Series Switched Resonator Based Dual-Band Oscillator

***Vivek Sharma*, Ravinder Yadav, and N. P. Pathak**

Radio Frequency Integrated Circuit (RFIC) Research Group
Electronics & Computer Engineering (ECE) Department
Indian Institute of Technology (IIT), Roorkee-247667 (India)

viveksharma16@gmail.com, luv2ravi120@gmail.com, nagppfec@gmail.com

Abstract

A series switched resonator based dual-band oscillator, employing single transistor, is reported. The oscillator employs a semiconductor diode, as switch, to change the resonator's effective length, thereby, controlling the oscillator's negative resistance to shift its output between two desired frequencies. Agilent's Advanced Design System (ADS) in conjunction with the electromagnetic simulation tool (EMDS) were used to design the oscillator. The measured characteristics of the fabricated dual-band oscillator, operating near 5.7 GHz and 6.48 GHz, indicate constant output power levels of 4.02 dBm with second harmonic power levels being at least 12 dB below. The measured characteristics also indicate -116.3 dBc/Hz and -95.23 dBc/Hz phase noise levels at 1 MHz offset for the above mentioned two cases, respectively.

1. Introduction

Multi-band oscillator is expected to become a key device for the next generation multi-band and multi-mode wireless radios [1]. Various switching based techniques have been proposed to achieve multi-band performance. Some of the topologies use separate oscillators [2] to obtain multi-band response while others use distinct resonators [3] or matching networks [4] to achieve the same. An alternative switched resonator technique is discussed, wherein, oscillator's negative resistance is controlled by modifying microstrip line resonator's length using a diode based electrical switch. The technique is utilized to realize a dual-band oscillator. The proposed series switched resonator based multi-band oscillator concept is discussed in section 2, while, section 3 provides implementation details of an experimental dual-band oscillator, based on the proposed scheme.

2. Series Switched Resonator Concept

An oscillator converts DC power to RF power using negative resistance characteristics of active devices. A typical microwave oscillator consists of frequency selective network, active devices and output matching network. Intuitively, the passive frequency selective network determines the generated frequency depending on its resonance frequency, while the active core provides enough negative resistance to compensate for any loss in the resonant structure. If required, an external positive feedback is added to the active device to sufficiently destabilize the circuit for oscillation.

Conventionally, multi-band oscillators are realized by reconfiguring the frequency selective network [3, 5]. Typically, a negative resistance cell is combined with a switch-controlled resonator. Distinct frequency selective circuit units are designed such that the negative resistance cell satisfies the necessary oscillating condition at their corresponding resonant frequencies. As shown in figure 1, the individual frequency selective unit elements are placed in parallel, while a switch selects one of them to produce the required frequency output.

The method of using parallel frequency selective circuit may degrade the phase noise due to coupling among the resonant elements, which are placed in parallel. Hence, the proposed multi-band oscillation scheme modifies the frequency selective network by varying only the microstrip length to select the desired frequency response, as depicted in the block diagram of figure 2 for dual-band case.

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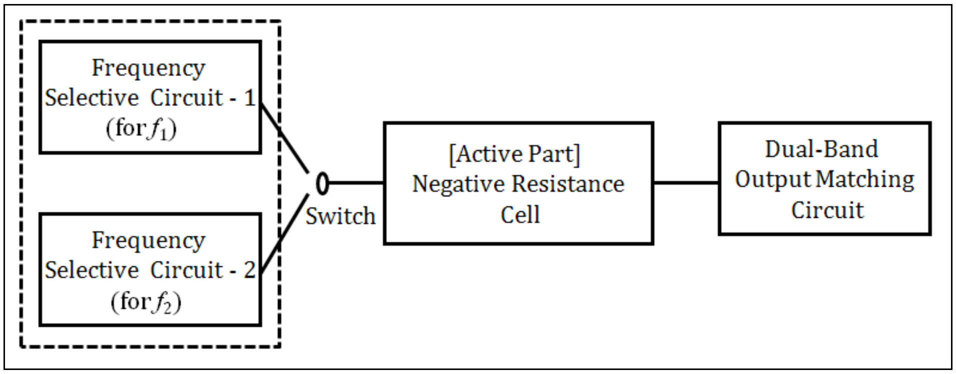


Figure 1. Parallel Switched Resonator Dual-Band Oscillator Block Diagram

At the network's input, two microstrip resonators of different lengths are connected in series through an electrical switch to define the required oscillating frequencies. Simultaneously, a dual-band output matching network is designed for optimum output power efficiency to a 50 Ω load at both the designed frequencies. The scheme is extendable to multi-band scenario using additional frequency selective circuits, connected through electrical switches, with appropriate multi-band matching network at the oscillator's output.

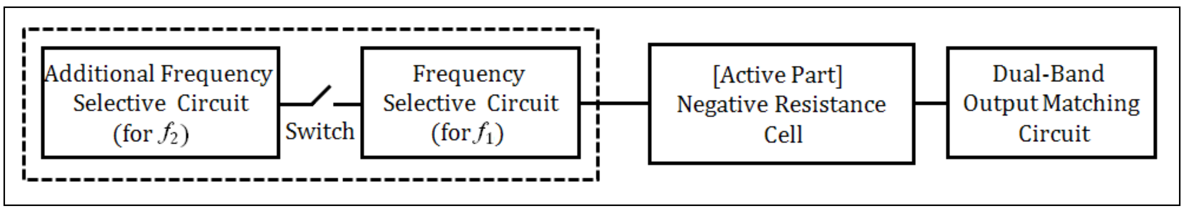


Figure 2. Proposed Series Switched Resonator Dual-Band Oscillator Block Diagram

3. Dual-Band Oscillator Implementation

A dual-band oscillator prototype was implemented using the proposed series switched resonator scheme with single transistor. The common-source configuration of a Hetero-Junction Field-Effect Transistor (NE4210S01) was used to generate appropriate negative resistances for dual-band oscillation at 5.2 GHz and 6.8 GHz. The transistor was dc biased through a bias-tee network, implemented using a high impedance (100 Ω) quarter wavelength (electrical length 90^0) microstrip line which is further shunted by a low impedance (20 Ω) quarter wavelength open stub. Biasing voltages of V_{DS} = 2 V and V_{GS} = -0.5 V were maintained at the source and the gate terminals of the transistor. It is known that oscillations are achieved at those frequencies where the stability parameter (K) value is less than one. In order to meet this instability condition for oscillations at both the desired frequencies, a bypass capacitor was added to the transistor's source terminal. In effect, the capacitor incorporates an external positive series feedback to the network, thereby, ensuring the required network destabilization. The bypass capacitor was implemented through microstrip transmission line. Instability was ensured as the circuit's stability factor (K) was found to be less than one for both the design frequencies.

Schottky diode was used as the frequency selection switch to change effective length of the microstrip line resonator, which forms a part of the overall oscillator circuit. Biasing circuit for the diode was designed in such a way that it didn't disturb the biasing voltage of the transistor. While, forward bias included complete length, reverse bias incorporated length of the resonator just before the diode as a part of the overall oscillator. Nevertheless, negative resistance condition for oscillation was maintained at both the designed frequencies, thereby, upholding oscillation at one frequency during forward bias and at another frequency in reverse bias case. The switch capacitance was taken into account while deciding resonators' lengths for the two frequencies. Dimensions of the resonators and the matching network were optimized using Agilent's Advanced Design System (ADS) in conjunction with the electromagnetic (EMDS) simulation tool to get the required oscillation frequencies for dual-band operation.

3.1 Fabricated Prototype

The oscillator was fabricated using hybrid microwave integrated circuit (MIC) technology, using the PTFE/glass/ceramic NH9338 substrate with relative permittivity (ε_r) of 3.38, 1.524 mm (60 mil) dielectric thickness and dissipation factor of 0.0025. The fabricated circuit is shown in figure 3.

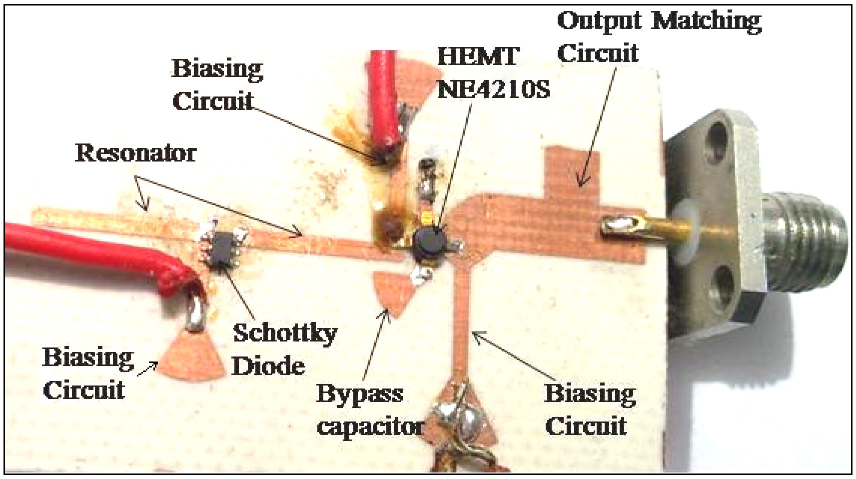


Figure 3. Hardware Prototype of Series Switched Resonator Based Dual-Band Oscillator

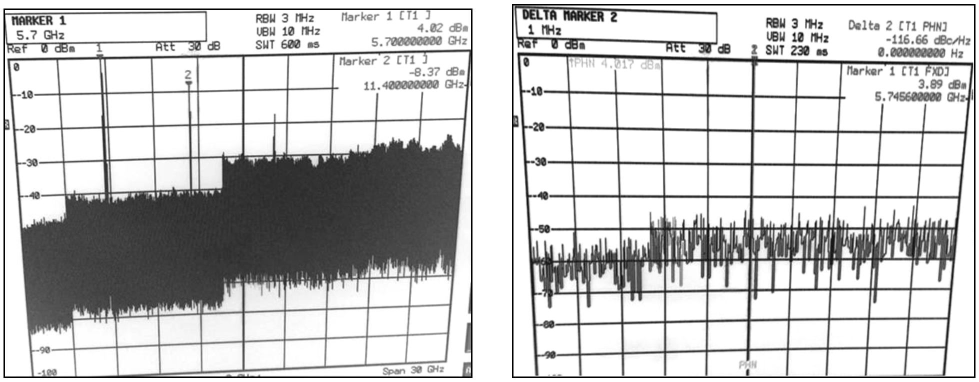
The dimensions of microstrip lines and gap widths among them, in the fabricated prototype oscillator are mentioned in table 1. The radial microstrip structures, used in the circuit, simulate corresponding capacitors with one end grounded.

Table 1. Various Dimensions in Fabricated Oscillator

S. No.	Structures		Width (mm)	Length (mm)
1.	Microstrip Line Resonators	(a) for f_1	1	13.1
		(b) additional for f_2	0.95	7.1
2.	Output Matching Network	(a) open shunt stub	3.35	3.35
		(b) transmission line	3.27	9.4
3.	Bias-Tee Networks (excluding 60^0 radial capacitors)	(a) for Schottky diode	0.87	4.49
		(b) for transistor's gate	0.99	7.25
		(c) for transistor's drain	0.9	6.59
4.	Microstrip line connecting transistor's source to ground (excluding 60^0 radial capacitor)		0.86	6.12
5.	Gaps between microstrip lines	(a) for diode	0.7	
		(b) for gate and source	0.64	
		(c) for source and drain	1.55	

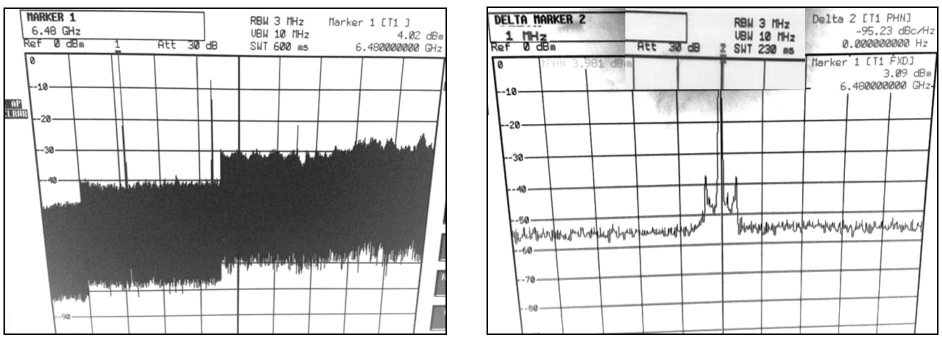
3.2 Experimental Results

The measured output power and phase noise levels for the previously mentioned biasing conditions are shown in figures 4a and 4b for the diode's reverse bias and figures 5a and 5b for forward bias conditions, respectively. The measured oscillator frequency, phase noise and output power were observed to be within 5-10% of the simulated values. The implemented dual-band oscillator exhibited constant output power level of 4.02 dBm at slightly different frequencies of 5.7 GHz and 6.48 GHz, for reverse and forward bias diode conditions, respectively. Second harmonics for both the cases were observed to be about 12 dB below the output power at fundamental frequencies. The phase noise performance was measured as -116.3 dBc/Hz and -95.23 dBc/Hz at 1-MHz offset for the two cases.



(a) (b)

Figure 4. Measured Output Power (a) and Phase Noise (b) for Reverse-Biased Diode Case



(a) (b)

Figure 5. Measured Output Power (a) and Phase Noise (b) for Forward-Biased Diode Case

4. Conclusion

The concept of series switched resonator was discussed as means to achieve multi-band operation in an oscillator. A prototype oscillator was designed based on the proposed technique to achieve dual-band operation while using only one transistor. Switching between the two desired frequencies was achieved using a semiconductor diode. The fabricated circuit exhibited sufficient phase noise performance while providing constant power output for both the reverse-bias and the forward-bias diode cases.

5. References

1. A. R. Rofougaran, M. Rofougaran, and A. Behzad, "Radios for Next-Generation Wireless Networks," *IEEE Microwave Magazine*, **6**, March 2005, pp. 38-43.

2. A. Kral, F. Behbahani, and A. A. Abidi, "RF-CMOS Oscillators with Switched Tuning," *Proceedings of the IEEE Custom Integrated Circuits Conference*, May 1998, pp. 555-558.

3. A. P. S. Khanna and R. Soohoo, "Fast Switching X and Ku Band Multi Frequency Dielectric Resonator Oscillator using a Single GaAs FET," *IEEE International Microwave Symposium MTT-S*, **1**, June 1987, pp. 189-191.

4. A. Yamagishi, T. Tsukahara, M. Harada, and J. Kodate, "A Low-Voltage 6-GHz-Band CMOS Monolithic LC-Tank VCO using a Tuning-Range Switching Technique," *IEEE Microwave Symposium MTT-S*, **2**, 2000, pp. 735-738.

5. B. Catli and M. M. Hella, "A Low-Power Dual-Band Oscillator Based on Band-Limited Negative Resistance," *IEEE Radio Frequency Integrated Circuits* (*RFIC*) *Symposium*, June 2009, pp. 251-254.