Uirapuru Receiver: RF Characterization of Horn Antenna Reception Chain

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Abstract

This document presents the Uirapuru Receiver project, which focuses on the radio frequency (RF) characterization of the horn antenna reception chain. Developed by the LABMET research group at UFCG under the guidance of Edmar Gurjão and Amilcar Queiroz, this project aims to provide high-precision S-parameter measurements and system analysis to support the development and reproducibility verification of the Uirapuru reception system.

Contents

1 Introduction

The Uirapuru Receiver project is dedicated to characterizing the RF properties of the horn antenna reception components. This work is essential for understanding the performance characteristics of the complete signal chain in radiometer systems, from antenna to digital backend.

The project emphasizes measurement accuracy and reproducibility, providing an open dataset with executable Jupyter Notebook for analysis. This approach ensures that the research findings can be verified and extended by other researchers in the field.

2 System Overview

The Uirapuru Receiver system consists of several key components in the RF signal chain:

- Horn antenna for signal reception
- Low Noise Amplifier (LNA) for signal amplification
- Hybrid coupler for signal splitting and combining
- Isolator to prevent signal reflections
- Filters for frequency selection
- Digital backend (SKARAB) for signal processing

Each component plays a crucial role in determining the overall system performance, particularly in terms of noise figure, gain, isolation, and signal fidelity.

3 Measurement Setup

Measurements were performed using a Rohde & Schwarz ZNB Vector Network Analyzer (VNA), which provides high-precision S-parameter measurements. The VNA was configured to measure various S-parameters across the frequency band of interest.

3.1 S-Parameters

S-parameters (scattering parameters) describe the electrical behavior of linear electrical networks when undergoing various stimuli. In this project, we focus on:

- **S11**: Input reflection coefficient, indicating how much power is reflected back to the source
- **S21**: Forward transmission coefficient, representing gain/loss from port 1 to port 2
- **S12**: Reverse transmission coefficient, representing gain/loss from port 2 to port 1
- **S22**: Output reflection coefficient, indicating how much power is reflected from the output

4 Data Analysis

The S-parameter data is stored in CSV format in the `S_parameters` directory. Each file contains frequency-dependent measurements that characterize different aspects of the receiver chain components.

4.1 Key Performance Metrics

Several key performance metrics are evaluated in this project:

1. **Port Isolation**: Measured using S21 between isolated ports
2. **Transmission Characteristics**: Gain/loss characteristics described by S21
3. **Reflection Stability**: Input/output matching represented by S11 and S22
4. **Frequency Response**: Overall bandwidth performance

5 Results and Discussion

5.1 LNA Performance

The Low Noise Amplifier (LNA) is a critical component in the receiver chain, providing signal amplification while adding minimal noise. Figure 1 shows the S21 parameter of the LNA, which represents its gain characteristic.

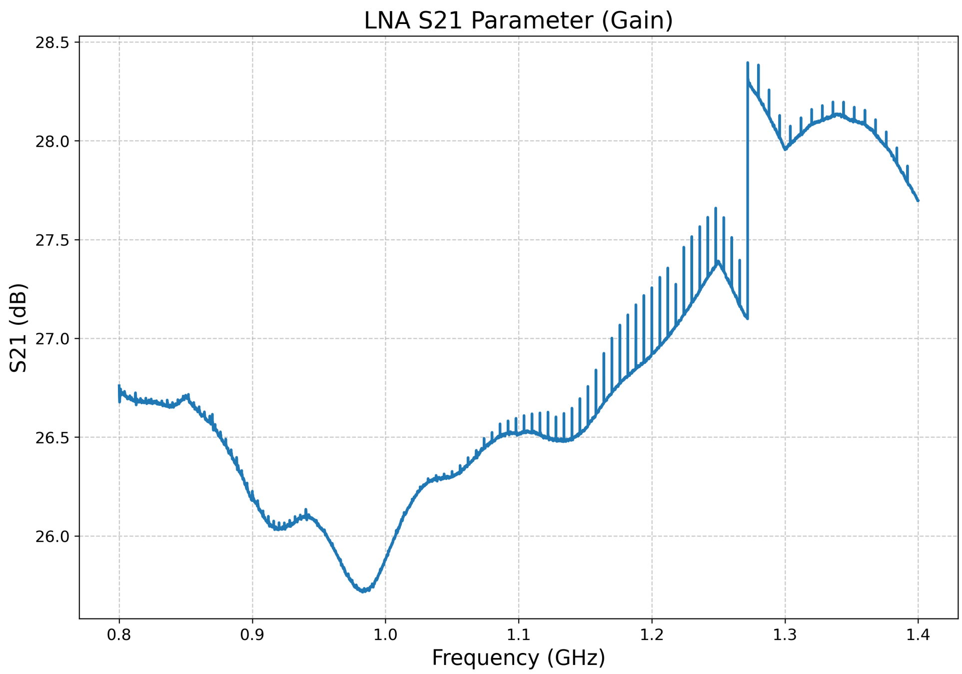


Figure 1: S21 parameter of the LNA showing gain versus frequency

5.2 Filter Response

The filter response is shown in Figure 2, demonstrating the frequency selectivity of the receiver chain. The S21 parameter indicates insertion loss and frequency response.

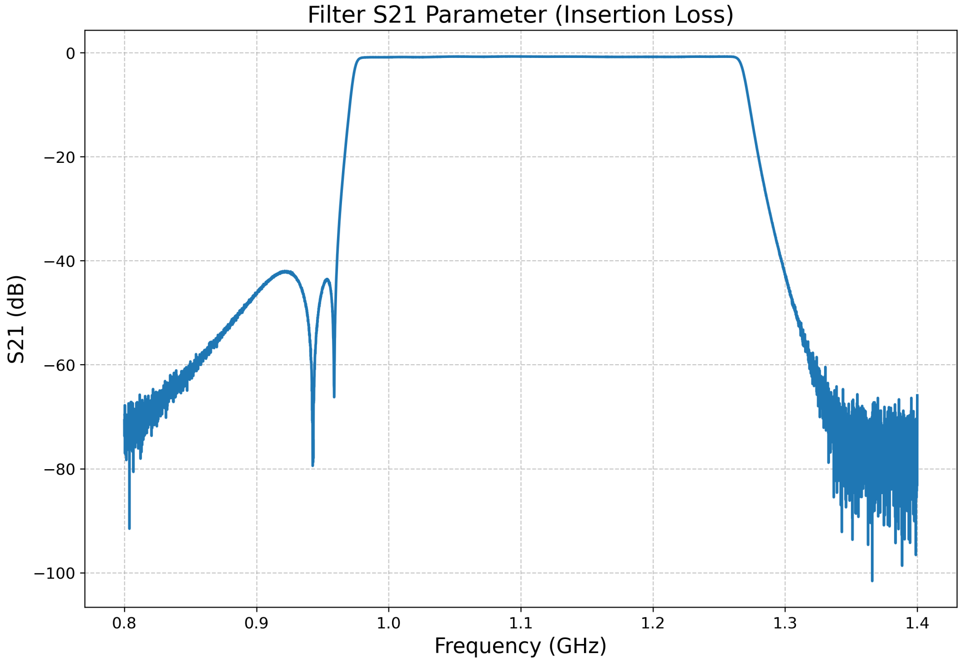


Figure 2: S21 parameter of the filter

5.3 Isolator Performance

The isolator S21 parameter, shown in Figure 3, demonstrates the forward transmission characteristics and isolation properties.

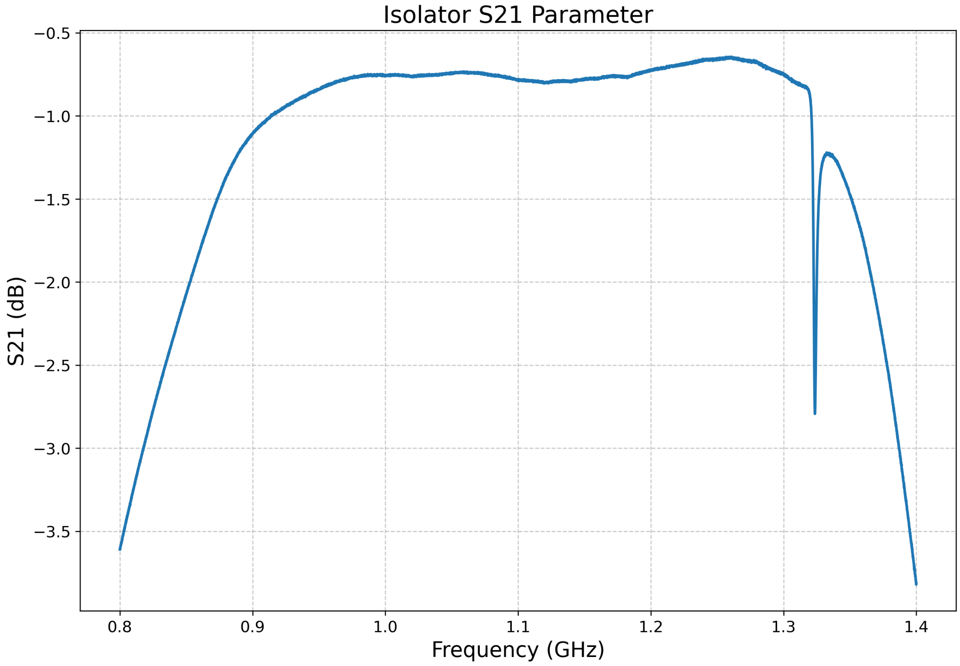


Figure 3: S21 parameter of the isolator

5.4 Component Comparison

Figure 4 shows a comparison of the S21 parameters of key components in the receiver chain, allowing for direct performance evaluation.

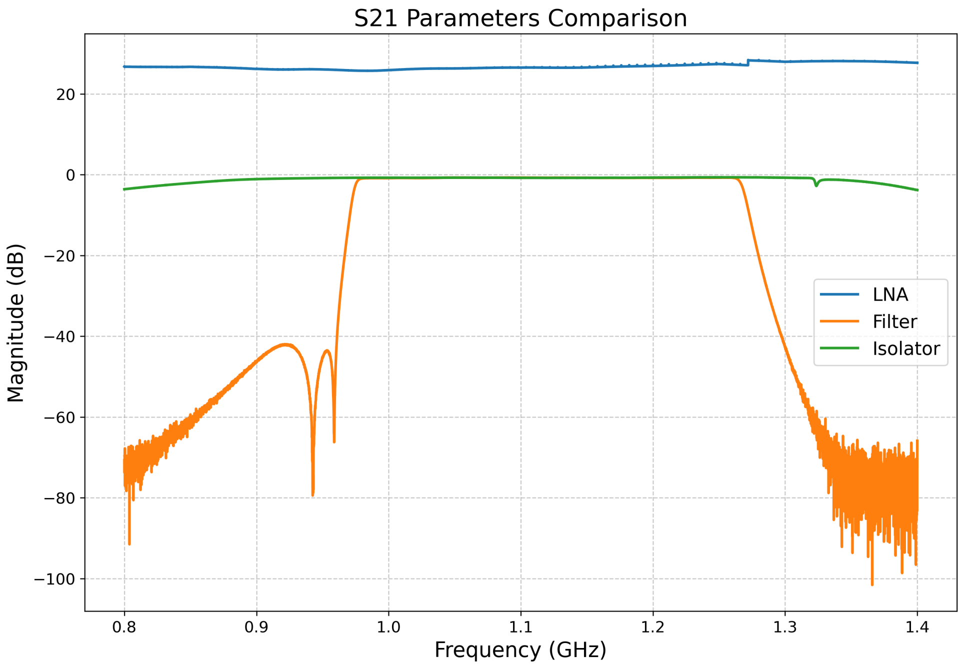
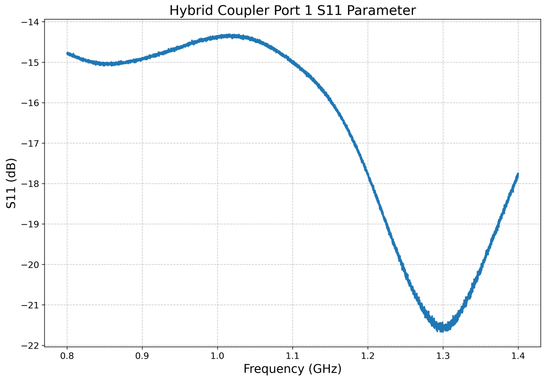


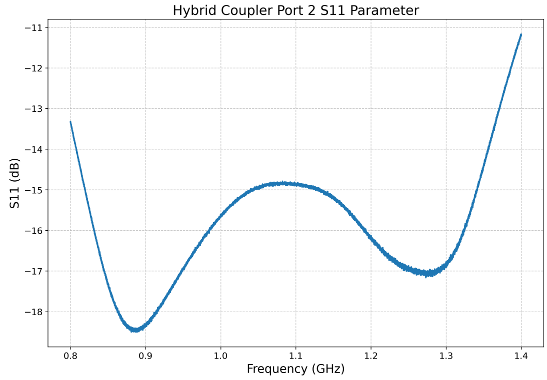
Figure 4: Comparison of S21 parameters for LNA, filter, and isolator

5.5 Hybrid Coupler Analysis

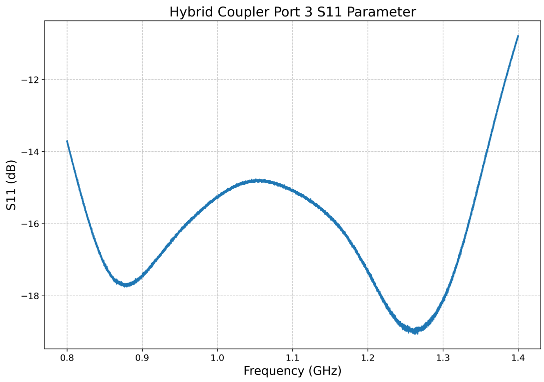
The hybrid coupler is a key component that splits and combines signals. Figures 5 and 6 show examples of the S11 and S21 parameters for different ports of the hybrid coupler.



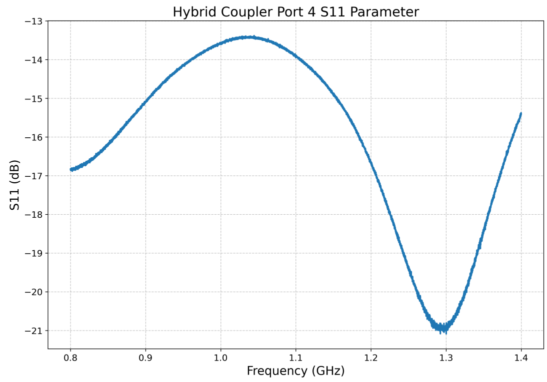
(a) Port 1 S11



(b) Port 2 S11

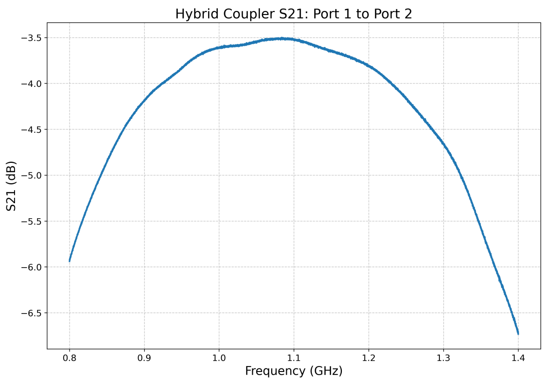


(c) Port 3 S11

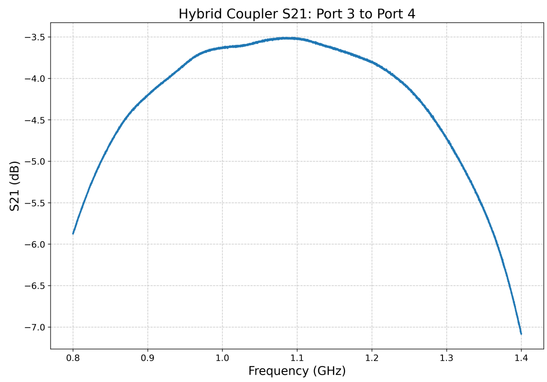


(d) Port 4 S11

Figure 5: Hybrid coupler S11 parameters for all ports



(a) Port 1 to 2



(b) Port 3 to 4

Figure 6: Examples of hybrid coupler S21 parameters

6 Methodology

The analysis methodology follows these steps:

1. Data acquisition using Rohde & Schwarz ZNB VNA
2. Data storage in standardized CSV format
3. Processing using Python with scientific libraries (NumPy, SciPy, Matplotlib)

4. Visualization and analysis using Jupyter Notebooks
5. Performance evaluation against design specifications

7 Conclusion

The Uirapuru Receiver project provides a comprehensive characterization of the RF reception chain components. The measured S-parameters offer valuable insights into the performance characteristics of each component and the integrated system. The open dataset and analysis tools enable reproducibility and further research.

Future work could extend this characterization to additional components and explore temperature and environmental effects on performance. The modular approach of the analysis framework facilitates easy extension to new measurements and components.

Acknowledgments

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