A DESIGN OF COMPACT MIMO DIELECTRIC RESONATOR ANTENNA

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ABSTRACT

Multiple Input, Multiple Output (MIMO) is an antenna technology for wireless communications in which multiple antennas are used at both the source (transmitter) and thedestination (receiver). The antennas at each end of the communications circuit are combined to minimize the errors and to optimize the data speed. MIMO-based antennas are of interest in relation to communication such as digital TV, wireless LAN, and mobile communications such as cellular phone or other portable communication devices. However, the size of the cellular phone is preferably small, and it therefore disadvantageous to include more than one antenna in such a device. This becomes even more of a factor as cellular phones need to communicate in different types of system. This means that if the MIMO concept is used for a small portable communication device, it may be difficult to provide antennas that have low incidence of coupling to each other especially if the device is to be kept small. In recent years a new type of antenna has evolved that is small and has high radiation efficiency. Those characteristics are highly desirable for using cellular phones. In a dielectric resonator antenna, a probe can excite a transmission mode in a resonating dielectric antenna volume. When applying a dielectric resonator antenna(DRA) type in a MIMO system and using it for the transmission of two or more signals using the same frequency, high coupling often occurs between different antenna signals. Also, where the incidence of the coupling between these antennas, signals is reduced. Dielectric resonator antenna offers several advantages such as wide bandwidth, small size ease of fabrication and high radiation efficiency. This paper presents characteristics of dielectric resonator antenna for 2.5GHz (UMTS band 7).

Keywords: Circularly polarized (CP) antenna, dielectric resonator antenna (DRA), Multiple Input-Multiple Output (MIMO) antenna, mutual coupling, polarization orthogonality.

INTRODUCTION

In microwave circuit the dielectric resonator (DR) was generally used as an energy storage element rather than used as a radiator but in open condition the dielectric resonator (DRs) behaves like radiator. Dielectric resonator antennas (DRA) are in the limelight because of their attractive features like that of small size, light weight, high temperature tolerance, and no excitation of wireless communications in which multiple antennas are used for both the source(transmitter) and the destination(receiver). Geometry of the single element along with dimension and working mechanics and simulated results are explained. Single element of MIMO antenna, linearly polarized MIMO antenna, circularly polarized MIMO antenna and proposed wideband circularly polarized MIMO antenna. Circularly polarized (CP) antennas have been widely used in the global positioning systems, satellite communications, and navigation systems owing to the superiority in mitigating polarization mismatch and suppressing multipath interference. Generally, a CP antenna can receive an arbitrarily oriented LP antenna. However, a left-hand CP (LHCP) wave and a right-hand CP (RHCP) wave are orthogonal to each other. In other words, an LHCP wave cannot be received by an RHCP antenna, and viceversa. Due to the advantages of circularly polarized antennas and MIMO antennas, the circularly polarized MIMO antennas were proposed recently for the sake of high transmission rate and communication reliability. Like the LP MIMO antenna, the research on the mutual coupling reduction of the CP MIMO antenna is also receiving increasing attention although still not too much at present An EBG structure was added between two CP dielectric resonator antennas to reduce the mutual coupling. In a mu-negative metamaterial filter-based decoupling technique was presented for CP MIMO monopole antennas, and in a two-layer transmission-type FSS was placed vertically above the CP patch antennas to decouple. These three designs all have decoupling structures placed between or above the antenna elements, which increase the system complexity or height significantly. There are other designs which used an RHCP antenna and an LHCP antenna to achieve high isolation. However, it is found that when the two CP antennas in such systems operate at the same time, the total radiation field is LP rather than CP. High capacity and high quality wireless communications can be achieved by employing multiple-input multiple-output (MIMO) systems, even without increasing the signal bandwidth or signal-to-noise (SNR) ratio. The channel capacity can be increased because multiple data streams can be transferred simultaneously by using multiple antennas at the transmitter and receiver. For the reduced from factor in wire less devices, the antennas for MIMO systems should also be made more compact. MIMO antennas is to minimize the signal correlation between antennas over a wide frequency range, despite the small spacing between the multiple antennas. When multiple antennas are placed within a spacing of 0/2, mutual coupling can degrade the radiation performances of the antennas and the channel capacity of MIMO systems. This requires low mutual coupling between the elements. It is reported in that the dielectric resonator antenna provides lower mutual coupling levels. However, further mutual coupling reduction is required. In this effort, a great deal of work has been reported to date on reducing the mutual coupling between antennas including applications of parasitic elements, EBG structures and metamaterial-based resonators. Recently, the authors introduced a double-layer mushroom EBG wall loaded between four cavities-backed slot antennas to reduce the mutual coupling between the antennas by 16DB at 2.4 GHz. However, thus structure is large and by adding the EBG wall, the antenna height is increased considerably. Another approach to reducing the effect of mutual coupling is reported in involves integrating split-ring resonators in the ground place of the patch antenna. This technique is shown to provide isolation improvement by 10 DB. However, the gain radiation pattern is not appropriate. Another technique in uses parasitic elements to reduce the mutual coupling between antennas by 6DB at 2.4 GHz. In, a new EBG structure loading between two DRA antennas is used to suppress the surface waves, and the coupling is reduced by 13GB over 57-64GHz. This approach, however, is only applicable to the arrangement of the antenna in the E-plane.

Designing Guidelines

Step -1 : Computation of the Microstrip patch antennas substrate parameters.

Step -2 : Define antenna parameters (L1,W1) and design a conventional antenna with a 50ohms feed line .

Step -3: Integrate a thin film material with high dielectric permittivity is 250 with different thickness.

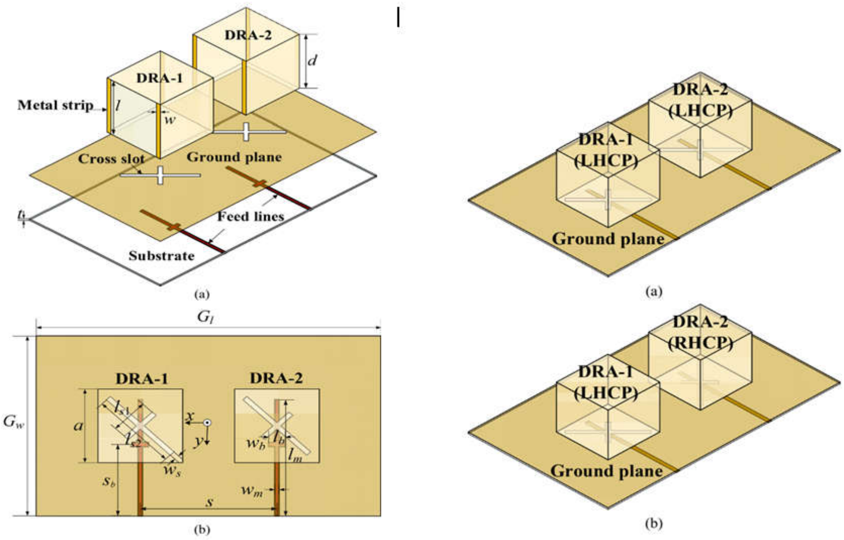
Step -4 : Simulation of the antenna for return loss and bandwidth and radiation pattern using HFSS.

Step -5 : Optimization of the dimensions of the patch via GA algorithms to enhance its performances.

Proposed Method

For designing a Dielectric Resonator Antenna with Multiple-inputs multiple-outputs to reduce mutual coupling between two antennas. The MIMO antenna consists of two identical dielectric resonator antennas (DRAs), which uses the same feeding cross slots to generate the circularly polarization. The antenna resonates at 2.5GHz with return loss of -30Db. Multiple-Input Multiple-Output (MIMO) antenna with circular polarisation (CP). This MIMO antenna is made up of two identical dielectric resonator antennas (DRAs), which produce the same CP fields by sharing the same feeding cross slots. In order to adjust the rotation direction of the E-field coupled in the passive (coupled) DRA, vary its polarisation property, and make it opposite (orthogonal) to that of the active (driven) DRA, four metal strips are printed on the lateral edges of each DRA. Polarization orthogonality considerably improves the isolation between the two CP DRAs without taking up additional space or degrading antenna performance. Moreover, the two CP DRAs can run simultaneously as well as separately using this decoupling approach.

Prototype



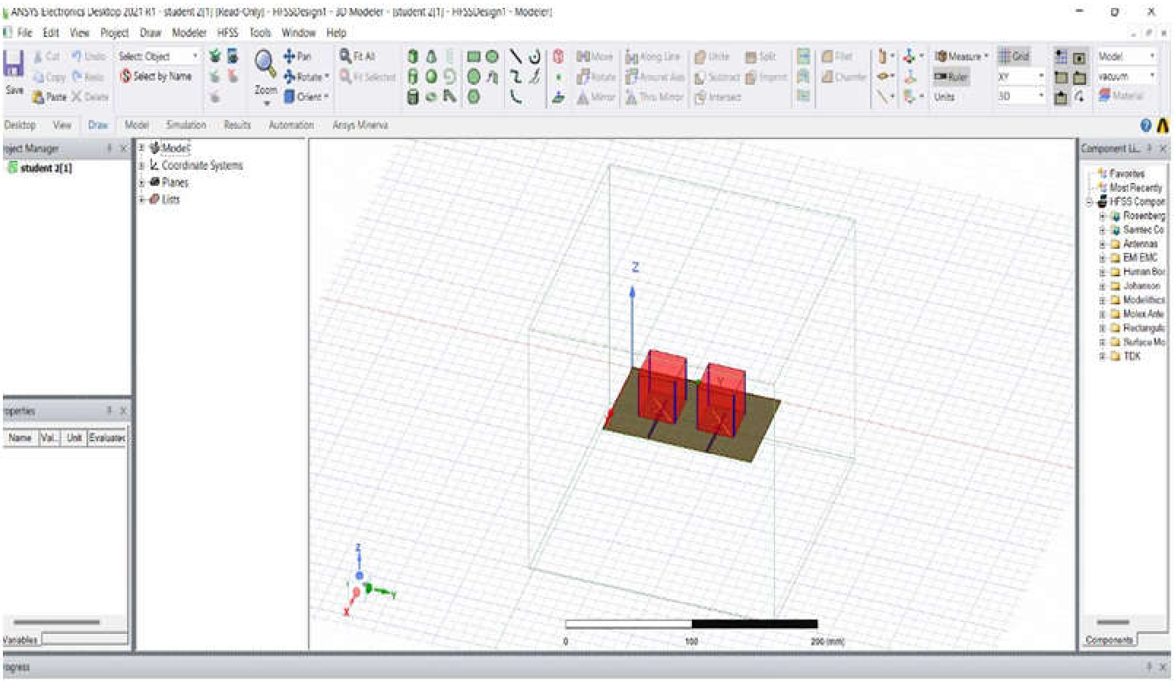
Antenna Geometry

Fig. 1 shows the configuration of the proposed CP 1 × 2 MIMO antenna, which mainly consists of two identical squareand a dielectric substrate printed with feeding circuits. The two square DRAs have a side length of a = 31 mm, a height of d = 31 mm, and a relative permittivity of ε_r= 9.5, and they are placed side by side with the centre-to-centre distance given by s = 50 mm (about $0.4\lambda_0$, where λ_0 is the free-space wavelength at 2.4 GHz). Printed on the lateral sides of each DRA, there are four metal strips, and these metal strips have the same length of l = 31 mm and width of w = 2.2 mm. It will be shown that the metal strips play an important role in decreasing the mutual coupling. The feeding dielectric substrate with a thickness of t = 0.8 mm and a permittivity of ε_{rs}= 3.38 is placed beneath the DRAs. To generate the CP field, a cross slot, formed by two orthogonal rectangular slots with unequal lengths l_{s1} = 14.5 mm and l_{s2} = 33 mm, is etched on the top surface (ground plane) of the dielectric substrate to excite the DRA. On the bottom surface of the substrate, a 50 microstrip feed line with width w_m= 1.8 mm and length l_m= 49 mm is printed to feed the cross slot. In addition, to improve the impedance matching, a transverse stub with width w_b= 1.8 mm and length l_b = 6 mm is added to the feed line. It is notable that the feeding circuits for the two DRAs are exactly the same, and using this feeding scheme, the LHCP field will be excited.The proposed CP MIMO DRA is designed at 2.4 GHz, and the detailed dimensions are also listed in the caption of Fig. 1.To interpret the mechanism of the proposed CP MIMO DRA, two reference MIMO antennas are investigated first. As shown in Fig. 2, reference Antenna I has a configuration similar to the proposed CP MIMO DRA, except that themetal strips are removed from the lateral sides of the DRAs. Therefore, when excited individually, both DRA-1 and DRA-2 radiate the LHCP waves. In reference Antenna II, the bare DRAs without metal strips are also used. But differently, the feeding cross slot of DRA-2 is rotated by 90° around the z-axis. In this case, the RHCP field will be obtained when Port-2 is excited.The simulated S-parameters of reference MIMO Antennas I and II are shown in Fig. 3(a). It can be seen that the reflection coefficients $|S_{11}|$ of the two antennas are nearly the same, but the transmission coefficients $|S_{21}|$ are quite different. At the operating frequency of 2.43 GHz, $|S_{21}|$ of Antenna I is only about −13 dB, whereas the mutual coupling decreases significantly in reference Antenna II . The results are easy to understand considering the polarization properties of the two DRAs. As mentioned above, DRA-1 and DRA-2 in Antenna I have the same polarization characteristics and they both radiate the LHCP waves when excited. Obviously, this will lead to a considerable mutual coupling between the two DRAs. However, in Antenna II, due to the use of different orientations in the feeding slots, DRA-1 radiates an LHCP wave while DRA-2 radiates anRHCP wave. That is to say, the polarization of DRA-1 and DRA-2 becomes orthogonal. As is well-known, the mutual coupling between two orthogonally polarized LP antennas is generally very low. Similarly, when placing two CP antennas with orthogonal polarization side by side, the mutual interference is also relatively weak.Although an enhanced isolation of ∼22 dB is achieved in reference Antenna II, it is found that for this MIMO antenna when the LHCP DRA-1 and RHCP DRA-2 operate simultaneously, the radiation field becomes LP. Fig. 3(b) shows the simulated axial ratios (ARs) of reference Antennas I and II. It is observed that good CP performance (AR <3 dB) is obtained from 2.38 to 2.52 GHz in Antenna I whether DRA-1 and DRA-2 are excited separately or concurrently. However, the situation in Antenna II is different. When only one DRA is excited, good AR can still be obtained in the band of 2.30−2.50 GHz. But the AR increases to over 50 dB when DRA-1 and DRA-2 are both excited, which means the wave radiated from MIMO Antenna II becomes an LP wave.

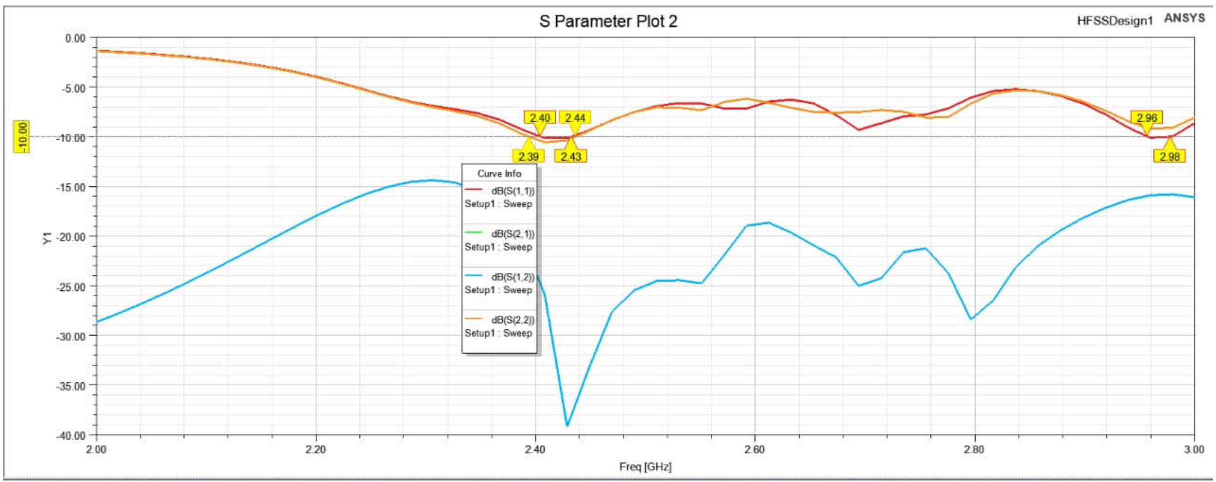
Therefore, the application of such MIMO system may be limited. Hence, we turn back to the configuration of reference Antenna I which applies two CP DRAs with the same polarization. As shown in Fig. 3, the key issue in this case is the relatively high mutual coupling. This is also the problem we will focus on next.

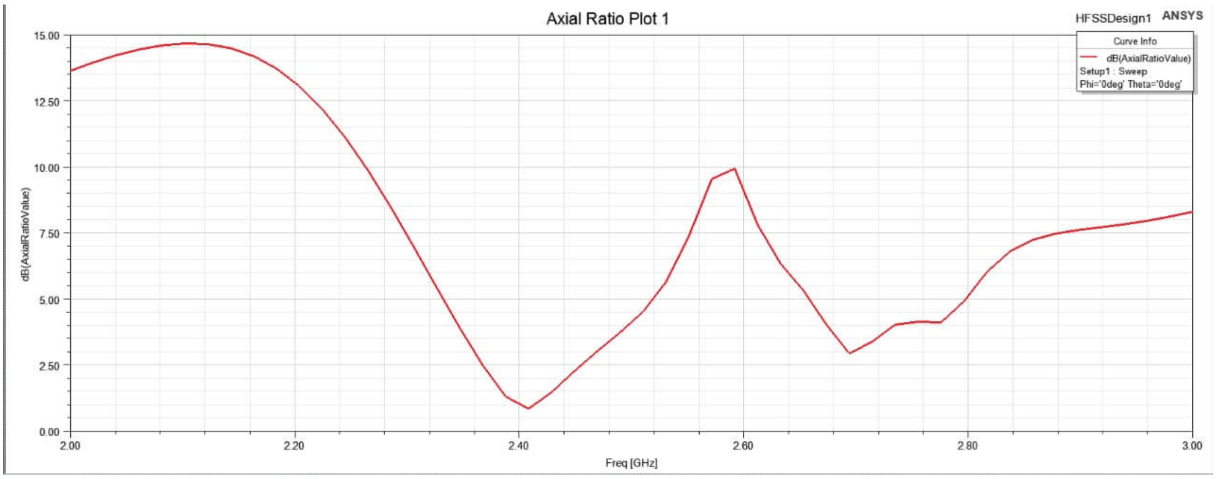
To further study reference Antenna I, Fig. 4 shows the E-field distributions in DRA-1 and DRA-2, at four different phases 0°, 90°, 180°, and 270°. It is assumed that only DRA-1 is excited and DRA-2 is passive. It can be seen from the figure that with the change in time, the direction of the E-field excited in active DRA-1 rotates clockwise and that coupled in DRA-2 rotates anticlockwise. At the same time, it should be noted that for DRA-1, the direction of wave propagation is along the +z axis, while the propagation direction is toward the −z-axis for DRA-2. That is to say, the E-field excited in the active DRA-1 and that coupled in the passive DRA-2 are both LHCP. According to the above analysis, if the coupled E-field in DRA-2 can be changed to RHCP, the port isolation may get improved. For this purpose, four metal strips are added to the two lateral sides of each DRA, as shown in Fig. 1.To analyse the effect of the metal strips, the performance including S-parameters, ARs, radiation patterns, and realized gains of the proposed antenna with metal strips and reference Antenna I without metal strips is compared.

Designing of Antenna in HFSS software



Results





CONCLUSION

In this mutual coupling reduction of a CP MIMO DRA has been investigated. It overcomes all the remarks occur in reference papers like radiation efficiency, reduction of the coupled surface current consequently causes increasing the isolation between the antenna elements.It has been shown that by simply adding four metal strips to the lateral sides of DRA, the rotation direction of the coupled E-Field in the passive DRA can be changed and accordingly the polarisation of the passive DRA can be made orthogonal to that of active DRA.

As a result, a maximum isolation enhancement of 31db is achieved owning to the polarisation orthogonality, without degrading the working bandwidth, the axial ratio and radiation pattern .This decoupling method skillfully makes use of the polarisation orthogonality and it requires no complex decoupling structure. In addition, good CP performance can be maintained whether the two DRAs operates separately or simultaneously.

REFERENCES

[1] .Yang Hu, Yong Mei Pan , Senior Member, IEEE, and Mei Di Yang, "Circularly Polarized MIMO Dielectric Resonator Antenna With decreasing Mutual Coupling", July 2019.

[2]. Jafargholi, A. Jafargholi, and J. H. Choi, "Mutual coupling reduction in an array of patch antennas using CLL metamaterial superstrate for MIMO applications," IEEE Trans. Antennas Propag., vol. 67, no. 1, pp. 179–189, Jan. 2019.

[3]. F. Liu, J. Guo, L. Zhao, G.-L. Huang, Y. Li, and Y. Yin, "Dual-band metasurfacebased decoupling method for two closely packed dual-band antennas," IEEE Trans. Antennas Propag., vol. 68, no. 1, pp. 552–557, Jan. 2020.

[4]. A. Dadgarpour, B. Zarghooni, B. S. Virdee, T. A. Denidni, and A. A. Kishk, "Mutual coupling reduction in dielectric resonator antennas using metasurface shield for 60-GHz MIMO systems," IEEE Antennas Wireless Propag. Lett., vol. 16, pp. 477– 480, 2017.

[5]. J.-Y. Lee, S.-H. Kim, and J.-H. Jang, "Reduction of mutual coupling in planar multiple antenna by using 1-D EBG and SRR structures," IEEE Trans. Antennas Propag., vol. 63, no. 9, pp. 4194–4198, Sep. 2015.

[6]. Q. Li, A. P. Feresidis, M. Mavridou, and P. S. Hall, “Miniaturized double-layer EBG structures for broadband mutual coupling reduction between UWB monopoles,” IEEE Trans. Antennas Propag., vol. 63, no. 3, pp. 1168–1171, Mar. 2015.

[7]. X. Tan, W. Wang, Y. Wu, Y. Liu, and A. A. Kishk, “Enhancing isolation in dualband meander-line multiple antenna by employing split EBG structure,” IEEE Trans. Antennas Propag., vol. 67, no. 4, pp. 2769–2774, Apr. 2019.

[8]. C.-Y. Chiu, F. Xu, S. Shen, and R. D. Murch, “Mutual coupling reduction of rotationally symmetric multiport antennas,” IEEE Trans. Antennas Propag., vol. 66, no. 10, pp. 5013–5021, Oct. 2018.

[9] . C.-M. Luo, J.-S. Hong, and L.-L. Zhong, “Isolation enhancement of a very compact UWB-MIMO slot antenna with two defected ground structures,” IEEE Antennas Wireless Propag. Lett., vol. 14, pp. 1766–1769, Mar. 2015. 22

[10]. S. R. Thummaluru , R. Kumar, and R. K. Chaudhary, “Isolation enhancement and radar cross section reduction of MIMO antenna with frequency selective surface,” IEEE Trans. Antennas Propag . , vol. 66, no. 3, pp. 1595–1600, Mar. 2018.

[11]. T. Hassan, M. U. Khan, H. Attia, and M. S. Sharawi , “An FSS based correlation reduction technique for MIMO antennas,” IEEE Trans. Antennas Propag., vol. 66, no. 9, pp. 4900–4905, Sep. 2018.

[12].Y. Zhu, Y. Chen, and S. Yang, “Decoupling and low-profile design of dual-band dual-polarized base station antennas using frequency-selective surface,” IEEE Trans.