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COMPARISON BETWEEN CYLINDRICAL CONFORMAL MONOPOLE, ICCLMA AND MINUSCULE ICCLMA WITH CIRCULAR PATCH

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ABSTRACT : *In this paper, a high gain small size antennas such as cylindrical conformal monopole antenna, ICCLMA (Inductively Coupled Capacitively Loaded monopole antenna), micro ICCLMA and micro ICCLMA with circular patch is compared. These different types of antenna topologies were designed with different 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 these antennas the minuscule ICCLMA with circular patch provides better reduction in size compared to other cylindrical conformal monopole antenna, and ICCLMA and higher gain respectively. The simulation results are done by using CST Microwave Studio. The minuscule ICCLMA with circular patch of radius 1.6765mm and overall size is 3.393X0.0474mm and the gain is 46.03 dB.*

Keywords *- Antenna radiation patterns, lumped elements, microstrip 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 ICCLMA, micro ICCLMA and minuscule ICCLMA with circular patch were compared with cylindrical conformal monopole antenna 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. In order to overcome the lower gain and poor polarization purity a novel antenna topology called Inductively Coupled Capacitively Loaded Monopole Antenna (ICCLMA) of total dimension is 15mm x 15mm [1]. Here to increase the gain, it is necessary to suppress the radiated fields from horizontal currents over resonating structure with small lateral dimensions. Because the E-field is parallel to the ground plane and will not contribute in the radiation. It can be accomplished in ICCLMA by using large capacitive top load as well as high Q lumped type resonant structure. Magnetic coupling is used to separating the radiating structure from the feed structure. Capacitive coupling is achieved by placing a capacitor in series with the signal to be coupled. By placing the feeding pin and shorting pin, vertical polarization can be obtained.

Micro ICCLMA is the very small size antenna of dimension 3.393mm x 0.0474 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 Cylindrical Conformal Monopole

The cylindrical conformal monopole antenna is designed by CST MWS. It consists of a monopole and parasitic disc. The antenna dimensions such as radius 20mm, height 10mm and co polarization angle α is 120 degree. Here the monopole antenna is conformed to a cylinder and connected to the feed point. For this antenna simulation, perfect electric conductor (PEC) material is used.

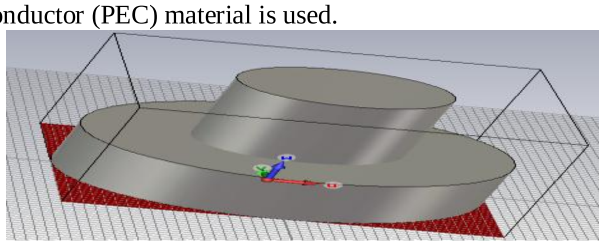


Fig. 1. Cylindrical conformal monopole antenna design

The antenna fidelity can be obtained is given by

$$F = max_{\tau}\left[\frac{\int_{-\infty}^{+\infty} Er(t)Ut(t+\tau)dt}{\sqrt{\int_{-\infty}^{+\infty}|Er(t)|^2dt}\sqrt{\int_{-\infty}^{+\infty}|Ut(t)|^2dt}}\right] \quad (1)$$

Where Er refers to the normalized waveform of the received pulse and Ut is the template pulse, which was taken to be the normalized source pulse. Within the main beam of the antenna, fidelity around 0.8 is achieved.

1.2 ICCLMA

The ICCLMA design of three layers of total dimension 15mm X 15mm using CST. The layers are ground plane, metallic trace and the metallic patch. Bottom layer is the ground plane which was designed in CST with length and height as 15mm and 1mm respectively. The material used is PEC. Above the bottom layer, metallic trace is placed in the middle layer which was designed with dimension 13.25mm and 1.57mm and material used is copper. Then the next layer is the metallic patch (top layer) which was designed with length and height as 12.25mm and 1mm respectively. The dielectric constant for three layers are same and it is 2.2.The vertical feeding pin and shorting pin were inserted in the middle and top layer respectively. The diameters of the pins were given as 0.5mm.

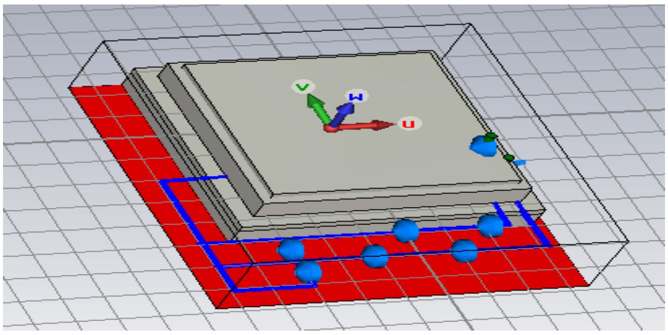


Fig. 2. ICCLMA design with lumped elements

The above ICCLMA design was based on the equivalent circuit model. The lumped elements were placed in the corresponding layers to increase gain and polarization purity. The inductors LI=2nH, L2=5nH are placed in the feeding pin and shorting pin respectively, the inductors are L3=1.9nH, L4=1nH were inserted in the top and middle layers and the shunt capacitor C1=0.488pF was placed in the metallic patch. Since the metallic trace is narrow, it can be represented by additional capacitance connected with the previously connected lumped elements. The metallic patch is represented by a shunt capacitor C1=0.488pF. Additional capacitances are introduced due to the placement of a narrow metallic trace in the middle layer. The values of the inductance and capacitances are related to the diameter of two pins and the width, length and height of metal sheets, respectively.

The fields of E-plane pattern ($\phi=\pi/2$) and H-plane pattern ($\phi=0$) is obtained is given by,

E-plane pattern ($\phi=\pi/2$)

$$E_r = 0, E_\phi = 0 \tag{2}$$

$$E_\theta = \frac{jabkE_{0e}-jkr}{2\pi r}\left\{\sin\theta\left[\frac{\sin\left(\frac{ka}{2}\sin\theta\right)}{\frac{ka}{2}\sin\theta}\right]\right\} \tag{3}$$

$$E_\theta = \frac{j2.25kE_{0e}-jkr}{2\pi r}\left\{\sin\theta\left[\frac{\sin\left(\frac{k1.5}{2}\sin\theta\right)}{\frac{k1.5}{2}\sin\theta}\right]\right\} \tag{4}$$

H-plane pattern ($\phi=0$)

$$E_r = 0, E_\theta = 0 \tag{5}$$

$$E_\phi = \frac{jabkE_{0e}-jkr}{2\pi r}\left\{\cos\theta\left[\frac{\sin\left(\frac{ka}{2}\sin\theta\right)}{\frac{ka}{2}\sin\theta}\right]\right\} \tag{6}$$

$$E_\phi = \frac{j2.25kE_{0e}-jkr}{2\pi r}\left\{\cos\theta\left[\frac{\sin\left(\frac{k1.5}{2}\sin\theta\right)}{\frac{k1.5}{2}\sin\theta}\right]\right\} \tag{7}$$

where a, b are antenna dimensions, k is constant. The electric field determines the co polarization of the radio waves. It is given by,

$$E_{CO} = E_\theta\cos(\propto-\phi) + E_\phi\sin(\propto-\phi) \tag{8}$$

The electric field determines the cross polarization of the radio waves. It is given by,

$$E_{Cross} = -E_\theta\sin(\propto-\phi) + E_\phi\cos(\propto-\phi) \tag{9}$$

where α=co polarization angle.

1.3 Minuscule ICCLMA with Circular Patch

The proposed minuscule ICCLMA with circular patch of total dimension is 3.393 x0.0474mm using CST. The design procedure for ICCLMA as well as the minuscule 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.

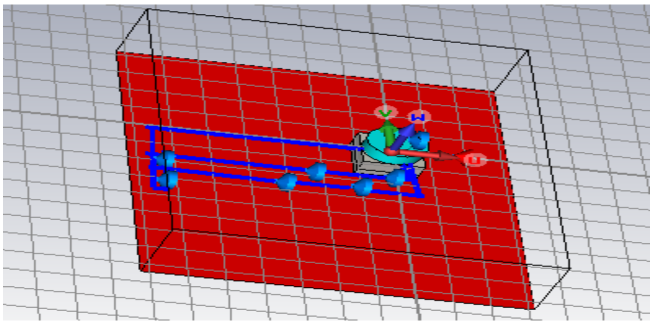


Fig. 3. Minuscule ICCLMA with circular patch design

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

$$X_f = \frac{L}{2\sqrt{\varepsilon_{reff}}} \quad (10)$$

$$X_f = 1.14\text{m}\Omega$$

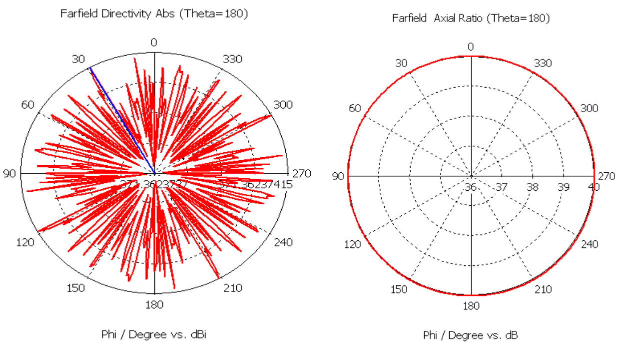
$$Y_f = w/2 \quad (11)$$

$$Y_f = 0.237\text{mho}$$

where Xf and Yf is the antenna input impedance and admittance.

IV. SIMULATION RESULTS

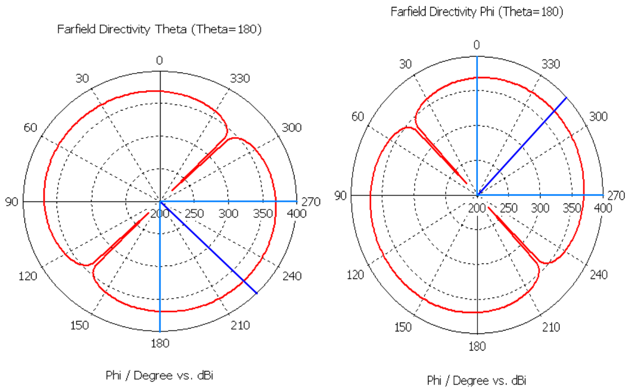
I) We designed the cylindrical conformal monopole antenna simulation results were shown in below figure.



(a) (b)

Fig. 4. Simulated (a) Farfield directivity abs (θ=180˚) and (b) Farfield axial ratio (θ=180˚) in cylindrical conformal monopole antenna design.

The frequency of antenna is 1.5 GHz. The main lobe magnitude as 371.4dB. The farfield axial ratio θ=180˚, main lobe magnitude value as 40dB.



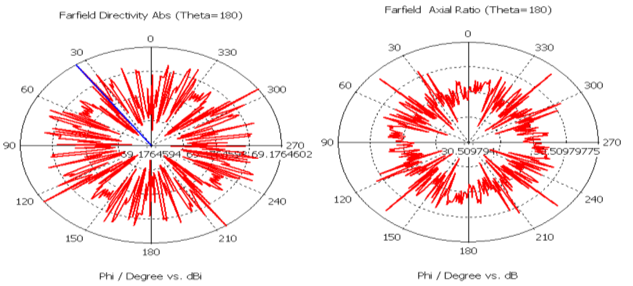
(a) (b)

Fig. 5. Simulated (a) Farfield directivity theta (θ=180˚) and (b) Farfield directivity phi (θ=180˚) in cylindrical conformal monopole antenna design.

Fig. 5(a) shows the farfield directivity theta at θ=180˚. Here the main lobe magnitude as 371.4dB and the main lobe direction as 225.0˚. Fig. 5(b) shows the Farfield directivity phi θ=180˚. Here the main lobe magnitude as 371.4dB, main lobe direction as 315.0˚ and the angular width (3dB) as 89.9˚. The gain of cylindrical conformal monopole antenna is 53.13dB.

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

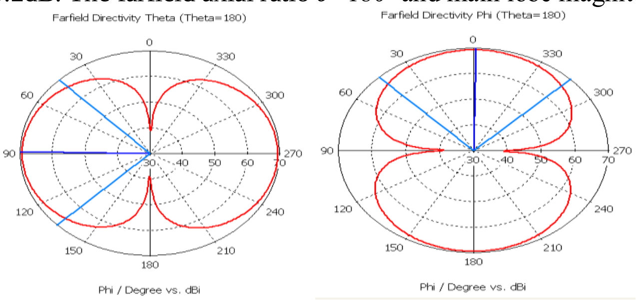
The farfield directivity abs at θ=180˚ and the farfield axial ratio at θ=180˚ output is shown in below figure.



(a) (b)

Fig. 6. Simulated (a) Farfield directivity abs (θ=180˚) and (b) Farfield axial ratio (θ=180˚) in ICCLMA design.

Here the vertically polarized radiation pattern is omnidirectional. The frequency of antenna is 2.5 GHz. The main lobe magnitude as 69.2dB. The farfield axial ratio θ=180˚ and main lobe magnitude value as 37.9dB.

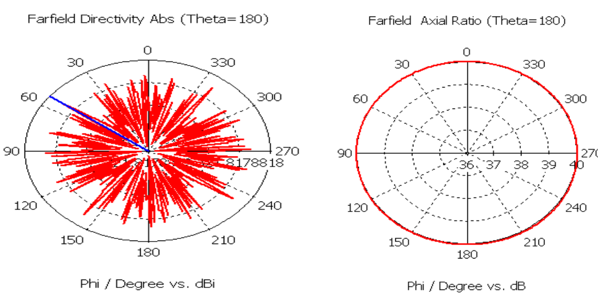


(a) (b)

Fig. 7. Simulated (a) Farfield directivity theta (θ=180˚) and (b) Farfield directivity phi (θ=180˚) in ICCLMA design.

Fig. 7(a) shows the farfield directivity theta at θ=180˚. Here the main lobe magnitude as 69.2dB and the main lobe direction as 90.0˚. Fig. 7(b) shows the Farfield directivity phi θ=180˚. Here the main lobe magnitude as 69.2dB, main lobe direction as 90.0˚ and the angular width (3dB) as 89.9˚. The gain of ICCLMA is 9.9 dB.

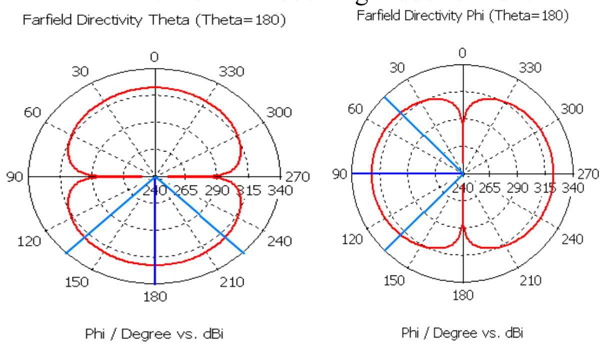
IV) We designed the minuscule ICCLMA with circular patch topology using CST software and the corresponding simulation results were shown in below figure.



(a) (b)

Fig. 8. Simulated (a) Farfield directivity abs (θ=180˚) and (b) Farfield axial ratio (θ=180˚) in minuscule ICCLMA with circular patch design.

In the above figure 8(a) shows farfield directivity absolute value at θ=180˚. It provides the omnidirectional radiation pattern. Here the frequency as 2.5GHz and the main lobe magnitude value as 321.8dB. Fig. 8(b) shows the farfield directivity axial ratio at θ=180˚.The main lobe magnitude as 40dB.



(a) (b)

Fig. 9. Simulated (a) Farfield directivity theta (θ=180˚) and (b) Farfield directivity phi (θ=180˚) in minuscule ICCLMA with circular patch design.

The corresponding farfield directivity theta at θ=180˚ is shown by Fig. 9(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. 9(b) shows the Farfield directivity phi θ=180˚. 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 minuscule ICCLMA with circular patch is 46.03dB. The proposed minuscule ICCLMA with circular patch provides higher gain as compared to the existing ICCLMA antennas.

V. TABLE

Comparison between Cylindrical monopole, ICCLMA and micro ICCLMA Output Parameters

Parameters	Cylindrical monopole	ICCLMA	Minuscule ICCLMA with Circular Patch
Dimension	20x10mm	15x15mm	3.393x0.0474mm
Main lobe magnitude	371.4dBi	69.2dBi	321.8dBi
Gain	53.13dB	9.9dB	46.03dB
Beam width	89.9˚	89.9˚	89.9˚
Main lobe direction	315. 0˚	90.0˚	90.0˚
Frequency	2.5GHz	2.5GHz	2.5GHz
S-Parameter magnitude in dB	-35.255	-19.796	-10.445

VI. CONCLUSION

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

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