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J. Piotr Starski	20171228	R1

Executive summary
"Experimental 20-40 GHz band InP MMIC based cryo LNAs prototyping"
ESA Contract No. 4000112768/14/D/JR

1 Introduction

This document describes shortly the achieved results in the project "Experimental 20-40 GHz band InP MMIC based cryo LNAs prototyping", ESA Contract No. 4000112768/14/D/JR.
The project was a joint venture between Chalmers University of Technology, MC2/Microwave Electronics Laboratory (MEL) and Low Noise Factory (LNF) both located in Gothenburg, Sweden.

The goal of the project was to design, process MMICs, manufacture, and test three different types of low noise amplifiers for frequency range 22-40 GHz intended for room and cryogenic operations.
Two of the amplifiers were equipped with coaxial interface and one with waveguide interface, Table 1.

Table 1
Types of developed LNAs

LNA version	Input	Frequency range	MMIC version
Cryogenic	Coaxial	22-40 GHz	LN20_40A
Cryogenic	WG	23-39 GHz	LNC23-42WB
Room	Coaxial	25.5-40.5 GHz	LNR23-42B

In the project, we have designed and processed two types of MMIC LNA chips, A and C, intended for cryogenic applications. MMIC of type C is also suitable for room temperature applications.

2 MMIC

We have designed and processed two different types of MMIC for this application. The processing was performed at clean room facility at Chalmers.
Fig. 1 shows the wafer after the processing.

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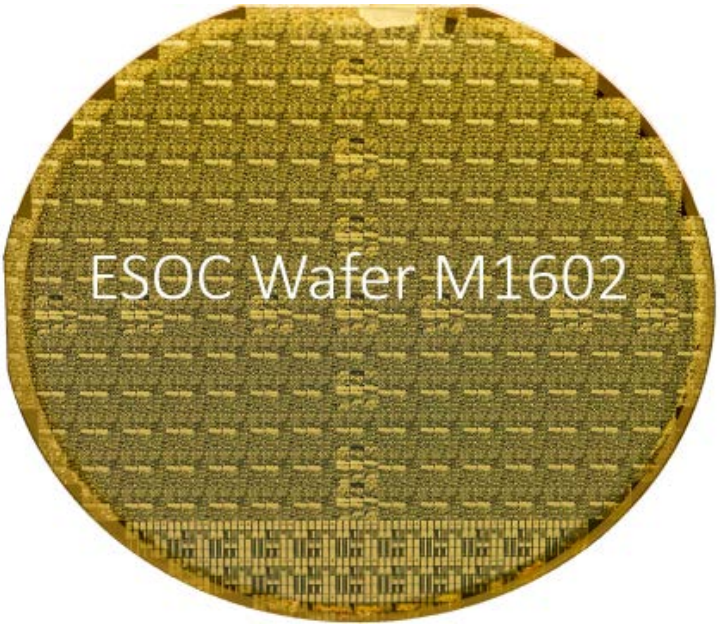

Fig. 1. A photograph of the processed M1602 wafer

The process is a complete 13-step procedure resulting in a MMIC. An example of the MMIC die is shown in Fig. 2.

The size of the die is 2x0.75 mm.

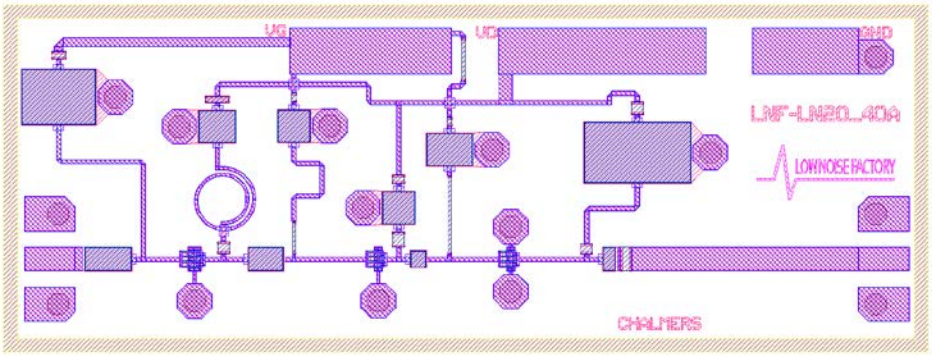

Fig.2. MMIC die, 3-stage LNA

2.1 LNF-LN20_40A amplifier, coaxial version

LNF-LN20_40A is intended for cryogenic operation. It has 2.92 mm F coaxial connectors on both sides. Measured NT and G for all units are shown in Fig.3

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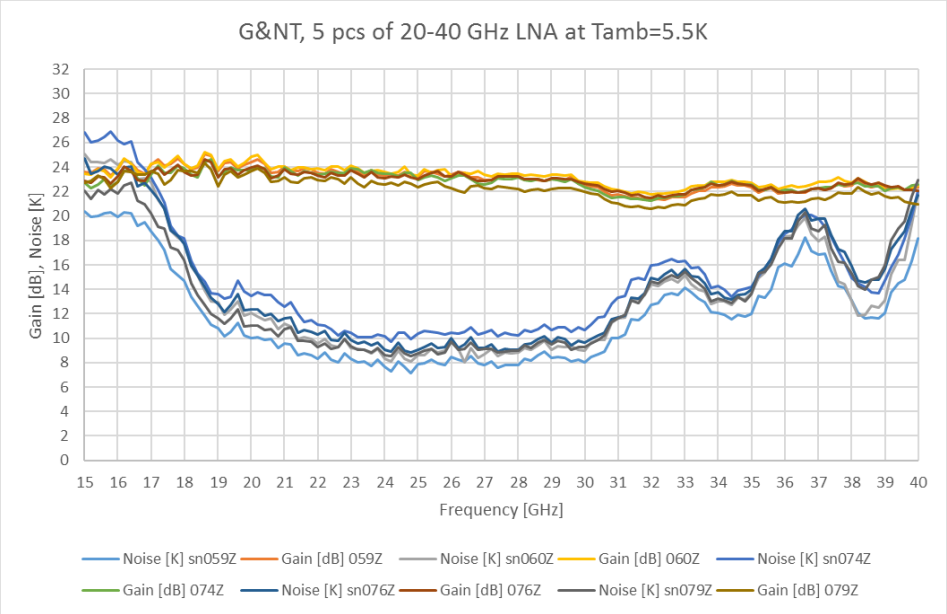

Fig. 3. Measured G and NT for LNF-LN20_40A, 5 units at 5.5K

Input match for these amplifiers at room temperature is shown in Fig. 4.

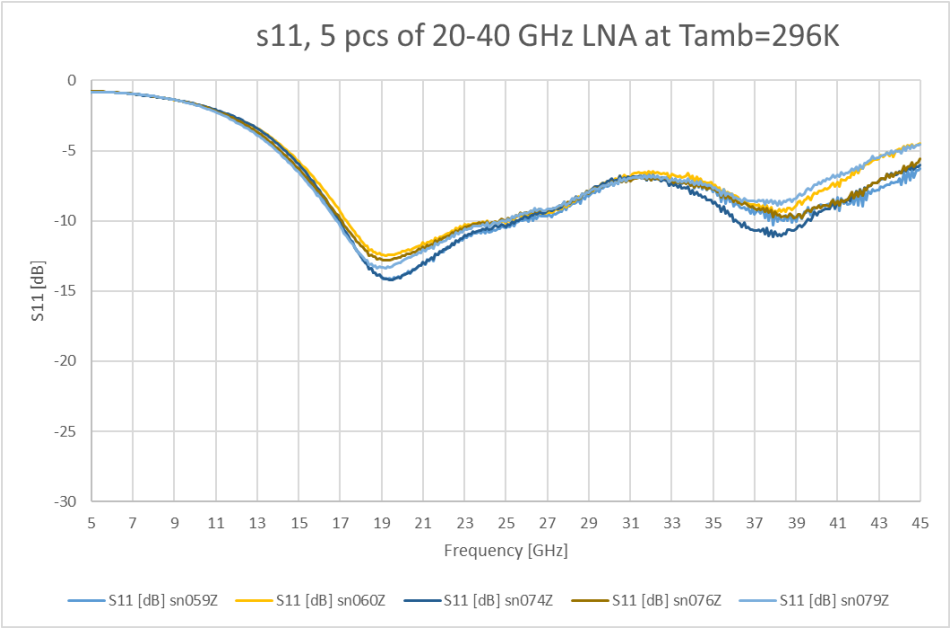

Fig. 4. Input match for 5 units of LNF-LN20_40A at 296K

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A photograph of one the units is shown in Fig. 5.

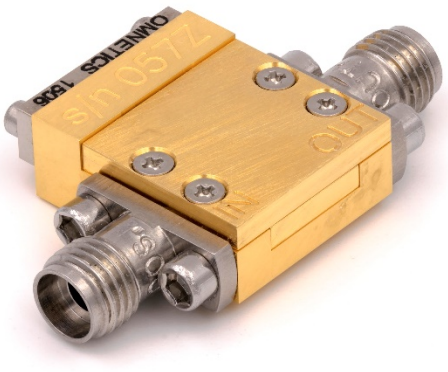

Fig. 5. A photograph of LNF-LN20_40A

2.2 *LNF-LNC23_42WB amplifier, wg version*

This is a LNA with waveguide interface intended for cryogenic operation. Has waveguide interface WR28 at both input and output
The measured G and NT at 5.5 K for all 10 units are shown in Fig. 6.

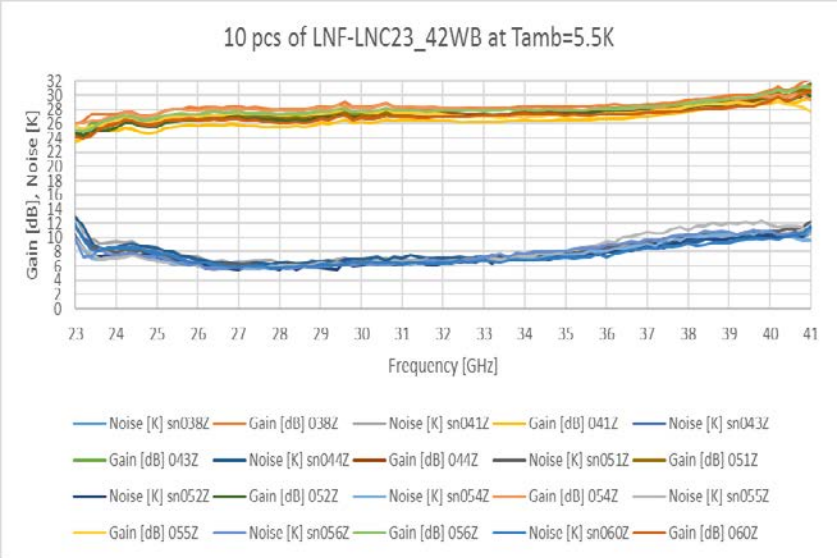

Fig. 6. Measured G and NT for LNF-LNC23_42WB, 10 units at 5.5K

Input match for these amplifiers at room temperature is shown in Fig. 7.

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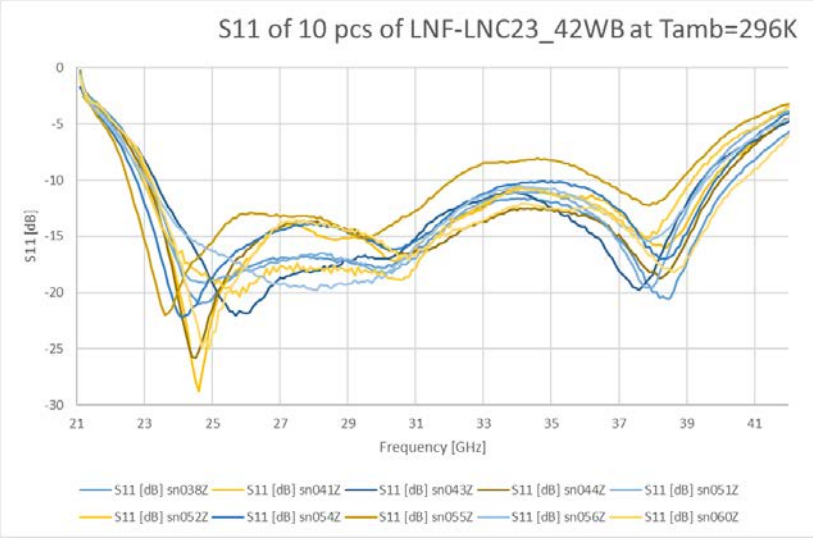

Fig.7. Input match for 10 units of LNF-LNC23_42WB at 296K

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A photograph of one the units is shown in Fig. 7.

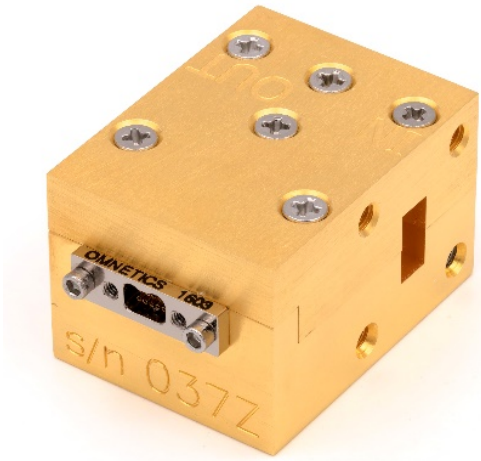

Fig. 8. A photograph of LNF-LNC23_42WB

2.3 LNF-LNR23_42B amplifier, coaxial version

LNF-LNR23_42B is intended for room temperature operation. It has 2.92 mm F coaxial connectors on both sides. Measured NT and G for all units are shown in Fig.9.

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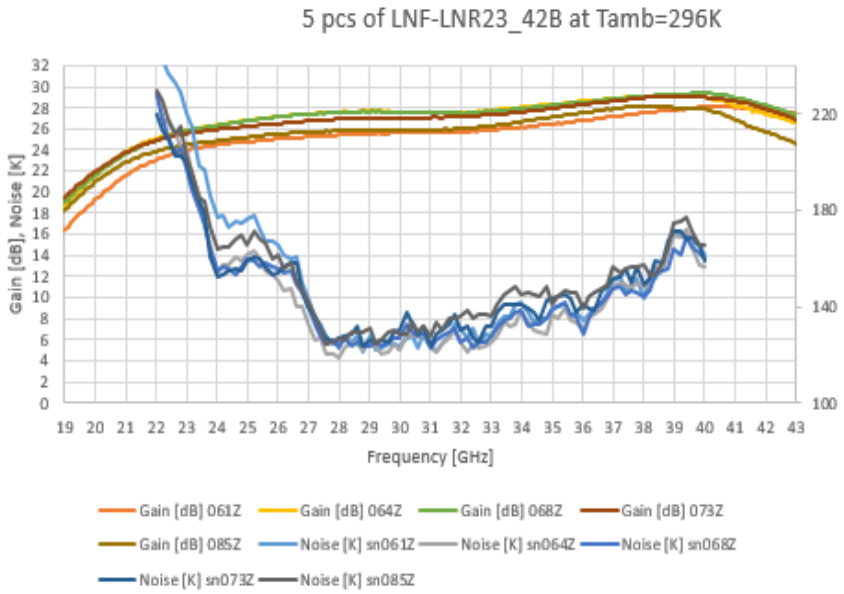

Fig.9. Measured G and NT for LNF-LNR23_42B, 5 units at 296K

Input match for these amplifiers at room temperature is shown in Fig.10.

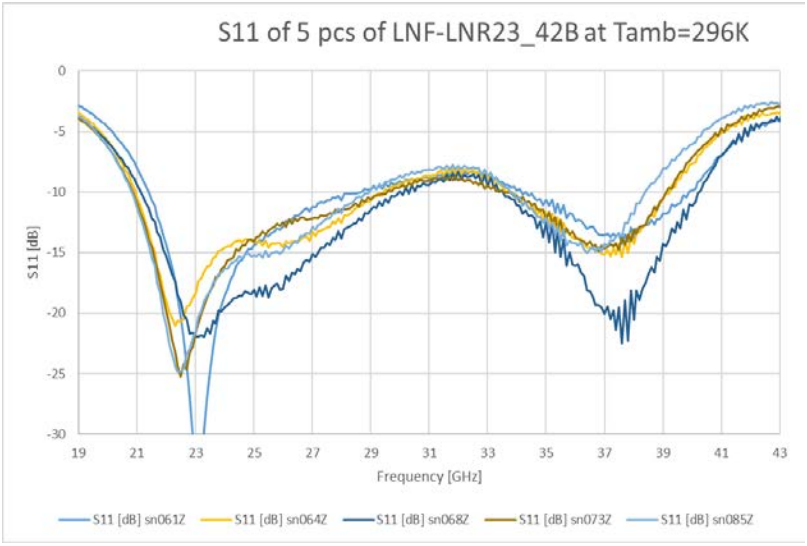

Fig. 10. Input match for 5 units of LNF-LNR23_42B at 296K

The amplifiers look identical to amplifiers in series LNF-LN20_40A, Fig. 5.

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3 Summary

The measured results at working conditions for all amplifiers are collected in Tables 2-4.

Table 2
LNF_LN20_40A

	Specifications	Measured value
Frequency range, GHz	22-40.5	22-40.5
G@296K&31GHz, dB	Not specified	23.7
G@5.5K&31GHz, dB	27	21.7*
NF@296K&31GHz, dB	1.5	1.66
NT@5.5&31GHz, K	12	11.7
Gain flatness	2 dB, p/p	0.006dB/40MHz, 0.15dB/1 GHz
Input VSWR@296K	1.8:1	2.3:1**
Output VSWR@296K	1.8:1	2.2:1
P1dB	-10dBm	-10.8dBm

* Gain specification is not met at cryogenic temperature
**The input match is outside the specification. The main reason is the diameter of the center pin in the coaxial connector. A second reason is the bonding wire between the input circuit and MMIC.

Table 3
LNF_LNC23_42WB

	Specifications	Measured value
Frequency range, GHz	22-40.5	23-40.5
G@296K&31 GHz, dB	Not specified	27.7
G@5.5K&31 GHz, dB	27	27.5
NF@296K&31GHz, dB	Not specified	1.56
NT@5.5K31GHz, K	12	6.6
Gain flatness	2 dB, p/p	0.012dB/40MHz 0.3dB/1 GHz
Input VSWR@296K	1.8:1	1.6:1
Output VSWR@296K	1.8:1	1.3:1
P1dB	-10dBm	Measurement was not performed

Table 4
LNF_LNR23_42B

	Specifications	Measured value
Frequency range, GHz	22-40.5	22-40.5
G@296K&31 GHz, dB	27	26.8
NF@296K&31GHz, dB	1.5	1.55
Gain flatness	2 dB, p/p	0,004dB/40MHz 0,1dB/1 GHz
Input VSWR@296K	1.8:1	1.6:1
Output VSWR@296K	1.8:1	1.3:1
P1dB	+5 dBm	Measurement was not performed

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4 Conclusions

We have designed, manufactured and tested three different types of amplifiers for 20-40 GHz range, Table 1.

The detailed results are summarized in this report. We have fulfilled most of the specifications. Gain of one of the amplifiers is below the specified value.

The noise of the amplifiers at cryogenic temperatures is much lower than specified.