精勤司天 诚信修文

Development of the K/Q/W tri-band cryogenic receiver for Tianma telescope

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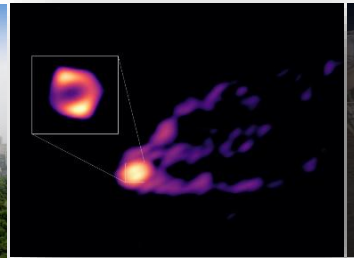
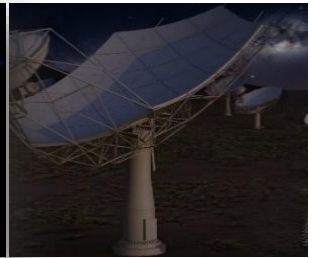
Shanghai Astronomical Observatory, CAS
Oct. 28, 2025



Outline

1. Overview
2. Specification
3. Scheme design
4. Current progress
5. Summary

Overview

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Overview

- **Millimeter-wave VLBI network**
  - Tianma (65 m)/Shigatse (40 m)/Changbaishan (40 m) radio telescope;
  - Observation frequency up to 110 GHz;
  - Form a world-class millimeter-wave VLBI network;
  - Operate as an independent network or interconnect with international stations (such as EATING).
- **Science**
  - Boost radio astronomy research capabilities by an order of magnitude;
  - Enable high-resolution astronomical observations;
- **K/Q/W tri-band cryogenic receiver plan**
  - Tianma 65 m in 2025/Q4;
  - Shigatse/Changbaishan 40 m in 2027/Q4.

Specification

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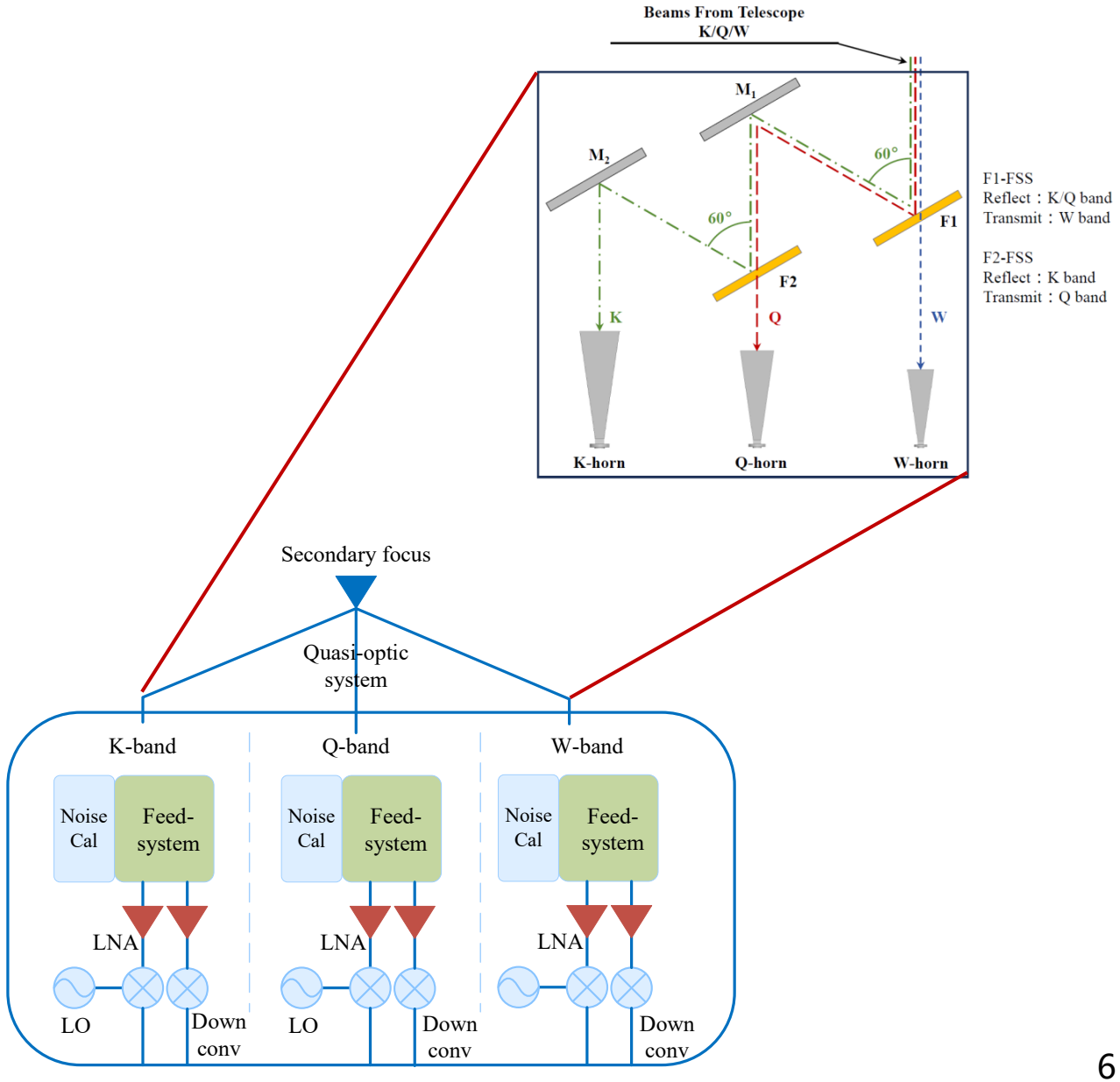
Specification

Requirements

Parameter	K-band	Q-band	W-band
Frequency range	18-26 GHz	34-50 GHz	80-110 GHz
Output frequency range	4-12 GHz		
Frequency coverage	Simultaneous observation		
Polarization	Circular polarization (LCP&RCP)		
Receiver noise temperature (with no optics)	≤40 K	≤50 K	≤120 K
Calibration method	Commercial noise source injected to the receiver		



Scheme Design

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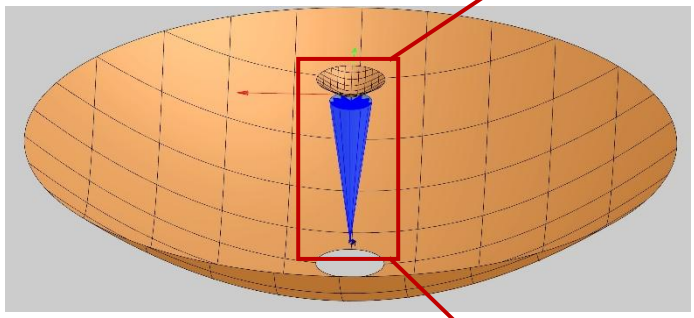
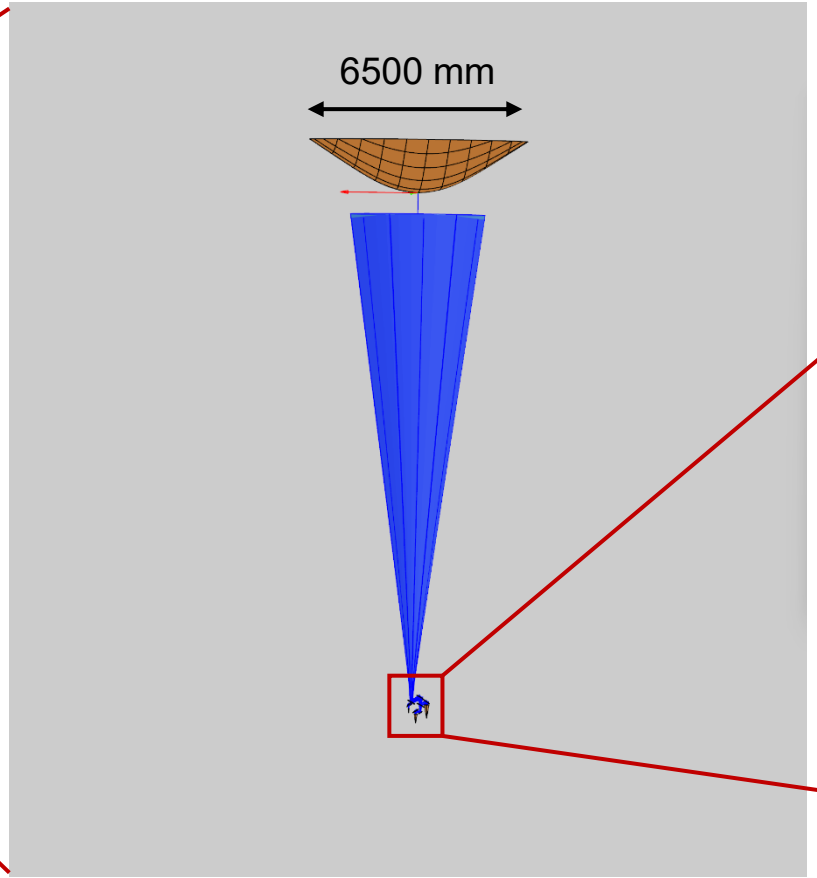
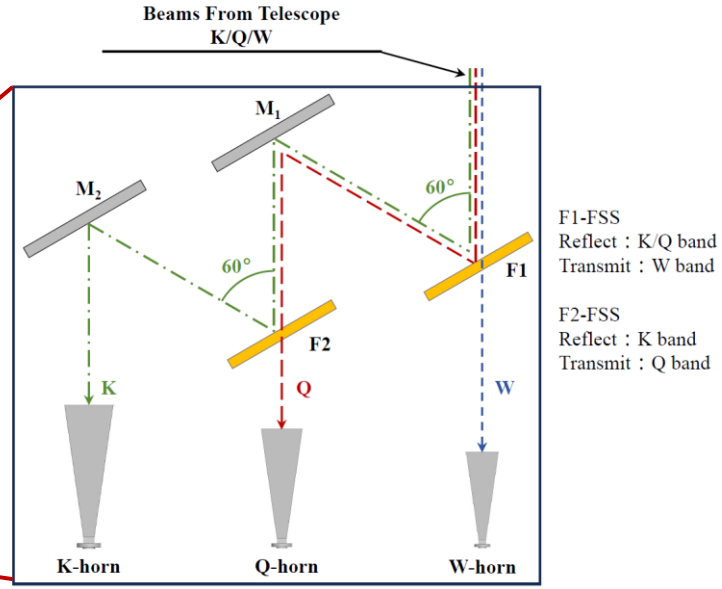
Scheme Design

Quasi-optical unit



65000 mm

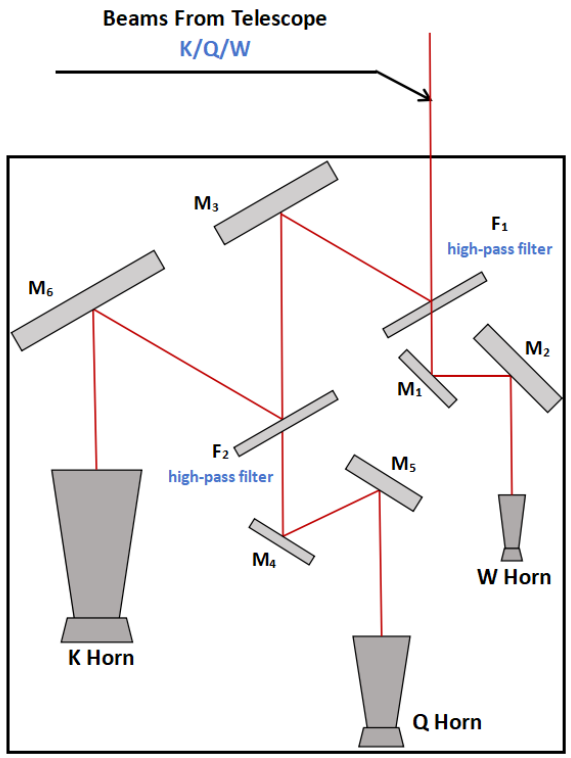




The quasi-optical unit is designed to enable simultaneous reception at the **K-band**, **Q-band**, and **W-band**. The design of this unit is based on the optical path of the **Tianma 65-m radio telescope**. The optical path was designed by **Osaka Metropolitan University (OMU), Japan**, and the **dichroic filters** were designed by the **Shanghai Astronomical Observatory (SHAO), China**.

Scheme Design

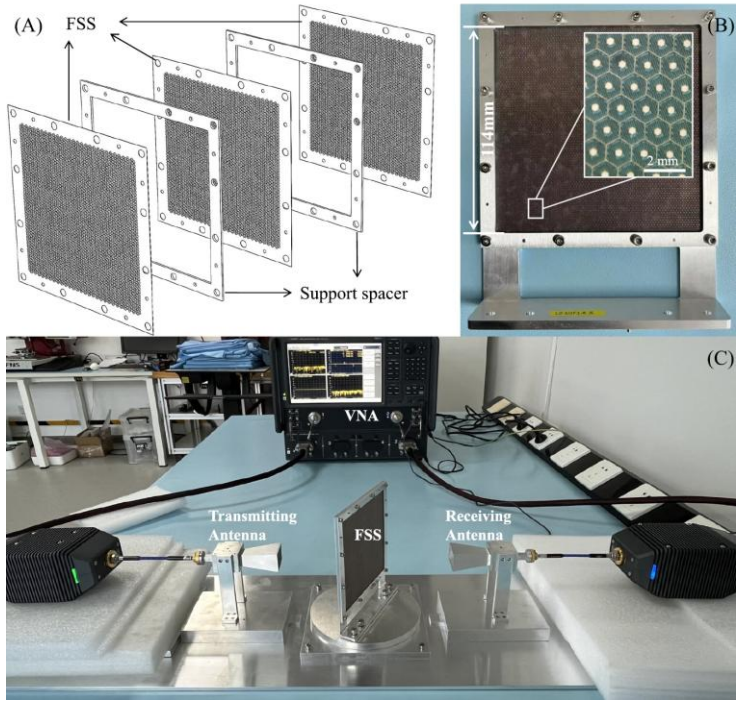
Quasi-optical unit design and related performance



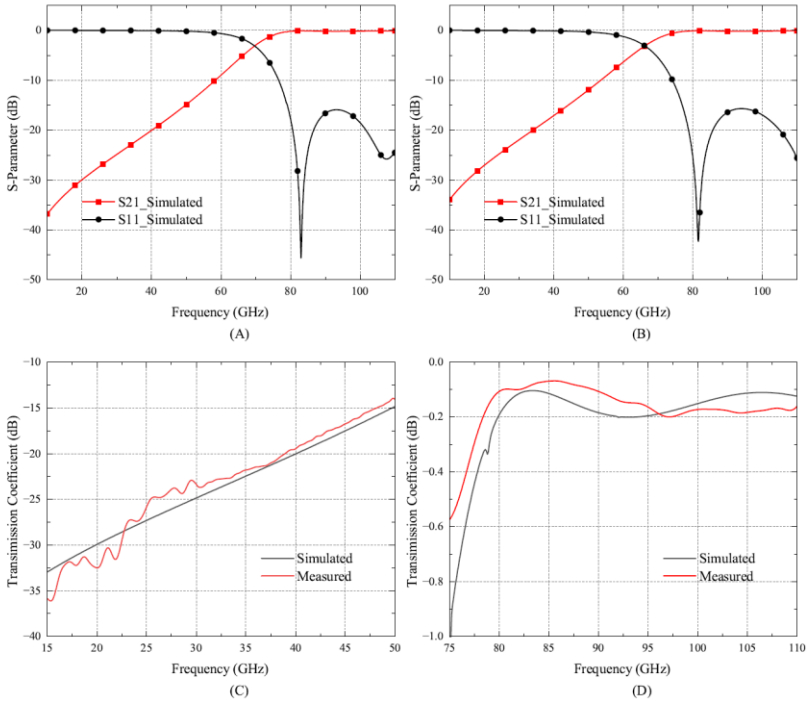
Surface accuracy (mm)	Frequency range (GHz)	Surface error loss (dB)	Surface error efficiency (%)	Blockage efficiency (%)	Aperture efficiency (%)	Antenna efficiency (%)
0.3	18	0.22	95.02	97.13	67.61	62.40
0.3	22	0.33	92.65	97.13	75.62	68.05
0.3	26	0.46	89.89	97.13	76.14	66.48
0.3	34	0.79	83.33	97.13	81.27	57.83
0.3	43	1.27	74.70	97.13	81.27	58.97
0.3	50	1.71	67.41	97.13	84.42	55.27
0.3	80	4.38	36.44	97.13	78.13	27.65
0.3	86	5.07	31.14	97.13	78.76	23.82
0.3	110	8.29	17.83	97.13	78.20	13.54

Scheme Design

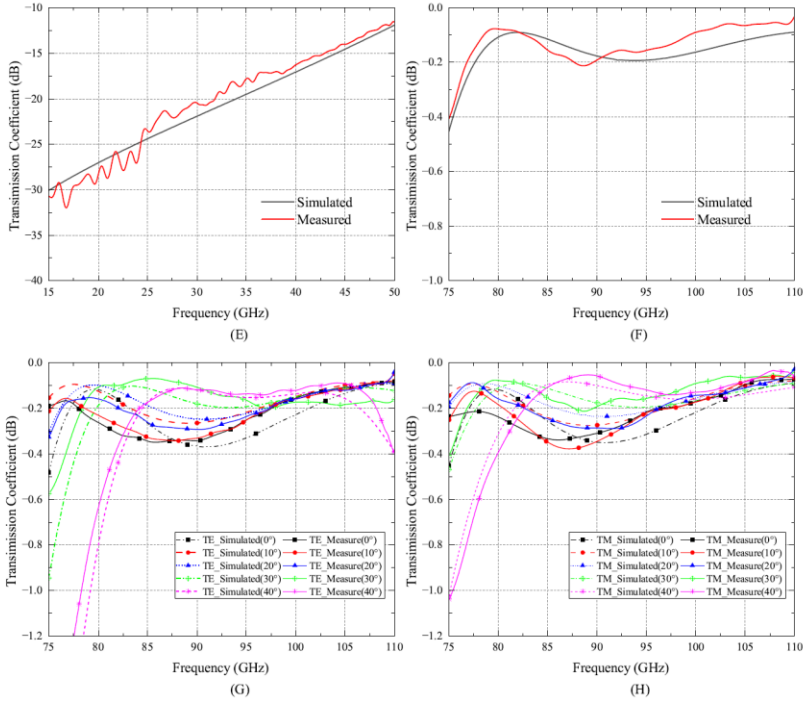
Quasi-optical unit---dichroic filter---KQ/W high-pass dichroic filter



Physical unit and laboratory tests



TE-polarization test results

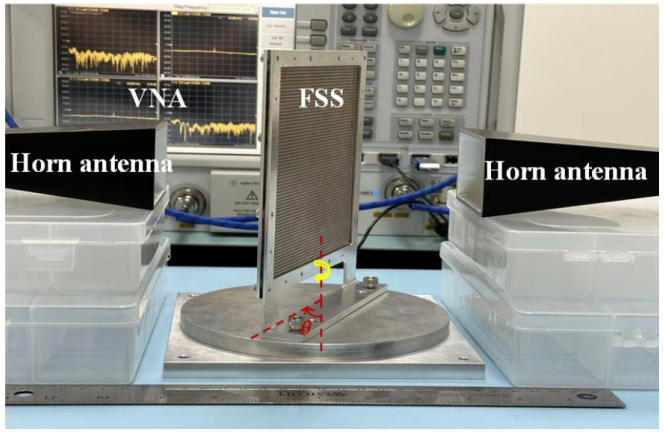


TM-polarization test results

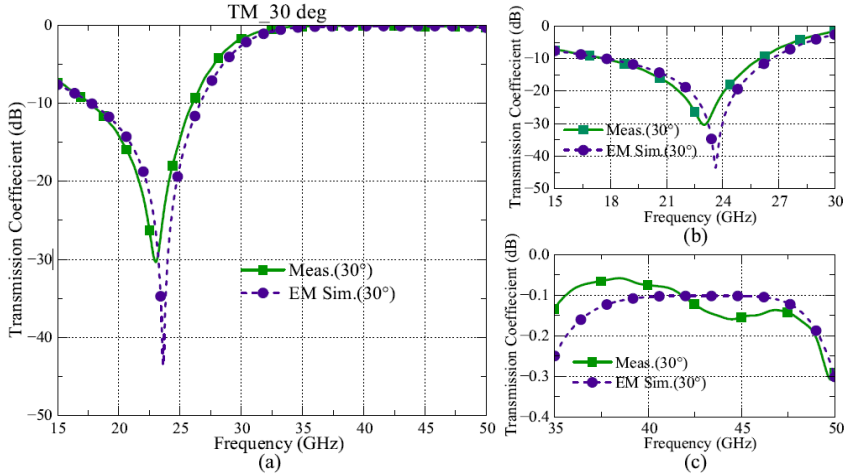
- For both **TE** and **TM** polarizations, the W-band insertion loss is less than **0.2 dB**, with some frequency points better than **0.1 dB**.

Scheme Design

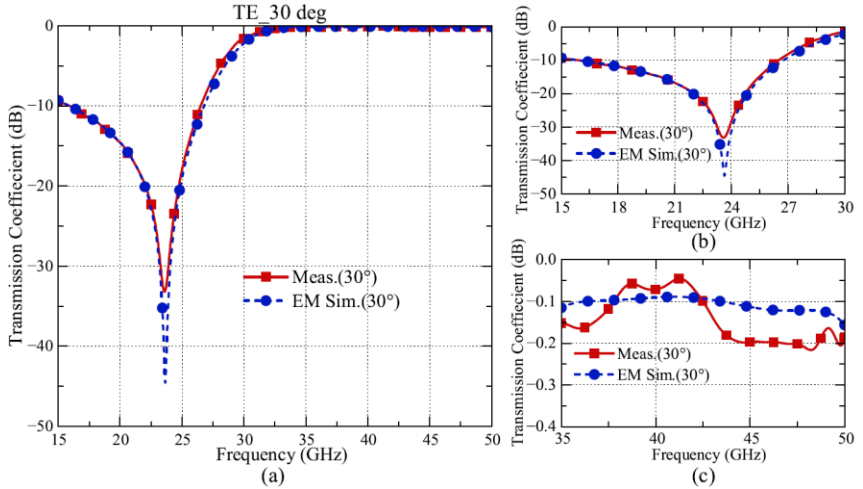
Quasi-optical unit---dichroic filter---K/Q high-pass dichroic filter



Physical unit and laboratory tests

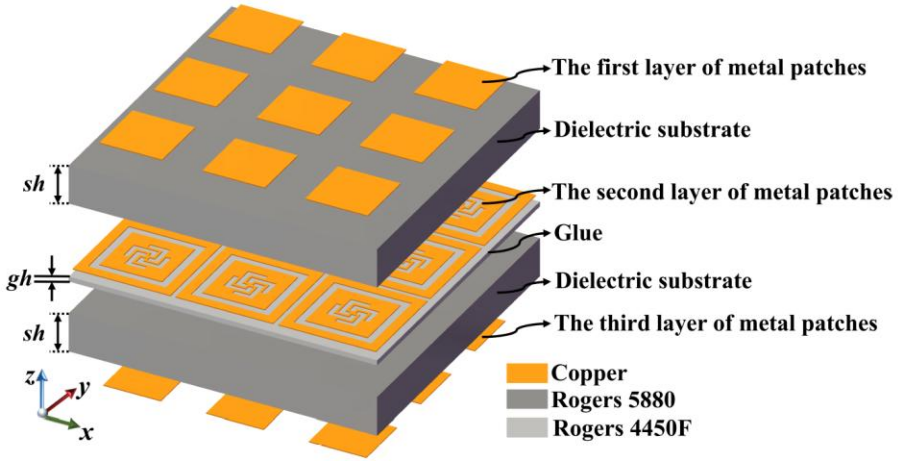


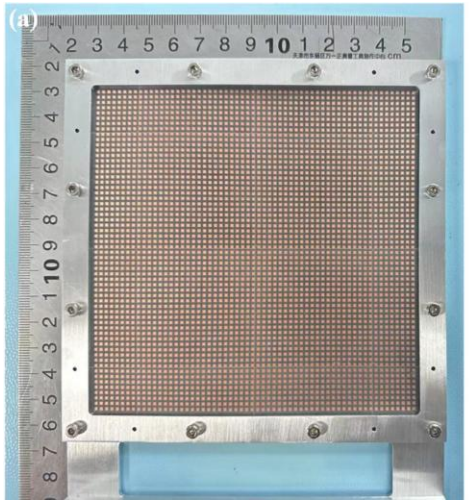
TE-polarization test results

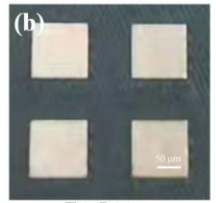


TM-polarization test results

- For both **TE** and **TM** polarizations, the Q-band insertion loss is less than **0.3 dB**.







Scheme Design

Cryogenic electronic unit---noise injection coupler

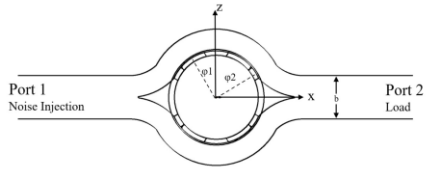


Figure 1a. Front view

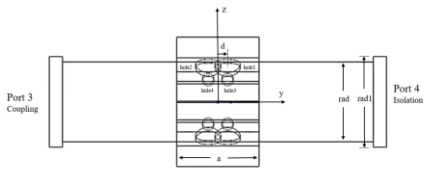
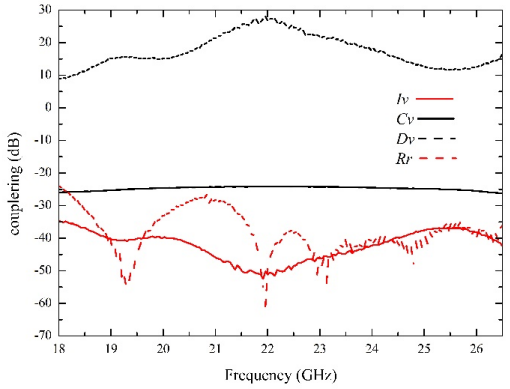
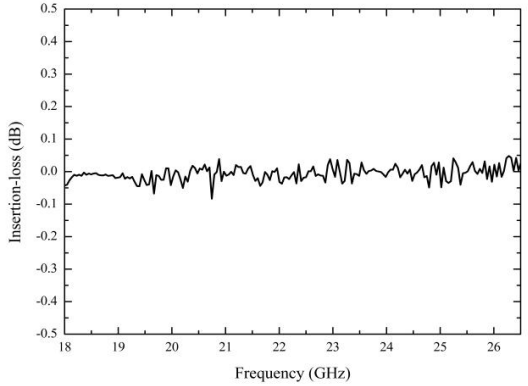
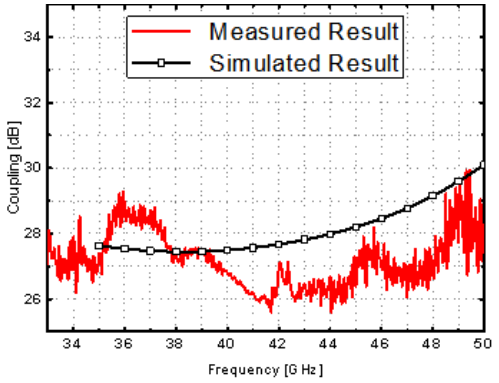


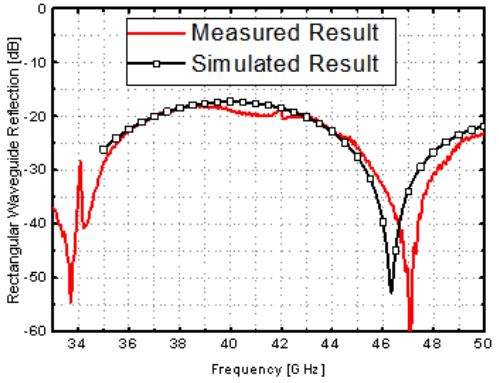
Figure 1b. Side view



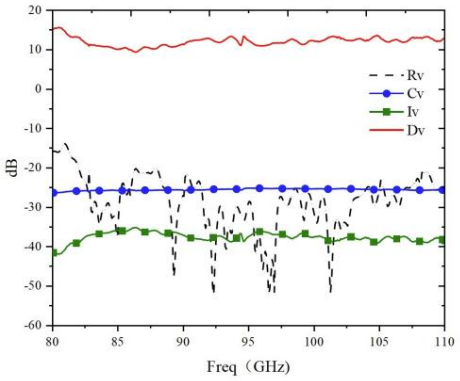


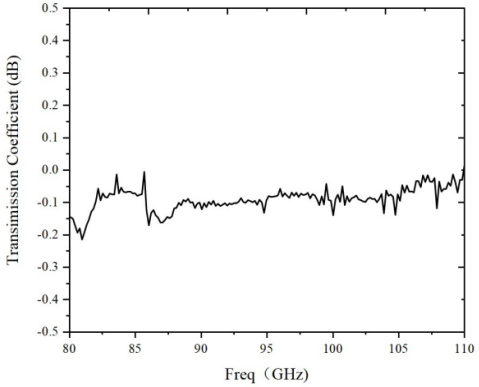
K-band coupler





Q-band coupler

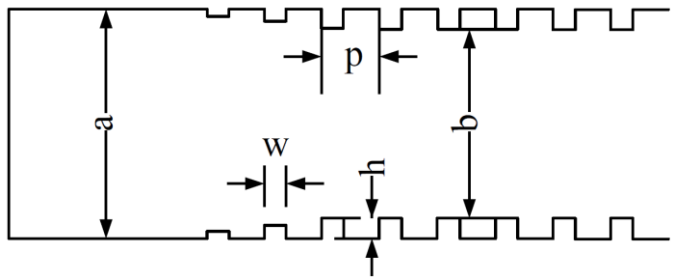


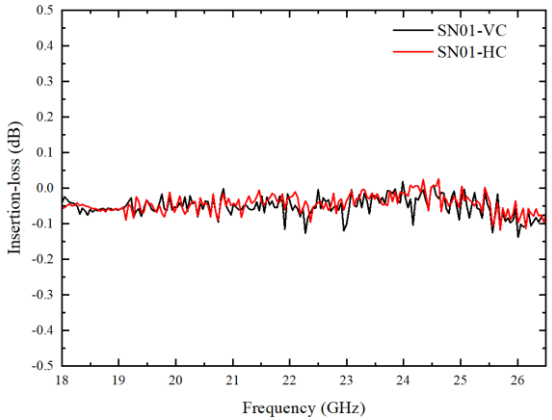


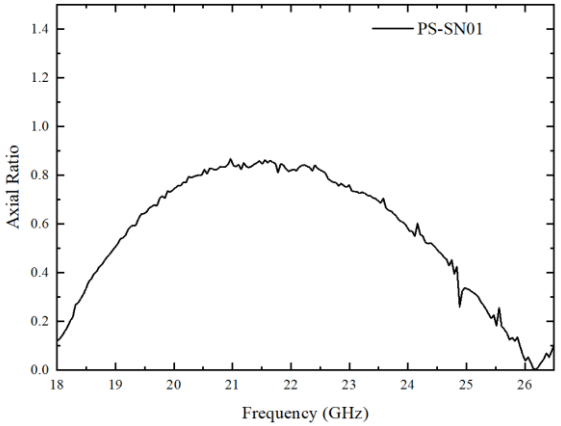
W-band coupler

Scheme Design

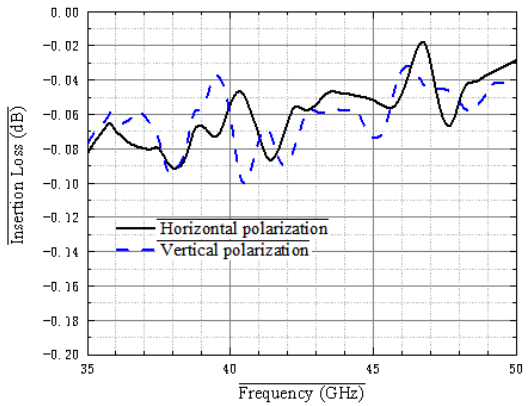
Cryogenic electronic unit---90° phase shifter

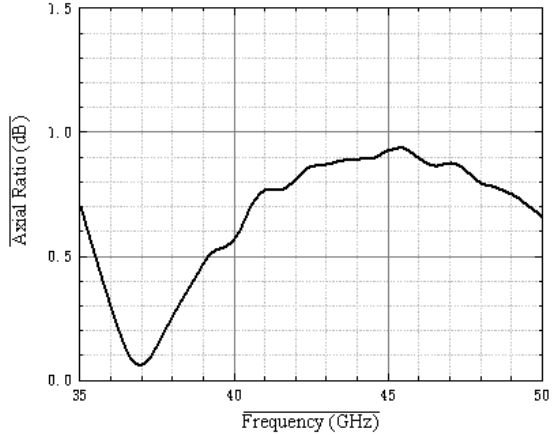




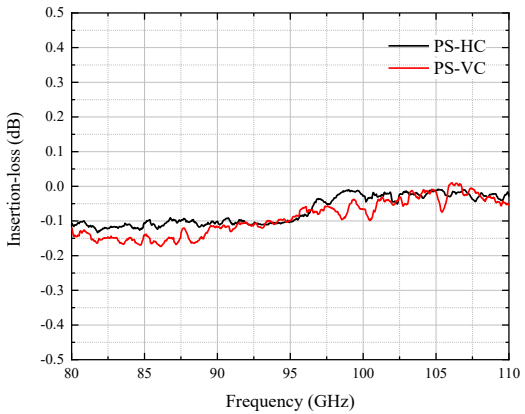


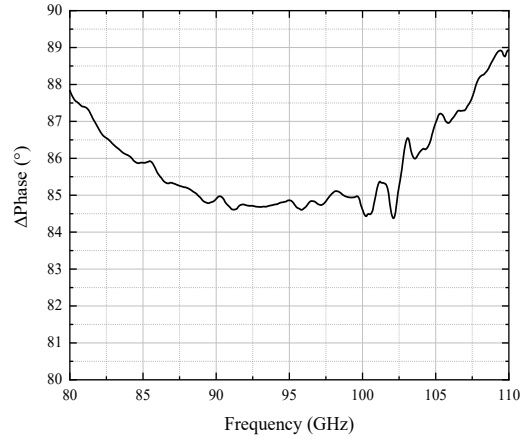
K-band phase shifter





Q-band phase shifter

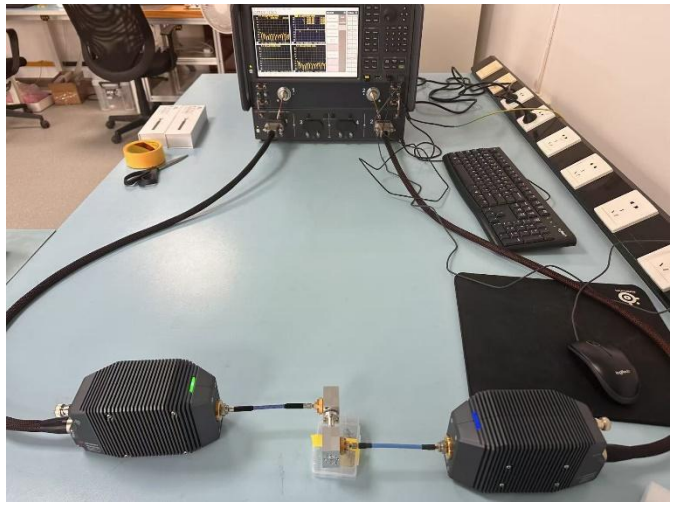


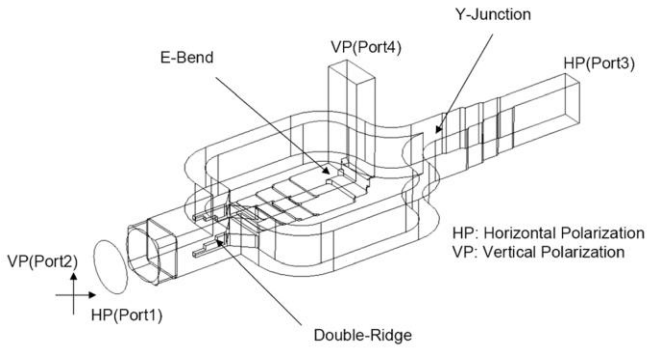


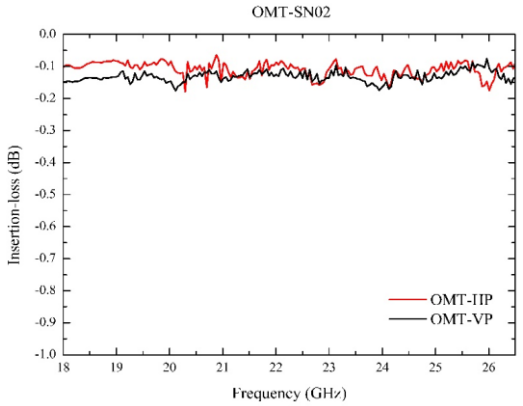
W-band phase shifter

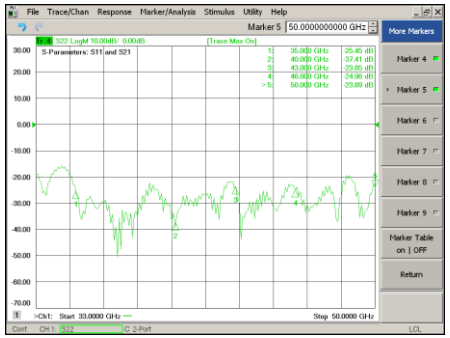
Scheme Design

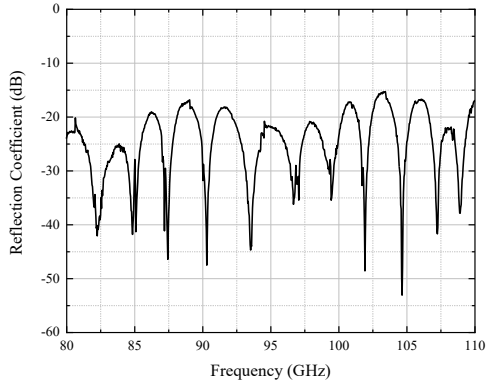
Cryogenic electronic unit---OMT

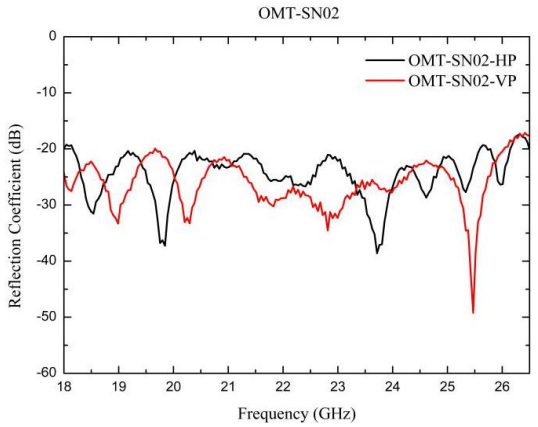




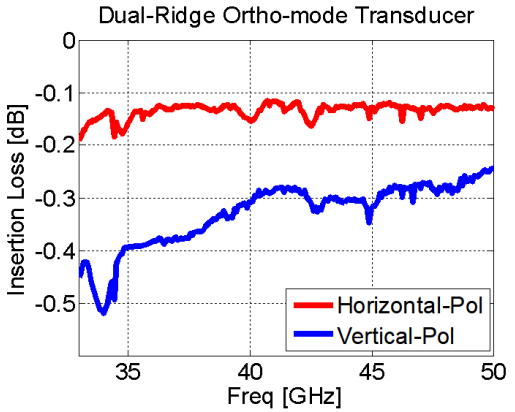




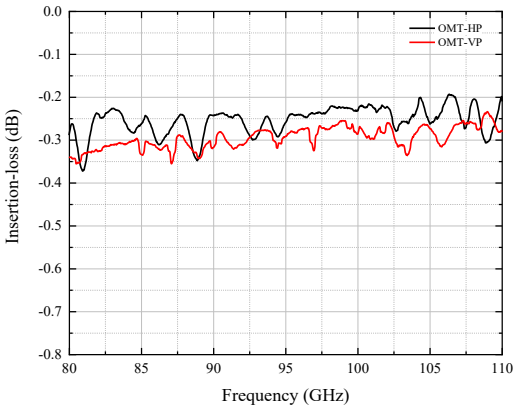




K-band OMT



Q-band OMT

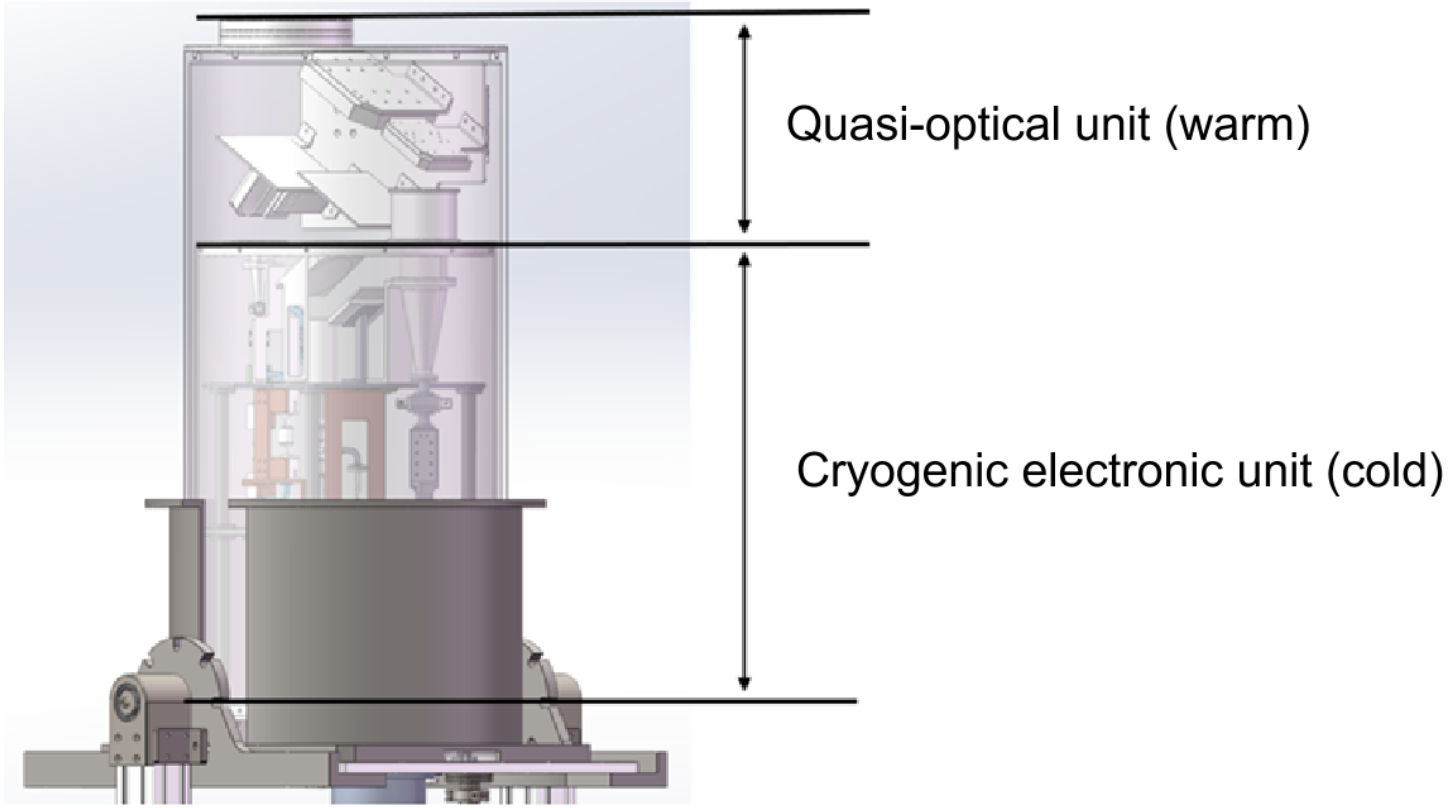


W-band OMT

Scheme Design

Cryogenic electronic unit---vacuum dewar

- To achieve high integration and miniaturization, the quasi-optical unit and the cryogenic electronic unit are both mounted inside the vacuum dewar housing; the quasi-optical unit's optical components operate at room temperature, while all other components operate at cryogenic temperature.
- The dewar's external dimensions are Φ487 × 1096 mm. the feed horn, noise injection coupler, phase shifter, OMT and LNA are supported by insulating material and connected to the cryocooler's second-stage cooling platform via cold straps.



Scheme Design

Cryogenic electronic unit---K/Q/W-band link noise temperature budget

Tianma K/Q/W tri-band receiver (K-band)							
	Temp	Active comp		Gain	Gain	Delta T	Trx
	(K)			(dB)	(linear)	(K)	(K)
Vacuum window	300			-0.1	0.977	6.988	6.988
IR filter	77			-0.05	0.989	0.912	7.900
Feed horn	20			-0.05	0.989	0.240	8.140
Coupler	20			-0.1	0.977	0.488	8.628
PS	20			-0.1	0.977	0.499	9.127
OMT	20			-0.2	0.955	1.034	10.161
CLNA	15	20	K	33	1995.262	22.963	33.124
SS coax	150			-3	0.501	0.086	33.209
UDC	313	5	dB	30	1000.000	0.777	33.987
Total							33.99

Tianma K/Q/W tri-band receiver (Q-band)							
	Temp	Active comp		Gain	Gain	Delta T	Trx
	(K)			(dB)	(linear)	(K)	(K)
Vacuum window	300			-0.1	0.977	6.988	6.988
IR filter	77			-0.05	0.989	0.912	7.900
Feed horn	20			-0.05	0.989	0.240	8.140
Coupler	20			-0.1	0.977	0.488	8.628
PS	20			-0.1	0.977	0.499	9.127
OMT	20			-0.4	0.912	2.116	11.243
CLNA	15	30	K	35	1995.26	36.068	47.311
SS WG	150			-0.8	0.832	0.0183	47.329
WG window	300			-0.4	0.912	0.0210	47.350
UDC	313	6	dB	30	1000.00	0.741	48.091
Total							48.09

Tianma K/Q/W tri-band receiver (W-band)							
	Temp	Active comp		Gain	Gain	Delta T	Trx
	(K)			(dB)	(linear)	(K)	(K)
Vacuum window	300			-0.1	0.977	6.988	6.988
IR filter	77			-0.05	0.989	0.912	7.900
Feed horn	20			-0.05	0.989	0.240	8.140
Coupler	20			-0.2	0.955	0.987	9.127
PS	20			-0.2	0.955	1.034	10.161
OMT	20			-0.4	0.912	2.215	12.376
LNA1	15	70	K	20	100.000	88.125	100.501
LNA2	15	70	K	20	100.000	0.881	101.382
WG comp	20			-2.5	0.562	0.196	101.578
SS WG	150			-4	0.398	0.051	101.629
WG window	300			-0.4	0.912	0.006	101.635
UDC	313	7	dB	30	1000.000	0.774	102.409
Total							102.41

Scheme Design

Room-temperature frequency conversion unit

The room-temperature frequency conversion unit features tri-band receiving channels and matching noise source products, for a total six receiving channels and three noise source output channels, distributed across two assemblies.

Product matching table

No.	Name	Number	Remark
1	K-band frequency conversion unit	1	/
2	Q/W-band frequency conversion unit	1	/

Specification

- Support LCP/RCP reception;
- Perform down-conversion with signal output;
- Deliver noise source outputs to the cryogenic electronic unit;
- Maintain a stable operating temperature for the noise source;
- 4-12 GHz IF output;
- Compatible with DBBC2 (with UDC) and DBBC3 (with filter);

Current Progress

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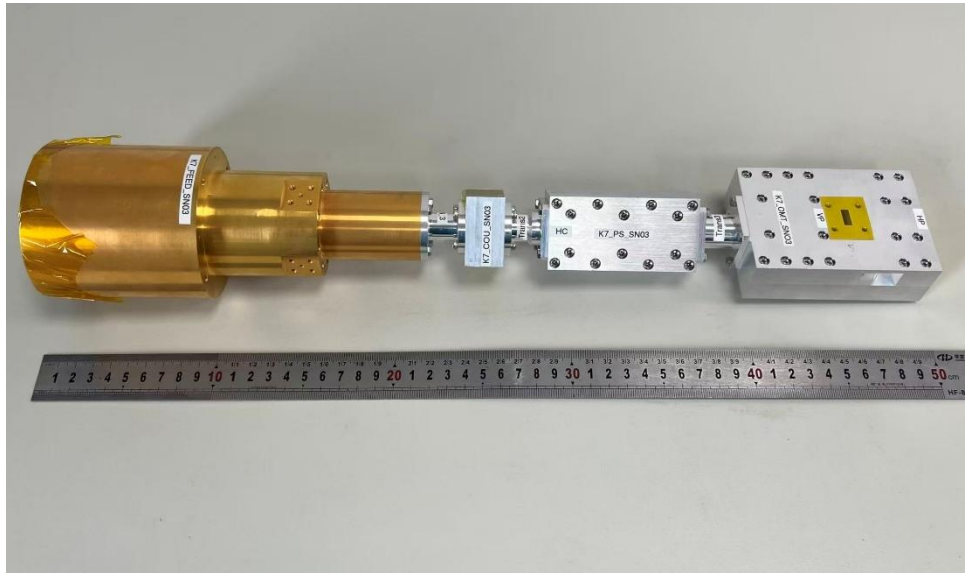
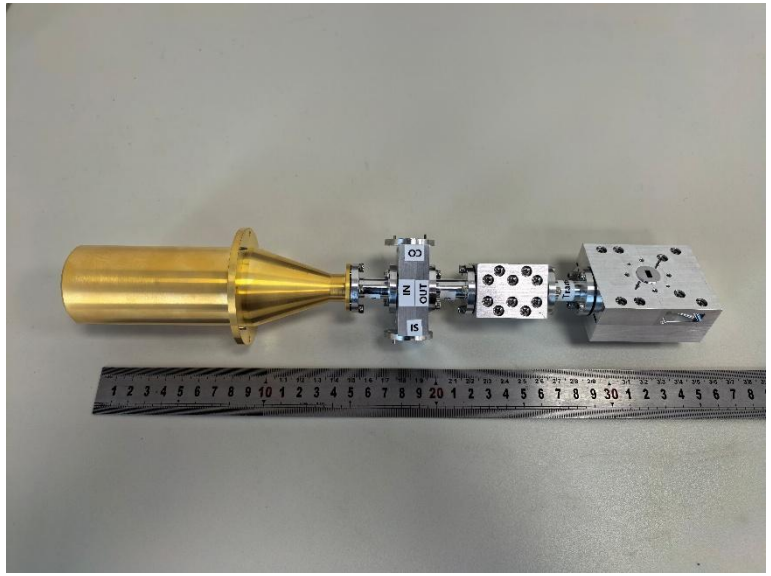
Shanghai Astronomical Observatory,CAS

Current Progress

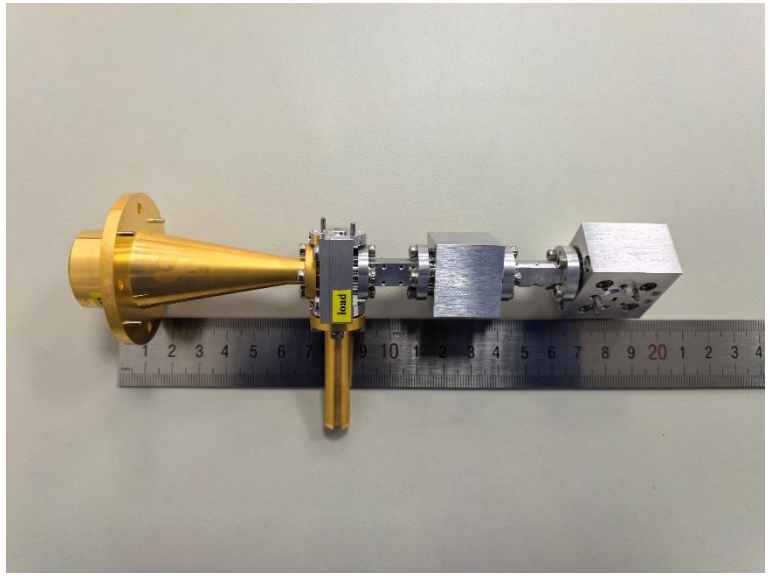
Feed horn, coupler, phase shifter and OMT



K-band

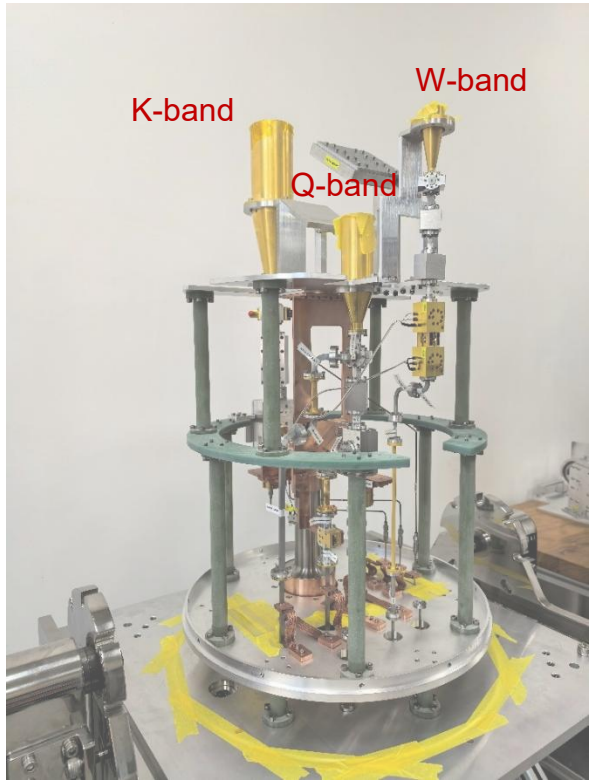


Q-band



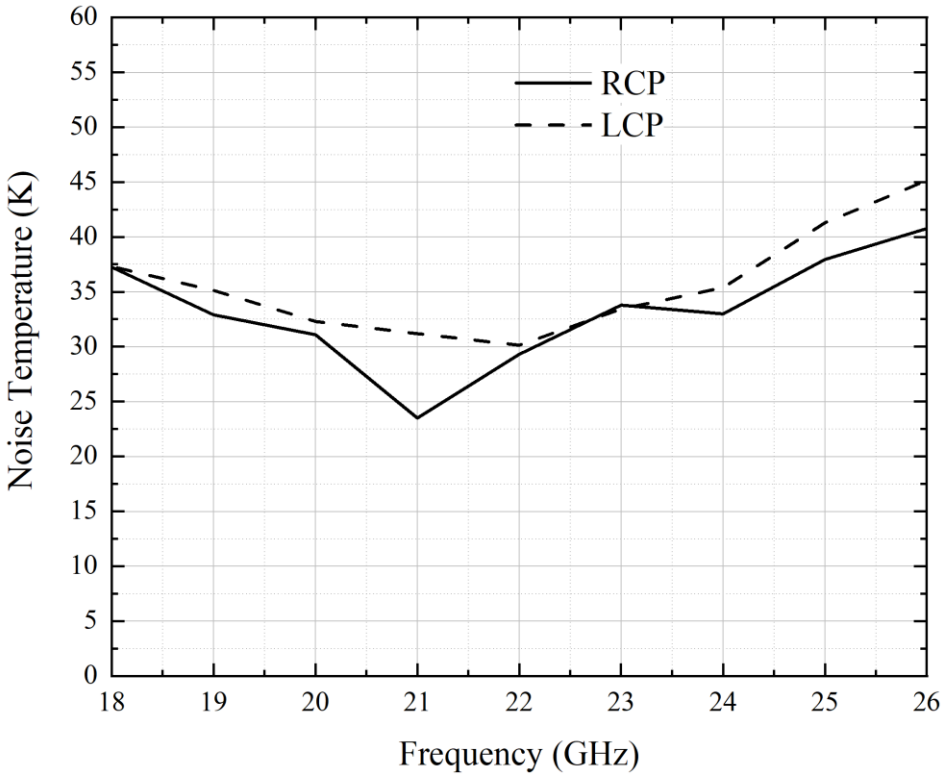
W-band

Current Progress



Cryogenic electronic unit

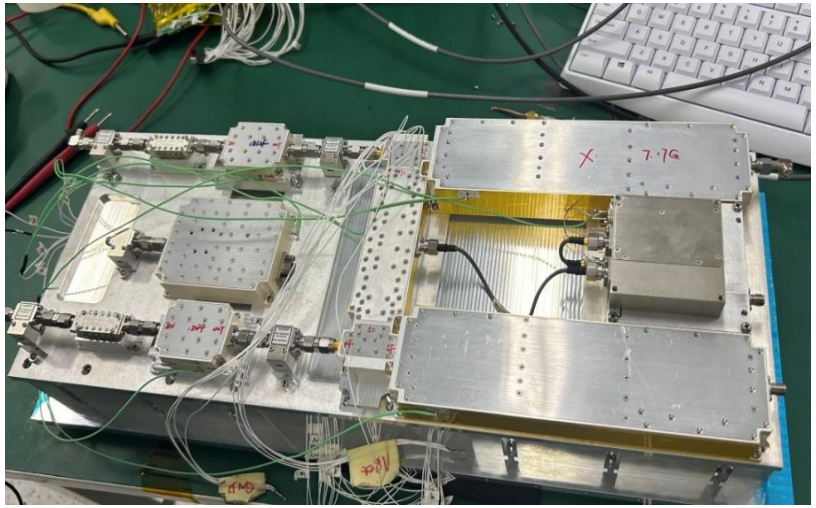
Lab system testing diagram



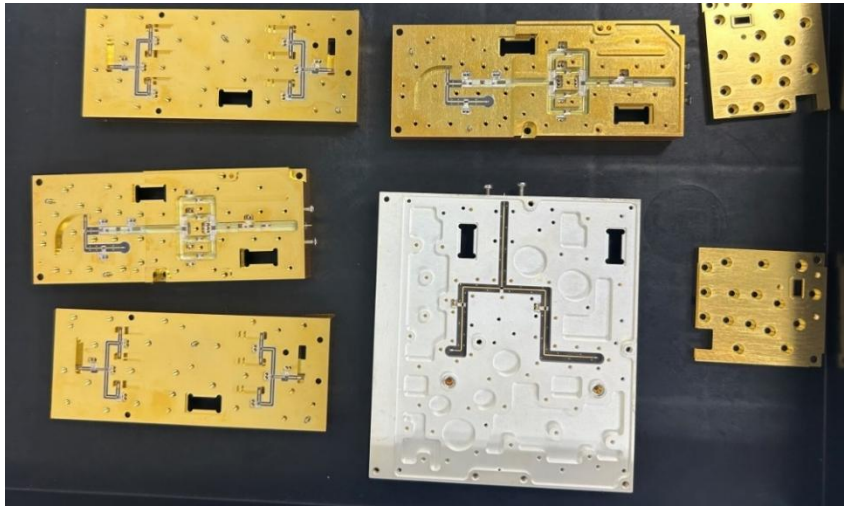
K-band receiver noise temperature measured results (with quasi-optics)

Current Progress

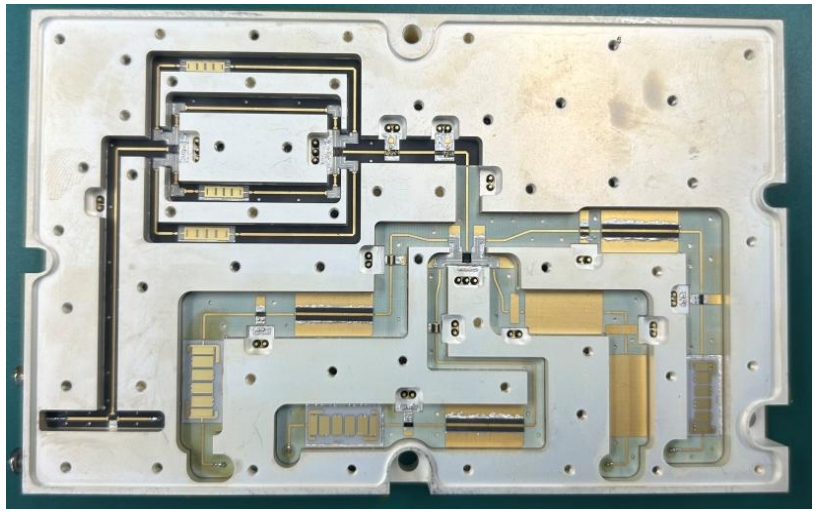
- The K-band room-temperature frequency conversion unit has completed initial commissioning, and the test results meet the technical specification.
- The Q/W-band room-temperature frequency conversion unit is still undergoing commissioning and is expected to be completed this month.



K-band frequency conversion unit



Q-band frequency conversion unit



W-band frequency conversion unit

Summary

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- Currently, Shanghai Astronomical Observatory (SHAO) has completed the development of individual units for the K/Q/W tri-band receiver of the Tianma Telescope, including the quasi-optical unit and the cryogenic electronic unit. The room-temperature frequency conversion unit is scheduled for commissioning this month.
- The K/Q/W tri-band cryogenic receivers for the 40-meter radio telescopes at both Shigatse and Changbaishan have entered development, and the telescopes are expected to be installed and commissioned by 2027/Q4.

Tianma 65 m

Shigatse 40 m

Changbaishan 40 m