Design of 5.8 GHz Integrated Antenna on 180nm Complementary Metal Oxide Semiconductor (CMOS) Technology

To cite this article: A H A Razak et al 2018 IOP Conf. Ser.: Mater. Sci. Eng. 341 012015

View the article online for updates and enhancements.
Design of 5.8 GHz Integrated Antenna on 180nm Complementary Metal Oxide Semiconductor (CMOS) Technology

A H A Razak, M I A Shamsuddin, A F M Idros, A K Halim, A Ahmad and S A M Al Junid
Electronics Architecture and Application (EArA) Research Group, Faculty of Electrical Engineering (FKE), Universiti Teknologi MARA, 40450 Shah Alam, Selangor

Email: hadi@ieee.org

Abstract. This project discusses the design and simulation performances of integrated loop antenna. Antenna is one of the main parts in any wireless radio frequency integrated circuit (RFIC). Naturally, antenna is the bulk in any RFIC design. Thus, this project aims to implement an integrated antenna on a single chip making the end product more compact. This project targets 5.8 GHz as the operating frequency of the integrated antenna for a transceiver module based on Silterra CMOS 180nm technology. The simulation of the antenna was done by using High Frequency Structure Simulator (HFSS). This software is industrial standard software that been used to simulate all electromagnetic effect including antenna simulation. This software has ability to simulate frequency at range of 100 MHz to 4 THz. The simulation set up in 3 dimension structure with driven terminal. The designed antenna has 1400um of diameter and placed on top metal layer. Loop configuration of the antenna has been chosen as the antenna design. From the configuration, it is able to make the chip more compact. The simulation shows that the antenna has single frequency band at center frequency 5.8 GHz with -48.93dB. The antenna radiation patterns shows, the antenna radiate at omnidirectional. From the simulation result, it could be concluded that the antenna have a good radiation pattern and propagation for wireless communication.

1. Introduction

System-on-Chip (SoC) is an implementation of a system into a chip. It is integrating all components of a computer or electronic system into a single chip. This makes the chip have compact design. Thus, it will reduce the size of the device to become smaller and the device shall able to attach to living things.

The aim of this project is to design an integrated antenna which will allow human to wear in their daily life. The size of the antenna has been set less then 2mm. The guideline of antenna sizing is based on the size of a die and Silterra CMOS 180nm technology. Loop antenna configuration has been chosen as antenna configuration. The configuration criteria are based on integrated circuit level component such as inductor and capacitor. The component structure may need to use same layer structure as antenna. The design geometry is revealed in figure 1.
Figure 1. Top view of loop antenna for integration with active devices.

This project designed a 5.8 GHz loop configuration antenna on chip antenna. The frequency of the antenna been chosen based on unlicensed Industrial, Scientific and Medical Band (ISM Band). Below shows ISM band table 1:

| Frequency Range (GHz) | Bandwidth (MHz) | Centre Frequency (GHz) | Availability         |
|-----------------------|-----------------|------------------------|----------------------|
| 2.400                 | 2.500           | 100                    | 2.450 Worldwide      |
| 5.725                 | 5.875           | 150                    | 5.800 Worldwide      |
| 24.00                 | 24.25           | 250                    | 24.13 Worldwide      |
| 61.00                 | 61.50           | 500                    | 61.25 Subject to local acceptance |

The simulation of the antenna was done by using High Frequency Structure Simulator (HFSS). This software is industrial standard software that been used to simulate all electromagnetic effect including antenna simulation. This software has ability to simulate frequency at range of 100 MHz to 4 THz. The simulation set up in 3 dimension structure with driven terminal.

1.1. Theory of antenna
The antenna is the main part of any wireless device, where without a proper design of the antenna, it will affect the transmitted and received data. Antenna is a device to convert an electric signal into a radio signal. The antenna will radiate energy from the signal into electromagnetic waves through the air. In this project, loop antenna will be used as the antenna design. Advantages of using loop antenna design; is that it has the same characteristics as dipole and monopole antenna. It is a simple design and hence less hassle for the designer with the design complexity. It also has a variety of shapes; circular, rectangular and elliptical. Frequency and wavelength can be described as below:

\[
\lambda = \frac{c}{f}
\]  

(1)

Where
\[
\lambda = \text{wavelength of frequency} \\
c = \text{constant speed of light} \\
f = \text{frequency}
\]

From the equation (1), the wavelength is inversely proportional to frequency. The highest value of frequency, the smallest wavelength will be produce. Based on the wavelength of the frequency, the size of the antenna will be affected. The size of the antenna is directly proportional to wavelength. Size of full wave antenna is \(\lambda/4\).
1.2. Substrate layer of antenna

Substrate layer of antenna is a very important part in designing antenna. Different dielectric material will form different frequency and radiation pattern for the antenna. Therefore, to design on-chip antenna it is a very important step to create layer of the die based on manufactory specification or technology. By follow the manufacturer specification, the output result of the antenna will produce approximate value for the practical design. Below shows the diagram of substrate layer of die and table of layer parameters:

![Diagram of substrate layer of die](image)

Table 2. Substrate layer of CMOS018 Technology [2].

| Layer   | Thickness (um) | Dielectric Constant |
|---------|----------------|---------------------|
| STI     | 0.309          | 4.2                 |
| OD      | 0.1079         | 4.2                 |
| POLY    | 0.2            | 0                   |
| ILDA    | 0.06           | 7.5                 |
| ILDB    | 0.6            | 4.2                 |
| METAL1  | 0.53           | 0                   |
| IMD1a   | 0.67           | 3.7                 |
| IMD1b   | 0.18           | 4.2                 |
| METAL2  | 0.53           | 0                   |
| IMD2a   | 0.67           | 3.7                 |
| IMD2b   | 0.18           | 4.2                 |
| METAL3  | 0.53           | 0                   |
| IMD3a   | 0.67           | 3.7                 |
| IMD3b   | 0.18           | 4.2                 |
| METAL4  | 0.53           | 0                   |
| IMD4a   | 0.67           | 3.7                 |
| IMD4b   | 0.18           | 4.2                 |
| METAL5  | 0.53           | 0                   |
| IMDTOPa | 0.55           | 3.7                 |
| IMDTOPb | 0.3            | 4.2                 |
| METAL6  | 2.39           | 0                   |
| PASS1   | 0.9            | 4.2                 |
| PASS2   | 0.5            | 7.5                 |
| AIR     | 40             | 1                   |
2. Methodology
In this section, it shows 2 main set up of project. First section it shows the dimension of antenna and lastly simulation set up.

2.1. Dimension of antenna
Right dimension of antenna may produce a good result. The good result is referring to centre frequency of the antenna, radiation pattern of antenna and etc. Below shows dimension of the antenna in micron:

![Figure 3. Top view of loop antenna with dimension.](image)

2.2. Simulation set up
In this section shows simulation set up for this project. There are two set up that have been implemented. The set up are terminal driven of the antenna and simulation setup. Below shows the driven terminal set up:

![Figure 4. Top view of loop antenna with driven terminal.](image)
From the figure above, the antenna has been set up as 2 port network system. The simulation had been set up as interpolating frequency sweep from 0.1GHz to 10GHz with 0.1GHz setup. This procedure is done to allocate the frequency range of the antenna.

3. Result and Discussion
Based on simulation set up above, result and findings obtained as shown in figure 5.

![3D of Integrated Antenna Layout in HFSS](image)

**Figure 5.** 3D of Integrated Antenna Layout in HFSS.

From the figure above shows antenna model set up in HFSS. The outer ring in the figure is a guide for 2mm size of a die. All result of the simulation for the antenna as shown in figure 6, below:

![S11 plot Graph of the simulation](image)

**Figure 6.** S11 plot Graph of the simulation.

From the figure 6 above shows the frequency drop of the antenna at 5.8 GHz with -48.93dB. From the result the antenna has met the targeted value. Figure 7 shows a graph of total gain of the antenna and radiation pattern:
Figure 7. Total Gain of the antenna.

Figure 8. Radiation Pattern.

Figure 7 above shows the total gain of the antenna at phi equal to 0° is -48.19dB, while at phi equal to 90° the value drop at -46.61dB. The value shows different of -1.58dB at phi equal to 0° and 90°. For the radiation pattern graph in figure 8 shows two different degrees of phi 0° and 90° and the lowest magnitude is -48.08 at angle -18.

4. Conclusion
The project presents a design of On-Chip Integrated Antennas for Biomedical Application. Designing integrated antenna into die may reduce the size of device and the size of integrated circuits may have more compact design. The simulation shows that the antenna has single frequency band at center frequency 5.8 GHz with -48.93dB. The antenna radiation patterns shows, the antenna radiate at...
omnidirectional. From the simulation result, it could be concluded that the antenna has a good radiation pattern and propagation for wireless communication.

5. Acknowledgment
Appreciation to the Universiti Teknologi MARA (UiTM) that provide the academic research training and also Ministry of education for supporting this research through Research Grant Scheme (RAGS) [File No: 600-RMI/RAGS 5/3 (195/2014)]. Not forgotten our thanks to Silterra Technology for access to their CMOS technology and CEDEC that provide a great training session.

References
[1] General Secretariat of ITU, Radio Regulation, International Telecommunication Union, Edition of 2012.
[2] Jazril bin Jamil Din and S.Madhanaraj, CMOS18 Electrical Design Rules, Silterra Kulim High Tech, Malaysia Edition of 2012.
[3] A. Shamin, 24 GHz Integrated Differential Antenna in Digital Bulk Silicon, Carleton University, Ottawa, Canada June 2004.
[4] Zhai Mingwei, Development of Integrated Multi-band Antenna for GSM and GPS Applications, Nayang Technological University, Nanyang Avenue, Singapore
[5] R. Hasse, W.Hunsicker and K. Naishadham, Analysis and Design of a Partitioned Circular Loop Antenna for Omni-directional Radiation, Georgia Tech Research Institute, Georgia Institute of technology, Atlanta, Georgia
[6] T. Sasamori, T. Tobana and Y. Isota, Input Impedance Measurement for Balanced Antenna by S-parameter Method, Akita Prefectual University, Japan.
[7] M. Kozlov and R. Turner, A Comparison of Ansoft HFSS and CST Microwave Studio Simulation Software for Multi-channel Coil Design and SAR Estimation at 7T MRI, Max Planck Institute for Human Cognitive and Brain Sciences, Germany.
[8] Minh Thuy Le, Design of high gain antenna at 5.8GHz Using Metamaterials Structure, IMEP-LAHC, Grenoble Inst. of Technol. (GINP), Grenoble, France