Low-Noise Pseudo Correlation Receivers for the Planck Low-Frequency Instrument

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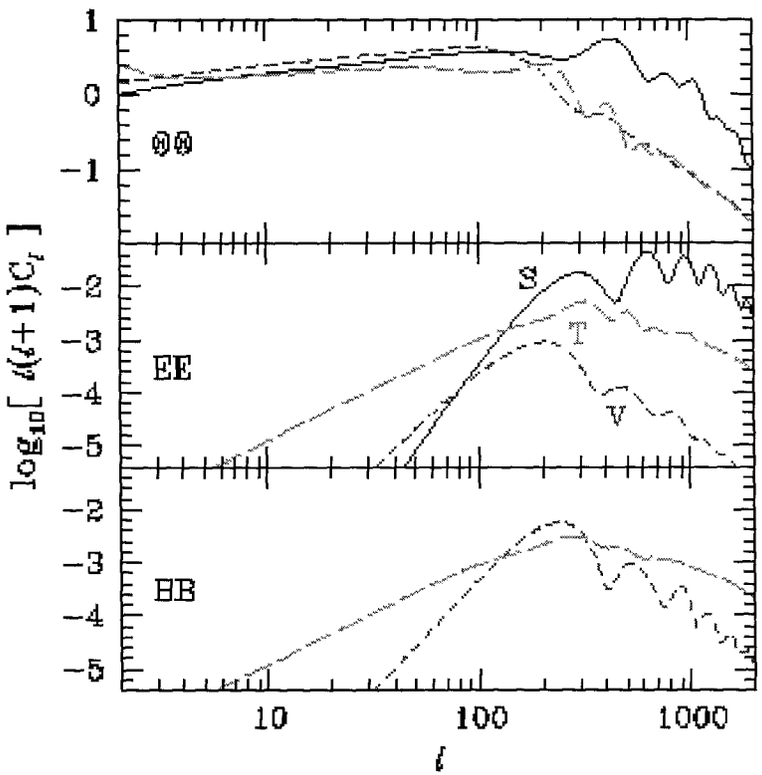
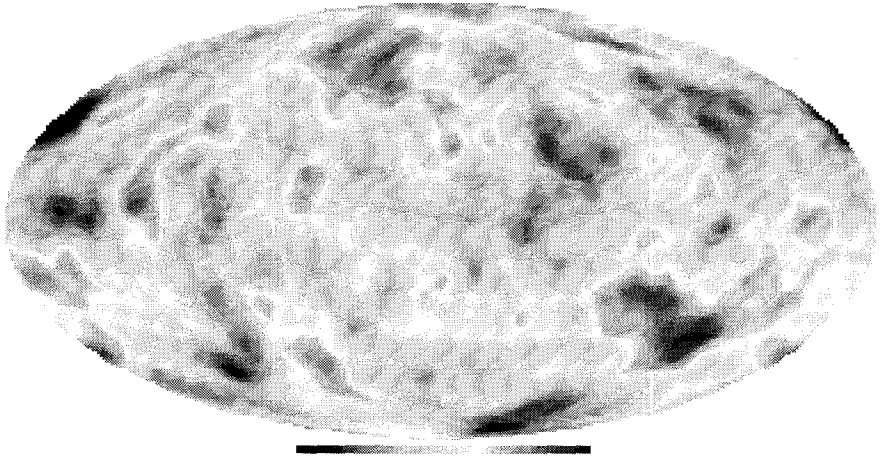


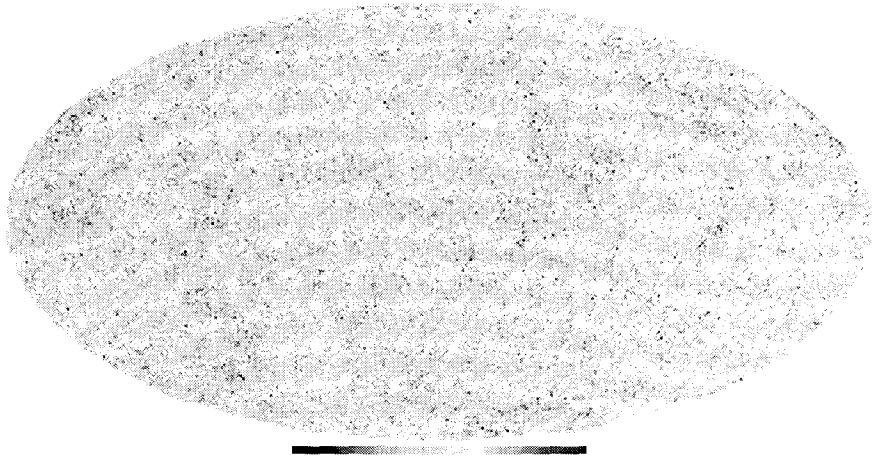
FIG. 8. Temperature and polarization power spectra for a scaling anisotropic stress seeds with the minimal characteristic time $B_1 = 1$ for scalars (S, solid), vectors (V, short-dashed), and tensors (T, long-dashed). Scalar temperature fluctuations at intermediate scales are dominated by acoustic contributions which then damp at small scales. B-parity polarization contributions are absent for the scalars, larger by an order of magnitude than E-parity contributions for the vectors and similar to but smaller than the E-parity for the tensors. Features in the vector and tensor spectra are artifacts of our choice of source and are unlikely to be present in a realistic model. The background cosmology is set to $\Omega_0 = 1$, $h = 0.5$, $\Omega_B h^2 = 0.0125$.

From: Hu&White '97

The Universe

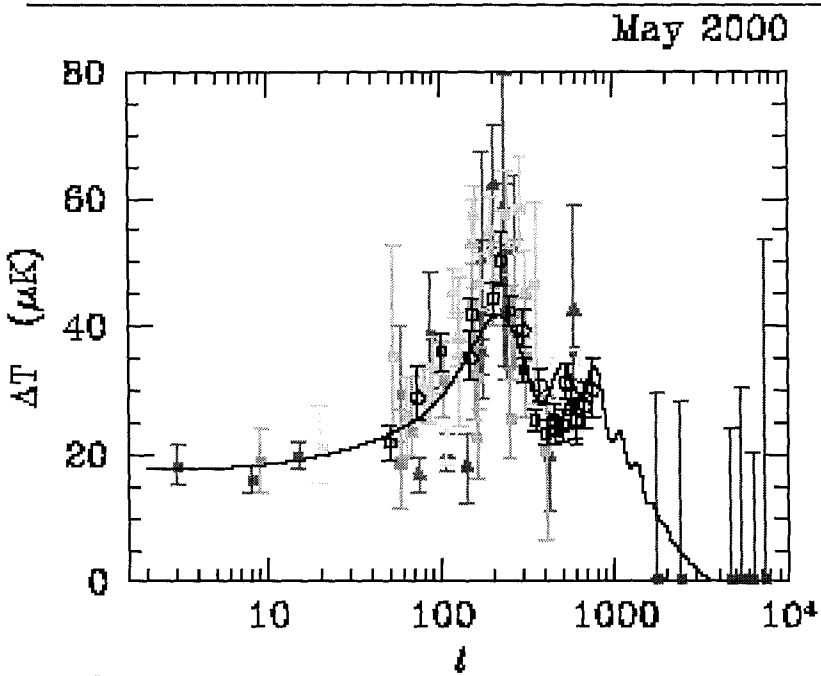


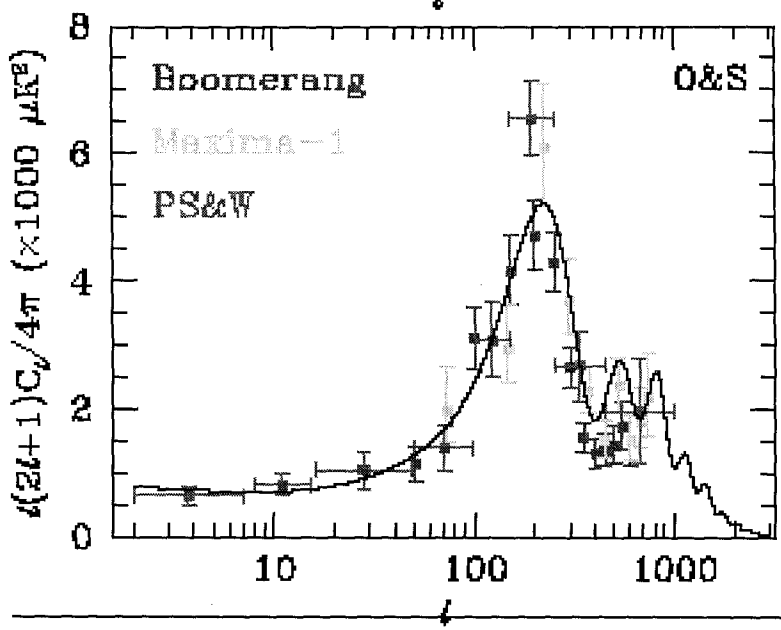
COBE Resolution

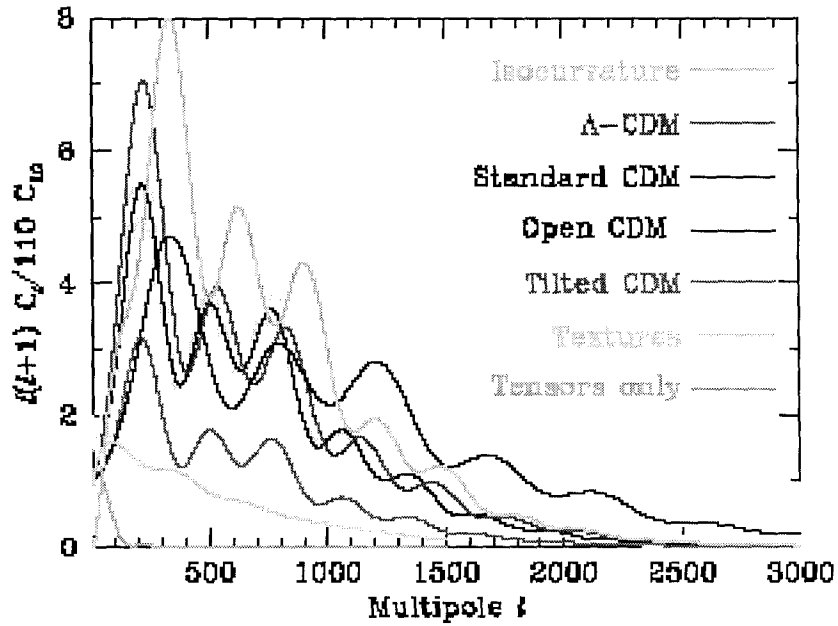


Planck Resolution

Current Results and Planck Expectations

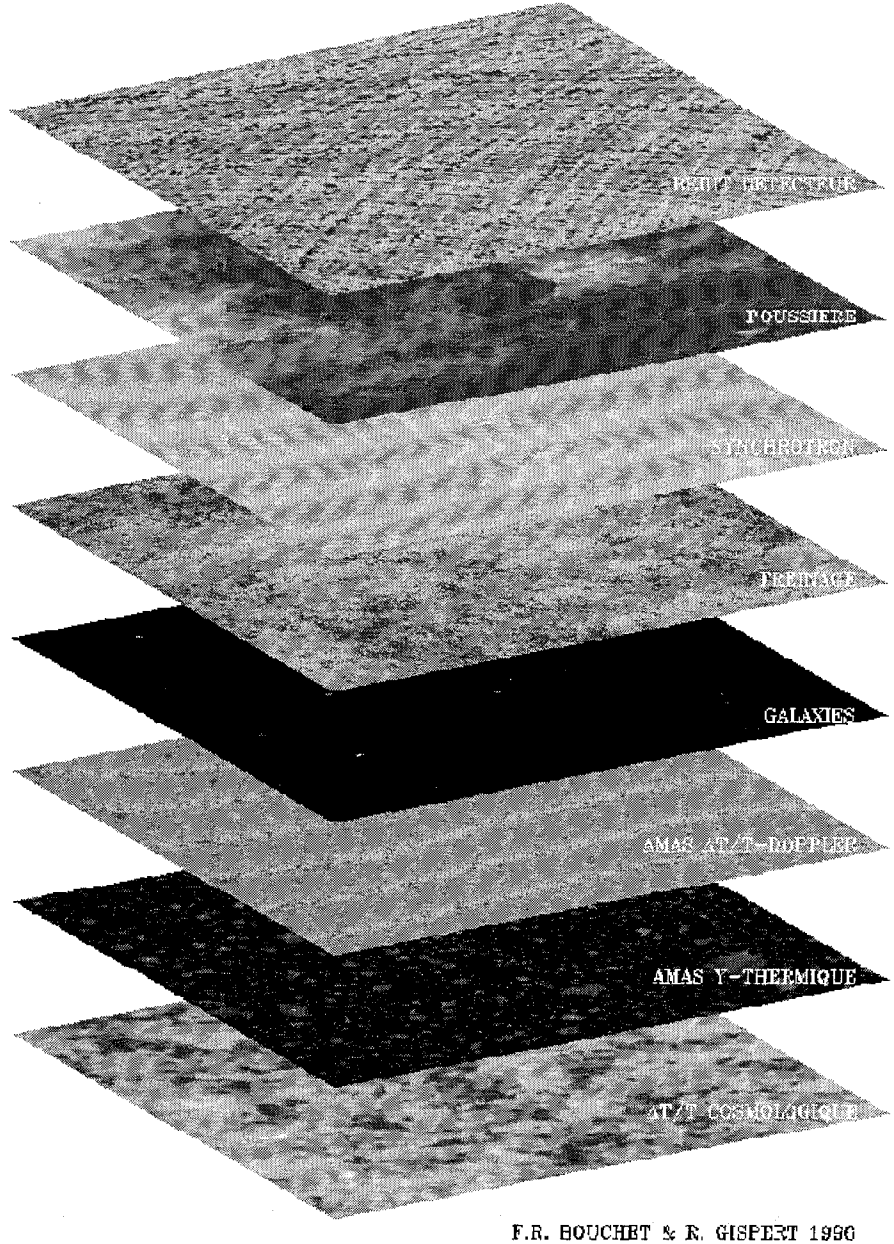






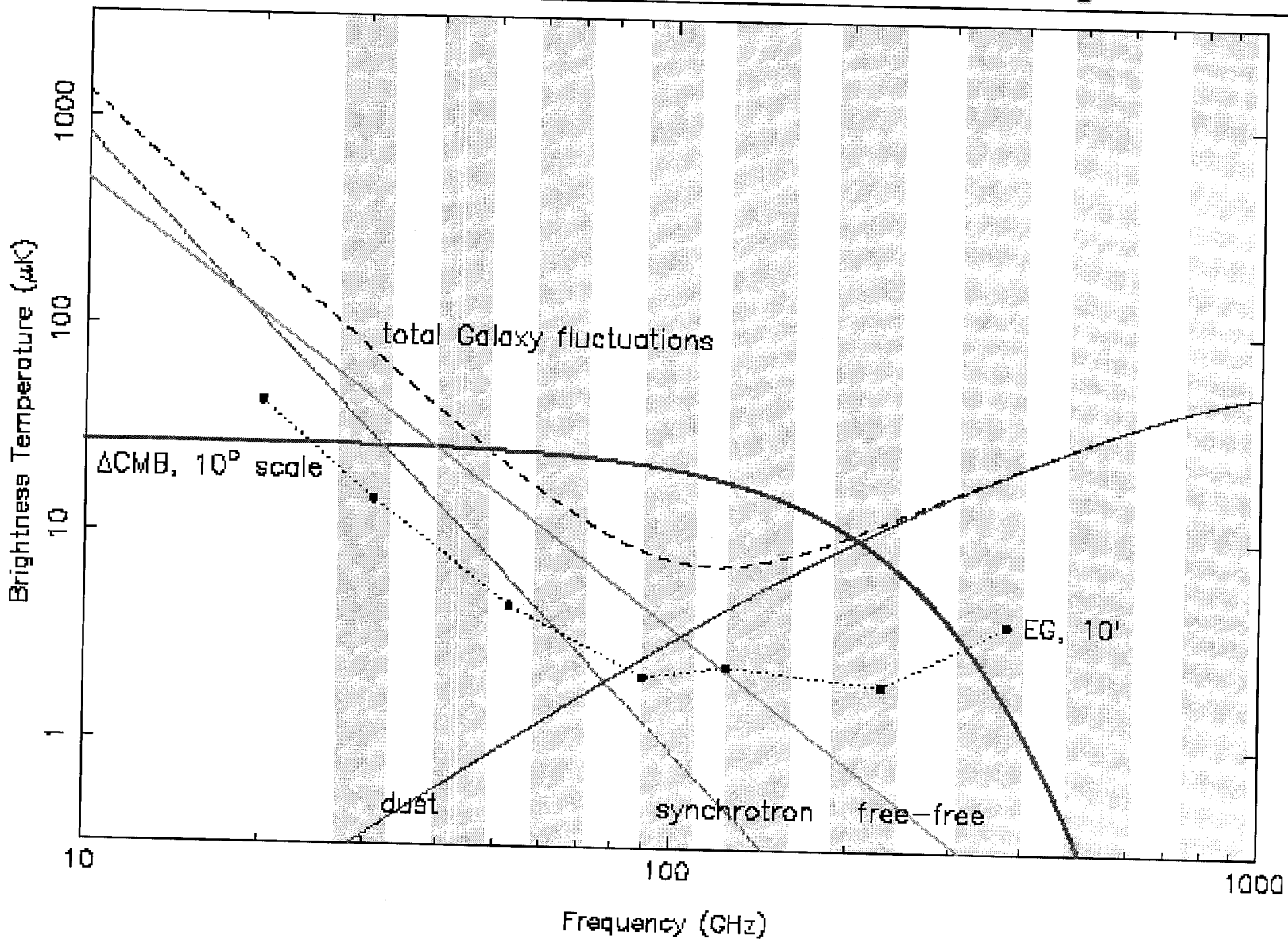
On angular scales greater than about 5′ the uncertainty in Planck's measurements of temperature anisotropies should be determined by the number of independent samples that the Universe provides, rather than by instrument noise.

Why Planck Needs 30–857 GHz: Foregrounds



F.R. BOUCHET & R. GISPERT 1990

Foregrounds and the CMB Have Different Spectra

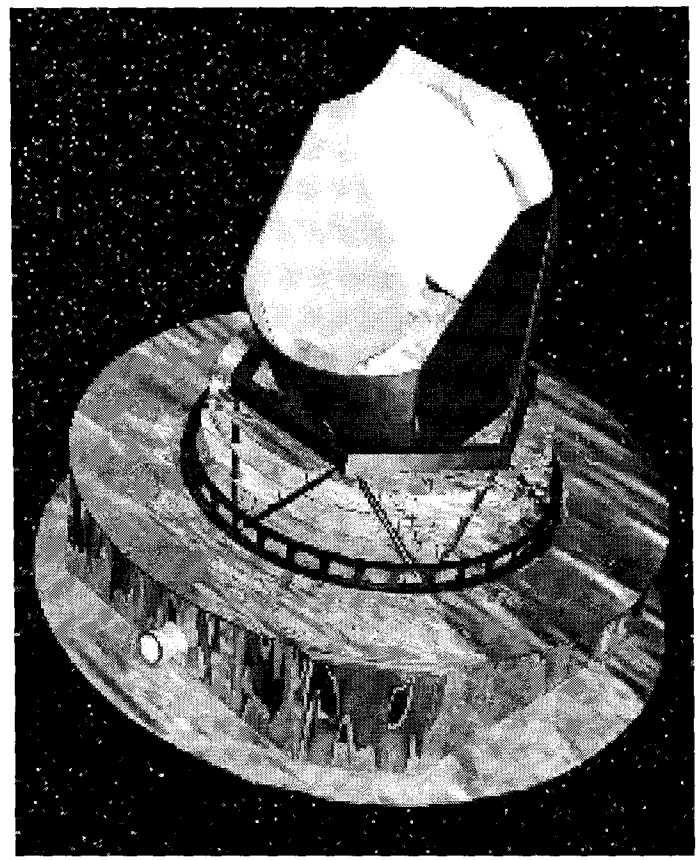


Planck Mission Overview

- Third generation space CMB mission
- Launch 2007 (was 2004) with FIRST
- Main objective: image over the whole sky the temperature anisotropies of the CMB, with FWHM as small as 5′ and sensitivity per resolution element of 5–12 μK
- L_2 Lissajous orbit
- Spin axis pointed at Sun, 1 rpm spin
  - Optical axis ≈perpendicular to spin axis
- Single, continuous, observing mode
- Two instruments
  - Low Frequency Instrument (30–100 GHz)

    56 channels of HEMT amplifiers cooled to 20 K by the H_2 sorption cooler
  - High Frequency Instrument (100–857 GHz)

    48 channels of bolometers cooled to 0.1 K by three coolers: sorption + 4 K ^{4}He JT + ^{3}He^{4}He dilution



Planck Mission Parameters

Launch: 2007
Optical System: 1.5 m off-axis Gregorian providing 5'-25' beams

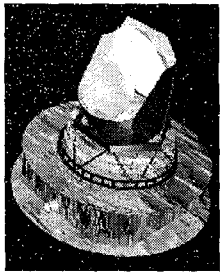
Low Frequency Instrument:

20 K InP HEMT amplifier based pseudo-correlation receivers

Frequency (GHz)	Fractional BW	# Channels	Sys Noise (K)	Sensitivity ($\mu K\sqrt{s}$)
30	0.2	4	10	90
44	0.2	6	15	100
70	0.2	12	23	90
100	0.2	34	32	80

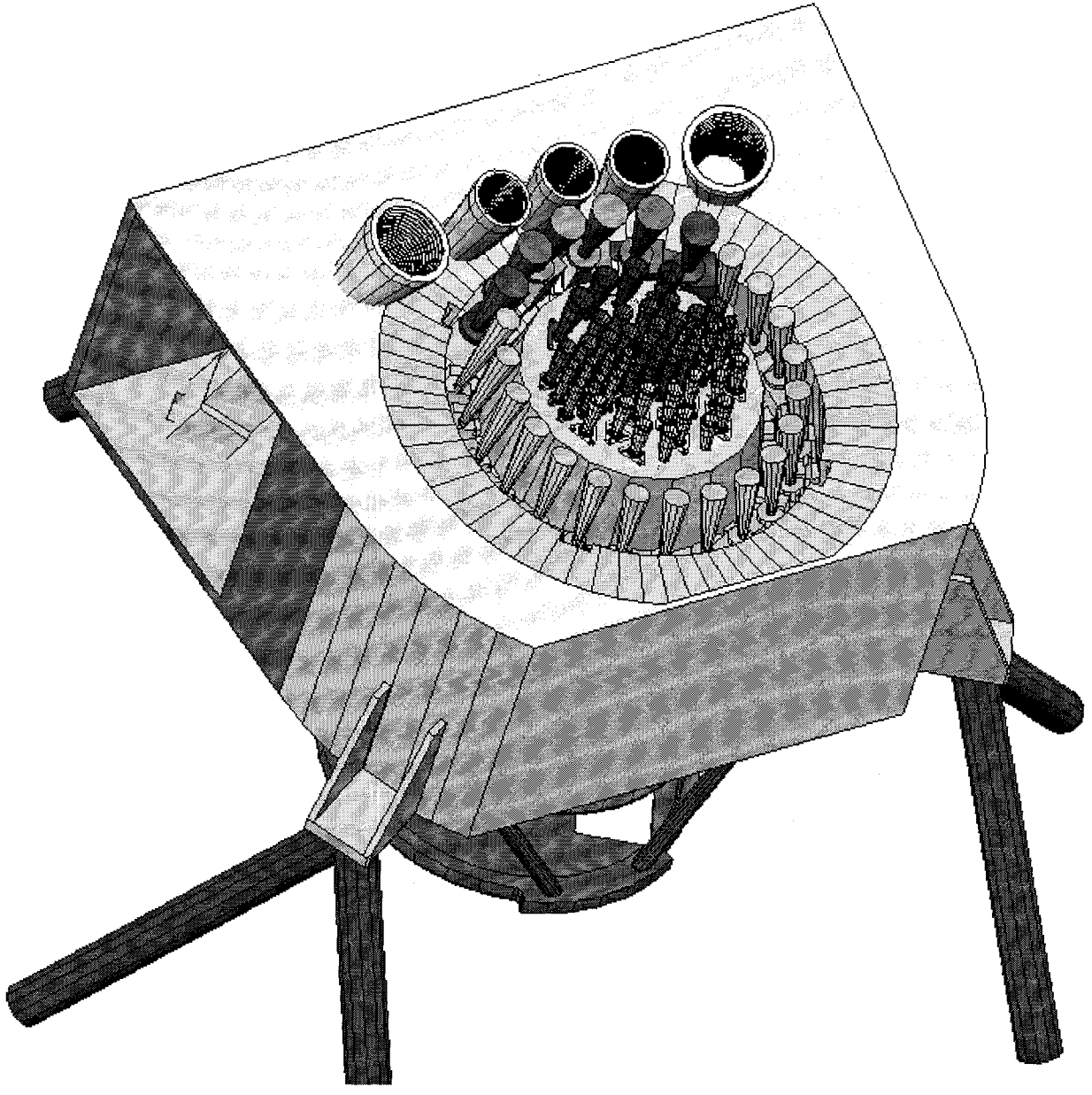
High Frequency Instrument
0.3 K Bolometers

Channel central frequency (ν)	**Ghz**	**100**	**143**	**217**	**353**	**545**	**857**
Beam FWHM	**(arcmin)**	**9.2**	**7.1**	**5**	**5**	**5**	**5**
Number of Unpolarised detectors		**4**	**5**	**6**	**6**	**/**	**6**
Number of polarised detectors		**/**	**7**	**8**	**/**	**8**	**0**
ΔT/T Channel NEDT (Intensity)	**(μK/K)Hz$^{-1/2}$**	**13.1**	**11.2**	**12.7**	**50.8**	**/**	**24000**
ΔT/T Channel NEDT (U and Q)	**(μK/K)Hz$^{-1/2}$**	**/**	**21.3**	**29.4**	**/**	**508**	**/**
ΔT/T Sensitivity (Intensity)	**(μK/K)**	**2.0**	**2.2**	**3.5**	**14**	**/**	**6600**
ΔT/T Sensitivity (U and Q) Polarised	**(μK/K)**	**/**	**4.2**	**8.1**	**/**	**140**	**/**



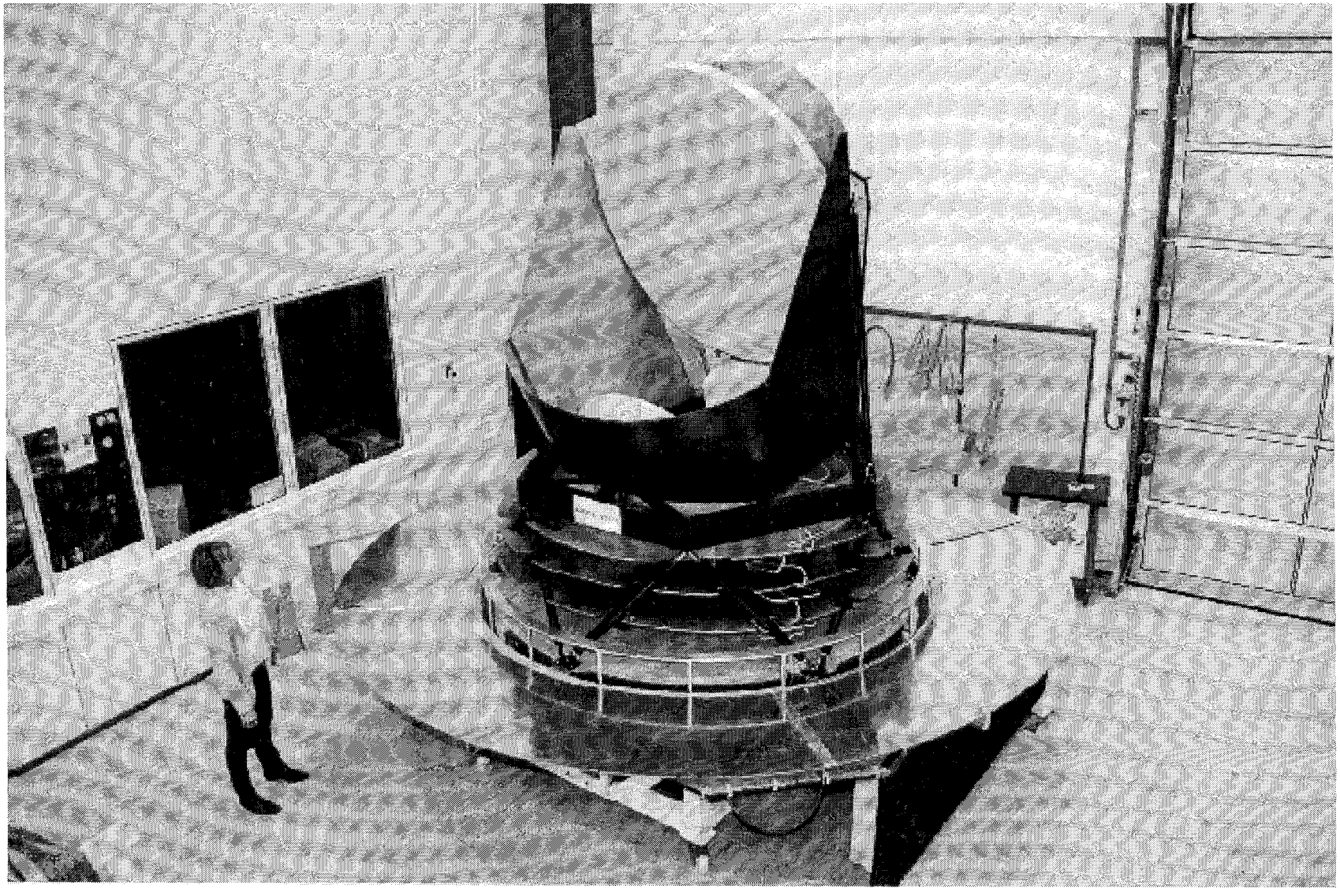
First / Planck Payload Review
23 May, 2000

PLANCK
HFI

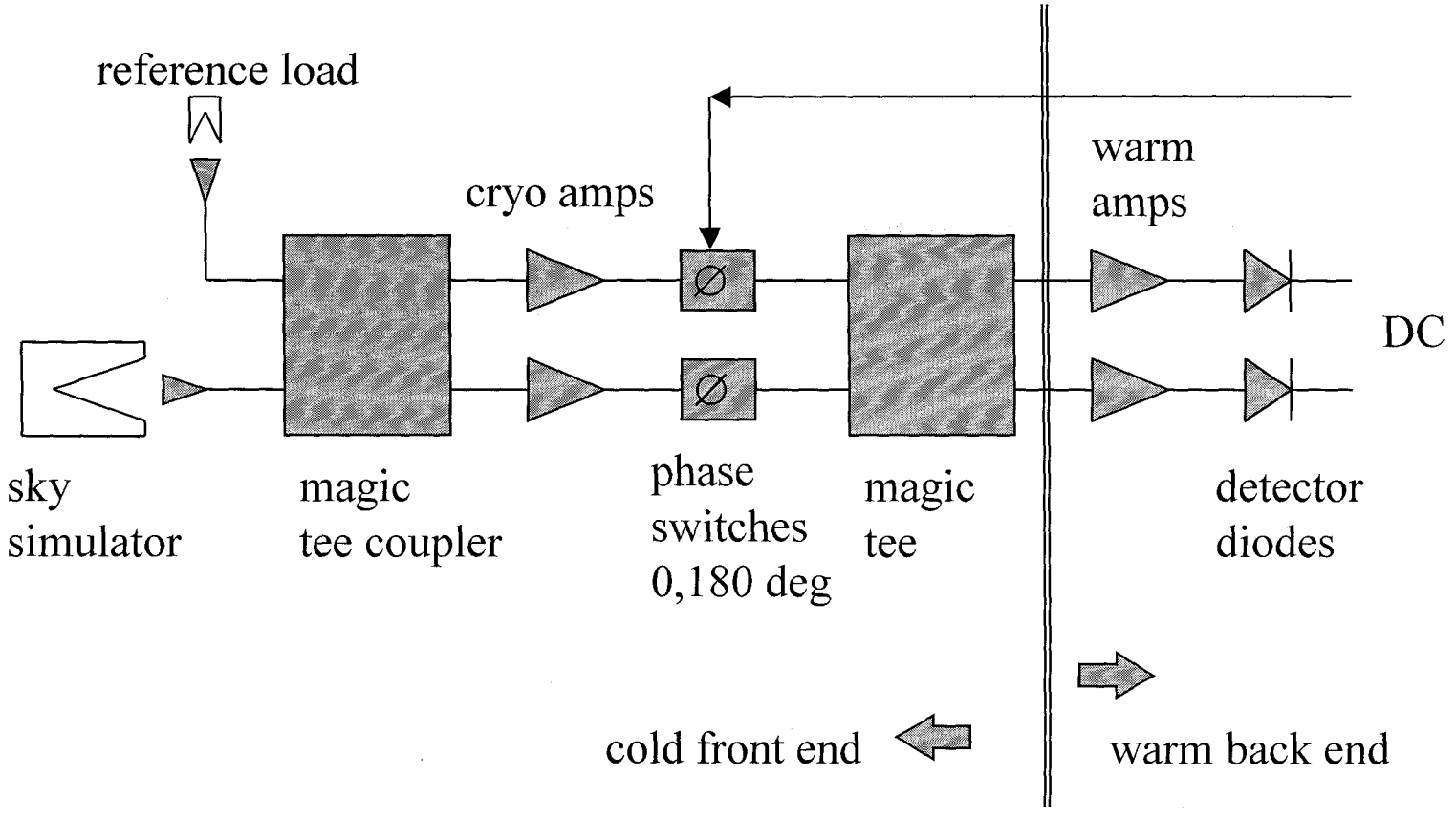


I.A.S. / J-L. Puget

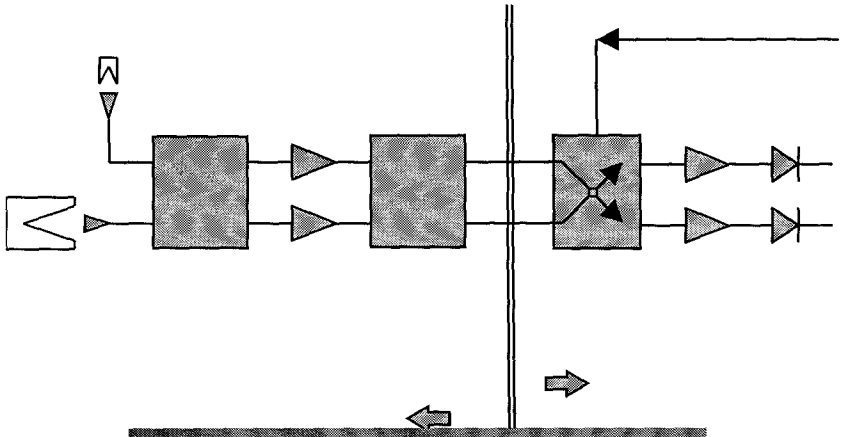
Planck Mock-Up

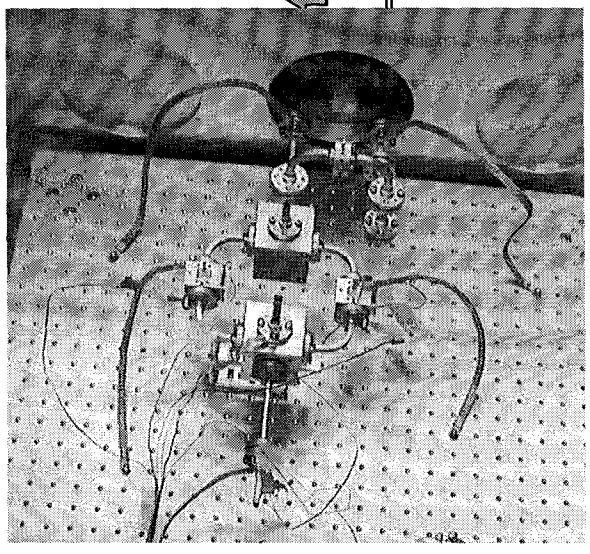


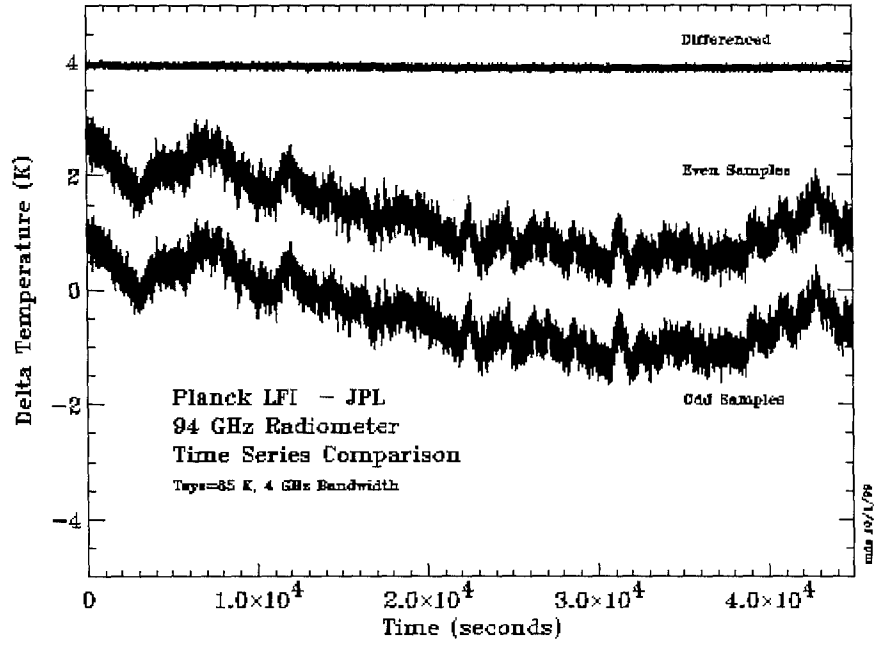
LFI 100 GHz Block Diagram - Baseline



JPL Prototype Demonstrator







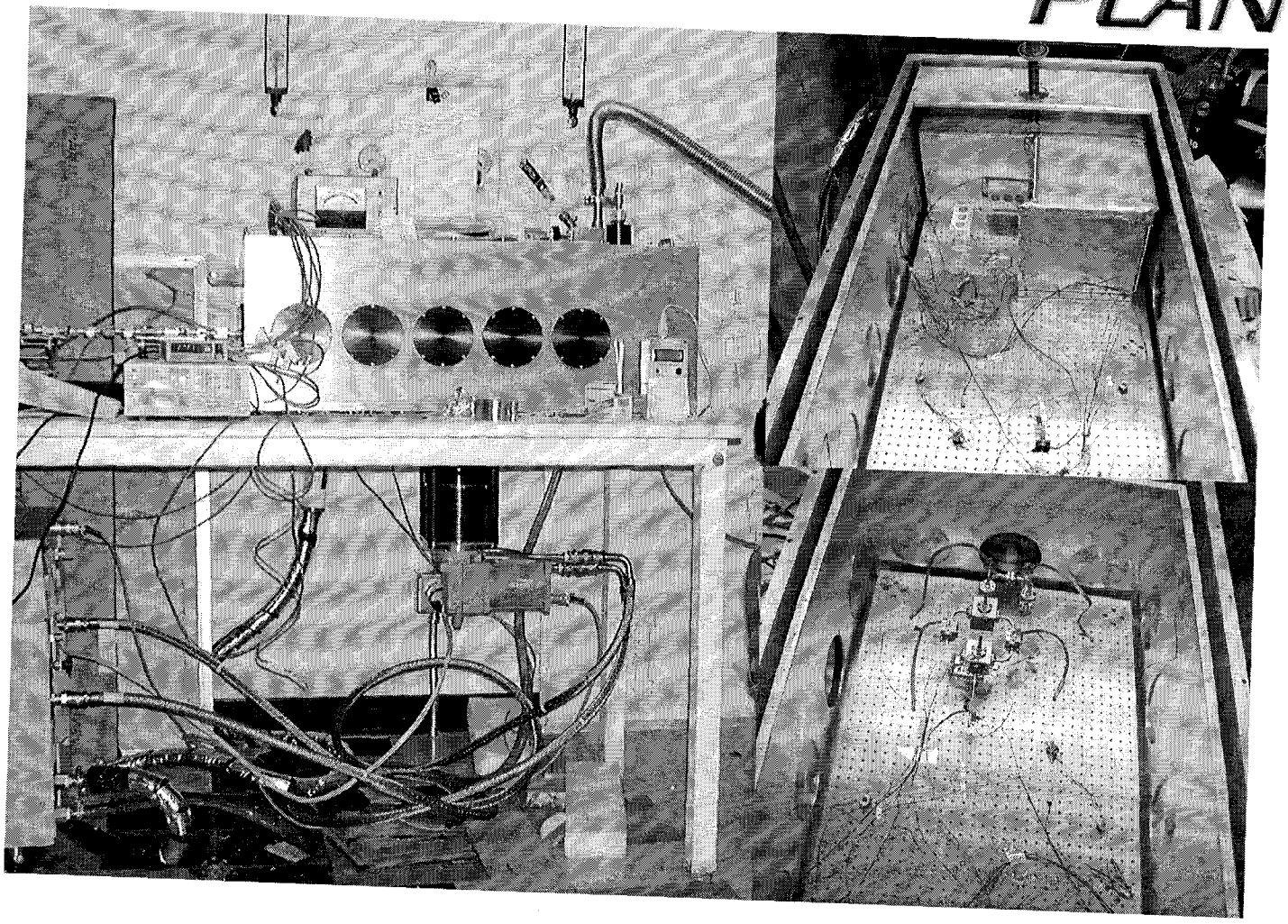
JPL

NASA

esa

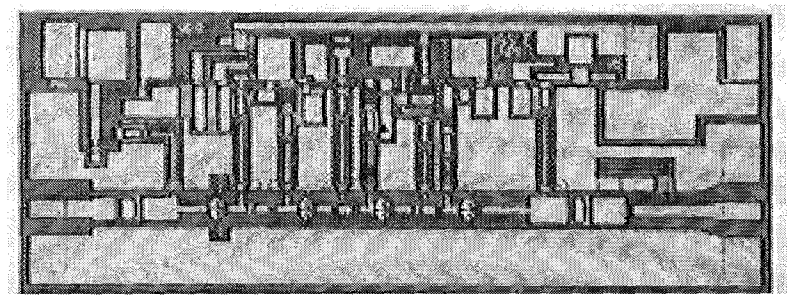
PLANCK

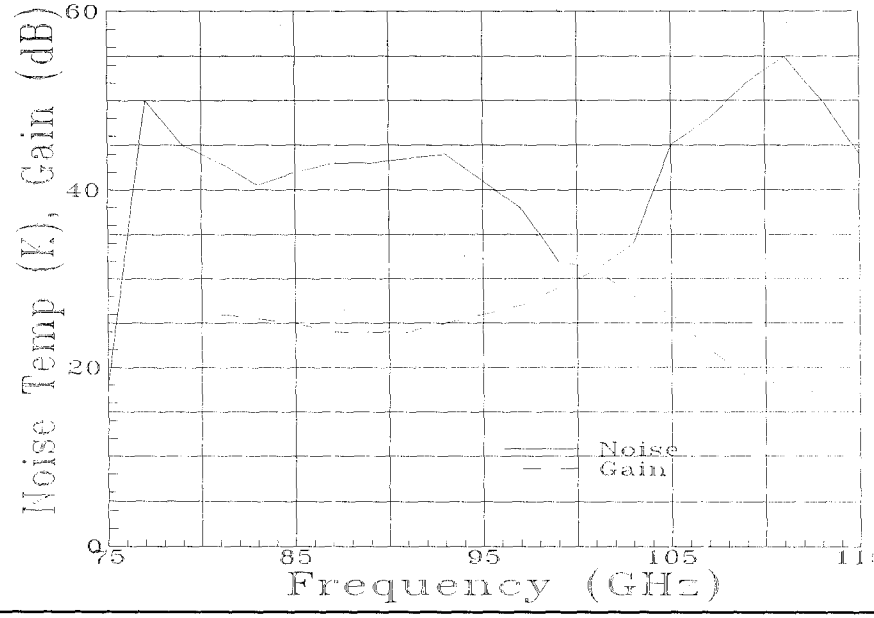
Cryostat



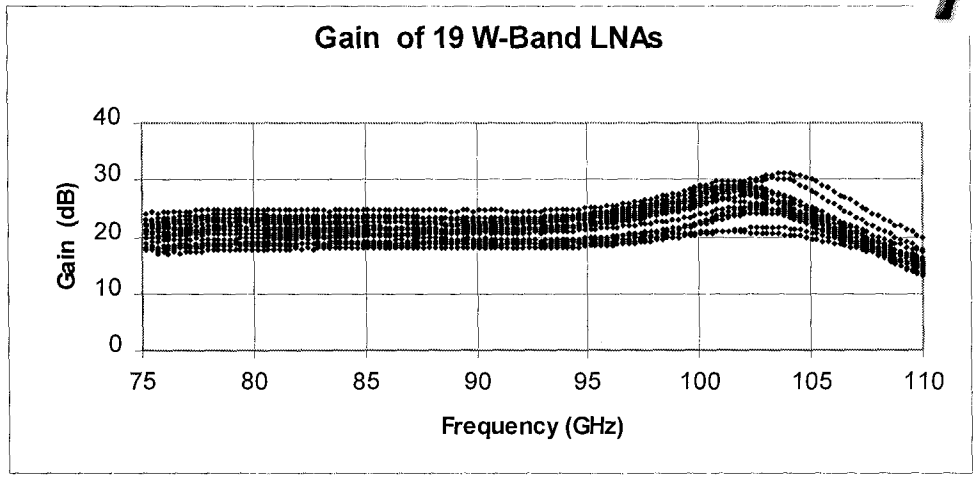
TRW 4-Stage CPW 80-115 GHz Amplifie

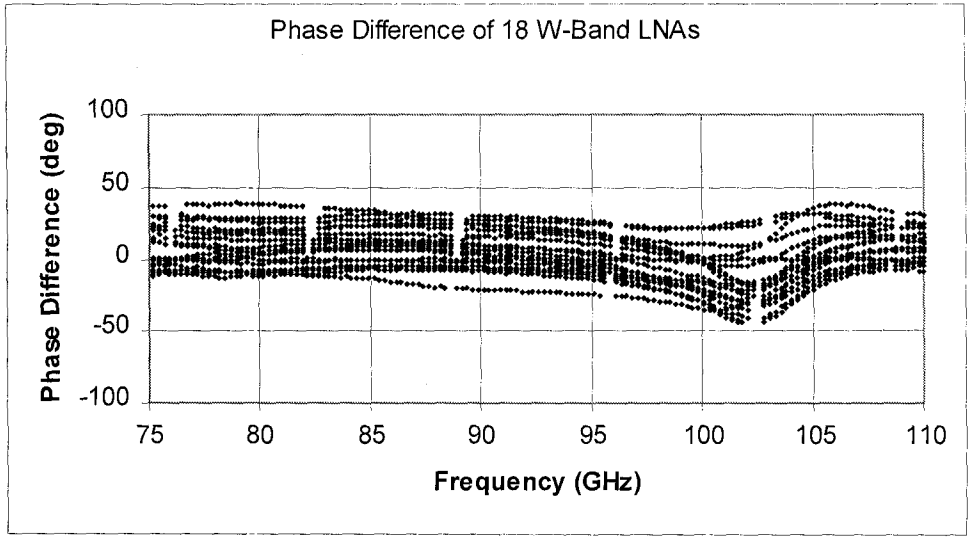
- Design by S. Weinreb
- 80-115 GHz >17 dB gain
- NF~ 3-4 dB at room temp
- Record low noise at cryo temps:
  - → < 45 K from 85-105 GHz
  - → < 40 K from 96-104 GHz
  - → 30 K noise at 100 GHz
- Yield:105 chips per wafer
- Ultra-low power operation
  - 20 dB gain at 1.4 mW
  - 15 dB gain at 0.54 mW
- Excellent Gain and Phase match (5 deg typ)



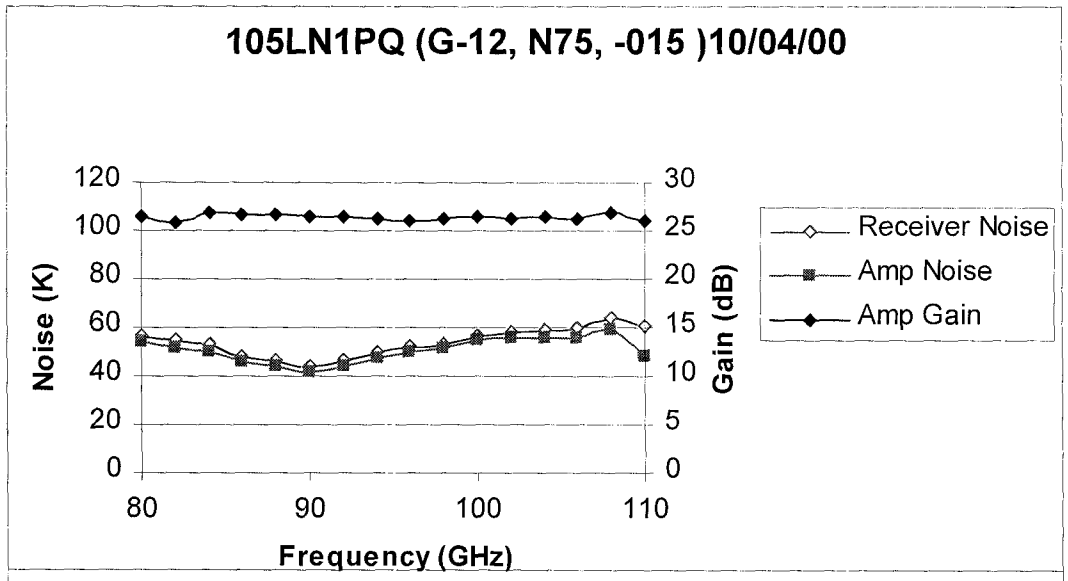


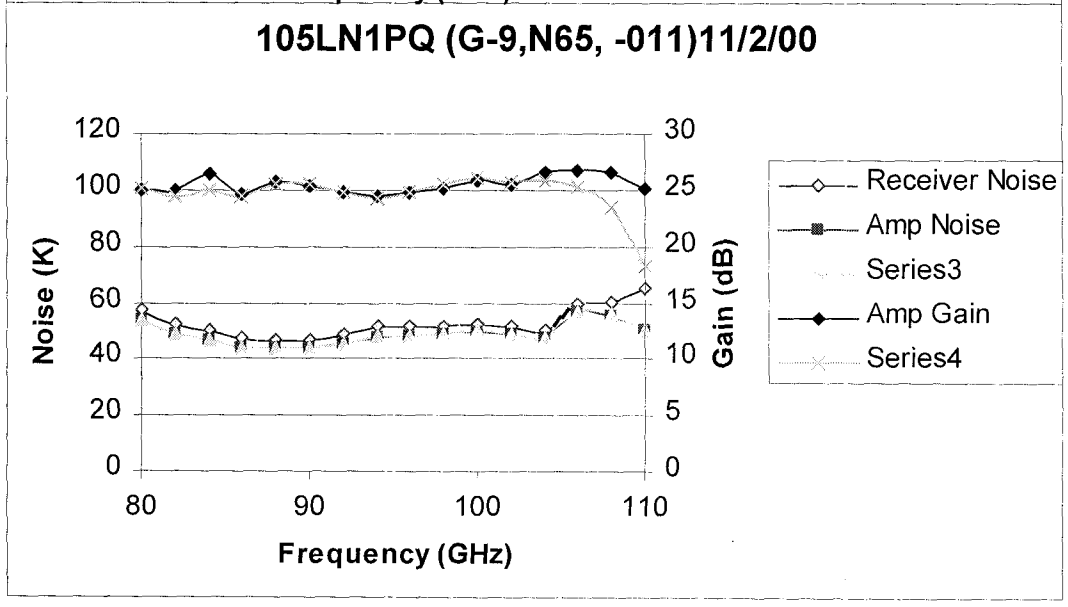
MMIC Module Repeatability



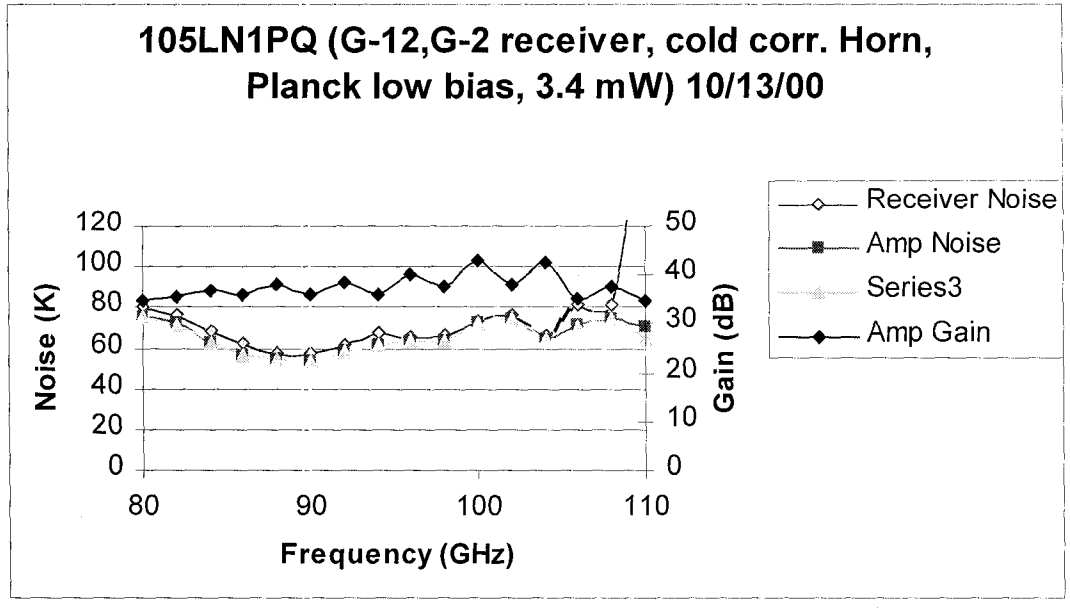


Improved Amplifier Performance

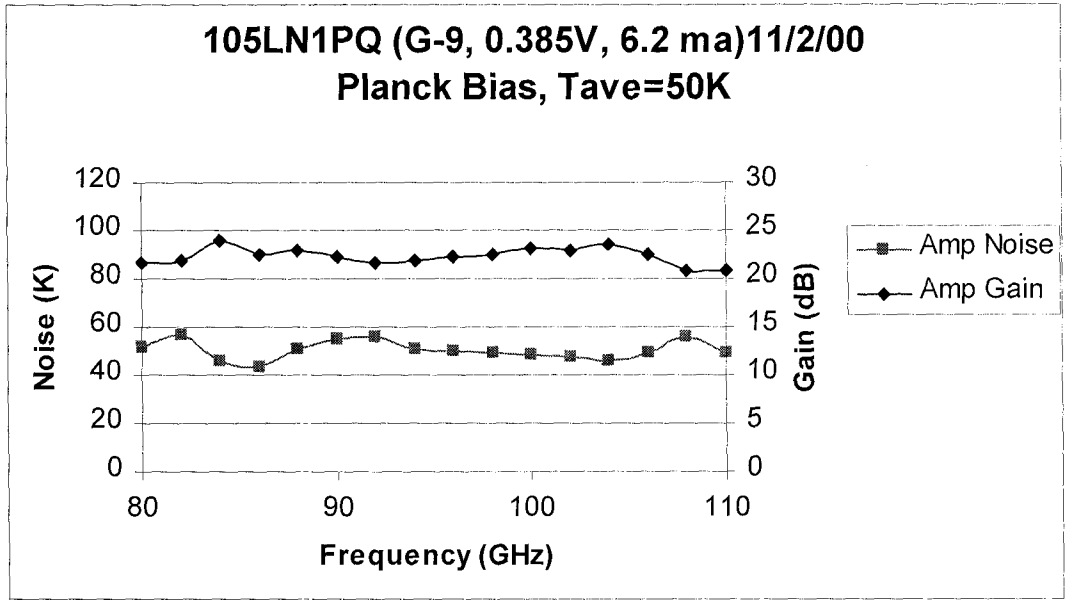




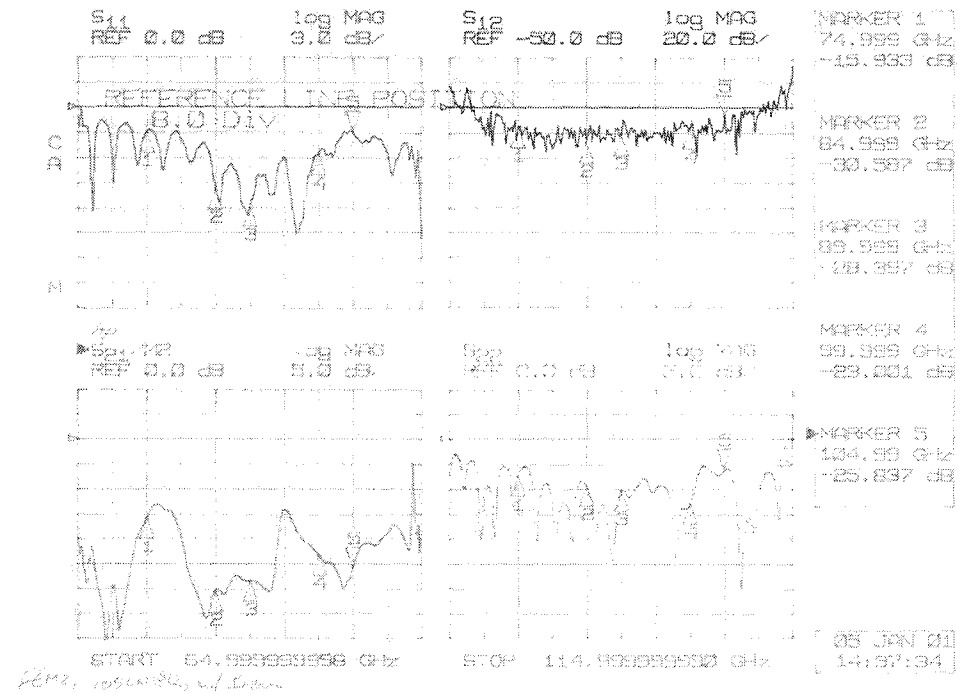
Optically Coupled Receiver Low Bias Operation



Low Bias Operation



TRW Integrated FEM with New Chips



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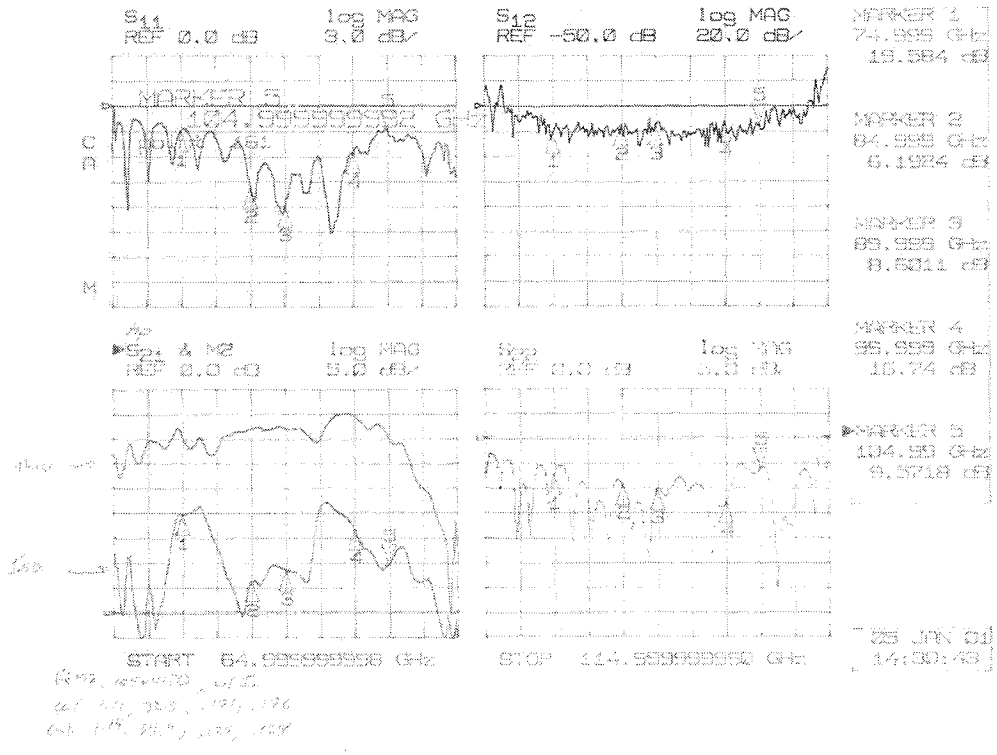
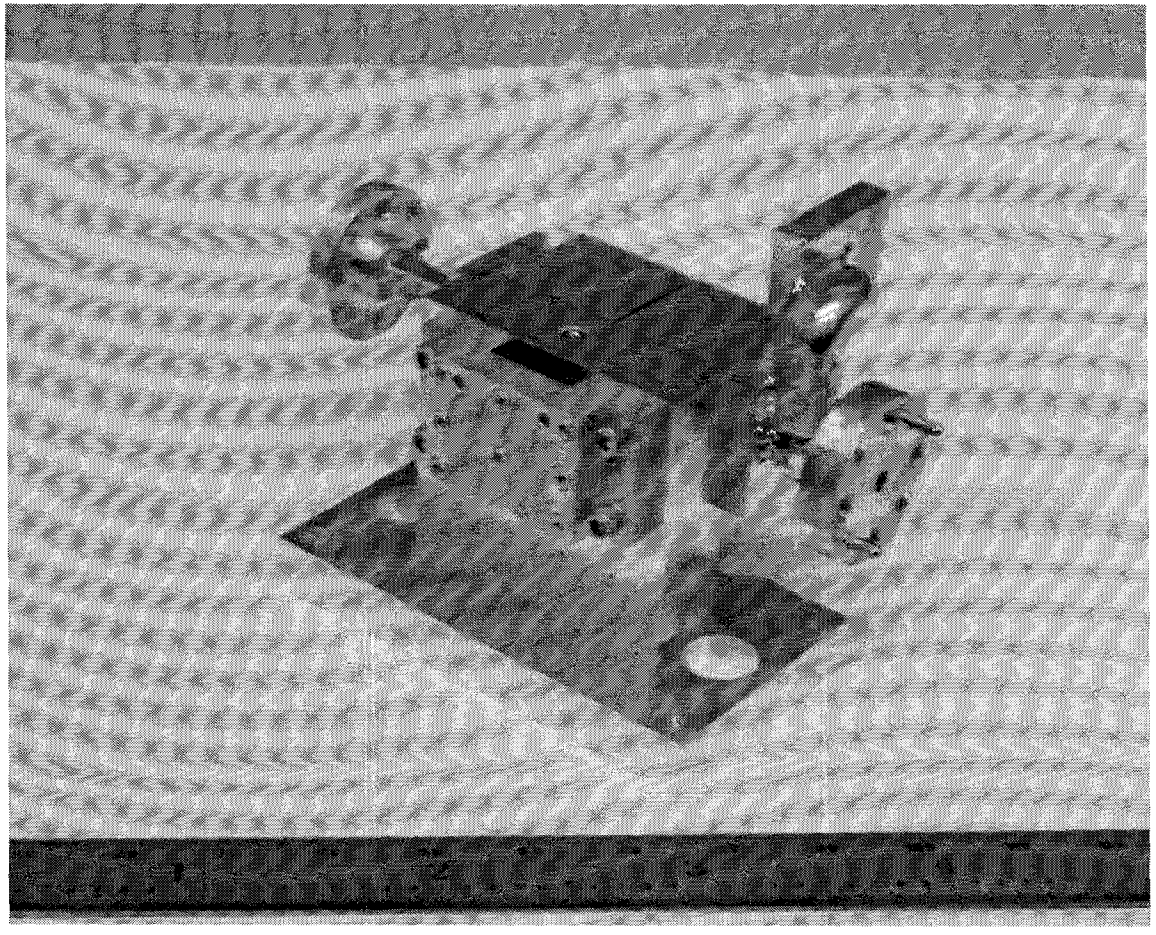


TRW Integrated FEM



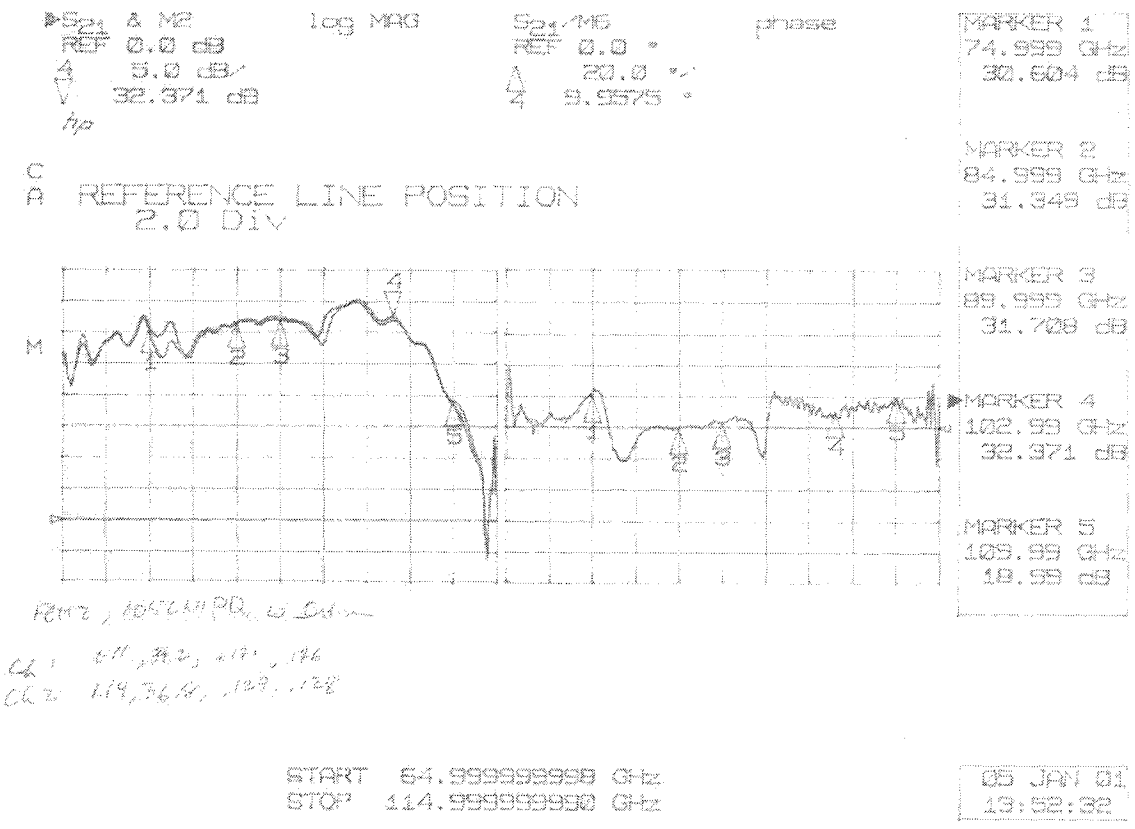
Results

MMICs Provide excellent gain and phase match in the two legs

Large amount of available gain can cause problems:

- Oscillations
- Gain compression (Non-linear effects below -20dBm)

Cavity modes are a concern, but are manageable

Ultra-low power operation results in minimal degradation

TRW Integrated FEM with New Chips