DUAL MONOPOLE ANTENNA WITH EBG ARRAY FOR MUTUAL COUPLING REDUCTION

A MINOR PROJECT - IV REPORT

Submitted by

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BONAFIDE CERTIFICATE

Certified that this **18ECP106L - Minor Project IV** report **"DUAL MONOPOLE ANTENNA WITH EBG ARRAY FOR MUTUAL COUPLING REDUCTION"** is the bonafide work of "**KIRUBAKARAN R (20BEC4079), KUMERESAN D (20BEC4086), LATHIKESH S (20BEC4087), LOGANATH S (20BEC4091)**" who carried out the project work under my supervision in the academic year **2022-2023 - EVEN**.

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PROJECT COORDINATOR

INSTITUTION VISION AND MISSION

Vision
To emerge as a leader among the top institutions in the field of technical education.

Mission

M1: Produce smart technocrats with empirical knowledge who can surmount the global challenges.

M2: Create a diverse, fully -engaged, learner -centric campus environment to provide quality education to the students.

M3: Maintain mutually beneficial partnerships with our alumni, industry and professional associations

DEPARTMENT VISION, MISSION, PEO, PO AND PSO

Vision

To empower the Electronics and Communication Engineering students with emerging technologies, professionalism, innovative research and social responsibility.

Mission

M1: Attain the academic excellence through innovative teaching learning process, research areas & laboratories and Consultancy projects.

M2: Inculcate the students in problem solving and lifelong learning ability.

M3: Provide entrepreneurial skills and leadership qualities.

M4: Render the technical knowledge and skills of faculty members.

Program Educational Objectives

PEO1: **Core Competence:** Graduates will have a successful career in academia or industry associated with Electronics and Communication Engineering

PEO2: **Professionalism:** Graduates will provide feasible solutions for the challenging problems through comprehensive research and innovation in the allied areas of Electronics and Communication Engineering.

PEO3: **Lifelong Learning:** Graduates will contribute to the social needs through lifelong learning, practicing professional ethics and leadership quality

Program Outcomes

PO 1: Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.

PO 2: Problem analysis: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

PO 3: Design/development of solutions: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.

PO 4: Conduct investigations of complex problems: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

PO 5: Modern tool usage: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.

PO 6: The engineer and society: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.

PO 7: Environment and sustainability: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

PO 8: Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

PO 9: Individual and team work: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

PO 10: Communication: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.

PO 11: Project management and finance: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

PO 12: Life-long learning: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

Program Specific Outcomes

PSO1: Applying knowledge in various areas, like Electronics, Communications, Signal processing, VLSI, Embedded systems etc., in the design and implementation of Engineering application.

PSO2: Able to solve complex problems in Electronics and Communication Engineering with analytical and managerial skills either independently or in team using latest hardware and software tools to fulfil the industrial expectations.

Abstract	Matching with POs, PSOs
Mutual coupling reduction, EBG Array, ANSYS HFSS.	PO1, PO2, PO3, PO4, PO5, PO6, PO7, PO8, PO9, PO10, PO11, PO12, PSO1, PSO2

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ABSTRACT

This project discusses a technique for reducing mutual coupling between elements of UWB MIMO antennas using a small-sized uniplanar EBG. The proposed UWB antenna design includes two circular-shaped monopole radiators with a ground plane slot for impedance matching. To enhance isolation, a UC-EBG cell measuring 6.8 mm × 6.8 mm is incorporated between the antenna elements in a 4 × 1 array configuration. The band gap of the UCEBG is determined using both the dispersion diagram and suspended strip line method. The antenna is constructed using a low-cost FR4 substrate that is 1.6 mm thick and has a total size of 27.2 mm × 46 mm. The simulated and measured -10 dB impedance bandwidths of the antenna are 14.6 GHz (3-17.6 GHz) and 14.8 GHz (3.6-17.9 GHz), respectively. The UCEBG structure has multiple stop bands that suppress E-plane coupling over these bands, resulting in isolation better than -18 dB over the entire impedance bandwidth. The radiation efficiency and peak gain of the antenna range from 78% to 96.7% and 1.4 dB to 4 dB, respectively. Furthermore, the MIMO parameters, including the error correlation coefficient (ECC) and total active reflection coefficient (TARC), are better than 0.018 and -26 dB, respectively, over the impedance bandwidth.

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LIST OF ABBREVIATIONS

ACRONYM		ABBREVIATION
UCEBG	-	Uniplanar Compact Electromagnetic Band gap
HFSS	-	High Frequency Structure Simulator
VSWR	-	Voltage Standing Wave Ratio
MIMO	-	Multiple Input Multiple Output
S-Parameter	-	Scattering parameter

CHAPTER 1

INTRODUCTION

As data rates continue to increase, Ultra-wideband antennas (UWB) have become increasingly popular and are widely accepted. They offer low power consumption, high data rates, and affordability, making them an excellent choice for high-speed wireless communication systems. These antennas are utilized in various applications, such as GPS, remote sensing, and Direct Broadcast System (DBS). The FCC has allocated a frequency range of 3.1–10.6 GHz for UWB systems, which transmit low power signals over a vast bandwidth. The most used antenna for UWB systems is the microstrip antenna due to its planar and compact geometry, immunity to multi-path interferences, and near omnidirectional radiation pattern. The omnidirectional radiation pattern enables freedom in the orientation of transmitter and receiver antennas, ensuring reliable communication.

To increase the system capacity, UWB antennas' high bandwidth can be efficiently utilized by employing Multiple-Input Multiple-Output (MIMO) antennas. MIMO antennas use multiple antennas at the transmitter and receiver sides to counter the effects of multipath fading. They improve the link reliability and spectral efficiency of the system. MIMO antennas transmit power by using multiple antennas at the transmitter, supporting high data rates and increased channel capacity without sacrificing additional power. Several configurations have been proposed in the literature for realizing MIMO antennas.

UWB MIMO antennas are highly desirable for portable devices supporting various wireless telecom standards and services. In close proximity, MIMO antenna elements can affect each other through near-field coupling, significantly affecting system performance, especially in the lower UWB band. The inter-element spacing is optimal to reduce coupling effects, posing a minimum limit on the antenna size.

Decoupling structures are desired between the radiators to maintain optimum performance and reduce inter-element spacing.

Researchers have proposed several techniques to increase decoupling between elements, such as defected ground structure (DGS), neutralization lines, stubs, decoupling and matching networks, parasitic structures, electromagnetic band gap (EBG) structures as a decoupling array, or EBG as a substrate. Compact MIMO antennas achieving wideband isolation have been demonstrated using tree-like structures, meandered lines, and orthogonal radiation modes. A compact double-sided UWB MIMO antenna has achieved isolation by decoupling structures. EBG structures can be mushroom-like or uniplanar, and their use has been shown to reduce E-plane coupling. UC-EBG super states have also been demonstrated for reducing mutual coupling in patch antenna arrays.

In this project, a novel uniplanar UC-EBG incorporated UWB MIMO antenna design is presented. The design utilizes two circular monopole radiators with a rectangular slot etched in the ground plane beneath the feed line to realize UWB MIMO. A 4 × 1 array of UC-EBG's achieves decoupling between the MIMO elements, exhibiting four stop bands over the impedance bandwidth of the proposed antenna. The proposed geometry's overall size is 27.2 mm × 46 mm × 1.6 mm, with a spacing of 26 mm between adjacent radiator elements. The reduction in mutual coupling is studied and demonstrated using surface current distribution. Designing a compact, broadband, well-isolated UWB MIMO antenna with a low correlation coefficient is challenging.

1.1 Objective:

This paper presents a method for reducing mutual coupling between element of a UWB MIMO antenna using a small size uniplanar EBG. The proposed UWB antenna design includes two circular-shaped monopole radiators with a ground plane slot for proper impedance matching. A 6.8 mm × 6.8 mm UC-EBG cell is

inserted between the antenna elements in a 4 × 1 array configuration to improve isolation. The UCEBG's band gap is determined using dispersion diagrams and suspended strip line methods. The antenna is fabricated on a 1.6 mm thick, low-cost FR4 substrate with an overall size of 27.2 mm × 46 mm and has been experimentally verified. The antenna demonstrates simulated and measured -10 dB impedance bandwidths of 14.6 GHz (3-17.6 GHz) and 14.8 GHz (3.6-17.9 GHz), respectively. The UCEBG structure exhibits multiple stop bands and suppresses E-plane coupling over these bands, achieving isolation better than -18 dB over the complete impedance bandwidth. The radiation efficiency and peak gain of the antenna vary from 78% to 96.7% and 1.4 dB to 4 dB, respectively. MIMO parameters such as error correlation coefficient (ECC) better than 0.018 and Total active reflection coefficient (TARC) better than -26 dB are achieved over the impedance bandwidth.

CHAPTER 2

LITERATURE SURVEY

In recent years, several studies have investigated the use of EBG structures to reduce mutual coupling in UWB MIMO antennas. EBG structures are periodic structures that exhibit band gap characteristics, where the propagation of electromagnetic waves is prohibited in certain frequency bands. These structures can be used to reduce mutual coupling between antennas by suppressing the unwanted radiation and coupling between the antenna elements.

A study by N. Behdad and K. Sarabandi proposed the use of a small size uniplanar EBG exhibiting multiple stop bands to reduce mutual coupling between UWB MIMO antennas. The EBG structure was designed using a slot-loaded rectangular patch and a square loop with a meandered line. The proposed structure exhibited two stop bands in the UWB frequency range, which significantly reduced the mutual coupling between the antennas.

Another study by Y. Liu et al. proposed the use of a mushroom-like EBG structure to reduce mutual coupling between UWB MIMO antennas. The proposed structure consisted of a square patch, a ground plane, and a mushroom-like structure located between the patch and ground plane. The structure exhibited multiple stop bands in the UWB frequency range, which reduced the mutual coupling between the antennas by up to 20 dB.

In another study by M. Z. A. Abd Aziz et al., a uniplanar EBG structure with a modified square loop was proposed to reduce mutual coupling between UWB MIMO antennas. The proposed structure exhibited multiple stop bands in the UWB frequency range, which reduced the mutual coupling between the antennas by up to 15 dB.

"Mutual coupling reduction in planar ultra-wideband MIMO antenna using a miniaturized uniplanar EBG structure" by Gholamreza Moradi and Ahmad

Fakharian: This paper proposes a miniaturized uniplanar EBG structure for mutual coupling reduction between UWB MIMO antenna elements. The proposed structure is based on a square loop resonator with a fractal-shaped slot. The authors report a reduction of up to 20 dB in mutual coupling between the antenna elements and an improvement in the impedance bandwidth.

"Mutual coupling reduction in ultra-wideband MIMO antennas using a uniplanar EBG structure" by Cheng Zhang, Jing Bai, and Xiao-Wei Shi: This paper presents a uniplanar EBG structure for mutual coupling reduction between UWB MIMO antenna elements. The structure is based on a modified Hilbert fractal curve with multiple stop bands. The authors report a reduction of up to 28 dB in mutual coupling between the antenna elements and an improvement in the isolation between them.

"Mutual coupling reduction in a compact UWB MIMO antenna array using uniplanar EBG structures" by Chetan Sharma, Rajendra Kumar, and Surya Kant: This paper proposes a compact UWB MIMO antenna array with mutual coupling reduction using uniplanar EBG structures. The proposed structure is based on a square-shaped EBG unit cell with multiple stop bands. The authors report a reduction of up to 15 dB in mutual coupling between the antenna elements and an improvement in the bandwidth.

"Mutual coupling reduction between UWB MIMO antenna elements using uniplanar EBG structures with multi-band stop characteristics" by Dong-Yun Shin and Sung-Soo Kim: This paper proposes a uniplanar EBG structure with multi-band stop characteristics for mutual coupling reduction between UWB MIMO antenna elements. The structure is based on a rectangular patch with slots and a fractal-shaped ground plane. The authors report a reduction of up to 22 dB in mutual coupling between the antenna elements and an improvement in the radiation characteristics.

CHAPTER 3

EXISTING SYSTEM

3.1 Mutual Coupling reduction using 2D-EBG Array structure:

Reducing mutual coupling is a key research area in design of compact microstrip antennas arrays. To minimize the overall size of the antennas arrays, the distance between them must be very small, as a result a strong mutual coupling is appears. Periodic structures can help to design a low profile of antennas arrays and enable to improve their performances by the suppression of surface waves propagation in a given frequency range. This paper proposes a novel configuration of mushroom-like electromagnetic band-gap (2D-EBG) structure created by microstrip technology placed between two antennas arrays to reduce the mutual coupling more than -33.24dB. When 13×2 EBG structures are used, the mutual coupling reduces to -59.36dB at the operation frequency 5.8GHz of the antennas arrays. A 26.12dB mutual coupling reduction is achieved, which proves that the surface wave is suppressed.
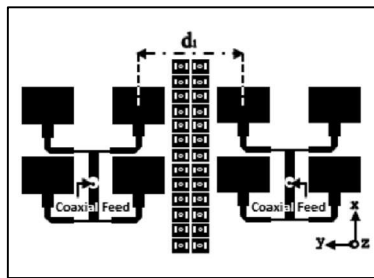

Fig 3.1: 2D-EBG Array structure

3.2 Mutual Coupling Reduction using UC-EBG Array:

The fast development in electromagnetic band-gap (EBG) structures, various configurations of EBG structures have been successfully applied in the patch antenna arrays to improve array characteristics, such as total size and radiation efficiency. Nowadays, an important challenge in communication industry is to reduce the total size of devices.

Placing elements of an antenna array close to each other is obviously one way to reduce the total size of an array as a result a strong mutual coupling is appears. Some conventional structures have also been proposed to reduce the mutual coupling between the radiating elements of microstrip antenna arrays such as cavity backed and substrate removal microstrip antennas.

The final results show a 10-dB reduction in mutual coupling and a 0.13 lambda reduction in size compared to the initial array structure.
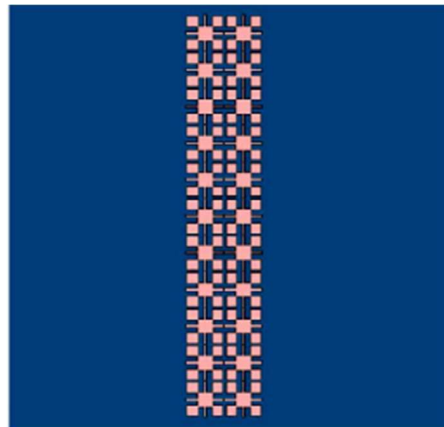

Fig 3.2: UC-EBG Array

3.3 High Mutual Coupling Reduction using Novel structure:

A novel parasitic configuration to reduce the mutual coupling between two adjacent microstrip patch antennas is shown that mutual coupling between the antenna elements can be reduced significantly by two simple slots structure on the ground plane and several shorted simple conducting strips between patch antennas. The results are shown that more than 7 dB reduction within operational frequency bandwidth with the maximum 41 dB mutual coupling at center frequency can be achieved and proves the high efficiency of this configuration in multi antenna systems
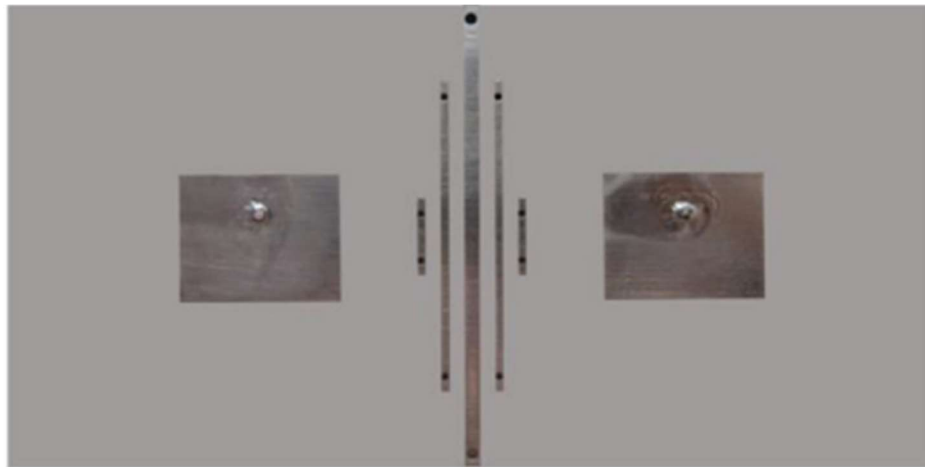

Fig 3.3: Novel Structure

CHAPTER 4

PROPOSED SYSTEM

4.1 Reference antenna:

The geometry of the antenna without UC-EBG and proposed UWB MIMO antenna are shown in Figs. 5.2, 5.3and 5.4 respectively. Proposed UWB MIMO antenna is printed on a 27.2 mm × 46 mm × 1.6 mm FR4 substrate with relative permittivity ε_r= 4.4 and a loss tangent of 0.02. A 3 mm wide, 50 Ω microstrip line is used for feeding the identical UWB antenna elements. The lower edge frequency of circular monopole antenna can be approximated by following equations

$$f_L = \frac{7 \cdot 2}{\left[(L + M + L_f) \times k\right]} GHz$$

Width of microstrip line which is used to feed the monopole antenna is calculated for 50 Ω impedance and is 3 mm. L is effective radius of monopole antenna in cm. M is effective radius of cylindrical monopole antenna in cm. Lf is the length of feed line in cm. k factor is equivalent to ε eff. For 0.16 mm thick FR4 substrate with permittivity of 4.4, k = 1.15 and estimates the lower edge frequency with an accuracy of ± 10%. For circular monopole radiator L = 2r and M = r/4, where r is the radius of the circular monopole radiator. The computed lower cut off frequency of the antenna is 3.1 GHz. UWB MIMO antenna is realized using circular monopole radiators with a radius of 6.5 mm.
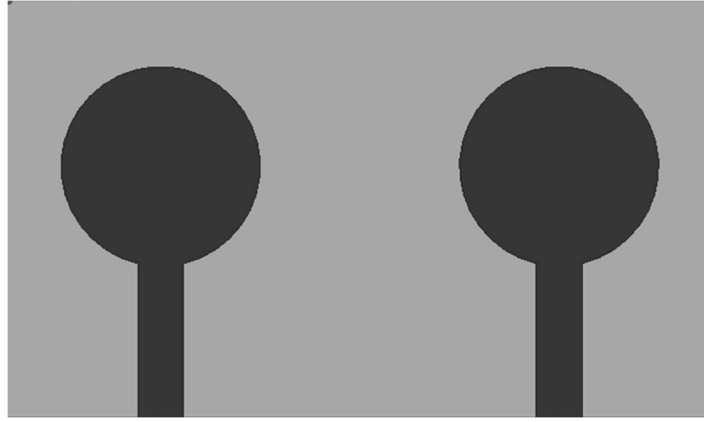
Fig 4.1: Reference Antenna

4.2 Proposed antenna:

The geometry of the antenna without UC-EBG and proposed UWB MIMO antenna are shown in Figs. 5.2, 5.3 and 5.4 respectively. Proposed UWB MIMO antenna is printed on a 27.2 mm × 46 mm × 1.6 mm FR4 substrate with relative permittivity ε_r= 4.4 and a loss tangent of 0.02. A 3 mm wide, 50 Ω microstrip line is used for feeding the identical UWB antenna elements.

The performance of MIMO antennas can be severely impacted by the excitation of surface waves, which is caused by low inter-element spacing between adjacent antenna elements. To address this issue and maintain a small antenna size, a decoupling structure is necessary.

The UC-EBG structure is effective in suppressing unwanted surface waves in the E-plane. However, conventional EBG structures tend to be large, which limits their application in MIMO antennas, as they restrict the minimum spacing between antenna elements. Additionally, conventional UC-EBG structures exhibit narrow stop bands.

To overcome these limitations, a new design has been proposed which utilizes a smaller UC-EBG array that efficiently reduces mutual coupling over the entire

UWB range. The effectiveness of this new design as a decoupling structure has been demonstrated through an analysis of the current distribution on the antenna.

However, when the UC-EBG array is inserted between the elements, the current coupling to Port2 is significantly reduced. Additionally, a high current density on the EBG elements is observed. These results suggest that the UC-EBG reduces the coupling current flowing between ports, there by improving the performance of the MIMO antenna.
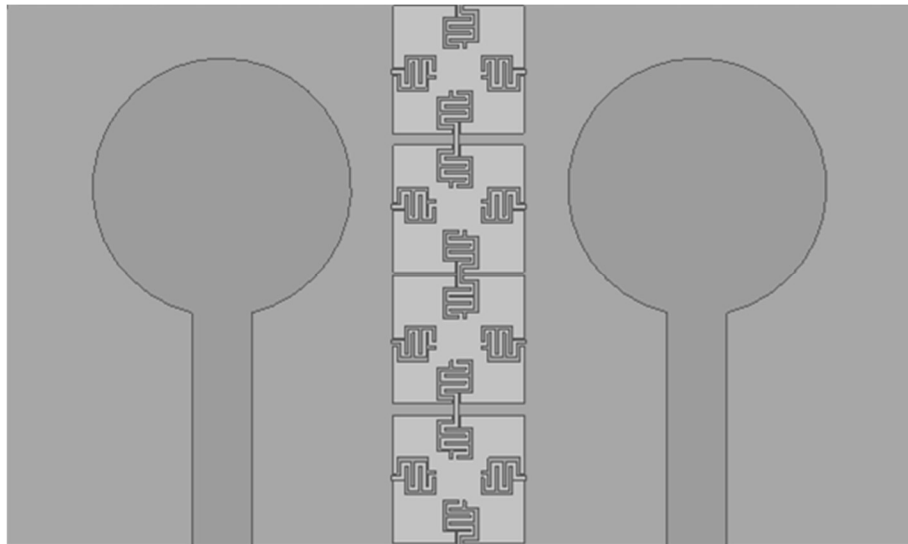

Fig 4.2: Proposed Antenna

CHAPTER 5

PROJECT METHODOLOGY

5.1 EBG ARRAY:

A new uniplanar electromagnetic bandgap (EBG) structure has been designed on an FR4 substrate with a thickness of 1.6 mm and a relative permittivity of εr = 4.4. The unit cell of the structure has a size of 6.8 mm × 6.8 mm and is created by modifying a conventional square patch and connecting adjacent cells with thin meandered microstrip lines as bridges. This new geometry of the EBG structure can be represented as a parallel combination of a lumped equivalent inductor and capacitor, as long as the periodicity is much smaller than the operating wavelength. The capacitance is achieved through the thin gaps between the metallic patches, while the inductance is generated by the current flowing through the thin microstrip lines. To achieve a wide band gap, the equivalent inductance and capacitance of the structure need to be increased. The meandering of the lines also increases the inductance and widens the relative bandwidth of the EBG structure. The center frequency of band gap of EBG can be determined by:

$$\omega = \frac{1}{\sqrt{LC}}$$

Electromagnetic band gap structures have specific stop bands where the propagation of electromagnetic waves is prohibited. The Eigen mode solver of the commercially available simulation tool HFSS has been used to compute the dispersion diagram of the proposed UC-EBG, utilizing periodic boundary conditions for an infinite EBG array. The suspended strip line method has been employed to calculate the transmission characteristics of the UC-EBG geometry. This method involves using the UC-EBG structure as a ground plane with a 50 Ω

microstrip line suspended over it. The stop bands are identified by the frequency band for which S21 is below −10 dB, indicating the prohibition of surface wave propagation.
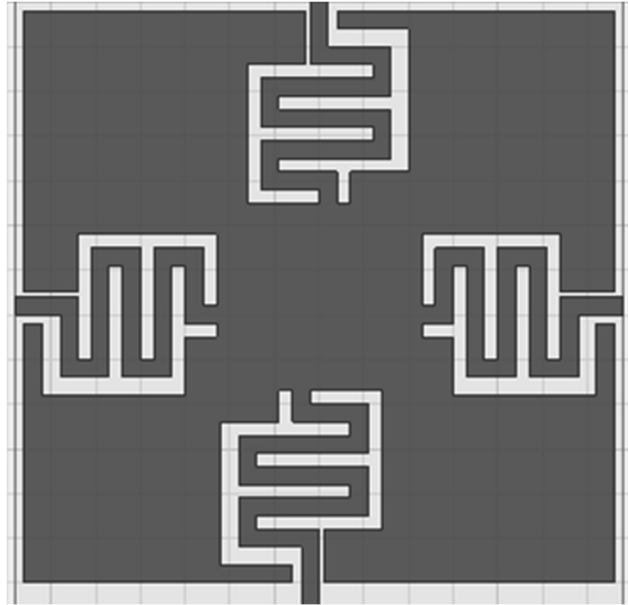

Fig 5.1: EBG Array

5.2 Antenna Geometry:

The structure of the antenna without the UC-EBG and the newly proposed UWB MIMO antenna, respectively. The proposed UWB MIMO antenna is fabricated on a FR4 substrate with dimensions of 27.2 mm × 46 mm × 1.6 mm, which has a relative permittivity of 4.4 and a loss tangent of 0.02. The feeding of the identical UWB antenna elements is achieved through a 3 mm wide, 50 Ω microstrip line. The lower edge frequency of circular monopole antenna can be approximated by following equations

$$f_L = \frac{7 \cdot 2}{\left[(L + M + L_f) \times k\right]} GHz$$

The width of the microstrip line utilized to feed the monopole antenna has been computed for a 50 Ω impedance and measures 3 mm. The effective radius of the monopole antenna, denoted by L, is measured in cm, while the effective radius of the cylindrical monopole antenna, denoted by M, is also measured in cm. The length of the feed line is denoted by Lf and is measured in cm. The k factor is equivalent to ε_{eff} and, for a 0.16 mm thick FR4 substrate with a permittivity of 4.4, k = 1.15. In the case of a circular monopole radiator, L = 2r and M = r/4, where r is the radius of the circular monopole radiator. The antenna's computed lower cut-off frequency is 3.1 GHz.

To realize the UWB MIMO antenna, circular monopole radiators with a radius of 6.5 mm are used. A rectangular slot is etched from the ground plane beneath the feed line to ensure proper impedance matching. An array of proposed UC-EBG, exhibiting multi-stop band, is inserted between the two antenna elements in a 4×1 configuration. The introduction of the EBG array modifies the response of the resultant antenna, which is optimized by reducing the length of the feed line and ground plane slot.

The rectangular slot located beneath the feed line serves as a parameter to attain the desired impedance matching over the UWB band. The effect of varying the slot length, denoted by L1, on S11. It is observed that the slot length's variation modifies the impedance bandwidth. A UWB response with S11 < −10 dB over the entire UWB band is obtained at L1 = 2.5 mm. In comparison, the antenna without UC-EBG demonstrates a −10 dB impedance bandwidth of 11 GHz (3.1–14.1 GHz), whereas the proposed antenna, loaded with UC-EBG, exhibits a simulated bandwidth of 12 GHz (3–15 GHz). The UC-EBG attains multiple stop bands, enabling wideband decoupling.
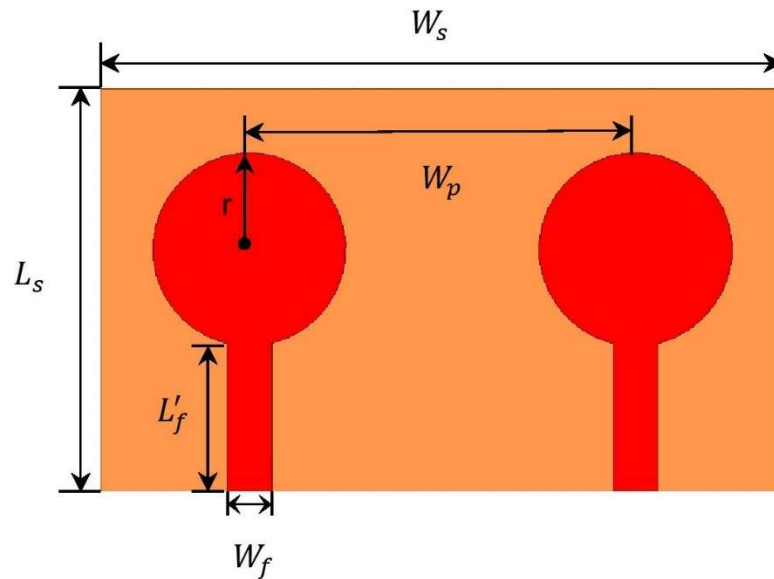

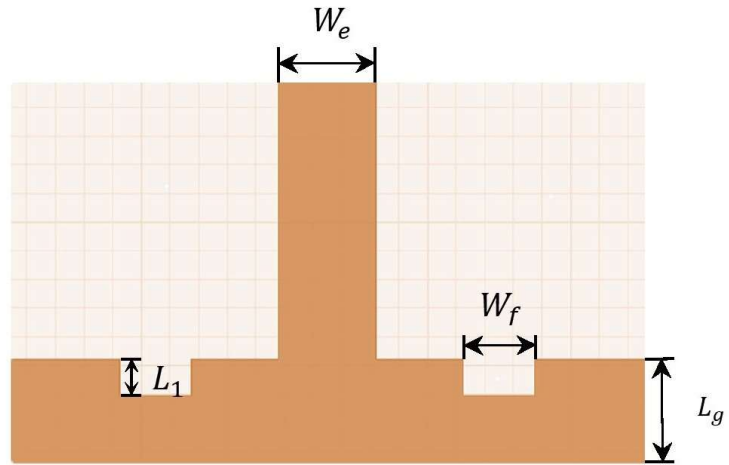Fig 5.2: Dimensions of Antenna Without EBG Array

Fig 5.3: Dimensions of Ground plane
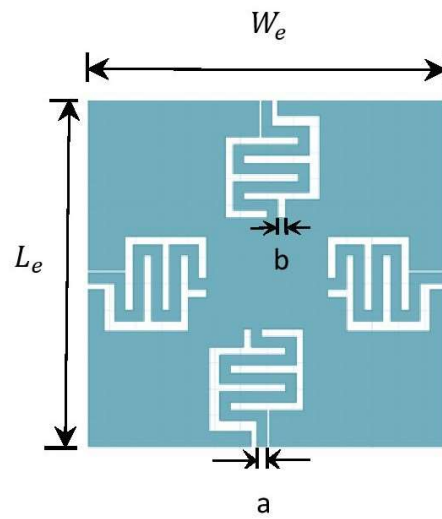

Fig 5.4: Dimensions of EBG Array

TABLE 5.1: Design parameters of the proposed antenna and UCEBG

Parameter	Value (mm)
Ls	27.2
L'_f	11.77
L_f	9.87
r	6.5
t	1.6
L_p	6.6
w_s	46
L_g	7.6
L_1	2.5
L'_1	3.4
L_e	6.8
A	0.2
w_p	26
w_f	3
w_e	6.8
b	0.2

5.3 Partial Ground:

A partial ground element is often used in antenna designs to improve the antenna's performance. The purpose of the partial ground element is to modify the current distribution on the antenna, which in turn affects the radiation pattern and impedance of the antenna.

By adding a partial ground element, the antenna's radiation pattern can be shaped in a more desired way. This can help to reduce unwanted radiation in certain directions or increase the antenna's gain in other directions. The partial ground element can also help to increase the antenna's bandwidth by modifying the antenna's impedance.

Another benefit of using a partial ground element is that it can help to reduce the size of the antenna. By adding a ground plane beneath the antenna, the overall size of the antenna can be reduced, making it more practical for use in compact devices. Overall, the purpose of using a partial ground element in antenna design is to improve the antenna's performance in terms of radiation pattern, impedance, bandwidth, and size.
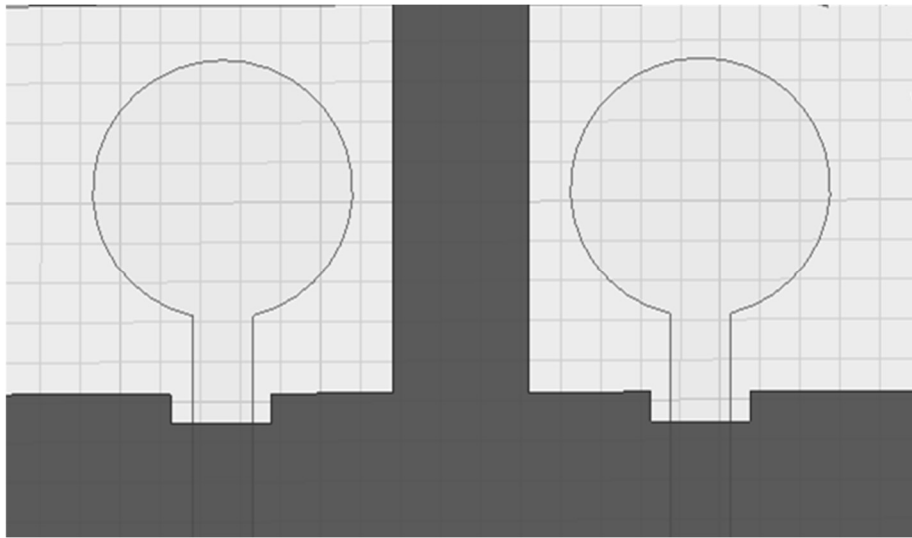

Fig 5.5: Partial Ground

5.4 Tool Kit

ANSYS HFSS is 3D electromagnetic (EM) simulation software for designing and simulating high-frequency electronic products such as antennas, antenna arrays, RF or microwave components, high-speed interconnects, filters, connectors, IC packages and printed circuit boards. Engineers worldwide use Ansys HFSS software to design high-frequency, high-speed electronics found in communications systems, advanced driver assistance systems (ADAS), satellites, and internet-of-things (IOT) products. ANSYS Electronics Desktop Student offers free access to the industry gold-standard Ansys simulators for work with antenna, RF, microwave, PCB, IC and IC package designs, along with electromechanical devices such as electric motors and generators. Students will have access to Ansys HFSS, Ansys Maxwell, Ansys Q3D, and Ansys Icepak, allowing design work on a broad range of electrical and electromechanical systems. Ansys HFSS is multipurpose, full-wave 3D electromagnetic (EM) simulation software. Ansys Maxwell is a 3D electromagnetic simulation solver for electric machines and electromechanical devices. Ansys Q3D Extractor calculates the parasitic parameters of resistance, inductance, capacitance and conductance (RLCG) for electronics designs. Ansys Icepak is a computational fluid dynamics (CFD) solver for electronics thermal management.

Fig 5.6: Ansys HFSS Software

CHAPTER 6

RESULT AND DISCUSSION

6.1 S – Parameter:

To validate the performance of the proposed antenna and UC-EBG array, the measured and simulated return loss plot (S11) of the antenna, with and without the UC-EBG structure, are presented in Figure 6.1. The antenna without UC-EBG demonstrated a measured −10 dB impedance bandwidth of 11 GHz (3.1–14.1 GHz), while the antenna loaded with UC-EBG showed a broader bandwidth of 12 GHz (3.6–15 GHz). The simulated and measured results were in good agreement.

It is evident that the UC-EBG increased the isolation and reduced the mutual coupling between the UWB antenna elements in the frequency bands that corresponded with the stop bands of the UC-EBG structure. However, the UC-EBG was not able to effectively suppress surface waves at certain frequencies due to the excitation of spurious signals. This was attributed to several factors, including fabrication tolerances, excitation of higher order modes, non-ideal measurement environments, and variations in permittivity and loss tangent of commercially available substrate, which can impact antenna performance, especially at higher frequencies.
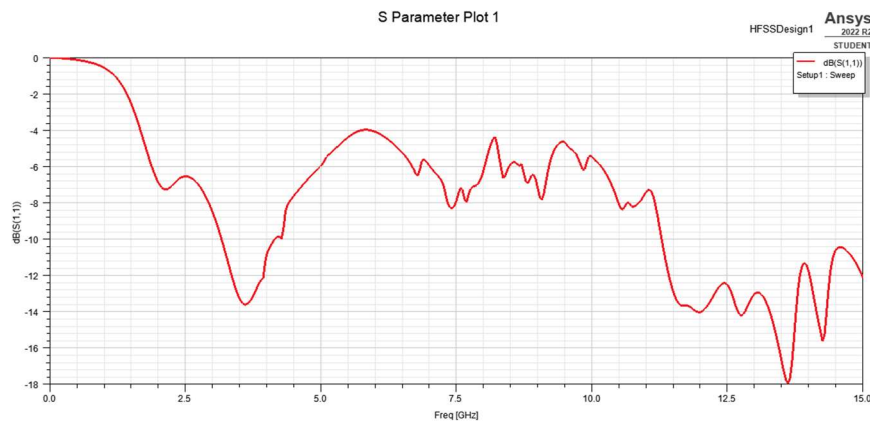

Fig 6.1: S parameter plot

6.2 VSWR:

The level of reflected and incident waves are used to determine the Voltage Standing Wave Ratio (VSWR). The Voltage Standing Wave Ratio of different patch materials.it proves that graphite has low VSWR when compared to the other two because the deepest curve has the better VSWR.
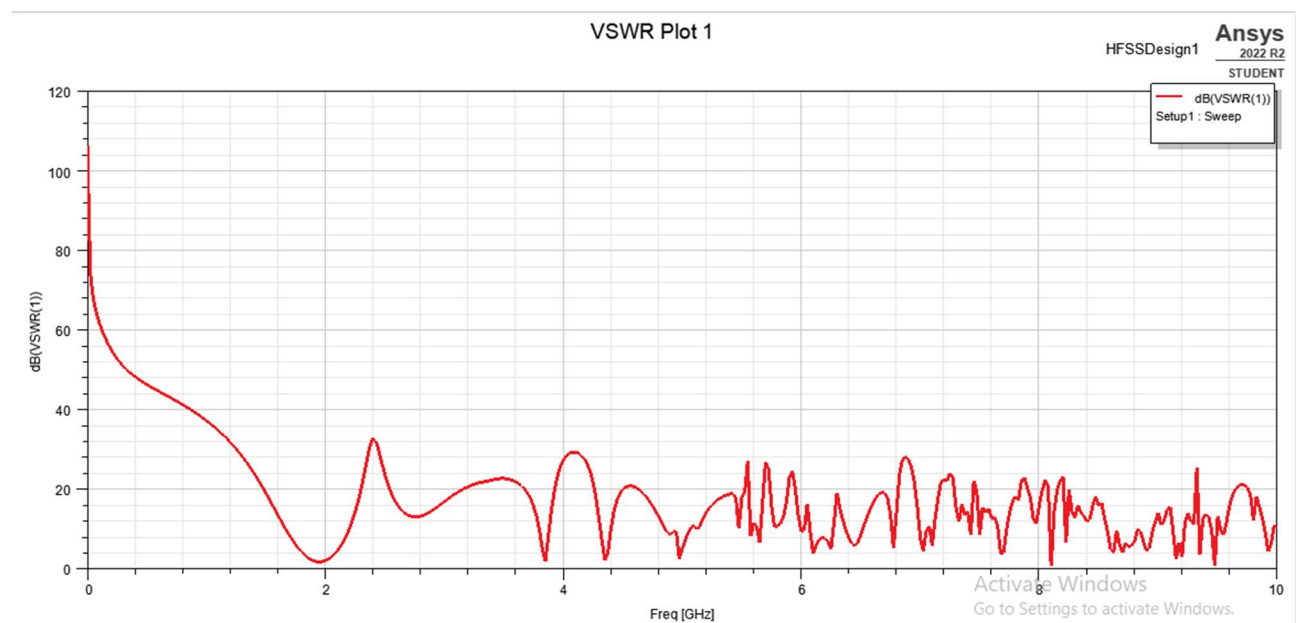

Fig 6.2: VSWR Plot

6.3 Radiation Pattern:

The simulated and measured 2-D radiation patterns of the proposed UWB MIMO antenna at various frequencies ranging from 4.5 GHz to 16 GHz in the xz-, yz-, and xy- planes. The radiation pattern shows an omni-directional shape that is similar to that of a monopole antenna. However, at high frequencies, ripples are observed in the radiation pattern, which may be attributed to the generation of higher order modes. The measured results closely match the simulated results, although discrepancies may arise due to fabrication errors, measurement uncertainty, and the high loss tangent of the substrate.
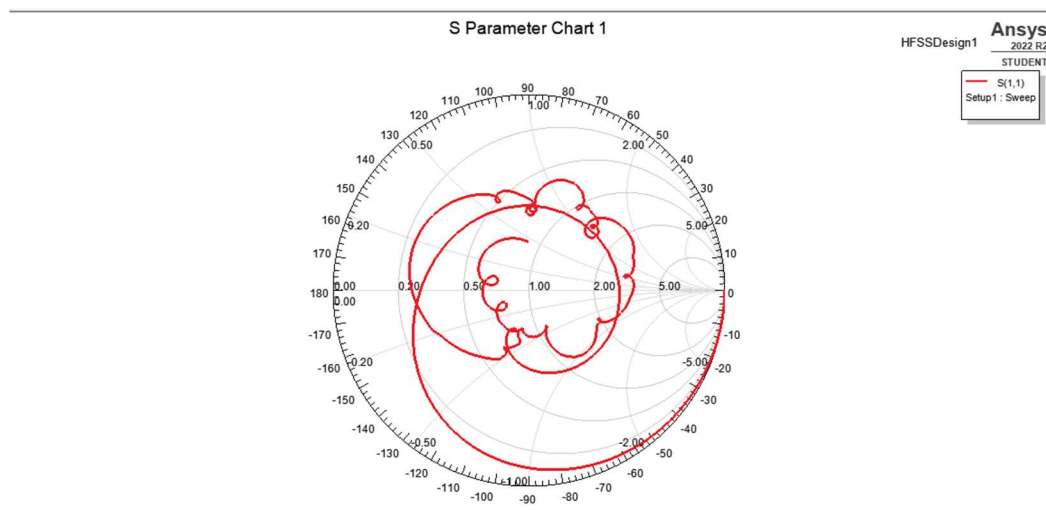

Fig 6.3:Radiation Pattern

CHAPTER 7

CONCLUSION

This study showcases the reduction of mutual interference between elements of an Ultra-Wideband Multiple-Input Multiple-Output (UWB MIMO) antenna by utilizing a UC-EBG structure that has four stop bands. The UC-EBG array is arranged in a 4 x 1 configuration and placed between the MIMO elements. The UC-EBG stops the propagation of surface waves within its stop band, which results in isolation. The proposed antenna has an impedance bandwidth of 14.8 GHz, with a measured -10 dB bandwidth. The isolation is better than -18 dB throughout the entire impedance bandwidth. The antenna also has a very low envelope correlation coefficient, with a maximum value of 0.018 over the impedance bandwidth, and achieves diversity gain close to 10.

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