Towards Long-range Backscatter Communication with Tunnel Diode Reflection Amplifier

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I. INTRODUCTION

Backscatter communication enables wireless transmissions at orders of magnitude lower power consumption compared to conventional wireless communication [1], [3]. The ultra-low power nature of backscatter is a key enabler for wireless transmissions on energy-harvesting sensors and paves the way for applications such as battery-free video streaming cameras [2]. A backscatter transmitter modulates an ambient RF signal by changing the impedance of the antenna which causes minute variations in the reflected signal [3].

Backscatter has been regarded as a short range communication mechanism achieving a range of tens of meters for applications such as RFID. LoRea [1] overturned this assumption for the first time by reaching a range of $3.4\,\mathrm{km}$ while consuming only $70\,\mu\mathrm{W}$ for transmission.

However, one of the key challenges with state-of-the-art backscatter systems is that they require the backscatter tag to be in close proximity to the RF signal source to achieve a large communication range, which limits practical application scenarios. In this paper, we present our preliminary efforts to overcome this limitation: We build upon recent work [4] which leverages tunnel diode based reflection amplifiers to achieve high gain at the backscatter tag. A tunnel diode is a 2-port device with a negative resistance at some bias voltages, providing high amplification gain of an input RF signal. In this paper, we investigate an unexplored aspect of tunnel diode amplifiers: the sensitivity of amplification gain to changes in the bias voltage and the input radio frequency power.

II. IMPLEMENTATION

We implement the tunnel diode reflection amplifier on an FR4 PCB board, as shown in Figure 1. We design the prototype reflection amplifier to achieve gain at frequency band of $868\,\mathrm{MHz}$. To achieve gain at a specific frequency interval, we developed a matching network using stubs. We implemented the matching network in three steps: *first*, we measured the S11-parameter of the tunnel diode (AL301A) with a vector network analyzer (VNA). *Second*, we simulated the matching network in Advanced Digital Systems. *Finally*, we tuned the length of the stubs experimentally to the desired frequency band. We obtained this result using a VNA, Bias tee, DC power supply, matching network and a tunnel diode, as can be seen in Figure 1. We used the attenuators to limit the power below the threshold of the VNA. The voltage was measured using a multimeter.

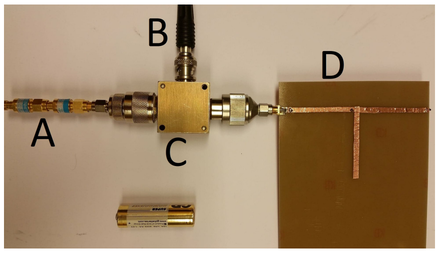

Fig. 1: *Setup to measure the S_{11}-parameter.* (A) Attenuators, (B) DC voltage supply, (C) Bias tee, (D) Matching network and tunnel diode. AA sized battery as reference in the bottom.

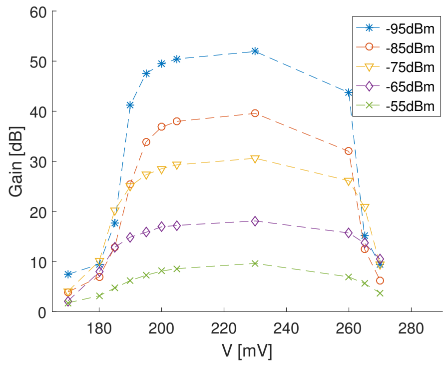

Fig. 2: *Power gained for different bias voltages*. The gain increases with lower incident signal strength.

III. RESULTS

To evaluate the design of our reflection amplifier, the power was measured with an VNA. We vary the bias voltages (170mV to 270mV), and output power of the VNA ($-55\,\mathrm{dBm}$ to $-95\,\mathrm{dBm}$). Figure 2 demonstrates the result of the experiment, where the Gain is defined as the absolute difference between the output power of the VNA and the power reflected by the tunnel diode. In Figure 2 it can be seen that the gain both increases and decreases exponentially with bias voltage. Between around 200mV to 250mV the change in gain with bias voltage is low. We also see that the maximum gain for the same bias voltage increases as we decrease the input power.

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