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Review: Approach for Antenna Signature Reduction and Antenna Array Mutual Coupling Reduction

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***Abstract*—Miniaturization of the signature of the antenna, preserving the bandwidth will be a challenge which increases the demand for applications of such antennas. Also the Mutual coupling is a problem in the antenna arrays which affects the antenna arrays. A fresh technique for the signature reduction in Micro strip patch antenna is used by introducing the Split Ring Resonator [SRR's] in-plane with the patch. This technique also scales down the signature by 42% with the substantial improvement in the bandwidth. Results of implementations are explained. Periodic structures helps in the reduction of the mutual coupling by surface wave propagation suppression in the given range of frequency. An band gap feature of EBG structure is implemented into antenna array system to reduce mutual coupling for both frequency domain. The slots of the mushroom EBG structure exhibit a better surface-wave-decoupling performance. Results are shown by its implementation.**

***Index Terms*— electromagnetic, metamaterials, microstrip, miniaturization.**

I. Introduction

Many researchers over centuries have germinated a dozens of versions in patch shape, feeding techniques, substrate configurations and array geometries [1-6], that surmounted its application. Previously for Microstrip antennas using different techniques model like transmission line, cavity model, and also full wave analysis has been referred. By designing a single model, infinite and finite arrays, stacked elements, arbitrary shaped elements and coupling using full wave analysis. Input resistance, bandwidth and the radiation efficiency is calculated by using formulas of rectangular Microstrip antennas are derived in [4]. These formulas require thin substrate as it involves approximations of a rigorous Somerfield solution.

Mutual coupling is main problem occurs in the antenna array. It considerably affects the operation antenna arrays of different types. The study of mutual coupling problem started very long back around few decades and attracted the interest of not just antenna engineers and researchers but also many researchers from other disciplines such as communications and biomedical imaging where antenna arrays are frequently used. Antenna array is able to provide spatial information of the signal distributions compared with a single antenna.

There are a wide range of claims associated with EBG structures for the two distinct properties; firstly the property of suppressing the propagation of surface waves along the structure. Also it eliminates surface waves by means of EBG structures can enhance the radiation efficiency of different kinds of antennas. The second remarkable property of EBG structures is their reflection phase characteristics which vary continuously from 180° to -180° in a frequency band.

Currently, high performance, smaller and light-weight compact antennas is receiving a considerable amount

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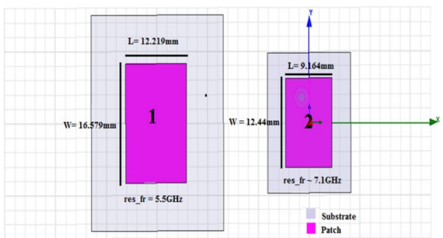
of attention for different types of wireless systems. Numerous designs are proposed and developed with the main objective of reducing the size of the antenna. These include resistive loading and meander-line loading of the patch antenna, Frequency selective structures, and Electromagnetic band-gap structures. These different structures produce interchange between the bandwidth and the physical size of the antenna. Also proposes of use of metamaterials to for the reducing the antenna size while simultaneously operating over a broader bandwidth. In this survey the performance of metamaterial loaded Microstrip patch antenna for WLAN application has been analyzed.

II. Conventional Antenna Design's

In this article, antenna miniaturization was realized for 5GHz WLAN frequency band.



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

Fig 1: Patch1 Rectangular patch antennas with Resonating Frequency 5.5GHz and Patch 2 7.09GHz 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 reduction in the size on resonant frequency. Frpm the Table above, the antenna dimensions, material properties and operating frequency details are shown in Table.1. From Table.1 it is clear that there is shift to high frequency led to decrease in patch dimension. This happened because of inverse relation between resonant frequency and antenna size.

A. Mutual coupling

The antenna is designed to operate for WiMax frequency 5.45GHz – 5.75GHz. for this design, the FR4 dielectric material (εr = 4.4) and height of substrate (h) 1.57mm were used. The microstrip antenna is excited by a coaxial probe and the feed point is located at the distance (dx) away from the center of the patch, the important parameters at 5.61GHz are summarized below.

TABLE II: DESIGN SPECIFICATIONS FOR SINGLE RECTANGULAR PATCH ANTENNA

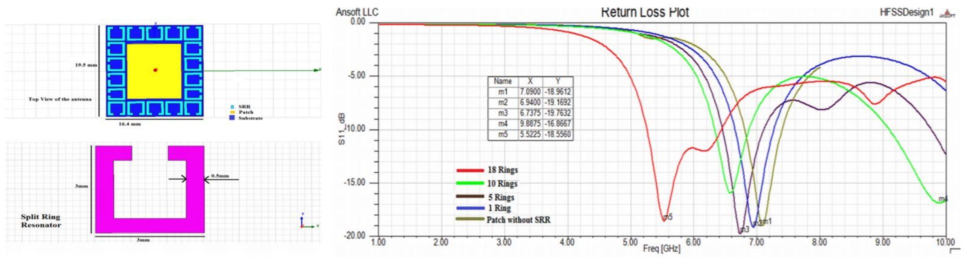
Shape of the antenna	Rectangular
Bandwidth	5.45GHz-5.75GHz
Dielectric constant substrate	4.4 (FR4)
Feeding method	Coaxial probe
Height of the substrate	1.57mm
Height of the patch	0.1mm

III. Unique Design

A. Antenna Signature Miniaturization

The rate of antenna miniaturization was limited by dependence on its wavelength [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 SRR's introduced to the patch geometry whi1ch are out-of-phase that showed potential for miniaturization and these structures are non-optimal and fabrication process would be difficult.



[a] [b]

Fig. 3: [a] Patch antenna 3D view and SRR simulated using HFSS, [b] Return Loss Plot depicting reduction in resonant frequency with the implementation of SRR

The virtual patch antenna and the setup are shown in Fig.3[a], 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. There will be shift in the resonanting frequency of the antenna, and is depicted in Fig.3[b], and it is essentially depended on the number of Split Ring Resonator elements in the vicinity of the patch. With this introduction of each SRR the resonant frequency went down to 6.94GHz from 7.09GHz and with the addition of different number elements, the resonant frequency moves to 5.52GHz with 42% diminution in antenna size was attained.

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 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.

TABLE. II: 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

B. Mutual Coupling Reduction

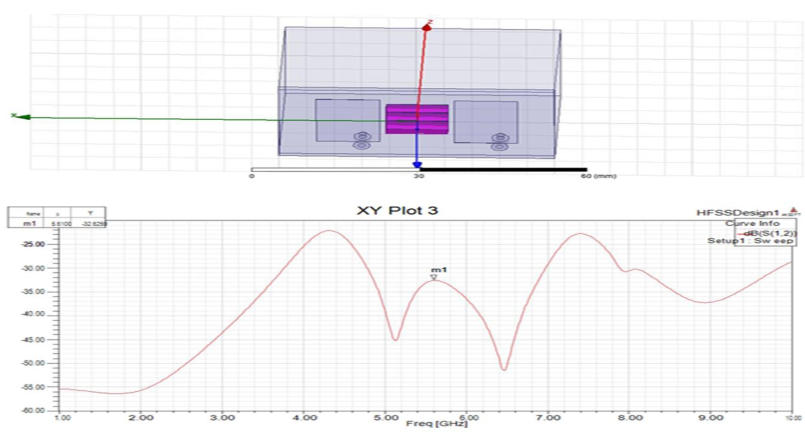


Figure 6: Simulated patch antenna array with EBG structure; & Mutual Coupling Effect with EBG Structure in Patch Antenna Array

TABLE III: SHOWING RESULTS OF COUPLING WITH AND WITHOUT EBG STRUCTURES

Without EBG Structure Results		**With EBG Structure Results**	
Input Voltage @ Port 1	1V	Input Voltage @ Port 1	1V
Output Voltage @ Port 2	120mV	Output Voltage @ Port 2	61.6mV
Coupling Loss (V2/V1)	0.12	Coupling Loss (V2/V1)	0.0616
20log(V2/V1) dB	-18.4163 dB	20log(V2/V1) dB	-24.2083 dB

IV. CONCLUSION

Here, we analyzed the results 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 previous was discussed emphasizing the aids of it. We performed simulation of patch antenna loaded with SRR which are in-plane with the patch and attained 42% physical size reduction. We also validated the significant improvement in bandwidth by simulation. Next time, we plan to fabricate the designed antennas and validate the simulation results. An approach for reduction of mutual coupling in an array for microstrip patch antenna has been showed. The Microstrip rectangular patch antenna array of 1x2 is designed for WiMax applications. In the presented design, the resonant frequency is 5.61GHz is considered. The Rectangular Mushroom like EBG structure is kept between the array elements to reduce the mutual coupling as well as the dimension of the ground plane is also decreased to achieve better results. The separation between antenna elements in 1x2 array is kept 13.5mm which is less than half wavelength. The proposed technique provides nearly -10dB of mutual coupling at resonant frequencies which is significantly better than the results obtained for the original arrays. The comparative studies of resulted mutual couplings indicate that the proposed mutual coupling reduction techniques provides a good results which is suitable for MIMO applications.

FUTURE WORK

The work can be enhanced by using different types of Electromagnetic Band Gap structures in rectangular patch antennas or any other antenna arrays to reduce the mutual coupling effect. Thus EBG structures are capable of reducing the problems associated with antenna arrays. These EBG structures in antenna arrays can be used in many wireless applications. This designed and fabricated antenna is replaces the older antenna which is bigger in size in WLAN applications. By implementing this miniaturized antenna in WLAN, we are providing the space for the WLAN designer where the space can be utilized for other applications.

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