URSI GASS 2021, Rome, Italy, 28 August - 4 September 2021

Software Defined Radio Based Drone Receiver Payload

Elizabeth A. Shi*(1), Mark Andrews(1), Caglar Yardim(1), Joel T. Johnson(1) and Joe Vinci(1)
(1) ElectroScience Laboratory, The Ohio State University, Columbus, OH, USA

Abstract

A drone receiver (RX) payload is built as a combination of an embedded software defined radio (SDR) and a low noise amplifier (LNA) and limiter circuit to sample radio frequencies (RF) that are transmitted from long distances. The system will be deployed during Costal Land-Air-Sea Interactions (CLASI) experiment in June in Monterey CA to measure EM propagation under ducting conditions [2]. This compact and lightweight system can be attached to a drone for collecting and recording data at high altitudes while maintaining the drone's mobility. This system is cost-effective and simple to operate. Since the SDR is embedded, the software can be uploaded into the SDR after which it can operate independently with no computer control. Limiter LNA both improves the overall noise figure of the receiver payload to $\sim 3-4$ dB while also acting as a limiter to protect the SDR.

1 Introduction

Although there are many existing numerical weather prediction models, operational wind forecasts have been inaccurate along coastal borders. Insufficient spatial resolution to accurately analyze coastal boundaries and inaccurate characterization of the physics at the coastal air-sea boundaries can create significant errors in these models. To better improve these models, the Coastal Land-Air-Sea Interaction (CLASI) group mission is to develop and/or modify parameterizations at these coastal boundaries and improve the modeling of evaporation ducts. CLASI will monitor these areas with a collection of Air-Sea Interaction Spar (ASIS) buoys, inner shelf spar buoys (I-SPAR), coastal/land-based towers, and a drone.

This paper documents the receiver (RX) payload that will be attached to the drone, Fig. 1. The RX payload that is attached to the drone is the SDR coupled with the low noise amplifier (LNA) limiter circuit. SDR systems are readily available and affordable [1]. This project uses the Ettus 320 (E320) Embedded SDR which allows the RX payload to be programmed in advance to communicate at the desired frequency with no required hardware modification to the SDR. Since the SDR is embedded, it begins measuring and recording data as soon as it is activated [3]. This alleviates the need to process the data through an external computer, which is often too heavy to attach to a drone. This approach allows for ease of adaptability, shortens the development effort and greatly reduces cost and complexity.

Figure 1. The system being tested with a DJI Drone. The final version will be deployed with an Aero System West Hexacopter.

2 Limiter LNA Design

As the SDR is only capable of withstanding a maximum input signal power of -15 dBm, a LNA limiter circuit is designed to protects the SDR against the risk of being burnt out when receiving high signal power while maintaining a low noise figure (NF). The LNA limiter circuit is placed in front of the SDR, as shown in Fig. 2, and extends the maximum range of input that the SDR can receive.

Most commercial low cost SDRs have poor noise figures. Our tests showed under normal operations with typical gain settings the E320 NF varies between 10-20 dB. Moreover, these smaller low cost, low weight systems also have low maximum allowable input power levels. For example, E320 has a maximum input power level of -15 dBm, making the system vulnerable. This also makes it impossible to add an LNA in front to improve NF since the LNA gain would further reduce the maximum allowable received input power.

This is addressed by use of a limiter LNA circuit used that can amplify signals with a gain of 12 dB and stronger signals are limited to -18 dBm. The maximum input of the entire system is extended to 17 dBm continuous wave and up to 29 dBm for brief periods of excitation. To verify that the LNA limiter circuit is working properly, it was connected to a signal analyzer (SA) and signal generator (SG) and a plot of the input and output powers can be seen in Fig. 3.

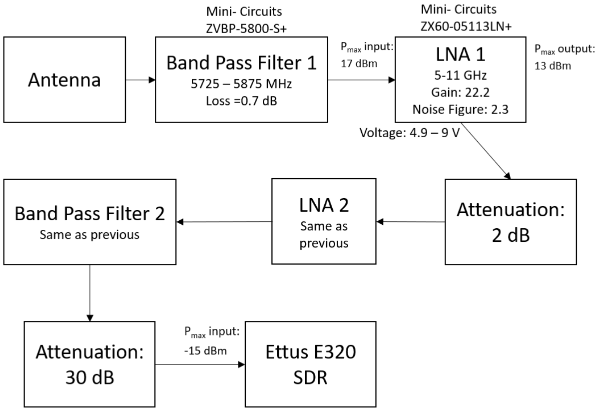

Figure 2. Schematics of the drone receiver payload. The signal is received by the antenna attached to the drone before it is sent through the LNA limiter circuit and passes to E320 SDR.

The system gain remains linear at around 12 dB (simultaneously acting as both LNA and limiter reduces the overall gain of the design) and the system starts to saturate up to-18 dBm after which the limiter LNA output will be limited to this level.

The combination of the SDR and the LNA limiter circuit will allow the system to record and collect signals from 3 ground and one aircraft-based transmitters that are 10 kHz spaced from each other at 5.888 GHz. Minimizing the size of this system proves to be an advantage, because it allows the system to be easily deployed as a payload on a drone. Since the system includes its own power source, the drone can be used more efficiently by maximizing the amount of time in the air and minimizing the power drawn from the drone batteries. In addition, the LNA limiter circuit mitigates the poor NF values of the SDR from approximately 10-20 dB to 3 dB. This allows for a clearer signal; therefore, increasing the capabilities of the system to detect low signal levels.

The LNA limiter circuit was designed to extend the functionality of the SDR since the SDR maximum input was limited to -15 dBm. This circuit includes two LNAs (Mini-Circuits - ZX60-05113LN+), two bandpass filters (Mini-Circuits - ZVBP-5800-S+), and a few attenuators as shown in the schematic in Fig. 2. The whole circuit is shielded to reduce RFI and interference by drone systems. In order to power the two LNAs, a power regulator is used to convert standard 3.7 V LiPo drone battery voltage to 5 V. One bandpass filter was used to filter the incoming signal and prevent the LNA from amplifying an unrelated signal. Once the correct signal is amplified, the other bandpass filter was used to filter the signal again.

The system is also successfully tested under low signal levels. Using a 100 kHz sampling rate and 1024 bins (corresponding roughly to a 98 Hz resolution bandwidth) and the maximum E320 SDR gain setting of 76 dB, the noise floor is measured at -150 dBm giving a NF of 4 dB.

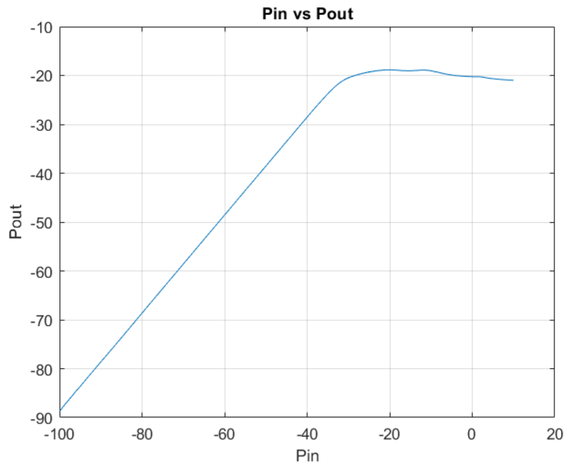

Figure 3. The plot depicts the input power (Pin) and output power (Pout) in dBm from the limiter LNA. The output increases linearly until ~ -30 dBm and it is limited at -18 dBm output.

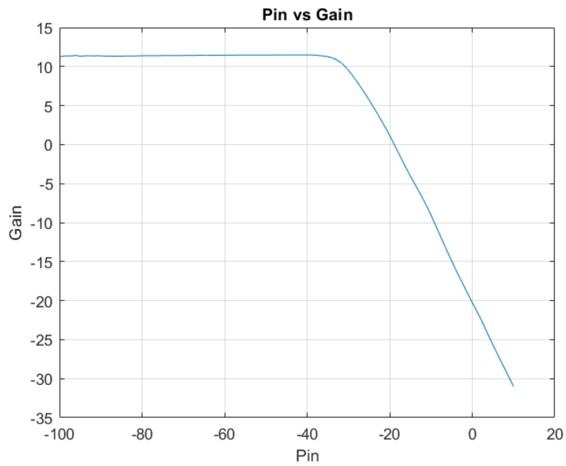

Figure 4. Gain vs. P_{in} for the limiter LNA. The typical system gain is 12 dB with a 1 dB compression point P_{out} of -22 dBm. System fully saturates and acts as a limiter at -18 dBm.

3 Conclusion

The agreement between the expected results and the simulated measurements validates the LNA limiter circuit is functioning as expected. The LNA limiter circuit will accurately extend the function of the SDR and prevent the SDR from overloading at higher signal power while enabling measurements of low signal levels. The system will be deployed in Monterey CA, in June 2021 as part of the Coastal Land-Air-Sea Interaction (CLASI) experiment to study the duct formations.

4 Acknowledgements

The authors would like to thank ONR grants N00014-18-1-2589, N00014-20-1-2100, and Facebook for providing funding for this research.

References

[1] A. Bello, “Radio Frequency Toolbox for Drone Detection and Classification,” Master of Science (MS) thesis, Electrical/Computer Engineering, Old Dominion University, Norfolk, VA, 2019. doi: 10.25777/9gkm-jd54

[2] A. Karimian, C. Yardim, P. Gerstoft, W. S. Hodgkiss and A. E. Barrios, "Refractivity estimation from sea clutter: An invited review," in Radio Science, vol. 46, no. 06, pp. 1-16, Dec. 2011, doi: 10.1029/2011RS004818.

[3] H. Fu, S. Abeywickrama, L. Zhang and C. Yuen, "Low-Complexity Portable Passive Drone Surveillance via SDR-Based Signal Processing," in IEEE Communications Magazine, vol. 56, no. 4, pp. 112-118, April 2018, doi: 10.1109/MCOM.2018.1700424.