Meta-material Inspired Monopole Antenna for LTE/Bluetooth/Wi-Max Subsystems

B Sai Sivakumar, P Pardha Saradhi, B T P Madhav, M Venkateswara Rao, G Kesava Sai

Abstract*- A Meta-material inspired hex-band antenna for LTE/ Bluetooth / Wi-Max subsystems is presented in this paper. The antenna presented is having dimensions of 52×33mm^2 printed on FR4 substrate of thickness 1.6mm. The proposed antenna achieved six resonance peaks at 3.1/4.1/6.4/6.8/8.4/12.5 GHz. The Split Ring Resonator introduced act as a part of defected ground structures, which improve the current directions. The final antenna proposed has circular polarization at frequencies 2.2/2.3/5.2 GHz. The presented antenna has a peak gain of 4.2dB.*

Index Terms*: Meta-materials, Split Ring Resonator, Circular polarization.*

I. INTRODUCTION

Meta-materials are not directly available in nature, they are the compact ones when compared over conventional material structures contain some properties like negative refractive index and negative permeability [1]. In nature, these metamaterials are not found, but they are made artificially. So, these properties made researchers to turn their eyes towards metamaterials and these materials achieved good name. These materials are used in antenna fabrication to achieve or enhance the performance of the antenna. Nowadays the research is going, on these metamaterials. They can achieve higher data rates and by using them in the antennas we can achieve good bandwidth, gain and efficiency, there is a large scope for advanced communication systems to avail services for the users with higher performance rate and achieve superior performances [2]. Nowadays in the wireless communication a revolution has been established with the help of some communication modules, such as, 4G mobile communication, Bluetooth, WLAN, Wi-Fi, GPS, Wi MAX, etc [3].

Today the electronics system designing industries are focusing on miniatured devices which is used for maintaining or increasing the performances of them, along with other wireless communication applications. There is a requirement of a radiating element is to operate at multiple frequency bands. We cannot achieve enhanced characteristics like higher gain, directivity, low profile and multiple operating frequency by a single patch [4].

Radio frequency devices work under different bands in frequency spectrum. In order to achieve a working stage under particular bands, the patch can be designed in a way the patch can be introduced with slots or SRR, which can work under different bands. These changes can enhance the characteristics of the antenna [5]. The microstrip antenna with patches is proposed as a low profile, high gain antenna, working at multiple frequencies, by using metamaterial structures. Metamaterials are composite materials which are made and doesn't exist in nature. These composite materials show their properties due to structures and not by their chemical composites [5]. The composites that exhibit negative refractive index are referred to as left-handed meta-materials (LHMs) [6]. The antenna proposed was designed using HFSS software. Venkat et. all have proposed a quad band metamaterial antenna that can operate at four frequencies whereas the proposed antenna in our article is able to operate at five frequencies particularly for the Bluetooth, WLAN, Wi-Fi, GPS, WiMAX, other applications. Meta fractal technique is used for reducing the size of the SRR. The microstrip antenna's size is reduced by using a fractal shaped CSRR structure [8].

II. ANTENNA DESIGN

2.1 Antenna Design and Analysis

In this article, construction of the antenna is done in three major steps. The antenna designed is fed with a coplanar waveguide (CPW) feed with SRR's which are circularly polarized. The first step consists of design of the antenna and its construction. The next step contains the characteristics of SRR with the help of a unit cell presented and in the final step we obtained the design of SRR. The dielectric material used in the construction is of antenna is FR-4, which contains ε_r of 4.4 and loss tangent of 0.22. This type of antenna has dimensions 52×32×1.6 mm^3. we fed the antenna with 50Ω transmission line using CPW feed. For Simulations and designing the iterations of antenna ANSYS HFSS software is used. The proposed antenna has achieved good results in simulation.

Revised Manuscript Received on 30 May 2019.

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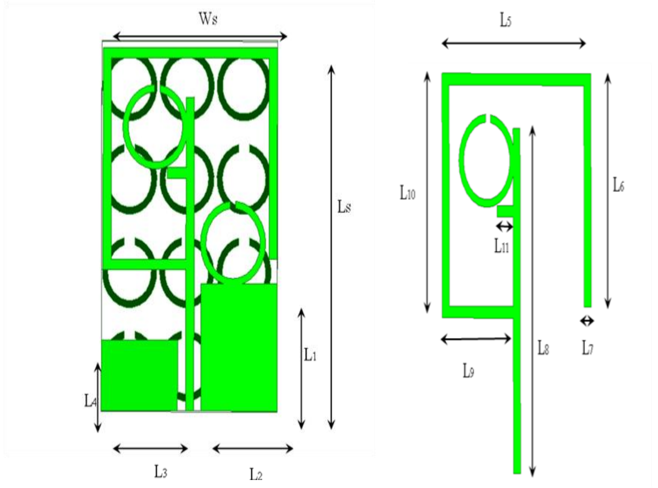
The proposed antenna has dimension of 52x32 mm² is printed on 1.6 mm thick (t) FR-4 substrate (ε_r=4.4) and loss tangent (δ) 0.02. In the ground plane slots are made. The material of the radiating patch is copper and on the back side the ground plane exists. The length of feed bis 1.5 mm and the variations in the feed line plays a crucial role in achieving resonance. A 50Ω compact coaxial wire is connected to the metallic strip of the antenna for testing. The combination of two ring resonators with splits on them and metallic strips form the required metamaterial structure. The internal structures of ring resonator, i.e. the upper part and lower part, are connected by a metallic strip, which appears to be a 'Z-shaped' structure.

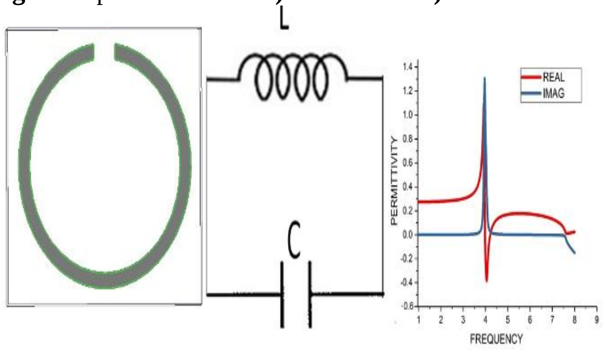
Table1. Antenna parameters

Antenna parameter	dimension (in mm)	Antenna parameter	dimension (in mm)
L1	18	L6	30
L2	14	L7	1.5
L3	14	L8	44.5
L4	10	L9	15.25
L5	32	L10	31.25
L11	3.45	Ls	52
Ws	33	-	-



a) **b)**

Fig 1. Proposed Antenna **a)** Front View **b)** Patch



a) **b)** **c)**

Fig 2. **a)** Unit Cell Structure **b)** Equivalent Representation **c)** Magnetic Response.

Based on theoretically analysis and basic equations, the mathematical formulae used to achieve the design procedure of the antenna proposed are stated below

The operating wavelength of the antenna is ' λ_0 ' and it is calculated by the given equation (1).

$$\lambda_0 = C/f_r \quad (1)$$

Where 'c' is the free space velocity of light and 'f'' denotes the resonant frequency.

The thickness of the substrate (h_s) is given by the equation (2):

$$h_s \leq \frac{0.3C}{2\pi f_r \sqrt{\varepsilon r^2 + 1}} \quad (2)$$

Where, ε_r denotes the substrate's relative dielectric constant.

The given equation (3) represents width of the strip W_s.

$$w_s = \frac{C}{2 f_r} \sqrt{\frac{2}{\sqrt{\varepsilon^2 + 1}}} \quad (3)$$

The presented antenna effective length (ΔL) is due to effective dielectric constant as shown in equation (4):

$$\Delta L = 0.412 h_s \left\{ \frac{\varepsilon_r + 0.3}{\varepsilon_r - 0.258} \right\} \left\{ \frac{\frac{w_s}{h_s} + 0.264}{\frac{w_s}{h_s} + 0.813} \right\} \quad (4)$$

The length of the presented antenna patch (Ld) is given by the equation (5):

$$L_d = \left\{ \frac{C}{2 f_r \sqrt{\varepsilon_{reff}}} \right\} - 2\Delta L \quad (5)$$

The effective di-electric constant of the antenna is given by the equation (6):

$$\varepsilon_{re} \approx \frac{\varepsilon_{r+1}}{2} + \frac{\varepsilon_{r-1}}{2} \left(1 + \frac{12h}{w} \right)^{-0.5} \quad (6)$$

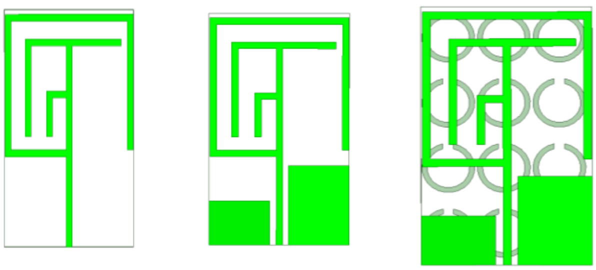
2.2. Generation of Hexa-band frequencies

SRR's are the mainly used technique in this presented antenna. In this model, the metallic upper and lower side bars are used to connect the metal strips. The split ring resonator internal side and the shape of the plane seems to be same as Z-shaped structure. The split ring resonator unit cell has a dimension of 8×1.635 mm^2 along X, Y, Z axes. In this model, an asymmetric ground is introduced. The main advantage of introducing an asymmetric ground is, it provides circular polarization. The antenna which was proposed, mainly works at five frequency bands particularly for Bluetooth, WLAN, Wi-Fi, GPS, Wi-MAX etc. applications. The circular polarization mainly used in satellite applications and tracking of targets.

Different techniques are used to achieve circular polarization. The amount of circular polarization produced or generated depends upon several factors. Those factors are size, shape and geometry of the antenna and in addition to this, the important factor is the orientation of the elements.

The proposed antenna has special features over other antennas which are using normal materials. The antenna is made by using meta-material which has negative permeability and negative permittivity, which meets the requirement of the antenna to work at high frequency ranges. The etching is done on the ground plane which is mainly used for providing additional resonant frequencies. The gap between resonator and ground acts as a capacitor.

In this method, iterations are performed. The SRR is mainly used to resonate at different frequencies so there would be a huge change in the reflection coefficient values which are caused due to introducing metamaterial with SRR.



a) b) c)

Fig 3. Proposed Antenna Iterations
a) Antenna1 **b)** Antenna2 **c)** Antenna3.

A multiple circular ring SRR slotted with dual-band antenna is proposed for smart applications with a partial ground.[2]. The antenna is fed with a microstrip feed line with 50Ω. Micro reconfigurable structures are used to produce sudden changes in the controlling ability. Typically, parameters like geometry, configuration, and metamaterial atom distribution effect the metamaterial responses. Split resonant rings (SRRs) which are rotatable periodically are placed on a less thick dielectric substrate to design a micro-mechanically tunable 3-dimensional antenna [3].

III. RESULTS

3. Results and Discussion

The six working bands of the proposed antenna at which they resonate are at 2.4/3.3/4.1/6.4/8.4/12.4 GHz. The frequencies at 2.55/3/5/6.5 GHz achieved circular polarization. The measured versus software defined results of circular polarized and scattering parameters of the designed antenna are shown in Figure 4 and 5 respectively.

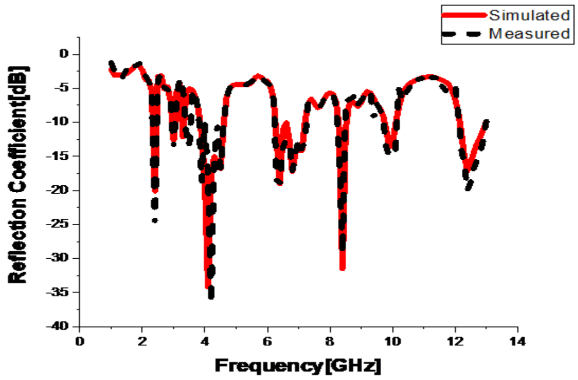


Fig 4. Measured versus simulated S_{11} results of the proposed antenna.

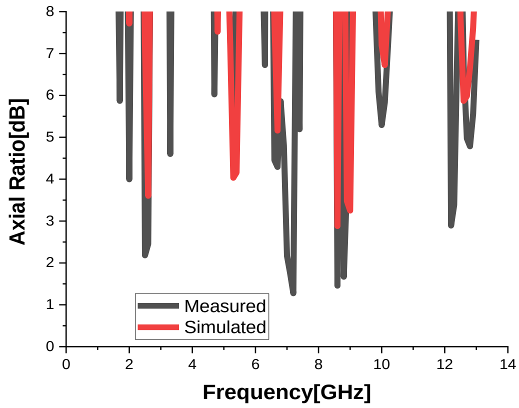


Fig 5. Axial Ratio versus frequency plot.

3.1. Parametric Analysis

Parametric analysis is done by varying the feed line width and the reflection coefficient results achieved by varying the feed width are as shown in the Fig-6.

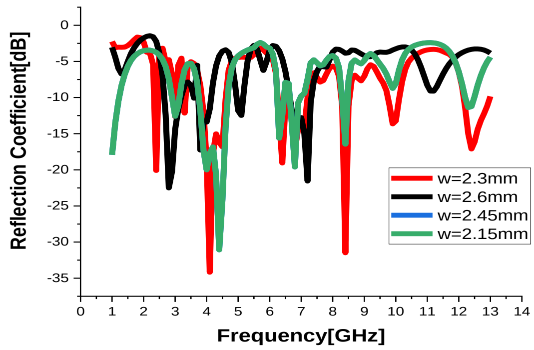


Fig 6. Reflection Coefficient Results for the parametric analysis done by varying the feed width.

3.2. Radiation pattern

This is the band of frequencies covering the bands of 2.2,2.5,3.2 GHz of frequencies. This is possible by the outer metallic strip that can generate the larger frequencies.

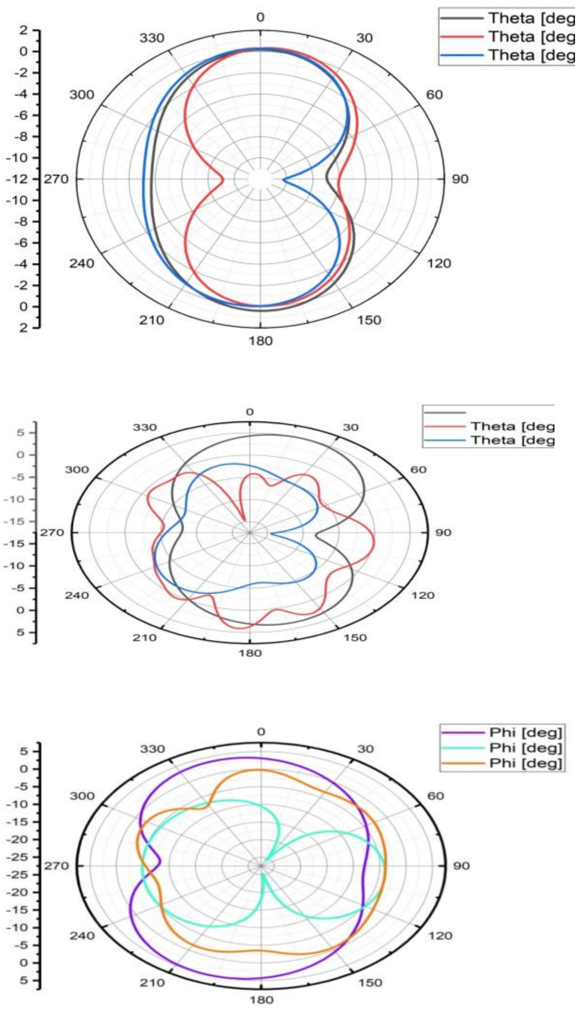


Fig 7. 2-D Radiation patterns at different phase angles.

IV.CONCLUSION

The proposed antenna has a Meta-material inspired antenna operating in six-bands with a triple band circular polarization is presented. The antenna presented works at six-bands and can be used for applications like Bluetooth, Wi-Fi, W-BAN (2.4GHz), and at 6.4/8.4/10/12.4 GHz have X-band applications. By introducing the SRR structure combined with metamaterial properties, a bandwidth enhancement is observed. The fabricated antenna results are in good relationship with the simulated antenna results.

ACKNOWLEDGMENT

We thank the technical support of DST through EEQ/2016/000604 and ECR/2016/000569, and KLEF for providing us opportunities to do the work.

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