International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249-8958 (Online), Volume-7 Issue-2, December 2017

Isolation Enhancement in a Printed UWB-MIMO Antenna System

Poorna Pathak, Sunil Kumar Singh

***Abstract:** UWB printed antennas are essential part of most of the wireless portable devices. Due to the induction of 4G and upcoming 5G technologies, the demand of higher data rate and larger channel capacity has become a serious issue. Multiple Inputs Multiple Output (MIMO) technology find its place among various existing wireless technologies as a solution to various short comings of UWB like multi path fading. The isolation performance of a previously proposed UWB-MIMO antenna is improved using meandered line parasitic monopole and a reflector composed of hexagonal ring cells. The proposed antenna works over 3.1-10.6GHz band with mutual coupling less than -21 dB. All simulations are done in ANSOFT HFSS 13.0.*

***Index Terms:** Isolation, Multiple Input Multiple Output, Mutual Coupling, Ultra Wide Band, Wireless Communication.*

I. INTRODUCTION

Due to its promising features, the Ultra Wide Band (UWB) technology has attracted tremendous attention from the community of researchers and a lot of work is done in this area while a lot more is still running in. The development of UWB systems got even accelerated after the authorization from Federal Communications Commission (FCC) for the unlicensed use of 3.1 – 10.6 GHz band for applications with low power emission in year 2002 [1]. UWB system also has their limitations such as propagation of surface waves in antenna substrate [2], these surface waves cause mutual coupling between antenna elements of any array and lead to degradation in radiation efficiency and channel capacity [3]. UWB systems also suffer from multipath fading as well as the data rate rates provided by them are not sufficient for growing demand so still need to be increased without increasing bandwidth and power levels due to international regulations. Multiple Input Multiple Output (MIMO) technology is a solution to these problems as it offers higher data rates in existing bandwidth and because it uses multiple antenna elements with different fading characteristics, it provides multiplexing gain and diversity gain which improves capacity and link quality. MIMO technology also suffers from mutual coupling between antenna elements especially when employed in portable devices because space availability in portables is very poor and so to meet the space utilization demands in such devices designers place them close enough to have just satisfactory performance which gives rise to mutual coupling which is a major performance degrading factor in MIMO systems. That is why to design MIMO antenna system with high isolation is the main design challenge.

Various techniques discovered to reduce mutual coupling which are studied in [5]. Apart from that some designers used antenna elements having different polarization characteristics to provide pattern diversity so that the antenna became able to receive signals with very low correlation [6], [7]. Pattern diversity is also achieved using perpendicular feeding arrangement [8] – [11]. Among these designs some were not able to operate over entire UWB and those operating in UWB either having very complicated structures or having overall area no less than 1400 mm^2. In [4], authors have designed an UWB-MIMO antenna with a compact size of 26x40 mm^2 operating over 3.1-10.6 band with isolation better than 15dB. As per general understanding 15dB means at least 5% of the total power fed in to port 1 will be coupled to port 2 and vice versa. Mutual coupling between antenna elements in an UWB-MIMO portable system must not be greater than -20 dB for satisfactory performance in a multipath fading environment [12], [13]. Keeping this in mind we have a goal to improve isolation and take mutual coupling at a level less than -20dB over entire band without disturbing size and shape of radiator to keep bandwidth same in our base paper which is [4].

II. ANTENNA DESIGN

The geometry of the base Antenna is shown in fig 1(a) and that of proposed antenna is shown in fig. 1(b). The antenna is designed on a substrate called Rogers RO4350B with a permittivity of 3.5, loss tangent of 0.004, a thickness of 0.8 mm. The antenna elements are fed using 50 ohm Microstrip feed lines of identical sizes. Antenna elements used are square in shape with identical sizes, and placed perpendicular to each other, because this is a natural way of providing good isolation between ports. In proposed antenna there is no change in substrate thickness or size or in the size or placement of patch antenna elements or in the size and placement of feed lines or ground plane or ground plane cut, all these elements are identical in every aspect in base antenna and in proposed antenna. The changes are only in ground stub shape and size which can be seen in fig 1. All the dimensions are in mm, and are listed in TABLE 1.

Manuscript published on 30 December 2017.
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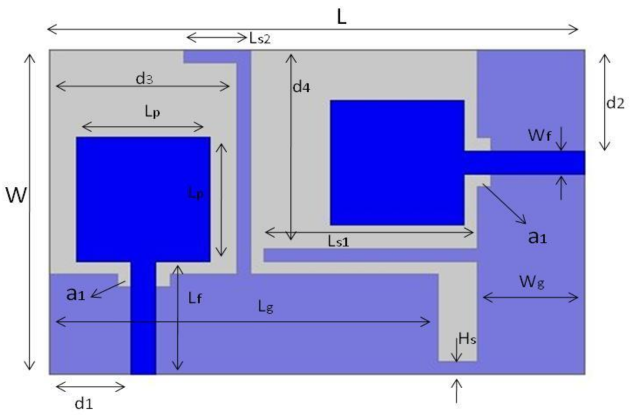
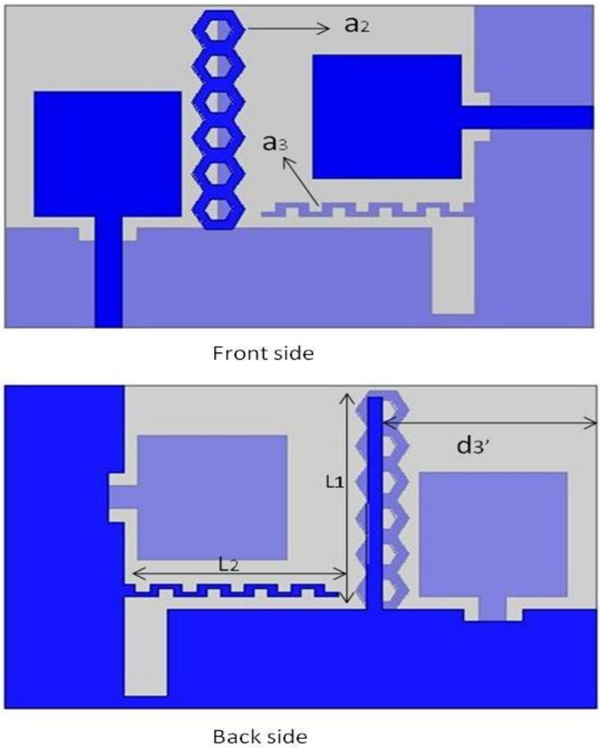


(a)



(b)

Fig. 1 (a) Base antenna design, (b) Proposed design.

TABLE 1

Lengths (mm)	W	L	L_p	L_f	L_g	L_1
	26	40	10	9	29	17
	L_2	L_{s1}	L_{s2}	d_1	d_2	d_3
	14. 5	16	5	6.1	8.1	14
	d_4	d_3'	W_g	W_f	H_s	
	16	14.5	8	1.8	1	
Area (mm^2)	a_1	a_2		a_3		
	4 x 1	17.5 x 3.6		1 x 0.7		

A. Modifications and Effects

Modifications are applied in such a manner so that base antenna's bandwidth remains unchanged, for that patch, feed line and ground are not disturbed. Our goal is to improve the isolation between antenna elements so we only focus on stubs which are mainly responsible for isolation. There are three stubs used in the base antenna which are a short stub2 connecting ground planes, a long stub placed parallel to patch 2 and connected to the respective ground and another long stub1 which is bent at top end and placed parallel to patch 1, this is also connected to respective ground. Taking first the short ground stub, it is used to connect two grounds, and increases isolation if removed, but we can't do that because it is not practical from device's point of view because in portable devices space availability is not good enough to have separate grounds and having common or connected ground is necessary. So we have option of modifying either stub1 or stub2 or both. Both the stubs are acting as parasitic monopole antennas to main radiators and also generating additional resonances at lower band below 4 GHz to improve bandwidths of square shaped radiators. Stub 1 in base design generates resonance around 4.8GHz and increases bandwidth of patch 1, this stub is long and so is bent to keep profile of antenna small when shifted by 0.5 mm away from patch it generate additional resonance at 3.8 along with previous one, but this shifting reduces isolation in lower band, which is compensated by a reflector composed of hexagonal rings of thickness of 0.8 mm. This reflector is placed asymmetrically to the stub1 which also have shortened as together with the reflector it compensates for length reduction. Stub2 is also shortened and modified to have a meandered line shape so that together with short ground stub and ground 1 it makes L shaped slot which is responsible for bandwidth of patch 2 and due to meandered shape it also works as a neutralization line and absorber for the surface waves, and hence increasing isolation at mid band up to -63dB. All the parameters are optimized and simulations are done in HFSS 13.0. Width of both the stubs is 1mm and height of both the ground planes is also identical to each other.

III. RESULTS AND DISCUSSIONS

S parameters of proposed antenna are shown in Fig.2. It is apparent from this figure that proposed modified UWB-MIMO antenna works over entire UWB region similar to the base antenna does; there are some obvious differences in values of reflection coefficient at various frequencies if compared to the base antenna S11.

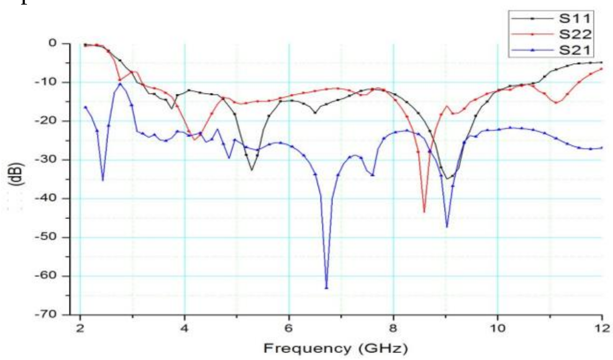


Fig. 2. S-parameters of Proposed Antenna

But it is because changes in isolation structure may have some effects on reflection coefficient values and reflector also affects the impedance matching of ports but we still have UWB performance in proposed antenna.

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It is clear from Fig. 2 that mutual coupling is less than -21dB throughout UWB region and best is -63dB around 6.8 GHz. The major reason behind this isolation is the presence of reflector made of hexagonal ring cells, as shown in Fig.3

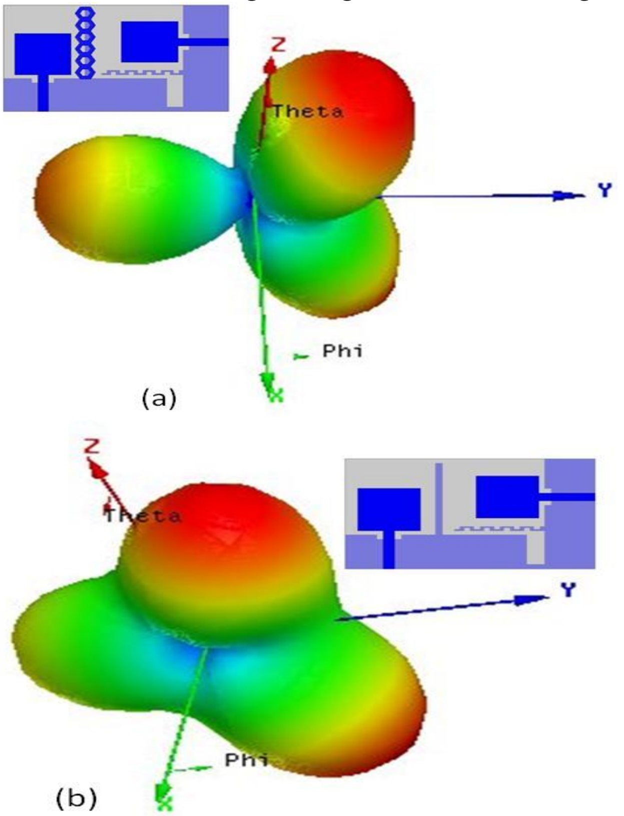

Fig. 3 (a) 3-D Radiation Pattern With Reflector, (b) 3-D Radiation Pattern Without Reflector.

It can be seen from this fig that reflector effectively decouples the patterns which provide good pattern diversity without any side-lobe generation.

Fig. 4 shows plot of peak gain in decibels vs frequency in GHz.

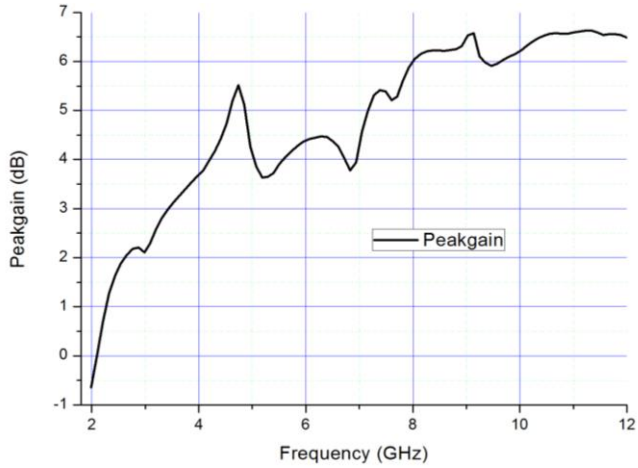

Fig. 4 Peak Gain Vs Frequency

This graph shows a usual tendency of increasing gain with increase in frequency as with frequency increase the ratio of wavelength to aperture of antenna decreases which is responsible for increased directivity of radiation and so increase in gain results if impedance matching of port is good.

Finally we have plot of Radiation efficiency vs frequency, of proposed MIMO configuration, which is also a major performance indicator, as shown in Fig. 5

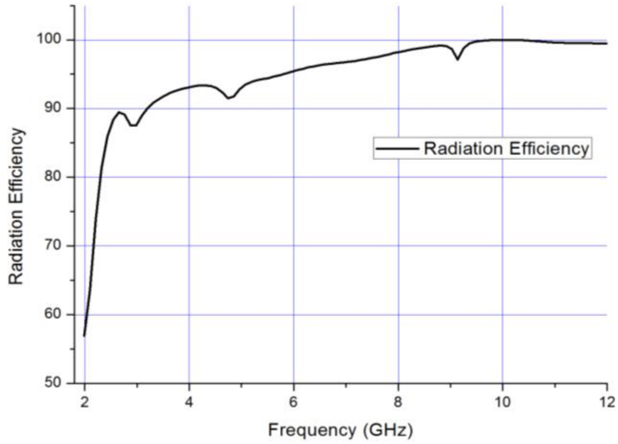

Fig. 5 Radiation Efficiency of Proposed MIMO Antenna

Radiation efficiency of proposed antenna as shown in above graph is more than 90% over entire UWB region. This graph indicates that most of the power is radiated and this due to pattern diversity provided by reflector. One more thing can be concluded from radiation efficiency plot that most of the power which is reflected by hexagonal cell reflectors in in-phase with that of radiated otherwise it might be affecting radiation efficiency adversely. Comparison of various parameters of base antenna and proposed antenna is given in TABLE 2

TABLE 2: Comparison of Base and Proposed Design

S. No.	Parameters	Base Design	Proposed Design
1	Size	26x40x0.8 mm^3	26x40x0.8 mm^3
2	S11	2.9-10.6 GHz	3.09-10.68 GHz
3	S22	2.9 to >12 GHz	3.12-11.56 GHz
4	S21	<-15 dB	<-21 dB
5	Peak gain	>2 dB	>2.5 dB
6	Radiation Efficiency	>80%	>90%

IV. CONCLUSION

The isolation performance of the UWB-MIMO antenna proposed in ref [4], is improved using meandered line parasitic isolator and reflector made of hexagonal ring cells along with increase in radiation efficiency and gain. The proposed antenna is capable of working over entire ultra wide bandwidth with mutual coupling less than -21dB between two ports.

All results show that proposed antenna has improved performance over the base MIMO antenna considered for the study. All simulations and optimizations are carried out using ANSOFT HFSS 13.0, which is based on FEM technique whose results generally show a matching with measured results upto 98-99%.

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AUTHOR PROFILE

Poorna Pathak was born in Jabalpur ,Madhya Pradesh, India ,in 1988. She completed her B. Engineering in Electronics and Communication Engineering from Takshshila Institute Of Engineering and Technology, Jabalpur in year 2010.She started her Master of Engineering degree in Microwave Engineering from Jabalpur Engineering College, Jabalpur, Madhya Pradesh in 2013. Currently she is working on MIMO antenna systems.

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