Reflection Amplifier for Radar Cross Section Enhancement Transponders

Pouyan Keshavarzian, *Student Member, IEEE*, and Michal Okoniewski, *Fellow, IEEE*

***Abstract*—Recent works have demonstrated reflection amplifier designs for backscattering applications. These circuits are used for improved efficiency in RF identification applications and also for retro-directive techniques. A remaining area of interest is exploring other multiport networks that can be combined with reflection amplifiers for large radar cross section (RCS) enhancement. A reflection amplifier is designed and tested as a step towards investigating multiport active loaded networks. The amplifier achieves a stable gain of 14dB at 5.3GHz with sub milliwatt power consumption.**

***Index Terms*—RCS enhancement, microwave backscattering, reflection amplifier**

I. INTRODUCTION

REFLECTION amplifiers, first introduced by Armstrong [1], have gone through a recent renaissance in research because of their improvement to the tag efficiency of radio-frequency identification (RFID) devices [2] and for applications in active retro-directive backscattering [3]. Multiport active loaded backscattering systems are advantages for applications requiring high gain such as radar cross section (RCS) enhancement in adverse weather conditions. Active loaded retro-directive techniques for N-Port systems using reflection amplifiers have been theorized and demonstrated in [4] however these systems have practical limitations at higher frequencies because of the number of Hybrid couplers required to synthesize an array of several elements. In this work a 5.3GHz reflection amplifier is designed and tested for the purposes of future research in practical multiport active scattering at high frequencies. To ensure stable performance of the amplifier, careful consideration has to be taken to understand the types of negative impedance generated by the amplifier as they require differing stability conditions [5].

II. DESIGN OF REFLECTION AMPLIFIER

Active scattering can be implemented using positive feedback on a transistor or with a device that intrinsically exhibits negative differential resistance such as a quantum tunneling diode. This amplifier is designed as a negative conductance or N-Type negative differential resistance with an Infineon BFP840FESD heterojunction bipolar transistor (HBT). Positive feedback is introduced with an inductance in the base which in turn creates a negative resistance looking into the collector of the transistor. A shunt inductance is added to the collector to turn the negative resistance into a negative conductance. The value of this inductor is chosen to resonant out the input junction capacitance of the collector. Figure 1 demonstrates this concept.

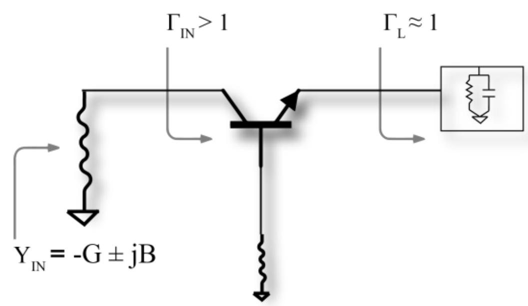

Fig. 1. Negative conductance amplifier general architecture.

The distributed circuit is then designed using Keysight ADS. Intensive harmonic balance simulations are conduced to characterize the large signal behavior of the device and ensure stability over a range of loads at various DC bias values. The microstrips are printed on Rogers 6010.2LM substrate.

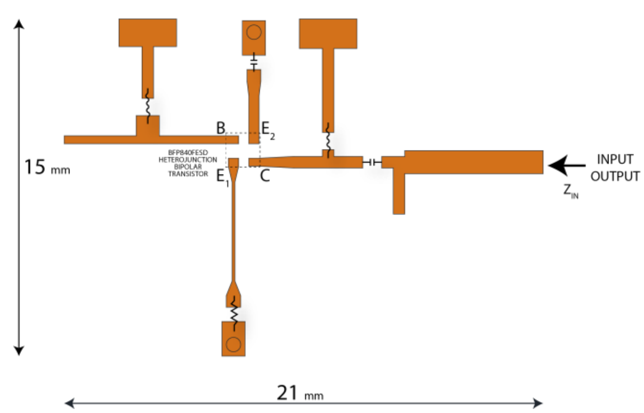

Fig. 2. Amplifier layout in ADS.

EM circuit co-simulation technique is used to ensure accurate characterization of the lumped circuit elements with the

P. Keshavarzian is an M.Sc. Student at University of Calgary, Calgary, AB T2N 1N4 Canada.
M. Okoniewski is a Professor with the Electrical and Computer Engineering Department, University of Calgary, Calgary, AB T2N 1N4 Canada.

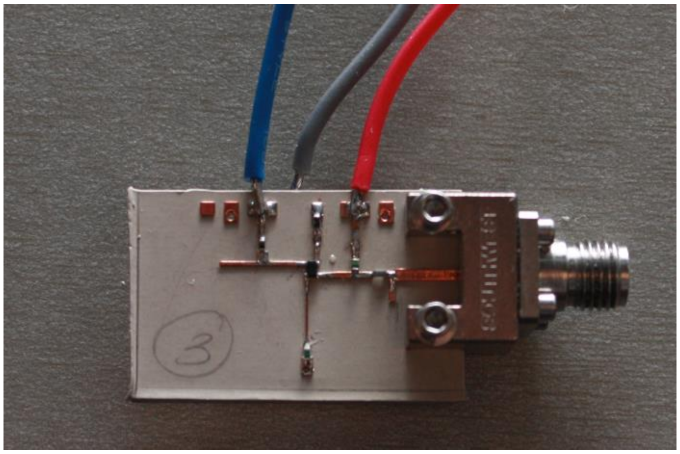

Fig. 3. Manufactured PCB with soldered components.

microstrips. The manufactured amplifier is shown in Figure 3.

III. RESULTS

A vector network analyzer is used to measure the reflection gain of the manufactured amplifier. Comparison between the simulated design and measured is demonstrated in Figure 4.

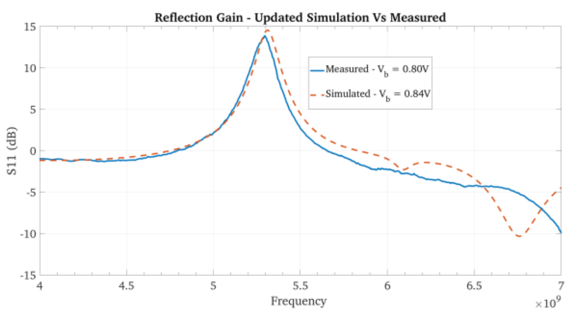

Fig. 4. Amplifier reflection gain.

The measured results match simulation with good fidelity. The amplifier power consumption is 542 µW when biased for a gain of 14dB. Power compression and non-linearities are introduced with an input of around -40dBm. This dynamic range allows for this amplifier to be used in many backscattering applications regardless of distance. Stability of the amplifier is confirmed using a spectrum analyzer.

IV. CONCLUSION

The realized amplifier achieves the goal of stable amplification at the desired frequency. The performance of the device matches many recent works published in literature and is capable of 14dB. This is critical for further research when combining several of these devices with beamforming networks. Furthermore the dynamic range of the device is excellent considering the magnitude of the stable gain achieved. Overall the project is a success and the device will be used as a stepping stone for evaluating novel transponders. These active scatters have applications in radar target enhancement, vehicle-to-vehicle (V2V) communication and tracking objects in adverse weather conditions. Research going forward will focus on practical high gain retro-directive techniques at millimeter-wave.

V. FUTURE PLANS

From here the remainder of the research will be conducted to finish my M.Sc studies. The MTT Pre-Graduate award has given me access to the large field of discovery going on in microwaves. As a result my passion for doing research in this field has been further fortified. I plan on continuing in this capacity either in Industry or PhD studies. I look forward to attending the International Microwave Symposium and am grateful for the support from MTT.

REFERENCES

[1] E. H. Armstrong, "Some recent developments of regenerative circuits," in *Proceedings of the Institute of Radio Engineers*, Boston, MA, USA, 1985,
pp. 585–590. vol. 10, no. 4, pp. 244–260, 1922.

[2] J. Kimionis et. al, "Enhancement of RF tag backscatter efficiency with low-power reflection amplifiers," *IEEE Transactions on Microwave Theory and Techniques*, vol. 62, no. 12, pp. 3562-3571, 2014.

[3] S. Chung et. al, "A novel bi-directional amplifier with applications in active van atta retrodirective arrays," *IEEE Transactions on Microwave Theory and Techniques*, vol. 51, no. 2, pp. 542–547, 2003.

[4] S. N. Hsieh and T. H. Chu, "Linear retro-directive antenna array using 90◦ hybrids," *IEEE Transactions on Antennas and Propagation*, vol. 56, no. 6, pp. 1573–1580, 2008

[5] K. Kurokawa, "Some basic characteristics of broadband negative resistance oscillators," *Bell Syst. Tech. Journal*, vol. 48, pp. 1937–1955, 1969.