Low Noise Amplifier (LNA) at 600 Gigahertz (GHZ)

ESA Contract: No. 4000132934/20/NL/FE

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In the field of e.g., climate studies and more generally earth observation, a strong need for global remote sensing persists. This is for instance the case for the study of vertically integrated cloud ice mass. Radiometers aim to detect the relatively weak signal composed of the thermal radiation of objects in the presence of background noise. These systems are of growing interest, as they feature low-power dissipation and complexity, small dimensions, are not limited to specific frequency bands by spectrum regulations and do not require any high-frequency signal or clock distribution. These key advantages make them highly attractive for low-power integration in space-born applications. Space-borne radiometry can become an essential tool for Earth observations. For the purpose of e.g. a vertically integrated cloud mass study, the radiometer needs to operate way above 300 GHz since appropriate water vapour lines exist at e.g. 448 GHz and above. In a radiometer receiver chain, the LNA is a crucial element that amplifies the incoming signal to overcome the noise contribution of the detector while minimising its own contribution to the system noise temperature.

In the Low Noise Amplifier at 600 GHz ESA activity that was initiated in 2021, LNA MMICs and modules addressing the typical submillimetre-wave radiometer frequencies 325 GHz, 448 GHz and 664 GHz were designed, fabricated and tested. Therefore, two state of the art technologies from Fraunhofer IAF were used for the project: A 35 nm mHEMT technology as well as a novel 20 nm InGaAs HEMT on Silicon technology. Looking at the key parameters in Table 1, these two technologies are well suited for the targeted frequency bands and also available in Europe.

Table 1: Key parameters of the 35 nm mHEMT Technology

μ_e $cm^2/(V \cdot s)$	9800
n_e (cm^{-2})	$6.1.10^{12}$
I_{dmax} (mA/mm)	1600
V_{bd} (V)	2.0
g_{mmax} (mS/mm)	2500
f_T (GHz	515
f_{max} (GHz)	>1000

On the basis of these technologies different amplifier designs were fabricated and showed promising results regarding gain and noise. On example the designed 664 GHz LNA [1] in Figure 1 was processed in both technologies. This LNA is based on IAF 35 nm mHEMT technology and is composed of six cascode stages, each using transistors with 2x5.5-µm cascode devices. An inductive series matching network using a thin-film interconnection for inter-device matching was utilized in the cascode configuration between the common-source and the common-gate transistor to compensate for parasitic device capacitances.

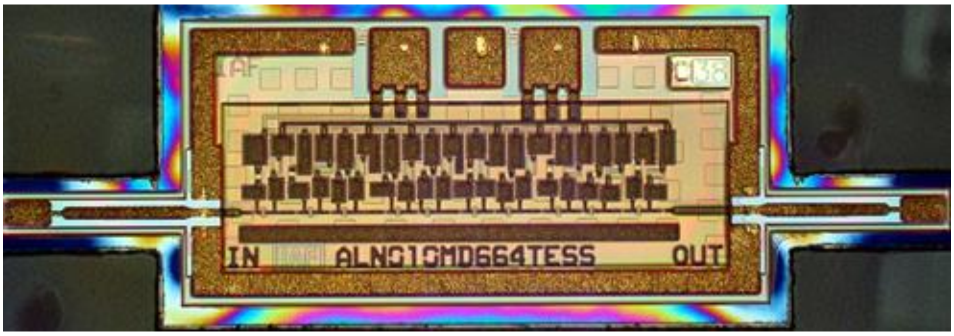

Fig. 1: Chip photograph of the 664 GHz 10-stage amplifier MMIC including RF antennas for the waveguide transition and DC pads.

The measured and simulated S-parameters are even more impressive and furthermore, shown in Figure 2.

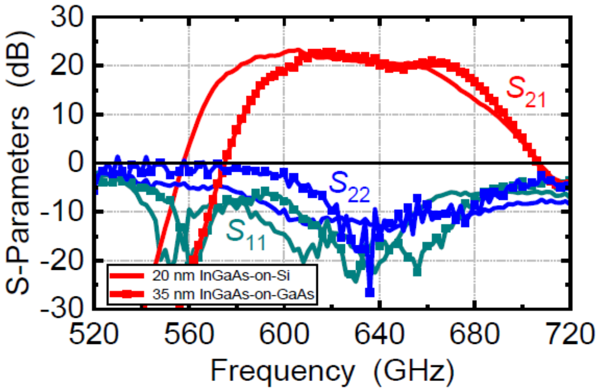

Fig. 2: On-wafer measured S-parameters of the ten stage WR-1.5 low noise amplifier MMICs with integrated on-chip transitions.

Furthermore, waveguide modules (Figure 3 - right) were developed together with additional versions of the amplifier circuits that include monolithically integrated transitions for optimum assembly (Figure 3 - left). These modules were assembled with the LNA MMICs chosen based on their performance.

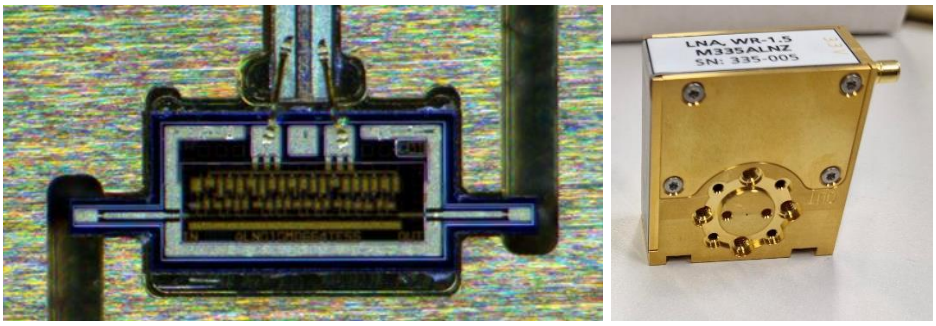

Fig. 3: Photograph of the ten stage WR-1.5 low noise amplifier MMICs with integrated on-chip transitions integrated (left) in the corresponding waveguide module (right).

The module shown in Figure 3 were again measured to demonstrate their performance on module level and show a complete European value chain as possible solution.

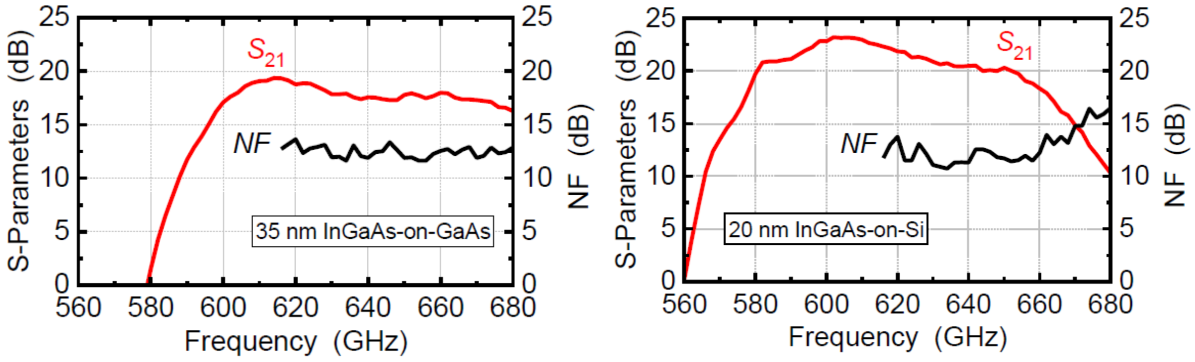

Fig. 4: Measured gain and room temperature (T=293 K) noise figure of the 35 nm InGaAs (left) and 20 nm InGaAs-on-Si WR-1.5 low noise amplifier module.

The measurement from Figure 4 shows that low noise amplifier MMICs operating at 325 GHz, 448 GHz as well as 664 GHz for radiometer applications are possible by use of the IAF mHEMT technology presented. The amplifier MMICs were manufactured and characterized and show outstanding performance with gain of 20 dB or more at the frequencies of interest and excellent noise figure.

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