IRJMETS
e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:04/Issue:07/July-2022 Impact Factor- 6.752 www.irjmets.com

ENHANCING THE QUALITY FACTOR AND INDUCTANCE OF RFIC INDUCTOR

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ABSTRACT

Inductors are one of the major constraints in the design of Radio Frequency Integrated Circuits (RFICs). Inductors are used in IC's in RF circuits like Low Noise Amplifiers (LNA), Voltage – Controlled Oscillators (VCOs), filters and impedance matching circuits. The main problem about inductors on chip is the large area, and the quality factor is very low. Low quality factor is attributed to the parasitic losses at the higher frequencies. Substrate eddy current losses is one among the contributing parasitic losses. Inductors on silicon are commonly shaped as spirals. This geometry is fairly easy to fabricate and allows for reasonably high inductance per unit area values. One of the method to improve the characteristics of RFIC inductor is varying the dimensions of inductor like width, thickness, number of turns and space between the turns of inductor. In this project we have taken varying width to enhance inductance and quality factor of RFIC inductor. We observe improvement in both the characteristics by varying width.

Keywords: Spiral Inductor, Quality Factor, HFSS, RFIC.

I. INTRODUCTION

Modern silicion integrated circuit are finding wide applications in the GHz frequency range.the CMOS and. BiMOS process provide high FT transistor allowing si RF-ICs to complete with Ga As ICs in the important low GHz frequency lossy si substrate makes the design of high Q reactive components difficult. despite this difficulty, the low cost of si ICs fabrication over GaAs ICs fabrication and the potential for integration with base bond cicuit makes Si the process of choice in many RFIC applications.

The demands placed on wireless communication circuits include low supply voltage, low cost, low power dissipation, low noise, high frequency of operation and low distortion. These design requirements cannot be met satisfactorily in many cases without the use of RF inductors. Hence, there is a greatly incentive design, optimize, and model spiral inductors fabricated on Si substrates.

Miniaturization of cellular devices with increasing number of functionalities at affordable prices is the current trend. Ever increasing data rates is a major factor pushing the boundaries in wireless revolution. Wireless revolution has it roots in technology scaling, innovation, and integration.

II. METHODOLOGY

To measure the performance of inductor we will consider two parameters namely, Q-factor and inductance. The following three methods to improve these parameters.

- Varying dimensions of RFIC inductor
- Designing various structures
- Using magnetic material

IMPROVING PERFORMANCE OF RFIC INDUCTOR BY VARYING DIMENSIONS

The dimensions of inductor are a) thickness of the metal, b) width of the metal, c) spacing between metal lines, d) internal radius of spiral structure, e) number of turns

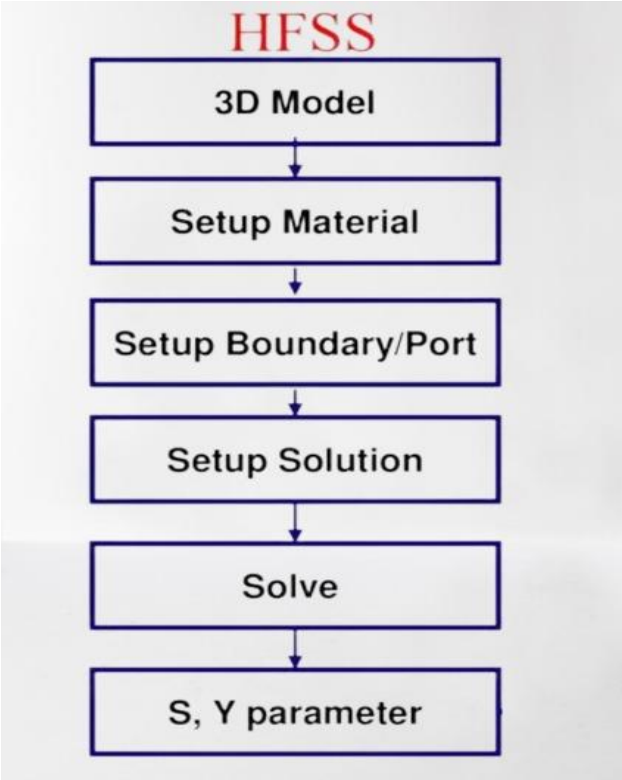

Figure 1: Block diagram

III. MODELING AND ANALYSIS

This diagram describes how to build the 3D spiral inductor model in HFSS (including drawing the geometric objects and assigning materials, boundaries, and excitations). The drawing operations are grouped bydielectric and conductor objects.

In this section you will set HFSS to refine the length of the tetrahedral elements for the spiral until they are below the specified value.

1.Under Model> Solids> My_Metal in the HistoryTree, right-click Spiral and choose. Assign Mesh Operation> Inside Selection> Length Based.

The Element Length Based Refinement dialog box appears.

2.Edit the settings as shown in the figure below and click OK.

3.Under Mesh in the Project Manager, right-click Length1 and click Select Assignment to highlight the object to which the mesh operation is assigned.

4. Click in the Modeler window's back ground area to clear the selection.

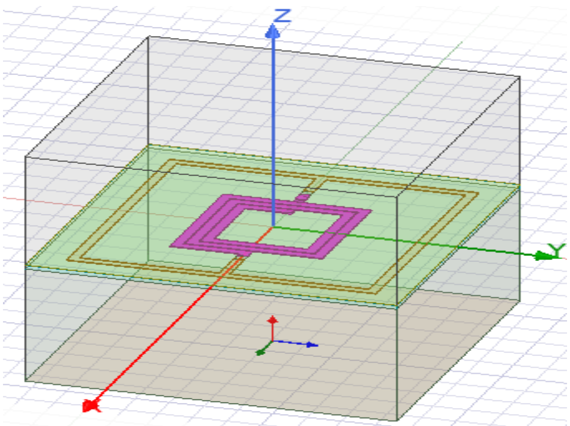

Figure 2: 3d view

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IV. RESULTS AND DISCUSSION

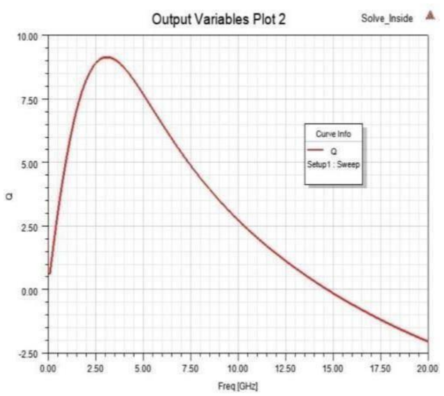
To Enhance the Quality factor and Inductance of RFIC inductor we have taken the method of varying dimensions of inductor. In this method we are varying thickness of metal lines. Here we have taken three cases. In first case thickness of 2µm and width 15µm was considered and in second case thickness of 3µm and width 15µmwas considered and in later case thickness of 2µm and width 10µm. We designed spiral inductor of 2.5 turns, width of the metal was 15µm and space between the turns was 1.5µm. Designed inductor was simulated using HFSS and the result was discussed below.

QUALITY FACTOR(Q)

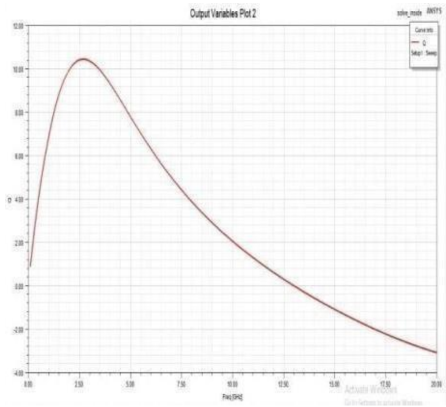
Case 1: Thickness of the metal 2µm, width of the metal 15µm

Case 2: Thickness of the metal 3µm, width of the metal 15µm

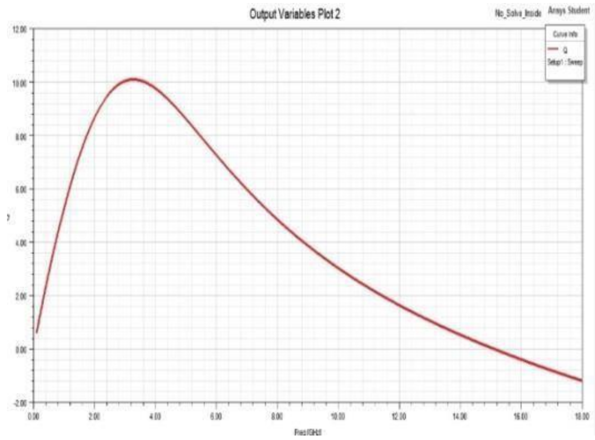
Case 3: Thickness of the metal 2µm, width of the metal 10µm



Thickness -2µm Width 15µm



Thickness-3µm Width 15µm



Thickness-2µm Width 10µm

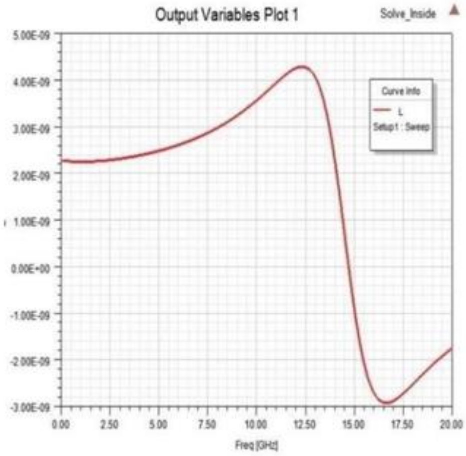
Figure 3: Quality factor

As seen from the graphs above when thickness is 2µm and width is 15µm maximum Q value is 9.2 at 3GHz and when thickness is 3 µm and width is 15µm, maximum Q value is 10.4 at nearly 3GHz. When thickness is 2µm and width is 10µm, maximum Q value is 10 at nearly 3GHz i. e. if thickness of metal increases there is increase in Q-factor.

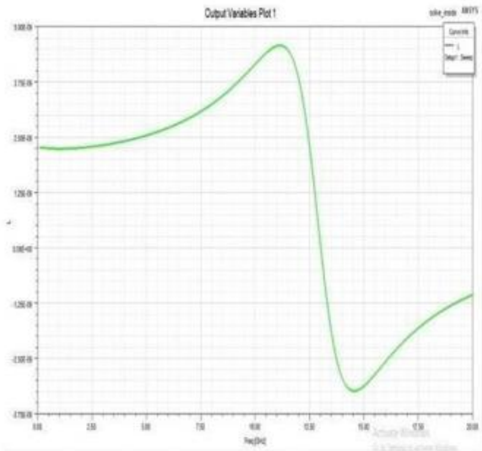
INDUCTANCE

Case 1: Thickness of the metal 2µm, width of the metal 15µm Case 2: Thickness of the metal 3µm, width of the metal 15µm Case 3: Thickness of the metal 2µm, width of the metal 10µm

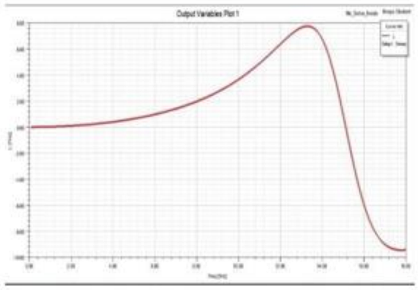
Similarly by the above simulation using HFSS, a 2.5 turns of spiral inductor with silicon dioxide and with space 15um using varying different dimensions with width of 15um , thickness of 2um and the obtained inductance(L) is 41.5NF with frequency(F) 12.5GHZ



Thickness 2µm Width 15µm



Thickness 3µm Width 15 µm



Thickness 2µm Width 10

Figure 4: Inductance

From the above graphs we observed that for thickness of metal 2 µm and width 15 µm, maximum inductance value is 4.3 nF at 12.25 GHz and for thickness of 3 µm and width 15 µmmaximum inductance value is 4.6 nF at 11.5GHz. and for thickness of 2 µm and width 10 µm maximum inductance value is 8 nF at 13GHz i.e. there is increase in inductance, if we increasethickness of metal by keeping other dimensions constant.

ADVANTAGES

- Traditionally, spiral inductors are made in square shape due to its ease of design, support from drawing tools and maximum inductance per unit area.
- Larger fill ratio has a smaller inductance because its inner turns are closer to the center of thespiral. Currents in opposite side turns are opposite in direction resulting in less positive mutual inductance or more negative mutual inductance, hence it is smaller in size.
- High reliability (which performs consistently well).
- High performance.

DISADVANTAGES

1. At very high frequency It occupies large area
2. Q-factor and inductance are low at very high frequency.

Resion: At high frequency eddy current losses and parasitic losses.

APPLICATIONS

1. Voltage-controlled oscillator.
2. Inductors in particular are used frequently in radio frequency IC's such as low-noise amplifiers.
3. Impedance matching circuit (the input impedance of an load or the output impedance of its corresponding signal source to maximize the power transfer or minimize signal reflection fromthe load).
4. Filter.

V. CONCLUSION

In this project we designed RFIC inductor by varying thickness of the metal. While designing we kept all other dimensions constant. Designed inductor is simulated using HFSS. From the resulted graphs, we observed that there is increase in both Q-factor and inductance, if thickness of the metal is increased. If these values are increased area occupied by RFIC inductor is decreased.

The performance of RFIC inductor can be still increased if we use magnetic material as one of the layer in various structures like 3-D, coupled and differential inductors i.e. if we combine second and third methods mentioned in Q-factor and inductance of RFICwill increase. i.e. combining these methods are the future work of this project.

ACKNOWLEDGEMENTS

We are grateful to our guides Prof. S. Rajendra Kumar for his continuous support and guidance. Through their guidance, we were able to successfully complete our project. Sincere thanks go to Dr. P. SATISH KUMAR, Head of the department of Electronic and Communication Engineering at ACE Engineering College, for his support and time. We are very grateful to my family and friends for their constant support and encouragement during the project period

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