大型国際プロジェクトと大学の役割
ALMAの場合

長谷川哲夫
国立天文台チリ観測所

自己紹介：ALMAにおける役割

- 1980- 野辺山宇宙電波観測所
  - 1983「野辺山の次」ブレーンストーミング参加
- 1988- 東大天文センター
  - 60cm望遠鏡2号機をチリに設置・運用
  - ASTE（アタカマ10mサブミリ波望遠鏡）の設置に参加
  - 学術会議天文研連委員としてLMSA計画を推進（シンポジウムの企画・実行など）
- 2000- 国立天文台
  - 2001-2004 日本側プロジェクトサイエンティスト
  - 2004-2008 日本側プロジェクトマネジャー
  - 2008-2012 JAO副プロジェクトマネジャー（チリ赴任）
  - 2012-2016 チリ観測所長（チリ赴任）

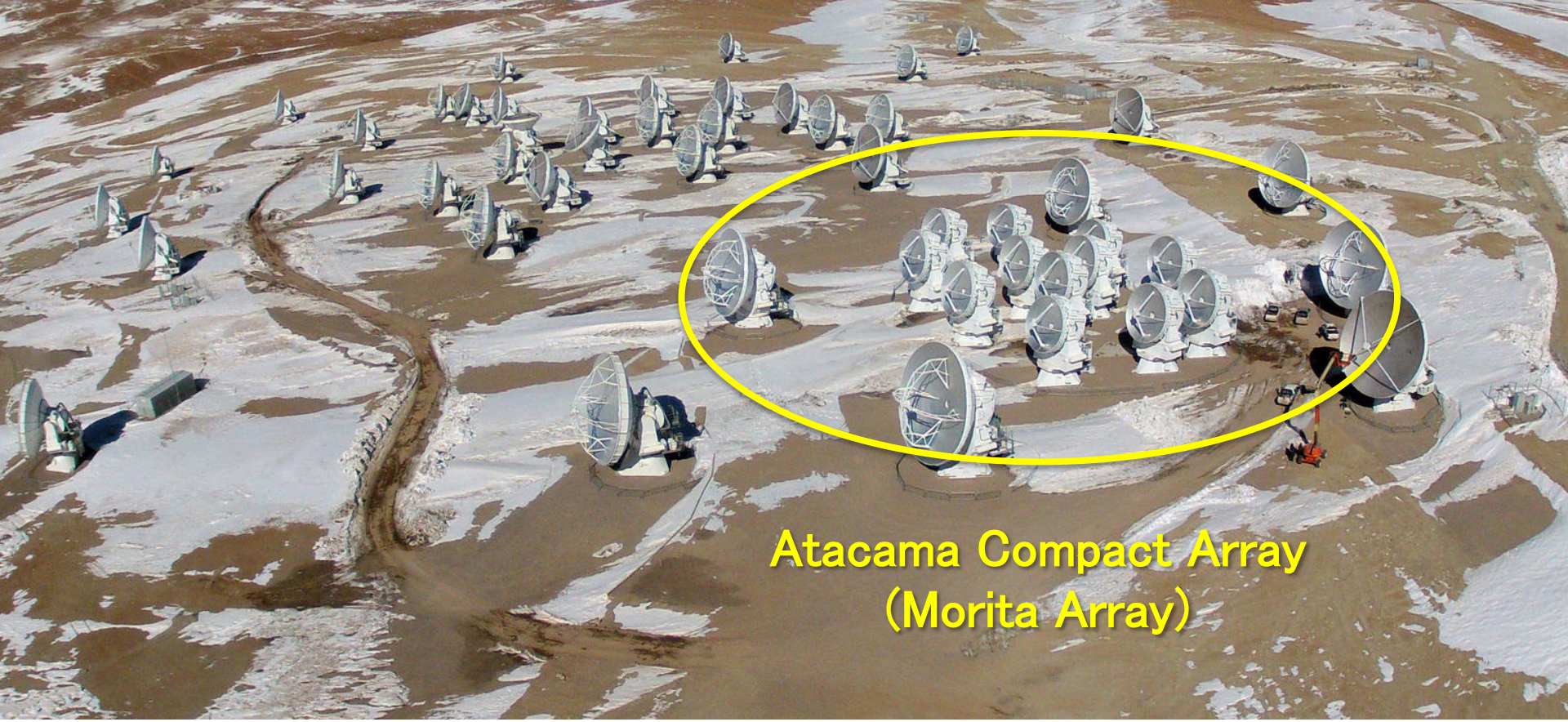
ALMA has three roots

- Started more than 30 years ago
  - LMSA (Japan, 1983-) 10-m x 50 antennas at a high altitude site in Chile, submillimeter wave
  - MMA (USA, 1983-) 8-m x 40 antennas at Hawaii, millimeter wave
  - LSA (ESO, 1991-) 15-m x 50 antennas at medium altitude site in Chile, millimeter wave


Signing a resolution for 3-way collaboration for ALMA
(2001 Apr, Tokyo)

Construction of ALMA

- 2002 North America and ESO part funded
- 2003 Groundbreaking
- 2004 Japanese part funded
- 2007 First antenna at the 2900 m site
- 2008 First receiver at the 2900 m site
- 2009 First antenna at the 5000 m site
- 2009 First fringe between two antennas
- 2011 Early science operation started
- 2013 Inauguration
- 2014 66^{th} antenna at the 5000 m site



Japan contributes 25%

The Atacama Compact Array (ACA) System

- Four 12-m and twelve 7-m precision antennas
- ACA correlator (ultra-high speed computer)

Receiver cartridges installed in all ALMA antennas (three bands at wavelengths 2mm, 0.6mm, and 0.35mm)

Computing software (joint development)

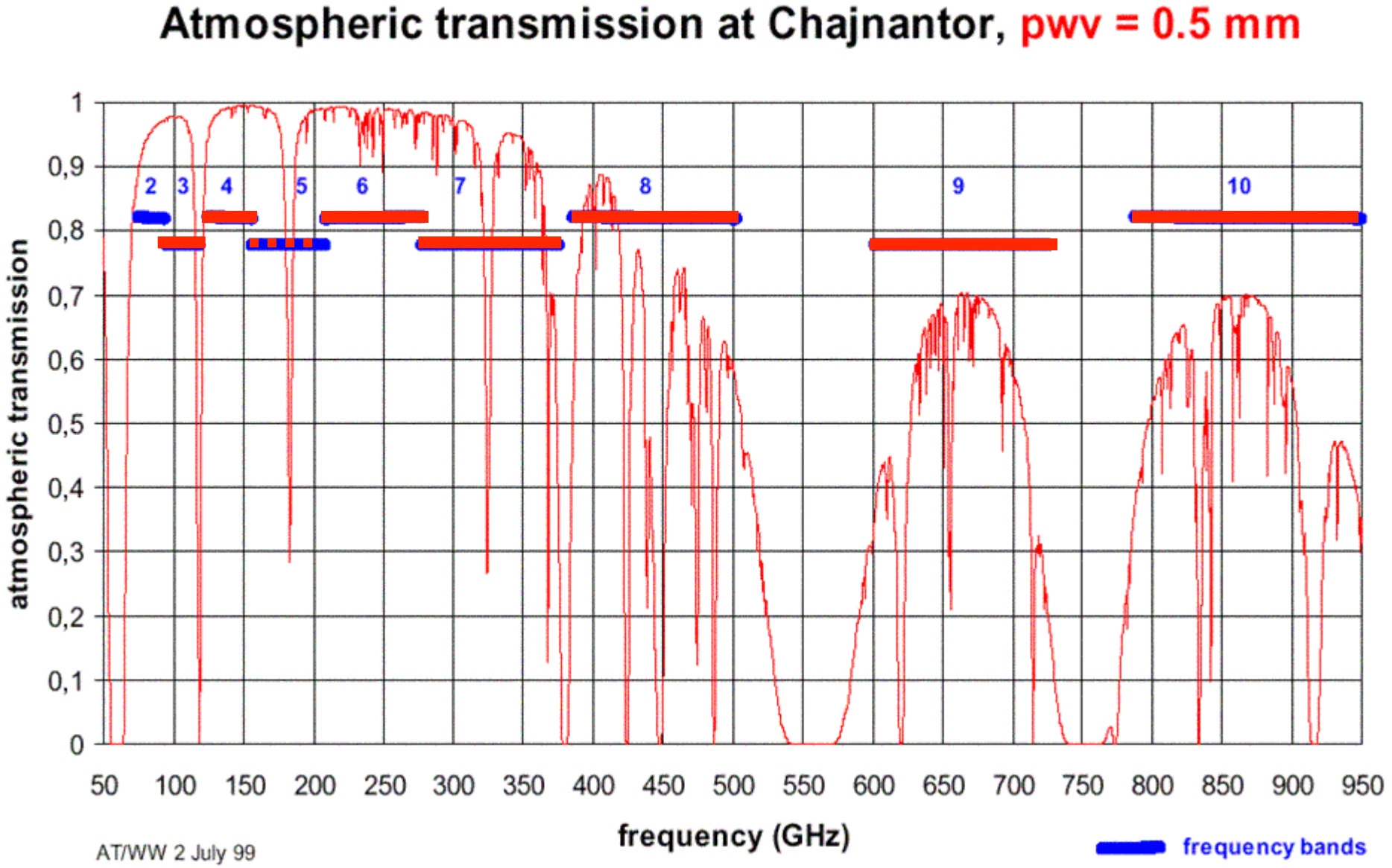
ALMA建設における大学・研究所等との協力

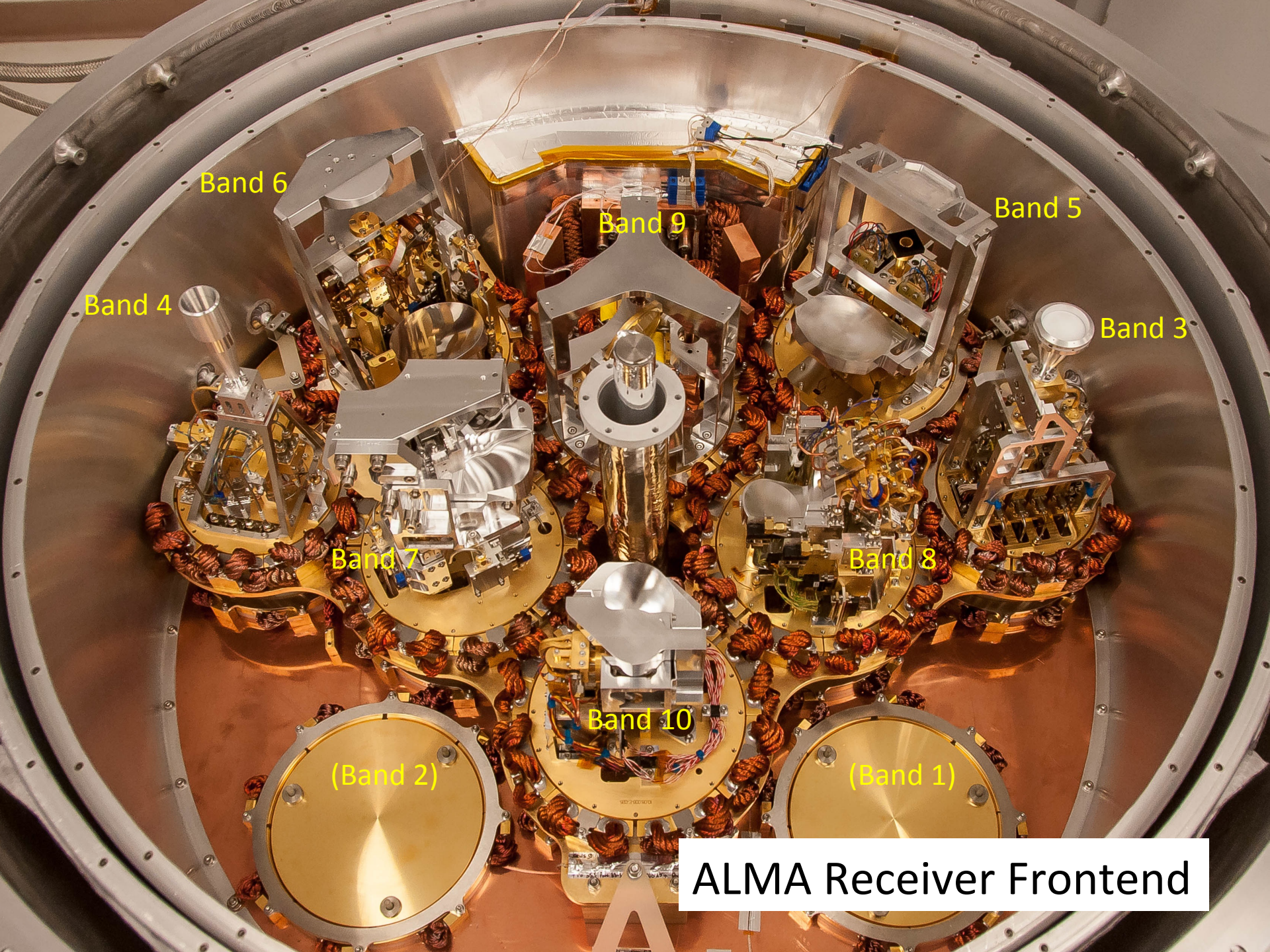
（主なもの、順不同）

- プロジェクト推進
  - 電波専門委員会ALMA推進小委員会
- サイト調査
  - 東京大学
- 受信機フロントエンド開発
  - 大阪府立大学、通信総合研究所、東京大学、名古屋大学、豊田高専
- 局部発振器系開発
  - NTT研究所
- 相関器開発
  - 茨城大学
- 観測法
  - 宇宙科学研究所

Receiver Bands

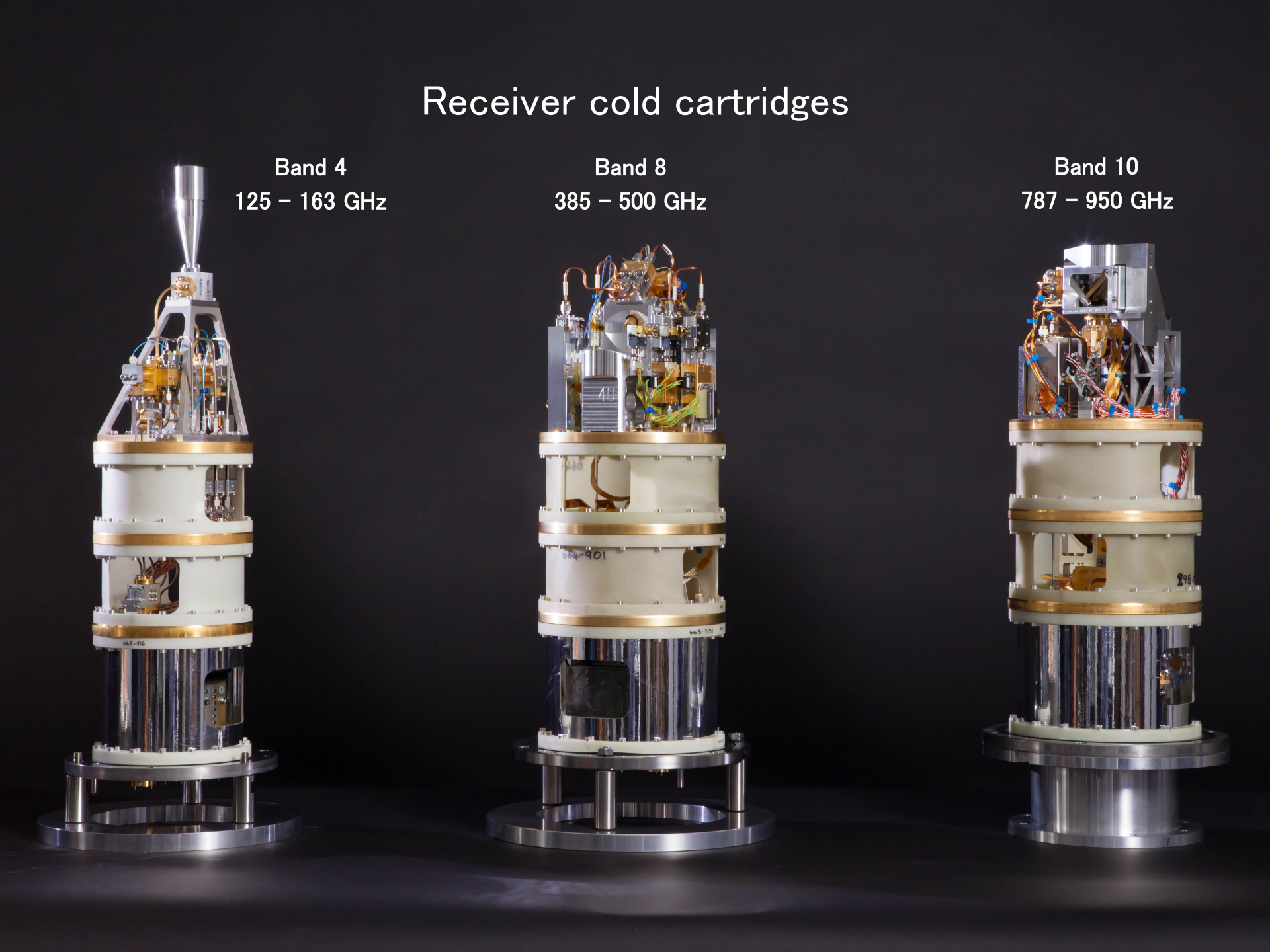
Band	RF range	Mixer	IF output	T_{RX} in 80% / 100% of RF	Responsibility
1	31.3 – 45 GHz	USB	4 – 12 GHz × 2	17 / 28 K	EA開発中
2	67 – 90 GHz	LSB	4 – 12 GHz × 2	30 / 50 K	–
3	84 – 116 GHz	2SB	4 – 8 GHz × 4	37 / 62 K	NA, NRC
4	125 – 163 GHz	2SB	4 – 8 GHz × 4	51 / 82K	JP, NAOJ
5	163 – 211 GHz	2SB	4 – 8 GHz × 4	65 / 108 K	EU実装中
6	211 – 275 GHz	2SB	4 – 8 GHz × 4	83 / 138 K	NA, NRAO
7	275 – 370 GHz	2SB	4 – 8 GHz × 4	147 / 221 K	EU, IRAM
8	385 – 500 GHz	2SB	4 – 8 GHz × 4	196 / 292 K	JP, NAOJ
9	602 – 720 GHz	DSB	4 – 12 GHz × 2	175 / 263 K	EU, NOVA
10	787 – 950 GHz	DSB	4 – 12 GHz × 2	230 / 344 K	JP, NAOJ


Atmospheric transmission at Chajnantor, pwv = 0.5 mm
atmospheric transmission
1
0,9
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0
2
3
4
5
6
7
8
9
10
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
800
850
900
950
frequency (GHz)
AT/WW 2 July 99
frequency bands



ALMA Receiver Frontend

Receiver cold cartridges



Band 4 カートリッジの場合
リーダー：浅山信一郎

- 大阪府立大学：基本設計・要素開発
  - 小川英夫教授、浅山信一郎（大学院生）を中心に、システム基本設計、部品の開発（設計・試作・実験）
  - プロトタイプ受信機を用いた観測デモンストレーション
  - 浅山信一郎博士論文

- 国立天文台：詳細設計・製造・メンテナンス
  - ALMA国際共同建設のなかで、日本（国立天文台）が製造を担当するバンドの1つとして提案、承認を得る
  - 浅山信一郎助教がリーダーとして着任
  - 詳細設計、設計審査（PDR, CDR, MRR）、製造、品質管理
  - ALMA受信機への組み込み
  - メンテナンス

これまでのやり方ではALMAは作れない

ALMA Memo # 453

An Integrated Sideband-Separating SIS mixer Based on Waveguide Split Block for 100 GHz Band

Shin'ichiro Asayama, Hideo Ogawa, Takashi Noguchi*,
Kazuji Suzuki†, Hiroya Andoh‡, and Akira Mizuno§

17 April 2003

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Abstract

We have been developing an integrated sideband-separating SIS mixer at 100 GHz based on waveguide split block. The measured single-sideband (SSB) receiver noise temperatures with L-band IF (f_0 = 1.5 GHz) are less than 60 K in the LO frequency range of 90–115 GHz, and minimum value of around 35 K is achieved at 100 GHz. The image rejection ratios are more than 11 dB in the frequency range of 90–110 GHz. We have installed the sideband-separating SIS mixer into an atmospheric ozone measuring system at Osaka Prefecture University and successfully observed an ozone spectrum at 110 GHz in SSB mode. This experimental result indicates that the sideband-separating SIS mixer is very useful for astronomical observation as well as atmospheric observation.

Keyword: sideband-separating mixer, SIS mixer, W-band, ozone spectrum

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§ Solar-Terrestrial Environment Laboratory, Nagoya University, 3-13 Honohara, Toyokawa, Aichi, 442-8507 Japan

ALMA memo 458

Preliminary Tests of Cartridge-Type Receiver System at Atacama Site

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Kimihiro Kimura[4], Kazuji Suzuki[5],
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[4]*Department of Earth and Life Sciences, College of Integrated Arts and Sciences, Osaka Prefecture University, 1-1 Gakuen-cho Sakai Osaka 599-8531, Japan*
[5]*The Instrument Development Center of School of Science, Nagoya University, Chikusa-ku, Nagoya 464-8602, Japan*
[6]*Department of Astrophysics, Nagoya University, Chikusa-ku, Nagoya 464-8602, Japan*

14 May 2003

Abstract

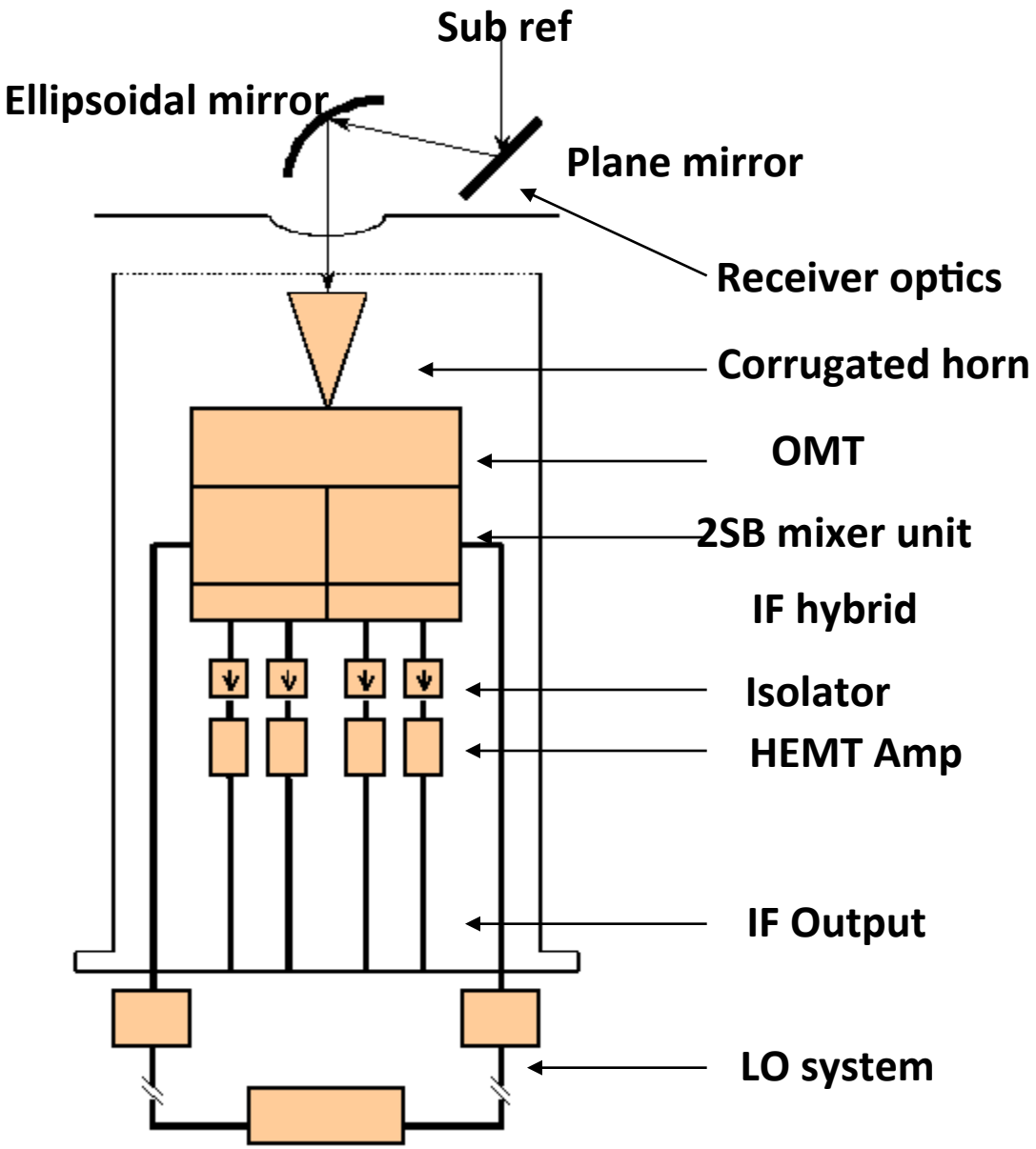
We have developed a cartridge-type receiver system composed of three cartridge-type receivers and a cryostat, which is designed to test on the Atacama Submillimeter Telescope Experiment (ASTE). It was preliminary evaluated at Pampa la Bola (alt. 4800 m) in the northern Chile since November 2002. The cryostat, which can house 3 cartridge-type receivers, has been developed with following technologies; a central pipe and bellows structure to reduce mechanical vibration; simple and efficient thermal links for plug-in cartridges; 3-stage Gifford McMahon cryocooler and an outdoor compressor. Engineering models of band 3 (100 GHz), band 8 (500 GHz), and band 10 (800 GHz) cartridge-type receivers were independently developed with cartridge-test cryostats. They were integrated into the cryostat at NAOJ, then the system was

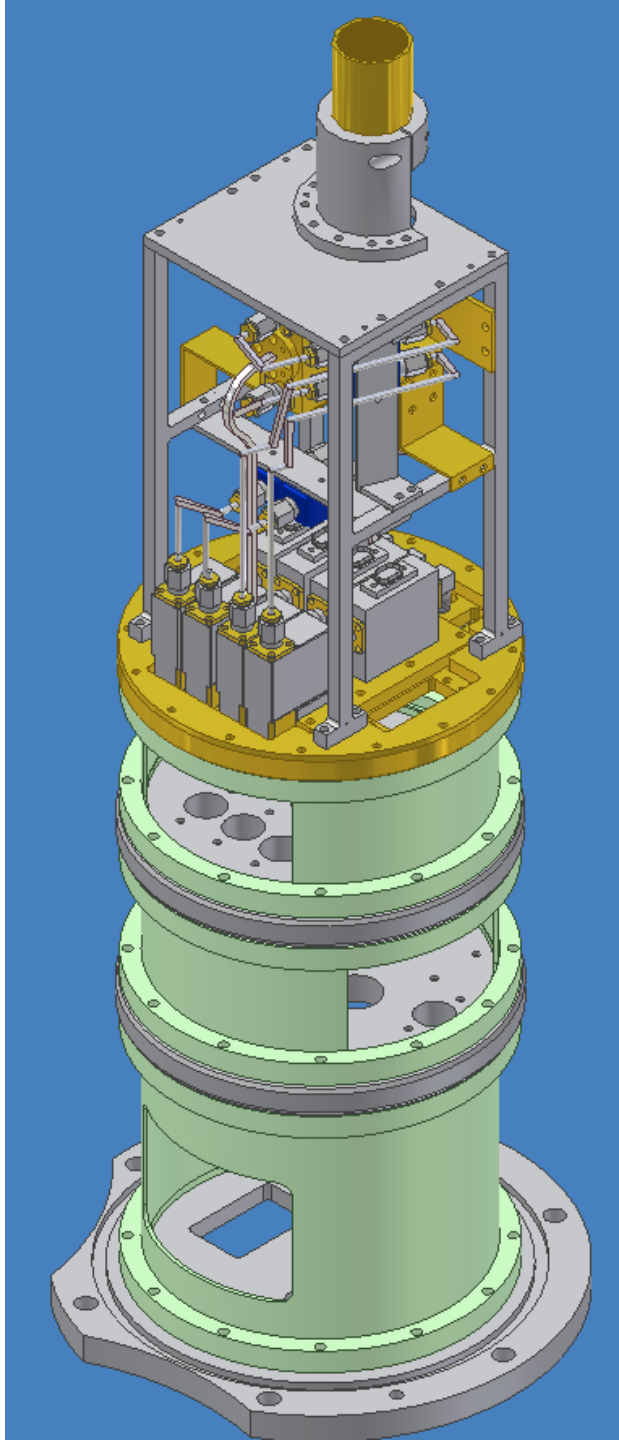
Current Status of the Band4 Cartridge Development

S. Asayama

05-April-2005

Band 4 Cartridge



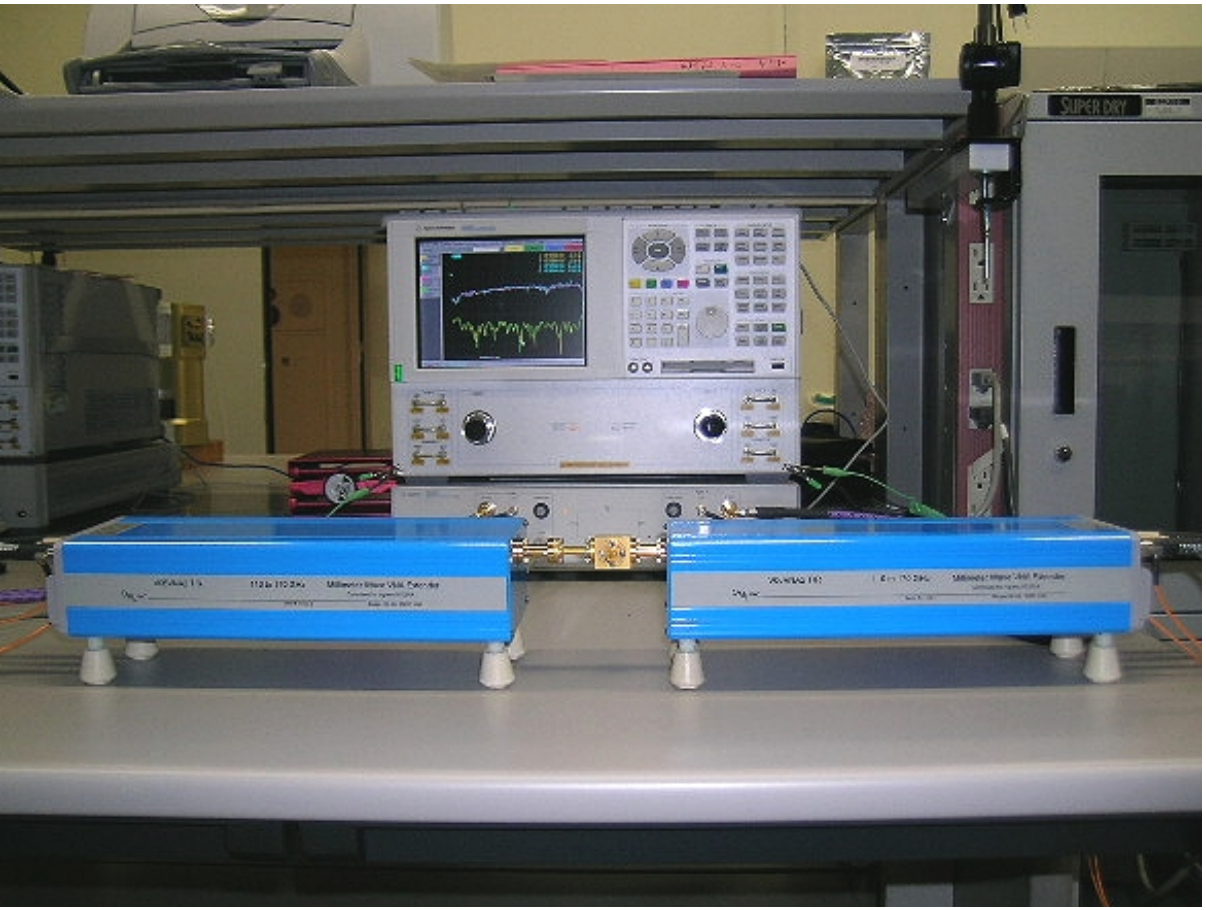


Band 4 cartridge Specifications

Trx Requirement	
T_{SSB} *over 80% of the frequency range*	T_{SSB} *at any frequency within the RF band*
51	85

- Two linear orthogonal polarizations
- Max. cross-polarization-20dB
- Sidebands 2SB (10dB image band suppression)
- IF bandwidth
  - **4GHz 2SB,upper and lower sideband**

D-band VNA (Agilent Technologies)

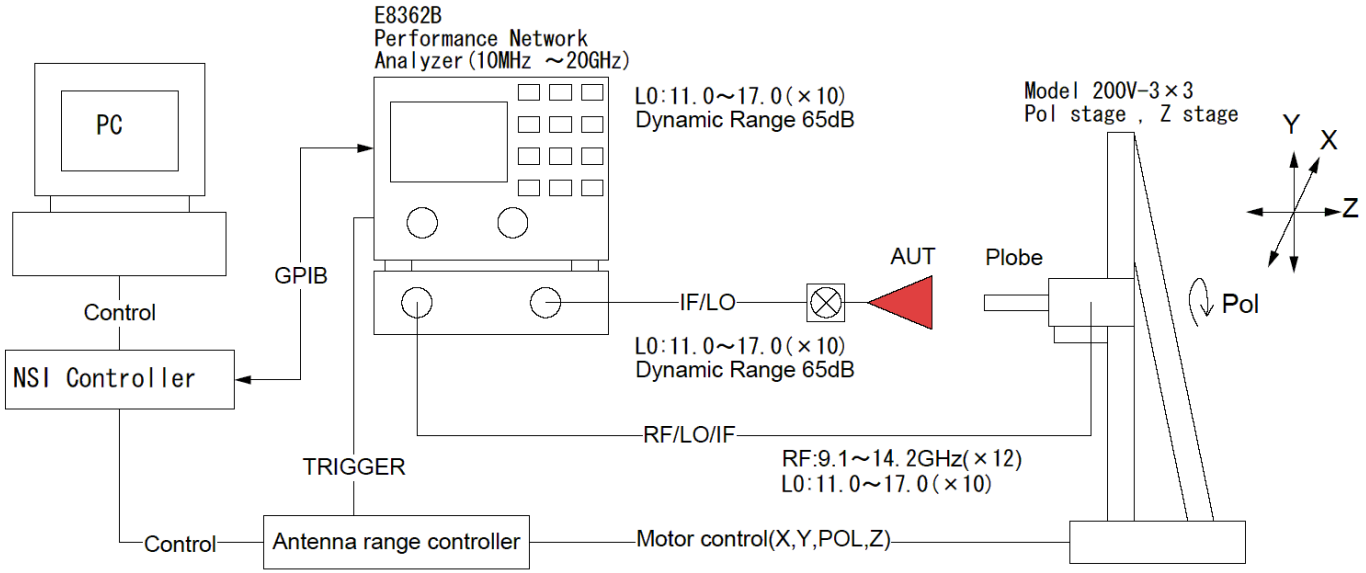


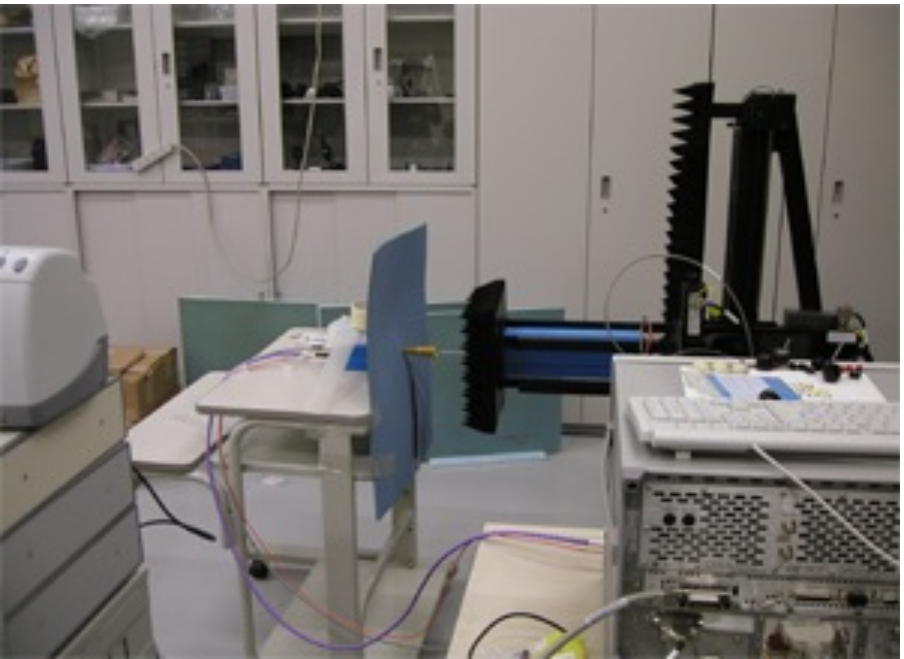
Freq: 110-170GHz

Dynamic range: >80dB

Full-2port measurment

Beam Pattern Measurement System

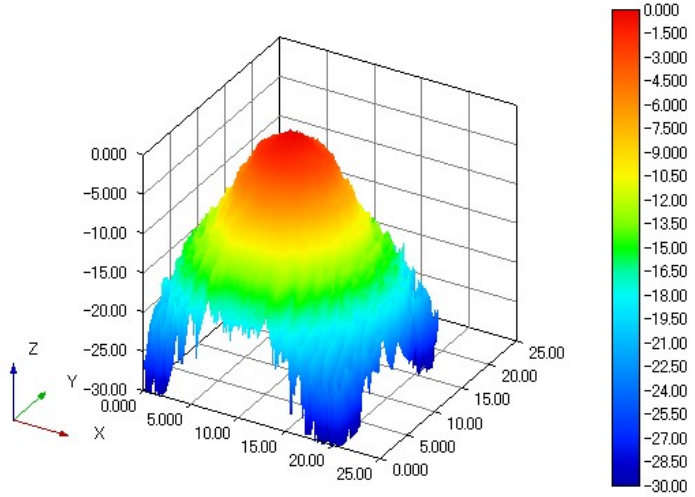




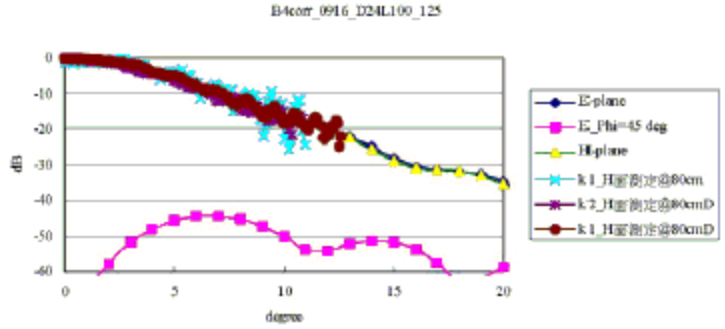
NSI Beam Pattern measurement system with Agilent VNA

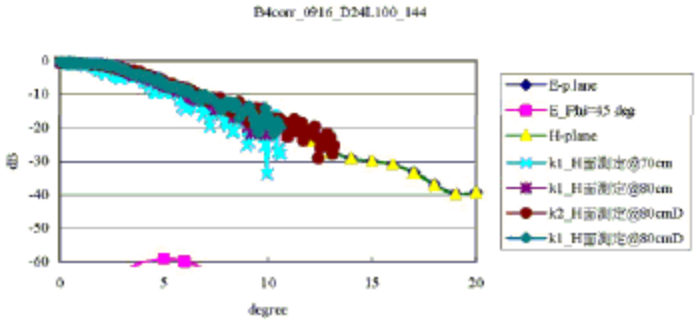
Band4 Corrugated Horn Measurements Results (Main Beam)

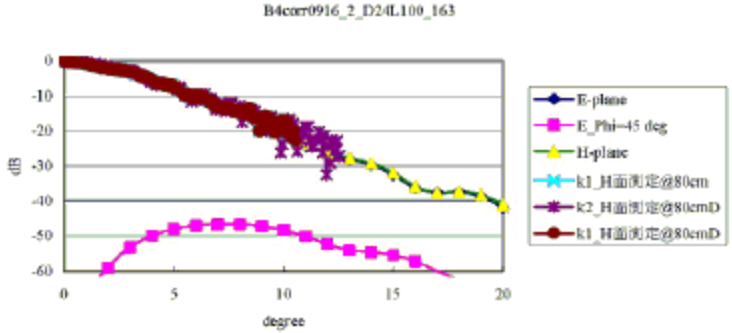
Cross-sectional view of the machined corrugated horn.



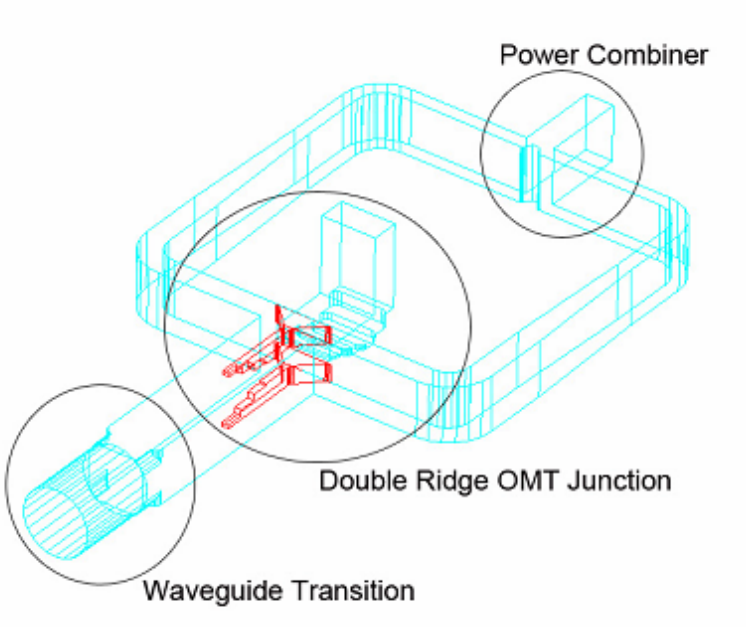
Beam pattern of the machined corrugated horn

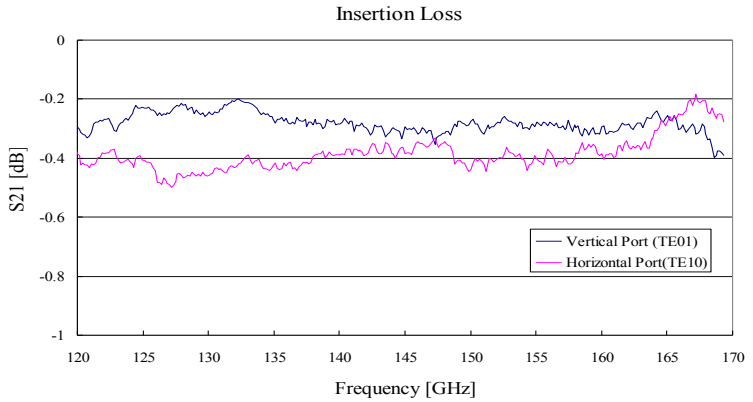


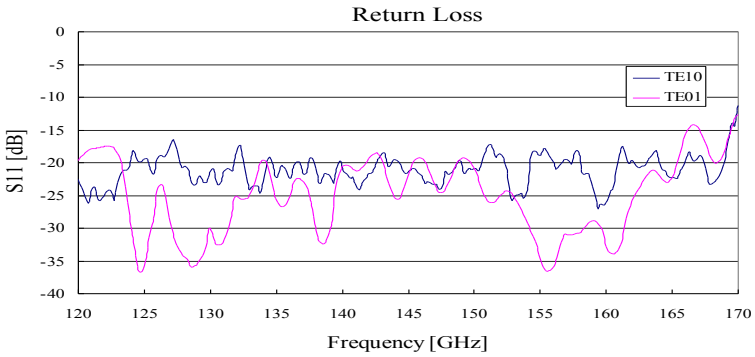


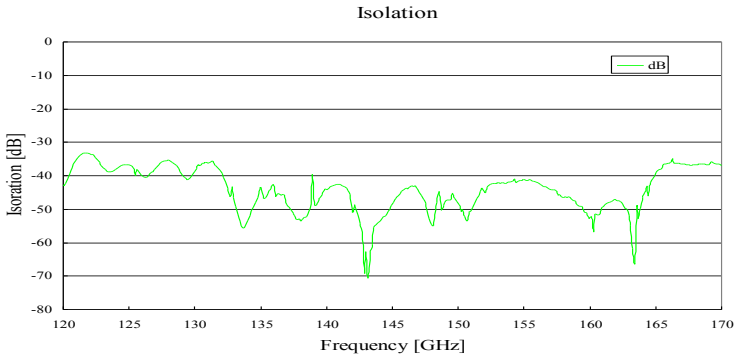


Band4 OMT Measurements Results

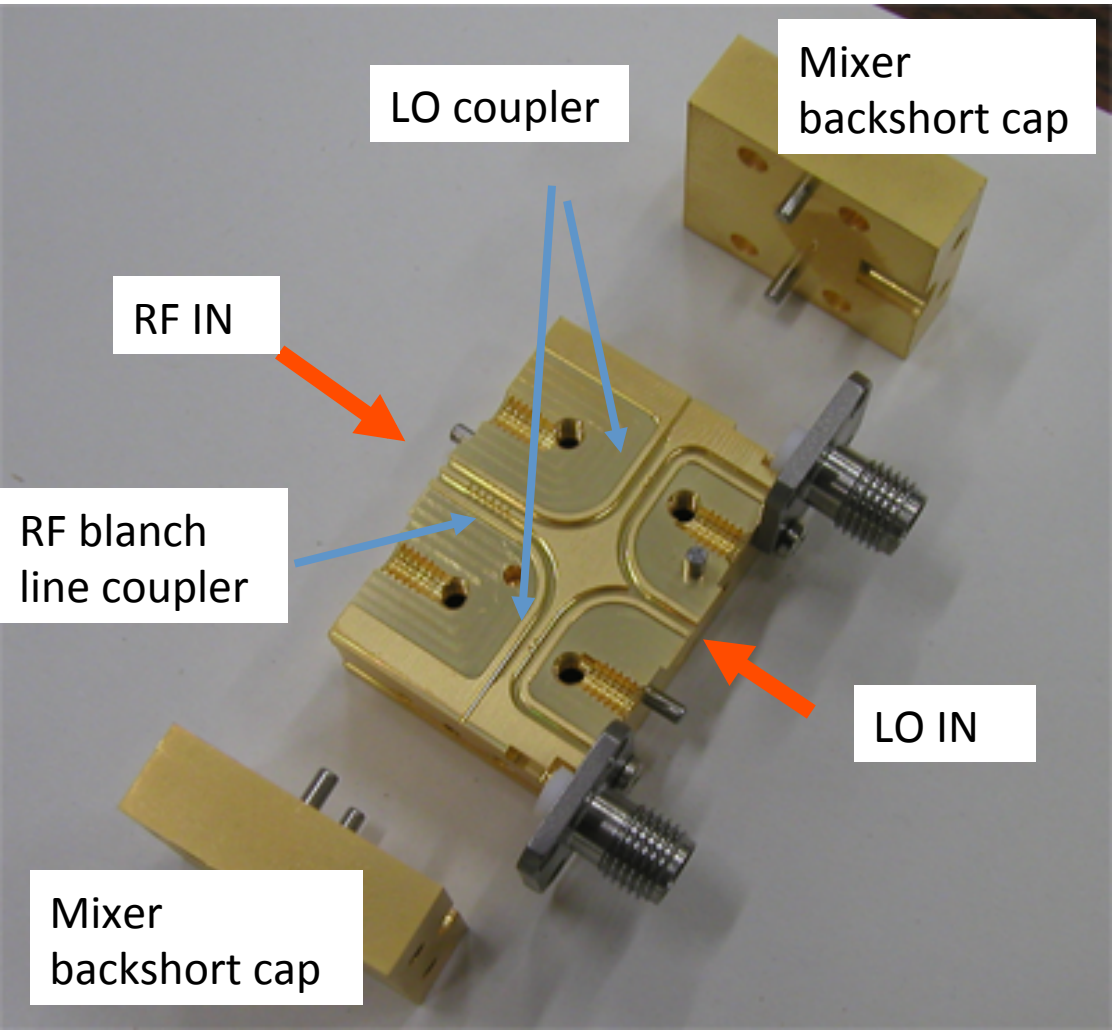


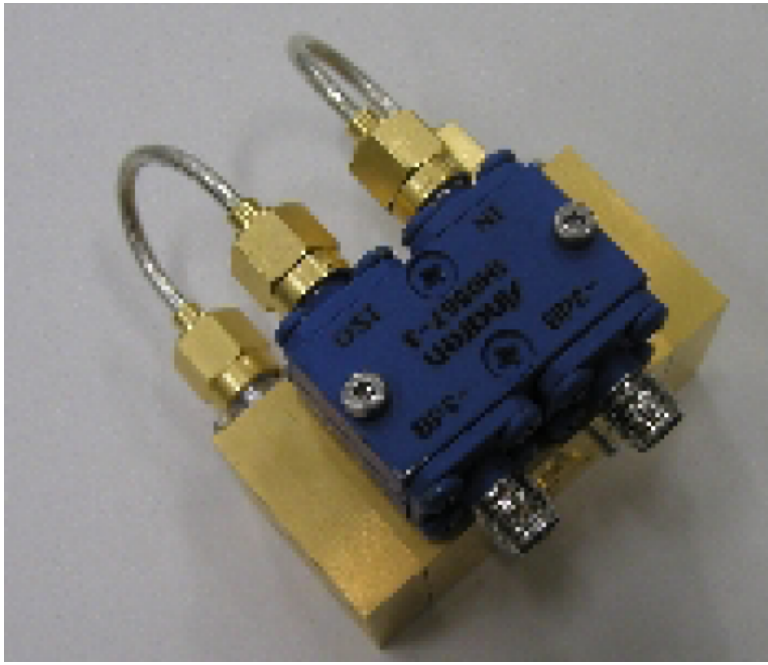






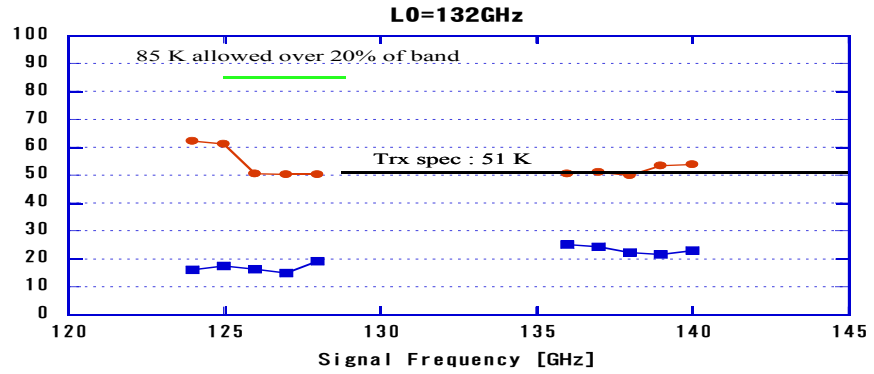
Band 4 Integrated 2SB mixer

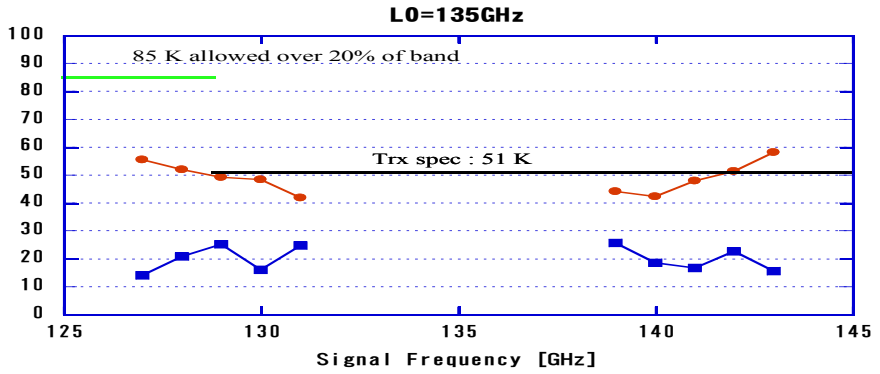


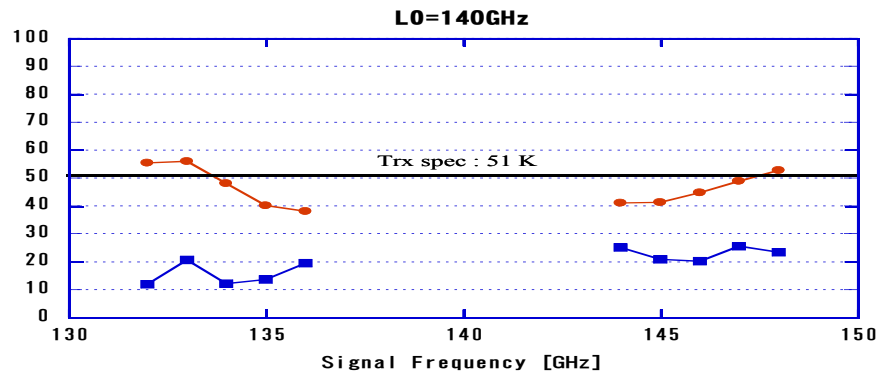


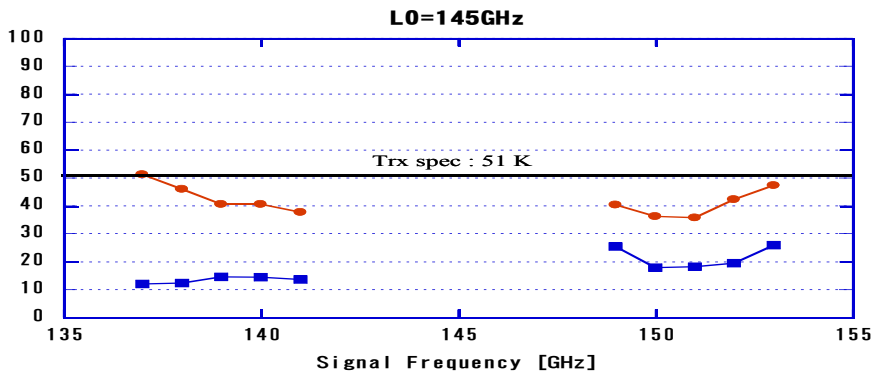
Preliminarily Results of the 2SB Mixer

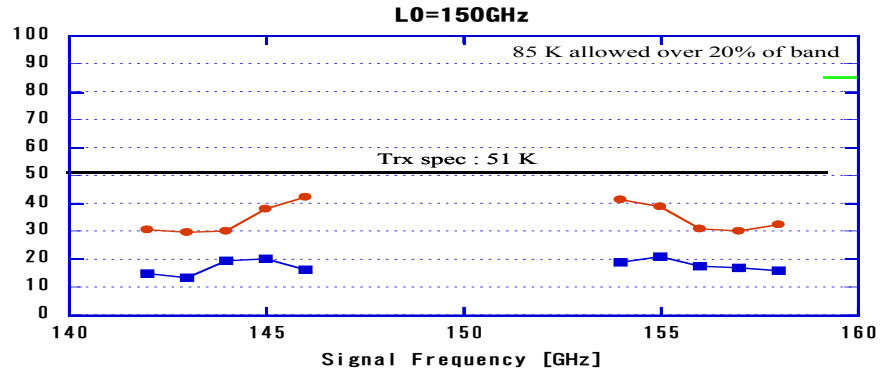
Red:Trx(SSB)
Blue:IRR

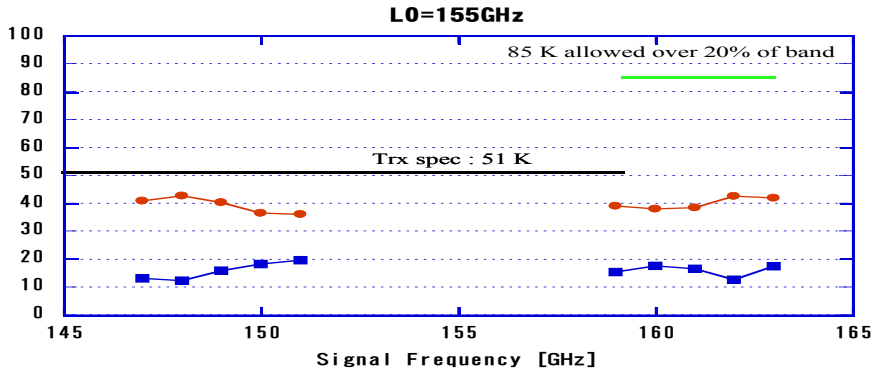












Band 10 カートリッジの場合
リーダー：鵜澤佳徳

- 国立天文台：基本設計・要素開発・詳細設計・製造・メンテナンス
  - ALMA国際共同建設のなかで、日本（国立天文台）が製造を担当するバンドの1つとして提案、承認を得る
  - 通信総合研究所より鵜澤佳徳准教授がリーダーとして着任
  - 通信総合研究所よりミクサー素子製作用のフィルム素材の提供を受ける
  - 小嶋崇文（大阪府立大院生、指導委託）がメンバーの一人として参加、ミクサーの改良に中心的役割を果たす
  - 小嶋崇文博士論文
  - 詳細設計、設計審査（PDR, CDR, MRR）、製造、品質管理
  - ALMA受信機への組み込み、メンテナンス

ALMA – need for development

- Current ALMA = technology around 2000
  - Basic design architecture in 1998 – 2003
  - Example: Receiver frontend
    - 2003 – first version of specifications
    - 2005 – Preliminary Design Review (PDR)
    - 2008 – first frontend at the site
    - 2010 – Critical Design Review (CDR)
    - 2013 – front end delivery complete

ALMA development pathways

- A list of 84 items
  - Based on scientific discussion (ALMA Science Advisory Committee, Project Scientists)
    - Sensitivity
    - Resolution
    - Field of view
    - Spectral coverage/Simultaneous frequency coverage
    - Imaging quality and calibration
    - Flexibility/Usability/Reliability and efficiency

Priorities for EA

- Studies & Small Projects
  - ALMA Calibration Source
    - Calibration at bands 3,6,7
  - High Critical Current Density (Jc) SIS Junction Device Development (including THz devices)
  - GPU Spectrometer for TP array (with KASI)
    - Supplements the ACA correlator
- Projects
  - Band 1 project (lead: ASIAA, Collaboration: NAOJ, U of Chile, NRAO, HIA)
    - Baseline capability (35-50GHz)
- ASTE development project (but extendable to ALMA)
  - Multi-beam receiver (with KASI)

教訓

- プロジェクトのニーズと大学・研究所のニーズをよく考える
  - 科学的ニーズ
  - 技術的要求

- 役割分担を考える
  - 大学：先端的、研究的開発
    - その中で学生が育つ
  - 天文台：共同利用を念頭に置いた装置の製作、メンテナンス
    - そのための組織、予算、人員

- プロジェクトに参加したらプロジェクトマネジメントは不可欠
  - マイルストンを刻み、進捗を「見える化」
  - 新しいアイディアの導入や設計変更には、手続きを踏む（configuration control, change control）