2.5 THz Receiver Front-End for Spaceborne Applications

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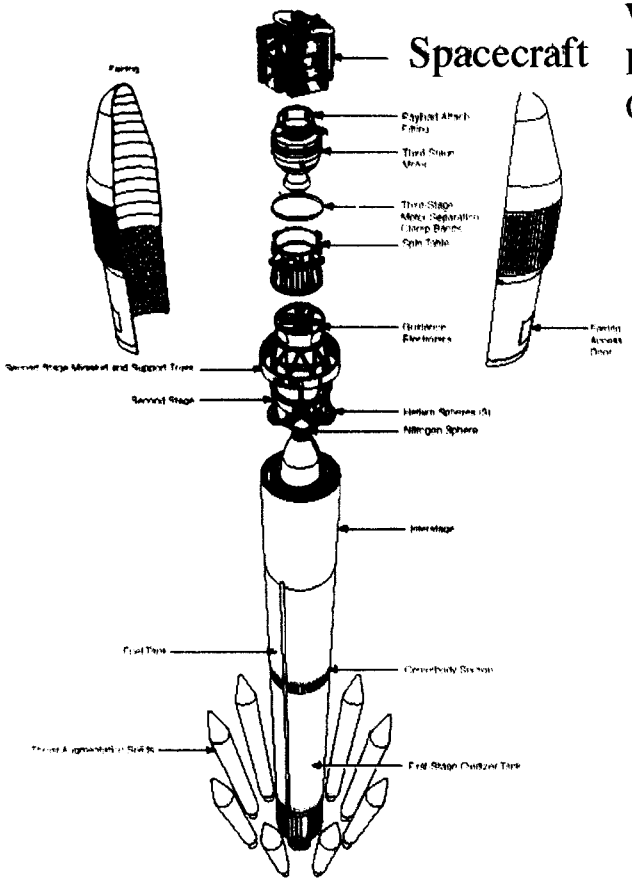
I. Chem-1 Satellite,
Microwave Limb Sounder (MLS)

II. Receiver Design
A. Diplexer
B. Mixer

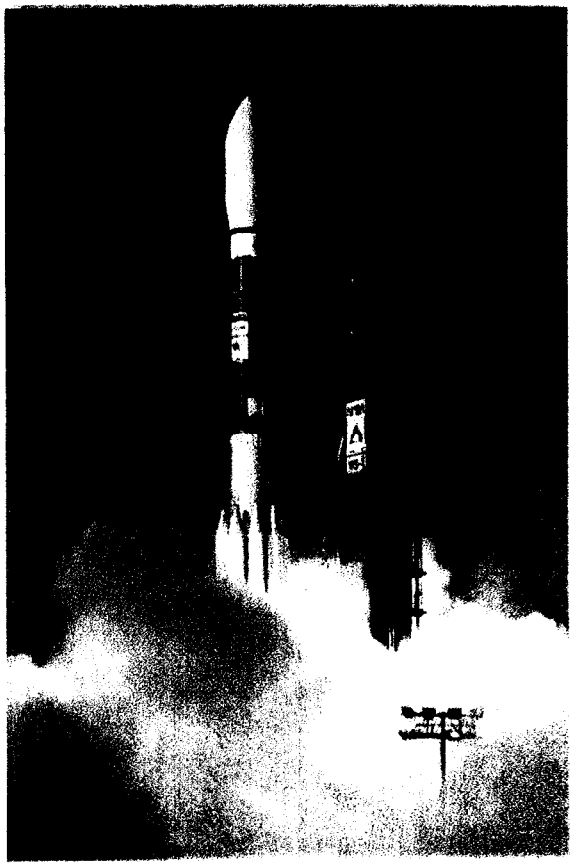
III. Test Apparatus

IV. Receiver Measurements

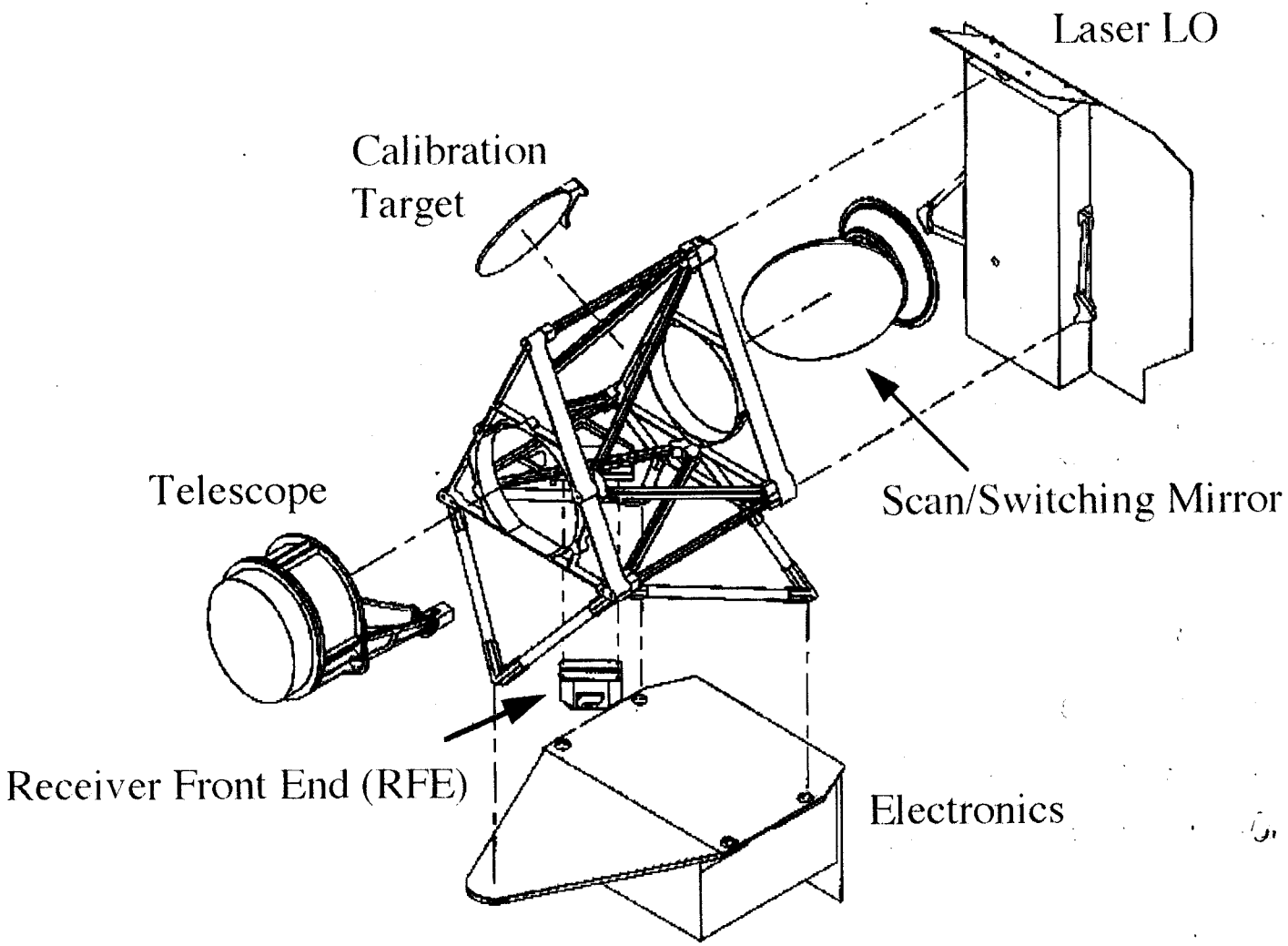
Launch Vehicle: Delta 7920



Chem-1 Spacecraft
Size: 2.7m x 2.3m x 6.9m stowed
4.7m x 17m x 6.9m deployed
Weight: 3,000 kg
Power: 4,700 W (EOL)
Orbit: 705 km, polar

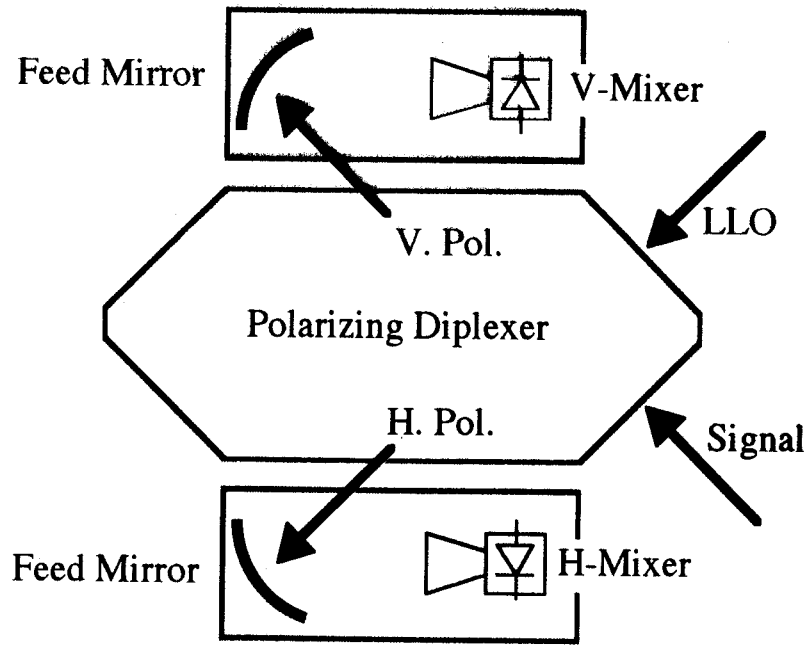


THz Module: Exploded View



Block Diagram: Optical Path

- Signal input from telescope (limb, space, or cal target)
- LLO input from DEOS laser
- Diplexer
- Off-axis ellipical feed mirror
- Mixer
- Feed mirror support (FMS)
- Receiver mounting plate secures the mixer and first IF components to the FMS



LO Frequency: 2522.7816 GHz

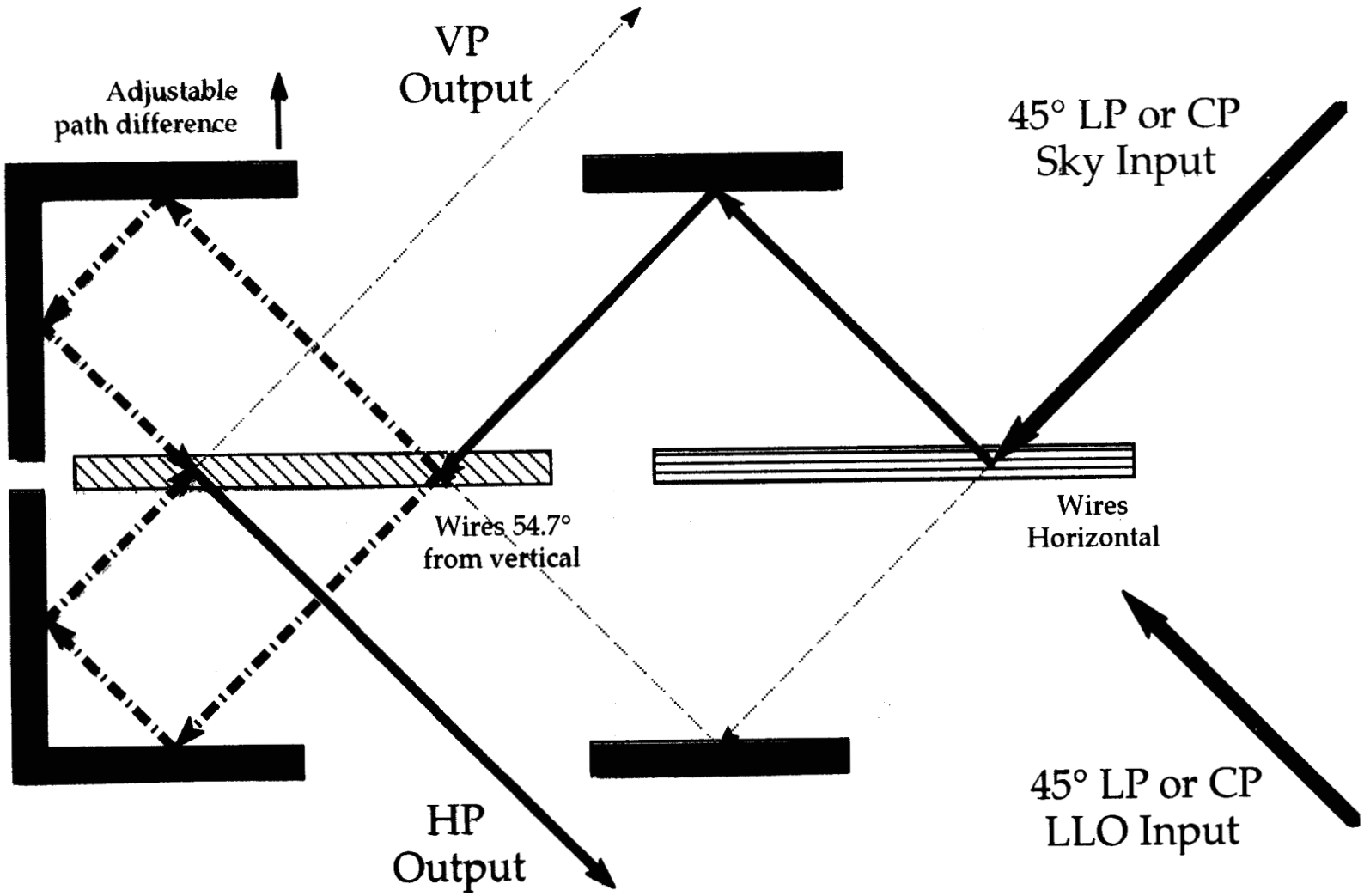
OH #1: 2514.3735 GHz (8.4 GHz IF)

OH #2: 2510.0057 GHz (12.8 GHz IF)

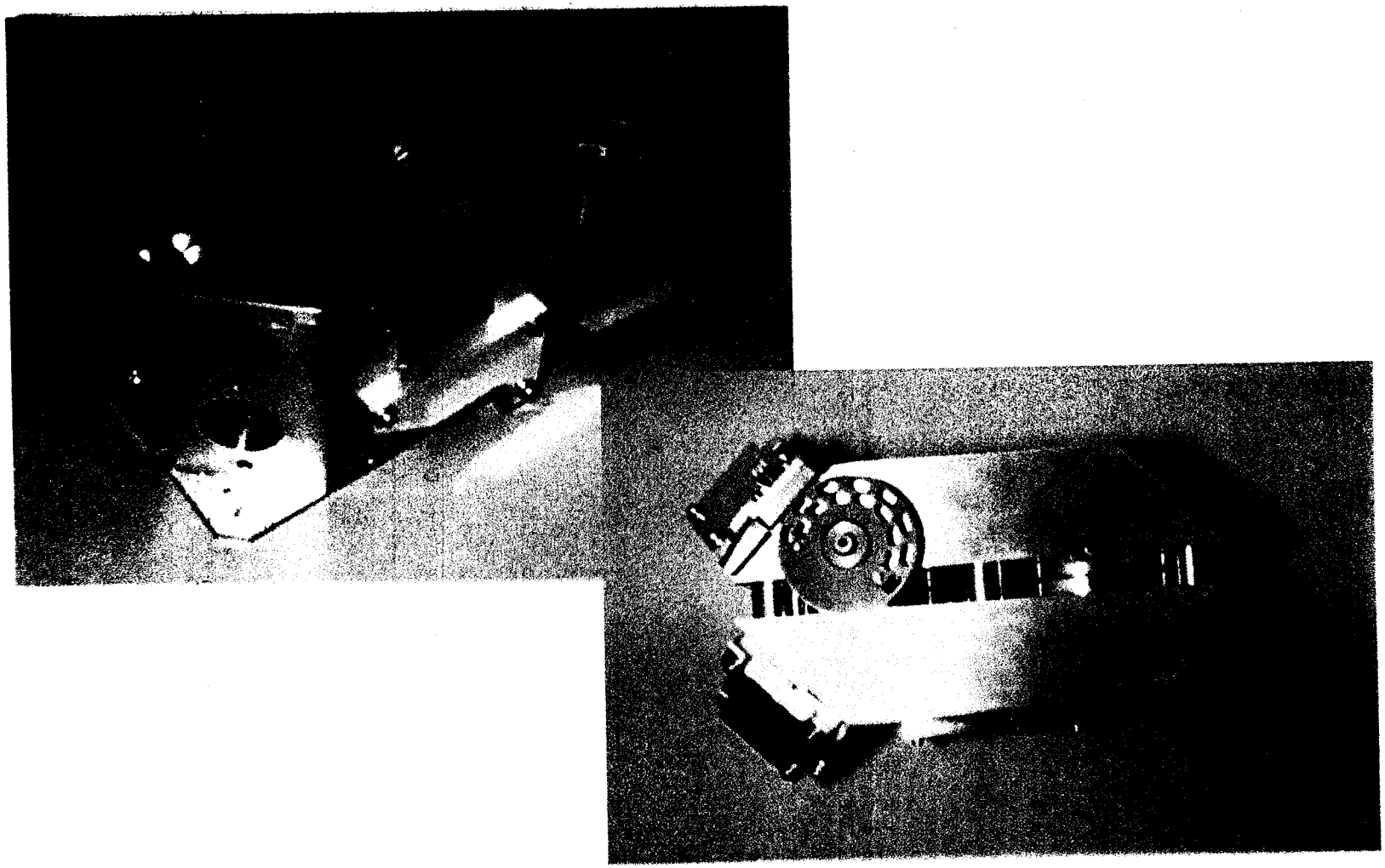
O2: 2502.3804 GHz (20.4 GHz IF)

$\lambda \approx 118\,\mu m$

Polarizing Diplexer: Concept



Polarizing Diplexer: Implementation

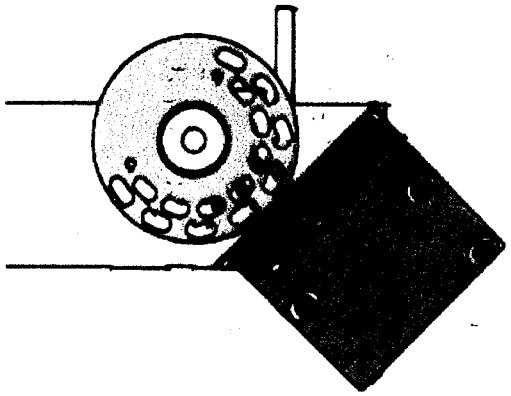


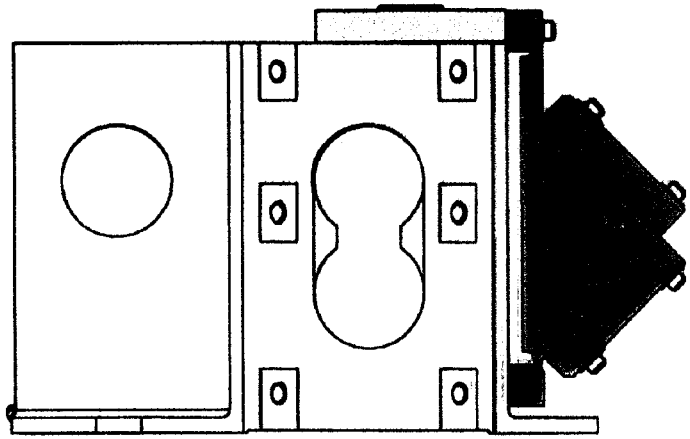
Diplexer: Path Length Adjustment

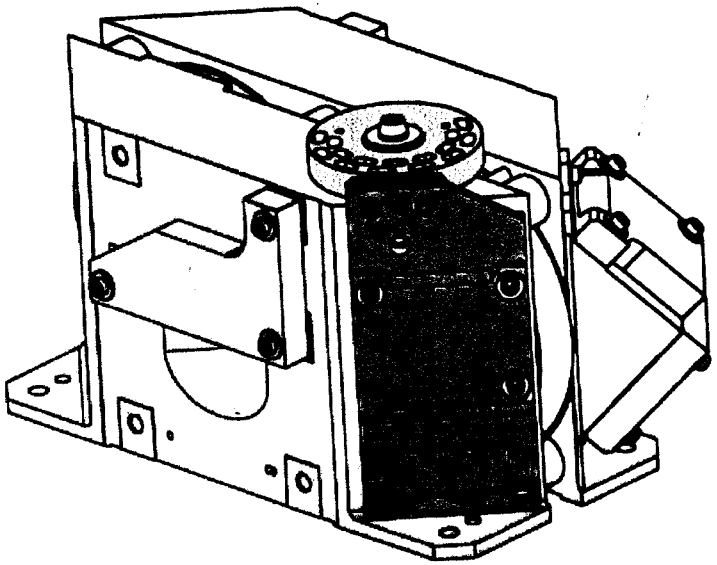
The yellow wheel is aluminum with magnaplate coating
- Attachment is de-centered for rotational extension
- To be secured for flight with setscrews and epoxy potting

The red slabs are low-thermal-expansion invar 36 (5 mm thick)
- Used to set the nominal path length difference at ≈ 10 mm

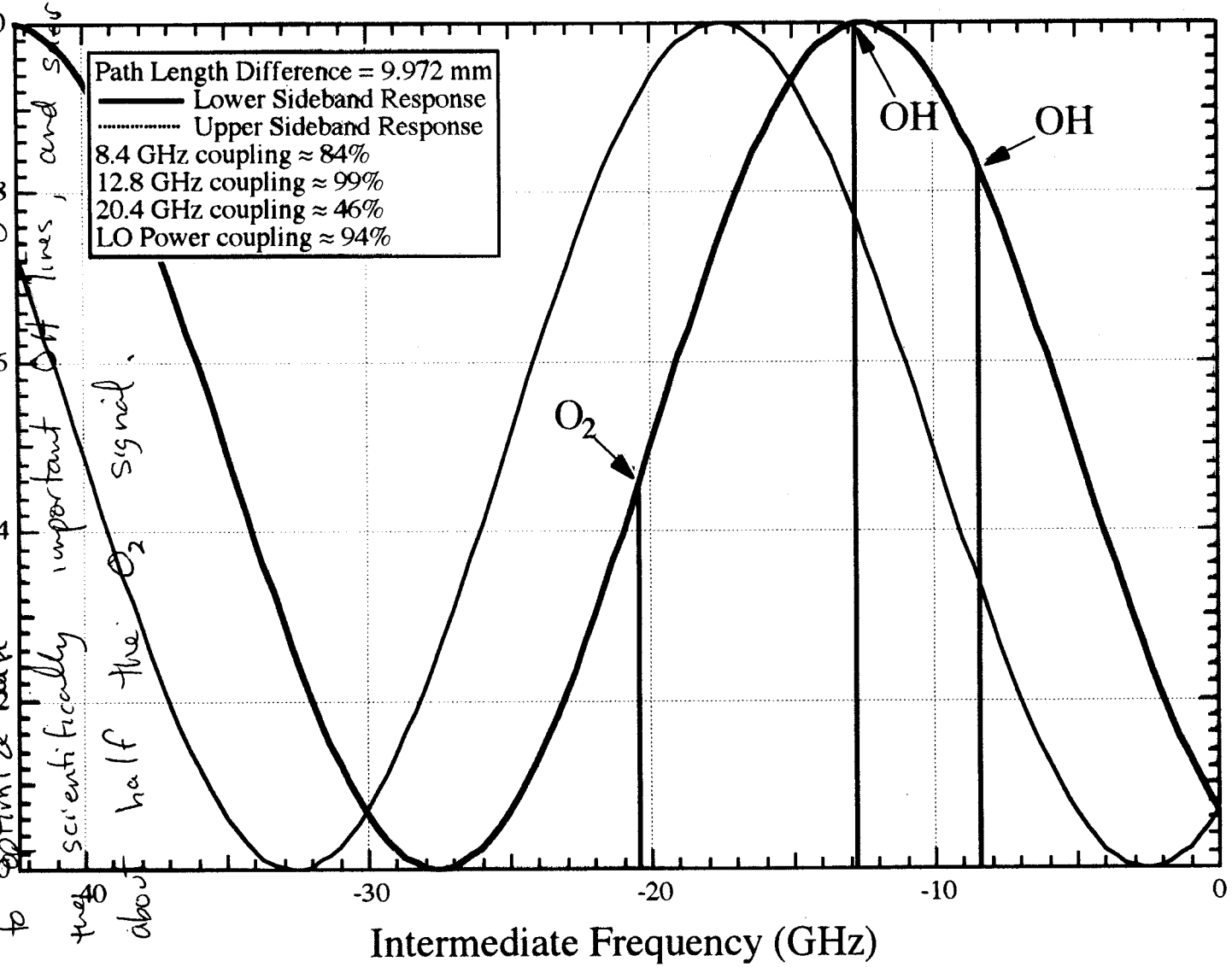
The green assembly is the tilting rooftop mirror
- Utilizes a flexure near the lower piece of invar
- Thermal expansion same as for fixed mirror; all relevant diplexer components are made from the same piece of Al alloy 7075-T7351







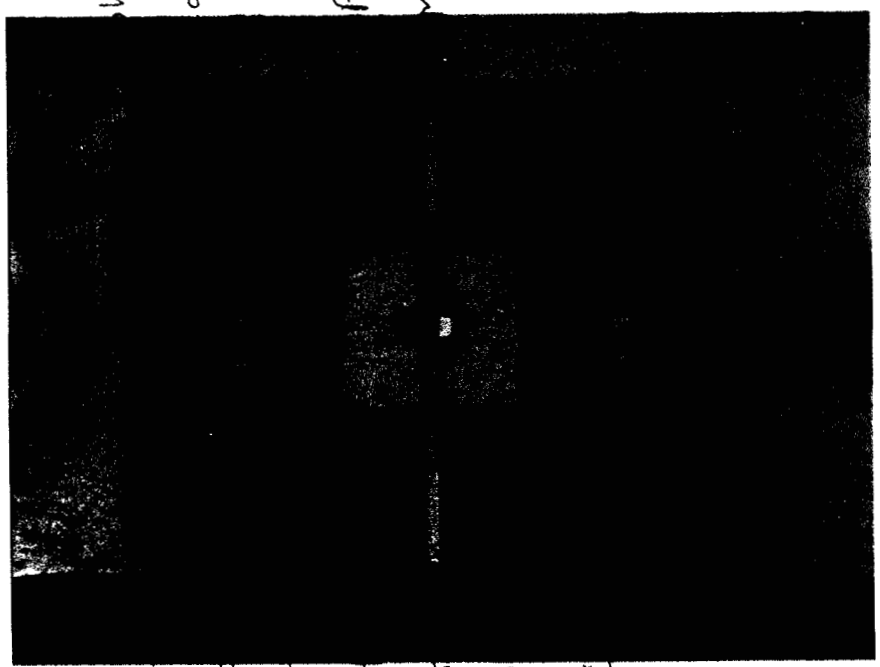
Diplexer: Path Length Adjustment (continued)

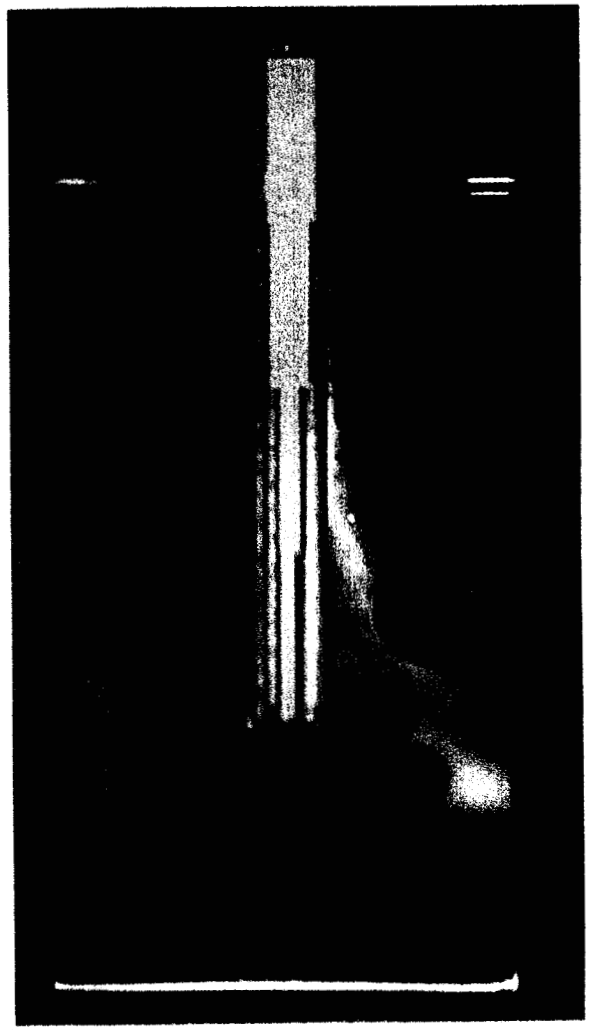


The M-P diplexing action gives us a sine-like transmission curve. If simultaneously we focus on to optimize all the scientifically important OH lines, and sacrifice the about half the O_2 signal.

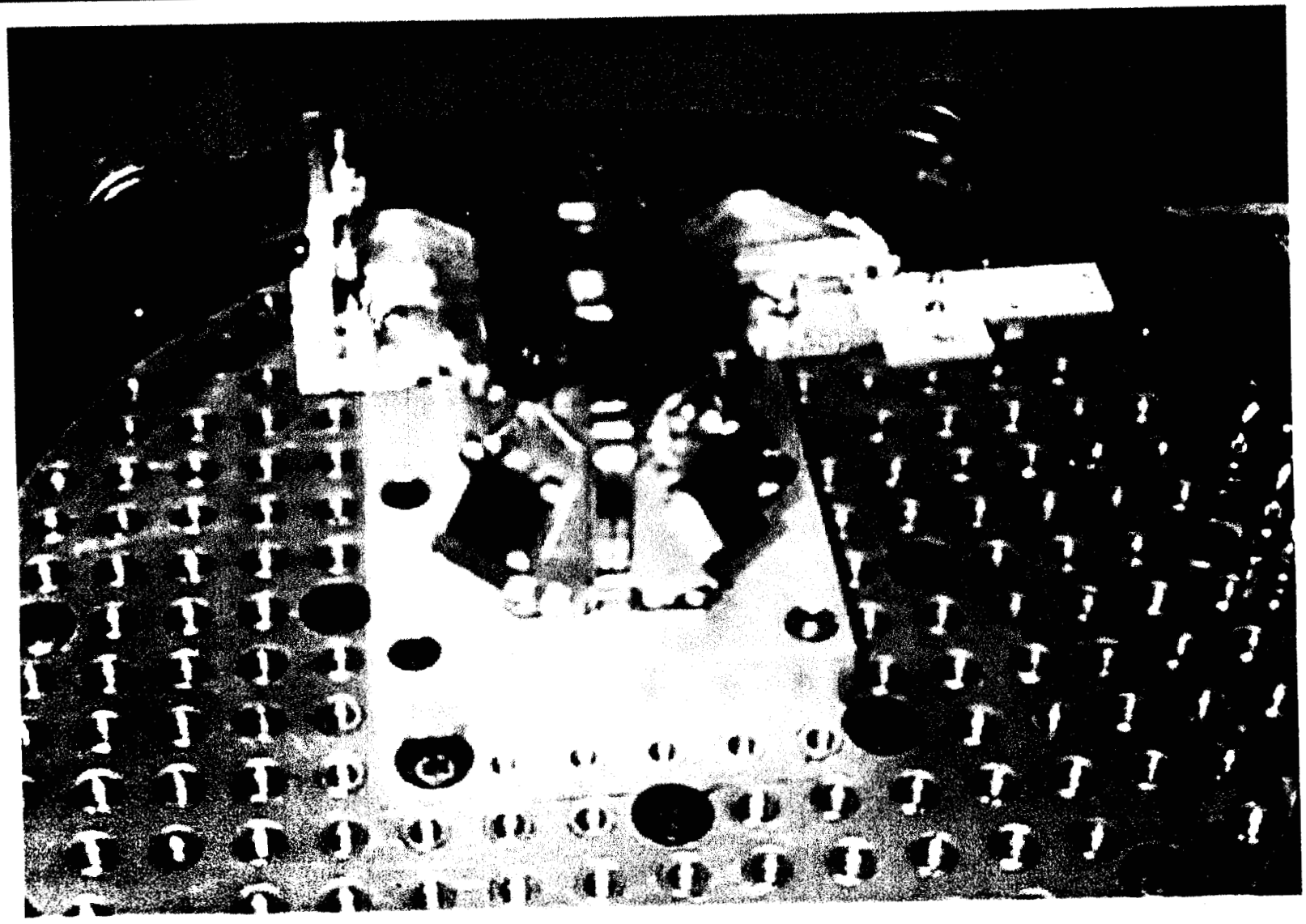
JPL Mixer: Mixerblock Mounting

- Membrane frame is 50 μm thick
  RF choke is 40 μm wide, 3 μm thick, 600 μm long
- Airbridge anode contact finger for minimal capacitance; anode is 1 x 0.2 μm
- Electroformed PIP horn and transition to 50 x 100 μm rectangular w.g.
  Note off-color electroformed "button" at lower right
- RF choke is centered in 30 μm tall x 50 μm wide w.g. (dicing saw)
- Hobbed backshort is fixed, aligned with holes, and sits on the membrane
- IF transformer on quartz, wirebond or beam lead connection to membrane
- Dual DC bias connections (through Pi filter for EM, PF)

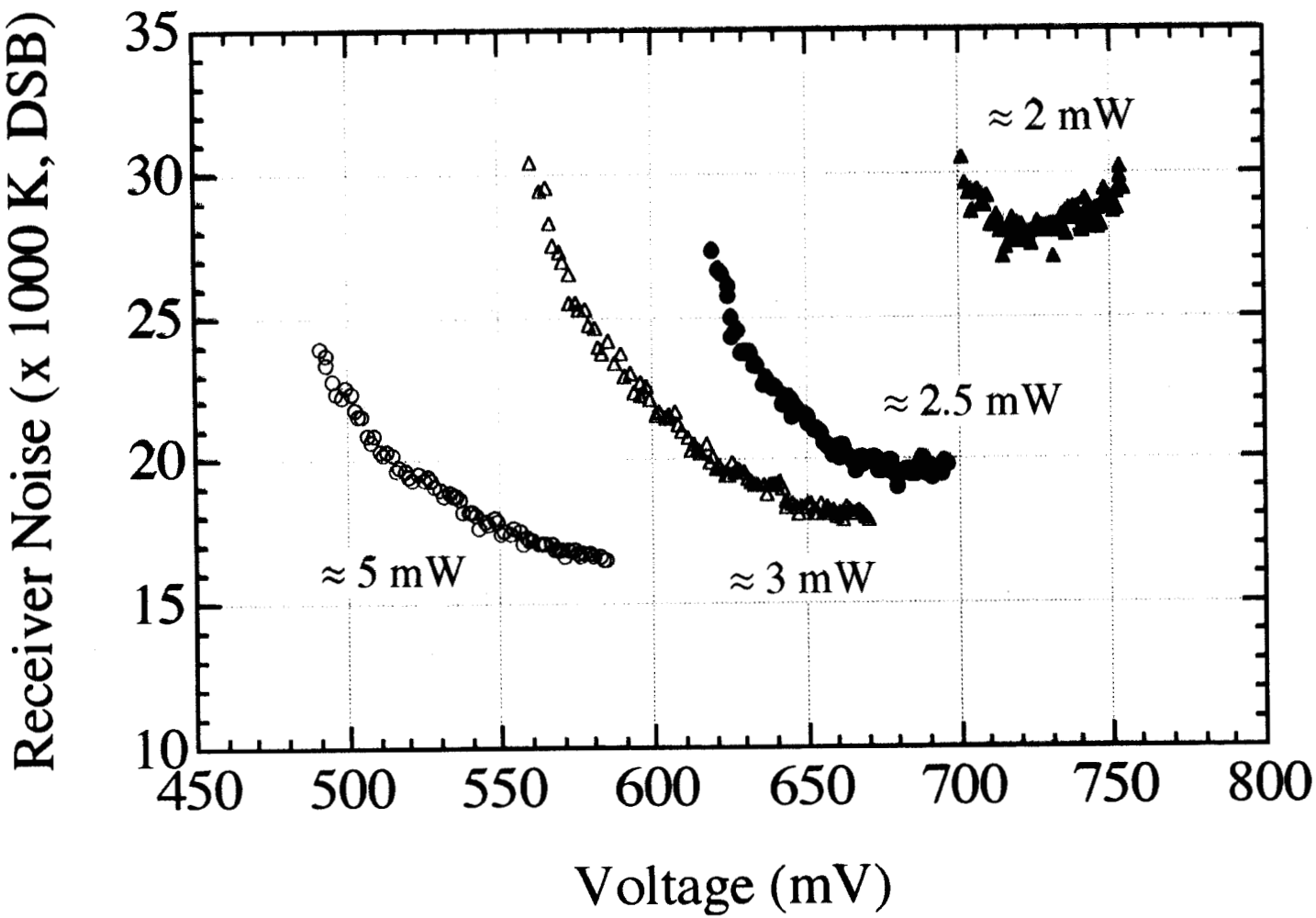




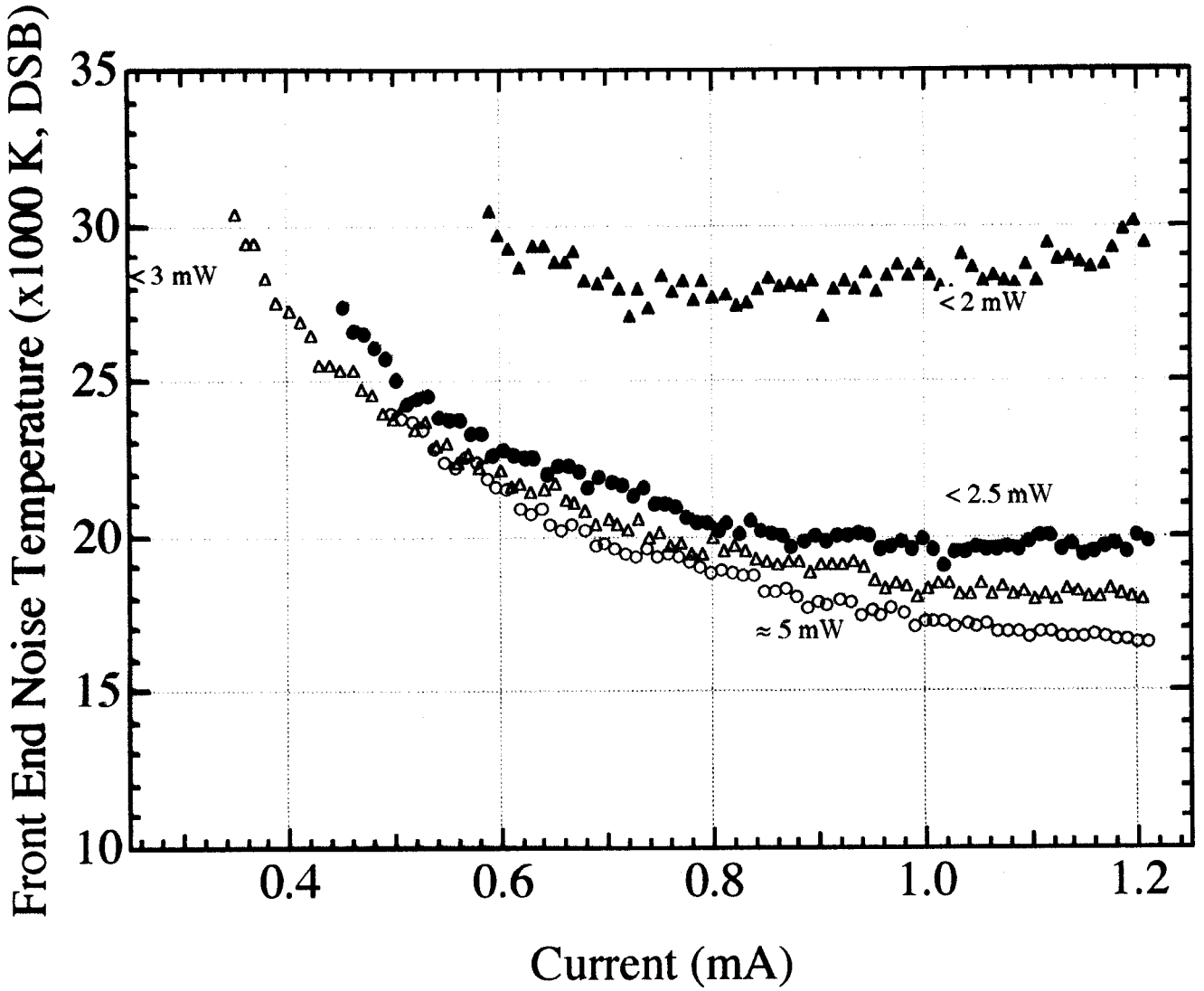
Receiver Front End



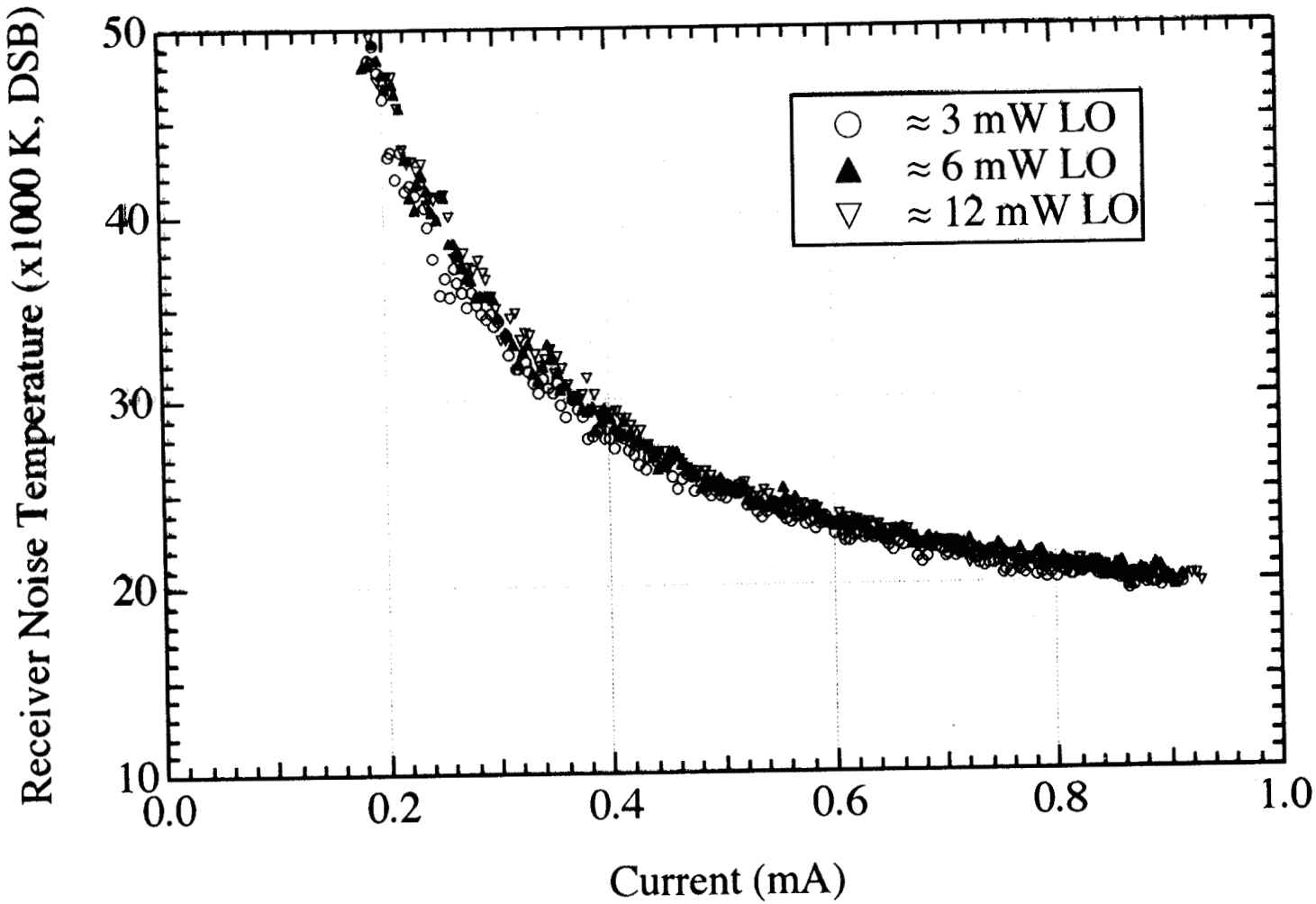
JPL Mixer: LO Power and Noise Temperature



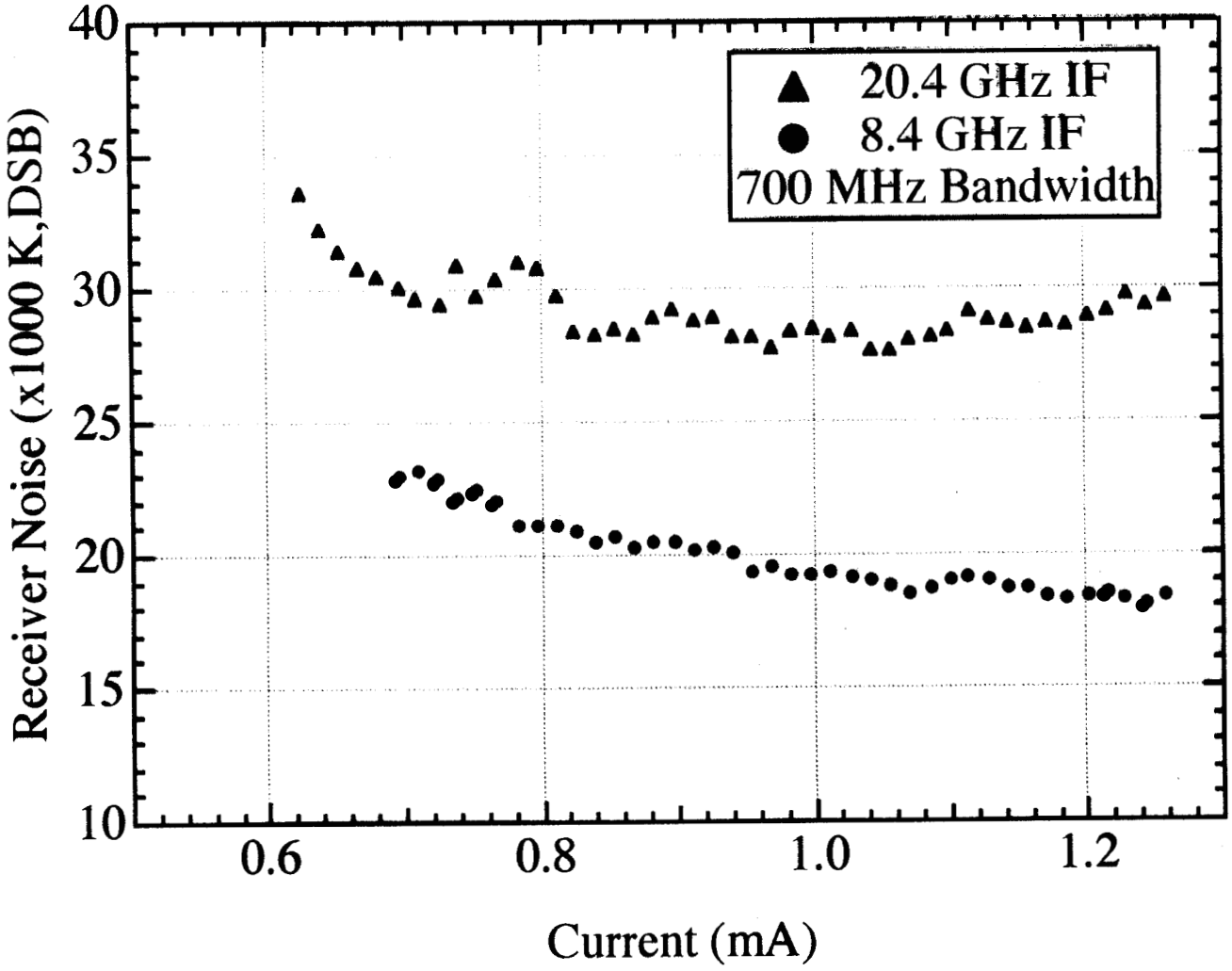
JPL Mixer: Current Bias!



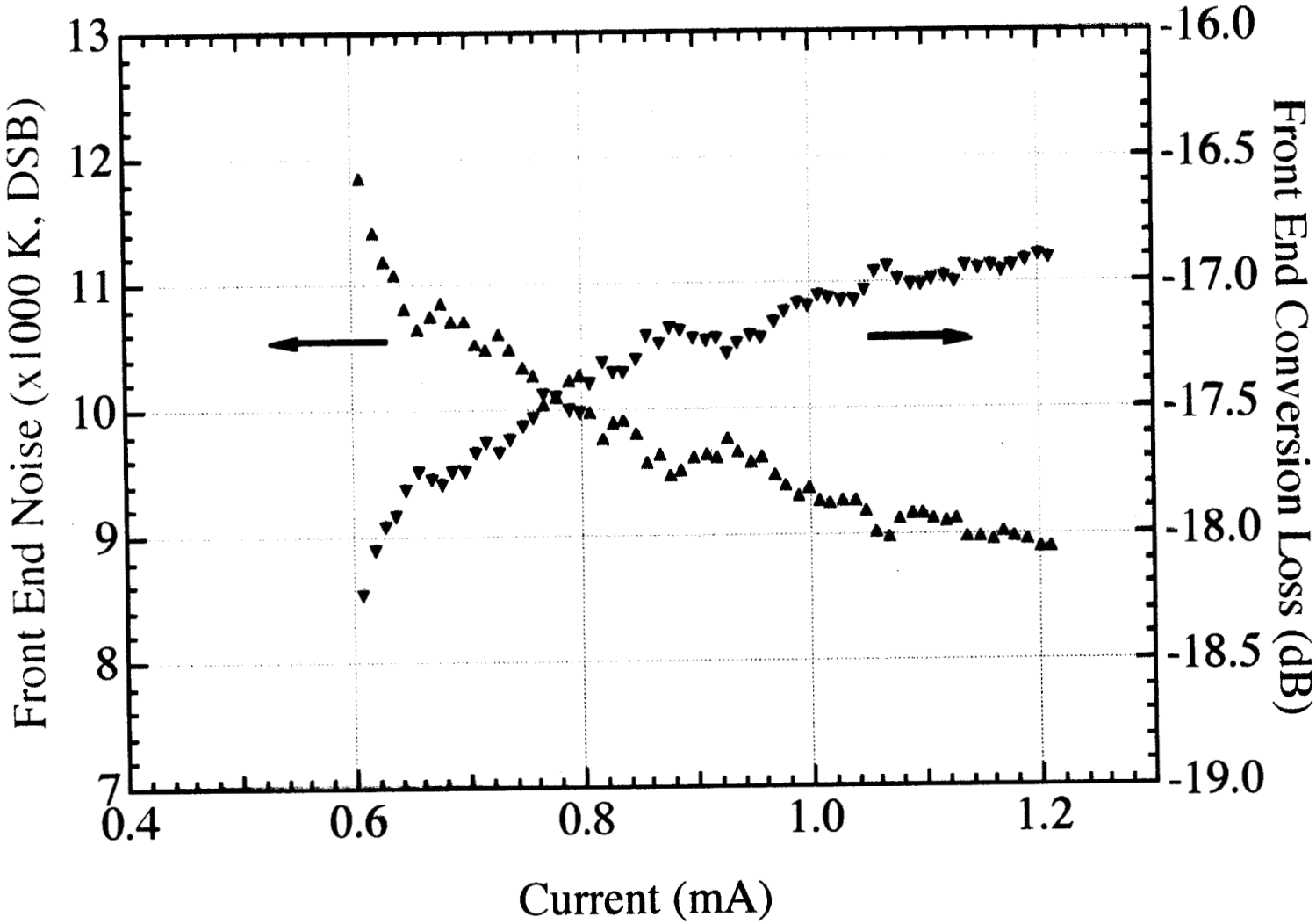
JPL Mixer: Current Bias!



JPL Mixer: Mixer Noise vs. IF



JPL Mixer: Noise Without IF Amplifier



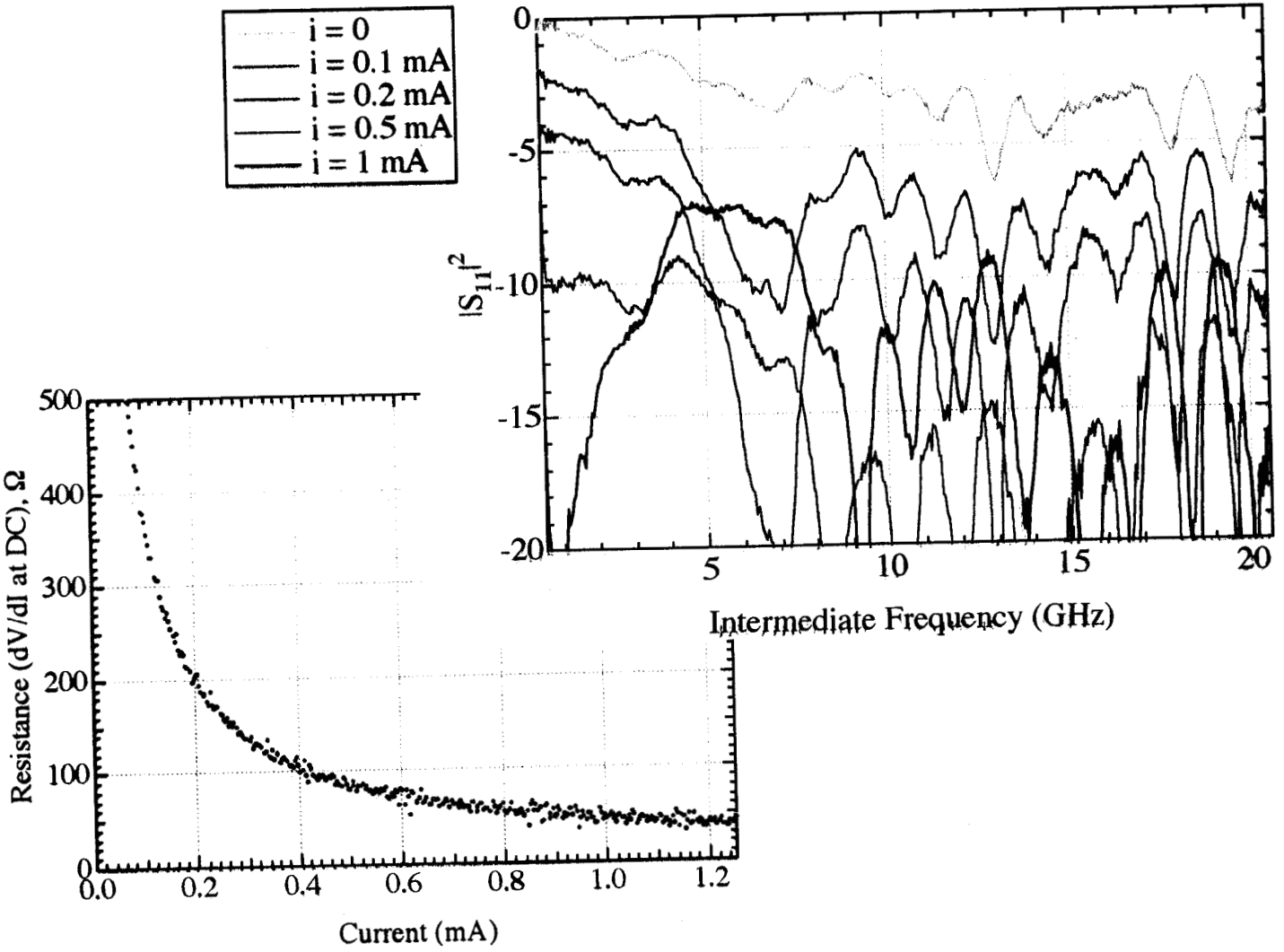
* Noise includes diplexer and atmospheric losses

Front End

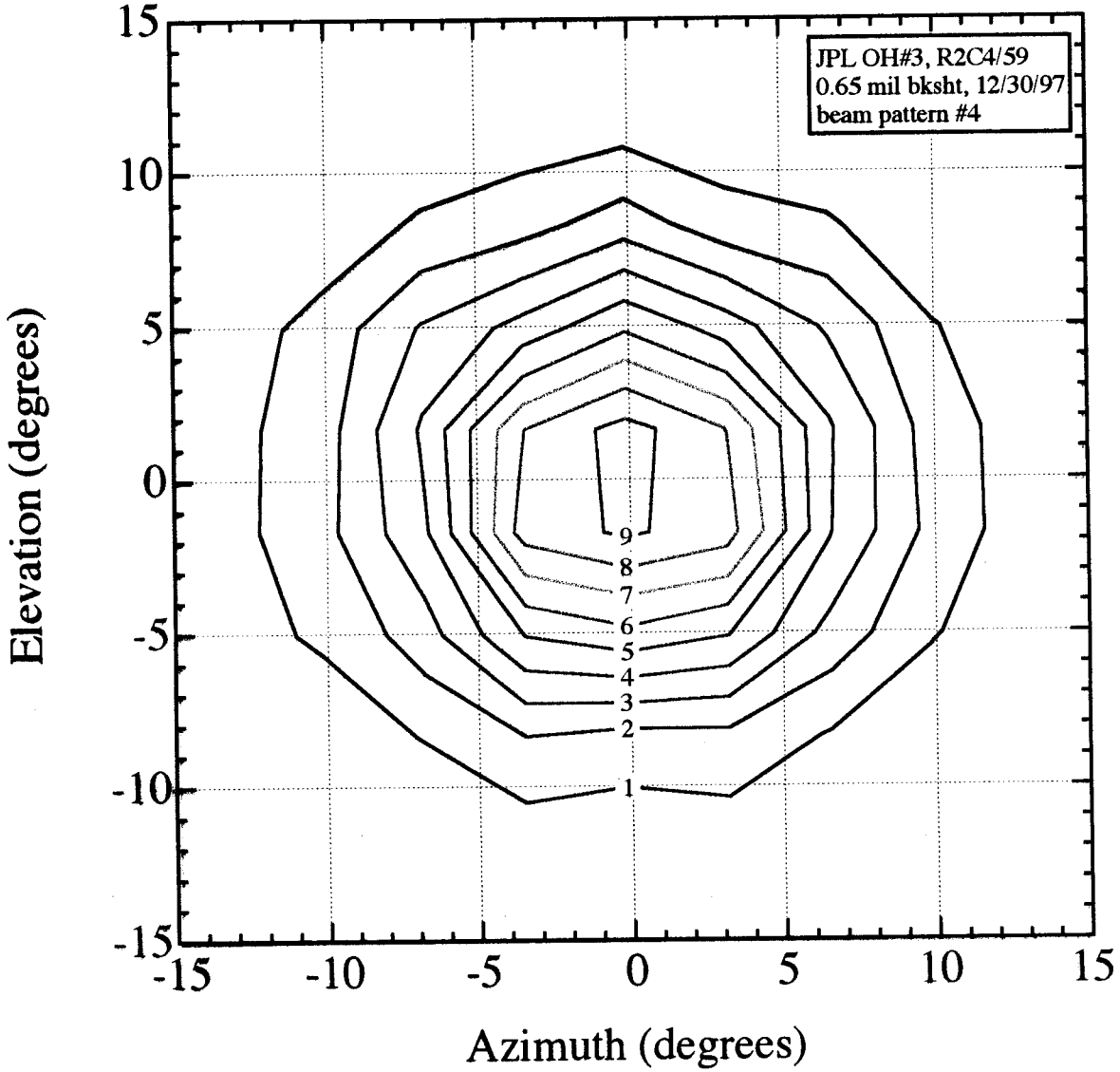
Requirement Summary:

• LO Frequency	2522 GHz
• Signal IF	8.4, 12.8, 20.4 GHz
• Rcvr. Noise	15,000 K, DSB (8.4,12.8) 45,000 K, DSB (20.4)
• LO Power	≈ 10 mW per mixer
• Beam	95% main, well-defined
• Lifetime	> 5 years
• Random Vibration	13 g rms
• Thermal	Test from -15° C to 60° C

IF Return Loss, 0.4 μm anode, 100 Ω transformer

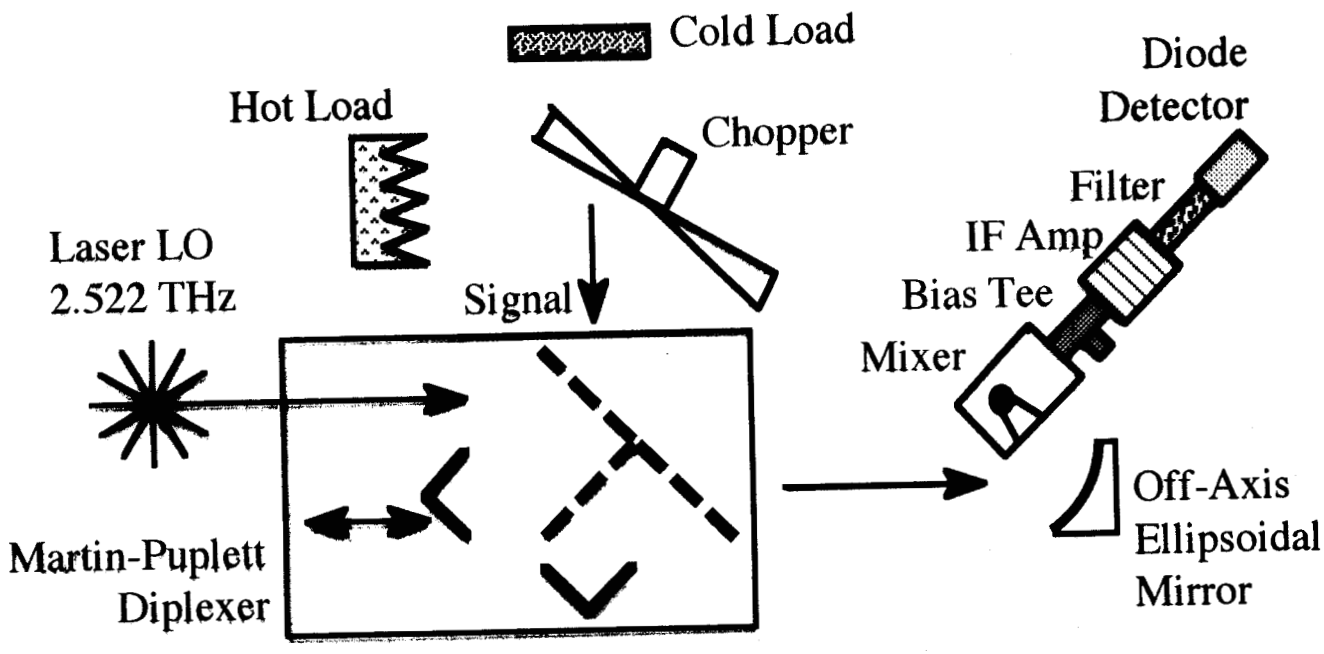


JPL Mixer: Pickett-Potter Horn Beam Pattern

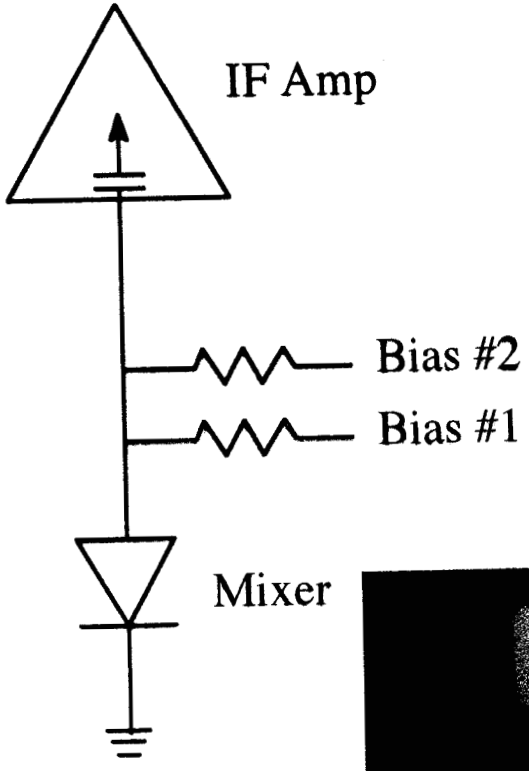


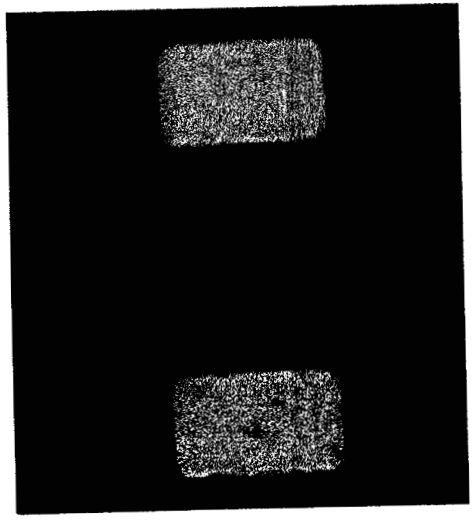
Theoretical
HPBW = 12°

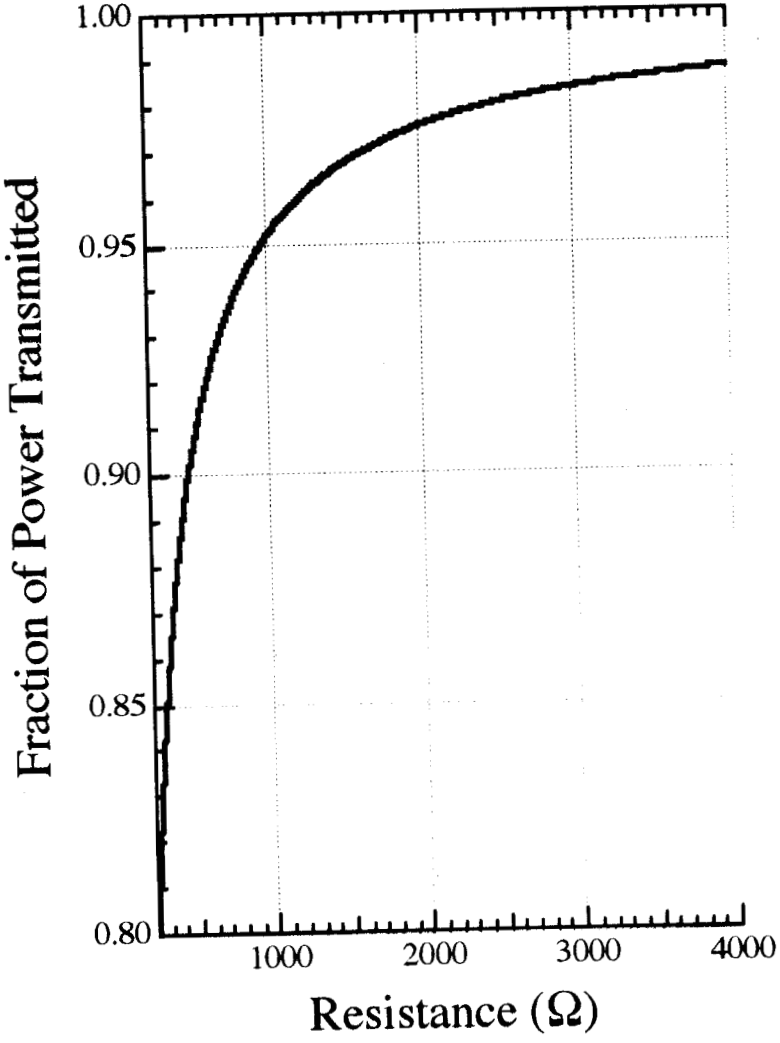
Test Configuration

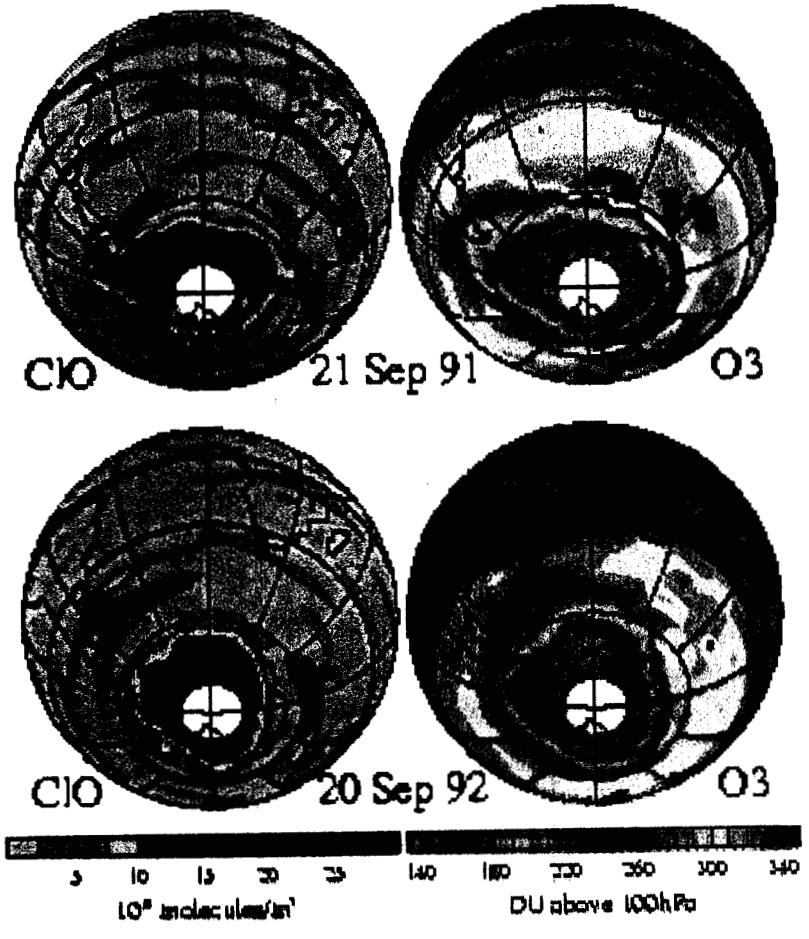


Bias T


IF Amp
Bias #2
Bias #1
Mixer

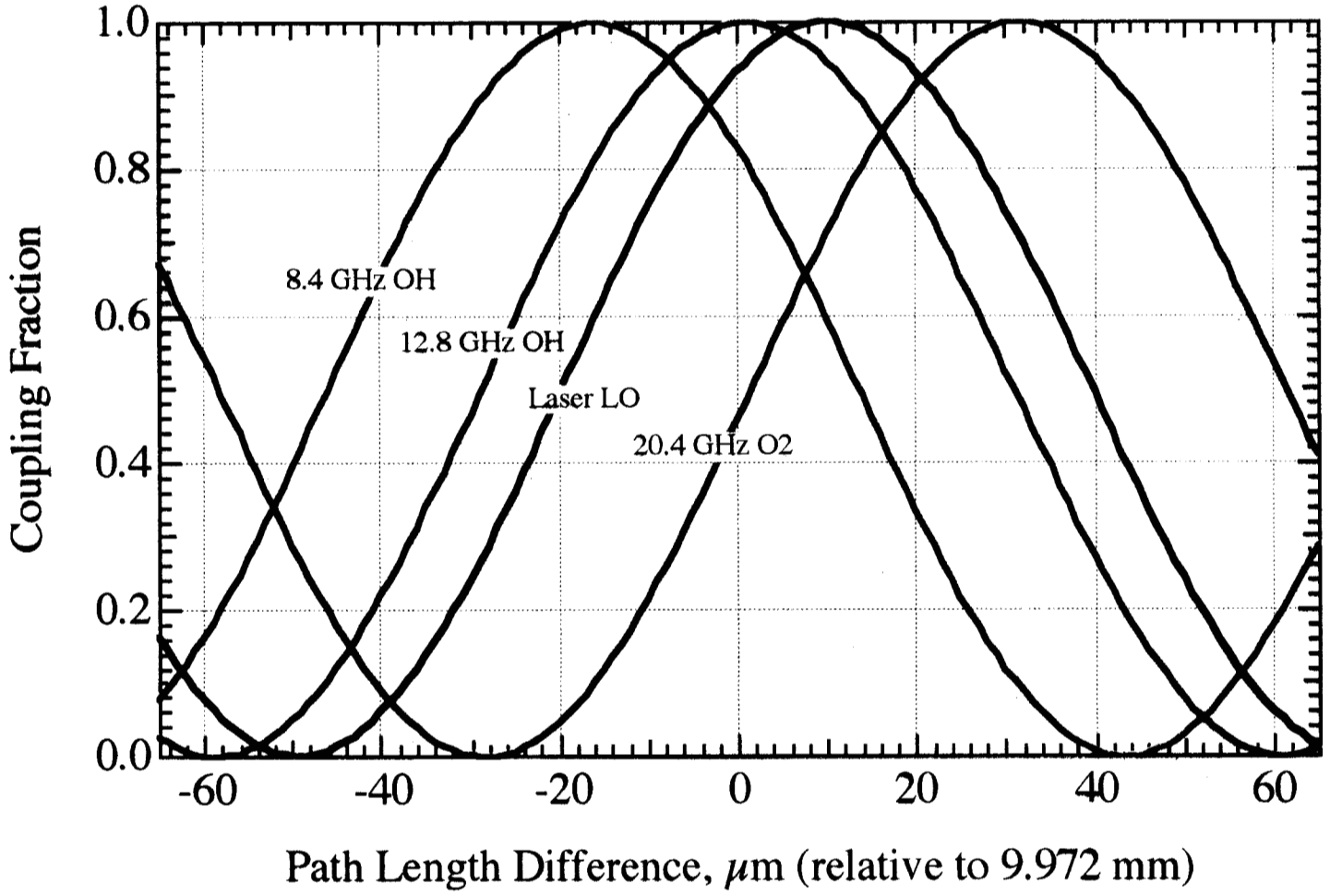



1.00
0.95
0.90
0.85
0.80
Fraction of Power Transmitted
1000
2000
3000
4000
Resistance (Ω)



Chlorine monoxide (ClO) and ozone (O3) measured by the Microwave Limb Sounder on NASA's Upper Atmosphere Research Satellite. ClO is the dominant form of reactive chlorine that destroys ozone. The white circular area around the pole is where no measurements are obtained.

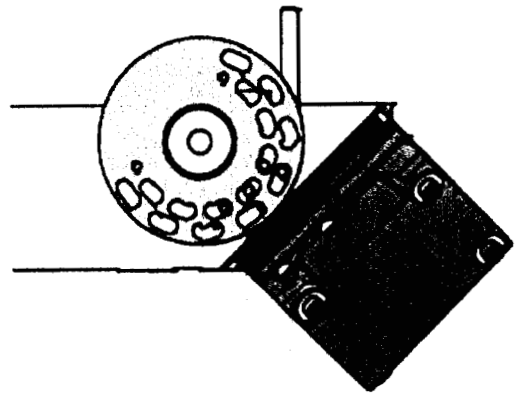
Diplexer: Path Length Adjustment (continued)

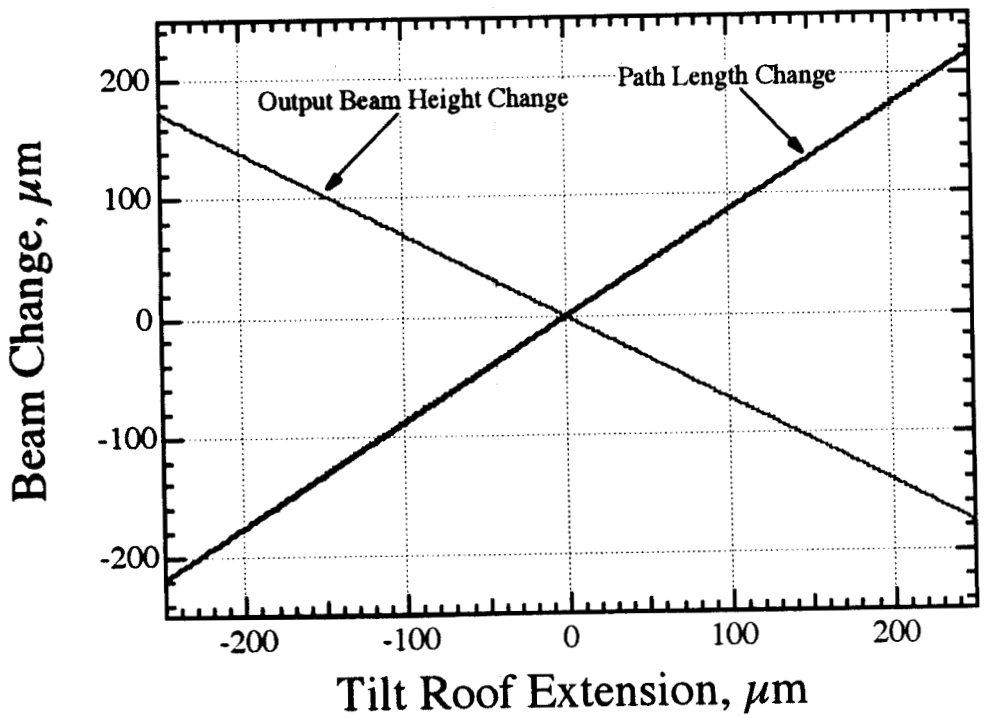


*Note that the "coupling fraction" refers to the proper polarization; the "uncoupled" power is simply in the undesired polarization, and is reflected or dissipated by the mixer (assuming no cross-pol sensitivity).

Diplexer: Path Length Adjustment (continued)

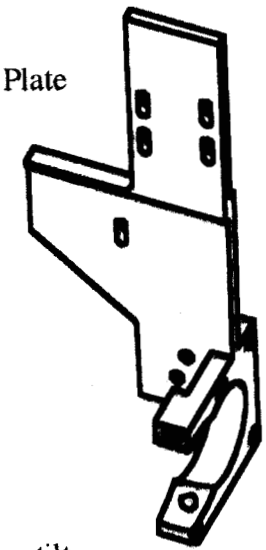
Rotating wheel is decentered by 0.010 inches.
Rotating wheel radius is 0.75 inches.
Flexure - to - invar distance is ≈ 2.5 inches.
Nominal input/output beam displacement is 0.866 inches (aperture > – 45 dB).
Extension of disk edge is 0.020 inches for 180° rotation, or, 2.8 μm/°.
A lateral shift of the wheel of 68 μm (≈ 2.7 mils) gives an extension of 0.57 μm.
An extension of 0.57 μm corresponds to a path length change of 0.5 μm.
A 180° rotation changes the path length by ≈ 440 μm.
A beam height offset of 100 μm causes ≈ 0.05% power loss.

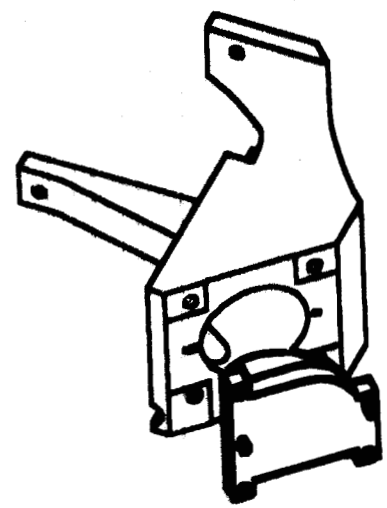




Best Linear Fits:
Path Length = 0.87 * Extension
Beam Height = – 0.70 * Extension

FMS: Exploded View

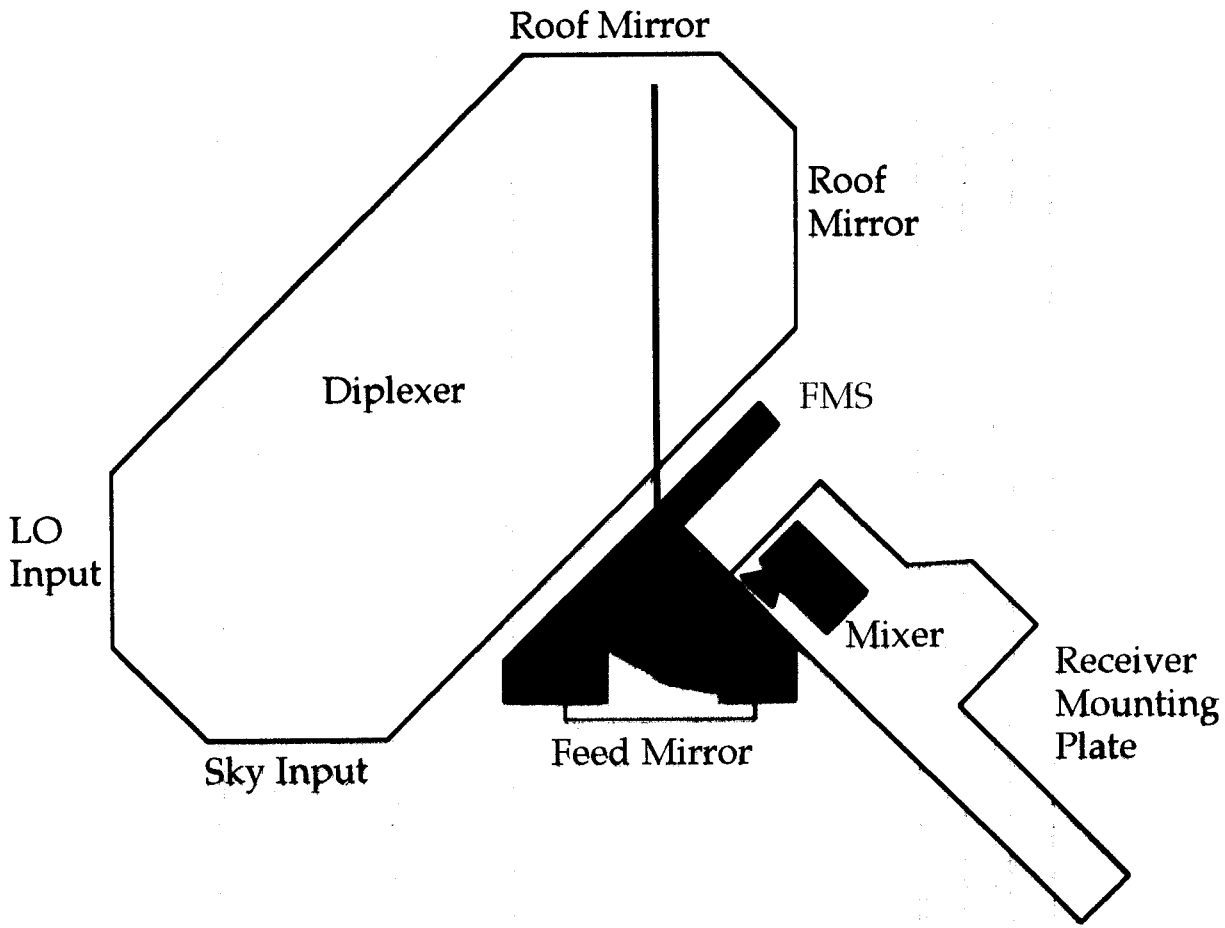




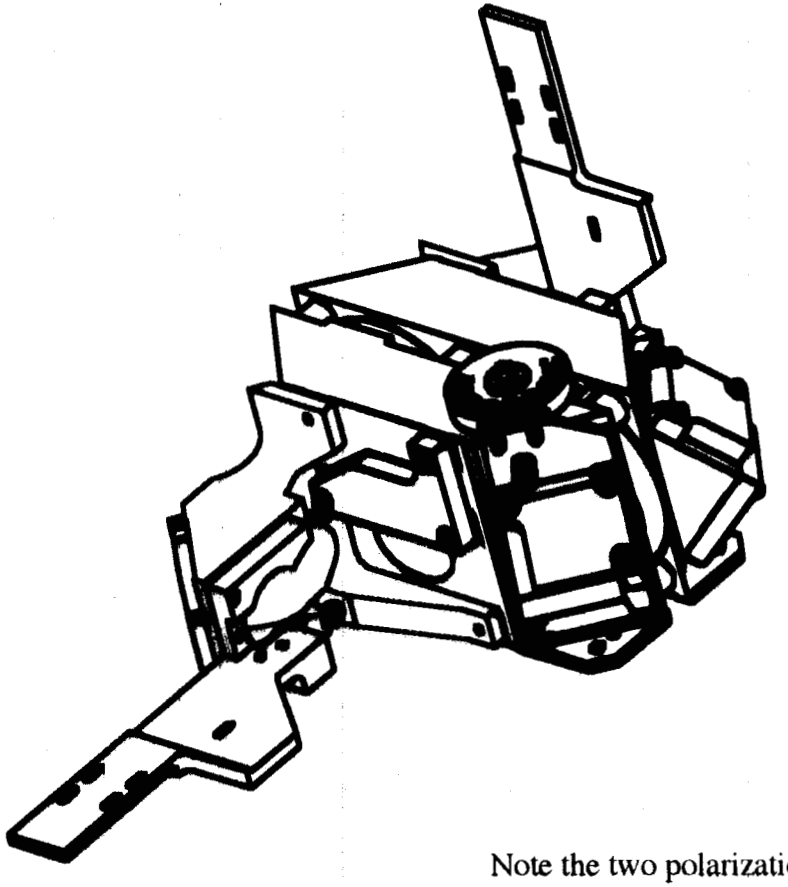
Note the following alignment tools:

- FMS 3-point mount for shimming of feed mirror tilt with respect to the diplexer. FMS is also pinned for rotation and x-y position with respect to the diplexer.
- Feed mirror pinned for rotation and x-y position. Tilt is adjusted with shimmed 3-point mount, effectively adjusting the x-y of the mixer.
- Receiver mounting plate 3-point mount for tilt and z-position of the mixer

FMS: Assembly View



Front End Assembly View



Note the two polarization configurations, with mirrored FMS structures and rotated receiver mounting plates.