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LETTER

Mutual coupling between identical planar inverted-F antennas

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Abstract

Mutual coupling between two identical planar inverted-F antennas (PIFA) located on an infinite ground plane is studied numerically. Several arrangements of side-by-side, collinear, parallel-in-echelon, and orthogonal PIFA antennas with element spacing varying from 0.06λ to 1.20λ are investigated at the design frequency of 1.9 GHz, and in the −6 dB bandwidth between 1.8 and 2.0 GHz. It is found that choosing configurations that maximizes the separation between the open-end of the PIFAs reduces the mutual coupling.

Keywords: Inverted-F antennas (PIFA); Mutual coupling; Side-by-side; Collinear; Parallel-in-echelon; Orthogonal configuration; MIMO systems

1. Introduction

The planar inverted-F antenna (PIFA) has advantages of having small and multiband resonant properties. These characteristics make the PIFA a suitable antenna candidate to mobile phones.

Shrinking the size of the mobile phone also affects the distance between the antenna and the other components, such as the loudspeaker and the camera decrease in size as well. This motivates the need for information regarding how the antennas should be placed on the ground plane as well as the placement of other components with respect to the antenna and the ground plane. The job is also motivated by the fact that applications such as diversity and multiple-input multiple-output (MIMO), e.g., may require an extra antenna inside the mobile phone, hence information regarding how these antennas should be oriented in order to minimize the coupling is also needed [1,2].

Cramming many antennas on the same finite-sized ground plane results in higher mutual coupling due to the smaller distances between the antennas [3].

However, mutual coupling between the antenna elements affects the correlation [4–7]. For a fixed sized mobile phone an increase in the number of antenna elements causes inevitably higher mutual coupling due to the smaller distances between the antennas [3]. The increased mutual coupling often results in higher spatial correlation, which again leads to a lower MIMO gain as compared to the case of fully uncorrelated antenna signals [8].

The main objective of this research is to explain the coupling between two identical PIFA antennas. Symmetrical as well as unsymmetrical coupling scenarios using two identical PIFAs located close to each other is investigated, in order to determine the mutual coupling versus separation for fixed orientations and mutual coupling versus orientation of the antennas for a fixed separation. The results illustrate how to orientate and locate the antennas in order to

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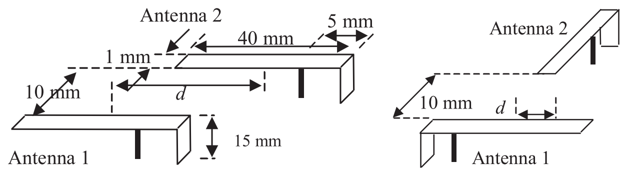

Fig. 1. Illustration of the different configurations that are investigated.

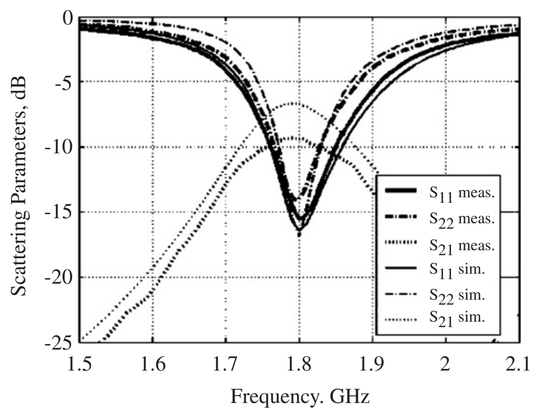

Fig. 2. Simulated and measured scattering parameters.

minimize the coupling. The scattering parameters are found by the use of the method-of-moment simulation program IE3D [9]. The experimental and the simulation results are in good agreement.

2. Materials and methods

This section is divided into two subsections. In Section 2.1, a two-antenna configuration is investigated based on simulated results as well as measurements on a fabricated prototype. Section 2.2 describes the different scenarios that are investigated.

2.1. Verification of the simulation results

The presented two-antenna configuration consists of two 40 mm long, 1.5 mm wide and 5 mm high PIFAs located orthogonal on a 40 mm × 100 mm ground plane. The feed point is located 5 mm from the edge where a 90° bend forms the short to the ground plane. The parallel and the orthogonal PIFA configuration are illustrated in Fig. 1.

Good agreements between the simulation and measurement results are seen in Fig. 2. Both antennas have resonant frequency at 1.8 GHz.

The measured total efficiency of Antenna A1 is higher than 40% between 1.7 and 1.9 GHz. Antenna A2 yields a total efficiency higher than 25%, as shown in Fig. 3.

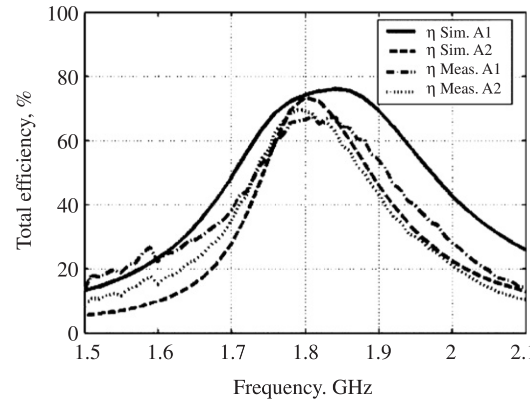

Fig. 3. Total efficiency for Antennas A1 and A2.

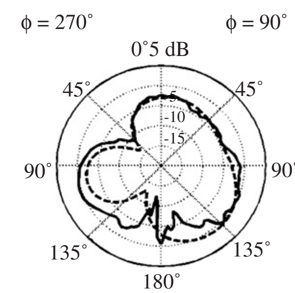

Fig. 4. Simulated (dashed) and measured (solid) radiation patterns cut at 1.8 GHz for Antenna A1 for $\phi = 90°$. The dips in the measured θ-cuts for $\phi = 180° \pm 12°$ are due to the antenna mounting and positioning system [10].

Good agreement between the simulated and measured radiation patterns is obtained, see Fig. 4. The measured maximum gain is 2.6 dBi for Antenna A1 (3.2 dBi simulated), and 1.5 dBi for Antenna A2 (1.7 dBi simulated).

The difference in the simulated and measured results could be explained by the difference between the two antennas, which are hand made, i.e., made by using a scalpel, and therefore not completely identical. Also, the effect from the coaxial cable used in the prototype affects the performance; especially the radiation pattern suffers from this.

2.2. Investigated scenario

The remaining investigations, which are presented in the following section, are based on a two-antenna configuration located on an infinite ground plane. The infinite ground plane is chosen in order to determine the influence of the distance and mutual orientation and not the effect of the location on a finite ground plane.

The investigated PIFA consists of a 40 mm × 1 mm patch located 15 mm above an infinite perfect conducting ground plane. The feed line is located 13 mm from the edge; where a 90° bend forms the short circuit to the ground plane, see illustration in Fig. 5.