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Microstrip Patch Antenna Miniaturization by using Split Ring Resonators which are in-Plane for WLAN Application

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ABSTRACT
Combining the antenna miniaturization and bandwidth preservation could increase the challenges of integrating the smaller, thinner, low profile, high efficient antennas into equipment for different applications. In this paper, a novel Microstrip Patch Antenna with reduced size for WLAN application is proposed. Introducing in-plane Split Ring Resonators (SRRs) in the vicinity of the patch, and found that the configuration escalated the miniaturization by 42%. The simulated results showed that there was significant improvement in bandwidth. The design and performance analysis of the proposed antenna was carried out using Ansoft HFSS.

Keywords
Compact, Electromagnetic Bandgap, Metamaterials, Microstrip, Miniaturization.

1. INTRODUCTION
Over the last century, many researchers have germinated a dozens of versions in patch shape, feeding techniques, substrate configurations and array geometries [1-6], that surmounted its application. In the past, the method of analysis for Microstrip antennas using transmission line model [1], cavity model [2], and full wave analysis [3] has been studied. It may be desirable to model single elements, finite and infinite arrays, stacked elements, arbitrary shaped elements and coupling using full wave analysis. Approximate formulas for input resistance, bandwidth and radiation efficiency of rectangular Microstrip antennas are derived in [4]. These formulas require thin substrate as it involves approximations of a rigorous Somerfield solution.

Later, broader bandwidth patch antennas were developed using proper matching networks [5], thick substrates [6] and parasitic loading [7]. The technique to assign separate frequency bands to each patch antenna was conceived and adopted to develop dual frequency patch antenna [8]. Multi-functional mobile antennas aimed at realizing multiple functional characteristics that include multi polarization antenna structure, efficient radiation characteristics with single feed arrangement became increasingly popular for indoor and outdoor wireless communication applications. Currently, high performance, smaller and light-weight compact antennas is receiving a considerable amount of attention for different types of wireless systems. Several designs were developed with the objective to reduce the size of the antenna. These include resistive loading [9] and meander-line [10] loading of the patch antenna, Frequency selective structures [11], and Electromagnetic band-gap structures [12]. These structures produce a tradeoff between the physical size of the antenna and its bandwidth. In lieu metamaterials can be used to reduce antenna size while simultaneously operating over a broader bandwidth. In the remainder of this paper, it is investigated, that the performance of metamaterial loaded Microstrip patch antenna for WLAN application. First designing of a Microstrip patch antenna operating at 5.5GHz frequency and demonstrate that by introducing metamaterial the physical size of the antenna can be reduced. Following that, with encouraging simulation results, it is examined impact of metamaterial on radiation pattern. Details of the results are presented below.

2. CONVENTIONAL ANTENNA DESIGN
In this article, antenna miniaturization was realized for 5GHz WLAN frequency band.

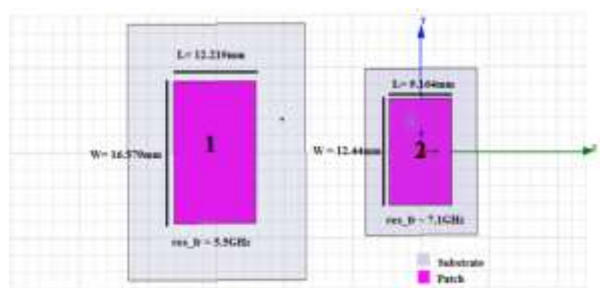

Fig 1: Rectangular patch antennas resonating at 5.5GHz (Patch1) and 7.09GHz (Patch 2) simulated using HFSS

Fig 1 depicts two patch antennas etched on same substrate with ε_r =4.4 and the co-axial feeding technique were applied to feed both the antenna. The first antenna resonates at 5.5GHz. An arbitrary high resonating frequency (7.09 GHz) was taken for second patch antenna to study the effect of reduced antenna size on resonant frequency. The antenna dimensions, material properties and operating frequency details are shown in Table.1

Table.1: Antenna Specification

Parameters	Patch 1	Patch 2
Resonant Frequency	5.5GHz	7.09GHz
Patch dimension	12.219 x 16.5976mm	9.364 x 11.784mm
Substrate	FR4 epoxy	FR4 epoxy
Substrate Thickness	1.57mm	1.57mm

From Table.1 it can be seen that the shift to high frequency led to decrease in patch dimension. This happened because of inverse relation between resonant frequency and antenna size.

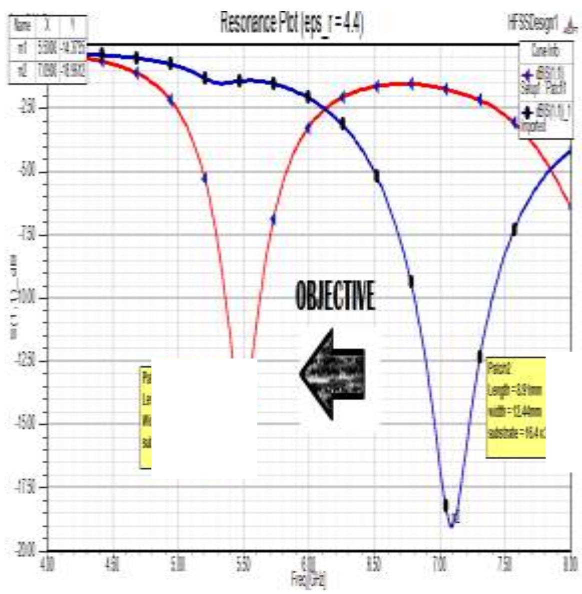

Fig.2: Return Loss Plot for Patch 1 & 2

As shown in Fig.2, patch 1 with dimension 12.219mm x 16.5976mm resonates at 5.5GHz and patch 2 with dimension 9.364mm x 11.784mm resonates at 7.09GHz. The objective of this article is to shift the resonating frequency down to 5.5GHz maintaining dimensions of patch 2 to achieve miniaturization.

3. NOVEL DESIGN FOR ANTENNA MINIATURIZATION

The cost of antenna miniaturization was limited by its wavelength dependence [7]. While the capacitive elements decrease the bandwidth, it only promises goals for miniaturization. But inductive elements are restricted to low frequency; the certainty of miniaturization is more than under conventional techniques in GHz frequency range. There are out-of-plane designs having SRRs deliberately introduced to the patch geometry that showed potential for miniaturization. However, such structures are non-optimal and fabrication process would be difficult.

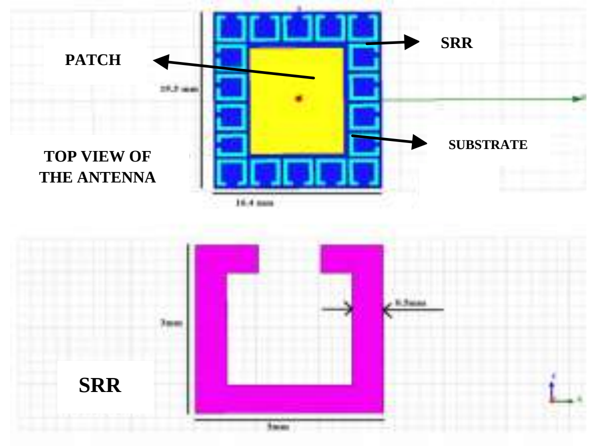

Fig. 3: 3D view of a rectangular patch antenna and SRR simulated using HFSS

The simulated patch antenna and the setup are shown in Fig.3, where the SRRs were placed in-plane with the antenna. Rings of dimension 3mm x 3mm with thickness equal to 0.5mm were placed outside the patch facing away from it.

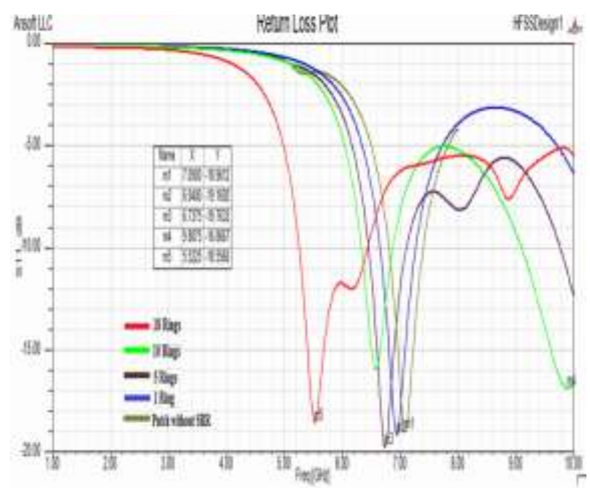

Fig.4: Return Loss Plot depicting reduction in resonant frequency with the introduction of SRR

The shift in the resonant frequency of the antenna, as depicted in Fig.4, largely depends on the number of SRR elements in the vicinity of the patch. With the introduction of one SRR the resonant frequency went down to 6.94GHz from 7.09GHz and with the addition of extra elements, the resonant frequency went down to 5.52GHz. Hence, in this design, 42% diminution in antenna size was attained.

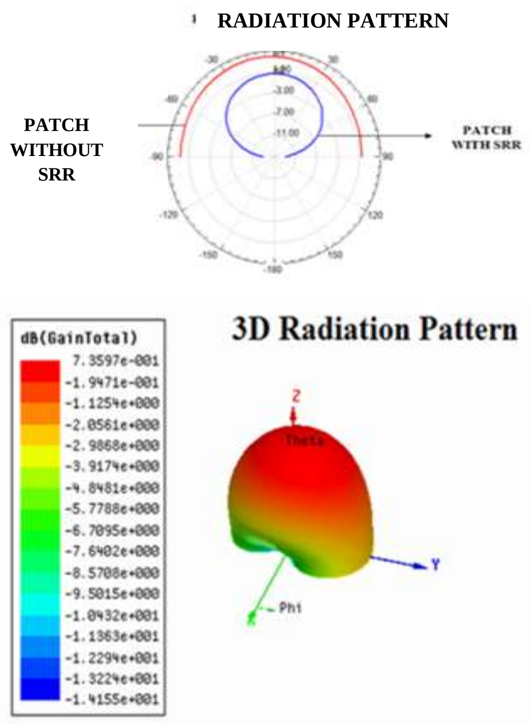

Fig.5: Radiation Pattern of Patch with &without SRR

Fig. 5 shows the radiation pattern of patch with and without SRR. The gain of the patch was 3.88dB and with SRR, it decreased to 0.69dB. While in-plane SRR configuration did increase miniaturization to 25 percent, there was a decrease in the gain due to increased interaction of the patch with SRR.

Table.2: Comparison of Antenna characteristics

Parameter	Patch without SRR	Patch with SRR
Frequency	7.09 GHz	5.52 GHz
Patch Size (mm)	9.364 x 11.784 x 0.1	9.364 x 11.784 x 0.1
S11 in dB	-18.96dB	-18.5560 dB
Gain	3.88 dB	0.69dB
Bandwidth	583MHz	1.1GHz

Table.2 shows the comparison of characteristics such as return loss, gain, and bandwidth for patch with and without SRR. The overall improvements of the Microstrip patch loaded with in-plane SRR is important to dispel any claim of preserving bandwidth but also to bring out contribution of these to reducing antenna size.

4. HARDWARE IMPLEMENTATION AND TESTING RESULTS

The software designed antenna of 5.5GHz was implemented and was fabricated. First the designed antenna from the HFSS was taken print on the Glass Sheet as shown in figure 6 below.

Fig 6: HFSS Design taken printed on Glass Sheet

With this print, the antenna of desired frequency is fabricated with exact measurements. The implemented antenna is as shown in the below figure 7.

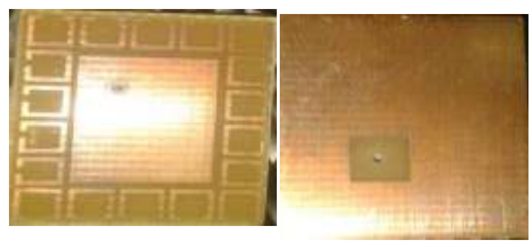

Fig 7: Fabricated antenna of 5.5GHz frequency

Also for connection of the antenna, SMA (Sub Miniature A) connector is used which is placed and soldered for the purpose of testing as shown in the figure 8.

Fig 8: SMA connector and Soldering of SMA connector on antenna

Testing of the designed antenna was done with the help of Coupler, Signal Generator and CRO. First the frequency was set from 5GHz to 6GHz range with the load shorted as shown in below figure 9.

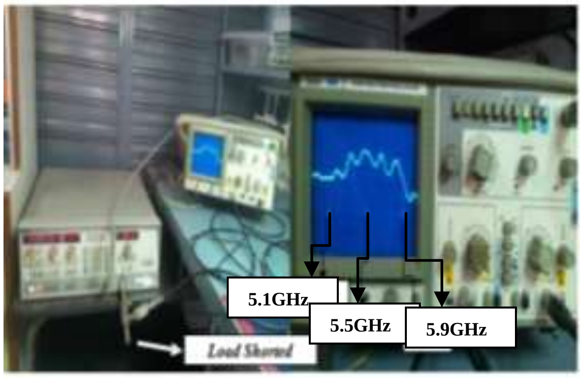

Fig 9: Input with Shorted Load

The load is replaced by the fabricated Antenna with the help of SMA connector. Now it is seen that at the 5.5GHz, the antenna is going to resonate by giving a dip at 5.5GHz point of the input and it is has shown in the figure 10.

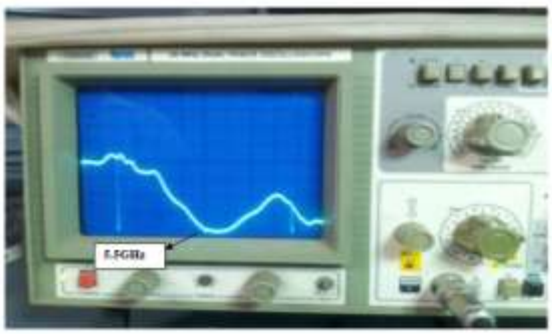

Fig 10: Dip showing Antenna Resonation at 5.5GHz

The entire setup of the testing of designed antenna is as shown below.

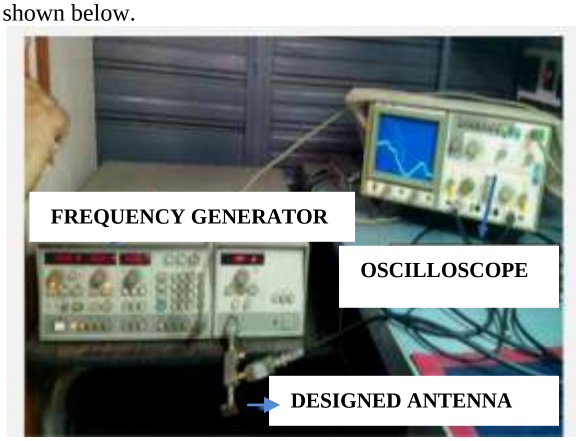

Fig 11: Testing Setup

5. CONCLUSION

Here the results are presented on Microstrip Patch Antenna by incorporating in-plane Split Ring Resonators. The objective of scaling down the resonant frequency of patch antenna from 7.09GHz to 5.5GHz maintaining the dimension of the former was discussed highlighting the benefits of it. Simulation was performed for patch antenna loaded with in-plane SRR and attained 42% physical size reduction. It is also demonstrated by simulation that there was significant improvement in bandwidth. The implemented and fabricated antenna was tested for single frequency i.e. for 5.5GHz. Next the plan has been done to fabricate the designed antenna array and validate the simulation results.

6. REFERENCES

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