[ME07] GaAs PHEMT single-ended mixers for 28 GHz applications

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Introduction

Mixers are key devices for front-end components in any transceiver of a communication system. The performance of a receiver rely heavily on the mixer operation in terms of its conversion loss (gain), noise figure, port-to-port isolation, intermodulation distortion and dynamic range. Microwave mixer can be designed by using Schottky-barrier diode or FET, either MESFET or HEMT. Using a FET rather than a diode as the non-linear element in a mixer has several advantages. Some of these include the possibility of achieving a conversion gain, using lower LO drive power and obtaining isolation between the signal ports of the FET.

FET can be used to provide frequency conversion in a number of different ways depending upon the bias configuration of the device. This paper presents the gate mixer and the drain mixer, both mixers are active mixers since they employed the non-linearity of the FET as the mixing element. Both mixers were constructed in a single-ended configuration by utilising GaAs PHEMT as a mixing device. These two GaAs PHEMT single-ended mixers operating at 28 GHz and suitable to be used in the application of Local Multipoint Distribution System (LMDS). LMDS is an integrated wireless broadband service offering bundled telephony, data voice and video.

Mixer Design and Operating Principle

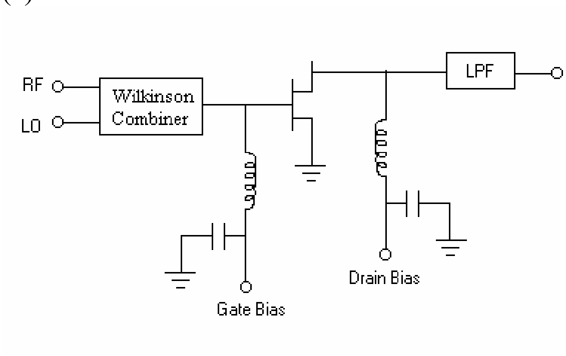
The mixers were designed using Libra Series IV software based on the foundry GMMT H40 smart library. The same transistor is used for both mixers that is a PHEMT with 0.25 µm gate length, two fingers with the widht of 60 µm.

Fig.1 (a) shows a block diagram for single-ended gate mixer. The PHEMT is in common-source configuration, the RF and LO signals are applied to the gate through a circuit combiner, whereby a Wilkinson combiner is employed in this design. The IF signal is extracted from the drain through a low pass filter which is in the form of a one stage LC network. The gate is biased near its pinch-off voltage and the drain is biased in saturation regime. In the gate mixer, the profile of the transconductance, g_m versus V_{gs} is the dominant factor in the frequency conversion process. When a sufficiently strong LO signal is applied to the gate of a FET biased close to pinch-off, the drain current will be modulated between zero and the saturation value I_{dss}. Simultaneously, FET transconductance, g_m, will also be vary between zero and its peak value. Thus, the applied LO voltage creates the time-varying transconductance, g_m and the RF mixes with it.

Fig.1 (b) shows a block diagram for single-ended drain mixer. The RF is applied to the gate, while the LO is applied to the drain through the LO filter and IF is extracted from the drain. The gate is negatively biased, and the drain is biased at the V_{ds}=V_{knee} to provide the optimum performance of the drain mixer. In the case of the drain mixer, the non-linearity at the knee of the I/V characteristics is used for this mixing action. Thus, the dominant contributor to frequency conversion is the variation of the drain-source resistance, R_{ds} and also the transconductance, g_m. The large LO signal applied to the drain modulates both the channel resistance, R_{ds} and the transconductance, g_m hence both of these non-linearities become time-varying functions with a period equal to that of the LO.

For both mixers, all the ports; RF, LO and IF port are matched to 50 Ω. The low pass filter prior to the IF port is used to filter out all the spurious response and to provide adequate LO to IF isolation.

(a)



(b)

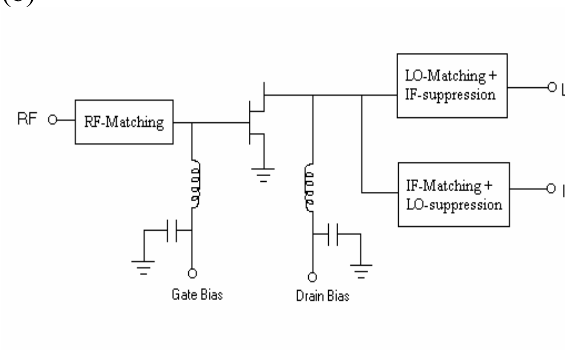


FIGURE 1 Block diagram for single-ended PHEMT mixers (a) gate mixer, (b) drain mixer

Simulation Results and Discussion

The two mixers which have been designed were simulated by using the Harmonic Balance Simulator available in Libra Series IV software. The single-ended gate mixer operates with LO power at +10 dBm, drain bias at 5.0 V and gate bias at -0.9V. Meanwhile the single-ended drain mixer operates with LO power at +15 dBm, drain bias at 1.4 V and gate bias at -0.4 V. Both mixers show good performance in terms of conversion loss, LO to RF isolation and LO to IF isolation as illustrated throughout Fig.2 till Fig. 5, with RF frequency swept from 24 to 32 GHz and IF frequency fixed at 1 GHz.

From the graf in Fig.2, it is noted that the conversion loss of a single-ended gate mixer is between 1.5 dB to 2.7 dB, whereby the lowest conversion loss is 1.5 dB at RF frequency equals to 27 GHz. Theoretically, the gate mixer is an active mixer and therefore it should provides a few dB of conversion gain due to the time-variant transconductance as the mixing element. Instead of conversion gain, this single-ended mixer gives around 2 dB conversion loss. This losses is due to the loss in Wilkinson combiner circuit, which is 3.9 dB.

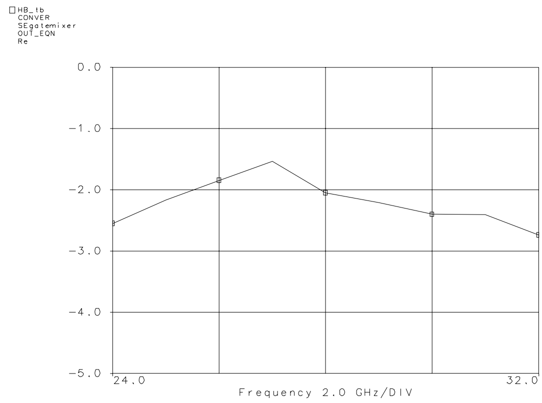


FIGURE 2 Gate mixer conversion loss versus RF frequency

The single-ended gate mixer also achieved adequate LO to RF isolation and LO to IF isolation as shown in Fig.3. The LO to RF isolation of this mixer is between 26 dB to 32 dB. This isolation is provided by the isolation between terminals of Wilkinson combiner. The LO to IF isolation of this mixer is between 25 dB to 29 dB. This isolation is due to the low pass filter at the drain and also inherent isolation between the transistor terminals.

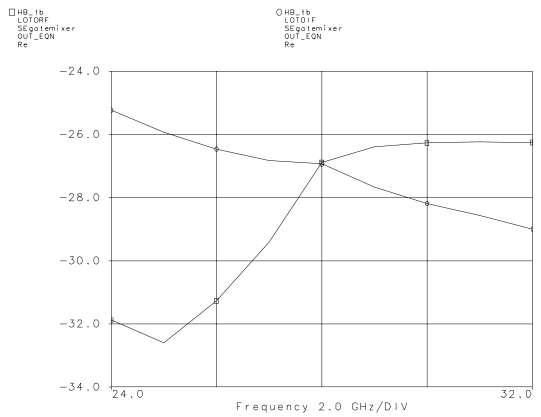


FIGURE 3 Gate mixer LO to RF isolation and LO to IF isolation

Fig.4 shows the conversion gain of the single-ended drain mixer, whereby the conversion gain is between 0.5 dB to 3.5 dB. The highest conversion gain achieved is 3.5 dB at RF frequency equals to 28 GHz.

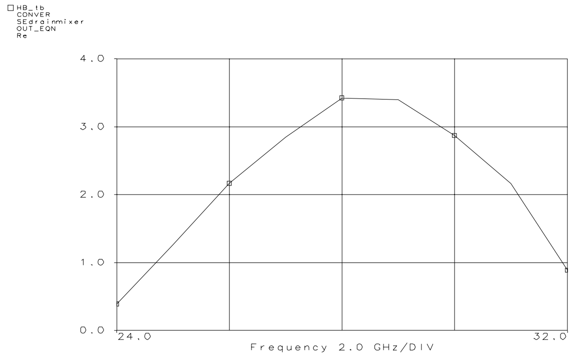


FIGURE 4 Drain mixer conversion loss versus RF frequency

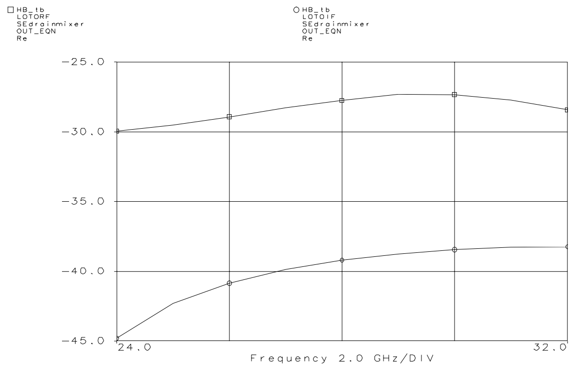


FIGURE 5 Drain mixer LO to RF isolation and LO to IF isolation

The LO to RF isolation of this mixer is between 27 dB to 30 dB, meanwhile the LO to IF isolation is between 38 dB to 45 dB as ilustrated in Fig.5. The LO to RF isolation is due to the inherent isolation between the transistor terminals.

The performance of both mixers at RF frequency equals to 28 GHz is summarized in Table 1. The single-ended drain mixer has lower noise figure which is only at 6.7 dB. This is because the operation of the drain mixer is due to the variation of V_{ds}, whereas the operation of the gate mixer is due to the variation of V_{gs}. The noise parameters sensitivity are mostly depending on the variation of V_{gs} compared to the variation of V_{ds}, therefore the gate mixer has higher noise figure than the drain mixer (De La Fuente 1998). The layout of both mixers are shown in Fig. 6 and Fig. 7 with the size of 0.94 mm × 2.0 mm for the gate mixer and 0.93 mm × 1.98 mm for the drain mixer.

TABLE 1 Performance of the two single-ended mixers with RF frequency at 28 GHz, LO frequency at 27 GHz and IF frequency at 1 GHz.

	Gate	Drain
Conversion Gain dB	− 2.0	3.4
LO power, dBm	+10	+15
Isolation LO/IF, dB	27	39
Isolation LO/RF, dB	27	28
Noise Figure, dB	10.8	6.7
P_{1dB} , dBm	+7	0
IIP3, dBm	15	22
Drain bias V_{ds}, V	5	1.4
Gate bias V_g, V	-0.9	-0.4

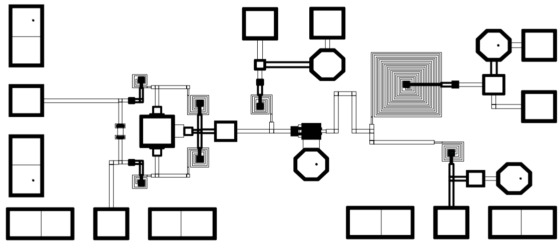


FIGURE 6 Layout of single-ended gate mixer

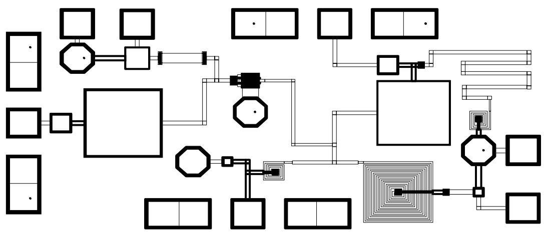


FIGURE 7 Layout of single-ended drain mixer

Conclusions

This paper has presented two active PHEMT mixers operates at 28 GHz, the single-ended gate mixer and the single-ended drain mixer. The single-ended drain mixer gives a few dB of conversion gain and it also has lower noise figure compared to the single-ended gate mixer.

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