Push-Pull Frequency Converter for Mobile Communication

A. V. Thangavelu, H.P. Moyer, M. Ghanevati, A.S. Daryoush, and R. Gutierrez*
Microwave Photonics Device Laboratory
Department of ECE, Drexel University, Philadelphia, PA 19104
*Phoenix Microwave Corp., Telford, PA 18969

ABSTRACT

This paper demonstrates a push-pull self-oscillating mixer (SOM) for wireless communications at 900MHz. Both up-conversion and down-conversion experiments are reported using this SOM. The conversion gain of the circuit is ≥+15 dB, IP3 of -3 dBm, SFDR of 102 dB.Hz$^{2/3}$, and an average power consumption of ≈37 mW.

INTRODUCTION

Personal Communication Services (PCS) are seen as a major commercial opportunity for microwave industry [1]. The basis for PCS system is the global interconnectivity using the handheld units to provide communications of data, audio, and video signals through a myriad of pico-cell linked to base stations [2] or a constellation of satellites [3]. The key for user friendliness of these systems is improvement in battery designs and implementation of low power consuming electronics. Hand held units for wireless communication systems require low cost, compact transceiver front ends with high performance. A conceptual presentation of a hand held unit is shown in Fig. 1, where the RF and IF signals are down- and up-converted to the IF and RF signals respectively, using a local oscillator and mixer assembly. The approach pursued here are to design and implement a lower power consuming self-oscillating mixer (SOM) to replace separate units of local oscillator, mixer, and buffer amplifier.

A push-pull SOM design is advocated to meet the performance requirements of an efficient microwave front end at the mobile communication frequency of 900 MHz. By combining both the oscillation and mixing functions into one circuit a high conversion gain is anticipated, eliminating the need for the buffer amplifier frequently used after conventional mixers. Furthermore, the SOM eliminates the requirement of high LO output power. Thus, a much lower prime power consumption is anticipated for this SOM than the combination of a stand alone LO, mixer, and buffer amplifier. The goal of this paper is to introduce the design and realization of a push-pull SOM in terms of power consumption, conversion gain, NF, and dynamic range.

DESIGN APPROACH

In the past self-oscillating mixers have been implemented with Darlingtion pairs [4] and dual-gate MESFETs [5]. The disadvantage of the Darlington pairs is a high power consumption which is unacceptable for mobile systems. Dual-gate MESFETs naturally lend themselves to a self-oscillating mixer topology but are slightly more expensive due to their implementation in GaAs, have a higher phase noise performance due to the inherently higher 1/f noise in GaAs FETs, and do not offer the harmonic rejection and efficiency inherent to a push-pull configuration.

The push-pull SOM topology was first proposed by Zhou and Daryoush [6, 7] at X-band using GaAs MESFET. The same circuit philosophy is now extended to a wireless communication frequency of 900 MHz using Si BJTs as shown in Fig. 2. In this circuit, stable oscillation is generated with a Class AB push-pull amplifier by providing positive feedback from its output to its input through a resonant tank circuit. Therefore, a 180° phase shift is required between the inputs and outputs of the two npn bipolar transistors operating in Class AB.

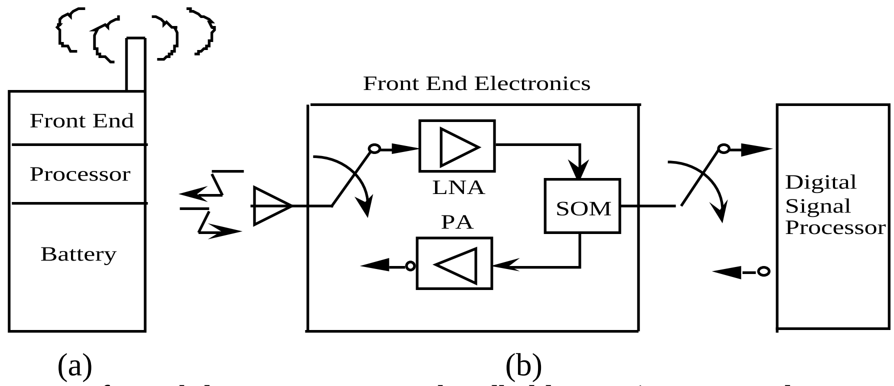

Fig. 1. Block diagram of a mobile communication handheld unit, a) conceptual representation of a handy set phone, b) microwave front end electronics used for up- and down-conversion of audio signals.

Since the operation of the push-pull SOM relies on an efficient method of realizing a 180° phase shift, a number of methods of achieving this phase shift were reviewed. Naturally, the use of coaxial or microstrip delay lines are not practical for 900MHz. Other approaches, such as totem pole design, were also considered. A 180° phase shift between base and collector of BJT is the basic operation principle of the totem pole design; however, having an extra transistor in front of the push-pull pair is less efficient than a passive method. Furthermore, the cost of an extra transistor and the possible difficulties in matching it to the push-pull amplifier are the least problematic; moreover, it also introduces additional reliability concerns. Finally, toroids are selected for their small size and low cost. However, toroids tend to be lossy, which could prevent the start of oscillation in the push-pull oscillator. A loss of 3 dB at 900 MHz is measured for a custom-designed toroids, which has to be overcome by gain of the push-pull amplifier.

The Siemens BFP-405 silicon BJT is selected for its high gain and low noise figure of ≤1dB at 900 MHz. Using a silicon BJT also improves the phase noise performance of the oscillator, since a Si BJT has inherently much lower flicker noise than a GaAs FET. A series tunable resonator provides feedback from the base of transistor Q1 to the collector of Q2. Quality factor of ≈ 100 is measured for a lumped element realization of this series resonator. The feedback capacitor is realized by selecting a varactor diode, to provide potential for VCO realization. The VCO operation could easily lend itself to realization of PLL to ensure high oscillator stability. Finally, the up-conversion (down-conversion) of the IF (RF) signal with LO is realized by taking advantage of the high nonlinearity of the Class AB operation of the push-pull transistors. The IF(RF) signal is injected into the base of the transistors through the input toroid and the RF(IF) signal is retrieved from the output toroid, as shown in Fig. 2.

EXPERIMENTAL RESULTS

The transistors are biased using a 5 V supply. The biasing resistors R1, R2, and R3 are selected to provide Class AB operation of the transistors (V_{ce} of 2.9 V with total I_c of 7.3 mA), where the 470Ω resistor controls the feedback coupling factor. The oscillator spectrum is shown in Fig. 3, where an output power of 0dBm with the phase noise of ≈ -90 dBc/Hz at a 10 kHz offset carrier. The measured output spectrum with an RF signal input of -40 dBm at 820 MHz is shown in Fig. 4. The spectra of the down-converted signal at 80MHz is shown in this figure. A similar performance is also observed for the up-conversion using an IF of 80MHz. The results are not depicted due to the space limitation. A conversion gain of greater than 15 dB is measured for both up and down conversion. However, Input-Output measurements of up- and down-conversion exhibits gain compression for input power above -30dBm. The conversion gain reduces to +5dB for -10dBm input power.

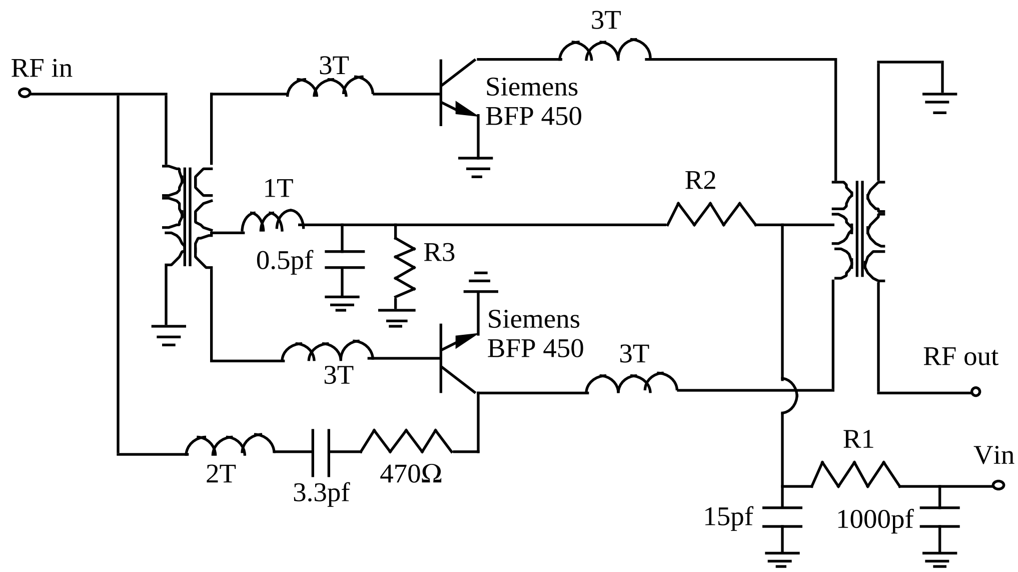

Fig. 2. Schematic circuit diagram of the push-pull self-oscillating mixer at 900MHz. Inductors are defined as number of turns of a no. 32 wire.

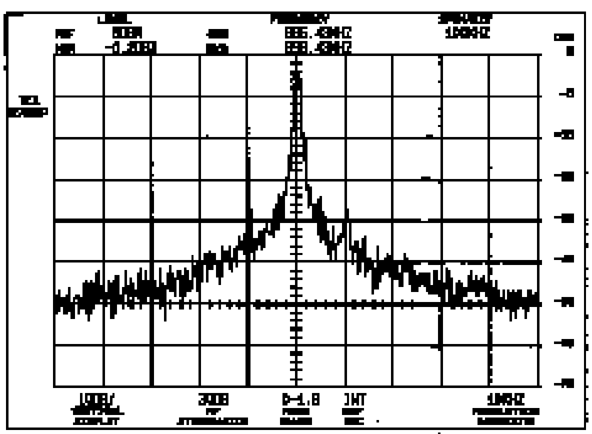

Fig. 3. Measured output spectrum of the push-pull SOM as a free running-oscillator. (Vertical scale of 10dB/div, Span of 100kHz/div, and Resolution BW of 10kHz. Marker level of -0.2 dBm at 896.43MHz.)

The two-tone third order intermodulation measurements are also conducted on this hybrid circuit. Fig. 5 depicts the overall measured characteristics of this SOM as a down-converter. A third order intercept point (IP3) of -2dBm is measured. A similar performance is also observed for the SOM as an up-converter. The measured DSB noise figure of the circuit is 6dB, with an estimated compression dynamic range (CDR) of 145 dB.Hz and the spurious free dynamic range is 102 $dB.Hz^{2/3}$.

CONCLUSIONS

This paper presents performance of a small hybrid SOM. The performance of this circuit in terms of conversion gain, power consumption and tuning capability is comparable with other known architectures [4, 5]. Furthermore, the power consumption of this configuration is only 37 mW as compared to a consumption of 75 mW for Anadigics architecture [4] and 250 mW for the HP circuit [5]. Overall, the proposed SOM has critical performance characteristics that makes it attractive for mobile communication systems.

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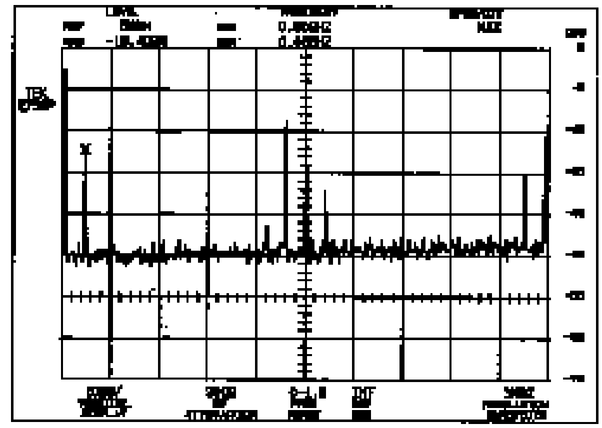

Fig. 4. Measured output spectra of the push-pull SOM driven by an RF input power of -40 dBm @ 820 MHz. Stable oscillation, RF, IF, harmonics and intermodulation signals are present. (Marker level of -19.4dBm at frequency of 80MHz.)

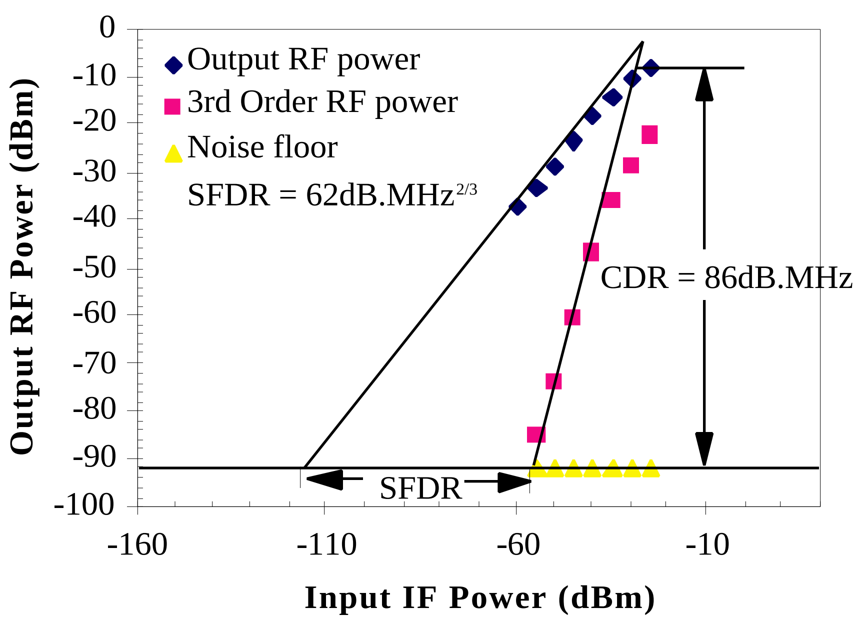

Fig. 5. Output power of the RF signal and the IMD levels as result of the input IF signal. The noise power level of the SOM is also depicted. The two tone signals are at 820 MHz and 821 MHz. Calculated dynamic range performance of the SOM is also indicated.

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