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Research paper

A 79GHz Adaptive Gain Low Noise Amplifier for Radar Receivers

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Abstract

This paper presents an Adaptive Gain 79GHz Low Noise Amplifier (LNA) suitable for Radars applications. The circuit schematic is a two stage LNA consists of Differential cascode configuration followed by a simple common source amplifier with an Adaptive Biasing (ADB) circuit. Adaptive biasing is a three- stage common source amplifier to decrease output voltage as input power increases. The circuit is simulated in 180nm CMOS technology and the simulation results have proved that the circuit operates at the center frequency 79GHz with adaptive biasing for adaptive gain. The gain analysis shows a decrease of 35-30dB with an increase in input power -50 to 0 dB. At 79GHz the circuit has achieved the input reflection coefficient (S_{11}) of -24.7dB, reverse isolation (S_{12}) of -3 dB, forward transmission coefficient (S_{21}) of -2.97dB and output reflection coefficient (S_{22}) of -5.62 dB with the reduced noise figure of 0.9 dB and a power consumption of 236 mW.

Keywords: *Adaptive Gain, Adaptive Biasing (ADB), Common Source LNA,*

1. Introduction

Recent advancement in wireless communication circuit design with variety of technologies drives innovative applications. The principle of information transfer through electromagnetic waves had revolutionised the existing wired communications systems. Though there are new emerging wireless technologies, radar stands out for their robustness to all weather conditions. Radars use electromagnetic waves to detect the distinct objects and their range. Basic blocks of the radar [1] are shown in the Fig. 1.
Radar receiver front ends consists of a Low noise amplifier (LNA), a mixer with Local oscillator and an IF amplifier. All radar applications need an LNA to achieve high signal -to -noise ratio at the receiver end. Also, high frequencies are more advantageous for the effective use of radar as they produce better echoes, in turn to detect smaller targets with smaller antennas. Based on recent European Telecommunications Standard Institute (ETSI) rules a small range of frequencies, the 77-81GHz spectrum are made licensed and had a restriction on the average effective isotropic radiated power(EIRP) of -3dBm/MHz [2].

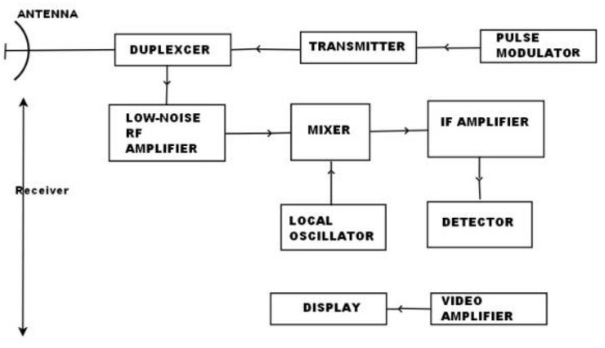

Fig. 1: Block diagram of RADAR Transceiver

The target sensing attribute of radars from a distance if applied to vehicles can avoid road accidents and enhance the security on roads. Automotive applications use radars with simpler front endcircuitry which can be implemented using CMOS technology with lesser area and low power consumption. Adaptive gain radar front-end involves an adaptive gain LNA with ADB circuit, decreases the gain when the input power increases, so as to increase the sensitivity of the system. Long-distance detection, the gain has to be high enough to amplify the weak received signals and to increase the SNR [6]. In contrast, when a radar is used for shortdistance detection, the gain has to be low enough to secure the margin of the input 1-dB compression point (P1dB) because the receiver can be saturated with very high signal powersat 79 GHz. A variable gain LNA is needed. conventional VGLNAs need external control signals to vary the gains, and this increases the complexity of receivers.
Amplifying the received signals without adding noise or reject interfering signals, optimising the probability of detectingthe signal by its bandwidth characteristics and providing a large dynamic range to accommodate large clutter signals are design considerations of radar receiver front end [8].
Low Noise Amplifier (LNA) with low noise figure and high gain increases the sensitivity of the receiver by amplifying the weak signals without contaminating them with noise, helpful for succeeding stages.However, excessive high signal powers at 77–81 GHz will saturate the radar receiver used for short range detection (usually 30meters) [7]. Hence a receiver needs an adaptive biasing technique to operate the radar with a control over the gain as per the target distance with in 30m.
Section II describes the proposed LNA with adaptive biasing technique. The simulation results and discussions are presented in section III and conclusions in section IV.

2. Proposed Low Noise Amplifier With Adaptive Biasing

Amongst all the configurations available to design an LNA, the differential cascode is suitable for the applications where high gain is essential with a less noise [3]. The small signal analysis for the differential cascode gain is shown below equation (1).

$$\frac{V_{out}}{V_{in}} = 2\left[\frac{g_{m1}r_0}{(1+g_{m1}X_{L1})r_0 + X_{L1}}\left[\frac{X_{L3}+\frac{X_{C1}}{2}X_{L1}}{\left(X_{L3}+\frac{X_{C1}}{2}\right)X_{L1}}\right]\right]\left[\frac{(1+g_{m2}r_0)R_2}{r_0+g_{m2}(R_s+2R_1)+R_s-R_2}\right]$$

(1)

A Two Stage DifferentialCascode LNA with an ADB circuit in the second stage is suitable for automotiveradar applications in 77-80 GHz range [4]. The CMOS circuit used in radars gets saturated when input power is high and leads to incorrect range of the object to be detected. This is common phenomena observed in high frequencies of gigahertz range. To solve the problem of saturation a principle of adaptive biasing is introduced in the second stage of LNA[4].

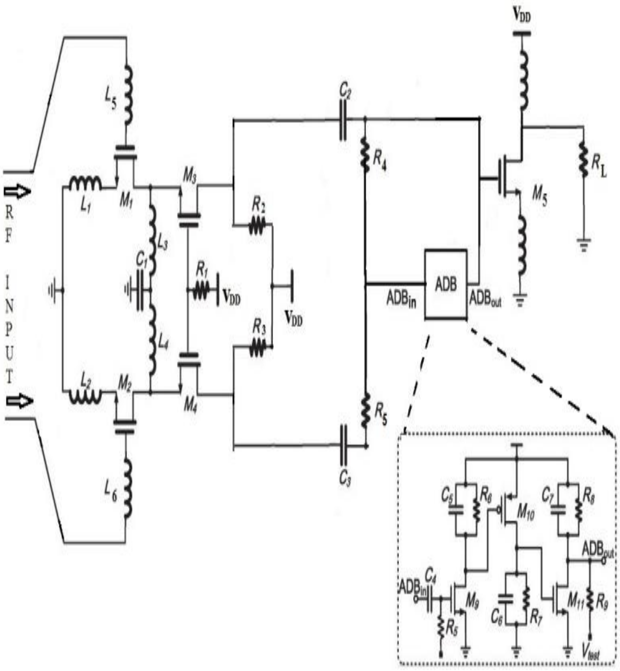

Fig. 2: Circuit Diagram of Proposed LNA

However, there are couple of problems associated with it like overall gain range is reduced, power consumption is increased and large area is needed to constitute two differential stages and two ADB circuits. Thus, the proposed LNA is designed to overcome these challenges. It consists of a differential cascode stage followed by a common source configuration with an ADB circuit as a second stage of LNA as shown in Fig (2).

3. Simulation Results and Disucssion

The proposed LNA is designed in 180nm CMOS technology using ADS (Advanced Design System) tool.

A. Gain Analysis:

The decrease of gain from 35 dB to 30dB with increase in RF POWER,the input power(-50dBm to 0dBm) is observed and shown in Fig. 3 for the center frequency of 79GHz with input and output load as 50Ω. Fig. 4 illustrated output voltage for the input power varying from -50dBm to 0dBm. It has been observed that the output voltage decreases with increase in power.

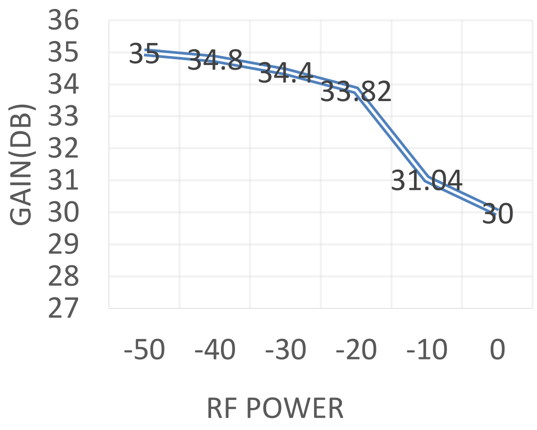

Fig 3: Gain analysis of Proposed LNA

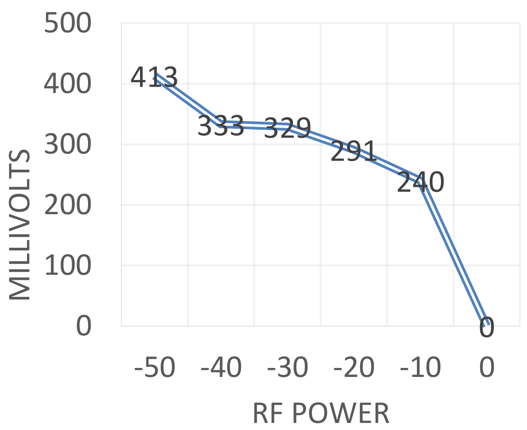

Fig. 4: Output Voltage of Proposed LNA for RF power input

B. S-Parameters:

Input reflection coefficient(S_{11}) defines the input matching of the LNA with source impedance of 50ohms.The proposed LNA has S_{11} of -24.7 dB as shown in Fig.5, at the desired frequency of 79 GHz which shows it as good impedance matching.

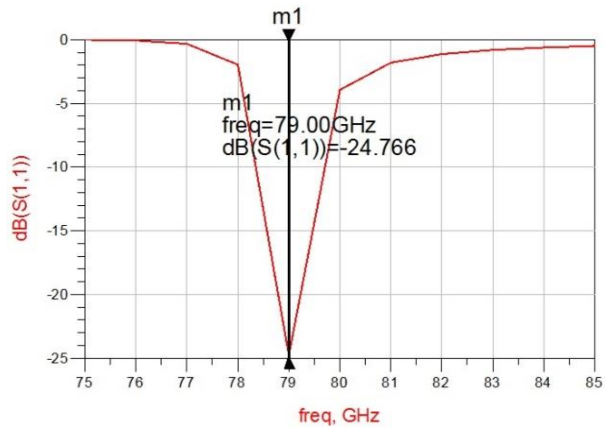

Fig. 5: Input Reflection Coefficient(S_{11})

Reverse Isolation of LNA is the measure of isolation of intermediate frequency components entering back into LNA through any feedback network. The proposed LNA has a reverse isolation of -3dB as shown in Fig.6.The Forward Transmission Gain gives a measure of gain of LNA from input port to output port. For the proposed LNA with ADB circuit S_{21} is -2.97dB which is shown in Fig.7.Output Reflection Coefficient S_{22} defines the output matching of LNA with output termination of 50 ohms. The proposed LNA has output reflection coefficient of -5.6 dB as shown in Fig .8.

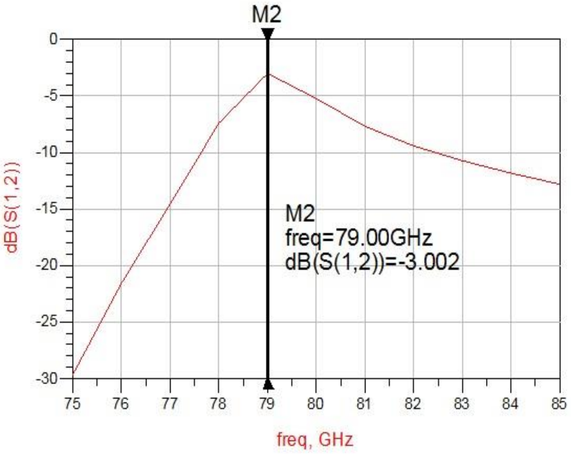

Fig. 6: Reverse Isolation (S_{12})

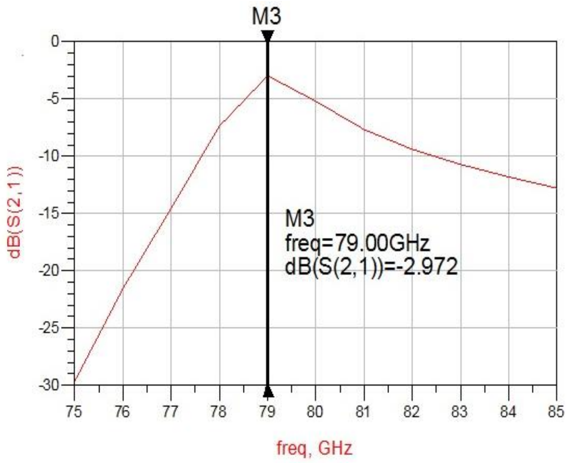

Fig.7: Forward Transmission Coefficient (S_{21})

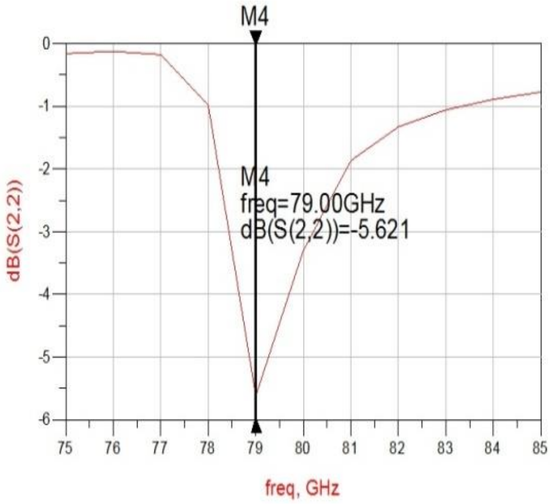

Fig. 8: Output Reflection Coefficient (S_{22})

C. Noise Figure:

For the better performance of radar receiver, LNA should have a noise figure of less than 5dB [4]. The simulation result of noise figure of the proposed LNA has attained 0.9dB, as illustrated in Fig. 9 which proves that the proposed circuit has better noise performance.

NOISE FIGURE :

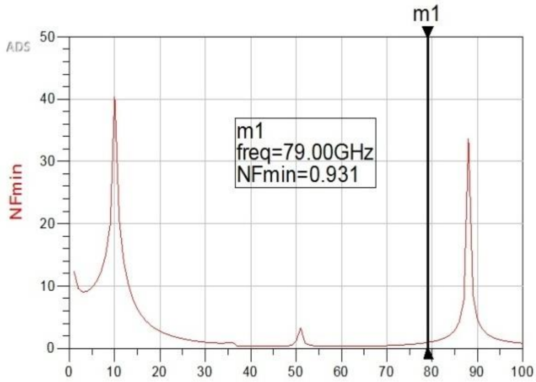

Fig. 9: Noise Figure of proposed LNA

D. Power Consumption:

Lesser Power consumption is one of the aspects of reliability for any CMOS circuits. Power consumption can be reduced by optimizing the design and configuration being used. The common source configuration with an ADB circuit can decrease power consumption to 236 milli watts as shown in Fig.10.The 'power1' is the equation for instantaneous power and 'Pavg2' is the equation of mean power calculated over the instantaneous power(power1) using ADS tool.

For Proposed Design:

Eqn pavg2=mean(power1)

pavg2
0.236

Fig. 10: Power consumption of Proposed LNA.

E. Linearity:

Linearity is often affected by gain compressions and intermodulations. Gain compression (P1dB)is the fall in the small signal gain at high input levels.Fig.11, shows the P1dB of -21 dB of LNA which occurs at -7dB of input power, RF_PWR. Fig. 12 illustrates the 3dB compression point at 7dBm of RF input power.

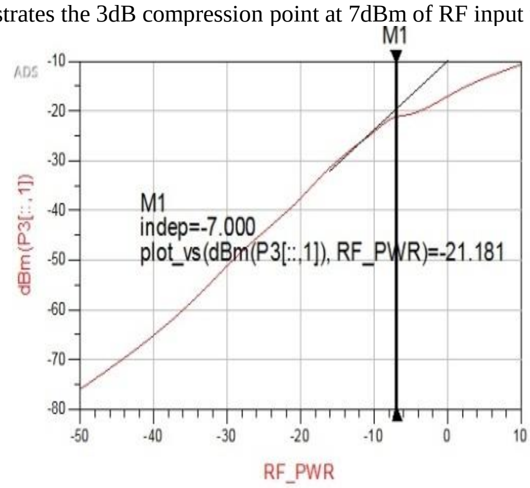

Fig.11: P1dB Compression point of LNA

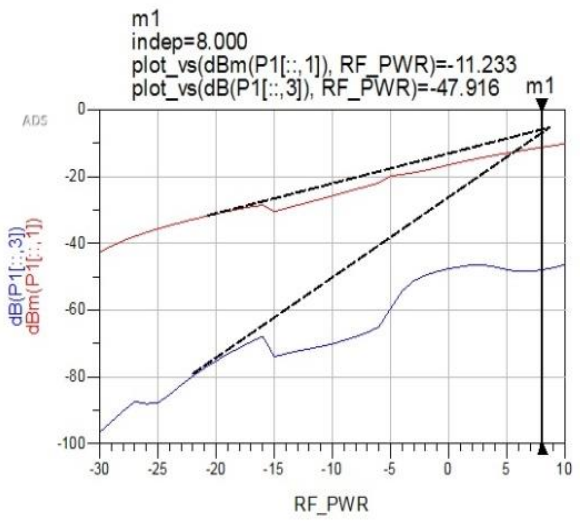

Fig.12: IIP3 of LNA with ADB circuit.

F. Performance Comparison:

The performance comparison shows that the proposed design has attained low noise figure, low power consumption and high gain, which is more suitable for 79GHz radar receiver.Table 1 compares the performance of the proposed LNA with the references [4] & [5]

Table1: Performance comparison of the proposed LNA

References	[5]	[4]	Proposed design
Technology	180nm	65nm	180nm
Frequency Operation(GHz)	76-77GHz	79GHz	79GHz
Voltage Gain(dB)	16	29.9-27.5 RF Power: -50 to 0 dB	35-30 RF Power: -50 to 0 dB
Noise Figure(dB)	13	4.85	0.9
Power Consumption (mW)	-	455	236
ADB Circuit	No	Yes (Two ADB Circuit)	Yes (One ADB Circuit)

4. Conclusion

The proposed LNA design proves that Adaptive biasing circuit has reduced the gain when there is an increase in input RF power, so that the MOS transistor does not get saturated(nonlinear). The proposed design has good noise figure, high gain and good impedance matching and low power consumption. Which satisfies the specifications of European Telecommunications Standard Institute (ETSI) in 79 GHz for automotive applications.

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