LOW NOISE AMPLIFIER DESIGN AND ANALYSIS FOR WIRELESS VOICE TRANSMISSION

Ch. Venkateshwarlu

ECE Department, St. Martin's Engineering College

ABSTRACT: LNA (Low-Noise Amplifier) is an integral part of wireless communication system. Generally weak modulated wireless signal such as one used for indoor wireless voice communication are affected by surrounding noise and signal at the receiver is quite weak. As such amplification of such signal at the digital level is near impossible. in this work we design and analyze the performance of LNA based wireless voice transmission system. We first design a wireless voice transmission through commercial mic. The receiver is attached to the PC audio port. We add the LNA component through a transistor switch to the receiver with the help of Arduino. In PC software we analyze the signal received in the presence of LNA and in the absence of it. We prove that LNA can lift the signal significantly, thereby providing a better voice level. We also analyze the voice quality of the signal by playing an audio file in PC which is transmitted back to the PC through our wireless mic. We show that MSE of the signal is reduced significantly by LNA. Therefore, our work not only propose a suitable design for low noise amplifier but at the same time offers a realistic simulation bed to study the performances of the amplifier.

Keywords: LNA, Arduino, PC, EC2 Microphone Transmitter, Receiver.

1. INTRODUCTION

Low noise amplifiers are being used extensively in microwave technology to boost the received signal strength because microwave transmission through co-axial cable results in significant attenuation of the signal. Certain version of LNA are also used in video transmission and in the repeater circuit in applications like video surveillance. However, the application area of LNA in wireless voice communication is relatively unexplored. So far band-pass filters are assumed to be good solution for voice communication. As LNA has proven signal lifting capabilities, it is a good candidate even for low noise voice communication. There is not much significant works that focus on exploring LNA as voice communication amplifier and more so not many works propose a test bed that can analyze the real signal input output of LNA so that their behavior can be studied. Thus, the problem statement can be summarized as to design a real time voice amplification module with LNA for wireless low-cost voice transmission and analyze the signaling properties of LNA.

The objective of the work is twofold. Firstly, we needed to build a low-cost wireless voice transmission system whereby we can acquire remote voice in PC so that that the noise figure can be appropriately analyzed and studied. Most of the existing wireless transmission now uses Bluetooth devices which has significantly better noise figure. But in analog voice transmission which has wider application like in public transmission and longer distance voice communication, noise and attenuation is major challenge. The objective was to build a LNA that could boost the signal of such transmission system.

The second objective was to build a simulation environment that could capture the input and output signal to LNA and provide to system for analysis. An audio port works like a digital filter for voice as the port in itself has certain filters to clean the audio signal. Therefore, analysis of the signal received by the audio port does not provide enough evidences of the functioning of the system. Hence the objective is to capture the raw data arriving at the LNA module and its output. This is achieved with the help of Arduino which now is extremely popular open-source hardware prototyping solution.

2. LNA IN RECENT TECHNOLOGY

LNA is generally used to amplify extremely weak signals. Signals captured by various antennas are good example of such signals. As such signals are extremely weak the amplifier must be placed closer to the antenna to avoid transmission losses from the antenna to the amplifier. Such a system is most popular in microwave transmission as the corresponding cable (coaxial) has extremely high attenuation, especially at microwave frequencies. As such 20% degradation in amplitude will result in 20% loss in signal to noise ratio. Considering a conventional Gaussian noise channel, a signal that could be received with 10db will now be received at 8db. This typically means one extra bit of noise in 10 bits transmitted.

This is shown in figure 1.1
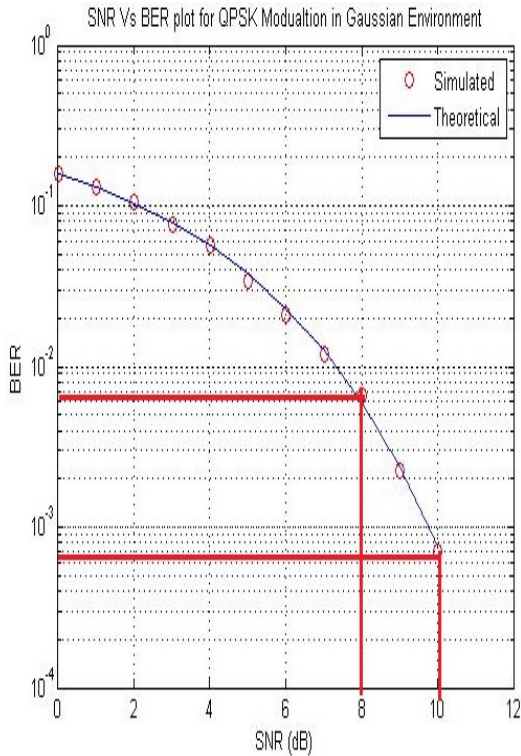
Figure 1.1: A typical SNR v/s BER analysis for QPSK Modulation scheme.

An LNA is either integrated with the recover or attached with the antenna whose output is fed to the receiver. According to Frii's Noise Figure formula actual noise figure (NF) performance of any receiver is mainly affected by first few receiver stages. In most of conventional receiver this directly corresponds to the theory that the performance of the recover directly depends on the first stage of receiver itself which is antenna signal acquisition. Hence LNA must be placed between the antenna and the receiver to achieve highest possible gain and to improve the receiver performance multi

fold. If the LNA is placed at different stages, it becomes highly unlikely that this will make any difference to signal conditioning and amplification. A typical LNA placement is shown in figure 1.2
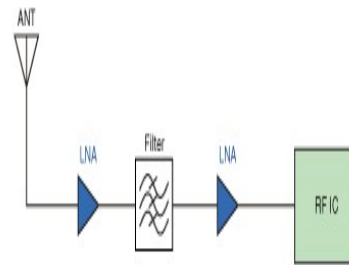

Figure 1.2: Two stage LNA added as the first stage of RF receiver

Now every amplifier amplifies the noise also and also adds it's own circuit noise to the signal. Therefore, it is very important that LNA in itself induce as little noise as possible that that it does not amplify the noise figure. This special criterion is attributed to the name "low noise amplifier".

3.　DESGIN　OF　LOW　NOISE AMPLIFIER

In the proposed work, LNA must be used in the context of an analog transmission that needs to be received digitally at the personal computer. Hence the arrangement must be such that it aids to signal boosting before

digitization of the received signal. The arrangement is shown in figure 1.3
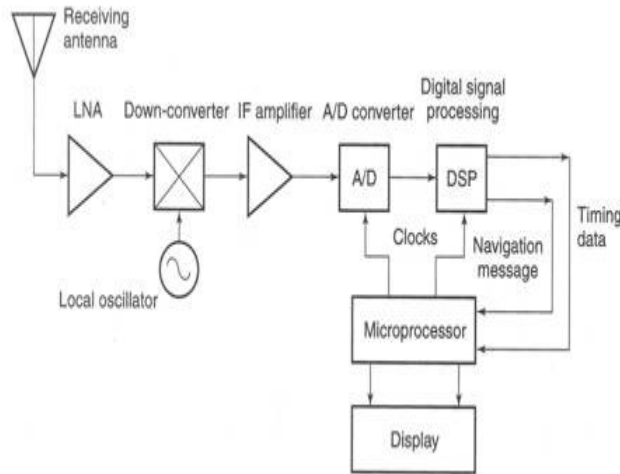


Figure 1.3: LNA arrangement for the proposed design

Here LNA more or less acts as an IF amplifier or intermediate frequency amplifier which is an important design in stereo system.

4. DESIGN METHDOLOGY

Circuit Diagram of LNA with Biasing

From above it is clear that LNA must have lower input resistance than output resistance and the impedance matching must be achieved through suitable inductance. We also need a switch M1 for switching the excitation at receiver. It can also be seen that the switch must have frequency selection though suitable filter circuit for matching the input operating frequency. To realize the above concept, we develop the following

circuit model where the AC switching of LNA is replaced by M2 and M3 respectively. M4 and M5 acts as output matching filter that eliminates the noise induced due to switching. Complete circuit is presented in figure below.
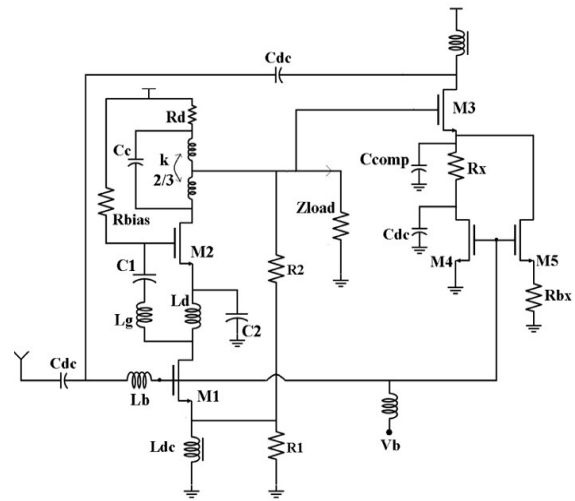
Figure: 4.1 LNA Circuit Used in this work

In this work we have designed and implemented real time LNA based voice transmission system which is able to amplify the low voice amplitude being received by a RF receiver from a weak mic signal. We have developed an environment to simulate and analyze the characteristic of the features of the signal which can be utilized to simulate and design LNA specific to other applications. The proposed work implements a radio receiver that is capable of accepting the wireless modulated signal from mic. We than input the received signal of this system to analog Arduino port.

Arduino reads the value and streams the value over Serial port. MATLAB based interface reads the signal and analyzes the signal. We than introduce the LNA circuit between the antenna and the receiver first stage and analyze the signal at the input and the output stage of the LNA. Results shows that the system improves the input signal voice band significantly over non LNA based system. This also results in better voice quality.

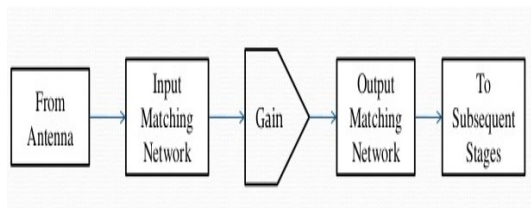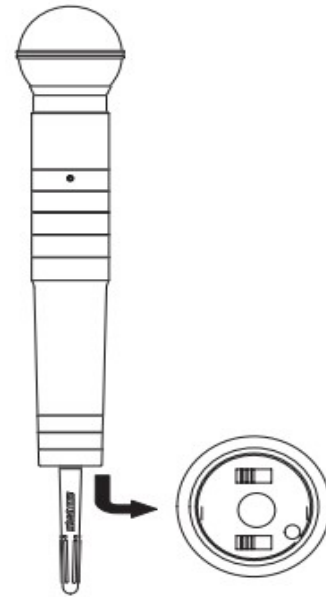## 5. HARDWARE DESIGN

5.1 Basic Architecture

Figure 5.1: Basic Block Diagram

5.2 Design of Mice and Transmitter

We use a ready commercial grade EC2 Wireless Mic with operating frequency between 160MHz to 250MHz. Frequency Stability supported by the system is ±32.5 PPM, ±5.5 KHz which meets the FCC regulations. EC2 transmitter's operating range is typically 600 feet or 182.8mW at 50mW Modulation. It withstands ±15 KHz deviation using a compressor and expander system with emphasis (both pre- and de- types). Total Harmonic Distortion is average 0.4% to 0.7% maximum. The dynamic range is 80Hz to 15KHz, +-2 db

6. SOFTWARE DESIGN

6.1. The Receiver Specification

The receiver specification is presented in the table below.

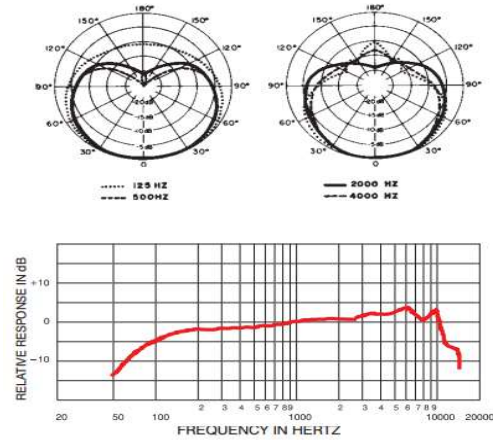| Non-VoiceSuppression	2.0 µV,2-50 µV
Output	–2 dB at 1 kΩ o/p impedance
Antenna Input Impedance	50Ω
Voltage Requirement	1.5 VDC
Current Requirement	200 mA

Figure 6.2 Antenna Response

6.2 Receiver Antenna Gain

The below figure shows that the antenna response is directional in nature that is when the transmitter mic is directed and kept closer to the antenna of the receiver, the gain is maximum. Gain tends to reduce around 60' angle. Also, the receiver is designed mainly over human voice frequencies and the gain in optimum between 200 Hz to 5 KHz. However normal voice will typically range between 330 Hz to 3.3 KHz. Therefore, this receiver fails to suppress both high frequency noise as well as low frequency noise. Therefore, there is a need of LNA.

7. RESULTS AND VALIDATION
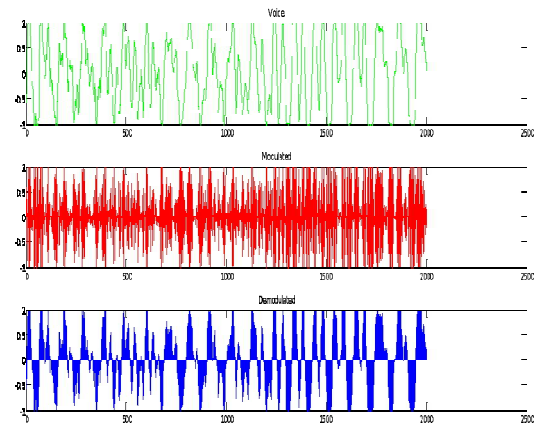
### 7.1 Voice Transmission over Channel

Figure 7.1: Simple Voice Transmission over Ideal Channel

For simulating voice transmission over channel, we record 10sec user speech sampled at 16 KHz. We then multiply this with a carrier frequency of 200MHz as our operating frequency for the Wireless voice transmission is 200MHz. The modulated signal is passed over the ideal channel first which means that no error is induced in the channel. Finally at the receiver, the signal is multiplied with the carrier signal again. No filter is implemented. It can be seen that multiplying with carrier increases the frequency of the signal where as doing the same at the receiver recovers the original signal back again with some noise. However, figure 7.1 does not clearly reveals the characteristics of the voice. Because it is rather difficult to understand the frequency domain characteristics of the signal from time domain data. Therefore, we perform FFT on y, R and D signals which are actual voice, modulated and received signal respectively. Figure 7.2 Show the graph.
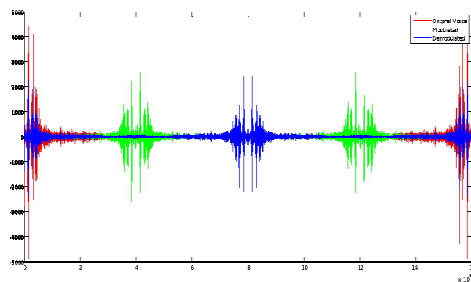
Figure7.2 Wireless voice transmission properties in frequency domain.

It can be clearly seen that in original voice (Red signal) mainly lies in the low frequency range. Modulation process changes the frequency of the signal to high frequency band (Green). Demodulation process obtains the signal in baseband (Blue). However, we can clearly see that though de-modulation recovers the low frequency component it does not eliminate the high frequency component. It can be seen that significant trail of blue remains in high frequencies. Hence low pass filter is an important step in receiver circuit.
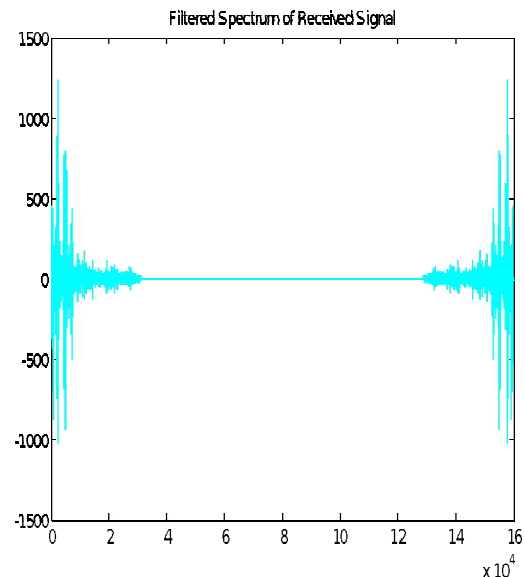
Figure 7.3: Low pass filtered received signal

After Low pass filtering stage however lifting the spectrum, any further would also lift the noise band hence giving distorted signal. As any spectrum lifting also ideally lifts the noise (containing both silence as well as other signals on the same spectrum,

it is highly impossible to design a filter that can lift only the voice band and suppress other parts.
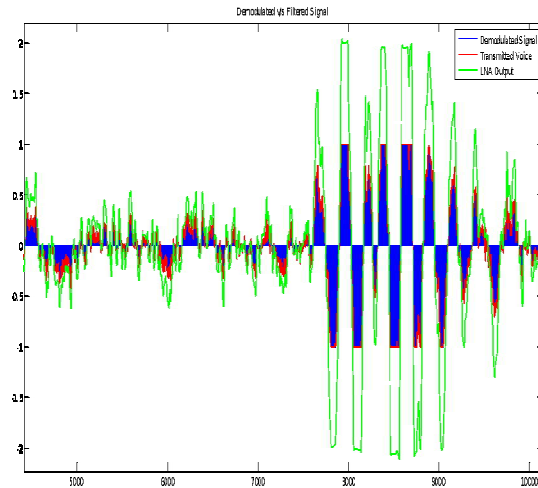
Figure 7.4 : LNA Output

It can be clearly seen that the proposed LNA does not amplify the noisy signal. However, it significantly lifts the voice signal. We can clearly see green signal being much higher amplitude than that of blue demodulated signal. Thus, when LNA is added at antenna stage before receiver, the signal quality improves significantly.

8. CONCLUSION

Low Noise Amplifiers are conventional electronics circuits used for amplifying band limited signal. This is an essential block in almost every type of communication systems. In modern day LTE based system extensively uses such amplifiers at the first stage of the receiver. The amplifier

commonly being used is of type hybrid which is capable of amplifying signals from various core networks. The simulation model analyzes the transmitted voice characteristic over the communication channel and correctly presents the characteristics in term of frequency domain analysis graphs.

The system can be used to study noise figure characteristic of the receiver and design ideal system for reducing the noise. By simulating the presence and absence of LNA with antenna and by proving that using LNA can significantly improve the quality of transmission we justify our proposed design.

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