Dual Band Microstrip Patch Antenna Array Incorporated with Split Ring Resonators

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Abstract- Antennas act as the driving force behind the recent advances in wireless communication technology. Since technology has never been static its trends goes on changing with the advent of microstrip patch antennas the size, weight and fabrication cost has been minimized. In this paper a unique miniaturized structure element is developed to achieve the dual band behavior of antennas. When no additional structures are added, traditional patch antenna array resonates at 2.4GHz with gain of 5.6dBi and bandwidth of 290MHz. when the same structure is incorporated with split ring resonator (SRR) which constitutes the properties of Metamaterial then an additional frequency is added up which resonates at 8.4GHz.All in all this proposed microstrip patch antenna array possess considerable gain and bandwidth.

Keywords- Antenna, SRR, Metamaterial

I. INTRODUCTION

A multiband microstrip patch antenna is preferred in most of the wireless applications because it squeezes the resonant dimensions of the antenna, and having an advantage of low profile, less weight, low fabrication cost , portability, integrability with millimeter and microwave circuits multiband operation[1]. Not only this, but also it replaces the usage of multiple antennas for different resonant frequencies. In the literature several traditional approaches have been reported to achieve multiband operation. The techniques include-by truncating the ground plane of conventional patch antenna, introduction of perturbation by cutting slots into the radiator etc. But, most of the techniques results in the increase of size of antennas thus making them bulky[2]. So in order to overcome the drawbacks faced by these conventional techniques a novel structure is proposed.

This proposed microstrip patch antenna resonates simultaneously at the frequencies of 2.45GHz and 8.4GHz respectively. This novel method of dual band microstrip patch antenna is obtained by incorporating some additional design structures to the conventional patch antenna array. The dual band operation is achieved by placing vias and inserting split ring resonator (SRR) to each of the rectangular microstrip patches of the array.

These split ring resonators (SRR) are artificially engineered single or double negative metamaterials which are also called zero index materials. These artificial materials are characterized by either dispersion relations or by constitutive electromagnetic parameters. In 1968, Veselago first time in his paper gave the theoretical explanation on materials with negative permittivity and permeability, simultaneously and also predicted some peculiar phenomena obtained from them. Smith et al. were the first to experimentally demonstrate the negative materials.[3]

Antenna designs incorporating metamaterials can setup the radiated power of an antenna. The newest metamaterial antennas radiate as much as 95% of an input radio signal. In general, standard antennas need to be at least half the size of the signal wavelength to operate efficiently[4]. Therefore in metamaterial loaded conventional antennas, matching of impedence occurs at frequency which is lower than the initial resonant frequency of their conventional counterparts. These interesting anomalous electromagnetic features result in size reduction and performance improvement of conventional antennas at no extra hardware cost and size.[5]

The proposed structure is analyzed using ansoft HFSS.V.14.

II. PAST RESEARCH

In the literature, various techniques are used to load the microstrip patch antennas with metamaterials have been reported [6–14]. In [6], Chen and Alu combined two resonances to enhance the antenna bandwidth by loading the elliptical patch antenna with mu-negative metamaterial. In [8], Andrea Alu et al. enhanced the radiation performance of the circular patch antenna by using metamaterial inclusions that fit in the dielectric region between the patch and the ground plane. Joshi et al. [9], embedded the SRR into the slot of a slotted patch antenna to match the impedance at the desired frequency band. In [10], Arora et al. loaded the feed line of the conventional patch antenna array with a pair of split ring resonators to enhance its bandwidth. The same group [12],designed a metamaterial superstrate to improve the gain of patch antenna array. These artificially engineered materials can also be directly connected to the antenna for reduction in size and enhancement of gain and bandwidth, like [13], where Palandoken et al. directly connected the unit cell of left handed metamaterial to a dipole antenna for obtaining the broadband performance and [13], where Du et al. connected the modified S-shaped resonator directly to the monopole antenna to achieve the multiband operation. However, most of these researches were associated with the performance enhancement of single patch antennas only. Therefore, a method is required, which should not only improve the performance of the antenna, but should also be capable to reduce its dimensions by lowering the existing resonant frequency or by generating an additional lower resonant frequency band.

Organization of the article:

This paper is organized into eight different sections. Introduction and past research has been discussed in first two sections of the paper. Design of metamaterial is discussed in third section. Fourth section presents the physical parameters of the antenna. The detailed design of conventional and proposed antenna array is presented in section five. Simulation results as well as the fabrication process are discussed in sixth and seventh sections of the paper. Finally, the communication is concluded in section eight.

III. DESIGN OF METAMATERIAL UNIT CELL

The structure of the split ring resonator unit cell is shown in fig 1. The dimensions of this split ring resonator unit cell are; length of outer split ring (Ls) =11.95mm, ring width (w) =0.2mm, split gap (g) =0.3mm and the gap between inner and outer split rings(s) =1mm.The dimensions of the split ring resonator unit cell are chosen in such a way that the overall size of the proposed antenna array does not increase at all.

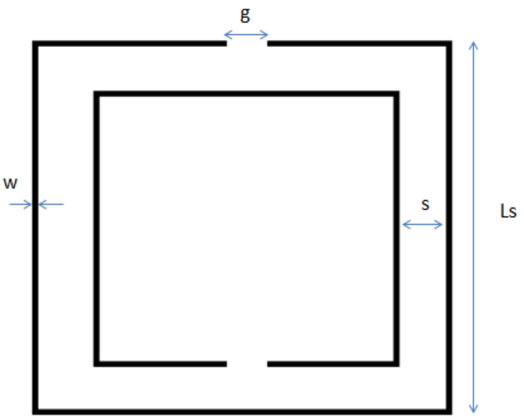

Fig.1: Metamaterial unit cell

IV. THEORITICAL ANALYSIS FOR DESIGN OF BASIC ANTENNA

Microstrip patch antennas are characterized by a large number of physical parameters than conventional microwave antennas.[14]

The basic antenna is designed for a resonating frequency of 2.45GHz.

Selection of substrate:

The dielectric materials play important role in antenna designing process. The thick substrate with low dielectric constant gives good performance and provides better efficiency, larger bandwidth, but large antenna element. While thin substrate with higher dielectric constant provides smaller element size however because of their greater losses they are less efficient and have relatively smaller bandwidth. The performance of antenna improves when the value of dielectric constant reduces The antenna is designed on a fibre reinforced (FR-4) epoxy and its dielectric constants ranges within

$2.2 \leq \varepsilon_r \leq 12$.

The antenna which we are using should have minimum power losses. FR-4 epoxy has the possibility dielectric constant of $\varepsilon_r = 4.4$. The material for the patch is copper and material for radiation box is air

Selection of patch dimensions:

The patch dimensions also place a crucial role on defining the performance of the microstrip patch antenna. The following dimensions using reference equations for the proposed microstrip patch antenna are

1. Calculation of Width (W) of patch:

$$W=\frac{c}{2f_0}\left(\sqrt{\frac{2}{\varepsilon_r+1}}\right)$$

Where w=width of the patch
c=velocity of light
f_0=resonant frequency
ε_r =dielectric constant

2. Actual length of the patch (L):

$$L=L_{eff}-2\Delta L$$

Where $L_{eff}=\frac{c}{2f_0\sqrt{\varepsilon_{eff}}}$
ΔL=change in length

3. Calculation of Length Extension:

$$\Delta L=\frac{0.412h\,(\varepsilon_{eff}+0.3)(\frac{W}{h}+0.264)}{(\varepsilon_{eff}-0.258)(\frac{W}{h}+0.8)}$$

Where h=1.4mm
ΔL=change in length

4. Effective dielectric constant of rectangular patch antenna:

$$\varepsilon_{eff}=\frac{\varepsilon_r+1}{2}+\frac{\varepsilon_r-1}{2}\left[1+12\frac{h}{w}\right]^{\frac{-1}{2}}$$

Where ε_{eff}=effective dielectric constant
L_{eff}=effective length
L=length of the patch
h=height of the substrate
Δl=change in length

5. Feed location design:

The coaxial cable position can be obtained by using

$$X_f=\frac{L}{2\sqrt{\varepsilon_{reff}}}$$

Where

X_f is the desire input impedance to match the coaxial cable

ε_{reff} is the effective dielectric constant.

$$Y_f=\frac{W}{2}$$

6. Ground dimensions:

It is essential to have a finite ground plane in practical conditions ,if the size of the ground plane is greater than the patch dimensions by approximately six times the substrate thickness all around the periphery. Therefore the ground plane dimensions would be given as

$L_g=6h+L$

$W_g=6h+w$

V. DESIGN OF BASIC ANTENNA

A basic microstrip patch antenna is designed by using copper as aconducting material and FR-4 Epoxy as a substrate i.e, dielectric material.the feeding that is used here is coaxial feeding technique.

Table 1

Dimensions of basic rectangular patch antenna:

PARAMETERS	VALUE
Length of patch(L)	40
Width of patch(W)	30
Height of substrate(h)	1.4
Length of substrate	100
Width of substrate	90

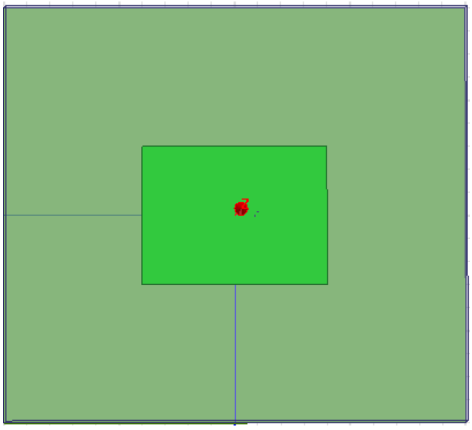
Fig.2: Basic rectangular patch antenna

Simulated results of basic antenna:

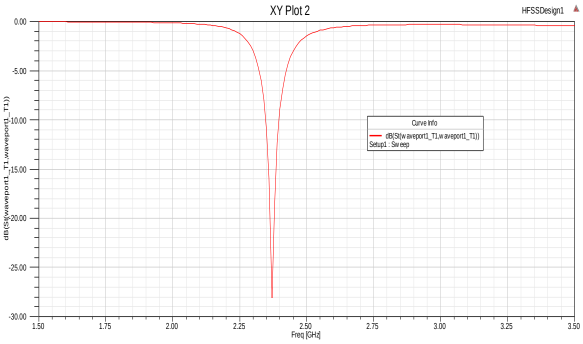

Fig.3: S11 Parameter

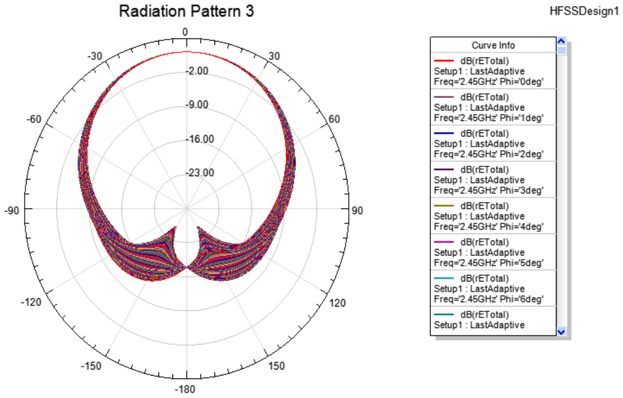

Fig.4:Radiation pattern

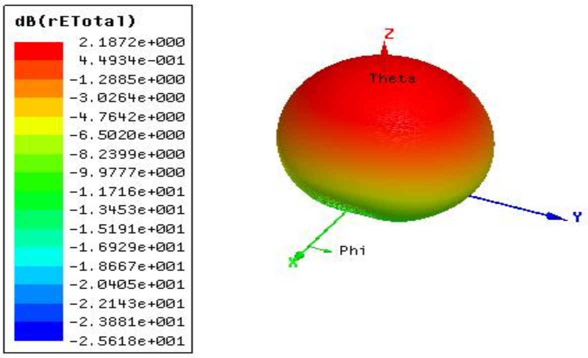

Fig.5: 3D Polar plot

VI. DESIGN OF THE CONVENTIONAL AND PROPOSED MICROSTRIP PATCH ANTENNA

The first part of this section deals with the design of a conventional microstrip patch antenna array. To improve this performance to achieve dual band behavior for its miniaturization, each patch of it is directly connected to an SRR. The design of this proposed metamaterial loaded shorted pin dual band patch antenna array is presented in the later part of this section.

The length of the quarter wave transformer and fifty ohm line is calculated as a=7.55mm, b =8.00mm also their widths are determined as c=0.5237mm and d=2.8758mm respectively.

Table 2

Dimensions of a conventional microstrip patch antenna aarray:

PARAMETERS	VALUE
Length of patch(L)	11.95mm
Width of patch(W)	15.88mm
Height of substrate(H)	1.48mm
Length of substrate	63.88mm
Width of substrate	63.88mm

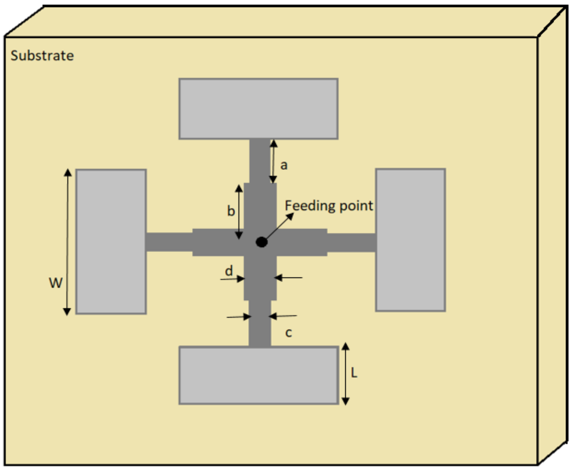

Fig.6: Conventional microstrip patch antenna array

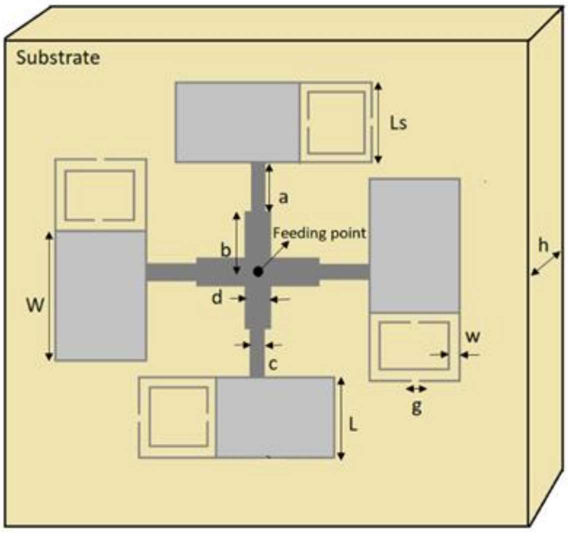

Fig.7: Conventional microstrip patch antenna array with SRR and vias.

IV. SIMULATION AND RESULTS

The three analytical parameters S11,VSWR and radiation pattern were observed and compared for both simulation results and laboratory measurements.

The return loss(S11) was simulated for proposed patch over a frequency range from(0 to 10GHz). As in figure ,

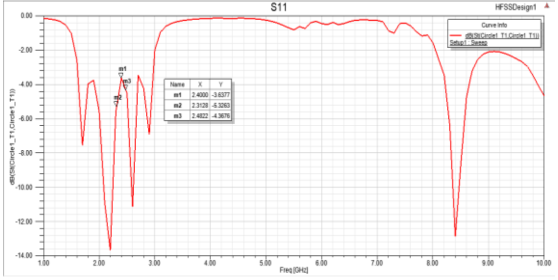

Fig.8: S11 parameter

The voltage standing wave ratio(VSWR) is a measure of how efficiently radio frequency power is transmitted from a power source ,through a transmission line into a load. The VSWR for the proposed antenna as shown in figure.5

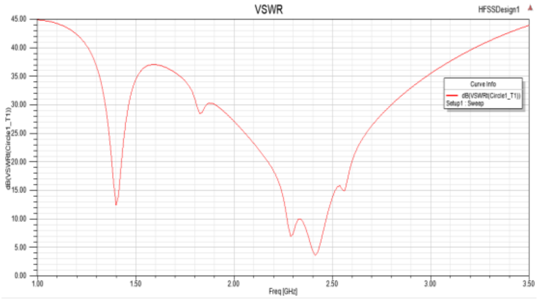

Fig.9: VSWR Measurement

V. CONCLUSION

In this paper, a novel approach of a dual band microstrip patch antenna array is designed with metamaterial and via holes to reduce the cost, size and enhancement of gain. For this, a coaxial feeding is provided to the proposed antenna array to match the impedence. The designed antenna array has been fabricated and tested to validate the design and it is observed that the simulated and measured results quite well agree with each other.

VI. REFERENCES

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