

**Report on the cryogenic performance
of some samples of commercially
available 3dB 180° coaxial hybrid
couplers for VLBI 2010 antenna feeds.**

I. Malo, J.D. Gallego.

IT-OAN 2012-14

*Centro Astronómico de Yebes
Apdo. 148 19080 Guadalajara
SPAIN
Phone: +34 949 29 03 11 ext.208
Fax: +34 949 29 00 63*

Fecha de creación	jueves, 24 de mayo de 2012
Fecha de guardado	viernes, 25 de mayo de 2012
Fecha de impresión	viernes, 25 de mayo de 2012



Change Record

Revision	Date	Affected Paragraphs(s)	Reason/Initiation/Remarks
A	2012-05-25	All	First Issue



TABLE OF CONTENTS

1	Introduction	4
2	Measurements.....	4
3	Conclusions	13



1 Introduction

The future receivers to be built for the new Yebes VLBI 2010 antenna should allow simultaneous operation (with the two orthogonal circular polarizations) in S, X and Ka band. This will be achieved using three in-focus coaxial horns. The present design is based on using a septum polarizer for Ka band in the inner horn, and two outer coaxial horns with four probes each for X and S band. Achieving the adequate field configuration to generate the circular polarization will involve the use of a combination of 180° and 90° coaxial 3 dB hybrid couplers. The minimum bandwidth required is 2.2-2.7 GHz in S band, 7.5-9 GHz in X band and 28-33 GHz in Ka band.

Modern cryogenic amplifiers obtain noise temperatures below 5 K in S and X band. Taking full advantage of this extreme sensitivity requires a very careful design of the feed. In particular, losses in horns, probes, input cables and hybrids couplers can severely degrade the performance and could very easily become the dominant contribution to the total receiver noise. In order to minimize the noise, the design of the VLBI 2010 receiver assumes that the hybrids will be cooled to cryogenic temperature.

Yebes has developed special designs for 3 dB 90° hybrids in several bands optimized for cryogenic operation, but unfortunately no design has been developed yet for any 3 dB 180° devices. For this reason some samples of commercially available units from Krytar and Pulsar have been evaluated with the aim of selecting the best option for the cryogenic VLBI 2010 receiver. The results obtained are presented in the following section.

2 Measurements

The 3 dB 180° hybrid couplers procured and evaluated in this work are presented in Table 1. Next, a table is presented for each unit evaluated with a summary of the performance measured in the total band defined by the manufacturer as well as in the sub-band to be used in the VLBI receiver. The ambient temperature guaranteed performance from the data sheet of the manufacturer is included as well for reference. The graphics of the most relevant parameters measured at ambient and cryogenic temperature as a function of frequency are presented side by side for easy comparison.

<i>Manufacturer</i>	<i>Band (GHz)</i>	<i>P/N</i>
Krytar	2 - 8	4020080
Krytar	4 - 12.4	4040124
Pulsar	2 - 4	JSO-02-465/1S
Pulsar	2 - 12	JSO-09-471/2S

Table 1. Commercial 3 dB 180° hybrid couplers evaluated..



MEASURED PERFORMANCE

Model	Krytar 2-8 GHz	
Part // Serial Number	4020080 // 133710	
Description	3dB 180°	
Frequency Band	2 – 8 GHz	
Nominal Coupling	3 dB	
Connector	SMA female	
<i>Temperature</i>	<i>297 K</i>	<i>16.5 K</i>
A. E. Insertion Loss dB (max.) ^{*1}	0.67 dB	0.31 dB
Return Loss (max. any port)	-17 dB	-14 dB
Amplitude Unbalance (max.)	± 0.34 dB	± 0.64 dB
Phase Unbalance (max.)	± 5.6°	± 4.8°

*1: Average Equivalent Insertion Loss (dB), $L_{eq} = 10 \log_{10} (|s_{11}|^2 + |s_{12}|^2 + |s_{13}|^2 + |s_{14}|^2)$

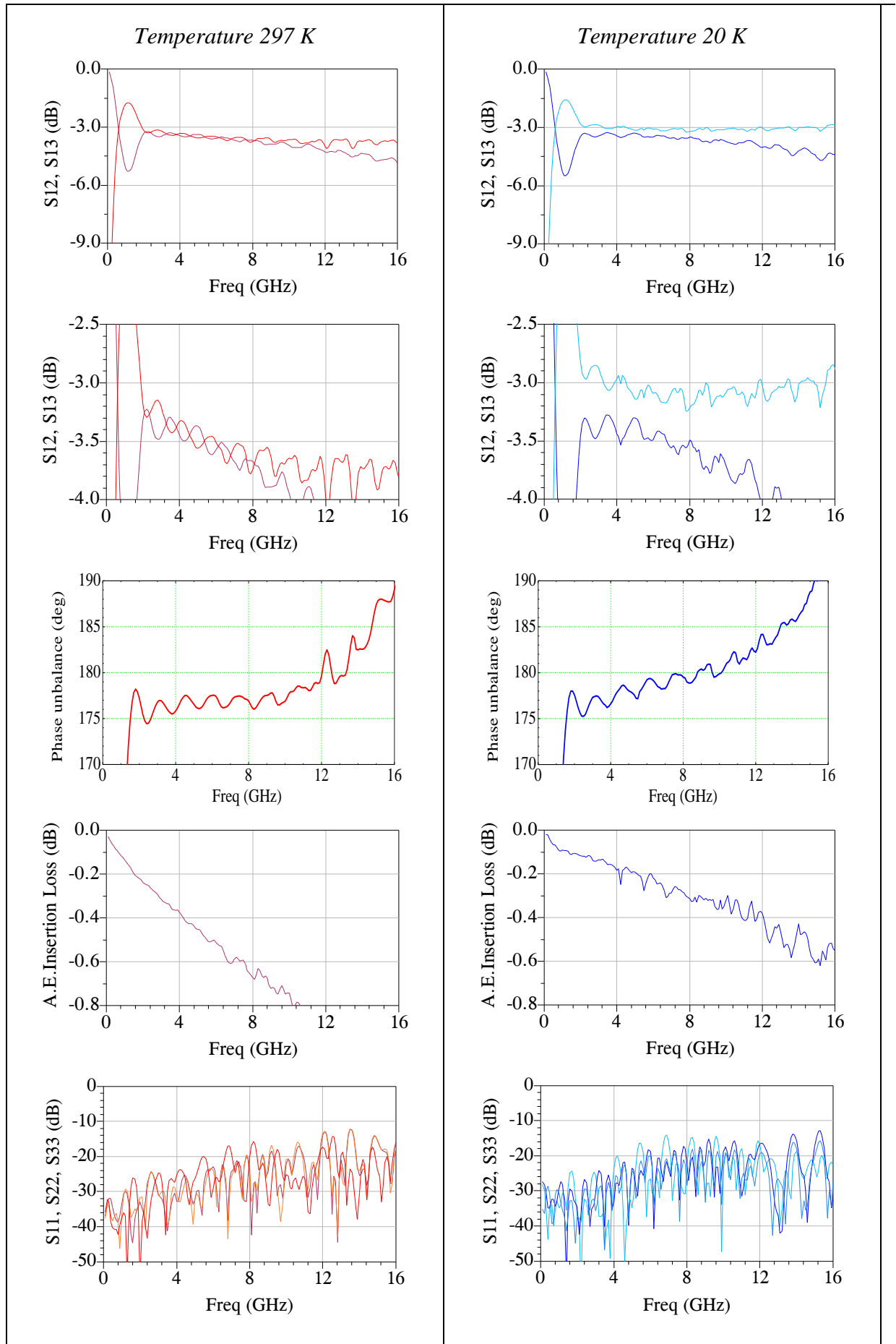
Frequency Sub-band	2.2 – 2.7 GHz	
Nominal Coupling	3 dB	
<i>Temperature</i>	<i>297 K</i>	<i>16.5 K</i>
A. E. Insertion Loss dB (max.) ^{*1}	0.28 dB	0.14 dB
Return Loss (max. any port)	-24 dB	-26.7 dB
Amplitude Unbalance (max.)	± 0.31 dB	± 0.61 dB
Phase Unbalance (max.)	± 5.6°	± 4.8°

DATA SHEET (T=300K)

Model	Frequency Range (GHz)	Coupling (dB)	Amplitude unbalance (dB)	Phase unbalance (deg)	Isolation (dB Min)	Maximum VSWR	Insertion Loss (dB Max)
4020080	2 - 8	3	± 0.3	± 8	18	1.4	1.1



MEASUREMENTS





MEASURED PERFORMANCE

Model	Krytar 4-12.4GHz	
Part // Serial Number	4040124 // 136872	
Description	3dB 180°	
Frequency Band	4 – 12 GHz	
Nominal Coupling	3 dB	
Connector	SMA female	
	<i>Temperature</i>	
	297 K	16.5 K
A. E. Insertion Loss dB (max.) ^{*1}	0.55 dB	0.26 dB
Return Loss (max. any port)	-17 dB	-18.2 dB
Amplitude Unbalance (max.)	± 0.33 dB	± 0.2 dB
Phase Unbalance (max.)	± 5.8°	± 3.1°

*1: Average Equivalent Insertion Loss (dB), $L_{eq} = 10 \log_{10} (|s_{11}|^2 + |s_{12}|^2 + |s_{13}|^2 + |s_{14}|^2)$

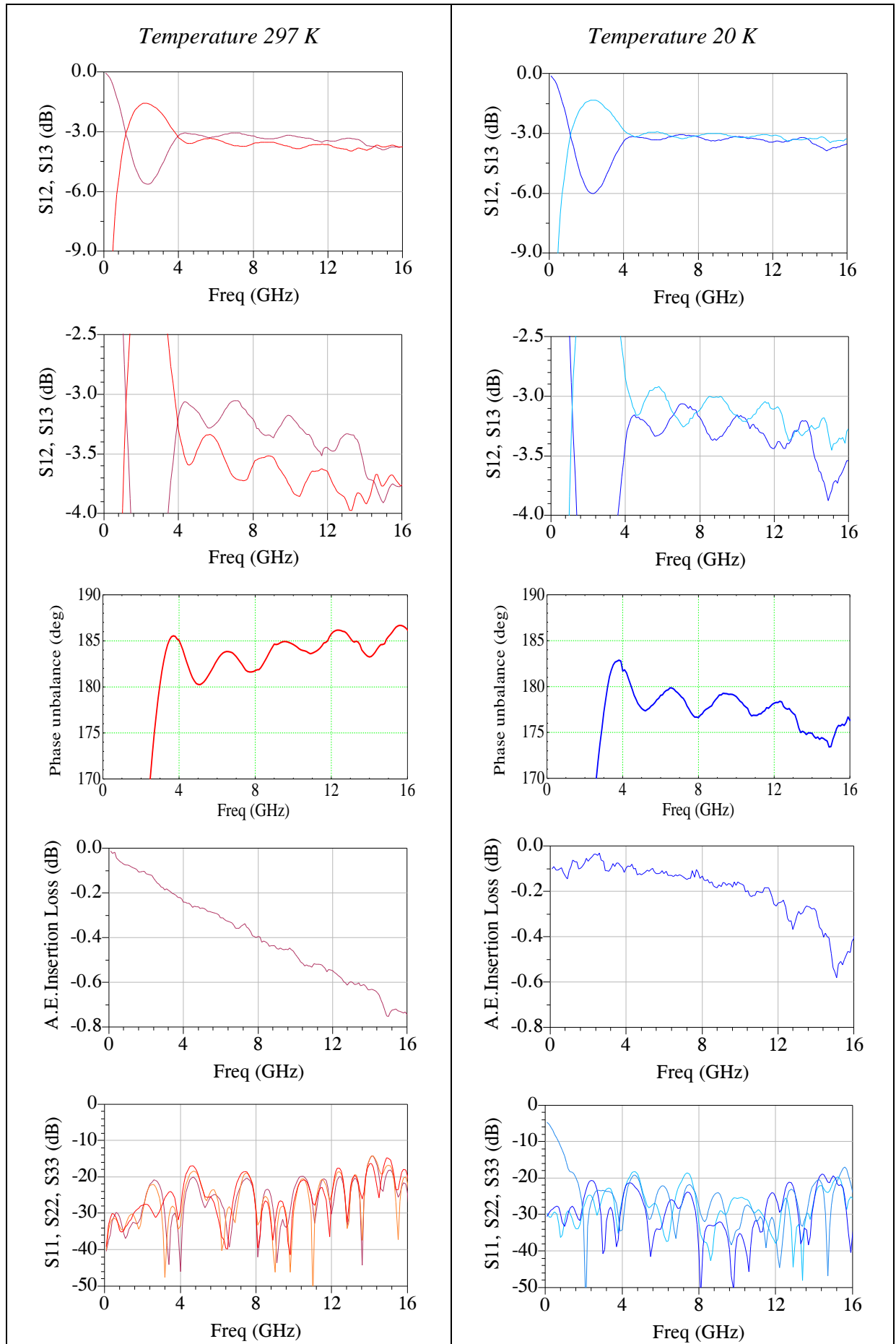
Frequency Subband	7.5 – 9 GHz	
Nominal Coupling	3 dB	
	<i>Temperature</i>	
	297 K	20 K
A. E. Insertion Loss dB (max.) ^{*1}	0.45 dB	0.17 dB
Return Loss (max. any port)	-19 dB	-18.5 dB
Amplitude Unbalance (max.)	± 0.3 dB	± 0.18 dB
Phase Unbalance (max.)	± 4.7°	± 3.1°

DATA SHEET (T=300K)

Model	Frequency Range (GHz)	Coupling (dB)	Amplitude unbalance (dB)	Phase unbalance (deg)	Isolation (dB Min)	Maximum VSWR	Insertion Loss (dB Max)
4040124	4 - 12.4	3	± 0.4	± 8	17	1.6	0.9



MEASUREMENTS





MEASURED PERFORMANCE

Model	Pulsar 2-4 GHz	
Part // Serial Number	JSO-02-465/1S // 1145-1	
Description	3dB 180°	
Frequency Band	2 – 4 GHz	
Nominal Coupling	3 dB	
Connector	SMA female	
	<i>Temperature</i>	
	297 K	16.5 K
A. E. Insertion Loss dB (max.) ^{*1}	0.37 dB	0.22 dB
Return Loss (max. any port)	-14.7 dB	-12.9 dB
Amplitude Unbalance (max.)	± 0.48 dB	± 0.62 dB
Phase Unbalance (max.)	± 5.3	± 11

*1: Average Equivalent Insertion Loss (dB), $L_{eq} = 10 \log_{10} (|s_{11}|^2 + |s_{12}|^2 + |s_{13}|^2 + |s_{14}|^2)$

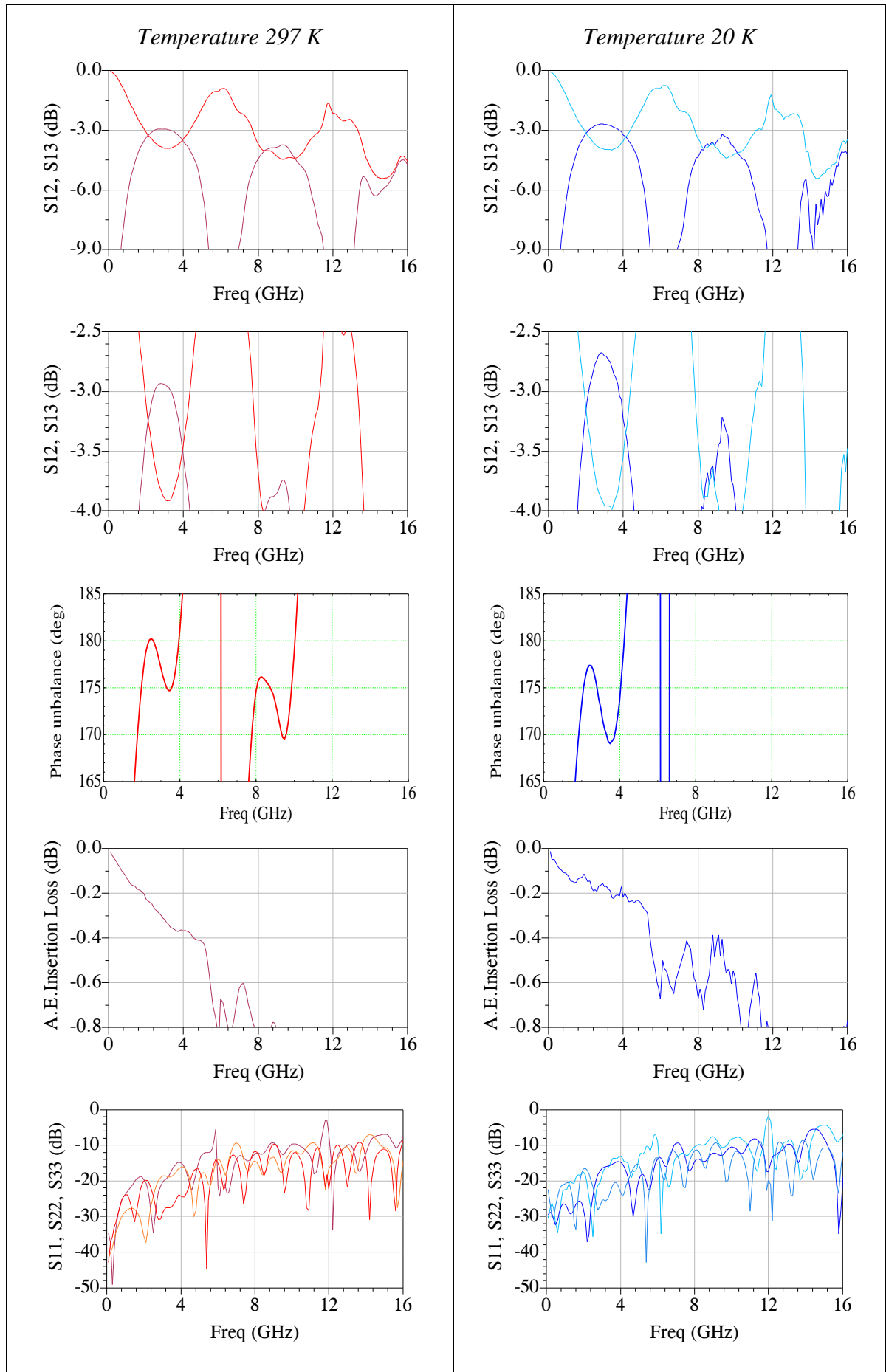
Frequency Sub-band	2.2 – 2.7 GHz	
Nominal Coupling	3 dB	
	<i>Temperature</i>	
	297 K	16.5 K
A. E. Insertion Loss dB (max.) ^{*1}	0.29 dB	0.19 dB
Return Loss (max. any port)	-22.1 dB	-16.9 dB
Amplitude Unbalance (max.)	± 0.42 dB	± 0.57 dB
Phase Unbalance (max.)	± 1.4°	± 4°

DATA SHEET (T=300K)

Frequency range (GHz)	Insertion loss (dB) max	Isolation A - B (dB) min	Amplitude unbalance ±(dB) max	Phase unbalance ±(deg) max	VSWR max.	Power rating (W) max.	P/N
2.00-4.00	0.6	20	0.5	10.0	1.60:1	80	JSO-02-465/1S



MEASUREMENTS





MEASURED PERFORMANCE

Model	Pulsar 2-12 GHz	
Part // Serial Number	JSO-09-471/2S // 1145-2	
Description	3dB 180°	
Frequency Band	2 – 12 GHz	
Nominal Coupling	3 dB	
Connector	SMA female	
	<i>Temperature</i>	
	297 K	16.5 K
A. E. Insertion Loss dB (max.) ^{*1}	1.3 dB	0.52 dB
Return Loss (max. any port)	-11.4 dB	-4.2 dB
Amplitude Unbalance (max.)	± 0.48 dB	± 2.7 dB
Phase Unbalance (max.)	± 11°	± 37.5°

*1: Average Equivalent Insertion Loss (dB), $L_{eq} = 10 \log_{10} (|s_{11}|^2 + |s_{12}|^2 + |s_{13}|^2 + |s_{14}|^2)$

Frequency Subband	2.2 – 2.7 GHz	
Nominal Coupling	3 dB	
	<i>Temperature</i>	
	297 K	16.5 K
A. E. Insertion Loss dB (max.) ^{*1}	0.4 dB	-
Return Loss (max. any port)	-20 dB	-15dB
Amplitude Unbalance (max.)	± 0.6 dB	± 0.18 dB
Phase Unbalance (max.)	± 7.2°	± 9.5°

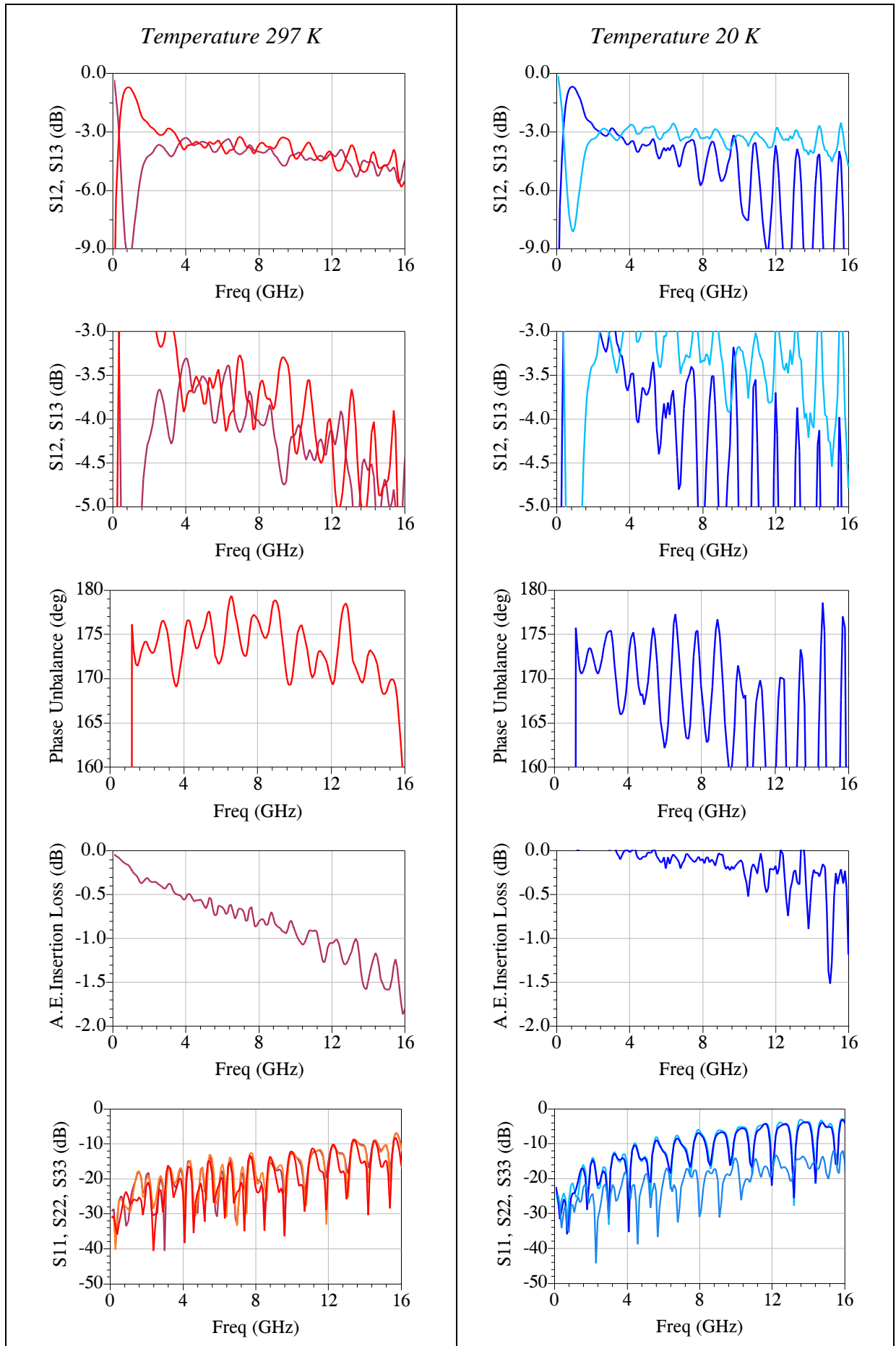
Frequency Subband	7.5 – 9 GHz	
Nominal Coupling	3 dB	
	<i>Temperature</i>	
	297 K	20 K
A. E. Insertion Loss dB (max.) ^{*1}	0.86 dB	0.17 dB
Return Loss (max. any port)	-12.6dB	-6 dB
Amplitude Unbalance (max.)	± 0.3 dB	± 1.15dB
Phase Unbalance (max.)	± 6.4°	± 17.2°

DATA SHEET (T=300K)

Frequency range (GHz)	Insertion loss (dB) max	Isolation A - B (dB) min	Amplitude unbalance ±(dB) max	Phase unbalance ±(deg) max	VSWR max.	Power rating (W) max	P/N
2.00-12.00	1.5	18	0.7	10.0	1.50:1	20	JSO-09-471/2S



MEASUREMENTS





3 Conclusions

All the hybrids survived the thermal cycling to cryogenic temperature. The devices were not disassembled since the plan is using them for the final receiver. No judgment can be made on the suitability of the construction techniques for cryogenic operation.

In general, all the units trend to under-couple when cooled. This is probably due to the differential contraction of the Teflon-based substrate used respect to the metal screws. The effect is very prominent in some units and almost negligible in others. In one of the them (Krytar 4-12.4 GHz) this effect actually helped in improving the cryogenic performance, since the unit was clearly over-coupled at ambient temperature.

For S band, the amplitude and phase unbalance at cryogenic temperature of the two units evaluated are higher than the required. A revision of the design specifications is needed in order to know if some of the hybrids tested can be used.

For X band, this unit of Krytar 4-12.4 GHz meets the specifications at cryogenic temperature. However, this Pulsar 2-12 GHz unit is not usable at cryogenic temperature because the return loss falls to -6 dB.