Dual-Mode E-Band Mixer for 6G mmWave Front-Ends: Simple structure with reconfigurable PT/Resistive Operation for Optimized Gain and Linearity

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***Abstract*—A dual-mode E-band mixer with a novel yet simple FET-based structure is designed and simulated using a 100 nm pHEMT PH10 process. The mixer employs a switchable impedance network and reconfigurable DC biasing to enable two distinct operational modes: a pump transconductance (PT) mode for higher conversion gain and a resistive mode for enhanced linearity. The results show that the mixer achieves a conversion gain of -4.2 dB in PT mode and -15.9 dB in resistive mode. In PT mode, with a 5 dBm LO drive, the input third-order intercept point (IIP3) is 1 dBm, and the input 1-dB compression point (IP1dB) is -4 dBm. In resistive mode, with a 2.6 dBm LO drive, the mixer achieves an IIP3 of 6 dBm and an IP1dB of 4 dBm. These results highlight the potential of the proposed design for 6G mmWave front-ends that require dynamic performance optimisation, such as balancing the trade-off between gain and linearity.**

I. Introduction

THE demand for high-performance mixers for 6G radio front ends is constantly growing. A mixer capable of operating in both modes while offering high gain and excellent linearity would provide significant flexibility in modern communication systems. Most reconfigurable mixers currently consist of a cascade of a mixer and a variable gain amplifier. Recently, efforts have been made to develop reconfigurable mixers where gain control is achieved directly within the mixer [1]–[3]. In [1], an active mixer was designed to achieve a conversion gain variation from 8 dB to 20 dB; however, it only attained a maximum IP1dB of -4 dBm. In [2], a passive diode mixer was presented, but suffered a conversion loss exceeding 11 dB. In [4], a 38GHz variable-gain mixer fabricated using a 65nm CMOS process is presented. The design employs an active–passive combined (APC) mixing core technique to enable control over the gain state and noise performance. The mixer demonstrates variable gain operation with the variation in output 1-dB compression point (OP1dB). Reference [3] introduced a broadband dual-mode double-balanced ring mixer with an active IF balun. However, this mixer exhibited high power consumption due to its complex ring mixer architecture and active balun.

In this paper, we presented a dual-mode 73 GHz (E-band) mixer with a novel yet simple FET-based structure and simulated using a 100 nm pHEMT PH10 process. The mixer employs a switchable impedance network and reconfigurable DC biasing to enable two distinct operational modes: a pump transconductance (PT) mode for higher conversion gain and a resistive mode for enhanced linearity. The proposed mixer is a promising candidate for 6G mmWave front-ends that require dynamic performance optimization, such as balancing the trade-off between gain and linearity.

Fig. 1 illustrates the structure and modes of operation. In PT mixing mode, the DC biasing is configured so that FET T2

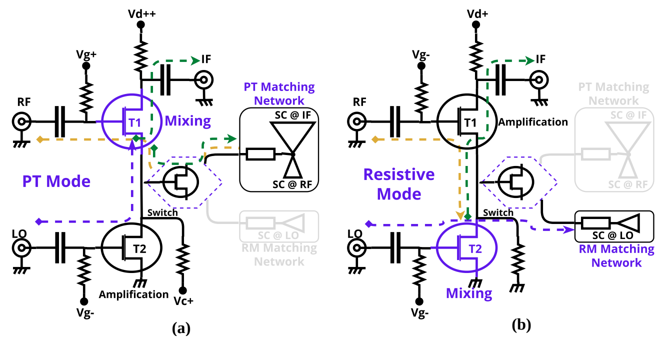

Fig. 1. Structure of mixer with operation modes (a)PT mixing (b)Resistive mixing

operates as an amplifier while T1 functions as a PT mixer, as shown in Fig. 1(a). A switchable impedance network between FET T1 and T2 is designed, and the PT matching network is selected to ensure that the RF and IF signals are shorted and do not reach FET T2. Similarly, in resistive mixing mode, T2 operates as a mixer while T1 functions as an amplifier, as shown in Fig. 1(b). This is achieved by adjusting the DC biasing, specifically by applying zero voltage at the drain of T2.

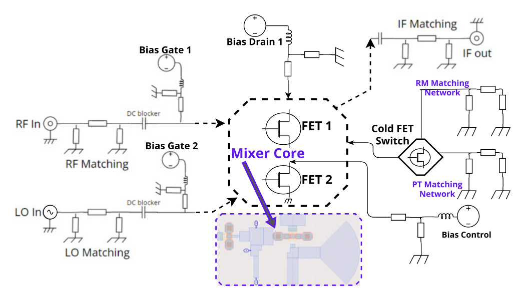

Fig. 2. The detailed structure of the proposed downconverter mixer

The detailed schematic of the proposed downconverter mixer is shown in Fig. 2. The mixer translates RF signals at 73 GHz to an IF of 13 GHz using a local oscillator (LO) signal at 60 GHz. A relatively large frequency offset between the LO and RF is intentionally chosen to facilitate the design of frequency-selective radial stubs. Specifically, this offset improves the effectiveness of shorting the RF signal at the drain of transistor T1 in PT mode and the LO signal at the same node in resistive mixing mode. If the RF and LO frequencies were too close, implementing narrowband radial stubs capable of selectively shorting only one of the signals in each mode would become significantly more challenging. Careful design of the matching networks, along with layout optimization, ensures efficient frequency conversion in both operating modes.

II. Results

The proposed dual-mode downconversion mixer layout is simulated using Keysight Advanced Design System (ADS) with a 0.1m GaAs pHEMT process from the UMS PH10 PDK. The mixer is designed to operate efficiently in both pump transconductance (PT) and resistive mixing modes. In PT mode, the drain voltage of transistor T1 is set to 6V, the gate voltage (Gate 1) is 2.53V, and the control voltage applied to the drain of T2 is 3.04V. This biasing results in a gate-source voltage (V_{gs}) of -0.51V for FET T1, placing it in the appropriate operating region for PT-based mixing. In resistive mode, the drain voltage of T1 is reduced to 3V, with Gate 1 biased at -0.28V. The control voltage at the drain of T2 is set to 0V, allowing T2 to function as a resistive mixing device under these bias conditions. Fig. 3 illustrates the mixer's performance, demonstrating a conversion gain of -4.2 dB in PT mode and -15.9 dB in resistive mode.

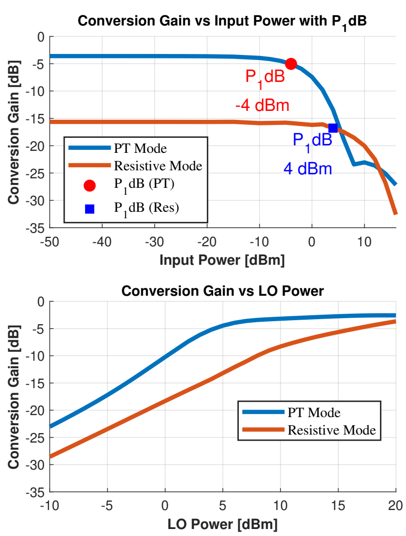

Fig. 3. Conversion gain plot against LO and RF input power

In PT mode, with an LO drive of 5 dBm, the input 1-dB compression point (IP1dB) is measured at -4 dBm. Conversely, in resistive mode, an LO drive of 2.6 dBm results in an IP1dB of 4 dBm. Due to its simple structure consisting of just 2 FET and no other active components, the mixer consumes very low power.

The isolation performance is illustrated in Fig.4, where the RF-to-IF and LO-to-RF isolations exceed 20dB, while the LO-to-IF isolation remains above 12dB. These results demonstrate the mixer's strong port-to-port isolation characteristics. Fig.4 also presents the RF and LO return loss performance, further confirming proper impedance matching at the respective ports.

Fig.5 presents the 3dB bandwidth performance of the proposed mixer, which exceeds 4 GHz in both the PT and resistive modes. These results highlight the mixer's consistent wideband operation across the two modes.

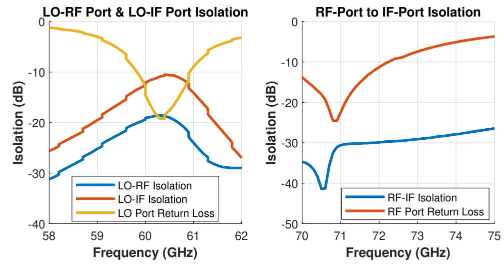

Fig. 4. Port-to-Port Isolation plots for the proposed mixer

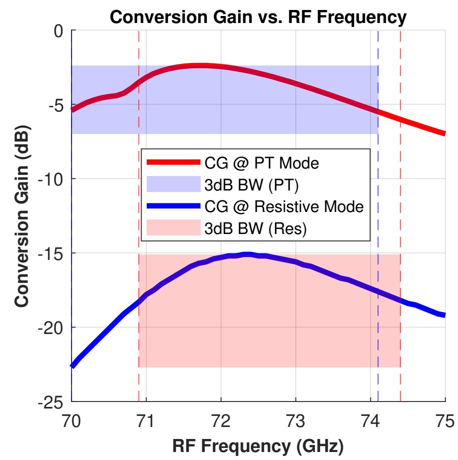

Fig. 5. 3 dB bandwidth performance of proposed mixer

III. Conclusion

A dual-mode E-band mixer leveraging a simple FET-based architecture has been designed and simulated using a 100nm pHEMT PH10 process. By integrating a switchable impedance network and reconfigurable biasing, the mixer supports both PT and resistive operation modes—offering flexibility between higher gain and improved linearity. Simulation results confirm a conversion gain of 4.2dB in PT mode and -15.9dB in resistive mode, with corresponding IIP3 and IP1dB values demonstrating effective trade-off control. These results validate the proposed mixer's suitability for 6G mmWave front-end applications where adaptive performance is critical.

References

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