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GaAs pHEMT Cascode Low Noise Amplifier for Wireless Applications

Arjuna Marzuki[1], Norhapizin K[2], Amiza Rasmi[2], Mohd Azmi Ismail [2,] Rasidah Sanusi [2], Ahmad Ismat Abdul Rahim[2], Mohamed Razman Yahya[2], Abdul Fatah Awang Mat[2], Zaliman Sauli[3], Ali Yeon Md Shakaff[3]

***Abstract*—This paper presents low noise amplifier (LNA) for wireless application which has been implemented in a 0.15µm GaAs pHEMT technology. The LNA was designed using cascode topology with feedback techniques which produces better gain and good stability over entire frequency. At 2.4 GHz, this amplifier achieves power gain of 23 dB, isolation of 35 dB and input reflection coefficient of -12 dB at 2.4 GHz. With operating voltage supply at 3V, the total current consumptions for the LNA is 18 mA.**

I. Introduction

Nowadays, there have been many extensive studies and efforts to improve the noise figure in RF transceivers. The low noise performance which is crucial for the RF Front-End makes Low Noise Amplifier (LNA) plays an important role in RF transceiver.

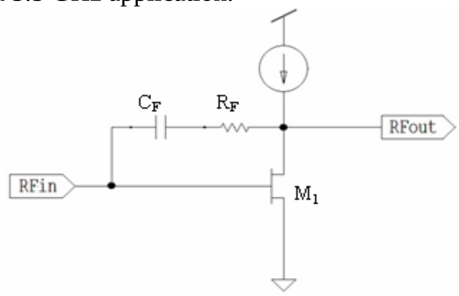
It is often for designing a multi-band, multi-mode IC, reconfigurable reference platform design approach is employed [1]. Several RF front-ends in parallel, each dedicated to a single standard, are usually adopted [1]. Broadband topologies have been proposed to process signals belonging to different standards [2], [3]. The main disadvantages of this approach is stringent linearity requirement

Basically, applying shunt feedback to a common source amplifier as shown in Fig. 1 (a) is a good basic building block for broadband amplifier. This technique allows the amplifier to be matched over a broad bandwidth while having minimal impact on the noise figure of the stage [4].

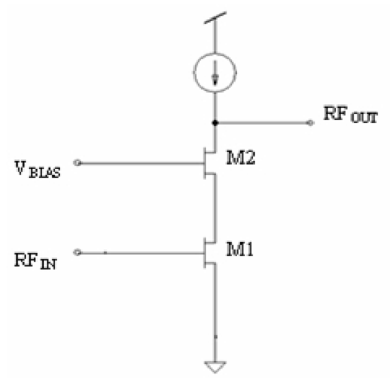
Referring to Fig. 1 (a), the resistor forms the feedback and the capacitor is added to allow for independent biasing of the gate and drain of the transistor. The capacitor can normally be chosen so that it is large enough to be a short circuit over the frequency of interest. This topology offers inferior isolation between output and input.

Fig. 1 (b) shows a cascode topology; here the cascode transistor M2 provides high impedance which isolates C_{GD} of transistor M1 from the output. This cascode transistor provides some isolation between input and output that can increase the stability [5].

In this work, the combination of circuits in Fig. 1(a) and (b) is proposed for LNAs. The work is focused on developing these circuits as core circuit and consequently LNA for 2.4 GHz and 5.5 GHz application.



(a)



(b)

Fig. 1 (a). Common Source Amplifier with Shunt Feedback
(b) Cascode Topology

II. LNA Circuit Design

A. *Core Circuit*

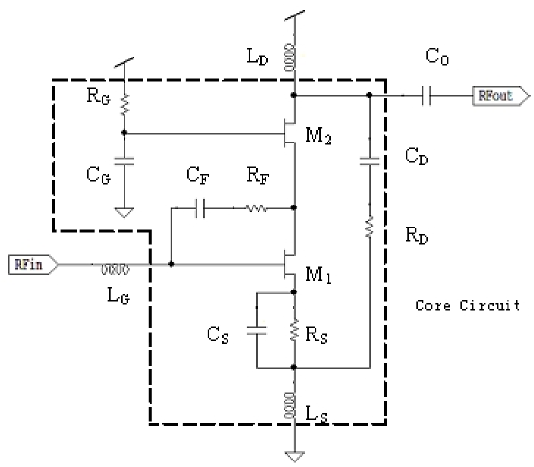


Fig.2. LNA Topology

Fig. 2 shows the schematic of the LNA. C_O, L_G and L_D are matching components for LNA while the core circuit is

1School of Electrical and Electronic Engineering,
2Universiti Sains Malaysia, Seri Ampangan, 14300 Nibong Tebal, Penang, Malaysia.
3Telekom Research & Development Sdn Bhd, Malaysia School of Microelectronic Engineering, Universiti Malaysia Perlis

within the dashed box. M_1 and M_2 are depletion mode devices, R_S is used to set voltage condition at M_1 gate. C_S is used to short R_S at interested frequencies. R_G is used to provide voltage to M_2 while C_G is used to eliminate any noise from the bias network. L_S is used for stability. C_D and R_D is used to further stabilize the LNA core circuit.

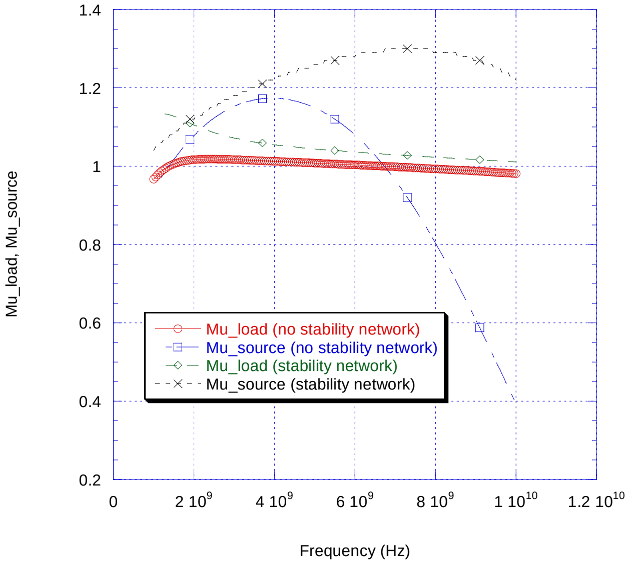


Fig. 3. Mu_load and Mu_source vs. Frequency

Fig. 3 shows the mu_load and mu_source parameters which indicate stability of the core circuit. From Fig. 3, it is obvious that the stability network of C_D and R_D is required to ensure unconditional stable for core circuit for frequency from 1 GHz to 10 GHz.

Fig. 4 shows core circuit of LNA, the test chip is measured and modeled for LNAs design.

B. *LNA Design*

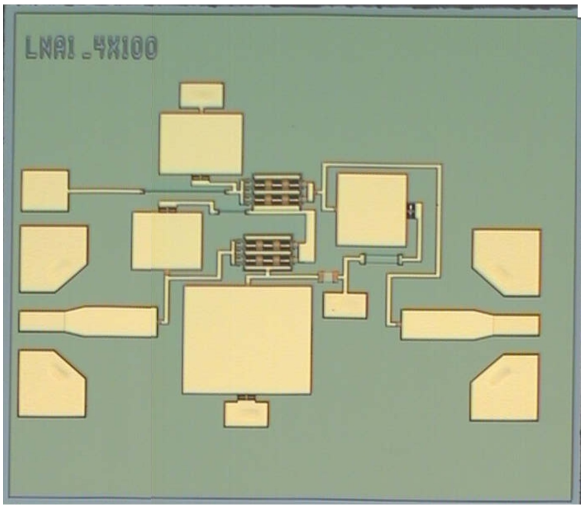


Fig. 4. Core Circuit (Without LS)

For LNAs design, the transistor M_1 and M_2 are Depletion-Mode pHEMT and have a gate width of 100µm and 4 fingers. Transistor M1 and M2 is biased at 0V and 1V respectively. In addition, all the components include inductors are on-chip passive components. Table I shows the simulation results and components value for 2.4 GHz and 5.5 GHz.

The C_F and R_F forms a feedback network for M_1. The feedback offer easy input matching for the LNA. It does degrade noise while improve the linearity. A simple and intuitive gain equation of LNA,

$$A_V = \frac{RF_{OUT}}{RF_{IN}} = \frac{g_{mcs} Z_L}{1 + \frac{Z_L}{r_{ocs}} + sC_{m2-gd} Z_L} \quad (1)$$

g_{mcs} is transconductance of M_1 with feedback network, Z_L is load impedance of the LNA, r_{ocs} is output impedance of the M_1 with feedback network. Obviously, R_F which forms the feedback network will affect the gain of the LNA. From Equation (1), the miller effect due to parasitic capacitance of M1 is eliminated.

III. Experimental results

A fully integrated 2.4 GHz LNA in a 0.15 µm pHEMT with spiral inductor has been designed and fabricated. As shown in Fig. 5, the LNA employ round inductors for matching components and MIM capacitor for output matching.

TABLE I LNAs Simulation Results and Components value

Parameter	2. 4 GHz LNA	5.5 GHz LNA
Gain(dB)	22.34	11
NF (dB)	1.5	1.6
Input P1dB(dBm)	-18	-10
S_{11}(dB)	-11.53	-9.2
S_{22}(dB)	-8	-8
V_{DD}(V)	3	3
I_D (mA)	18	18
R_F(Ω)	1500	1500
C_F (pF)	8	8
R_S (Ω)	50	50
C_S (pF)	33	33
C_D (pF)	10	10
R_D (Ω)	520	520
R_G (Ω)	5000	5000
C_G (pF)	10	10
L_S (nH)	0.3	0.3
C_O (pF)	0.6	0.15
L_D (nH)	6.7	3.7
L_G (nH)	5.2	0.9

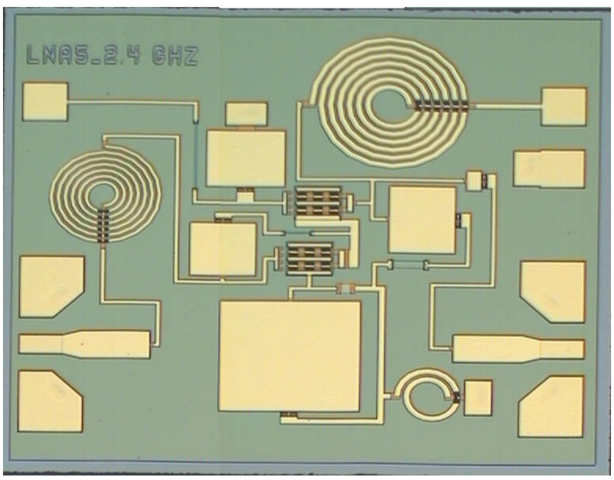


Fig. 5. Die Photo of the 2.4 GHz LNA

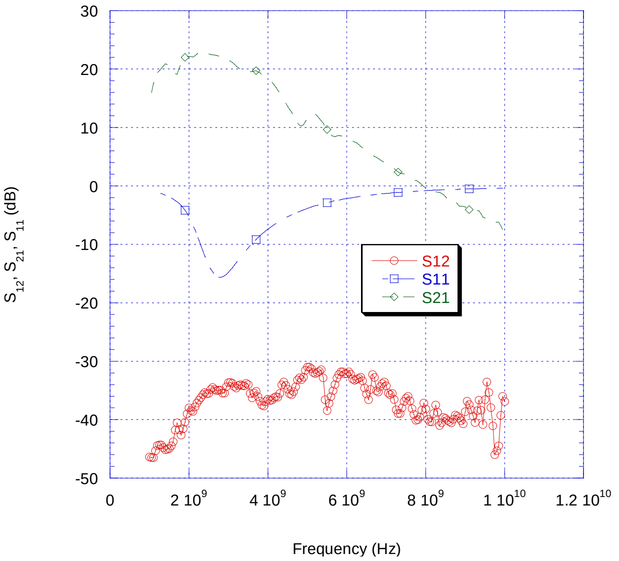


Fig. 6. S-Parameters of LNA

Fig. 6 shows the input reflection coefficient (S_{11}) of the LNA. The S_{11} is lower than -10 dB from 2.3 GHz to 3.5 GHz. The measured gain (S_{21}) is 23 dB at 2.4 GHz. The isolation (S_{12}) is -35 dB at 2.4 GHz. The LNA is biased with V_{DD} = 3V and it consumes 18 mA. Noise figure and linearity measurement is in progress.

IV. Conclusion

A Multiband LNA is proposed. A core circuit is designed and used in multiband LNA design. A fully integrated 2.4 GHz pHEMT LNA with spiral inductor has been designed and tested. The implementation of cascode topology with feedback gives high impact on gain and stability. With the s-parameter result of S_{21} and S_{12} is 23 dB and -35 dB respectively, it has been proven that the implemented topology is successful to reduce input-output coupling while producing high gain. Significant stability improvement has been shown by employing stability feedback network which comprises of capacitor and resistor.

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Arjuna MARZUKI was born in Kedah, Malaysia in 1975. He received B.Eng in electronics from University of Sheffield, UK in 1997 and MSc from Univ. Sains Malaysia in 2004. After graduating with his first degree, he joined Hewlett-Packard as RFIC Design engineer. Currently he is a lecturer in Universiti Sains Malaysia.