ISSN(Online): 2320-9801
ISSN (Print): 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Website: www.ijircce.com

Vol. 5, Issue 2, February 2017

Design of Low Noise Amplifier For MRI Scanner using Cascode Technology

Shailesh H. Yadav

Research Scholar, Dept. of Electronics and telecommunication, Mumbai University, Maharashtra, India.

ABSTRACT*:* This paper presents Design and Implementation of Low Noise Amplifier for MRI (Magnetic Resonance Imaging) Scanner using Cascode amplifier. Magnetic resonance imaging is a non-invasive imaging tool to generate anatomical and functional images of the human body with no ionizing radiation.MRI generates images with excellent soft tissue contrast and, thus, is particularly useful for neurological, musculoskeletal, cardiovascular, and oncological imaging. [1][2]. The RF signal reflected from human organs is received by receiving antenna followed by LNA. The received signal should undergo proper Data processing with high gain and Low noise figure, which is achieved by using good low noise amplifier (Pre-amplifier) at 1st stage of Receiver. Low noise amplifier (pre-amplifier) maintains total noise performance (SNR) of receiver. This paper shows design of Low noise cascode amplifier for MRI Scanner, having noise figure near to 0.6 dB with gain greater than 20 dB at frequency of 63.87 MHz, Bandwidth is 5 MHz.

KEYWORDS*:* MRI, pHEMT, non-invasive, Cascode, ADS, Optimization**.**

I. INTRODUCTION

Low noise performance is always the first consideration in MRI system design. The RF transmit path (Tx), RF receive path (Rx), and gradient control path all need a very low noise floor, so low noise amplifiers, higher resolution DAC and ADC, and low phase noise clocking must be selected in all the signal chains of an MRI system. The signals are detected from hydrogen nuclei in water or fat molecules, and the signal acquisition is based on the phenomenon of nuclear magnetic resonance, which deals with the interactions between nuclear spin and magnetic fields. The signal localization is achieved by the application of linear gradients of a magnetic field [1][2] .

As the first active stage of receivers, Low Noise Amplifier (LNA) play a critical role in the overall performance and their design is governed by the parameters. LNAs are key components in the front-end receiver system, which amplify the received Radio Frequency (RF) signal from antenna. All receivers require an LNA with sufficient sensitivity to discern the residual signal from the surrounding noise and interference in order to reliably extract the embedded information. To achieve this goal, the LNA has to be design for optimal noise figure and optimizing the noise figure is referred to minimizing the input noise resistance [3][4].

In this paper Cascode technology is used for designing low noise amplifier for MRI Scanner. Cascode amplifier provide high Gain ,low noise figure, High slew rate and high stability over large bandwidth[8][9].The low strength signal received from human organs by LNA(pre-amplifier) at receiver will be strengthen with high SNR, Since Amplified signal preserved desired SNR of system, the Data-Processing and Data extracting process on signal will be efficient.

II. LITERATURE SURVEY

Low noise amplifiers (LNAs) play a key role in radio receiver performance. As shown in [1,2],In the MRI scanner, the signal received from the human body may have low strength and affected by the noise. The low noise amplifier strengthen the received signal by pre-serving desire Signal-to-noise (SNR) ratio of the MRI scanner . The most critical design goal for an MRI receiver front-end is superior noise performance while the distortion properties are of less importance as the receiver will always work in its linear operation region. According to author in [3,4], Five

ISSN(Online): 2320-9801
ISSN (Print): 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Website: www.ijircce.com

Vol. 5, Issue 2, February 2017

characteristics of LNA design are under the designers control and directly affect receiver sensitivity: noise figure, gain, bandwidth, linearity, and dynamic range. Controlling these characteristics, however, requires an understanding of the active device, impedance matching, and details of fabrication and assembly to create an amplifier that achieves optimal performance with the fewest trade-offs. The RF design engineer works to optimize receiver frontend performance with a special focus on active device. All receivers require an LNA with sufficient sensitivity to discern the residual signal from the surrounding noise and interference in order to reliably extract the embedded information.

According to author in [6, 7], First step for designing a Low noise amplifier is selection of Transistor, since we are designing LNA at microwave frequency with low possible noise figure and high gain, HEMT and HBT devices are suitable. Among HBT and HEMT device, GaAs HEMT device provide low noise figure with higher gain and has wide range of frequency of operation from 50Mz - 10GHz.Amount of drain current generated in GaAs HEMT is very large as compare to HBT. GaAs HEMT provide high linearity, can operate at single voltage and having thermal stability. According to author in [8,9] different methods are available for designing of low noise amplifier with lumped as well as distributed components. Simultaneous matching method is most widely used method for designing of bilateral low noise amplifier. In the design process of amplifier, it is needed to choose a reasonable matching point at which amplifier have lower noise and larger gain. The basic strategy is to obtain matching network to achieve an optimum noise source resistance around 50Ω and cancel the noise correlation susceptance.

III. SELECTION OF DEVICE

Since transistor has its maximum available gain (MAG) and minimum intrinsic noise figure (NFmin), selection of the transistor is the crucial stage in LNA design. The requirement of LNA for MRI Scanner is, its the noise figure should be near to 0.6dB and gain should be greater than 20dB to achieve this we have selected GaAs pHEMT device. GaAs pHEMT devices generate very little noise due to the hetero-junction between the doped AlGaAs layer and the extremely thin un-doped GaAs layer, the basic advantage of pHEMT is Gain linearity [9]. SiGe devices are also available in the market but they have high noise figure and low gain linearity as compare to GaAs HEMT devices. In this paper for designing of LNA for MRI Scanner ATF-531p8 enhancement mode pHEMT device has selected, which meets almost all the designing requirement [6][7].

Its operating range from 50-MHz to 6GHz, 0.6dB noise figure and 20dB Gain make it fit for the desired application. The device is 100% RF and DC tested. LNA is biased at Vds=4.72 V and Id=128 mA and Vgs=0.533 V [11][12].

IV. STABILITY CIRCUIT

Stability is important to consider when designing microwave Low noise amplifiers. To Design unconditionally stable LNA is a goal of LNA designer otherwise unstable LNA turns into an Oscillator. Instabilities are primarily caused by three phenomena: internal feedback of the transistor, external feedback around the transistor caused by external circuit, or excess gain at frequencies outside of the band of operation. The conditions for amplifier stability are established by requiring that the reflected power from the amplifier ports be smaller than the incident power.

There are different methods by which we can stabilize the LNA circuit [9].

(a) Adding a series resistance:

A small resistance is added in series with the gate of the transistor. This will improve the stability, but this technique is not used in the LNA design, because resistors are potential sources of thermal noise. This will increase the Noise figure of the amplifier.

(b) *Output Resistive loading* :

This is a most preferred method for LNA stabilization, this method should be properly used cause it affects the power gain and OIP3 dB.

(c) feedback network between output and input:

It lowers the gain at lower frequency and improve the stability. Due to this network matching between noise figure and S11 is become difficult.

ISSN(Online): 2320-9801
ISSN (Print): 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Website: www.ijircce.com

Vol. 5, Issue 2, February 2017

we have used feedback network between input and output to achieve the stable circuit. In this design DC biasing circuit and stability network are in combination. In ADS **'StabFact'** block is use to check the stability, it is equivalent to K(Rollet's factor). If **k>1** then the system is unconditionally stable. Formulae for 'k' is

$$k = \frac{1-|S11|^2-|S22|^2+|\Delta|^2}{2*|S12*S21|} \quad \ldots\ldots\ldots\ldots(1)$$

V. DESIGN METHOD

Noise Figure is one of the most important parameters to evaluate the radio performance of communication system. It is a measurement of degradation of signal-to-noise ratio (SNR) between the input and output of the component. The total signal received at the input of the amplifier does not only consist of the signal sent by the transmitter, but in addition, it includes the unavoidable noise signal originating from the internal resistance of the antenna [3][4]. To obtain a sufficiently high level of signal power with a reasonable signal-to-noise ratio (S/N) at the output of the LNA, the noise inherently generated in the amplifier must be kept as low as possible, therefore while designing low noise amplifier NF and gain is very important parameters [5][8][9].

$$\mathbf{NF = Fmin + \frac{Rn}{Ge(Ysource)}|\,Ysource - Yopt|^2} \ldots\ldots(2)$$

Where,

Fmin = minimum noise figure of transistor

Rn = noise resistance (shows how NF changes due to deviation between Ysource and Yopt

Ysource = The normalized admittance present to the LNA input

Yopt(Sopt) = normalized input admittance at which noise factor is minimum

From the above equation (2), it is clear that, in order to obtain minimum noise figure Yopt should be equal to Ysource. Input matching network deals with the noise figure of the entire LNA. So in this paper in order to achieve low noise figure ie noise figure approximately equal to minimum noise figure we try to make Yopt equals to Ysource and design input matching network[8][9]. We obtained the optimum source reflection coefficient 'Sopt' (reciprocal of Yopt) and matched it with source impedance Zsource (reciprocal of Ysource) by using software ADS (Advance Design System).

Output matching network decide the gain of low noise amplifier. Signal present at the output of Device (Transistor or FET) must be deliver to load without any loss, this is achieved by using proper output matching network [4][5]. In this paper we calculate output impedance using software ADS and did matching of that with complex conjugate of load impedance to obtain output matching network [3].

The microwave Simulation software Advanced design System (ADS) is used in designing of LNA in this paper. The above is schematic of LNA using cascode technology is complete design of Low noise amplifier (LNA) by using Lumped elements at 63.87MHz frequency by using matching network method discussed above, in ADS. While implementing LNA, Dielectric material is used to support Electrical characteristics of LNA . Material used for designing is FR4 (Flame Resistance 4) with ε =4.6 and tanδ = 0.001.

ISSN(Online): 2320-9801
ISSN (Print): 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Website: www.ijircce.com

Vol. 5, Issue 2, February 2017

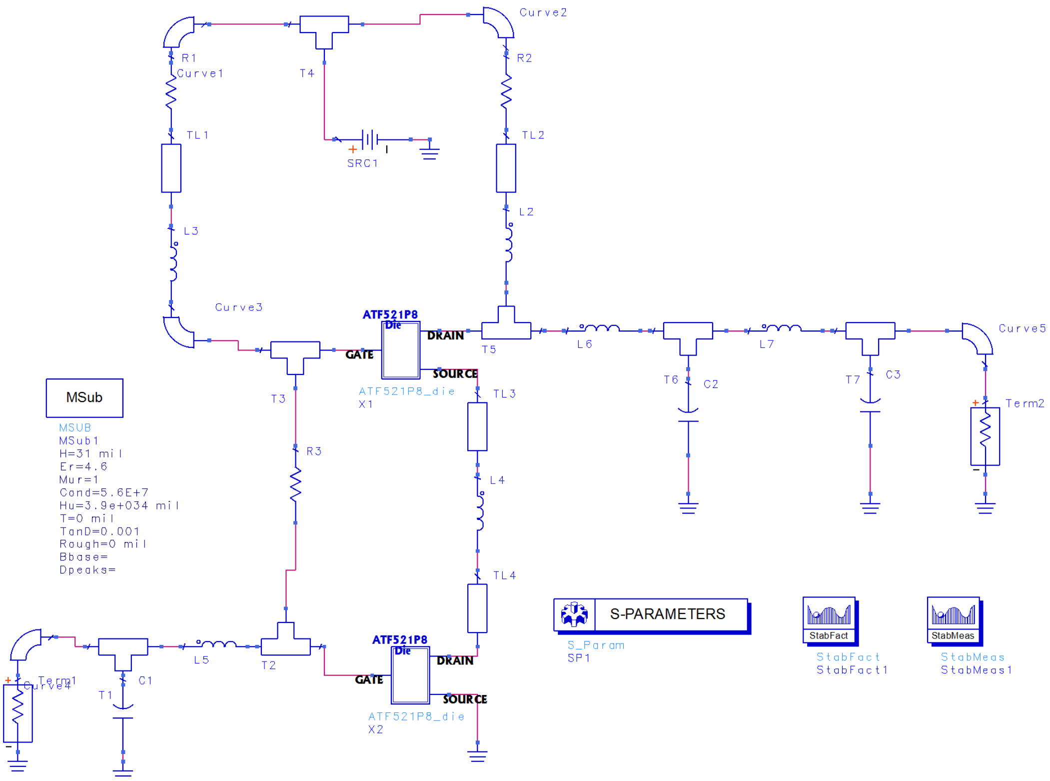

Figure 1. Schematic design Of Low noise amplifier using Cascode technology for MRI Scanner

VI. OPTIMIZATION/TUNING

Sometimes it happens that after designing entire LNA we do not get exact result, at that time we need to optimize our result up to the desired goal, for this purpose optimization/Tuning feature is used in ADS software. Optimization/Tuning feature optimize the values of lumped components to optimize the result. Problems of trade-off between gain and noise figure for LNA get solve by using optimization technique [3].

In our designed LNA, all results are optimized results.

VII. SIMULATION RESULT

Obtained results of designed LNA are shown in the figure's below.

Figure 2 shows Input return loss (S11) and output return loss (S22). Return loss is a measure of how well devices or lines are matched. A match is good if the return loss is high(negative). A high (negative) return loss is desirable and results in a lower insertion loss.Return loss indicates losses of power due to reflection of signal from the ports. High (negative) values of return loss shows reflection of power is less therefore power loss is low. The values of (S11) and (S22) must be equal or less than (-10) dB for good performance of LNA. The obtained value of S11 is (-8.229 dB) near to (-10 dB) and S22 is (-10.207 dB).

ISSN(Online): 2320-9801
ISSN (Print): 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Website: www.ijircce.com

Vol. 5, Issue 2, February 2017

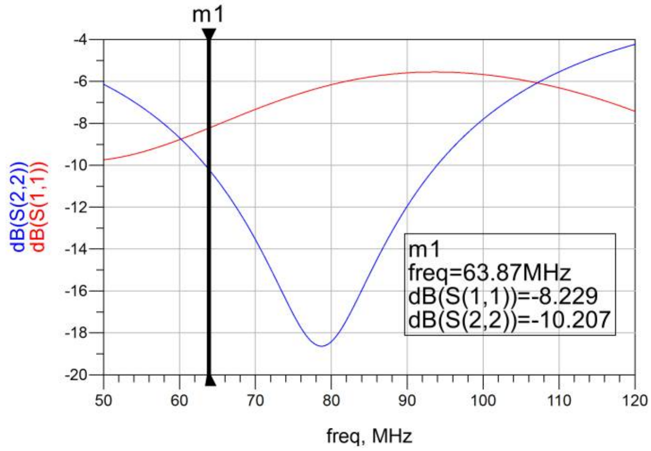

Fig.2. S11 and S22 of Schematic

Figure 3 shows Gain S21 and Insertion loss S12, of designed LNA. Insertion loss is a loss resulting from the insertion of a device in a transmission line, expressed as the reciprocal of the ratio of the signal power delivered to that part of the line following the device to the signal power delivered to that same part before insertion. High value of Gain and very low value of Insertion loss indicate low loss and high transfer of power from input port to output port of designed LNA. The gain achieved S21 is greater than 20 dB and Insertion loss is near to -30dB at 63.87MHz. For Good performance of LNA value of Insertion loss should be very less.

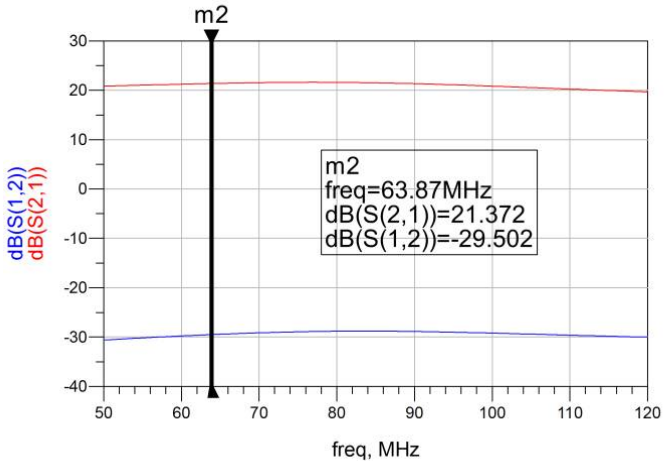

Fig.3. S21 and S12 of Schematic

Figure 4 shows minimum noise figure (Fmin) and noise figure (nf2) of Designed LNA. Noise figure(nf2) of LNA indicates that LNA will provide output signal of noise figure for which it is designed irrespective of noise strength of signal input to LNA ie LNA attenuates the noise signal up to the level it is designed for. The noise figure (nf2) achieved is near to 0.6 dB at 63.87MHz with Bandwidth of 5 MHz.

ISSN(Online): 2320-9801
ISSN (Print): 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Website: www.ijircce.com

Vol. 5, Issue 2, February 2017

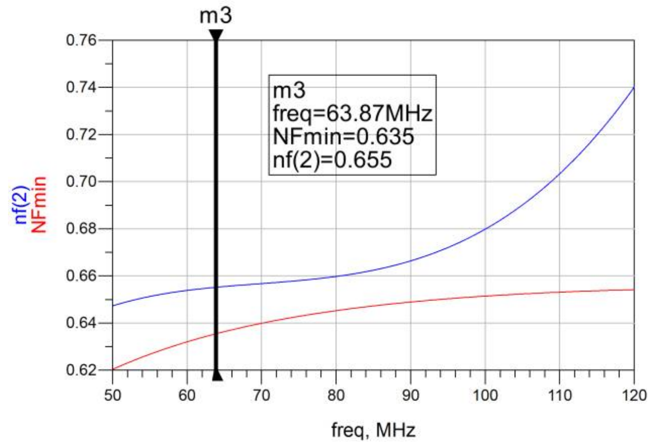

Fig 4. Noise figure(nf2) of Schematic circuit

Figure 5 shows Stability factor (K) of designed LNA. Stability factor indicates system is stable for the desired frequency range ie signal will not oscillate while operation of device in the designed frequency range. For stability of device K should be greater than 1.In our designed LNA K >1 therefore circuit is fully stable at 63.87MHz.

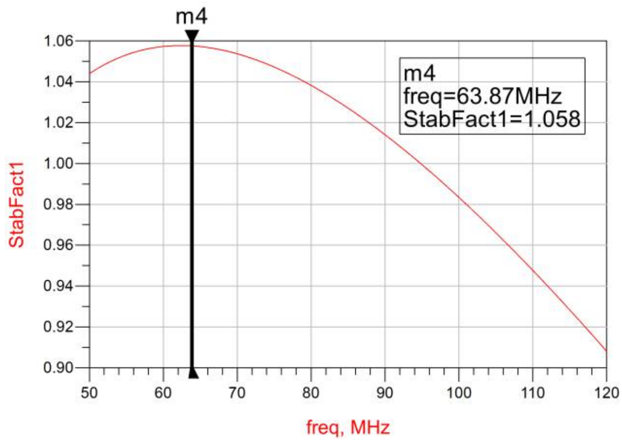

Fig.5. Stability factor K of Schematic circuit.

VIII. CONCLUSION

At a system level, noise figure and Linearity decides receivers sensitivity. A fully integrated LNA for MRI Scanner using cascode technology has been designed by using E-pHEMT GaAs device. Cascode technology provide better stability, better Gain, high linearity and low noise figure. The obtained results are satisfying desired results or near to desired results. Obtained **noise figure** is near to **0.6 dB** by maintaining trade-off with gain and input return loss (S11) at 63.87 MHz frequency with Bandwidth of 5 MHz. **Gain** is **greater than 20 dB** , Input return loss **(S11)** and output return loss **(S22)** are near to **-10 dB**. Value of Rollet's Factor (K) shows designed LNA is Stable at 63.87 MHz frequency with Bandwidth of MHz. Comparison of Expected and obtained results is shown in the table below.

ISSN(Online): 2320-9801
ISSN (Print): 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Website: www.ijircce.com

Vol. 5, Issue 2, February 2017

Parameters	Expected results	Obtained results
S11	≤ (-10) dB	-8.229
S22	≤(-10) dB	-10.207
S21	≥ 20 dB	21.327
S12	≤ (-30) dB	-29.502
Nf2	≤ 0.6 dB	0.655
K	> 1	1.058

IX. ACKNOWLEDGEMENT

I would like to thank Mr. Rajesh Harsh Head of Technology Innovation Division S.A.M.E.E.R. (Society of Applied Microwave Electronics Engineering and Research) IIT Campus, Bombay for his sustained guidance and encouragement on this topic and Dr. Udhav Bhosle, Principal of MCT Rajiv Gandhi Institute of Technology and Kishore G. Sawarkar, HOD EXTC of Rajiv Gandhi Institute Of Technology for their constant source of Inspiration.

REFERENCES

1. Prof. Dr. Hans H. Schild, “MRI made easy”, ©Copyright by Schering AG Berlin/Bergkamen ,1990.
2. Robert H. Coverly , “MRI Fundamentals”, IEEE Microwave Magazine, june 2015.
3. Shailesh H. Yadav, Kishor G. Sawarkar, “Design and Implementation of low noise amplifier for MRI Scanner”, In IEEE Transaction on Recent trend in Electronics, Information and Communication technology (RTEICT)”, page no.769-772, May 2016.
4. Cindy Yuen, Clifford k. nishimoto, Michael w. glenn, Yi-ching pao,Ross a. larue, Robert norton, “A Monolithic Ka-Band HEMT Low-Noise Amplifier”, IEEE transactions on Microwave theory and techniques, Vol. 36,page No. 12, December 1988.
5. Wang Yawei, Yu Weihua, “Design and simulation of W-band LNA”,IEEE ISSN 978-1-4673-6329-7, 2013 .
6. Moumita Bhoumik, “Electrical Characteristics of GaAs Nano- HEMT”,In International Journal of Engineering and Advanced Technology (IJEAT) ISSN: 2249 – 8958, Volume-3, Issue-2, December 2013.
7. Remy Leblance, Ahmed H Akhiray and Sander Weinreb “Noise measurement of HEMT Transister and application to wideband very low noise figure”, In IEEE transaction on Microwave theory and technology, 2013.
8. D.M. Pozar, “Microwave engineering, 3rd edition”, Wiley publication.
9. Guillermo Gonzalez, “Microwave transistor amplifier analysis and design”, Prentice hall, INC., Englewood cliffs, N.J. 07632.
10. J. Staudinger, R. Hooper, M. Miller, and Y. Wei, “Wide Bandwidth GSM/WCDMA/LTE Base Station LNA with ultra-low sub 0.5 dB Noise Figure”, In IEEE Radio & Wireless Symposium 2012, San Jose CA, page no. 223-226, Jan. 2012.
11. ATF-531p8, High Linearity Enhancement Mode pHEMT , Data sheet, Avago Technology.
12. ATF 531p8, “900 MHz High linearity low noise amplifier”, Application Note 1372, Avago Technology.