ALMA cartridge-type receiver system for Band 4

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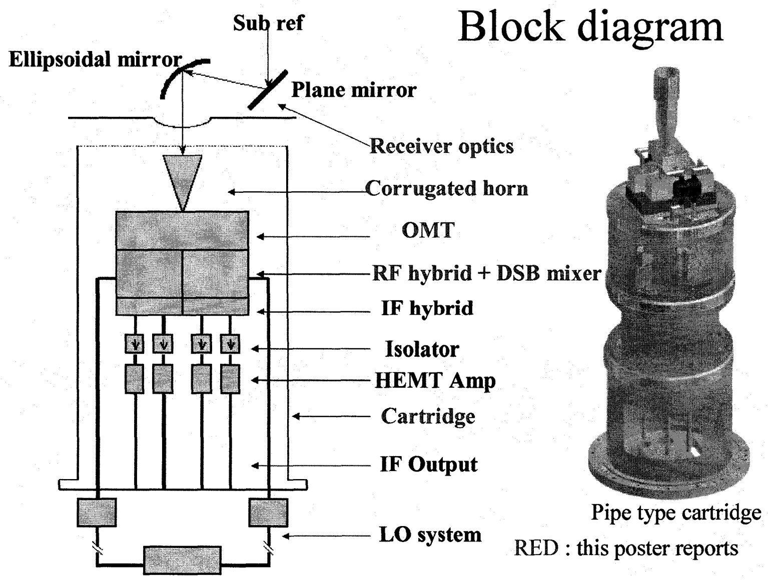
We are developing the ALMA (Atacama Large Millimeter/Sub-millimeter Array) Band4(125--163GHz) receiver. Individual ALMA frequency bands are implemented asself-contained cartridges. The cartridge-type receivers are mounted in the 4 K dewar on theCassegrain receiver cabin of ALMA 12m telescope. The receivers are asked to receive two linearly polarized orthogonal signals. The diameter of the Band 4 cartridge is 140 mm.

Specifications

- Freq 125—163GHz
- Trx(SSB) over 80% _ 47K (goal 26K) any freq _ 76K (goal 40K)
- Two linear orthogonal polarizations
- Max. cross-polarization -20dB
- Sidebands DSB or 2SB (10dB image band suppression)
- IF bandwidth 4GHz 2SB,upper and lower sideband

ALMA Band4 cartridge-type receiver

Block diagram

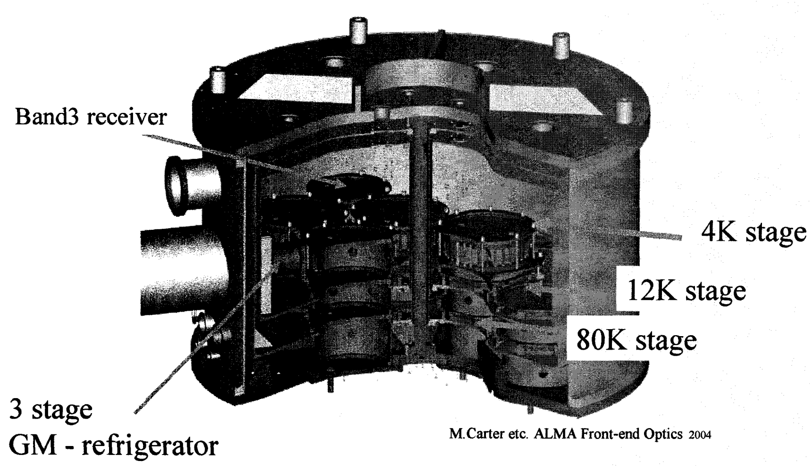


Pipe type cartridge

RED : this poster reports

ALMA dewar

Ten cartridge-type receivers are equipped with in ALMA dewar.
Band 4 receiver is located in 335mm offset from the center of dewar.
A position of band 4 receiver is symmetric with band 3 receiver.



M.Carter etc. ALMA Front-end Optics 2004

ALMA Band4 optics

05/09/2003

Composition

Warm optics
- plane mirror
- ellipsoidal mirror

Cooled optics
- corrugated horn

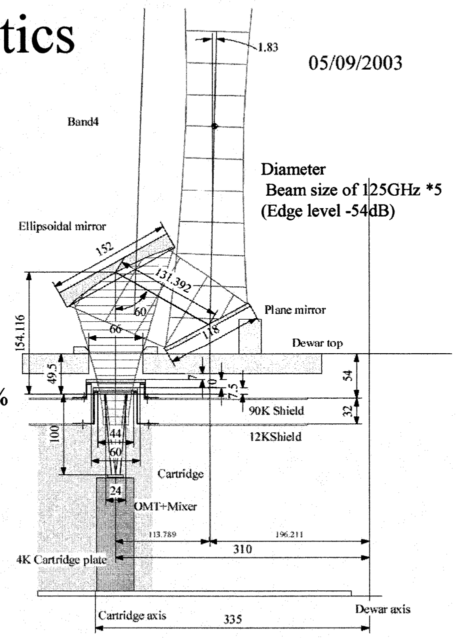
Performance goals of receiver optics

Minimize window apertures

Minimize added noise

Maximize aperture efficiency: Reduction < 5%

Aberrations:	< 1%
Truncation loss:	< 1%
Dissipative losses:	< 1%
Scattering losses:	< 1%
Polarization loss:	< 1%



Optics parameter(Band4)

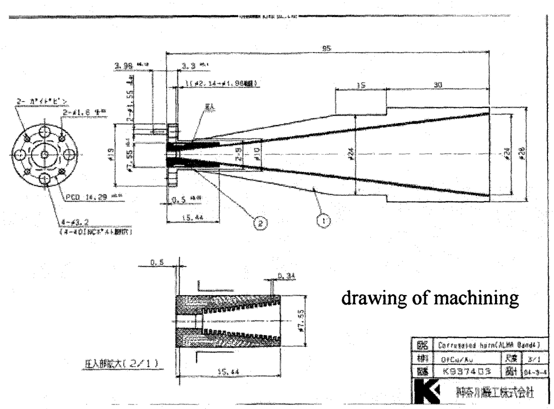
Frequency (GHz) (mm)	Design Parameters	125 2.398340	144 2.081892	163 1.839218
Horn diameter	24.0			
Horn axial length	100.040			
Horn slant length	100.757			
Horn waist, w_0		6.103	5.760	5.431
Horn waist offset, $z(w_0)$		-37.8211	-44.704	-50.923
Waist at horn aperture, w_{ha}		7.722	7.722	7.722
d_1 15	4.116			
R_{s1} 21	1.417	204.339	211.423	217.416
f_1 15	0.474			
R_{i1}	522.006	570.832	521.972	488.714
Waist at mirror 1, w_{M1}	(dia = 152)	24.773	23.590	22.761
1	60.0			
d_2	128.268			
Waist at mirror 2, w_{M2}	(di a = 118)	19.496	18.033	16.981
2	61.834			
$z_{w(Cass.)}$ 24	5.188	248.091	245.107	243.102
$w_{Cass.}$		14.343	12.453	11.004
$d_{mirror-subrefl}$		6367.356	6367.356	6367.356
$w_{subrefl}$	(dia = 750)	319.035	319.035	319.035
$R_{subrefl}$	6000.00	6000.000	6000.000	6000.000
Edge Taper (dB)	12.00	12.00	12.00	12.00
Multimode E Taper (dB)		9.50	9.50	9.50

Dimensions in mm

This optics are calculated by the frequency independent matching of gaussian beam(TA-SHING 1983 IEEE). In any frequencies, Shape of a beam becomes equal in a sub-ref and horn aperture.

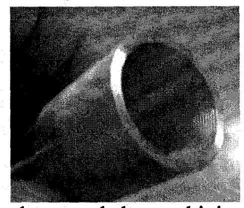
Design of corrugated horn (Band4)

Now We are producing the corrugated horn by a method of electro-former or machining.



drawing of machining

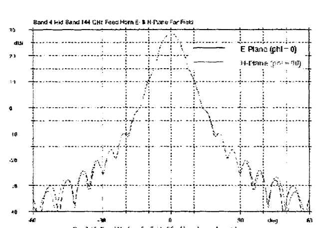
Slot width 0.34mm
Ridge width 0.34mm
Slot depth
slot1=0.80mm
slot2=0.68mm
slot3=0.60mm
slot4=0.55mm
slot5--aperture(134)=0.52mm



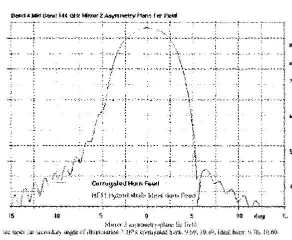
horn made by machining

Simulation of radiation pattern

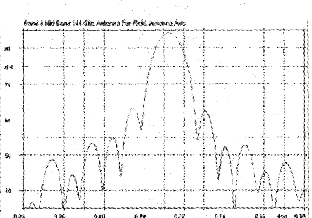
A pattern of corrugated horn and an antenna pattern do simulation by GRASP8(TICRA). GRASP8 is based on well-established analysis techniques such as Physical Optics (PO) supplemented with the Physical Theory of Diffraction (PTD), Geometrical Optics (GO) and Uniform Geometrical Theory of Diffraction (GTD).



Horn beam pattern



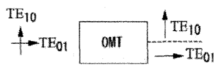
Beam pattern for sub-ref



Antenna beam pattern

Simulation by C.Y.Cham etc. (University of Cambridge,UK)

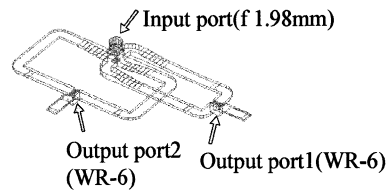
Band4 Ortho Mode Transducer (OMT)



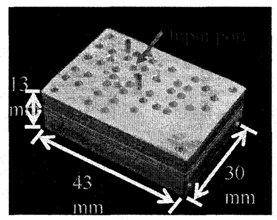
Higher mode TE_{11},TM_{11} excitation → "small"

Goals of performance

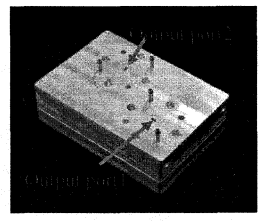
Insertion loss	**<0.2dB**
Return loss	**> 20dB**
Isolation	**> 30dB**



front

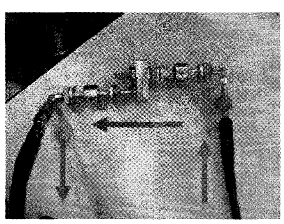


rear

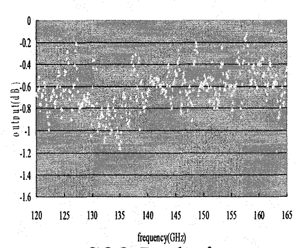


OMT measurement performance

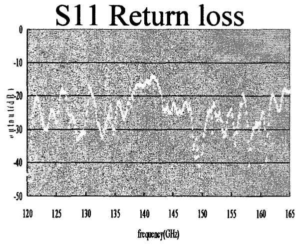
We measured OMT by MVNA.



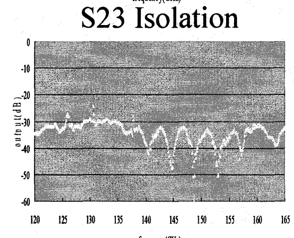
S21 Insertion loss



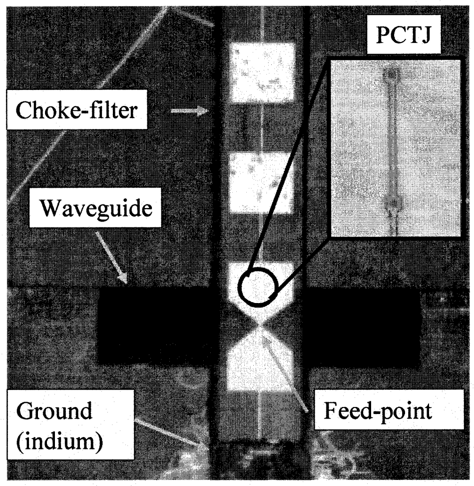
S11 Return loss

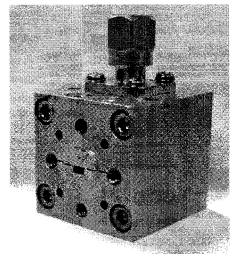


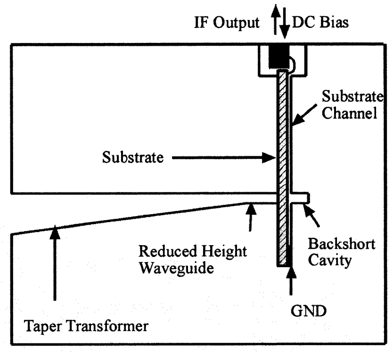
S23 Isolation



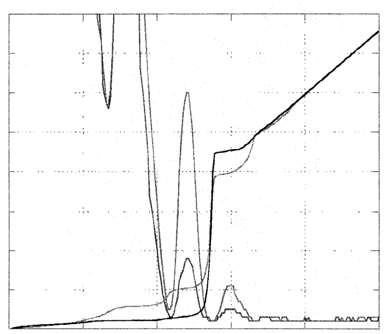
Half reduced height mixer mount
for ALMA Band4





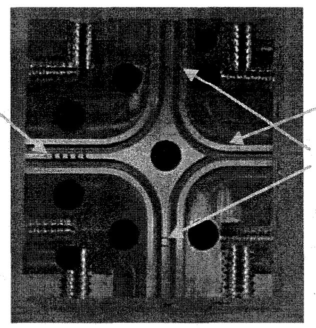


Band4 DSB mixer results



Sideband-Separating Mixer Unit for ALMA BAND 4

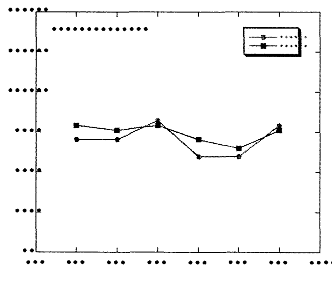
The Sideband-Separating Mixer Unit contents two LO coupler, an RF blanch line coupler and LO divider.

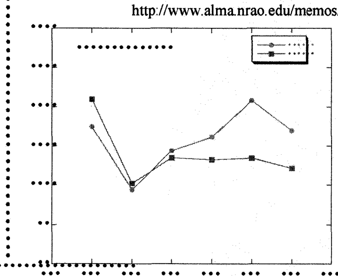


Receiver noise temperatures of ALMA Band4 Sideband-Separating Mixer

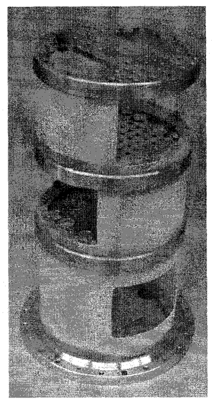
principle, the image rejection ratio of a receiver can be measured by injecting CW signals of known relative amplitudes into the upper and lower sideband measuring each IF response. At millimeter wavelengths, however, it is difficult to determine with sufficient accuracy the relative amplitudes of two RF signals separated in frequency by twice the IF frequency. In case of a sideband-separating mixer, the image rejection ratio can be measured accurately injecting CW test signals in the upper and lower sidebands, even when the relative power level of the test signals are not known (*). In a ideal sideband-separating mixer, CW signals into the upper sideband and lower sideband appears separately at the two output ports. Since the image rejection ratio of an actual mixer is not perfect, a CW signal into one sideband appears at both IF output ports. In this case, the image rejection ratio can be determined by measuring the difference in the peak value referred to the noise revel at the corresponding output.

* Shin'ichiro Asayama (OPU/NRO), et al.
"Preliminary Tests of Waveguide Type Sideband-Separating SIS Mixer for Astronomical Observation" ALMA Memo 481
http://www.alma.nrao.edu/memos/index.html



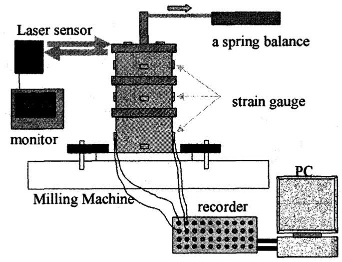


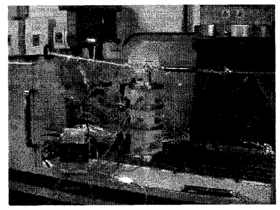
The measurement of cartridge distortion

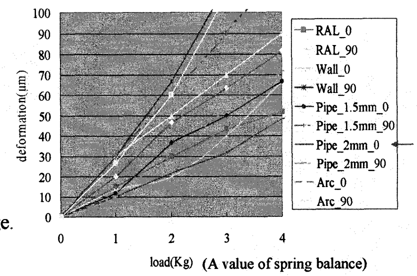


Pipe-type f140 cartridge

We adopted a pipe-type(thick 2mm) cartridge.
Because this type is strong to incline.







Conclusion

We are developing the ALMA Band4 cartridge-type receiver.

Development

+ Receiver optics	Design is end .
+Corrugated horn	In evaluation of a prototype.
+OMT	In evaluation of a prototype.
+ Sideband-Separating Mixer	In evaluation.
+Cartridge	Decision of a design. In production.

We are designing and assembling the receiver systems.
We aim at production of the first receiver system within 2004.