

An Efficient Decoupling Technique for the Nearly Placed Microstrip Antennas

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Abstract—This article proposes a simple single-layer decoupling method that minimizes the coupling between closely placed antennas ($0.03\lambda_0$ edge-to-edge distance) arranged in an E-plane configuration. The proposed decoupling design includes a centrally shorted transmission line incorporated within the available space between the two antennas. It provides a remarkable level of isolation by changing the mode of the coupled field. A prototype is fabricated to verify the practicability of the reported structure. The measured results indicate that an isolation of 21 dB is attained across a bandwidth of 2.5%. The measured radiation pattern exhibits a maximum gain of 5 dBi in the broadside direction. The capability of attaining high isolation with a simple structure makes this antenna an appropriate candidate for MIMO, array, and full-duplex applications.

I. INTRODUCTION

The rapid growth of wireless communication necessitates the construction of high-performance full duplex antennas and MIMO (multiple-input, multiple-output) antennas. MIMO antenna systems offer wide channel capacities, higher data transmission rates, and full-duplex antennas double the spectral efficiency by transmitting and receiving simultaneously. Also, the microstrip arrays have been widely used in wireless communications due to their compact size, low-profile design and affordable production costs. In MIMO systems, FD antennas, and arrays, the mutual coupling is often strong due to the close proximity and surface waves. The coupling deteriorates the overall performance of the antenna system; therefore, decoupling the antennas is essential for better results.

Some techniques have been suggested to diminish the mutual coupling of E-plane and H-plane array antennas [1]– [6]. However, it is always challenging to minimize the coupling in the E-plane array due to the strong coupled field. The reported decoupling approach includes a dual-layer structure [1], DGS [2], [6], lumped elements [4], EBG [3] and quarter patch antennas [5] achieving high levels of isolation. These approaches necessitate sufficient space between the antennas to accommodate the decoupling structure, making a complex design, large profile size, and DGS always generates backlobe radiations.

However, in this paper, a simple centrally shorted transmission line is used to decouple the antennas (arranged in an E-plane configuration), without requiring any extra space and DGS. The presented decoupling design works on the principle of changing the mode of the coupled field. The fabricated prototype exhibits a 21 dB isolation over the entire band of 3.48 GHz to 3.57 GHz.

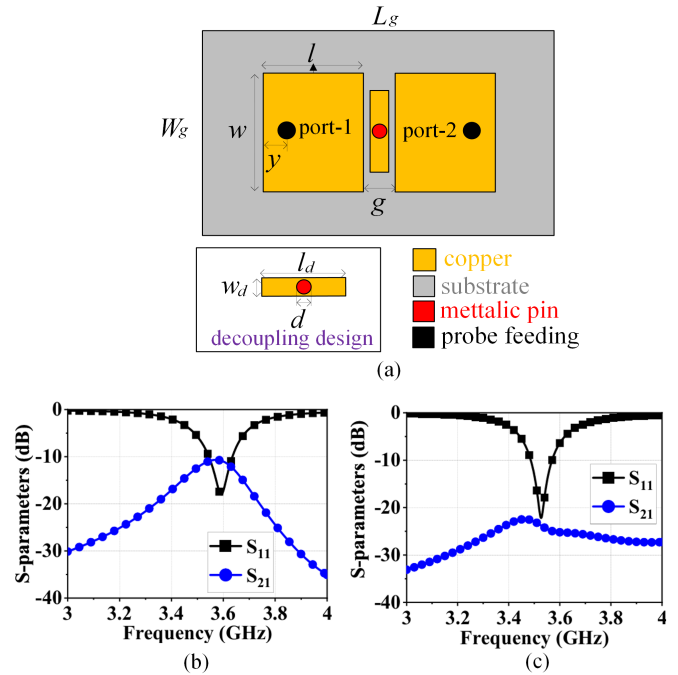


Fig. 1. (a) Proposed antenna structure (Dimensions: $W_g=50$ mm, $L_g=80$ mm, $w=34.85$ mm, $l=26.36$ mm, $y=8$ mm, $g=3$ mm, $w_d=1.37$ mm, $l_d=20.6$ mm, $d=0.97$ mm); Simulated s-parameters (b) without decoupling design, (c) with decoupling design.

II. ANTENNA DESIGN

The proposed structure consists of two symmetrically closely placed E-plane array radiating patches ($0.03\lambda_0$ edge-to-edge distance) and a decoupling line (shorted at the center), as depicted in Fig. 1(a). The complete configuration is designed over a single-layer Roger-5880 substrate which has a dielectric constant of 2.2 and a thickness of 1.57 mm. Both microstrip patch antennas are fed through a coaxial probe feed (Fig. 1(a)). A complete decoupling mechanism is elaborated further in this section:-

A. Working Principle

As seen in Fig. 1 (b), a very high mutual coupling ($|S_{21}| = 10$ dB) occurs between the two antennas without using any decoupling design. Both antennas are half-wavelength long, i.e., they operate in the first resonance mode ($TM_{0/1}$). To effectively reduce this coupling, a decoupling structure is included in the space available between the two antennas. The decoupling structure consists of a microstrip line that is shorted in the center by inserting a via (Fig. 1(a)). The dimensions

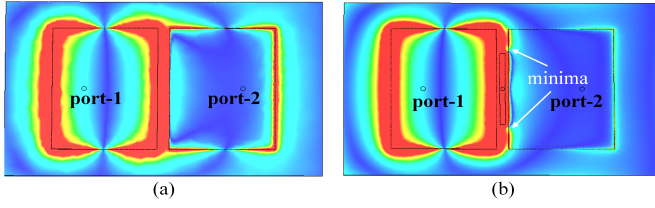


Fig. 2. Electric field distribution (here, port-1 is a Tx and port-2 is a Rx) (a) without decoupling structure, (b) with decoupling structure.

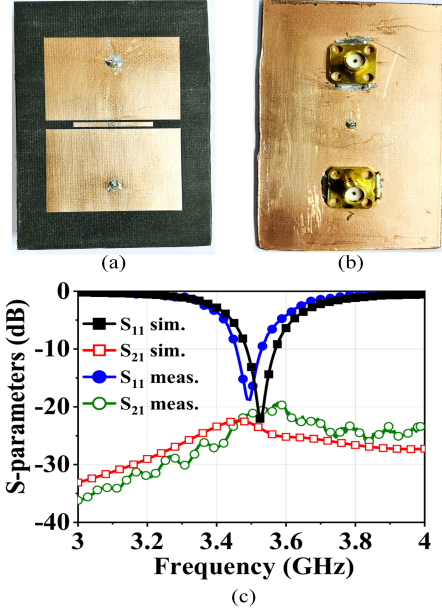


Fig. 3. Fabricated prototype (a) top-view, (b) bottom-view, (c) Simulated versus measured s-parameters.

of the microstrip line are optimized to achieve the highest isolation at the desired frequency. Adding a via at the center of the decoupling line changes the mode of the coupling field, while port-2 operates in the same mode as port-1 ($TM_{0/1}$). Therefore, the coupling reduces due to the difference in modes between the coupled field and the receiver field, consequently the isolation ($|S_{21}|$) enhanced to 23 dB as depicted in Fig. 1(c).

For a better understanding of the decoupling mechanism, the electric field over the radiating edges of the Tx (port-1) and Rx (port-2) antenna is plotted in Fig. 2. In Fig. 2(a) two closely placed antennas have maximum mutual coupling between the two ports, with a continuous electric field pattern at adjacent edges of both antennas (indicating no changes in the coupled electric field) as both antennas operate in the same mode ($TM_{0/1}$) and no decoupling is implemented between them. In contrast in Fig. 2(b) the implementation of the decoupling design changes the pattern of the coupled field, that is, the mode of the coupled field is different than $TM_{0/1}$, while port-2 operates in the $TM_{0/1}$ mode; hence, the coupled field is not able to excite port-2 at the desired frequency (frequency of the $TM_{0/1}$ mode). The proposed decoupling design produces two minima in the coupled field as shown in Fig. 2(b) which in result changes the mode of the coupled field. Therefore, a very

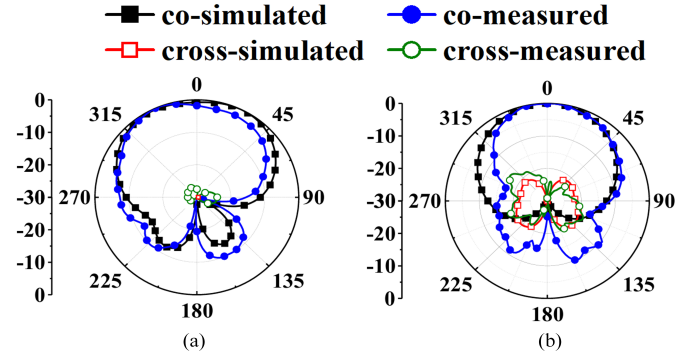


Fig. 4. Simulated versus measured normalized radiation pattern for (a) E-plane, (b) H-plane.

high isolation of 23 dB is achieved within the 2.5% fractional bandwidth (Fig. 1(c)).

III. MEASUREMENT

A fabricated prototype verifies the presented method. The top and bottom views of the fabricated prototype are illustrated in Fig. 3(a) and Fig. 3(b), respectively. The photolithography procedure is used to construct the physical structure. S-parameter measurements were performed using a Keysight VNA and provided an excellent match with the simulated results, as illustrated in Fig. 3 (c). The isolation of upto 21 dB is achieved with a fractional bandwidth of 2.5%. Far-field measurements were conducted in an anechoic chamber. The measured radiation pattern exhibits good performance, achieving a maximum gain of 5 dBi in the broadside direction. The cross-polarization value is less than -20 dBi.

IV. CONCLUSION

The proposed technique effectively reduces the strongly coupled field between the closely placed antennas. The decoupling synthesis is elaborated through electric field distribution. The excellent agreement between the simulated and measured results validates the proposed decoupling method.

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