Design of Four Elements MIMO Antenna Using the Theory of Characteristic Mode

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Abstract **– This paper presents an analysis of MIMO antennas consisting of notch antenna and loop antenna for a wide area mobile communication system with bi-directional radiation patterns. The notch antenna radiates a horizontally polarized wave while the loop antenna radiates a vertically polarized wave. The MIMO antenna is designed for 4G applications with the resonance frequency at 3.5 GHz. The antenna produces a good bi-directional pattern with a good isolation and the analysis is carried out using characteristic mode analysis.**

Index Terms **— notch antenna, loop antenna, MIMO, characteristic mode analysis, bi-directional pattern.**

1. Introduction

The growing demand to increase the data rates for wireless communication systems is rising with the needs for an efficient and high rate data transmission system that can operate in existing frequency. Multiple-input multiple-output (MIMO) system is one of noticeable solutions as it can improve the channel capacity for an indoor base station [1]. The challenge however is to design a dual polarized MIMO antenna with low profile design and high isolation characteristic [2]. In this paper, a pair of dual polarized antenna composing of vertical polarization element and horizontal polarization element is proposed. The principal polarization radiation patterns are bi-directional which is suitable for a wide area line-of-sight (LOS) channel environment. The theory of characteristic mode analysis (CMA) is used for the analysis because it provides an in-depth physical insight into the behavior of an antenna [3]. CMA is a current mode, numerically obtained for discretionally shaped conducting bodies while providing a physical explanation of the radiation phenomena. A mode is at resonance when its characteristic angle is or close to 180 degree. The proposed antenna is simulated in MWS software.

2. Two elements composite antenna

A composite antenna is constructed by combining a notch antenna and a loop antenna for vertically and horizontally polarized element, respectively. The loop antenna is mounted on the ground plane with the notch antenna positions on top of the loop antenna. Fig.1 shows 2 different configurations for the notch antenna where in configuration B, the notch antenna is rotated 90° from in configuration A. The CM analysis is presented in Fig. 2 where J1 and J2 mode represents the loop and notch antenna excitation, respectively. The solid line is when each antenna is excited independently while the dot line and the dash line describe the composite excitation in respect to configuration A and B. In the case of configuration A, the solid line coincides with the dash line for J2 mode at the resonance frequency describing a no relation condition between the loop antenna and the notch antenna. On the other hand, configuration B shows a relation exists between loop and notch antenna when the dot line differs from the solid line in J2 mode. From these results we confirmed that the configuration A demonstrates a better construction as compared to configuration B. Fig. 3 shows the current distribution and the radiation pattern for each J1 and J3 modes.

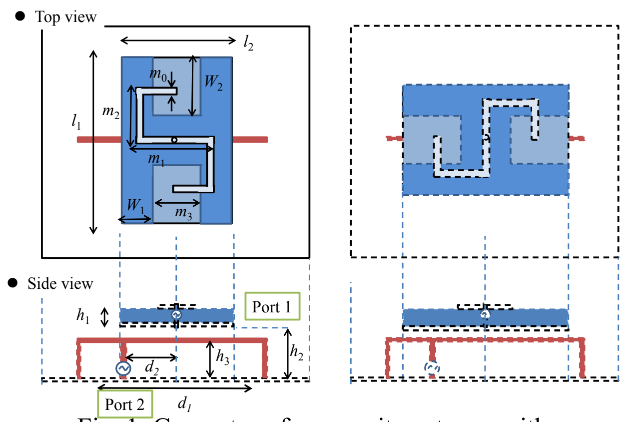


Fig. 1. Geometry of composite antenna with configuration A on the left and configuration B on the right. W_1=35.5, W_2=19, W_3=14.5, W_4=3, M_1=17, M_2=7, M_3=11.5, M_4=1, h_1=1.2, h_2=10, h_3=7, d_1=37.5, d_2=14 [mm].

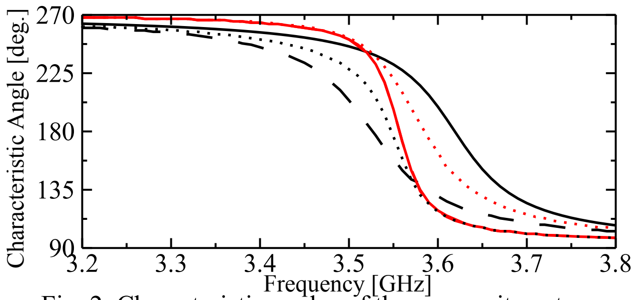
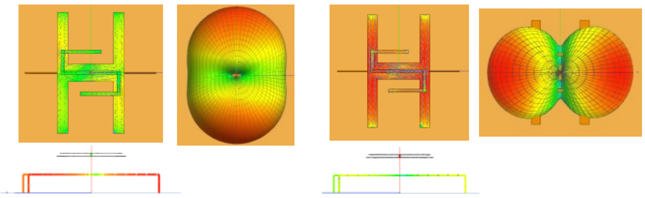


Fig. 2. Characteristic angles of the composite antenna with (a) black line for J1 mode and (b) red line for J2 mode. Solid line is for independent excitation, dash line is for component A and dot line is for component B.



J1 mode J2 mode

Fig. 3. The current distribution (left) and radiation pattern (right) for each J1 and J2 modes.

3. Four elements MIMO antenna

Two composite antennas in configuration A proposed in the previous section is combined together with one of them is rotated at 90° from the other and the center to center distance is at 0.6λ. Fig. 4 shows two different arrangements for the antenna position which are x direction away and diagonally away, mounted on a ground plane of 200 mm square in dimension. Port 1 and Port 3 is the excitation for the notch antennas while Port 2 and Port 4 is for the loop antennas. Fig.5 shows CMA of two different arrangements. The dash dot dash line and the short dash line describe the composite excitation in respect to x direction away and diagonally away. The short dash line is close to dash line than dash dot dash line. The result shows that the influence of composite antenna towards each other is less in diagonally away configuration. The reflection and mutual characteristics are shown in Fig.6 where both S_{11} and S_{22} show good readings below -10 dB. The isolation for the diagonally away arrangement is better than the x direction away at 16 and 13 dB, respectively. From these results we confirmed that the diagonally away demonstrates a better construction as compared to x direction away. Fig.7 shows the bi-directional radiation pattern for Port 1 and 2 excitations in horizontal plane with a very small cross polarization. The maximum gain is at 8.5 dB.

4. Conclusion

Four elements MIMO antenna operating at 3.5 GHz is proposed in this paper. A horizontally polarized pattern is obtained from a notch antenna while a vertically polarized pattern is produced by a loop antenna. The antenna presents a low profile design with bi-directional radiation patterns. The theory of characteristic modes is used to analyze the potential current modes of the antenna to investigate the factors affecting the isolation between the antenna elements. The antenna in diagonally away configuration is confirmed as the optimal configuration because it has higher isolation and good bi-directional patterns. The gain and isolation obtained is at 8.5dB and 16dB, respectively.

References

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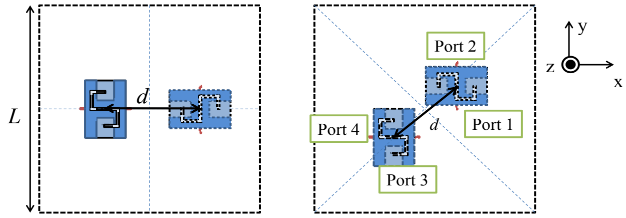


(a) x direction away (b) diagonally away

Fig. 4. Different arrangement for four element antenna mounted on the ground plane with L=200 and d=0.6λ [mm].

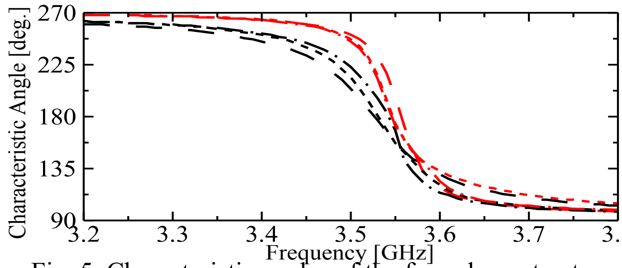


Fig. 5. Characteristic angles of the four element antenna with (a) black line for J1 mode and (b) red line for J2 mode. Dash line is for component A, dash dot dash line is for x direction away and short dash line is for diagonally away.

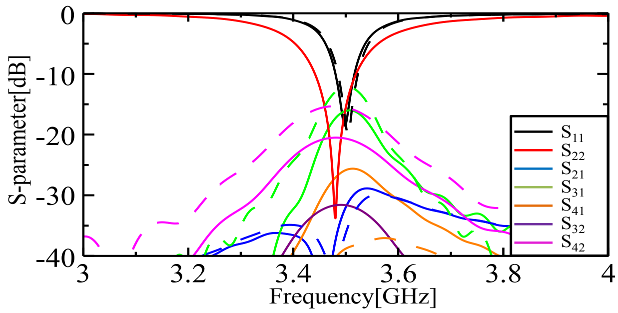
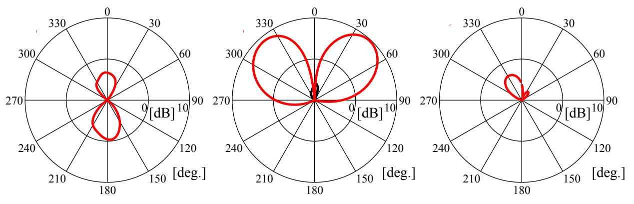


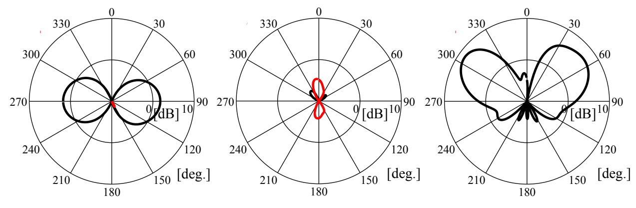
Fig.6. S-parameter results with dash line for x direction away and solid line for diagonally away.

Port 1



(a)xy-plane (b)yz-plane (c)zx-plane

Port 2



(a)xy-plane (b)yz-plane (c)zx-plane

Fig. 7. Radiation patterns with black line for E-theta and red line for E-phi.