# Cosmic Microwave Background Polarization Receivers: QUIJOTE experiment

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*Multi Pixel Camera Receivers*,
RadioNet- FP7, 2nd Engineering Forum Workshop (Bonn, 16-17 November 2009)

# QUIJOTE CMB experiment overview

- Q-U-I JOint TEnerife (Stokes parameters Q, U and I)
- Cosmic Microwave Background (CMB) polarization receivers
- To obtain five polarization maps in the frequency range 11- 30 GHz
- Angular resolution: ~1 degree

# QUIJOTE experiment consortium

**Instituto de Astrofísica de Canarias (IAC), Tenerife (Spain): Coordinator**


**Instituto de Física de Cantabria (IFCA), Santander (Spain)**

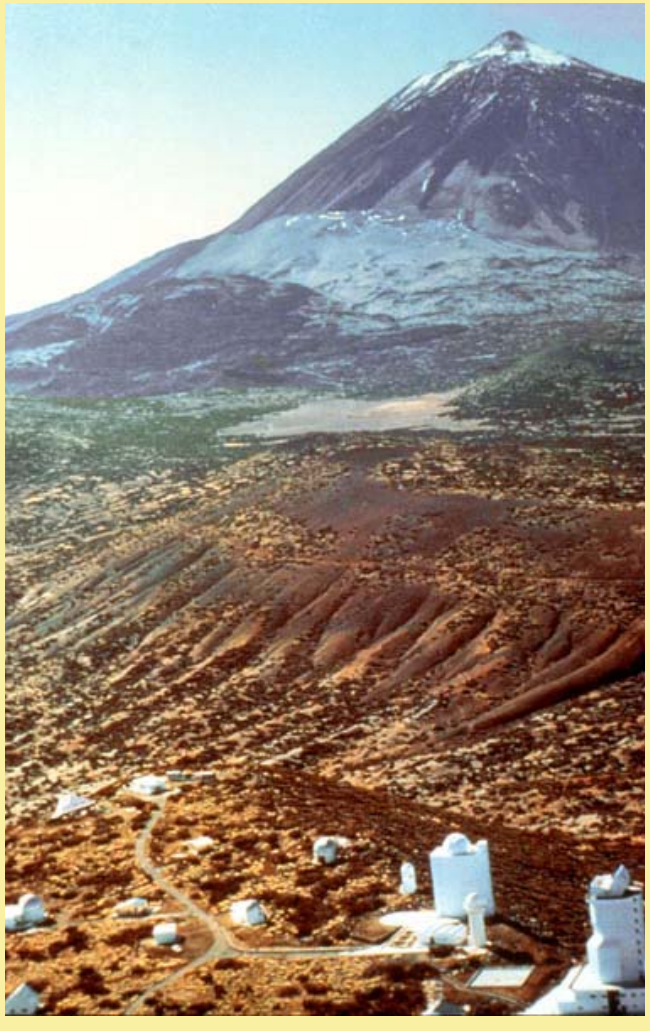

**Universidad de Cantabria (UC), Santander (Spain)**


**University of Cambridge, (UK)**

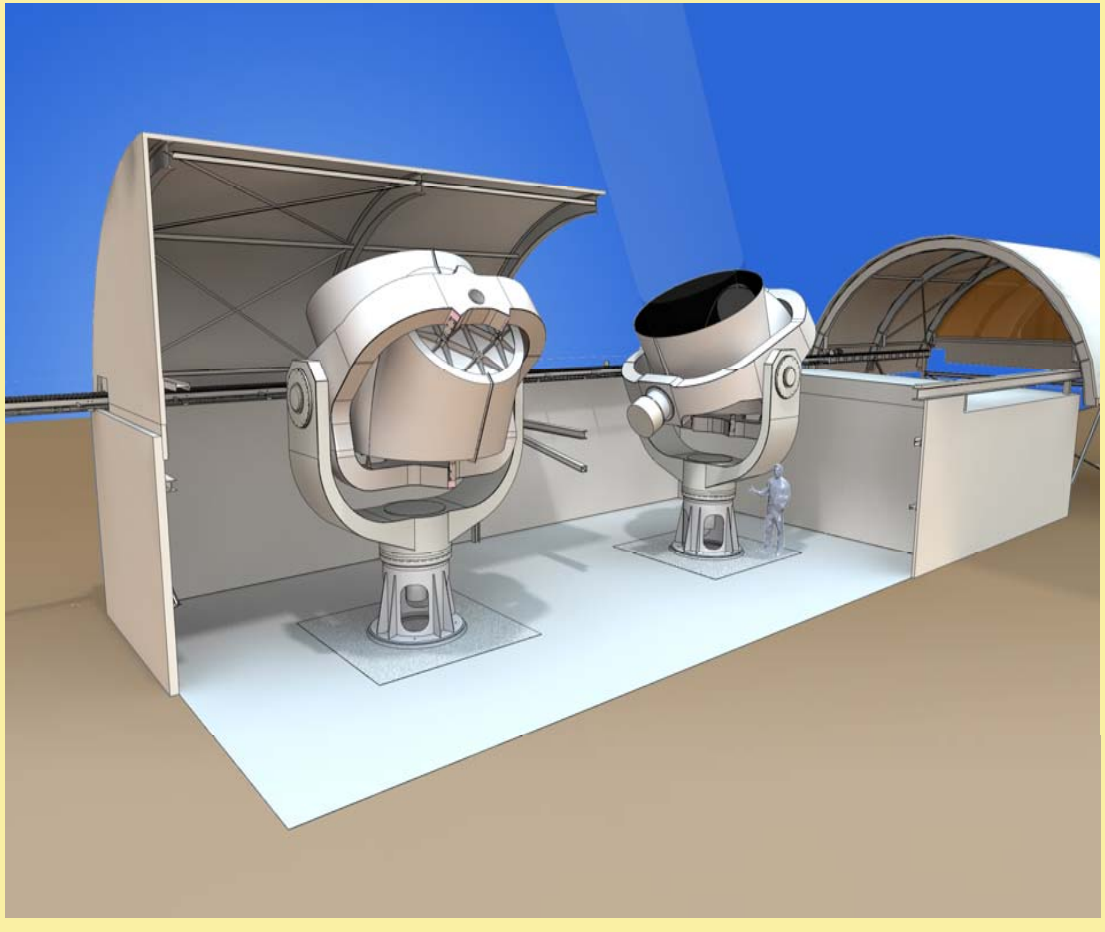

**University of Manchester, Jodrell Bank Centre for Astrophysics (UK)**


**IDOM, Bilbao (Spain)**

# Observatorio del Teide (Tenerife, Canary Islands)



Izaña site, 2.390 m



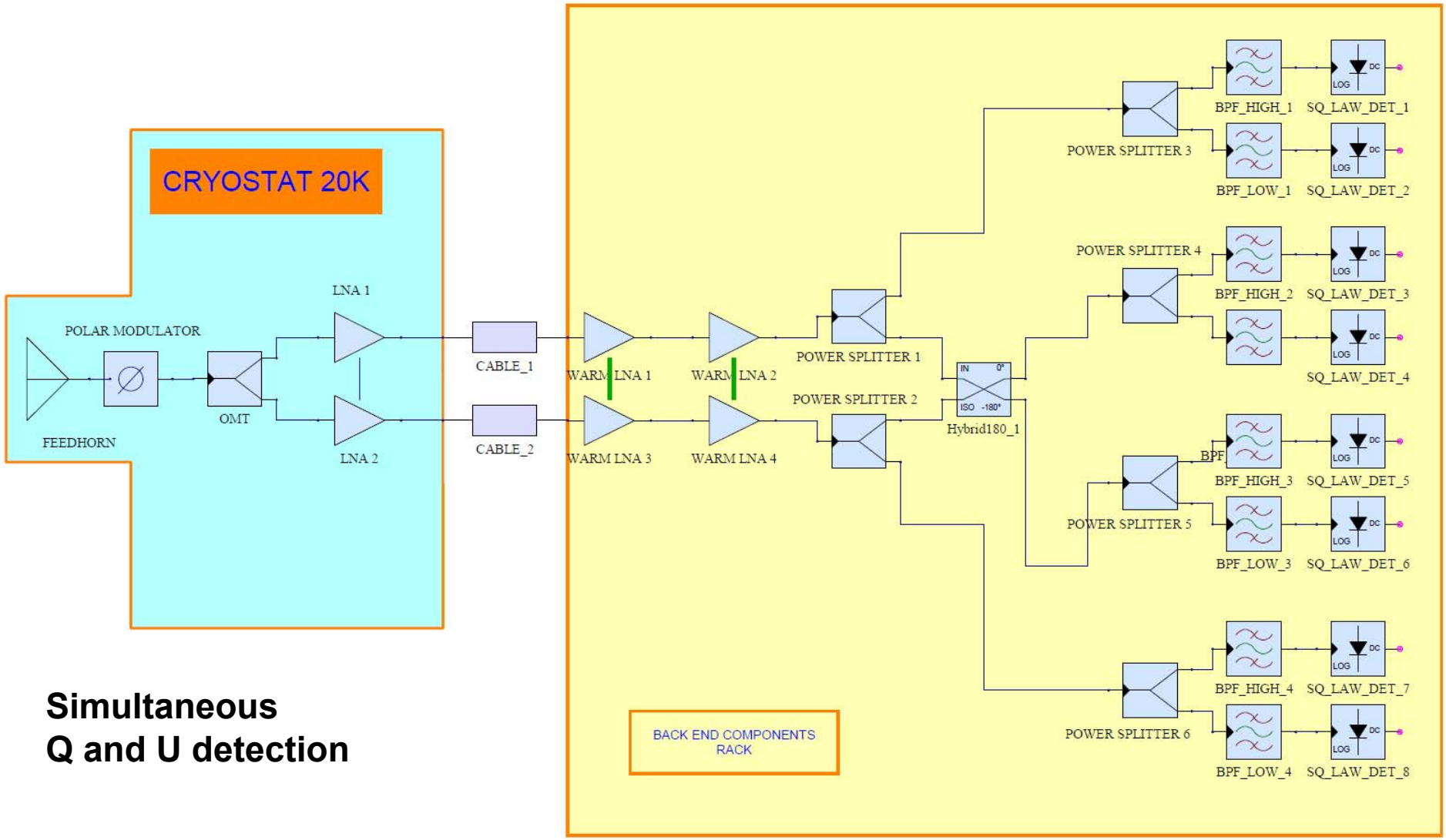
QUIJOTE Instruments 1 and 2 and enclosure

# QUIJOTE Experiment. Basic features

| | Instrument 1 | | | | | Instrument 2 |
|---|---|---|---|---|---|---|
| **Frequency (GHz)** | **11.0** | **13.0** | **17.0** | **19.0** | **30.0** | **30.0** |
| **Bandwidth (GHz)** | **2.0** | **2.0** | **2.0** | **2.0** | **8.0** | **8.0** |
| **Number of channels** | **8** | **8** | **8** | **8** | **2** | **32** |
| **Beam FWHM (deg) (*)** | **0.92** | **0.92** | **0.60** | **0.60** | **0.37** | **0.37** |
| **$T_{sys}$ (K)** | **20.0** | **20.0** | **20.0** | **20.0** | **30.0** | **20.0** |
| **Sensitivity (mK $s^{1/2}$)** | **0.22** | **0.22** | **0.22** | **0.22** | **0.34** | **0.05** |
| **Sensitivity per beam (Jy $s^{1/2}$)** | **0.24** | **0.34** | **0.24** | **0.30** | **0.43** | **0.07** |

(*) Pixel = a square with each side is FWHM (Full Width at Half Maximum) of the beam.

# Low frequency channels in QUIJOTE 1




**Simultaneous**
**Q and U detection**

**Low frequency channels: 11-13 GHz and 17-19 GHz: eight channels per pixel**

## Output detected voltage in QUIJOTE 1 - Low frequency channels

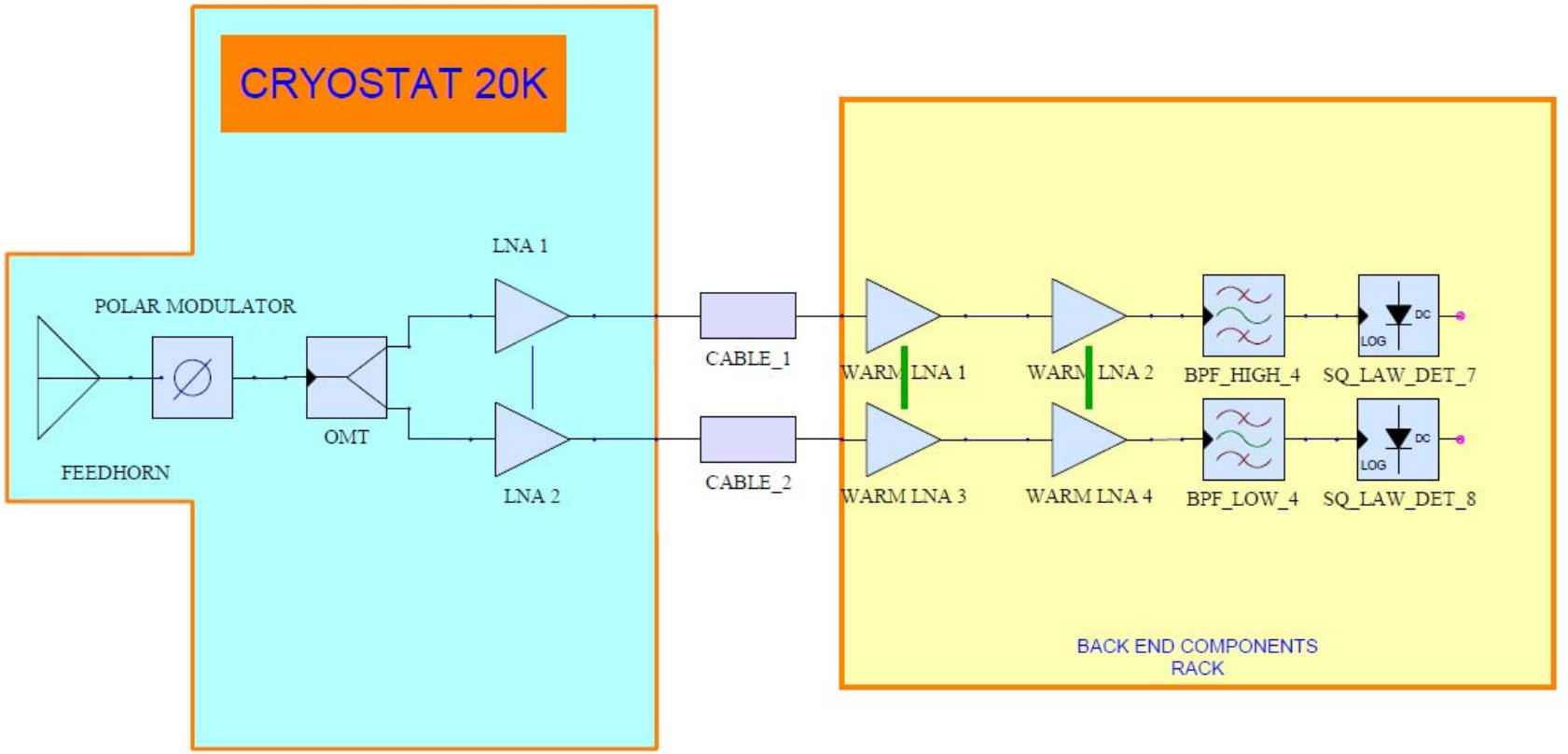
$$V = \frac{1}{2} I + \frac{1}{2} Q \cos(4\varphi) + \frac{1}{2} U \sin(4\varphi)$$

Q, U and I = Stokes parameters

φ = Position angle of the modulator

These parameters depend on the time and on the channel

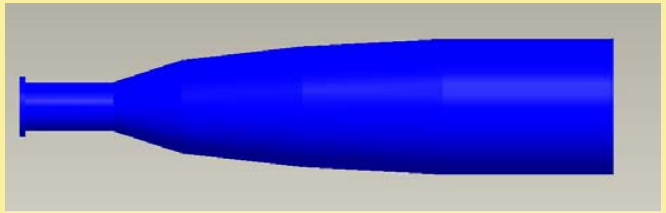
# 30 GHz channel in QUIJOTE 1



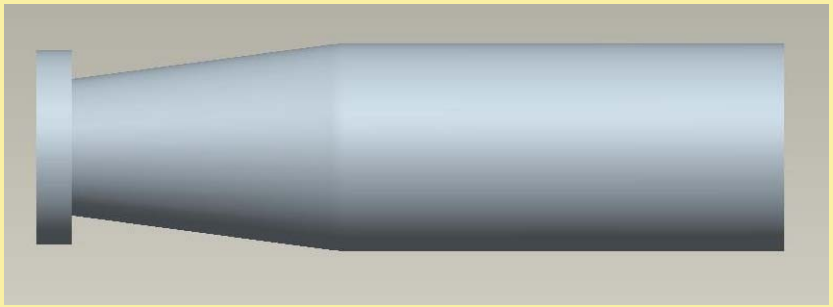

**Modulator to stabilize gain drift. Simple design: two channels per pixel.**

# QUIJOTE 1: Focal plane distribution

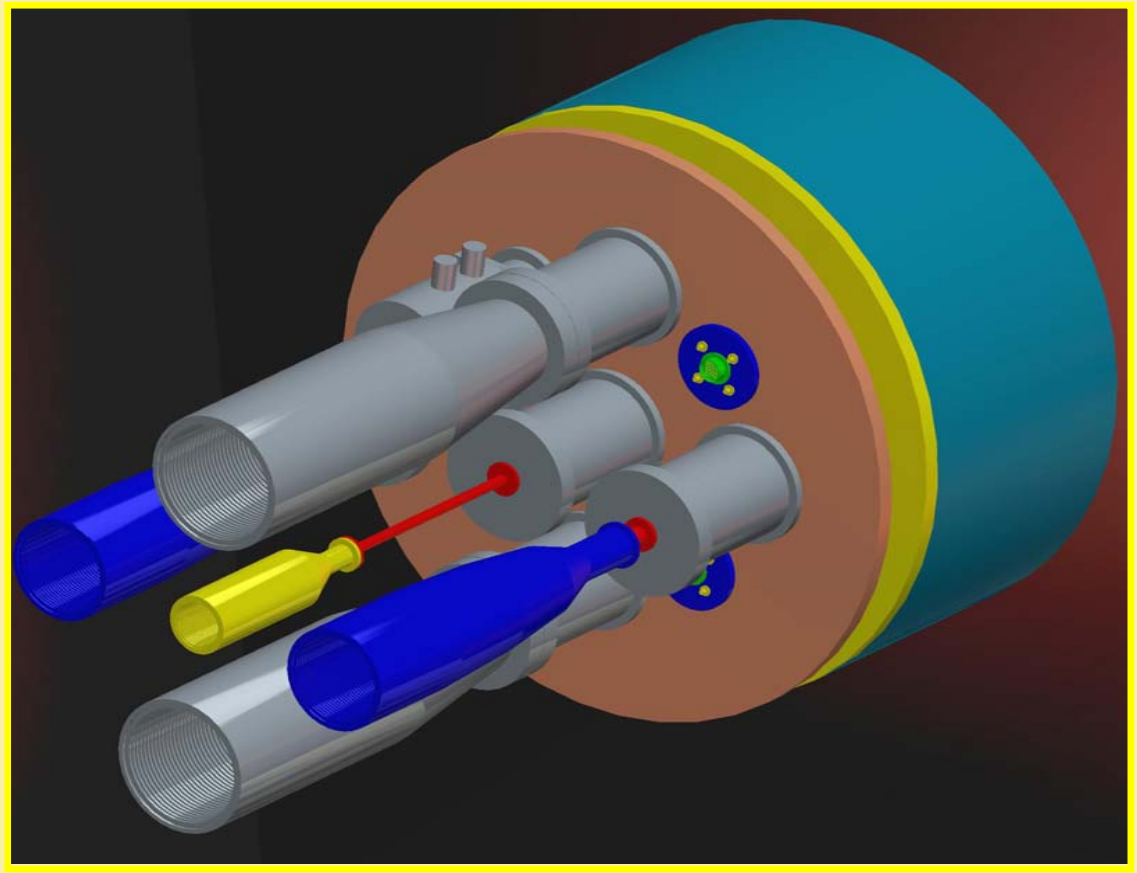
26-36GHz Horn



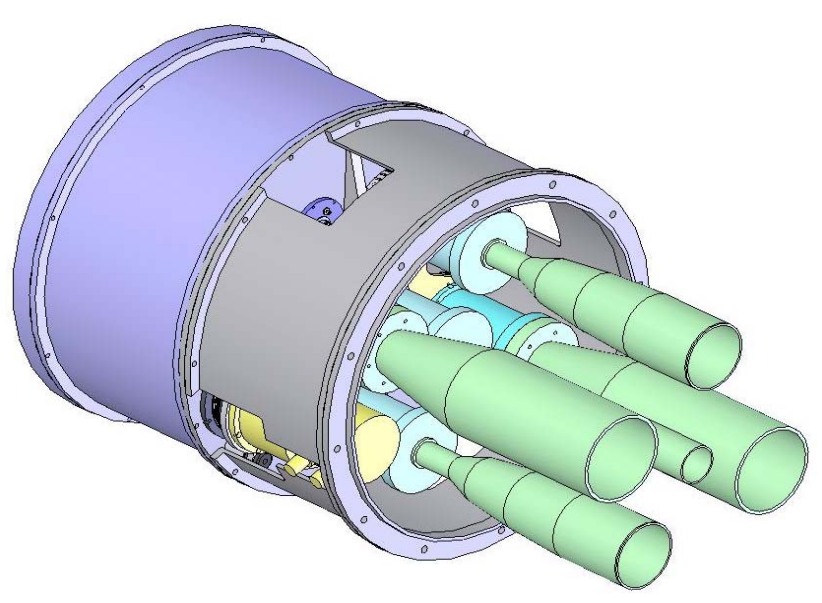
14-20GHz Horn

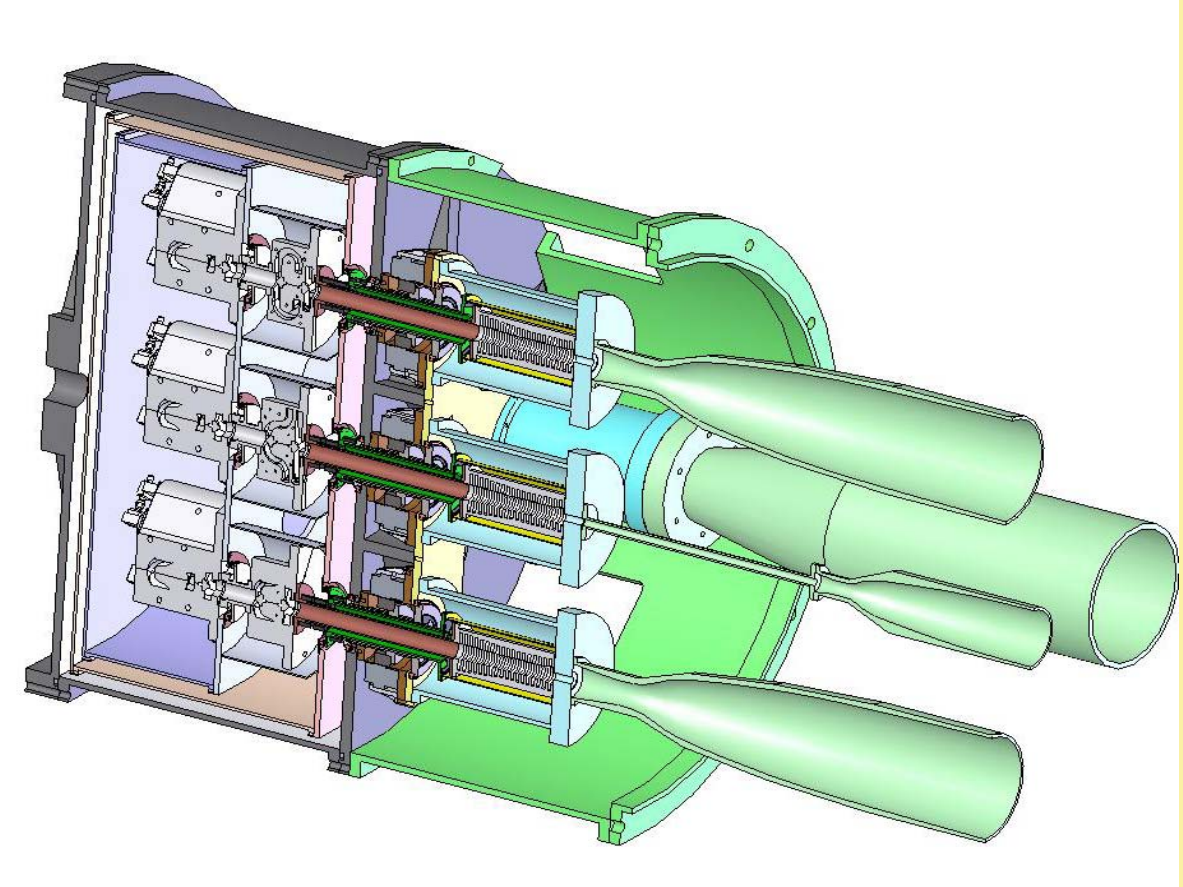


10-14GHz Horn

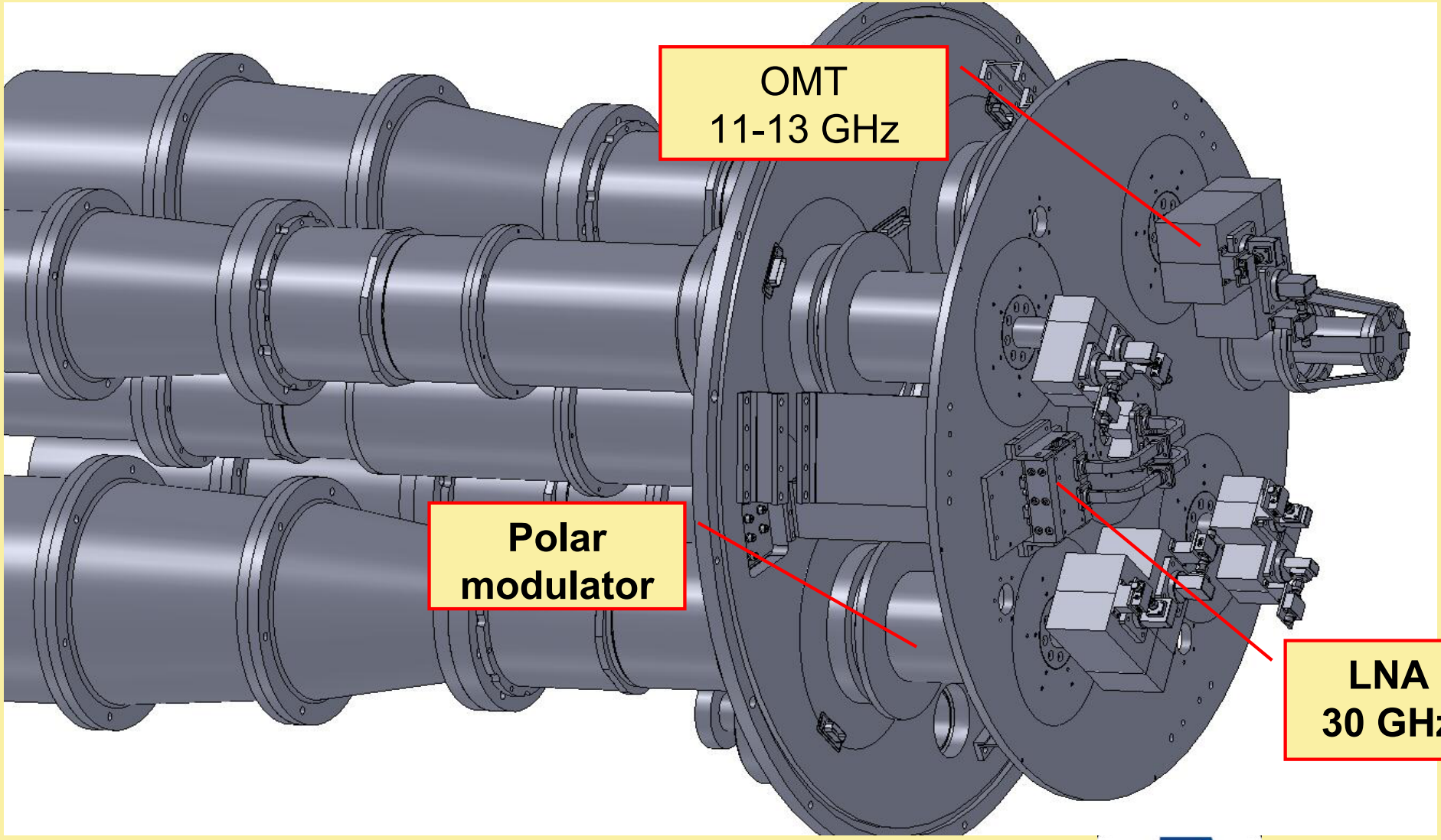


# QUIJOTE 1: Mechanical design (version May 2008)





# QUIJOTE 1: Mechanical design (version Feb. 2009)



# QUIJOTE 1: Horns

**Corrugated feed-horns**

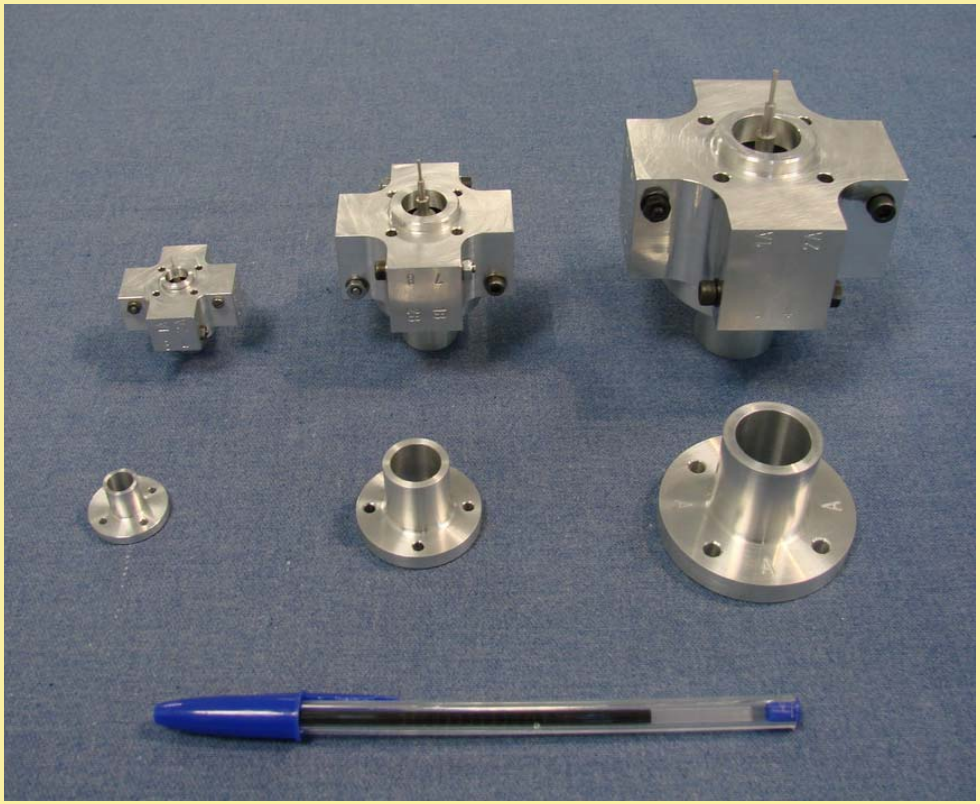
**10-14 GHz**

**14-20 GHz**

**26-36 GHz**

# Polar Modulator

- Key component of the polarimeter
- Rotating polar modulator (40 Hz): switch out 1/f noise
- Incoming signal modulated at 4 x (modulator frequency)
- Cryogenically cooled: low losses, low impact on noise
- Waveguide component: turnstile 4-way junction

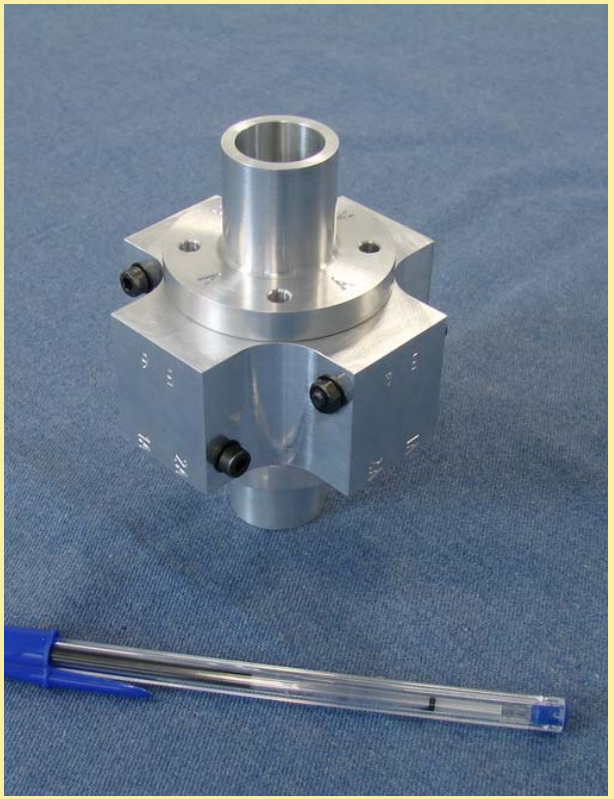


**Units:**

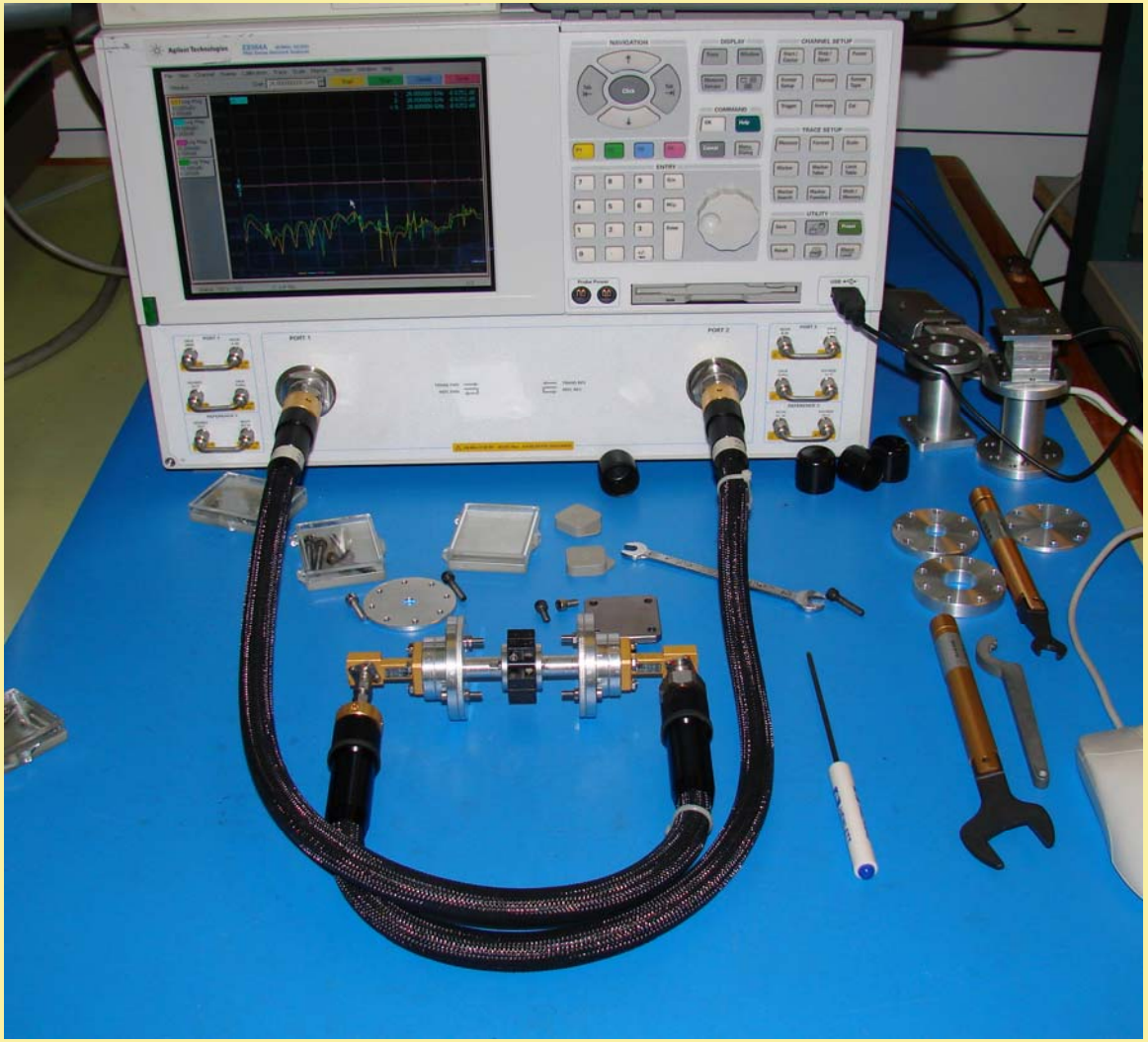
**10-14 GHz**

**14-20 GHz**

**26-36 GHz**

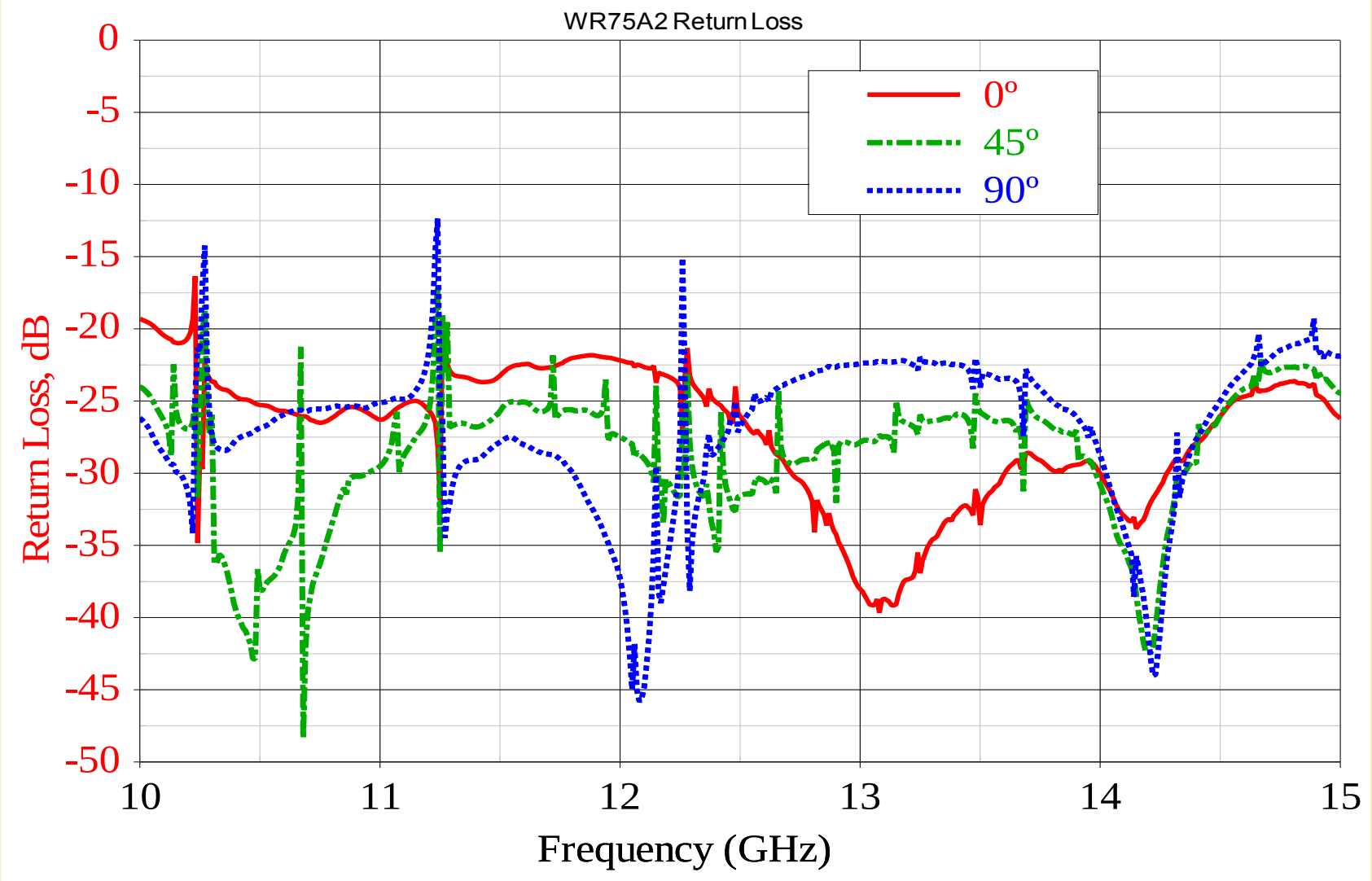


# Polar Modulator S-parameter tests

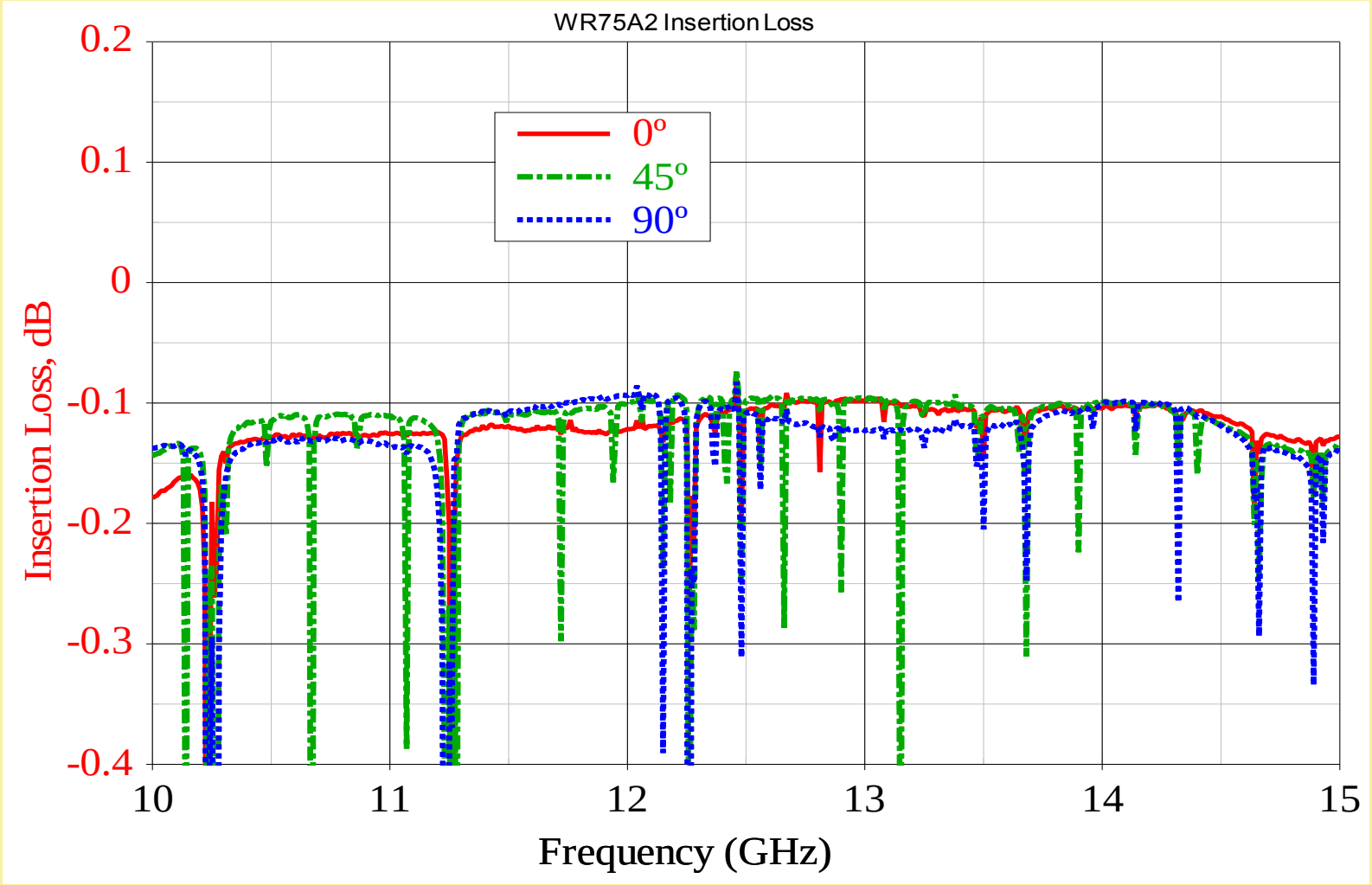


- Low return losses
- Low insertion losses
- High polar isolation
- Tests at 3 polar modulator orientations: 0º, 45º and 90º
- Plots: spikes caused by misalignment of the circular waveguide interfaces
- Tests at Room Temperature

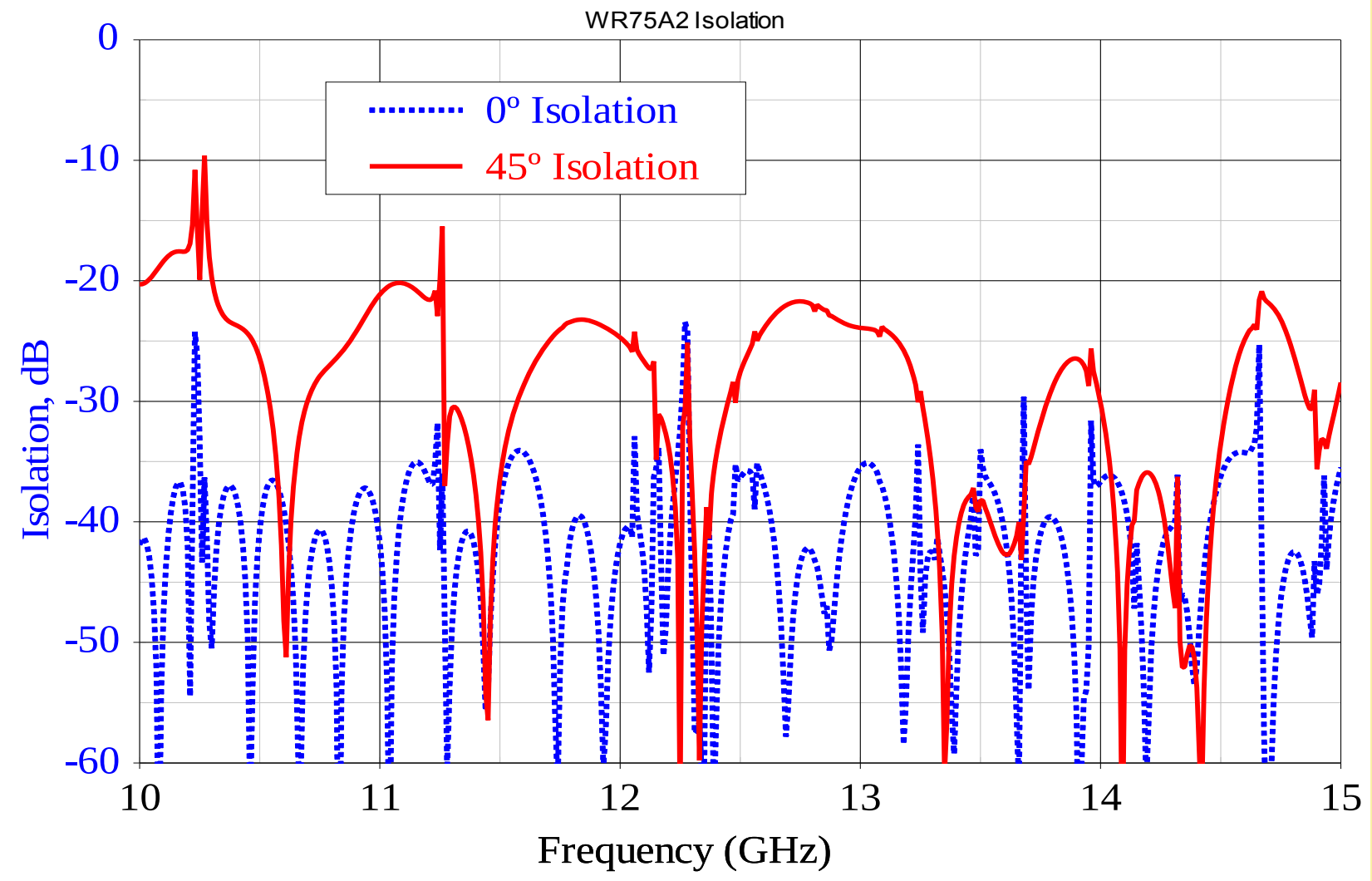
# Polar Modulator Return Loss



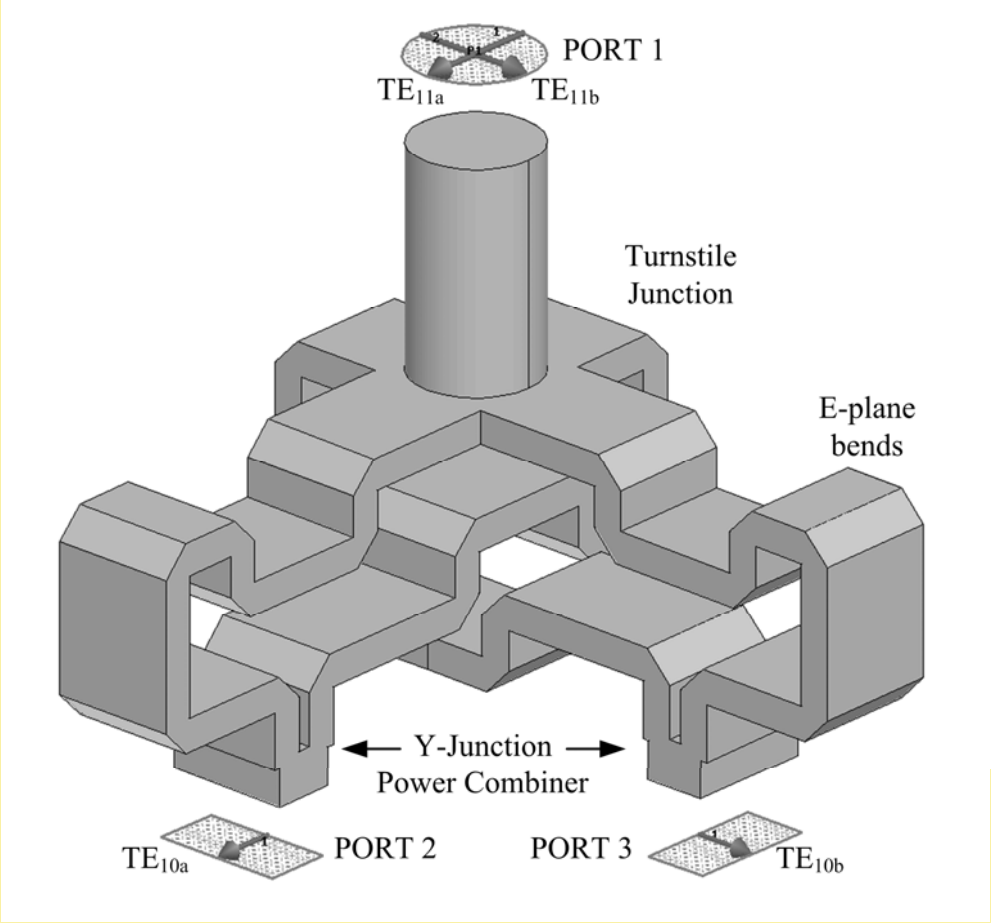
# Polar Modulator Insertion Loss



# Polar Modulator Isolation

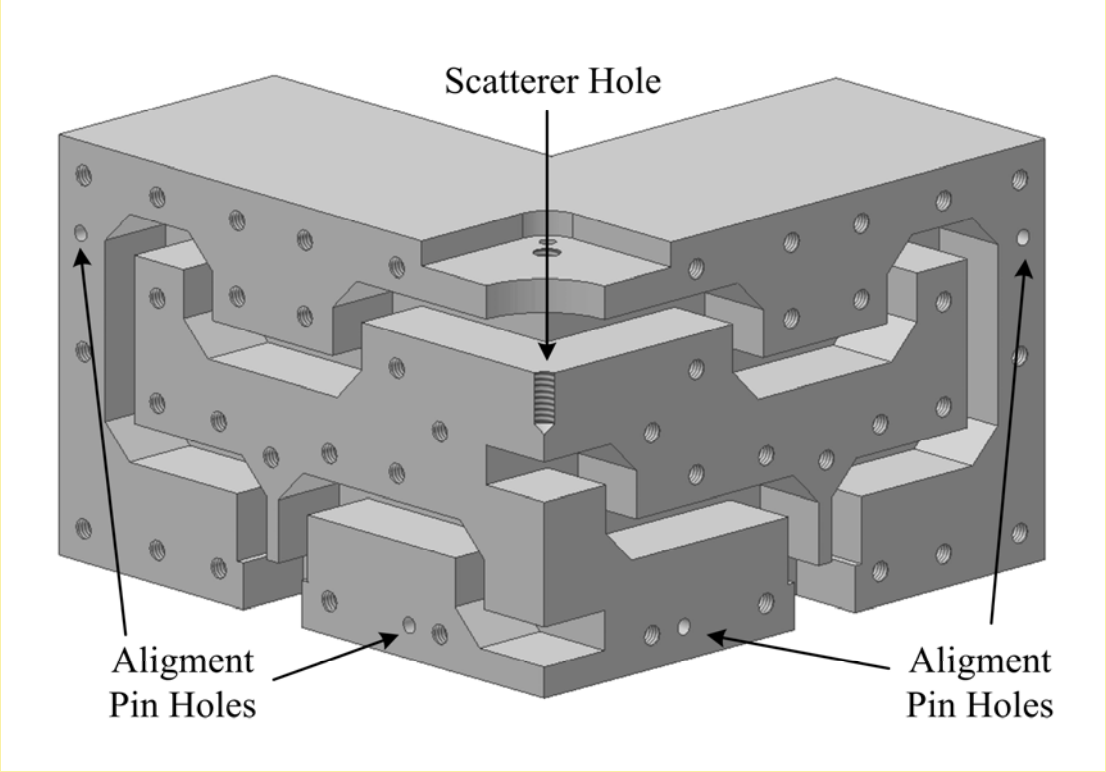


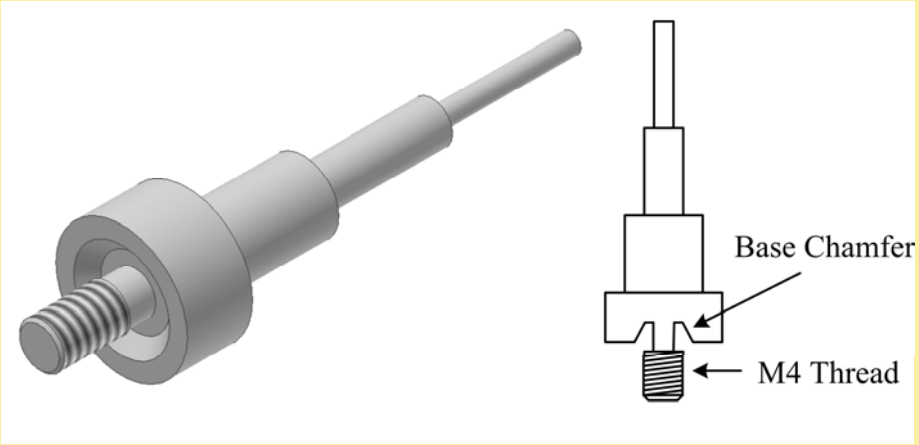
# Orthomode Transducer (OMT)




- Separates linear orthogonal polar components
- Sets a limit in the cross-polarization
- Based on turnstile junction
- Phase balanced outputs
- Broadband (> 40 % bandwidth)

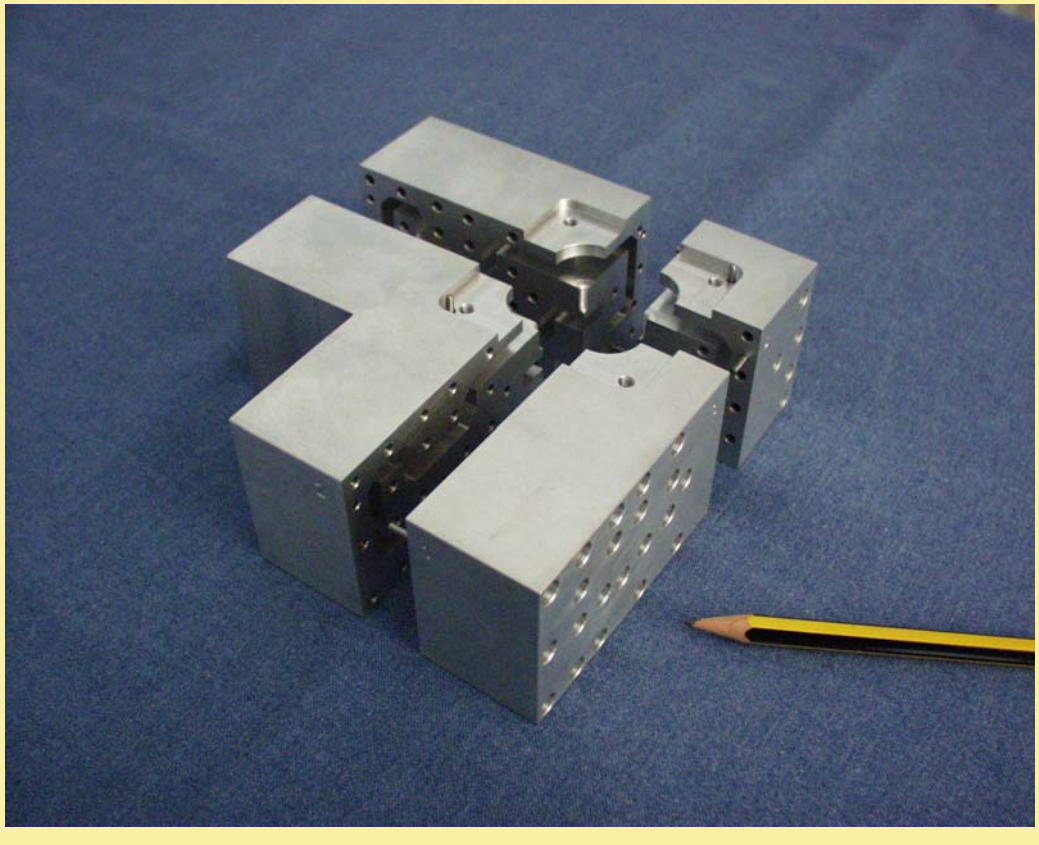
# Orthomode Transducer (OMT)

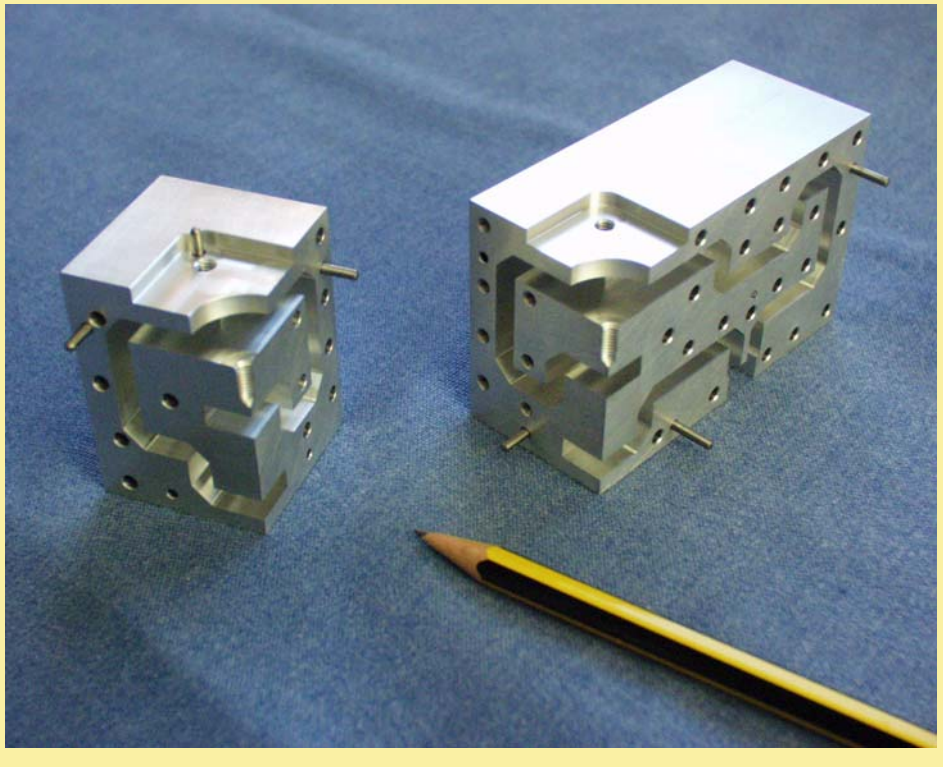



- Reduced height rectangular waveguide
- Optimized E-plane bends
- Scatterer: a critical part of turnstile junction
- Scalable structure (WR75, WR51, WR28)

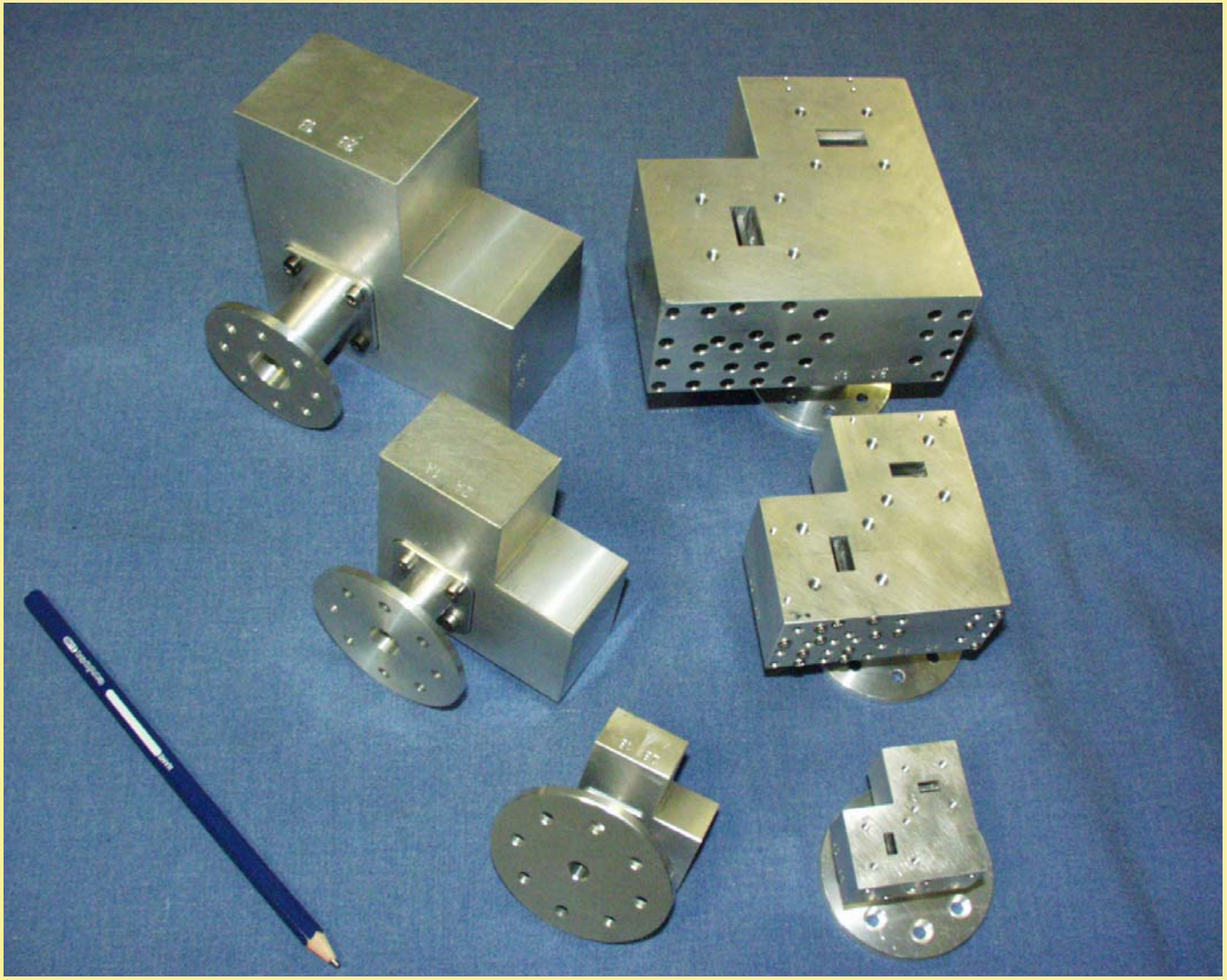
# Orthomode Transducer (OMT)





**OMT parts (WR75 version, 10-14 GHz)**

# Orthomode Transducer (OMT)



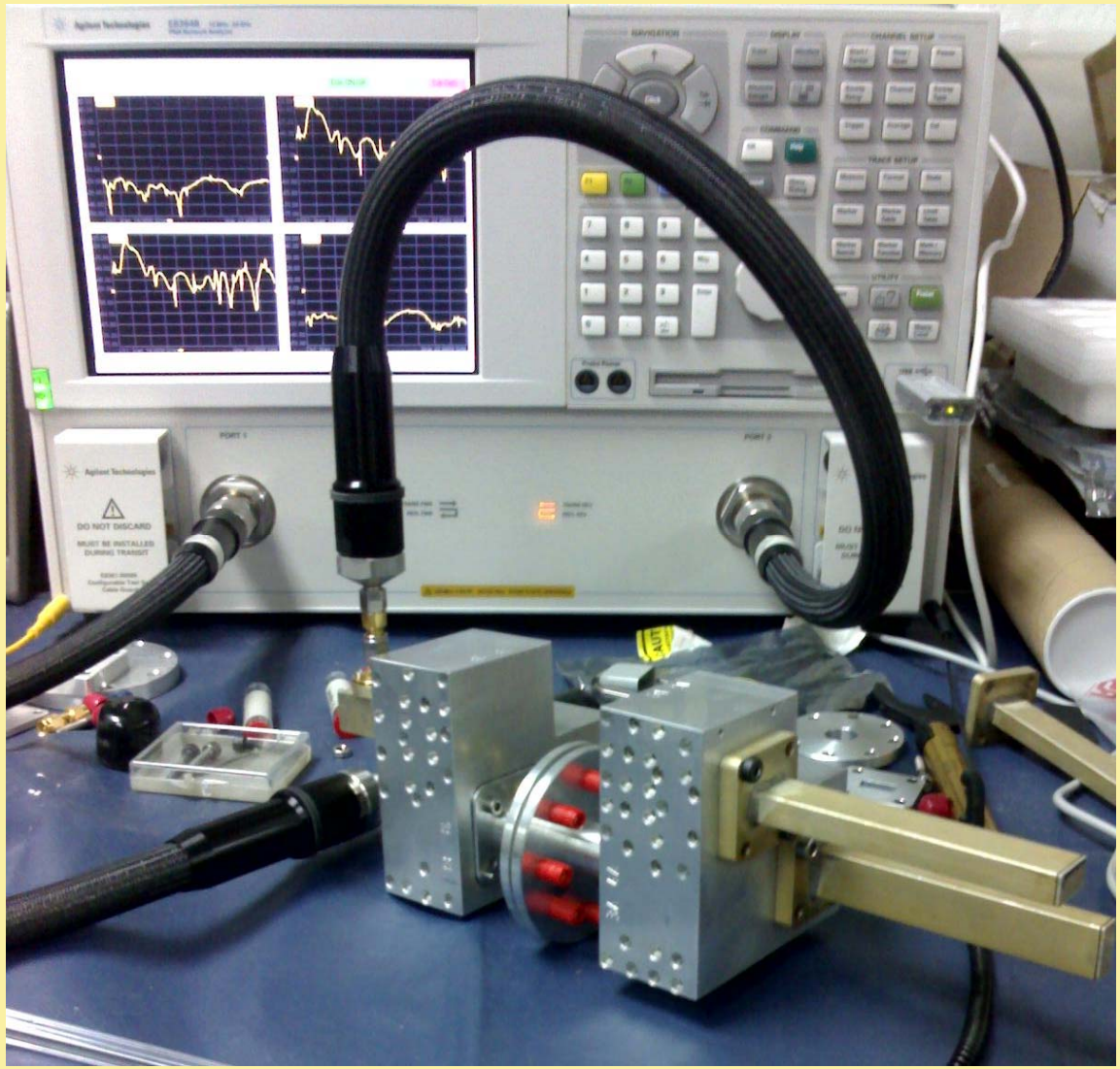
**Units:**

**10-14 GHz**

**14-22 GHz**

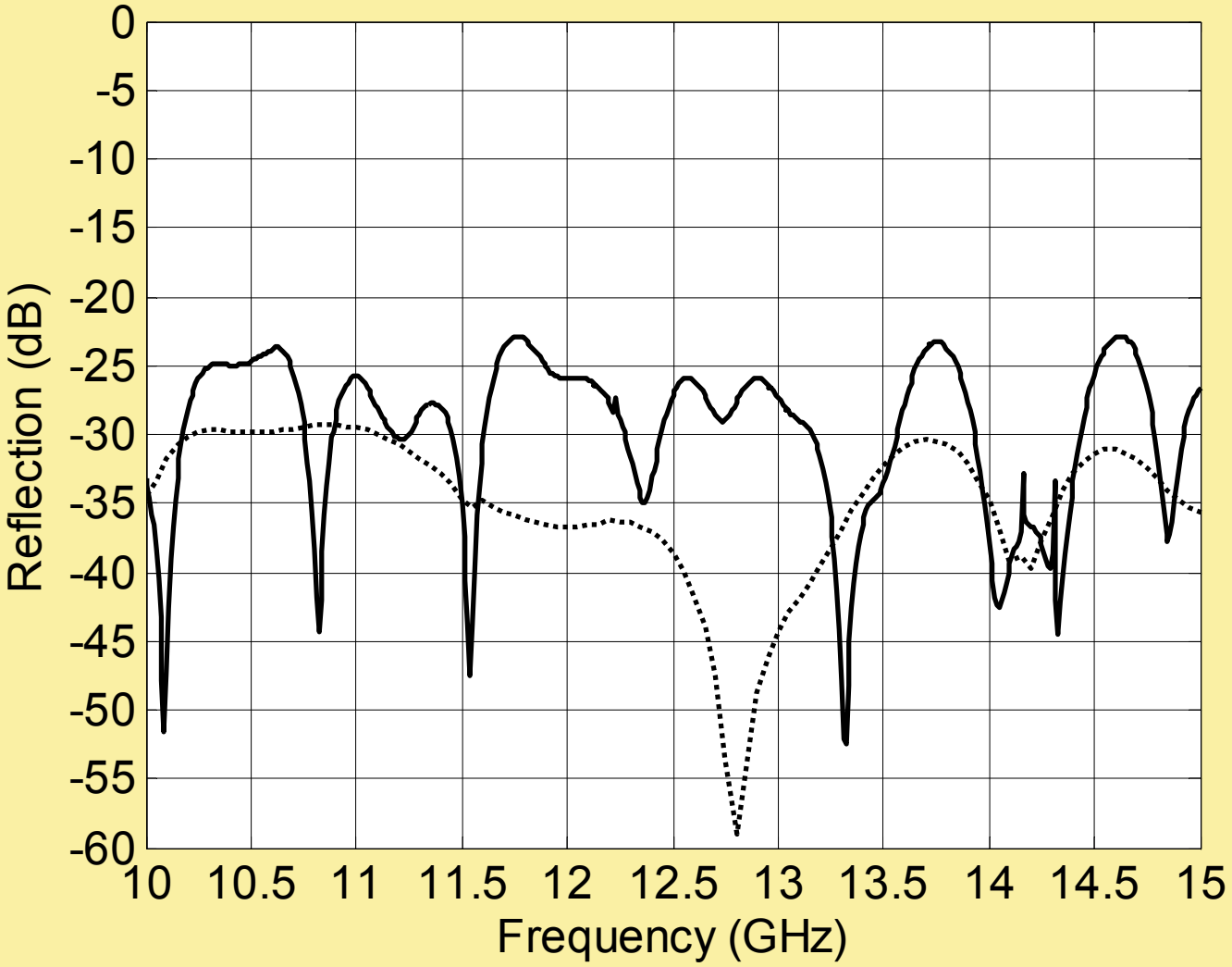
**26-36 GHz**

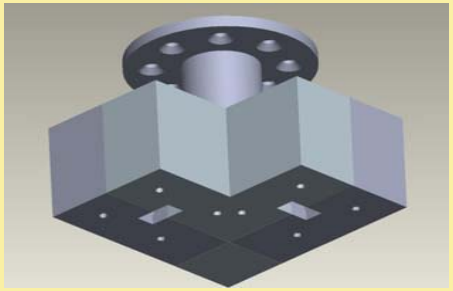
# Ortho Mode Transducer (OMT) S-parameter tests



- Low return losses
- Low insertion losses
- High isolation
- Excellent phase balance
- Tests at Room Temperature

# OMT Return Loss



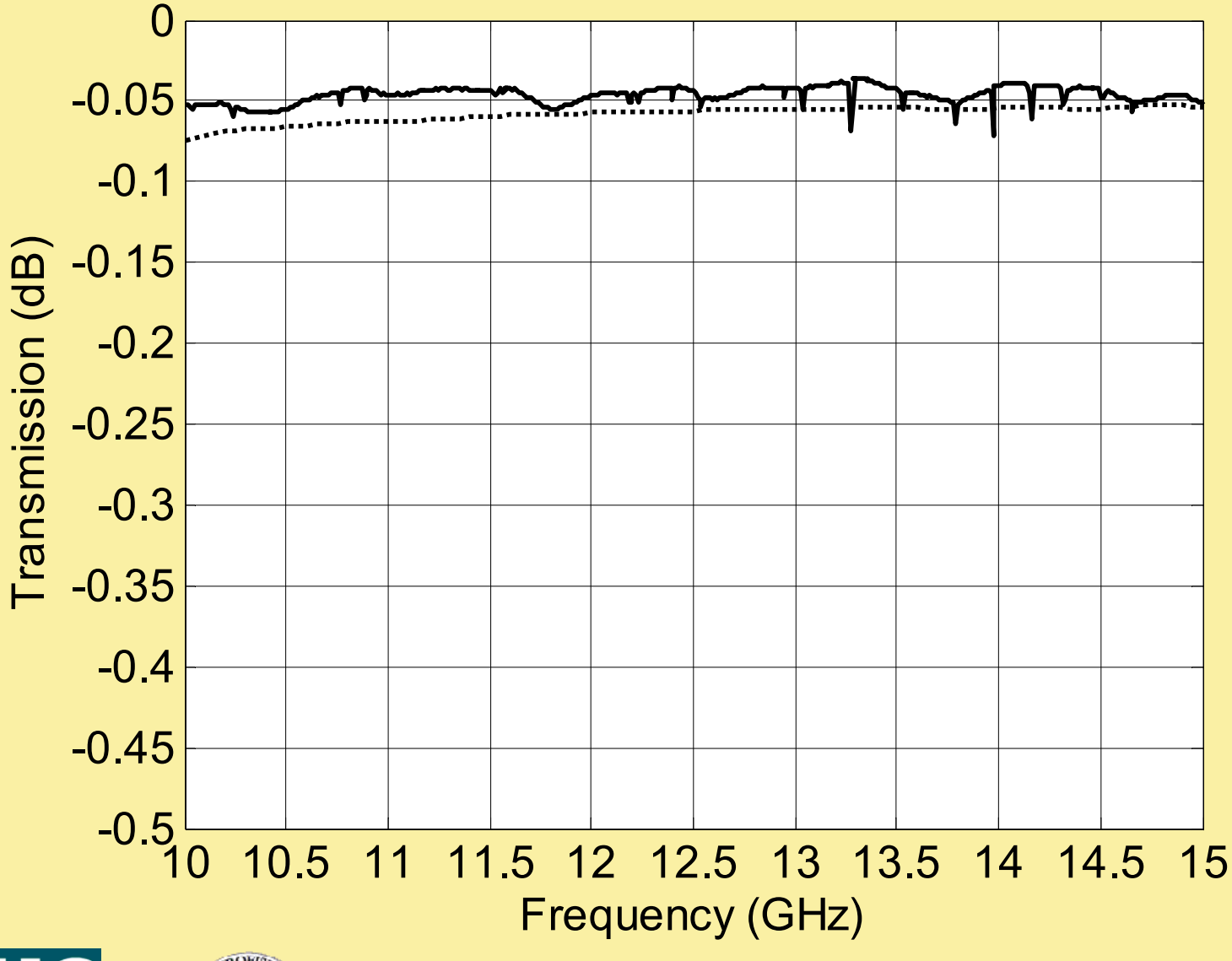



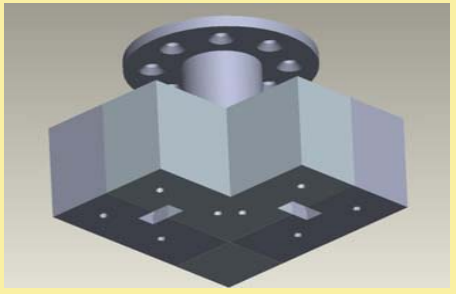
**better than 23 dB**

solid line: test

dashed line: simulation

# OMT Insertion Loss



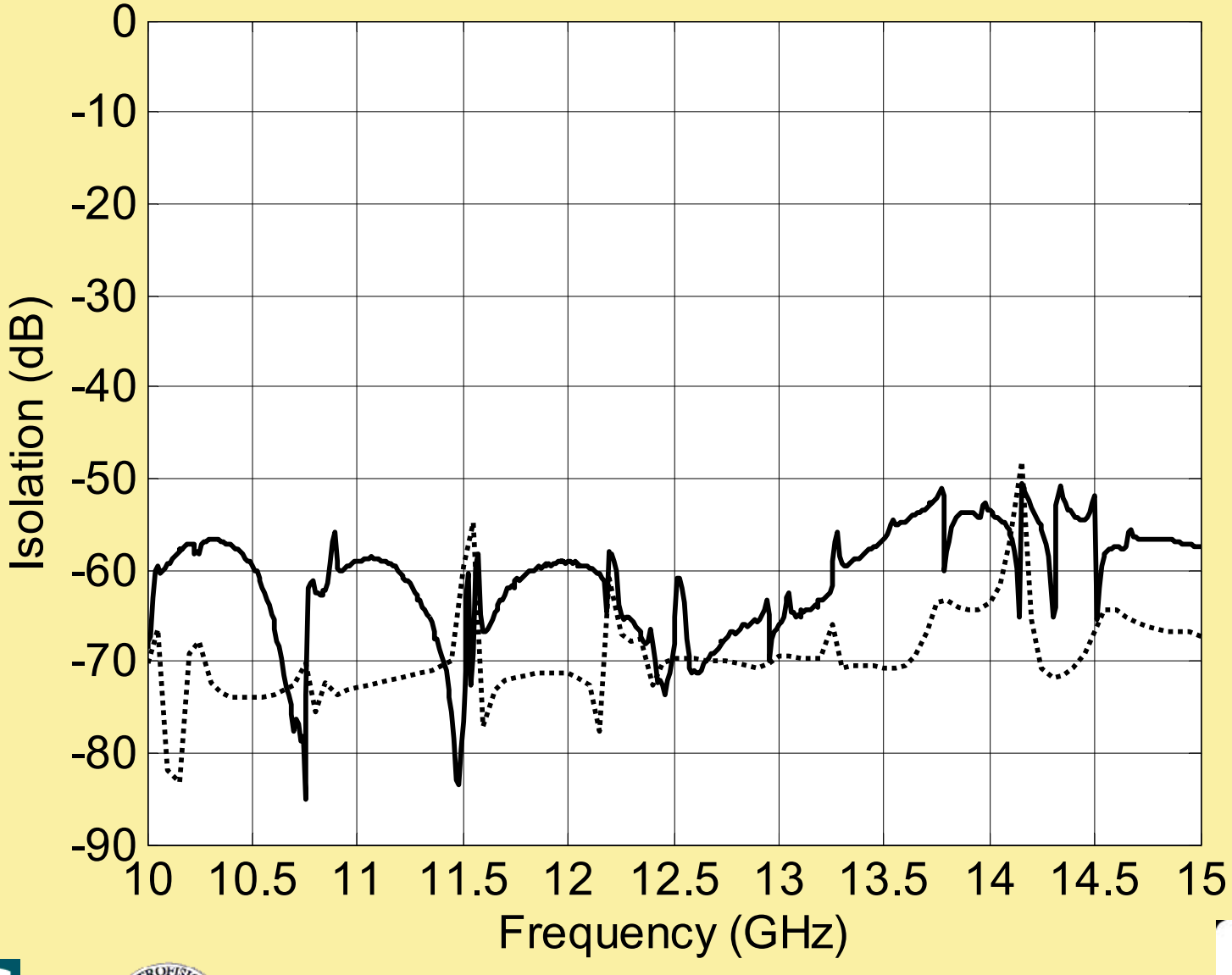



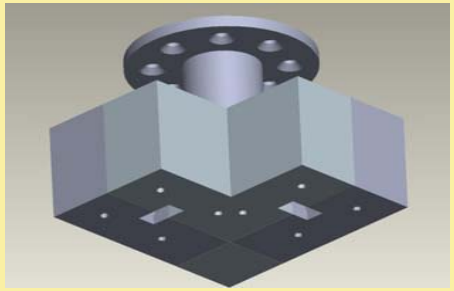
**≈ 0.05 dB**

solid line: test

dashed line: simulation

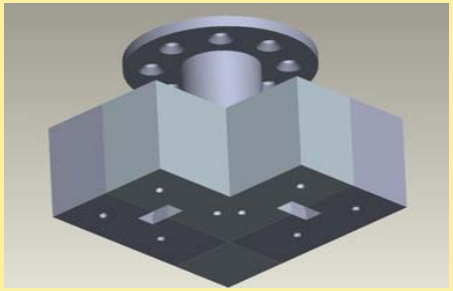
# OMT Isolation (between rectangular ports)

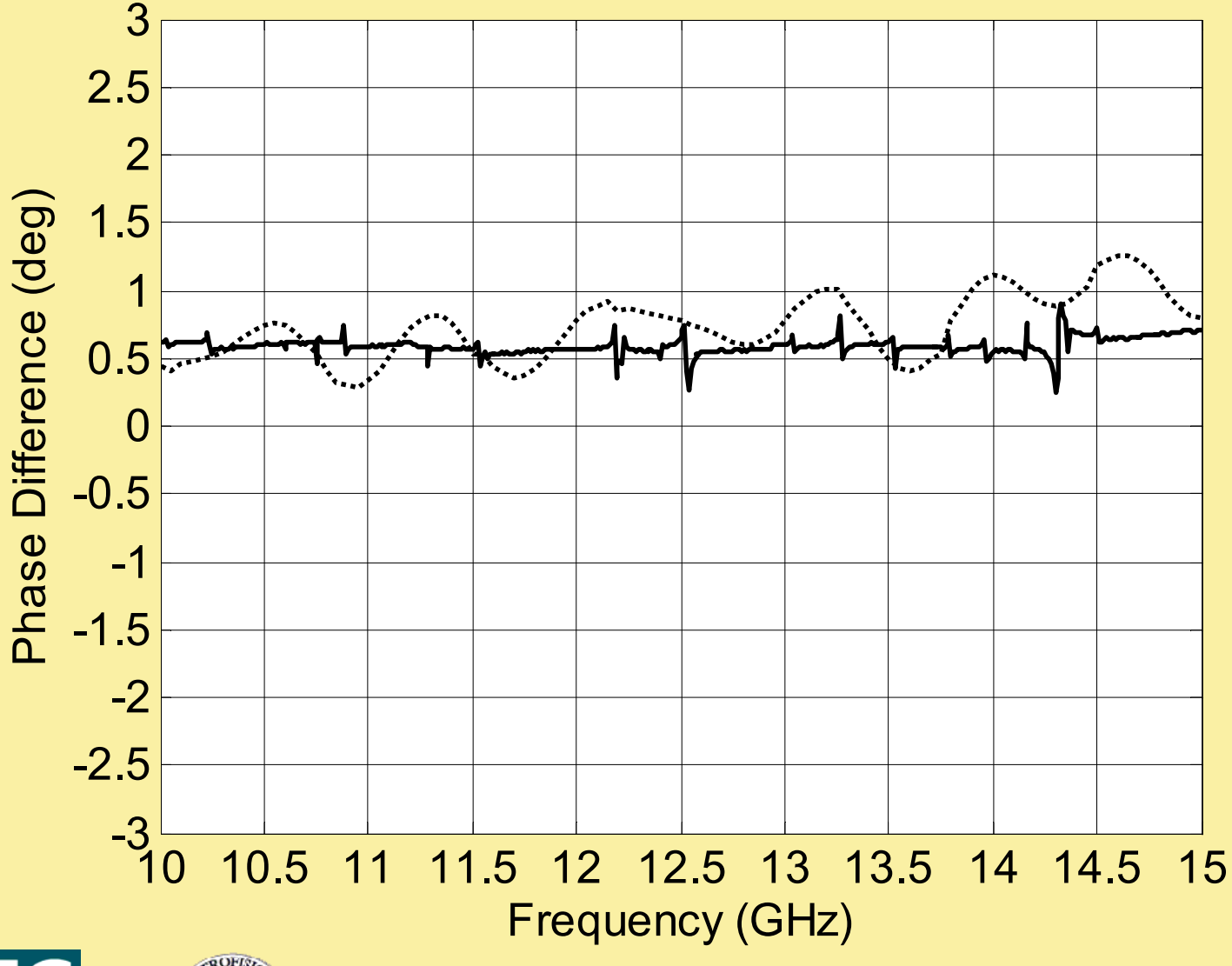


**better than 50 dB**

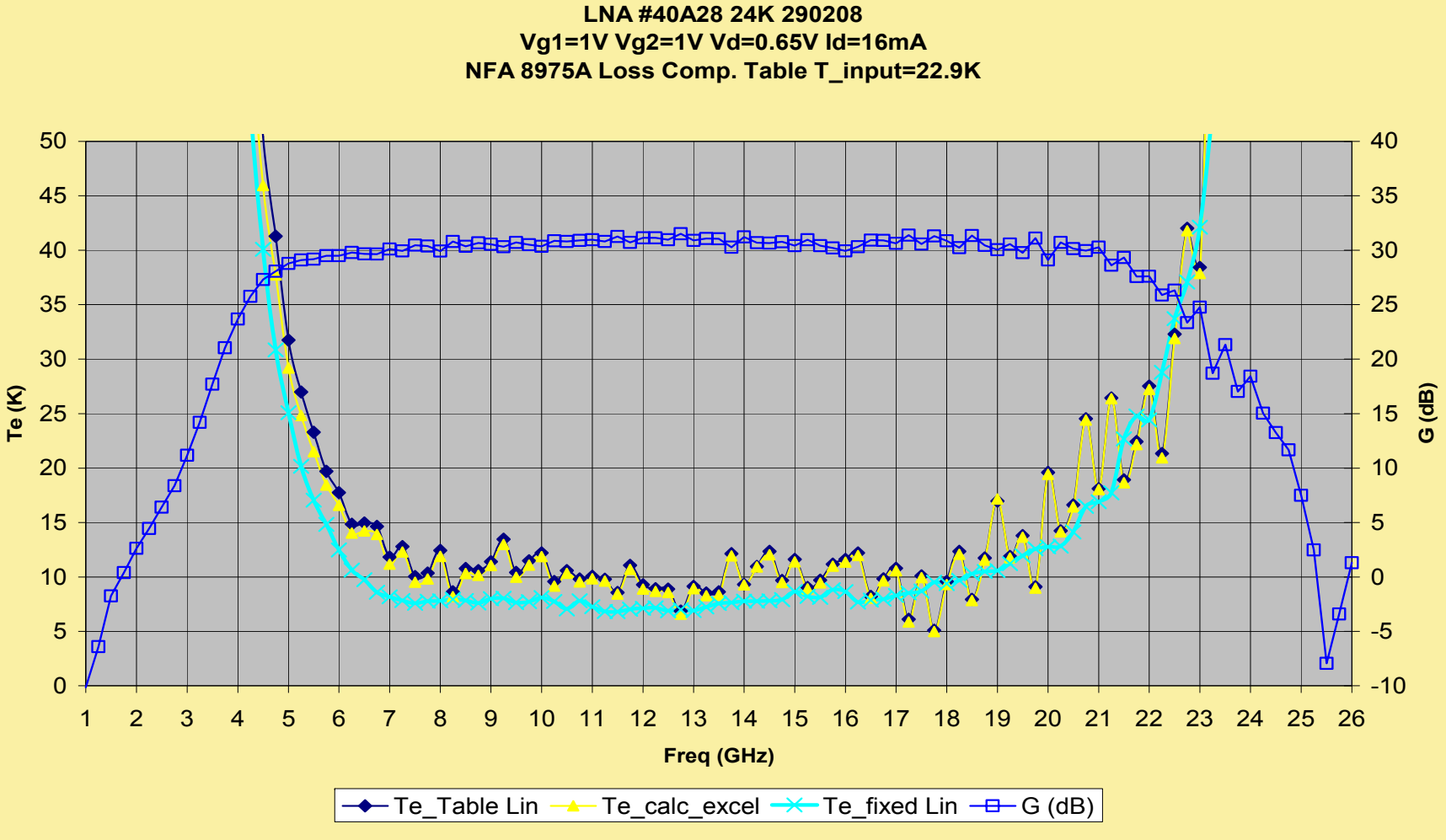
# OMT Phase balance (between rectangular outputs)





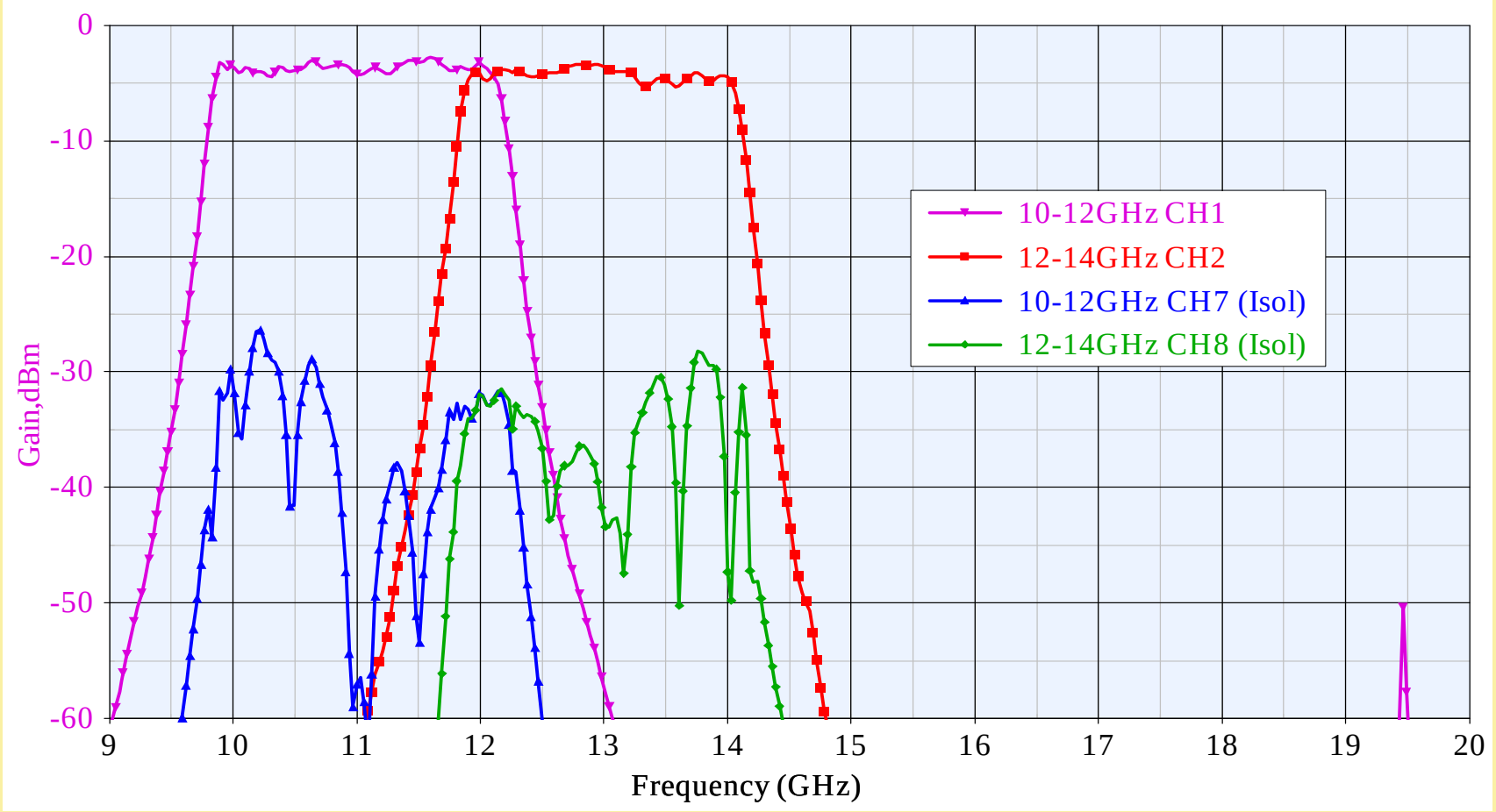

**Δphase < 0.7º**

# Cryo LNA. Gain and Noise Temperature



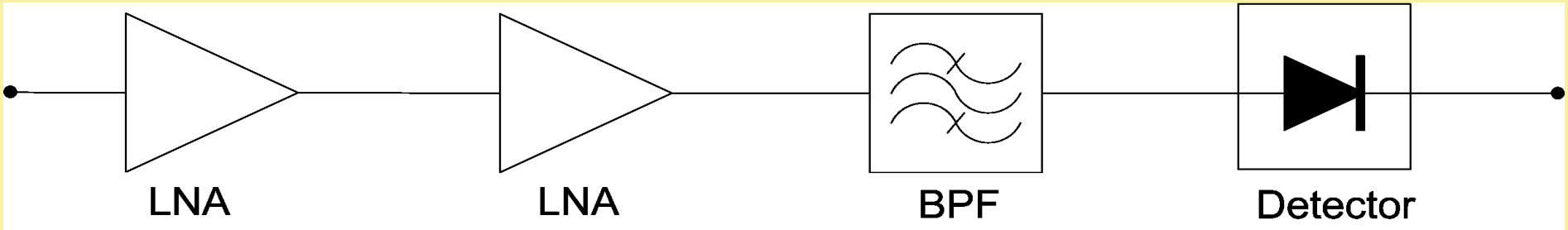

## LNA for low frequency channels

# 10-14 GHz BEM rack RF Gain (QUIJOTE 1)



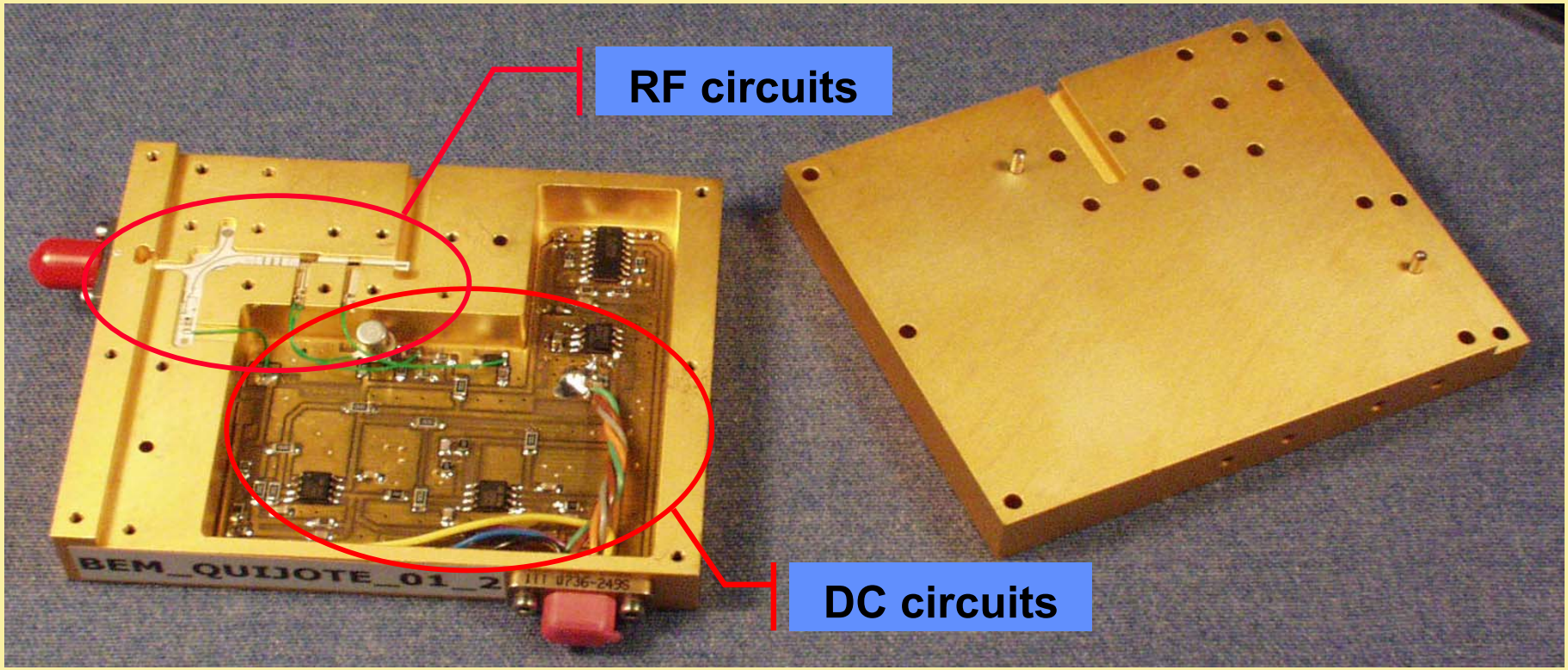
# 30 GHz BEM (QUIJOTE 1)

30 GHz BEM Block diagram (video amp not included)




Bandwidth: 26 to 36 GHz
Noise temperature < 500 K

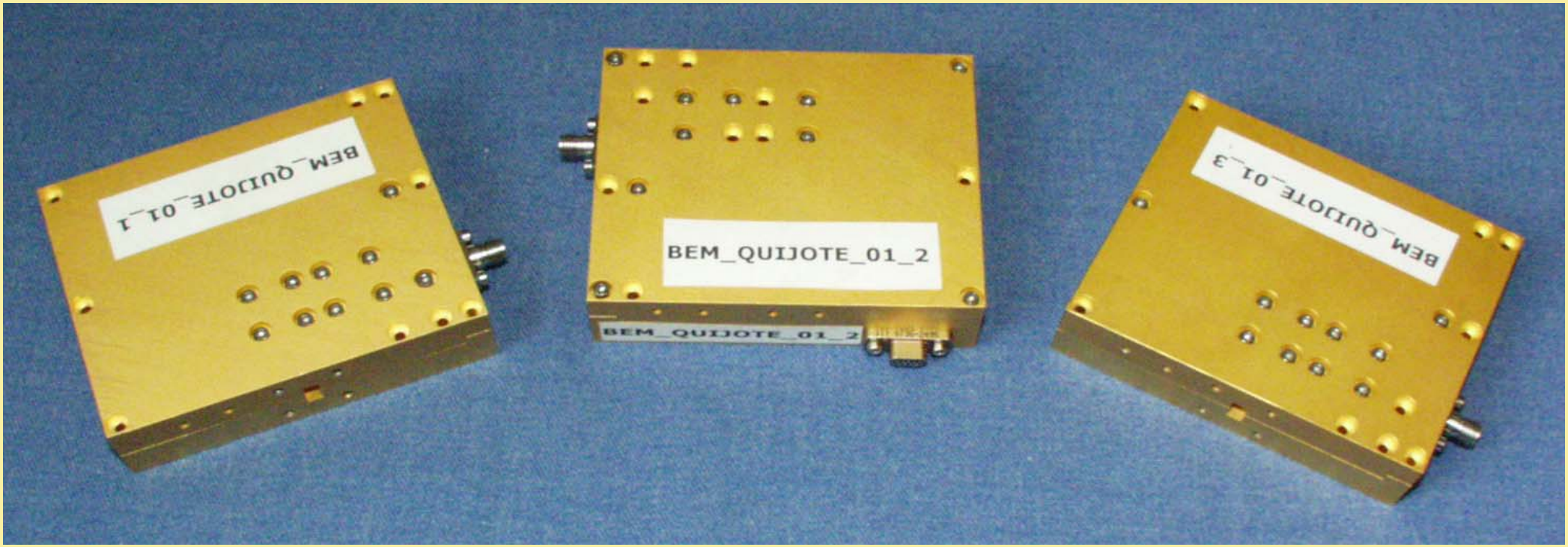
# 30 GHz BEM (QUIJOTE 1)



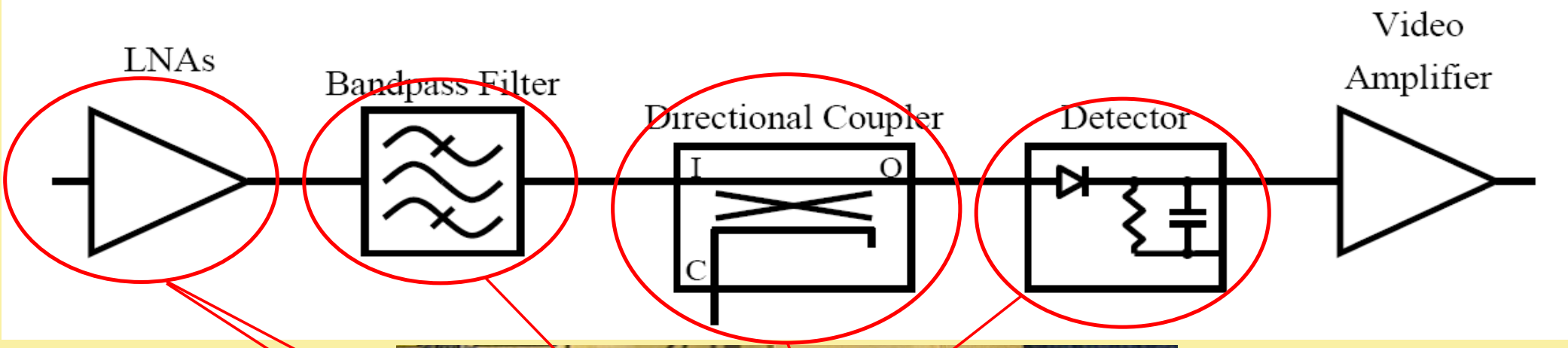

BEM branch (top cover removed)

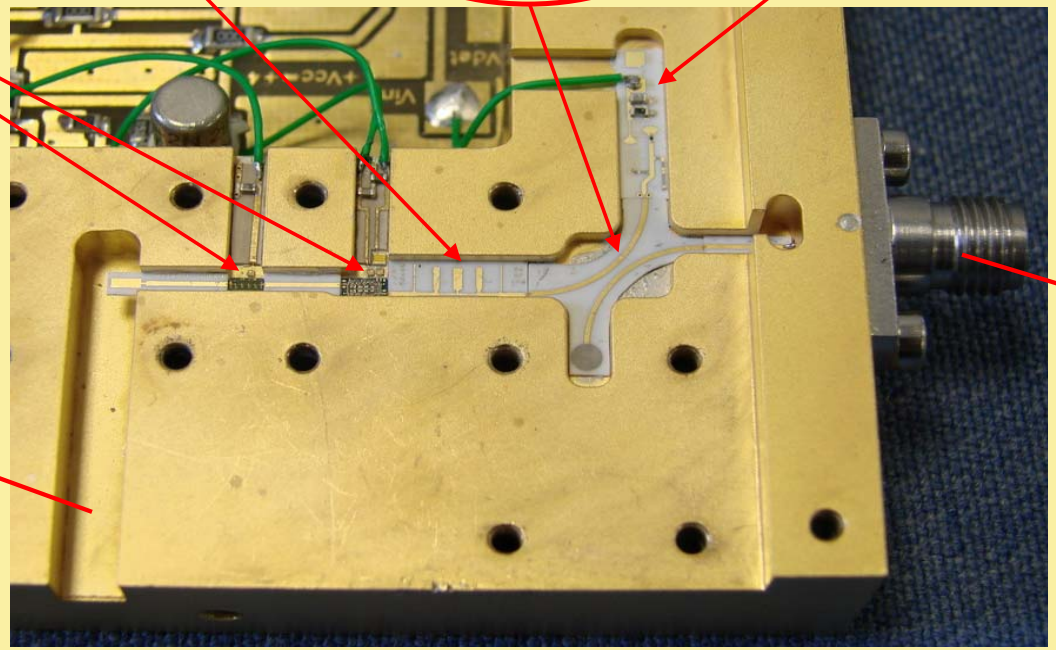
# 30 GHz BEM (QUIJOTE 1)

Manufactured BEM units: 2 + 1 (spare)



# 30 GHz BEM (QUIJOTE 1)

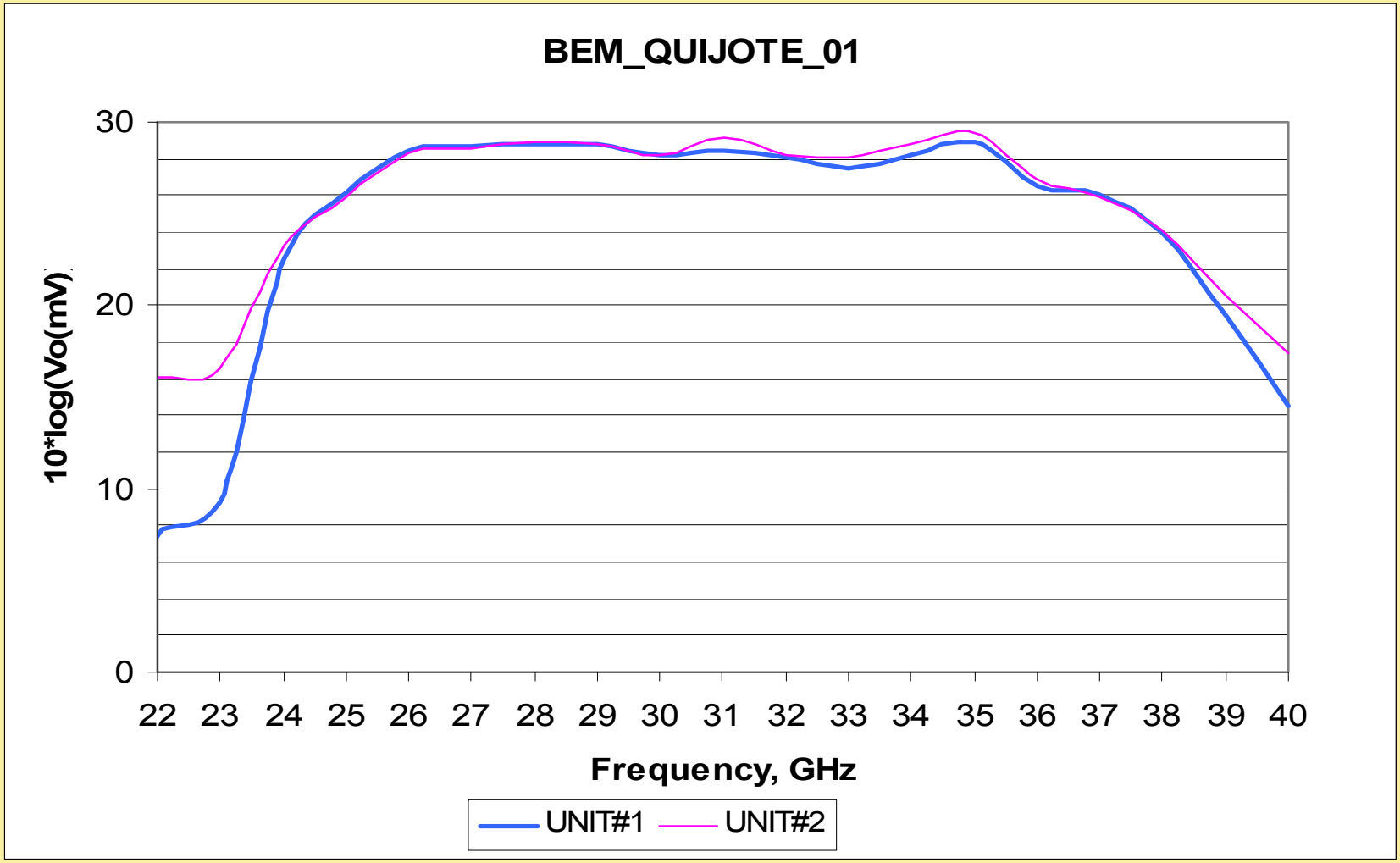


**Waveguide input**

**RF sample output (K connector)**

# Test results (30 GHz BEM)




Gain vs. frequency for two units (detector included).

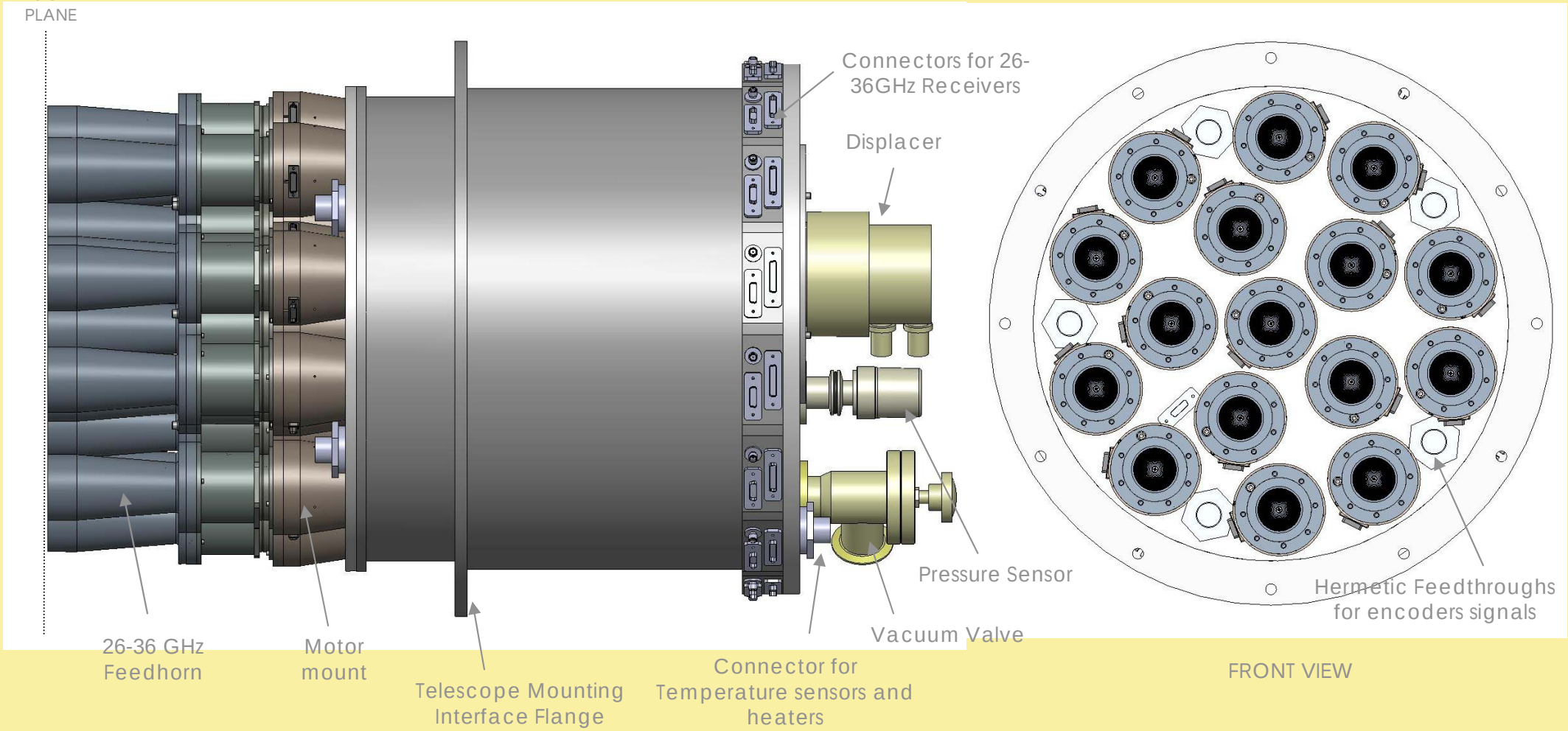
# QUIJOTE 1 - Planning

- Dec. 2009: Cryostat and polar modulators in IAC (Tenerife)
- Jan. 2010: OMT and feed-horns installation
- Mar. 2010: FEM + BEM integration. RF and radiometric testing

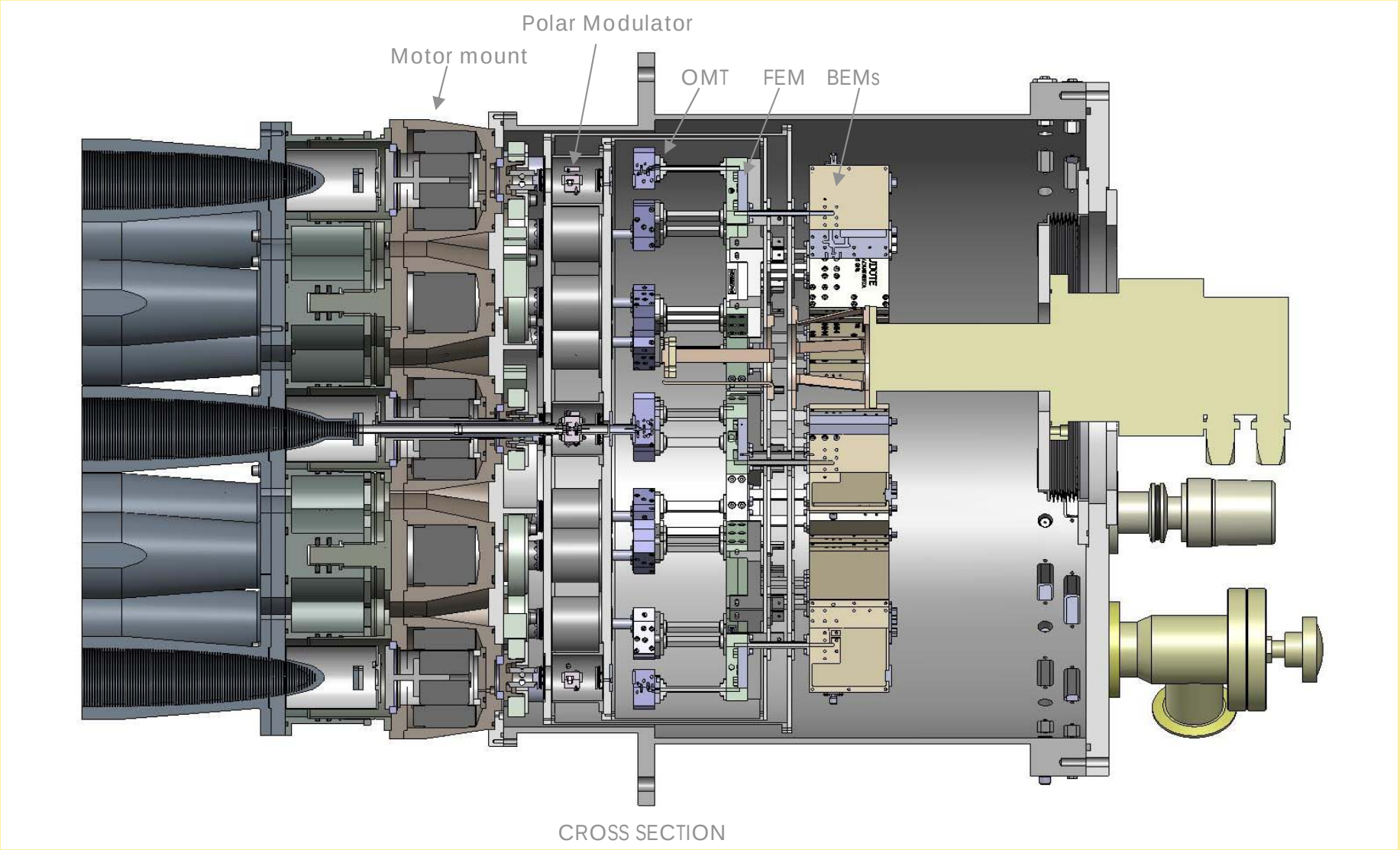
  Transport telescope to Izaña
- Apr. 2010: Preliminary start-up and commissioning

# QUIJOTE 2 – 30 GHz Instrument

"If QUIJOTE 1 proves successful"



# QUIJOTE 2 – The 30 GHz Instrument



# QUIJOTE enclosure building

**November 2008: Covering main structure**

# QUIJOTE enclosure building

**May 2009: final quality tests**

# Telescope manufacturing

**September 2008:**
**Telescope parts and assembly**

**December 2008:**
**Telescope shipping**

# Telescope transport

**Dec. 2008 – Jan. 2009: from Bilbao to La Laguna (IAC)**

**Truck in Bilbao**

**Ship to Tenerife**

# Telescope QUIJOTE 1
# IAC (La Laguna, Tenerife)
## May 2009

# QUIJOTE Second Consortium Meeting (May 2009)

# The QUIJOTE CMB Experiment

For further information visit:
**http://www.iac.es/project/cmb/quijote/index.php**