

# Mutual Coupling Reduction Using Metamaterial Supersubstrate for High Performance & Densely Packed Planar Phased Arrays

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**Abstract:** This paper proposes on an effective mutual coupling suppression technique for planar phased array. This is achieved locating a metamaterial superstrate patch between radiation elements of phased array. The superstrate patch is realised by incorporating slots inside the patch, where the slots are arranged in 2×3 array column. The proposed mutual radiation decoupling technique is implemented on FR-4 substrate. Average coupling suppression of 5 dB is achieved on a low permittivity substrate over its operational frequency band. The proposed technique is (i) simple to implement; (ii) planar design; (iii) easily realised in practice; (iv) overcomes the shortcomings of poor front-to-back ratio previously reported in other radiation suppression techniques; and (v) applicable for densely packed microstrip. Furthermore, the proposed planar technique is highly versatile for various applications having stringent performance requirements.

**Keywords:** Mutual coupling, metamaterial decoupling strip, antennas, phased array.

## I. INTRODUCTION

Microstrip antennas have become popular in wireless communication systems, because of their light weight, low profile, and ease to design antenna array [1-15]. Array antenna offer advantages of high gain and beamforming ability that is important for EMI immunity and radar applications [16]. However, with the growing needs for compact array antennas, the footprint of the array antenna becomes smaller and consequently the performance of the array antennas such as radiation

pattern and antenna gain is significantly degraded by strong mutual coupling and cross talks between neighboring antenna elements.

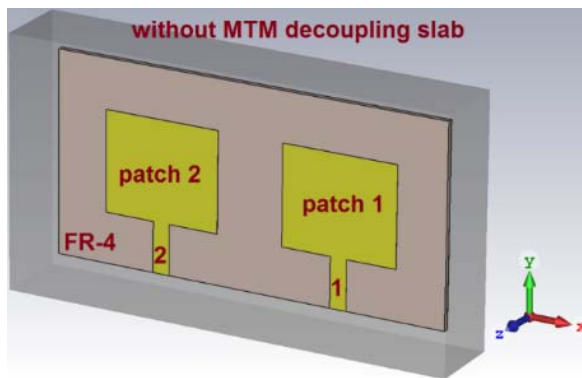
Various techniques have been investigated previously to reduce the mutual coupling between antenna elements by using periodic structure [17-19]. In paper [20] [21], mutual coupling reduction is achieved by introducing walls with mushroom PBG etched on them that are located between antenna elements. Mushroom-like electromagnetic band-gap (EBG) has also been used to reduce mutual coupling reduction in [22] [23]. In [24], DGS is etched off in the ground plane to reduce mutual coupling between two parallel individual planar inverted F antennas (PIFAs). In another technique presented in [25] complementary split-ring resonators (CSRRs) are etched away from the substrate ground plane in a location between two patch antennas.

In this paper a mutual coupling suppression technique is described that is applicable for densely packed microstrip array antennas. Reduction in mutual coupling is realised by inserting a metamaterial superstrate patch between adjacent radiation elements. The superstrate patch includes dielectric slots. The proposed technique is shown to accomplish 5 dB reduction in the mutual coupling between two patch antennas with no degradation in radiation characteristics.

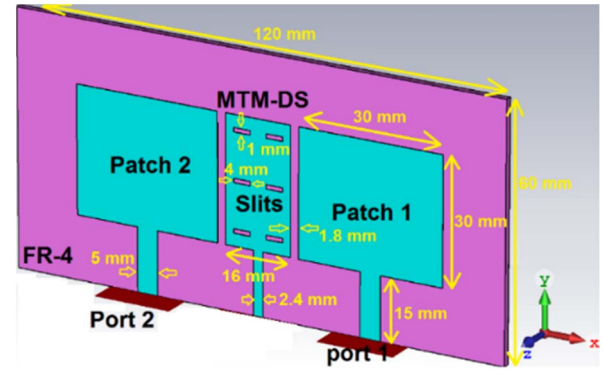
## II. METAMATERIAL DECOUPLING SLAB DESIGN

The initial design consists of  $2 \times 1$  array of square patches arranged symmetrically on the dielectric substrate as shown in Fig. 1(a). The structure is implemented on FR-4 substrate with thickness of 1.6 mm and dielectric constant of 4.3 and  $\tan\delta$  of 0.025. The S-parameter response of the  $2 \times 1$  antenna array is shown in Fig. 2. The antenna has a bandwidth from 9.55 GHz to 10.65 GHz, and resonance is observed at 9.76 GHz and 10.23 GHz with impedance matching of -42 dB and -27 dB, respectively. The maximum transmission coefficient  $S_{12}$  representing the degree of mutual coupling is around -19 dB between 10.2 GHz to 10.7 GHz. The mutual coupling at the resonance frequencies of 9.76 GHz and 10.23 GHz are -31 dB and -23 dB, respectively.

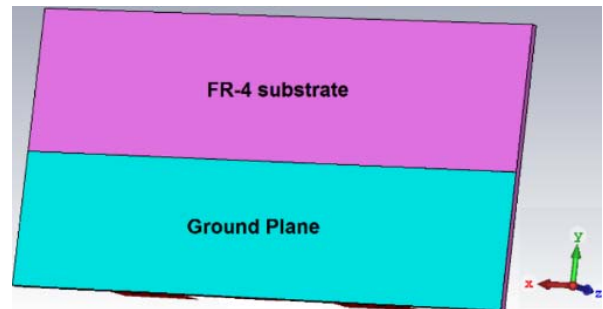
Fig. 1(b) shows the  $2 \times 1$  array of square patches with the proposed metamaterial supersubstrate patch that is inserted between the two patches. The superstrate decoupling patch is realised by incorporating slots inside the patch, where the slots are arranged in  $2 \times 3$  array column. It is evident from Fig. 2 the mutual coupling between the two main patches is reduced by 5 dB over the antenna's operating frequency band. It is also observed with the inclusion of the decoupling patch the operating bandwidth increases by 160 MHz. The frequency bandwidth of the  $2 \times 1$  array is from 9.55 GHz to 10.81 GHz, which corresponds to a fractional bandwidth of 12.38%. Radiation characteristics of the proposed antenna at the two resonant frequencies are shown in Fig. 3, which shows the antenna offers acceptable gain and directivity at its resonant frequencies.



(a) Antenna array without metamaterial decoupling supersubstrate (MTM-DS)



(b) Proposed design with MTM-DS



(c) Bottom view of antenna ground plane

Fig. 1. Layout of the proposed antenna with and without metamaterial decoupling supersubstrate.

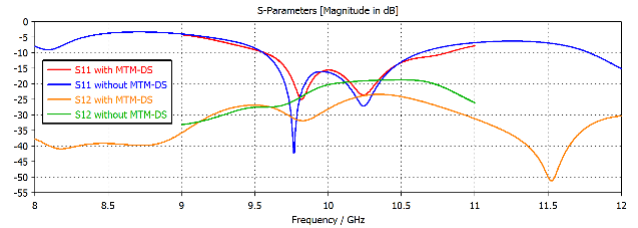
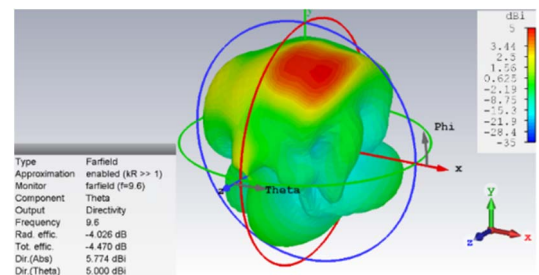
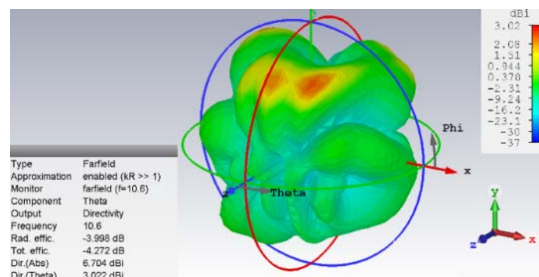


Fig. 2. Antenna transmission and reflection-coefficient S-parameters.



(a)



(b)

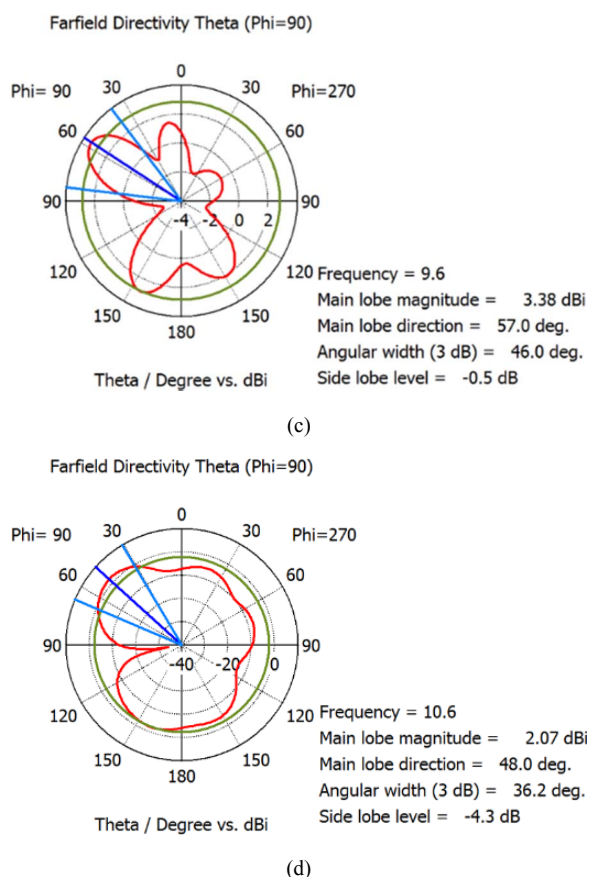


Fig. 3. Radiation characteristics of the proposed antenna with MTM-DS.

### III. CONCLUSION

An innovative metamaterial supersubstrate is shown to decouple mutual coupling that is caused by surface and space waves in a  $2 \times 1$  patch array by 5 dB. The supersubstrate comprised a rectangular patch with  $2 \times 3$  array of slots. The proposed technique is shown to enhance the antenna's bandwidth by 160 MHz without degrading its gain performance. Its features include easy design and implementation that is suitable for densely packed planar phased array antennas.

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