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Li, Q.; Feresidis, Alexandros

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Miniaturised Two-layer Slit-Patch Structure for Decoupling Printed Antennas

Q. Li and A. P. Feresidis

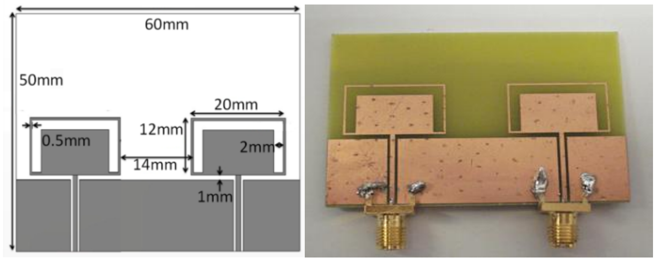
A miniaturised double-layer slit-patch structure is introduced for decoupling two closely spaced CPW-fed printed monopoles with a common ground. The double-layer structure consists of a slit etched on the common ground between the antennas and a conducting dipole element printed on a very thin dielectric film separating the two layers. Simulated results of the antennas' performance as well as measurements of fabricated prototypes are presented.

Introduction: Mutual coupling effects between the individual elements of antenna arrays, such as those employed in modern compact multiple-input-multiple-output (MIMO) communication devices with stringent space restrictions, degrade the performance of the overall antenna system. The reduction of mutual coupling between closely spaced antennas has attracted significant research interest in recent years. Improved antenna designs that result in lower mutual coupling values have been presented [1]. The use of single [2] and multiple [3] defects (slots or slits) on a ground plane has also been proposed due to the ease of fabrication and applicability with different antenna types. Miniaturised convoluted slit geometries were recently presented for decoupling PIFAs on handheld devices [4].

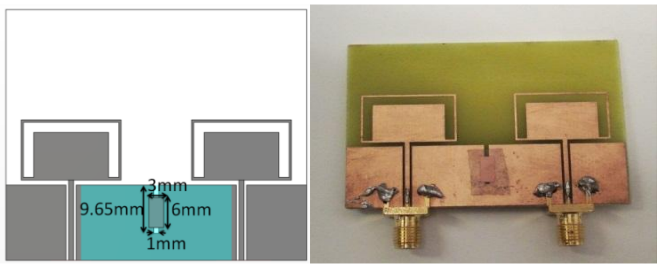
In this paper, novel miniaturised two-layer slit-patch structures are proposed for significantly reducing the mutual coupling between two printed co-planar waveguide (CPW) fed monopoles. The proposed linear miniaturized structures not only allow for a very close separation between the monopoles but also occupy very little space on a very compact ground plane. The results of S-parameters, surface currents and radiation patterns are presented. Two fabricated prototypes have been experimentally tested and the measurements are presented.

Decoupling printed monopoles on compact ground plane: A two-element CPW-fed monopole array is printed on a 60x50mm², 1.5 mm thick, FR-4 dielectric substrate (ε_r=4.5). The layout and dimensions of the original two-element array configuration, designed to operate at a central frequency of approximately 2.45GHz is depicted in Fig. 1(a). At this frequency, the two printed monopoles are 14 mm apart, i.e. approximately 0.11 free-space wavelengths. A photograph of the fabricated structure is also shown in the same figure. Due to the small separation between the two antenna elements, the simulated and measured S_{21} between them was found to be just over -14 dB as shown in Fig. 2a. The mutual coupling between the two monopoles is mainly attributed to the strong currents that are excited on the common ground plane as shown in Fig. 5a.

A very thin two-layer linear slit-patch structure is proposed here as a miniaturized element inserted in the common ground plane between the two monopoles in order to significantly reduce their mutual coupling. A short linear slit (9.65mm length and 1mm width) is etched at the centre of the ground plane, as shown in Fig. 1(b). Due to the small length of the slit, which is much less than quarter-wavelength, its effect on the S_{21} is very small and is not shown here for brevity. A conducting patch (4mm length and 0.4mm width) is printed on a very thin (0.055 mm) dielectric substrate with ε_r=3 and is positioned centrally over the linear slit as shown in Fig. 1b. With the proposed slit-patch structure between the two printed monopoles, a minimum is obtained in the mutual coupling (S_{21}) between the two antennas, due to the strong resonance of the slit-patch structure. An isolation better than -24dB in both simulation and measurement is achieved at the resonant frequency of the monopoles, as shown in Fig. 2(b). When the separation between two antennas reduces to 8mm, compared with a conventional ground plane, the insertion of the two slit-patch structures (shown in Fig 3) reduces the measured S21from -12dB to values lower than -20dB across antenna operating frequency band, as shown in Fig 4. There is a slight discrepancy between measurements and simulations due to the fabrication inaccuracies as well as the manual alignment of the conducting patch over the slit.

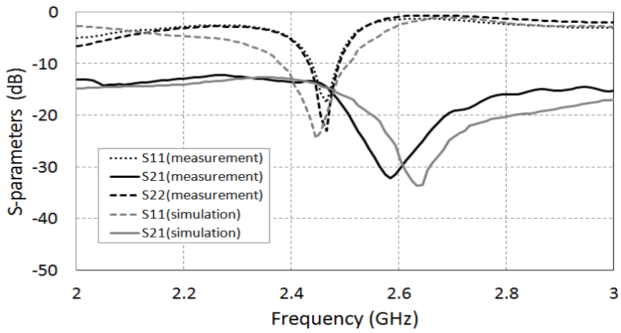


a

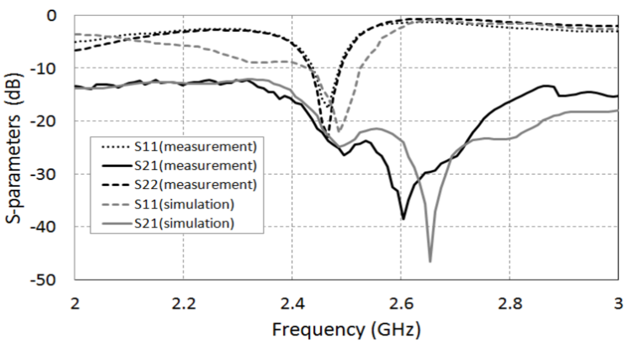


b

Fig. 1 *Printed CPW-fed monopole array*
a with a uniform ground plane
b with proposed miniaturized slit-patch structure in the ground plane*c*



a



b

Fig. 2 *Simulated and measured S-parameters*
a Two-element array (with a uniform ground plane)
b A miniaturized slit-patch structure is inserted in the ground plane

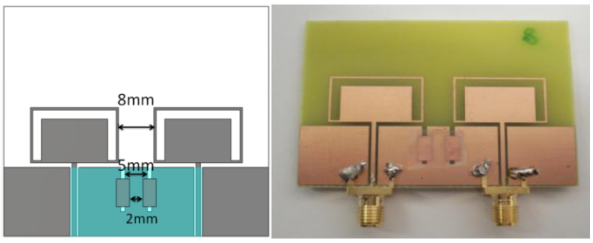


Fig. 3 *Two Printed monopoles (8mm) with two slit-patch structures*

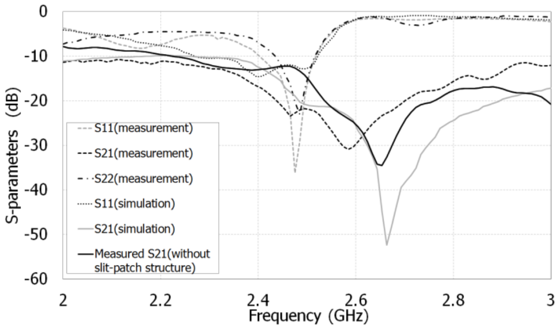
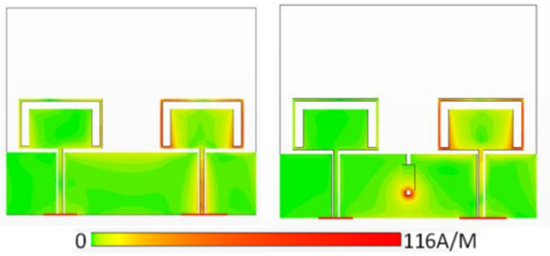


Fig. 4 *Simulated and measured S-parameters of the printed monopole array with two slit-patch EBG structure shown in Fig. 3*



a *b*

Fig.5 *Current distribution*

a Two-element array (with a uniform ground plane)

b A miniaturized slit-patch structure is inserted in the ground plane

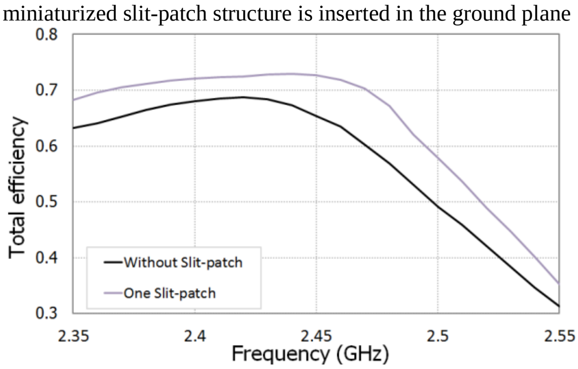


Fig.6 *Total efficiency*

Currents and radiation patterns: When the printed CPW monopole array is built with a compact uniform ground plane (Fig. 5a), a significant current propagates along the edge of the ground thus producing a high mutual coupling between the antenna elements. After the proposed slit-patch structure is inserted in the ground between the two antennas (Fig. 5b), it is evident that very little current reaches the passive element on the left. The total efficiency has also been calculated from the simulated results using: $\eta_{tot} = \eta_{rad}(1 - |S_{21}|^2 - |S_{11}|^2)$. The total efficiency of the antenna array shows a slight improvement of just over 5% across the operating bandwidth after the slit-patch structure is employed between two antennas (Fig. 6).

Conclusion: A novel approach for realizing miniaturised structures that significantly reduce the electromagnetic coupling between closely spaced printed monopoles has been presented. An S21 minimum of less than -24dB was obtained by virtue of the resonance of a very thin two-layer slit-patch structure while the total antenna efficiency increased by approximately 5%.

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Q. Li (*Electronics and Photonics, Institute of High Performance Computing, A*STAR, 138632, Singapore*)
E-mail: liq@ihpc.a-star.edu.sg

A. P. Feresidis (*School of Electronic, Electrical and Computer Engineering, University of Birmingham, B15 2TT, UK*)
E-mail: a.feresidis@bham.ac.uk

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