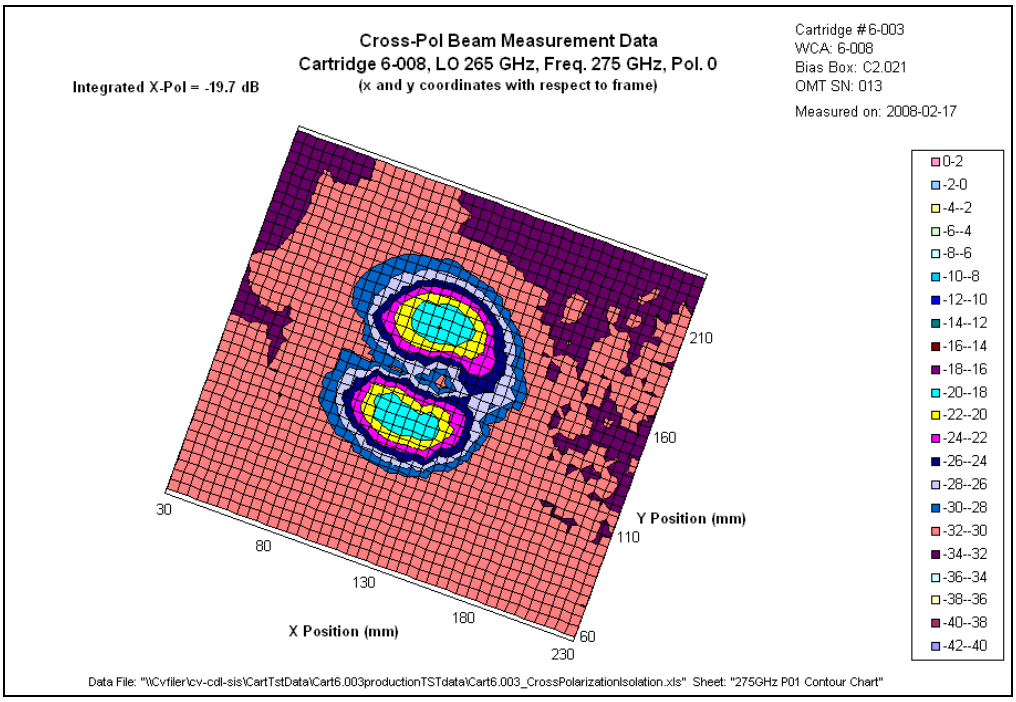
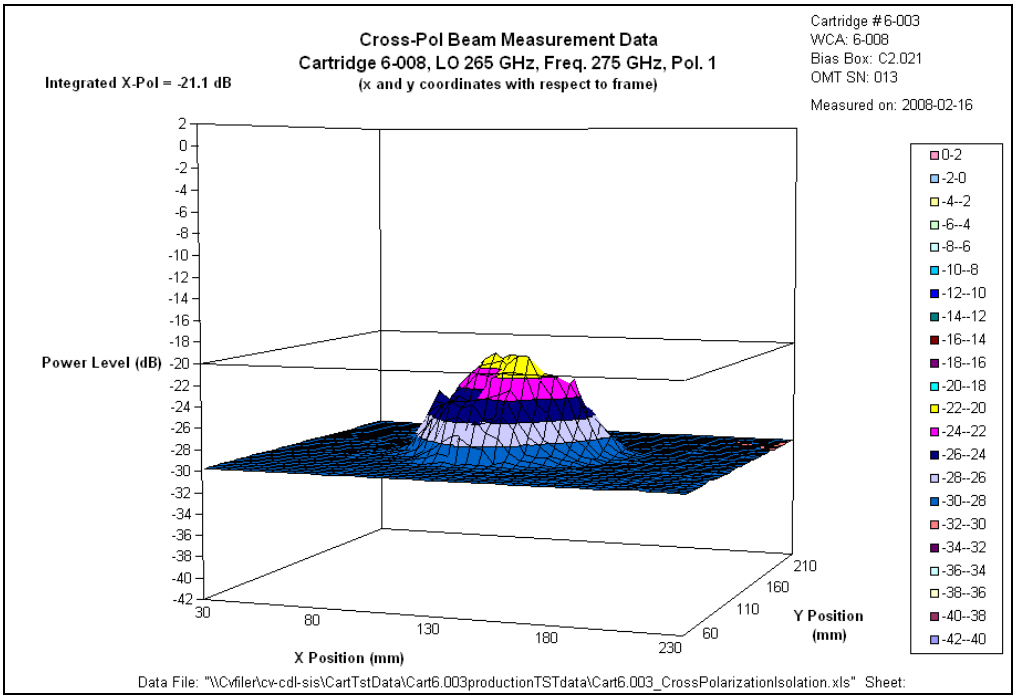
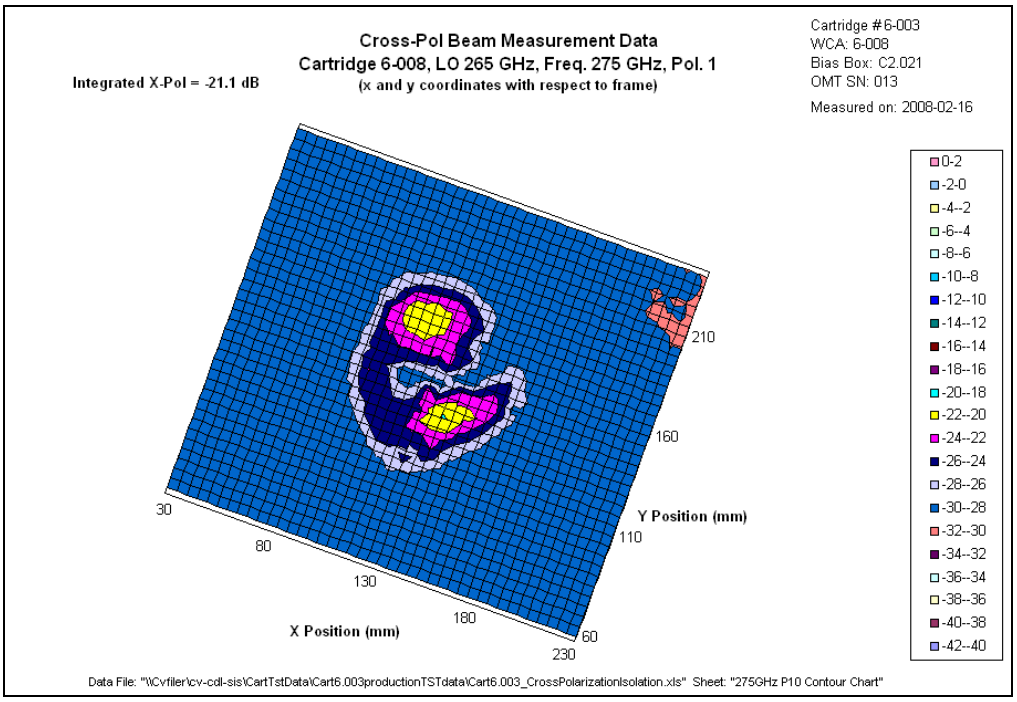


Figure 63: Cross-Polarization Isolation, RF=275 GHz, Pol 1





3.10. Measured Mass (FEND-40.02.06.00-00310-00/T)

Using the procedures given in [RD 22], overall mass and the center of mass were measured for the cartridge and are specified in [RD 22] but repeated here for completeness. The center of mass is shown in Figure 64.

Figure 65 includes a density-volume calculation for the mass of a bare cartridge with no cartridge-specific holes and shows the measured *cold* mass of the cartridge is just 108 g over the cold mass that RAL used to measure cool-down times.

Figure 65 also shows the overall mass of the cartridge is 1.121 kg over specifications given in [AD 01]. For reference, the overall mass of the complete cartridge, which includes:

- cold cartridge assembly with all components,
- warm IF amplifiers and their interconnecting cables, and
- warm cartridge assembly

measures 14.4 kg.

Figure 64: Center of Mass Location

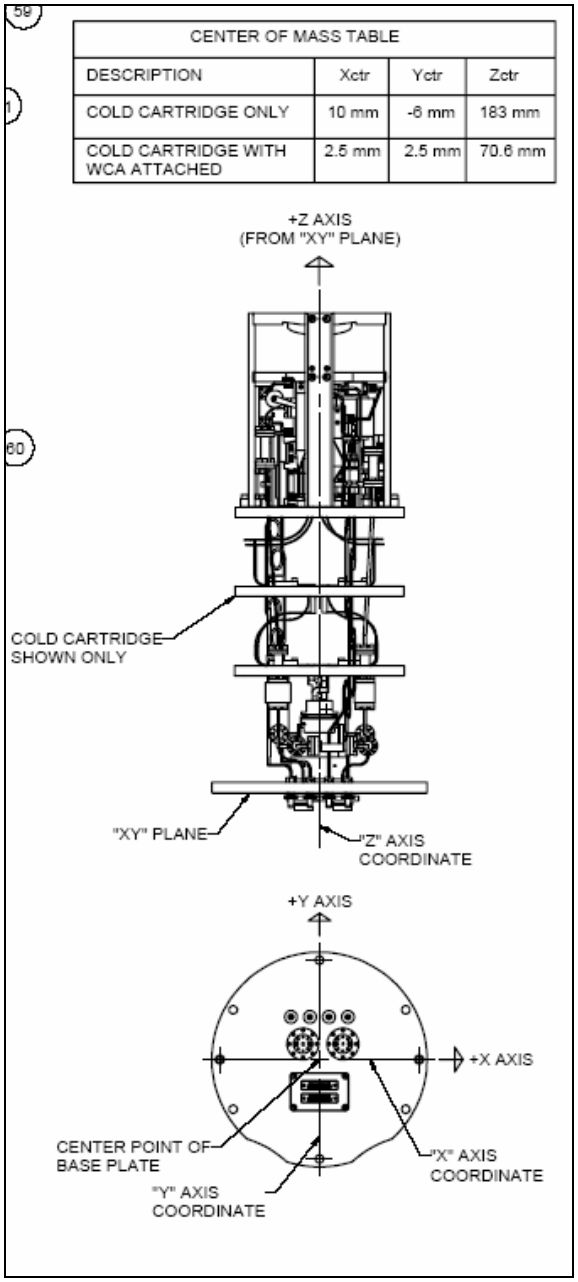


Figure 65: Measured and Calculated Masses

Mass of Band 6 Cartridge												
Unmachined Plates (Calculated Mass)												
Plate	**Material**	**Radius (mm)**	**Height (mm)**	**V (cm^3)**	**Density (g/cm^3)**	**Mass (g)**						
4 K	Copper	84.5	10	224.3	8.950	2,008						
15 K	Copper	84.8	10	225.6	8.950	2,020						
110 K	Aluminum	85.0	10	227.0	2.715	616	4,643	(B) Mass of Un-Machined Cold Stages				
300 K	Stainless	108.0	11	403.1	7.870	3,172	⇦	(D) Mass of 300K Plate				
Machined Plates with Holes (Measured Mass)												
4 K						1,717						
15 K						1,756						
110 K						535						
300 K						2,909						
Mass Removed from Plates (Calculated)												
4 K						291						
15 K						263						
110 K						81	635	(E) Mass removed by				
300 K						263		machining cold stages				
Delivered G-10 Sections (Measured Mass)												
4 K - 15 K						183						
15K- 110K						187						
110K-300K						290						
All Inner Stage Screws (Measured Mass)						86	746	(C) Mass of cartridge body				
								without cold stages and 300 K plate:				
Added mass to cartridge body with no holes						2,000	⇦	(A)				
Mass added to 4K Plate by electronics												
A-Frame with mirror						527.4						
Mirror Mount with Mirror						448.9						
4 Koller Heat Sinks						450.6						
Heat Straps						72.8						
Temp and Heater Mounts						14.3						
Coils, Arms, and Cores						91.9						
OMT, Feedhorn, W/G's						178.3						
MXR-Preamps, Hybrids						531.2						
4 Cables						37.9						
4 2db Pads						29.8						
Ribbon Cable and Pigtail Connectors						22.9						
Screws						59.4	2,465	Total Mass added to				
								4K Plate (Measured)				
Mass Added to 15K Plate (Measured)						139						
Mass Added to 110K Plate (Measured)						139	2,743	(F1) Mass of components				
								on Cold Stages				
Mass of cartridge body as received from RAL					B+C+D-E	9,197						
Mass of material *removed* by machining cold stages					E	635						
Configuration evaluated by RAL for cool down time					A+B+C+D	10,562	⇦	(G)				
Mass of cartridge and *cold* components					B+C+D-E+F1	10,670	⇦	(H)				
Cold Stage mass in excess of configuration tested by RAL					**H-G**	**108**						
Cold cartridge mass with all components (measured)						11,683	⇦	(J)				
Max. specified cold cartridge mass w/ all components					G	10,562						
Total cold cartridge mass in excess of specification					**J-G**	**1,121**						
File:	\\cvfiler.nrao.edu\cv-cdl-sis\Cartridge\Documentation\Center Mass Pics\MassMeas1.xls										Sheet:	Calculated

3.11. Vibration and Acceleration Testing (FEND-40.02.06.00-00480-00/R, T) (FEND-40.02.06.00-00490-00/R, T)

Vibration and acceleration testing of this cartridge is described in [RD 33].

3.12. Eigenfrequency Data (FEND-40.02.06.00-00320-00/A, R)

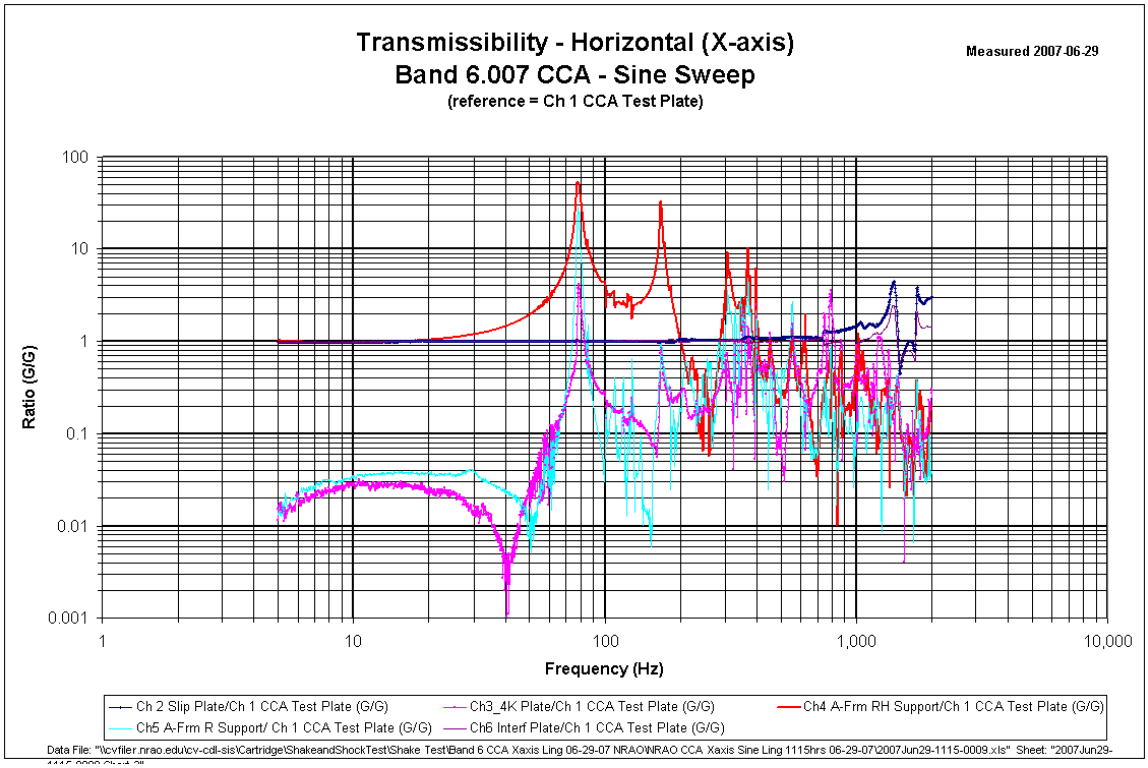
As described in [RD 33], cartridge eigenfrequencies are above the specified 70 Hz limit, but the more meaningful parameter is cartridge mechanical gain[1] present at frequencies below 70 Hz. Figure 66, slightly modified from [RD 33], shows that the cold cartridge body has a mechanical gain of around 6 at 70 Hz and the gain at 70 Hz for all excitation directions is summarized in Table 14.

Table 14: Cartridge 007 Results

Excitation Direction	Eigen-freq. (Hz)	Gain @ 70 Hz
Side-to-Side (x-axis)	78	6
Front-to-Back (y-axis)	79	6
Vertical (z-axis)	85	0.03

[1] Mechanical gain is a dimensionless quantity defined as the acceleration response normalized by the acceleration excitation.

Figure 66: Sample Vibration Gain Data (from Cartridge B6-007)



3.13. Stabilization Time (FEND-40.02.06.00-00300-00/T) (FEND-40.02.06.00-00305-00/T)

The Acceptance Test Plan [RD 04] specifies that stabilization time shall be measured using procedures given in [RD 27] for *one* cartridge from the pre-production batch. The time to stabilize from a non-operational mode for Cartridge B6-004 was measured and the results are provided in the Band 6 Cartridge Design Report, [RD 34].

Stabilization time from the stand-by mode was also measured and is documented in the Band 6 Cartridge Design Report, [RD 34].

3.14. Cartridge Cold Plate Alignment – Angular (FEND-40.03.00.00-00230-00/T)

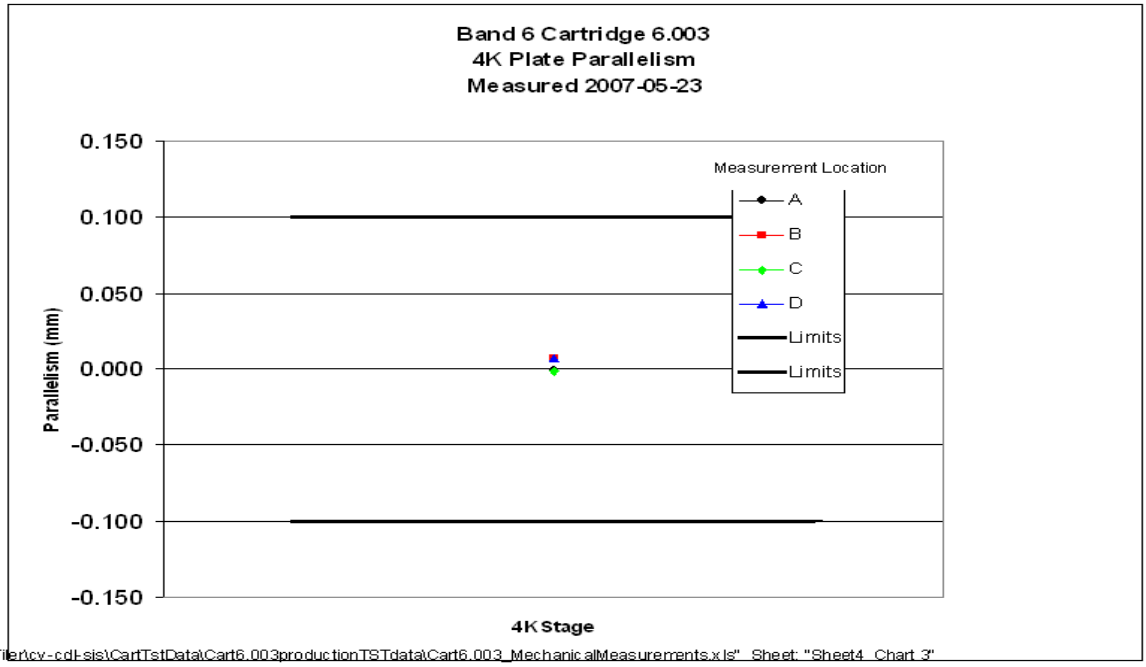
Mechanical measurements of the cold cartridge body after installation of the Band 6 components were performed to confirm the cartridge continues to meet RAL's angular, horizontal, and vertical alignment specifications given in [RD 32].

The cryostat specification states the cold plate (4K) angular alignment shall be < 1 mrad.

Mechanical measurements of parallelism using the procedures in [RD 25] and summarized in Figure 67 show the worse-case parallelism is 0.007 mm so the angular misalignment is:

$$\theta_{Tilt} = \tan^{-1}\left(\frac{0.007}{169}\right) = \quad 0.04 \text{ mrad}$$

Figure 67: Measured Parallelism of 4K Plate



3.15. Cartridge Cold Plate Alignment – Linear (FEND-40.03.00.00-00235-00/T)

The cryostat linear specification states the cold plate (4K) linear alignment shall be < 0.8 mm in horizontal directions and < 3.0 mm in the vertical direction.

Concentricity measured relative to the 300K plate using the procedures in [RD 25] and presented in Figure 68 show horizontal alignment is well within specifications.

Vertical alignment is also well within specifications, as shown in Figure 69.

Figure 68: Measured Concentricity of 4K Plate

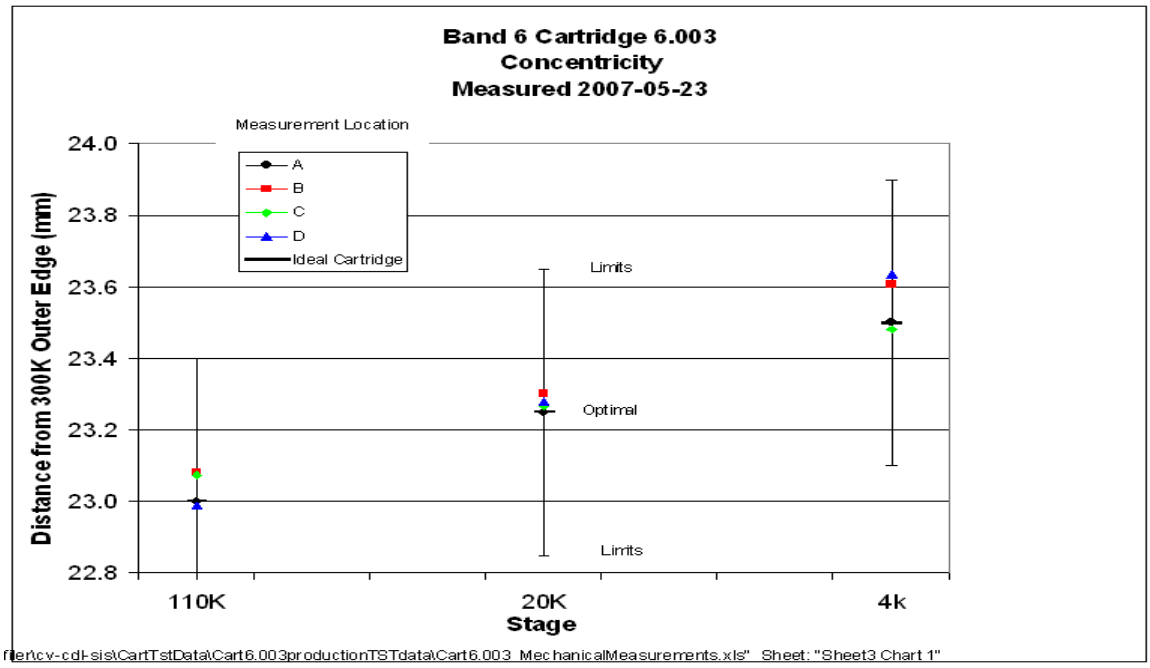
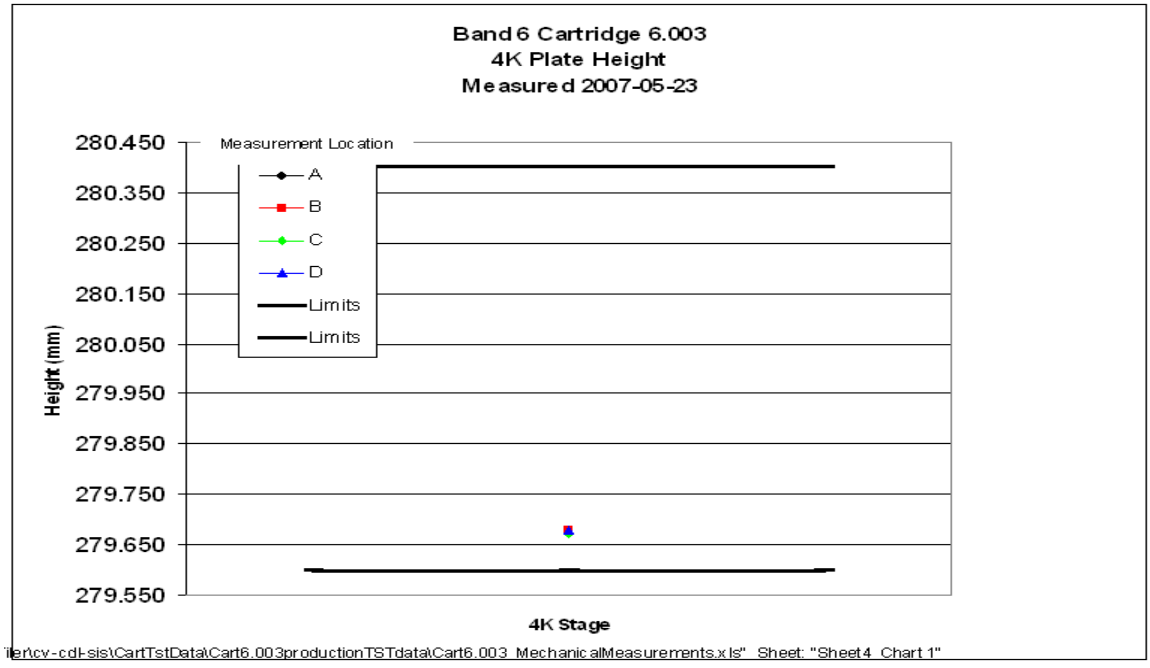


Figure 69: Measured Height of 4K Plate



3.16. Spurious Frequencies (FEND-40.00.00.00-00120-00/T)

Spurious response data was measured according to the procedures given in [RD 14]. As shown in Figure 70 and Figure 71, no spurious responses are observed in the IF output spectrum when the receiver is connected to the cold load.

Figure 70: Spurious Response for Pol 0

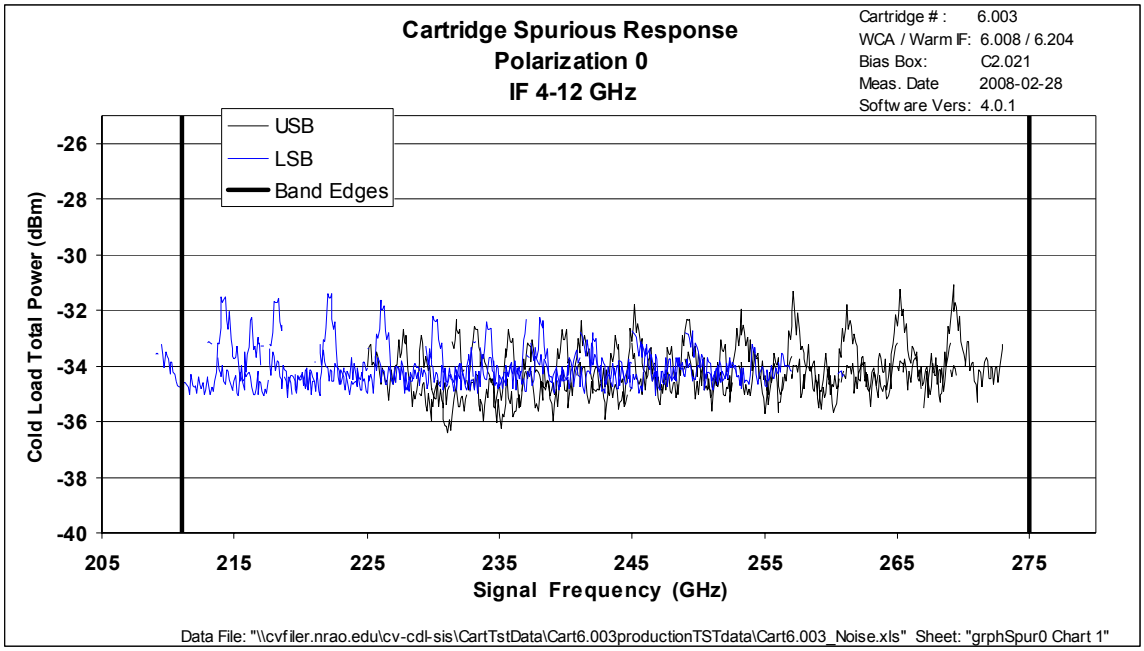
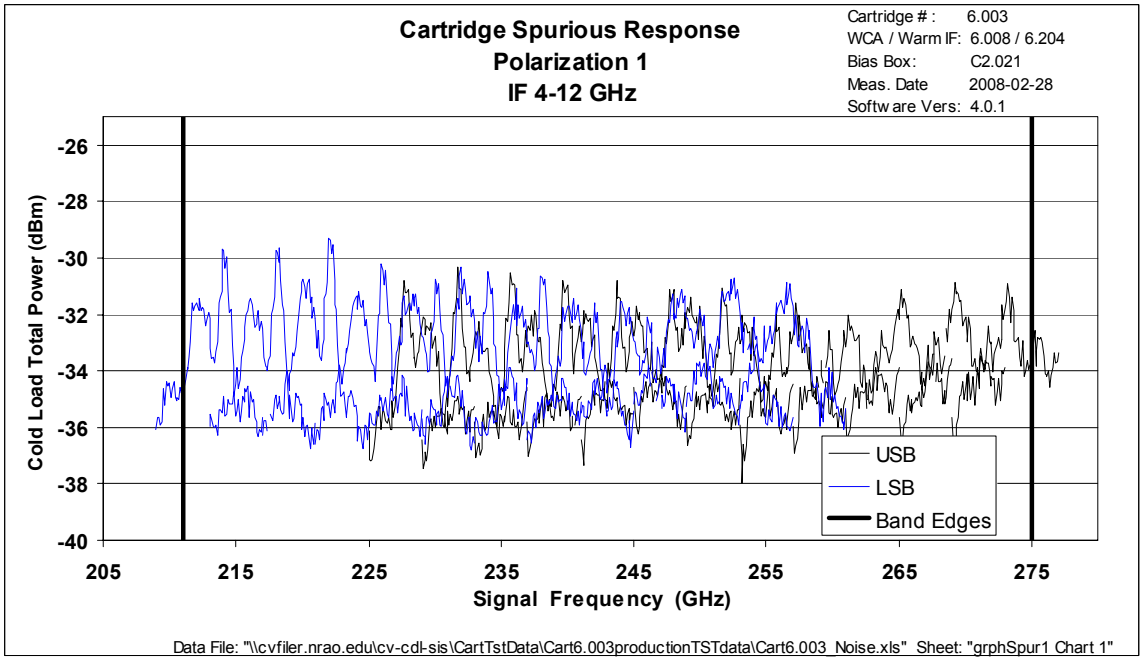


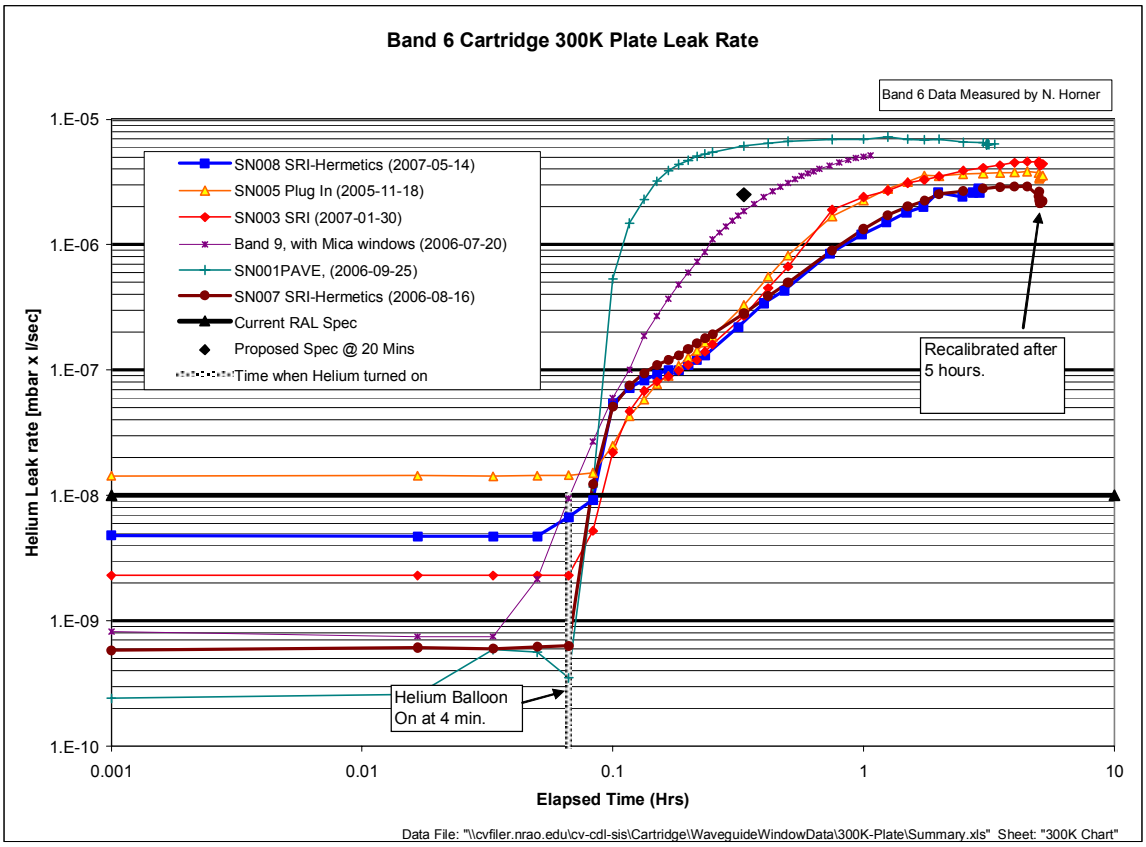
Figure 71: Spurious Response for Pol 1



3.17. Leak Rate (FEND-40.02.06.00-00470-00/R)

Using the procedures given in [RD 24], the leak rate of the 300K plate was measured and is 2.8×10-7 mbar×liters/sec after 20 minutes. The leak rate is compared in Figure 72 to leak rates of other 300K plates.

Figure 72: Measured Leak Rates of 300K Plates



4. Rework Status

The known rework remaining for the cartridge is shown in Figure 73. Replacement of the waxed lacing cord and Buna-n o-rings will improve cartridge outgassing properties, and the SRI connector will tentatively be replaced by a Glenair connector for better reliability.

Figure 73: Rework Status of Band 6 Cartridges

	Cartridge Serial Number							
	001	002	003	004	005	006	007	008
Rework								
Low Loss OMWG from Aerowave	2008-01-04	2006-12-01	2007-01-23	2006-12-01	2006-12-01	2007-06-12	2006-12-01	2007-02-06
Heater Resistors replaced with 290 ohm	2006-10-04	2006-10-06	2007-01-23	2006-10-10	2006-10-14	2007-06-12	2006-10-24	2007-02-09
LED wiring updated	2006-10-04	2006-10-06	2007-01-23	2006-10-10	2006-10-14	2007-06-12	2006-10-24	2007-02-09
2nd LO Waveguide Support	2007-12-27	2006-10-06	2007-01-23	2007-11-03	2006-11-03	2007-06-12	2006-10-24	2007-02-06
3rd & 4th LO Waveguide Support	2007-12-27	2006-12-14	2007-01-17	2007-02-26	2006-08-07	2007-06-12	2006-12-14	2007-02-06
SRI Hermetics Connector Installed	2007-12-26	2007-02-21	2007-01-29	2006-09-27	2007-02-20	2007-02-16	2007-02-21	2007-02-06
Mixer Hybrid screwed into A-Frame		2006-10-06	2007-01-29	2006-10-10	2006-10-14	2007-06-12	2006-10-24	2007-02-08
IF cables replaced with ruggedized connectors		2006-10-24	2007-01-29		2006-11-03	2007-06-12	2006-10-24	2007-02-09
G10 Sections with proper foil	2007-02-24	2006-10-06	2007-02-16	2006-10-06	2006-11-03	2006-10-06	2006-10-06	2007-02-06
Tapped holes in 300K section	2008-01-04	2007-01-23	2007-01-23	2006-10-15	2006-09-20	2006-10-15	2006-10-15	2007-02-06
Add frame gnds to pigtails	Not Used	Not Used	Not Used	2007-05-07	Not Used	Not Used	Not Used	2007-04-20
Remove frame gnds to pigtails	Not Used	Not Used	Not Used	2007-05-18	Not Used	Not Used	Not Used	2007-05-11
Install Bias protection cards with frame gnds	2008-01-07	2007-05-24	2007-08-10	2007-05-18	2007-06-14	2007-06-12	2007-05-23	2007-05-11
Cover holes in 110K and 15K plates	2008-01-04				2007-06-14	2007-06-12		
Install Mixer-Preamps with Potted Connectors		2007-05-24	2007-05-20	2007-05-18	2007-06-14	2007-06-12	2007-05-23	2007-04-20
Intall horns with chamfered rims	2008-01-07	2007-05-24	2007-08-10	2007-05-18	2007-06-14	2007-06-12	2007-05-23	2007-04-25
Install shield for bias protection card	2008-01-07	2007-11-30	2007-07-10	2008-01-23	2007-07-23	2007-10-25	2007-07-30	
Add epoxy to magnet coil iron pieces		2007-11-30	2007-07-20	2008-01-23	2007-08-02	2007-08-15	2007-08-15	
Check ESN on bias protection cards.	2008-01-07	2007-11-30	2007-08-15	2008-01-23	2007-11-27	2007-10-25	2007-10-15	
Replace Glued G10 sections	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Replace Buna-N with Viton O-Rings	2008-01-04			2008-01-23				
Replace Waxed Lacing Cord with Dacron Cord		2007-11-30		2008-01-23				
Replace SRI Connector with Glenair								
Key:	Green Cells - Rework completed							
File:	\\cvfiler.nrao.edu\cv-cdl-sis\Cartridge\Production\Status.xls							
Viewing Date:	2008-01-30 17:40							

5. Compliance Matrix

The table below discusses compliance for each requirement.

Serial No	Item	Specification Num. FEND-40.04.06.00- (unless otherwise specified)	Measured Value	Method	Status	Ref. Section or Figure	Comments
1	**General Requirements**						
1.1	**Operation modes**						
1.1.1	Operational	00010-00/I		D	NT		Compliance confirmed at CDR.
1.1.2	Non-operational	00020-00/I		D	NT		Compliance confirmed at CDR.
1.1.3	Stand-by	00025-00/I		D	NT		Compliance confirmed at CDR.
1.1.4	Transport with antenna transporter	00030-00/I		D	NT		Compliance confirmed at CDR.
1.1.5	Transport with the front end service vehicle	00040-00/I		D	NT		Compliance confirmed at CDR.
1.2	Compatibility with front end	00050-00/I		D	NT		Compliance confirmed at CDR.
1.3	**Design for production**						
1.3.1	Technology	00060-00/R		D	NT		Compliance confirmed at CDR.
1.3.2	Series production	00070-00/R		D	NT		Compliance confirmed at CDR.
1.3.3	Standard parts	00080-00/R		D	NT		Compliance confirmed at CDR.
1.4	Mechanical tuning	00090-00/R		D	NT		Compliance confirmed at CDR.
1.5	Metric hardware	00110-00/R		D	PC		The design was reviewed for compliance at the CDR. Some internal mixer and preamp fasteners, which are not handled by ALMA

Serial No	Item	Specification Num. FEND-40.04.06.00- (unless otherwise specified)	Measured Value	Method	Status	Ref. Section or Figure	Comments
							site personnel, are Imperial. Details in [RD 31].
1.6	Solar observing and safety	FEND-40.00.00.00-00050-00/A, T		D	NT		No testing is planned for verification of this requirement. This is an overall FE requirement and analysis shall be reviewed at *Front End* CDR.
2	**Functional Requirements**						
2.1	Mixer type	00120-00/R	SIS mixer type	D	NT		Compliance confirmed at CDR.
2.2	Mixing scheme	00130-00/R	Sideband separating with both sidebands available	D	NT		Compliance confirmed at CDR.
2.3	Frequency coverage						
2.3.1	RF input port	00140-00/R	211-275 GHz	D	NT		Compliance confirmed at CDR.
2.3.2	LO input port	00150-00/R	221-263 GHz	D	NT		Compliance confirmed at CDR.
2.3.3	IF output bandwidth	00160-00/R	Each polarization provides 8 GHz	D	NT		Compliance confirmed at CDR.
2.4	Polarization state	00170-00/R	Dual linear	D	NT		Compliance confirmed at CDR.
3	**Performance Requirements**						
3.1	Cartridge noise performance	00180-00/T	Noise in 100 MHz BW is worse than 1.25 times mean noise temp. by the following percentages: Pol 0 USB = 13.6 % Pol 0 LSB = 3.7 % Pol 1 USB = 12.7 % Pol 1 LSB = 2.3 %	T	NC	3.1 Table 7	RFW submitted ([RD 38]), but note that new revised FE specifications ([RD 41]) no longer include this requirement.

Serial No	Item	Specification Num. FEND-40.04.06.00- (unless otherwise specified)	Measured Value	Method	Status	Ref. Section or Figure	Comments
3.2	Image band suppression or sideband mismatch	00190-00/T	All image rejection ≥ 10 dB	T	C	3.1.1 Table 8 Figure 7 Figure 8	
3.3	Cartridge IF output						
3.3.1	IF output power	00200-00/T					
3.3.1.1	*Total in-band power*		Pol 0: -32 < LSB < -29 dBm -32 < USB < -29 dBm Pol 1: -30.5 < LSB < -28 dBm -29.5 < USB < -27 dBm	T	C	3.2 Figure 35 Figure 36	
3.3.1.2	*Total power*		Pol 0 : -29 ≤ LSB ≤ -27.5 dBm -30 ≤ USB ≤ -27.5 dBm Pol 1: -28 ≤ LSB ≤ -26 dBm -29.5 ≤ USB ≤ -27 dBm	T	C	3.2 Figure 37	
3.3.2	IF power variations	00210-00/T					
3.3.2.1	*2 GHz sub-band*		Pol 0: 4.0 dB Pol 1: 6.0 dB	T	NC	3.2 Figure 33 Figure 34	Pol 1 exceeds max gain slope specification of 4 dB. RFW [RD 43] filed.
3.3.2.2	*Full IF band (4 GHz)*		Pol 0: 4.0 dB Pol 1: 6.2 dB	T	NC	3.2 Figure 31 Figure 32	Pol 1 exceeds max gain slope specification of 6.0 dB RFW [RD 43] filed.
3.4	Gain saturation/compression	00230-00/T	Pol 0: 1.9% Pol 1: 1.3 %	T	C	3.3 Figure 38	

Serial No	Item	Specification Num. FEND-40.04.06.00- (unless otherwise specified)	Measured Value	Method	Status	Ref. Section or Figure	Comments
3.5	Amplitude stability	00240-00/T					
3.5.1	*Allan variance of IF output power in any channel*		Pol 0: $\leq 2 \times 10^{-7}$ @ 0.1s $\leq 4 \times 10^{-5}$ @ 100s Pol 1: $\leq 2 \times 10^{-7}$ @ 0.1s $\leq 4 \times 10^{-5}$ @ 100s	T	C	3.4 Figure 40 Figure 41	
3.5.2	*Differential polarization Allan variance*				NT		Shall be evaluated at the ATF on the sky.
3.6	Signal path phase stability	00250-00/T	Pol 0, 221 GHz: $\leq$ 8 $\times 10^{-2}$ degs @ 10s $\leq$ **7 $\times 10^{-1}$ degs @ 300s** Pol 1:, 221 GHz $\leq$ 1 $\times 10^{-1}$ degs @ 10s $\leq$ 5 $\times 10^{-1}$ degs @ 300s Pol 0, 245 GHz: $\leq$ 9 $\times 10^{-2}$ degs @ 10s $\leq$ **7.5 $\times 10^{-1}$ degs @ 300s** Pol 1:, 245 GHz $\leq$ 1 $\times 10^{-1}$ degs @ 10s $\leq$ 5 $\times 10^{-1}$ degs @ 300s Pol 0, 265 GHz: $\leq$ 1 $\times 10^{-1}$ degs @ 10s $\leq$ **2 $\times 10^{-1}$ degs @ 300s** Pol 1:, 265 GHz $\leq$ 1 $\times 10^{-1}$ degs @ 10s $\leq$ **8 $\times 10^{-1}$ degs @ 300s**	T	NC	3.5 Figure 42 Figure 43 Figure 44 Figure 45 Figure 46 Figure 47	Phase stabilities worse than spec are shown by bold and underlined font. RFW filed: [RD 44].

Serial No	Item	Specification Num. FEND-40.04.06.00- (unless otherwise specified)	Measured Value	Method	Status	Ref. Section or Figure	Comments
3.7	Optics						
3.7.1	RF beam efficiency	00260-00/T	Pol 0: ≥ 93.1% Pol 1: > 93.2%	T	C	3.6 Figure 54	Although specifications [AD 01] require efficiencies greater than 90%, cartridge must meet 92% efficiency when tolerance and pointing losses are included.
3.7.2	Edge Taper	00260-00/T	10 dB at 239 GHz	T	NC	3.6	The edge taper specification is 10.5 dB in [AD 01] and the North American Front End Integration Center measures 10 dB at 239 GHz. RFW [RD 42] filed.
3.7.3	Polarization alignment	00270-00/T	Pol 0 aligned with RAL cartridge radius axis	T	C	3.7 Table 12	
3.7.4	Polarization alignment accuracy	00280-00/T	+1.0° ≤ Pol 0 ≤ +1.0° +0.5° ≤ Pol 1 ≤ +2.0°	T	C	3.8 Figure 57	
3.7.5	Cross-polarization Isolation	00290-00/T	18.6 dB @ 271 GHz and 18.0 dB @ 275 GHz Cross-Pol is ≥ 20 dB at all other 18 measured frequencies	T	NC	3.9 Table 13	RFW [RD 40] submitted.
3.8	Stabilization time						
3.8.1	From non-operational mode	00300-00/T	Allan Deviation: 0.08 degs @ 1 s 0.5 degs @ 300 s	T	C	3.13	By design, controlled by LO stabilization time.
3.8.2	From stand-by mode	00305-00/T	< 3 s	T	C	3.13	By design, controlled by LO stabilization time.
3.9	Spurious Response	FEND-40.00.00.00-00120-00/T	None Observed	T	C	3.16 Figure 70 Figure 71	

Serial No	Item	Specification Num. FEND-40.04.06.00- (unless otherwise specified)	Measured Value	Method	Status	Ref. Section or Figure	Comments
4	**Mechanical and Electrical Requirements**						
4.1	Mass	00310-00/T	11.7 kg complete cold cartridge 10.7 kg cold mass	T	NC	3.10 Figure 65	Complete cold cartridge mass spec is 10.6 kg so cartridge is 1.12 kg over. Mass for RAL cool-down test was 10.56 kg and mass of cold stages is just 0.11 kg over. Generic RFW [RD 39] submitted.
4.2	Eigen-frequency	00320-00/A, R	**Table 14: Cartridge 007 Results** **Excitation Direction** / **Eigen-freq. (Hz)** / **Gain @ 70 Hz** Side-to-Side (x-axis) / 78 / 6 Front-to-Back (y-axis) / 79 / 6 Vertical (z-axis) / 85 / 0.03	T	C	3.11 Table 14	Spec is compliant, but see referenced section for description of mechanical gain present below 70 Hz.
4.3	Volume	00330-00/I	Dia = 140 mm Length = 475 mm	D	C		Compliance confirmed at CDR.
4.4	Orientation	00340-00/A, R, T		T	NT		Testing not required by cartridge group, as confirmed in Cartridge Test Plan [RD 04]. To be tested at FEIC.
4.5	Thermal load	00350-00/A	4K: 1.8 mW 15K: 68 mW 110K: 680 mW	A	C		Compliance confirmed at CDR. Details in [RD 34]
4.6	Bias requirements	00360-00/R	SIS 6-wire	D	C		Compliance confirmed at CDR. Details in bias ICD [RD 35]

Serial No	Item	Specification Num. FEND-40.04.06.00- (unless otherwise specified)	Measured Value	Method	Status	Ref. Section or Figure	Comments
4.7	Connectors and RF ports						
4.7.1	RF input port interface	00370-00/R	Mirrors/Horn	D	C		
4.7.2	LO input port interface	00380-00/R, I	WR-10 waveguide	D	C		
4.7.3	IF output port interface	00390-00/R, I	Female BMA coax	D	C		Compliance confirmed at CDR. Complies with IF Switch ICD [RD 08]
4.7.4	Bias connectors	00400-00/R, I		D	C		Compliance confirmed at CDR.
4.8	Cartridge cold plate alignment	FEND-40.03.00.00-00230-00/T[2] and FEND-40.03.00.00-00235-00/T[3]	Angular = 0.04 mrad Misalignment: Vertical = ±400 µm Horizontal = ±200 µm	T	C	3.14, 3.15 Figure 67 Figure 69 Figure 68	

[2] Spec from [RD 32] (slightly restated): "The tilt of any "4 K" stage relative to the plane of the mechanical interface between FESS and cryostat shall be < 1 mrad angular misalignment.

[3] Spec from [RD 32]: "The position of the actual centre of any "4 K" stage relative to the centre of the cryostat top plate compared to the nominal position shall be less than the following values:

- Linear misalignment in horizontal direction* : < 0.8 mm
- Linear misalignment in vertical direction +: < 3.0 mm

* Translation of the actual centre of the "4 K" stage versus the nominal centre 2

+ Actual position of a point at the top of the "4 K" stage versus the nominal position of that point

The vertical direction being defined as perpendicular to the plane in which the FESS ring is located.

Serial No	Item	Specification Num. FEND-40.04.06.00- (unless otherwise specified)	Measured Value	Method	Status	Ref. Section or Figure	Comments
5	**Operating Conditions**						
5.1	Local oscillator	The following seven LO test requirements shall be met by providing copies of the LO test documentation data from measurements made at the time of in-house and on-site LO acceptance testing. All LO assemblies should have been tested for compliance to these test requirements prior to their integration with the receiver cartridge.					
5.1.1	LO input port	00420-00/T					Testing not required for Band 6 PAI
5.1.2	LO power requirement	00430-00/T					Testing not required for Band 6 PAI
5.1.3	LO sideband and phase noise	00440-00/T					Testing not required for Band 6 PAI
5.1.4	LO amplitude stability	00450-00/T					Testing not required for Band 6 PAI
5.1.5	LO phase stability	FEND-40.00.00.00-00600-00/T					Testing not required for Band 6 PAI
5.1.6	LO frequency switching	FEND-40.00.00.00-00530-00/T to FEND-40.00.00.00-00590-00/T					Testing not required for Band 6 PAI
5.1.7	LO phase switching	FEND-40.00.00.00-00630-00/T					Testing not required for Band 6 PAI
5.2	Thermal environment	00460-00/T		A	NT		All cryostats should have been tested for compliance to these test requirements prior to their delivery to the integration center.
5.2.1	*Temperature ranges*						Testing not required for Band 6 PAI
5.2.2	*Temperature stability*						Testing not required for Band 6 PAI
5.2.3	*Warm-up time*						Testing not required for Band 6 PAI
5.3	Vacuum conditions	00470-00/R	2×10^{-7} mbar×liters/sec after 20 minutes	T	C	3.17 Figure 72	Meets the revised 20-min spec given in [RD 45]

Serial No	Item	Specification Num. FEND-40.04.06.00- (unless otherwise specified)	Measured Value	Method	Status	Ref. Section or Figure	Comments
5.4	Environmental operating conditions						
5.4.1	Vibration	00480-00/R, T		T	C	3.11	
5.4.2	Acceleration	00490-00/R, T		T	C	3.11	
5.5	Storage/shipping conditions	00500-00/R		D	NT		Compliance confirmed at CDR.
5.6	Electromagnetic compatibility	00510-00/T		T	NT		To be tested at the FEIC.
5.7	Radio frequency interference	FEND-40.00.00.00-00730-00/T		T	NT		To be tested at the FEIC.
5.8	Monitor and control						
5.8.1	Mixer voltage and current	00520-00/R		D	C		Compliance confirmed at CDR.
5.8.2	Magnet current	00530-00/R		D	C		Compliance confirmed at CDR.
5.8.3	Temperature	00540-00/R		D	C		Compliance confirmed at CDR.
5.8.4	Removal of trapped flux	00550-00/R		D	C		Compliance confirmed at CDR.
6	**Reliability, Availability, Maintainability and Safety Requirements**						
6.1	Continuous operation	00560-00/R		D	NT		Compliance confirmed at CDR.
6.2	Mean time between failure	00570-00/A		D	NT		Compliance confirmed at CDR.
6.3	Lifetime	00580-00/R		D	NT		Compliance confirmed at CDR.

6. Discrepancy Matrix

The table below lists requirements not meeting full specifications.

Serial No	Item	Specification Num. FEND-40.04.06.00- (unless otherwise specified)	Measured Value	Method	Status	Ref. Section or Figure	Comments
3.1	Cartridge noise performance	00180-00/T	Noise in 100 MHz BW is worse than 1.25 times mean noise temp. by the following percentages: Pol 0 USB = 13.6 % Pol 0 LSB = 3.7 % Pol 1 USB = 12.7 % Pol 1 LSB = 2.3 %	T	NC	3.1 Table 7	RFW submitted ([RD 38]), but note that new revised FE specifications ([RD 41]) no longer include this requirement.
3.7.5	Cross-polarization Isolation	00290-00/T	18.6 dB @ 271 GHz and 18.0 dB @ 275 GHz Cross-Pol is > 20 dB at all other 18 measured frequencies	T	NC	3.9 Table 13	RFW [RD 40] submitted.
3.3.2	IF power variations	00210-00/T					
3.3.2.1	*2 GHz sub-band*		Pol 0: 4.0 dB Pol 1: 6.0 dB	T	NC	3.2 Figure 33 Figure 34	Pol 1 exceeds max gain slope specification of 4 dB. RFW [RD 43] filed.
3.3.2.2	*Full IF band (4 GHz)*		Pol 0: 4.0 dB Pol 1: 6.2 dB	T	NC	3.2 Figure 31 Figure 32	Pol 1 exceeds max gain slope specification of 6.0 dB RFW [RD 43] filed.

Serial No	Item	Specification Num. FEND-40.04.06.00- (unless otherwise specified)	Measured Value	Method	Status	Ref. Section or Figure	Comments
3.6	Signal path phase stability	00250-00/T	Pol 0, 221 GHz: < 8 × 10-2 degs @ 10s < 7 × 10-1 degs @ 300s Pol 1:, 221 GHz < 1 × 10-1 degs @ 10s < 5 × 10-1 degs @ 300s Pol 0, 245 GHz: < 9 × 10-2 degs @ 10s < 7.5 × 10-1 degs @ 300s Pol 1:, 245 GHz < 1 × 10-1 degs @ 10s < 5 × 10-1 degs @ 300s Pol 0, 265 GHz: < 1 × 10-1 degs @ 10s < 2 × 10-1 degs @ 300s Pol 1:, 265 GHz < 1 × 10-1 degs @ 10s < 8 × 10-1 degs @ 300s	T	NC	3.5 Figure 42 Figure 43 Figure 44 Figure 45 Figure 46 Figure 47	Phase stabilities worse than spec are shown by bold and underlined font. RFW filed: [RD 44].
3.7.2	Edge Taper	00260-00/T	10 dB at 239 GHz	T	NC	3.6	The edge taper specification is 10.5 dB in [AD 01] and the North American Front End Integration Center measures 10 dB at 239 GHz. RFW [RD 42] filed.
1.5	Metric hardware	00110-00/R		D	PC		The design was reviewed for compliance at the CDR. Some internal mixer and preamp

Serial No	Item	Specification Num. FEND-40.04.06.00- (unless otherwise specified)	Measured Value	Method	Status	Ref. Section or Figure	Comments
							fasteners, which are not handled by ALMA site personnel, are Imperial. Details in [RD 31].
4.1	Mass	00310-00/T	11.7 kg complete cold cartridge 10.7 kg cold mass	T	NC	3.10 Figure 65	Complete cold cartridge mass spec is 10.6 kg so cartridge is 1.12 kg over. Mass for RAL cool-down test was 10.56 kg and mass of cold stages is just 0.11 kg over. Generic RFW [RD 39] submitted.