Preamplifier Effect on the Performance of Distributed Active Mixer

Zahra Zare[#1], Ahmad Hakimi[#2], Farhad Sheikhhosseini[*3], Masoud Movahhedi[#4]

[#]*Department of Electrical and Computer Engineering, University of Shahid Bahonar Kerman*
Kerman, Iran

[1]z.zare.158@gmail.com

[2]hakimi@mail.uk.ac.ir

[4]movahhedi@ieee.org

[*]*Department of Electrical and Computer Engineering, Tarbiat Modares University*
Tehran, Iran

[3]f_sheikh@modares.ac.ir

***Abstract*— In this paper, a new distributed active mixer is presented. The scheme is based on the conventional Gilbert-cell multiplier with complementary transconductance stage. By adding the preamplifier and non-uniform artificial transmission lines on the topology, the new distributed active mixer is obtained. Comparison of the new mixer with the topology in absence of preamplifier shows that it has higher conversion gain and lower noise figure. The proposed mixer is simulated in a 0.18µm CMOS technology, with a LO power of 5 dBm and IF frequency of 70 MHz. The simulated circuit has a conversion gain of 12 dB over -3dB bandwidth and an average input third-order intercept point (IIP3) of -3 dBm within the entire frequency range. It consumes a dc power of 64 mW from a 2 V supply voltage.**

***Keywords*— Active mixer, complementary transconductance stage, conversion gain, non-uniform transmission lines, preamplifier.**

I. Introduction

Mixer uses to transform the signal from radio frequency to intermediate frequency band. It plays an important role in specifying the critical system characteristics such as the conversion gain (G_C), noise figure, linearity, and image rejection.

Gilbert-cell multiplier is widely used as a down conversion mixer. The bandwidth of Gilbert-cell multiplier is limited by the RC time constant especially in the RF and LO ports [1].

There are different state-of-the-art techniques to achieve high bandwidth in mixers. Recently, ladder networks [2], [3] and transformers [4], [5] have been employed at the input ports of the mixer. These circuits are interested in non-uniform conversion gain over the input frequency range. In contrast, distributed mixers have uniformity of gain due to the widespread use of artificial transmission lines [6], [7]. In order to improve mixer linearization, the flow injection method and class AB are presented in [8] and [9], respectively.

In this paper, a new distributed active mixer based on the conventional Gilbert-cell multiplier with complementary transconductance stage is introduced. By adding preamplifier and non-uniform artificial transmission lines on the topology, the new distributed active mixer is obtained and high G_C and low noise figure are achieved.

This paper is organized as follows. Section II begins with introduction of mixer core including Gilbert-cell mixer and flow injection method, then it continues with explaining the preamplifier and non-uniform artificial transmission lines which are used for gain, noise figure, and bandwidth improvement. The proposed distributed mixer and its simulation results with 0.18µm CMOS technology are provided in Section III. Finally, conclusion is given in Section IV.

II. Mixer Core

A. Gilbert-Cell Mixer

Fig. 1 shows the circuit schematic of the conventional Gilbert-cell mixer. It is composed of the transconductance stage (M1 and M2) in order to convert voltage signal into the current, switching stage (M3 – M6) to steer current and finally resistive loads to transform current to the voltage. So the G_C is given by the following relation [10]:

$$G_c = \frac{2}{\pi} R_L \sqrt{\mu_n C_{ox} (W/L)_n I_{ss}} \qquad (1)$$

where R_L is the load resistance, I_{ss} is the tail current and $(W/L)_n$ is the aspect ratio of transistors M_1 and M_2.

B. Flow Injection Method

To increase transconductance for upgrading G_C, the flow injection topology with complementary transconductance stage as shown in Fig. 1, have been suggested. By choosing the current ratio of the complementary stage, $\alpha = I_\beta / I_{ss}$, G_C has enhanced and is obtained according to the following relation [1].

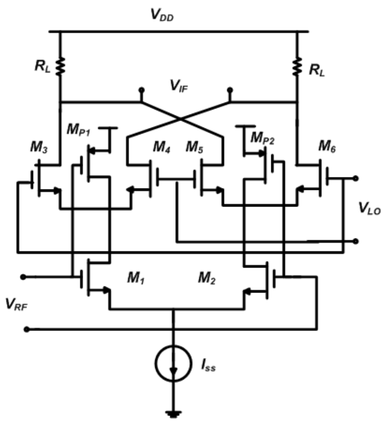


Fig. 1 Schematic of the Gilbert-cell mixer with the complementary transconductance stage

$$G_c{'} = \frac{2}{\pi} R_L \sqrt{\mu_n C_{ox} (W/L)_n I_{ss}} + \frac{2}{\pi} R_L \sqrt{\mu_P C_{ox} (W/L)_p \alpha I_{ss}} \quad (2)$$

where $(W/L)_p$ represents the aspect ratio of transistors M_{P1} and M_{P2}.

C. Non-uniform artificial transmission lines

Due to the inherently high cut-off frequencies and low return losses, the distributed structure with input uniform artificial transmission lines is preferred.

A major constraint of the mixer with uniform distributed structure is the limitation of gain-bandwidth product. A non-uniform artificial transmission line [11] is used to overcome the constraint. Lumped element model of this topology is shown in Fig. 3.

The device size in each stage of transmission line is reduced by *K* coefficient in progress to the end of the line consecutively.

D. Preamplifier

To improve conversion gain and noise figure of the distributed mixer, a preamplifier stage as shown in Fig. 4 is employed. Using preamplifier reinforces the input wave and then delivers it into the mixer circuit. The conversion gain of the Gilbert-cell mixer with the complementary transconductance stage and the preamplifier is given by:

$$G_c{''} = g_{preamplifier} \times (\frac{2}{\pi} R_L \sqrt{\mu_n C_{ox} (W/L)_n I_{ss}} + \frac{2}{\pi} R_L \sqrt{\mu_P C_{ox} (W/L)_p \alpha I_{ss}}) \quad (3)$$

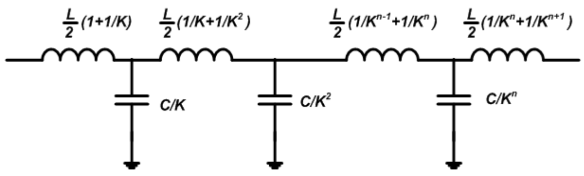


Fig.2 Lumped element model of the non-uniform transmission line

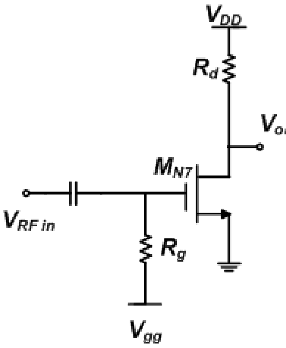


Fig. 3 Circuit schematic of the preamplifier

where $g_{preamplifier}$ is given by:

$$g_{preamplifier} = R_d \sqrt{\mu_n C_{ox} (W/L)_{preamplifier} I_d} \,,$$

R_d is the load resistance, I_d is the drain current, and $(W/L)_{preamplifier}$ is the aspect ratio of the common source transistor in the preamplifier stage.

Obviously the coefficient $g_{preamplifier}$ leads to achieve high conversion gain in comparison with (2).

III. PROPOSED MIXER STRUCTURE

By using the flow injection method, non-uniform distributed structure and preamplifier in the Gilbert-cell mixer, broad-band mixer is achieved and its complete scheme is shown in Fig. 4.

In this structure, non-uniform artificial transmission line is placed at the RF stage. On the other hand to simplify the structure, a uniform artificial transmission line is considered for the LO signal.

Employing a capacitor at source is one of the most commonly used techniques to improve the bandwidth [12].A modified network is utilized in the transconductance stage to increase the bandwidth. The aforementioned modified network is composed of an inductance L_s which stand in series with the capacitance C_s.

To lessen the influence of the parasitic capacitance at the output node of the tranconductance stage, an inductance L_m between the tranconductance and commutating stages is employed. Therefore, an LC ladder network with broadband characteristic is formed and parasitic capacitance is separated too [13].

Finally, two common drain transistors are placed at the IF port of the mixer with the target of impedance matching at the output.

A. *Simulation Results*

The proposed mixer is simulated in a 0.18 µm CMOS technology with 2V supply voltage. The simulation results of the circuit in Fig. 5 exhibit improvement in conversion gain and noise figure considerably. Figure (6), (7) and (8) compare the conversion gain, port to port isolation and noise figure of the distributed mixer with and without the preamplifier, respectively. It should be noted that the circuit is simulated with the local oscillator power of 5 dBm and IF frequency of 70 MHz. It has 12 dB conversion gain over -3dB bandwidth of 20 GHz, 14 dB noise figure and IIP3 about -3dBm within the entire frequency range while consuming only 64mW.

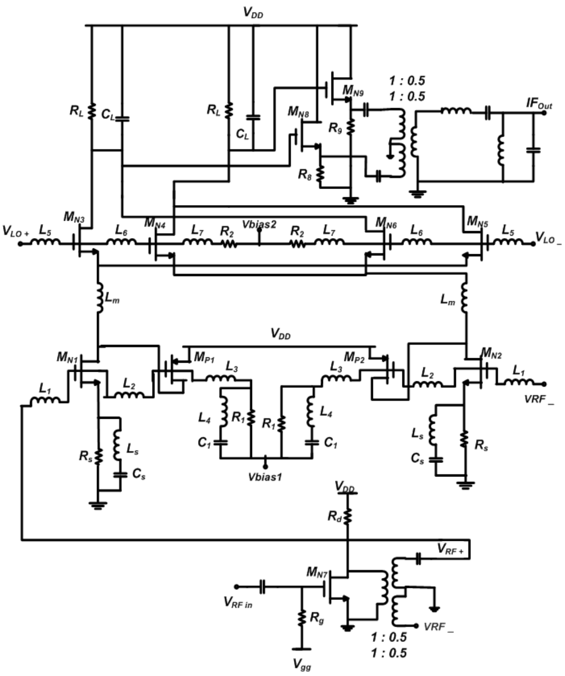


Fig. 4 Complete circuit schematic of the proposed distributed mixer

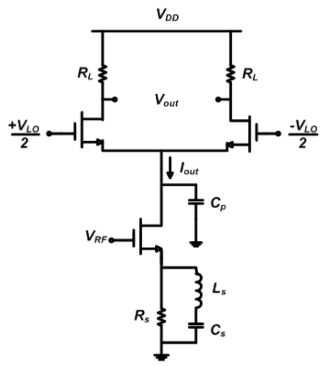
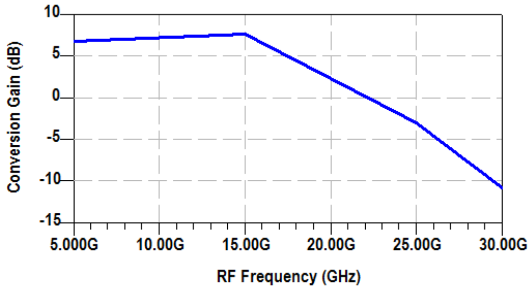
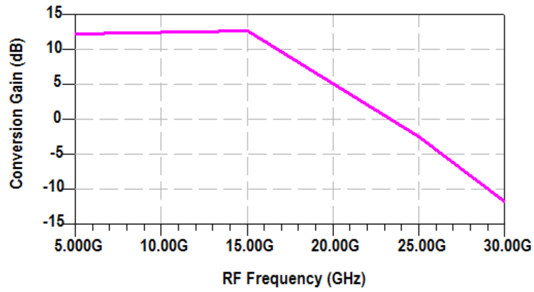


Fig. 5 Modified network with inductance and capacitance in source

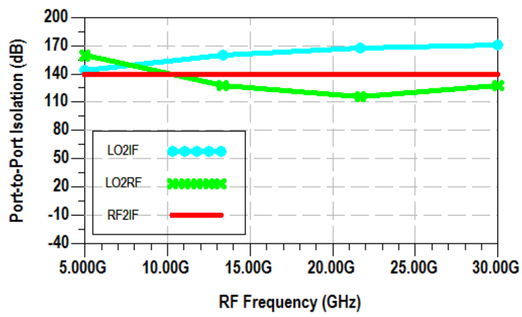


(a)

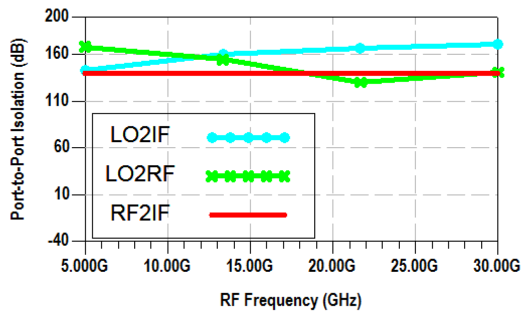


(b)

Fig. 6 Conversion Gain of the proposed mixer: (a) without preamplifier (b) with preamplifier



(a)



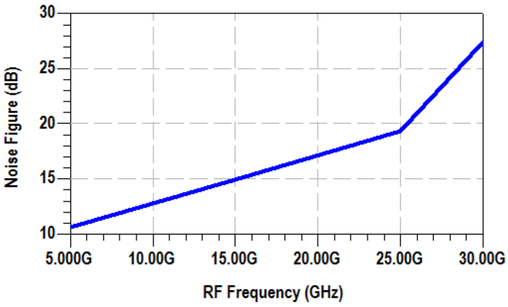
(b)

Fig. 7 Port-to-Port Isolation of the proposed mixer: (a) without preamplifier (b) with preamplifier

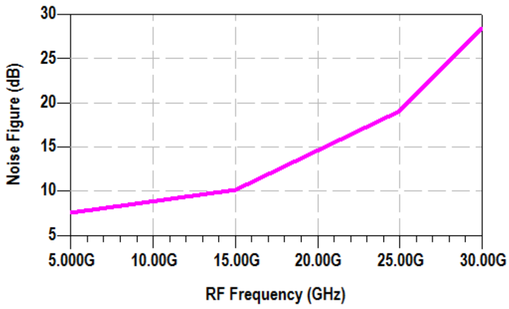
TABLE I

PERFORMANCE SUMMARY OF THE DISTRIBUTED DOWN CONVERSION MIXER

	Conversion Gain	SSB NF	IIP3	Bandwidth	Isolation	Power consumption	Dc supply voltage
This work before preamplifier	6.5 dB	19 dB	-4 dBm	20 GHz	LO2IF ≥ 140 dB and LO2RF ≥ 110 dB	59 mW	2 V
This work after preamplifier	12 dB	14 dB	-3 dBm	20 GHz	LO2IF ≥140 dB and LO2RF ≥130 dB	63.4 mW	2 V



(a)



(b)

Fig. 8 Noise figure of the proposed mixer: (a) without preamplifier (b) with preamplifier

IV. CONCLUSION

A new distributed active mixer has been presented in this paper. By applying a flow injection method to the Gilbert-cell mixer, high linearity and gain are obtained. A broadband matching technique, non-uniform transmission lines, is applied to achieve the flatness of conversion gain over broad bandwidth. By utilizing the preamplifier, the conversion gain (G_C) and the noise figure (NF) have been considerably modified in comparison with its scheme in the absence of the preamplifier.

REFERENCES

[1] C. R. Wu and H. H. Hsieh,"An ultra wideband distributed active mixer MMIC in 0.18 µm CMOS technoloy "IEEE Trans. Microw. Theory Tech. vol. 55, no. 4, April.2007

[2] . M. D. Tsai and H. Wang, "A 0.3-25-GHz ultra-wideband mixer using commercial 0.18 µm CMOS technology," IEEE Microw. Wireless Compon. Lett., vol. 14, no. 11, pp. 522–524, Nov. 2004

[3] J. H. Tsai and P. S. Wu and C.S.Lin and T.W.Huang and G. J. Chern and W.C.Huang,"A 25–75 GHz Broadband Gilbert-Cell Mixer Using 90-nm CMOS Technology," IEEE Microw. Wireless Compon. Lett., vol. 17, no. 4, April.2007

[4] C.-S. Lin, P.-S.Wu, H.-Y. Chang, and H.Wang, "A 9-50-GHz Gilbertcell down-conversion mixer in 0.13 µm CMOS technology," IEEE Microw.Wireless Compon. Lett., vol. 16, no. 5, pp. 293–295, May.2006.

[5] J.H.Tsai and H.Y.Yang and T.W.Huang and H.Wang, "A 30–100 GHz Wideband Sub-Harmonic Active Mixer in 90 nm CMOS Technology," IEEE Microw.Wireless Compon. Lett.vol. 18, no 8, August.2008

[6] A. Q. Safarian, A. Yazdi, and P. Heydari, "Design and analysis of an ultrawide-band distributed CMOS mixer," IEEE Trans. Very Large Scale Integr. (VLSI) Syst., vol. 13, no. 5, pp. 618–629, May 2005.

[7] K. L. Deng and H. Wang, "A 3-33 GHz PHEMT MMIC distributed drain mixer," in IEEE Radio Freq. Integr. Circuits Symp., Jun. 2002, pp. 151–154.

[8] Vojkon Vidojkovic,"Low Voltage,Low Power Folded Switching Mixer with Current Reuse in 0.18 um CMOS" ISCAS 2004, pp569-572

[9] Barrie Gilbert, "The Micromixer:A Highly Linear Variant of the Gilbert Mixer Using a Bisymmetric Class AB Input Stage" IEEE Journal of Solid-State Circuits, vol. 32, pp 1412-142 3, Sept,1997

[10] T. H. Lee, The Design of CMOS Radio-Frequency Integrated Circuits.Cambridge, U.K.: Cambridge Univ. Press, 1998.

[11] A. Yazdi and P. Heydari, "A novel non-uniform distributed amplifier," in IEEE Int. Circuits Syst. Symp., May 2004, vol. 1, pp. 613–616.

[12] B. Razavi, Design of Integrated Circuits for Optical Communications. New York: McGraw-Hill, 2002.

[13] B. Analui and A. Hajimiri, "Bandwidth enhancement for transimpedance amplifiers," IEEE J. Solid-State Circuits, vol. 39, no. 8, pp. 1263–1270, Aug. 2004.