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MUTUAL COUPLING ANALYSIS ON LARGE ARRAY ANTENNA WITH DIFFERENT POLARIZATION FOR MIMO APPLICATION

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ABSTRACT

This paper proposes the analytical comparison analysis of the mutual coupling for a large array antenna between a single-polarized and a dual-polarized type antenna with the existence of a spatial diversity. The large array antenna using multi dipole antennas with different configurations and antenna spacing are studied. The result shows that the improvement of the mutual coupling is at least 7 dB by using the dual-polarized star configuration with the slanted $\pm 45^0$ dipole antennas and antenna spacing; D = $\lambda/2$. In addition, these different antenna configurations provide coupling result improvement that is comparable to the square lattice configuration with D = λ and this offers a significant size reduction for the large array antenna. Even though, the mutual coupling is the main interest in this study, other antenna parameters such as gain and beamwidth are included in this paper to provide a more comprehensive analysis.

Keywords: mutual coupling, polarization diversity, array configuration, antenna spacing.

INTRODUCTION

A large array antenna or a massive-multiple input multiple output (MIMO) technology was recently proposed as an eminent solution for providing a high-speed wireless communication in a future cellular generation. This option becomes much more prominent when the frequency spectrum availability is scarce and restricted. One main advantage of the MIMO system is that it could improve the capacity and the reliability of non-line-of-sight (NLOS) signal propagation due to a rich scattering environment, without increasing the bandwidth or the transmitted power. To achieve this, a large number of antenna elements are required in order to increase the data throughputs and to save power consumption. Instead of having more multi-element antennas (MEA), it has reported that the spatial and polarization diversity are able to improve the channel capacity. For example, a dual-polarized antenna configuration delivers approximately 14% higher capacity than single-polarized configuration [1].

This paper proposed a study for large array antenna of MEA with a certain antenna configuration that requires it to operate at a lower frequency. As a result, the size of the MEA increases and hence this would increase the overall physical dimension of the MIMO antenna. This drawback could impede the deployment of the large MIMO antenna at the installation site as it would require a larger space area resulting impractical antenna installation for a crowded base station tower. In addition, this would also incur a significant total cost ownership (TCO) e.g. installation, maintenance cost etc. to the telecommunication operators. To mitigate this issue, a reduction of distance between antenna elements with different antenna configuration was proposed to reduce the overall physical dimension of the MIMO antenna [2]. A number of publications had demonstrated the impact of antenna compactness by having more antenna elements with different configuration [3]. There was also a study on the effects of increasing the number of antennas by reducing antenna spacing in fixed physical space [4]. Unfortunately, this approach reduced the angle spread and the spatial diversity due to reduction of the separation between antennas and increase in transmit diversity by increasing the number of elements [5]. In addition, this leads to the increase of antenna mutual coupling in which increases the signal correlation that causes a distorted radiation pattern and decreases the channel capacity. Therefore, a minimum wavelength of antenna separation of the transmitted frequency is typically proposed to secure minimal correlation between the communication channels.

In order to achieve a practical large array antenna dimension, this paper investigates mainly on the effect of the mutual coupling and other antenna parameters on a single-polarized and a dual-polarized type antenna. The fixed number of antenna elements with various configuration arrangements and spacing are opted for the best mutual coupling performance.

METHODOLOGY

In this paper, CST Microwave Studio (CST MWS) was used to study and analyse the performance of different antenna polarization with different 4x4-array configuration and antenna spacing; D. These multi-element antennas consisting of dipole antennas with different antenna configurations were arranged in a certain fashion to employ antenna diversity scheme through spatial and polarization diversity. Single polarizations of 4x4-array antenna of square and triangular lattice configurations with spatial diversity were introduced to evaluate the mutual coupling performance. In addition, the dual polarizations of 4x4-array antenna of star and diamond configurations with spatial diversity were included. Antenna gain and half-power beamwidth result were also included to study the effect of different antenna configurations and different antenna spacing.

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ANTENNA ARRAY CONFIGURATION

Operating at 850 MHz, this large array antenna utilizes dipole patch antennas as multi-element antennas using FR4 material with dielectric constant εr = 4.4 as shown in Figure-1. From the simulation, a single dipole patch antenna manages to achieve a return loss of -37 dB at 850 MHz as shown in Figure-2. A broad bandwidth of 220 MHz is observed at a return loss of -15 dB. Figure-3 shows this dipole antenna has an omnidirectional radiation pattern with an antenna gain of 2 dB. An antenna gain of 7 dB with a directional radiation pattern was achieved when a finite a ground plane was introduced.

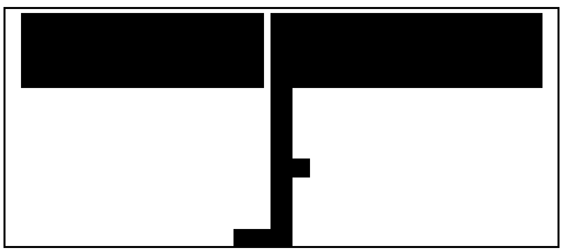


Figure-1. A dipole patch antenna.

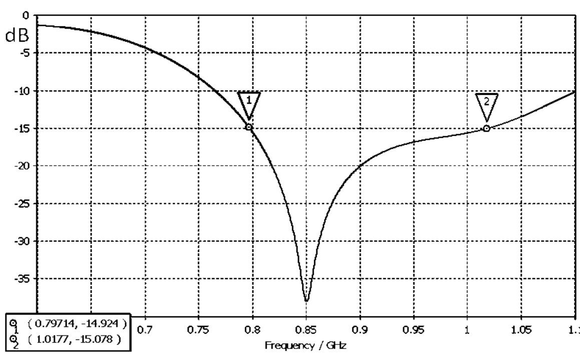
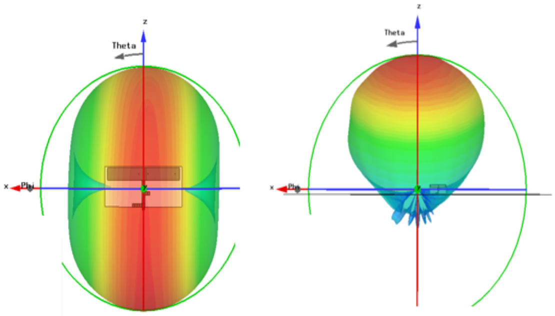


Figure-2. Return loss of a dipole patch antenna.



(a) (b)

Figure-3. Radiation pattern of a dipole patch antenna, (a) without ground plane, (b) with ground plane.

Figure-4 shows a partial segment of 4x4-array dipole antenna with different configuration and antenna spacing; D. These 16 dipole antennas are aligned in 4 columns and 4 rows with different configuration and λ, λ/2 and λ/4 are selected for the antenna spacing. The antenna spacing; D = λ and D = λ/4 of the square lattice configuration are included as the reference for this analysis. Each array antenna configuration has a metal backplate as a finite ground plane as this MIMO antenna is used for a directional antenna. Figure-4(a) and Figure-4(b) shows a square lattice and a triangular lattice configuration respectively with equal antenna spacing. Both of these configurations employ single polarizations. The square lattice configuration has 4x4-array dipole antennas align horizontally in row and vertically in column arrangement with equal antenna spacing. In comparison to the square lattice, the triangular lattice has dipole antennas in vertical downward offset arrangement in a second and a fourth column with equal antenna spacing. Figure-4(c) and Figure-4(d) shows a star and a diamond configuration with slanted ± 450 dipole antennas to provide dual polarizations. In CST MWS, all excitation ports of these dipole antenna configurations with different antenna spacing are simultaneously excited at 850 MHz to simulate the performance.

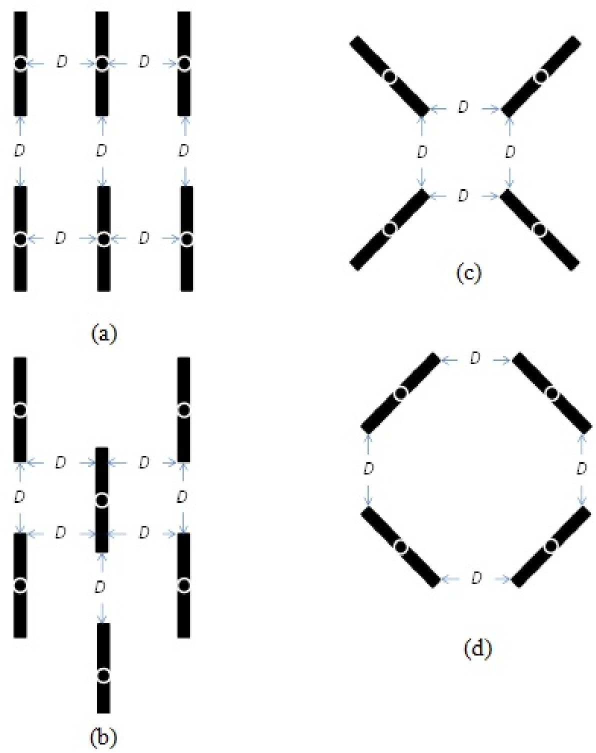


Figure-4. Different configuration of 4x4 dipole antenna array with antenna spacing; D (a) square lattice, (b) triangular lattice, (c) star, (d) diamond.

Figure-5 shows the total antenna area of 4x4-array dipole antenna and the ground plane with different

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configuration and antenna spacing. This total antenna area shows that a compact size array antenna can be achieved by a significant antenna space reduction between dipole antennas as proposed; λ, λ/2 and λ/4 but it requires a detailed analysis for the antenna performance. The compact designed antenna is favoured due to its practicality for site deployment, reduce total cost ownership (TCO) and manufacturing cost reduction.

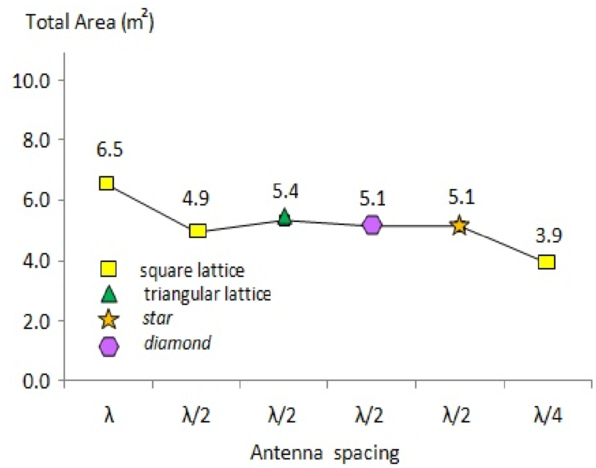

Figure-5. Total antenna area of 4x4 antenna array with different configuration and antenna spacing.

RESULT

Figure-6 shows the maximum mutual coupling level of 4x4 dipole antenna array with different configuration and antenna spacing. For a square lattice configuration, the mutual coupling level increases significantly as the antenna spacing reduces from λ, λ/2 to λ/4. The overall best coupling result is achieved by the square lattice configuration at -25 dB with D = λ. The worst coupling result is produced by the square lattice configuration at -8.6 dB with D = λ/4. At D = λ/2, the triangular, the star and the diamond configurations show better mutual coupling level compared to the square lattice configuration. Amongst these configurations, the star configuration produces the best coupling result at -23.8 dB followed by the triangular lattice (-21.6 dB) and the diamond configuration (-18.7 dB). This shows that the dual polarization type antenna with slanted ± 450 dipole antenna have better coupling level compare to the single polarization type antenna. In addition, the triangular lattice with a single polarization that has vertical offset configuration provides better coupling level compared to the square lattice at D = λ/2.

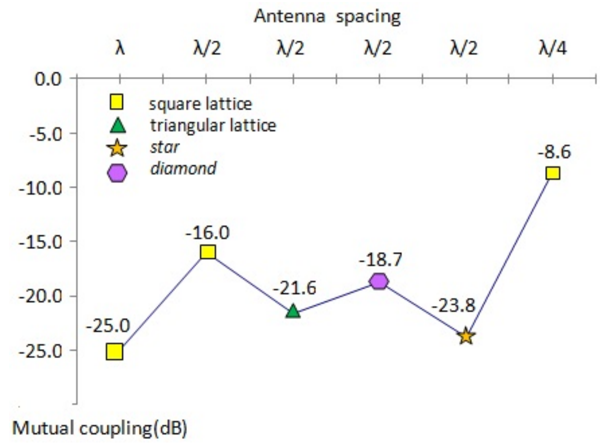

Figure-6. Maximum mutual coupling of 4x4 antenna array with different configuration and antenna spacing.

Figure-7 shows the antenna gain of 4x4 dipole antenna array with different configuration and spacing. The result shows that the square lattice configuration with *D* = λ has the maximum gain at 19.9 dB. As the antenna spacing reduces from λ, λ/2 to λ/4, the antenna gain of the square lattice configuration decreases to 15.2 dB at *D* = λ/4 with a maximum gain reduction by 4.2 dB. Amongst other configuration at *D* = λ/2, the *star* configuration has the lowest antenna gain at 13.3 dB followed by the *diamond* configuration at 17.4 dB. This shows that the dual polarization antenna with slanted $\pm 45^0$ dipole antennas has lower gain compared to a single polarization due to different polarization of the antenna elements.

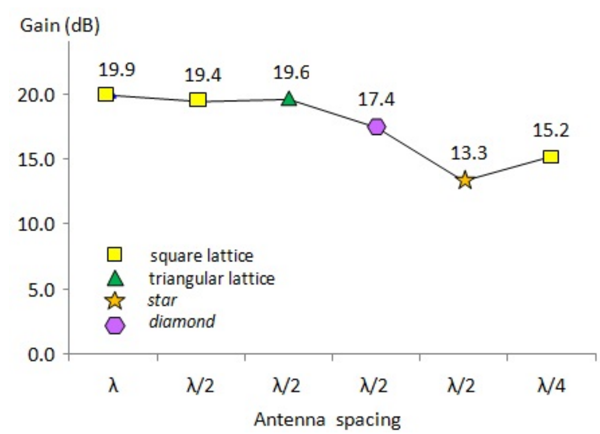

Figure-7. Gain of 4x4 antenna array with different configuration and antenna spacing.

Figure-8 shows the antenna half-power beamwidth (HPBW) or 3 dB-beamwidth at Φ = 00 and Φ = 900 of 4x4 dipole antenna array with different configuration and spacing. The result shows the antenna HPBW of the square lattice configuration at Φ = 900 increases drastically for whereas a moderate increase in the beamwidth at Φ = 00 as the antenna spacing reduces.

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The square lattice configuration with antenna spacing; D = λ has the minimum beamwidth of 13.20 at Φ = 900 and 8.90 at Φ = 00. In comparison, the square lattice configuration with antenna spacing; D = λ/4 has the maximum beamwidth of 46.50 at Φ = 900 and 18.10 at Φ = 00. At D = λ/2, a beamwidth difference of 120 is observed between Φ = 00 and Φ = 900 at every configuration. In addition, there is not much difference in the beamwidth for the single and the dual polarized antenna configurations at Φ = 00 and Φ = 900.

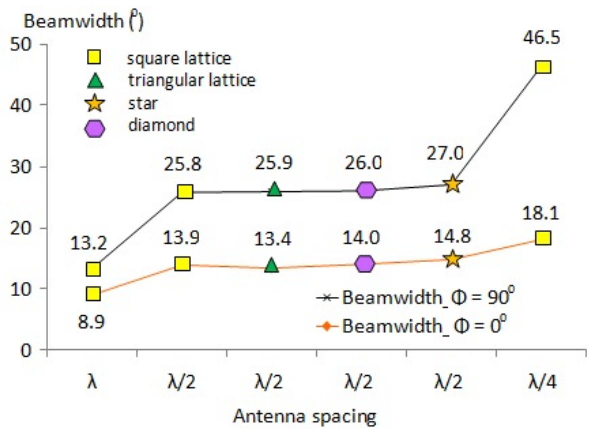

Figure-8. Half-power beamwidth of 4x4 antenna array with different configuration and antenna spacing.

CONCLUSIONS

This paper presented the analytical analysis of improving the coupling effect for the 4x4-dipole antenna array by employing different polarization diversity and different antenna array configuration in the presence of the spatial diversity. Single-polarized of square and triangular lattice antenna with dual-polarized star and diamond antenna configurations are demonstrated and analysed. The dual-polarized star configuration with slanted ± 450 dipole antennas and antenna spacing; D = λ/2 has significantly improve the coupling level but at the expense of lower antenna gain. The single-polarized triangular lattice with antenna spacing; D = λ/2 provides better overall results in coupling and antenna gain. Based on these results, a more compact multi-element antenna (MEA) can be designed with smaller antenna spacing and lower coupling level at lower frequency.

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