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Design of Pseudomorphic High Electron Mobility Transistor Based Ultra Wideband Amplifier Using Stepped Impedance Stub Matching

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Abstract: - In this paper, the design of an ultra wideband low noise amplifier using pseudomorphic high electron mobility transistor is described. The amplifier achieves a flat gain across the bandwidth and has minimized input and output return loss. The circuit also has a very low noise which is less than 2 dB. A detailed design is carried for low noise amplifier and simulated on serenade simulation tool. The amplifier is fabricated on RT duroid substrate (ε_r=2.2) and the results of simulated and fabricated amplifier have been compared. Impedance matching is achieved using a stepped impedance stub. The amplifier also consumes very low power for operation.

Keywords: *– High Electron Mobility Transistor, Stepped Impedance Stub, Ultra Wideband*

I. INTRODUCTION

The introduction of the paper should explain the nature of the problem, previous work, purpose, and the contribution of the paper. The contents of each section may be provided to understand easily about the paper. Ultra wideband amplifier technology is a short range communication technology that uses low power and operates in 3.1 to 10.6 GHz band. UWB is able to transmit more data in a given period of time than the more traditional technologies such as WLAN, Bluetooth etc. The potential data rate over a given RF link is proportional to the bandwidth of the channel and the logarithm of the signal-to-noise ratio (Shannon's Law) [1]. UWB can transmit and receive wireless signals at rates in excess of several hundred of Mbits per second, while consuming a small amount of power without interfering with existing communications signals. UWB application is not limited to wireless; the technology is used for medical imaging, automotive radars, and security systems applications.

Microwave amplifiers are a necessary building block in designing of any microwave transmitter, receiver or trans-receiver circuit. Microwave amplifiers require matched termination rather than open or short circuited termination that is characterized by S- parameters. S- Parameters can be used to express many electrical properties such as gain, return loss, Voltage standing wave ratio (VSWR), reflection coefficient and amplifier stability.

Previous work on ultra wideband amplifier show different technologies that are used for its design and implementation. A low noise amplifier was designed using a reactive feedback technique in 0.13µm CMOS technology . The idea was to use reactive feedback to reduce the noise levels and stabilizing the gain. The amplifier was designed using a cascode gain cell, input filter and output buffer and a negative feedback was applied to that.[2]. In [3], a low noise amplifier in common-gate configuration was designed. In this the reactive matching was extended to wideband matching using butterworth filter. Another low noise amplifier in 130 nm CMOS was made using current reuse technique and worked in 3 to 5 GHz band. The authors used LC band pass filter for input matching of the amplifier.[4] Letter on ultra wideband high gain GaN power amplifier is studied. The letter proposed a three stage power amplifier with feedback design for better gain and output. The GaN HEMTs which require low power have been used to design the amplifier[5]. Since, the GaN HEMTs have high voltage and high power density capabilities; therefore, they are used in designing of power amplifiers [6]. An ultra wideband amplifier was designed using an ERA- 1 amplifier and study was based on the designing of

UWB amplifier using MMIC. The source amplifier used roll off and power supply circuit to get low noise [7]. For Our designed amplifier, The source is matched to load using stepped impedance stub. The amplifier thus designed is simulated in serenade and fabricated on RT duroid substrate with dielectric constant of 2.2.

II. AMPLIFIER DESIGN

An Ultra-wideband (UWB) low-noise amplifier (LNA) is usually the first stage of an UWB receiver. As approved by the FCC, the UWB receiver has a 3.1-10.6 GHz frequency range and so our UWB LNA design will focus on this bandwidth. The UWB LNA is designed to amplify the weak incoming RF signal without adding significantly to the noise level. To meet this requirement, the noise figure of a UWB receiver should normally be less than 7 dB.

The amplifier is designed using the concepts of two port network. The schematic of the amplifier and the designed structure is shown in figure 1 (a) & 1(b).

The first step in designing of the amplifier is choosing a perfect active device that has a good wideband working range. For the designed amplifier, NE3201S01 which is a pseudomorphic Hetero-Junction FET that uses the junction between Si-doped AIGaAs and undoped InGaAs to create very high mobility electrons. It has a gate length Lg ≤ 0.20μm and gate width Wg = 160 μm.

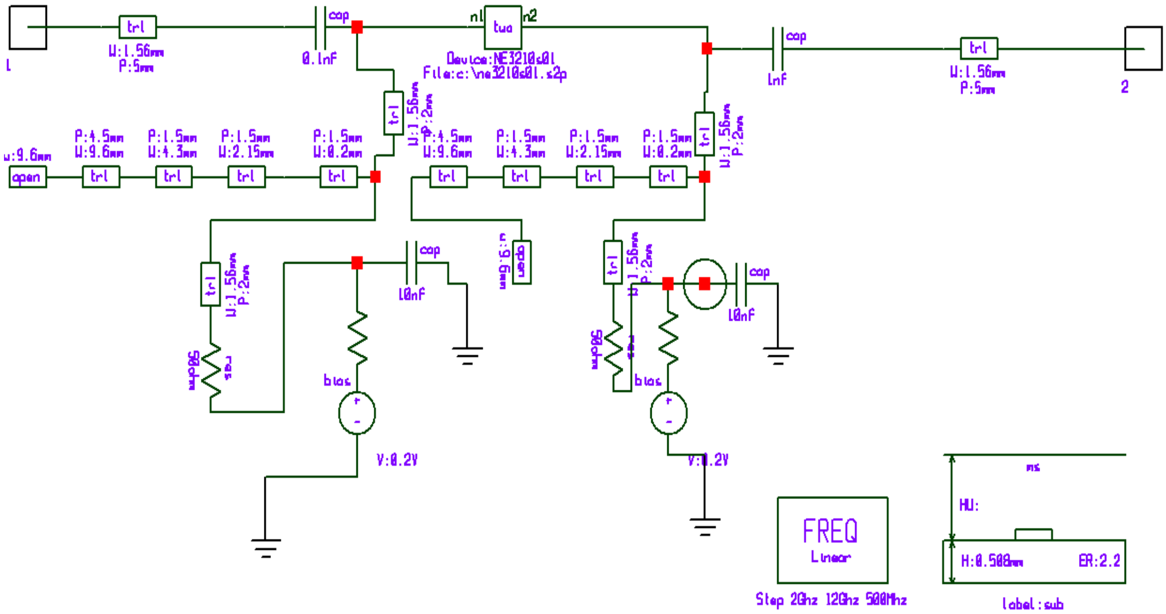


Fig. 1(a) Ultra wideband amplifier design using pHEMT

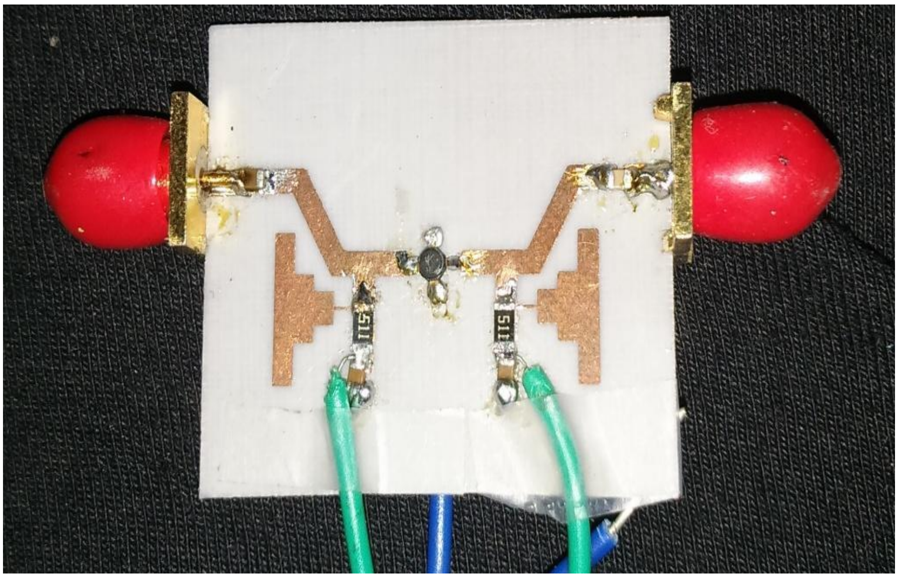


Fig. 1 (b) Fabricated Ultra wideband amplifier using step impedance stub matching technique

At the input of the amplifier, a DC blocking capacitor is chosen for the frequency of operation. This technique helps to isolate the DC bias settings of the two coupled circuits.The next step in designing of the amplifier is designing a bias network. The designed amplifier uses potential divider bias for its operation. [8]
Maximum gain will be realized when these sections provide a conjugate match between the amplifier source or load impedance and the transistor. Because most transistors exhibit a significant impedance mismatch (large $|S11|$ and $|S22|$), the resulting frequency response may be narrowband.. maximum power transfer from the input matching network to the transistor will occur when $\Gamma_s = \Gamma_{in}^*$ and $\Gamma_L = \Gamma_{out}^*$ [9]. With the assumption of lossless matching sections, these conditions will maximize the overall transducer gain. this maximum gain will be given by

$$G_p = \frac{1}{1-|\Gamma_s|^2} |S_{21}|^2 \frac{1-|\Gamma_L|^2}{|1-S_{22}\Gamma_L|^2} \quad (1)$$

In the circuit schematic shown in Figure 6.1, the input matching network is designed using a stepped impedance stubs. A classical wideband amplifier topology is designed using quarter-wavelength stub, in which λ/4 length shunt stubs are used. while λ/4 connecting lines are used for coupling. The different sections of the stub are designed by calculating the stub widths for L and C in different sections of a wideband filter.
For impedance matching of a wideband amplifier, a band pass filter is applied and the matching circuit is designed by using a stepped impedance band pass filter with stubs of lengths λ/4. Besides stability and gain, another important design consideration for a microwave amplifier is its noise figure.

$$F = F_{min} + \frac{R_N}{G_S}\left|Y_s - Y_{opt}\right|^2. \quad (2)$$

where the following definitions apply:
$Y_S = G_S + j B_S$ = source admittance presented to transistor.
Y_{opt} = optimum source admittance that results in minimum noise figure.
F_{min} = minimum noise figure of transistor, attained when $YS = Yopt$.
R_N = equivalent noise resistance of transistor.
G_S = real part of source admittance.

III. RESULTS AND DISCUSSIONS

The ultra-wideband low-noise amplifier design should optimize the overall performance according to the following criteria:
• wide bandwidth from 3.1 to 10.6 GHz (7.5 GHz frequency range),
• high and flat gain through 3.1-10.6 GHz bandwidth,
• low noise figure over the entire bandwidth,
• high linearity through the entire bandwidth,
• low input and output return loss through the whole bandwidth, and
• low DC power consumption.
An ultra wideband amplifier working in frequency range of 3.1 to 10.6 GHz has been designed and fabricated and the results of simulation and measured results have been recorded and compared. The amplifier achieves flat gain across the bandwidth and attains a maximum of over 9 dB in the band. Fig. 2 Shows the simulated and measured gain of UWB amplifier.

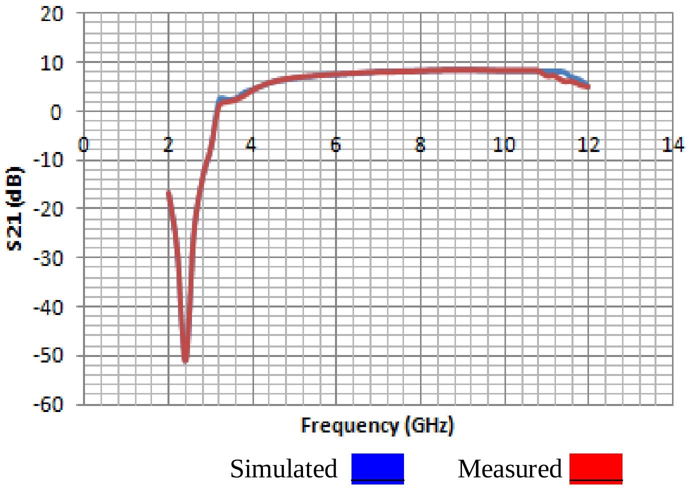
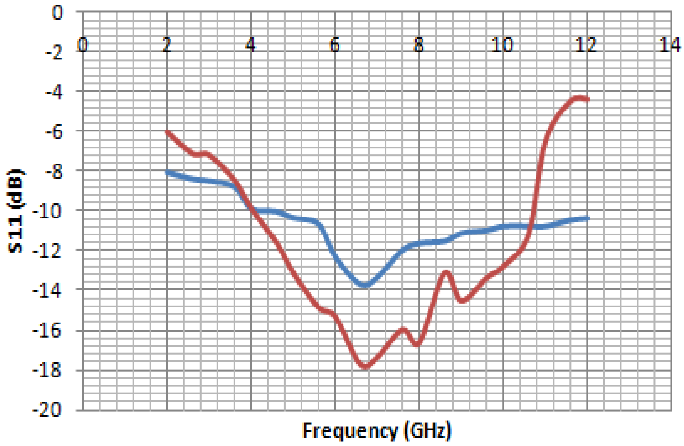


Fig. 2 Simulated and measured gain of UWB amplifier.

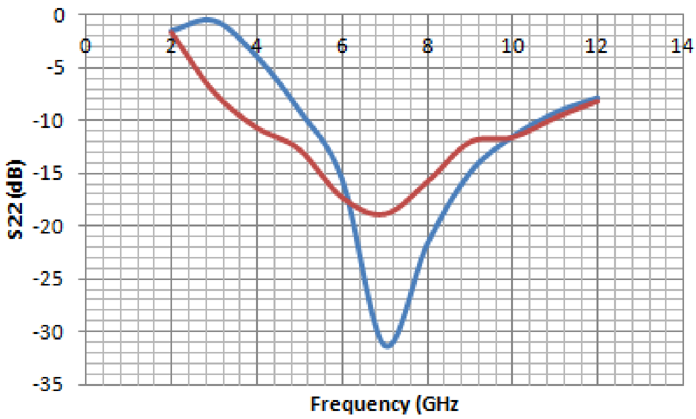
Because of the better input match, both simulated nad measured input reflection coefficients are less than -10 dB in the whole of bandwidth. The input reflection coefficent S_{11} of the amplfier is shown in Fig. 3.



Simulated Measured

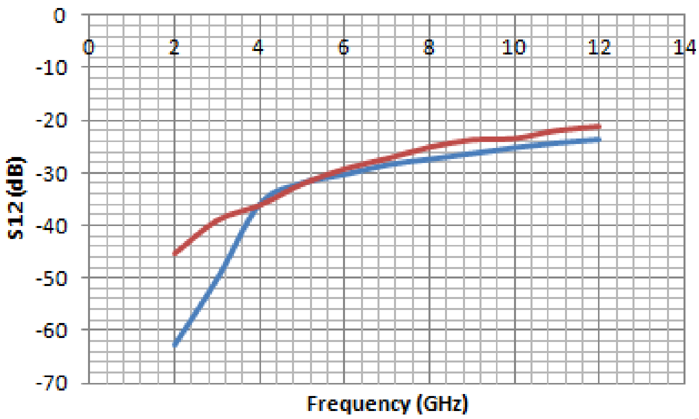
Fig. 3 Simulated and Measured Input reflection coefficient of the amplilfier

The designed ultra wideband amplifier has a good output reflection coefficient which is below -10dB in the whole of UWB range. The circuit also has a good reverse isolation that achieves a minimum of -39 dB in th band of interest. The measured and simulated output reflection ceofficient and reverse isolation of the amplifier is shown in Fig. 4 and 5 respectively.



Simulated Measured

Fig. 4 Simulated and measured output reflection coefficient of the UWB amplifier.



Simulated Measured

Fig. 5 Simulated and measured reverse isolation of the UWB amplifier.

In RF front-end circuit designs, the noise is caused by the small current and voltage fluctuations that are generated within the devices themselves. Noise figure in amplifiers must be controlled at the initial stage, since for a higher noise figure, the further stages of the amplifier if added will amplify noise to a larger extent and hence the performance can degrade. The ultra wideband amplifier design discussed in this paper has a very low noise figure across the whole bandwidth from 3.1 to 10.6 GHz and is shown in Fig. 6.

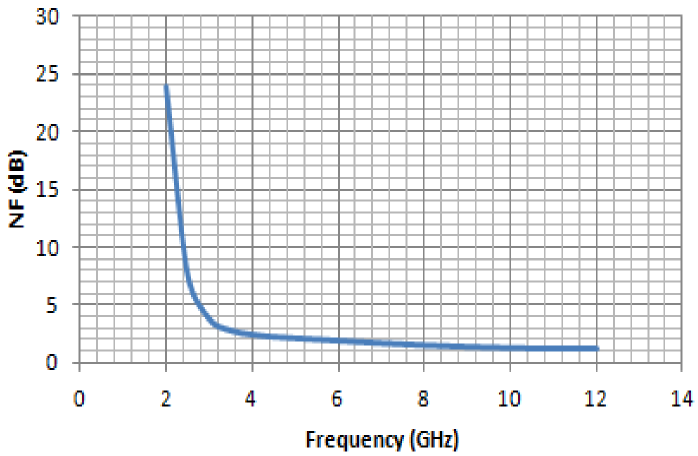


Fig. 6 Simulated Noise figure of the Ultra Wideband amplifier

The power consumption of an LNA can be defined as:

$P = I_D V_{DD,}$

Where I_D is the DC current of the amplifier circuit and V_{DD} is the Supply voltage. The power consumption of the amplifier is only 10 mW, which is quite low.

IV. CONCLUSION

A low power Ultra wideband amplifier has been designed using NEC3210S01 as the active device and applying step impedance stub matching technique for reducing return losses. Voltage divider bias is used for biasing of the transistor. The transistor has input and reflection coefficients which are less than -10dB in across the bandwidth. The amplifier also has a low noise figure, which is less than 2dB. The amplifier is simulated and fabricated using MIC fabrication technique and simulated and fabricated amplifier results have been studied and compared.

Table I Comparison with other works

Parameter	This work	In [3]	In[7]
Frequency	3.1-10.6	3-10	4-9.3
S_{21}(dB)	>8Db	6.1-7.8	7.1
S_{11}(dB)	< -10	<-9	< -10
S_{22}(dB)	<-10	< -10	< -10
S_{12}(dB)	<-25dB	<-30dB	<-18dB
NF (dB)	2-3	4-5	-
Power(mw)	10	7.2	-

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