Anwenderforum für Fernmeldetechnik, AFCEA Computer, Elektronik und Automatisierung

AFCEA Bonn e.V. Studienpreis 2021/2022

Kernthesen der Arbeit

Titel der Arbeit:	Design and Implementation of an Ultra-Wideband Radar Receiver Operating up to 50 GHz and Frequency Band Characterization in a Cryogenic Environment
Tag der Einreichung:	29.04.2021
Hochschule:	RWTH Aachen
Verfasser/in:	Peter Toth
Betreuende/r Professor/in:	Peter Knott

*Kurze Beschreibung (1 Seite !) der **Kernthesen**.*
Was ist die Quintessenz der Arbeit?

Motivation: Noise-sensitive applications such as radio astronomy, space debris detection and quantum computer hardware demand minimal noise contribution of the utilized system blocks. Particularly the field of quantum computer and space debris detection has gained tremendous momentum in recent years. **Cryogenic cooling** techniques are crucial for these applications. However, temperatures in the range of a few Kelvins pose a significant challenge for state-of-the-art **millimeter-wave transceiver** architectures, which are deemed suitable in these fields.

Challenge**:** Conducting a detailed receiver chain system design is a crucial step in project planning. The performance of a low-noise amplifier (LNA) is a key parameter since it dominates the receiver chains noise figure and, therefore, the capability to recover highly attenuated signals. However, reliable performance characteristics of LNAs at cryogenic temperatures are rare to obtain from manufacturers. Characterizing the amplifiers requires a **highly specialized setup** to reach temperatures in the single-digit Kelvin range and measure noise power level differences of 0.015 dB at **power levels near −170dBm**. Moreover, such cryogenic LNAs are mostly highly customized and, therefore, niche products. Because of this, the **system designer is limited** by the component availability.

Design**:** This master thesis presents a custom-designed 43 GHz wideband, temperature-controlled amplification system with a programmable gain of up to 60 dB. A complex three-path configurable circuit topology provides flexible high gain amplification over a broad bandwidth, as depicted in Fig. 1. **The device is designed for highly accurate noise figure measurements of LNAs** in the single-digit noise temperature range operated in a cryogenic environment.
The thesis includes the full practical implementation, including a multilayer high-frequency PCB with custom RF shielding, firmware programming for the digital interface and excessive verification measurements with a custom implemented automated measurement setup. These steps result in the device as visualized in Fig. 2. Finally, a proof of concept measurement in the cryogenic lab of the FHR, as shown in Fig. 3, verifies device functionality and the application relevant usability. The noise figure measurement performed with the designed amplifier yields relative error reduction by a factor of 80.

Conclusion: This thesis successfully demonstrated the design, implementation and verification of a custom-built homodyne receiver-based amplifier. Due to its configurable three-path signal path, the amplifier is compatible with a broad range of LNAs operating in different frequency bands and with varying power gains. **This device allows the in-house characterization and verification of cryogenic-usability of self-designed amplifiers and off-the-shelf components**. Moreover, such a preamplifier relaxes the requirements of the utilized spectrum analyzer or noise figure meters in the downstream measurement setup.
A condensed form of this work was accepted for publication at the regional flagship conference of the IEEE CAS society.

Appendix

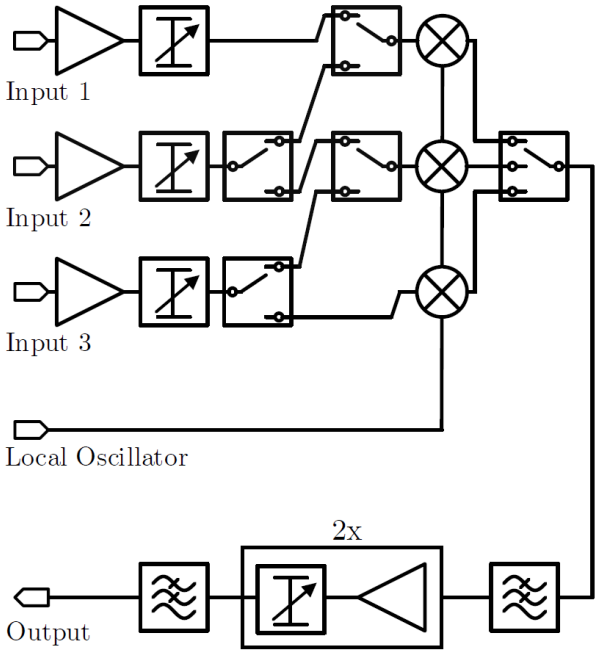

Fig. 1: Three path RF core circuit topology of proposed broadband amplifier

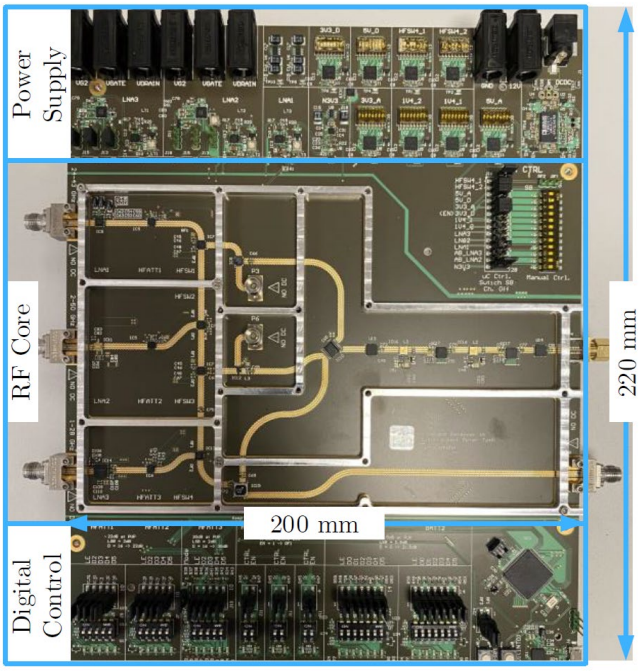

Fig. 2: Manufactured broadband amplifier PCB.

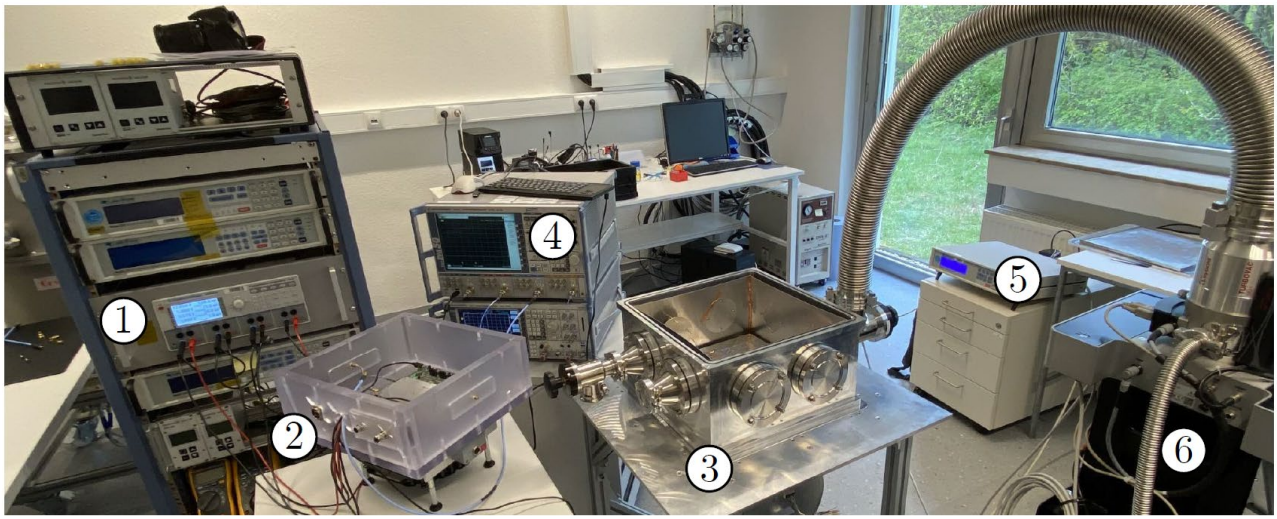

Fig. 3: Proof of concept measurement setup. 1-Power supply, 2-Wideband receiver in thermoenclosure, 3-Dewar, 4-Measurement device stack, 5-Temperature sensor terminal, 6-Vacuum pump

Publication List

- P. Toth et al.," Ultra Wideband 43 GHz Preamplifier with Up to 60 dB Adjustable Gain for Accurate Noise Figure Measurement of Cryogenic LNAs", In: 28th IEEE ICECS, Dubai, UAE, Nov. 2021. Acceptance notification received 15th of September 2021.