HEMT LOW NOISE AMPLIFIER DESIGN USING GAIN BOOSTING TECHNIQUES FOR G-BAND APPLICATION

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ABSTRACT:

This paper presents the design and analysis of the high electron mobility transistor (HEMT) low noise amplifier with low noise figure, less reflection and high power gain for G Band frequency range using impedance matching technique and bandwidth enhancement technique. The linearity issue in broadband Radio Frequency front end is introduced, followed by an analysis of the specifications and requirements of a broadband low noise amplifier through consideration of broadband, multi standard front end design. Metal Oxide Semiconductor Field Effect Transistor non linearity characteristics cause linearity problems in the radio frequency front end system. Due to overcome this linearity problem and achieve less reflection in the circuit we use High Electron Mobility Transistor. HEMT has given current gain to frequencies greater than 600 GHz and power gain to frequencies greater than 1 THz. So also we have used bandwidth enhancement technique to reduce noise and reflection. Simulation is done in LT spices software.

KEYWORDS: *Low noise amplifier, High electron mobility transistor, Coupling capacitor, Signal to noise ratio, Noise figure, Hetero-junction bipolar transistor*

1. INTRODUCTION

The Low Noise Amplifier (LNA) is the most critical section of a receiver front end in term of receiver performance. With different configurations many circuits have been proposed for Low Noise Amplifier in different applications. The primary function of LNA is to amplify weak signal simultaneously removing additional noise generated in the circuit. The LNA performance is measured by power gain and noise figure. LNA is used in various aspects of wireless communication, like wireless LNAs cellular communication and satellite communication.

A radio receiver for a radio frequency signal comprises of an amplifier and mixed for signal amplification and frequency conversion. A low noise amplifier receivers RF signals, it amplifies RF signals and gives the amplified RF signal to mixer which adds signal from local oscillator. The LNA amplifies signal provides steady gain over specified frequency bandwidth. The LNA is capable of decreasing most of the incoming noise and amplifying a desired signal within a certain frequency range to increase signal to noise ratio.Low noise amplifier working for radio frequency range constructed using SiGe millimeter wave technology for various bands. These LNA were constructed using SiGe hetrojunction bipolar transistor or by GaAs or GaN or InP high electron mobility transistor (HEMT)[1,2,3].

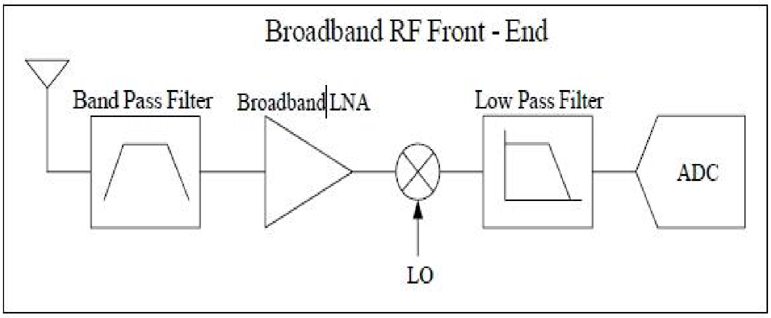


Fig. 1 Block diagram of broadband RF front end

Different measurement parameters are:-

S-parameter:-Scattering or S parameter is a measurement of reflected power and transmitted power in a network as a function of frequency as shown in figure 2. We calculate magnitude and phase.It is efficient way to describe circuit behaviour 2.

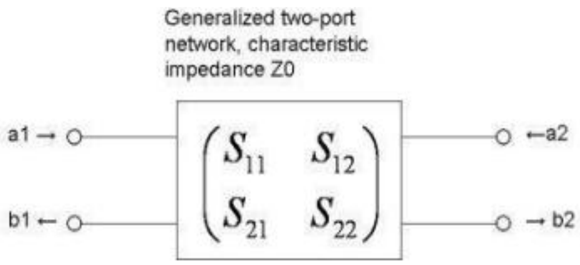


Fig. 2 Two port network

S_{11} =b_1/a_1 ,S_{12}=b_1/a_2 ,S_{21}=b_2/a_1 and S_{22}=b_2/a_2
Where
S_{11} - Reflection coefficient at Port1, S22 - Reflection coefficient at Port2
S_{12} - Isolation (Reverse), S_{21} - Insertion loss (passive device case)

Noise figure: noise figure and noise factor are measure of degradation of the signal to noise ratio (SNR), caused by components in a radio frequency (RF) signal chain .It is number by which chain .it is a number by which performance of an amplifier or a radio receiver can be specified with a lower value indicating better performance. The Noise Figure (NF) is given by

$$\text{Noise Figure (NF)} = 10 \log_{10} \frac{(\text{S.N.input})}{(\text{S.N.output})}$$

Fig. 3 Noise figure

2. METHODOLOLY

2.1 Coupling capacitor

AC potential can be transfer from 1 circuit sector to another which is having DC potential. Capacitor is used for stopping the path of straight current while allowing alternate current. In the analog circuit AC signals is passed through one to another circuitswhile DC is blocked. Bias setting of two circuits is isolated as shown in figure 3.

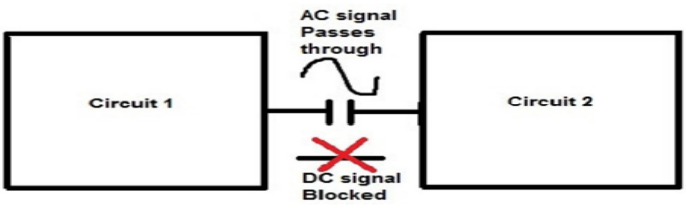


Fig. 4 Capacitor Coupling

Coupling capacitor allows irregular or signal current to pass while blocking direct current. So it is used widely for joining two stages in radio and amplifier circuits as shown in figure 4, also called as blocking capacitor or stopping capacitor. It is used in substation in a wave trap region where common means is AC power line and DC signals needs to be attenuated or blocked[4-5].

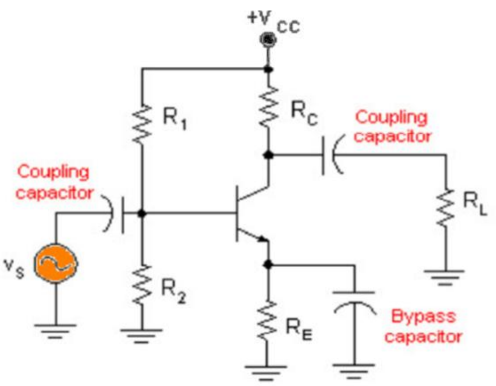


Fig. 5 Circuit diagram of transistor amplifier

2.2 RLC output matching network

The major work of matching network in RF design is to provide maximum powertransfer. In RLC the most fundamental elements that is registered, inductor and capacitor are applied across voltage supply. These elements are linear &passive in nature that is they are absorbing energy and not reduce energy. They have linear relationship between voltages and currentthere are many ways to across voltage supply. The most common method is to connectthese elements across voltage supply either in series or in parallel.The RLC circuit has property of resonance in the same way as that LC circuit exhibits but in this circuit the oscillation dies are rapidly as compare to LC circuit because of the presence of resistor in the circuit. The parallel RLC circuit is exact opposite of series RLC circuit[6-8]. Series RLC circuit is shown in figure 5.

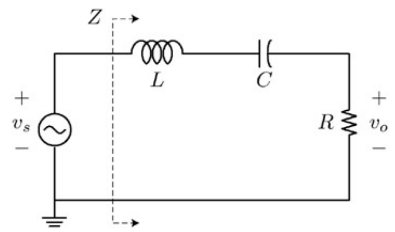


Fig. 6 Series RLC matching network

In radio communication, for proper matching of transreceiver to an antenna, modern antenna tuner has been developed. Now manual version with tunable capacitor and switched tab inductors has been available now a day. A modern antenna tuners are automated in transmit mode, trans receiver, the tuner of the trans receiver automatically adjust to get the best impedance match possible for maximum power transfer (MPT). Measurement of the standing wave ratio in the transmission line is the criterion for determining correct match. In amateur radio and the military application, automatic tuners are used extensively. Here multiple antennas of different frequency are used [9-10].

2.3 High electron mobility transistor

High electron mobility transistor) is a field device which has Hetero-interface acting like channel shown in figure 6. The name high electron mobility is due to the motion of electron mobility due to which potential well is created near the Hetero-interface. HEMT uses III–V compound semiconductor as channel material. HEMT also has very less noise figure so useful for communication sector. They are also used in high frequency application like radar and LTE satellite HEMT uses special PN Junction. It is called as Hetero-junction and it has junction consisting of different materials on either side of the junction. The common material used is Aluminium gallium arsenide (AlGaAs) and gallium arsenide (GaAs). GaAs provide a high level of basic electron used mobility which is essential for operation of the device silicon has much low level of mobility so it is never used in HEMT [11-15]

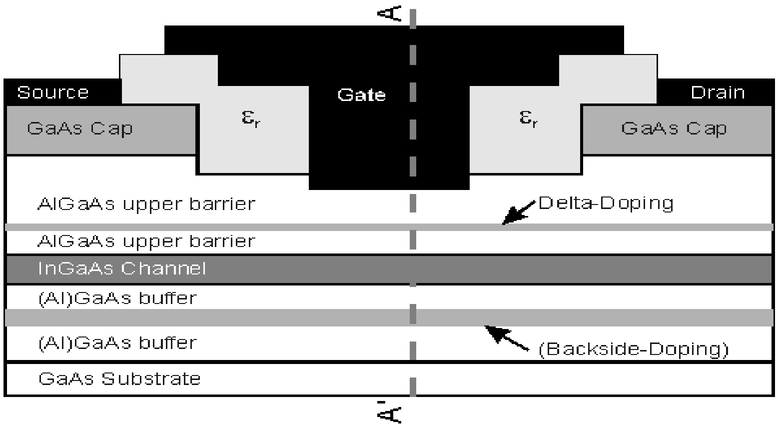


Fig. 7 Circuit diagram of high electron mobility transistor

3. IMPLEMENTATION OF WORK

The two amplifiers are separately implemented using exclusively cascade cores and common emitter (CE) HEMT to determine which transistor configuration yields a lower NF and better overall performance when exclusively used to design stable multistage GaAs HEMT low noise amplifier.
There are mainly three parameters that are noise figure, bandwidth enhancement technique and matching impedance. Also the transistors which are used high electron mobility transistor (HEMT) instead of the Hetero-junction bipolar transistor (HBT). This is a common emitter cascade arrangement low noise amplifier shown in Figure 7. The improvements which are made are attachment of the input matching network. The input matching network here is coupling capacitor. This coupling capacitor will block the unnecessary dc coming in the input way. It is called as the blocking capacitor or the stopping capacitor. It will block all the DC components coming in the way. In the intermediate stage we have the LC series arrangement connected.

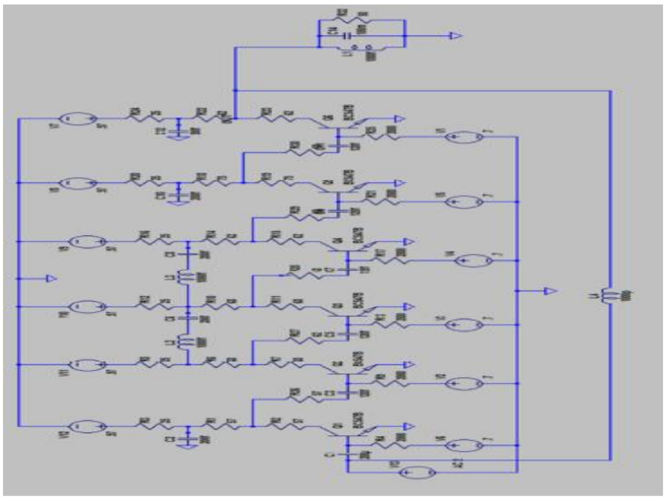


Fig. 8 Implementation of proposed design

This is for bandwidth enhancement technique. Capacitor act as the high pass filter which will block low frequency and inductor will act as low pass filter which will block the high frequency component. Both are connected in the series arrangement. Bandwidth enhancement technique will nullify the internal reflection in the circuit or else it can be minimized. Last arrangement of this circuit is the RLC output matching network it matches remaining circuits with the load.

4. SIMULATION RESULT

a) **Input Noise (IN):-** The input of the design is given in terms of input noise .The noise is calculated in the frequency range from 110 GHz to the 210 GHz. In figure 8, X–Axis shows the frequency range from
110GHz up to 210 GHz and the Y- axis shows the noise figure in pV/√Hz.

Input noise at 110GHz = 20 nV/Hz&Input noise at 210GHz =38 nV /Hz

Total RMS noise is 9.4476 Mv

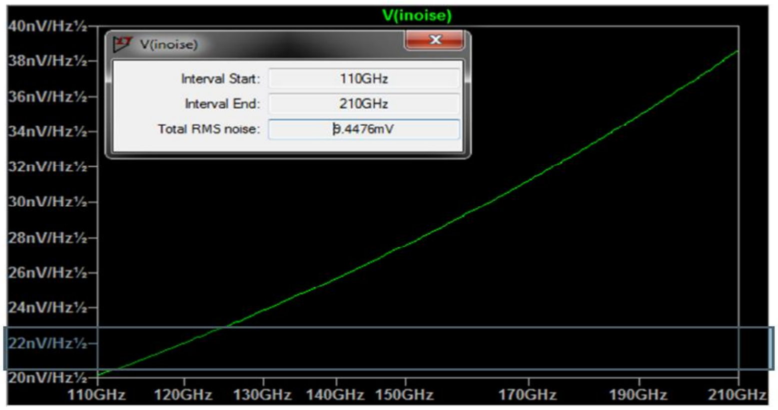


Fig. 9 Input noise of proposed design (GHz)

b) **Output Noise (ON):-**The output of the design is given in terms of output noise (ON) as shown in figure. In figure 9, X –axis shows the frequency range from 110GHz up to 210 GHz and the Y- axis shows the noise figure in pV/√Hz.The total RMS noise is the 0.096769 V. The graph shows the output noise at different frequency.

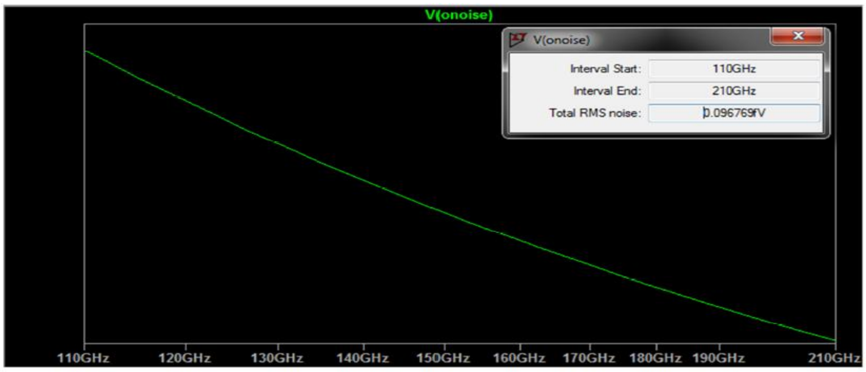
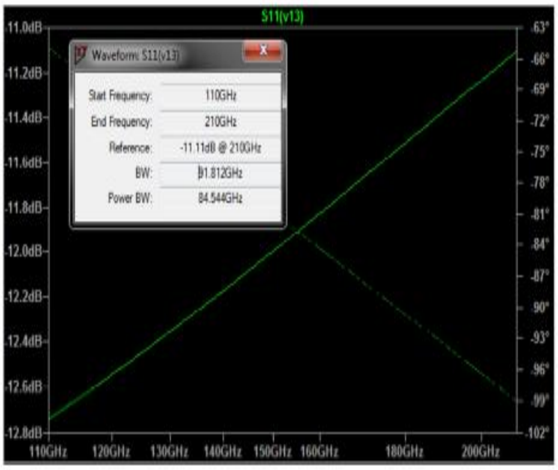
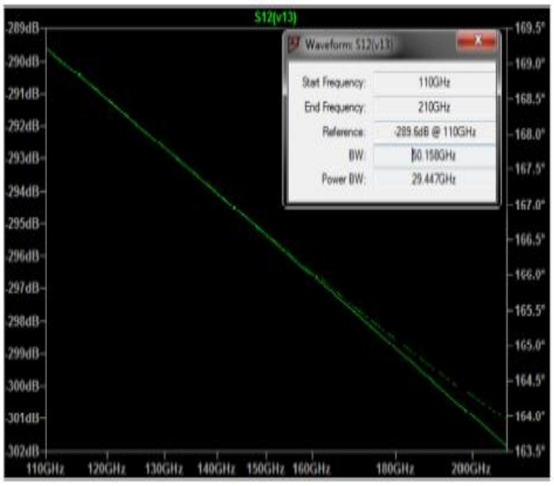


Fig. 10 Output Noise of Proposed design (GHz)

c) **S-Parameter:-**Now the simulation results for S- parameter for 110 to 210 GHz frequency, shown in the figure 10**,** in which X- axis shows the frequency range in GHz and Y-axis shows the bandwidth in S parameter in decibel (dB).





S-parameter bandwidth = 91.81 GHz, Bandwidth BW=50.158 GHz Power bandwidth=84.544 GHz, Power bandwidth=29.447 GHz

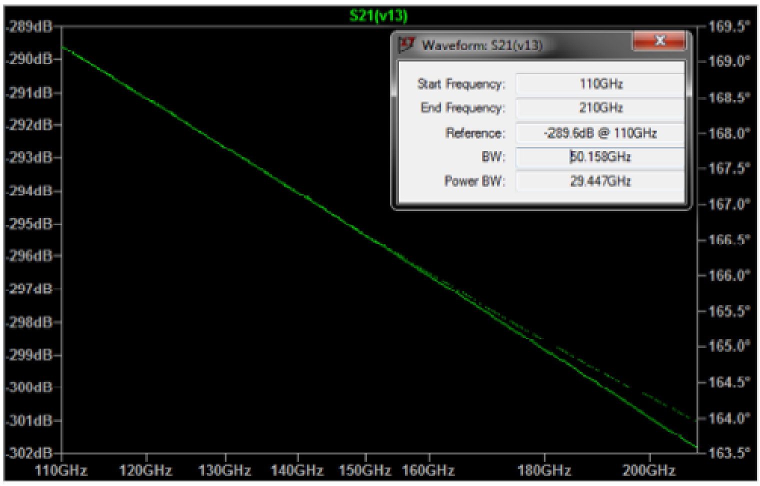


Fig. 11 Simulation result of scattering parameter

Bandwidth = 50.158 GHz & Power bandwidth = 29.44GHz

d) Power Dissipation across transistor:

The power dissipation across transistor with respect to time plays an important role for design of low noise amplifier that is also called power losses at the output end. In the figure 11, X axis shows the time in micro second and Y- axis shows the output power of the circuit in watt.

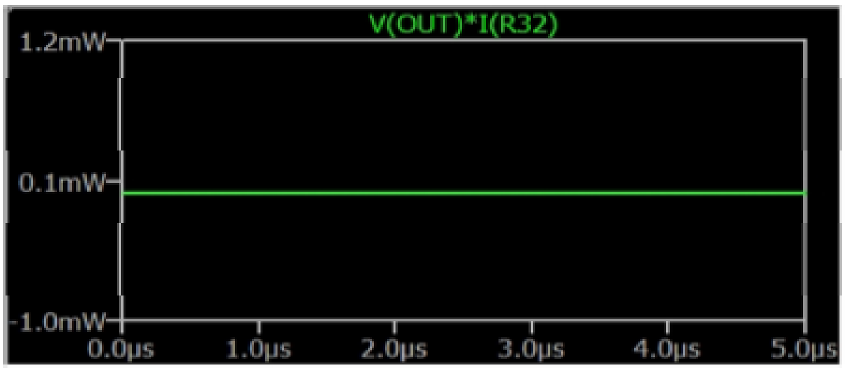


Fig. 12 Graph showing power dissipation across R32 resistor

5. CONCLUSION

The proposed design is a low noise amplifier using HEMT transistor and gain boosting technique for GHz frequency range. Power dissipation, S-parameter transfer function, input and output noise graph has being plotted using LT spice software. Use of matching network, output matching network and coupling capacitors is a good choice to achieve adequate simulation. Also, it is probably possible to achieve even lesser degradation in the corner simulation if wanted. Here we have designed low noise amplifier (LNA) for high frequency application. Here high electron mobility transistor (HEMT) is used to produce high performance at GHz range frequency.They produce low noise and current variations. Bandwidth enhancement technique that is here we have used capacitor and inductor connection in series will increases the bandwidth range and hence results in less noise and reflection.

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