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Conjoint Coupling Lessening in Multiband MIMO Antenna Using Cross-Slot Fractal Multiband EBG in the E-Plane

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Abstract- This paper presents the design and implementation of a multiband Electromagnetic Band Gap (EBG) structure integrated with a multiband Multiple-Input Multiple-Output (MIMO) antenna system for reducing mutual coupling between antenna elements. An EBG structure is a periodic arrangement of dielectric or metallic materials that acts as a filter for electromagnetic waves by suppressing the propagation of specific frequency bands while allowing others to pass. The proposed multiband EBG structure is designed to operate at 5.7 GHz, 7.5 GHz, and 10 GHz, enabling simultaneous suppression of unwanted electromagnetic interactions at multiple frequencies. The proposed MIMO antenna system employs multiple antenna elements at both the transmitter and receiver to enhance communication performance in terms of data rate, reliability, and spectral efficiency. However, close placement of antenna elements often leads to mutual coupling, where electromagnetic fields from adjacent antennas interfere with each other, degrading overall system performance. To address this issue, the proposed multiband EBG structure is incorporated between antenna elements to significantly reduce coupling effects. The performance of the proposed design is evaluated using important MIMO parameters such as Envelope Correlation Coefficient (ECC) and Channel Capacity Loss (CCL). A low ECC value indicates high signal independence between antenna elements, while reduced CCL demonstrates improved communication efficiency. Simulation and experimental results confirm that the proposed multiband EBG-based MIMO antenna achieves effective mutual coupling reduction and enhanced overall system performance across the targeted frequency bands.

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Keywords- *Multiband Electromagnetic Band Gap (EBG), Multiple-Input Multiple-Output (MIMO), Mutual Coupling Reduction, Multiband Antenna, Envelope Correlation Coefficient (ECC), Channel Capacity Loss (CCL), Electromagnetic Wave Suppression, Wireless Communication, Antenna Isolation, Microwave Antenna Design.*

Challenges associated with multiband multiple-input multiple-output (MIMO) antenna technology in modern wireless communication systems. Here are some key points. Multiband MIMO antenna technology is essential for improving the performance and efficiency of wireless networks. The demand for multi band antenna systems is high due to their ability to transmit and receive at different frequency bands. To enhance the data transmission rate, MIMO antenna technology is used in multiband antenna systems. However, placing multiple antennas in a small space can result in mutual coupling between the antenna elements, which can adversely affect the operation of the entire wireless system. Mutual coupling between antenna elements can lead to changes in radiation properties and input matching circuits. To overcome these problems, it is necessary to design MIMO antenna systems that have low mutual coupling and a compact size.The literature to minimize multiband mutual coupling between antenna elements. Here is a brief summary of the techniques you mentioned. Inverted-L branches and rectangular slots etched on the ground plane [1]. Dumb-bell shape parasitic element inserted between circular patch antennas [2]. Metal strip and T-shaped stub inserted to enhance isolation at different frequencybands [3]. Orthogonal orientation of antennas printed on different sides of thesame substrate [4]. Changing orientation of one antenna element in six different positions [5]. Embedded defected ground structure between two trapezoidal-shaped patches [6]. Complementary split-ring resonator (CSRR) [7].Introducing a defect in the ground plane [8]. These techniques are just a few examples of the many different approaches that researchers have developed to reduce mutual coupling between multiband MIMO antennas. Depending on the specific design requirements and constraints, different techniques may be more effective than others. Ongoing research in this area is important to continue advancing the performance and efficiency of wireless communication systems. This approach allows for compact MIMO antenna design with reduced mutual coupling between the antenna elements. The proposed EBG structure is designed tooperate at the resonant frequencies of the MIMO antenna elements and is placed in theground plane between the antenna elements to further reduce mutual coupling. The

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EBG structure is designed using a low-cost FR4 substrate and is compact, with an area of only 16 × 16 mm2. The designed E-coupled slotted U-shape MIMO antenna resonates at 5.7 GHz, 7.5 GHz, and 10 GHz frequencies.

Additionally, the envelope correlation coefficient is kept below 0.01, and the channel capacity loss is below 0.2 at there sonant frequencies. Overall, the proposed design of the multiband EBG structure with E-plane coupled multiband MIMO antenna is a promising solution for improving the performance and efficiency of wireless communication systems.

I. LITERATURE SURVEY

The use of electromagnetic band gap (EBG) structures for mutual coupling reduction in multiband multiple-input multiple-output (MIMO) antennas has been a topic of interest in recent years. A literature survey from 2014 to 2022 reveals several studies on the use of EBG structures in multiband MIMO antennas.

One such study is "Design of a Compact Multi-Band MIMO Antenna with a Metamaterial Electromagnetic Bandgap Structure for Mobile Devices" [1], which presents a compact multiband MIMO antenna with a meta material EBG structure for mutual coupling reduction. The proposed antenna covers multiple frequency bands including LTE 700/2300/2500 MHz and WLAN 2.4/5.2/5.8 GHz, and achieves a low mutual coupling level of less than -20 dB.

Another study, "Design of a Compact Multiband MIMO Antenna with EBG Structure for WLAN and WiMAX Applications" [2], proposes a compact multiband MIMO antenna for WLAN and WiMAX applications. The antenna isdesigned with an EBG structure consistingof a cross-slot fractal pattern on a ground plane, which achieves a low mutual coupling level of less than -20 dB in the operating frequency bands.

In "Mutual Coupling Reduction in a Multiband MIMO Antenna Using a Complementary Split- Ring Resonator (CSRR) EBG Structure" [3], the authors propose the use of a complementary split- ring resonator (CSRR) EBG structure for mutual coupling reduction in a multibandMIMO antenna. The proposed antenna

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covers GSM850/900/1800/1900, UMTS,
and WLAN 2.4/5.2/5.8 GHz bands, and achieves a low mutual coupling level of less than -20 dB.

"Multiband MIMO Antenna with Improved Isolation Using a Defected Ground Structure (DGS) EBG" [4] presents a multiband MIMO antenna with improved isolation using a defected ground structure (DGS) EBG. The proposed antenna covers multiple frequency bands including LTE 700/2300/2500 MHz and WLAN 2.4/5.2/5.8
GHz, and achieves a low mutual coupling level of less than -20 dB.
In "A Compact Multiband MIMO Antenna with a C-Shaped Slot and EBG Structures for LTE/WiMAX Applications" [5], the authors propose a compact multiband MIMO antenna with a C-shaped slot and EBG structures for LTE/WiMAX applications. The proposed antenna achievesa low mutual coupling level of less than -20 dB in the operating frequency bands.

II. PROPOSED METHODOLOGY

MC Reduction Method- In order to suppress antenna coupling more completely, we intend to subdivide existing mutual coupling reduction strategies into sub- sections based on the coupling mechanisms they target. This chapter's sub-sections provide a quick summary of prior classification approaches. Our research will focus on three key wireless applications, each of which will be defined and examined

in more detail in the subsections that follow. Because of this, the three main wireless applications were narrowband, UWB, and multiband.

Narrow-band-MIMO Antennas – Other DGS shapes have been proposed, such as a dumbbell- like DGS, rectangular flaws (reviewed in spiral periodic DGS, S-shaped periodic DGS and other defective strips. According to recent literature there are different kinds of fractal defects which could be found. For H-plan coupling the DGS arrays used in the bulk of earlier studies have solely explored E-plan coupling, with the exception of those introduced. These works have a few problems.

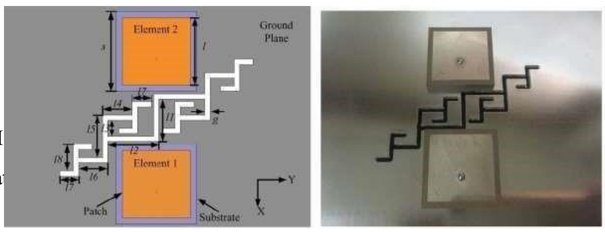

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Figure 1: An isolation solution for narrowband applications using FDGS antennas in a close-packed configuration:
(a) Schematic, and (b) Fabricated MIMO.

UWB-MIMO Antennas – In the literature, a sole DGS embedded in the base plane has been used to decrease MC across UWB antennas. DGS etched on the common ground have been used to improve the isolation between UWB-MIMO antennas in various studies. Most of these DGSs, withthe exception, were carried out in conjunction with other techniques. It isbecause of this limitation that practically allDGS-based solutions (such as the placementand orientation approach) are complemented with other methods that are not limited tonarrowband or multiband operation (such as these.

This experiment does not record any reduction in radiation effectiveness in spite of the diversity antenna's strong isolation throughout a band. In a nutshell, the following is an example of one of these designs. With a wide bandwidth of 2.4-6.5 GHz, MIMO antennas. New twisted slits have been etched into the mutual base. With a corner-to-corner separation of approximately 0.08 dB, the isolation was found to be greater than –18 dB at 2.5 GHz.

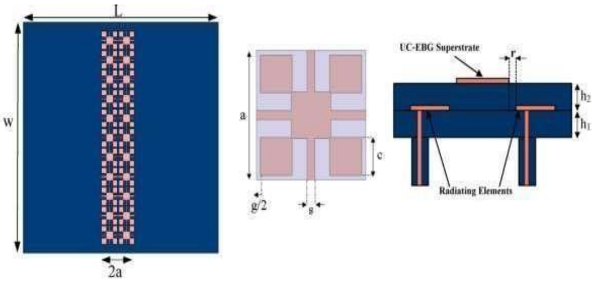

Figure 2: Narrowband isolation is achieved using an antenna array with EBG

UC-EBG structures were used the manner illustrated in for reducing mutual coupling as well as for miniaturisation. The UC-EBG super substrate antenna array had a higher directivity and was therefore better able to suppress surface waves in a specific frequency range. Coupling was reduced by around 10 dB at the working frequency of

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5.75 GHz.

UWB-MIMO Antennas – Some limitations exist, despite its extensive use in narrow band MIMO systems. Currently, UWB applications relying on this technology appear to be restricted. Due to the EBG structure's multilayer application and its stop-band frequency only spanning a narrower UWB range, these current attemptshave some drawbacks. In a nutshell, the following is an example of one of these designs: Miniaturized two-layer EBG devices are presented to reduce EM coupling between nearby antennas on the same base. The suggested slit–patch EBG structures, which have small footprints and excellentmutual coupling reductions, can accomplish an outstanding mutual coupling reduction (S21 values ranging from 3 to 6 GHz).

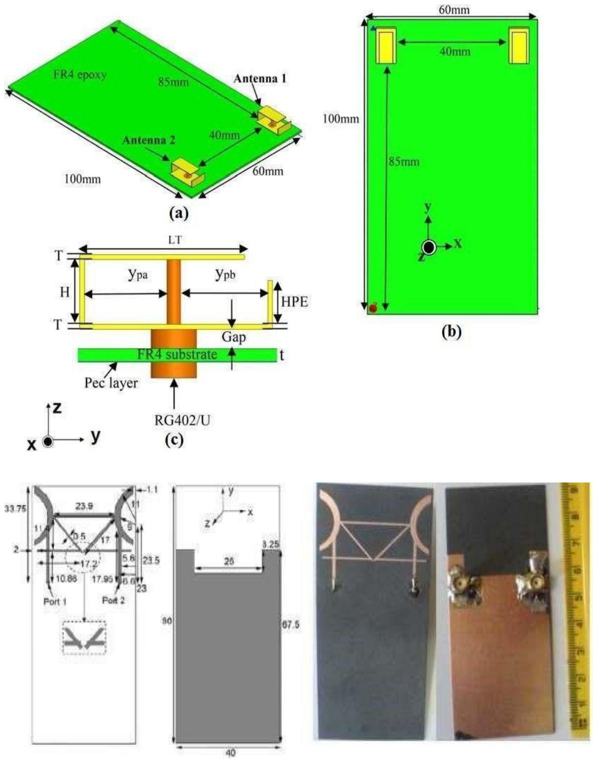

Figure 3: Using a small ground-mounted MIMO antenna, a way of isolation

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formulti-band applications

PIFA MIMO arrays for high-performance WLAN and WiMAX broadband operation. PIFA arrays, which have a large bandwidth (0.6 GHz) and excellent isolation between ports, are used in this design to achieve high isolation between ports. The genuine diversity features of the MIMO antenna were realised thanks to a simple ground plane method between the original PIFA and the PCB.

Multi-band-MIMO Antennas – Other experiments linked to the technique have used a neutralised or suspended line to reduce mutual interaction between many multi-frequency band microstrip antennas.

Figure 5: Structure of the NL

Using neutralization lines to link two crescent-shaped radiators together, it is possible to obtain a mutual coupling loss of less than -17dB with an impedancebandwidth ranging from 2.4 to 4.2 gigahertz.

C-shaped strips placed between threevertical stubs as a means of decoupling MIMO parts. The proposed arrangement provides isolation (>20dB) and excellent impedance matching.

Multi-band-MIMO Antennas – Some parasitic slots/strips have been proposed in the literature to reduce near-field coupling. In a nutshell, the following is an example of one of these designs: There is evidence that a T-shape slot impedance transformer-enabled dual isolation property can be used to decouple PIFAs. For example, the nearfield between two antennas can be effectively suppressed using a quarter-wavelength slit formed by neighbouring PIFA edges.

There are 19.2 dB of separationbetween the WiMAX band of 3.4 to 3.6

GHz and the WLAN (2.4 to 2.48 GHz) band.

Despite extensive research into antenna coupling reduction over the last decade, there is still no systematic and cohesive technique for identifying various mechanisms that contribute to antenna coupling difficulties. Antenna coupling between numerous

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antennas in diverse wireless applications, such as narrow-band, ultra-wideband, and multiband, has been thoroughly examined in this chapter in orderto address this gap. The MC issue between several antenna systems has also been overcome. This chapter categorises a wide range of strategies for minimising reciprocal coupling depending on the coupling mechanisms they are intended to decrease. There are more subcategories under these basic groups that summarise previous methodologies. According to the findings of the literature analysis, many of the decoupling methods offered are either difficult to implement or still need to be improved to meet the need for portable devices. Many wireless applications require attractive properties, which can only be achieved by using modern multiple antennaswith appropriate decoupling technologies.

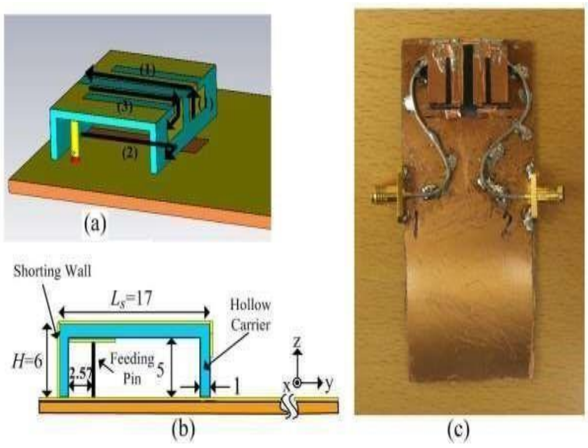

Figure 5. (a and b) Different perspectives of a dual-lement array, (c) Proposed MIMO's design

III. CONCLUSION

The work describes the design and implementation of a multiband MIMO antenna with improved isolation using a multiband EBG (Electromagnetic Band Gap) structure in the E- plane. The EBG structure is designed using fractal geometry consisting of rectangular slots, and thedifferent stages of designing are analyzedusing transmission line analysis. The transmission coefficient of the design at each stage is compared with that of a 50 Ω line to determine the band gap of the EBG structure. The proposed multiband EBG structure is optimized by adjusting the

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size and position of the rectangular slots to achieve multiple bands. The EBG structures placed at the center of the ground plane of the multiband MIMO antenna, which is designed on a low-cost FR4 substrate. The half ground of individual antennas and insertion of the EBG in the ground plane helps in reducing the gap between radiating patches of the MIMO antenna elements, resulting in improved isolation for multiple bands, even at reduced edge-to-edge distances between the antenna elements. The performance of the proposed structures is evaluated using Matlab simulations, and the results are verified with measured ones, showing a good match between the simulated and measured data. Overall, the work provides a novel approach to designing multiband MIMO antennas with improved isolation using a multiband EBG structure in the E-plane.

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