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High Performance 60 GHz LNA Design for Variable Gain Amplifier by Using 150 nm GaAs Technology

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ABSTRACT: The use of broad bandwidth for multi-gigabit data transmission has been increased widely. The VGA which is nothing but variable gain amplifier has high bandwidth. The 60 GHz band used into transceiver for various high speed communication activities. LNAs are essential building blocks for wireless receivers. The LNA designed with 150 nm GaAs FET technology. LNA designed with IR rejection filter gives 24.964 dB gain and 2.701 dB minimum Noise Figure. The LNA consists of four stages into a cascaded form of common source. 1 V voltage supply requires for circuit operation.

KEYWORDS: VGA (Variable Gain Amplifier), LNA (Low Noise Amplifier), GaAs (Gallium Arsenide), IR (Image Rejection).

I. INTRODUCTION

The need of broad bandwidth for multi-gigabit data transmission has been increased over past few years. The IEEE WLAN 802.11ad amendment has been adopted by the industry under WiGig brand name and integrated into Wi-Fi alliance. WiGig of 60 GHz transceiver is presented in 150 nm GaAs Technology [2]. The transceiver covers the entire 60 GHz band from 55 GHz to 60 GHz. The gallium arsenide transistor functions at frequencies in excess of 250 GHz. GaAs devices are relatively intensive to overheat owing to their wider energy band gap. GaAs is made up of gallium and arsenic and more efficient on high frequency circuit which has faster speed and lower heat generation than silicon semiconductors. For such high frequency rejection, GaAs based many number of devices are used [2].

A variable gain or voltage-controlled amplifier is an electronic amplifier which varies its gain depending on a control voltage. VGA is the critical component in modern wireless transceivers design. Such designs are widely used to provide a fixed output power for different input signals to improve transceivers dynamic range. The gain variation obtained by analog or digital controlled VGA [4]. For the analog VGA requires extra circuitry to generate an exponential function for achieving a dB linear gain.

The Input for VGA is provided by LNA when it is used into receiver section. LNAs are important building blocks of nearly all the wireless receivers. The Noise Figure and gain of LNA play vital role in determining the total Noise Figure of the receiver [5]-[8]. LNA is the a component which amplifies the signal while lowering Noise Figure of high frequency signal so that it is used widely for communication. LNAs are generally connected to the external of RF receiver.

II. RELATED WORK

The LNA shown in following fig.1 which consists of Six CE stages in HB instantiation where five stages are in LB case since CE stage has an inherently more favourable noise measure per stage as compared with that of CB stage configuration in this technology[10]. Three CBEBC HBT transistors in parallel with a normal current density and they are used in the input stage. The matching of CE stages utilize shielded microstrip transmission lines thus minimizing interaction between adjacent components and allowing dense layout with the maintaining good model to hardware

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correlation. For filter out image frequency with minimum loss and maximum bandwidth a fifth order elliptic filter is embedded in LNAs output matching network [10].

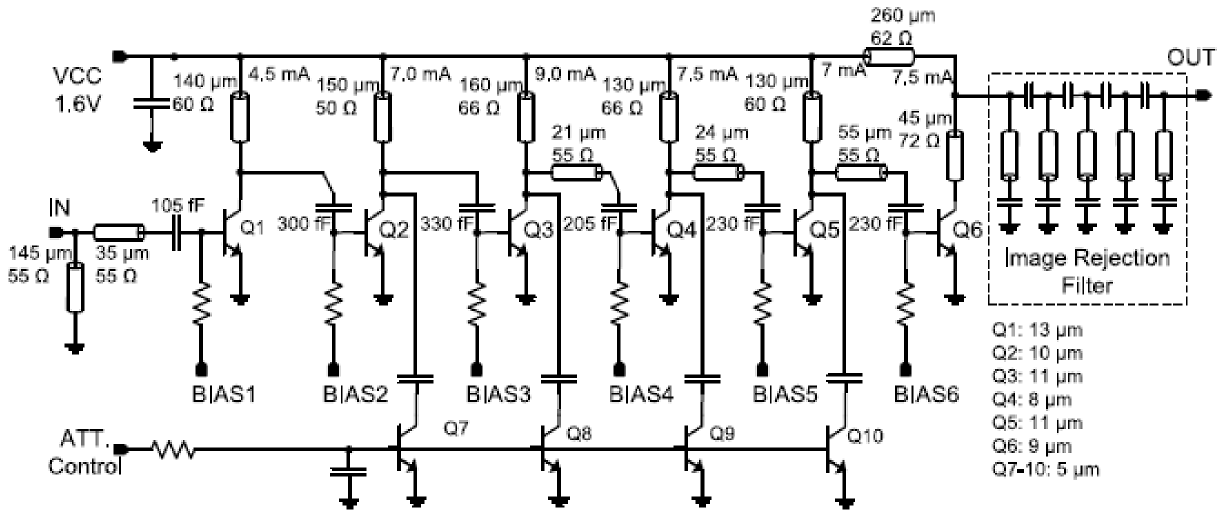

Fig.1. LNA with Attenuator with IR Filter

The following fig.2 shows the schematic of the proposed GaAs EE_FET based on LNA which is composed of three stage cascaded common-source topology. The output of every CS stage has high pass circuit i.e. parallel combination of R and C, which allow only high frequency and for low frequency and for low frequency it will act as open circuit. The common source circuit provides a medium I/O Impedance levels. The 1st stage at the input is used for noise and input impedance matching and stages are designed to achieve output matching with better power gain.

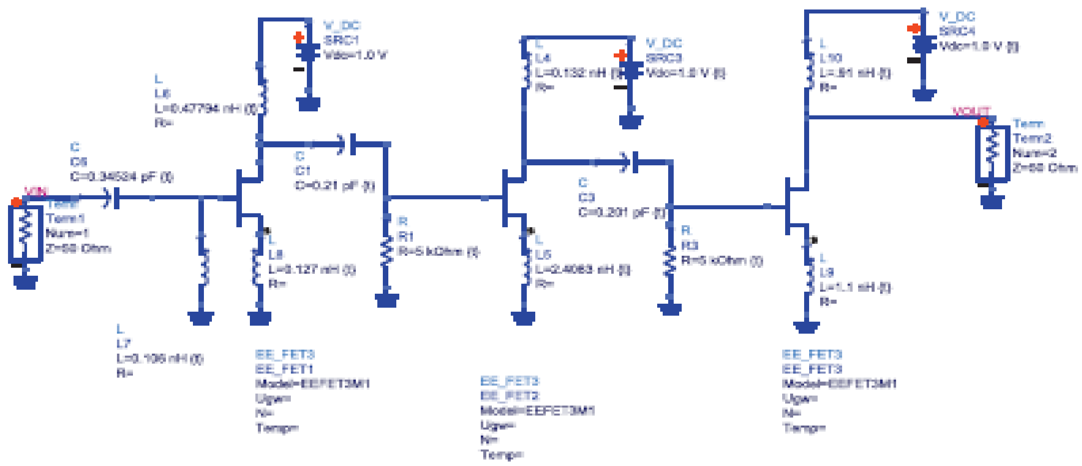

Fig.2. Three stage Non-Linear Based GaAs EE_FET LNA

III. SYSTEM THEORY

The Low Noise Amplifier is commonly used in communication system and it is the 1st stage of the RF receiver and it is commonly used for the amplification of poor or weak received signals. GaAs FET is used mainly for high performance in microwave applications and in semiconductor technology RF amplifier [10]. GaAs is composed of gallium and arsenide and more efficient on high-frequency circuit for fast operation speed lower heat generation than

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silicon semiconductor. Licence free 60 GHz ratio frequency have unique characteristics and it offers several GHz bandwidth for data transmission, the beam width is much narrower and suitable for suitable for short range broadband communication which makes different from traditional 2.4 GHz or 5 GHz license free radio frequency and from licensed-band millimeter wave radios. The block diagram is represented below in fig.3 which gives information about the system overview.

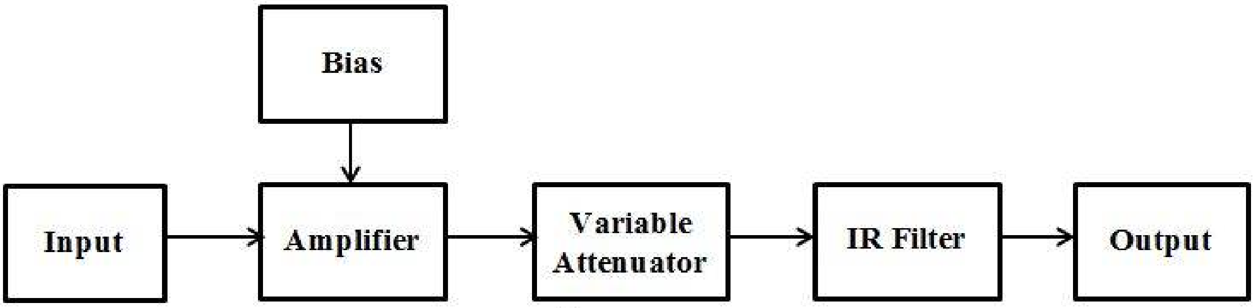

Fig.3. System Block Diagram

The LNA design and IR rejection filter consists of the above blocks. The RF input is provided to the Amplifier. For the further process, four stage amplifiers are used. The Amplifiers used into the four stages are 1st biased. The second and third Amplifiers are connected with the variable attenuator. The output of all such transistors is provided to the IR rejection filter. After the filter the output goes to the other terminals of the receiver.The main circuit diagram is formed by using ADS 2015 software tool.

IV. Design and Implementation

A. *Low Noise Amplifier with Attenuator*

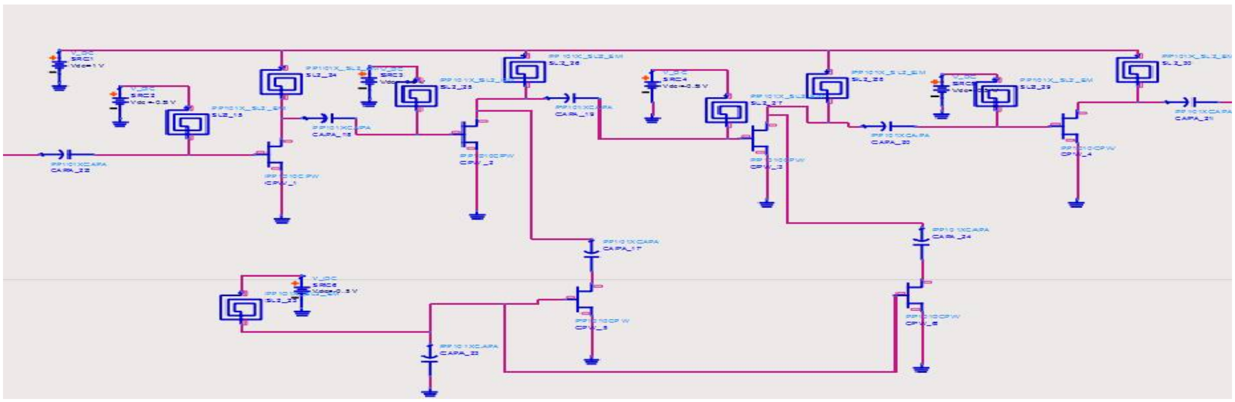

Fig.4. Circuit Diagram of LNA with Attenuator

The LNA shown in fig.4 which consists of four stages of common-source. The 60 GHz frequency has characteristics which has several GHz bandwidth for data transmission.GaAs technology becomes most popular technology for 60 GHz transceiver. GaAs FET based LNA are cascaded with the four stages which acquires better gain, minimum Noise Figure by using low power [5]. The circuit diagram explained with the use of GaAs FET. The LNA is made up of GaAs FET. The LNA is formed with four cascaded common-source topology.

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B. IR Filter

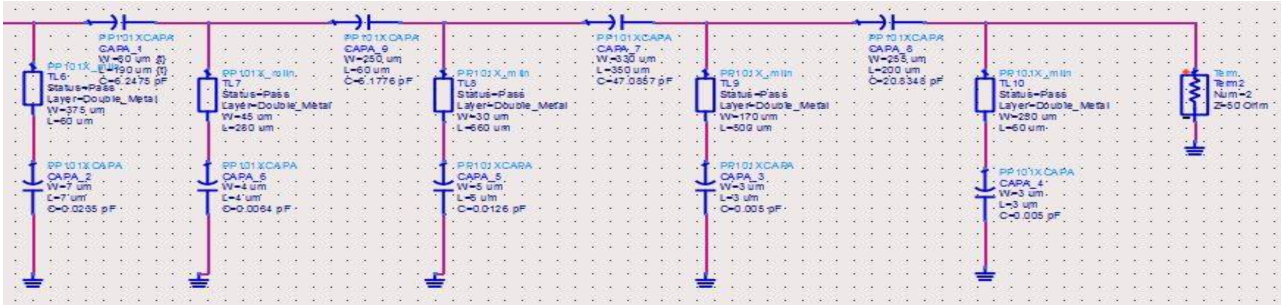

Fig.5. IR Filter circuit

The LNA output connected with the IR Rejection filter is also made up from C and L. To avoid the rejection effects occurs into the mixer so that IR Rejection filter used.

C. Input Matching Network

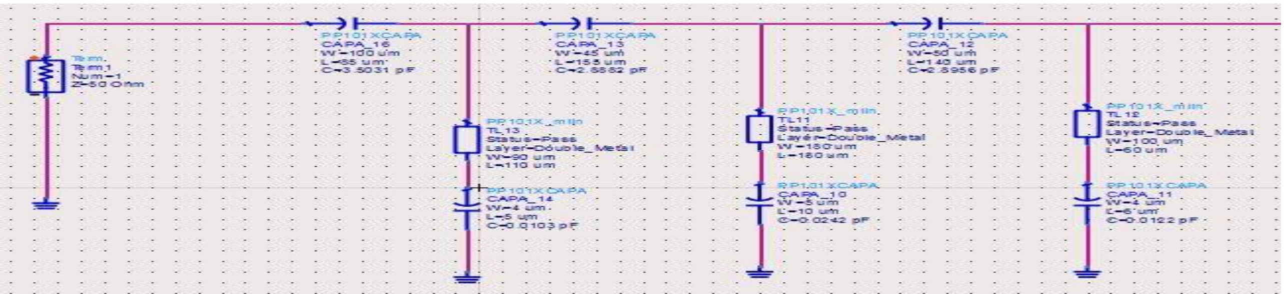

Fig.6. Input matching Network Circuit

The input side of LNA there is combination of C and L. At the beginning input is used for noise and input impedance matching.

V. SIMULATION RESULTS

A. Stability

The stability factor checked and which is represented by K. The K value should be higher than 1 i.e. K>1 for the 60GHz frequency band, so GaAs FET system is stable. The fig.7 and Table-1 shows the stability factor for frequency band of 55 GHz-65GHz. The Table-1 is also shown below consists of values of K at various frequencies.

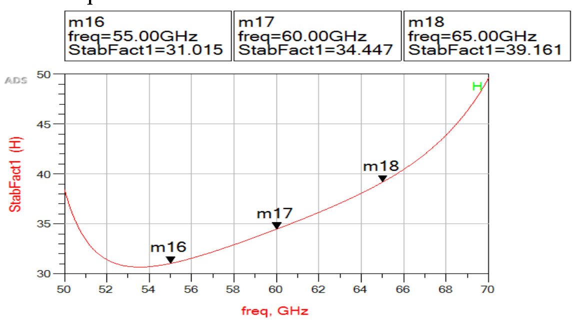

Fig.7. Stability Factor

Frequency (GHz)	Stability Factor
55	31.015
60	34.447
65	39.161

Table-1. Stability

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B. Forward Transfer Gain and Return Loss

Following fig shows that the Input reflection coefficient i.e. S11 which is also known as return loss and its value is less than -10 dB for the frequency spectrum band of 60 GHz. The forward transfer gain indicated by S21 of LNA which is higher than 20 dB for same frequency band spectrum.

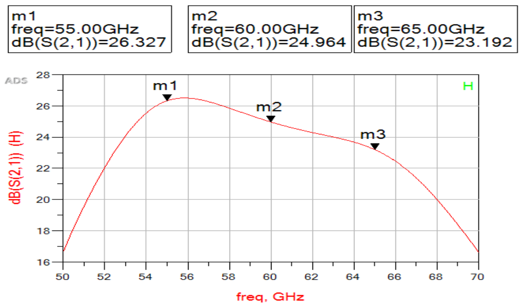

Fig.8 Forward Transfer Gain

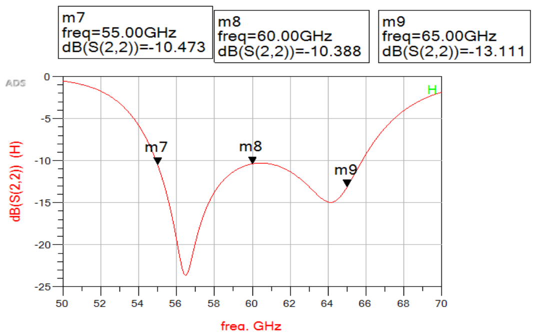

Fig.9 Return Loss

C. Noise Figure

The Noise Figure of this proposed LNA with IR Rejection Filter is described into following fig.10. Noise Figure for the 60 GHz Frequency spectrum band is 2.701 dB.

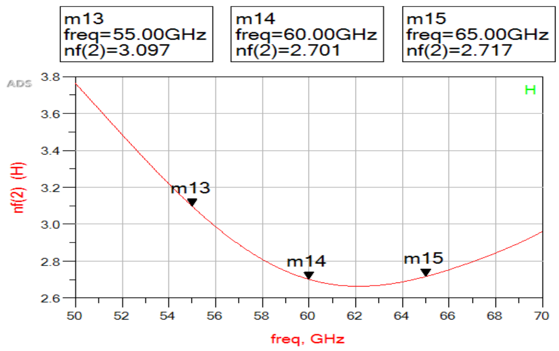

Fig.10. Noise Figure

D. IC Layout

Fig.11. Layout of IC for LNA Design

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Ten pin IC is generated by using ADS 2015 with the 150 nm GaAs IC Technology. The full LNA design is covered into this IC except IR Rejection filter. The whole four stage cascading is covered into this IC Package. The IC is formed with the dimension as (1318μm ×683μm).

VI. Conclusion and Future Work

High Performance 60 GHz LNA for variable gain amplifier using 150 nm GaAs technology with IR filter provides high gain value of 24.964 dB and better stability factor of 34.447 with minimum noise figure of 2.701 dB for 60 GHz frequency. The return loss is less than -10 dB. The system requires 1V of power supply with 16.6 mW of power consumption. The chip area requirement is about 0.90 mm^2. The designed LNA with IR filter has many applications working on 60 GHz unlicensed band for transceiver in communication system.

VII. Acknowledgement

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