Triple Band Planar Monopole Antenna for MIMO Application

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Abstract— A triple band planar monopole antenna for MIMO application is presented in this paper. The antenna array consists of two triple band monopole antennas with three copper strips, which operate at three frequency bands (2.4, 3.5 and 5.8 GHz). The antenna has been simulated using CST software and the prototype has been fabricated using FR4 substrate. The antenna provides the −10 dB bandwidths (BWs) of 308 MHz (from 2.2275 to 2.5354 GHz), 472 MHz (from 3.337 to 3.809 GHz) and 1.688 GHz (from 5.488 to 7.176 GHz) for 2.4, 3.5 and 5.8 GHz respectively. The antenna array achieve low mutual coupling of −22 dB at separation distance of 10 mm, which is approximately $\lambda/12$. There is good agreement between the measurement and simulation results in terms of return loss and radiation pattern.

1. INTRODUCTION

The high data rate transmission and reduced transmit power demand have attracted a lot of research interests to investigate the use of Multiple Input Multiple output (MIMO) in wireless applications. The MIMO systems demonstrate the increased efficiency in rich multipath environment [1]. Small size, low profile and simple structure are required in some of the antenna arrays for MIMO application, so that more than one antenna can be placed as close as possible without increasing the mutual coupling between the antenna elements. Achieving high data rate and low mutual coupling is a challenging task in small device, as more than one antennas have to be placed together. A lot of studies have been conducted on the investigation of how to reduce mutual coupling between antenna elements [2, 3] while still keeping them as close as possible. However, most of the studies that have been reported have the demerits of complex antenna structures and large separation distances.

A triple band monopole antenna array for MIMO application has been presented in this paper. The antenna array achieved low mutual coupling of −22 dB at a separation distance of 10 mm, which is approximately $\lambda/12$. There is good agreement between the measurement and simulation results in terms of return loss and radiation pattern.

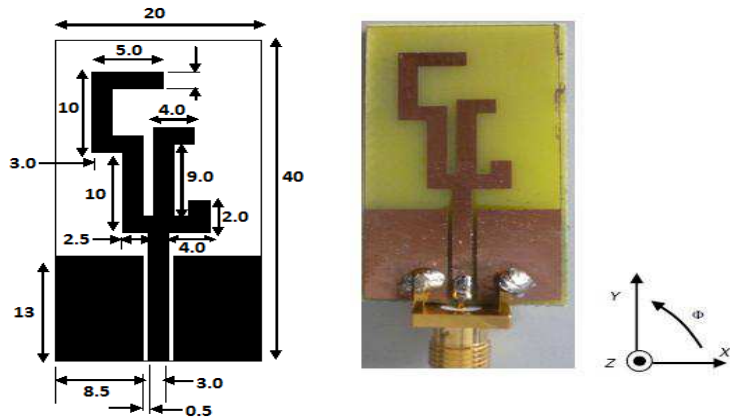
2. ANTENNA DESIGN

The geometry and dimension of the proposed triple band monopole antenna and the antenna array are shown in Figures 1(a) and 2 respectively; while the prototype of the triple-band antenna array is shown in Figure 1(b). The antenna consists of three copper strips which contribute to the three resonance frequencies of the proposed antenna. The antenna has been designed using CST Microwave studio software. The substrate used is FR4 with permittivity of 4.5, loss tangent of 0.019 and thickness of 1.6 mm. It has been observed that the resonance frequency is influenced by the antenna's copper strip length which is approximately one-quarter of wavelength of the operating frequency. The two triple band monopole antennas are placed orthogonal to each other separated by distance, d. The antenna has overall dimensions of $20 \times 40 \times 1.6\,\mathrm{mm}^3$ and $40 \times 75 \times 1.6\,\mathrm{mm}^3$ for single triple band monopole antenna and the antenna array as shown on Figure 1(a) and Figure 2 respectively. The prototype of the triple-band antenna is shown in Figure 1(b).

3. RESULTS AND DISCUSSION

The triple band monopole antenna and antenna array have been analyzed for MIMO application. The antennas are placed firstly in parallel and then orthogonal to each other, separated by distance, d. It has been observed that the orthogonal configuration gives lower values of mutual coupling, and has therefore been used in this investigation.

The comparison between the simulated and measured return losses of the proposed monopole antenna are shown in Figure 3(a). The return loss results are based on port 1. As it can be observed



(a) (b)

Figure 1: Triple band monopole antenna (a) geometry and (b) prototype [4].

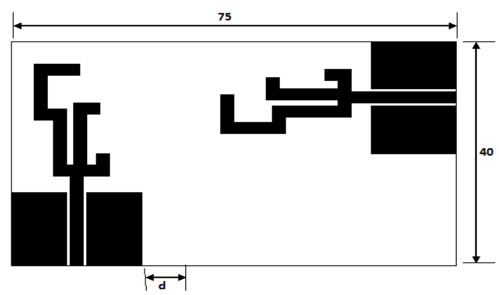
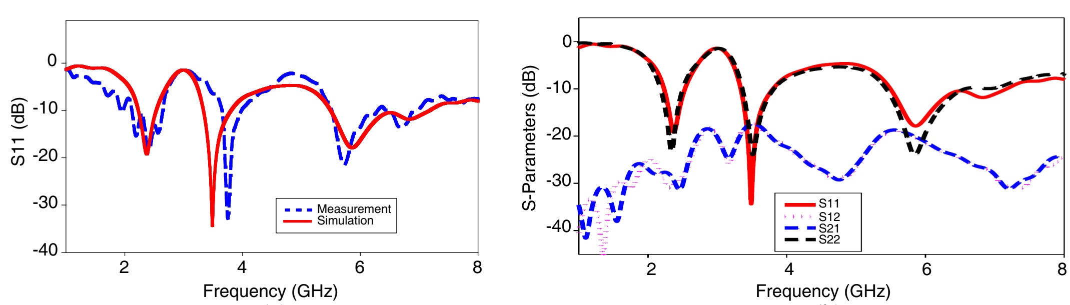


Figure 2: Geometry of triple band monopole antenna array.

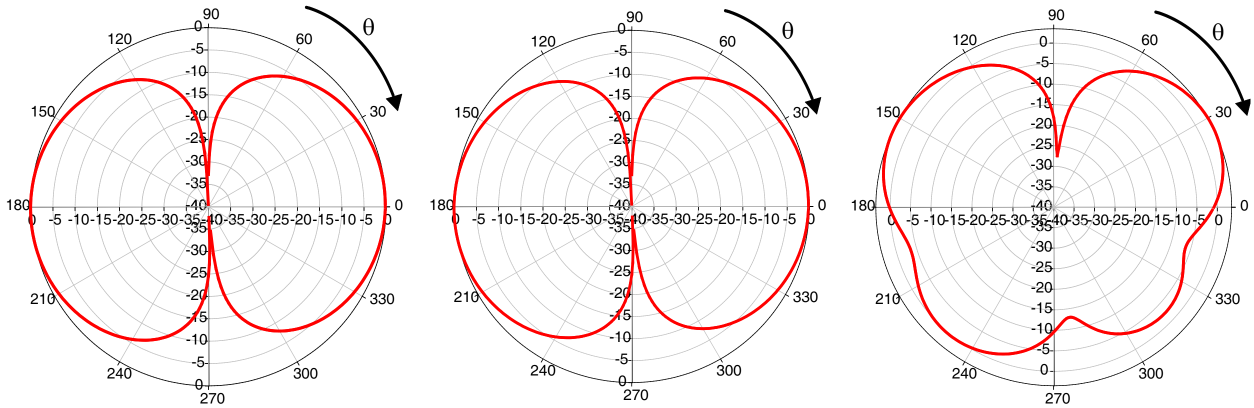
from Figure 3(a), the antenna provides the -10 dB BWs of 308 MHz (from 2.2275 to 2.5354 GHz), 472 MHz (from 3.337 to 3.809 GHz) and 1.688 GHz (from 5.488 to 7.176 GHz) for 2.4, 3.5 and 5.8 GHz respectively. It can be seen that the measured and simulated return loss characteristics of the optimized antenna are in good agreement, with small deviation in the measurement results at 3.5 GHz. The antenna also satisfies the requirements of the 2.4/5.8 GHz WLAN and 3.5 GHz WiMAX antenna applications. The simulated S-parameters of the proposed monopole antenna array are shown in Figure 3(b). It can be seen that the antenna array achieved low mutual coupling of -22 dB at separation distance of 10 mm, which is approximately $\lambda/12$ of the first resonant frequency.



(a) (b)

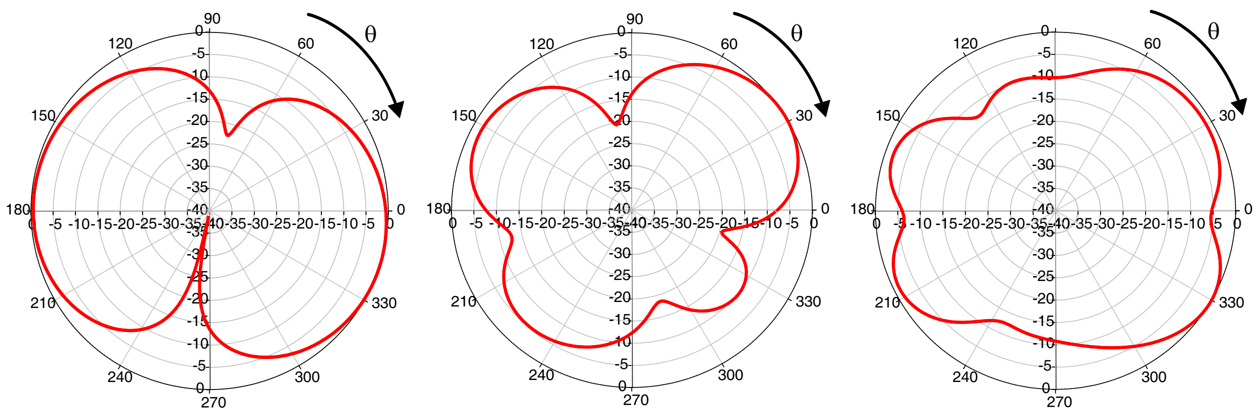
Figure 3: (a) Measured and simulated return losses of triple band monopole antenna and (b) simulated S-parameters results of antenna array.

The simulated radiation pattern of the proposed antenna array has been analyzed. The E-plane and H-plane radiation patterns at 2.45 GHz, 3.5 GHz and 5.8 GHz were investigated. Figure 4 shows The E-plane radiation patterns are shown in Figure 4 at the afore-mentioned frequency bands. It can be seen that the E-plane radiation pattern are bi-directional Figure 5. The corresponding H-plane radiation patterns are shown in Figure 5. It was observed that H-plane radiation patterns



(a) (b) (c)

Figure 4: Simulated E-plane radiation pattern of the proposed triple-band antenna array at (a) 2.45 GHz, (b) 3.5 GHz, (c) 5.8 GHz.



(a) (b) (c)

Figure 5: Simulated H-plane radiation pattern of the proposed triple-band antenna array at (a) 2.45 GHz (b) 3.5 GHz (c) 5.8 GHz.

are close to omnidirectional at 3.5 GHz and 5.8 GHz, while it is bi-directional at 2.45 GHz.

4. CONCLUSIONS

A monopole antenna array for MIMO application has been presented in this paper. The proposed antenna provides the -10 dB BWs of 308 MHz (from 2.2275 to 2.5354 GHz), 472 MHz (from 3.337 to 3.809 GHz) and 1.688 GHz (from 5.488 to 7.176 GHz) for 2.4, 3.5 and 5.8 GHz respectively. The antenna array achieved low mutual coupling of -22 dB at a separation distance of 10 mm, which is approximately $\lambda/12$. There is good agreement between the measurement and simulation results in terms of return loss and radiation pattern.

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REFERENCES

1. Foschini, G. J. and M. J. Gans, "On limits of wireless communications in a fading environment when using multiple antennas," *Wireless Personal Communications*, Vol. 6, 311–335, 1998.
2. Iddi, H. U., M. R. Kamarudin, T. A. Rahman, and R. Dewan, "Design of dual-band B-shaped

monopole antenna for MIMO application," *2012 IEEE Antennas and Propagation Society International Symposium (APSURSI)*, 1–2, 2012.

3. Mohsen, S., M. Alireza, T. Ahad, and H. Teimur, "Mutual coupling reduction of microstrip antennas using defected ground structure," *10th IEEE Singapore International Conference on Communication Systems, ICCS 2006*, 1–5, 2006.
4. Iddi, H. U., M. R. Kamarudin, T. A. Rahman, A. Y. Abdurahman, M. Khalily, and M. Jamlos, "Triple-band CPW-fed planar monopole antenna for WLAN/WiMAX application," *Microwave and Optical Technology Letters*, Vol. 55, 2209–2214, 2013.