Silicon based Antennas-The Concept and Implementation

[1] Ranjana Trivedi [2] Ritesh Saraswat [3] Susheela Choudhary [4] Pradeep Kumar Sharma,
[1][2] Associate Professor, [3][4] Sr. Assistant Professor
[1][2] JIET Group of Institution, Jodhpur [3][4] JIET, Jodhpur
[1]ranjana.trivedi@jietjodhpur.ac.in[2]ritesh.sarasat@jietjodhpur.ac.in[3]susheela.choudhary@jietjodhpur.ac.in
[4] pradeep.sharma@jietjodhpur.ac.in

Abstract: **— The miniaturization of system is the growing demand of electronic industry. As we need to reduce the size, it needs a high level integration and low powers circuits for a small battery requirement. We need the small wave lengths and integrated antennas on chip for high frequency systems. Fractal structure antennas can be used for the structure of an antenna that can be compact in size with large band width. The fabrication process for this is well-matched with the standard CMOS process. A multiband Minkowski fractal patch antenna and Sierpinski carpet fractal antenna on an SOI substrate show a small return loss of for both the bands. The radiation efficiency, bandwidth and directivity are respectively according to the requirements**

I. INTRODUCTION

From last two decade we have seen the drastic exponential development in the field of antennas. It is that we can change the different dimensions of Antenna like aperture according to different usages. Besides this there are also many major developments in siliconization in each and every field, as we want everything on ICs now a day. So here is the concept how to make an antenna using semiconductor devices. As we all know that antenna working depends on the radiating element's parameters, like the sizes, positions, and shapes of the radiating elements over the aperture. Changing these parameters of the radiating elements enables using the same antenna aperture for multiple functions. We have many conventional methods for this. In this approach there is nothing like predefined conductive elements, which perform a fix pattern and give result according to requirement. This approach uses only well-defined channels on the surface of the high resistivity silicon wafer. On the side p-i-n devices are the main building blocks of these channels. These are basically optimized to reach a relatively high conductivity which is nearly like of a metal, under dc control [1]. When we apply dc current to a SPIN device it will create carriers in the intrinsic region. And it will act to be metal-like and conductive at RF frequencies. A number of factors, including the carrier lifetime, carrier concentration, and channel depth decide the conductivity of the surface p-i-n devices. We can develop the material by same the photolithography process on silicon.

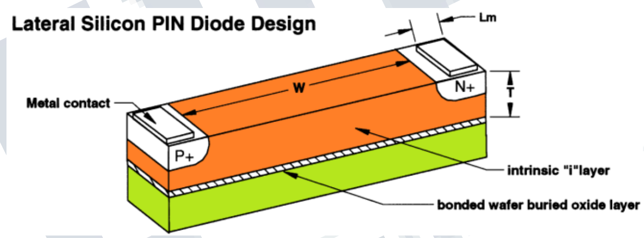

Fig: 1

Now days the miniaturization of system is the growing demand of electronic industry and it should be supporting to the high data rates also. As we need to reduce the size, it needs a high level integration and low powers circuits for a small battery requirement. If we require the true solution for system-on-chip [2-3] then we need the small wave lengths and integrated antennas on chip for high frequency systems. Normally the antennas are not on chip we need to integrate antennas with chip using bond wires, but the externally integrated antennas become bulky or narrow bandwidth. In this concept we can take the fractal antennas on the place of normal antennas as they are multi resonant and less space required in nature. Fractal is a structure which is actually very complex but self similar [4]. "Mandelbrot" defined this structure. Fractals are the actually large number of small units of non integer dimensions which stack up with each other to enlarge a complex structure, this structure can be used for the structure of an antenna that can be compact in size with large band width. Fractal antennas have also the space filling properties which increases the effective electrical length of the antenna and therefore this approach reduces the size of the antenna.

Fractal antennas have been verified in PCB and LTCC mediums [5, 6]. According to my best knowledge, there have only been two expressions of a silicon based fractal antennas, which are Sierpisnki [7] and Minkowski topologies [8]. But there are challenges in on-chip antenna measurements. The act of Sierpisnki carpet fractal antenna is compared on low and high resistivity silicon substrates. This paper presents an on-chip fractal antenna. The antennas can be characterized for intra-chip communication and also for different applications.

II. SYSTEM ON CHIP ANTENNA FABRICATION

The fabrication process for this is well-matched with the standard CMOS process. The stack for this process has been shown in fig 2 which is commercial it is just like the standard CMOS process like in-house stack in Fig. 3. There are some differences between the two stacks. As large silicon area is available in in-house fabrication, we can design an on-chip array. Even with the minor differences, the two stacks are equivalent in terms of substrate properties, which mean that the antenna performance can be replicated in the standard CMOS process with ease.

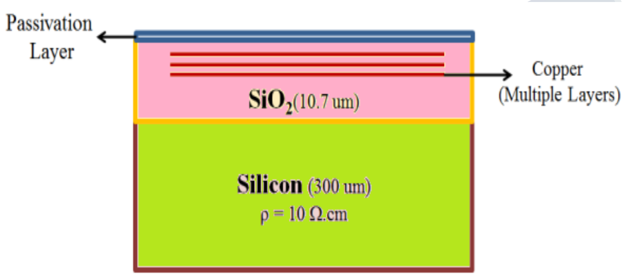

Fig: 2 Comercial

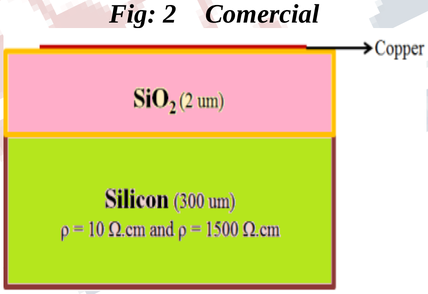

Fig: 3 In-house

III. THE CONCEPT

A Sierpinski fractal structure is shown here. This Sierpinski fractal structure can be realized through multiple iterations on a basic geometrical shape such as triangle, rectangle, circle or square [7]. We can also design a carpet fractal which is similar to the square patch. The first we can design the solid square patch which can be termed as the zero order iteration. Then after that first order iteration is implemented by etching a square from the center. This first order should be one-third of the dimensions of the main patch. Further the next two iterations occupy squares which are nine times and twenty seven times smaller than the main patch. The fractal design is shown in Fig. 4. It can be termed as the third order Sierpinski carpet fractal antenna. We can compare it with a conventional patch antenna and can see in a simulation that for the same stack up, the patch antenna has a resonant length of 1.65 mm where as the fractal antennas for first second and third iterations have of 1.6 mm, 1.42 mm and 1.33 mm. Here the patch antenna has impedance bandwidth of 3.75 % of the center frequency (24 GHz) and the all three fractal antennas provide a bandwidth of 5.4 %, 7.9 % and 13 % respectively. Here we can see the third iteration provides a size reduction of 36 %. The large bandwidth and reduced size of the fractal design exhibits its advantages over a simple patch antenna.

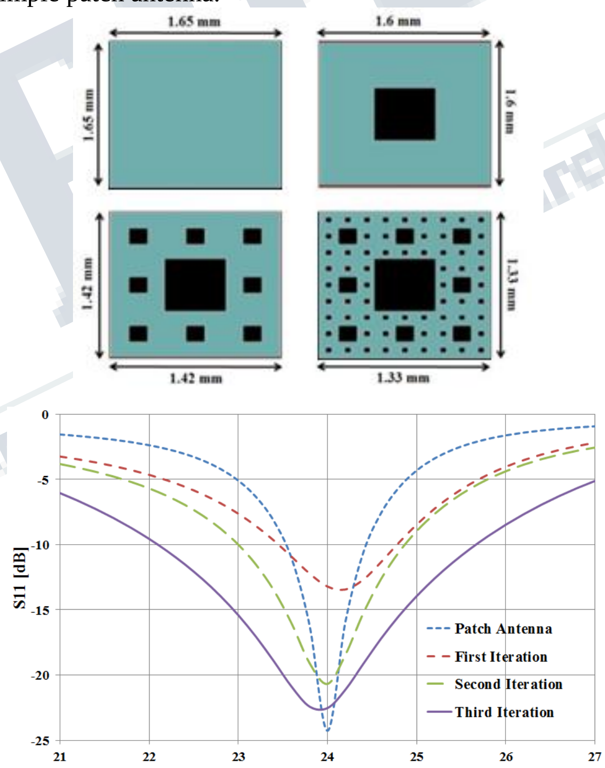

Fig: 4 Sierpinski fractal antenna designs

The second one is a Murkowski fractal patch antenna design. It is basically a miniaturization of loop antenna using the fractal technique. This is known as Murkowski square loop antenna. The Minkowski fractal antenna was created by using the initial square loop then to iterate at each side of the loop. The Example of Minkowski square loop is shown in figure 2 with second third and fourth iterations. This can be easily designed and the advantages of this antenna structure are very great like its low profile, simple geometry, and easy integration with MMICs and the main advantage is that they are low cost, easily fabricated. They also provide nearly stable radiation performances.

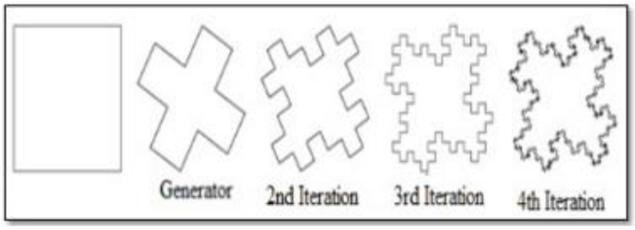

Fig: 5 Minkowski fractal Antenna designs

IV. DISCUSSION

We can see here the Minkowski fractal patch antenna on SOI substrate with single iteration in figure 5. Also we can explain multiband operation of the designed antenna is by using the Return loss versus frequency graph. The expected return loss is less than -10 dB and it can be considered perfect because below -10dB return loss, reflections are negligible. VSWR means standing wave ratio which tells about the impedance mismatch. VSWR should be always less than 2. And the Radiation pattern explains that direction of radiating of antenna. It is always desired that for the applications like mobile applications and multiband support it makes it compatible for multi-application.

We can also design the Sierpinski fractal antenna on Ansoft's High Frequency Structure Simulator (HFSS) which is employed to simulate the antenna designs. We can use Coplanar Waveguide (CPW) inset feed for the antenna design as shown in Fig. 6. This type of feeding mechanism allows easy fabrication and can be easily integrated with the circuits in CMOS technology. The figure 5 shows the expected 3-D view of Sierpinski fractal antenna. As there is no ground plane under the substrate the radiation pattern which we can get is Omni-directional in E plane (yz plane). The low resistivity silicon antenna shows low gain but it is useful in applications when required communication range is short. In addition, low resistivity silicon is appropriate for integration with circuits as they need low resistivity silicon to avoid latch up [9]. The main thing is that the antennas in high resistivity silicon medium show higher efficiency. They can be used for short or medium range wireless communication.

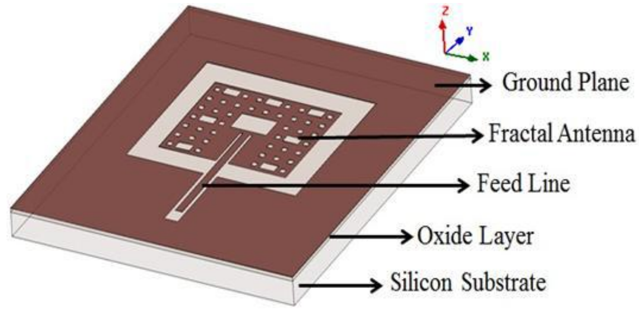

Fig 6

V. CONCLUSION

A multiband Minkowski fractal patch antenna and Sierpinski carpet fractal antenna on an SOI substrate is proposed in this paper. Both the antennas can be designed and characterized on high resistivity and low resistivity silicon substrates in a CMOS compatible process. The design of both the antennas is much smaller and shows a large bandwidth as compared to a standard patch antenna. These both antennas show a small return loss of for both the bands. The radiation efficiency, bandwidth and directivity are respectively according to the requirements. This discussion proves the validity of the fractal technique to form an antenna on chip with efficient performance. This discussion result shows a good agreement with next generation mobile terminal applications. If we want to improve the gain, we can make an array of these antennas which can be implemented on high resistive silicon and enhances the communication range. The designs can also be implemented for intra-chip communication by varying the partition between the antennas on a single chip, thus representing their suitability for applications such as wireless on-chip systems.

REFERENCES

1. C. H. Lee, Picosecond Optoelectronic Devices. Orlando, FL: Academic, 1984, pp. 161–171.

2. A. Shamim, L. Roy, N. Fong, N. G. Tarr "24 GHz On-Chip antennas and balun on bulk silicon for air transmission," *IEEE Transactions on Antennas and Propagation*,, vol. 56, no. 2, pp. 303-311, February 2008.

3. P. Popplewell, V. Karam, A. Shamim, J. Rogers, L. Roy, C. Plett, "A 5.2 GHz BFSK transceiver using injection locking and an on-chip antenna" *IEEE Journal of Solid State Circuits,* vol. 43, no. 4, pp. 981-990, April 2008

4. D. H. Werner, S. Ganguly, “An Overview of Fractal Antenna Engineering Research”, *IEEE Antennas and Propagation Magazine*, vol. 45, no. 1, pp. 38-57, 2003.

5. D. P. Karmakar, D. Soren, R. Ghatak, D. R. Poddar, R. K. Mishra, “A Wideband Sierpinski Carpet Fractal Cylindrical Dielectric Resonator Antenna for X Band Application”, *IEEE Applied Electromagnetics Conference, AEMC’09,* pp. 1-3, 2009.

6. 12. F. A. Ghaffar, M. U. Khalid, K. N. Salama, A. Shamim, “24 GHz LTCC Fractal Antenna Array SoP with Integrated Fresnel Lens”, *IEEE Antennas and Wireless Propagation Letter*, vol. 10, no. 10, pp. 705-708, July 2011.

7. 13. T. Kikkawa, K. Kimoto, and S. Watanabe, “Ultra wideband characteristics of fractal dipole antennas integrated on Si for ULSI wireless interconnects,” *IEEE Electron Device Letters*, vol. 26, no. 10, pp. 767–769, Oct. 2005.

8. Gianvittorio, J. P. and Y. Rahmat-Samii, “Fractal antennas: A novel antenna miniaturization technique, and applications,” IEEE Antennas Propagation Magazine, Vol. 44, No. 1, 20–36, 2002.

9. B. A. Floyd, C. M. Hung, Kenneth K. O, “Intra-Chip Wireless Interconnect for Clock Distribution Implemented With Integrated Antennas, Receivers, and Transmitters”, *IEEE Journal of Solid State Circuits*, vol. 37, no. 5, pp. 543

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