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A Review on Performance Analysis of Unilateral & Bilateral Methods of Microwave Amplifier Based on S-Parameters

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Abstract— The main objective of this paper is to design a Low Noise Amplifier (LNA) providing desired gain using smith chart & S- parameters based techniques using unilateral figure of merit &bilateral figure of merit methods (whichever is applicable after calculation)comparitively . Here a LNA is designed &simulated to obtain an optimum gain with minimum noise figure for WiMAX application at center frequency 3.5GHz with noise figure targeted are less than 2 dB while gain is more than 10 dB using one of the stated methods. The entire simulation & design is carried out with the AWR Microwave Office design tool and the simulation results for each of the stages are clearly presented. For optimization of gain and noise figure techniques are implemented viz. Feedback & Balance Amplifier.

Keywords— WiMAX, Low Noise Amplifier, AWR Microwave Office, Noise Figure , Bilateral,Unilatrral.

I. INTRODUCTION

Solid-state microwave amplifiers play an important role in communication where it has different applications, including low noise, high gain, and high power amplifiers. The high gain and low noise amplifiers are small signal low power amplifiers and are mostly used in the receiver side where the signal level is low. The small signal S parameter can be used in designing these low power amplifiers. The high power amplifier is used in the transmitter side where the signal should be at a high level to cross the desired distance.

1.1 Scheme of Implementation:

The key to obtaining low noise in an amplifier is the type of transistor that is used in the design. The most common types of transistors used in LNAs at microwave frequencies are gallium arsenide field-effect transistors (GaAs FETs) and high electron mobility transistors (HEMTs). Gallium arsenide is preferred over silicon due to its superior performance at microwave frequencies.

The final stage of design involves building matching networks around the transistor which optimize the transistor for best noise performance. Transistor ATF-54143 S parameter model from Avago Technology is used to design & simulate the LNA as it meet the specifications and recommended by Avago Technology . Amplifier can be considered as a two port network.

II. LITERATURE REVIEW

Giancarlo Lombardi, et al. [1] Presented the paper "Criteria for the Evaluation of Unconditional Stability of Microwave Linear Two-Ports:A Critical Review and New Proof". A critical review of the different criteria used to verify the unconditional stability of active two-port networks has been presented. The problem of unconditional stability for active two-port networks has been widely discussed in literature. A geometrical condition involving the stability circles and the Smith circle is generally found.

M.H. Misran, et al. [7] Presented the paper "Design of LNA for WiMax Application".He designed a single stage LNA by adding an input and output matching and DC bias in the transistor. The LNA design is test with two technique of broadband amplifier design which is a Feedback Amplifier and Balance Amplifier. For input and output matching of the component, microstrip stub element matching is used. The length and distance of the stub matching are found by calculation. The gain and noise figure are affected when the stub matching element is inserted in the design. From two of the design, the Feedback Amplifier design gave the best performance. George Fikioris, et al. [3] presented the paper "Analytical Studies Supplementing the Smith Chart". This paper is an analytical study focusing on formulas that can enhance understanding of transmission lines. In deriving the formulas, mathematical techniques that can benefit students are employed. Also smith chart & some basic problems connected to lossless terminated transmission lines were studied analytically.

III. UNILATERAL VS. BILATERAL METHODOLOGY

3.1Actual Methodologies:

The amplifier could be matched for a variety of conditions such as low noise applications, unilateral case and bilateral.

A. Unilateral Assumption

$$U = \frac{|S11||S12||S21||S22|}{(1-|S11|^2)(1-|S22|^2)}$$

$$\frac{1}{|1+U|^2} < Gt\backslash Gtu(max) < \frac{1}{|1-U|^2} \text{........(3.2.1)}$$

If error lies in $\pm 0.5\ dB$ unilateral mode is valid otherwise its case of bilateral design. In the unilateral case, we set

$$S12 = 0$$

B. Bilateral Assumption

The relation for Γ_S is,

$$\Gamma_S = \frac{B_1 \pm \sqrt{B_1^2 - 4|C_1|^2}}{2C_1} \text{ ......(3.2.2)}$$

Where, $B_1 = 1 + |S_{11}|^2 - |S_{22}|^2 - |\Delta|^2$ ...... (3.2.3)

$C_1 = S_{11} - \Delta S_{22}^*$ ...... (3.2.4)

Similarly, we obtain Γ_L as,

$$\Gamma_L = \frac{B_2 \pm \sqrt{B_2^2 - 4|C_2|^2}}{2C_2} \text{ ......(3.2.5)}$$

Where, $B_2 = 1 + |S_{22}|^2 - |S_{11}|^2 - |\Delta|^2$ ......(3.2.6)

$C_2 = S_{22} - \Delta S_{11}^*$ ......(3.2.7)

IV. THE DESIGN APPROACH OF LNA

The drain source current was chosen to be 60 mA with a 3 V drain-to-source voltage, the gate-to-source voltage was 0.59 V. The S-Parameters for centre frequency 3.5 GHz

$S_{11} = 0.59531 < 149.49^0$

$S_{12} = 0.084715 < 21.523^0$

$S_{21} = 4.4315 < 42.261^0$

$S_{22} = 0.09583 < -169.43^0$

Step1:

K – Δ Test

$\Delta = S_{11}S_{22} - S_{12}S_{21}$

$\Delta = 0.373 < 107.4$

$\Delta = 0.3735 < 107.4^0$

$$K = \frac{1 + |\Delta|^2 - |S11|^2 - |S22|^2}{2|S12S21|}$$

K=1.033

As K>1, Δ<1 DUT is unconditionally stable.

Step2: Unilateral Assumption

$$U = \frac{|S11||S12||S21||S22|}{(1-|S11|^2)(1-|S22|^2)}$$

On Substitution values, we get

U=0.04

$\frac{1}{|1+U|^2}$=10log (0.90) = -0.59dB & $\frac{1}{|1-U|^2}$ = 10log (1.10) =0.63 dB

As error does not lie in $\pm 0.5\ dB$ .So unilateral mode is not valid .So it is the case of **bilateral design**.

Step3: Matching network designed using stub

So using bilateral method,

From equations (3.2.2) to (3.2.7),

Γ_L = 0.671<100.5

Γ_S = 0.847< -152.8

A microstrip stub element matching is used in both the input and output of the LNA. To design the stub matching, the length of the stub, *l* and the distance of the stub from the load, *d* need to be found.

V. SOFTWARE ASPECTS: SIMULATIONS.

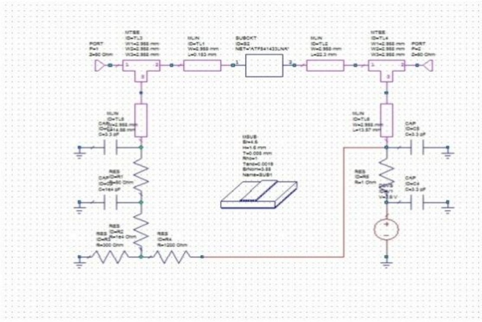

Fig 5.1: Simple LNA using AWR

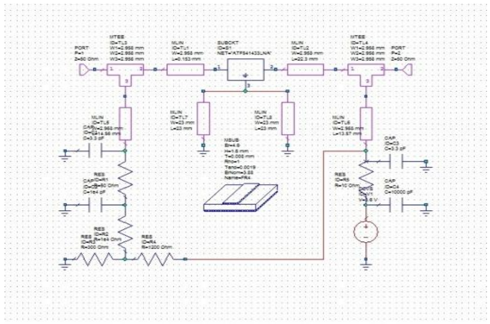

Fig 5.2: With Feedback Amplifier (Without VIA)

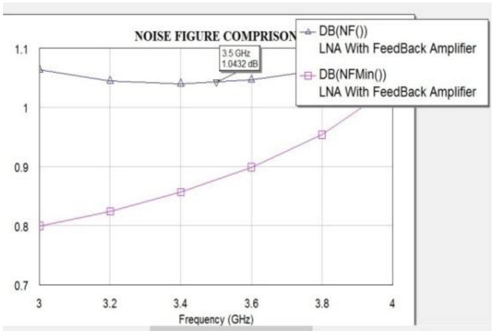

Fig 5.3: Without VIA NF Analysis

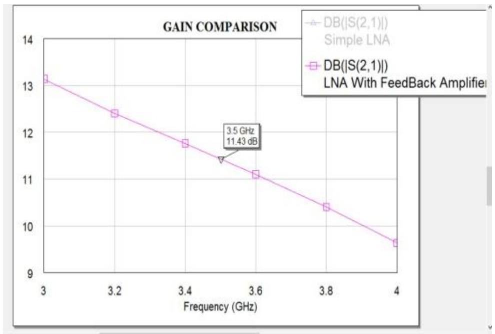

Fig 5.4: Without VIA Gain Analysis

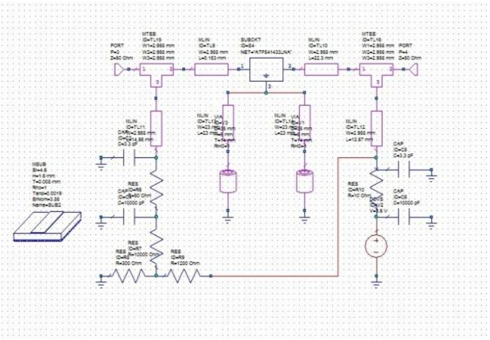

Fig 5.5: With Feedback Amplifier (With VIA)

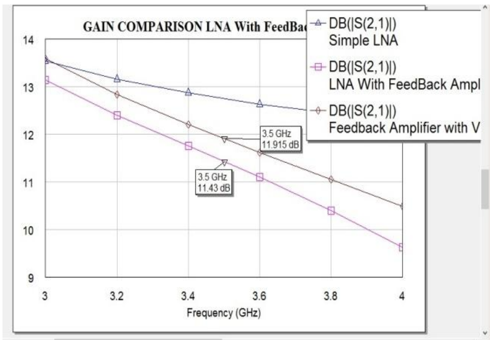

Fig 5.6: With VIA Gain Analysis

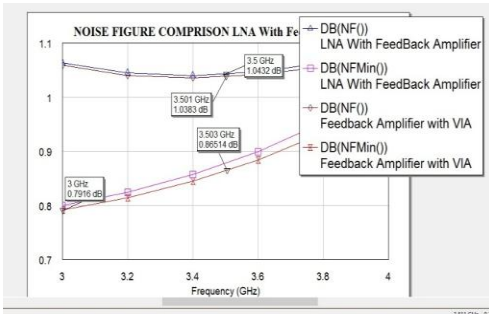

Fig 5.7: With VIA NF Analysis

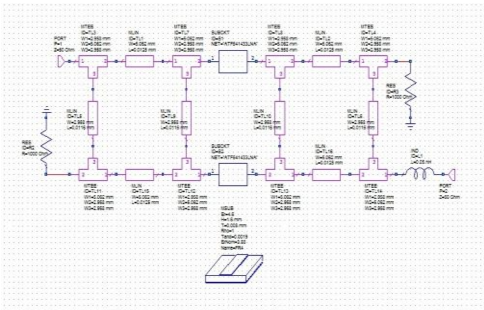

Fig 5.8: LNA with Balance Amplifier

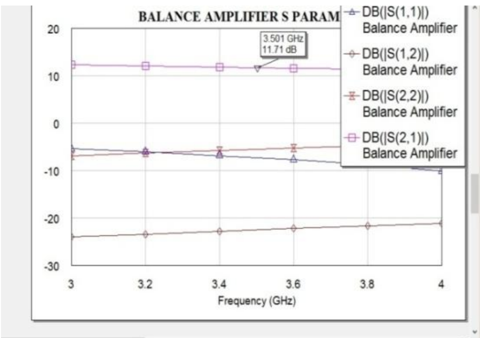

Fig 5.9: Gain Analysis Balance Amplifier

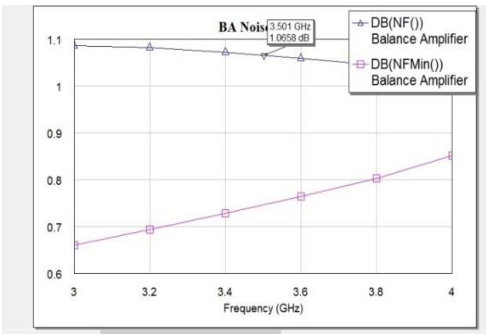

Fig 5.10: NF Analysis Balance Amplifier

VI. CONCLUSION AND FUTURE WORK

For input and output matching of the component, microstrip stub element matching is used. The length and distance of the stub matching are found by calculation. The gain and noise figure are affected when the stub matching element is inserted in the design. The calculations done are using the center frequency which is 3.5 GHz.

The methods of the amplifier designing was studied . A single stage LNA is designed using bilateral figure of merit starting from S-parameters.For optimizing LNA performance two technique of broadband amplifier design which is a Feedback Amplifier and Balance Amplifier implemented. From these two designs, the best technique applied is Feedback Amplifier with VIA, which gives the most satisfactory results for its gain and noise figure.

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