

Antenna Design and Comparison of Micro ICCLMA with Circular and Rectangular Patch

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Abstract : In this paper, a high gain small size antennas are micro ICCLMA (Inductively Coupled Capacitively Loaded monopole antenna) with circular patch and micro ICCLMA with rectangular patch is presented. These different types of patch antenna topologies were designed with same dimensions to produce higher gain. We begin with the comparison between the antenna designs, requirements and continue with a discussion issues and simulation results. Each antenna topology is then discussed including the limitations and advantages of each. In fact, each technique is uniquely designed to produce size reduction and higher gain antennas. Among two antennas the micro ICCLMA with circular patch provides higher gain as compared to other micro ICCLMA with rectangular patch. The antenna design simulation results were done by using CST Microwave Studio. The gain of micro ICCLMA with circular patch is 46.03 dB.

Keywords - Antenna radiation patterns, lumped elements, monopole antennas, patch antennas, vertically polarized antennas.

I. INTRODUCTION

In modern research on high gain small size antennas has been developed by an increasing interest in the use of wireless communication applications. For near ground communications where both the transmit and receive antennas are placed near the ground is by many orders of magnitude lower than any other antenna orientation configurations [12]. Applications such as unattended ground sensors (UGS), vertically polarized antennas with omnidirectional radiation pattern are highly desired. As the antenna size reduction is obviously major problem in wireless communication devices. Therefore several methods have been investigated for extremely short monopole antennas with very high lateral dimensions, while maintaining high radiation efficiency. With the development of wireless communication devices and mobile phone technology, it has become significant to provide low profile antennas with omnidirectional radiation pattern [6]. There are various size reduction techniques used in the design of small antennas in which reactive inductive loading and reactive capacitive loading. In [7], electrically small antennas are further investigated and the performance such as impedance matching, the radiation pattern, the radiation efficiency, quality factor (Q), and polarization to be reported. In [8], the antenna is characterized with fractal geometries and the performance, it can be summarized that increasing the fractal dimension of the antenna leads to a higher degree of miniaturization. Applications of fractal geometry are becoming mostly used in the fields of science and engineering. Antenna miniaturization can generally be categorized into two methods are Miniaturizing the antenna topology using space filling compression technique and Antenna miniaturization using magneto-dielectric materials [9]. The spatial network Method [18]-[19] provides strong radiation with an omnidirectional pattern in the horizontal direction. The dielectric truncation [14]-[15] is not close to the source, and then the space wave power is unaffected. It gives better efficiency. For certain applications, where the bandwidth can be compromised, it is found that by a comprehensive analysis of a new wide bandwidth compact antenna called (WC) wide compact J-pole antenna provided 50% impedance bandwidth [10]. Although these exist many antenna miniaturization techniques, most of them cannot provide high gain. However it is difficult to implement in practice, because these antennas include a multilayer geometry. An extremely (LMMMA) low profile multi element miniaturized monopole antenna [20] based on superposition of multiple quarter-wave segments that are meandered and spiraled around to suppress the radiation from horizontal currents above the ground plane. The LMMMA produces purely vertically polarization which leads to lower gain. Recently, a low profile antenna called micro inductively coupled capacitively loaded monopole antenna (ICCLMA) in which the techniques such as in-plane capacitive coupling, top loading, shorting pin achieve improved polarization purity and high gain with antenna miniaturization. The micro ICCLMA with circular patch and micro ICCLMA with rectangular patch were compared and the simulation results were obtained.

II. OVERVIEW OF ANTENNAS

Miniaturized antennas offer several advantages over classical antennas like low cost, easy to design, planar shape, conformability, etc. First we investigate unidirectional cylindrical monopole antenna [21] with

40mm diameter and 25mm height. Here the radiation pattern is unidirectional, in which the major radiation is in the backward direction, off the apex of the antenna. The overall frequency range of this antenna is between 500MHz and 2GHz. The cylindrical conformal monopole antenna includes the lumped elements are loaded R (resistance) and C (capacitor).These parameters are used to minimize reflections of the antenna. The lumped elements are serially connected. The value of resister and capacitor is 100Ω and 1.5pF . By using this lumped element approach impedance transformation can be accomplished easily.

Although there are many antenna approaches, most of them have lower gain and poor polarization purity. The new antenna topology called Micro ICCLMA. Micro ICCLMA is the very small size antenna of dimension $3.393\text{mm} \times 0.0474\text{ mm}$. It includes the lumped elements values are related to the diameter of two pins and the width, length and height of metal sheets, respectively. The perfect electric conductor (PEC) material is used for simulation. Micro ICCLMA is used typically at frequencies between 2 to 3 GHz. The dimensions of the antenna are chosen based on the system size requirements.

III. ANTENNA DESIGN

1.1 Micro ICCLMA with rectangular patch

The proposed micro ICCLMA with three layers of total dimension is $3.393 \times 0.0474\text{mm}$ using CST. The vertical feeding pin and shorting pin were inserted in the middle and top layer respectively. The diameters of the pins were 0.5mm. In newly developed ICCLMA, the same equivalent circuit model is to be followed by changing the lumped elements values corresponding to their enlarged gain value.

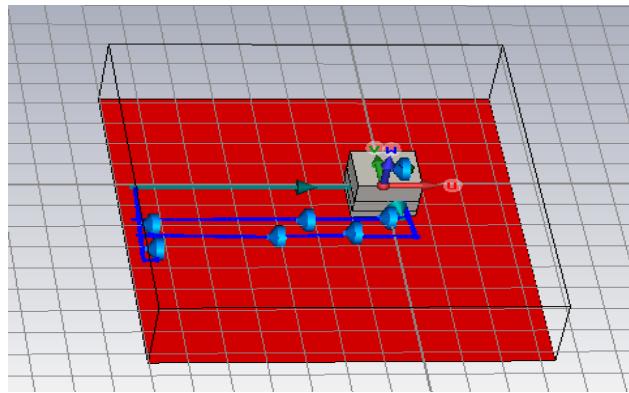


Fig. 1. Micro ICCLMA design with lumped elements

The inductors $L_1=5\text{nH}$, $L_2=5\text{nH}$ were placed in the feeding pin and shorting pin respectively and the additional inductors are $L_3=1.9\text{nH}$, $L_4=1\text{nH}$ were inserted in the top and middle layers respectively. The shunt capacitor $C_1=0.788\text{pF}$ was placed in the metallic patch. Here the additional capacitors $C_2=1\text{pF}$, $C_3=1\text{pF}$ were inserted into the layers because the metallic trace is narrow. The resistor $R=1.5\Omega$ was inserted into the top layer. The antenna dimensions (length and width) were calculated by using the formula as given by,

$$L = \frac{\lambda_0}{2} = 2\Delta L \quad (1)$$

$L=3.393\text{mm}$

where ΔL denotes the dimension of the patch and L denotes the actual length of the antenna.

$$\Delta L = 0.412h \frac{(\epsilon_{r,eff}+0.2)(\frac{W}{h}+0.264)}{(\epsilon_{r,eff}-0.258)(\frac{W}{h}+0.8)} \quad (2)$$

$\Delta L = 1.69\text{mm}$

where h represents the height of the substrate.

Width of the antenna is calculated by using the formula is given by,

$$W = \frac{c}{2f_0} \left[\sqrt{\frac{2}{(\epsilon_r+1)}} \right] \quad (3)$$

$W = 0.0474\text{mm}$

where ϵ_r represents the dielectric constant, f represents the frequency range, and C represents the velocity of light.

The effective dielectric constant ($\epsilon_{r,eff}$) is given by,

$$\epsilon_{r,eff} = \frac{\epsilon_r+1}{2} + \frac{\epsilon_r-1}{2} \left[1 + 12 \frac{h}{w} \right]^{1/2} \quad (4)$$

$\epsilon_{r,eff} = 2.21$

1.2 Micro ICCLMA with Circular Patch

The proposed micro ICCLMA with circular patch of total dimension is 3.393 x 0.0474mm using CST. The design procedure for micro ICCLMA as well as the micro ICCLMA with circular patch is similar. But the main difference between these two types of antenna is patch. In this type of antenna using the patch as circular. Here the circular patch radius is 1.6765mm and the height is 1mm. The lumped elements were connected corresponding to the equivalent circuit model of ICCLMA antenna.

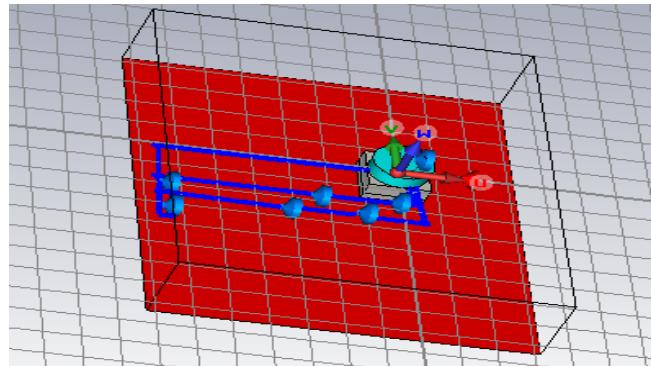


Fig. 2. Micro ICCLMA with circular patch design

Antenna input impedance and admittance of the antenna were obtained is given by,

$$X_f = \frac{L}{2\sqrt{\epsilon_{eff}}} \quad (5)$$

$$\begin{aligned} X_f &= 1.14 \text{m}\Omega \\ Y_f &= w/2 \\ Y_f &= 0.237 \text{mho} \end{aligned} \quad (6)$$

where X_f and Y_f is the antenna input impedance and admittance.

IV. SIMULATION RESULTS

I) We designed the micro ICCLMA with rectangular patch using CST software and the corresponding simulation results were shown in below figure.

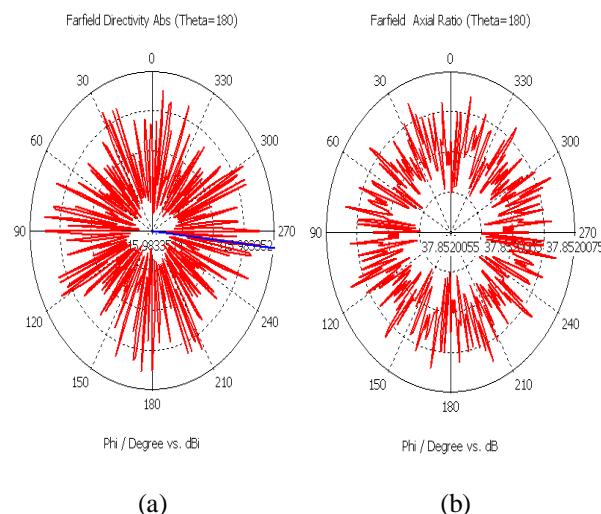


Fig. 3. Simulated (a) Farfield directivity abs ($\theta=180^\circ$) and (b) Farfield axial ratio ($\theta=180^\circ$) in micro ICCLMA with rectangular patch design.

In the above figure 3 (a) shows farfield directivity absolute value at $\theta=180^\circ$. It provides the omnidirectional radiation pattern. Here the frequency as 2.5GHz and the main lobe magnitude value as 316.0dB. Fig. 3(b) shows the farfield directivity axial ratio at $\theta=180^\circ$.The main lobe magnitude as 37.9dB.

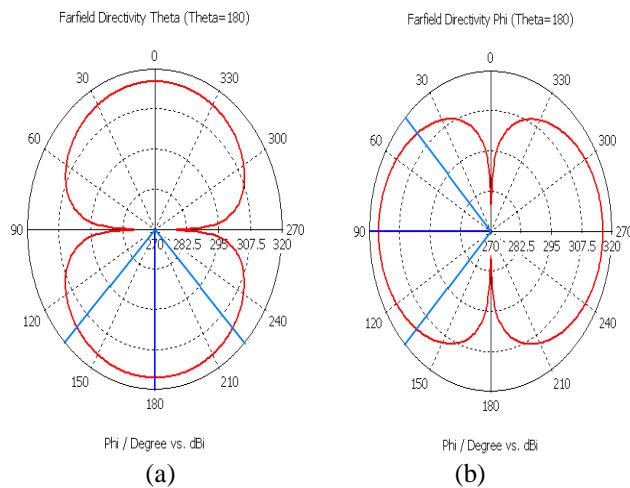


Fig. 4. Simulated (a) Farfield directivity theta ($\theta=180^\circ$) and (b) Farfield directivity phi ($\theta=180^\circ$) in micro ICCLMA with rectangular patch design.

The corresponding farfield directivity theta at $\theta=180^\circ$ is shown by Fig. 4(a). It provides the figure of eight radiation pattern and the main lobe magnitude as 316.0dB, the main lobe direction as 180.0deg and the angular width as 89.9 deg. Fig. 4(b) shows the Farfield directivity phi $\theta=180^\circ$. Here the main lobe magnitude as 316.0dB, the main lobe direction as 90.0deg and the angular width as 89.9 deg. The gain of this micro ICCLMA is 45.2 dB.

II) We designed the micro ICCLMA with circular patch topology using CST software and the corresponding simulation results were shown in below figure.

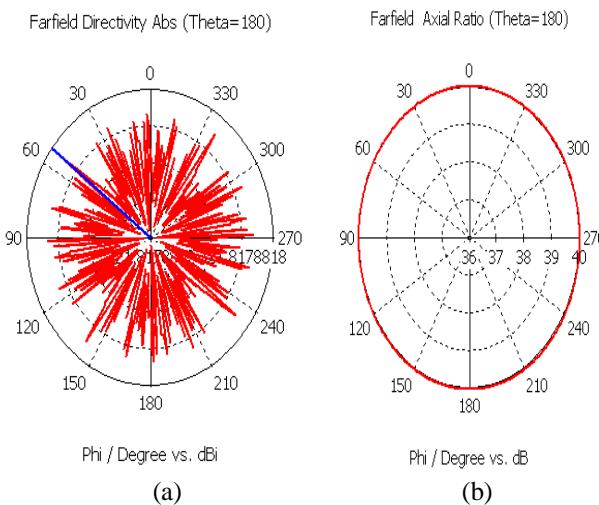


Fig. 5. Simulated (a) Farfield directivity abs ($\theta=180^\circ$) and (b) Farfield axial ratio ($\theta=180^\circ$) in micro ICCLMA with circular patch design.

In the above figure 5(a) shows farfield directivity absolute value at $\theta=180^\circ$. It provides the omnidirectional radiation pattern. Here the frequency as 2.5GHz and the main lobe magnitude value as 321.8dB. Fig. 5(b) shows the farfield directivity axial ratio at $\theta=180^\circ$. The main lobe magnitude as 40dB.

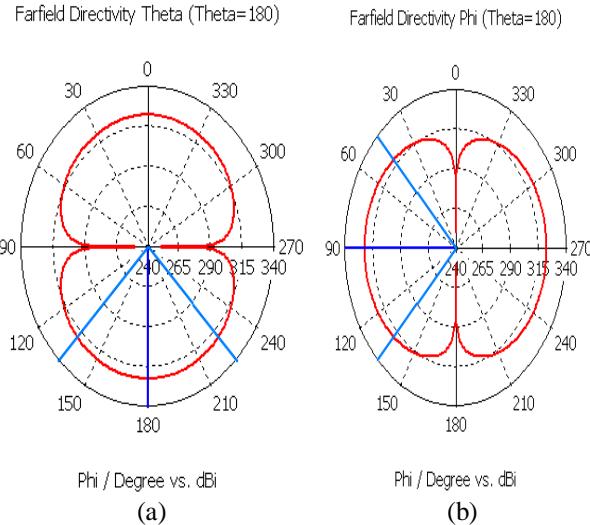


Fig. 6. Simulated (a) Farfield directivity theta ($\theta=180^\circ$) and (b) Farfield directivity phi ($\theta=180^\circ$) in micro ICCLMA with circular patch design.

The corresponding farfield directivity theta at $\theta=180^\circ$ is shown by Fig. 6(a). It provides the figure of eight radiation pattern and the main lobe magnitude as 321.8dB, the main lobe direction as 180.0deg and the angular width as 89.9 deg. Fig. 6(b) shows the Farfield directivity phi $\theta=180^\circ$. Here the main lobe magnitude as 321.8dB, the main lobe direction as 90.0deg and the angular width as 89.9 deg. The gain of this micro ICCLMA with circular patch is 46.03dB. The proposed micro ICCLMA with circular patch provides higher gain as compared to the existing ICCLMA antennas.

V. TABLE

Comparison between micro ICCLMA with rectangular patch and micro ICCLMA circular patch design
Output Parameters

Parameters	MicroICCLMA with Rectangular Patch	MicroICCLMA with Circular Patch
Dimension	3.393x0.0474mm	3.393x0.0474mm
Main lobe magnitude	316.0dBi	321.8dBi
Gain	45.2dB	46.03dB
Beam width	89.9°	89.9°
Main lobe direction	90.0°	90.0°
Frequency	2.5GHz	2.5GHz
S-Parameter magnitude in dB	-6.736	-10.445

VI. CONCLUSION

In this paper, antenna design and parameters comparison of micro ICCLMA with rectangular patch and micro ICCLMA with circular patch were presented using CST and the radiation pattern performance of the E-plane and H-plane pattern are obtained. The micro ICCLMA with rectangular patch and micro ICCLMA with circular patch topology provides better reduction in size, improved polarization purity and high gain compared to other existing antennas. The reduced size of the micro ICCLMA with rectangular patch and circular patch antenna is suitable for mobile radio communications, wireless communications.

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