# A Hybrid Decoupling Technique for Mutual Coupling Improvement of Polarization Diversity MIMO Antenna

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***Abstract*—This paper proposes the improvement analysis of the mutual coupling for a dual-polarized antenna array with the introduction of parasitic elements at low frequency. The 4x4 antenna array with 16 dipole antennas have a *star* configuration with slanted ± 45$^0$ dipole antennas and antenna spacing; *D* = λ/2. The parasitic elements are located in between the antenna array with the spacing of λ/4. In this study, the height of the parasitic element is varied with respect to the height of the dipole antenna. The analysis result shows that the maximum improvement of the mutual coupling can be achieved when the height of the parasitic element is half of the height of the dipole antenna with the existence of dual-polarized radiation pattern. A maximum improvement of 19 dB can be achieved to provide an antenna isolation of 37 dB with this hybrid decoupling technique.**

***Index Terms*—Mutual Coupling; Parasitic Element; Antenna Array; Polarization.**

## I. INTRODUCTION

In MIMO application, a rich scattering environment offers an opportunity to increase the channel capacity for providing high-speed wireless communication. A large array of multiple element antennas (MEA) is required to achieve this in order to increase the data throughputs and reliability of non-line-of-sight (NLOS) signal propagation. As a result, the size of the antenna element increases in which this will lead to the increase of the overall physical dimension of the MIMO antenna. This will require a larger space area at the installation site resulting impractical antenna installation for the crowded base station tower. This also will incur a significant total cost ownership (TCO) e.g. installation, maintenance cost etc. to the telecommunication operators. In addition, the large scale antenna arrays will generate negative consequences on weight, wind load and visual impact. To mitigate this issue, the reduction in the space distance between antenna elements is proposed [1]. A number of papers have demonstrated the impact of antenna compactness by having more antenna elements with different configuration [2]. There is also a study on the effects of increasing numbers of antennas by reducing antenna spacing in a fixed physical space [3]. For example, this approach reduces the angle spread and the spatial diversity due to reduction of the separation between antennas and increase in transmit diversity [4].

Unfortunately, a close proximity of MEA at low frequencies introduces strong mutual coupling and severe MIMO performance degradation. Instead of radiating, a part of the input power is coupled within neighbouring antenna elements which induce high signal correlation between the radiated antenna elements. This phenomenon distorts the array radiation pattern and changes the input impedance of the antenna elements. As a result, this reduces signal-to-noise-ratio (SNR) and degrades the channel capacity. There are a number of different decoupling techniques that have been proposed such as the position and the orientation of the antennas [5], parasitic elements [6,7,8], defected ground structures [9], slots [10], resonator structure [11,12], vias, electromagnetic bandgap structures, meta-surface, metamaterial structure [13]. Instead of these techniques, it was reported that the spatial and polarization diversity were able to improve the mutual coupling of MEA and channel capacity of MIMO application. For example, a dual-polarized antenna configuration has approximately 14% higher capacity than co-polarized configuration [14]. Unfortunately, using the polarization diversity technique alone to improve the mutual coupling could not achieve satisfactory result. Therefore, a hybrid decoupling technique is introduced to further reduce the mutual coupling effect.

This paper mainly investigates on the mutual coupling improvement of the polarization diversity type antenna array with the introduction of parasitic elements at a lower frequency. Operating below 1 GHz, this orthogonal polarized antenna features multiple *star* configurations of 4x4-array dipole antenna. Each *star* configuration comprises of slanted ± 45$^0$ dipole antennas with the inter-element spacing of λ/2. Parasitic elements with spacing of λ/4 are introduced in between the antenna elements. This paper is organized with introduction and research background in Section 1. Section 2 presents the methodology of this research work and the configuration of the multi-element antennas and parasitic elements. The analysis from the simulation result is presented in Section 3 and followed by the conclusion in Section 4.

## II. METHODOLOGY

CST Microwave Studio (CST MWS) was used to simulate and analyse the mutual coupling performance of a dual polarized large antenna array with the introduction of the parasitic elements. These large array antennas consisting of dipole antennas were arranged in a *star* configuration to employ antenna diversity scheme through spatial and polarization diversity. Operating at 850 MHz, this large antenna array employs dipole patch antennas as multi-element antennas by using FR4 material with dielectric constant $\varepsilon_r$ = 4.4 as shown in Figure 1. The dipole antenna has width, *W* = 153 mm and height, *H* = 67.5 mm.

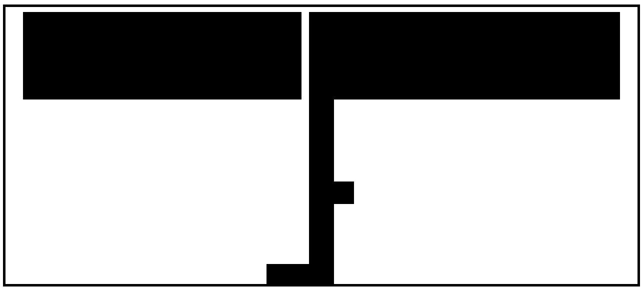

Figure 1: A dipole patch antenna

Figure 2 shows a *star* configuration of 4x4-array dipole antenna with antenna spacing; *D*. The antenna array has a *star* configuration with slanted ± $45^0$ dipole antennas. The distance between the closest edge of the slanted dipole antenna is fixed at $D = \lambda/2$. At each row, these dipole antennas are separated by the parasitic elements in between the antennas with spacing of $\lambda/4$. Each antenna array configuration has a metal backplate as a finite ground plane as this large antenna array is used for a directional antenna. Figure 3 shows a side view one of the dipole antennas with the parasitic element. The rectangular parasitic element has a fixed width, $w$ = 173 mm and is made of aluminium. The height of the dipole antenna and the parasitic element is $H$ and $h$ respectively.

A series of simulation were carried out to further reduce the mutual coupling of the dual-polarized large antenna array. In this analysis, the height of the parasitic element, $h$ is varied with respect to the height of the dipole antenna, $H$ as shown in Figure 3. The overall mutual coupling results are analysed for $0 \leq h/H \leq 1$. To start with, every S-parameter of the mutual coupling of the isolation ports is observed when the large antenna array is without the parasitic element ($h/H$ = 0). A selected mutual coupling data is opted for improvement that based on the isolation < 20 dB. These data are categorized based on the coupling adjacency of the dipole antennas i.e. side-by-side, top-down and diagonal coupling. Then, the height of the parasitic element, $h$ is incremental increased until it reaches the full height of the dipole antenna ($h/H$ = 1) and all isolation data are recorded.

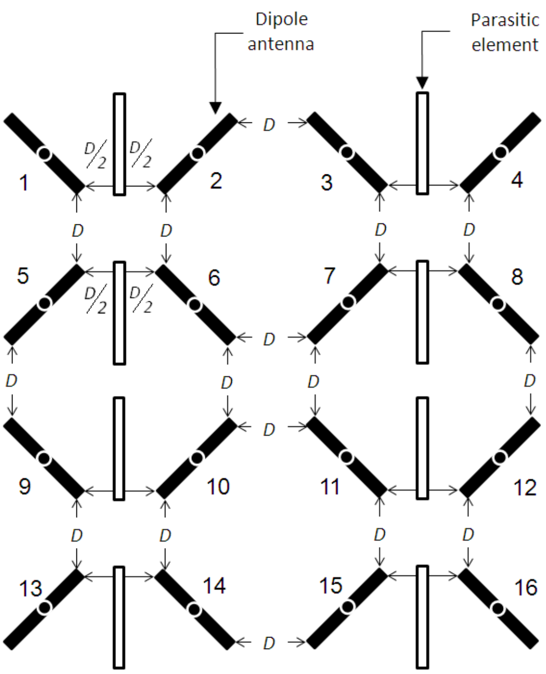


Figure 2: A *star* configuration of 4x4-array dipole antenna

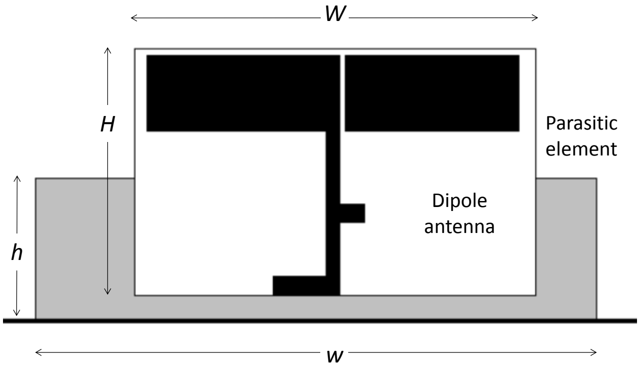


Figure 3: A side view of the dipole antennas with the parasitic element

## III. RESULT

From the simulation, a single dipole patch antenna managed to achieve a return loss of 37 dB (VSWR = 1.03) at centre frequency of 850 MHz. A bandwidth of 220 MHz with operating frequency from 797 MHz to 1.017 MHz is obtained at a return loss of 15 dB (VSWR = 1.43) as shown in Figure 4. Figure 5 shows this dipole antenna has an omnidirectional radiation pattern with an antenna gain of 2 dB. A directional radiation pattern is observed when this dipole antenna has a finite a ground plane with an antenna gain of 7 dB.

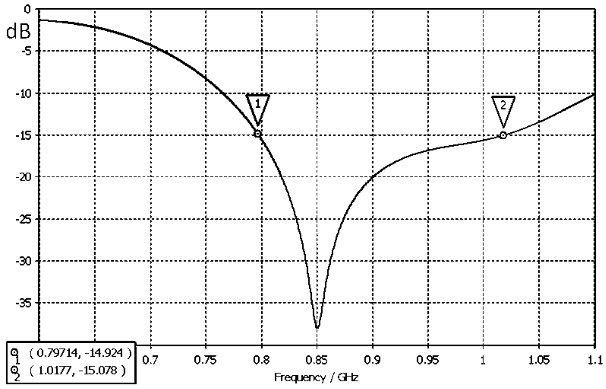


Figure 4: Return Loss of a dipole patch antenna

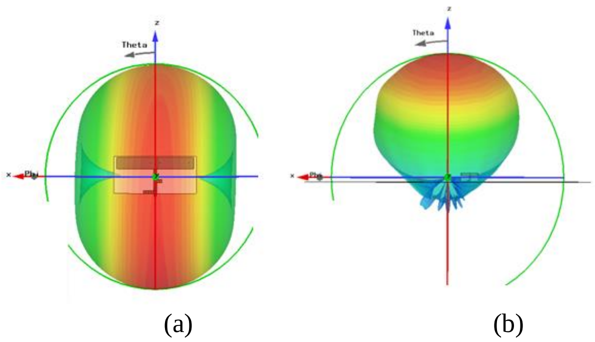


Figure 5: Radiation pattern of a dipole patch antenna, (a) without ground plane, (b) with ground plane

Figure 6, 7 and 8 show the side-by-side, top-down and diagonal coupling level of different port selection of the *star* configured dipole antenna array respectively when the large antenna array is without the parasitic element ($h/H$ = 0). The side-by-side coupling has the minimum and maximum coupling level at 20 dB and 18 dB respectively with an average of 19 dB. The top-down coupling has the minimum and maximum coupling level at 33 dB and 28 dB respectively with an average of 30 dB. The diagonal coupling has the minimum and maximum coupling level at 30 dB and 28 dB respectively with an average of 29 dB. Based on these results, the side-by-side coupling has the worst coupling level compared to the top-down and the diagonal coupling. Therefore, a priority is given to the side-by-side coupling to be further improved.

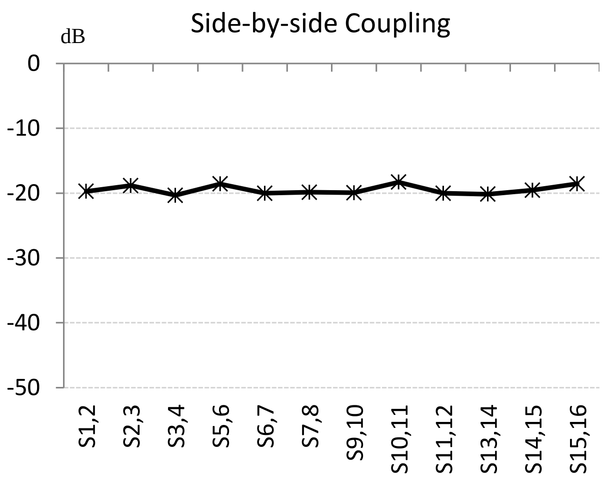


Figure 6: Side-by- side coupling (without parasitic element)

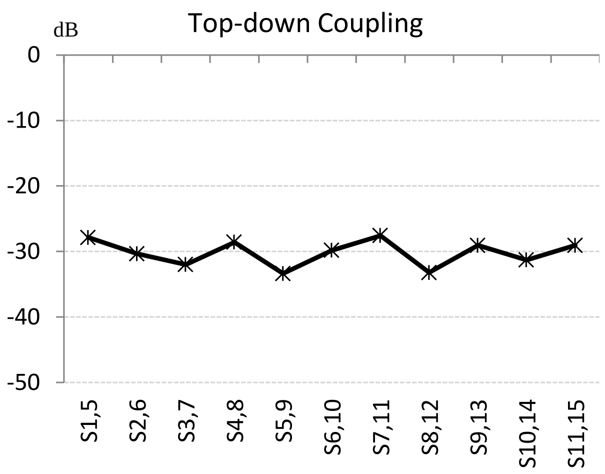


Figure 7: Top-down coupling (without parasitic element)

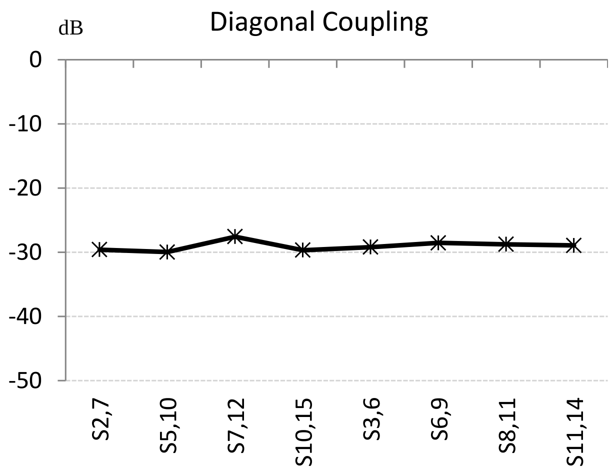


Figure 8: Diagonal coupling (without parasitic element)

Figure 9 shows the side-by-side coupling level of different port selection of the *star* configured dipole antenna array at different *h*/*H* ratio. Note that the parasitic element at *h*/*H* = 0.5 delivered better coupling level compared to other *h*/*H* ratio. Overall, the parasitic element at *h*/*H* = 0.5 provides a significant improvement with the minimum and maximum coupling level are at 37 dB and 25 dB respectively with an average coupling of 31 dB. This can be compared to the large antenna array that is without the parasitic element *h*/*H* = 0, the minimum and maximum coupling level of the selected port isolations are 20 dB and 18 dB respectively.

Figure 10 shows the top-down coupling level of *star* configured dipole antenna array at different *h*/*H* ratio. The parasitic element at *h*/*H* = 0.5 provides a major variance compared to other *h*/*H* ratio with the minimum and maximum coupling level are at 43 dB and 28 dB respectively with an average coupling of 33 dB. Overall results show that the coupling level of all isolation port is below 20 dB for every *h*/*H* ratio. This can be observed at *h*/*H*= 0.7 where the maximum coupling level is 25 dB.

Figure 11 shows the diagonal coupling level of *star* configured dipole antenna array at different *h*/*H* ratio. The parasitic element at *h*/*H* = 0.7 provides a major coupling variance compared to other *h*/*H* ratio with the minimum and maximum coupling level are at 40 dB and 30 dB respectively with an average coupling of -33 dB. At full height of the parasitic element; *h*/*H* = 1.0, the minimum and maximum coupling level are at 25 dB and 23 dB respectively with an average coupling of 24 dB. Overall results show that the coupling level of all isolation port is below 20 dB for every *h*/*H* ratio.

The results from Figure 9, 10 and 11 can be summarized in Table 1 below. This coupling level at *h*/*H* = 0.5 shows a great improvement result especially for the side-by-side coupling compared to the large antenna array which is without the parasitic element. Based on these results, it can be concluded that the introduction of parasitic elements at in between the antennas with spacing of λ/4 offer a significant coupling improvement

Table 1
Coupling Level

| Coupling Type | *h*/*H* = 0 | | | *h*/*H* = 0.5 | | |
|---|---|---|---|---|---|---|
| | Min | Max | Average | Min | Max | Average |
| side-by-side | -20 | -18 | -19 | -37 | -25 | -31 |
| top-down | -33 | -28 | -30 | -43 | -28 | -33 |
| diagonal | -30 | -28 | -29 | -35 | -28 | -30 |

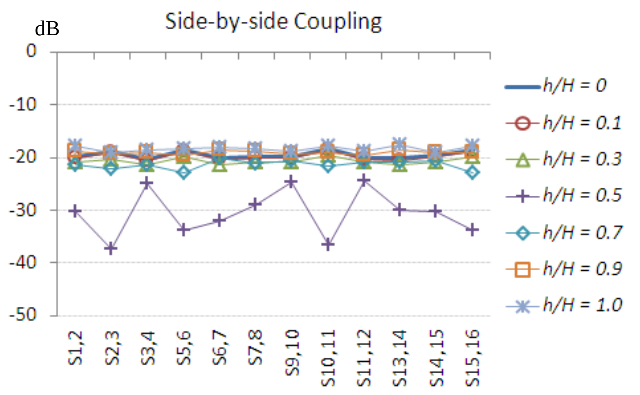


Figure 9: Side-by- side coupling at different *h*/*H*

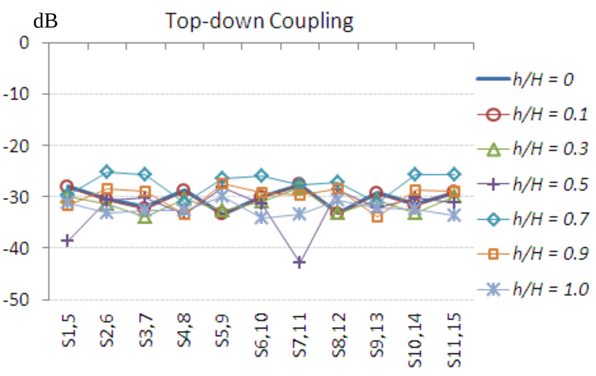


Figure 10: Top-down coupling at different *h/H*

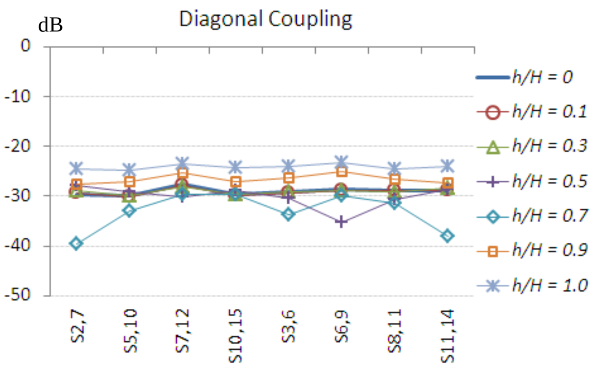


Figure 11: Diagonal coupling at different *h/H*

## IV. CONCLUSION

This paper presents the analytical analysis of improving the coupling effect for the 4x4-dipole antenna array that has a *star* configuration with slanted ± $45^0$ dipole antennas, antenna spacing; D = λ/2 by employing different height ratio of the parasitic elements in between the antennas with spacing of λ/4. This dual-polarized *star* configured dipole antenna array is demonstrated and analysed with and without parasitic elements. Based on the results, it can be concluded that the introduction of parasitic elements at *h/H* = 0.5 in between the antennas with spacing of λ/4 offer a significant coupling improvement (> 25 dB) especially for the side-by side coupling effect compared to the antenna array without the parasitic element. Based on these results, there is a potential for designing a compact antenna array with more multi-element antenna with smaller antenna spacing and lower coupling level at lower frequency.

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