A Low Mutual Coupling Multiband MIMO Antenna

Vilas V. Mapare
Electronics Engineering,
Faculty of Engineering & Technology
Sant Gadge Baba Amravati University, Amravati-444 602

Dr. G.G. Sarate
Electronics Engineering,
Faculty of Engineering & Technology
Sant Gadge Baba Amravati University, Amravati-444 602

Abstract – In this paper, a triple band MIMO antenna is proposed. The mutual coupling between 1x2 antennas is investigated. The mutual coupling between antennas is suppressed by incorporating a novel planner ladder shaped EBG structure. The optimization of proposed EBG for intended band is done using HFSS. A prototype of a single element, 1x2 antennas without EBG and 1x2 antennas with EBG is fabricated and tested on VNA.

Keywords–Electronic Bandgap Structure; MIMO Antenna; Multi-band Antenna;

I. INTRODUCTION

The factors affecting the performance of MIMO antennas are categories in three main types: Antenna Size, device usage models and mutual coupling between a pair of antennas. The size of the antenna is dependent on the bandwidth of operation and required operation of frequency. In 1x2 antennas both the antennas are placed on same longitudinal chassis, they will produce the same radiation pattern. Since both the antennas are coupled in the same mode, they experience mutual coupling. The power introduced into one antenna is partially coupled in second antenna source resistance, and is subsequently lost [1]. Various techniques have been deployed to minimize the mutual coupling in MIMO antennas as the placement of Electronic Band-gap Structures in between the two antennas [2], [3] and [4], slotted complementary split ring resonator [5], negative magnetic metamaterial [6] and meta-material monopole antennas [7].

Electronic Band-gap Structures are a viable solution for reducing electromagnetic interference. Same may use for reducing the mutual coupling between two closely-placed antennas.In this paper, we have designed a novel planner ladder shaped EBG structure for suppressing the mutual coupling between closely placed multi-band antennas. The multi-band response has been achieved by exciting the higher modes.

II. DESIGN OF SINGLE ELEMENT

Rectangular patch microstrip antenna is chosen as basic configuration due to the simplicity of design and good radiation characteristic. The antenna is designed using a transmission line model [8-9]. The antenna is simulated on FR4 Epoxy substrate of thickness 1.6mm. The configuration of the basic element is depicted in fig. 1. The antenna is designed for 50 Ω CPW feeding.

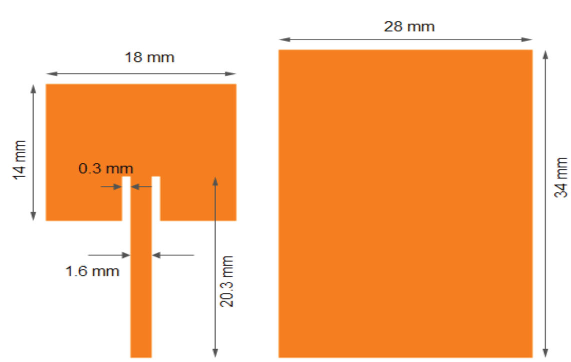
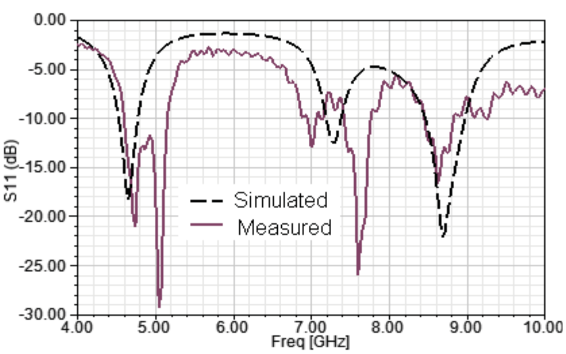


Figure 1 Configuration of single element

A prototype of the single element is fabricated and shown in fig. 2. The prototype of a single element is tested on Keysight VNA and the results are shown in fig. 3. The antenna exhibits triple band response at 5, 7.8 and 8.6 GHz. By suitably selecting the feeding point the higher modes are excited and triple band response is achieved. However, during measurement, a wideband response is observed at dominant TM_{01} mode. Another band at 7GHz is also observed which an extension of the TM_{02} mode.

(a) (b)

Figure 2 Prototype of the single element



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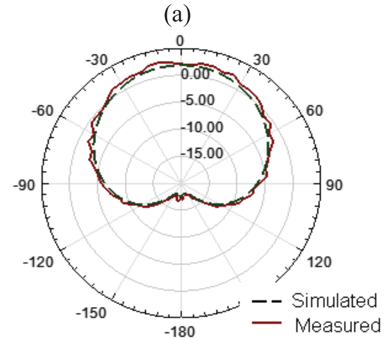

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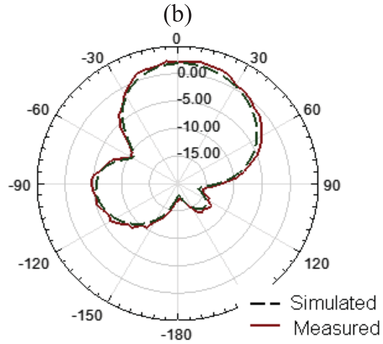


(c)

Figure 3 Results of single element (a) Return loss (b) E-plane (5 GHz) (c) H-plane (5 GHz)

II. MUTUAL COUPLING ANALYSIS

If antennas are placed closer, they suffer from mutual coupling thus results in poor radiation efficiency. In this section, an MIMO antenna (1x2 Configuration) is designed using the single element designed in an earlier section. Two elements are placed on the common substrate and a common ground plane. The configuration of the 1x2 antenna is illustrated in fig. 4.

The lower resonant frequency of the antenna is 5 GHz thus result in the longest wavelength. This can be observed in fig. 5 that for λ_0, $\lambda_0/2$, $\lambda_0/4$, and $\lambda_0/8$ separation there is no change in resonant frequency but for $\lambda_0/6$, there is a frequency shift for both modes TM_{01}, and TM_{02}. This is due to the odd multiple of $\lambda_0/2$. The simulated mutual coupling of the 1x2 antenna is illustrated in fig. 6. This can be clearly observed that as the separation between two antennas is decreased the mutual coupling is increasing. There is a tradeoff between the size of the MIMO antenna and the Radiation efficiency.

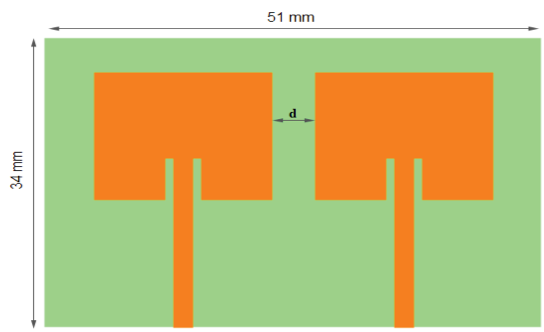


Figure 4 Configuration of 1x2 antennas

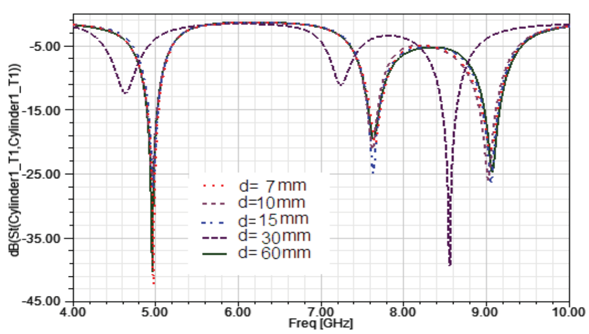


Figure 5 Return losses of 1x2 antennas for different separation

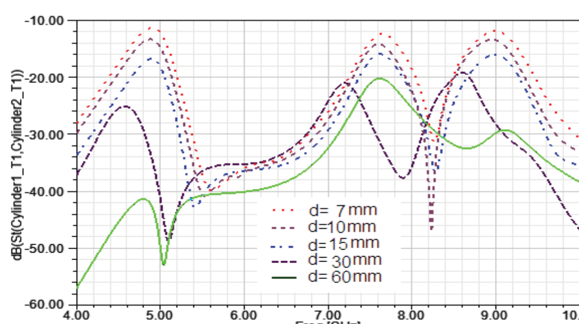
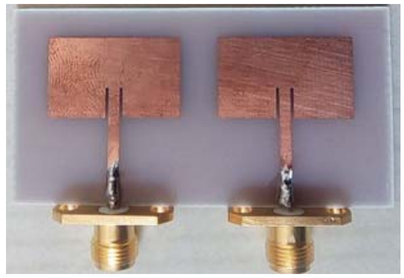
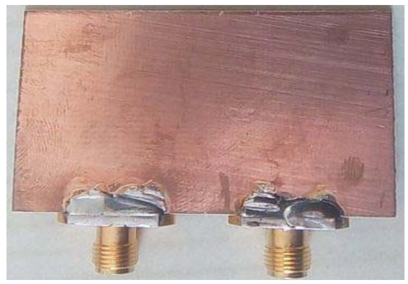


Figure 6 Mutual coupling of 1x2 antennas for different separation

A prototype of the 1x2 antenna with separation 6 mm is fabricated and shown in fig. 8. The antenna is tested on VNA and results are shown in fig. 9. A good agreement is found between simulated and the measured results.

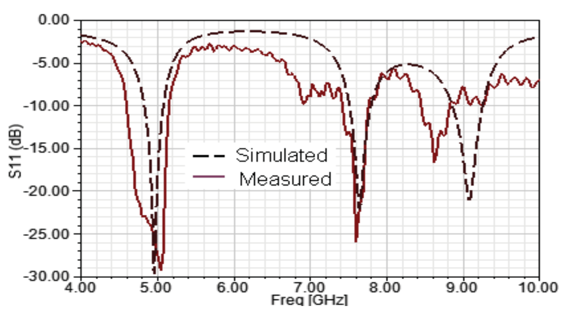


(a)



(b)

Figure 8 Prototype of 1x2 antennas (a) Patches (b) Ground



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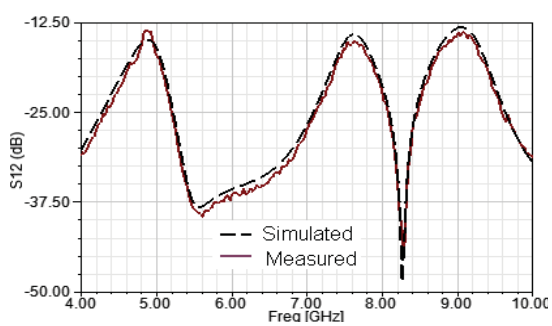

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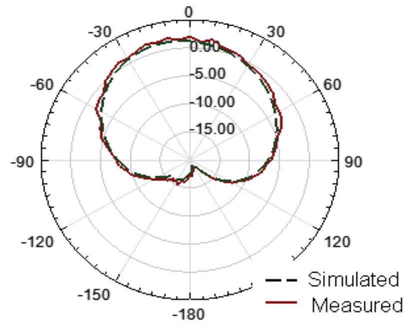

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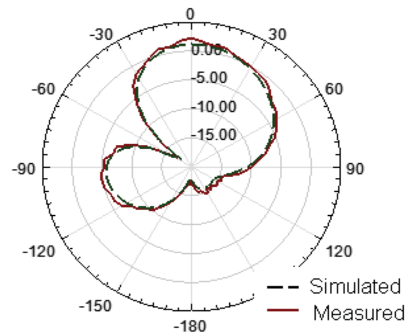
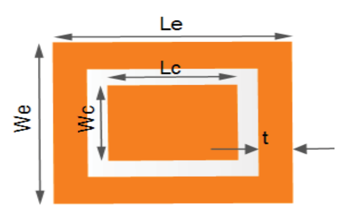


(d)

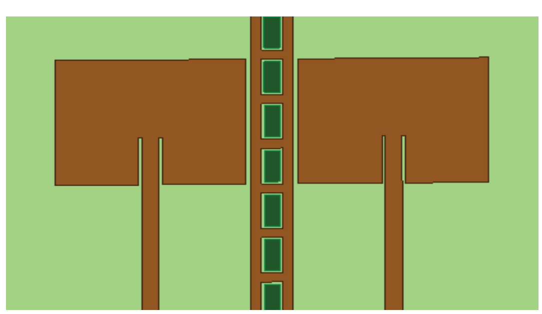
Figure 9 Results of 1x2 antennas (a) Return Loss (b) Mutual Coupling (c) E-plane 5 GHz (d) H-plane (5 GHz)

III. SUPPRESSION OF MUTUAL COUPLING

In this section, a novel planner ladder shaped EBG structure is proposed and incorporated between two antennas for the suppression of mutual coupling. A suitable EBG structure when placed between two closely placed antennas cancel the surface wave thus results in low coupling between antennas. The dimensions of the proposed EBG are optimized by using Ansoft HFSS software. The configuration of the proposed EBG is shown in fig. 10. A comparison of 1x2 antennas without EBG and with novel EBG is done and presented in table I.



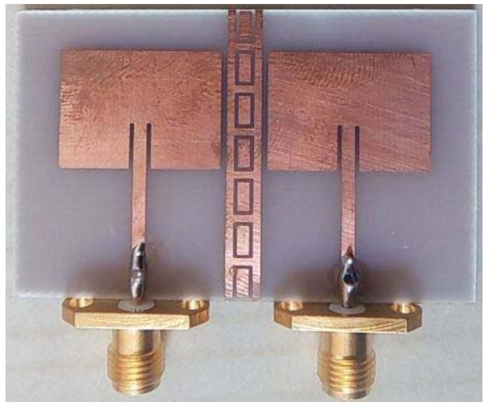
(a)



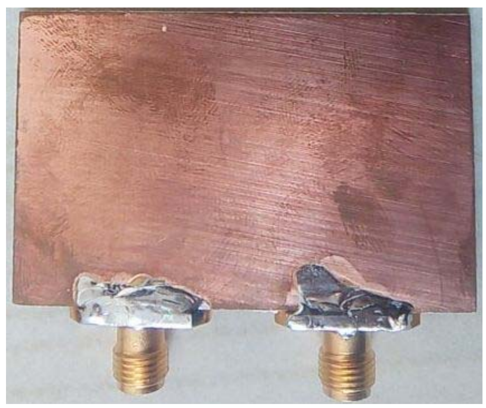
(b)

Figure 10 Configuration of 1x2 antennas with EBG (a) Unit cell of EBG (We=4mm, Le=6mm, t=1mm, WC=1.5mm and Lc=3.5mm) (b) 1x 2 antennas with EBG

A prototype of the proposed design is fabricated and shown in fig. 11. The prototype is tested on VNA and good agreement is found between simulated and measured results. The results of the proposed antenna are depicted in fig. 12.

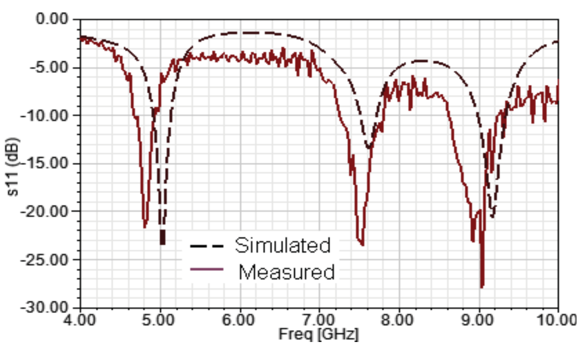


(a)

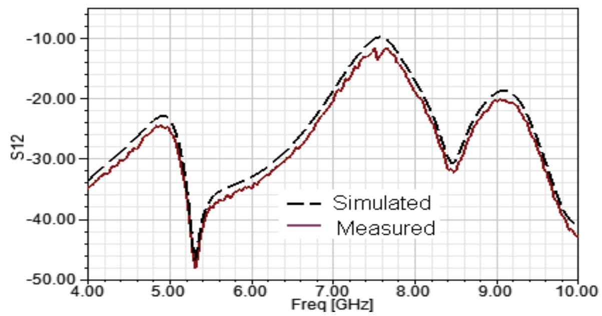


(b)

Figure 11 Prototype of proposed multiband 1x2 antenna with low mutual coupling



(a)



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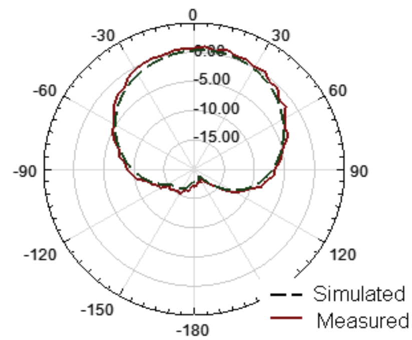

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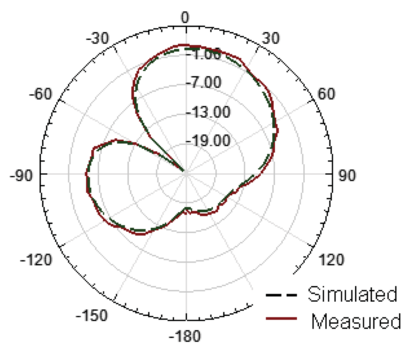

(d)

Figure 12 Results of proposed antennas (a) Return loss (b) Mutual Coupling, (c) E-plane (5 GHz) (d) H-plane (5 GHz)

Table I Comparative results of 1x2 antennas with and without EBG

Structure	S11 (dB)			S12 (dB)		
	B-1	B-2	B-3	B-1	Ba-2	B-3
Without EBG	-28	-26	-16	-11	-12	-12
With EBG	-21	-23	-28	-24	-14	-20

II. CONCLUSION

Mutual Coupling between antennas is investigated and EBG structure is incorporated between 1x2 antennas. A novel ladder shaped coplanar EBG is proposed for mutual coupling reduction. The proposed work intends to achieve low Mutual coupling without a reduction in gain of antennas. This work has attempted to explore the design challenges of MIMO antenna and its possible solutions. A single element for triple band (5, 7.8 and 8.6 GHz) is designed. The proposed EBG has good return loss and mutual coupling in all three bands. A prototype of a single element, 1x2 MIMO antennas without EBG and 1x2 antennas with proposed Ladder-shaped EBG is fabricated and tested on VNA. Good agreement is found in measured and simulated results which validate the design

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