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Review Summary on Design of Multiband Patch Antenna using EBG for Mutual Coupling Reduction

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Abstract:- **Mutual Coupling (MC) is the exchange of energy between multiple antennas when placed on the same PCB, it being one of the critical parameters and a significant issue to be considered when designing MIMO antennas. It appears significantly where multiple antennas are placed very close to each other, with a high coupling affecting the performance of the array, in terms radiation patterns, the reflection coefficient, and influencing the input impedance. Moreover; it degrades the designed efficiency and gain since part of the power that could have been radiated becomes absorbed by other adjacent antennas' elements. The coupling mechanism between multiple antenna elements is identified as being mainly through three different paths or channels: surface wave propagation, space (direct) radiation and reactive near-field coupling. In this paper, various coupling reduction approaches that are commonly employed in the literature are categorized based on these mechanisms. Furthermore, a new comparative study involving four different array types (PIFA, patch, monopole, and slot), is explained in detail. This thesis primarily focuses on three interconnected research topics for mutual coupling reduction based on new isolation approaches for different wireless applications (i.e. Narrowband, Ultra-wide-band and Multi-band). First, a new Fractal based Electromagnetic Band Gap (FEBG) decoupling structure between PIFAs is proposed and investigated for a narrowband application. Excellent isolation of more than 27 dB (Z-X plane) and 40 dB (Z-Y plane) is obtained without much degradation of the radiation characteristics. It is found that the fractal structures can provide a band-stop effect, because of their self-similarity features for a particular frequency band. Second, new UWB-MIMO antennas are presented with high isolation characteristics. Wideband isolation (≥ 31 dB) is achieved through the entire UWB band (3.1-10.6 GHz) by etching a novel compact planar decoupling structure inserted between these multiple UWB antennas. Finally, new planar MIMO antennas are presented for multi-band (quad bands) applications. A significant isolation improvement over the reference (≥ 17 dB) is achieved in each band by etching a hybrid solution.**

Keywords:-*Multiband Patch Antenna, Electromagnetic Band Gap (EBG), Mutual Coupling Reduction, Wireless Communication, Antenna Design, Surface Wave Suppression.*

Introduction

The rapid advancement in wireless communication systems has led to the increasing demand for compact, efficient, and high-performance antennas. Multiband patch antennas are widely used due to their lightweight, low profile, and ease of integration with modern communication devices. However, one of the significant challenges in designing multiband patch antennas is the mutual coupling between adjacent antenna elements, which can degrade performance, reduce radiation efficiency, and increase interference. Electromagnetic Band Gap (EBG) structures have emerged as a promising solution to mitigate mutual coupling in antenna arrays.

Objective

This study focuses on the design and analysis of multiband patch antennas integrated with EBG structures to reduce mutual coupling. The primary objective is to explore the impact of EBG on the performance of multiband patch antennas, particularly in terms of mutual coupling reduction, bandwidth enhancement, and radiation pattern improvement.

Methodology

Antenna Design: A multiband patch antenna is designed to operate at multiple frequency bands, such as 2.4 GHz, 5.2 GHz, and 5.8 GHz, which are commonly used in Wi-Fi and other wireless communication systems.

The EBG structure is optimized to achieve the desired bandgap characteristics.

Simulation and Analysis: The performance of the multiband patch antenna with and without EBG is evaluated using electromagnetic simulation tools (e.g., HFSS, CST). Key parameters such as S-parameters (S11, S21), gain, radiation patterns, and mutual coupling are analyzed.

Fabrication and Testing: The designed antenna is fabricated, and its performance is measured using a vector network analyzer (VNA) and an anechoic chamber to validate the simulation results.

Correlation of different antennas types at varying separation

Envelope Correlation Coefficient (ECC) between antenna array elements is investigated according to antennas separation variation, in this work, ECC of different microstrip antenna array types was evaluated using S-parameters of the MIMO system as defined before in Equ, which assumed that antennas system are lossless, and the antennas are excited separately, keeping the other antennas matched terminated. Although the calculation of ECC using S-parameters approach in is a very simple and fast, it is only accurate for the case of loss free antennas. In general; the antennas tend to be more correlated (coupled). A strong mutual coupling means a high correlation between the received signals by antenna elements; the high level of correlation affects and degrades all the performance parameters of the MIMO and diversity system, as an example, the antenna efficiency becomes worse and both system channel capacity and diversity gain will decrease.

Table 1: Comparison of the ECC in dB at 1.9 GHz between four different antenna types at varying separation (in terms of λ_0)

Separation	PIFA	Patch	Monopole	Slot
0.3 λ_0	-38	-30	-14.83	-10.6
0.4 λ_0	-31	-33.8	-21.87	-19.2
0.5 λ_0	-42	-56	-22	-27.8

In Figure 1, the envelope correlation coefficient for the different antenna types is investigated when the separation between these antennas are varying from 0.3 λ_0 to 1.0 λ_0.

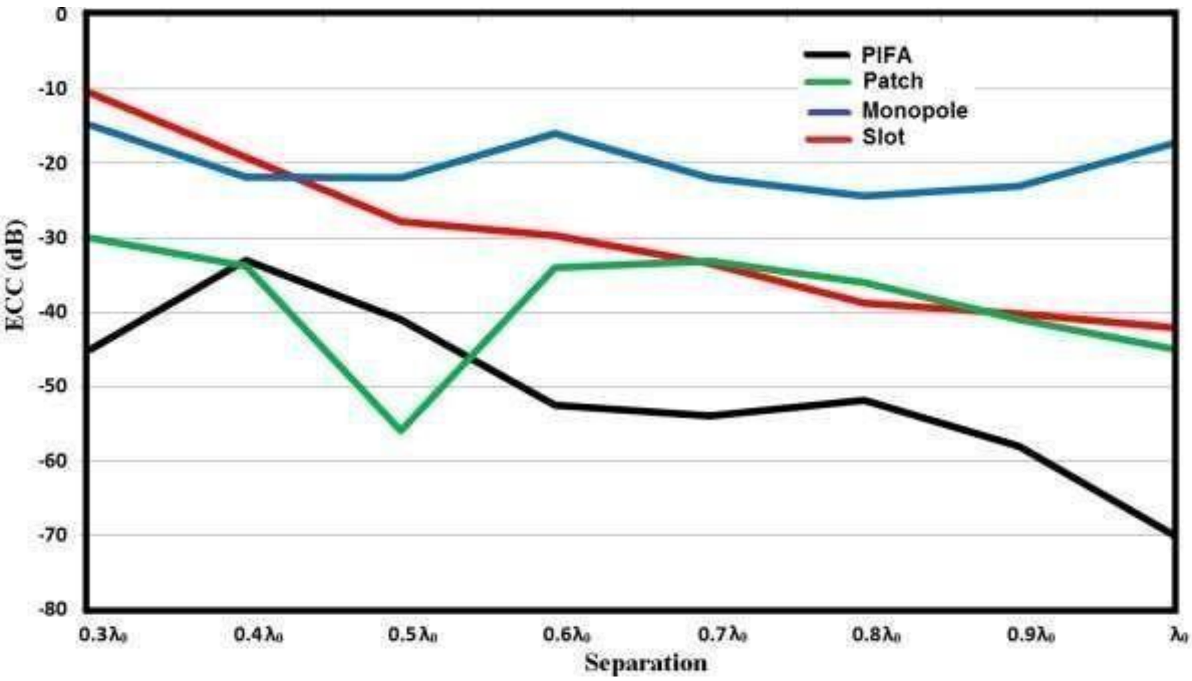

Figure 1: Comparison of envelope correlation coefficient (ECC) with different antennas types at varying separation (in terms of λ_0)

From the simulated results, the envelope correlation coefficient in the working band of the Patch antenna and PIFA antenna are respectively; lower than -30 dB (at separation $\leq 0.58\ \lambda_0$) and -40 dB (at separation $\geq 0.58\ \lambda_0$), which are smaller than that other antenna types (slot and monopole). This observation indicates better behavior and diversity performance of MIMO antenna system will be achieved by using these antenna types (PIFA and patch).

Performance of different antennas types at a fixed separation

Finally, a comparison of various antenna performance parameters at resonant frequency including return loss, BW, gain, directivity and radiation efficiency for different microstrip antenna array types is shown in Table 2 at fixed minimum separation between these antennas (d = 0.3 λ_0).

Table 2: Comparison table of the antennas performance between four different antenna types at fixed separation (d = 0.3 λ_0)

Antenna type	f_r, GHz	S_{11}, dB	BW, %	Gain, dBi	Dir, dBi	Rad eff, %
PIFA	1.93	-23.2	1.90	2.7	3.8	75
Patch	1.92	-21	2.63	3.1	5.45	55
Monopole	1.93	-22	30	1.4	1.5	90
Slot	1.94	-24.8	12.2	2.3	2.48	86

It is apparent from Table 2 that both PIFA and patch arrays achieve a narrower (lower) performance in terms of BW, with a close values of 1.90 % and 2.63 %, respectively, followed by the slot antenna array with a moderate BW value of 12.2 % and finally the monopole antenna array achieves a wider BW performances with a value of 30 %. It should be noted that the considered BW corresponds to the frequency range over which VSWR is < 1.92. Means a return loss of 10 dB or about 11% reflected power. As regards the radiation characteristics, the patch antenna array offers a higher directivity and gain with an average efficiency factor (55 %) as seen in the same table. In the second position comes the PIFA array that achieves a reasonable directivity of 3.8 dB with moderate radiation efficiency of 75%, immediately followed by slotand monopole antenna arrays with highest radiation efficiency (≥ 90 %), with a reasonable directivity of 2.48 dB and 1.5 dB; respectively.

Summary:

In MIMO systems, more than one antenna is implemented on a small terminal. However, having multiple antennas on small terminals (such as mobile handsets or PDAs), while maintaining their performance, remains a significant challenge task for each antenna designer in terms of reducing the MC and correlation effects between these MIMO antennas. In this chapter, the essential background theory to the mutual coupling (MC) problem in microstrip array antennas has been discussed. The essential requirements/challenges when designing multiple antennas in small terminals regarding the antenna coupling mechanisms and isolation enhancement approaches have been identified. For a multiple-antenna configuration, it is essential to quantify the contribution of each of the underlying coupling mechanisms and to identify the dominant ones. Only through these types of investigations, is it possible to devise a systematic method for improving antenna isolation, either by choosing one suitable coupling reduction approach or through a combination of more than one. There are different possibilities for reducing MC between different microstrip antennas. In fact, several methods have been suggested in the extant literature for minimising or even eliminating such coupling effects based on the antenna structure and its radiation as well as feeding mechanisms, such as using EBG, DGS, resonators, or inserting slots/slits in the ground plane. In general, each isolation technique has its advantages and disadvantages depending on the decoupling approach employed; a brief comparison of the isolation techniques has been provided.

Furthermore, a new comparative study involving four different microstrip antenna array types (PIFA, patch, monopole, and slot), based on diversity performance (mutual coupling effects and correction), has been explained in detail. The major content of this chapter is a manuscript published and presented at the Loughborough Antennas and Propagation.

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Search with: "Multiband Patch Antenna" AND "EBG" AND "Mutual Coupling" for more recent works (2020–2024).