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Planar Multiband Antenna using Split Ring Resonators for WLAN and WiMAX Applications

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***Abstract*— A novel compact multiband microstrip antenna design using Meta materials suitable for WLAN and WiMAX applications is presented in this paper. The proposed design has a acceptable gain and resonates at multiple frequencies. High gain and multiband operation are achieved by using joined Split Ring Resonator structures. These SRRs are embedded over the ground plane and below (in the middle) the substrate. Reflection coefficient less than -10 dB is achieved at all the desired frequencies which show that the antenna radiates more than 80 percent of the power. The overall gain of the antenna obtained is 6 dB with the use of above-mentioned structure. A rectangular microstrip patch is mounted over an inexpensive FR4 substrate with dielectric constant of 4.4 and a thickness of 1.60 mm. Simulation tool used to carry out design and analysis is HFSS (High Frequency Structural Simulator) technology.**

***Keywords*— High gain, Multiband, Microstrip Patch Antenna, Metamaterials, SRR structures.**

I. INTRODUCTION

The usage of radiating elements in today's short and long distance communication plays prominent role and its demand is on the rise. Based on the requirement (like throughput, distance, etc.), the spectrum allocation, transmission bandwidth, radiated power may vary accordingly. Antenna plays a vital role for radiating or receiving the EM waves through the wireless channel. The most important radiation characteristics of an antenna are its directional characteristics and also in system point of view some of them include: 1) Small size 2) Less power and 3) Affordable cost [1] [3].

The recent trends in the antenna design suggest that the planar microstrip circuits are the advanced and most desired circuits with its very less fabrication cost, low profile and ease of implementation. These planar elements also finds its applications in microwave links, RF systems such as AWA and mm-wave sensing devices, `airborne, radars, medical applications, reflector feeding elements, due to its diversified advantages like low profile, less weight, and ease of implementation with IC's[2][3]. However, the planar circuits also suffer from disadvantages like narrow operational bandwidth (approximately<5%), less gain (less than 6dB) and unwanted emission of surface waves, etc. results into limited use of these devices in many other applications [1].

Operational bandwidth of this type of radiating elements is very narrow and back radiation of EM waves below the ground plane results into the difficulty in matching the input impedance of aerial device. It has been observed from the literature that the fraction impedance bandwidth can be improved by dispatching the conventional Perfect Electrical Conductor surface and using a Perfect Magnetic Conductor instead. With this arrangement, the reflections at the input terminal of the aerial device can be minimized for a wide range of frequencies. There are several materials which are artificially constructed, generally known as EBG structures can also be used for this purpose [4].

To improve or increase the efficiency and to operate the radiating device at different frequencies various designs with simple structures are presented, these designs includes the use different array configurations, materials with negative refractive index, elements arranged in stacked , and designing with different materials. Antennas designed with array configurations like broad-side and end-fire leads to increase in the physical dimension of the patch and also needs a corporate feeds for broadside design and hybrid directional couplers for end fire design [4]. This result into increase in the design complexity and also affects the radiation efficiency due to the back radiation from the feeding point. The gain improvement using super substrate materials and stacked arrangements may require multiple layers with different relative permittivity's and also decreases the operational bandwidth. Applying meta-materials is another technique that these drawbacks can be overcome. with this approach, by using them, the antenna aperture efficiency is significantly improved without increasing the antenna size [5].

The major issue in designing the patch antenna are surface waves and can be mitigated by two methods and the same have been applied to design a planar antenna with appropriate characteristics on high-dielectric constant substrate. One such technique utilizes micromachining technology, while the other technique uses the concept of metamaterial artificial structures. In the first technique, some section of the substrate right below the radiating aerial element is extracted to obtain a low effective dielectric-constant. With this approach, power loss due to surface-wave excitation is reduced and efficiency improves. The another approach uses artificial Metamaterials [6][7]. The proposed design is designed using both the approach.

This innovative design approach and its variants are analyzed using High Frequency Structure Simulator (HFSS) which is based on Finite Element Method (FEM) and the various antenna parameters, such as, return loss and the Voltage Standing Wave Ratio analyzed and also its radiation pattern is plotted to illustrate the performance of the proposed antenna design.

II. USE OF METAMATERIALS

A hypothetical structure called artificial material which exhibits negative values of relative permittivity and permeability. These type materials cannot found in real time which are capable of directing electromagnetic radiation. But this structure can be made experimentally by using Split Ring Resonators (SRR). These artificial left-handed structures or metamaterials were designed, theoretically analyzed, and experimentally verified [7]. The practically designed Metamaterials have been applied in microwave frequency band.. Also in many of the applications, artificial structures with stacks of SRRs under patch antenna were designed and it is observed that the resonant frequency of the original patch antenna can be significantly shifted [9][12].

The size of the antennas that are small compared to the wavelength of operation can reflect most of the signal back to the excitation point. A artificial metamaterial antenna with superstrate dielectric constant exhibits as if it were much greater than its usual size[2]. Established simple lithography techniques can be used to print these elements on a PC board. Major application areas of metamaterial radiating elements are, radar space communications, GPS, satellites, space vehicle navigation systems and airplanes [10].

The miniaturization of the microwave antennas is possible using metamaterials, with optimum radiation efficiency and reasonably good operational bandwidth. Planar radiating elements using the artificial materials exhibits the possibility of overcoming radiation efficiency-bandwidth limitations for conventionally designed, miniaturized antennas[11][12].

Different kinds of SRRs are also used, such as 1-cut single ring SRR (1C-SRR), 2-cut single SRR (2C-SRR), edge-coupled SRR (EC-SRR) and broadside-coupled SRR (BC-SRR). SRR can be of circular, square or rectangular shape. A SRR is basically a LC circuit having inductance L and capacitance C, when excited by a time-varying field[5][8].

In the proposed antenna, rectangular EC-SRR has been used with a wire-strip in order to create artificial DNG metamaterial. The metamaterial structure is inserted in the substrate of this antenna. And simulations were run on antennas with metamaterial.

The objective of this paper is to enhance the operational frequency bands that is to radiate at multiple frequencies and , in a completely different approach, and also the gain of a conventional planar antennas by incorporating the artificial resonating periodic patterned structures directly above the ground plane and between the substrate.

III. MICROSTRIP PATCH ANTENNA: DESCRIPTION AND DESIGN PRINCIPLE

In general, the impedance bandwidth of a resonant radiating element exhibits smaller bandwidths since it has only one resonant frequency. If the design consists of resonating lengths which are two or more, with each one operating at its own resonance, the overlapping of these multiple resonances may lead to operate at multiple-frequency of operation [3].

The basic structure consists of a conducting patch on one side of a FR4 substrate which has a ground

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conducting plane on other side as shown in the figure below. This radiating element is made of copper or gold material. This element is a strip conductor of length L and width W which are designed based on resonant frequency. The thickness of the antenna is t. The rectangular planar radiating element is designed so that it can operate at the desired frequency. The length of the antenna is generally chosen to be lying between the range give below

$$0.333\lambda_o < L < 0.5\,\lambda_o,$$

Where, λ_o is the free space wavelength. The thickness of the structure is should follow the below condition $t<<\lambda_o$.

The height h of the dielectric substrate is usually

$$0.003\lambda_o \leq h \leq 0.05\,\lambda_o$$

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IV. DESIGN SPECIFICATIONS

The design consists of the calculation of the following parameters[2].

1. Width (W) of radiating element:

$$W=\frac{c}{2fo\sqrt{\frac{(\mathcal{E}r+1)}{2}}}$$

where $c = 3x10^8$ m/s, $\mathcal{E}_r = 4.4$ & $f_o = 2.4$ GHz,

We obtain: W = 38.04 mm

2. Calculation of $\mathcal{E}_{reff}$

$$\mathcal{E}_{reff}=\frac{\mathcal{E}r+1}{2}+\frac{\mathcal{E}r-1}{2}\left[\sqrt{\left(1+12\frac{h}{w}\right)}\right]$$

Substituting $\mathcal{E}_r = 4.4$, W =38.04 mm and h = 1.6 mm

We get: $\mathcal{E}_{reff} = 4.08$

3. Length:

$$\Delta L= 0.412\frac{\left(\frac{W}{h}+0.264\right)(\mathcal{E}reff+0.3)}{(\mathcal{E}reff-0.258)\left(\frac{W}{h}+0.8\right)}$$

Substituting $\mathcal{E}_{reff} = 4.08$, W = 38.04 mm and h = 1.6 mm

We get: $\Delta L = 0.73$mm

4. Actual Length of patch: (L_{eff}):

$$L_{eff} = \frac{c}{2fo\sqrt{\mathcal{E}reff}} \quad \text{and} \quad L = L_{eff} - 2\Delta L$$

Substituting $L_{eff} = 30.86$ mm and $\Delta L = 0.73$ mm

We get: L = 29.4 mm

5. Calculation of inset feed point:

Conductance (G):

$$G=\frac{1}{90}\left(\frac{W}{\lambda o}\right) = 0.001$$

Calculation of resonant input resistance (R_{in}):

$$R_{in} = \frac{1}{2G} = 500\Omega$$

$$R_{in}(y=y_o) = R_{in}(y=0)\cos^2\left(\frac{\lambda o}{L}yo\right)$$

$$y_o = 11.6881\text{mm}$$

The parameters for the patch in HFSS simulation tool are the following:

- Dielectric constant = 4.4
- Operational Frequency (fr) = 2.4 GHz.
- Substrate hieght = 1.6 mm.
- Speed of light (c) = 3×10^8 ms^{-1}.
- Practical width (W) of patch = 38.04mm.
- Loss Tangent (tan δ) = 0.019
- Actual Length (L) of patch = 29.4mm.
- Practical width (W) of substrate = 38.04mm.
- Effective Length (L) of substrate = 40.562mm.
- Width of SRRs = 1mm.

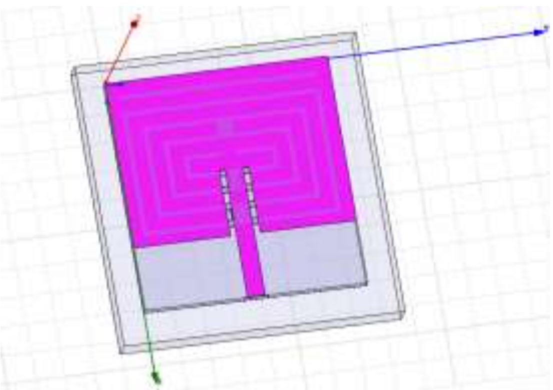

Fig. 1 Structural View of Patch

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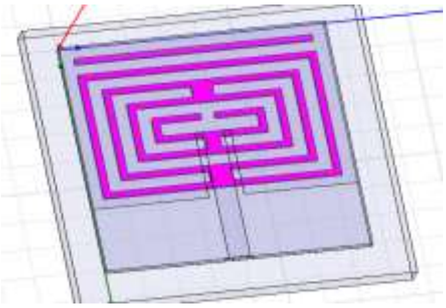

Fig. 2 Structural view of SRRs (above the ground and between the substrate)

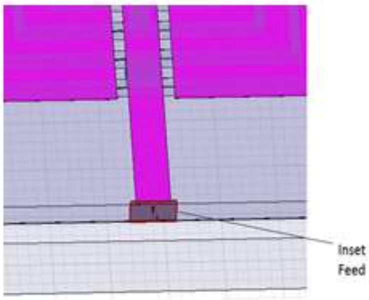

Fig. 3 Inset Feed

V. SIMULATION RESULTS USING HFSS

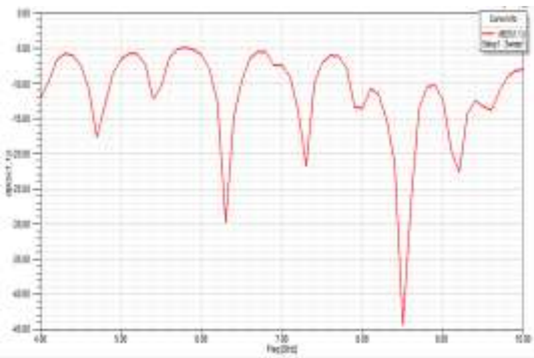

Fig. 4 Return loss(S11) plot for Proposed Antenna

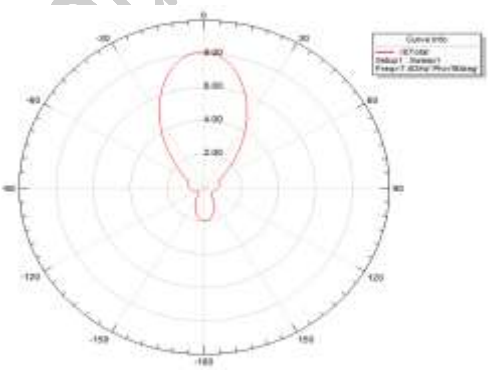

Fig. 6 Radiation Pattern for proposed patch antenna.

TABLE: Return Loss vs Frequency

Frequency	Return Loss
4.7	-17.7348
5.4	-13.3073
6.3	-28.5255
7.3	-19.3818
7.9	-14.3919
8.5	-39.9250
9.2	-24.1817

For the design of antenna, a substrate of thickness 1.6 mm is chosen below which split ring resonators of width 1 mm is placed. With these arrangements, the electrical length of the patch is changed which results into resonance at multiple frequencies. The frequency at which antenna radiates and electrical length are inversely proportional, increasing the number of rectangular split ring resonators increases the number of resonant frequencies. The designed antenna is excited using inset feeding and with a proper impedance matching. The plot of return loss versus frequency shows that, very less amount of the power is reflected back to the excitation side. At some specific frequencies like 4.7 GHz and 5.4 GHz and 6.3 GHz, more than 80 percent of the power is radiated by the antenna. It is also observed that the radiation pattern is directional with decreased beam width, and the gain of the antenna achieved is approximately 6 dB.

VI. CONCLUSIONS

A compact planar multi-band microstrip antenna loaded with meta material which radiates at multiple frequencies is presented in this paper. Simulation results shows that the designed antenna exhibits good directional pattern at all desired frequencies with acceptable gain of approximately equal to 6 dB. In this approach inset feeding technique is incorporated for proper impedance matching.. It can be seen that by using SRRs structure we can get multiband operations and high gain of the microstrip patch antenna. The structure has simple rectangular split ring resonators and can easily be fabricated with very less cost. The designed antenna can be a good solution for WLAN and WiMAX application with miniaturized size. It is also observed that the proposed design can also be used for low band 5G applications. The return loss parameters at various frequencies are tabularized which shows that most of the excited power is radiated by the antenna.

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