New Balanced Self Oscillating Mixer Using DGS Resonator

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***Abstract*— In this paper, a balanced self-oscillating mixer (SOM) using DGS resonator operating at 5.2 GHz is presented. Since H-slot DGS (Defected Ground Structure) resonator achieves a high Q factor, it provides low phase noise for the oscillator. A balanced mixer is utilized and provides good LO-RF isolation since two LO signals (LO+, LO-) are suppressed at the RF input port. The oscillator generates balanced 4.77 GHz signal using an H-slot DGS. The IF at each port achieves 1 dB conversion gain at 430 MHz with 5.2 GHz RF input signal. This SOM presents a good linearity because IIP3 is observed about 6 dBm and 1 dB compression point is -4 dBm. Therefore, this SOM structure proposed here is suitable for WLAN environment.**

I. INTRODUCTION

The first active FET SOM, which combinates a mixer and an LO source in one single device, has been developed in [1]-[6]. There are various advantages related to the SOM technique: cost is reduced due to lowered component count and thus higher reliability, more compact solution offers easier integration into monolithic microwave integrated circuit (MMIC), and furthermore total power consumption is lowered. However, single ended mixer structure has been widely utilized for SOM on hybrid microstrip technology, which only has single input (RF) and single output (IF).

In this paper, a new configuration of microwave balanced SOM with H-slot DGS resonator technique is proposed. This is believed to be a very advantageous technique: due to the H-slot resonator, it improves quality factor (Q) of resonator [7]-[8], which results in enhancing phase noise for oscillator, and it has more compact structure. Due to balanced output (+IF, -IF), this structure is strong to noise. Furthermore, a cascode structure and balanced LO signals make high RF-LO isolation. The SOM can be used for a large number of applications: SOMs needed in radar systems, radiometry, imaging applications, communication systems, transceiver front-ends, etc. The H-slot DGS resonator is designed for oscillator to accomplish the lower phase noise performance, and the oscillator is fed to mixer using the same FET.

II. DESIGN

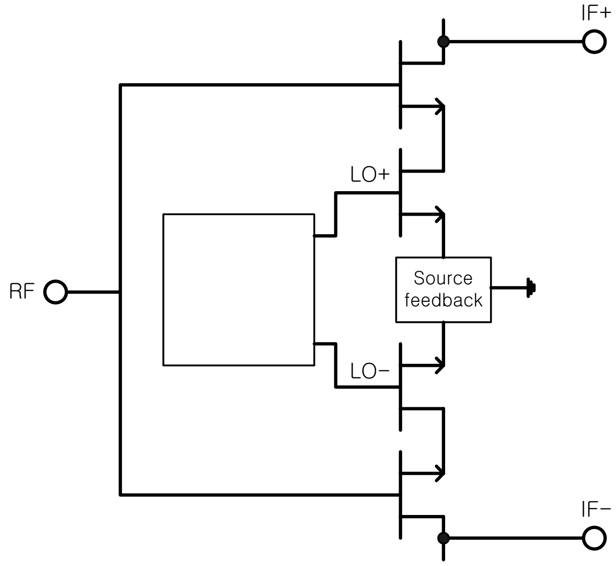
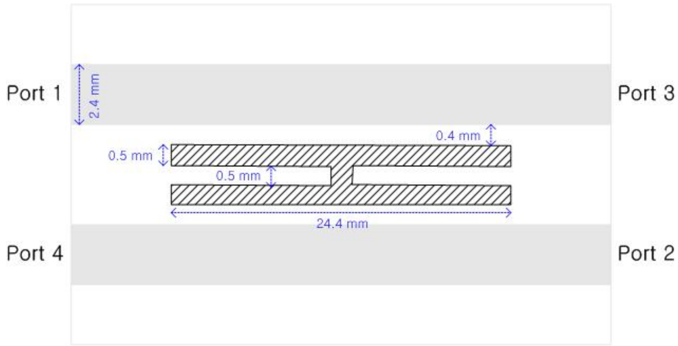


Fig. 1. Proposed self-oscillating mixer (SOM) block diagram

Fig.1 shows the circuit diagram for the proposed SOM. The balanced LO signals are generated 180° output of phase and the RF signals are combined with these LO signals at the gates of transistors. At the drain outputs, mixing products can be enhanced by combining the IF outputs 180° out of phase. Transistor biasing is realized for creating the oscillating circuit to maximize the output power of oscillator. The mixer circuitry reuses the FET already used for oscillator. This proposed structure consists of a resonator using H-slot DGS resonator, components for operating oscillator, and components for operating mixer.

A. Oscillator Design

An H-slot DGS resonator is employed for the oscillator since this DGS provides high Q factor in a balanced structure.



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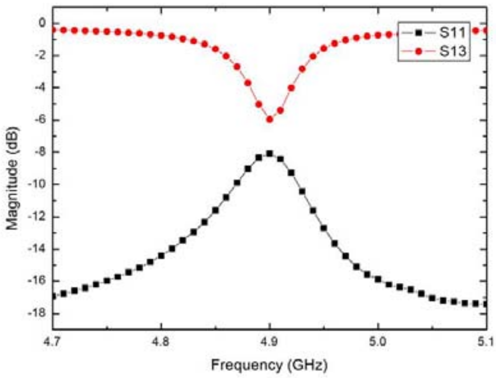

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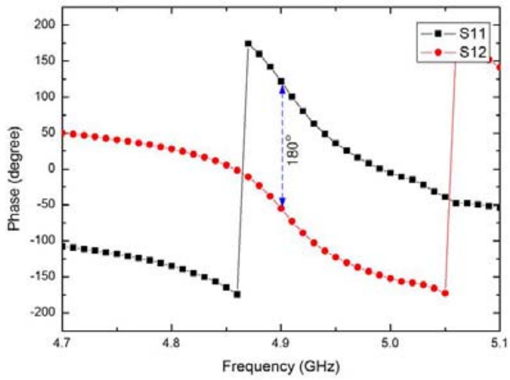


(c)

Fig. 2. H-slot defected ground structure (DGS) resonator (a) physical structure, (b) simulation result of transfer characteristics of H-slot DGS resonator (magnitude), (c) simulation result of transfer characteristics of H-slot DGS resonator (phase).

Fig.2(a) illustrates the configuration of an H-slot DGS resonator built on the ground plane. The characteristic impedance of the microstrip line on the top plane is assumed to be 50 Ω and a full-wave simulation is performed by using the ADS- Momentum. H-slot DGS resonator for high Q factor exhibits the band rejection characteristic and a flat and lossless pass band which can be utilized for the oscillator design.

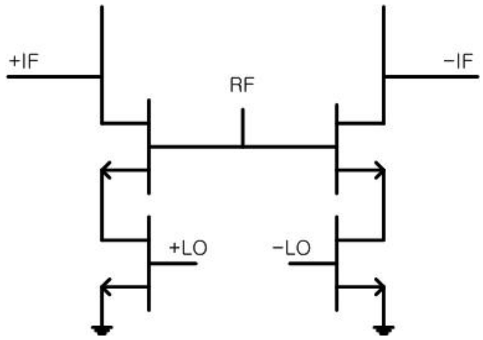


Fig. 3. The proposed balanced mixer block diagram.

The phase difference between port 1 and port 2 (or port 3 and port 4) of this proposed H-slot DGS resonator is maintained 180°. Therefore, port 3 and port 4 are terminated with 50 Ω resistors in the proposed SOM. Fig.2(b) and Fig.2(c) show the simulation result for the amplitude and phase responses of S-parameters of the H-slot DGS resonator. At the resonant frequency which is designed as 4.9 GHz, a band rejection characteristic is observed. The 2nd harmonic of the oscillator using H-slot DGS resonator is suppressed because the DGS structure usually does not show resonant frequency at the 2nd harmonic.

The design of a feedback oscillator is well known so that it basically consists of a cascode FET amplifier, a resonator and a feedback lines. The oscillating function of SOM is obtained using the H-slot DGS resonator, with a microstrip feedback.

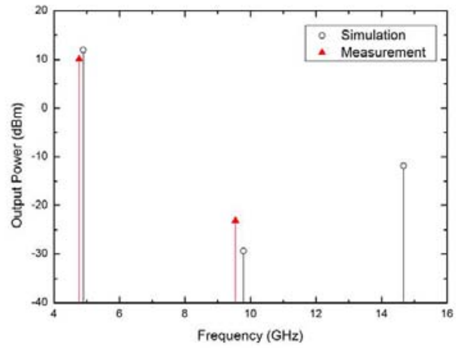
B. Mixer Design

The mixer operation is implemented by a balanced configuration. For mixer, FETs used for the oscillator function are reused for reducing the number of components and power consumption. Fig.3 shows the basic block diagram for the mixer. Using balanced LO outputs two balanced IF signals are generated. This structure provides high RF-LO isolation, because balanced LO signals are cancelled out at the RF port. The considerable conversion gain is achieved employing the cascode configuration and the linearity is improved with the balanced structure. Finally, two balanced IF signals are generated through the FETs.

III. SIMULATION

The proposed circuit has been simulated for designing the mixer and oscillator with the Agilent ADS 2005A using HB simulation. This circuit has been designed with relative dielectric constant 2.2 and substrate height 0.787 mm on RT/Duroid 5880 substrate. H-slot DGS resonator is optimized as shown in Fig.2(a) with width = 0.5 mm, length = 24.4 mm, and spacing = 0.5 mm. The ATF13786 is used for oscillator with the bias of V_{DD} = 3.5 V, V_{GS1} = 0.5 V, and V_{GS2} = -0.6 V.

Simulation results are shown in Fig.4. Fig.4(a) shows the output spectrum for the oscillation of SOM. At 4.88 GHz,



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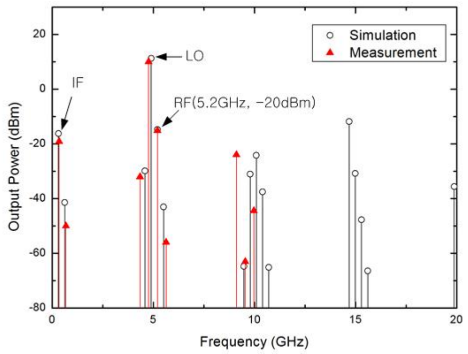

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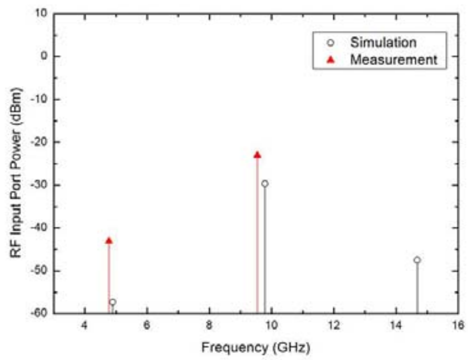

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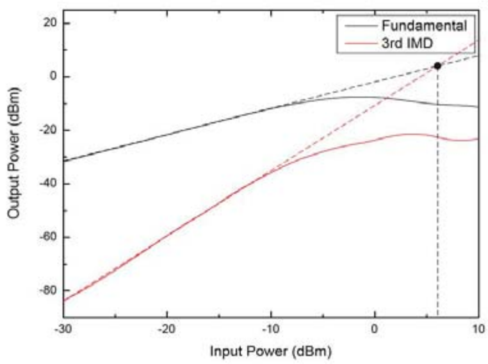

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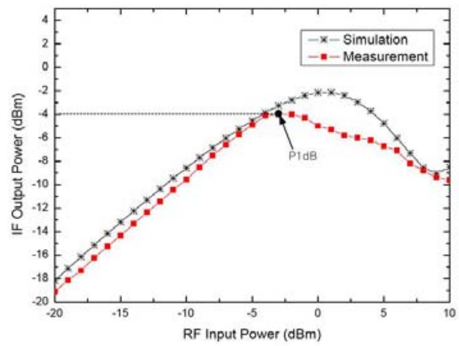


(e)

Fig. 4. Simulation and measurement results of SOM. (a) Results of oscillation (magnitude spectrum), (b) Results of mixing spectrum, (c) LO leakage spectrum, (d) Simulation Result of 3 rd order intercept point, (e) Measurement results of 1-dB compression point.

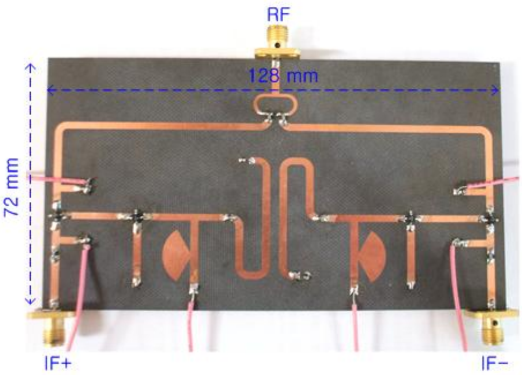
oscillation output is printed, and output power at the IF ports is 11.282 dBm. Mixing simulation is performed as shown in Fig.4(b). The RF signal used here is -20 dBm at 5.2 GHz. The simulation result shows that mixed outputs are generated at 319.8 MHz. Mixed output conversion gain is obtained 4 dB on simulation. Fig.4(c) shows the LO power appeared at the RF input port. In the simulation, RF-LO isolation is obtained 43 dB at the RF port. In addition, IIP3 simulation result is shown in Fig.4(d). In Fig.4(d), this structure has good linearity because IIP3 simulation result shows 6 dBm with the two tone signals excited at 455MHz and 405MHz. Fig.4(e) shows the IF output power versus input RF power. The 1 dB compression point is observed -4 dBm.

IV. MEASUREMENT

The proposed SOM is fabricated as shown in Fig.5. Total SOM dimension is 128 x 72 mm and H-slot DGS resonator length is 24.4 mm on bottom layer providing the resonant frequency at 4.9 GHz.

In Fig.4(a), the oscillation of the SOM is measured by a spectrum analyzer (Anritsu MS2668C). The measured result shows 10.08 dBm output power at the oscillation frequency of 4.77 GHz. The measured oscillation frequency is a bit deviated by 110 MHz compared to the simulation, furthermore the oscillating power is almost the same as the simulated one. As shown in Fig.6, the phase noise is obtained -115 dBc at 1 MHz offset which is comparable to the general oscillator.

-20 dBm input RF power at 5.2 GHz is generated using an Agilent E8527D signal generator. In Fig.4.(b), the IF power achieves -18.1 dBm at the one IF port with the other IF port terminated. IF frequency is measured 430 MHz and conversion gain is obtained 1 dB.



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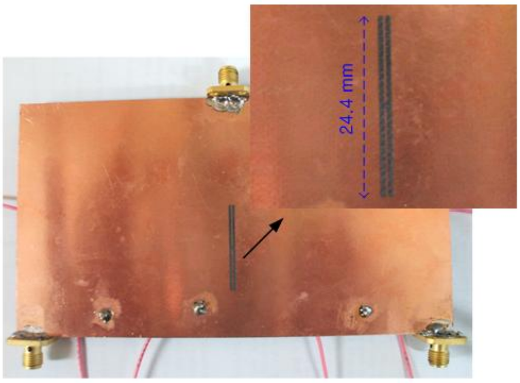

(b)

Fig. 5. Photograph of the fabricated SOM (a) Top view, (b) Bottom view.

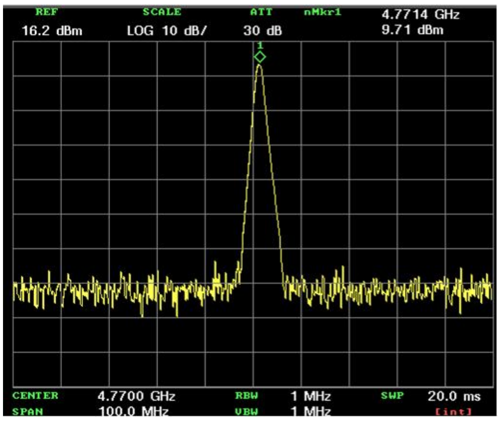

Fig. 6. Measurement of SOM oscillator.

V. Conclusion

The proposed SOM is compared with other SOMs in Table 1. SOMs published previously that were fabricated on hybrid technique do not achieve the conversion gain. However, this proposed SOM shows 4 dBm conversion gain. Good IIP3 and P1dB illustrate that the linearity of this proposed SOM is better than that of others due to DGS resonator.

TABLE I
COMPARED SOM

Parameters	[2]	[4]	This work
RF freq.	30 GHz	5.9 GHz	**5.2 GHz**
IF freq.	1.7 GHz	160 MHz	**430 MHz**
Conversion gain	-8.6 dB	-7 dB	**4 dB**
Pout (LO)	-	10 dBm	**10.08 dBm**
IIP3	-	-	**6 dBm**
P1dB	-9dBm	-	**-4 dBm**

A new SOM topology, by applying the H-slot DGS resonator technique, is proposed in this paper. A design method is developed to implement the DGS SOM, which can also be applied to DGS oscillator design. The oscillation of circuit is stabilized at 4.77 GHz, and the mixing with LO yields IF at 430 MHz. Due to the high Q factor of the H-slot DGS resonator, a good phase noise is achieved. The suppression of harmonics was performed very efficiently in the oscillating operation for this topology. The balanced configuration for oscillation and mixer can underlie circuits for suppressing the unwanted harmonics, also a good RF-LO isolation. Furthermore, this structure shows a good IIP3, measured 6 dBm. Therefore, this proposed structure accomplishes linearity enhancement very effectively. The proposed SOM structure in this work can be applied to MMICs for various wireless systems.

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