OPEN ACCESS
International Journal of Engineering Innovations in Advanced Technology
ISSN: 2582-1431 (Online), Volume-4 Issue-4, December 2022

Wearable Antennas For Wireless Applications

Mehaboob Mujawar
Research Scholar, Department of ECE, The Glocal University, Mirzapur, Saharanpur (U.P), India.
Email: mehaboob311134@gmail.com

Dr R Purushotham Naik
Associate professor, Department of ECE, The Glocal University, Mirzapur, Saharanpur (U.P), India.
Email: rpnaik.naik3@gmail.com

Dr M Pavithra Jyothi
Associate professor, Department of ECE, SHADAN Women's College of Engg. & Tech., India.
Email: pavitrajyothi@gmail.com

***Abstract* - This research paper suggests both the design and the execution of wearable antennas for use in wireless applications. The primary objective of this research is to concentrate on the design and hardware implementation of various types of antennas using various techniques, such as the addition of Meta-materials, flexible substrates, formation of EBG structures, antenna arrays, and antenna slots, as well as to analyze the performance of antennas for wearable applications. In addition, the research will look at how well antennas perform in situations where they are worn on the body. There are three unique designs for a wearable microstrip patch antenna that operate at dual bands (2.5 and 5.2 GHz). The first antenna is based on a regular ground plane, but the other two antennas are both based on different forms of two-dimensional electromagnetic band gap (EBG) structures. Numerous aspects were taken into consideration during the design of these two-alternative dual-band EBG structures employing wearable substrates in order to improve the performance of the suggested conventional ground plane (dual band) wearable antenna. This was done in order to enhance the overall performance of the wearable antenna. The first EBG in the form of a mushroom is about 22.7% less in size than the second EBG, which has slots in the shape of a plus sign. It has been demonstrated that the EBG with plus-shaped slots and the mushroom-shaped EBG are superior.**

Keywords – EGB, Wearable Antennas, Band Gap, Two-dimensional, Microstrip.

1. INTRODUCTION

The existing method of communication is plagued by a number of challenges, including those pertaining to the modernization of equipment, downsizing, data transfer speeds, bandwidth, impedance matching, and other related issues. Also, these communication gadgets reveal their capacity to communicate with other technologies in order to enhance the quality of human life. Although utilising a wide variety of different pieces of equipment, modern communication methods emphasized wireless communication more than cable systems did. Wireless communication got off to a strong start and is now one of the most developed fields in the world, despite the fact that there were many people who disagreed with its development. As a result of advancements in technology, wireless communication has also seen considerable gains in the areas of data rate, bit rate, baud rate, miniaturization, and the speed with which it can communicate across wider distances. When it comes to wireless communication, the "ANTENNA" is the most valuable component of the interface.

Manuscript received Dec 10, 2022; Revised Dec 25, 2022; Accepted Dec 31, 2022

A. Antenna:

Antennas are often recognized as the single most critical component of any radio frequency (RF) system and play a significant role in the operation of modern communication systems. A variety of applications call for the use of a variety of antennas. An antenna may be defined as "a radiating element that receives and transmits radio waves," according to one definition. Radiating pieces also serve the function of linking the transmitter, receiver, and free space used for communication. Every piece of communication hardware that uses empty space as its medium needs antennas in order to function properly as interceptors. Heinrich Hertz is credited with building the very first radio antenna in the year 1886. Guglielmo Marconi demonstrated the feasibility of long-distance communication in the year 1901. Since the usage of mobile phones and other wireless electronic devices continues to grow at a fast pace, there is a growing need for ultra-wideband antennas that have a low profile, have a low power consumption, and are extremely efficient in the duties that they perform. After then, antennas became an essential part of all communication equipment and were included into the communication lines used by airplanes and ships for navigation.

B. Definition of Antenna:

An antenna is a metallic device that produces and receives radio waves and may take the shape of a rod or wire. This is the most basic explanation of what an antenna is. In addition to this, it acts as a transitory interface between the space and the element that is driving the movement.

Radiators of electromagnetic waves are another possible use for them.

• Since it is able to detect electromagnetic waves, this radiating component is sometimes referred to as a "EM Sensor." Since it is able to convert radio frequencies into electrical current that has the same frequency, it is also known as a "Electromagnetic Transducer."

It is possible for an antenna to function as a coupling device during the process of the transmission of signals into free space, which is why the term "Impedance Matching device between free space and the Line of Transmission" is used to describe it. It is also known as a "Temperature Sensor" (Temperature Sensor).

As a result of the fact that an antenna may be used to a number of different uses, as shown by the definitions, it has developed into a companion for modern people. This antenna is a reliable component of the overall system that facilitates communication.

C. Functions of Antenna

1. Receiving sections make use of antennas because of their ability to convert one kind of energy into another. For example, electromagnetic energy (EM energy) may be converted into electrical energy, and electrical energy can be converted back into EM energy.

2. It performs the function of an impedance matching device for the transmission line.

3. It acts as a component of transition between waves that are directed and waves that are free in space.

4. It sends messages in the desired direction while simultaneously blocking signals going in the other way.

5. It measures temperature and operates as a remote sensing device, both of which allow it to serve as a device for detecting temperature.

D. Types of Antennas

An antenna is a kind of communication connection that transmits and receives radio wave energy. Antennas may be found in many different forms. Conductive materials are used in the construction of an antenna. These antennas perform the functions of both fundamental transceivers and interfaces, making it possible for energy to be communicated between sources despite the presence of open space between them. The interface serves as what is described as a transitory structure due to its purpose. There are several antennas that may radiate energy, and many of them work in one of two ways: they either release energy in one direction while suppressing it in all other directions, or they do the opposite.

An antenna that radiates its energy equally in all directions is referred to as an isotropic antenna, whereas an antenna that radiates its energy only in one direction is known as a directional antenna. The emission pattern of the one-of-a-kind antenna will govern the area in which communication may take place. There are many different applications and technical considerations that go into classifying antennas; thus, they are broken down into the following categories:

1. Metal wire antenna

2. Apertures

3.Microstrip Patch

4. Arrays

E. Wire Antenna

On the top of autos, ships, and several other types of vehicles, a wired antenna is a simple metal structure that serves the goal of facilitating communication. They are designed to be convenient and may be used for a variety of purposes, such as a straight wire, a loop, or a helix, for example. Some of the antenna in the array that was just described will have distinctive geometries. One example of this is a loop antenna, which may be constructed in a variety of shapes including a triangle, square, ellipse, rectangle, and so on. The round and square types of constructions are the ones that are most often seen for this loop antenna. Some of the wire antennas are seen in Figure 1.

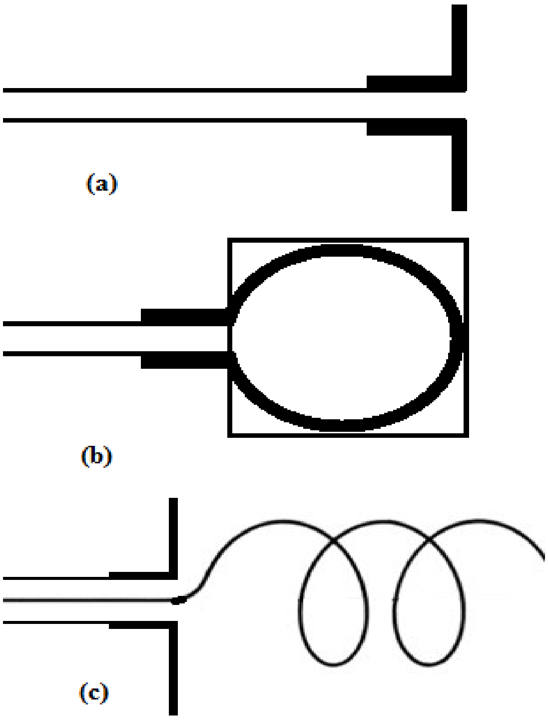

Figure 1: Wire Antenna Types a) Dipole b) Loop & c) Helical Antennas

2. LITARATURE SURVEY

R. Wongsan et al. [12] spoke about the technique of using metamaterials on EBG in order to create a high gain antenna at MBS. He did this by transmitting electromagnetic fields from a 1x4 slot array equipped with a PEC reflector via the cavity of a curved woodpile EBG, which is the method that is most suitable for gain improvement. The approach that was offered cut down on the length of the array while simultaneously boosting its gain. In addition, the approach that was presented provided a view of the base station in every direction. When the conclusions from the simulation were compared to the data from the experiment, it provided a qualitative comparison that was acceptable. It was discovered that the directional gain of each panel ranged between 17.1 and 17.2 dBi.

T. Elkarkraoui et al.[13] developed a circularly polarized antenna with EBG that works at 60GHz as part of their body of work in the field of study. The antenna was a cross-dielectric-resonator antenna, and it had a superstrate located at the frequency selective surface (FSS), which functions as an excitation source. It was validated by a combination of numerical and experimental analysis, as the performance of the antenna was analyzed. The proposed antenna showed a bandwidth of 11.07% between 56 and 63 GHz, an axial -ratio of 5.04% between 58.90 and 62.10 GHz, and a gain of 16.7 dBi in the pass band. These measurements were taken throughout the frequency range of 56 to 63 GHz.

C. Mourtzios According to the findings of a research conducted by et al. on a low profile wire dipole antenna, a well designed EBG has the potential to resonate at more than one frequency and is also capable of driving into higher modes in addition to performing its primary job (14). Both the operational properties of the hybrid antenna as well as the performance of the antenna in real-world mobile communication scenarios were evaluated. The observed analytical results demonstrate that the developed radiators are competitive with the conventional microstrip antenna and that they may be successfully employed for modern wireless communication networks, which may be a mobile or fixed unit. This conclusion was reached as a consequence of the fact that the developed radiators achieved the observed analytical results.

We explored and presented an MSA that reduces mutual coupling in MIMO as well as arrays; this work was done by Naser-Moghadasi, M., et al. For wireless communication applications operating at 5.35 GHz, we make use of an MSA that has the specified dimensions of 36 mm by 68 mm by 1.6 mm. This is something that we are aware of. The gadget is lauded for being much more condensed in comparison to the earlier antenna. Even though the findings of the comparison were excellent in every way, he used HFSS to simulate the results of return loss and antenna layout at 5.4GHz. This was done so that he could better understand the implications of these results. In the case of brand new structures, the comparable model is made available.

M-EBG structures were investigated in the research papers of M. Hajj and colleagues [16] by combining MSA in an array, which consists of a great number of radiating components. They are chosen for their ability to function in passive ambient conditions while using a certain radiating aperture. Controlling the radiating aperture allows for the production of a directivity beam pattern when using this cutting-edge method. Beam scanning and Directivity reconfigurability were both made feasible as a result of the approach that was offered. As the beam scanning has been expanded to a range of -58 degrees to +58 degrees, the mutual interaction between the radiating components in this model has been lowered, which means that the model cannot be accepted. This method also reduces the cost of the antenna, and the results of all of the simulations demonstrate that the strategy has a lot of potential.

3. DESIGN CONSIDERATIONS OF EBG STRUCTURES

A. *Principle of EBG and Designing Considerations*

From the definition the Electromagnetic wave propagation in a specific band of frequency, for any angle and any polarization states may be assisted or avoided by the Periodic structures known as EBG structures. They will have a pure periodic structure generally built by either dielectric or metallic conductors. If a special design is integrated on conductive surfaces, the radiofrequency surface properties may be possible to alter. The quality of the structure is explained by effective medium and all its parameters in single form, when the period of the surface design is less than the wavelength.

The Mushroom like EBG structures that was proposed by Sievenpiper, have greater surface impedance and can provide compact size in antenna design. At their resonant frequency the EBG structure acts like a Perfect Magnetic Conductor (PMC) that reflectsall the electric field. The above nature of EBG tells us that they are perfect structures that increase forward gain by decreasing back radiations in the antenna. The Mushroomlike structures is best out of its kind because they have very low loss, low profile and can be integrated to any antenna. As shown in Fig 3.6 they are arranged in a seq According to the definition, electromagnetic wave propagation in a certain frequency band, for any angle and any state of polarization, may be promoted by periodic structures known as EBG structures, or it may be prevented by these structures entirely. They will typically have a pure periodic structure and be built of either metallic or dielectric conductors. In addition, they will be made of conductors. If a certain design is incorporated on conductive surfaces, then it may be possible to modify the RF surface properties. [Case in point] [Case in point] It is possible for the effective medium and all of its properties to express the quality of the structure in a single form when the period of the surface design is less than the wave length.

The suggested EBG structures by Sievenpiper that look like mushrooms have a greater surface impedance and have the potential to offer compact dimensions for the building of antennas. At its resonance frequency, the EBG structure demonstrates the characteristics of a Perfect Magnetic Conductor (PMC), reflecting the whole electric field. These are excellent shapes that improve forward gain by decreasing back radiation in the antenna, as shown by the features of EBG that were mentioned above. The structures that resemble mushrooms are the best of their kind due to the fact that they may be attached to any antenna and have a very low level of loss. As shown in Figure 3.6, metal structures that are connected to a ground are often used to arrange components into a successively continuous two-dimensional structure. This is shown in the figure.uential continuous two dimensional structure using in general metal structures that are connected to a ground

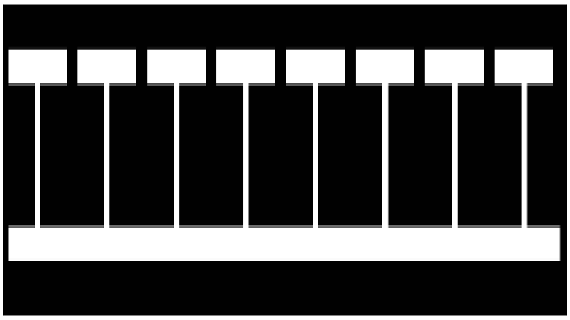

Figure 2: Mushroom like EBG Cross Section

plate constructed using what are known as through vertical pillars. Since these projections mimic the structure of a mushroom, the EBG that looks like a mushroom was given that name. When attempting to visually represent these EBG topologies, grouped circuit components such as inductors and capacitors are used. At lower frequencies, transverse magnetic (TM) waves may flow through the structure, but transverse electric (TE) waves may travel through the structure at higher frequencies (TE). Within the range of frequencies that have been established, the structures prohibit transverse electromagnetic (TEM) and transverse magnetic (TM) waves from passing through them.

It is impossible for electricity to flow across the EBG structure since it is shown by a parallel resonant LC circuit. This circuit is used to show the equivalent circuit of the EBG structure. The element that is physically near to its adjacent element is responsible for the capacitive action, whereas the element that is made up of a single stretch of metal across its whole is responsible for the inductive action. Fig. 27 depicts an analogous circuit for an EBG that looks like a mushroom. The position of the band gap will move closer together as the inductance or capacitance rises.

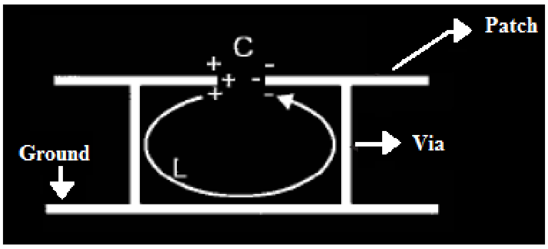

Figure 3: Equivalent circuit of Mushroom like EBG

B. EBG Structures Their Arrangements

Several of the EBG structures that are utilized for microstrip antennas have the best directivity, lobe pattern, and return loss at broadside results, despite the fact that microstrip antennas employ more than one EBG structure. This explains why the input frequency band will not overflow the surface wave band gap, even when a thin grounded dielectric slab is used. Because of this, the grounded slab that the microstrip antenna is attached to is rendered useless. The well-known PEC and PMC have reflection phases of 180 and 00, respectively, when the plane wave is incident on them in normal incidence. EBG structures made it possible to satisfy the PMC-like requirement for specific frequency bands by opening up new possibilities.

The reflection phase of the EBG structures changes with respect to frequency from +1800 to -1800, which distinguishes them from PMC surfaces in that they are not only the same as PMC surfaces but also distinct from them. This feature, which characterizes the EBG for microstrip antenna, creates a conductive surface for microstrip antennas, which are needed in mobile and wireless communication devices and gadgets. These devices and gadgets are used in mobile and wireless communication.

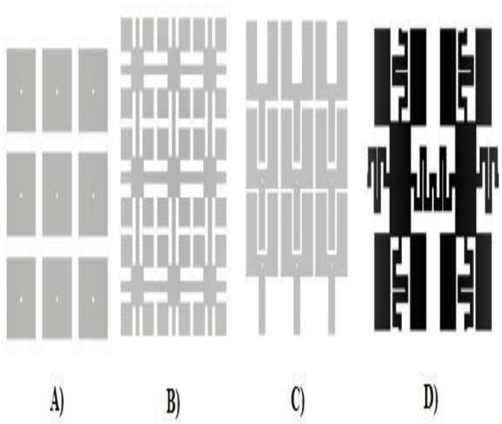

Figure 4 : Various EBG structures with arrangements A)Mushroom like B) Uni-Planar C) Fork like D) Bent Strip Line

The blueprint for the EBG structures is yet another essential concept. These structures are conceived of as inductive and capacitive devices with a range of geometries; each of these geometries has a frequency bandgap that is distinct from the others. The following list contains a number of significant EBG structures:

Microstrip antennas are used in a wide variety of applications, and each of these uses calls for a one-of-a-kind EBG structure. The EBG, which has the appearance of a mushroom, is one of the most essential structures among them. Sieven, Piper, Yang, and others first put out the idea for this approach in the year 1999. Up until that moment, the only types of structures that had been employed were those that resembled rod or wood piles.

The EBG structure in the form of a mushroom and the EBG structure in the shape of a fork each occupy 10% and 7% of the available unoccupied regions, respectively. The uni-planar design requires substrates with high stop band frequencies and dielectric constants. This is necessary since the configuration drastically reduces the amount of open space available. While the bent strip line EBG structure is similar to the uni-planar EBG structure in terms of the period of the lattice structure, the bent strip line EBG structure should be provided costly substrates for use in low frequency antenna applications. With the aid of this research, the EBG structure need to be reduced in size, and for low frequency antenna applications, substrates that are available at more reasonable prices have to be used. Comprehensive mathematical examinations of the structures are looked at in order to make a decision about which EBG structures should be used for antenna applications.

3. DESIGN METHODOLOGY

A. Conventional Approach

The CST MWS software was utilized for all of the designs and simulations that were performed for this investigation, and the frequency range that was employed was from 2 to 5.5 GHz. The geometrical model of the dual band wearable patch antenna that has been proposed is shown in Figure 1. Polyethylene foam was used to build a substrate that was 3 millimeters thicker, had a compact size of 68 millimeters by 73 millimeters, and had a relative permittivity of 1.05 [34]. The overall dimensions of the radiating patch were 44.75 and 47 millimeters. A

50 microstrip feed line was used in the production of the dual band textile antenna that was recommended. The dimensions of the proposed dual band textile antenna were found by applying the concept of transmission lines to the problem.

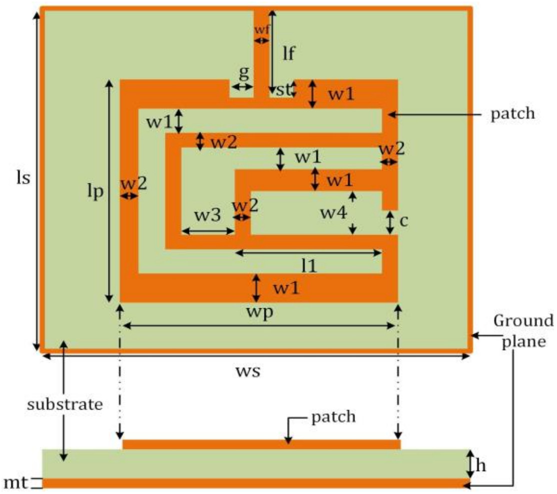

Figure 5: Geometrical model of the proposed dual band microstrip patch antenna.

B. Dual Band EBG Unit Cells

This section provides a summary of the creation and analysis of two distinct unit cells derived from two distinct EBG structures in order to accommodate the given frequency bands (2.5 GHz and 5.196 GHz). As the substrate material, these two EBG structures each have a thickness of 3 millimeters and are made of polyethylene. The resonant frequency, also known as the natural frequency, of the unit cell is established by the effective capacitance (C) and inductance (L).

where the permeability of free space is zero and the permittivity of free space is zero, respectively. Figure 32 illustrates the design that was used for both of the dual band EBG unit cells. The first one is the typical EBG unit cell, and it looks like a mushroom. Overall, its measurements are 32.5 millimeters by 32.5 millimeters, and it has a square shape. The radius of the through is 1.5 millimeters. The first EBG unit cell is not the same as the second unit cell, which looks more like a mushroom than the conventional EBG unit cell. The slot in the plus sign is added to the unit cell after it has been modified. Because of the enhanced capacitance provided by the slots, the recommended unit cell is much more compact than the mushroom-shaped EBG unit cell that is more often used [36]. The second EBG unit cell that has a plus-shaped slit measures 26.5 millimeters by 26.5 millimeters in terms of its total dimension. The size of the second EBG unit cell is about 18.46% less than that of the normal EBG unit cell, which is shaped like a mushroom. The plus-shaped groove that may be seen in the second EBG unit cell has dimensions of 3 millimeters in width and 13 millimeters in length.

The in-phase reflection of the dual-band EBG unit cells may be seen in Figure 33. This reflection was mentioned before. It is important to notice that every EBG unit cell has an in-phase response on the resonances that are adequate (2.5 GHz and 5.2 GHz).

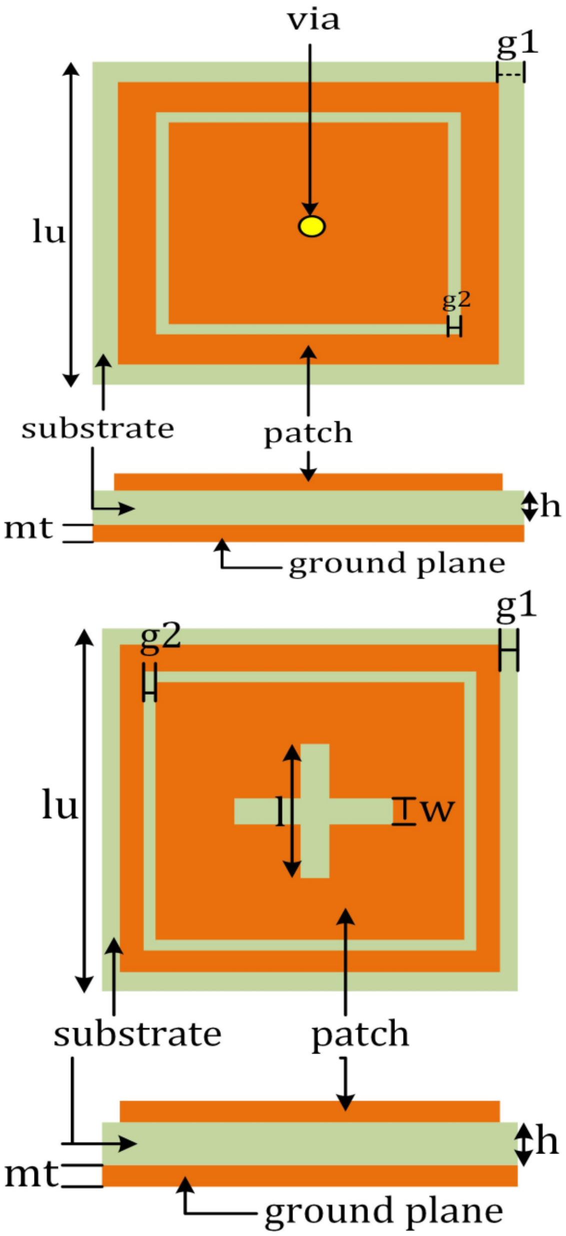

Figure 6. EBG unit cells. (a) Mushroom-like EBG unit cell. (b) Unit cell with plus-shaped slots.

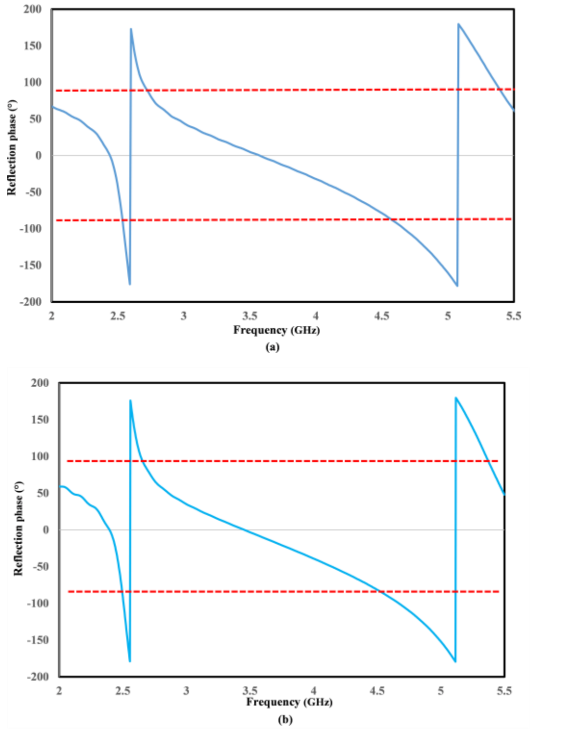

Figure 7. In-phase reflection of EBG unit cells. (a) Mushroom-like unit cell. (b) Unit cell with plus-shaped slots.

C. Electromagnetic Band-Gap Array

Suppression of surface waves is one of the most important aspects of EBG structures because it prevents the propagation of surface waves. Suppressing surface waves may minimize the size of an antenna's side and back lobes while simultaneously boosting its gain, directivity, and other attributes. It is possible to get the scattering characteristics for the two EBG surfaces by using the two port transmission line techniques that are shown in Figure 34. It is presumed that one of the two ports is the source of the excitation, and the other port, which is located on the right, is thought to be a matched load. The size of the second EBG array that has plus-shaped slots is 136 mm 136 mm, whereas the total size of the EBG array that looks like a mushroom is 176.5 mm 176.5 mm.

The transmission and reflection coefficients for the two different EBG structures are shown in Figure 35. This proves that the S21 is less than 15 dB at both frequencies for each and every EBG (2.5 GHz and 5.196 GHz). As a consequence of this, both EBG structures have the potential to dampen surface waves within the necessary frequency ranges (2.5 GHz and 5.196 GHz). As compared to the second EBG structure, which has slots in the form of a plus, the conventional mushroom-shaped EBG array is about 22.94% more compact.

CONCLUSION

This paper shows and evaluates the design of a compact dual-band microstrip patch antenna working at 2.5 and 5.2 GHz for a number of important parameters. The antenna is designed to operate at these frequencies. By using not one but two distinct EBG ground planes, the proposed dual-band conventional ground plane antenna achieves a higher level of overall performance in comparison to its predecessor (in terms of directivity, gain, efficiency, and other features). It has been discovered that antennas modeled after EBGs perform much better than antennas constructed using conventional ground planes. In addition, we examined the performance of the recommended dual-band conventional ground-plane antenna under a variety of bending conditions. The results of our research have led us to the conclusion that the intended antenna will, despite changes in bending radius, continue to keep its tuning.

REFERENCES

[1] Xiangfang, R.; Lei, S.; Miaomiao, L.; Xiying, Z.; Han, C. Research and sustainable design of wearable sensor for clothing based onbody area network. *Cogn. Comput. Syst.* **2021**, *3*, 206–220.

[2] Ali, S.M.; Sovuthy, C.; Imran, M.A.; Socheatra, S.; Abbasi, Q.H.; Abidin, Z.Z. Recent advances of wearable antennas in materials, fabrication methods, designs, and their applications: State-of-the-art. *Micromachines* **2020**, *11*, 888.

[3] Elsheakh, D.M.; Abdallah, E.A. Different feeding techniques of microstrip patch antennas with spiral defected ground structure for size reduction and ultra-wide band operation. *J. Electromagn. Anal. Appl.* **2012**, *4*, 410–418

[4] Fallahpour, M.; Zoughi, R. Antenna miniaturization techniques: A review of topology-and material-based methods. *IEEE Antennas Propag. Mag.* **2017**, *60*, 38–50.

[5] Ahmad, A.; Arshad, F.; Naqvi, S.I.; Amin, Y.; Tenhunen, H.; Loo, J. Flexible and compact spiral-shaped frequency reconfigurable antenna for wireless applications. *IETE J. Res.* **2020**, *66*, 22–29.

[6] Mahfuz, M.H.; Islam, M.R.; Park, C.W.; Elsheikh, E.A.; Suliman, F.; Habaebi, M.H.; Malek, N.A.; Sakib, N. Wearable Textile Patch Antenna: Challenges and Future

Directions. *IEEE Access* **2022**, *10*, 38406–38427.

[7] Ali, U.; Ullah, S.; Khan, J.; Shafi, M.; Kamal, B.; Basir, A.; Flint, J.A.; Seager, R.D. Design and SAR analysis of wearable antenna on various parts of human body, using conventional and artificial ground planes. *J. Electr. Eng. Technol.* **2017**, *12*, 317–328.

[8] Augustine, R.; Alves, T.; Sarrebourse, T.; Poussot, B.; Mathew, K.; Laheurte, J.M. Polymeric ferrite sheets for SAR reduction of wearable antennas. *Electron. Lett.* **2010**, *46*, 197.

[9] Augustine, R.; Alves, T.; Zhadobov, M.; Poussot, B.; Sarrebourse, T.; Sauleau, R.; Thomas, M.K.; Laheurte, J.M. SAR reduction of wearable antennas using polymeric ferrite sheets. In Proceedings of the Fourth European Conference on Antennas and Propagation, Barcelona, Spain, 12–16 April 2010; pp. 1–3.

[10] Jensen, M.A.; Rahmat-Samii, Y. EM interaction of handset antennas and a human in personal communications. *Proc. IEEE* **1995**,*83*, 7–17.

[11] Li, H.; Tsiaras, A.; Lau, B.K. Analysis and estimation of MIMO-SAR for multi-antenna mobile handsets. *IEEE Trans. Antennas Propag.* **2017**, *65*, 1522–1527.

[12] Ramachandran, T.; Faruque, M.R.I.; Islam, M.T. Specific absorption rate reduction for sub-6 frequency range using polarization dependent metamaterial with high effective medium ratio. *Sci. Rep.* **2022**, *12*, 1–18.