Performance Analysis of 1.8 GHz to 5 GHz HEMT Multiband Mixer

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Abstract
This paper presents the design methodologies and implementation of HEMT RF down conversion Mixer for 1.8 GHz to 5 GHz wireless and mobile applications. In many recent receiver designs, the front-end mixer determines the receiver’s sensitivity and better isolation for the system. Single transistor mixer are developed for such an applications i.e. a Common source configuration, where the LO signal is applied to the source of the HEMT transistor for better isolation and lower power requirements. The mixer has the conversion gain of 4.4 to 8.5 dB, noise figure of 2 to 2.5 dB and a low power consumption at 2.5 V supply with better isolation of multiband mixer.

Keywords: High Electron Mobility Transistor (HEMT), Local Oscillator (LO), Noise Figure (NF), Conversion Gain (CG), intermediate frequency (IF) and Common Source (CS) configuration mixer.

Introduction
The mixer plays an important role in wireless and mobile communications by providing the ease of conversion of frequencies between different frequencies band [6]. Many RFIC has exploited the use of superhetrodyne receiver because of its image rejecting advantage to lower the noise figure but this architecture occupies larger area than the other architectures [1]. Another well-known architecture for the RF front end design is the Direct Conversion Receiver which avoids the use of image rejecting filter, since it doesn’t produces image frequencies in the system [9].

Devices like CMOS, MESFET, BiCMOS and HBT were basically used in RF applications, whereas HEMT devices has features like very low noise, high operation frequencies capabilities. HEMT have better noise performances when compared with other devices like CMOS, HBT, BiCMOS and BJT. HEMT circuits are normally restricted to simpler analog circuits, with a small transistor count due to its high process fluctuations. HEMT devices with less transistor count can be used in RF front end circuit with high bandwidth and low noise [2, 7].

Several mixer topologies have been implemented across the years to accomplish better performance of the mixer in RF front end receiver [2]. The down conversion mixer have been used at the receiver circuit for translating RF and LO to get intermediate frequency (IF). Mixers are generally used for translation of frequencies and at the core of all mixers which have been used presently is the multiplication of two signals in the time domain. Multiplication of two frequencies thus results in the outputs as sum and difference of the input signals i.e. RF and LO [8]. In general the output terms will have three types of products the output: DC, intermodulation products of harmonics and harmonics of the input. The work of the mixer is to have low undesired terms. These undesired terms can be readily removed to some extend by applying the LO input to the source of the transistor thereby providing better RF to LO isolation [2, 10]. This paper describes HEMT based single ended topology for mixer which has been used for lowering the noise of the system with better conversion gain and isolation.

This paper is organized as follows: Section II covers the topology of the proposed Mixer. Section III explains the design process of the proposed Mixer. Section IV shows the Results and discussion of Mixer Section V shows the performance summary of Proposed Mixer.

Design and Analysis of Proposed Mixer
Mixer is a time-variant weakly non-linear system. Figure.1 shows the single transistor mixer i.e. common source transistor. The mixer is used for frequency translation, therefore the RF input is given through the gate of the transistor whereas local oscillator(LO) input is given through the source terminal of the transistor for the better RF and LO isolation. In order to drive the DC gate voltage the biasing voltage and biasing resistor is used at the gate terminal of the transistor, whereas a tank filter circuit of L and C has been used for better IF isolation.

![Figure 1: Proposed HEMT Mixer](image-url)
The drain current of the given mixer can be analysed as:
\[ I_{ds} = KV_{bias} + V_{RF} + V_{LO} - V_T \]  
\[ = KV_{RF}V_{LO}\cos(\omega_{LO} - \omega_{RF})t \]  

The \( I_{ds} \) can be analysed from the given circuit in the Figure 2.

![Figure 2: \( I_{ds} \) of the Proposed Mixer](image)

The conversion gain in a down conversion mixer is the ratio of IF signal to that of the RF signal, the conversion gain of the proposed HEMT Mixer can be given as:
\[ \text{Conv. Gain} = \frac{I_{ds}(\omega_{IF}=\omega_{LO}-\omega_{RF})}{V_{RF}(\omega_{RF})} \]  
\[ = KV_{LO} \]  

The number of transistor is responsible for noise and gain of the mixer [3]. the gain can be increased either by tuning the LO frequency or the drain to source current. In the proposed Mixer design the increasing transconductance reduces the noise and increases the gain of mixer.

**Simulation Results**

The proposed mixer has been designed using Agilent Advanced Design System (ADS) software for 1.8 GHz to 5GHz.

**Transient Analysis**

The transient analysis of proposed mixer for frequency 1GHz can be illustrated as in Figure 3.

![Figure 3: Intermediate Frequency at 1GHz](image)

In figure 3 the RF is 1.8 GHz and LO is 0.8GHz which gives an intermediate frequency of 1GHz. When a RF input of 2.1 GHz and LO of 1.1GHz is given to the single transistor we get IF of 1GHz which can be shown in figure 4.

![Figure 4: Intermediate frequency at 1GHz](image)
When the RF input is at 2.4GHz and LO is at 0.4GHz the intermediate frequency is at 2GHz. This has been presented in the Figure 5.

Figure 5: Intermediate frequency at 2GHz

Figure 6 shows the intermediate frequency (IF) at 2.4GHz when RF input and LO is 5GHz and 2.6GHz.

Figure 6: Intermediate frequency at 2.4GHz

Conversion Gain
The conversion gain of proposed mixer of frequency range 1.8GHz to 5GHz can be depicted as below in Figure 7

Figure 7: Conversion Gain of Proposed Mixer

Isolation
Isolation is the measurement of the leakage or feedthrough of one port to another. Isolation between RF to LO at 1.8GHz frequency is -41.938 dB and it is illustrated in Figure 8.

Figure 8: Isolation of RF to LO at 1.8GHz

Isolation between RF to LO at 2.1GHz frequency is -42.414 dB and it is illustrated in Figure 9.
Isolation between RF to LO at 2.40GHz frequency is -41.938 dB and it is illustrated in Figure 10.

Isolation of RF to IF at 1.8GHz is seen to be -15.070 dB, this can be presented in the below Figure 12.

Isolation between the RF and LO port is found to be -32.820 dB at 4.9GHz. This can be shown in Figure 11.

Isolation of RF to IF at 2.1 Hz is seen to be at -13.632 dB, this can be illustrated in the below Figure 13.
Isolation of port RF to IF can be seen at frequency of 2.4GHz with isolation of -12.354 dB in Figure 14.

Isolation of port RF to IF can be seen at frequency of 4.9GHz with isolation of -5.448 dB in Figure 15.

Isolation of RF to IF at 2.1GHz

Isolation of RF to IF at 2.4GHz

Isolation of RF to IF at 4.9GHz

Noise Figure

The noise figure of the proposed Mixer is can be illustrated in the below Figure 16 which is less than 2 dB for 1.8GHz To 5GHz.

Noise figure can be calculated as:

\[ F = \frac{N_{IF}}{N_{RF} \times \text{Conv.Gain}} \]  

(5)

Figure 13: Isolation of RF to IF at 2.1GHz

Figure 14: Isolation of RF to IF at 2.4GHz

Figure 15: Isolation of RF to IF at 4.9 GHz

Figure 16: Noise Figure of Proposed Mixer

Linearity

The linearity of the proposed mixer for 1.8GHz to 5GHz can be represented in the Figure 17. The IIP3 input intercept point at 3dB is 28dBm.
The performance summary of the Proposed Mixer can be depicted in Table 1, which shows the different parameters of the mixer.

**Table 1: Performance Parameter of Mixer**

<table>
<thead>
<tr>
<th>Frequency of operation</th>
<th>Parameters</th>
<th>Proposed Mixer</th>
<th>Reference [5]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.8GHz to 5GHz</td>
<td>Noise Figure</td>
<td>&lt;2dB</td>
<td>&lt;12dB</td>
</tr>
<tr>
<td></td>
<td>Conversion Gain</td>
<td>5-10dB</td>
<td>7-10dB</td>
</tr>
<tr>
<td></td>
<td>Isolation RF to LO</td>
<td>-32to-42dB</td>
<td>&lt;35dB</td>
</tr>
<tr>
<td></td>
<td>Isolation RF to IF</td>
<td>-5 to -15dB</td>
<td>&lt;30dB</td>
</tr>
<tr>
<td></td>
<td>Supply Voltage</td>
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<td>3.3V</td>
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<tr>
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<td>SiGe BiCMOS</td>
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</table>

**Conclusion**

The proposed mixer was intended for 1.8GHz to 5GHz Multiband Mixer. The mixer was designed and simulated in ADS software with high Conversion gain, less noise figure of around 2dB, better port to port isolation as well as consumes less supply voltage.

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**References**