COPLANAR WAVE GUIDE FED MICROSTRIP ANTENNA LOADED WITH SPLIT RING RESONATOR FOR ULTRA WIDE BAND APPLICATIONS

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ABSTRACT

In recent day’s antenna design based on Metamaterial is gaining more popularity due to enhanced radiation. Also, for inherent impedance matching coplanar wave guide (CPW) antennas are used. In this paper high efficiency multi band antenna for various wireless applications is discussed. This proposed design uses two annular split rings as radiating layer with CPW feed. In order to achieve Metamaterial property, Split Ring Resonator (SRR) element is loaded in the proposed design due to which a better drastic change has been observed in the antenna parameters. SRR structure reduces the total copper area in the ground layer and minimizes the conductive losses. Measured result shows that the Resonance is achieved between 3.55 and 12.10 GHz with a maximum gain of 5.01 dB.

Keywords: Coplanar Wave Guide (CPW), Gain, Impedance Matching, Metamaterial, Microstrip Antenna, Split ring resonator.

I. INTRODUCTION

The Communication between humans was first by sound through voice. With the craving for somewhat more separation correspondence came, gadgets, for example, drums, at that point, visual strategies, for example, signal banners and smoke signals were utilized. These optical specialized gadgets, obviously, used the light part of the electromagnetic range. It has been only very recent in human history that the electromagnetic spectrum, outside the visible region, has been employed for communication, through the use of radio.

One of mankind’s greatest natural resources is the electromagnetic spectrum and the antenna has been instrumental in harnessing this resource [1]. An antenna is a device that is made to efficiently radiate and receive radiated electromagnetic waves. There are several important antenna characteristics that should be considered when choosing an antenna for your application is antenna radiation patterns, power gain, directivity and polarization.

Antennas are elements converting electrical signals to electromagnetic waves based on the principles of Maxwell’s theorem [2]. He constructed a Tesla’s tower and conducted experiments on transfer of information. He succeeded in his theories, but they were not approved because there was no mathematical proof for his theories and experiments. Maxwell was the one to take advantage of Tesla’s theorems and proposed with mathematical relation between electrical and magnetic fields around a energized coil [13,14]. When analogue feed is given to the strip of the antenna, the metal patch is powered up and emits magnetic flux based on the Maxwell’s equation. The ground is used to terminate the electrical circuit. The radiation emitted from the patch emerges at the ground creating a magnetic field between the two layers of antenna. The substrate material is used to control the flux merging into the ground. The amount of radiation depends on the dielectric material used and the thickness of the material used. This emitted magnetic field creates a electric field which is perpendicular to the magnetic field.
creating it. This in turn creates a magnetic field and so on. This is how the electromagnetic wave propagates in the medium.

The double negative material concept with “C” shaped is printed and developed in 1968 by Veselago [3], metallic structure with negative permeability in 1996 by Pendry et al. [4] and Nonmetallic periodic structure in 1999 [8]. Artificial metamaterial split ring resonator is designed and tested by the researcher Smith et al. [12]. SRRs with various applications according to their prosperities such as filters, antennas, and waveguides were presented by many researchers [15-17].

When magnetic excitation is given to split ring resonator, current will be induced and will behave as a LC circuit with resonant frequency (ω₀) [5-9]. That resonant frequency will be calculated as

\[ \omega_0 = \sqrt{\frac{1}{2LCa_0}} \]  

Where C is the capacitance of combination of even and odd mode per unit length between the rings [3,5], a₀ is half the length of the split-ring resonator which is the average length of SRR from center to the structure

\[ C = C_e + C_0 \]  

Wider the gap in resonator will affect the resonant frequency; a₀ is calculated as by considering the ring gap as ‘g’

\[ 8a_{0eq} = 8a_0 - g \]  
\[ a_{0eq} = a_0 - g/8 \]

Therefore eq. (1) can be modified as

\[ \omega = \sqrt{\frac{1}{2LCa_{0eq}}} \]

Various types of feeding techniques are reported in that coplanar wave guides placing vital role in antenna design. It diminishes the unpredictability in configuration by utilizing the patch and the ground plane on a similar side of the substrate [2]. CPW antenna comprises radiating element and feed element. Feed element embraces coplanar waveguide, whose advantage is that feed layer and patch emanating surface can be on a similar plane [10, 11]. Consequently, the element can without much of a stretch interface with the radio recurrence circuit of back end, which can likewise effectively coordinate with PCB circuit. Also, it can improve the impedance characteristics [7, 20]. Generally coplanar wave guide has substrate with high dielectric constant, and its wavelength inside the wave guide is less than λ₀ in free space therefore electromagnetic field is accumulated between medium and air interface. Coplanar waveguide is utilized as transmission line to conduct TEM wave, with constraints.

Here we examined, coplanar wave guide microstrip patch antenna with a SRR which is reconfigurable. The simulation is done using HFSS software; two frequency bands are obtained having the resonant frequencies 4.19, and 8.1GHz. The substrate material selected is FR4 with a dielectric constant value 4.4., This Flame Retardant material is the dielectric substrate that is widely used in antenna design [17-19]. This recently designed antenna finds its applications in ultra wide band applications

II. DESIGN METHODOLOGY

The significant prerequisite for remote interchanges in present day times is a radio wire of littler size to limit the heaviness of the equipment. In this work, transmission line model has been used for the design of proposed antenna. The proposed design is done using a standard FR4 substrate material with dielectric constant of 4.4 and 1.6 mm thickness. The radiating layer and ground layer structures are described below. Fringing fields between the edge of the microstrip conductor and the ground plane will decide radiation. The electrical dimension of the
open ended microstrip line will be larger than physical dimensions, its length have been extended by fringing field \( \Delta l \) and empirically

\[
L_{\text{eff}} = L + 2 \Delta L
\]  

(6)

For a given frequency effective length of the half wave length will be

\[
L_{\text{eff}} = \frac{C}{2f_0 \sqrt{\varepsilon_{\text{reff}}}}
\]  

(7)

A. Top Layer Design

The top radiating layer consists of CPW fed annular split rings with radius \( r_1 \) and \( r_3 \). Figure 1 shows the structure of top layer of the antenna using transmission line model. The averaged diameter of the inner and outer annular ring is kept at \( \lambda/2 \) and \( \lambda/8 \), respectively where \( \lambda \) is the free space wavelength. The dimensions of the annular split rings used in this design are \( r_1=6 \text{ mm}, r_2=9 \text{ mm}, r_3=10 \text{ mm}, r_4=13 \text{ mm} \). The CPW feed has dimensions defined by \( L_1=20 \text{ mm}, L_2=13 \text{ mm}, L_3=3.5 \text{ mm}, L_4=1 \text{ mm} \) and \( L_5=18 \text{ mm} \).

B. Ground Layer Design

Ground layer has been analyzed using three different configurations. Full ground plane is used in Iteration I as shown in the fig 4. In iteration II the performance of antenna with ground mid open is studied shown in Fig 4. Here \( G_1=G_2=45 \text{ mm}, G_3=G_4=G_5=G_6=2.5 \text{ mm} \) and \( G_7=41 \text{ mm} \). Full Ground configuration on the ground planed yielded peak resonance frequencies at with return loss of respectively. ground with mid open configuration exhibited resonance frequencies at. In iteration-III, Metametrial based structure is used on the ground as shown in the figure 5. This configuration provides good bandwidth, low loss, and high gain when compared to iteration I and II. The dimensions are \( G_1=G_2=45 \text{ mm}, G_3= G_4=G_5=G_6=5.25 \text{ mm}, G_7=35.5 \text{ mm}, G_8=33 \text{ mm}, G_9=33 \text{ mm}, G_{10}=2 \text{ mm}, S_1=S_2=2.5 \text{ mm} \). The fundamental magnetic resonant frequency of rectangular SRR is calculated using Equations 9 and 10.

\[
f_{\text{SRR}_m} = \frac{C}{2\pi^2} \sqrt{\frac{3w}{\varepsilon_r(r - 2t - w)^3}}
\]  

(8)

\[
\lambda_{g_{\text{SRR}_m}} = 2\pi^2 \sqrt{\frac{(r - 2t - w)^3}{3w}}
\]  

(9)
III. SIMULATED RESULTS AND DISCUSSIONS

The proposed design is simulated using Ansoft HFSS software and the results are obtained for the metamaterial ground configuration. The bounded reflection is called as return loss. In antenna it is proportional to the signal which is reflected due to impedance mismatch. From the reflection coefficient S11 plot in Fig. 5, it is observed that the antenna exhibits a return loss of -43.31 and -57.75 dB at 4.19 and 8.1 GHz resonance frequencies respectively. This value indicates only small reflection of 1% percentage of in the proposed antenna.
Standing wave ratio of maximum voltage to minimum voltage is known as Voltage Standing Wave Ratio. This will indicate the impedance mismatch; Ideal value should be 1:1 for effective radiation and it is also equivalent to reflected power. Fig 6 implies that VSWR of the antenna is 1.013 and 1.002 at resonance frequencies 4.19 and 8.1 GHz.

The amount of power transmitted in the direction of peak radiation is known as gain of an antenna. Fig 7 shows gain for two different frequencies. It can be seen from 7(a), at 4.19 GHz the gain obtained is 4.08 dB and 5.01 dB is the maximum gain obtained at 8.1 GHz.
Radiation pattern is a significant parameter of the antenna which is a plot of far field radiation characteristics. In general microstrip antenna has less radiation power and narrow bandwidth. These types of antenna result lesser in gain also. To improve the gain patch type of microstrip is used. Radiation patterns are represented using spherical coordinates.

Here aperture model is used for far field evaluation. By accounting edge effect and using Green’s function far field for any m, n, p mode is given by

\[
\vec{E}(\vec{r}) = \frac{je^{-jkr}}{2\pi} \left[ E_i \hat{i} + E_\phi \hat{\phi} \right] \tag{10}
\]

Total field is expressed by sum of two element array with every one element is characterized by radiation slots and non radiating slots. Array factor of two identical radiating elements separated by a distance ‘Leff’ along y direction is given by

\[
(AF)_y = 2 \cos \left( \frac{k_0 L_{eff}}{2} \sin(\nu) \sin(\phi) \right) \tag{11}
\]

Non radiating slot with effective length ‘Leff’ and height ‘h’ radiated field is given by

\[
E_\nu = \frac{kh_{eff} E_0 e^{-jkr}}{2\pi r} \left[ Y \cos(\phi) \sin(X) \frac{\cos(Y)}{\left( Y^2 - \left( \frac{\pi^2}{4} \right) \right)} \right] e^{j(X+Y)} \tag{12}
\]

\[
E_\phi = \frac{kh_{eff} E_0 e^{-jkr}}{2\pi r} \left[ Y \sin(\phi) \cos(\nu) \sin(X) \frac{\cos(Y)}{\left( Y^2 - \left( \frac{\pi^2}{4} \right) \right)} \right] e^{j(X+Y)} \tag{13}
\]

Where

\[
Y = \frac{kL_{eff}}{2} \sin(\nu) \sin(\phi) \tag{14}
\]

\[
X = \frac{k_0 h}{2} \sin(\nu) \cos(\phi) + \frac{m\pi}{2} \tag{15}
\]
\[
Z = \frac{k_o W}{2} \cos(\nu) + \frac{n\pi}{2} \quad (16)
\]

Since the array factor in x direction is

\[
(AF)_x = 2j\sin\left(\frac{k W}{2}\cos(\nu)\right) \quad (17)
\]

IV. MEASURED RESULT

To verify the simulated results the prototype has been fabricated. Very careful and exact fabrication process is required to produce radiating behavior similar to the simulated model. Photolithographic process is commonly used method for fabrication. In this technique fabrication of microstrip antenna consists of three main procedures. They are, UV exposure, developing and etching process. The E5062A RF network analyzer is used to measure the return loss characteristics. The major features of the E5062A are measurement frequency range at high frequencies required for RF devices measurements. It allows basic RF network analysis with easy operation based on the use of a GUI (Graphic User Interface). The windows operating system installed in this machine is customized for more effective operation, and has different functions that are not part of the windows operating system for ordinary PCs (personal computers).

After the successful completion of fabrication procedure, the return loss parameter of fabricated antennae is measured using Agilent E5062A ENA series RF network analyzer.

The proposed antenna is fabricated using FR4 material, which is shown in figure 9, is tested using vector network analyzer and is shown in Fig 8. From the figure it can observed that the proposed design obtained a Ultra Wide Band frequency between the frequencies 3.55 and 12.10 GHz with a minimum return loss -37dB at 4.2 GHz.

Fig.8. Measured result of proposed antenna
A compact coplanar waveguide fed microstrip patch antenna using split ring resonator is proposed for Ultra Wide Band applications with a maximum gain of 5.02 dB and VSWR < 2. The proposed design is fabricated and tested and the measured result obtained a wide frequency between 3.55 and 12.10 GHz with minimum return loss. The obtained wide band frequency and minimum return loss id due to the split ring resonator and coplanar waveguide that is used in the proposed design. The measured results show favorable characteristics so that it can be used for practical applications.

REFERENCES


Fig.9. Top layer (a) and bottom layer (b) of the fabricated antenna

V. CONCLUSIONS