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Design of Low Pass Filter using Integrated Fractal Passive Components for GSM Application

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ABSTRACT

In this paper, Elliptical Low pass filter working at GSM band is realized using multilayer fractal spiral inductor and fractal spiral capacitor based 0.18μm process. Multilayer fractal inductor and fractal spiral capacitor is shown to have good Q factor values. The influence of fractal passive components on the insertion loss of low pass filter is analyzed by EM simulations. The designed 3.17nH multilayer inductor has a maximum Q of 30 @ 6 GHz and the realized LPF GSM/AMPS band has the insertion loss of 0.4dB and return loss of more than 15dB in the passband.

General Terms

Multilayer fractal inductor, GSM Applications

Keywords

Fractal spiral capacitor, High Frequency Structural Simulator(HFSS), Low pass Filter(LPF), Inductance value(L), Multilayered fractal inductor, Quality factor(Q), Self Resonant Frequency(SRF)

1. INTRODUCTION

Low-cost portable wireless communication systems depend on the ultra-low power RF building blocks in silicon-based technologies[1]-[2]. In the transmitter at the output stage of the power amplifier, low pass filter is used to suppress the unwanted signals and attenuate higher order harmonics. Transmission lines are generally used to realize filters at higher frequencies. However, LPF based on distributed elements occupy larger area and difficult to integrate with on chip products. Recent studies demonstrate that lumped element filters are effective alternatives. Various Integrated LPF are proposed using passive components such spiral capacitors and Metal Insulator Metal(MIM) capacitors and Inter digital Capacitors(IDC)[3]-[4]. As the technology goes down the usage of MIM capacitors are limited due to larger size. Whereas usage of IDC are limited due to large parasitics. Fractal spiral capacitor reported in[5]-[6]shown to have good Q factor with miniaturized size. And another important component determining the performance of low pass filter is inductor. Inductors designed using fractal geometry are proven to be effective[7]-[8]. This paper demonstrates the design and characterization of a 3rd order Low Pass Filter based on multilayer fractal spiral inductor and fractal spiral capacitor. Multilayer fractal spiral inductor[9] has higher inductance value over standard inductors. The improvement in the inductance value is because of inclusion of Hilbert curve which intern improves effective conductive without altering the die area. Spiral capacitors on the other hand have the highest Q value over IDC and MIM capacitors. The organization of the paper as follows, section 2 describes the elements of Low pass Filter topology and how each of them affects the filter characteristics. EM analysis of filter elements is described in section 3 followed by results and discussion in section 4, finally conclusions are drawn in section 5.

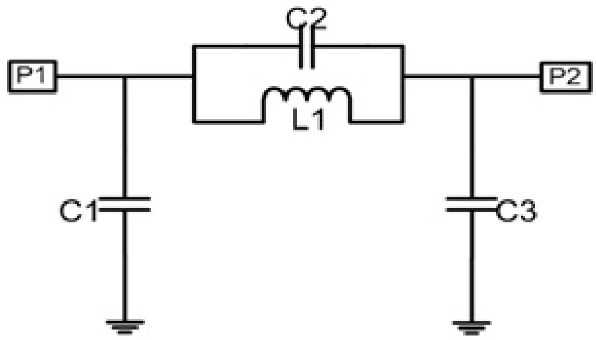

Fig. 1. Elliptical low pass filter

2. LOW PASS FILTER TOPOLOGY

Low insertion loss and sharp cutoff is a important parameter to reduce the interference from spurious transmission of a low pass filter. To meet these requirements, Low pass filter is designed with high performance multilayer fractal spiral inductor and fractal spiral capacitor. Elliptical low pass has been designed for cut-off frequency of 2.4GHz in a standard 0.18μm CMOS process. The schematic diagram of the LPF is shown in Fig.1. Filter of this type is used to reduce the higher order harmonics.

2.1 Analysis of embedded passive elements

2.1.1 Multilayer fractal inductor. Passive components design must be done prior to the design of elliptical low pass filter. The fractal passive components designed based on Multilayer configuration. Multilayer fractal inductor is designed to achieve an inductance of 3.17nH is as shown in Fig.2 The structure is designed with a turn width of 8μm and spacing of 2μm. The space filling property of Hilbert curve has been exploited to increase the metal run of the conductor which leads to increased inductance value compared to standard inductors. The metal turns of the structure runs on different layer to avoid overlapping of tracks, thus the intertwining capacitances(C_s) are negligibly small. The inductance and Quality factor of the multilayer fractal spiral inductor is calculated using the equation.1 and equation.2.

$$L = \frac{-1}{2\pi f * Im(Y_{11})} \quad (1)$$

$$Q = \frac{Im(Y_{11})}{Re(Y_{11})} \quad (2)$$

Fig.3 shows the inductance and Q factor plot of the inductor. The Multilayer fractal structure achieves a higher Q factor of 30 at 6 GHz frequency and the Q factor of 22 at 2.4GHz. Table.1

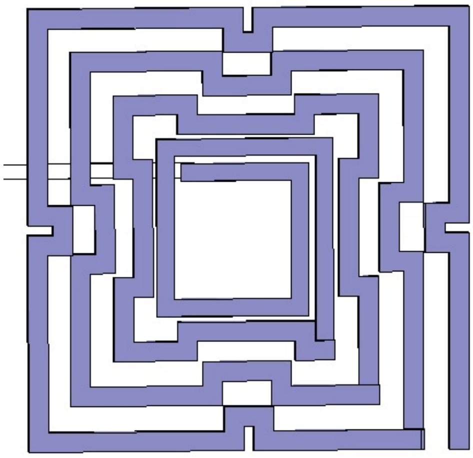

Fig. 2. Multilayer fractal spiral inductor

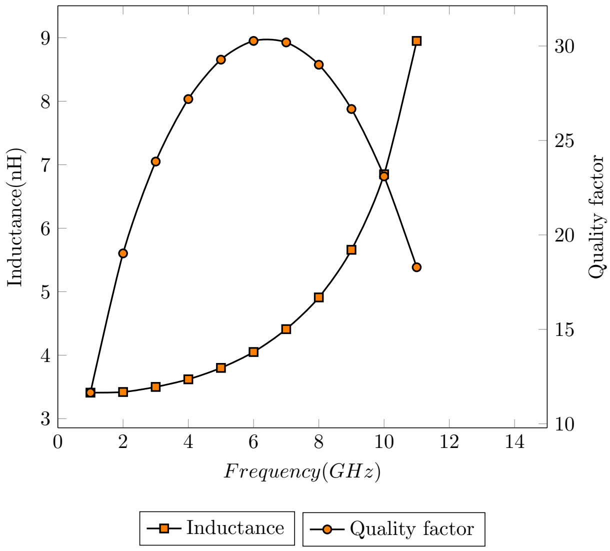

Fig. 3. Performance plots for Multilayer fractal inductor

Table 1. Standard inductors comparision

Inductor type	Area($\mu\, m^2$)	l(nH)	Q @2.4GHz
Square Planar	240x240	3.169	10
Circular	245x245	3.172	12
Stacked inductor	100x100	3.145	3
fractal inductor	160x160	3.167	11

shows the comparison of the standard inductors with the multi-layer fractal spiral inductor[9].

2.1.2 Multilayer fractal spiral capacitor. The concept of fractal spiral capacitor[6] is extended to multilayer to improve the capacitance density without any change in on-chip area. The three dimensional representation of a multilayer fractal spiral capacitor is shown in Fig.4. It consists of two metal layers, where each metal layer is comprised of two conductive metal components. The conductive components are cross-coupled so that the total capacitance is the sum of the vertical flux between the metal layers and the lateral flux along the edges between the two conductive components in each of the metal layers. The lateral flux between the conductive components in a metal layer increases the capacitance per unit area and decreases the bottom-plate parasitic capacitance. The alternate metal traces are coupled with the adjacent metal layers to provide vertical flux. The process of

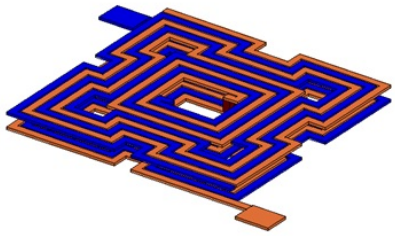

Fig. 4. Multilayer fractal spiral capacitor

cross coupling can be further extended to bottom layers to increase the capacitance per unit area.

$$C = \frac{-1}{2\pi f * Im(Y_{21})} \quad (3)$$

$$Q = -\frac{Im(Y_{11})}{Re(Y_{11})} \quad (4)$$

The capacitance values(C_1,C_3) of 1.29 pF C_2 of 0.26pF are achieved using fractal spiral capacitor with an outer diameter of 100μm in multilayer and single layer fabrication . The capacitance and Q factor values are shown in Fig.5 and Fig.6.The components required for the filter design are summarized in Table.2.

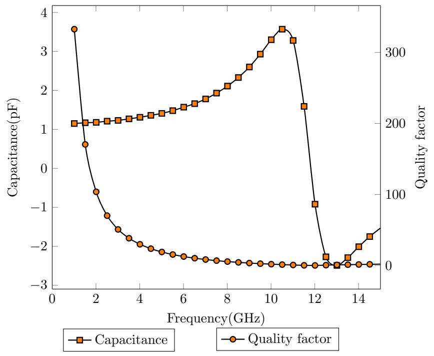

Fig. 5. Performance plots for multilayer fractal capacitor with OD= 100μm

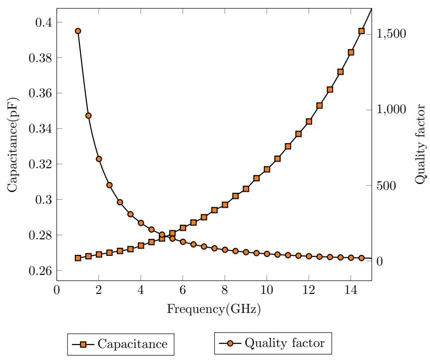

Fig. 6. Performance plots for singlelayer fractal capacitor with OD= 100μm

Table 2. List of designed components for LPF

Component	Area($\mu\, m^2$)	C/L	Q factor@2.4GHz
C_1,C_3	100x100	1.29pF	80
C_3	100x100	0.26pF	150
L_1	160x160	3.17nH	22

3. RESULTS AND DISCUSSION

Fig. 7 shows the 3D representation of the elliptical low pass filter with the proposed fractal passive components. The simulation of the filter is carried out using a High-Frequency Structural simulator (HFSS). The simulation results are illustrated in Fig.8. From

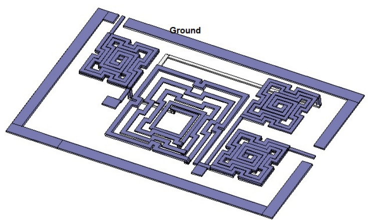

Fig. 7. Layout of LPF filter with proposed fractal passive components

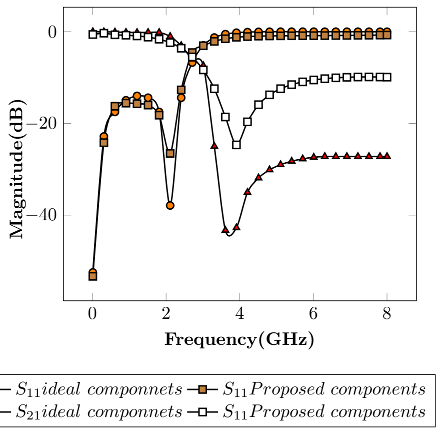

Fig. 8. Comparison results of circuit simulations and EM simulation of LPF

Table 3. Comaparision with LPF in the literature

Ref.,	f_0(GHz)	IL(dB)	Return loss(dB)
[10]	2.4	0.5	15
[11]	2.4	0.4	13
Proposed work	2.4	0.4	15.5

the results shown in Fig.8,the LPF with proposed fractal components achieves an insertion loss of only 0.4dB and a return loss of 15dB in the pass band. Table.3 summarizes the validation of the proposed filter with the reported LPFs. The proposed filter shows an equivalent or better characteristics than the reported works with 10% reduction in on-chip area.

4. CONCLUSION

3^{rd}order Low pass filter working at GSM band is realized using Multilayered fractal spiral inductor and fractal spiral capacitor based 0.18μm process is proposed. The Multilayered fractal inductor and fractal spiral capacitor is shown to have good Q factor values. The influence of fractal passive components on the insertion loss of low pass filter is analyzed by EM simulations. The realized LPF GSM/AMPS band has the insertion loss of 0.4dB and return loss of more than 15.5dB at the pass band with miniaturized area.

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