Design of Low Noise Amplifier using distributed components for 3GHz applications

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***Abstract*—This work deals with the designing of an efficient low noise amplifier for 3Ghz applications. The amplifier is designed using A TF-55143 GaAs pHEMT device model by Avago Technologies. . LNA should be designed to trade-off noise figure, gain, bandwidth, and return loss. The aims of design are to provide enough gain along with minimum noise figure. The LNA designed operate in bandwidth(2.5GHz to 3.5GHz), Noise Figure (NF) $<$ 1 dB, constant gain $>$ 16 dB and matched over the bandwidth. By using double stub matching, the design gives lowest NF around 1 dB . The comparative analysis of the LNA design is discussed in this work.**

***Index Terms*—Low noise amplifier(LNA), gain, noise figure, 1-dB compression point.**

I. Introduction

A low noise amplifier as its name suggests is an amplifier which minimizes the added noise power and enhances the signal power to optimize the overall SNR of a system. The use of LNAs is very widespread and they are used in all kinds of radio frequency (RF) communications systems to accept the signal at the receiver end of a communication system, which is weak, and then it boosts the signal to a sufficient level while minimal noise to the system. Figure:1 shows the basic design of LNA consisting of source, input matching circuit design ,Dc biasing circuit, output matching circuit design and load.

II. Design Aspects

Advanced Design System (ADS) simulation tool is used for designing the low noise amplifier. The low noise amplifiers are designed with the help of the S - parameters of the active device being used. These parameters are responsible for determining the stability of the device and hence the amplifier. Active device used in this work is Avago technologies ATF-55143 GaAs pHEMT, which is a low noise enhancement mode PHEMT designed for use in low-cost commercial applications in the VHF through 6 GHz frequency range. The ATF-55143 device operates as a normal FET requiring input and output matching as well as DC biasing. Using Agilent Technologies EEsof Advanced Design System Software the amplifier circuit can be simulated in both linear and non-linear modes of operation.

For efficient operation of LNA , the vital parameters to be considered are maximum gain, minimum noise figure (NF_{min}) , return loss, stability .To obtain the bias point (Idd = 30mA, vdd =3V) , gate bias applied is around 0.5236V .The stability in the device is checked using μ-Test and K - Δ test. K - Δ test-A device will be unconditionally stable if Rollet's condition, defined as

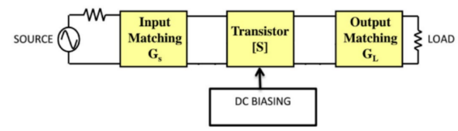

Fig. 1. Single stage low noise amplifier block diagram.

$$K = \frac{1-|S_{11}|^2-|S_{22}|^2+|\Delta|^2}{2|S_{12}S_{21}} < 1$$

Along with the auxiliary condition that $|\Delta| = |S_{11}S_{22}{-}S_{12}S_{21}| < 1$ are simultaneously satisfied.

Condition for stability is that if $K > 1$ and $|\Delta| < 1$ then device is unconditionally stable.

μ-Test- this test combines the S- parameters in a test involving only single parameter μ, defined as

$$\mu = \frac{1-|S_{11}|^2}{|S_{22}-\Delta S_{11}^*|+|S_{12}S_{21}|} > 1$$

where if $\mu > 1$ the device is unconditionally stable.

To design an LNA we are doing optimization between noise figure and gain , noise figure is given by

$$F = F_{min} + \frac{4R_N}{Z_0}\frac{|\Gamma_S-\Gamma_{opt}|^2}{(1-|\Gamma_S|^2)|1+\Gamma_{opt}|^2}$$

From the obtained s parameters, we can obtain Γ_{in} and Γ_{out} as

$$\Gamma_{in} = \Gamma_S^* = S_{11} + \frac{S_{12}S_{21}\Gamma_L}{1-S_{22}\Gamma_L}$$

$$\Gamma_{out} = \Gamma_L^* = S_{22} + \frac{S_{12}S_{21}\Gamma_S}{1-S_{11}\Gamma_S}$$

$$\Gamma_{in} = \frac{Z_L-Z_0}{Z_L+Z_0}$$

$$\Gamma_{out} = \frac{Z_S-Z_0}{Z_S+Z_0}$$

A critical step in any RF design is impedance matching and how efficiently the design is implemented and matched to get the optimum gain and noise at the operating frequency. ADS has “Single stub matching ” and “LineCalc” utilities which were used to match the circuit first at the source impedance

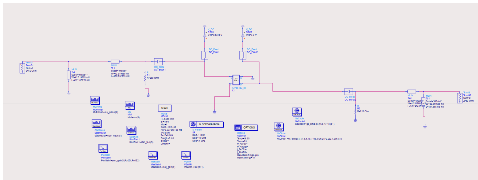

Fig. 2. LNA using distributed components.

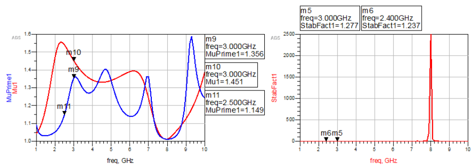

Fig. 3. Stability check.

and then at the load impedance. The values calculated from the ADS utility was also verified by hand calculations. ADS has “HB1tone” and “HB2tone” utilities that where used to calculate 1-dB compression point and third order intercept point.

III. Stimulated Results and Discussion

The low noise amplifier designed is shown in figure:1 The stability factors obtained for complete designed amplifier including the matching network is shown in figure:3 .from the plots it can be seen that in entire band up to 10GHz , both the K and μ values are grater than 1 (means device is unconditionally stable).

Figure:4 shows the noise factor obtained, From plot we see both nf and NF_{min} are around 1 which was required. At 3GHz Nf_{min} is 1.2.

TABLE I

Shows the calculated values of minimum noise figure ,Rn , Sopt at 3GHz frequency before impedance matching.

freq	NFmin	Rn	Spot	freq
3.000 Ghz	1.196	4.086	-0.262+j0.032	3.000 Ghz

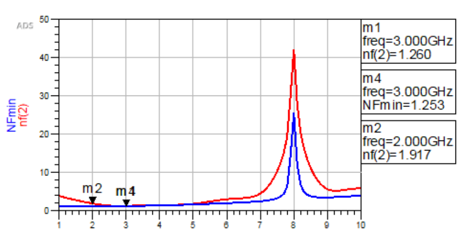

Fig. 4. noise figure

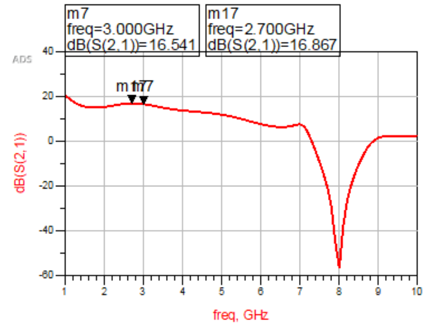

Fig. 5. noise figure

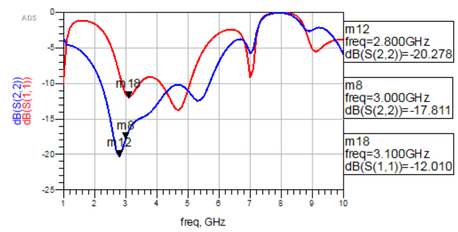

Fig. 6. Return loss

Figure:5 shows the gain plot. In entire band (2.5GHz – 3.5GHz) , the gain is greater than 16dB.

Figure:6 shows the input return loss(S_{11}) and output return loss (S_{22}). Output loss in the 2.5GHz -3.5GHz band is less than $-15dB(-20.278dB$ at $2.8GHz$ and $-17.811dB$ at $3GHz)$ but input return loss is slightly garter than $-15dB$ in this band .

figure:8 shows the output power 1dB compression point . At gain compression of 1.1dB and frequency of 3GHz , 1dB compression points comes out as 17dB.

Figure:9 shows the calculated output third order intercept (TOI) point . At frequency of 3GHz , the value comes out 24.277 dBm

TABLE II

SUMMARY OF LNA PERFORMANCE AND COMPARISON TO PREVIOUSLY PUBLISHED DESIGNS.

Ref.	Technology	Freq(GHz)	Input Return	Output Return	Gain	NF(db)	Op1(dBm)	TOI(dBm)
This Work	$ATF-55143GaAspHEMT$	$2.5-3.5$	<-14	<-15	>16	1.1	17	24.277
[1]	$0.13umCMOS$	$0.1-6.5$	-10	–	19	4	–	-6.7
[2]	$0.13umCMOS$	$0.2-3.8$	-9	–	19	3	–	1
[3]	$(PHEMT)ATF-36163$	$2-4$	-24.3	-23.03	21	0.662	–	–
[4]	$0.2umGaAsHBT$	$1-6$	-10	-11	29.1	<4.3	–	–

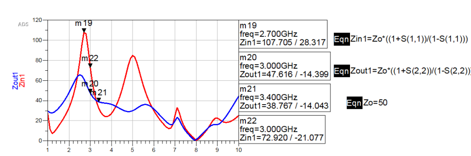

Fig. 7. input/output impedence.

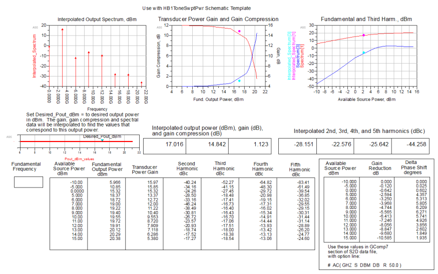

Fig. 8. Output power 1-dB compression point OP1dB (dBm)

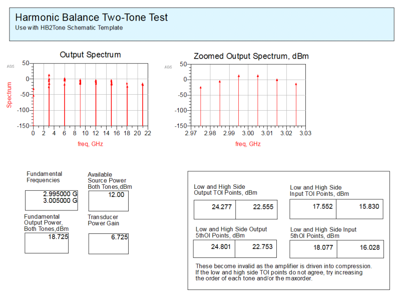

Fig. 9. Output Third Order Intercept (TOI) point (dBm).

IV. Conclusion

The design of low noise amplifiers are performed in ADS software and the results are obtained. The LNA designed operate in bandwidth(2.5GHz to 3.5GHz), Noise Figure (NF) is around 1.2 dB at 3GHz frequency, constant gain $>$ 16 dB is obtained and matched over the bandwidth. The input return loss is around 13dB and output return loss is less than -15dB in the range 2.5GHz -3.5GHz . the 1dB compression at 3GHZ is at 17dB and TOI at 24.277dB.there is trade off between the noise figure and return loss. Also trade-off was found between third intercept point and noise figure.

V. Refrences

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