

## Design and Simulation for UHF Oscillator using SAW with Different Schematics

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### Abstract

Various schematics for colpitts oscillator with fixed ultra-high frequency using either LC tank circuits or one port surface acoustic wave resonator are presented. Four circuits used to achieve 433.9 MHz oscillating frequency, Two of them using NPN Bipolar junction transistor, while the others using operational amplifier with high speed, gain and accuracy. A comparison between using passive elements as a source of resonance frequency and using SAW resonator is introduced. Another comparison between using an equivalent lumped circuit instead of SAW package in oscillator design is also introduced. Two different software tools are used to achieve the required simulation. Proteus and ADS tools are used in simulation with AC, S-parameters and hybrid simulation. This paper is considered a direct application for SAW resonators in widebandwidth ASK Transmitter / Receiver.

**Keywords:** oscillator, Resonator and SAWR

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### 1. Introduction

There is no doubt that surface acoustic wave devices are now applied in basic and important applications as filters, sensors, correlators and resonators. SAW resonator is recently preferable than crystals in design of oscillators as a frequency selective component. It can be used to achieve large scale of frequencies from low range up to Gigahertz [1-2]. Various types of oscillators are presented using different schematic design as generic oscillator, clap, Hartley, VCO, colpitts, and crystal oscillators [3]. In previous studies, LC tank circuits were used due to its simplicity for design, then crystal oscillators were famously used in order to its stability according to temperature change. Now SAW component achieve more stability than crystal oscillator does. Many other features of using SAW devices like its minimum insertion loss [4], low cost and fabrication not complicated. In this paper, a previously modeled of one port SAW resonator is used in a fixed frequency oscillator circuit [5]. A previous work of using SAW resonator in VCO design is presented [6]. The aim of this paper is to achieve 433.9 MHz colpitts oscillator using SAW resonator with high quality factor. We also introduced a design for the oscillator using primarily LC tank circuits. In both cases, oscillator is built with negative feedback structure using bipolar junction transistor or operational amplifier as shown in Figure 1.

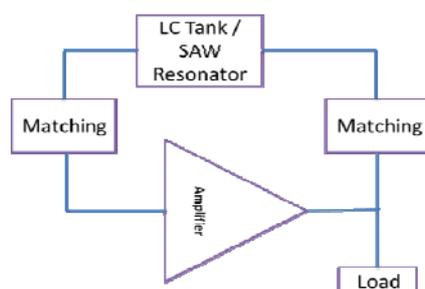


Figure 1: General Block Diagram of Colpitts oscillator using LC tank or SAWR

## 2. Oscillator Schematics and Simulation Results

In this section, various schematic for fixed frequency oscillator of 433.92MHz are introduced. The main criteria of oscillator is that a portion of output being feedback to the input. The insertion loss is basically depending on the oscillating frequency.

### 2.1. Ordinary Oscillator Circuit Design with BJT

Ordinary design of colpitts oscillator based on simple LC tank circuit shown in Figure 2, that connected between base and collector of BJT amplifier or between output pin and input pin of operational amplifier to deliver sine wave in output. LC tank network form a capacitive voltage divider that controls the oscillation frequency.

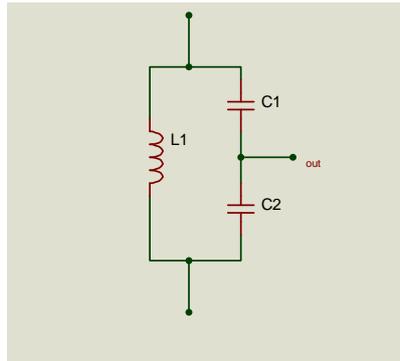


Figure 2. LC - Tank Circuit of ordinary colpitts oscillator

To achieve oscillator at 433.9 MHz, we use the following equation for frequency of oscillation to estimate values for L1, C1 and C2.

$$f_{osc} = \frac{1}{2\pi\sqrt{LC_{eq}}} \quad (1)$$

$$C_{eq} = \frac{C_1 * C_2}{C_1 + C_2} \quad (2)$$

With simple calculations, we assumed equated values for both two capacitors C1 and C2 and equal 20pF, so at 433.92 MHz, the expected value for the coil is 13.45nH we can design a simple ordinary circuit for colpitts oscillator using ADS is preceded in Figure 3.

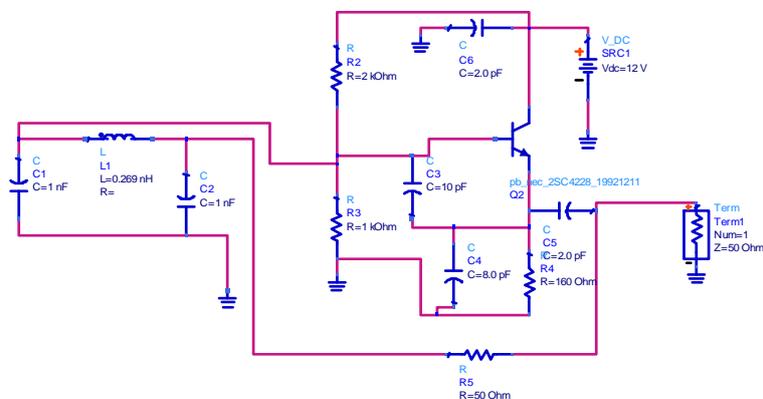


Figure 3. Schematic of ordinary 433.9 MHz colpitts oscillator with BJT

The AC Sweep response (Gain in dB) of the output waveform of ordinary oscillator is shown in Figure 4 and it is procedure using proteus tool. A band of frequencies between 420 MHz and 450 MHz is selected to ensure the oscillation frequency.

Figure 5 indicates the impedance parameters (S-parameters) for reflected transmitted signal of the oscillator and it is procedure for the same circuit using ADS tool. Smith chart is also obtained to indicate the overall impedance of the oscillator circuit.

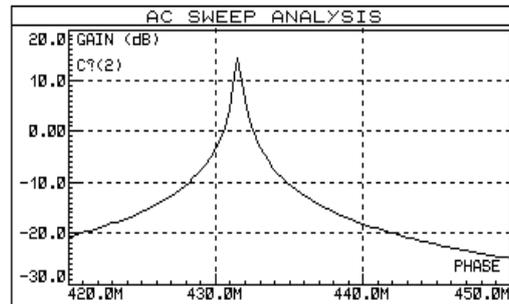


Figure 4. AC sweep response of LC colpittsoscillator (Using Proteus)

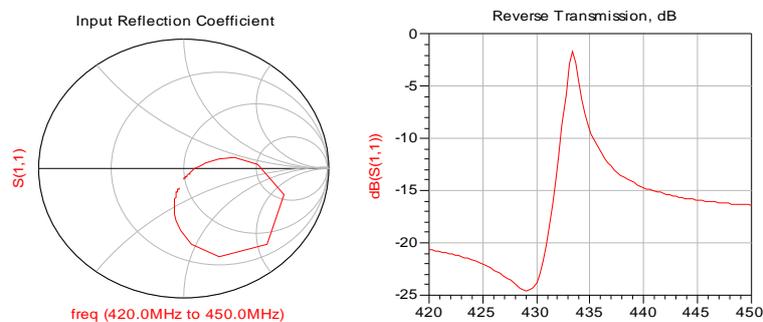


Figure 5. Smith chart and S-parameters response of LC colpitts oscillator (Using ADS)

In order to sustain the oscillations, operational amplifier may also be used with high frequency and negative and positive feedback rather than BJT. Another configuration with OPAMP is built using ADS and proteustools in the next section.

## 2.2. Ordinary Oscillator Circuit Design with OPAMP

The previous tank circuit is re-used with High speed, Low noise operational amplifier and negative feedback to achieve gain. The positive feedback (Tank circuit) is added to sustain oscillation. Figure 6 indicates 433.92 MHz oscillator with the same tank circuit parameters but with replacing the NPN bipolar junction transistor with high precision OPAMP. Another parameter values suggestion for C1, C2 and L1 is chosen to achieve the same frequency of oscillation.

We applied S-Parameter simulation using ADS tool and Figure 7 recording S11 for the expected output and indicate the maximum value at approximate frequency of 433.92 MHz (434 MHz). Smith chart that records impedance circle is also monitored within the same figure. The maximum of S11 is downwards due to negative feedback of operational amplifier that inverts the expected curves.

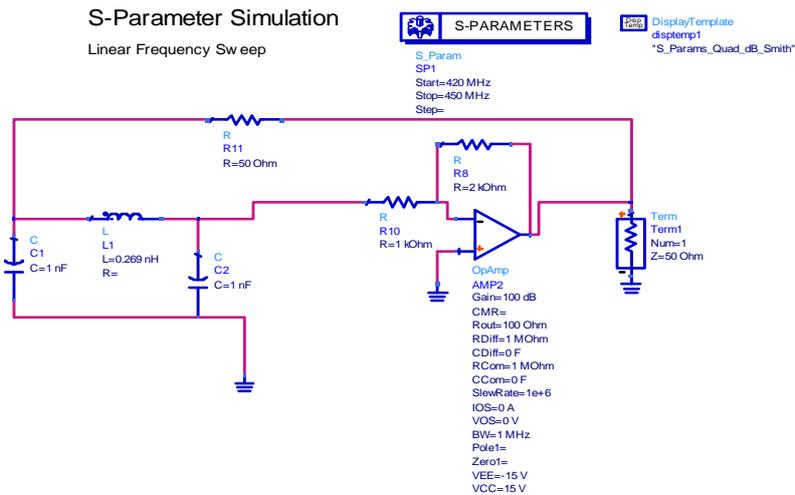


Figure 6. Schematic of ordinary 433.9 MHz colpitts oscillator with OPAMP

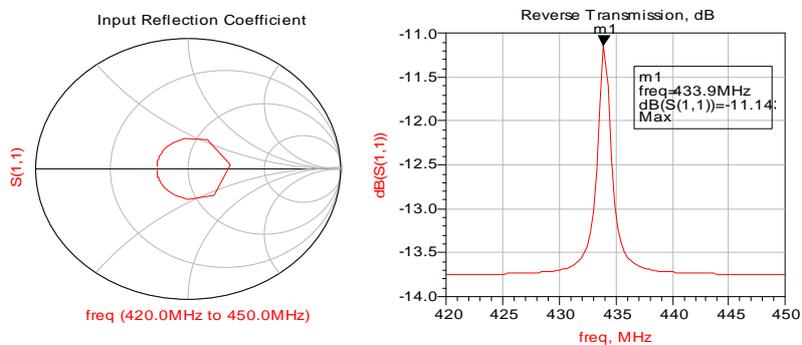


Figure 7. Smith chart and S-parameters of Oscillator

**2.3. SAW Localoscillator Circuit using ECM and BJT**

Now, the LC tank circuit is replaced with equivalent circuit model of one port SAW resonator that estimated in [5]. To achieve approximately 12624 Quality factor, so the series parallel resonance with parameters estimated as shown in Figure 8. Applying the AC sweep simulation, we obtain sinusoidal waveform shown in Figure 9. Snapshot for the output signal is captured for a small frequency range in proof the max/min gain occurs at the designed frequency 433.9 MHz. Proteus used to obtain the result. The values of C1, C3 and R1 are calculated to achieve the same desired oscillating frequency. S11 value for using SAWR is better than simulated in Figure 5 using tank circuit.

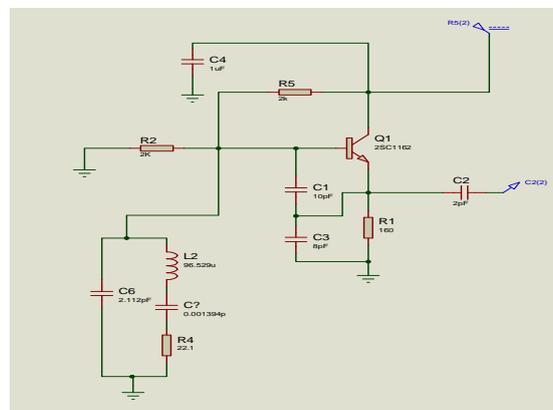


Figure 8. Using ECM for SAW resonator in local oscillator design and BJT

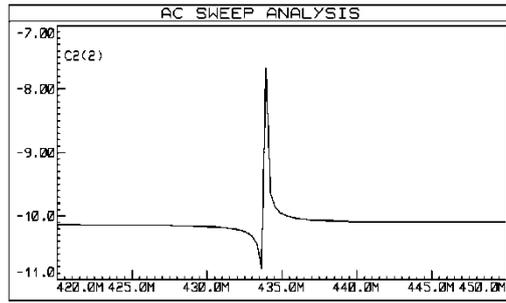


Figure 9. AC sweep response of ECM-SAW oscillator

**2.4. SAW Oscillator Based on OPAMP using SAW Resonator**

In this section, another configuration of SAW oscillator using one port SAW resonator instead LC tank circuit and based on operational amplifier with high gain. Figure 10 is for using the equivalent circuit model for one port SAW resonator, while Figure 11 introduces embedded package component in ADS for SAW resonator. The design is procedure Referring to (SARCC433M92BXM0) SAWR with equivalent circuit model of ( $L1 = 96.529 \mu\text{H}$ ,  $C2 = 0.001394 \text{ pF}$ ,  $R4 = 22.1 \text{ ohm}$  and  $C1 = 2.112 \text{ pF}$ ) with quality factor calculated as 11908 according to values of equivalent passive parameters of SAW resonator [7]. The closed loop gain is designed to be (2). Using ADS with s-parameter simulation we got Figure 12-13. 50 ohm terminal impedance is added for simulation. The output obtained from using SAW resonator is relatively better than that obtained from passive LC tanks circuit of Figure 5. Figure 14, is a comparative study of using LC tank circuit and SAW resonator on the S11 parameter of the same oscillator.

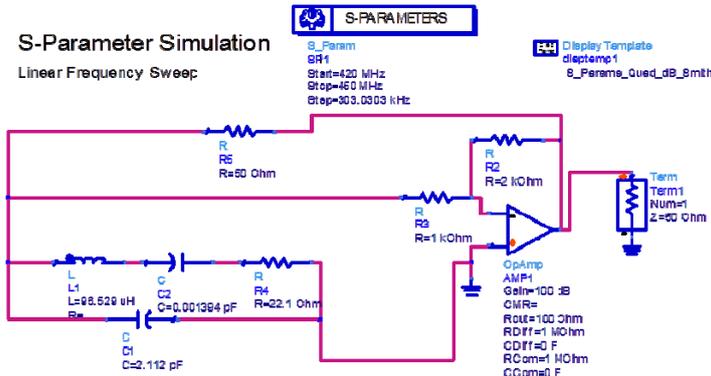


Figure 10. Using ECM for SAW resonator in OPAMP oscillator design

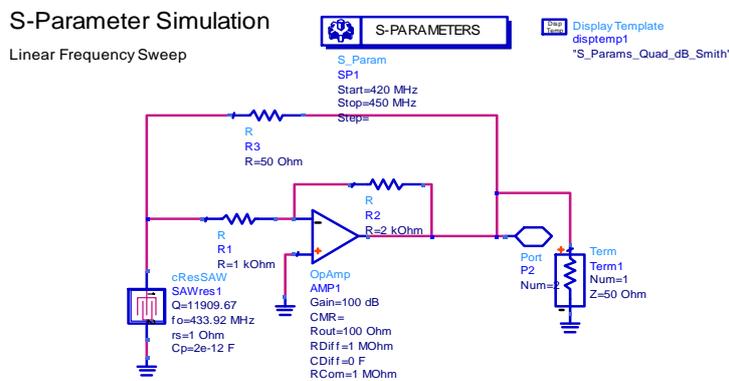


Figure 11. 433.9MHz oscillator using fixed frequency SAWR

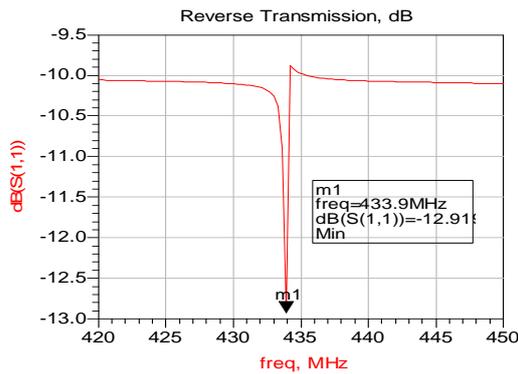


Figure 12. S11 for OPAMP oscillator using ECM of SAWR

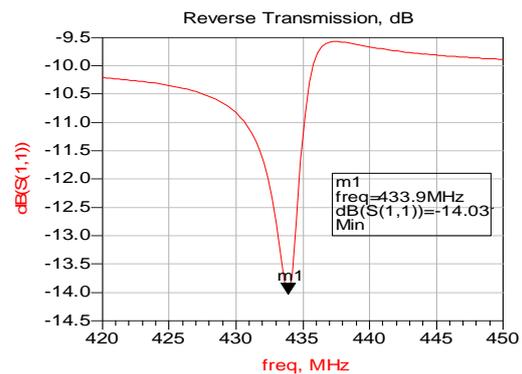


Figure 13. S11 of 433.9MHz oscillator using fixed frequency SAWR

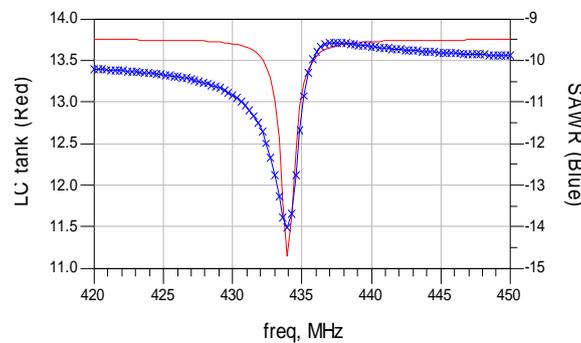


Figure 14. S11 parameter while using LC tank circuit versus SAW resonator

### 3. Conclusion

Some different schematics for design of 433.92 MHz colpittsoscillator are presented in this paper. Both BJT and OPAMP are used in the design using either SAW resonator or ordinary passive elements (LC tank circuit). ADS and proteus are CAD tools used in procedure the design schematics and simulation for AC sweep and S-parameters. Using SAW resonator leads for a high accuracy oscillator with minimum insertion loss and best gain. SAW resonator is the best choice for oscillator design because of its stability, high speed and fixed frequency of oscillation.

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