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Design of Low Noise Amplifier using MOSFET Transistor for Xband Application

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Abstract **- Maximum power gain and minimum noise figure of are equally important in communication receivers. However both cannot be achieved simultaneously also trade-off between these two gives a complex design. In this project a single stage Low Noise Amplifier (LNA) design using Nonlinear MOSFET model have been proposed for X-band applications like radar, satellite ground station services and Direct Broadcast Satellite (DBS) service. Advanced Designed System (ADS) tool has been used to construct and simulate the circuit. The performance parameters of the amplifier such as Noise Figure, Gain, VSWR, 1 dB compression point, Third Order Intercept point (TOI), Harmonic power levels, Dynamic Range are analyzed by considering all device parasitic elements including package parasitic. A hybrid Microwave Integrated Circuit (MIC) which uses minimal microwave discrete components and micro strip transmission lines for biasing and matching networks have been adopted here. Compared to the High Electron Mobility Transistor (HEMT) with three stages, This LNA based MOSFET design provides 11 dB better gain with single stage. The IIP3 is also well improved to 15 dBm rather than −1 dBm reported. The 1 dB compression range is also quite better as 7 dBm.**

Keywords: Low noise amplifier, ADS, VSWR, X Band application, HEMT, MOSFET.

I. INTRODUCTION

The low noise amplifier is one of the basic functional blocks in radio communication systems. The main interest of the LNA to the input of the analog processing chain is to amplify the signal without adding significant noise so as to allow a better analog and digital signal processing of information by following the modules of the LNA. The general structure of LNA includes an active device characterized by its S-parameters and surrounded on both sides by impedance adaptation networks.

The objective of this paper is to design a broadband low noise amplifier based on MOSFET transistors in the X band with a minimum number of elements such as inductors and capacitors. It gives the satisfactory results when compared with design of LNA with HEMT transistor. So that anyone can easily follow the steps that led to the realization of the final circuit. First, a theoretical study of the circuit will be conducted which is stable and adaptable. Then the simulation of the result is evaluating through the ADS tool. In recent years, there is an ever-growing demand for low-power and low-noise mixed signal integrated circuits for applications in portable medical systems. A high level of system integration is required to implement bio-potential system with mixed signal circuits. The most commonly observed bio-potentials used for medical diagnosis are monitored non-invasively with electrodes placed on the surface of the skin.

X band Low noise amplifiers are designed based on the circuit topology. The Low noise amplifier's presented by Bronskowski topology, and then the design is implemented in ADS using CMOS technology with a supply voltage of 3.3V. It occupies large area and has large power consumption. So, the supply voltage of X band Low noise amplifiers is kept around 1V to ensure less power dissipation, but conventional analog circuit topologies will not work with this supply voltage due to the fact that as the device sizes are scaled down.

The threshold voltage of MOS transistors does not reduce, as this could cause increased leakage currents. This problem can be reduced by using alternate MOSFETS like floating gate MOSFETs, bulk driven MOSFETs and DTMOS. A 1.2V Low noise amplifier has been integrated in a 0.35 μm CMOS process using floating gate input transistors in order to increase the input common mode voltage range of the Low noise amplifier. Due to the capacitive division, the input signal gets attenuated resulting in poor gain& less gain bandwidth product and inferior noise properties.

II. DESIGN OF LOW NOISE AMPLIFIER

Low Noise Amplifier (LNA) is the important basic building block of any analog circuit. The conventional Low Noise Amplifier has a high voltage gain in input stage, and a second stage having high current gain with a last stage is

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called buffer stage. Buffer stage provides small voltage gain and large current gain. The first two stages are responsible for providing the overall voltage gain of the Low Noise Amplifier circuit.

This Low Noise Amplifier circuit sometimes called as the Wilder architecture. Compensating capacitor is placed between the output of the first stage & the input of the second stage. The main sub-circuits namely a differential stage, current mirror, and output common source stage (also called class-A amplifier) utilized in the present design are presented here. The block diagram of LNA shown below.

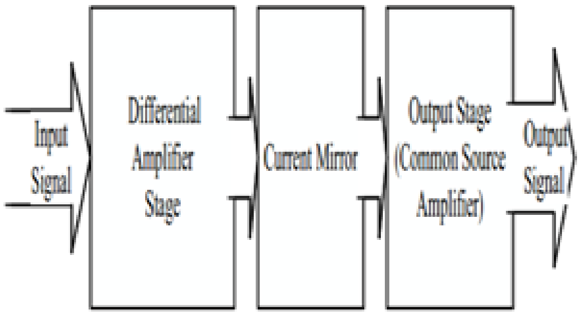

Figure 1: Block Diagram of LNA

2.1 Input stage

The differential amplifier represents the input stage and is the main circuit block of low-power high-gain operational amplifier. The input stage is simple n-channel differential amplifier with current-source loads. This gives the widest possible input common mode range, with enhancement MOSFETs without using the parallel input stage. The p-channel transistors whose source terminals are connected to the output of the differential amplifier are biased so that the voltage across the source-drain terminals of the current-source load. This gives the maximum input common mode voltage and allows the power supply to vary without limiting the positive input common-mode voltage. The differential amplifier stage facilitates in achieving high gain in the system. The inputs are given as out of-phase to the common source NMOS connected in differential form.

2.2 Current Mirror

The high gain of LPHG LNA is because of the current mirror circuit used in between the input and output stages. The current mirror circuit folds the differential-ended output current of the input stage into single-ended output stage. The current mirror circuit forms a cascade current sink and therefore leads to class-A operation, which boosts the overall gain.

The maximum sinking source of current flow in the load capacitor. This increases the output trans-conductance. This current is then used to bias the output stage transistor in to the saturation region, such that the output stage amplifies the single-ended output of the first stage

2.3 Output stage

This stage is implemented using a simple common source amplifier which is also called as class-A amplifier. To reduce the output resistance and increase the current driving capability, a simple approach is to increase the bias current in the output stage. This is effectively achieved by using a simple Class-A at the output stage and using Miller compensation for the second stage gain. The frequency range over a certain Voltage Standing Wave Ratio (VSWR) is known as bandwidth.

Since the bandwidth is a function of the tolerable mismatch, it can vary depending upon the application. The VSWR was not mentioned in the original specifications, but it is one of the most important parameters in antenna design.

Gain states that ratio of the intensity, in a given direction, to the radiation intensity that would be obtained if the power accepted by the antenna were radiated isotropically.

III. DESIGN OF LNA WITH HEMT

Hetero junction field effect transistor (HEMT: High Electron Mobility Transistor) is a component which operates near the MOSFET. The difference is that the HEMT uses a hetero junction, that is to say a junction between materials having different energy bands, consequently when to move the electrons constitute the drain-source current in a non-doped semiconductor, to reduce the transportation time and thus boost the performance in frequency. The rate of electrons is in fact even better than the doping of the semiconductor is small, since the dispersion of ionized impurities is reduced.

In the microwave spectrum of electromagnetic waves 8 GHz to 12 GHz frequency range is classified under X band by IEEE. There are various applications operating under this band like traffic light, detection system, Police Speed RADAR, Radio Navigation, Amateur Radio, etc. The main usage for X band frequencies for these applications is high immunity towards atmospheric attenuation and being robust even in harshest weather conditions. Even in rain, sand storm and other much worse weather conditions there is high link available for the users.

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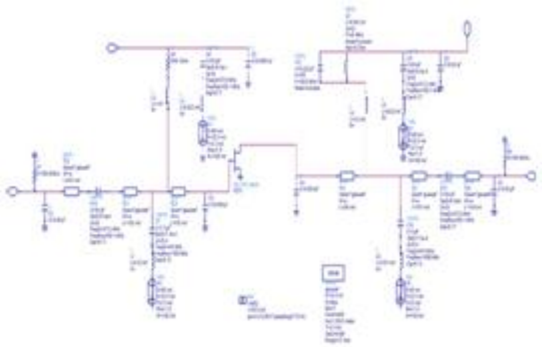

Figure 2: Circuit Diagram for LNA with HEMT

In this project work various low noise amplifiers are designed for X band applications which ranges from 8 GHz to 12 GHz and the center frequency considered is 10.5 GHz. This frequency is used for Police Speed RADAR Application. This technique used to obtain a high power gain of 13.051 dB and optimum noise figure of 1.468 dB and minimum VSWR of 1.007 at the source side and 1.022 at the load side of the amplifier. This point is however very important, because this adaptation derives the optimization of transmitters and receivers hence link optimization. From several lines of investigation have been considered, giving as many procedures to solve the problem. Currently, it is not possible to conclude on the effectiveness or precision of one or other of these methods and to keep only one. Research shows that not everything has been explain about broadband adaptation. It comes usually to determine the values of three or four passive elements, inductors or capacities.

In Figure-2 represents the design of low noise amplifier using HEMT where the RF choke components are connected with HEMT. The lumped components are collected from ADS library. The low noise amplifier is designed using RF choke connected both gate and drain terminal of the active device.

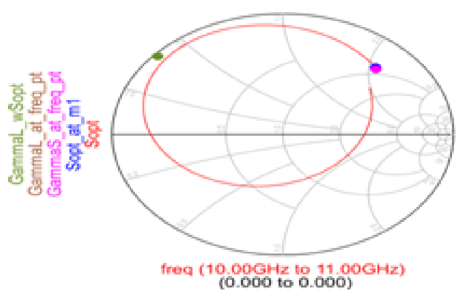

Figure 3: Gain & Insertion loss for HEMT

In Figure-3 x axis represents frequency and y axis represents dB from which we determine the gain and insertion loss. Hence the parameters values are obtained where power gain is 1.4db and the insertion loss is -39.709 db.

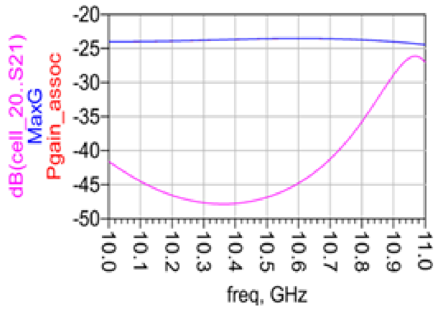

Figure 4: VSWR for HEMT

Figure-4 represents the VSWR and the result of VSWR is 1.92.

IV. DESIGN OF LNA WITH MOSFET

Metal-Oxide-Semiconductor field-effect transistor is a kind of field-effect Transistor (FET), most usually made-up by the controlled oxidation of silicon. It contains an insulated gate, whose voltage determines the conductivity of the device. This ability to change conductivity with the amount of applied voltage can be used for amplify or switch electronic signals. A metal-insulator-semiconductor field-effect transistor or MISFET is a term almost identical with MOSFET. Another synonym is IGFET for insulated-gate field-effect transistor.

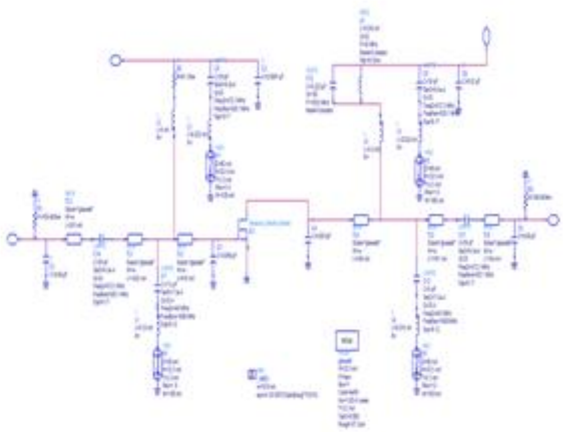

Figure 5: Circuit Diagram for LNA using MOSFET

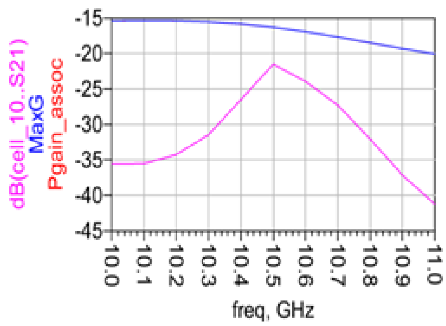

Figure 6: Gain & Insertion loss for MOSFET

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In Figure-5 represents the design of low noise amplifier using MOSFET where the RF choke components are connected with MOSFET. The lumped components are collected from ADS library. The low noise amplifier is designed using RF choke connected both gate and drain terminal of the active device.

In Figure-6 x axis represents frequency and y axis represents dB from which we determine the gain and insertion loss. Hence the parameters values are obtained where power gain is 3.2db and the insertion loss is -45.030 db.

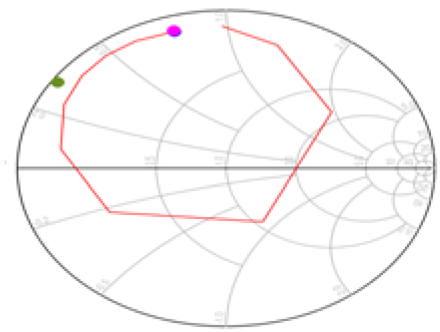

Figure 7: VSWR for MOSFET

In Figure-7 represents the VSWR .The result of VSWR is 1.04.

V. COMPARISON TABLE

TABLE I
Comparison result of two modified transistors

PARAMETERS	GaAs/HEMT transistor	MOSFET
Frequency	10GHz	10GHz
Insertion loss	-39.709 db	-45.030db
VSWR	1.92	1.04
Gain S12	1.4 db	3.2db

VI. CONCLUSION

In this paper work various low noise amplifiers are designed and the results are obtained using ADS software. Different components similar to lumped components, distributed components, and RF choke are used for getting better noise immunity, gain and minimum VSWR. Considering the overall comparison results from Comparison Table, we can conclude that the RF choke designed low noise amplifier is providing better performance such as power gain of 3.2 dB, 1.468 dB noise figure, source side VSWR of 1.007 and load side VSWR of 1.044 which shows that minimum reflections will occur both at the input and output side of an amplifier resulting in maximum power transfer from source to load. The bandwidth constraint in these designs can be solved by implementing multistage cascading techniques in LNA design.

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