Coplanar Waveguide Fed Circularly Polarized Band Antenna with Defected Ground Structure

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Abstract*-A compact Metamaterial multiband antenna is proposed for wireless local area network (WLAN), worldwide interoperability for microwave access (Wi-MAX) and international telecommunication union (ITU) band applications using a modified Triangular Split Ring Resonator (TSRR). The designed TSRR with metamaterial property to obtain desirable negative permeability bands that help in accommodating all three frequency bands of interest in a single device. This approach leads to the considerable reduction of the device structure. The overall dimension of the proposed antenna structure has a compact size of 60 x 50 x 1.53 mm and covers specific bands from the frequency spectra of 2.5, 5.1, and 8.25 GHz for WLAN, Wi-MAX, and ITU, respectively, with uniform radiation characteristics. The designed antenna structure is simulated using the High Frequency Structural Simulator (HFSS).The detailed analysis of the results obtained is presented. It is determined that the performance of the proposed antenna is superior to that of the existing antennas in the literature.

Keywords- Defected Ground Structure, Metamaterial, Microstrip Patch Antenna, Circular Polarization, Split ring resonator

I. INTRODUCTION

In its simplest form, the micro strip patch antenna is having the structure like a sandwich. The three entities are basically required to construct a patch antenna and these are mainly the dielectric PCB material called substrate, and two conducting sheets namely radiating patch and ground planes.

To construct the patch antenna, it uses the micro strip structure. In the earlier days 'strip line' was primarily used to circuit fabrication and this uses two ground planes and in between them a slat strip or the conducting trace was placed to guide the RF energy. In the later procedures, the top ground was removed which finally have two conductors which we call as the micro strip transmission line. Basic Antenna structure is shown in Fig 1.

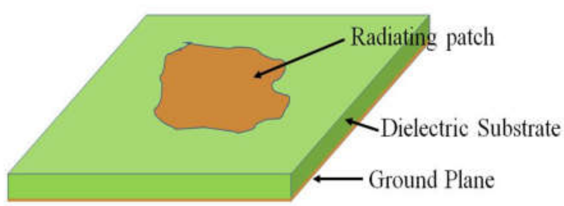

Fig.1 Basic architecture of Microstrip patch antenna

Circular polarization of an electromagnetic wave is a polarization state in which, at each point, the electric field of the wave has a constant magnitude but its direction rotates with time at a steady rate in a plane perpendicular to the direction of the wave. In electrodynamics the strength and direction of an electric field is defined by its electric field vector. In the case of a circularly polarized wave the tip of the electric field vector, at a given point in space, describes a circle as time progresses. At any instant of time, the electric field vector of the wave describes a helix along the direction of propagation. A circularly polarized wave can be in one of two possible states, right circular polarization in which the electric field vector rotates in a right-hand sense with respect to the direction of propagation, and left circular polarization in which the vector rotates in a left-hand sense.

A Metamaterials is a material engineered to have a property that is not found in naturally occurring materials. They are made from assemblies of multiple elements fashioned from composite materials such as metals or plastics. The materials are usually arranged in repeating patterns, at scales that are smaller than the wavelengths of the phenomena they influence. Metamaterials derive their properties not from the properties of the base materials, but from their newly designed structures. Their precise shape, geometry, size, orientation and arrangement gives them their smart properties capable of manipulating electromagnetic waves: by blocking, absorbing, enhancing, or bending waves, to achieve benefits that go beyond what is possible with conventional materials.

Appropriately designed metamaterials can affect waves of electromagnetic radiation or sound in a manner not observed in bulk materials. Those that exhibit a negative index of refraction for particular wavelengths have attracted significant research. These materials are known as negative-index metamaterials.

The main advantages of DGS are that it introduces slow wave effect. This effect produced because of the DGS equivalent and components. The transmission line with DGS gives a higher effective impedance and also introduces high slow wave effect, which provides rejection band in some frequency range. The microstrip line with DGS has a large electrical length as compared to conventional microstrip for the same physical length. Thus, DGS helps to lower resonance frequency and therefore to reduce the size of an antenna .

II. ANTENNA DESIGN

Circular polarization has acknowledged as one of the extremely required characteristics of an ultra wideband antenna. Though, circular polarization which is the restricting instance of the most common elliptical polarization is hard to accomplish because of the stringent demands on the phase and is understood just about two orthogonal components of the electric field vector in exact phase quadrature. Generally, circularly polarized antennas were utilized for point to point satellite communications and accordingly, the antennas used to understand circular polarization had no space restrictions and could offer to be large. Crossed dipoles, Archimedean Spirals and Yagi-Uda's gave the required circular polarization characteristics. Additionally, the issue of spectrum by Federal Communications Commission (FEC) for Personal Area Network (PAN) operations has employed an increasing demand on the flexibility of the basic micro strip patch antenna need to be compact in size, robust in design and almost omnidirectional in radiation while in the meantime providing a large impedance bandwidth to fit for a numerous application in the ultra-wideband region.

In the present work, basic structure of rectangular monopole is converted into trapezoidal shape with tapered step ground. Different iterations of radiating element as well as defected ground structures are examined in this work to analyze the circular polarization characteristics of the antenna. A defected structure etched in the metallic ground plane of a micro strip line is one of the smart solutions. It provides deep and extensive stop band, sharp cut off with its compact size to encounter evolving applications. Current model consisting of a compact ultra-wideband uses an individual split ring resonator which is excited by a monopole antenna.

Figure 2 shows the antenna structures o. In the structures structures, resonant frequencies are notched in the wide band by incorporating a split ring resonator shaped slots on the radiating element. The initial designs are modified by using a split ring resonator (SRR) which is placed almost on the radiating element to notch band of frequencies and to observe the notch band characteristics in the designed wideband antenna.

slot perimeter S_{per} is given by

$$S_{per} = 2L + 2W - 2R1 - 2R2 + \frac{\pi}{2}(R1 + R2) \qquad \text{………… (1)}$$

Stub Height h_s is given by,

$$h_s = S + \sqrt{L_s - \frac{(W_{s1} - W_{s2})^2}{2}} \qquad \text{…………... (2)}$$

The slot perimeter can be assessed to two guided wavelengths at the lower resonant frequencies. The Upper and lower resonant frequency is given as f_1 and f_2 respectively. The monopole like operation of antenna takes place and the upper resonant frequency is given by

$$f_1 = \frac{2C}{S_{per}\sqrt{\epsilon_{reff}}} \qquad \text{...…….. (4)}$$

$$f_2 = \frac{C}{4 hs \sqrt{\epsilon_{reff}}} \qquad \text{………… (5)}$$

In the above expression "c" is the velocity of light in free space and" ε_{reff}" is the effective relative permittivity of the substrate and it is given by the formula

$$\epsilon_{reff} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2}\left[1 + \frac{12h}{2}\right]^{\frac{-1}{2}} \quad \text{……… (6)}$$

The basic Antenna structure is shown in the fig (2)

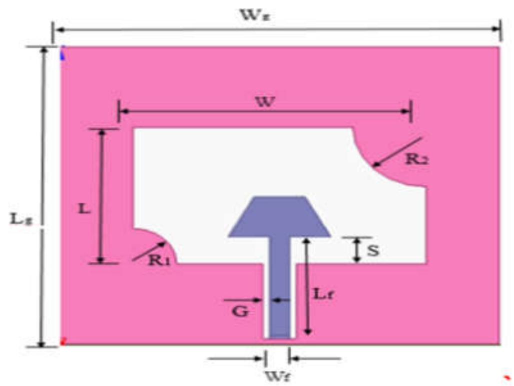

Fig2.Basic Antenna Model

III. ANTENNA MODELS AND DIMENSIONS WITH SPLIT RING RESONATOR

Fig 3 shows the trapezoidal shape slot antenna on defected ground structure. The antenna is designed on FR4 substrate of dimensions 60 x 50 x 1.53 mm. A ground is also printed in the same side of substrate along with radiating patch element. A rectangular slot of dimensions 40 X 23 mm is etched on ground plane and is excited by CPW feed line. The feed line is ended with a trapezoidal shaped tuning stub extended into the center of slot. The rectangular slot is cut into two circular arcs at lower left corner and upper right corner and having different radii to serve as perturbations required for recognizing circular polarization. The distance between the stub and the ground plane is represented as "S"and the spacing between the feed line and the ground plane is represented by "G ".The trapezoidal shape stub has widths of Ws_1 and Ws_2 and has length as Ls.The dimensions are shown in table1.

(a) (b) (c)

Fig.3 Antenna Models (a) Trapezoidal Monopole With SRR, (b) Trapezoidal Stub Monopole With SRR And DGS, (c) Trapezoidal Stepped Stub Monopole With SRR And DGS

Table.1 Dimensions for Antenna Design

Parameter	Dimensions (in mm)	Parameter	Dimensions (in mm)
Wg	60	Lf	16.62
Lg	50	Wf	2.8
W	40	S	3.68
L	23	G	0.85
R1	6	Ws1	7
R2	10	Ws2	14
Ls	7.5	H	1.53

IV. RESULTS AND DISCUSSIONS

A. Return Loss Vs Frequency Characteristics Of SRR:

Figure 4.1 shows the corresponding reflection coefficient characteristics of the antennas. The notching is occurred between 5 to 6 GHz which is popularly known for WLAN communication band. With the antenna model 6 we obtained a perfect notch band between 5.4 to 6.2 GHz (WLAN).

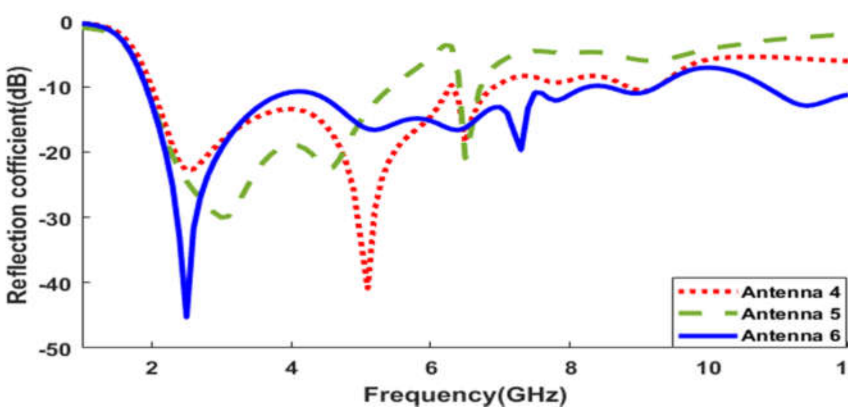

Fig.4.1 Reflection Coefficient Of Antenna Models

B. Impedance Vs Frequency Characteristics Of SRR:

An impedance bandwidth of 127% is attained from the modified structure of antenna model. Figure 4.2 shows the impedance characteristics of the antenna models. The impedance characteristics of the antenna is observed at the resonating frequencies with minimum values at resonating frequencies the impedance curves touch the 50 Ω at resonating frequencies. All the models are showing an average impedance of 50 Ω.

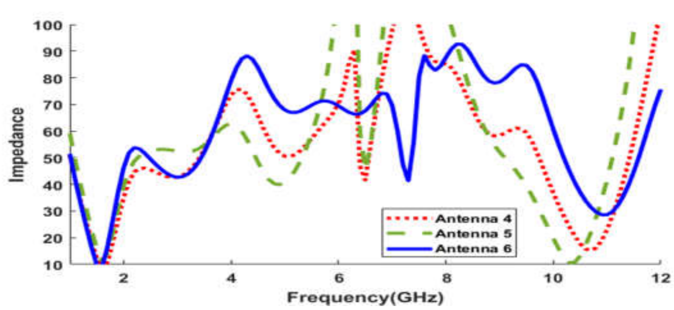

Fig4.2 Impedance Vs Frequency Of Antenna Models

C. Directivity Vs Frequency Characteristics Of SRR:

Fig 4.3 shows the gain and directivity plots of the modified notch antennas. At notch band frequencies we can observe the reduction in gain and directivity. At the notch frequencies the antenna peak gain plot shows sudden decrease in the gain in the notch frequencies. Even in the antenna iterations gain of the antenna remains the constant when compared with previous model's antenna.

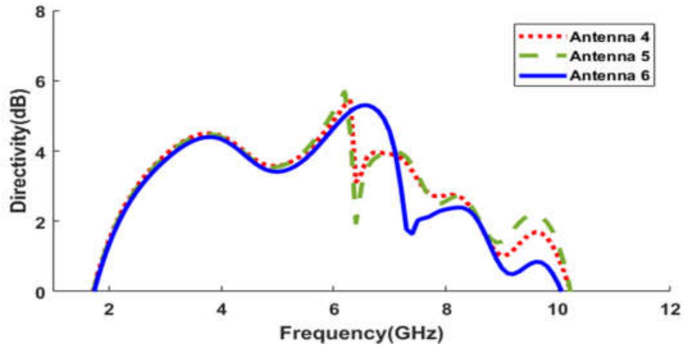

Fig 4.3 Directivity Of Antenna Models 4, 5 And 6 With Respect To Resonant Frequency

D. Peak Gain Of SRR Antenna:

The peak gain of SRR antenna shown in Figure4.4.For the antenna 5 shows the very less gain which is not preferable. The variation of gain is changed to positive and provides the maximum gain of 6dBi at the resonating frequency. For the antenna 4 and antenna 6maximum gain of 6.1dBi is observed at the resonating frequency.

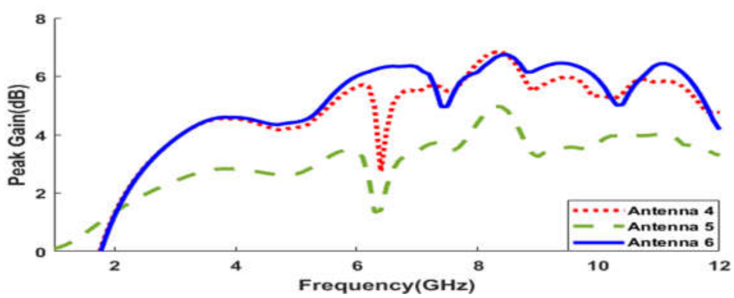

Fig.4.4 Peak Gain of Antenna Models 4, 5 And 6 With Respect to Resonant Frequency

E. Axial Ratio Of SRR Antenna:

Figure 4.5 shows axial ratio versus frequency plot of the notch band antennas. Except at notch band(5.4 GHz to 6.2 GHz), at other operating bands antenna models are providing 3 dB axial ratio.

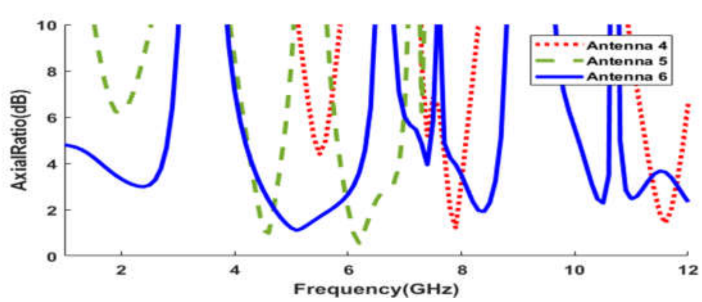

Fig.4.5 Axial Ratio Of Antenna Models 4, 5 And 6 With Respect To Resonant Frequency

V. CONCLUSIONS

From the designed antenna models, the following conclusions were drawn: A novel structure of trapezoidal monopole antenna with defected ground structure is designed in this work. A modified structure is drawn from the basic structure with split ring resonator to notch frequency band from 4.5 to 5 GHz and achieved circular polarization. Peak realized gain of 6.4 dBi and directivity of 3.8 dB is attained from the modified antenna structure. Antenna is showing dipole directional radiation pattern. At notch band antenna is showing low gain with disturbed radiation pattern. Circular polarization with axial ratio bandwidth of 45% and 68% is attained for the proposed antenna in both the pass bands. The proposed optimized antenna model is fabricated on FR4 substrate and tested for reliability on ZNB 20 vector network analyzer. Measured reflection coefficient is showing bandwidth of 3.8 GHz at first resonant band and 4 GHz at second resonant band. The measured results are in very good agreement with simulated results taken from HFSS.

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